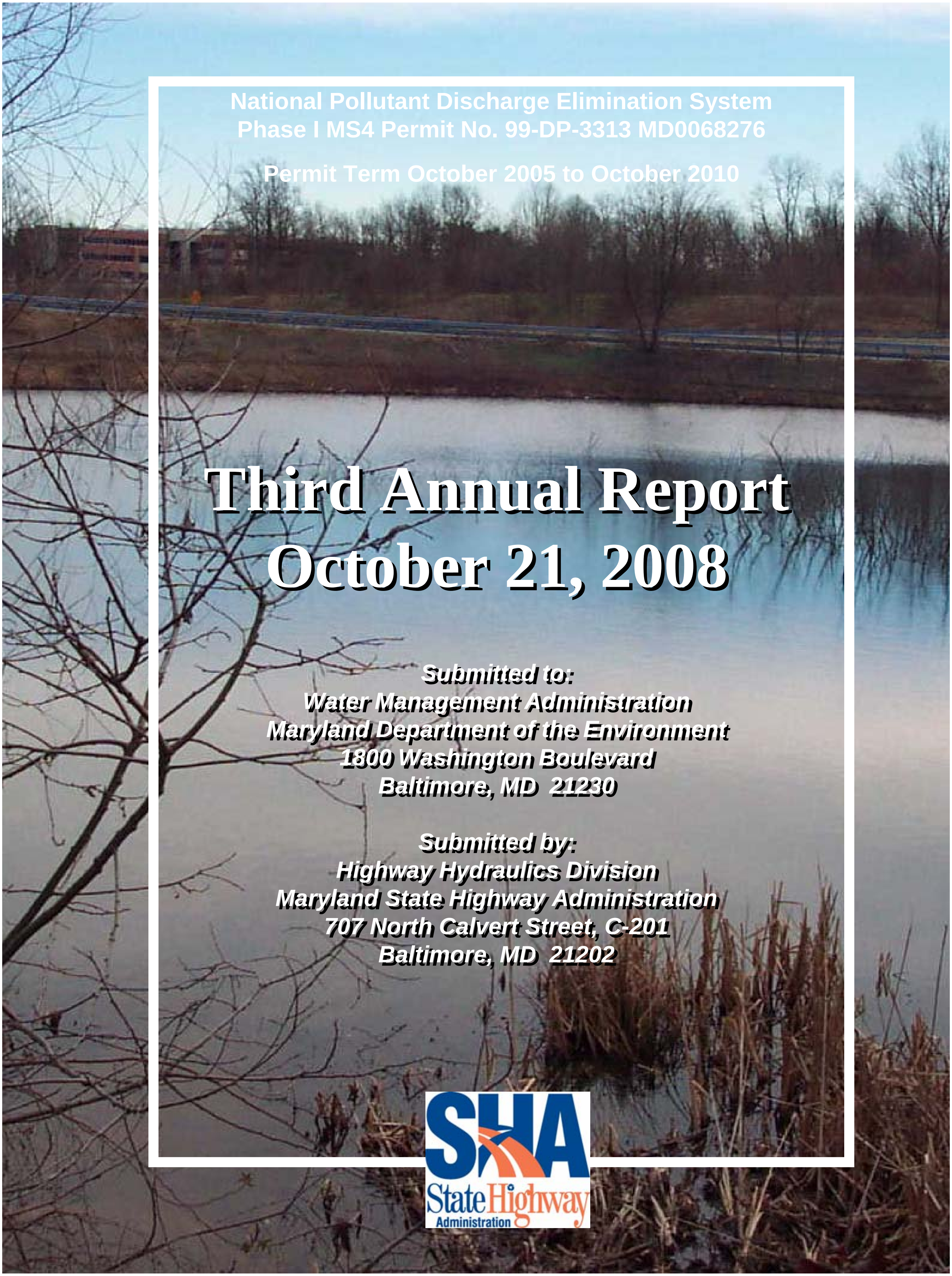

National Pollutant Discharge Elimination System
Phase I MS4 Permit No. 99-DP-3313 MD0068276

Permit Term October 2005 to October 2010

Third Annual Report
October 21, 2008

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

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

State Highway Administration
Maryland Department of Transportation

John D. Porcari, *Secretary*
Neil J. Pedersen, *Administrator*

October 21, 2008

RE: Third Annual NPDES MS4 Phase I Report
Permit Term: 10/2005 to 10/2010
Permit No.: 99-DP-3313 MD0068276

Mr. Brian Clevenger
Sediment, Stormwater and Dam Safety Program
Water Management Administration
Maryland Department of the Environment
1800 Washington Blvd., Suite 440
Baltimore, MD 21230-1708

Dear Mr. ~~Clevenger~~: Brian

We are pleased to submit this annual report for the third year of the current NPDES Phase I MS4 permit. This work represents the commitment and hard work of many individuals within our organization and the consultant community. It also represents the SHA commitment to an environmental ethic within our organization as we seek not only to remain in compliance with this important program and permit, but to further efforts to restore Maryland's waterways and the Chesapeake Bay.

We look forward to the coming year and continued growth of our program as well as the partnership between our two agencies. Should you have questions or require additional information, please contact me at (410) 545-8390 or our NPDES coordinator, Ms. Karen Coffman, at (410) 545-8407.

Sincerely,

Karuna

Karuna Pujara, Chief
Highway Hydraulics Division

KP/KC

CC: Ms. Dana Havlik
Mr. Brandon Scott
Mr. Michael Stewart

Phase I National Pollutant Discharge Elimination System
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Executive Summary

The Maryland State Highway Administration (SHA) is submitting this third annual report 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 2007 to September 2008. 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.

Source Identification – Work on the last two Phase I counties, Carroll and Charles, was completed. This completes our source identification requirement for this permit term, a full year prior to the deadline. Work also continues on our NPDES GIS viewer tool that will enable all users to access the data. Impervious accounting efforts also continue with four more counties completed, Anne Arundel, Carroll, Frederick and Montgomery.

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. We have extended the grass swale study for another year. 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 looks at the functioning of infiltration facilities that have transitioned to wetlands in terms of quality and quantity stormwater treatment.

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 regulations, we have continued to measure our performance in areas of erosion and sediment control during construction. We are also continuing to work towards our internal business goal of maximizing the number of functionally adequate stormwater facilities statewide.

Our many training programs have been augmented with several new initiates including an environmental ethic project that has been undertaken by the Advanced Leadership Program Class of 2009. This project seeks to instill an environmental ethic within SHA both organizationally and for individual employees. Other new initiatives include the formation of a high-level environmental advisory committee that meets with SHA senior managers several times a yea, a new SHA Recycles campaign and participation in the annual SHA Performance Excellence Training Conference (PETC).

Another important initiative is a pilot to place the operations and maintenance responsibilities for permanent stormwater management facilities with a private company. A design build operations and maintenance (DBOM) contract was let for bid for facilities within Charles County.

Watershed Assessment – Coordination with local NPDES jurisdictions continues. We are also moving forward with water quality sites within the Patuxent River Watershed. In partnership with the Green Highways Partnership and the Conservation Fund's Green Infrastructure Initiative, we have developed a stormwater watershed study for the US 301 project that seeks to predict water quality affects of the proposed alternates on sensitive watersheds in Prince George's and Charles Counties. Work continues on the EPA Green Highway grant in developing an implementation framework for watershed-based stormwater design within SHA.

Watershed Restoration – Of the fifty-two retrofit sites SHA has developed, ten have been completed, twenty-eight are in construction and fourteen are in design. Overall, 453 acres of impervious surfaces are treated by these retrofit projects that include upgrading stormwater facilities and stream stabilization or restoration efforts.

Assessment of Controls – Despite unwavering support from the City of Gaithersburg and the local community, the Long Draught Branch stream restoration project had to be cancelled because we were unable to obtain support from various environmental agencies. A detail of events and the final monitoring report are included. We have replaced this effort with the infiltration basin transitional study mentioned under discharge characterization, above.

Program Funding – Our NPDES program remains a fully funded.

Total Maximum Daily Loads – By remaining in compliance with this permit, SHA is controlling stormwater pollution to the maximum extent practicable. SHA is also developing an implementation strategy to address inclusion of pollutant loadings and waste load reductions into future permit requirements.

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 1-1
- B Legal Authority 1-1
- C Source Identification 1-1
- D Discharge Characterization 1-10
- E Management Program 1-13
- F Watershed Assessment 1-32
- G Watershed Restoration 1-34
- H Assessment of Controls 1-38
- I Program Funding 1-47
- J Total Maximum Daily Loads 1-47

Part 2 **Special Programmatic Condition and Response 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 3-8
- 3.4 Other Topics 3-16
- 3.5 Summary 3-17

Appendix A *Draft* SHA Standard Procedures Chapter 2: Source Identification & Inventory A-1
Appendix B ***Draft*** SHA Standard Procedures Chapter 5: Illicit Discharge Detection and Elimination Procedures B-1
Appendix C ***Draft*** SHA Standard Procedures Chapter 6: Data Management C-1
Appendix D Impervious Layers (FR, AA, MO, CL, CH) D-1
Appendix E Grassed Swale Pollutant Removal Efficiency Studies – Part III (Progress Report). E-1
Appendix F Underground Stormwater Management Thermal Mitigation Studies (Progress Report) F-1
Appendix G SOIRP Remediation Sites G-1
Appendix H Illicit Discharge Screening Reports H-1
Appendix I Long Draught Branch Stream Restoration Monitoring Plan I-1
Appendix J Industrial NPDES Capital Improvement Summary J-1
Appendix K *Draft* SHA Standard Procedures Chapter 7: Best Management Practice Assessment Guidelines for Maintenance and Remediation K-1
Appendix L ALP Environmental Survey L-1
Appendix M Long Draught Branch Alternative Analysis and Correspondence M-1

CD Report PDF Files, BMP Enhancement Project Documents, Databases

List of Figures

Figure **Page Number**

1-1 Organizational Chart for NPDES Permit Administration.. 1-2
1-2 Source Identification and GIS Development Status 1-3
1-3 SHA-Owned Impervious Surface Treatment in 8 NPDES Counties........................ 1-8
1-4 Rooting Depths of Various Native Grasses 1-10
1-5 Average ESC QA Inspections.. 1-15
1-6 Annual Earth Day Exhibit from Highway Hydraulics Division............................. 1-27
1-7 HHD Performance Excellence Training Conference Exhibit................................. 1-30
1-8 Long Draught Branch Project and SHA Owned BMPs within Seneca Creek Segment.. 1-39
1-9 Long Draught Branch Concept Reforestation and Planting Design 1-39
1-10 Lond Draught Branch Failed In-Stream Dam (Constructed 1972)......................... 1-44
1-11 SHA Roadway Functional Classifications by NPDES County 1-49

3-1 Stormwater Management Facilities Inspection and Remediation Program.............. 3-7
3-2 BMP 15313 3-9
3-3 BMP 13007 3-9
3-4 BMP 13007 3-9
3-5 Infiltration Trench Investigation along MD 43.. 3-11
3-6 Infiltration Trench Remediation along MD 43 3-11
3-7 Functional Enhancement of Infiltration Basins at US 50 3-13
3-8 BMP 2273 3-14
3-9 BMP 2481 3-14
3-10 BMP2522 3-14
3-11 SWM Functional Upgrades at I-97 3-15
3-12 BMP Inspections... 3-17
3-13 BMP Viewer Screen Captures 3-17
3-14 Progress in SWM Facility Program Progress 3-18

List of Tables

Table		Page Number
1-1	NPDES GIS Viewer Development Progress	1-5
1-2	Source Identification Update Schedule	1-6
1-3	SHA Impervious Accounting	1-9
1-4	ESC Training Held by SHA (10/2007 to 9/2008)	1-17
1-5	Winter Materials Used by SHA	1-19
1-6	Industrial NPDES Permit Status	1-22
1-7	Capital Expenditures for Pollution Prevention BMPs	1-22
1-8	Outfall Inspection Ratings	1-23
1-9	Harford County Outfall Stabilization Project (HA3565174)	1-24
1-10	Baltimore County Outfall Stabilization Project	1-24
1-11	Illicit Discharge Screenings	1-25
1-12	Adopt-A-Highway Program	1-27
1-13	Sponsor-A-Highway Program	1-27
1-14	Partnership Planting Program	1-28
1-15	2008 Pesticide Training	1-30
1-16	Environmental Permits Tour	1-31
1-17	Watershed Retrofit Projects	1-35
1-18	Capital Expenditures for NPDES at SHA	1-47
3-1	Current Statewide SWM Facility Inventory Summary	3-2
3-2	SWM Facilities Remedial Ratings Summary by County	3-3
3-3	Minor Maintenance Summary	3-8
3-4	Minor Maintenance Cost Year 2007/2008	3-9
3-5	BMP Major Maintenance Summary	3-10
3-6	Major Maintenance Cost Year 2007/2008	3-10
3-7	BMP Enhancement and SWM Remedial Projects Summary	3-12
3-8	SWM Functional Upgrades in Anne Arundel County	3-15

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.

This is the third annual report for the re-issued permit. Part One of the report 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.

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.

Ms. Karen Coffman
SHA NPDES Coordinator
Highway Hydraulics Division
(410) 545-8407
kcoffman@sha.state.md.us

NPDES Industrial Permits and associated activities are coordinated by:

Ms. Sonal Sanghavi
Director
Office of Environmental Design
(410) 545-8640
ssanghavi@sha.state.md.us

B Legal Authority

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

C Source Identification

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.

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. 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.

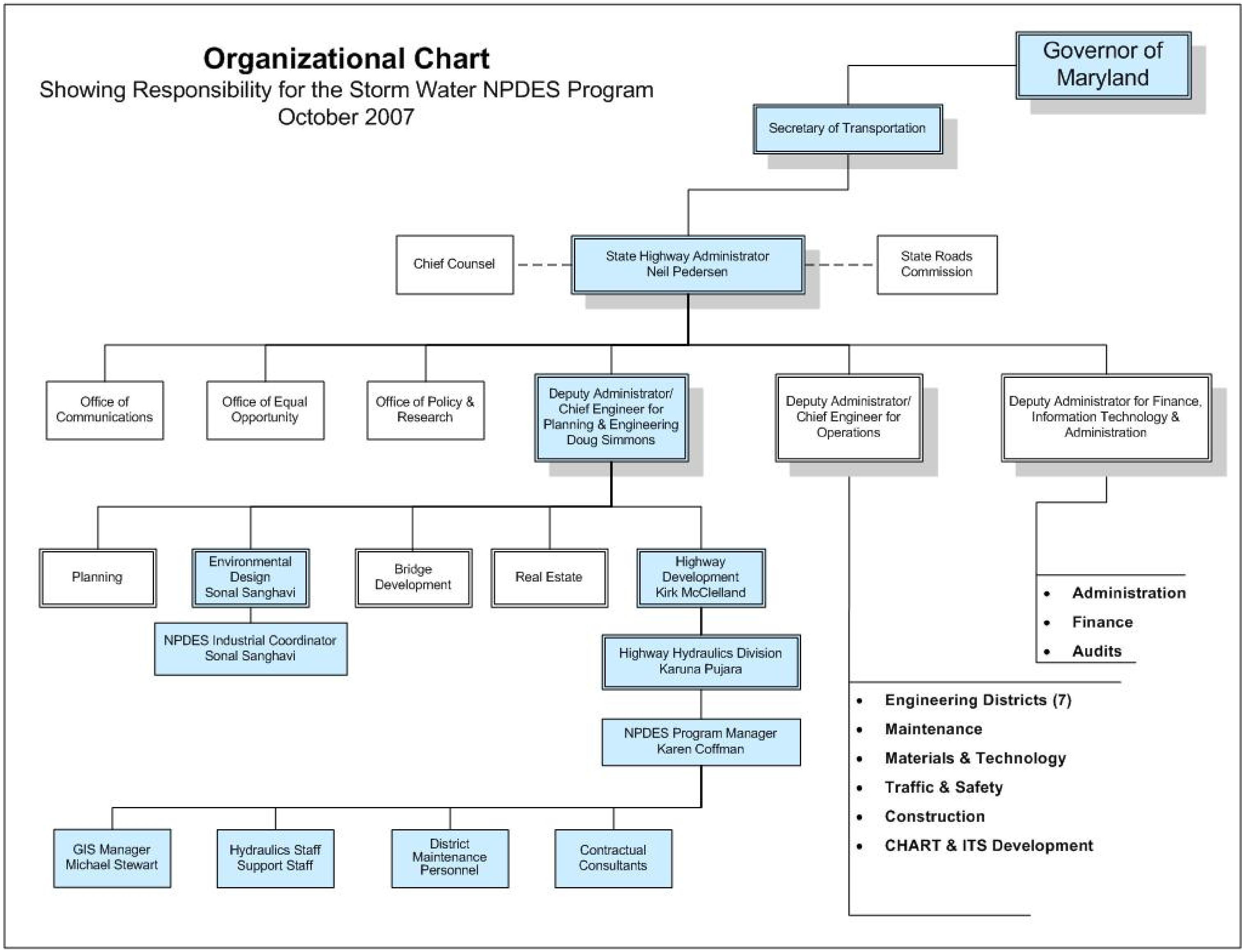


Figure 1-1 Organizational Chart for NPDES Permit Administration

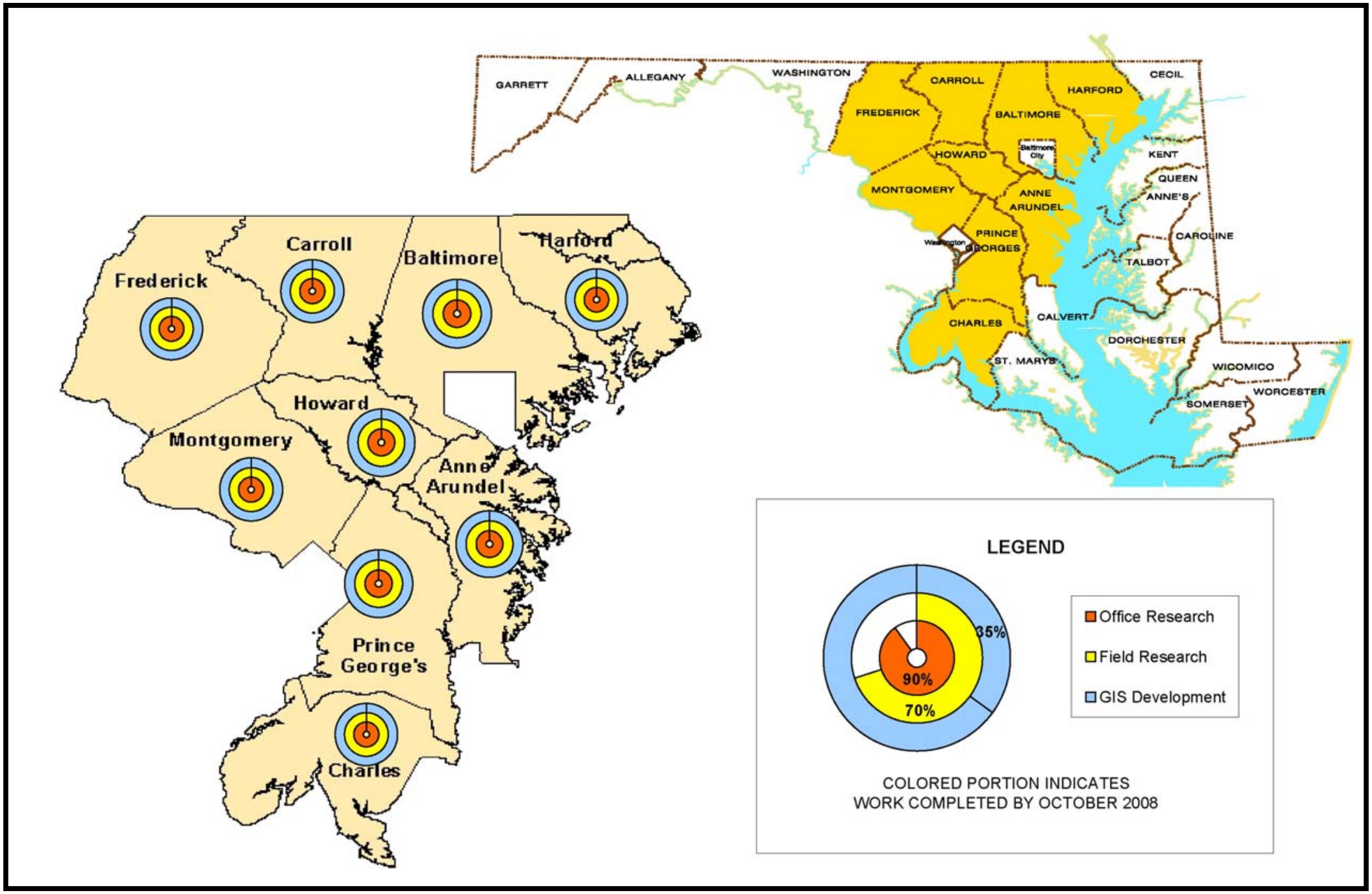


Figure 1-2 Source Identification and GIS Development Status – 100 % Complete

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 has completed the identification and GIS development for our storm drain systems and stormwater management facilities, well before the October 21, 2009 deadline. Figure 1-2 summarizes the status of the source identification effort by SHA. Specific information for Carroll and Charles county efforts is included below. Information on source ID updates for the remaining counties is included under section C.1.c, Update Source ID Data.

Carroll County – The GIS development for this county was completed in May 2008. The number of post-construction stormwater facilities identified is 41. The number of major outfalls for illicit discharge screening is 104.

Phase of Source ID	% Complete
Office Research	100
Field Research	100
GIS Development	100

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.

Phase of Source ID	% Complete
Office Research	100
Field Research	100
GIS Development	100

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 the 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.

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. Draft documentation for the update process and user guides for the applications can be found in Appendix C.

NPDES GIS Viewer Application

A GIS viewer application tool is being developed to utilize the power of the enterprise GIS server and allow SHA to manage these assets effectively. It will consist of a number of modules and is being developed, a module at a time, according to the list below. Table 1-1 lists percent complete for each module.

- **GIS Viewer** – 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 GIS data as well as manage updates. 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.
- **BMP Numbering Module** – facilitates generating and maintaining unique BMP numbers in a secure, automated manner. Unique BMP numbers are generated individually or en-mass 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 the impervious accounting by SHA district and 6-digit watersheds and facilitates updating impervious layers as new projects and stormwater management facilities are built.
- **Outfall & Storm Drain Inspection & Remediation (SOIRP) Program Module** – facilitates the management of the storm drain and outfall inspection data, maintenance, remediation or enhancements.

Table 1-1 NPDES GIS Viewer Development Progress

Phase of Development	% Complete
NPDES GIS Viewer Platform	80
SWM Program Module	5
BMP Numbering Module	80
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

The focus over the last year was to update the source identification (Chapter 2), and illicit discharge, detection and elimination standards (Chapter 5). We also focused on beginning to draft the data management standards (Chapter 6) and the BMP remediation standards (Chapter 7). Drafts of each of these chapters are included in the appendices.

GIS Development Workshops

Over the last year upgraded our workshops for training our GIS developers and inspectors on SHA NPDES GIS standards and MS4 permit conditions. Our next step in improving the training is to develop self-training tools that will enable the field and office personnel to view training material on their own without the need for formal workshops.

The modules that have been developed include:

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

Workshops were held February 27 and 28, 2008 that included source identification and GIS data management. Workshops were held December 11 and 12, 2007 for IDDE field training, outfall stability and stormwater BMP inspections.

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. Source identification updates are performed on completed counties every three years or once the maintenance and remediation efforts are complete. Additional storm drain infrastructure and BMPs are identified and added to the databases. Future updates will be performed according to Table 1-2. The following county database updates are in progress:

- Prince George's,
- Anne Arundel.

Table 1-2. Source ID Update Schedule

County	Source ID Complete	1st Update	2nd Update
Howard	**01/2001-C**	**01/2005-C**	*11/2008*
Montgomery	**01/2001-C**	**09/2006-C**	*09/2009*
Anne Arundel	**08/2003-C**	**8/2008-I**	
Prince George's	**03/2003-C**	**9/2008-I**	
Baltimore	**03/2004-C**	*11/2008*	
Harford	**08/2005-C**	*01/2009*	
Frederick	**09/2006-C**	*09/2009*	
Carroll	**05/2008-C**		
Charles	**06/2008-C**		

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

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

Howard County - The initial 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. The current number of post-construction BMPs identified for this county is 247. Number of major outfalls for illicit discharge screenings is 153.

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 267. 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	98
Field Research	5
GIS Development	1

The completed updated GIS development is anticipated by December 2009.

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	98
Field Research	1
GIS Development	1

The completed updated GIS development is anticipated by October 2009.

Baltimore County – The inventory, database and GIS model of drainage features were completed in March 2004. The current number of post-construction BMPs identified for this county is 167. Number of major outfalls for illicit discharge screenings is 262.

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 109. 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 75. 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 41. 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 Charles and Carroll counties were included in the 2007 report and examples for the other counties was included in the 2006 report.. Since examples of our data for the nine counties have been delivered previously, no examples of source data are included in this report.

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 focused our efforts over the last year on implementing the impervious area accounting process using Feature Analyst. Of the nine NPDES Phase I MS4 counties, all have been completed with the exception of Prince George's county. Prince George's county is anticipated to be completed in May 2009.

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. One county remains to be processed.
5. **Implementation –** Impervious surface layers are currently being developed. See discussion below.
6. **Annual Reporting –** We have provided information here to track our progress.

Impervious Layers

IN 2007, we reported the completion of four of the nine impervious surface layers: Charles, Howard, Harford, and Baltimore. This year, we have developed an additional four layers: Anne Arundel, Frederick, Carroll and Montgomery. Maps of the new layers are included in Appendix D. We also included a map of the Charles county layer with BMP drainage areas since the map in the 2007 report did not have the drainage areas delineated. Prince George's county is under development.

We have also determined the amount of impervious being treated by stormwater management structural facilities for the completed counties. Pavement being treated by grass swales or other non-structural measures are not accounted for at this time. Because these layers are generated through a process that reads the photogrammetry, there are inaccuracies. But as a general quantity representing the amount SHA owns within an entire county, we feel it is a good estimate.

Figure 1-3, below illustrates the relationship between SHA impervious surfaces along with the amount that is being treated by structural stormwater BMPs. Table 1-3 lists the actual accounting numbers and percentages associated with each county.

The challenge is to keep the impervious layers and BMP treatment accounting updated as new impervious areas and stormwater management facilities are built.

Impervious Accounting Protocol

The impervious accounting protocol is the methodology for developing impervious surface layers and then accounting for the stormwater treatment of the various categories of impervious surfaces that SHA deals with. A draft protocol has been developed and was included in the 2007 report.

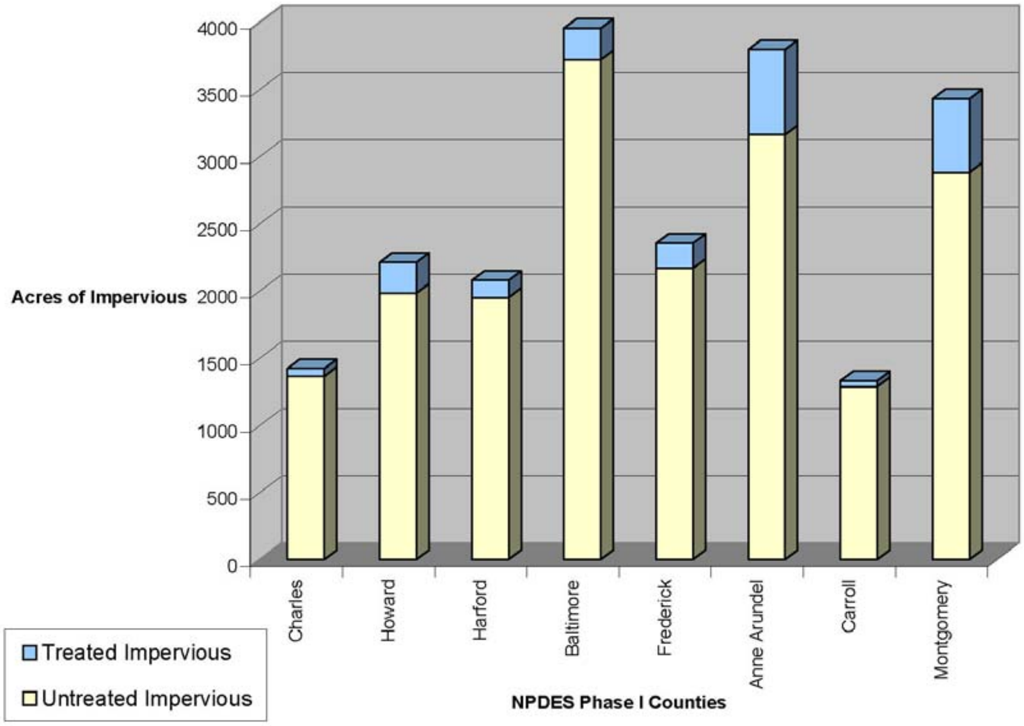


Figure 1-3 SHA-Owned Impervious Surface Treatment in 8 NPDES Counties

Table 1-3. SHA Impervious Accounting

County	Untreated SHA Impervious (AC)	Treated SHA Impervious (AC)	Total SHA Impervious in County (AC)	Percent SHA Impervious Treated
Charles	1364	57	1421	4.2%
Howard	1982	229	2211	11.6%
Harford	1949	129	2078	6.6%
Baltimore	3718	236	3954	6.3%
Frederick	2166	187	2353	8.6%
Anne Arundel	3162	633	3796	20%
Carroll	1286	44	1330	3.4%
Montgomery	2882	546	3428	18.9%
Prince George's	-	-	-	-

Note: Numbers current to 10/2008. Treatment is by structural BMPs.

The procedure for importing new impervious surface information from Microstation CADD files to the GIS layers is under development. Once complete and implemented, this process will allow us to track our progress in treating stormwater runoff from impervious surfaces without having to rerun the Feature Analyst models repeatedly.

The final protocol will address these remaining issues:

- **Define 'Stormwater Treatment' –** This issue seeks to tie down what is meant by stormwater treatment and the types of BMPs that are recognized as providing treatment. Specifically the questions of structural versus non-structural BMPs and water quality versus quantity will be addressed.

  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 1-3 or Table 1-3.)

  7. Non-SHA Impervious Treated by SHA BMP. (Not shown on Figure 1-3 or Table 1-3.)
     a. SHA Structural BMP Treatment
     b. SHA Non-Structural Treatment

  8. SHA Impervious Treated by Others (Not shown on Figure 1-3 or Table 1-3.)
     a. Other Structural BMP Treatment
     b. Other Non-structural BMP Treatment

- **Integrate into Water Quality Bank –** Impervious accounting will be integrated with tools developed to track the current SHA/MDE water quality banking agreement and process.

- **Standard Accounting Procedures –** This entails anticipating all contingencies and identifying methods to address them. An example of a contingency that falls outside the defined standard condition is acres of non-SHA owned impervious area treated by SHA BMPs and SHA requests that credit be allowed to offset SHA impervious that is not treated. Another would be SHA impervious that is treated by a facility owned by another entity.

- **Quality Assurance –** Develop quality assurance mechanisms.

- **User Documentation –** Develop process, database and GIS user documentation.

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 III.* 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 E.

  We encountered several problems with sustaining the grasses. Because the grasses have not had adequate time for their roots to establish, we are extending this study into summer 2009. We think this will give a better understanding of the affects the grasses have on the water quality removal capabilities of these grass swales.

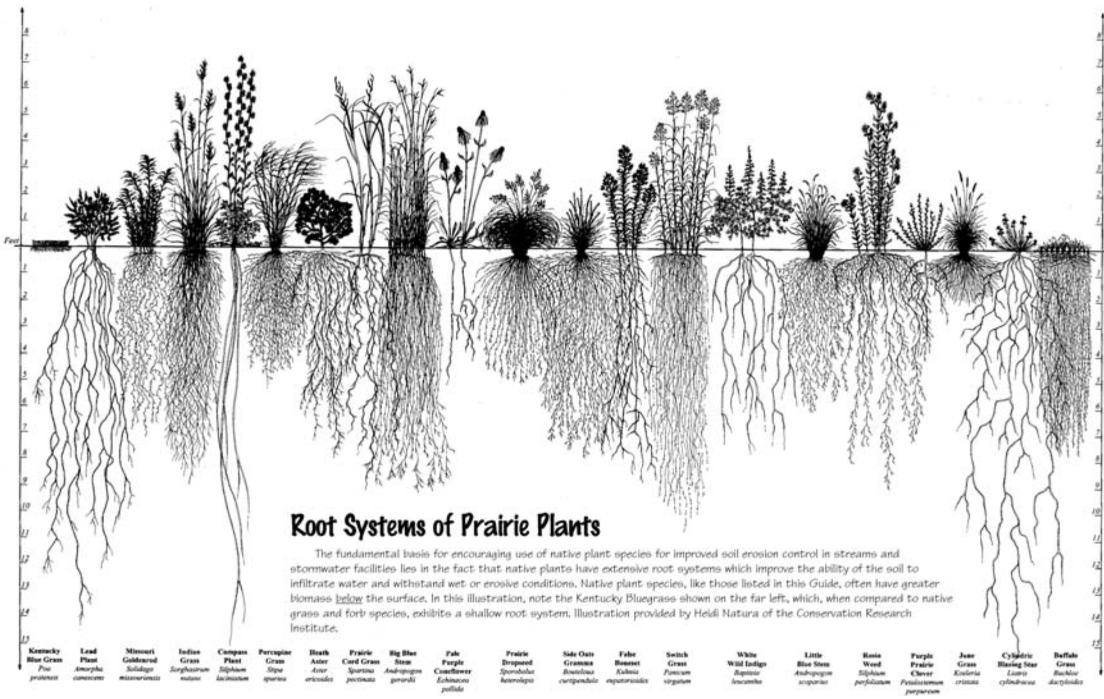


Figure 1-4 Rooting Depths of Various Native Grasses

Two new studies are being undertaken.

- *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.

  Because this study was recently initiated, no progress report is included at this time.

- *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.

As the Stormwater Act of 2007 encourages Environmental Site Design (ESD), it can be expected that use of infiltration trenches and basins may increase. Because this study was recently initiated, no progress report is included at this time.

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* – A progress report is provided was as Appendix F of the 2007 report. 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:

Highway Runoff Discharge Characterization

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

Stormwater Best Management Practices

- *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.

Deicing Materials

- *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.

Total Maximum Daily Loads

- *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.

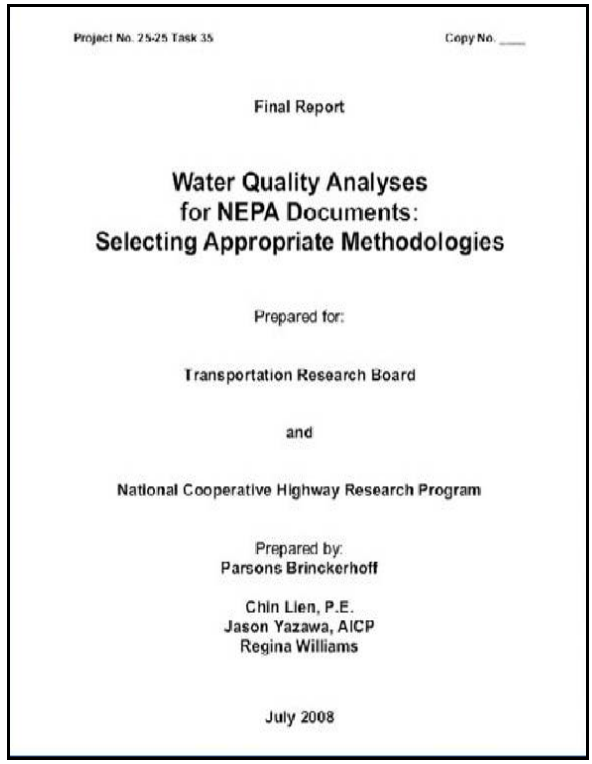
Illicit Discharges

- *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.

Watershed-Based Strategies

- New! *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.

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

The Maryland State Highway Administration has a strong environmental commitment that will only increase as the new Stormwater Management Act of 2007 is implemented. Through this legislation, emphasis will be placed on the use of environmental site design (ESD) techniques. We are actively participating in focus groups organized to develop regulations and guidelines for implementing this law.

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.

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 is also pursuing research and development studies to improve our understanding of the impacts certain BMPs have on the environment. The current study is:

- *Thermal Impact of Underground Stormwater Management Storage Facilities on Highway Stormwater Runoff* – The goal of the study is to identify and document the thermal reduction effects on stormwater in underground storage facilities. Three sites have been identified and monitoring equipment has been installed at two of the sites along I-83 in Baltimore County. Instrumentation has been installed to measure temperature at the inflow and outflow. Development of a predictive model will be investigated. Additional information for this study will be provided as it progresses. A progress report is included in Appendix F.

Completed Studies by SHA

- *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 or 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

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 *1994 Standards and Specifications for Soil Erosion* for all projects. We also comply with Federal NPDES construction ESC requirements by continuing to submit Notification of Intent (NOI) forms to MDE for all projects that disturb one acre or greater and by posting the resulting NPDES Construction Permits at construction sites.

SHA has partnered with MDE in developing the revised details and revisions to the ESC standards document. We are actively providing technical and CADD support and envision publication in 2009 or 2010 for these revised standards.

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.

SHA tracks QA inspections and ratings for reporting to our business plan (see Figure 1-5). Increased numbers of inspections and better documentation have improved the overall performance of our ESC program. 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.

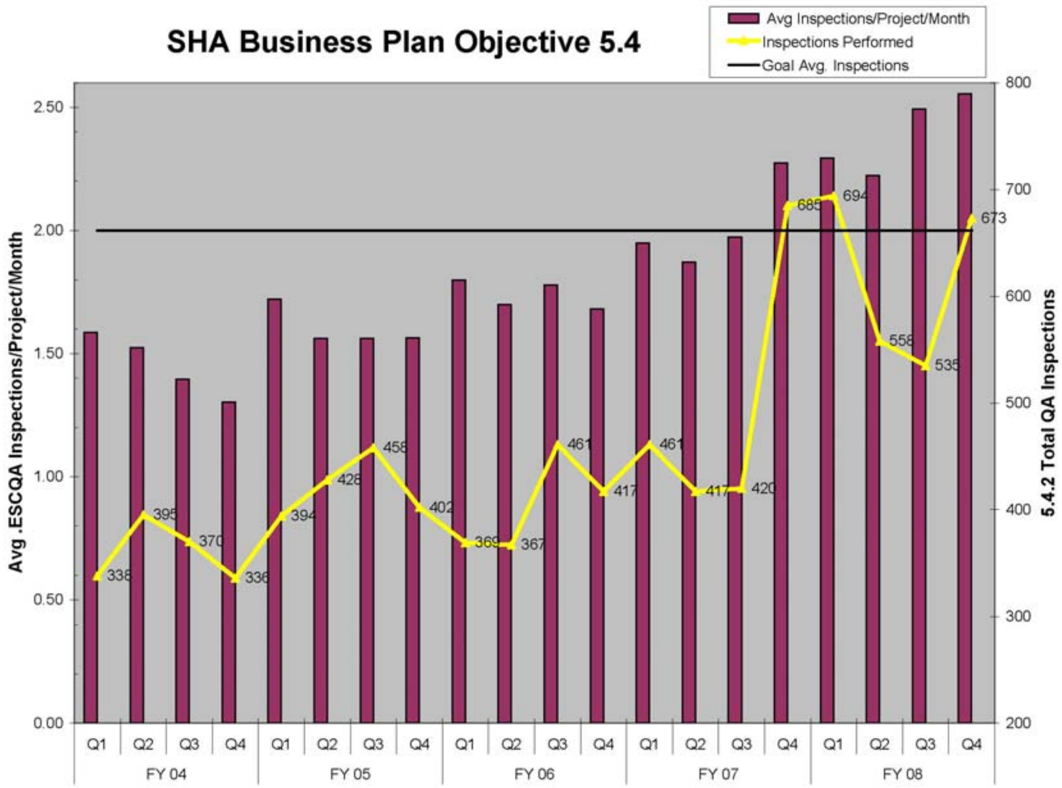


Figure 1-5 Average ESC QA Inspections

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.

Poor Turf Establishment Increases Erosion

Quality Turf Improves Soil Retention

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

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 manner that is easy to access and carry.

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.

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 and course material has been developed. The Level II training began in June 2007.

Table 1-5 ESC Training Held by SHA (10/2007 to 9/2008)

Type of Training	No. of Participants
Responsible Personnel (Green Card)	763
BEST Level I (Yellow Card)	542
BEST Level II (Designer's Training)	65

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.

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.

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.

SHA sweeping standard is to ensure 95% of the traveled roadway is clear of loose material, with less than 1 inch in depth along curb and gutter of closed sections of roadways. In addition, our standard is also to ensure 90% of buildup of lose material along open sections of roadways does not exceed 1 ½ inches in depth along the shoulder.

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.

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 1-5 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)	One of the primary liquid winter materials used by SHA for deicing operations. Freeze point of -26° F and proven cost-effective in the colder regions (northern and western counties).
Caliber M-100	Magnesium chloride based deicer with a corrosion inhibiting additive.
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 previous annual reports, SHA has initiated the development and implementation of a Compliance Focused Environmental Management System (CFEMS). SHA continues to proceed with implementing elements of the CFEMS and has recently initiated a statewide training effort covering a variety of media areas including stormwater management. This effort will cover 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.

The CFEMS is being developed and implemented in a phased approach and will span a five-year period. The initial phase of environmental assessments at SHA's primary maintenance facilities was completed in the spring of 2007. In addition to the initial assessments, SHA's Environmental Compliance Division (ECD) has implemented a routine inspection program that began in May 2008. Compliance inspections covering all media areas are conducted at each primary maintenance facility on a weekly basis by facility personnel and on a monthly basis by SHA's District Environmental Coordinators (DEC). The DECs work directly for SHA's ECD and 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. Additional capital improvements that relate to stormwater pollution prevention will likely emerge from the CFEMS development efforts described above. SHA's Environmental Compliance Division 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 the Environmental Compliance Division to insure pollution prevention and permit requirements are being met at SHA maintenance facilities. As stated in the previous annual report, SHA performed detailed site assessments at maintenance facilities covered under an Industrial Discharge Permit in 2001 and 2005. Information gathered during these site assessments was used to prepare (2001) and update (2005) Stormwater Pollution Prevention Plans (SWPPP) and Spill Prevention, Control, and Countermeasure Plans (SPCCP) (2005).

SHA initiated work in 2006 to upgrade both the SWPPPs and SPCCPs; pilot assessments and plans were development for the Frederick maintenance facility. SHA has recently completed draft versions of SPCCPs for the 15 primary maintenance facilities that exceed the above ground petroleum product storage threshold and has initiated the update of all SWPPPs Statewide. Updates for both SPCCPs and SWPPPs will be completed by February 2009.

SHA continued to develop BMPs by designing and implementing capital improvements. BMPs are identified as work progresses towards updating relevant pollution prevention plans and routine inspections continue to provide valuable data. Appendix J summarizes the status of BMP implementation for maintenance facilities Statewide. The following list details the major pollution prevention efforts and maintenance facility improvements since the last annual report.

Completed Projects:

- Washbay treatment system upgrade completed for Leonardtown maintenance facility
- Draft SPCCPs completed at 15 primary maintenance facilities
- Sewer connection for Hanover Complex vehicle maintenance and wash bays advertised
- Stormwater management BMP re-inspections completed for all maintenance facilities
- Battery Storage / Spill Kit procurement complete for primary maintenance facilities
- Re-vegetation test plots assessed, now implementing remediation phase of salt contamination issue at Stevensville satellite maintenance facility
- Stormwater management retrofit design complete for the Glen Burnie maintenance facility
- UST inspection / inventory completed for maintenance facilities with vehicle fueling stations

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 primary maintenance facilities on a weekly and monthly basis
- Erosion control design for eroded area at Annapolis maintenance facility

Initiated Projects:

- SWPPP updates initiated Statewide
- Wetland / waterway delineations ongoing at primary maintenance facilities
- Multimedia training initiated Statewide
- Grit Chamber assessment and upgrade design at Prince Frederick and Marlboro maintenance facilities
- Oil/water separator upgrade evaluation Statewide
- Re-vegetation test plots constructed as the initial phase of salt contamination remediation for Stevensville maintenance facility.
- Stormwater management retrofit design complete for the Glen Burnie maintenance facility.
- UST inspection / inventory completed for maintenance facilities with vehicle fueling stations.

On-Going Projects:

- Statewide oil-water separator maintenance program.
- Statewide discharge sampling and reporting program for facilities with Individual Discharge Permits.

Initiated Projects:

- Stormwater management BMP re-inspections underway for maintenance facilities
- Battery Storage/Spill Kit procurement underway at maintenance facilities.
- 3rd round of SWPPP updates / Statewide Shop Improvement Plan under development.
- Washbay treatment system upgrade desing underway at Hereford maintenance facility.
- Erosion control design for eroded area at Annapolis maintenance facility.
- Grit Chamber assessment and upgrade design at Prince Frederick and Marlboro maintenance facilities.

Table 1-6 Industrial NPDES Permit Status

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

Note: SW = Surface Water, GW = Groundwater

Table 1-7 shows SHA's capital expenditures towards industrial pollution prevention BMPs from the current and past four fiscal years.

Table 1-7 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	$ 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. As discussed in the previous annual report, the Illicit Discharge Detection and Elimination inspections are now handled as a separate entity in the NPDES Program (see Section E.5.c).

As part of the source identification training and workshops (see Section C.1.b, Data Compatibility) there are now separate chapters for the IDDE and the SOIRP inspections in the NPDES Standard Procedures manual. We have also developed distinct training modules for each of these programs.

Inspections for the SOIRP program will result in developing strategies for maintaining, repairing or otherwise remediating storm drain and outfall stabilization projects. The resulting remediation actions can be constructed through our open-end construction contracts, transportation enhancement fund projects or advertised projects.

The inspection standards for illicit discharge, detection and elimination have been developed as draft Chapter 5 that is included as Appendix B. The workshop module incorporates video clips of acquired from EPA demonstrating field procedures for illicit discharge screenings and sampling.

As mentioned above under Section C.1.b, Data Compatibility, SHA will be investigating converting our training modules into self-learning tools.

Table 1-8 Outfall Inspection Ratings

	Outfall Inspection Ratings							
County	**No Rating**	**1**	**2**	**3**	**4**	**5**	**Total Inspected**	**Number of Pipes**
Montgomery[2]	356	682	8	19	22	3	1,090	16,589
Frederick	1,079	2,894	340	161	139	12	4,625	9,092
Baltimore[1]	672	1,652	38	23	24	2	2,411	14,306
Harford	103	277	291	130	46	5	852	4,140
Howard	373	287	138	119	14	1	932	3,980
Charles[3]	3	36	4	3	1	2	49	7,380
Carroll[3]	141	1,293	143	117	71	23	1,788	4,629
Anne Arundel[4]	-	-	-	-	-	-	-	8,073
Prince George's[4]	-	-	-	-	-	-	-	14,916
Totals	**2,727**	**7,121**	**962**	**572**	**317**	**48**	**11,747**	**83,105**

Notes:
1. The outfall inspection program began halfway through the Baltimore Co. MS4 inventory and inspections. Therefore, approximately 50% of the pipes and outfalls were inspected for Baltimore Co.
2. Outfall inspections performed on pipes in Montgomery Co. addressed updates only, not all possible pipes.
3. Numbers for Charles and Carroll Counties have been updated since the last annual report.
4. PG and AA county updates are in progress. This information is not yet available.

Table 1-9 Harfard County Outfall Stabilization Project HA3565174

Map No.	Location	Pipe Size
7	MD 543 Approximately 45' North of Old Pylesville Road	18" CMP
32	MD 543 Approximately 420' Southeast of Doyle Road	18" CMP
25	MD 543 Approximately 820' Southwest of Chestnut Hill Road	15" CMP
26	MD 136 350' Southeast of Poplar Grove Road	18" CMP
22	MD 136 150' North of E Medical Hall Road	18" CMP
16	MD 146 @ MD 152	30" RCP
19	MD 136 Approximately 100' West of Carea Rd.	12" RCP
21	MD 136 - 500' North of MD 543	12" PVC
37	MD 924 100' South of Victory Lane	30" CMP
5	MD 165 Approximately 4000' West of Rocks Road	24" CMP
6	MD 165 300' Northwest of Old Pylesville Road	30" RCP
8	MD 165 Approximately 1200' North of Ady Road	30" RCP
40	MD 156 Approximately 2165' Southwest of Timothy Road	12" CMP
43	MD 646 Approximately 730' South of Whiteford Road	36" RCP
44	MD 646 Approximately 1300' Northeast of Bay Drive	18" RCP
9	US 40 Approximately 1200' Northeast of Old Post Split	15" CMP
51	US 40 Approximately 4000' Southwest of Otter Point Road	24" RCP
49	US 40 Approximately 640' Northeast of Long Bar Harbor Road	18" RCP
48	US 40 Approximately 1000' Southwest of Spesutia Road	15" RCP
50	US 40 Southwest of Otsego Street	18" RCP

Note: For map numbers, see Appendix G

Table 1-10 Baltimore County Outfall Stabilization Project (Construction Contract Number TBD)

Map No.	Location	Pipe Size
8	I-83 SBL at Baltimore City/County line	24" RCP
9	US 1 at 695 Ramp	24" RCP
13	MD41	18" RCP
17	I-695/ I-95 Interchange	18" CMP
19	MD41 north of Satyr Hill Rd.	30" CMP

Note: For map numbers, see Appendix G.

E.5.b Document each Outfall's Attributes

SOIRP outfall inspections have been conducted on the outfalls in Carroll and Charles Counties and the ratings have been evaluated. Also, Anne Arundel and Prince George's County updates are in progress.

Inspections using the SHA SOIRP Program outfall inspection protocol were previously conducted on seven of the counties listed in Table 1-8, 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. Maps of the 20 sites in Baltimore County and 52 sites in Harford County that are being targeted along with a list of the sites are included in Appendix G. The current plan is for SHA to construct a select number of repairs in Baltimore County as an advertised construction contract. The method of construction for the Harford County sites will be determined once a more defined scope is generated for the sites. SHA has initiated the evaluation and design phase for 20 poorly rated sites in Harford County.

Failed Pipe Outfall at Site 43 in Harford County

Failed Outfall at Site 43 in Harford County

E.5.c Illicit Connection Investigations

During the last reporting period, Charles and Carroll county storm drain systems were evaluated for illicit discharges. There was one report generated for Carroll County that contained seven suspected illicit connections. This report was forwarded to Carroll county NPDES coordinator for follow up. The Carroll county report is attached as Appendix H.

Charles county investigations resulted in no suspected illicit discharge connections being identified and therefore, no report was generated.

An Illicit Connection at MD 140 in Carroll County

E.5.d Use Appropriate Enforcement Procedures

We followed up with the findings by sending the Carroll county report to the Carroll county NPDES contact, James Slater, who agreed to follow up with the connections.

Table 1-11 below details the past and current illicit detections.

Table 1-11 Illicit Discharge Screenings

County	Outfalls Screened	Outfalls w/ Flow Observed	Illicit Discharge Reports
Frederick	39	46	16
Harford	53	16	1
Howard	209	172	2
Montgomery	217	26	3
Charles[1]	85	27	0
Carroll[1]	104	84	7
Totals	**707**	**371**	**29**

Notes: 1. GIS development was completed in these counties over the last reporting period and the current numbers are reflected in the table.

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

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

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 Sixth Annual Earth Day Celebration on Tuesday, April 24, 2008 at the SHA headquarters complex. The SHA NPDES had two exhibits in this year's event: the NPDES Program and the Erosion and Sediment Control Program. The programs participated by preparing educational exhibits and manning the booth to answer questions (see Figure 1-6). This annual event organized by the SHA Office of Environmental Design brings many groups and environmental organizations together to highlight accomplishments and initiatives being undertaken by SHA and others. Approximately 360 SHA employees and 100 students ranging from 2nd grade to high school attended the event.

  Distributing environmental literature and brochures at this event is a key method of disseminating information to the public. The Earth Day celebration was also accompanied by a clean up day on Saturday, April 5th to remove litter and manage vegetation along the Patuxent River at Governor's Bridge Road. SHA volunteers teamed up with other MDOT volunteers for the clean up. People throughout these organizations were encouraged to attend.

Figure 1-6 Annual Earth Day Exhibit from Highway Hydraulics Division

Table 1-12 Adopt-a-Highway Program

County	No. Groups Participated	Miles Adopted
Prince George's	1	25
Harford	35	75
Baltimore	73	148
Anne Arundel	10	43
Charles	9	32
Howard	6	23
Frederick	16	35
Carroll	50	52
Totals	200	433

- **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.

- **Sponsor-a-Highway Program** – SHA has launched a two-year pilot 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.

Table 1-13 Sponsor-a-Highway Programs

County	Miles for Sponsorship County	Miles Sponsored
Prince George's	78.6	30.2
Baltimore	74.2	42.7
Anne Arundel	89.3	50.8
Howard	35.6	15.5
Queen Anne's	29.2	12.0
Total Miles in Program	306.9	151.2

- **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 1-14 lists the numbers of plants, counties of participation and numbers of volunteers for the last reporting period.

Table 1-14 Partnership Planting Program

County	No. Trees/Shrubs	No. Volunteers
Charles	53	20
Frederick	15	10
Harford	172	50
Howard	100	20
Prince George's	15	15
Totals	355	115

- **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.

  There were thirteen projects in 2007, including four projects sponsored by SHA. Examples of these projects were discussed in detail in the 2007 report. For this reason, we are not including additional information here.

- **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 2008 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 statistics for these efforts through the following training programs below:

- New! **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 small wind energy pilot study was designed and stakeholder buy in was obtained. A grant was received from the Maryland Energy Administration to install a 1.7 KW wind energy system at the Westminster Maintenance Shop.

The Campaign is leading the effort with SHA Office of Administration to provide employees across the organization with networked access to SHA Duplicating Services resources to reduce paper waste and promote conservation efforts in response to the SHA Bright Ideas Program. A recycling survey was developed and is being piloted by District 5 in anticipation of statewide distribution to all SHA facility Recycling Coordinators, and subsequent outreach to all facilities.

- New! **SHA Environmental Ethic Project** – The Advanced Leadership Program (ALP) Class of 2009 was enlisted to take on the challenge of developing an SHA Environmental Ethic initiative for the State Highway Administration. An environmental awareness survey has been developed and is included in Appendix L.

- New! **Performance Excellence Training Conference (PETC) –** The Highway Hydraulics Division's (HHD) NPDES, Erosion and Sediment Control (ESC) and Stormwater Facility programs sponsored an exhibit at the SHA Performance Excellence Training Conference held December 7, 2007 in Annapolis, Maryland. This conference is held 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 HHD exhibit highlighted efforts by the ESC and BMP programs to increase performance in construction erosion and sediment control and permanent BMP asset management including: SHA ESC quality assurance inspections and ratings improvements, contractor ESC incentives and liquidated damages, SHA Basic Erosion and Sediment Training (BEST) Levels I and II training courses, accurate Limit of Disturbance (LOD) demarcation, research on coagulants and flocculants in sediment control, BMP functional adequacy business goal, improved BMP inspection criteria and procedures manual, innovative contracting (design-build-maintain) for BMP lifecycle improvements, initiation of BMP As-Built Certification process, pursuit of alternative stormwater practices such as stream restoration, implementation of stormwater site development criteria guidance and review process for improving sustainability of stormwater BMPs.

HHD PETC NPDES Exhibit

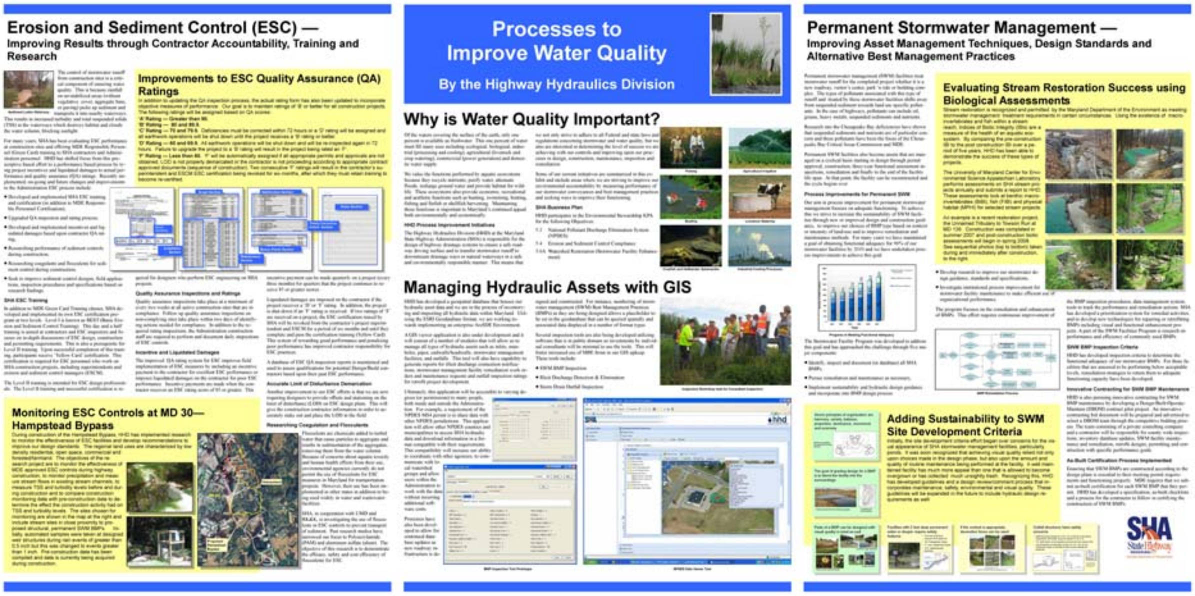


Figure 1-7 HHD PETC Training Conference Exhibit

- New! **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 program provides training to all new SHA engineers and includes training concerning the MEPA/NEPA, Environmental Permitting, Stormwater Management, and Erosion & Sediment Control. In 2008, 70 individuals attended these modules including 20 who graduated on August 2008**.**

- **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 2008 was 22.

- **Statewide Pesticide/Vegetation Management Training (2008)** – This training provides annual vegetation management updates including pesticide training and certification. Table 1-15 lists the numbers of participants by SHA district.

Table 1-15 2008 Pesticide Training

SHA District	Number Trained
1	6
2	23
3	7
4*	-
5	21
6*	-
7	9
Totals	66

* Numbers for Districts 4 and 6 were not available at time of reporting.

- **Annual Vegetation Management Conference (2007) –** This annual conference is sponsored by the Office of Environmental Design and the Maryland SHA Statewide Vegetation Management Team, and 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 2007 conference was held on October 24 and numbers of attendees were 105.

- **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, 7 classes were held with 125 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.

Table 1-16 lists the number of people who were trained over the last reporting period.

Table 1-16 Environmental Permits Tour

SHA District	Number Trained
1	53
2	61
3	-
4	63
5	36
6	14
7	47
Headquarters	32
Totals	306

- **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.

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.

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.

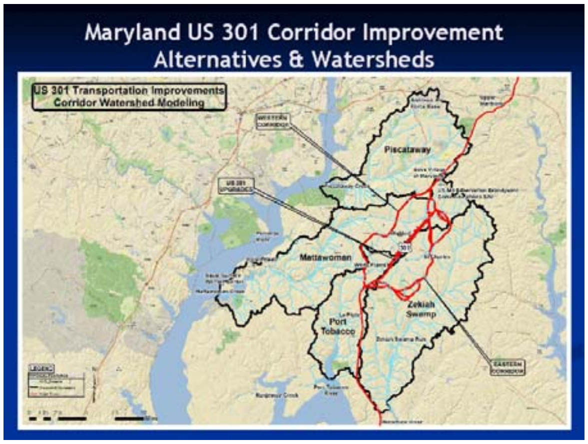
F.3 Impervious Area Retrofits

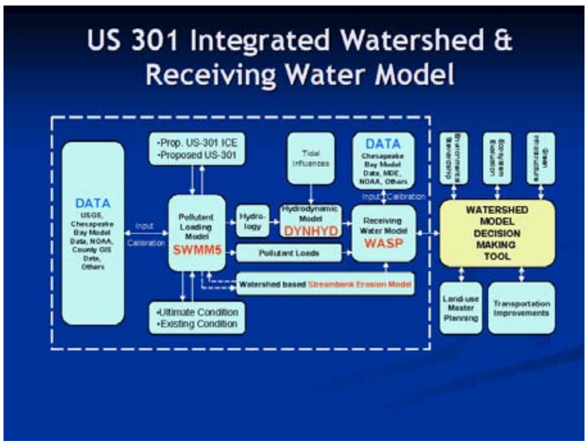
As we progress in the impervious area accounting process described in Section C.3, we will be identifying sites that prove suitable for developing as stormwater facilities to treat additional impervious surfaces in these counties. These efforts will be coordinated within a watershed, tributary strategy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

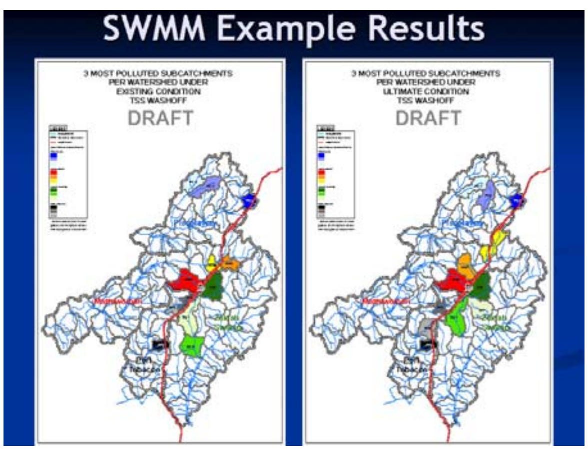
Additionally, as part of our Water Quality Banking Agreement with the MDE Sediment and Stormwater Division, SHA is actively pursing locating water quality retrofit sites in areas with poor or no runoff control infrastructure. A site search has been completed for the Patuxent River Area (02-13-11) and 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 as a green highway. This entails assessing the watershed-level impacts of the various alternatives. 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 studied in the model include:

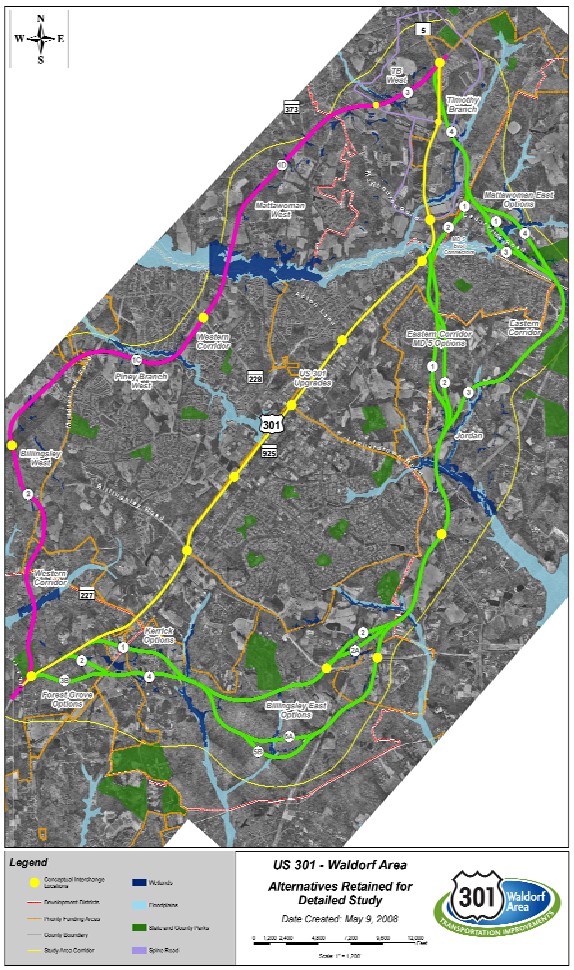
- Nutrients
  - Total Phosphorus (TP)
  - Ortho-Phosphorus (PO4)
  - Nitrite/Nitrate (NO2/NO3)
  - Total KjeldahlNitrogen (TKN)
  - Ammonia (NH3)
  - Total Organic Nitrogen (TON)
- Metals
  - Copper
  - Zinc
  - Cadmium
  - Lead
- Bacteria
  - Biochemical Oxygen Demand (BOD)
  - Chemical Oxygen Demand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

The study is also taking into consideration Maryland's Green Infrastructure initiative. The study is continuing and final results are not currently available.

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 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 will examine ways to implement a watershed decision-making process within SHA, local jurisdictions, and regulatory agencies. The primary focus of the study is from a transportation-centric view, however it is possible that the framework developed may have a wider range of applicability as the basis of the study is viewing the watershed holistically when planning and implementing stormwater management. The study emphasizes watershed restoration and preservation above-and-beyond minimum regulatory and NPDES requirements and promotes elements of green infrastructure.



Retained Alternatives for the US 301 Project

For 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.

During the first year of the study, SHA also began an examination of four 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 will be further examined to determine the effectiveness of the trials and incorporate appropriate steps or methods beneficial to the framework in development. Two years remain of this three-year study and the end product will be a guideline document to implementing the watershed-approach framework and will include recommendations for future further studies, as well as a complete explanation on how the guidelines were developed.

During the second year of the study, SHA began drafting the framework guidelines. The document explains what the GHP is and the purpose and goals of the GHP. It also explores highway project needs as well as watershed needs, and how to assemble the information. Ranking of priorities, including associated cost-benefit analyses are also illustrated. SHA also began drafting a gap analysis to identify areas in which still require further examination. Examples include accountability tracking, credits and trading, and ultimate ownership.

One year remains of this three-year study, and the end product will be a guideline document for implementing the watershed-approach framework and will include recommendations for future further studies, as well as a complete summary on how the guidelines were developed.

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

SHA currently has fifty-two enhancement projects in various stages of planning, design and construction (one was eliminated-2250- due to construction constrains and Long Draught Branch was eliminated due to permit issues). Documentation on these projects was included in the 2007 report and included contract drawings and bid tabulations (for projects that have Table 1-17 is an abbreviated list of the proposed projects by watershed. Documentation will be included for the projects that are currently under design when they are successfully advertised for bid.

The database for Table D was included in the 2007 annual report. No new projects have been added so we have not included the database with this report.

Table 1-17 Watershed Retrofit Projects

Projects by Watershed	Retrofit Type	Status
Lower Susquehanna River – 02-12-02		
1. BMP 12076	Visual Enhancement	Construction
Bush River Area – 02-13-07		
2. BMP 12069	Visual Enhancement	Construction
3. BMP 12072	Visual Enhancement	Construction
4. BMP 12073	Visual Enhancement	Construction
5. BMP 12075	Visual Enhancement	Construction
6. BMP 12081	Visual Enhancement	Construction
7. BMP 12082	Visual Enhancement	Construction
Gunpowder River – 02-13-08		
8. I-83 Outfall Stabilization of Tributaries to Gunpowder Falls	Bioengineered Outfall Stabilization	Design
Patapsco River – 02-13-09		
9. BMP 2120	Functional Enhancement	Construction
10. BMP 2121	Functional Enhancement	Construction
11. BMP 2122	Functional Enhancement	Construction
12. BMP 2250	Functional Enhancement	Removed from List
13. BMP 3281	Visual Enhancement	Construction
14. MD 139 Tributary to Towson Run Stabilization	Bioengineered Stream Stabilization	Complete
15. BMP 2111	Functional Enhancement	Construction
16. BMP 2112	Functional Enhancement	Construction
17. BMP 2098	Functional Enhancement	Complete
18. BMP 2099	Functional Enhancement	Complete

Table 1-17 Watershed Retrofit Projects

Projects by Watershed	Retrofit Type	Status
19. BMP 2476	Functional Enhancement	Complete
20. BMP 2477	Functional Enhancement	Complete
West Chesapeake Bay – 02-13-10		
21. BMP 2019	Functional Enhancement	Construction
22. BMP 2022	Functional Enhancement	Construction
23. BMP 2027	Functional Enhancement	Construction
24. BMP 2029	Functional Enhancement	Construction
25. BMP 2031	Functional Enhancement	Construction
26. BMP 2088	Functional Enhancement	Construction
27. BMP 2481	Functional Enhancement	Complete
28. BMP 2522	Functional Enhancement	Complete
29. BMP 2273	Functional Enhancement	Complete
30. BMP 2491	Functional Enhancement	Complete
31. BMP 2185	Functional Enhancement	Final Review - Design
32. BMP 2198	Functional Enhancement	Final Review - Design
33. BMP 2201	Functional Enhancement	Final Review - Design
34. BMP 2203	Functional Enhancement	Final Review - Design
35. BMP 2204	Functional Enhancement	Final Review - Design
36. BMP 2205	Functional Enhancement	Final Review - Design
37. BMP 2206	Functional Enhancement	Final Review - Design
38. BMP 2208	Functional Enhancement	Final Review - Design
39. BMP 2210	Functional Enhancement	Final Review - Design
40. BMP 2211	Functional Enhancement	Final Review - Design
41. BMP 2220	Functional Enhancement	Final Review - Design
Patuxent River – 02-13-11		
42. BMP 16059	Functional Enhancement	Construction
43. BMP 16202	Functional Enhancement	Construction
44. BMP 2488	Functional Enhancement	Construction
45. BMP 16217	Functional Enhancement	Construction
46. BMP 16219	Functional Enhancement	Construction
47. BMP 16380	Functional Enhancement	Construction
48. Unnamed Tributary to Rocky Gorge Reservoir adjacent US 29	Stream Stabilization	In Design

Table 1-17 Watershed Retrofit Projects

Projects by Watershed	Retrofit Type	Status
Lower Potomac River – 02-14-01		
49. BMP 16456	Functional Enhancement	Completed
Washington Metropolitan-02-14-02		
50. 16607	Functional Enhancement	Construction
51. 16609	Functional Enhancement	Construction
52. 16653	Functional Enhancement	Construction
53. Long Draught Branch Restoration/ Stabilization	Stream Stabilization	Cancelled Due to Agency Comments
Middle Potomac River – 02-14-03		
54. Tributary to Tuscarora Creek Stabilization at US 340 and US 50	Stream Stabilization	Final Review - Design

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 a listing of current projects was included in the 2007 report.

The following is a summary of such efforts undertaken during the report period:

- **Laurel Lakes Task Force – PG County**.The SHA project 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 SHA's 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 has on the watershed. We will also continue to attend task force meeting and 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 design has been delayed due to funding shortages. There is no design schedule established currently.

- **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.** SHA worked with the county to prepare a watershed assessment study and actively participated in a multi-agency effort to address watershed water quality concerns in this watershed. SHA is supporting this project through the TEP review process for 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. SHA has previous recommended this project for TEP funding award.

- **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. 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 in entering the construction phase.

G.3 Report and Submit Annually

SHA will submit information on our watershed restoration activities including retrofit proposals, costs, schedules, implementation status and impervious acres proposed for management. This information will be included in subsequent reports.

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 specified in the permit, and submit date annually.

H.1 Restoration Site Approved by October 21, 2006

The Long Draught Branch restoration project was our approved watershed restoration site for monitoring. However, difficulties in obtaining wetlands and waterways permits caused us to cancel this effort. Detailed information on the regulatory process that occurred at Long Draught is included below and in Appendix M. We are now focusing our monitoring on a new study which evaluates the pollutant removal and environmental effectiveness of infiltration basins that have transitioned into wetland facilities. For more detail on this study, see Section D, Discharge Characterization, above. This study is called *Wet Infiltration Basin Transitional Performance Studies* and is being conducted in partnership with the University of Maryland, Department of Civil Engineering.

Concerning the Long Draught Branch project, over the reporting period, SHA made much progress in designing the project and obtaining necessary approvals. Our progress included:

- Coordinated with the City of Gaithersburg on Covenants to assure legal construction access through private property;
- Finalized the design plans, specifications and estimates in anticipation of advertising the project in the summer of 2008;
- Submitted for final stormwater management and erosion and sediment control approval;
- Received forest conservation plan approval from City of Gaithersburg;
- Initiated and performed the pre-construction monitoring as proposed in the MDE approved monitoring plan that was included in the 2007 annual report as Appendix L.

Despite this progress and due to lack of support of some of the regulatory agencies, SHA has not been able to obtain some of the required environmental permits to restore Long Draught Branch. As a result, the project was removed from the advertisement schedule and the funding cancelled. Additional information concerning the review and design process, and ultimate cancellation is provided below. It is our hope that this project be re-activated and we will appreciate any support that MDE can provide to achieve this goal.

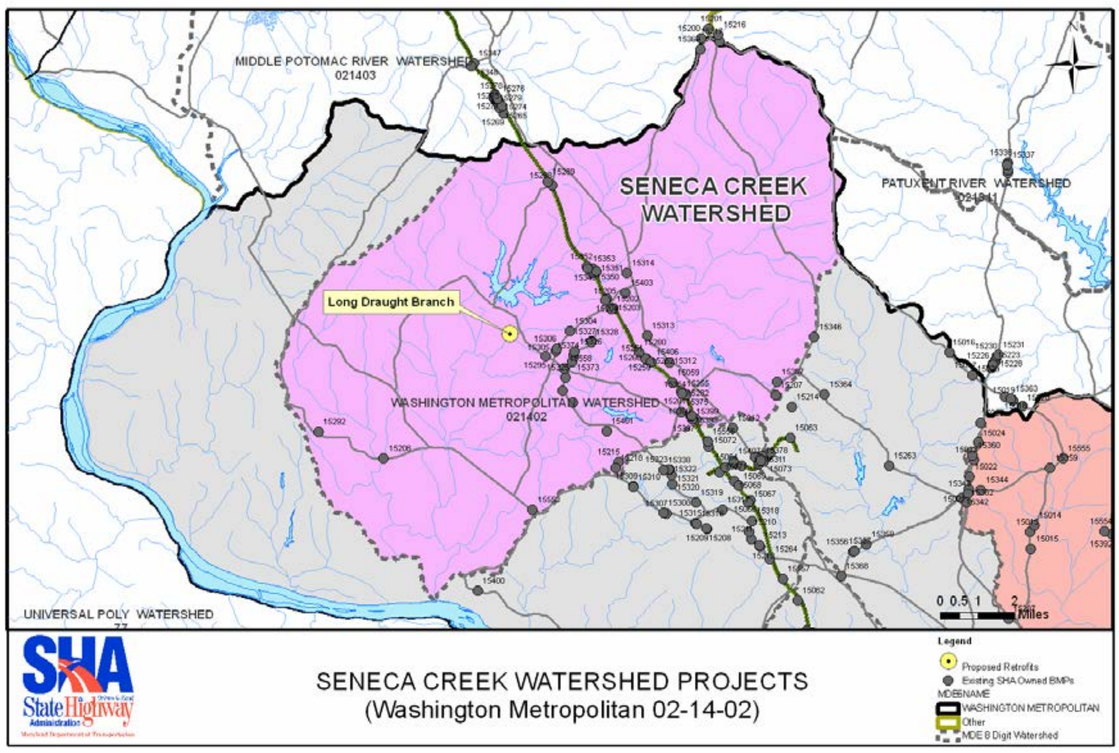


Figure 1-8 Long Draught Branch Project and SHA Owned BMPs within Seneca Creek Segment

Figure 1-9 LDB Project Concept Reforestation and Planting Design

LDB Project Goals and Benefits

The proposed project to restore Long Draught Branch between MD 117 and an existing failed in-stream dam was designed to enhance habitat, improve water quality and significantly decrease or eliminate channel and floodway degradation within the project reach. The specific goals of this project are:

- **Vertical reconnection of the hyporheic zone with base and flood flows in order to maximize water quality benefit** — Greater infiltration and groundwater recharge opportunities within the restoration site would be achieved through reconnection to the floodplain. Further, the floodplain and associated wetland pockets would promote periods of extended base flow and/or greater overall base flow discharges to the downstream environment.

- **Remove source of nutrients** — Downstream nutrient loads, particularly phosphorus and nitrogen reduction with the excavation and removal of approximately 17,000 cubic yards of accumulated sediment. It has been estimated, based upon nutrient testing of on-site sediment samples, that 6.7 tons of total phosphorus and 16.6 tons of total nitrogen would be removed. Proposed floodplain conditions would consist of a highly vegetated surface with root zones that extend well into base flow and/or groundwater elevations. The newly created floodplain area has been designed as a riparian wetland system. An attached floodplain with increased vegetative cover and wetland characteristics would significantly enhance de-nitrification and reduction of downstream nitrogen loads.
- **Ameliorate catastrophic failure of existing in-stream dam (that was constructed in 1972) and associated erosion and forest impacts**
- **Reduce sediment reaching Clopper Lake (Sediment TMDL)** — Decreased sedimentation in downstream reaches and Clopper Lake will result from the elimination of the mechanisms for stream bank erosion and by the removal the failing SWM dam currently holding a large quantity of sediment.
- **Improve channel geomorphology** — The restored channel would result in much more aesthetically pleasing recreational environment for the community that has been very supportive of the proposed improvements through the design process.
- **Facilitate improved wildlife habitat**
- **Facilitate improved aquatic habitat**
- **Restore floodplain functions**

SHA also believes that this project will fulfill the threefold purpose stated in the *2000 Maryland Stormwater Design Manua*l which is:

1. To protect the waters of the State from adverse impacts of urban stormwater runoff;
2. To provide the most effective structural and non-structural BMPs for development sites;
3. To improve the quality of BMPs that are constructed in the State, specifically with regard to performance, longevity, safety, ease of maintenance, community acceptance and environmental benefit.

Progressing Dam Breach

Down-cutting Channel Downstream from Storm Drain Outfall


Development Encroaching in Floodplain


Stream Degradation and Bank Erosion


Disconnected Floodplain with Associated Tree Failures

Project Support and Approvals

It should be acknowledged that the City of Gaithersburg provided extraordinary support for this project from the beginning and throughout. SHA is thankful to all individuals that provided support for engineering, community involvement and embraced this project.

The project has also been fully supported by the US Army Corp of Engineers and the MDE – Water Management Administration, Erosion and Sediment Control Division. The pre- and post-construction monitoring plan was approved by MDE –Sediment, Stormwater & Dam Safety Division. The final Forest Conservation Plan was reviewed and approved by the City of Gaithersburg- Planning & Code Administration.

Chronological Milestones

In April 2007, after SHA coordinated with the MDE NTWW division, the final design was presented to MD DNR and an interagency meeting. All attending agencies concurred conceptually on the purpose and need for this project. DNR expressed concerns regarding the stormwater management approach of allowing the 'first flush' directly into the active stream valleys and channels which diverges from the standard MDE stormwater practice of retaining the first flush and slowly releasing it.

Final design construction documents were submitted in September, 2007. Concurrently, erosion and sediment control plans were submitted to the MDE Plan Review Division in order to continue the stormwater review process. At the same time, Forest Conservation and Forest Stand Delineation (FSD/FCP) plans were submitted to the City of Gaithersburg for review under their local Forest Conservation Act ordinance. The FSD/FCP plans were approved in June 2008.

Additional technical investigations were made on November 2, 2007, by Dr. Dorothy Merritts, of Franklin and Marshall College. Subsurface geoprobes were taken to determine the soil profile of the valley bottom. Eight subsurface cores were encased and brought back to the laboratory for evaluation. The results showed one-half to five foot thickness of sediments through the valley bottom that are comprised of silt and clay material dating to approximately 1750. It is generally understood, that this legacy soil has two to four times the available phosphorous than the historic floodplain encased below. The banks of the actively eroding channel are comprised mostly of these fine sediments. This investigation and analysis confirmed the design intent of removing the source of nutrients and sediments while creating a sink with an accessible and well vegetated wetland floodplain system.


Failing Infrastructure and Outfalls within Degrading Reach of LDB

The Final Design Report was submitted to DNR December 7, 2007 for their review and comment. On December 9, 2007, the MDE WMA NTWW division expressed written concerns for an extensive loss of forested buffer associated with this project. The letter stated this to be a concern shared with MD DNR. Additionally, general concerns about potential floodplain scour as well as other minor technical and 'value added' comments were provided.


Impacted Trees in Floodplain

Responses to MDE's comments were generated collaboratively between the SHA Environmental Programs Division (EPD) and Highway Hydraulics Division (HHD). Responses were provided on January 31, 2008, as well as a meeting on the same day between SHA personnel and their design consultants and the review consultants on behalf of the WMA. The morning-long discussion went through each comment and response and each were thoroughly discussed. Generally, progress was thought to have been made in alleviating MDE and DNR concerns. Additional comments were provided by, US Fish and Wildlife Service, on January 31, 2008.


Physical Monitoring at Eroding Banks

In March, 2008, an additional memorandum from US Fish and Wildlife Service and DNR was received. Collectively, these memorandums expressed concern with loss of riparian forest buffer and non-standard water quality treatment. DNR requested a meeting with all associated agencies to discuss and finalize judgment on this proposal.

On March 20, 2008, MDE WWP placed the project on Public Notice. Because no comments were generated by the public notice process, it was understood by SHA that all comments and concerns about this project had been addressed to MDE satisfaction.


Falling Trees at Floodplain near Failing Dam

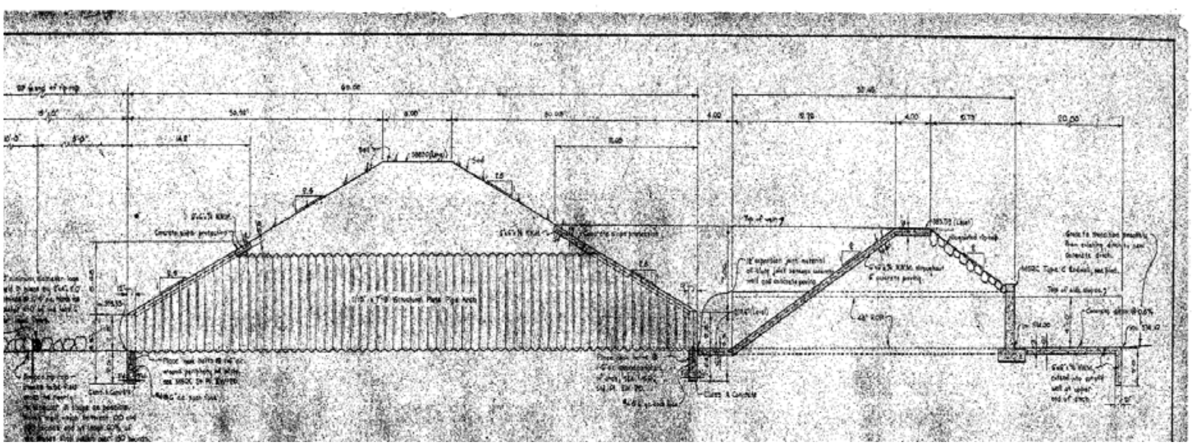
From March to June, 2008, SHA coordinated with DNR and MDE to meet and resolve the issues being raised by the agencies. By late June, the 95% complete design plans were ready at SHA. Forest review with the City of Gaithersburg was completed on June 25, 2008 with signed and sealed approved plans were secured by SHA. Advertisement date was set for August, 2008.


LDB Confluence with Clopper Lake

Correspondence between SHA and the regulatory agencies occurred through June and into July, 2008. On July 16th, 2008, an office meeting was held by SHA to discuss the project with regulatory agencies. DNR expressed concern with existing tree loss at the project site. Alternatives had been discussed in past regulatory meetings, but DNR had not been present although they had been invited. Many discussions occurred at this meeting. Although this project has been in design for three years, during this meeting the project was evaluated from its conception. One alternative proposed to SHA by the agencies was to reconstruct the failing in-stream dam.


Debris and Sediment Upstream of Dam

After a lengthy discussion it appeared that the agencies were potentially agreeable to the proposed design. The meeting resolution was for SHA to provide to the agencies details of the design alternatives that were considered prior to selection of the final design option. These alternatives can be used to compare impacts to the forested buffer by each alternative. As requested, SHA prepared a summary report to compare impacts of four different alternatives which is included in Appendix M of this report. A follow-up field meeting was scheduled for August 7, 2008 to discuss these alternatives.



As built plans of the in stream dam that failed a year after its construction in 1972

Figure 1-10 Long Draught Branch Failed In-stream Dam (Constructed 1972)

After the field meeting between SHA and DNR officials, DNR maintained the position that they cannot support the project based on "long standing environmental review policy related to riparian impact minimization." SHA has been unable to convince the regulatory agencies to permit the project unless the preferred design is altered to the point that SHA could not support since the project goals would be greatly compromised.

A letter from DNR dated September 18, 2008, was received by SHA providing written confirmation of DNR's position. MDE WWP response was received on October 14, 2008, outlining that MDE supports the natural resource agencies' position. Both letters are included in the Appendix M of this report to summarize the position of MDE-Nontidal Wetlands and Waterways Division, MD DNR Watershed Services and the US Fish and Wildlife Service. According to these letters, these agencies will not permit the project based upon the SHA preferred design.

SHA Response to Agency Concerns

Concerning the issue raised about forest buffer and tree impacts, SHA believes that the impending dam failure will inevitably do more environmental damage than the proposed restoration. This anticipated damage includes tons of sediment moved downstream to Clopper Lake, devastation to existing forested area and downstream aquatic environments, severely migrating channel head cut and resultant instability of the channel for many years that could threaten the stability of adjacent parking lots, dwellings and MD 117.

A breach analysis was performed (Appendix M) and Alternate 1 is the no-build option. This analysis anticipates that 1.9 acres would be impacted by a complete dam breach that would encompass 47 trees greater than 18 inch DBH. During the first 2.2 hours, an estimated 12,000 tons of sediment would be moved downstream. The ultimate impact to the area will last for many years as the channel seeks to stabilize, resulting in much worse impacts and greater numbers of trees ultimately failing than we are able to quantify.

Dam with Upstream Debris and Sediment

Development Encroachment Limits Access for Flood Flows and Results in Bank Erosion

Instability and Rapid Migration of Stream Channel

Design Alternates 2 and 3 show fewer trees being impacted but have serious drawbacks that threaten success of the project. The preferred Alternate 4, while actually impacting more trees initially (54) will ultimately stabilize the reach in such a way that success is guaranteed and no new tree failures will be anticipated. Compare this to the inevitable breached dam and years of instability that will result in untold numbers of trees being impacted. A reforestation plan was included in the project and approved by the City of Gaithersburg.

Our NPDES post-construction monitoring plan and the continuing SHA commitment to monitor for biological components after construction to assess the success of the project are other factors that should encourage agency confidence in this project.

It is unfortunate that SHA has not been able to fulfill its commitment to construct this project and prevent the foreseeable breach of the failing in-stream dam. SHA has presented its concerns regarding the dam instability to the regulatory agencies. It has been pointed out that MDE has placed specific TMDL goals for Long Draught Branch and the fact that the instability of this stream reach itself currently exceeds the daily loads of suspended sediments, even with the partially breached dam in place. The loads of sediments and attached pollutants (phosphorus and nitrogen) will greatly escalate once the failing dam fully breaches and will be transported to the recreational waters of Clopper Lake. The SHA preferred alternate for the proposed restoration would reduce the daily loads of suspended sediments, phosphorous and nitrogen to be within the TMDL goals for Long Draught Branch.

H.2 Monitoring Plan

Based on the approval of this project by MDE-WMA, significant monitoring (physical, chemical and biological) was performed. Monitoring data was included in the 2007 annual report and in this current report in the Appendix I.

SHA has included the results of the chemical and biological monitoring in Appendix I of this report. This monitoring period between November 2006 and August 2008 contained only twenty total events; of those, seven were storm events. The data indicate that concentrations for most constituents did not vary when comparing base flow (dry weather) samples and storm samples. However, concentrations of BOD upstream were much higher during the storm events and TKN concentration upstream was significantly higher during the base flow. Pollutant concentrations varied between upstream and downstream chemical monitoring sites for Phosphorous, Lead, TSS, and Ammonia, with elevated concentrations at the downstream location.

Physical pre-construction monitoring was completed to document the existing conditions and to assess the current stream stability. Rosgen Level I and II assessments were performed to determine the channel geometry, profile and pattern, bed composition, stream classification and bankful discharge. The data is also provided Appendix I.

The biological monitoring was performed using MBSS methods. The MPHI score for the stream reach was 26.30 which is lower than the average for Non-Coastal Plain streams (54.74). The Long Draught Branch Fish IBI Score was measured at 1.44 while the average Fish IBI Score for Non-Coastal Plain streams is 2.8. More details are included in the biological monitoring report in the Appendix I.

Since the project has been cancelled, SHA will not continue with the monitoring efforts of Long Draught Branch. The monitoring from the *Wet Infiltration Basin Transitional Performance Studies* will continue our efforts to meet this permit condition.

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 funds and SHA Operations and Maintenance funds in completing NPDES requirements.

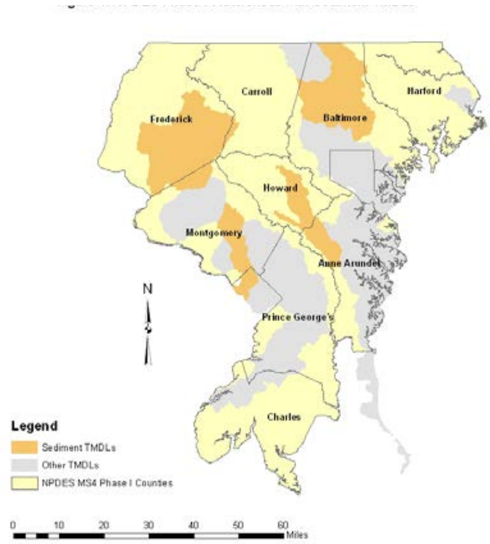
Required Fiscal Analysis Data

Currently, SHA tracks spending for the entire NPDES program 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.

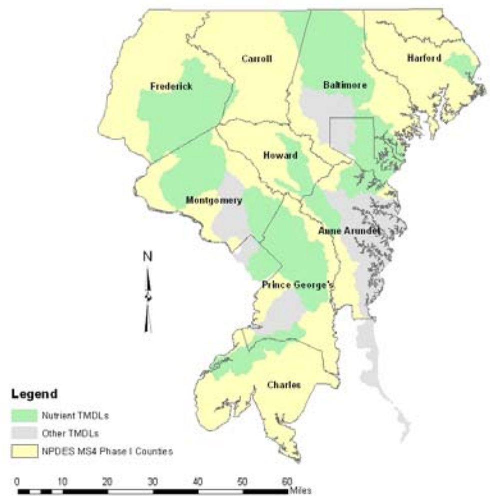
According to our current records, the total spent for MS4 NPDES and BMP Programs plus Industrial NPDES are listed in Table 1-18, below.

Table 1-18 Capital Expenditures for NPDES at SHA

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



Sediment TMDLS



Nutrient TMDLS

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.

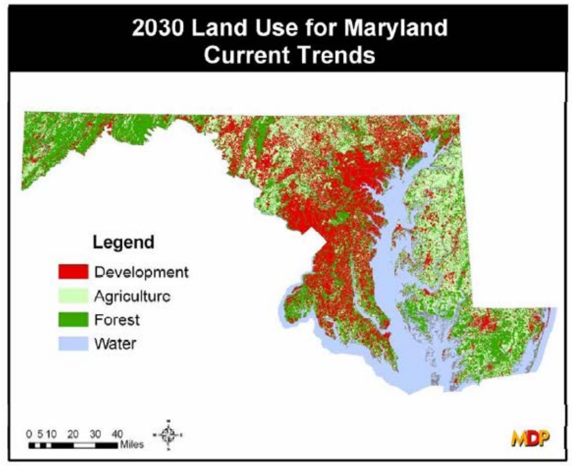
However, we are aware that the next permit terms will have greater TMDL involvement with waste load allocation requirements. To this end, SHA is working to develop a TMDL implementation strategy for our agency that will encompass many facets of our organization on many levels. Some of these aspects include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

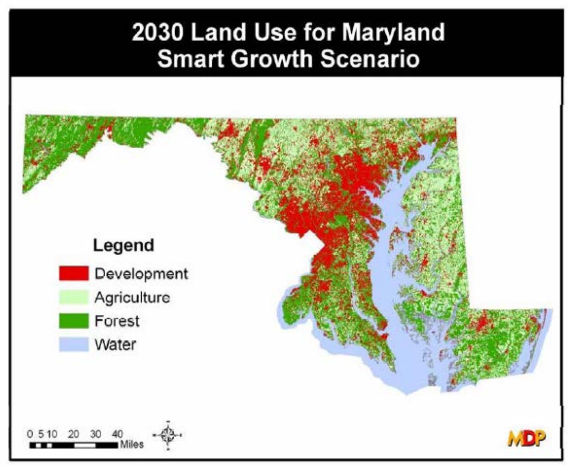
TMDL Watersheds and Tier II Streams
Of particular concern will be awareness of which watersheds are impaired by which pollutants and which watersheds are considered Tier II watersheds where the anti-degradation policy applies. Assessing the SHA involvement in the watershed impairment is important and we are working towards developing tools to determine this and developing an understanding of the models that have been utilized in generating the TMDL documents. Working with watershed organizations, the MDE Science Services Division and Water Management Administration, local NPDES jurisdictions and the local communities will be of high importance.

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. 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.

SHA Impervious Surfaces and Land Uses
SHA will need to address critical thinking concerning placement of impervious surfaces. Planning road improvements with the need to strategically implement 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 1-17 illustrates the breakdown between 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

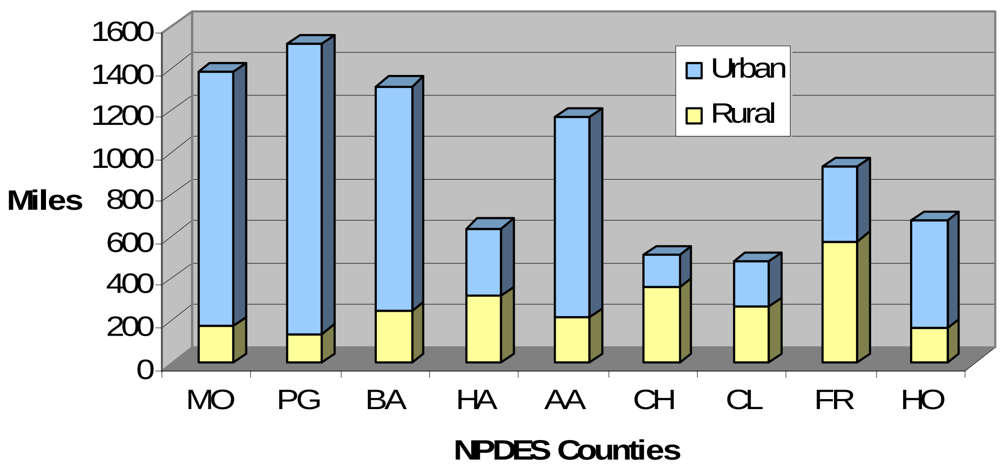


Figure 1-17 SHA Roadway Functional Classifications by NPDES County
(2007 Lane Miles)

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

Special Programmatic Condition

This section addresses the special condition contained in Part V. of the permit that reads:

> *Since the signing of the Chesapeake Bay Agreement in 1983, Maryland has been working toward reducing the discharge of nutrients and sediments to the Chesapeake Bay. SHA's highway network traverses all ten of the Bay's major tributaries in Maryland. This NPDES permit encourages the SHA to coordinate with localities specified in Part I.B. of this permit and assist with the implementation of the Tributary Strategies designed to meet the nutrient and sediment reduction goals.*

SHA is committed to reducing the discharge of nutrients and sediments to the Chesapeake Bay. The fact that the State and Federal highway networks traverse all the major Bay tributaries in Maryland points out the important role we have in impacting the success of statewide tributary strategies. In Part One of this report, we discuss in detail our many efforts underway to keep the Chesapeake Bay perspective in view while at the same time plugging into local watershed level activities. Here, we discuss efforts on a state, regional or national level.

Urban Stormwater Work Group (USWG)

SHA is a participating member of the Urban Stormwater Work Group. The USWG is a Chesapeake Bay Program committee that is a combination of the Nutrient Subcommittee and the Toxics subcommittee and seeks to address issues related to the prevention and reduction of chemical contaminants, nutrients and sediment from urban and suburban runoff. As a participating member, SHA is particularly aware of the challenges in establishing the BMP efficiencies for the Bay Model. The USWG work plan focuses on the following five initiatives:

- Stormwater Directive Implementation,
- Tributary Strategies Development, Implementation and Modeling Support,
- Low Impact Development (LID) and Environmental Site Design (ESD),
- Maintenance of Urban Stormwater BMPs,
- Innovative Technologies.

Green Highways Partnership (GHP)

SHA has been a founding partner in the Green Highway Partnership, an effort by EPA, FHWA and SHA. The mission statement of the GHP is: "Through concepts such as integrated planning**,** regulatory flexibility**,** and market-based rewards**,** GHP seeks to incorporate environmental streamlining and stewardship into all aspects of the highway lifecycle."

Green highways are defined by an effort to leave the project area "better than before" through community partnering, environmental stewardship, and transportation network improvements in safety, functionality, and aesthetics. What this means differs from project to project, and location to location, and SHA has partnered with EPA to define the green highway parameters for stormwater management. In this capacity, SHA is involved in demonstration projects promoting innovative stormwater management practices. These include developing a watershed-based approach for managing stormwater (through a grant initiative with EPA) and partnering with Prince George's County and the Chesapeake Bay Alliance to implement a decision support model that operates as a guiding principle for stormwater concept development.

SHA's early involvement in the Green Highway Initiative included:

- Executive Session, College Park, MD, Nov. 2005 – Participated in roundtable planning effort.
- Green Highways Forum, College Park MD, Nov. 2005 – Moderated sessions, lead workshops, presented.
- Anacostia Executive Charette, College Park, MD, Nov. 2006 – Participated in executive meeting intended to beg+in a dialogue on restoring the Anacostia watershed.

SHA's recent involvement in the Green Highways Partnership includes:

- US 301 Green Highways Charrette, April 2007 – US 301 has been targeted to be the first major green highway project. The main components of green highway recognition are watershed-based stormwater management, recycling and reuse of materials, ecological design and enhancement, and sustainability.
- Framework to Implement a Watershed-Based Approach to SWM – A grant from the EPA to develop a framework for DOTs to implement a major component of the green highway philosophy. This is discussed in Section F.4**.**

Chesapeake Bay Tributary Strategies

As active members of the Chesapeake Bay watershed, SHA is also active in the tributary strategies published by the Maryland Department of Natural resources in the document *Maryland's Chesapeake bay Tributary Strategy Statewide Implementation Plan, August 2, 2007*. Under other state initiatives to address the implementation gaps, SHAs involvement is described as:

Maryland State Highway Administration (SHA) – Transportation Components

New Erosion/Sediment Control Program
SHA has launched new erosion and sediment control policies that took effect on all SHA projects advertised after April 1, 2006. Changes to the program provide for: • New incentives and revise liquidated damages for erosion and sediment control; • Mandatory enhanced training and certification requirements for inspectors, contractors, designers, and engineers, including SHA personnel, over and above the MDE "Green Card" training; • Improved limit of disturbance labeling on construction plans; and • An improved E&S rating form for Quality Assurance (QA) inspectors.

Environmental Monitors
Several MDOT agencies employ separate Environmental Monitors for large, complex or design/build projects to work closely with all parties to inform and resolve issues as they arise.

Green Highways Partnership
SHA is a leader and active participant in the Green Highways Partnership, a proactive approach to improving the environmental performance of highways and their integration into watersheds through coordination with local governments and the private sector. Green highways are defined by an effort to leave the project area "better than before" through community partnering, environmental stewardship, and transportation network improvements in safety and functionality.

What this means differs from project to project, and location to location and SHA has partnered with EPA to define the Green highway parameters for stormwater management. In this capacity, SHA is involved in demonstration projects promoting innovative stormwater management practices. These include developing a watershed-based approach for managing stormwater (through a grant initiative with EPA) and partnering with Prince George's County and the Chesapeake Bay Alliance to implement a decision support model that operates as a guiding principle for stormwater concept development.

In addition to their transportation mission, SHA is a supporter of watershed based stormwater management. They define this vision of stormwater management as a concept that recognized that highways coexist with other land uses in watersheds, and a collaborative approach with others by providing an opportunity for highway agencies to plan and deliver stormwater management that is not only a better fit for the watershed, but is also sustainable, exhibits improved visual quality and is cost effective.

SHA has created a GIS database in response to NPDES requirements and this tool has proved useful in supporting the Green Highway initiative by allowing GIS analysis tools to be employed in establishing and responding to watershed priorities. The result is improved monitoring of the system overall, improved effectiveness of stormwater management on a local and statewide level, and better decisions making for future facilities.

Transportation Enhancement Program

In addition to the management of stormwater on construction projects MDOT, supports the use of the Transportation Enhancement Program (TEP) to fund watershed improvement projects, such as stream restorations, fish blockage removal, wetland restorations and stormwater retrofits. Since 2000 the TEP has funded 30 such proposals, both by local governments and as SHA projects.

Green Infrastructure

SHA is working with DNR and other resource agencies in using Maryland's Green Infrastructure (GI) Program to assist in decision making under the National Environmental Policy Act (NEPA). Through the assessment and mapping of existing natural lands, DNR identifies the areas that are most valuable in providing ecosystem services, such as cleaning the air, filtering and cooling water, storing and cycling nutrients, sequestering carbon, and protecting areas against storm and flood. The GI process also identifies land cover "gaps" that can be targeted for restoration. In the planning process for major projects, such as improvements to U.S. 301 through Waldorf, green infrastructure assessment and mapping is assisting planners in avoiding the most ecologically valuable land during the selection of projects alternatives. As project planning progresses, the GI process can be used to enhance mitigation of necessary impacts by identifying ecologically significant land for conservation and targeting impaired areas for restoration.

Continuing Commitment

The initiatives and collaboration discussed above and throughout this document testify to our concern for the survival of this valuable resource, the Chesapeake. Our commitment is in the hope that it can endure to grace the lives of generations to come.

PART THREE

Stormwater Management Facilities Program

3.1 Introduction

This section of the report summarizes Maryland SHA's Stormwater Management (SWM) Facilities Program activities between October 2007 and October 2008.

Based on the latest estimates SHA owns about 2,016 stormwater management (SWM) facilities statewide that were constructed since the early 1980'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 had updated the BMP inspection manual that became a 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 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 facility is not functioning as designed. Several issues may exist that have compromised the BMP performance or indicate failure

E **Severe Problems** – exist, and 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 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 2008.

Table 3-1 Current Statewide SWM Facility Inventory Summary

District	County	No. BMPs	Totals
1	Dorchester	24	150
	Somerset	13	
	Wicomico	46	
	Worchester	67	
2	Caroline	4	129
	Cecil	15	
	Kent	6	
	Queen Anne's	102	
	Talbot	2	
3	Montgomery	266	448
	Prince George's	182	
4	Baltimore	169	280
	Harford	111	
5	Anne Arundel	428	596
	Calvert	41	
	Charles	100	
	St. Mary's	27	
6	Allegany	38	66
	Garrett	12	
	Washington	16	
7	Carroll	41	347
	Frederick	55	
	Howard	251	
State			**2,016**

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

This year SHA completed the statewide inventory and inspections of SWM facilities located at SHA maintenance shops, rest areas, weight stations and salt dome areas. Totally 58 BMPs were identified and inspected. The SHA shops BMP inventory has been merged with the current statewide database.

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of BMP	Number Inspected	Rating				
		I	II	III	IV	V
Allegany County						
Detention	**10**	3	0	7	0	0
Extended Detention	**13**	8	1	1	3	0
Retention	**4**	2	2	0	0	0
Infiltration Basin	**0**	0	0	0	0	0
Infiltration Trench	**5**	5	0	0	0	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**5**	5	0	0	0	0
Totals	**37**	**23**	**3**	**8**	**3**	**0**
Anne Arundel County						
Detention	**37**	32	0	2	3	0
Extended Detention	**17**	17	0	0	0	0
Retention	**41**	35	3	2	1	0
Infiltration Basin	**51**	22	2	2	21	4
Infiltration Trench	**270**	157	53	9	40	11
Shallow Marsh	**2**	2	0	0	0	0
Other	**6**	6	0	0	0	0
Totals	**424**	**271**	**58**	**15**	**65**	**15**

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of BMP	Number Inspected	Rating I	II	III	IV	V
Baltimore County						
Detention	**28**	22	4	2	0	0
Extended Detention	**4**	3	0	1	0	0
Retention	**18**	15	1	2	0	0
Infiltration Basin	**34**	25	0	2	6	1
Infiltration Trench	**70**	35	5	12	15	3
Shallow Marsh	**7**	6	1	0	0	0
Other	**5**	4	1	0	0	0
Totals	**166**	**110**	**12**	**19**	**21**	**4**
Carroll County						
Detention	**6**	0	4	2	0	0
Extended Detention	**1**	1	0	0	0	0
Retention	**4**	2	1	1	0	0
Infiltration Basin	**2**	2	0	0	0	0
Infiltration Trench	**18**	7	3	6	2	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**8**	2	3	3	0	0
Totals	**39**	**14**	**11**	**12**	**2**	**0**
Charles County						
Detention	**6**	3	3	0	0	0
Extended Detention	**11**	4	7	0	0	0
Retention	**13**	3	10	0	0	0
Infiltration Basin	**8**	2	1	3	2	0
Infiltration Trench	**43**	6	9	20	8	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**18**	16	2	0	0	0
Totals	**99**	**34**	**32**	**23**	**10**	**0**
Frederick County						
Detention	**14**	14	0	0	0	0
Extended Detention	**5**	4	1	0	0	0
Retention	**14**	14	0	0	0	0
Infiltration Basin	**1**	1	0	0	0	0
Infiltration Trench	**12**	11	1	0	0	0
Shallow Marsh	**1**	1	0	0	0	0
Other	**7**	7	0	0	0	0
Totals	**54**	**52**	**2**	**0**	**0**	**0**

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of BMP	Number Inspected	Rating				
		I	II	III	IV	V
Garrett County						
Detention	**1**	1	0	0	0	0
Extended Detention	**2**	2	0	0	0	0
Retention	**2**	1	1	0	0	0
Infiltration Basin	**0**	0	0	0	0	0
Infiltration Trench	**4**	4	0	0	0	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**2**	2	0	0	0	0
Totals	**11**	**10**	**1**	**0**	**0**	**0**
Harford County						
Detention	**14**	11	3	0	0	0
Extended Detention	**5**	4	0	1	0	0
Retention	**9**	8	1	0	0	0
Infiltration Basin	**19**	15	3	1	0	0
Infiltration Trench	**59**	30	11	1	17	0
Shallow Marsh	**3**	3	0	0	0	0
Other	**0**	0	0	0	0	0
Total	**109**	**71**	**18**	**3**	**17**	**0**
Howard County						
Detention	**13**	13	0	0	0	0
Extended Detention	**27**	27	0	0	0	0
Retention	**25**	21	1	3	0	0
Infiltration Basin	**65**	61	1	3	0	0
Infiltration Trench	**17**	9	0	0	7	1
Shallow Marsh	**103**	76	0	0	20	7
Other	**16**	16	0	0	0	0
Totals	**221**	**179**	**2**	**5**	**27**	**8**
Kent County						
Detention	**0**	0	0	0	0	0
Extended Detention	**4**	3	1	0	0	0
Retention	**1**	1	0	0	0	0
Infiltration Basin	**0**	0	0	0	0	0
Infiltration Trench	**0**	0	0	0	0	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**0**	0	0	0	0	0
Totals	**5**	**4**	**1**	**0**	**0**	**0**

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of BMP	Number Inspected	Rating				
		I	II	III	IV	V
Montgomery County						
Detention	**29**	26	1	0	2	0
Extended Detention	**27**	25	0	2	0	0
Retention	**43**	35	3	3	2	0
Infiltration Basin	**19**	15	0	1	3	0
Infiltration Trench	**118**	104	0	2	12	0
Shallow Marsh	**6**	6	0	0	0	0
Other	**21**	19	2	0	0	0
Totals	**263**	**230**	**6**	**8**	**19**	**0**
Prince George's County						
Detention	**13**	11	1	0	1	0
Extended Detention	**4**	2	1	0	1	0
Retention	**34**	31	2	0	1	0
Infiltration Basin	**16**	13	1	1	1	0
Infiltration Trench	**84**	32	24	9	15	4
Shallow Marsh	**21**	19	1	0	1	0
Other	**5**	5	0	0	0	0
Totals	**177**	**113**	**30**	**10**	**20**	**4**
Queen Anne's County						
Detention	**2**	2	0	0	0	0
Extended Detention	**0**	0	0	0	0	0
Retention	**16**	12	0	3	1	0
Infiltration Basin	**1**	1	0	0	0	0
Infiltration Trench	**8**	6	0	1	1	0
Shallow Marsh	**11**	9	0	2	0	0
Other	**63**	0	63	0	0	0
Totals	**101**	**30**	**63**	**6**	**2**	**0**
Washington County						
Detention	**7**	7	0	0	0	0
Extended Detention	**0**	0	0	0	0	0
Retention	**2**	2	0	0	0	0
Infiltration Basin	**2**	0	1	0	1	0
Infiltration Trench	**2**	2	0	0	0	0
Shallow Marsh	**0**	0	0	0	0	0
Other	**2**	2	0	0	0	0
Totals	**15**	**13**	**1**	**0**	**1**	**0**

* This inventory includes only inspected and rated BMPs. Additional facilities have been identified since the last inspections cycle.

STORMWATER MANAGEMENT FACILITIES
INSPECTION AND REMEDIATION PROGRAM

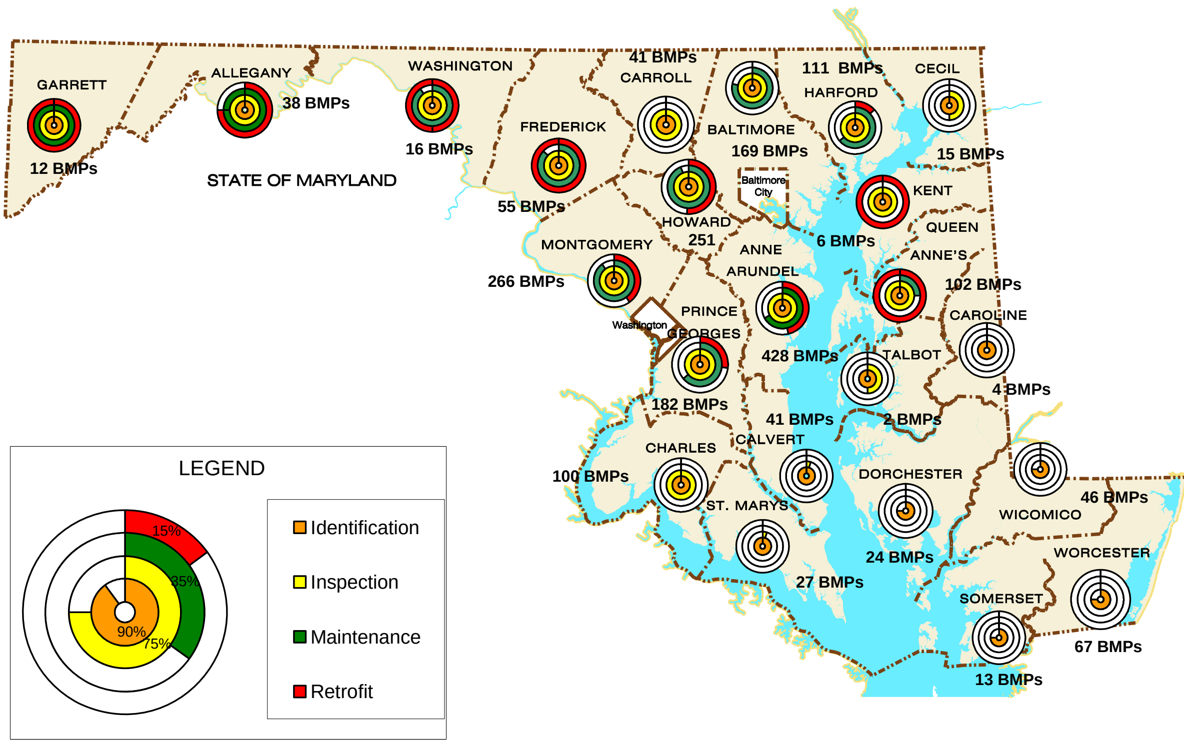


Figure 3-1 SWM Facilities Inspection and remediation Program

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 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 two $1.5 million Open Ended Maintenance contracts that were advertised during the summer 2005. These contracts perform both routine and major maintenance on the average of every 24 months. Due to an extensive workload, routine maintenance tasks are completed by a contractor selected through a competitive bidding process rather then SHA Office of Maintenance crews. However, once the statewide inventory/ inspection database and full cycle of maintenance are completed, the SWM routine maintenance tasks may be managed by individual SHA District maintenance offices.

Table 3-3 lists the number of facilities requiring routine maintenance and the total number that were maintained since the last report to this date. The Table 3-4 summarizes the routine maintenance cost by county between October 2007 and October 2008.

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 proposed scope was presented at MDQI conference in January 2008 to large audience of engineering and construction companies, and it was advertised in August 2008. The notice to proceed will be given in March 2008 to the selected winning team composed of an engineering company partnering with a construction firm with SWM maintenance experience. The team will be responsible for a county wide inspections, inventory database updates, SWM facilities maintenance and remediation, 10 retrofits design, permitting and construction with specific performance goals for 3 years.

Table 3-3 Minor Maintenance Summary

County	District	BMPs for Maintenance	BMPs Maintained 10/2007 to 10/2008
Baltimore	4	12	2
Frederick	7	2	10
Harford	4	18	2
Montgomery	3	6	13
Total		**38**	**27**

Table 3-4 Minor Maintenance Cost
Year 2007 / 2008

Funding Allocation	Funding Amount
Baltimore County	**$1,344.00**
Frederick County	**$10,905.67**
Harford County	**$4,601.00**
Montgomery County	**$13,018.84**
Total	**$29, 869. 51**

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 dredging of accumulated sediments and inflow points' stabilization.

Figure 3-2: BMP15313 - Significant Inflow and Accumulation of Sediments and Debris

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 MOT. Figure 3-3 shows very typical remediation activity – SWM pond inflow channel stabilization.

Major maintenance is underway in all inspected counties. Table 3-5 lists the total number of facilities requiring major maintenance and the total number that were maintained between October 2007 and October 2008. Table 3-6 summarizes the associated costs in each county

Figure 3-3 : Inflow Channel Stabilization (BMP13007) - during construction

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

Table 3-5 BMP Major Maintenance Summary

County	District	BMPs Yet to Be Maintained	BMPs Maintained 10/2007 to10/2008
Allegany	6	8	4
Anne Arundel	5	15	13
Frederick	7	0	2
Garrett	6	0	1
Harford	4	3	10
Howard	7	5	3
Montgomery	3	8	59
Prince George's	3	10	4
Queen Anne's	2	6	9
Washington	6	0	1
Total		**55**	**106**

Table 3-6 Major Maintenance Cost
Year 2007 / 2008

Funding Allocation	Funding Amount
Allegany County	$13,115.53
Anne Arundel County	$162,107.05
Frederick County	$3,967.21
Garrett County	$4,261.63
Harford County	$19,735.25
Howard County	$55,801.28
Montgomery County	$150,608.22
Prince George's County	$19,265.24
Queen Anne's County	$61,128.05
Washington County	$9,624.77
Total Costs	**$ 499, 614. 23**

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 wells in order to identify and monitor the 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. Among other projects, SHA initiated remediation project for number of non-functioning infiltration trenches along MD 43 in Baltimore County.

Figure 3-5 Infiltration Trench Investigation along MD 43 – sites to be replace in kind

Figure 3-6   Infiltration Trench Investigation / Remediation Project along MD 43 – sites targeted for enhancement and retrofit

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. The Anne Arundel County project has been separated into 2 phases due to the permitting issues and each phase was advertised at different time. The status of the current projects is summarized in Table 3-7. The total cost does not include $1, 750,000 for projects currently under preliminary design.

Table 3-7: 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 to be completed in Fall 2008
2	Functional Enhancement of SWM Facilities - Phase 2	AA	7	AA5535174	$1,961,326	Bid Opening Date 10/18/07 Under Construction
3	Stormwater Functional Enhancements in AL County	AL	3	AL3555174	$828,324	Advertisement Date 02/05/2009
4	I-97 SWM Facilities Functional Upgrades	AA	14	AA5355174	1,326,318	Advertisement Date February 2009
5	Glen Burnie SHA Maint. Shop Bioretention Retrofit	AA	1	AT387A21	$178,108	Advertisement Date in Spring 2009
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	5	AA5515174	PI Estimate $800,000	Under Design Preliminary Investigation
8	MD 355 – Retrofit of SWM Facility 15012	MO	1	MO410A21	*Preliminary $250,000*	Currently on- Preliminary $250,000 hold
9	MD 32 and US 50 – Failed Infiltration Basins Retrofit	AA	5	TBD	*Preliminary $500,000*	Field Investigation, Concept design
10	MD 43 – Failed Infiltration Trenches Retrofit Project	BA	10	TBD	*Preliminary $700,000*	Field Investigation, Concept design
	Total		**51**		**$7,831,897**	

Before the construction (11/2005)

During Construction (10/2007)

After construction (10/2008)

Vegetated islands and shallow areas

Deep Pools

Aquatic plants and native grasses

Figure 3-7Functional Enhancement of Infiltration Basin at US 50 - Before, During and After Construction (BMP 2488)

Before construction (11/2005) *During Construction (10/2007)* *After construction (10/2008)*

Figure 3-8 Reconstruction of Infiltration Basin into Pocket Wetland at US 50 (BMP 2273)

Before the construction (11/2005) *During Construction (10/2007)* *After construction (10/2008)*

Figure 3-9 Reconstruction of Infiltration Basin into Micropool Extended Detention Pond (BMP 2481)

Before construction (11/2005) *During construction (10/2007)* *After construction (10/2008)*

Figure 3-10 Reconstruction of Infiltration Basin into Micropool Extended Detention Pond (BMP 2522)

Figures 3-7 through 3-0 show the construction completion of SWM facilities enhancements in Anne Arundel County. The design process included Visual Quality review as a part of the landscaping design to assure successful establishment of the aquatic and upland plantings.

SHA continues the final design efforts with SWM Functional Upgrades project in Anne Arundel County. The selected sites are shown in Figure 3-11.and summarized in Table 3-8.

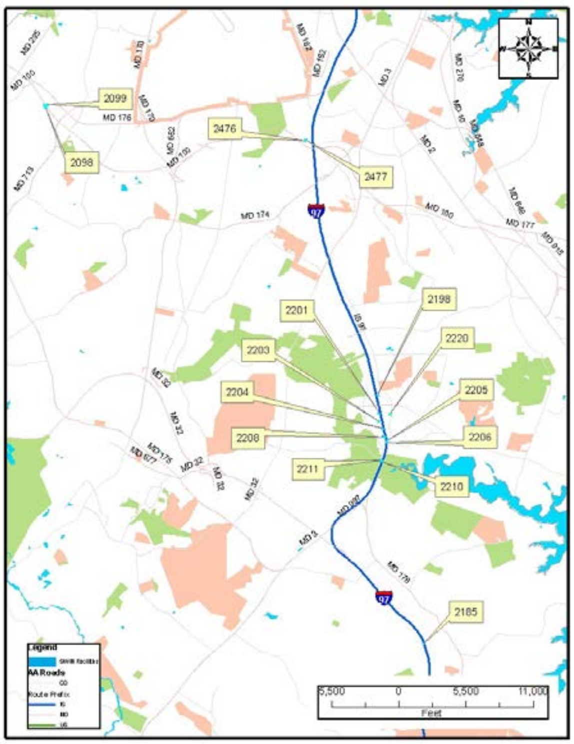


Figure 3-11 SWM Functional Upgrades Sites Along I-97 in Anne Arundel County

Proposed project includes infiltration trenches enhancements or replacement to increase treatment from 1/2 to 1 inch of runoff and as well as to improve water quality treatment to meet current standards. Most selected sites are in environmentally sensitive watersheds including Severn River. The enhancements focus on maximizing pollutant removal efficiencies and improving functionality by upgrading facilities to meet today's standards. The project will be advertised in February 2009 with notice to proceed in April 2009.

No .	BMP No.	SWM Facility	SHA Road	Proposed Enhancement
1	2098	Infiltration Trench	MD 100	Dry Swale (O-1)
2	2099	Infiltration Trench	MD 100	Dry Swale (O-1)
3	2185	Infiltration Trench	I-97	Sand Filter (O-1)
4	2198	Infiltration Trench	I-97	Dry Swale (O-2)
5	2201	Infiltration Trench	I-97	Dry Swale (O-2)
6	2203	Infiltration Trench	I-97	Dry Swale (O-1)
7	2204	Infiltration Trench	I-97	Dry Swale (O-2)
8	2205	Infiltration Trench	I-97	Dry Swale (O-1)
9	2206	Infiltration Trench	I-97	Dry Swale (O-1)
10	2208	Infiltration Trench	I-97	Dry Swale (O-1)
11	2210	Infiltration Trench	I-97	Dry Swale (O-1)
12	2211	Infiltration Trench	I-97	Underground Sand Filter (F-2)
13	2220	Infiltration Trench	I-97 / MD 178	Dry Swale Filter (F-1)
14	2476-2477	Infiltration Trench	I-97 / MD 1(	Wet Pond (P-2)

Table 3-8 SWM Functional Upgrades in Anne Arundel County

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 SWM facilities.

In summary, the proposed enhancements will contribute to improvement of water quality in the

environmentally sensitive watersheds such as Severn River, South River and Patapsco River.
-

3.4 Other Topics

3.4.1 Data Management

To-date SHA has performed inventory of SWM drainage infrastructure in seven counties and BMPs in all twenty-three counties. In addition, SHA has performed field inspections of BMPs in thirteen counties and initiated five additional counties. SHA has proceeded with the second cycle re-inspection in four counties. This work involves the 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 that consolidates the data previously stored in ESRI ShapeFiles and MS Access relational database. The geodatabase has a 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 addition, SHA is developing automated Quality Assurance (QA) checks to ensure the quality of the data being routinely created by either SHA staff or consultants.

Along with the new database format, a new data viewer tool is being developed to replace the old BMP Viewer. 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 can be used to view data from various levels such as a highway corridor, MSHA district, County, or watershed.

The primary goals of the new tool are the:

- Design Web-based environment using up-to-date technology,
- Preserve functionality of the current desktop tool,
- Develop new components which capture and streamline the existing BMP business process and rules.
- Assist in data management for BMP maintenance and remediation tasks

Figure 3-13 includes several screen captures of the newly developed tool. Currently the BMP Viewer functionality includes the following components:

- Mapping Tool
- Data Query Builder
- Grid View Tools
- Detail Reporting View
- Historical Data View
- Maintenance Activities Tracking
- Design Project Management Tool

The new BMP 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.

3.4.2 Standard Procedures Updates

Since the last Annual Report SHA completed additional updates to the Standard Procedures Manual including *Chapter 3 Best Management Practice Field Inspections & Data Collection Procedures* to improve the standardization of all relevant data. The current document includes the updates on the data collection as the result of the integration of the data into Geodatabase and SHA’s continued efforts to improve the NPDES Program.

In addition, SHA has developed a first draft for the *Chapter 7 BMP Assessment Guidelines for Maintenance and Remediation* to standardize and streamline the field inspections, assessment for remedial actions and development of maintenance work orders for the contractor. The Document is included in Appendix K.

Figure 3-12 BMP Field Inspections during Standards Procedures Workshop

In order to maintain consistency and compatibility in the data collected during source identification and BMP inspection, SHA continues conducting NPDES Standard Procedures Workshop for outfall inspections, BMP inspections and illicit discharge screening. (Figure 3-12) Approximately 25 consultants and SHA engineers completed the 3 day training in December 2007 and another group of 20 is scheduled for training in November, 2008.

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 help to make timely decisions on remedial actions, and meet NPDES permit requirements.

SHA's Business Plan goes beyond the NPDES permit requirements by promoting the statewide inventory and a high-level of BMPs performance. The goal is to bring 90 percent of SHA owned SWM facilities to their functionality by FY 2010. Figure 3-13 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 watershed of Chesapeake Bay.

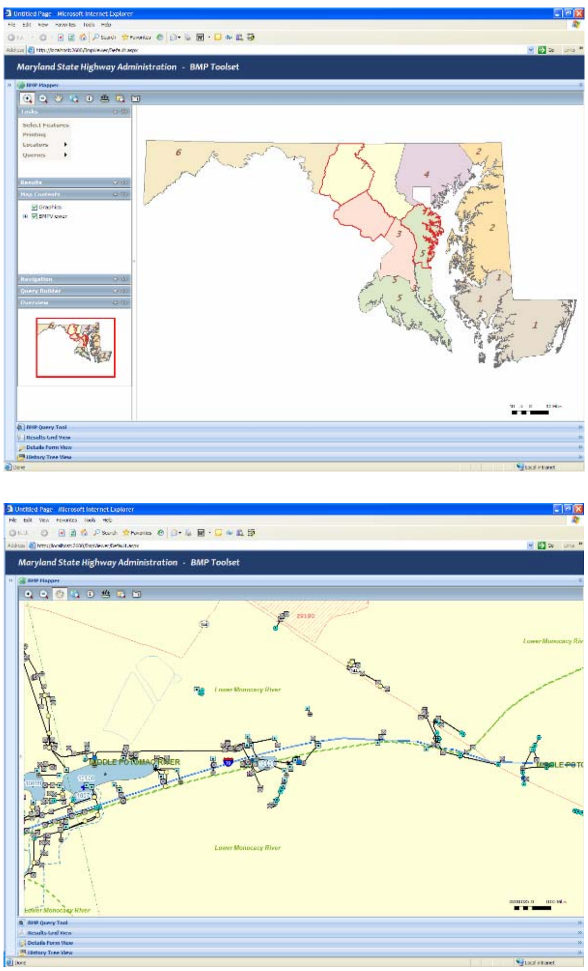


Figure 3-13 BMP Viewer Screen Captures

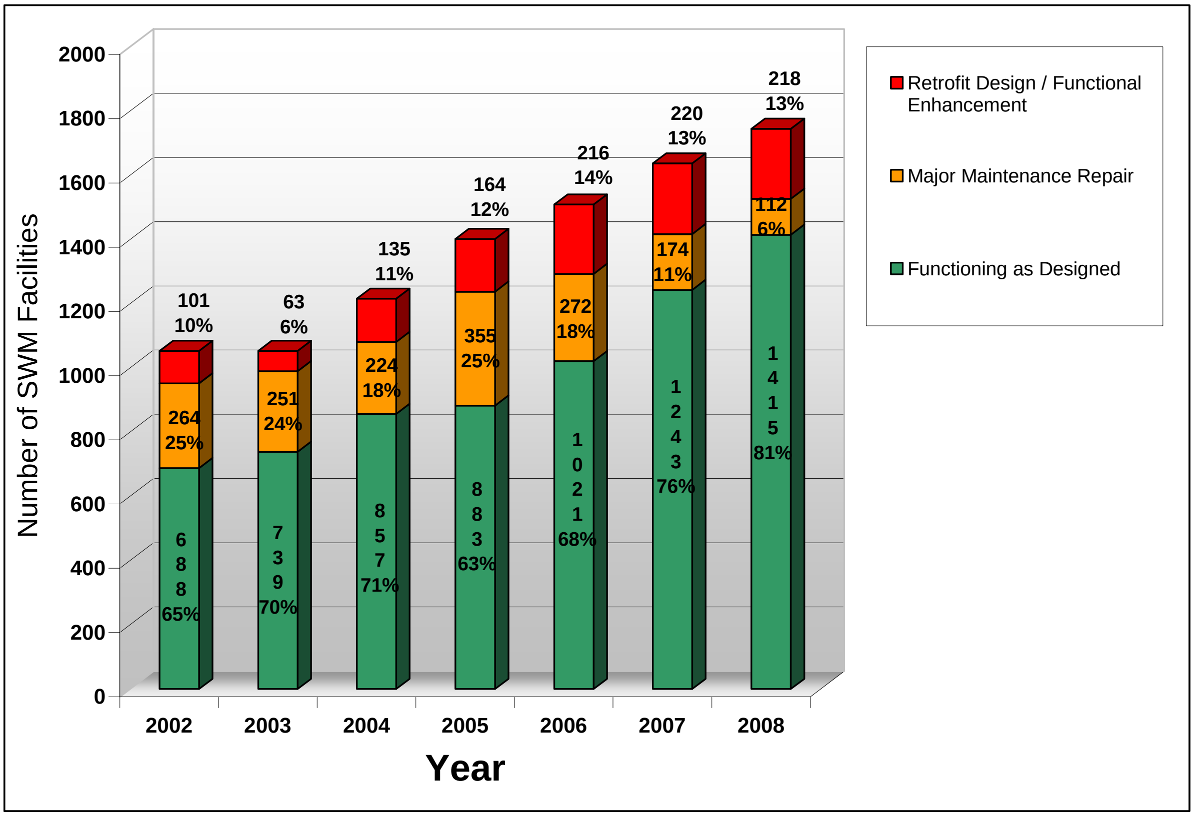


Figure 3-14 Progress in SWM Facilities Program

APPENDIX A:

GIS Standard Procedures
Chapter 2: Source Identification & Inventory

Draft October 2008

Chapter 2

Source Identification & Inventory

October 2008

DRAFT

Table of Contents

2.0 INTRODUCTION……………………………………………………………………………8

2.1 DRAINAGE FEATURES TO BE IDENTIFIED AND INVENTORIED………………...9

2.1.1 Structures………………………………………………………………………………. 10
2.1.1.1 End/Head Structures………………………………………………………………. 11
2.1.1.2 Inlet Structures……………………………………………………………………. 13
2.1.1.3 Connection Structures……………………………………………………………… 13
2.1.1.4 Control Structures…………………………………………………………………..16
2.1.2 Conveyances……………………………………………………………………………..19
2.1.2.1 Pipes, Cross Culverts, and Driveway Culverts…………………………………………... 20
2.1.2.2 Ditches………………………………………………………………………………… 22
2.1.2.3 Hydraulic Connectors…………………………………………………………………. 22
2.1.3 Stormwater Management Facilities…………………………………………………….... 23
2.1.4 Other Features……………………………………………………………………... .. 24

2.2 ORGANIZING DATA FOR ENTRY………………………………………………….. 24

2.2.1 Creating Drainage Systems……………………………………………………….. ... 25
2.2.2 System Numbering………………………………………………………………….. . 27
2.2.3 Maintaining Connectivity Using Storm Drain Features……………………………...... 30
2.2.3.1 Using Ditches, Open Conveyance, and Ditch Intersections…………………………… 30
2.2.3.2 Using Pipe Connections……………………………………………………………. 34
2.2.3.3 Using Pipe Directions………………………………………………………………… 35
2.2.3.4 Connecting to Public or Private Systems……………………………………………... 37
2.2.3.5 Representing Walls with Multiple Pipes………………………………………………. 38

2.3 WORK FLOW PROCESS…………………………………………………………..... 41

2.3.1 Obtain Versioned Geodatabase for Geographic Area……………………………... 41
2.3.2 Identify and Prioritize SHA Roadways and Project Areas………………………......... 41
2.3.3 Process Contract Drawings and Other Information………………………………. ...... .42
2.3.4 Develop Delivery Schedule and Status Map……………………………………… .. 42
2.3.5 Verify Attributes in Database……………………………………………………..… 44
2.3.6 Verify Features in Field……………………………………………………………... 44
2.3.7 Develop Pilot Study……………………………………………………………………45
2.3.8 Develop Spatial Features…………………………………………………………..... 45
2.3.9 Populate Geodatabase…………………………………………………………….. ...46

2.4 INVENTORY ACTION KEY……………………………………………………………...47

2.5 DATABASE TABLE STRUCTURE…………………………………………………….. .49

2.5.1 Tabular Data Format Conventions……………………………………………….. 53
2.5.2 CONTRACT Table………………………………………………………………….. .53
2.5.3 STRUCTURES Feature Class………………………………………………………..... 56
2.5.3.1 END_HEADWALL Table……………………………………………………………. 61
2.5.3.2 INLET Table…………………………………………………………………………... 62
2.5.3.3 MANHOLE_CONN Table……………………………………………………………. 63
2.5.3.4 PUMPSTN Table……………………………………………………………………... 64
2.5.3.5 SWMRISER Table…………………………………………………………………. 65
2.5.3.6 WEIR Table……………………………………………………………………….... 66
2.5.3.7 STRUCTURE_ISSUE Table………………………………………………………... 66
2.5.4 DRAINAGE_STRUCTURE Feature Class…………………………………………. 68

2.5.5 CONVEYANCE Feature Class……………………………………………………… .. 68
2.5.5.1 DITCH Table……………………………………………………………………. 72
2.5.5.2 PIPES Table……………………………………………………………………... 73
2.5.5.3 PIPE_INSPECTION Table………………………………………………………. 74
2.5.5.4 P_INSP_PHOTO Table…………………………………………………………. 74
2.5.5.5 P_INSP_REC Table…………………………………………………………… ...74
2.5.5.6 P_INSP_SUBRATINGS Table…………………………………………………. .74
2.5.6 FLDSC_SITE Table…………………………………………………………….... 75
2.5.6.1 INSPECTION Table……………………………………………………………. 75
2.5.6.2 FLOW_CHAR Table……………………………………………………………. 75
2.5.7 SWMFAC Feature Class……………………………………………………….... 75
2.5.7.1 BMP_INSPECTION Table……………………………………………………… 82
2.5.7.2 BMP_CENTROID Feature Class………………………………………………… 82
2.5.8 DRAINAGE_SWMFACILITY Feature Class……………………………….... 82
2.5.9 FILE_ATTACH_SWM and FILE_ATTACH_STR Tables……………………….…... 84
2.5.10 FILE_SCAN Table..……………………………………………………………87
2.5.11 META_INFO Table ..…………………………………………………………..88
2.5.12 OWNER Table ………………………………………………………………...90
2.5.13 AGREEMENT Table ..…………………………………………………………91
2.5.14 FILE_ATTACH_AGREE Table ....…………………………………………….92
APPENDIX 2-A DOMAIN VALUES FOR SOURCE IDENT. PARAMETERS ....………928

List of Figures

Figure 2.1 – Driveway Culvert Connectivity 21
Figure 2.2 – Hydraulic Connectors 23
Figure 2.3 – Drainage System Example 1 25
Figure 2.4 – Outfalls and Systems into a BMP 26
Figure 2.5a – System Number Example 1 28
Figure 2.6a – Ditch and Ditch Intersection Example 1 32
Figure 2.6b – Ditch and Ditch Intersection Example 2 33
Figure 2.6c – Ditch and Ditch Intersection Example 3 34
Figure 2.7 – Pipe Connection Example 35
Figure 2.8a – Pipe Direction Example 1 36
Figure 2.8b – Pipe Direction Example 2 37
Figure 2.9 – Private Storm Drain Feature Collection 38
Figure 2.10 – Multiple Pipes per End Structure 39
Figure 2.11 – Status Map 43
Figure 2.12 – Inventory Action Key 48
Figure 2.13- Example Plan Sheet 58
Figure 2.14 – Example Plan Sheet 70
Figure 2.15 – Dam Height Measurement 79
Figure 2.16 – Treatment Area Example 1 83
Figure 2.17 – Treatment Area Example 2 83
Figure 2.18 – Example of Photo Labeling 85
Figure 2.19 – Folder Structure Example for Scans 87

List of Tables

Table 2.1 – Storm Drain Features Represented in Geodatabase 9
Table 2.2 – County Codes for Maryland 27
Table 2.3 – Example Legend for Status Map 44
Table 2.4 – Function Class per Structure Type 59
Table 2.5 – Standard Photo Naming Conventions 86

Chapter 2
Source Identification

2.0 INTRODUCTION

Section 2 discusses the standard methodology for inventorying all drainage system components owned or maintained by SHA. This section serves as an instruction manual for collecting data and populating the NPDES Geodatabase. Each storm drain feature in the inventory and associated information that is entered into the geodatabase is discussed. The methods presented here for identifying the appropriate information and entering that information into the geodatabase will ensure consistent data population by database developers and users. It is highly recommended that teams use the Field and Office Editing Tool (FET and OET) to edit the geodatabase.

The data being collected is organized into series of drainage systems with stormwater management facilities that are interconnected allowing for flow tracing function through distinct systems. Closed and open storm drain structures are connected by pipes and ditches to create the drainage system. Stormwater management facilities (SWMF) are inventoried with the storm drain system. A drainage system is defined as a series of storm drain structures or point features (i.e., manholes, inlets, endwalls) that connect hydraulically through conveyance features such as pipes and/or ditches. A system can include both open and closed storm drain features. The procedures for inspecting SWMFs, outfalls, and pipes are discussed in Chapters 3, 4, and 5.

The first part of Chapter 2 will define the storm drain features that are collected for the inventory. These structures include inlets, manholes and connectors, end structures, pipes, and ditches. It is expected that the team has past design experience with SHA and that the team is familiar with the storm drain standards for SHA. The purpose of the definition is to re-familiarize the team with storm drain infrastructure features.

The next part of Chapter 2 will discuss how to create the connectivity between storm drain structures. It will clarify specific rules and situations when creating the connectivity and populating the database. The purpose of these rules and examples is to maintain consistency between consultants working on the storm drain data collection tasks. It is recommended that these rules and situations be reviewed and understood prior to conducting field work.

A work flow process for the procedures of collecting storm drain infrastructure is defined and described next. This is a step by step procedure for the inventory of storm drain features. Procedures for inspections are discussed in Chapters 3, 4, and 5.

Finally, Chapter 2 will discuss the database structure, tables, and fields that are populated during the inventory process. The database contains feature classes, associated tables, and fields that are defined. This section of the manual will explain examples and rules to be followed during the data collection process. The tables and rules should be reviewed prior to conducting data entry and all questions should be submitted to SHA for confirmation.

In this report, feature class items, table names, and domain values are printed in capital letters (e.g. PIPES) and field names are printed in italics (e.g. *conveyance_id).*

2.1 DRAINAGE FEATURES TO BE IDENTIFIED AND INVENTORIED

All SHA-owned roadways, visitor centers, rest areas, weigh stations, park and rides lots, and access utility permits are to be investigated for storm drain features. These include storm drain structures, conveyances, and stormwater Best Management Practices (BMPs). The collection of storm drain data does not include a formal inspection of each structure, but major issues are to be alerted to SHA. The initial data is acquired from design or "As-Built" plans that are provided by SHA and is then verified in the field. The following bulleted list describes how data is collected and represented:

- Contract plans are reviewed to identify storm drain infrastructure
- The SHA drainage system will be located and captured with a GPS
- The storm drain features will be represented spatially in a geodatabase
- Storm drain features will be assigned a number and associated data entered in tabular format

The storm drain features that will be represented spatially in the geodatabase are listed in Table 2.1.

Table 2.1 – Storm Drain Features Represented in Geodatabase

Feature Name	Feature Type
Endwalls, Headwalls, End Sections, Projection Pipes	Point
Inlets, Springheads	Point
Manholes, Junction Boxes, Ditch Intersection, Pipe Connections, Wye Connections, Capped Inlets, Pipe Bends, Pipe Direction	Point
Pump Stations	Point
Risers (or Storm Water Management Structure)	Point
Weirs, Emergency Spillways	Point
BMP Centroid	Point
Pipes	Arc
Ditches	Arc
Hydraulic Connectors	Arc
Stormwater BMPs	Polygon
Drainage Areas to Stormwater BMPs	Polygon

Feature Name	Feature Type
Drainage Areas to Structures	Polygon

Tabular database elements include information about the drainage system elements and reference data to enable cross-linking of database tables. Many of the fields in the tables have coded value domains to ensure uniformity of data and assist in the integration of the database. The domain values and descriptions are included in Appendix 2-A. The geodatabase structure schematic (Appendix 6-A) also includes details on the coded value domains, including acceptable values and details on feature classes and related database tables.

Although the purpose of the field verification is not to rate the structural condition of the drainage features, field crews sometimes observe infrastructure that require immediate SHA attention. If this occurs the problem should be documented with digital photographs and SHA notified upon return to the office. Problems that pose an immediate threat to the general public should be brought to SHA's attention immediately.

Field Equipment

The following list of equipment should be available while verifying storm drain feature in the field. Consultants should maintain the following list of field equipment:

- Handheld PC – Some of the data forms to be filled out are available in digital format and will be discussed later. A field editing application has been developed and is recommended for use to edit and populate SHA's geodatabase. More information on the office and field editing application and hardware is explained more in Chapter 6.
- GPS unit with extra batteries
- Digital camera with extra batteries
- Sampling kit – temperature, pH, phenol, chlorine, detergents, copper, ammonia
- Waders/hip boots
- 25-foot measuring tape
- ADC Map book
- Safety vests
- First aid kit
- Machete
- Clipboard
- Manhole puller
- Distance wheel

The next section of Chapter 2 is definitions of storm drain structures to be inventoried. Rules for creating connectivity and organizing data rules can be found in Section 2.2. Detailed information on the specific tables and fields to be populated can be found in Section 2.4.

2.1.1 Structures

Physical structures to be identified and inventoried include headwalls, endwalls, cross culverts, pumping stations, stormwater risers and weirs, inlets, pipe connections, and manholes. Storm drain structures are represented as point features in the database. Several database features are included that are not existing physical structures, but are employed to facilitate connection of drainage systems in the database. These second type of structures include pipe directions and hydraulic connectors, and are discussed later in this chapter. For detailed descriptions of each feature refer to the SHA Book of Standard for Highway and Incidental Structures, Category 3 "Drainage". The Standard Manual for storm drain features can be found online at:

http://www.marylandroads.com/

The following are brief discussions of the structures to be collected.

2.1.1.1 End/Head Structures

An end/head structure is any structure at the upstream or downstream end of a culvert or pipe. These can include headwalls, endwalls, endsections, and projection pipes. Often the end/head structure is designated on the contract sheets and field verified. When contract plans are not available for a roadway, the SHA Book of Standard for Highway and Incidental Structures should be referenced if structure types are unfamiliar with field teams.

Inspections will be performed on outfall pipes, structures, and area and will be described in more detail in Chapter 3, 4, and 5. It is asked that the field crew be cognoscente of outfall areas at the downstream end of outfall pipes, as they will be inspected. Outfall areas are not inventoried but should be made aware of during the inspection process.

Headwalls (HW) are structures that are placed at the upstream end of pipes and culverts to provide a stable or hydraulically desirable entrance to the conveyance. Headwalls are usually concrete but can be constructed of wood or masonry, such as brick or concrete block. Wall structures on the upstream side of a culvert or pipe are inventoried as headwalls. Plan sheets may designate the upstream end of a pipe or culvert as an endwall, but these structures should be inventoried as headwalls. All wall end structures at the upstream end of a pipe or culvert should be inventoried as headwalls.

Examples of headwall structures

Endwalls (EW) are structures that are placed at the downstream end of pipes and culverts to provide a stable or hydraulically desirable exit to the conveyance. Endwalls are usually concrete but can be constructed of wood or masonry such as brick or concrete block. All wall structures on the downstream side of a culvert or pipe are inventoried as endwalls. Plan sheets may designate the downstream end of pipe or culvert as a headwall, but these structures should be inventoried as endwalls. All wall end structures at the downstream end of a pipe or culvert should be inventoried as endwalls.

Examples of endwall structures

End Sections (ES) are structures that transition the ends of pipes into slopes and provide stability to the pipe entrances and outflows. They do not affect the hydraulic capacity or efficiency of the pipes. They can be constructed of concrete, metal, or plastic (HDPE). End sections can either be inventoried at the upstream or downstream end of a pipe.

Examples of end sections

Projection Pipes (PP) are not physical structures but represent the upstream and downstream end of a pipe if an end structure on a pipe does not exist. Projection pipes are captured spatially as a feature, and represent the ends of pipes.

Examples of projection pipes

2.1.1.2 Inlet Structures

Inlets are structures that collect storm drain runoff. Inlets convey the runoff to closed storm drain systems, open conveyance, or outfalls. There are many different types of inlet structures, and all are discussed in the SHA Standard Design Manual and should be reviewed prior to conducting an inventory. Spring head are inventoried as inlets.

<u>Inlets (IN)</u> are hydraulic structure chambers below surface grade that collect storm drain runoff. An inlet either has a grate or open sides/curb to allow runoff to enter the storm drain system. Inlets are often constructed of concrete, masonry brick, or concrete block.

Example of inlet structures

<u>Spring Heads (SH)</u> are inventoried as inlets. Spring heads are inventoried only where they emerge and are connected to a storm drain system. Spring heads are inventoried because they provide evidence for the presence of ground water for dry weather flows during illicit discharge field screening operation. Spring heads may be identified from contract drawings or identified during the field inventory. They are mostly found in rural areas.

Example of a spring head

2.1.1.3 Connection Structures

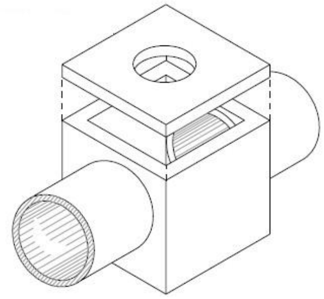
A connection structure is a storm drain structure that connects conveyance (pipes and ditches) within a system, and is not an inlet, riser, or pumping station. These can include manholes, ditch intersections, junction boxes, pipe connections, Y connections, capped inlets, pipe bends, and pipe directions. Because field crews are not required to open manhole lids and enter closed storm drain structures, no designation type is necessary for connection structures. All of the attribute data for these structures will be collected from contract drawings, including connection material and top of manhole elevations. The existence of connection structures should be field verified, even though the attributed data will be collected from contract drawings. A GPS point is to be recorded at the best estimated location in the field based on contract plan sheets for structures that are buried. The verification of attribute table data for structures that cannot be verified in the field will be completed based on plan sheet information. This also holds true for structures that are buried or cannot be accessed; the attribute data should be obtained from plan sheets.

Manholes (MH) are hydraulic structures that connect pipes through a system. They are used as access points to a system, to change direction or invert elevations for pipes, as a junction to change pipe size and/or material, and as a junction of multiple pipes to a single pipe. Manholes are frequently paved over or buried but are still inventoried. Unless it is certain that the manhole does not exist, the manhole is inventoried. Manholes with lids that have designed holes to allow runoff to enter are inventoried as manholes and not inlets.

Example of manholes

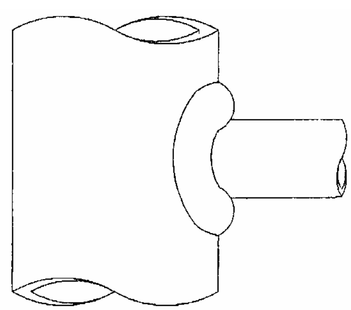
Ditch Intersections (ID) are geographic representations of where ditches meet, begin a system or end a system, and are captured as point features. These features are used to define the extents of ditches. The proper use of ditch intersections and the criteria for collecting ditches is explained in more detail in Section 2.2.3.1.

Junction Boxes (JB) are underground hydraulic structures that connect pipes through a system. They are used to change direction or invert elevations for pipes, to change pipe size and/or material, and to connect multiple pipes to a single pipe. Identifying junction boxes in the field is difficult because these structures are usually buried with no part of the structure exposed to the surface. Junction boxes are only inventoried from contract drawings and should never be assumed in the field, unless the field crew is certain the structure is a junction box. If the field crew suspects that pipes are merging together and no contract plans are available to confirm this, the connection should be inventoried as a pipe connection and not a junction box.



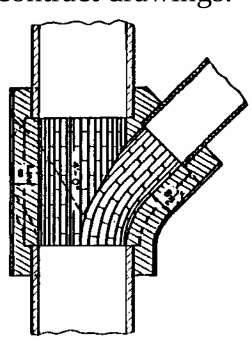
Example of a junction box in detail view

<u>Pipe Connections (PC)</u> are locations throughout the conveyance of a system where two or more pipes connect. A pipe connection is also captured at the location where a closed storm drain pipe connects to a culvert or stream crossing. The proper use of pipe connections and the criteria for collecting ditches is explained in more detail in Section 2.2.3.2.



Example of pipe connection in detail view and photograph inside of pipe

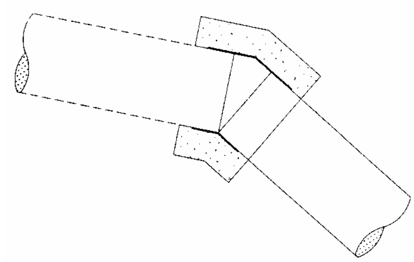
<u>Wye Connections (YC)</u> are hydraulic structures that join two pipes together within a system's conveyance. Wye connections will be identified from contract drawings and should not be assumed in the field. Instead of assuming a wye connection structure in the field, assume a pipe connection. Access to wye connections will not be possible in the field, so the material should be determined from the contract drawings.



Example of wye connection in detail view

Capped Inlets (CI) are inlets that have been capped for some reason, such as roadway widening. These are not inventoried as inlets, but as connectors. Capped inlets should be identified from the contract drawings and should not be assumed in the field.

Pipe Bends (PB) are locations along a conveyance where a pipe makes a significant turn in direction and are usually shown on As-built plan sheets. Pipe bends can be actual physical features, or used to facilitate an accurate representative of the pipe. Pipe bends will be identified from contract drawings and will be at the discretion of the Team to determine if a pipe bend is necessary. Pipe bends can also be used if the pipe turns and no pipe bend feature is identified on the plans, such as pipes that make slight S-turns.



Example of a pipe bend in detail view

Pipe Directions (PD) are not physical features in the field, but represent connectivity with private storm drain systems when an upstream or downstream private structure cannot be located in the field. If an SHA storm drain flows into or out of a private storm drain structure, then the first or last structure in the private system is inventoried. Pipe directions are used in the inventory when it is obvious that an SHA storm drain system is flowing into or from a private system, but the private downstream or upstream connection is outside of SHA right-of-way (ROW) and cannot be found. In these situations, a PD is inventoried so that the pipe feature can be created and pipe attributes can be recorded. Pipe directions are not used within SHA ROW because SHA would like to know the exact access point for every system. The proper use of pipe direction and the criteria for collecting pipe directions is explained in more detail in Section 2.2.3.3.

2.1.1.4 Control Structures

A control structure is any type of structure that controls flows. Control structures will most often be riser or weir structures. Although, other structures such as inlets, headwalls, endsections, projection pipes, and pump stations can function as a control structure. Riser structures and weirs are collected in separate tables because they require collection of additional attributes not associated with other types of control structures. Information about risers and weirs that is collected in the field and from contract sets includes material, riser type, trashrack existence, and orifice invert elevations. Monitoring wells and infiltration trench observation wells are not considered control structures, and are not inventoried but identified in the inspection process.

Riser Structures (SW) are vertical structures extending from the bottom of a stormwater BMP that are used to control discharge rates from a BMP for specified design storms. Riser structures are normally constructed of concrete or corrugated metal. Riser structures may or may not have low flow orifices and/or trashracks. Typically riser structures are designed with different type of inflow devises to control flow out of stormwater BMPs and are normally connected to an outfall pipe. During the BMP inspection process (Chapter 3), BMP control structures will be examined for flaws and structural integrity.



Example of riser structure in stormwater BMPs

Weir Structures (SW) are earthen notches or other water barriers, such as a concrete or gabion wall structure, in a berm dam through which flow of water out of a stormwater BMP is regulated and controlled. Weirs are constructed from concrete, wood, metal, earthen, or riprap. Weir structures may or may not have low flow orifices and/or trashracks. Because earthen spillway embankment weirs may be difficult to find in the field, efforts should be made to identify weir structures prior to conducting a field inventory.


Example of concrete weir structures

Emergency Spillways (EM) are depressions or notches in cut that convey stormwater BMP overflow in a controlled manner, rather than allowing it to overtop the embankment. The material of an emergency spillway can be concrete, earthen, or riprap. Emergency spillways are inventoried if they exist for a stormwater BMP, and are recorded in the WEIR table. Because earthen emergency spillways may be difficult to find in the field, they should be identified prior to conducting a field inventory.

Example of emergency spillways

<u>Pumping Stations (PS)</u> are mechanical pumps stored in a pump house that pump or lift stormwater uphill to a high point where gravity can again take over. Pump stations are considered control structures because they control the quantity of water being pumped. Pump stations are rare and are mostly identified from contract drawings. Attribute information is collected from contract plans and include number of pumps, station name, maximum capacity, and installation date. The field team only needs to locate the pump house and are not to enter the pump station.

Detail of plan view and photos of pump station

2.1.2 Conveyances

Conveyance features to be identified and inventoried include both actual, physical features (pipes and ditches) and a database features (hydraulic connectors). Conveyance is represented as line features in the database. Although they do not physically exist, hydraulic connectors should be inventoried to facilitate connection of drainage systems through SWM facilities; this is the only case where a hydraulic connector is created. Refer to Section 2.1.2.3 for rules on hydraulic connectors. Not every pipe or ditch conveyance is inventoried as explained in Section 2.1.2.1, but generally all conveyances between structures are inventoried. Conveyance features will have an upstream and downstream structure. When contract plans are not available showing proper conveyance for a storm drain system, conveyance can be determined by looking at the pipe(s) direction inside of structures. Field crews are not required to open manhole lids, and conveyance can be assumed at the field crew's discretion when plans are not available.

2.1.2.1 Pipes, Cross Culverts, and Driveway Culverts

Pipes connect structures together in a system to maintain conveyance. Pipes consist of closed storm drain pipes, cross culverts, and driveway culverts. Rules for collecting cross culvert and driveway culvert pipes are described below. The following are rules that should be followed when collecting pipes within the storm drain network:

- All pipes between closed storm drain structures are inventoried.
- Pipes $\leq$ 5 feet in height are inventoried within SHA ROW
- Pipes that are > 5 feet in height are not inventoried if they do not connect to closed storm drain structures
- Pipes that are > 5 feet in height but do connect to closed storm drain structures are inventoried with the storm drain network
- Closed storm drain systems that outfall through a pipe or culvert that is > 5 feet in height are inventoried

Pipe size, shape, invert, and material are recorded for all pipes. Because field crews are not required to open grates or manhole lids, this attribute information is gathered from contract plans. Pipe sizes and material should be verified in the field by observation through inlet grates and at end structures (headwalls, end sections, outfalls, projection pipes). Field crews should become familiar with different pipe sizes and materials prior to conducting field inventory.

Cross Culverts are pipes, boxes, or arches that convey water from one side of the ROW to the other side, usually under the roadway. Cross culverts are inventoried as pipes. Depending on the situation and culvert size, not all cross culverts will be inventoried. The following are rules that should be followed when collecting driveway culverts:

- The culvert height is determined from contract plans when available. Otherwise care should be taken to measure and estimate the actual culvert height in the field. This may require estimating the depth of sedimentation at the culvert ends to determine the feet of buried culvert.
- Culverts that are $\leq$ 5 feet in height are inventoried
- Culverts that are > 5 feet in height are not inventoried
- A culvert that is > 5 feet in height that have closed storm drain tying into them is not inventoried. Instead the most downstream structure in the closed storm drain system is inventoried as a pipe connection at the location the storm drain system connects to the culvert.

Driveway Culverts and entrance culverts are pipes, possibly with an end structure, that conveys water under driveways, utility access roads, or stormwater BMP access roads. Not all driveway culverts will be inventoried within SHA ROW.

There are rules that should be followed when collection driveway culverts. The rules are as follows:

- Private driveway culverts and culverts at farm or other access points that do not require access permits, should not be inventoried. Culverts under entrance drives that provide 2-way or greater traffic such as multi-family residential, commercial, public, or industrial properties are inventoried. Culverts under SHA-owned stormwater maintenance access or other utility access roads should also be inventoried.

- If the private driveway or access drive culvert has a closed storm drain structure such as an inlet or riser on the upstream or downstream end of the pipe, then the culvert should be inventoried.

- If a driveway culvert is excluded from the inventory, other adjoining closed drain structures completing the system should be connected using a ditch. The ditch in this case should be drawn through the culverts as if the culvert does not exist. Refer to Figure 2.1.

Figure 2.1 – Driveway Culvert Connectivity

Example of driveway culvert not being inventoried, but instead a ditch representing flow between closed storm drain features

The picture above is an example of an area that has driveway culverts, but only the one at the upstream end is actually collected because there is an inlet connected. The ditch line in the database passes through the other driveway culverts that are not inventoried.

As part of the inspection task, outfall pipes are inspected for integrity and illicit discharge. The inspection of pipes and outfalls is explained in Chapters 4 and 5.

2.1.2.2 Ditches

Ditches and open conveyance are channels or flow paths that connect open structures (headwalls, endsections, endwalls, projection pipes) in a system to maintain the conveyance. Attributes collected for ditches include material (vegetative, concrete, riprap, etc.), bottom width, and side slope. Not all ditches or open channels within SHA ROW are to be inventoried in the geodatabase. Ditches to be inventoried are the following:

- Ditches or open conveyance between open structures
- Ditches or open conveyance ≥ 2 feet in bottom width
- Ditches or open conveyance that flow into stormwater BMPs regardless of bottom width

2.1.2.3 Hydraulic Connectors

Hydraulic Connectors connect the outfalls into stormwater BMPs to the control structure of the stormwater BMP to maintain conveyance through the system. Hydraulic connectors are used to represent connectivity through a stormwater BMP from inflows to control structures. Inflow points and control structures for stormwater BMPs should be connected with a hydraulic connector, including infiltration trenches. If hydraulic connectors do not exist in the previous inventory, the current development should create them. The hydraulic connector line features are stored in the CONVEYACNE feature class (Section 2.5.5), and no additional attribute information is collected. The connector is use so that connectivity between structures is maintained through stormwater BMPs, and network tracing can occur.

Hydraulic connectors can either be created using the office or field editing application, or other GIS editing tools. The following are rules to follow when creating hydraulic connectors in the geodatabase:

- Hydraulic connector features should be created for every stormwater BMP that has an inflow and control structure, including ponds, basins, infiltration trenches, underground storage facilities, swales, or bioretention facilities.

- Hydraulic connectors should be manually sketched because they are only used for connectivity purposes. It is not required to GPS hydraulic connectors.

- Hydraulic connector line features should be contained within the stormwater BMP polygon outline. It may be necessary to modify and correct line features to conform to the stormwater BMP shape.

- If a ditch conveys flows into a stormwater BMP, then a ditch intersection point will be placed on the stormwater BMP outline as the downstream structure for that ditch as described earlier. A hydraulic connector line feature should snap from this ditch intersection point to the control structure. (see Section 2.x for rules on creating ditch intersections)

Figure 2.2 shows an example of the use of hydraulic connectors through stormwater BMPs.

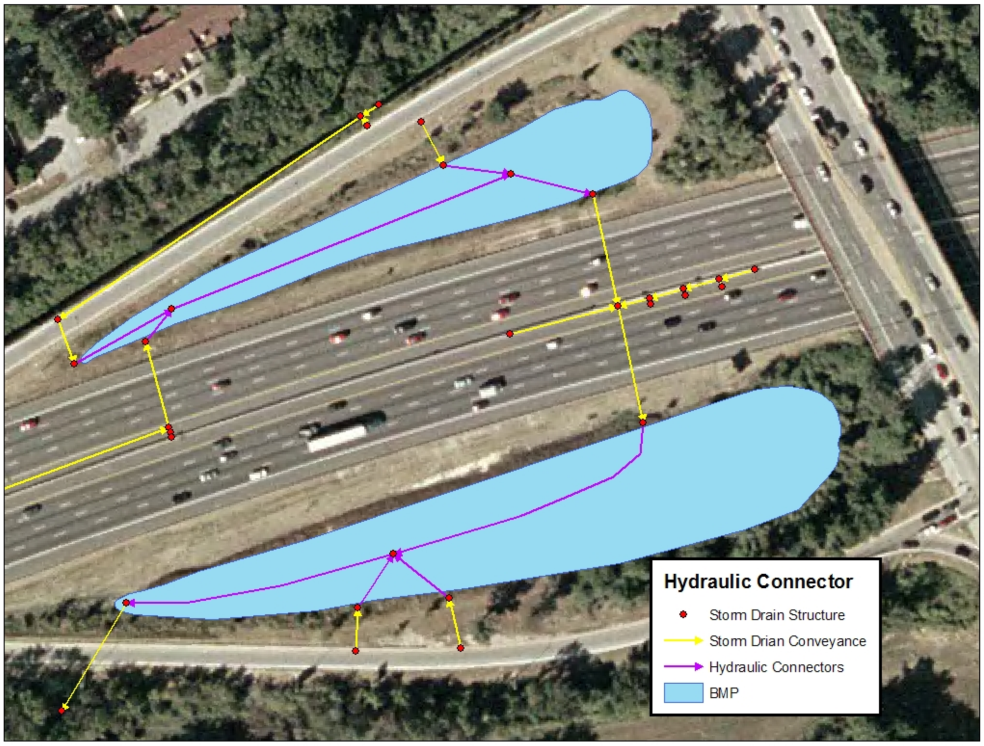


Figure 2.2 - Hydraulic Connectors

Example of the use of hydraulic connectors. Every stormwater BMP that has an inflow and control structure should have these features to maintain the connectivity.

2.1.3 Stormwater Management Facilities

Stormwater management facilities (SWMF) are structural best management practices (BMPs) that temporarily store or treat stormwater runoff to reduce flooding, remove pollutants, and provide other amenities. Stormwater BMPs are impoundment areas that treat stormwater runoff to reduce flooding, remove pollutants, and provide other benefits such as wildlife attraction. Pollutant removal can be accomplished through retaining permanent pools of water, detaining water temporarily and then releasing it slowly, infiltrating runoff into the ground, filtering the water through a medium into the ground, or combining multiple treatments.

SHA will supply the consultant with a list of BMPs for the County. If a stormwater BMP is receiving SHA runoff, the feature is inventoried, regardless of the owner. Attributes recorded for each stormwater BMP feature include type, location, status, and owner. Refer to the *Maryland Stormwater Management Management Guidelines for State and Federal*

Projects - Volume I & II stormwater BMP types and common features related to stormwater BMPs. Chapter 3 discusses procedures and criteria for inspecting stormwater BMPs.

2.1.4 Other Features

Combined Sewer Systems

The NPDES Municipal Separate Storm Sewer System (MS4) permits apply only to storm sewers that are separate from sanitary sewers. There are instances when an SHA drainage system ties into a combined county or city system (Combined Sewer Outfall - CSO) that conveys both storm and sanitary discharge. In this instance, the SHA system should be identified and inventoried up to and including the connection with the CSO. A notation should be made in the comments field of the private connecting structure that the connecting system is a CSO. CSOs should not be inspected for stability or illicit discharges (Chapter 4 and 5).

Drainage Systems that Cross County Lines

If it is determined that a drainage system crosses a County boundary, the system should be inventoried with the county where the system outfall is located. This will prevent a single system from being inventoried twice. Coordination with SHA may be required to ensure proper data management. For these situations, the systems may consist of two different system numbers. This is the only situation where one system might have two different system numbers.

NPDES Industrial Features

Drainage information for SHA maintenance shops, fueling facilities, vehicle maintenance facilities, and district offices is collected as part of the NPDES industrial permits and is handled through the SHA Environmental Compliance Division (ECD). This information will not be inventoried as part of the Highway Hydraulics Division (HHD) inventory/inspection, but the geodatabase includes ECD maintained structures, conveyances, and stormwater BMPs. Stormwater BMPs associated with these SHA industrial facilities are included in this geodatabase; however, the effort to identify and inspect them is initiated through the ECD. If you have any questions, contact the SHA NPDES coordinator in HHD for clarification.

2.2 Organizing Data for Entry

The database design is organized around drainage systems and stormwater BMPs. An important aspect of the storm drain systems is connectivity of the features by conveyance. Numbering these drainage systems and stormwater BMPs assures identification for tracking, maintenance, and design. This section will discuss numbering and creating a digital representative of the drainage system. It will also explain how to use certain features available in the GIS software to represent the storm drain infrastructure and develop connectivity through the system.

If the intent of the project is an update to the existing geodatabase, new contract drawings are reviewed in conjunction with the existing geodatabase. Features that are new or require updates should be highlighted on the construction drawings and assigned system and structure numbers. When adding systems and/or structures to an existing system, the geodatabase should be queried for the next available system and/or structure number. Structures and systems should be pre-numbered prior to field work. This will save time in the field and allow for quick entry of system, structure, and stormwater BMP numbers.

2.2.1 Creating Drainage Systems

A drainage system is defined as a series of storm drain structures or point features (i.e., manholes, inlets, endwalls) that connect hydraulically through conveyance features such as pipes and ditches. A system can include both open and closed storm drain features. Figure 2.3 is an example of a drainage system.

Figure 2.3 – Drainage System Example 1

Example of Drainage System Consisting of Lines and Points

In the database, drainage systems consist of line and point features that connect to form a continuous flow. Systems are determined by reviewing the design plans and identifying drainage features. Beginning with the most downstream structure, such as an outfall or connection to a private system, and following the system upstream the consultant should identify features.

Systems can have multiple branches, which should merge to one location. For limits of roadway where storm drain design plans are not available, it will be necessary to create systems using field observations and experience to determine connectivity.

Stormwater BMPs are also identified from design plans and through field observations. Stormwater BMPs that collect SHA runoff are inventoried in the geodatabase. Stormwater BMPs are considered separate features from storm drain systems. Multiple drainage systems can flow into or out of stormwater BMPs. Each outfall into the stormwater BMP is the beginning, most downstream structure of the system (see Figure 2.x). The stormwater BMP control structure and outfall for a stormwater BMP are treated as a separate system.

Pipes, ditches, and hydraulic connectors are used to represent the hydraulic connectivity within a system. These line features are connected (snapped) to the structure features. This snapping is necessary to perform flow tracing through each system. Each line feature should be drawn upstream to downstream so that arrows point in the flow direction when symbology is placed on the line feature class. All conveyance features must be snapped to an upstream and downstream structure feature record.

Hydraulic connectors are used to connect the outfalls into a stormwater BMP to the stormwater BMP control structure. This creates a network of different storm drain systems that merge together at the BMP outfall structure. The use of hydraulic connectors is described in Section 2.1.2.3. Figure 2.4 is another are examples of separate systems flowing into and from a stormwater BMP.

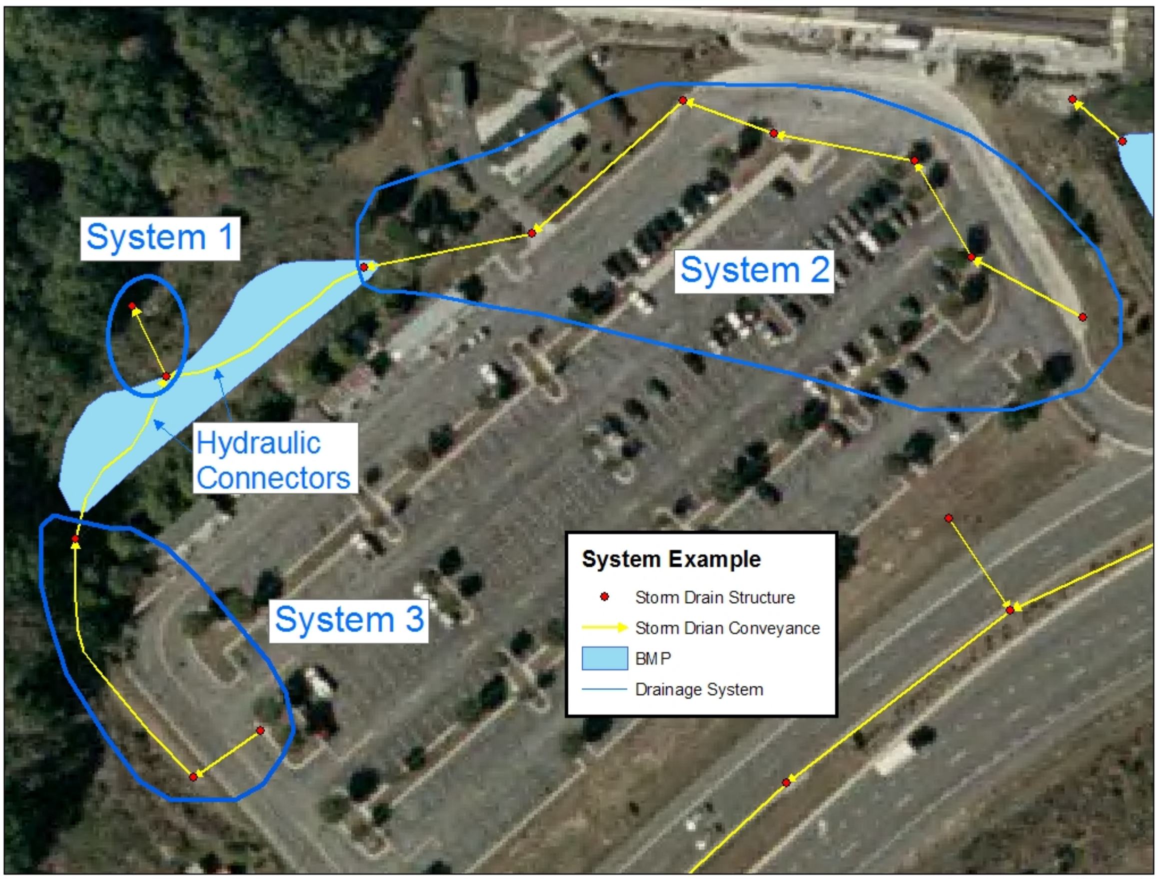


Figure 2.4 - Outfalls and Systems into a BMP

Both the field and office editing applications will allow the user to create conveyance as described in more detail in Chapter 6. The consultant may decide at what point in the process that conveyance is created. If conveyance will be created in the office, it is still necessary to field verify and collect conveyance information, such as pipe size, ditch material, etc. If a conveyance feature makes a slight bend and a pipe bend is not designed on the plan sheets, it may be necessary to edit these conveyance feature lines to represent the contract plan.

2.2.2 System Numbering

Each drainage system receives a unique seven-digit identification number. The first two (2) digits indicate the county where the system is located. Table 2.2 lists the county code numbers for Maryland. For county codes that begin with a zero (ex. Baltimore County 03), the leading zero is not dropped from any naming convention. The remaining five (5) digits are generated within the geodatabase, if a number does not already exist for a structure feature. For example, 1300140 is system 140 located in Howard County (County Code 13).

Table 2.2 – County Codes for Maryland

Code	County	Code	County
01	Allegany	13	Howard
02	Anne Arundel	14	Kent
03	Baltimore	15	Montgomery
04	Calvert	16	Prince Georges
05	Caroline	17	Queen Anne’s
06	Carroll	18	St. Mary’s
07	Cecil	19	Somerset
08	Charles	20	Talbot
09	Dorchester	21	Washington
10	Frederick	22	Wicomico
11	Garrett	23	Worcester
12	Harford	24	Baltimore City

The individual drainage structures located within a system receive a unique three (3) digit identification number. For example, 1300140.007 is the seventh (.007) structure in the 140^{th} drainage system in Howard County.

Numbering begins with the most downstream structure, usually the outfall, which is assigned the structure number of .001. Structures are then numbered as the system is traced upstream. For initial data collection or adding new systems, the most downstream structure in any system should be numbered .001. **This is convention only, and structures may be numbered out of sequence in the existing geodatabase. Outfalls may have structure numbers other than .001 only during updates.** During subsequent updates, structures should not be renumbered. Re-numbering of structures will result in the loss of historic data.

Recall that each system the flows into a BMP is a separate system. The control structure and outfall for a stormwater BMP also starts a new system. Figures 2.5a and 2.5b show examples of system, structure, and BMP numbering.

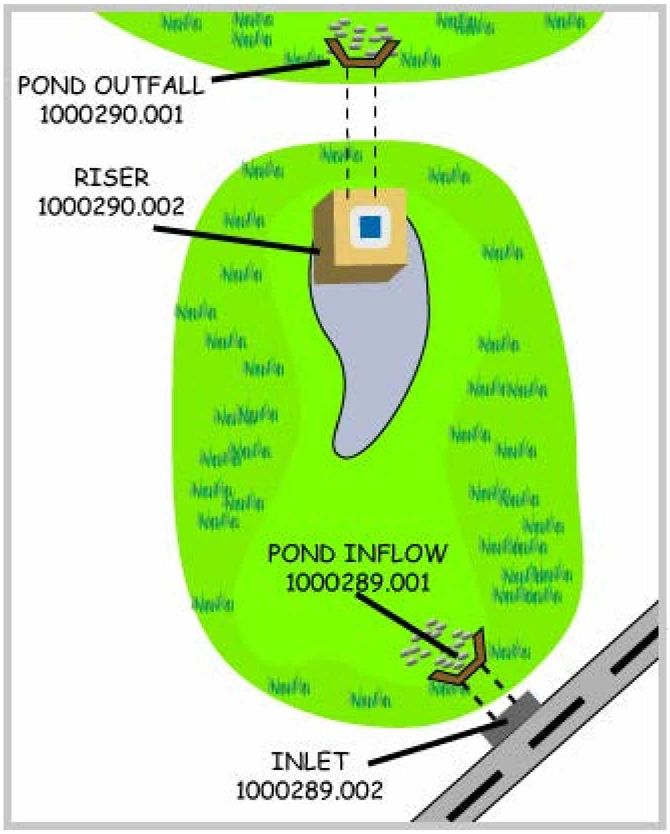


Figure 2.5a - System Number Example 1

Notice that the outfall into the stormwater BMP is a separate system from the riser and outfall structure system.

Figure 2.5b – System Number Example 2

System numbering example through a stormwater BMP. Notice that the outfall systems into the stormwater BMP are separate systems from the riser and outfall structure system.

SHA will supply a list of stormwater BMPs to the consultant. Stormwater BMP numbers may also be located on contract drawings. If a stormwater BMP does not have an identification number, then one is assigned by the consultant using a list of stormwater BMP numbers blocked off by SHA. The consultant should assign new BMP numbers from that blocked list and consult SHA when the numbers in the block have been exceeded. Stormwater BMP numbers will not be changed unless otherwise specified by SHA.

BMPs are numbered similarly to structures. Each stormwater BMP receives a unique six-digit identification number. The first two (2) digits indicate the county where the system is located. Table 2.2 lists the county code numbers for Maryland. For county codes that begin with a zero (ex. Baltimore County 03), the leading zero is not dropped from the naming convention. The remaining four (4) digits are generated within the geodatabase. For example, 130550 is the 550th BMP located in Howard County (County Code 13).

2.2.3 Maintaining Connectivity Using Storm Drain Features

Most of the connectivity between closed storm drain structures, such as inlets, manholes, or junction boxes can be found on contract plans or determined using field observations. During previous inventories, questions have arisen about how to collect and spatially represent certain features and conveyance in the geodatabase. Specifically, these questions have included ditches, pipe connections, pipe directions, hydraulic connectors, connection to or from private storm drain systems, and multiple pipes in a single-wall structure. This section discusses how to use specific features to represent the storm drain infrastructure and maintain conveyance through a system.

2.2.3.1 Using Ditches, Open Conveyance, and Ditch Intersections

Ditches are line features in the database. Care should be taken to ensure they are snapped to adjacent structure features. This will ensure connectivity for flow tracing.

Ditches can be drawn manually or located using GPS equipment in the field. If GPS data is used, the consultant should clean up the line in the geodatabase to remove any jagged lines. In some cases, it may be difficult to collect GPS data for a ditch due to slope, vegetation, access, etc. These ditches can be digitized from orthophotos if necessary.

Ditch Intersections are point features in the geodatabase. A ditch intersection is used in association with ditches and open conveyances to connect, intersect, begin, and end a ditch line feature.

The following are guidelines to follow when creating ditches and ditch intersections in the geodatabase:

- All ditches and open conveyance should have an upstream and downstream point feature
- Ditch lines should intersect other ditch lines at a ditch intersection point feature
- Place a ditch intersection where a ditch bends significantly or where 2 or more ditches intersect
- Place a ditch intersection as the upstream and downstream structure at ditches that do not connect to storm drain structures such as endwalls, headwall, end sections, or inlets
- Place a ditch intersection where ditches intersect a stormwater BMP polygon feature outline
- Place a ditch intersection where ditches leave or enter the SHA ROW line
- Place a ditch intersection where a ditch changes material

- Place a ditch intersection where two “long” ditches flow into the same inflow structure.

Figures 2.6a to 2.6c show examples of how to use ditch intersections and ditches properly to represent the storm drain connectivity.

Figure 2.6a – Ditch and Ditch Intersection Example 1

Place a ditch intersection as the upstream and downstream structure at ditches that do not connect to storm drain structures such as endwalls, headwall, end sections, or inlets. Place a ditch intersection where ditches intersect a stormwater BMP polygon feature outline.

Figure 2.6b – Ditch and Ditch Intersection Example 2

Ditch lines should intersect other ditch lines at a ditch intersection point feature. Do not merge ditches at outfall structures. Ditches can intersect at inflow structures. Use IDs when two "long" ditches flow into the same inflow structure. Place a ditch intersection where a ditch changes material

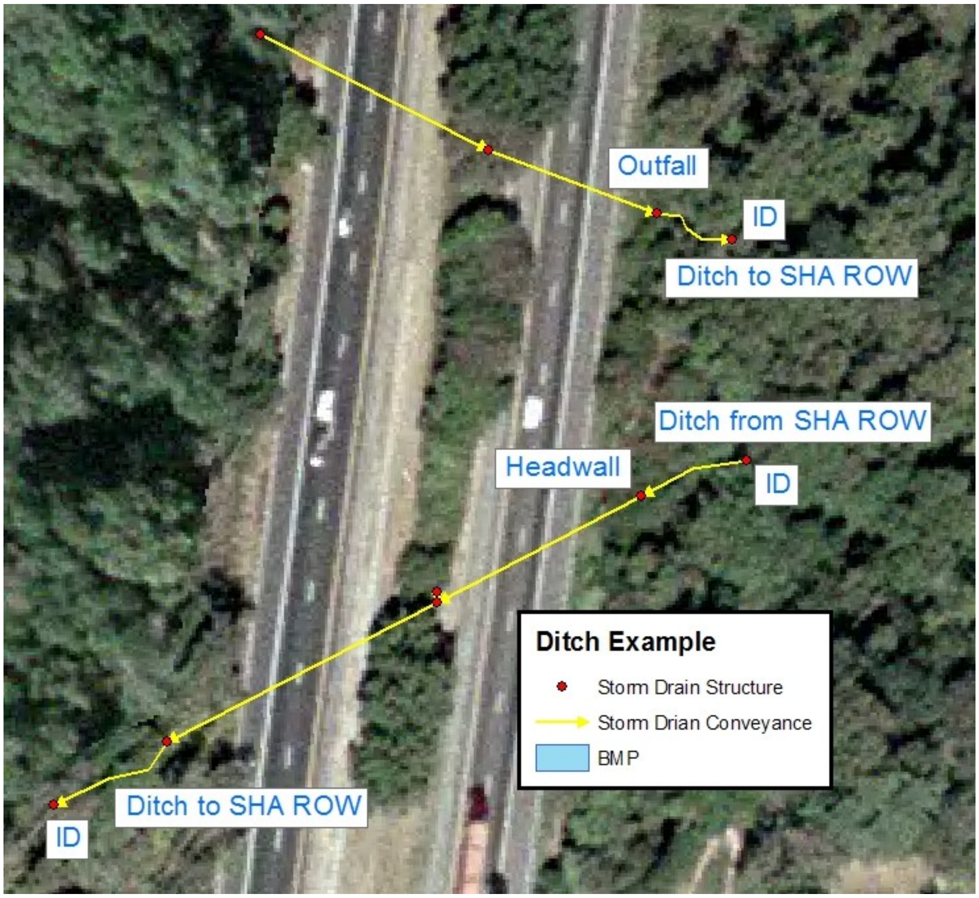


Figure 2.6c – Ditch and Ditch Intersection Example 3

Place a ditch intersection where ditches leave or enter the SHA ROW line if the ditch has a bottom width ≥ 2 feet.

2.2.3.2 Using Pipe Connections

Pipe connections are point features in the database. A pipe connection is used in association with pipe to indicate the location where two pipe meet, where a pipe changes material, or as designated on plan sheets. Pipe connections are often identified form plans sheets, but can also be assumed in the field.

The following are guidelines to follow when creating pipe connections in the geodatabase:

- Place a pipe connection as identified from contract plan sheets.
- Based on field observations, if it is obvious, that two pipes are merging together then a pipe connections can be assumed and inventoried. Plan sheets should always be thoroughly checked.

- If a manhole feature (or other connection structure feature) is identified on contract plans but the manhole is buried or paved over and cannot be field verified, do not inventory the manhole as a pipe connection. Instead, inventory the structure as shown on contract plan sheets.

- A pipe connection feature should not be inventoried to indicate the direction of pipe if upstream or downstream structures feature cannot be located.

- Place a pipe connection feature where a pipe material changes.

- Pipe connections should be used where a closed storm drain system outfalls into a culvert or stream crossing that is > 5 feet in height. If a culvert is < 5 feet in height, then the culvert ends as well as the pipe or box are inventoried. Culverts are not inventoried if the height is > 5 feet in height. In this case, the pipe connection into the culvert would be the most downstream structure in a system. If multiple system pipes outfall into a culvert > 5 feet in height, then each pipe connection starts a new system. Figure 2.7 shows examples of when to use a pipe connection instead of inventorying the culvert.

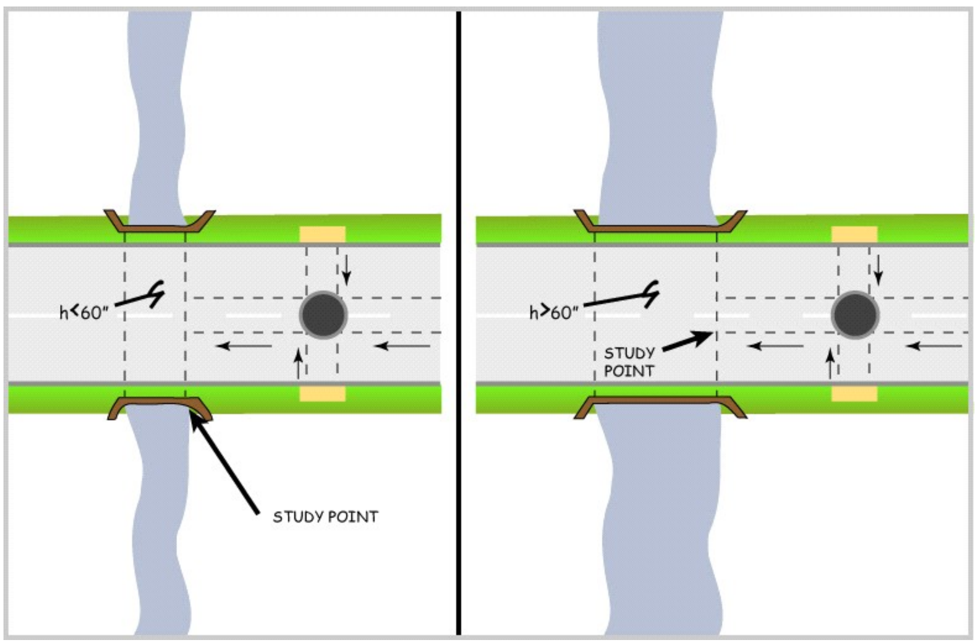


Figure 2.7 – Pipe Connection Example

A pipe connection should be used when closed storm drain systems outfall into a culvert that is > 5 feet in height. When a culvert pipe or box is ≤ 5 feet in height, then the culvert ends and conveyance are inventoried with the inflow systems.

2.2.3.3 Using Pipe Directions

Pipe directions are point features in the database. A pipe direction is inventoried when a pipe is identified at an SHA-owned structure feature that connects to or from a private storm drain system outside of SHA ROW, and the private upstream or downstream structure cannot be located.

The following are guidelines to follow when creating pipe directions in the geodatabase:

- Place a pipe direction point approximately 10 feet in the pipe direction if an SHA structure connects to a private storm drain structure, and the private structure cannot be located.
- Pipe direction points should not be included within SHA ROW, and all systems within SHA ROW should end or begin with a physical feature (manhole, endwall, inlet, etc.).
- A common occurrence where a pipe direction feature would be inventoried include private inflows into SHA owned stormwater BMPs

Figures 2.8a and 2.8b show examples of how pipe direction features should be inventoried.

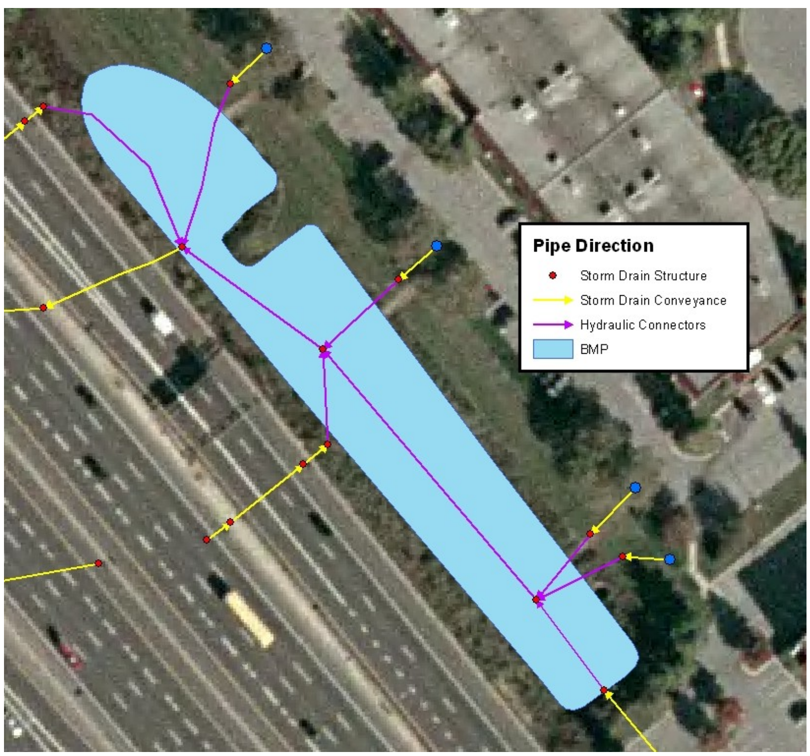


Figure 2.8a – Pipe Direction Example 1

This BMP has four private inflows. The upstream structures on the private inflows could not be found so a pipe direction feature was inventoried in the direction of the pipe.

Figure 2.8b – Pipe Direction Example 2

This SHA storm drain system flows into a private storm drain system outside of SHA ROW. The private downstream structure could not be located, so a pipe direction feature is inventoried.

2.2.3.4 Connecting to Public or Private Systems

The inclusion of drainage elements not belonging to SHA will be required in some instances where information on the drawings is incomplete or ambiguous. Every effort should be made by the geodatabase developer to resolve any uncertainties and ensure accuracy of the data. Where uncertainty is unavoidable, drainage elements or systems should be included in the geodatabase.

Where SHA drawings show work performed on county or private owned roads, storm drain systems should be recorded because they were constructed under a state contract. If the work completed on a county or private owned road is extensive, the consultant should contact the SHA NPDES coordinator to check if the system was turned over to the county and whether it should be included in the geodatabase.

The following are guidelines to follow when connecting SHA storm drain to private owned storm drain features:

- Storm drain infrastructure appearing on the contract drawings should be inventoried unless the consultant is absolutely certain that the feature is not owned by SHA.

- Stormwater BMPs collecting SHA runoff should be inventoried, regardless of ownership. Section 3.4 discusses inventorying private owned BMPs.

- When SHA storm drain systems flow into or from a private system, the first private downstream or upstream feature outside of SHA ROW is inventoried and included in the SHA system.
- When SHA storm drain systems flow into or from a private system, but the private downstream or upstream feature outside of SHA ROW cannot be found, a pipe direction feature is inventoried in the pipe direction as discussed in Section 2.2.3.3.
- If an SHA system conveys to a major outfall or to a stormwater BMP located outside of SHA ROW, then the private structures along the main trunk line to the major outfall or BMP are inventoried as in Figure 2.9.

Figure 2.9 – Private Storm Drain Feature Collection

The SHA storm drain eventually outfalls into a stormwater BMP outside of SHA ROW. The private structures and the conveyance are inventoried along the main trunk line of the storm drain system. The private upstream structure was also inventoried at the left side of the example.

2.2.3.5 Representing Walls with Multiple Pipes

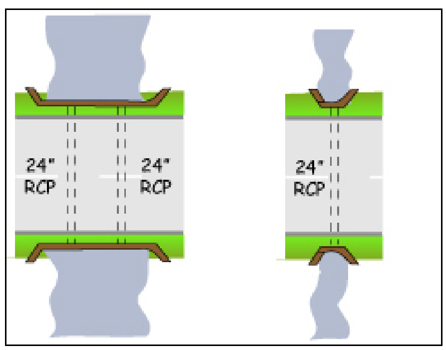
When headwalls and outfalls have multiple pipes associated with them, the contract drawing may only show one headwall or outfall. In order to represent multiple pipe conveyance features between one upstream and one downstream structure feature, the end or headwall may need to be represented as two features with the same attribute information. Figure 2.10 shows examples of some different scenarios.


Figure 2.10 – Multiple Pipes per End Structure

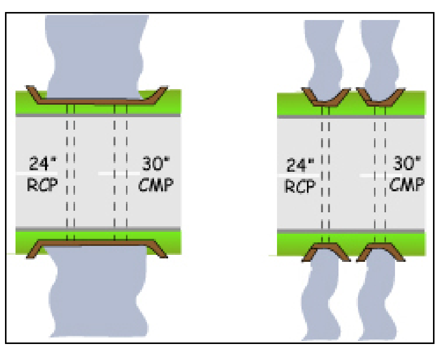
The endwall on the left should be represented as two features and two systems in the geodatabase. The endwall on the right might be represented as one, two, or three features depending on structures associated with any of the outfall pipes.

To properly represent these scenarios consistently and account for all pipes associated with the structure features, rules have been established:

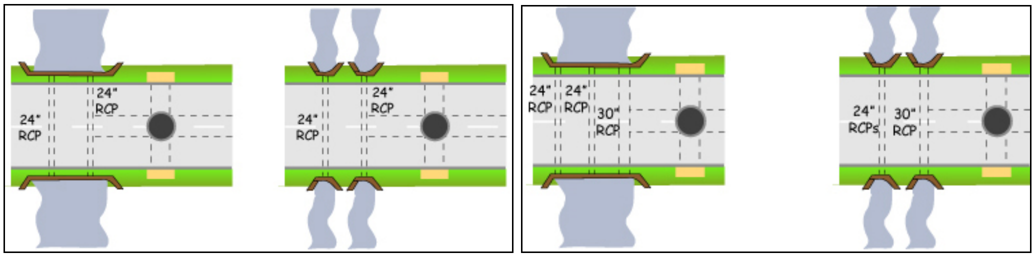
1. If multiple pipes (same size and material) are connected to a single wall and no other structures are associated with the pipes, then only one structure feature should be created, and the cross sectional area for the single pipe conveyance should be multiplied by the number of pipes in the PIPE table (Section 2.5.5.2) to indicate multiple pipes. This situation would be considered one system.



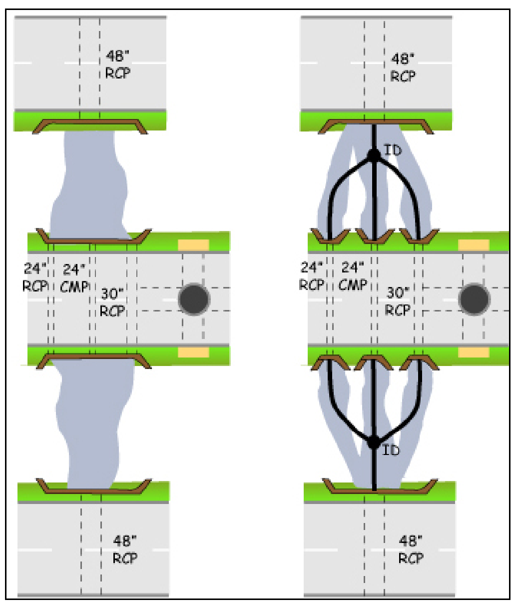
2. If multiple pipes of different size and/or material are connected to a single wall, then multiple end structures should be created (next to each other spatially) with the same attributes and connected to parallel pipes. This situation would create multiple systems.



3. If multiple pipes (same size and material) are connected to a single wall, and one pipe has additional storm drain connected to it, then multiple end structures should be created (next to each other spatially) with the same attributes and parallel pipe created accordingly. This situation would create multiple systems. This scenario also holds true when multiple pipes are involved and some are twin pipes.



4. When a ditch flows into these types of scenarios, all of these rules are ignored, and the entire conveyance becomes one system. The end structures are still divided with the same attribute information, but now each end structure is part of the same system, and the ditch flows to each headwall or from each endwall. If the out-flowing ditches do not connect to another storm drain structure, the system should end with a ditch intersection to connect all storm drain features to one system.



2.3 WORK FLOW PROCESS

The following is the step-by-step procedure for performing source identification of storm drain features. Consultants are encouraged to use innovative methods and technology to perform the work, but to be mind-full of the need for consistent end products. Any deviation from the standard process should be discussed and agreed upon with the SHA program manager. Documentation of work flow processes will be revised as new technologies and methodologies are developed.

2.3.1 Obtain Versioned Geodatabase for Geographic Area

SHA will supply the consultant with a versioned geodatabase including all SHA storm drain features for a county. The consultant will be responsible for updating the geodatabase with new or edited storm drain, conveyance, and stormwater BMP data for the geographic area they are assigned.See Chapter 6, Data Management, for specific data management information particular to the geodatabase and recommended office technical architecture.

2.3.2 Identify and Prioritize SHA Roadways and Project Areas

The consultant should identify the project areas within the geographic area assigned. Once this information is compiled, the roadways and other project areas to be inventoried should be listed and prioritized. Project areas include SHA-owned and maintained roadways, park and rides, visitor centers, and weigh stations. A working GIS and legend should be developed to document this analysis and included in progress reports to SHA. Information that can be helpful in completing this task and can be provided by SHA includes:

- SHA centerlines
- SHA right-of-way
- SHA grid mapping
- Orthophotography
- SHA Highway Location Reference Manual
- SHA impervious mapping.

There are also many GIS coverages and shapefiles that are available and should be requested from SHA. The coverages may include: roadway centerline, roadway outline, right-of-way, building coverage, sanitary sewer coverage, county outline, watershed boundaries, stream and water coverage, topography and contours, and orthophotos.

It is also helpful to have county-owned storm drain layers or other NPDES-jurisdiction source-identification information for the geographic region if available. The consultant should coordinate with SHA to obtain the most recent GIS base data available for the subject geographic region. License agreements should be processed through SHA for use of the data.

2.3.3 Process Contract Drawings and Other Information

Once the locations and priorities of the work areas are established, source documents for each route should be compiled and reviewed. This source data includes hard copies and/or digital imagery of SHA storm drain and stormwater BMP contract drawings as well as access and utility permit drawings. SHA will also supply a list and available design plans for known stormwater BMPs to the consultant in digital format.

Contract design drawings that will be provided by SHA include: title sheet, index of sheets, plan sheets, roadway typical sections (for side ditches), pipe profiles, geometry and coordinate sheets, SWM details, SWM landscape plan sheets, structure schedules, and summary sheets. If any sheets are missing, they should be requested from SHA.

Documents should be arranged in geographic and then chronological order to determine the most accurate representation of what is currently in the field. In most cases, this is the contract set for the most recent roadway project that has modified the roadway. However, in some cases the most recent set might be a noise wall or safety project that had no impact to roadway drainage, and therefore, a previous contract set may be a better indicator of existing drainage conditions.

Access/Utility Permit Drawings and Agreements

Existing access or utility permit drawings within the target roadway should be obtained where possible. Often, SHA systems are modified under these agreements. Furthermore, maintenance responsibilities for structures and BMPs are identified within the access permit agreements. Obtaining these permits and agreements is particularly important when features are located in or near the SHA right-of-way and ownership is questionable.

Access and utility permits are issued by SHA to developers who wish to obtain access to SHA-owned roadways for entrance drives, stormwater management, utilities or other utilization of our right-of-way. Drawings of these facilities, which are located on SHA right-of-way, are maintained by SHA or otherwise held in a joint-use agreement are also included for use in developing the database.

2.3.4 Develop Delivery Schedule and Status Map

A delivery schedule should be developed and delivered to SHA. The delivery date for the completed geodatabase will be determined by SHA and should be used in developing the schedule. Because anticipated delivery dates are reported to Maryland Department of Environment (MDE) in the NPDES annual reports, the consultant should make every effort to adhere to the date. Any deadline extension should be discussed with and approved by SHA.

The schedule should include the roadways to be collected, the order and estimated timeframe for beginning and completing the work on each roadway, and a map and legend. This schedule should be updated as work progresses and delivered as part of the progress reports included in monthly invoices.

Figure 2.11 is an example of a map and status legend that should be submitted to SHA with the progress reports. This map consists of a line shapefile that represents the extent of contracts being verified.

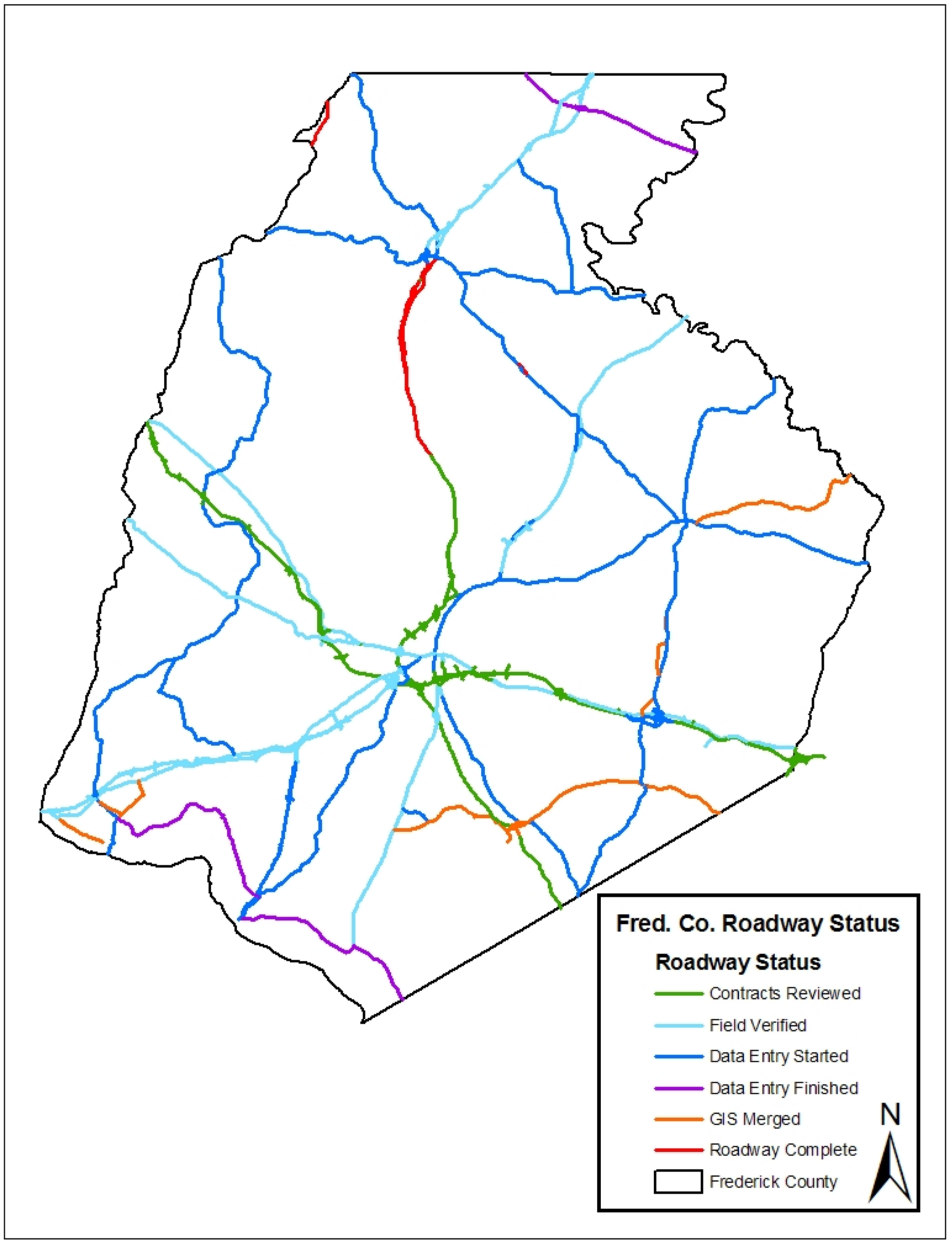


Figure 2.11 - Status Map

Status values should also be assigned that represents the completeness of the line limit. The following status values should be used and symbology set on the map to distinguish these values:

Table 2.3 – Example Legend for Status Map

Status Value	Description	Symbology Color
1	Contracts Received from SHA	Green
2	Contracts Reviewed	Light Blue
3	Field Verification Started	Dark Blue
4	Field Verification Completed	Purple
5	Data Entry Completed	Orange
6	QA/QC Completed	Pink
7	Data Merged w/ Master County Database	Red

2.3.5 Verify Attributes in Database

Attributes of the SHA features shown on contract drawings should be verified with the geodatabase. If conflicting information exists between the contract plan and the existing geodatabase, the plan date assigned to each feature will determine if the feature attributes need to be updated. If the existing plan date for a feature in the database is earlier than the new contract plan date at hand, then the feature attributes should be updated. If the feature date in the database is later than the new contract plans, then it can be assumed that the most-up-to date information for the feature has been entered in the database, and no updating is needed.

If attribute data from an existing database inventory is missing, it may be necessary to complete this information if contract drawings are now available. Attributes that may require verification from contract drawings include feature type, material, and location. This information may be missing in the database because contract drawings were not available during the initial inventory.

2.3.6 Verify Features in Field

Using the contract drawings and current geodatabase as a guide, field crews should perform a systematic review of the roadways in the project area. GPS points should be obtained for all identified stormwater features to be included in the geodatabase. During the field verification, the consultant may find it beneficial to also perform BMP, pipe, and outfall inspections, which will be discussed later in Chapters 3, 4, and 5.

Deviations in the field from the information shown on the contract drawings should be corrected in the database using the field and office application. Deviations can include differences in structure locations, structure types, materials, standards, or others as encountered. Manholes should only be opened under safe conditions and if necessary to verify the source information.

Structure and conveyance features should only be updated or verified if they appear on contract plan sheets or are within the vicinity of the features being verified. The intent of the field verification is not to update the entire database for a county. Multiple tables and fields have been added to the geodatabase over the years to address changes in the program requirements. The newer fields may be unpopulated in the existing database tables for certain features and they can be left blank unless newer information for the feature exists on contract plans or data is verified through field verification.

2.3.7 Develop Pilot Study

It is recommended that the consultant conduct a pilot study on a smaller area of the county to test their internal GIS and database development processes. This pilot study will clarify the understanding of the standard procedures as well as allow the consultant to become familiar with the editing applications. The pilot study should be conducted in an area where new storm drains need to be inventoried and where existing storm drain features need to be edited. The entire work flow process from 'Process Contract Drawings' to 'Populate Geodatabase' should be followed for this pilot study.

The database, storm drain contract sheets, and manuals will be supplied to the consultant by SHA so that the consultant can review the data and choose a pilot study area accordingly. A meeting with SHA will be held to discuss the pilot study. The consultant should supply a location map of the planned study area, schedule for completing the data collection and submittal, a plan for collecting data, and a list of questions for this meeting.

Once the pilot study area and consultant processes have been approved by SHA, field work can commence in the area. The data for the roadway pilot study is entered into the geodatabase and submitted to SHA for review. A meeting between SHA and the Consultant will be scheduled to discuss results, questions, and future field work. The intention of the pilot study submittal is to verify that the Consultant is conducting work properly and that a full understanding of the database exists. Once work has commenced on the pilot study, questions should be addressed to SHA as they arise.

2.3.8 Develop Spatial Features

The intent of the NPDES Geodatabase is a planning-level inventory of drainage infrastructure. GPS or other field survey equipment can be used to locate new or spatially incorrect structures and stormwater BMPs. GPS units should have the capability to collect data with sub-meter accuracy. The target accuracy for the horizontal location of structures for this program should be ± five (5) feet. Minimum required accuracy is ± twenty (10) feet. The intent is to add new features and better locate existing features that are not within acceptable horizontal tolerances. Structures should be located accurately with respect to surrounding features. For example, they should be on the correct sides of the roads, traffic islands, etc.

Creating conveyance features in the database is explained in Section 2.1 and Section 2.2.

BMP centroids are also created and assigned appropriate records based on the SWMFAC feature class. The BMP centroid is a center point feature for the stormwater BMP polygon feature. Centroids for all BMP feature classes should be generated together outside of the editing applications and merged with the geodatabase. Chapter 6 describes these processes in more detail.

Drainage and treatment areas, defined in Section 2.5.4 and Section 2.5.8, are also delineated for major outfalls and stormwater BMPs.

2.3.9 Populate Geodatabase

The geodatabase was developed using ESRI ArcMap software and is composed of six feature classes with associated relationship tables. Database information will be extracted from a combination of contract drawings and field verification. Care should be taken so that the data in the geodatabase represents the most current attribute information for each drainage feature. For example, the most recent contract set may not have inverts for features that were constructed with an earlier project. The earlier contract plans should also be reviewed.

If conflicting information is found between contract drawings, the more recent data should be used. If a structure is shown as existing on multiple contracts, the newer data should be used. In some circumstances, data will be extracted from multiple contracts. The intent is to record the most recent data where it exists. When the contract under which the structure was constructed is not available, use the contract from the most recent set of drawings where data was obtained.

An office and field editing application has been developed to assist in the data entry for both an initial data capture and update of a county's storm drain infrastructure. Documentation and users guides on the applications are located in Chapter 6.

Section 2.5 offers a detailed description of the features and tables that make up the database. Chapter 6 describes the methodology for performing data entry and interacting with the geodatabase.

2.4 INVENTORY ACTION KEY

The inventory action key shown in Figure 2.12 was developed to aid in the storm drain feature inventory process. The key will aid in determining the course of action required from any scenario that is encountered. The key also shows where inspection and screening of pipes and structures should be conducted. Inspection procedures and standards are outlined in more detail in Chapters 3, 4, and 5.

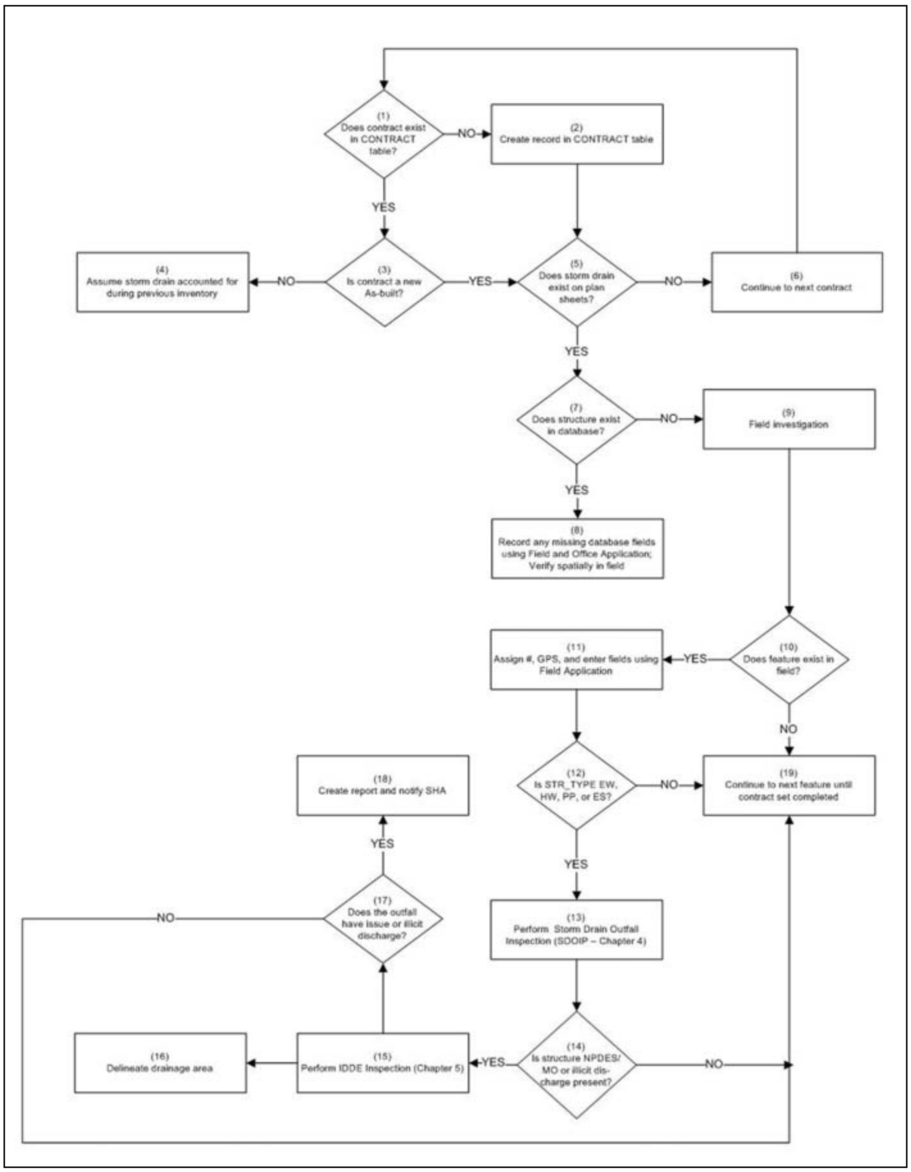


Figure 2.12 - Inventory Action Key

Inventory Action Key Steps:

1. Does contract exist in CONTRACT table? Check to see if the contract number is in the CONTRACT table. Verify using both the CONTRCT_SHA and CONTRCT_PLAN field. If plan set does not exist in CONTRACT table, record is created (step 2). If plan set does exist in CONTRACT table, proceed to step 3. For detail on the CONTRACT table refer to Section 2.5.2.

2. Create record in the CONTRACT table. Populate the fields associated with the contract plans set. Refer to Section 2.5 for table field descriptions in the CONTRACT table (proceed to step 8).

3. Is plan set that exists in CONTRACT table an as-built or greenline plan set? If not, it can be assumed that the plan set has been reviewed and all data has been entered during a previous inventory (step 4). If plan set is an as-built, verify that new or modified storm drain features exist on plan set (step 5).

4. If a contract plan set has been reviewed during a previous inspection, it is not necessary to review that plan set again. Double check to be sure the plan set is not an as-built, and check plan date to be sure it matches the date in CONTRACT table.

5. Does the as-built or new plan set have new or modified storm drain features? If no, then continue to next contract plan set (step 6). If there is a new storm drain feature or changes to an existing storm drain design, then verify if the feature exists in the database (step 7).

6. Continue to the next contract set and determine if the contract exists in the CONTRACT table (step 1).

7. Does the feature exist in database? Older contract sets might have been missed during a previous inventory, and features might have been captured without plan sets. Be aware that if an update of a county is being performed, some of the contract sets from SHA might be older plans. Information must be verified. If the feature exists, record any missing or changed data in the database, and spatially verify in field (step 8). If the feature does not exist in the database, it is a new feature and needs to be inventoried (step 9).

8. A feature may have been captured from a previous inventory with no plan set and that data may need to be entered and field verified from a contract. Continue to next feature until all data is verified.

9. The new feature needs to be field verified. Look for storm drain feature in the field and verify status, type, and other required attributes mentioned in the standard procedures manual and Section 2.5. Once in the field, continue to step 10.

10. Does the storm drain feature exist in the field? If the feature does not exist, continue to the next feature until the contract set is completely reviewed (step 19). If the feature does exist, capture the feature in the field with a GPS and record associated data about the storm drain feature (step 11).

11. Record GPS location and assign the feature a number. Enter all available data in appropriate tables, forms, and fields using the field application, and office application when necessary. Proceed to step 12.

12. Is storm drain structure type an endwall, headwall, end section, or projection pipe? If the structure is one of these types, perform a pipe and outfall inspection as described in Chapter 4 (step 13). If the structure type is anything other than these structure types, continue to next structure (step 19)

13. Perform a pipe and outfall inspection of all daylighting pipes as outlined in Chapter 4 of the standard procedures manual. Continue to step 14.

14. Is the structure a major outfall or is illicit discharge present? If either of these conditions, perform an Illicit Discharge Detection and Elimination (IDDE) inspection as outlined in Chapter 5 (step 15). If the structure is neither of these, continue to next feature (step 19)

15. Perform an IDDE inspection of the outfall as outlined in Chapter 5 of the standard procedures manual. Continue to step 16 & 17.

16. Delineate a drainage area for major outfalls as outlined in Section 2.5.4

17. Does the outfall have problems or illicit discharge? If issues or illicit discharge are present then a report is created for SHA (step 18). An example of a report is in Appendix 5-A. If there are no issues, continue to next feature (step 19).

18. If illicit discharge or issues are present, prepare and submit a standard report to SHA as soon as possible. Chapter 5 outlines information to include in this report.

19. Review the entire contract set for storm drain features until all feature data is reviewed and represented in the geodatabase.

2.5 DATABASE TABLE STRUCTURE

This section provides a narrative description of the geodatabase table structure and should be read in conjunction with the stormwater NPDES geodatabase structure schematic in Appendix 6-A.

The geodatabase is composed of six feature classes and multiple attribute tables that are linked with relationship classes. The attribute tables and feature classes are joined using a unique identifier field in each table. The unique identifier field is auto-populated with a Global Unique Identifier (GUID), and is never modified or changed by the consultant. A GUID value is a unique number that is produced when adding storm drain features or inspections using the field and office editing tools. If the field and office editing tools are not used to inventory and inspect the storm drain infrastructure, and the data will subsequently be merged into the master database, the GUID values for the unique GUID identifiers will need to be populated using any variety of GUID generators.

The following are short definitions of the feature classes and attribute tables in the geodatabase. Detailed descriptions of fields and tables within the feature classes and attribute tables are discussed starting at Section 2.5.

STRUCTURES Feature Class – stores information such as contract number, structure type, structure status, or date verified about storm drain structure features in the geodatabase. The STRUCTURES feature class is joined to the following tables using the STRUCTURE_ID field:

END_HEADWALL table – stores information pertaining to end or head structures such as endwall, headwalls, end sections, and projection pipes.

INLET table – stores information pertaining to all inlets and spring boxes.

MANHOLE_CONN table – stores information pertaining to manholes and other connection features such as pipe connections, pipe direction, ditch intersections, or junction boxes.

PUMPSTN table – stores information pertaining to pump stations.

SWMRISER table – stores information pertaining to stormwater management facility risers, i.e. box risers and CMP risers.

WEIR table – stores information pertaining to weir structures and emergency spillways.

STRUCTURE_ISSUES table – stores structure issues and maintenance items pertaining to each structure. There can be many STRUCTURE_ISSUES records for one STRUCTURE record.

FLDSC_SITE table – stores structure location and other screening information for outfall structures if an illicit discharge screening is performed or if the structure is a major outfall. The FLDSC_SITE table is also linked to the INSPECTION table via the STRUCTURE_ID field.

SWMFAC Feature Class – relates the STRUCTURES and SWMFAC features classes using the STRUCTURE_ID field to identify structures that are control structures for stormwater BMPs and inflow structures into stormwater BMPs.

CONVEYANCE Feature Class – relates the STRUCTURES and CONVEYANCE features classes to identify the upstream and downstream structures for a conveyance feature.

DRAINAGE_STRUCTURE feature class – links drainage areas to the STRUCTURES table using the STRUCTURE_ID field. All major outfalls must have a drainage delineated for the structure.

INSPECTION table – stores location and description information about structures that are major outfalls or are screened for illicit discharge. The following tables are linked via the **INSPECT_ID** field:

FLOW_CHAR table – stores data and descriptive information regarding dry weather flow, if dry weather flow is present during an outfall screening.

FILE_ATTACH_STR table - stores attached documentation relating to a stormwater BMP inspections. Documents can include jpg photos of the screened structure and other map, hand drawing, or marked-up plan sheet.

SWMFAC Feature Class – stores information such as contract number, BMP type, BMP status or date verified about stormwater BMPs in the geodatabase. The SWMFAC feature class is joined to the following tables using the **FACILITY_ID** field:

BMP_INSPECTION table – stores information relating to the inspection of stormwater BMPs. There can be many inspections per facility.

FILE_SCAN table – stores the scans of contract plan sheets related to the stormwater BMPs design.

DRAINAGE_SWMFACILITY feature class – links the treatment area to the SWMFAC table using FACILITY_ID field. All BMPs that receive SHA runoff must have a treatment area delineated for the structure.

BMP_CENTROID feature class – stores centroid for stormwater BMP polygons and links to the SWMFAC table via the FACILITY_ID field.

BMP_INSPECTION table – stores information relating to the inspection of stormwater BMPs. The BMP_INSPECT_ID field is used to link to the following tables:

BMP_INSPECTION_ACTION table – stores maintenance items identified during field inspection of BMPs. There can be many BMP_INSPECTION_ACTION records per BMP inspection.

CONCERNS – stores pollution and invasive species present during the BMP inspection. There can be many CONCERNS records per BMP inspection.

FILE_ATTACH_SWM table – stores attached documentation relating to the BMP inspections. Documents may include jpg photos of the facility and other map, hand drawing, or marked-up plan sheet.

CONVEYANCE Feature Class – stores information such as conveyance type, length or conveyance status about conveyance features in the geodatabase. The CONVEYANCE feature class is joined to the following tables using the CONVEYANCE_ID field:

PIPES table – stores information about pipes, such as size, material, shape, etc. Pipe inspections are also linked to the PIPES table via the CONVEYANCE_ID field.

DITCH table – stores information about ditches, such as material and bottom width

PIPE_INSPECTION table – stores site location information pertaining to pipe inspections for records in the PIPES table. This table is linked to sub-tables that describe the pipe conditions in more detail via the P_INSPECT_ID. The following are the sub-tables that are linked to the PIPES table:

P_INSP_PHOTO table – stores the photo names relating to the pipe inspections.

P_INSP_REC table – stores additional attributes about the pipe being inspected and condition of the outfall area.

P_INSP_SUBRATING table – stores the pipe conditions information and inspection comments for each pipe in the PIPES table that is inspected.

CONTRACT table – contacts are recorded in this table and linked to the STRUCTURES, SWMFAC, CONVEYANCE features classes and the FILE_ATTACH and AGREEMENT tables via the CONTRACT_ID field. The CONTRACT table stores contract information such as plan date, limits of work and vertical datum.

META_INFO table – stores information about feature data collection, such as method for creating the feature, creator of the feature, and the date the feature was created. It is linked to the STRUCTURES, SWMFAC, and CONVEYANCE features classes via the META_ID field.

OWNER table – stores data about the owner of a feature and is linked to the STRUCTURES and SWMFAC feature classes via the OWNER_ID.

AGREEMENT table – maintenance and entry agreements between SHA and a second party are noted in this table. The table is linked to the CONTRACT, STRUCTURES, and

SWMFAC table via the *contract_id* field. The *agree_id field* is used to link to the following table:
FILE_ATTACH_AGREE table – store attached documentation related to the maintenance or entry agreement.

2.5.1 Tabular Data Format Conventions

In this report, feature class items, table names, and domains (and domain values) are printed in capital letters (e.g. PIPES) and field names are printed in italics (e.g. *conveyance_id)*. This section of the manual will discuss the feature classes, tables, and fields that are populated in the geodatabase while performing an inventory of storm drain infrastructure. Tables related to stormwater BMP, outfall/pipe, and illicit discharge inspections are discussed in Chapters 3, 4, and 5, respectively.

All data entered as an acronym will not have periods following each letter; for example: CMP or BCCMP. Words that are abbreviated will have a period following the abbreviated word. Coded domain values exist within the geodatabase for some fields that will ensure consistent data entry. To ensure these values are entered in the proper format, coded values should be entered into the database tables and not the description of the value.

The feature classes, attribution tables, and associated field information is illustrated on the geodatabase design schematic in Appendix 6-A. The schematic includes associated relationships between each feature class and the tables, as well as the coded domain values set in the geodatabase to be used for data input. Domains and coded values are also available in Appendix 2-A. The *comments* field in some tables adds to or clarifies data given in other fields. Comment fields should be used liberally to alleviate questions or issues.

2.5.2 CONTRACT Table

The CONTRACT table provides an index of the design contracts under which storm drain infrastructure was constructed for consistency with the SHA filing system. Contract plan sets are entered into the CONTRACT table whether or not the contract was used in the inventory and inspection process. Some contracts may show noise wall details or lane widening, and may not have affected the storm drain infrastructure. These contracts should still be entered into the CONTRACT table so that they are not review during future inventory tasks. All contract plan sets received from SHA must be entered into the CONTRACT table in the geodatabase.

Unique Contract Identifier *(contract_id)* **–** The contract identifier is a unique GUID value that provides a link to other features and tables. This is a unique identifier that will auto-populate when entering contracts using the office editing application. The CONTRACT table is linked to the STRUCTURES, CONVEYANCE, and SWMFAC feature classes and to the FILE_SCAN table by the *contract_id* field. Once this value is populated it will never be edited or changed.

A feature will receive the *contract_id* of the contract it was designed or modified under. When a particular feature is shown on multiple contract drawings as an existing feature, and the information about the feature varies, the feature should be associated with the most recent contract drawings it appears on. The information on the most recent contract should then be entered for the storm drain
feature in the associated tables.

SHA Contract Number (*cntrct_sha)* **–** This value represents the SHA contract number for the project, in a standard format. Contract numbers are recorded so that each set of numbers is separated by a dash (-) and all numbers are in three-digit combinations. When the number on the contract does not fit the standard format, zeros should be place in front of the number to create the appropriate number of characters. For example, if a contract reads M-3-356-35, then M-003-356-035 is recorded in this field. If a contract reads M-3, then M-000-000-003 is recorded in this field.

In the case of multiple contract numbers listed on a single contract plan set, each contract number should receive its own record in the CONTRACT table, with the same attributed information and fields populated for each entry. In these cases, each contract record is assigned an individual *contract_id*, and the primary (first) contract number (*contract_id*) listed is used to link with other features. For example, if a contract number for a plan set is M-124-195-106, M-147-189-004, two records in the CONTRACT table will be created for this single contract plan set, and the first contract number (M-124-195-106) will be used to link to the feature classes and associated tables.

There are contract numbers that begin with a two letter county abbreviation followed by a series of numbers and/or letters (ex. MO123456N7. These contract numbers should be left as is and not conformed to the standard. Therefore, contract number AA34R-N31 should be entered as is appears on the contract title sheet.

Plan Contract Number *(cntrct_plan)* **–** This field records the contract number exactly as it appears on the plan. In the example above, “M-3-356-35” and “AA34R-N31” would be entered in this field. For contracts that have multiple contract numbers, all the numbers should be entered here separated by commas for each CONTRACT record. The geodatabase will not allow a “null” value for this field.

Access Permit Number *(access_per)* **–** If an access permit exists that impacted a drainage feature then the access permit number should be entered into this field. An SHA contract number should be present on the access permit so that a CONTRACT record can be recorded. The field allows a string of up to 15 characters. If no access permit exists for this contract or feature, the field should be left blank.

Right of Way Plat Map Number (*plat_no*) **–** If a plat map is available, this string field allows for the plat map number to be recorded. Plat maps will be given to the consultant by SHA, but they are not required to perform the inventory. An SHA contract number should be present on the plat map so that a CONTRACT record can be recorded.

County *(cnty_code)* – The field records the county code associated with the majority of the work under the contract. On occasion, limits of work on a contract will go beyond the county boundary on a contract set. If this is the case, the other counties are noted in the *com_cntrct* field. A list of the county codes can be found in Table 2.2 and in the D_COUNTY_CODE domain table.

Municipality *(muni_code)* – The municipal code field is for SHA's use and is not populated by the consultant.

Route Prefix *(rte_prefix)* – The field is populated from the codes contained in the D_PREFIX_CODES domain table. The values are route codes for interstate, U.S., Maryland, county, or unknown, and describe what type of roadway the contract covers.

Route Suffix *(rte_suffix)* – The field is populated from the codes contained in the D_SUFFIX_CODES domain table. The values are codes for alternate route, business route, scenic route, ultimate (proposed) route, and unknown, and describe what type of roadway the contract covers. If no suffix exists for the roadway, then a this field is left blank.

Route Number *(rte_no)* – This field records the route number in integer format. For example – MD 355 is entered as 355, and I-695 is entered as 695.

Section Length (*sect_len)* – Section length defines the length in miles of the contract work. If the limit of work length is not defined on the cover sheet, the length can be determined by using station numbers on the plans set, scaled from plans, or by using measurement tools in GIS.

Project Limits *(prj_limits)* – The project limits field contains a narrative description of the project limits (e.g. from Maple Road to I-95). This is usually found on the cover sheet. If limits are not clearly defined, it may be necessary to identify the limits using other mapping (ADC book, GIS, etc.).

Year Built *(year_built)* – This value represents the actual year of construction completion. Often, this is not included on the plans. If a year built is unknown, the field is left blank.

Plan Date *(plan_date)* – This field records the last year (including revisions) shown on the drawings. If a plan date is unknown, the field is left blank.

Contract Comments *(com_cntrct)* – This field records additional information considered relevant by the researcher and clarify the response given in the other fields if necessary. It allows 120 characters.

Vertical Datum *(v_datum)* – The vertical datum used in the contract design is recorded here and uses the D_V_DATUM domain value. If the vertical datum is unknown, the field is left blank. It should not be assumed that any contract that has a plan date prior to 1988 will have a vertical datum of 1929.

2.5.3 STRUCTURES Feature Class

Storm drain structures within SHA ROW are inventoried. Information on private storm drain structures will need to be collected if a private system ties into SHA owned storm drain features. The only structures that are not inventoried within SHA ROW are single residential driveway culvert end structures (See Section 2.1.2 and Section 2.2.3 for more details), bridge inlets, under drains, roof drainage, or other private tie-ins, with the exception of the first or last structure from a private storm drain system. If an under drain pipe has an end structure (such as an endwall), then the structure is inventoried, with the under drain pipe size and material in the *com_eh* field in the END_HEADWALL table (Section 2.5.3.1). Refer to Section 2.1 and Section 2.2 for a more detailed description on how to inventory different storm drain features.

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to other features and tables. This is a unique identifier that will auto-populate when entering structures using the office and field editing application. Once this value is populated, it will never be edited or changed.

SHA Structure Number *(sha_str_no)* – When interpreting drawings, each structure in a drainage system should be identified and numbered during the feature-capture phase described in Section 2.2.2. This field contains the seven (7)-digit system identification number followed by the three (3)-digit unique structure identifier (e.g. 1300140.007). Every structure must be assigned an SHA structure number. The geodatabase will not allow a "null" value for this field.

When performing a re-inventory of a county, it will be necessary to know the last system number in the geodatabase for that county, as well as the next structure number in a system if features are being added to an existing system. A database review will be necessary to identify new system and structure numbers to ensure that duplication of *sha_str_no* does not occur. Error checking within the editing applications is performed that will not allow users to enter a duplicate structure number. Structure numbers should never be changed, to ensure that historic data is not lost.

During the initial inventory of a county, the most downstream structure should be identified as the .001 structure in system. If, while performing a re-inventory, it is discovered that an existing system in the geodatabase has been extended downstream, the new downstream structure(s) does not need to be the .001 structure, since structure numbers are never changed. It is okay to delete structures from a system, and use that structure's number again as part of the same system.

Contract Identifier *(contract_id)* – The contract identifier serves as a link between the STRUCTURE feature and the CONTRACT table. Enter the *contract_id* corresponding to the contract under which the structure was constructed or modified. For example, an inlet that is capped should contain the structure type "CI" in the *struct_type* field. The *contract_id* field should contain the contract ID that did the capping. When using the editing applications, the existing contract numbers for a feature will be selected based on the *cntrct_plan* field in the CONTRACT table, and the *contract_id* field will auto-populate in the STRUCTURES table.

The *contract_id* and *plandate* fields are dependent on one another. The following are guidelines to follow when populating the *contract_id* and *plandate* fields.

- A storm drain feature is assigned the *contract_id* and *plandate* under which it was built <u>or</u> modified.
- If a storm drain feature appears on a contract drawing as existing, and no earlier plans show the original design of that feature, the *contract_id* is the contract number of the plans showing the feature as existing, and the *plandate* is recorded as 9999.
- If a storm drain feature is shown as existing on two sets of plans, and the original design plans are unavailable, use the *contract_id* of the older existing plan set, and the *plandate* is recorded as 9999.
- If no plans exist for a feature, then *contract_id* is left blank, and *plandate* is recorded as 9999.

Figure 2.13 is an example of existing and proposed storm drain features on the same contract plan sheet.

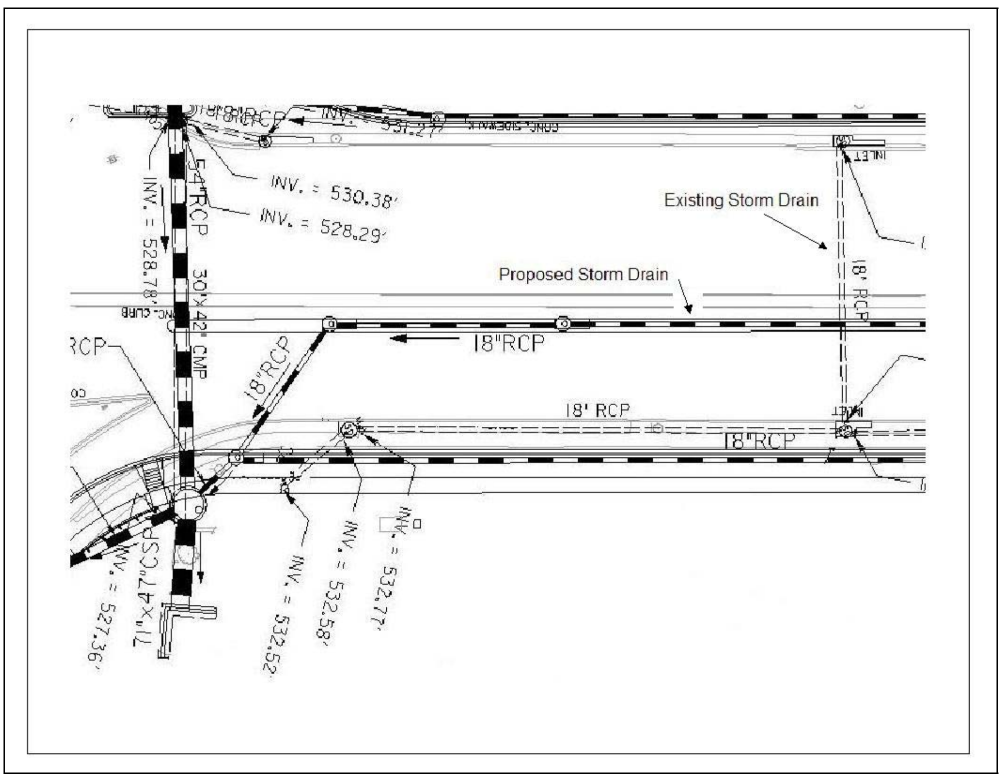


Figure 2.13- Example Plan Sheet

The plan sheet above is the only available plan showing the existing storm drain features. The original plan sheets for the existing storm drain were not available. In this case, the contract_id for the existing features would be the contract number from this plan set because the existing features appear on it. The plandate would be 9999 for the existing features because the original design sheets are not available.

SHA Structure Type *(str_type)* – Storm drain features are assigned a structure type from the domain table D_STRUCT_TYPE. The domain includes values such as inlet, endwall, headwall, ditch intersection, etc. The geodatabase will not allow a "null" value for this field. The following are guidelines to follow when selecting a structure type:

- If a structure has been modified under several contracts, the type of structure, as it exists today, should be entered and field verified.

- When the structure type is unknown, an educated guess should be made for the type, and the unknown option chosen for that type. For example, if a structure type is unknown, but it is assumed to be an inlet, "UNK IN" would be chosen from the domain list.

- Pipes projecting from fill material that have no structure attached are entered as projecting pipe. This includes box culverts with no defined endwall (refer to Section 2.1.2 and Section 2.2.3 for more information on cross culvert inventory).

- Headwalls, end sections, and other inflow structures at the upstream end of a pipe are not considered inlets, unless the structure is an inlet or spring head/box. These "head" structure should be inventoried as END_HEADWALL structures.

- Any wall structure at the upstream end of a pipe is inventoried as a headwall. Any wall structure at the downstream end of a pipe is inventoried as an endwall.

- Headwalls, end sections, and projection pipes controlling flow out of a BMP as a control structure are inventoried based on the structure type and <u>not</u> as risers.

Mile Point *(st_ml_pt)* – The state mile point field contains the mile marker value closest to the structure. Because data is not widely available on contract drawings, this field is not required at this time.

Function Class *(func_class)* – The function class of a feature is selected from the D_FUNC_CLASS domain. The purpose of this field is to identify whether the structure is serving as an inflow (IF), outflow (OF), connection (CN), or control structure (CS). If a structure is controlling flow out of a BMP, that structure is considered a control structure (CS), and not an inflow (IF) structure. For example, a headwall controlling flow out of a stormwater BMP will be inventoried as a headwall but will be assigned a *func_class* value of

CS. The geodatabase will not allow a "null" value for this field. Refer to Table 2.4 for a list of valid *func_class* values per structure type (*str_type*).

Table 2.4 – Function Class per Structure Type

STR_TYPE	FUNC_CLASS		STR_TYPE	FUNC_CLASS
Inlet	IF, CS		Endwall	OF
Spring Head	IF		Headwall	IF, CS
UNK IN	IF, CS		End Section	IF, OF, CS
Manhole	CN		Projection Pipe	IF, OF, CS
Ditch Intersection	CN		UNK EH	IF, OF, CS
Junction Box	CN		Storm Water Management Structure	CS
Pipe Connection	CN		UNK SW	CS
Pipe Direction	CN		Pump Station	CS
Junction Box	CN		UNK PS	CS
Pipe Bend	CN		Emergency Spillway	CS
Y Connection	CN			
Capped Inlet	CN			
UNK MH	CN			

*CN = Connection, CS = Control Structure, IF = Inflow, OF = Outflow

Owner Identification *(owner_id)* – The owner identifier serves as a link between the STRUCTURE feature and the OWNER table. Enter the *owner_id* corresponding to the organization that owns and maintains the storm drain feature. When using the editing applications, the owner of a feature will be selected from the *org_name1* field in the OWNER table, and the *owner_id* field will auto-populate in the STRUCTURES table. Section 2.3.12 describes the OWNER table and fields.

Maryland Watershed *(md_wshd)* – The field is populated with values from the D_WATERSHED domain. The domain contains the Maryland watershed basin codes as found in COMAR 26.08.02.08U. The geodatabase will not allow a "null" value for this field. A value of 99-99-99 for "Out of State" should be entered in this field for structures that drain outside of Maryland watersheds. A Maryland watershed GIS shapefile should be used to determine this value for each structure. The *md_wshd* field should be populated after all the data is collected and represented spatially. Once all data is entered into the geodatabase, an intersect tool in GIS can be used to populate this value for all structures in the database.

Discharge Point *(discharge_pt)* – The point discharge location is defined as the most downstream feature of a system regardless of *str_type* where flow leaves SHA ROW. Use 1(Yes) or 2(No) in the D_BOOLEANVALUES domain to identify if the structure is a discharge point. The following are guidelines to follow when assigning a structure as a discharge point:

- A discharge point is the most downstream structure in the system and can correlate with any type of structure, outfall, or pipe connection except a ditch intersection.
- If the most downstream structure in a system is a ditch intersection feature, the discharge point will be the next structure upstream (the outfall structure).
- All outfalls into and out of stormwater BMPs are study points since these features end separate systems.
- If a ditch is inventoried without physical end structure, the downstream ditch intersection is the discharge point.
- Some systems may have two outfall points, and therefore two discharge points would be recorded for these systems, one for each most downstream structure.

Plan Date *(plandate)* – Refer to **Contract Identifier** *(contract_id)* description above.

Date Verified *(date_ver)* – The field records the Month/Day/Year that the database information was verified in the field. The *date_ver* field corresponds to the *feat_status* field. For all *feat_status* options, use the date the feature was field verified. If a structure cannot be field verified because it is proposed (PRO), unable to be verified (UTV), or abandoned (ABD), the *date_ver* is the date the structure information was entered in the database tables. The geodatabase will auto-populate the date verified with the date of the edit. A "null" value is not allowed for this field.

Feature Status *(feat_status)* – The field describes the status of the feature and is populated with values from the D_FEAT_STATUS domain. This field should be verified in the field. The geodatabase will not allow a "null" value for this field. The following are guidelines to follow when entering a feature status value:

- If a structure appears on the plans, but is buried, paved, submerged, etc. in the field, then the *feat_status* for that structure is EXIST, and comments should be provided similar to: "Assumed structure; buried?"
- If it is known that a structure does not exist in the field, and the feature is not PRO, UTV, or ABD, that feature can be left out of the database and is not inventoried.
- The domain includes the following values:
  - Existing – Existing structure in active use. The information may be incomplete for existing features and is completed when older plans (showing the data) are examined.

Pending retrofits are flagged as existing features, and only the existing data is entered. Proposed retrofit data is not entered, until field verified.

- Abandoned – Existing structure no longer in use. The database information should be completed. Capped inlets are not abandoned, but should have a *feat_status* of EXIST if shown on contract plans. Abandoned structures would be endwalls and manholes where the pipe(s) is bricked-up and other structures that no longer convey stormwater.
- Proposed – Structure shown on contract drawings that have not been constructed yet. For proposed structures, attribute data is collected from the contract set if the structures have not been built yet. Further investigation may be necessary to determine invert elevations, top of grate elevations, etc. from the profile drawings.
- Unable to Verify – Structure thought to exist, but unable to be field-verified due to inaccessibility or other issues. The required geodatabase information should be completed based on the obtained contract drawings.

Date Abandoned *(dateabandoned)* – The field records the year the structure was abandoned. This will usually correspond to the plan date on a newer contract set showing the abandonment. If the structure is not abandoned, this field is left blank.

Metadata Identification *(meta_id)* – The value is the same as in the META_INFO table described in Section 2.3.11, and provides the link between the structure feature and the metadata. A new metadata record should be created for each day an inventory is conducted. The geodatabase will not allow a "null" value for this field.

Major Outfall *(maj_outf)* – The field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify if the structure is a major outfall. An outfall is considered a major outfall if the inside diameter of the pipe is ≥ 36 inches (1018 square inches) or equivalent flow area for non-circular pipes for closed storm drain systems. Outfall into and out of a BMP can be considered major outfalls. This field should be verified in the field.

If a system ends at a closed storm drain structure (such as an inlet), because the downstream outfall cannot be found, and the pipe is ≥ 36 inches in diameter, then that inlet would be considered a major outfall. A system will usually have only one structure that can be a major outfall, which will be the most downstream structure or outfall. If a situation arises where a system has two outfalls ≥ 36 inches in diameter, then each outfall will be assigned as a major outfall. Refer to Chapter 5 for more information on major outfalls.

Additional Structure Comments *(comments)* – This field allows for additional information and comments related to the structure. This field is only used to describe unique situations and clarify the response given in the other fields if necessary. It allows 255 characters.

2.5.3.1 END_HEADWALL Table

The END_HEADWALL table is used to record additional attribute information about the structures on the upstream or downstream end of a pipe that daylights. Inlets, manholes, connections, and control structures are not stored in this table. Structure types included in this table are endwall (EW), headwall (HW), end section (ES), projecting pipe (PP), and unknown end/headwall (UNK EH).

To properly inventory end and head structures that carry multiple pipes, refer to Section 2.2.3.5.

Unique Structure ID *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated an end/head structure, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the END_HEADWALL table with the *structure_id*. The geodatabase will not allow a "null" value for this field.

Endwall/Headwall Designation *(desg_eh)* – This field contains a description of the end or head structure type and references the D_EH_TYPE domain. These domain values are abbreviations from structure types in the SHA Standard Design Manual. This domain list has values that describe the end/head structure and include B, C, E, F, G, and H end/headwalls, wingwalls, end support walls, endsections, projection pipes, and an option of other end/headwall structures not included in the domain list. For example, a Type C End or Headwall is abbreviated CEW. This information should be verified in the field.

Endwall/Headwall Material *(mtrl_eh)* – This field describes the material of the end/head structure and uses values from the D_MATERIAL_END domain. The domain includes codes for the material, such as concrete, metal, or masonry and brick. The geodatabase will not allow a "null" value for this field. This information should be verified in the field. The following are guidelines to follow when assigning the material:

- If an end structure is constructed of multiple materials, then the majority of material is the value.
- The material for a projection pipe is the same as the material of the associated pipe.
- If an end structure cannot be field verified for any reason, the material on the contract plans is entered.

Endwall/Headwall Comments *(com_eh)* – This field contains comments specific to the endwall structure. The field allows 120 characters and should be used liberally. Structure type does not need to be entered here; this is represented by the *desg_eh* field.

2.5.3.2 INLET Table

The INLET table is used to record additional attribute information about inlet and spring head/box structures. Structure types included in this field are inlet (IN), springhead (SH), and unknown inlet (UNK IN).

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated an inlet structure, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the INLET table with the *structure_id*. The geodatabase will not allow a "null" value for this field.

Inlet Designation *(desg_in)* – This field contains a description of the inlet type and references the D_INLET_TYPE domain. This domain has values that include COG, COS, Double Grate WR Inlets, H Combination Inlets, etc. These domain values are abbreviations from structure types in the SHA Standard Design Manual. For example, a Type WR Inlet with a double grate is abbreviated 2WR. The inlet type should be verified in the field. It is expected that the field team be familiar with inlet types prior to conducting field work.

COG/COS Length *(inlet_len)* – The length of COG and COS inlets is recorded here and refers to values in the D_INLET_LENGTH domain. The domain includes codes for the lengths of standard COG and COS inlets only. All other inlet types will have an *inlet_len* equal to NULL. This data should be verified in the field. Often the inlet length is identified on contract plans. If not, then a field measurement of the COC or COS opening is necessary.

Inlet Material *(mtrl_in)* – This field describes the material of the inlet structure and uses values from the D_MATERIAL domain. The domain includes codes for the inlet material, such as concrete, metal, masonry, brick, etc. If an inlet structure is constructed of multiple materials, then the majority of material is the value. Often inlet material is identified on contract plans, but the material should be verified in the field.

Grate Elevation *(top_of_grt)* – This field records the elevation, in feet, of the top of grate from contract plans. If this information is unavailable, then the field is left blank.0

Inlet Comments *(com_in)* – Comments specific to the inlet structure are recorded here. The field allows 120 characters, and should be used liberally. Structure type should not be entered here, but in the *desg_in* field instead.

2.5.3.3 MANHOLE_CONN Table

The MANHOLE_CONN table is used to record additional information for storm drain structural connections. Structure types included in this table are manhole (MH), ditch intersection (ID), junction box (JB), pipe connection (PC), pipe direction (PD), wye connection (YC), capped inlet (CI), pipe bend (PB), and unknown manhole (UNK MH). Pipe connections that end a system at a box culvert or stream crossing will still be inventoried in the MANHOLE_CONNECTION table.

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated a manhole or connection structure, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the MANHOLE_CONN table with the *structure_id*. The geodatabase will not allow a "null" value for this field.

Connection Material *(mtrl_conn)* – This field describes the material of the manhole or connection and uses values from the D_MATERIAL domain. The domain includes codes for connection material such as concrete, metal, masonry, brick, grass, etc. Since manhole lids will not typically be opened and other connection features are not visible, the material for this field should be captured using contract plans when available.

The following are guidelines to follow when assigning a material for a connection structure:

- If the material for a manhole or junction box is not on the contract sheets, then the value of UNK is entered.
- If a manhole or connection structure is constructed of multiple materials, then the majority of material is the value.
- If the structure is a ditch intersection, the material is the same material as the ditch it represents. If one continuous ditch changes material, a ditch intersection can be inventoried to distinguish the material change, and the material is that of the upstream ditch.
- If the structure is a pipe connection, the material is the same material as the pipe it represents. If one continuous pipe changes material, a pipe connection can be inventoried to distinguish the material change, and the material is that of the upstream pipe.
- The material for a pipe direction, pipe bend, or wye connection is that of the pipe it represents.
- Access to capped inlets will not be possible in the field, so the original inlet material should be determined from the contract drawings, otherwise UNK is entered.

Top of Manhole Elevation *(top_of_mh)* – This field contains the elevation, in feet, of the top of manhole from contract plans.

Manhole Comments *(com_mh)* – Comments specific to the manhole structure are recorded here. The field allows 120 characters, and should be used liberally. Structure type should not be entered here.

2.5.3.4 PUMPSTN Table

The PUMPSTN table is used to record additional information for pump stations. Structure types included in this table are pump station (PS) and unknown pump station (UNK PS).

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated a pump station, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the PUMPSTN table with the *structure_id*. The geodatabase will not allow a "null" value for this field.

Station Name *(station_name)* – The name of the pump station as it appears on the plan is recorded here. If no station name is given, an appropriate descriptive name should be entered.

Install Date *(install_date)* – This field contains the year that the pump station was installed as it appears on plans.

Number of Pumps *(no_of_pumps)* – This field records an integer corresponding to the number of pumps present at the station as it appears on plans.

Pump Maximum Capacity *(max_capacity)* – This field contains the maximum pump capacity of the pump station, in cubic feet per second (cfs) as it appears on plans.

2.5.3.5 SWMRISER Table

The stormwater management riser table is used to record additional information for BMP riser structures. Weirs and other structures that function as a control structures are not included in the riser table. Structure types included in this table are SWM structure (SW) and unknown SWM structure (UNK SW).

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated a riser, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the SWMRISER table with the *structure_id*. The geodatabase will not allow a "null" value for this field.

Material *(mtrl_riser)* – Describes the material of the riser structure and uses values from the D_MATERIAL_END domain. The domain includes codes for the riser material, such as concrete, metal, masonry, brick, etc. If a riser structure is constructed of multiple materials, then the majority of material is the value.

Trashrack *(trashrack)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify if the riser has a trashrack on the main opening of the riser and not the low flow orifice. This information should be verified in the field.

Invert Stage 1 *(stage_inv1)* – This field records the invert elevation of the lowest outflow control on the riser structure, in feet as it appears on plans.

Invert Stage 2 *(stage_inv2)* – This field records the invert elevation of the second lowest outflow control on the riser structure, in feet as it appears on plans. If none exists, this field should be left blank.

Invert Stage 3 *(stage_inv3)* – This field records the invert elevation of the third lowest outflow control on the riser structure, in feet as it appears on plans. If none exists, this field should be left blank.

Invert Stage 4 *(stage_inv4)* – This field records the invert elevation of the fourth lowest outflow control on the riser structure, in feet as it appears on plans. If none exists, this field should be left blank.

Outlet Type *(outlet_type)* – This field describes the type of riser structure and uses values from the D_RISER domain. The domain includes codes for the type of riser and includes box shape riser, pipe riser, unknown, and other. The riser type should be verified in the field.

2.5.3.6 WEIR Table

Records in this table are strictly weirs and emergency spillways. Structure types included in this table are SWM structure (SW) and unknown SWM structure (UNK SW).

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. When a structure is designated a weir, the *structure_id* is carried over and populated in this field. The editing applications will auto-generate a record in the WEIR table with the *structure_id*. The geodatabase will not allow a “null” value for this field.

Material *(mtrl_weir)* – This field describes the material of the weir and uses values from the D_MATERIAL_WEIR domain. The domain includes codes for the weir material, such as riprap, wood, concrete, etc. If a riser structure is constructed of multiple materials, then the majority of material is the value. The material type should be verified in the field.

Trashrack (*trashrack)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify if the weir has a trashrack, which should be verified in the field.

Invert Stage 1 *(stage_inv1)* – This field records the invert elevation of the lowest outflow control on the weir structure, in feet as it appears on plans.

Invert Stage 2 *(stage_inv2)* – This field records the invert elevation of the second lowest outflow control on the weir structure, in feet as it appears on plans. If none exists, this field should be left blank.

Invert Stage 3 (*stage_inv3)* – This field records the invert elevation of the third lowest outflow control on the weir structure, in feet as it appears on plans. If none exists, this field should be left blank.

Invert Stage 4 *(stage_inv4)* – This field records the invert elevation of the fourth lowest outflow control on the weir structure, in feet as it appears on plans. If none exists, this field should be left blank.

2.5.3.7 STRUCTURE_ISSUE Table

The purpose of this table is to record issues and hazards related to structures. Each structure can have multiple issues recorded. Issues relating to sedimentation of structures, structure damage, or inability to access are recorded for structures in the STRUCTURE_ISSUE table. These values are at the discretion of the field team.

Unique Structure ID *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. The editing applications will auto-generate this value when issues are selected. The geodatabase will not allow a "null" value for this field.

Structure Issue *(attention)* - This field identifies if a feature has a structural or hazardous issue and uses values in the D_ATTENTION domain. An H hazard value should only be used if the structure needs to be immediately addressed. The valid values for this field are as follows:

H – Hazardous conditions to traffic or pedestrians. This can include road damage, sidewalk damage, missing grates, missing manhole lids, or any other condition that should be addressed immediately.

Examples of roadway, curb, and shoulder damage that would receive an "H" value for structure issue. Inlet grate damage in high traffic areas should also receive an "H".

1(Y) – A condition exists but the issue is not potentially hazardous to traffic or pedestrians, and should be resolved at a later date.

Examples of structure conditions that should be noted as a "1" but are not necessarily affecting the public, such as clogged inlets and damaged structures away from general public.

2(N) – The condition exists, but no action needs to be taken at this time. An example of this would be minor damage to an outfall wall off the shoulder, outfall pipes submerged, and structures that could not be accessed. This value should be verified in the field.

Examples of structures that would receive a "2" value for structure issues, such as submerged structures or structures with minor accumulation of debris and sediment.

Type of Problem/Issue *(structure_issue)* – This field describes the structure issue and uses the values from the D_ISSUE_TYPE domain. Multiple structure issues can be recorded per structure, and can include structures that are unable to be accessed, buried and submerged structures, issues related to grates and manhole lids, and issues related to the overall structure condition. The field application will allow the field team to select these issues as needed.

2.5.4 DRAINAGE_STRUCTURE Feature Class

Drainage areas to structures are polygon features that include all storm drain flow, both runoff and through closed storm drain networks, exiting a system through a major outfall (defined in Section 2.5.3). Typically, drainage areas are not delineated to other feature types, but the functionality is present to allow for it. The drainage area for a major outfall should include all structures associated with the major outfall systems.

Topographic contour line coverage should be used when delineating drainage areas. Base map topography, the storm drain network, and field observations are utilized to delineate drainage areas to major outfalls.

If accurate topography is unavailable, then these areas should be field verified. Other source data that will aid in delineating drainage areas include: orthophotos, roadway edges, buildings, county storm drain coverage, and stormwater management design reports. This information is available through SHA.

The editing application does not allow for drainage area delineation. Instead, drainage areas should be delineated using basic GIS tools and imported into the master geodatabase. Refer to Chapter 6 for a more detailed description on how to merge drainage areas into the geodatabase.

Unique Structure Identifier *(structure_id)* – The structure identifier is a unique GUID value that provides a link to the STRUCTURE table. Since the editing application is not used to delineate drainage areas, it is up to the user to populate the *structure_id* properly per drainage area feature. The geodatabase will not allow a "null" value for this field.

2.5.5 CONVEYANCE Feature Class

The CONVEYANCE feature class contains the feature information for pipes, ditches, and hydraulic connectivity paths. Pipes and ditches within SHA ROW are inventoried. Under-drain pipes, roof drains, and bridge drains are not inventoried. Refer to Section 2.1.2 for guidelines on inventorying pipes, ditches, and hydraulic connectors. All conveyance features must have an upstream and downstream *structure_id* associated with them.

The editing application will allow the user to pick the upstream and downstream structure to create pipe conveyance as described in Chapter 6. Ditches should be surveyed using a GPS and snapped to the upstream and downstream structures. Ditch shapes may need to be modified using ArcGIS tools to represent field conditions, depending on the GPS signal strength and ability to survey the ditch. Heavy vegetation, fences, slopes, and walls may make it impossible to survey a ditch; therefore, the ability to manually digitize a ditch is possible using the editing application.

Hydraulic connectors are strictly used to represent connectivity from inflow point(s) to the control structure of a stormwater BMP. There is no associated table that stores information about the hydraulic connector feature. Refer to Section 2.1.2.3 for guidelines on creating hydraulic connectors.

Unique Conveyance Identifier *(conveyance_id)* – The conveyance identifier is a unique GUID value that provides a link to other features and tables. This is a unique identifier that will auto-populate when entering conveyance features using the office and field editing application. Once this value is populated, it will never be edited or changed.

Conveyance Type *(conv_type)* – This field describes the type of conveyance being collected and uses values for the D_CONV_TYPE domain. The domain contains values for pipe, ditch, and hydraulic connector. There are associated tables that are used to describe the pipes and ditches. The geodatabase will not allow a “null” value for this field.

Contract Identifier *(contract_id)* – The contract identifier serves as a link between the CONVEYANCE feature and the CONTRACT table. Enter the *contract_id* corresponding to the contract under which the conveyance was constructed or modified. For example, if a pipe is extended, the *contract_id* field should contain the contract ID that did the extending. When using the editing applications, the existing contract numbers for a feature will be selected based on the *cntrct_plan* field in the CONTRACT table, and the *contract_id* field will auto-populate in the CONVEYANCE table.

The *contract_id* and *plandate* fields are dependent on one another. The following are guidelines to follow when populating the *contract_id* and *plandate* fields.

- A conveyance feature is assigned the *contract_id* and *plandate* under which it was built or modified.
- If a conveyance feature appears on a contract drawing as existing, and no earlier plans show the original design of that feature, the *contract_id* is the contract number of the plans showing the feature as existing, and the *plandate* is recorded as 9999.

- If a conveyance feature is shown as existing on two sets of plans, and the original design plans are unavailable, use the *contract_id* of the older existing plan set, and the *plandate* is recorded as 9999.
- If no plans exist for a feature, then *contract_id* is left blank, and *plandate* is recorded as 9999.

- Ditches are often not shown on the contract drawings, but the flow is clearly conveyed to another upstream or downstream structure. If both the upstream and downstream structures have the same contract identifier, it can be assumed that the ditch was constructed under the same contract. If it can be reasonably assumed that the ditch was significantly impacted during the construction of either structure, the newer contract identifier should be used.

Figure 2.14 is an example of existing and proposed conveyance features on the same contract plan sheet.

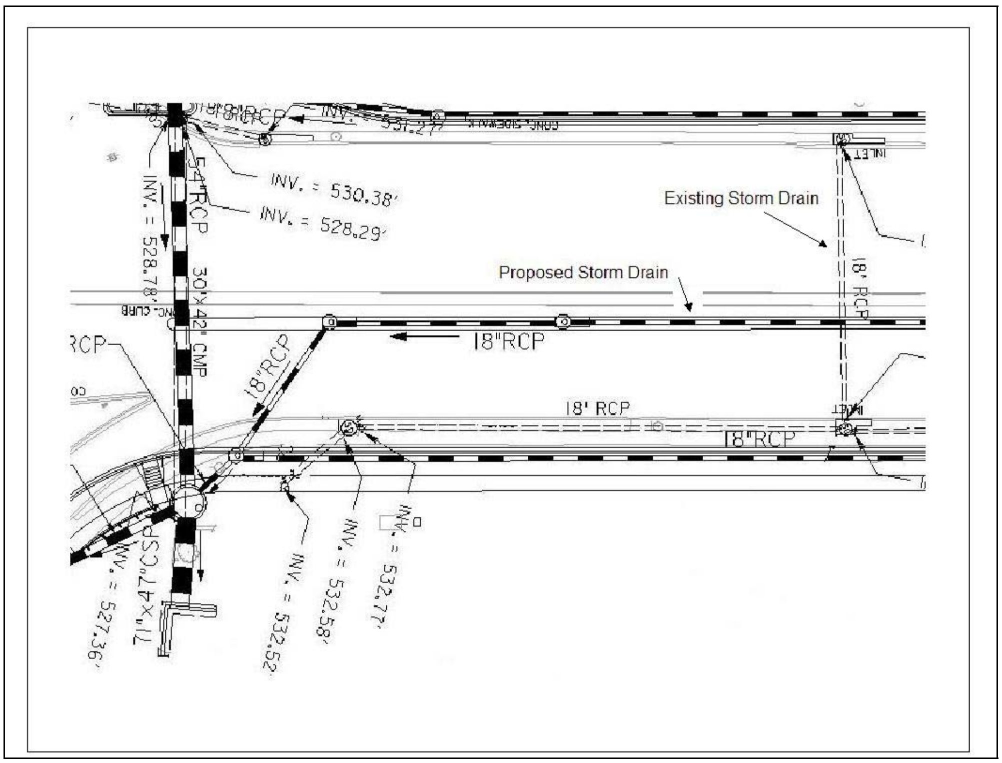


Figure 2.14 – Example Plan Sheet

The plan sheet above is the only available plan showing the existing conveyance features. The original plan sheets for the existing storm drain were not available. In this case, the contract_id for the existing features would be the contract number from this plan set because the existing features appear on it. The plandate would be 9999 for the existing features because the original design sheets are not available.

Upstream Structure Identifier *(upstrm_str)* – The upstream structure identifier should contain the same *structure_id* value in the STRUCTURES table that corresponds to the upstream structure of the conveyance. The geodatabase does not allow a "null" value for this field; all conveyance features must have an *upstrm_str* value. The *upstrm_str* value will auto-populate in the CONVEYANCE table when the upstream structure is selected for a conveyance when using the editing application.

Downstream Structure *(dnstrm_str)* – The downstream structure identifier should contain the same *structure_id* value in the STRUCTURES table that corresponds to the downstream structure of the conveyance. The geodatabase does not allow a "null" value for this field; all conveyance features must have an *dnstrm_str* value. The *dnstrm_str* value will auto-populate in the CONVEYANCE table when the downstream structure is selected for a conveyance when using the editing application.

Unit Length *(unit_len)* – This field records the length of the conveyance in feet and should be populated using pipe profiles and schedules from contract plan sheets. The geodatabase will not allow a "null" value for this field. The following are guidelines to follow when assigning a conveyance a unit length value:

- Unit length should be populated based on pipe profiles or schedules.
- If profiles or schedules are not available, the *unit_len* can be scaled from the plan views.
- When plans are not available or the storm drain layout does not match the contract plans, *unit_len* can be populated using GIS tools once conveyance has been spatially represented.
- The length for ditches and hydraulic connectors should be the flow path length and may not be a straight line.

Upstream Invert Elevation *(invert_in)* – This field records the upstream invert elevation in feet as it appears on plans. If plans or invert elevations are not available, this value is left blank. When a pipe appears on multiple contract plans sheets, and the invert elevations vary between these plans sheets, use the invert elevation from the more recent contract plans sheet.

Downstream Invert Elevation *(invert_out)* – The downstream invert elevation is recorded here in feet as it appears on plans. If plans or invert elevations are not available, this value is left blank. When a pipe appears on multiple contract plans sheets, and the invert elevations vary between these plans sheets, use the invert elevation from the more recent contract plans sheet.

Additional Conveyance Comments *(com_conv)* – This field allows for additional information and comments related to the conveyance. This field is only used to describe unique situations and clarify the response given in the other fields, if necessary. It allows 255 characters.

Plan Date *(plandate)* – Refer to **Contract Identifier** *(contract_id)* description above.

Feature Status *(feat_status)* – The field describes the status of the feature and is populated with values from the D_FEAT_STATUS domain. This field should be verified in the field. The geodatabase will not allow a "null" value for this field. The following are guidelines to follow when entering a feature status value:

- If a conveyance feature appears on the plans, but is buried, paved, submerged, etc. in the field, then the *feat_status* for that structure is EXIST.

- If it is known that a conveyance feature does not exist in the field, and the feature is not PRO, UTV, or ABD, that feature can be left out of the database and is not inventoried.

- The domain includes the following values:

  - Existing – Existing conveyance features in active use. The information may be incomplete for existing features and is completed when older plans (showing the data) are examined. Pending retrofits are flagged as existing features, and only the existing data is entered. Proposed retrofit data is not entered, until field verified.
  - Abandoned – Existing conveyance features no longer in use. The database information should still be completed.
  - Proposed – Conveyance features shown on contract drawings that have not been constructed yet. For proposed conveyance features, attribute data is collected from the contract set if the features have not been built yet. Further investigation may be necessary to determine invert elevations, pipe material and size, etc. from the profile drawings.
  - Unable to Verify – Conveyance features thought to exist, but unable to be field-verified due to inaccessibility or other issues. The required geodatabase information should be completed based on the obtained contract drawings.

Date Abandoned *(dateabandoned)* – The year the structure was abandoned is recorded here. This will usually correspond to the plan date on a newer contract set showing the abandonment. If the structure is not abandoned, this field is left blank.

Metadata Identification *(meta_id)* – This value is the same as in the META_INFO table described in Section 2.3.11, and provides the link between the structure feature and the metadata. A new metadata record should be created for each day an inventory is conducted. The geodatabase will not allow a "null" value for this field.

2.5.5.1 DITCH Table

All significant ditches are to be inventoried as described in Sections 2.1 and 2.2.

Unique Conveyance Identifier *(conveyance_id)* – The conveyance identifier is a unique GUID value that provides a link to the CONVEYENCE table. When a conveyence is designated a ditch, the *conveyance_id* is carried over and populated in this field. The editing applications will auto-generate a record in the DITCH table with the *conveyance_id*. The geodatabase will not allow a "null" value for this field.

Ditch Bottom Width *(bottom_width)* – This field should be filled in only when the ditch bottom width is ≥ 2 feet. The value is recorded in feet (rounded up). For V-channel ditches and ditches with a bottom width < 2 feet, the field is left blank. This field can be populated using plans, but should be field verified.

Trapezoid Side Slope *(trap_ss)* – The trapezoid side slope refers to the slope of the sides of a trapezoidal or V-channel ditch represented as a ratio of some number to 1. For example, 2 would represent a 2:1 slope. This field can be populated using plans, but should be field verified.

Material *(mtrl_ditch)* – This field describes the ditch material and uses values from the D_MATERIAL_DITCH domain. The domain includes values such as riprap, concrete, vegetated, etc. This field can be populated using plans, but should be field verified.

2.5.5.2 PIPES Table

The primary source pipe information is contract plan sheets. Care is taken with as-built contract sets because revisions are not always depicted on pipe profile sheets. Pipe direction, material, size, and connectivity should be verified in the field if this information is gathered from plans. Refer to Section 2.1 and 2.2 for guidelines on inventorying pipes

Unique Conveyance Identifier *(conveyance_id)* – The conveyance identifier is a unique GUID value that provides a link to the CONVAYENCE table. When a convayence is designated as a pipe, the *conveyance_id* is carried over and populated in this field. The editing applications will auto-generate a record in the PIPE table with the *conveyance_id*. The geodatabase will not allow a "null" value for this field.

Pipe Diameter *(pipe_size1)* – This is the pipe diameter or major pipe axis length for non-circular pipes. Pipe sizes are entered in inches. The following are guidelines for determining pipe diameter size:

- Pipe sizes should be determined from contact plans, but field verified. It is not necessary to open manhole lids or inlet grates, but it is recommended that a 25-foot measuring tape and flashlight be carried in the field to measure and verify pipe sizes in the field.

- Pipes attached to manholes and other connection structures cannot be field measured, but pipes attached to inlets and end/head structures should be verified.

- If pipes are buried with sediment or cannot be field verified, use the pipe size shown on the contract plans. If no plans are available, the consultant should make every attempt to field verify the pipe size. If the size can absolutely not be determined and plans sheets are not available, the field can be left blank.

Minor Dimension *(pipe_size2)* – This field records the minor dimension of non-standard pipes. Pipe sizes are entered in inches. The same guidelines used for *pipe_size1* are to be followed.

Cross-sectional Area *(xs_area)* – The cross-sectional area field contains the flow area of the pipe in square inches. If multiple pipes are associated with a single end structure feature, then the cross sectional area for the single pipe conveyance should be multiplied by the number of pipes, as discussed in Section 2.2.3.5. The *com_conv* field below should be used to clarify what is represented.

Cross-sectional Shape *(xs_shape)* – This field describes the cross-sectional shape of a pipe and uses values from the D_SHAPE domain. Values include round, arch, box, trapezoid, and ellipse. This data can be populated using plans, but must be field verified when able.

Material *(mtrl_pipe)* – This field describes the pipe material and uses values from the D_MATERIAL_PIPE domain. Values include reinforced concrete, corrugated metal, cast iron, etc. This data can be populated using plans, but must be field verified when able. When a single pipe changes material, a pipe connection feature can be added so that multiple PIPES records can be created to reflect different materials, as discussed in Section 2.2.3.2.

Pressure *(pressure)* – The pressure field identifies how flow is controlled through the pipe and uses values from the D_PRESSURE domain. Values included whether the flow through the conveyance is controlled through gravity, a force drain, or inverted siphon. Most pipes will be controlled through gravity.

2.5.5.3 PIPE_INSPECTION Table

Pipe inspections should be conducted on pipes that have an end or head structure. Pipes between closed storm drain structures are not inspected. The fields contained in this table are detailed in Chapter 4, Storm Drain Outfall Inspection Program (SDOIP).

2.5.5.4 P_INSP_PHOTO Table

This table is populated as part of the SDOIP inspection. The fields contained in this table are detailed in Chapter 4.

2.5.5.5 P_INSP_REC Table

This table is populated as part of the SDOIP inspection. The fields contained in this table are detailed in Chapter 4.

2.5.5.6 P_INSP_SUBRATINGS Table

This table is populated as part of the SDOIP inspection. The fields contained in this table are detailed in Chapter 4.

2.5.6 FLDSC_SITE Table

An illicit discharge screening inspection should be conducted at every major outfall and at outfalls and structures where an illicit discharge is suspected. The fields contained in this table are detailed in Chapter 5, Illicit Discharge Detection and Elimination Program (IDDE).

2.5.6.1 INSPECTION Table

This table is populated as part of the IDDE inspection. The fields contained in this table are detailed in Chapter 5.

2.5.6.2 FLOW_CHAR Table

This table is populated as part of the IDDE inspection. The fields contained in this table are detailed in Chapter 5.

2.5.7 SWMFAC Feature Class

Stormwater BMPs that receive SHA runoff are inventoried. SHA will supply the consultant with a list of stormwater BMPs for a County and it is the Teams responsibility to identify additional stormwater BMPs along SHA ROW. Stormwater BMP design plan sheets will be supplied to the Team, and should be used as the source for the stormwater BMP inventory.

Stormwater BMPs that are inventoried include, but are not limited to, ponds, wetlands, infiltration practices, and filtration practices. Stormwater BMPs are inventoried and recorded in the SWMFAC feature class. Due to the large number of different types, sizes and shapes of these facilities, the SWMFAC table entries are not as standardized as the storm drain structure elements.

Facility Identifier *(facility_id)* – The facility identifier is a unique GUID value that provides a link to other features and tables. This is a unique identifier that will auto-populate when entering stormwater BMP features using the office and field editing application. Once this value is populated, it will never be edited or changed.

SWM Facility Number *(swm_fac_no)* – This is a unique number, commonly referred to as the 'BMP Number' by SHA. Proper stormwater BMP numbering convention is described in more detail in Section 2.2.2. The following are guideline to follow when create a new BMP number:

- Stormwater BMP numbers will usually be present on the design plans sheets. If not, the next available BMP number in sequence for the county should be used to identify the stormwater BMP.

- Stormwater BMPs that are identified during the field inventory where no contract plans are available will receive the next available BMP number in sequence for the county.

- When a stormwater BMP is retrofitted or undergoes a significant enhancement, the stormwater BMP number is not changed. The attributes for the stormwater BMP may change enough that it will be necessary to create a new BMP feature in the SWMFAC feature class. If a retrofit changes a stormwater BMP to the point where the attributed data does not reflect the original design of the stormwater BMP, a new feature should be created with the same stormwater BMP number as the original feature. In these situations, the *swm_fac_no* will be duplicated in the feature class table. The *feat_status* of the old BMP is then changed to RMV for removed, and all future inspection should reflect the new BMP feature.

- If a stormwater BMP is a combination facility (for example sand filters with extended detention) then multiple records should be created to represent each asset of treatment for the overall facility. In these cases, each asset of treatment will receive a *swm_fac_no* value.

- Historically, the stormwater BMP number was a three (3)-digit unique number preceded by the county code. Although all of the database records have been migrated to the new format, historic documents may refer to this old numbering structure. If this situation arises, a zero should be placed after the preceding county code, making the number a four (4)-digit unique number preceded by the county code.

SWM Facility Number Legacy *(leg_swm_fac_no)* – This field stores the original stormwater BMP number prior to 2007. The original numbering convention for a facility was only five (5) digits, which may be referenced in reports, manuals, and other documentation. If the stormwater BMP is a new stormwater BMP, and a new *swm_fac_no* is assigned, the new number is copied into the *leg_swm_fac_no*.

Environmental Compliance Owned BMP *(ec_bmp)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify if the BMP is maintained by SHA's Environmental Compliance Division. These stormwater BMPs are not inspected with the MS4 inspections but are still stored in the database.

SWM Facility Number Other *(swm_fac_no_other)* – If a stormwater BMP is jointly owned or is a private facility, the identification number for the stormwater BMP of the other owner is stored in this field.

Contract Identifier *(contract_id)* – The contract identifier serves as a link between the SWMFAC feature and the CONTRACT table. Enter the *contract_id* corresponding to the contract under which the stormwater BMP was constructed or modified. When using the editing applications, the existing contract numbers for a feature will be selected based on the *cntrct_plan* field in the CONTRACT table, and the *contract_id* field will auto-populate in the SWMFAC table.

The *contract_id* and *plandate* fields are dependent on one another. The following are guidelines to follow when populating the *contract_id* and *plandate* fields.

- A storm drain feature is assigned the *contract_id* and *plandate* under which it was built or modified.

- If a stormwater BMP appears on a contract drawing as existing, and no earlier plans show the original design of that feature, the *contract_id* is the contract number of the plans showing the feature as existing, and the *plandate* is recorded as 9999.

- If a stormwater BMP is shown as existing on two sets of plans, and the original design plans are unavailable, use the *contract_id* of the older existing plan set, and the *plandate* is recorded as 9999.

- If no plans exist for a feature, then *contract_id* is left blank, and *plandate* is recorded as 9999.

Facility Designation *(designation)* – The facility designation describes the category of the stormwater BMP used in the facility (pond, infiltration, etc.) and uses values from the D_DESIGNATION domain. Plans should be used to identify the stormwater BMP type, but then verified in the field. The consultant should be familiar with stormwater BMP design and types as referenced in the SHA Book of Standard for Highway and Incidental Structures.

Designation Subcategory *(design_sub)* – The facility designation subcategory is a more detailed description of the facility designation (wet pond, shallow marsh, etc.) and uses values from the D_DESG_SUBCATEGORY domain. Plans should be used to identify the stormwater BMP type, but then verified in the field. The consultant should be familiar with BMP design and types as referenced in the SHA Book of Standard for Highway and Incidental Structures.

In-Stream *(in-stream)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify if the stormwater BMP is constructed within Waters of the U.S. GIS coverage (stream coverage) and other mapping can be used to determine if a stormwater BMP was designed in-stream.

Appurtanence Comments *(com_appurt)* – This field records a description of additional treatment or features such as SWM ponds that have infiltration treatment. This field can also describe features that have been added or removed that may impact the performance of the facility. The inspector must be cognizant of entries in this field when inspecting a stormwater BMP. Should the modifications to the BMP be significant, it should be considered a new stormwater BMP and a new feature created with the old feature classified as removed as per the description under *swm_fac_no*.

MDE Number *(mde_no)* – *This field r*efers to the MDE permit number assigned to a project when the facility was designed. The MDE number is required on the contract set and should be filled in when available.

Vicinity Map Coordinate *(vic_bmp)* – The location of the BMP is recorded here based upon an ADC map book. The format of the field should be (map, grid, year), where year is the year of the ADC book. For example: 12,F11,1996. As of 2008, ADC created a new grid system for their maps, which should be used when possible. This new grid system is a four (4)-digit map number with sub grid, and should be entered as 4095,A3,2008. The geodatabase will not allow a "null" value for this field.

Legacy Vicinity Map Coordinate *(leg_vic_bmp)* – As of 2008 ADC has changed their map grid system. The legacy coordinate is recorded here since it may be referenced in reports, manual, and other documentation. For new features, the *vic_bmp* record should be copied to the *leg_vic_bmp* field. The geodatabase will not allow a "null" value for this field.

Site Description *(loc_bmp)* – This field records a description of the site with the nearest cross street(s). It should represent the location of the access gate or road. Access to a stormwater BMP is important and it should be indicate here as well if there is an easier way to access the facility. The site description should be clear enough so that anyone attempting to visit the facility can find and access the facility trouble free. A good description will also save time when trying to find the facility during future inspection and maintenance activities. The geodatabase will not allow a "null" value for this field.

Road Name *(road_name)* – This field contains the SHA route number that the BMP is located along. If the BMP is not near an SHA roadway, then the name of the road adjacent to the facility should be recorded in this field. For example: MD 32. The geodatabase will not allow a "null" value for this field.

Owner Identification *(owner_id)* – The owner identifier serves as a link between the STRUCTURE feature and the OWNER table. Enter the *owner_id* corresponding to the organization that owns and maintains the storm drain feature. When using the editing applications, the owner of a feature will be selected from the *org_name1* field in the OWNER table, and the *owner_id* field will auto-populate in the SWMFAC table. Section 2.3.12 describes the OWNER table and fields.

Fence Material *(fence_mat)* – This field records the material that the fence is constructed of and uses values from the D_FENCE domain. When a fence is constructed of multiple materials, select the material that the fence is predominantly constructed of. If there is no fence, a value of zero is recorded. This material type should be verified in the field.

Dam Height *(dam_height)* – This field records the height of the embankment (feet), which is measured from the invert of the principle spillway outfall to the crest of the embankment as shown in Figure 2.15 by dimension H1. In the case of an excavated pond, or if the outfall is far removed from the embankment, the dam height is measure from the pond bottom to the crest of the embankment as shown by dimension H2. Plans should be used to identify the dam height, but then verified in the field.

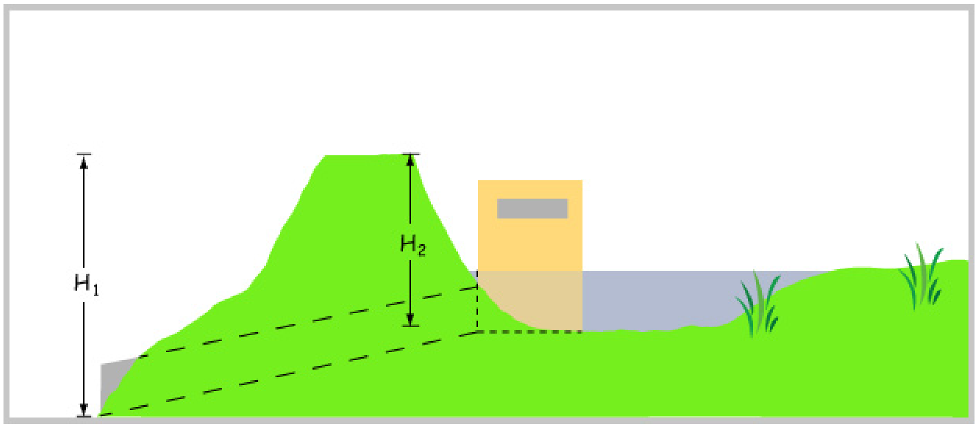


Figure 2.15 - Dam Height Measurement

Seepage Control (*seep_cont*) – The seepage control field uses 1(Yes) or 2(No) D_BOOLEANVALUES fields to indicate if the barrel was designed with an anti-seep collar or other seepage control measure. Plans should be used to identify this feature.

Observation Well *(ob_well)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES fields to identify the presence or absence of an observation well. Plans should be used to identify this feature, but then verified in the field. Observation wells can be associated with any type of BMP and should be distinguished from clean out wells.

Trench Depth *(trch_dep)* – The depth of the infiltration trench should be recorded here to the nearest tenth of a foot. Trench depths should be determined from contract drawings, but every effort should be made to confirm the depths in the field by removing well caps. Cutting the lock or well cap is approved by SHA, but should be noted in the *com_overal* field in the SWMFAC feature class.

Be aware that some observation wells extend above the top of grade, and this extension should not be included in the depth measurement. This measurement is the depth of the trench and not the observation well, although most times the observation well is equivalent. Where multiple wells are located in a single stormwater BMP, measurement of the downstream well is sufficient.

Trench Width *(trch_wdth)* – This field records the width of only infiltration trenches in feet. Plans should be used to identify this feature, but then verified in the field. If plans are not available, then an accurate measurement should be taken in the field.

Trench Length *(trch_ln)* – This field records the length of only infiltration trenches in feet. Plans should be used to identify this feature, but then verified in the field. If plans are not available, then an accurate measurement should be taken in the field.

Hazardous Classification *(haz_class)* – This field records the Soil Conservation Service-Maryland Department of Natural Resources hazard classification for the embankment, if an embankment exists, as it appears on plans. This field uses values form the D_HAZ_CLASS domain. The domain includes values for low hazard (A), significant hazard (B), and high hazard (C) for the hazard class, if it is identified on the contract drawings. If no hazard class is shown but the facility is a MD-378 pond, enter "MD-378" from the domain list. Otherwise, this field receives a "NULL" value. See the *NCRS-MD Code No. 378 Pond Standards and Specification* manual for requirements on what constitutes a MD-378 pond.

Overall Comments *(com_overal)* – Additional information and comments related to the inventory of a BMP should be recorded here. This field is only used to describe unique situations and clarify the response given in the other fields if necessary. It allows 120 characters.

1-Year Peak Discharge *(q_1yr)* – This field records the one-year peak discharge out of the facility, in cfs as it appears on plans. If the stormwater BMP was designed for this peak discharge or this information is not available, the value is left blank.

2-Year Peak Discharge *(q_2yr)* – This field records the two-year peak discharge out of the facility, in cfs as it appears on plans. If the stormwater BMP was designed for this peak discharge or this information is not available, the value is left blank.

10-Year Peak Discharge *(q_10yr)* – This field records the 10-year peak discharge out of the facility, in cfs as it appears on plans. If the stormwater BMP was designed for this peak discharge or this information is not available, the value is left blank.

100-Year Peak Discharge *(q_100yr)* – This field records the 100-year peak discharge out of the facility, in cfs as it appears on plans. If the stormwater BMP was designed for this peak discharge or this information is not available, the value is left blank.

Plan Date *(plandate)* – Refer to **Contract Identifier** *(contract_id)* description above.

Feature Status *(feat_status)* **–** The field describes the status of the feature and is populated with values from the D_FEAT_STATU_BMP domain. This field should be verified in the field. The geodatabase will not allow a "null" value for this field. The following are guidelines to follow when entering a feature status value:

- If a stormwater BMP appears on the plans, but cannot be accessed in the field, then the *feat_status* for that structure is EXIST, and comments should be provided similar to that describe the why the stormwater BMP could not be accessed.

- All stormwater BMPs located from contract drawings should be included and inventoried in the geodatabase regardless of the features status.

- The domain includes the following values:

- Existing – Existing BPM in active use. The information may be incomplete for existing features and is completed when older plans (showing the data) are examined. Pending retrofits are flagged as existing features, and only the existing data is entered. Proposed retrofit data is not entered, until field verified.
- Abandoned – Existing BMP no longer in use. The database information should be completed.
- Proposed – Facility shown on contract drawings that have not been constructed yet. For proposed facilities, attribute data is collected from the contract set if the structures have not been built yet. The shape of the stormwater BMP should be generated from the contract drawings.
- Unable to Verify – Facility thought to exist, but unable to be field-verified due to inaccessibility or other issues. The required geodatabase information should be completed based on the obtained contract drawings. The shape of the BMP should be generated from the contract drawings or from orthophotos.
- Not Built – Facility shown on design plans that was not built during construction, or the contract drawings were never executed. A feature should still be recorded in the SWMFAC feature class so that the stormwater BMP contract plans are not pulled again during future inventories. The shape of the stormwater BMP should be generated from the contract drawings. The required geodatabase information should be completed based on the obtained contract drawings.
- Removed – Facility was constructed, but was removed under a subsequent contract. The required geodatabase information should be completed based on the contract it was originally constructed under, or the most recent data available. The shape of the BMP should be generated from the contract drawings.

Note: "Removed" and "Not Built" stormwater BMPs should only be inventoried if they have been assigned a stormwater BMP number. Removed stormwater BMPs with no stormwater BMP number should not be inventoried, but the plans should be forwarded to SHA.

Date Abandoned *(dateabandoned)* – The year the facility was abandoned should be recorded here. This will usually correspond to the plan date on a newer contract set showing the abandonment. If the structure is not abandoned, this field is left blank.

Metadata Identification *(meta_id)* – This value is the same as in the META_INFO table described in Section 2.3.11, and provides the link between the structure feature and the metadata. A new metadata record should be created for each day an inventory is conducted. The geodatabase will not allow a "null" value for this field.

4 Miles of Airport *(4mi_Vicinity_airport)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to indicate if the stormwater BMP is located within four miles of an airport. Stormwater BMPs within this zone must not have a permanent pool. A shapefile, available from SHA, should be used to identify stormwater BMPs within four miles of a stormwater BMP.

2.5.7.1 BMP_INSPECTION Table

A BMP inspection is required for all stormwater BMPs that SHA maintains. Several tables are associated with the BMP inspections and are detailed in Chapter 3, Best Management Practices.

2.5.7.2 BMP_CENTROID Feature Class

The BMP_CENTROID feature class stores the coordinates of the stormwater BMP centroid. This feature should be auto-generated through GIS tools outside of the editing applications and then merged into the geodatabase. Refer to Chapter 6 for a more detailed description on how to merge centroids into the geodatabase.

Facility Identifier *(facility_id)* **–** The facility identifier is a unique GUID value that provides a link to the SWMFAC feature class. These values should be auto-generated when the centroids are created from the SWMFAC feature class. The geodatabase will not allow a “null” value for this field.

2.5.8 DRAINAGE_SWMFACILITY Feature Class

This feature class is used to depict the treatment areas to stormwater BMPs. The treatment area is a polygon feature that includes the drainage being directly treated by a stormwater BMP. Treatment area polygon features should not overlap each other, but represent only the drainage being treated. The purpose is to not account for treated drainage multiple times in the treatment area polygon feature. The editing application does not allow for treatment area delineation. Instead, treatment areas should be delineated using basic GIS tools and imported into the master geodatabase. Refer to Chapter 6 for a more detailed description on how to merge drainage areas into the geodatabse.

Topographic contour line coverage should be used when delineating treatment areas. Base map topography, the storm drain network, and field observations are utilized to delineate treatment areas to stormwater BMPs.

If accurate topography is unavailable, then these areas should be field verified. Other source data that will aid in delineating treatment areas include: orthophotos, roadway edges, buildings, county storm drain coverage, and stormwater management design reports. This information is available through SHA.

Figure 2.16 and 2.17 are an example of treatment areas delineated for stormwater BMPs.

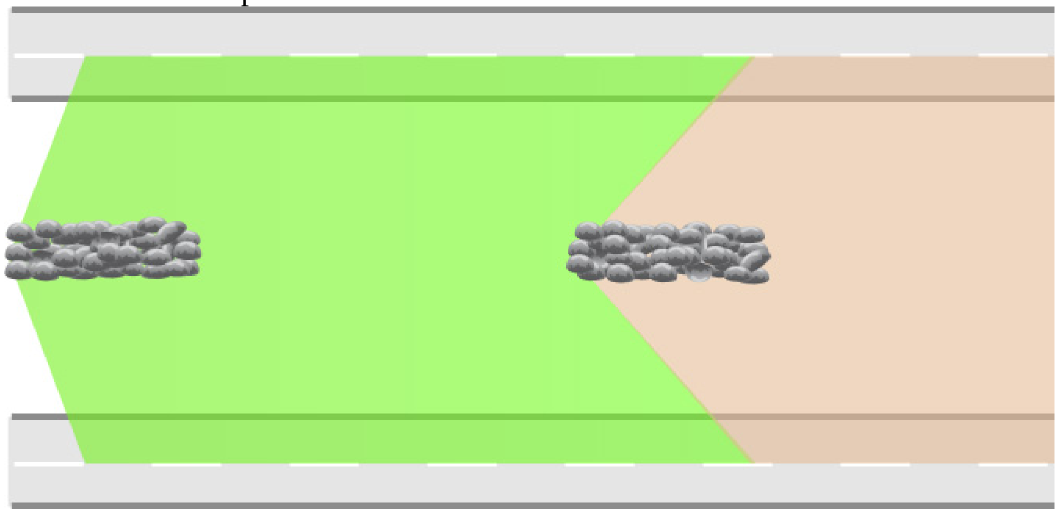


Figure 2.16 – Treatment Area Example 1

Treatment area for two infiltration trenches in series

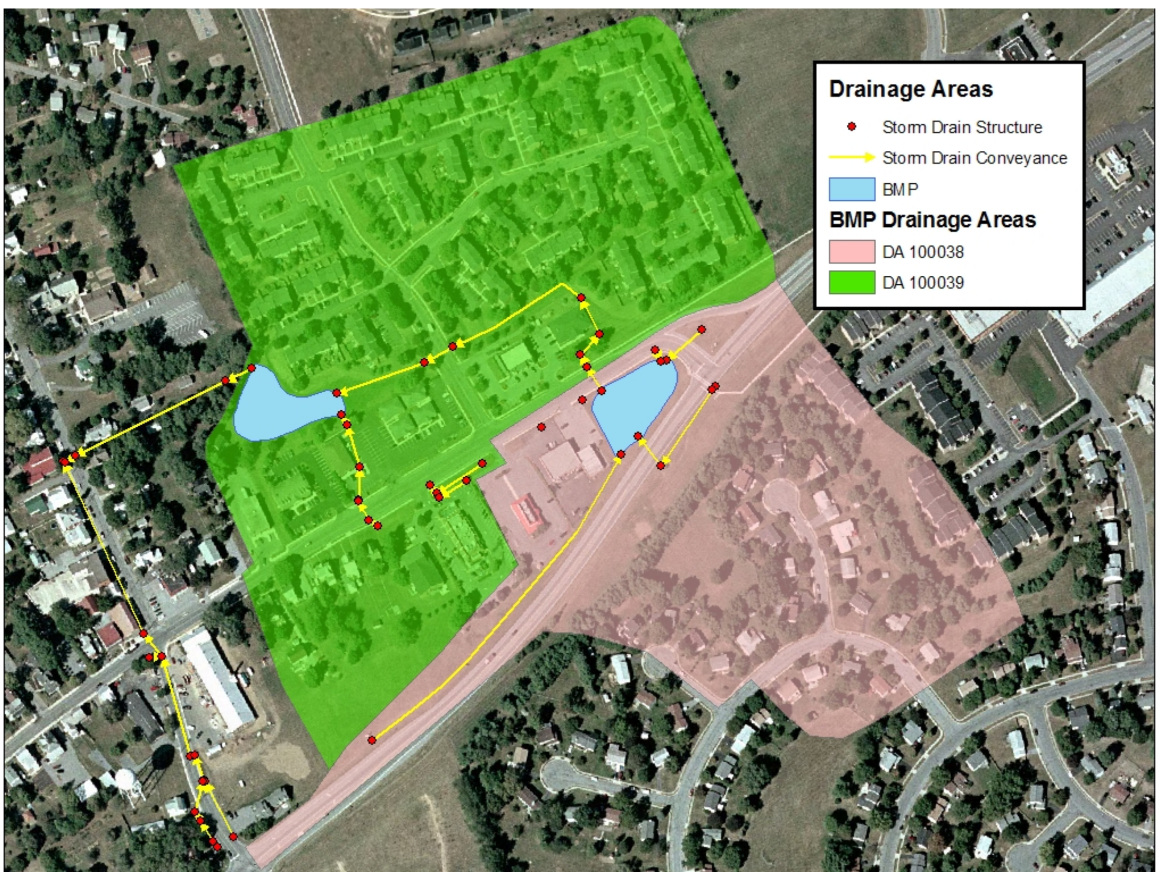


Figure 2.17 – Treatment Area Example 2

Treatment area for two BMPs in series

The editing application does not allow for treatment area delineation. Instead, treatment areas should be delineated using basic GIS tools and imported into the master geodatabase. Refer to Chapter 6 for a more detailed description on how to merge treatment areas into the geodatabase.

Facility ID *(facility_id)* **–** The facility identifier is a unique GUID value that provides a link to the SWMFAC table. When a stormwater BMP has a treatment area, the *facility_id* is carried over and populated in this field. Since the editing application is not used to delineate treatment areas, the user should populate the *facility_id* properly per treatment area feature. The geodatabase will not allow a "null" value for this field.

Treatment Area *(treatment_area)* **–** This value represents the drainage that a facility and no other stormwater BMP is treating in acres. When stormwater BMPs are in a series, the treatment areas can be summed to get the overall drainage area.

2.5.9 FILE_ATTACH_SWM and FILE_ATTACH_STR Tables

The FILE_ATTACH tables link digital files of features obtained during the field screening, inspections of structures, and inspections of the stormwater BMPs. These documents can be photographs, Excel files, Word documents, or .pdfs. All documentation other than photographs should be submitted in .pdf format, unless otherwise notified by SHA.

The most efficient and manageable digital photograph format is JPEG (aka .jpg). This format can be generated by most digital cameras and is read by most computer applications. Care must be taken to balance image quality (i.e. low, medium, high resolution) with file size. The lowest resolution should be used that is still sufficient to clearly view the subject. File sizes should be under 2 MB.

Photographs are taken at every major outfall and/or illicit discharge screening. The photograph is an attempt to provide an overall view of the site and also any site conditions associated with the field screening. If possible, the photograph position should be directly downstream of the outfall in an attempt to capture the outfall structure and the receiving drainage way.

SHA requires multiple images be captured for stormwater BMPs to document site conditions. Where possible, the photographs should be comprehensive to reflect the inspection results and include relevant information relating to the stormwater BMPs performance. Photographs to be included with the inspection include: overall of stormwater BMP, inflows into the stormwater BMP, the stormwater BMP outfall, control structure/riser, emergency spillway, and observation wells. Photographs of maintenance issues should also be taken and recorded in the geodatabaseThe consultants should make every attempt to capture photographs in the same location as past inspections. If necessary, the photograph location can be described in the *comments* field in the corresponding table.

Field photographs should be labeled with the date and a description including the structure or stormwater BMP number. This label should be imbedded within the image. If a digital camera is not available, a conventional camera may be processed digitally, or the hard copy scanned into a digital image. The labeling on the photograph can be created with any photograph imaging software. Refer to Figure 2.18 for an example of photograph labeling.

Figure 2.18 - Example of Photo Labeling

Inspection Identifier *(inspect_id)* – The inspection identifier is a unique GUID value that provides a link from the FILE_ATTACH_STR table to the INSPECTION table. This field links the images to the INSPECTION table (described in Chapter 5). When an image record is added to the FILE_ATTACH_STR, this value is auto-populated by the editing application. There can be multiple images per inspection. In order to associate an image with a structure, the proper tables must be completed, including the FLDSC_SITE and INSPECTION table. The geodatabase will not allow a "null" value for this field.

The FILE_ATTACH_STR table only stores images related to the major outfall and illicit discharge inspections. Images of damaged structures, hazards, or issues that the field team finds necessary to report to SHA should only be included in a report to SHA.

BMP Inspection Identifier *(bmp_inspect_id)* – The stormwater BMP inspection identifier is a unique GUID value that provides a link from the FILE_ATTACH_SWM table to the BMP_INSPECTION table. This field links the images to the BMP_INSPECTION table (described in Chapter 3). When an image record is added to the FILE_ATTACH_SWM, this value is auto-populated by the editing application. There can be multiple images per inspection. In order to associate an image with a BMP, a record must be included in the BMP_INSPECTION table. The geodatabase will not allow a "null" value for this field.

File Name *(filename)* – This is the standard filename of the photograph taken during the inspection. The filenames of the photograph and other associated documents should consist of the *sha_str_no* or *swm_fac_no* (depending on table) followed by a descriptor and then the date using YYYYMMDD format. For example, stormwater BMP #150306 would have a photograph of an inflow named 150306-inf-20060218.jpg, if a photograph was taken February 18, 2006. Leading zeros for representing county codes should not be dropped. The different segments of the file name must be separated by a dash (-) from all other part of the filename. For example, if a stormwater BMP has multiple inflows the proper naming convention for each inflow would be the following: 150325-inf-a-200060218.jpg and 150325-inf-b-200060218.jpg. Naming conventions have been standardized as shown in Table 2.5.

Table 2.5 – Standard Photo Naming Conventions

Subject	Naming Standard
Riser	012345-RIS-date.jpg
Outfall	-OUT-date.jpg
Inflow	-INF-a-date.jpg -INF-b-date.jpg
Emergency Spillway	-ES-date.jpg
Embankment	-EMB-date
Overall	-012345-date.jpg – *no type necessary -012345-a,b,c-date.jpg
Erosion	-ERO-date.jpg
Low Flow Orifice	-LOWFLOW-date.jpg
Control Structure	-CS-date.jpg (used when the CS is a HW, ES, IN, or PP, etc.
Weir	-WEIR-date.jpg
Fence	-FEN-date.jpg
Hazards	-HAZ-date.jpg
Evidence Blocked	-HAB-date.jpg
Access of Habitation	-ACC-date.jpg
Major Outfalls	1234567.001-date.jpg
Illicit Discharges	1234567.001-ILL-date.jpg
Other – Maintenance Items	1234567.001-OTHER-a,b,c-date.jpg; 012345-OTHER-.jpg

When adding photos to an inspection record using the editing application, this *filename* format will be selected from lists of standard naming convention segments, and the filename field will be auto-populated from these selections. Refer to Chapter 6 for a more detailed description of adding documentation to the FILE_ATTACH_STR and FILE_ATTACH_SWM. The geodatabase will not allow a "null" value for this field.

Comments *(comments)* – Comments are used for any additional information about the photograph or documentation. The field allows 255 characters and should be used liberally.

Information such as structure type or condition (buried, heavy vegetation, etc.) should be added here. These comments are useful when the structure cannot be seen in the photo because it is covered with heavy vegetation, buried, submerged, etc. Comments also assist in accessing maintenance actions.

2.5.10 FILE_SCAN Table

The FILE_SCAN table contains the filenames of the contract drawings or other scanned documents for stormwater BMPs. The most efficient format is TIFF (aka .tif) imagery. SHA will supply all scanned contract drawing relating to the stormwater BMP design and function in digital format to the consultant for the BMPs SHA owns and maintains. All scans should be grouped by contract number and stormwater BMP number, and compiled into the following folder structure shown in Figure 2.19. If a scan does not have the *swm_fac_no* label, then the *swm_fac_no* label should be written onto the scan, then re-scanned and stored in the FILE_SCAN table. The folder format is route number, contract number, stormwater BMP number. There are times when a title sheet or detail sheet might reflect two stormwater BMPs under the same contract. For these situations, the sheet does not need to be duplicated in multiple stormwater BMP number folders, but simply fall under the contract folder. All scanned files should be delivered to SHA in this folder structure format.

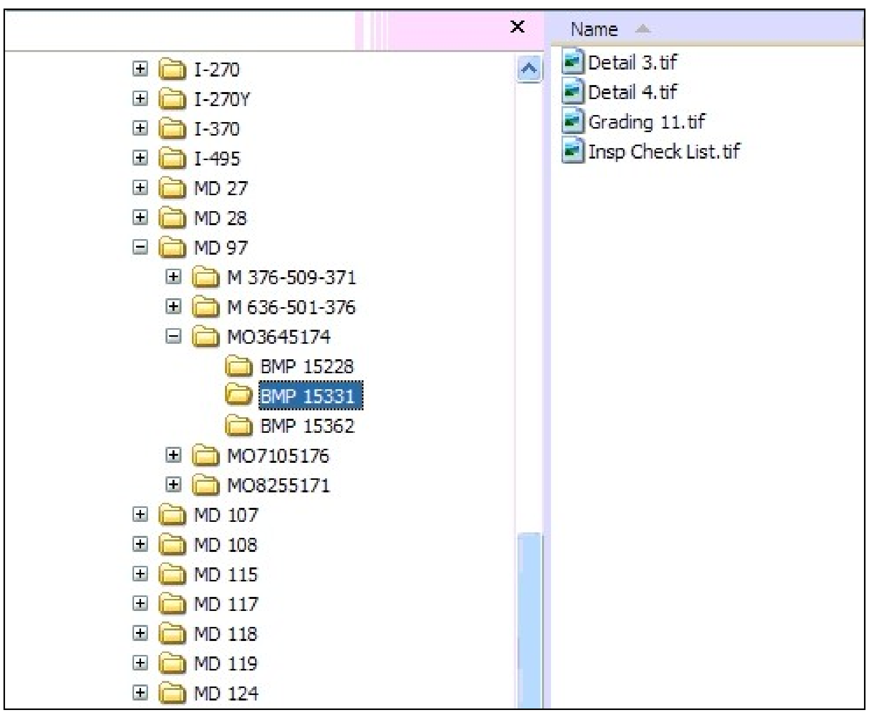


Figure 2.19 – Folder Structure Example for Scans

Example of folder structure for scanned contract plan sheets for BMPs

Facility Identifier *(facility_id)* – The facility identifier is a unique GUID value that provides a link to the SWMFAC feature class. The editing applications will allow the user to select the scanned documents and will auto-generate this value in the FILE_SCAN table. The geodatabase will not allow a "null" value for this field.

Contract Identifier *(contract_id)* – The contract identifier serves as a link between the FILE_SCAN and the CONTRACT tables. Enter the *contract_id* corresponding to the scanned image. When using the editing applications, the user can select from a list of contract numbers from the CONTRACT table, and the *contract_id* field will auto-populate in the FILE_SCAN table. The geodatabase will not allow a "null" value for this field.

File Name *(filename)* – This field contains the full filename and subdirectory paths containing the scanned image. Image files are typically .tiff images. The directory path for stormwater BMP drawings would consist of a directory for route number, a subdirectory for the contract number, and a subdirectory for the BMP number. For Route 650 in Montgomery County, this would read "\MD650\529-501-371\BMP 15330\[filename]." This directory will contain all of the .tiff images associated with that BMP. The contract number folder will store related contract sheets for BMPs designed under the same contract. These sheets may include the title sheets, vicinity maps, and index sheets relating to the contract set. The geodatabase will not allow a "null" value for this field.

Documents related to access permits will also be scanned and related via this table. The filename of the scan should be the hydraulic file number that is included on all access permit files with a sequential suffix indicating the order in which the files are created. Therefore, a letter for the recommended approval of access permit 05-AP-AA-006 would be saved as 05-AP-AA-006_01.pdf. Unlike the scanned contract documents, the file path is not required in the case of access permits and should be stored in a common folder called "Access_Permits_[CountyName].

Comments *(comments)* – Comments are used for any additional information about a FILE_SCAN record. The field allows 120 characters, and should be used liberally.

2.5.11 META_INFO Table

The purpose of the META_INFO table is to keep track of information regarding the creation and updating of the data. The META_INFO table records metadata about each structure, pipe, and SWMF. Multiple features can and will have the same META_INFO record.

Metadata Identifier *(meta_id)* – The metadata identifier is a unique GUID value that provides a link to the STRUCTURES, CONVEYANCE, and SWMFAC feature classes. The editing applications will auto-generate this value as new metadata records are created. The geodatabase will not allow a "null" value for this field.

Datacreate *(datecreate)* – This field should be populated when the feature is created. Each feature only needs one META_INFO record, which should represent the date the feature was created spatially, and not when the associated data about the feature was entered. If an existing feature in the geodatabase is updated, then the feature should receive a new

META_INFO record with the appropriate date. The geodatabase will not allow a "null" value for this field.

Creator *(creator)* – Name of the individual, consultant, or office that created the data. Abbreviations should be used when necessary. For example, State Highway Administration should be recorded as SHA. The geodatabase will not allow a "null" value for this field.

Information Base *(info_base)* – This field records the source of the spatial feature, whether it is existing, as-built, design information, or field located, and uses values from the D_INFO_BASE domain. The geodatabase will not allow a "null" value for this field.

Definitions of the D_INFO_BASE values are as follows:

- **GPS** – spatial representation of a feature was generated in the field using a GPS device
- **As-built** – spatial representation of a feature was generated using as_built contract drawings, and digitized into the geodatabase. These features can include structures that could not be located, could not be accessed, buried, covered with vegetation, paved, guarded by dog, etc.
- **Design** – spatial representation of a feature was generated using contract drawings, and digitized into the geodatabase.. These features can include structures that could not be located, could not be accessed, buried, covered with vegetation, paved, guarded by dog, etc. Most pipes will have an *info_base* of *design or As-built*, unless contract plans are not available. See note below for more details on assigning INFO_BASE value to pipes.
- **Field** – spatial representation of a feature cannot be accessed and surveyed in the field using GPS, but there is evidence that the structure exists. Evidence of features in the field might be a drainage ditch, sump area, erosion, cracked pavement around manhole lid, etc.
- **Aerial** – spatial representation of a feature cannot be accessed and surveyed in the field using GPS, but the location is determined from orthophotos. Sometimes it is possible to see surface structures and BMPs on orthophotos. This might be a common occurrence in medians of heavily trafficked highways.

Note: Storm drain structures and BMPs should be surveyed using GPS where possible. When the ends of a pipe are surveyed using GPS, but most of the data for the location, inverts, type, etc. of the pipe are obtained from the as-builts, "*as-built*" should be entered into this field. If simply design plans are used, then "*design*" should be entered. The justification for this is that the plans identify the connectivity of the pipe, illustrate that there are no underground connections (junction boxes), and provide the basic information on the type, slope, and inverts. Thus, the plans provide more detailed information for this pipe than could be determined through GPS alone. Pipes that are created from field observations where no plans are available should received an *info_base* value of "*field*".

Parent Metadata Identifier *(parent_meta_id)* – This field contains the *meta_id* from the last revision, which allows for tracking of data modification. If a structure or stormwater BMP is changed in any fashion, then a new *meta_id* record is assigned to that feature. The original *meta_id* value for that feature should be entered in the *parent_meta_id* of the newly assigned *meta_id* to keep an historic record of how the feature was originally created.

2.5.12 OWNER Table

The purpose of this table is to store contact information for the owners of the stormwater infrastructure. It is assumed that SHA owns and maintains all storm drain features in the geodatabase unless otherwise noted by the *owner_id* field. If the consultant determines that a particular feature belongs to another entity, the feature should be recorded in the geodatabase and the owner information documented accordingly. The editing application will allow the user to select the owner based on the *org_nam1* field in the OWNER table.

SHA understands that it may be impossible to gather all the information in the owner table, but as a minimum SHA requires that the *owner_code* and *org_nam1* field be populated. The remaining owner information can be obtained with the help of SHA.

Unique Owner Identifier *(owner_id)* – The owner identifier is a unique GUID value that provides a link to the STRUCTURES and SWMFAC feature classes and the AGREEMENT table. Some standard values have been pre-populated within this table. The consultant should review these standard values before creating another OWNER record. The editing applications will auto-generate this value as new owner records are created. The geodatabase will not allow a "null" value for this field.

Owner Code *(owner_code)* – This code describes the owner of the feature and uses values from the D_OWNER domain. These values include SHA, joint-use, private, public, and unknown ownership. The geodatabase will not allow a "null" value for this field.

Organization Name 1 *(org_nam1)* – This field documents the organization name that owns and maintains the feature such as Howard County.

Organization Name 2 *(org_nam2)* – This is a second field for organization name such as Department of Public Works.

Contact Name *(contact_nam)* –The name of individual at the organization who is responsible for the stormwater BMP should be recorded here.

Street Address 1 *(street1)* – The street address for the *contact_nam should be recorded here.*

Street Address 2 *(street2)* – This field provides an additional street address for the *contact_nam, such as a suite or building number..*

City *(city)* – The city for *contact_nam should be recorded here.*

State *(State)* **–** This field records the state for *contact_nam.*

Zip Code *(zip)* **–** This field records the zip code for *contact_nam.*

Contact Phone Number *(phone1)* – The phone number of contact person at owner organization should be recorded here.

Alternate Contact Phone Number *(phone2)* **–** An alternate phone number of contact person at owner organization can be recorded here.

Fax Number *(fax)* **–** The fax number of contact person at owner organization should be recorded in this field.

Email *(email)* – The e-mail address of contact person at owner organization should be recorded here.

Web *(web)* **–** The Web URL of owner organization should be recorded here.

Comments *(comments)* – This field will document additional comments about the owner organization, and allows for 120 characters.

2.5.13 AGREEMENT Table

The purpose of this table is to store entry and maintenance agreements for storm drain infrastructure. This table will be populated by SHA and is not the consultant's responsibility. The consultant will refer to this table and select the agreement record, if an entry or maintenance agreement exists for a feature. The editing application will allow the user to select the agreement record based on the owner information.

Unique Owner Identifier *(owner_id*) **–** The owner identifier is a unique GUID value that provides a link between the AGREEMENT and the STRUCTURE and SWMFAC feature classes and the OWNER table. Some standard values have been pre-populated within this table. The consultant should review these standard values before creating another OWNER record. The editing applications will auto-generate this value as new owner records are created. The geodatabase will not allow a "null" value for this field.

Unique Agreement Identifier *(agree_id*) **–** The agreement identifier is a unique GUID value that provides a link between the AGREEMENT and the FILE_ATTACH_AGREE table. The editing applications will auto-generate this value as new agreement records are created. The geodatabase will not allow a "null" value for this field.

Agreement Type *(agreement_type*) – This field describes the agreement type and uses values from the D_AGREE_TYPE domain. The agreement will either be a maintenance or entry agreement. The geodatabase will not allow a "null" value for this field.

Agreement Expiration Date *(agree_exp_date)* – This field documents the date the agreement expires in format DD/MM/YYYY. If a date is unavailable, the value is left blank.

Agreement Comments *(agree_com)* – This field contains additional comments about the agreement and allows for 120 characters.

2.5.14 FILE_ATTACH_AGREE Table

The purpose of this table is to store a record for the agreement scan. Each agreement should be scanned and stored as a .tiff image. There can be multiple scanned records per AGREEMENT record.

Unique Agreement Identifier *(agree_id)* **–** The agreement identifier is a unique GUID value that provides a link between the AGREEMENT and the FILE_ATTACH_AGREE table. The editing applications will auto-generate this value as agreement scans are selected for an AGREEMENT record. The geodatabase will not allow a "null" value for this field.

File Name *(filename)* **–** This is the filename of the agreement scan. The filename for the agreement consists of the *swm_fac_no* or *sha_str_no* followed by the private entity name, followed by the date in YYYYMMDD format. For example, BMP #150306 on WalMart property would be named 150306_Walmart_20060218.tif, if the document was received February 18, 2006. All files in this table should be stored in a folder named "File_Attach_Agree"

Comments *(comments)* **–** Comments are used for any additional information about the maintenance or entry agreement. The field allows 120 characters and should be used liberally.

APPENDIX B:

GIS Standard Procedures
Chapter 5: Illicit Discharge, Detection & Elimination Procedures

Draft October 2008

DRAFT CHAPTER 5: ILLICIT DISCHARGE, DETECTION & ELIMINATION PROCEDURES

Chapter 5

Illicit Discharge Detection and Elimination (IDDE) Procedures

October 2008

DRAFT

Table of Contents

5.0 Illicit Discharge Detection and Elimination Program (IDDE) 5-1
5.1 Introduction.. 5-4
5.1.1 Illicit Discharge 5-4
5.2 IDDE Sample Locations 5-5
5.2.1 Hot Spots 5-7
5.3 Field Equipment.. 5-8
5.4 Illicit Discharge Screening.. 5-9
5.4.1 FLDSC_SITE Table 5-9
5.4.2 INSPECTION Table.. 5-10
5.4.3 FLOW_CHAR Table 5-12
5.5 Potential Causes for Illicit Discharge Flows... 5-14

Appendices

Appendix 5-A – Example of Illicit Discharge Report 5-17
Appendix 5-B – Example Photo Labeling 5-22
Appendix 5-C – Example Hot Spots Report.. 5-26
Appendix 5-D – Outfall Screening Inspection Form 5-32

List of Figures

Figure 5.1 – Discharge Point Location for Culverts...5-6

Figure 5.2 – Screening Location Examples... 5-7

List of Tables

Table 5.1 – Discharge Type Parameters Can Detect...5-14

Table 5.2 – Land Use, Generating Sites, and Activities That Produce Illicit Discharges......... 5-16

Chapter 5

Illicit Discharge Detection and Elimination

5.1 INTRODUCTION

The Illicit Discharge Detection and Elimination (IDDE) procedures are developed as a guide for performing illicit discharge inspections on storm drain outfalls for the Maryland State Highway Administration (SHA). Illicit discharge inspections are performed as part of the SHA National Pollutant Discharge Elimination System (NPDES) permit.

The discharge of stormwater containing pollutants, which have not been reduced to the maximum extent practicable, is prohibited.

An IDDE inspection should be performed at major outfall locations. Major outfalls are storm drain systems that outfall through 36-inch diameter (or equivalent cross-sectional area) or greater conveyance structures or open systems that drain greater than 50 acres. For industrial uses or designated hot spots, the major outfall is defined as 12-inch diameter (or equivalent cross-sectional area) conveyance structures or open systems that drain greater than two (2) acres. Cross culverts and driveway culverts are not considered major outfalls unless closed storm drain discharge into them.

In the past, inspections have been performed on major outfalls that discharged into Waters of the U.S. or NPDES outfall. The term NPDES outfall has prompted much discussion of meaning and confusion amount inspector, so SHA now requires an IDDE inspection be performed on any outfall pipe that is 36-inches or greater. The purpose of the IDDE inspection is to identify impaired flows entering Waters of the U.S. SHA assumes that all pipes 36-inches or greater eventually discharge into Waters of the U.S. Based on this assumption all major outfalls will be evaluated for illicit discharge.

5.1.1 Illicit Discharge

The EPA defines an illicit discharge as any discharge from a storm drain pipe to a Municipal Separate Storm Sewer System (MS4) that is not entirely composed of stormwater, except those allowed in conjunction with an NPDES permit or resulting from fire fighting activities. The Center for Watershed Protection defines an illicit discharge as a discharge from a storm drain that has measurable flow during dry weather (48 hours of dry time) that contains pollutants or pathogens.

There are different types of dry weather discharge that can affect Waters of the U.S.

- Sewage flows from sewer pipes or septic systems
- Wash water flows from laundry wastewater, commercial car washes, fleet washing, floor washing that drains to shop drains, and swimming pool drainage
- Liquid waste flows such as oil, paint, radiator flushing, and plating wastewater;
- Tap water flows from leaks in the water supply system
- Landscape irrigation flows from excess water used for residential and commercial irrigation needs
- Groundwater and spring water flows from high water table levels, cracks, and seeps in geology

Discharges from the following are not be considered a source of pollutants or illicit discharge when properly managed:

- Water line flushing
- Landscape irrigation
- Diverted stream flows
- Rising groundwaters
- Uncontaminated groundwater infiltration to separate storm sewers
- Uncontaminated pumped groundwater
- Discharge from potable water sources
- Foundation drains
- Air conditioning condensation
- Irrigation waters
- Springs
- Footing drains
- Lawn watering
- Individual residential car washing
- Flows from riparian habitats and wetlands
- De-chlorinated swimming pool discharges
- Street wash water
- Fire fighting activities

5.2 IDDE SAMPLE LOCATIONS

Illicit discharge and dry weather screening should be performed on the downstream most structure of a system for pipes that are 36-inches or greater. SHA requires that all major outfalls be inspected and screened if an illicit discharge is present anywhere in the system. If the SHA system ends in a closed storm drain structure and the pipe entering the structure is 36-inches or greater, then the IDDE inspection should be performed at this structure. SHA also requires that an outfall screening be performed on any outfall that has a suspected illicit discharge, regardless of the pipe size. Research has shown that greater than 50 percent of illicit discharge flows are from pipes that are less than 36 inches in diameter. These pipes would not be classified as a major outfall by SHA, but should still be identified and screened.

In some circumstances, a storm drain will discharge into a cross culvert. If the cross culvert is greater than or equal to five (5) feet in height, the culvert is considered accessible. In this case, the connection between the storm drain pipe and the culvert would be the outfall. This connection could be a pipe connection to the culvert, or a manhole, inlet, or junction box that drops directly into a culvert.

Safety is always the primary consideration. If the cross culvert conveys an active stream, is excessively long, or posses other hazards as defined by confined space entry guidelines, the culvert should not be entered. It may be necessary to collect a dry weather flow sample from inlets or manholes upstream of the connection to the culvert.

If the cross culvert is less than five (5) feet in height, the culvert is considered inaccessible, and the downstream end of the culvert is considered the outfall. In this case, the cross culvert should be inventoried with the storm drain system as described in Chapter 2. The upstream structures should be investigated for dry weather flow, and a sample should be taken from upstream structures and not the culvert outfall if possible; especially if the culvert conveys a stream. If the upstream structures are not accessible, a sample should be analyzed from the culvert outfall.

Figure 5.1 and 5.2 help identify where to perform an IDDE screening and inspection.

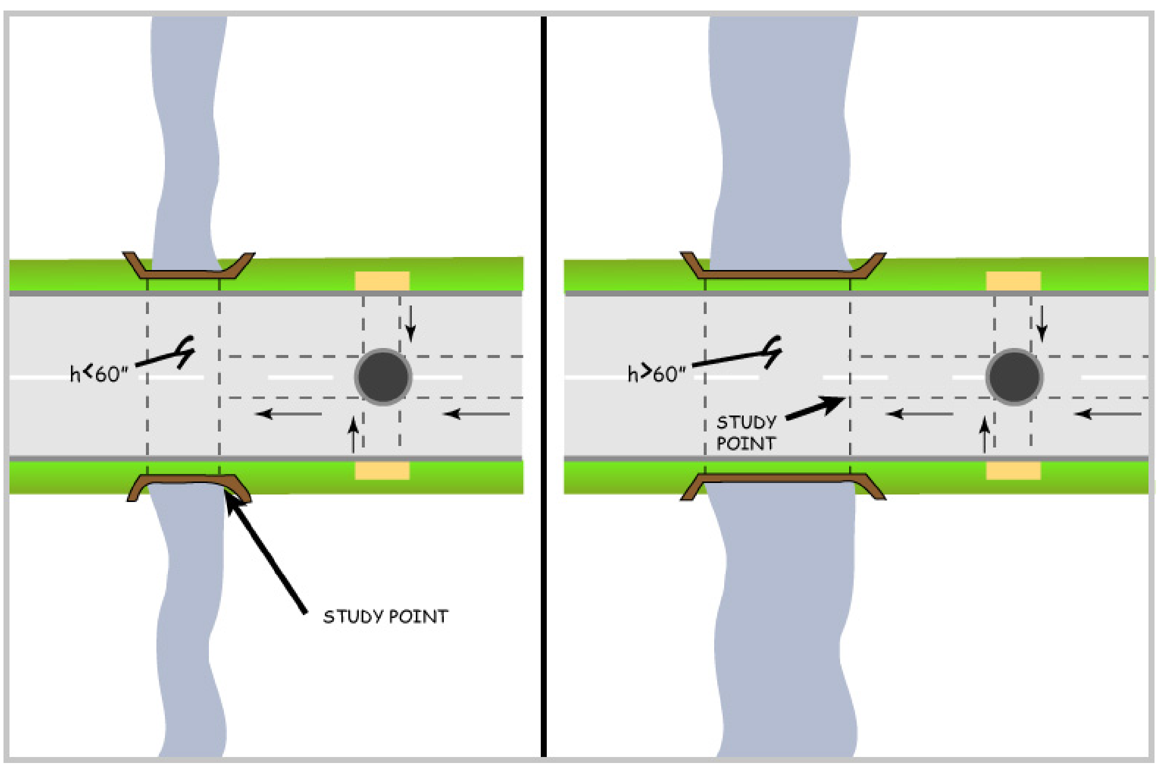


Figure 5.1 – The image on the right shows a storm drain system discharging into a culvert that is less than 5 feet in height. This culvert is considered inaccessible and a screening may need to be performed at the downstream end of the culvert. The image on the left show a storm drain system discharging into a pipe that is greater than 5 feet in height which would not be included in the inventory. Instead the pipe connection to the culvert would be considered the major outfall, and a screening performed on the pipe connection. If the pipe connection is inaccessible, then a screening should be performed on the next upstream structures.

Cross culverts of any size pipe are not considered major outfalls. If a system outfalls, then flows into a cross culvert, then the main system outfall would be the sampling location. If a sample is collected at another structure other than the most downstream outfall, that structure ID should be noted in the *sample_str_id* field in the INSPECTION table as described later. The third example in Figure 5.2 is an example of this situation. The 54 inch pipe outfall would be the major outfall, but a sample should be taken where the closed storm drain outfalls. Figure 5.2 describes the structure location where an IDDE screening should take place.

A. The system is two cross culverts and would not be considered a major outfall. No screening is necessary unless an illicit discharge is suspected

B. The system is two cross culverts and would not be considered a major outfall, regardless of the pipe size. No screening is necessary unless an illicit discharge is suspected

C. The closed storm drain flows into a cross culvert that is greater than 36 inches making the downstream end of the culvert a major outfall. Since the downstream structure is a culvert, the IDDE screening should take place at the outfall from the closed storm drain system

D. The upstream system discharges into an inlet that discharges through a 36 inch pipe, forming on continuous system. The IDDE screening should take place at the most downstream outfall.

E. The closed storm drain flows into a stream but is not a major outfall. An IDDE screening is only performed if an illicit discharge is suspected

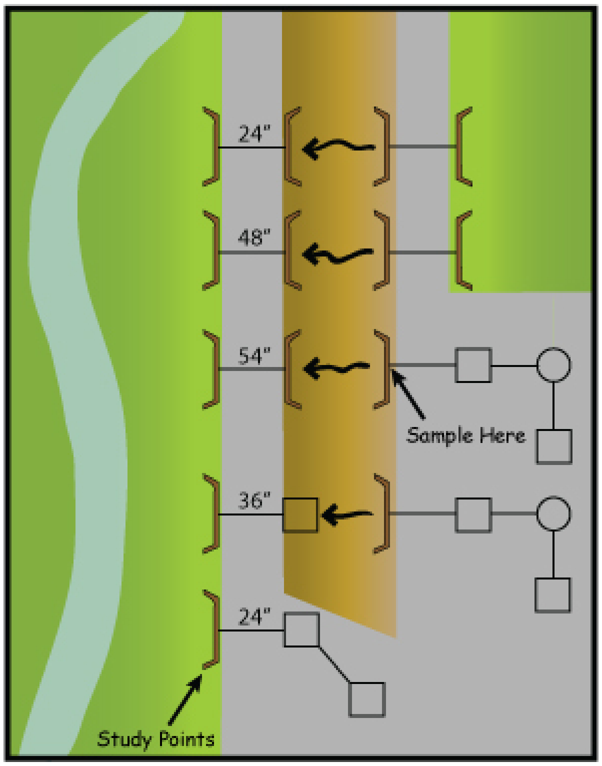


Figure 5.2 – Screening Location Examples

Outfalls from BMPs can be considered major outfalls. Outfalls into BMPs can also be considered major outfalls if the pipe cross-sectional area of the outfall pipe is greater than or equal to 1018 in^2.

In addition to the illicit discharge screening, physical inspections of the outfalls should be performed. Ratings of the outfall structure, culvert (pipe), and downstream water course are conducted in the field. Ratings and screening information can be captured using the field application, on paper, or a combination of the two, depending on the capabilities of the team performing the inspection.

5.2.1 Hot Spots

Although the impetus for the inspection protocol is major outfalls, this procedure can be followed for any outfalls deemed necessary by SHA such as hot spots. Hot spots are areas where there is an existing concern about pollutant discharge.

Hot spots are defined by SHA or the local county government as areas where there are concerns about possible illicit discharges and/or outfall damage. These are often identified by county stormwater divisions, based on citizen complaints. The local county government stormwater entity should be contacted and informed of the plan to inspect SHA-owned major NPDES outfalls. The consultant should offer to inspect known hot-spot areas adjacent to SHA-owned property. Storm drain outfalls/systems classified as hot spots should be included in the NPDES geodatabase with the proper owner information. After the inspection of a hot-spot area, a report should be prepared and submitted to SHA describing the results. A sample report is included in Appendix 5.0-C.

5.3 FIELD EQUIPMENT

Consultants should maintain the following list of field equipment for outfall inspections:

- Handheld PC – Some of the data forms to be filled out are available in digital format and will be discussed later. Additionally, a handheld PC with Arcpad displaying the NPDES geodatabase data coupled with a GPS unit is extremely helpful for locating outfalls.
- GPS unit with extra batteries
- Digital camera with extra batteries
- Sampling kit – temperature, pH, phenol, chlorine, detergents, copper, ammonia
- 300 ml. sampling bottles
- Waders/hip boots
- 25-foot measuring tape
- ADC Map book
- Safety vests
- First aid kit
- Machete
- 2 gallons of distilled water for cleaning of test tubes, bottles and other apparatus, and because some sampling tests require clean/distilled water
- 1-gallon water container that is cut in half to collect low flow samples
- 25-foot extension pool used to connect a sample bottle for manhole sample extraction
- Clipboard
- Location maps of outfalls
- List of outfalls with ADC location, structure type, pipe size, and type
- Manhole puller
- Distance wheel

5.4 ILLICIT DISCHARGE SCREENING

SHA bases its Illicit Discharge Detection and Elimination Program on MDE requirements. All the parameters screened in the field must be reported to MDE in SHA's annual report. An illicit discharge screening will be performed on major outfalls on a two-year cycle, and annually for hot spots. The location of major outfalls can best be determined by querying the geodatabase. A query on the STRUCTURES table, for the field of *maj_outf* = "Y" will yield a list of all major outfalls in the county. If the geodatabase has not been completed for the area to be inspected, outfalls will need to be located based upon contract drawings, GIS data, and field inspections.

If the storm drain outfall cannot be located or accessed in the field, is buried or submerged, or is a pipe connection, then storm drain manholes or inlets upstream of the outfall should be checked for dry weather flow. For storm drain systems that may have changed since previous inspections, it may be necessary to track down the new outfall location using pipe connectivity and topography. If a major outfall location absolutely cannot be identified, an inspection should be conducted on an upstream structure (inlet/manhole), and a reason should be stated in the comments field of the Field Screen (FLDSC_SITE table) table why the outfall was not located as well as what type of structure the inspection was conducted on.

5.4.1 Field Site Screening

The geodatabase contains several tables to keep track of illicit discharge screening. Data entry for a site can be performed digitally through the use of a portable computer, or manually on printed forms. If digital data capture is intended, it is recommended to have copies of the printed forms as a backup.

If this is the first visit to the inspection site the FLDSC_SITE table is to be filled out once a sampling site has been reached. If this is a re-inspection, this table should be checked and updated as necessary. This table should also be used if an illicit discharge is discovered at outfalls less than 1018 in^2 and any outfall that requires inspection.

The FLDSC_SITE table describes basic information about the screening site. All fields should be filled in with the exception of *RCN*.

Unique Structure ID *(structure_id)* – This unique integer field allows the link between the features and the associated database tables. The geodatabase will not allow a "null" value for this field.

Hotspot *(hotspot)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to identify whether this inspection site is a hot spot. See section 5.2.1 for the definition of a hot spot.

Vicinity Map Coordinate *(vic_screen)* – The location of the BMP based upon an ADC map book is entered here. The format of the field should be (map, grid, year), where year is the year of the ADC book. For example: 12,F11,1996. The geodatabase will not allow a "null" value for this field.

Site Description *(loc_screen)* – This field contains a description of the site with the nearest cross street(s). The consultant should indicate if there is an easier way to access the sampled outfall (ex. climbed over fence, access gate along RT 100, access through woods from Maple Street). The geodatabase will not allow a "null" value for this field.

Sample Station Description (*desc_sta)* – This field contains a description of the station where the field screening is performed (i.e., open channel, manhole, outfall, or inlet). The valid values for *desc_sta* are as follows (D_STATION domain):

Station Code	Description
OC	Open Channel
MH	Manhole
OU	Outfall
PC	Pipe Connection
IN	Inlet

Pipe Outfall Description *(desc_outf)* – Pipe outfall is a simple description of the culvert material using D_DESC_OUTFALL domain.

Runoff Curve Number *(rcn)* – The Soil Conservation Service Runoff Curve Number is estimated by the soil of the drainage area and the predominant or weighted land use. This value may be present on plans; if not this value is left blank.

Distance to Stream *(streamdist)* – The distance from the end of the outfall pipe to Waters of the U.S. is entered here. This value should be measured in the field to the nearest foot. If impossible to measure in the field, then the distance can be measured using the county stream coverage in GIS or based on USGS maps.

Additional Site Comments *(com_site)* – This field contains any general comments about the site.

5.4.2 Outfall Inspection/Screening

Illicit discharge samples should be taken after 72 hours of dry weather. The INSPECTION table should be filled out each time a site is screened.

The INSPECTION table is filled in for every inspection of an outfall, even if the outfall is not a major outfall. In the event that an illicit discharge is detected, a second inspection is required between four (4) and 24 hours after the first screening for follow-up measurements.

In this case, a second entry in the INSPECTION table for the outfall is entered with the appropriate information reflecting that inspection

Unique Inspection ID *(inspct_id)* – This unique integer allows the link between the INSPECTION table and the FLOW_CHAR table. Since an outfall can have multiple re-inspections, this field is a unique number generated for each inspection. The geodatabase will not allow a "null" value for this field.

Unique Structure ID *(structure_id)* – This unique integer allows the link between the features and the associated database tables. The geodatabase will not allow a "null" value for this field.

Inspector (*inspectr*) – The inspector field documents the initials of the members of the inspection team. The geodatabase will not allow a "null" value for this field. Multiple entries in this field should be separated by commas. This field should be used primarily for quality assurance by the organization performing the inspections.

Date of Screening (*date_scrn*) – This field documents the date that the inspection was performed. The geodatabase will not allow a "null" value for this field. The entry format is YYYYMMDD.

Date of Last Rain *(last_rain)* – The date of the last day of rain should be entered here. A screening should be conducted at least 72 hours after a rain event. The entry format of this date is YYYYMMDD.

Sampled Outfall Identification Number *(sample_str_id)* – This value identifies the structure where the sample was taken. Most often, this will be the outfall, but can be an upstream structure if a sample is more accessible at that location due to ponding water at the outfall, heavy vegetation, fence, etc.

Time of Screening *(scrtime)* – This field records the time of the inspection (for example 15:37).

Flow Observed *(flowobserv)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES field to document the presence of a dry weather flow.

Algae Growth Present (*algaegrow)* – This field uses 1(Yes) or 2(No) D_BOOLEANVALUES to describe if algae is present in the water. *Note that a commonly occurring natural bacterium produces a water surface layer that resembles an oil sheen. The bacterial surface is "breakable" and not as iridescent as an oil sheen, and is not indicative of an illicit connection. Iron in the soil is used by several bacterial species and produces a bright orange stain and is also not indicative of an illicit connection. These photos are of iron flocculant precipitates.

Examples of iron flocculant

The remaining fields are paired. The first field of the pair contains the standard domain code as prescribed by MDE. The second field of the pair allows additional description if required.

Odor Type and Description *(odor_type and odor_desc)* – This field describes any unusual odors detected and uses the D_ODOR domain values.

Deposit Type and Description (*depos_type and depos_desc)* – This description documents deposit observations in the structure, discharge, and surrounding area and uses the D_DEPOSITS domain values.

Vegetation Type and Description *(veget_type and veget_desc)* – This field identifies evidence of enhanced or stunted growth and uses the D_VEGETATION domain values.

Condition Type and Description (*cond_type and cond_desc)* – This description documents the condition of the end of pipe or end-structure and uses the D_STRUC_COND domain values.

Erosion Type and Description (*eros_type and eros_desc)* – This field describes erosion or deposition in and around the outfall and the downstream channel, and uses the D_EROSION domain values.

Depth of Flow *(depth)* – If there is flowing water at the outfall, the depth is recorded in inches and the FLOW_CHAR table is filled out for the inspection. If flow is not observed, then a "0" value should be input. If dry weather flow exists, the outfall should always be sampled unless stated otherwise in your contract with SHA.

Additional Inspection Comments *(inspct_com)* – This field contains any additional information about the inspection. The comment field should be used liberally to note characteristics of the pipe and end structures and the downstream channel that may have been affected by pollutant material. These include structural damage; unusual staining; odors; unusual plant growth or lack thereof; algae growth; floatables such as trash, oil sheen or surface scum; deposits; excessive erosion; land uses; or other evidence of illicit connections at the outfalls.

*Suds on the water surface at an outfall may not indicate an illicit discharge. Suds that break up quickly may simply be caused by water turbulence and may not indicate an illicit flow. Suds that have a strong fragrant odor may indicate the presence of washwater (detergents).

5.4.3 Flow Measurements/Characteristics

The presence of flow during dry weather is considered to be one piece of evidence (but not conclusive) indicating the presence of an illicit discharge. All flowing water at major outfalls, with the requisite 72 hours of dry weather, must be chemically sampled immediately on site. Chemical analysis will be performed using field test kits such as the Storm Drain Pollution Control Test Kit manufactured by the LaMotte Company or the Hach Stormwater Test Kit. Outfalls will be tested for pH, phenol, chlorine, detergents, copper, and ammonia. The following table lists the acceptable limits for the parameters being screened:

Acceptable Chemical Sample Limits	
pH	6.5 - 8.5
Phenol	< 0.17 mg/L
Chlorine	< 0.40 mg/L
Detergents	< 0.50 mg/L
Copper	< 0.21 mg/L
Ammonia	< 0.30 mg/L

If the sample does not exceed the values in the table above for any chemical constituents, a follow-up inspection is not required. If the sample does exceed any of the values above, a follow-up inspection and second sampling is required between four (4) and 24 hours after the first sample was taken. The second sample screening should be recorded as a separate inspection from the first. If the second sample still shows a value greater than the values in the table, the consultant must attempt to track the source of the dry weather flow and notify SHA immediately with a report. Possible sources of dry weather flow are discussed in Section 5.5

The report should include photographs, a description of the location of the illicit discharge, and an explanation of the problem. Appendix 5.0-A contains a sample illicit discharge report. Tracking the source of the dry weather flow will be limited to only inherently safe activities. Manholes will not be opened within traffic areas, confined space entry will not be performed, etc. If the outfall has standing water, it is recommended that either the sample be taken just downstream where flow resumes in the channel or at the next upstream structure in the system where water is flowing. Standing water may accumulate pollutants and skew the sample results.

In some situations, the outfalls are not located close to the field inspection team's vehicle. In this case, sampling bottles can be used to transport sample water back to the vehicle rather than transporting the chemical testing equipment to the outfall. Temperature and pH should always be measured immediately after the sample is collected. Sample bottles should be thoroughly rinsed with the water being sampled. After the tests are performed at the vehicle, the sampling bottles and sampling equipment (test tubes, tube caps, thermometers, etc.) should be thoroughly rinsed with distilled water.

The FLOW_CHAR table should also be filled out when flow is observed at the outfall. If the scope of work between SHA and the consultant states that only suspected polluted flow needs to be sampled, color, clarity, and floatables should still be assigned values.

Unique Inspection ID *(inspct_id)* – This unique integer allows the link between the INSPECTION table and the FLOW_CHAR table. Since an outfall can have multiple re-inspections, this field is a unique number generated for each inspection. The geodatabase will not allow a "null" value for this field.

The following three fields are paired. The first field of the pair contains the standard domain code as prescribed by MDE. The second field of the pair allows an additional description if required.

Flow Color Type and Description *(color_type and color_desc)* – This field describes the color type of flow and uses the D_COLOR domain values.

Flow Clarity Type and Description *(clar_type and clar_desc)* – This description documents the clarity of the flow and uses the D_CLARITY domain values.

Flow Floatable Type and Description *(float_type and float_desc)* – This field describes any floatables that are present in and around the flow and uses the D_FLOATABLES domain values. Trash is not an indicator of an illicit discharge, but should be noted.

Flow Temperature *(watertemp)* **–** Water temperature recorded in degrees Fahrenheit should be entered here. Temperature should be measured immediately after taking the sample.

Air Temperature (*airtemp)* - Air temperature recorded in degrees Fahrenheit should be entered here. Temperature should be measured immediately after taking the sample.

The remaining fields, **pH***(pH)***, Phenol***(phenol)***, Chlorine***(chlorine)***, Detergents***(detergents)***, Copper***(copper)*, and **Ammonia***(ammonia)* can be populated with results from a standard testing kit. With the exception of *pH*, these values should be entered in mg/L.

Additional Flow Comments *(com_flow)* – This field contains any additional information about the flow.

Photos should be taken from downstream looking upstream towards the outfall structure. Photos should also be taken of severe channel erosion, structure damage, pipe separation, embankment failure, etc. Requirements for all photographs can be found in Chapter 2.0, Source Identification. Sample photographs are shown in Appendix 5.0-B. Drainage areas should be delineated for all major NPDES outfalls as outlined in Chapter 2.0.

5.5 *Potential Causes for Illicit Discharge Flows*

Each parameter being screened (pH, phenols, chlorine, detergents, copper, and ammonia) has a specific list of potential sources. It may be possible to track the source of an illicit discharge based on the failed parameter and land use. Table 5.1 describes the indicator parameter used to detect illicit discharges.

Parameter	Discharge Types Parameter Can Detect			
	Sewage	Washwater	Tap Water	Industrial or Commercial Wastes
pH		x		x
Phenols	x			x
Chlorine			x	x
Detergents	x	x		x
Copper				x
Ammonia	x	x		x

Table 5.1 – Discharge Type Parameters Can Detect

pH – Most natural flows have a neutral pH value around 7, although groundwater can vary. The pH value is a good indicator of liquid wastes from industrial practices. pH is often not conclusive of an illicit discharge, but it can identify outfalls that may have other issues.

Phenol – These are caused by organic decay such as rotting vegetables and fruits. Phenols are also found in gasoline, plastics, asphalt, pesticides, and sewage.

Chlorine – This chemical is used to disinfect tap water. Chlorine is very volatile and may be difficult to detect in the discharge, although high chlorine levels may be an indication of a water line break, swimming pool discharge, or industrial discharge from bleaching processes.

Detergents – Sewage and washwater contain detergents used for laundry, dishes, and industrial and commercial cleansers.

Copper – Brake pads are a major source of copper in stormwater. Copper is also associated with industrial and manufacturing runoff, along with other metals.

Ammonia – Ammonia is present in sewage and washwater. Ammonia can be an indicator of a sanitary line break or failing septic system.

If a screened parameter is above the allowed limits, the source of the dry weather flow may be correlated to the land use within the drainage area to the outfall. There are many activities that can lead to illicit discharges. Table 5.2 (next page) identifies some activities based on land use that can produce illicit discharge. The table may be helpful in determining the source of the illicit discharge.

Table 5.2 – Land Use, Generating Sites, and Activities That Produce Illicit Discharges (CWP 2004)

Land Use	Generating Site	Activity Producing Discharge
Residential	• Apartment • Multi-Family • Single-Family Detached	• Car Washing • Driveway Cleaning • Spills (oil, gas) • Equipment Washdown • Power Washing • Swimming Pool Discharge • Septic System Maintenance • Broken Water Line • Lawn/Landscape Watering
Commercial	• RV parks • Car Dealers • Companies • Car Washes • Commercial Laundry/Dry Cleaning • Gas Stations/Auto Repair Shops • Marinas • Garden Centers • Restaurants • Swimming Pools	• Building Maintenance • Dumping/Spills • Irrigation for Landscaping • Outdoor Fluid Storage • Vehicle Fueling • Vehicle Repair • Vehicle Washing • Washdown of Greasy Equipment • Dumpsters/Grease Disposal Dumpsters • Swimming Pool Discharge • Power Washing
Industrial	• Auto Recyclers • Beverage and Brewing • Construction Vehicle Washouts • Distribution Centers • Food Processors • Garbage Truck Washouts • Metal Plating Operations • Paper and Wood Products • Petroleum Storage • Printing	• All Commercial Activities • Industrial Process Water or Rinse Water • Loading and Un-loading Area Washdowns • Outdoor Material Storage (Fluids)

Table 5.2 – Land Use, Generating Sites, and Activities That Produce Illicit Discharges (CWP 2004)

Institutional	• Cemeteries • Churches • Hospitals • Schools and Universities	• Building Maintenance • Power Washing • Irrigation for Landscaping • Parking Lot Maintenance • Vehicle Washing
Municipal	• Airports • Landfills • Maintenance Depots (SHA Shops) • Fleet Storage Areas • Public Works Yards • Street and Highways	• Building Maintenance • Power Washing • Irrigation for Landscaping • Parking Lot Maintenance • Vehicle Washing • Vehicle Fueling • Vehicle Repair • Outdoor Fluid Storage • Dumping/Spills • Road Mainteance

APPENDIX C:

GIS Standard Procedures
Chapter 6: Data Management

Draft October 2008

Chapter 6

Data Management

October 2008

DRAFT

Table of Contents

6.1 NPDES DATA STAKEHOLDERS 6-7

6.1.1 Maryland Department of the Environment 6-7
6.1.2 Maryland State Highway Administration 6-8
6.1.3 Engineering Consulting Firms 6-8

6.2 DATA MANAGEMENT ARCHITECTURE AND PROCESSES 6-9

6.2.1 Process 1 6-10
6.2.2 Process 2 and 3 6-10
6.2.3 Process 4 - Checking out Data from SHA to Consultants 6-10
6.2.4 Process 5 - Consultant Production Database 6-10
6.2.5 Process 6 and 7 – Consultant In-House Data Processing 6-11

6.3 OFFICE EDITING TOOLS 6-11

6.3.1 Office Editing Environment Preparation 6-11
6.3.2 Office Editing Toolset 6-13
6.3.3 Editing Structure Attributes 6-15
6.3.4 Creating a New Structure 6-23
6.3.5 Editing BMP Attributes 6-25
6.3.6 Editing Conveyance Attributes 6-30
6.3.7 Flip Pipe Tool 6-32
6.3.8 Create Conveyance 6-33

6.4 FIELD EDITING TOOLS 6-34

6.4.1 Overview and requirements 6-34
6.4.2 Loading data into FET 6-35
6.4.2.1 Network Structure 6-41
6.4.3 Application Tool & Status Bars 6-42
6.4.4 Mapping Interface 6-43
6.4.4.1 Interactive Map Toolbar 6-44
6.4.4.2 Map Information Toolbar 6-45
6.4.4.3 Geometry Tools 6-46
6.4.4.4 GPS Toolbar 6-46
6.4.5 Inventory Interfaces 6-47
6.4.5.1 BMP (Stormwater Management Facility) 6-48
6.4.5.2 Conveyance (SDOIP) 6-52
6.4.5.3 Structure (IDDE) 6-54
6.4.6 Inspection Interfaces 6-56
6.4.6.1 BMP (Stormwater Management Facility) 6-56
6.4.6.2 Conveyance (SDOIP) 6-61
6.4.6.3 Structure (IDDE) 6-60
6.4.7 GPS Interface 6-67
6.4.8 User Settings 6-69

6.5 SPECIAL SPATIAL EDITING 6-70

6.6 NPDES VIEWER 6-70

6.7 QUALITY ASSURANCE/QUALITY CONTROL 6-70

6.8 MDE DATA EXPORT 6-70

Appendices

List of Figures

List of Tables

Chapter 6
Data Management

A robust data model has been developed by Maryland State Highway Administration (SHA) using ESRI's geodatabase framework in support of the National Pollutant Discharge Elimination System (NPDES) program. The data therein has been collected to provide for the management of SHA's stormwater infastructure. In order for the data to retain its value, it must be maintained in a consistent manner and the model employed in a uniform fashion. The purpose of this document is to describe the concepts and processes that are to be utilized to maintain the data, including the roles of stakeholders, tools for updating and viewing the data, as well as overall practices to follow when working with the model

SHA has adopted ESRI software solutions as the standard platform for managing its GIS data. The ESRI framework consists of both Desktop and Server–based GIS components. The NPDES program actively manages its datasets using combinations of the following framework tools:

- ArcGIS Desktop
- ArcGIS Engine
- ArcGIS Server
- ArcSDE

6.1 NPDES Data Stakeholders

There are three primary stakeholders in the NPDES program and the resultant data. They are the SHA, Maryland Department of the Environment (MDE), and engineering consulting firms. Each of these stakeholders has different roles and responsibilities in the program.

6.1.1 Maryland Department of the Environment

MDE has been authorized by the U.S. Environmental Protection Agency (EPA) to manage the Maryland NPDES program as mandated by the Clean Water Act. SHA's NPDES permit is therefore an agreement between SHA and MDE regarding the program that SHA is implementing to meet the requirements of NPDES.

MDE is therefore a final consumer of the NPDES data, in that it must be made available to them. They will utilize it for reporting on progress regarding NPDES in the State, but will not necessarily use it on a daily basis.

Since MDE is responsible for all NPDES permitting in the State, they need to acquire data from all jurisdictions required to have NPDES permits. They therefore have a standard data format that they require the data to be delivered in. Their format is currently a series of non-spatial data tables that can be submitted in standard Microsoft Excel, or Microsoft Access. The tables do not match the format of the data that SHA maintains. SHA must export the NPDES data into the MDE format on a yearly basis. This process is described in section 6.8.

6.1.2 Maryland State Highway Administration

SHA is the primary stakeholder in the data model. They are the creators, maintainers, and primary users of the data. Within SHA, the Highway Hydraulics Division is the primary stakeholder division. However, the information stored in the NPDES data set is valuable to other operating divisions and is shared accordingly.

The data itself is stored as an ESRI Geodatabase in ArcSDE 9.2 using Oracle 9i as the data engine. The data model has been described in detail in preceding chapters and a copy of the schema is located as an appendix to this manual. The SHA database is the master database and is used both within ArcGIS and also with custom applications.

As the owners and maintainers of the data, SHA is also responsible for ensuring the quality of the data that is entered into their data model. Day to day updates of the data is performed by a skilled GIS analyst. Updates that are received from outside of Highway Hydraulics are reviewed and quality control checked. This process is described in section 6.7.

6.1.3 Engineering Consulting Firms

Engineering consulting firms provide resources to assist SHA in the maintenance and update of the NPDES data. Typically, the consulting firms are provided with a checked out version of the data representing a geographic extent for which they are responsible. The consulting firm performs updates ranging from inspections to adding new construction. The updated data must then be provided back to SHA, quality control checked, and then synchronized back into the master database.

The data model that has evolved for the NPDES program is sophisticated and as such requires care in its management. Recognizing that consulting firms have different GIS/IT technical resources available to them, a conscious effort has been put forth to develop tools and processes that can be used to manage and update the data. The tools and processes that have been outlined in the following sections are based upon an architecture that minimizes the level of software required and as such hopes to minimize cost. If consulting firms have more sophisticated levels of ESRI software than what is described, they should leverage their expertise and available technology to the best of their ability to meet the same data management goals.

6.2 Data Management Architecture and Processes

Data management is the process and mechanisms for not only the transfer of data between stakeholders, but also the manipulation of the data by the stakeholders. Each stakeholder has different data responsibilities and requirements. Figure 6.1 is a simplification of the data management by the stakeholders.

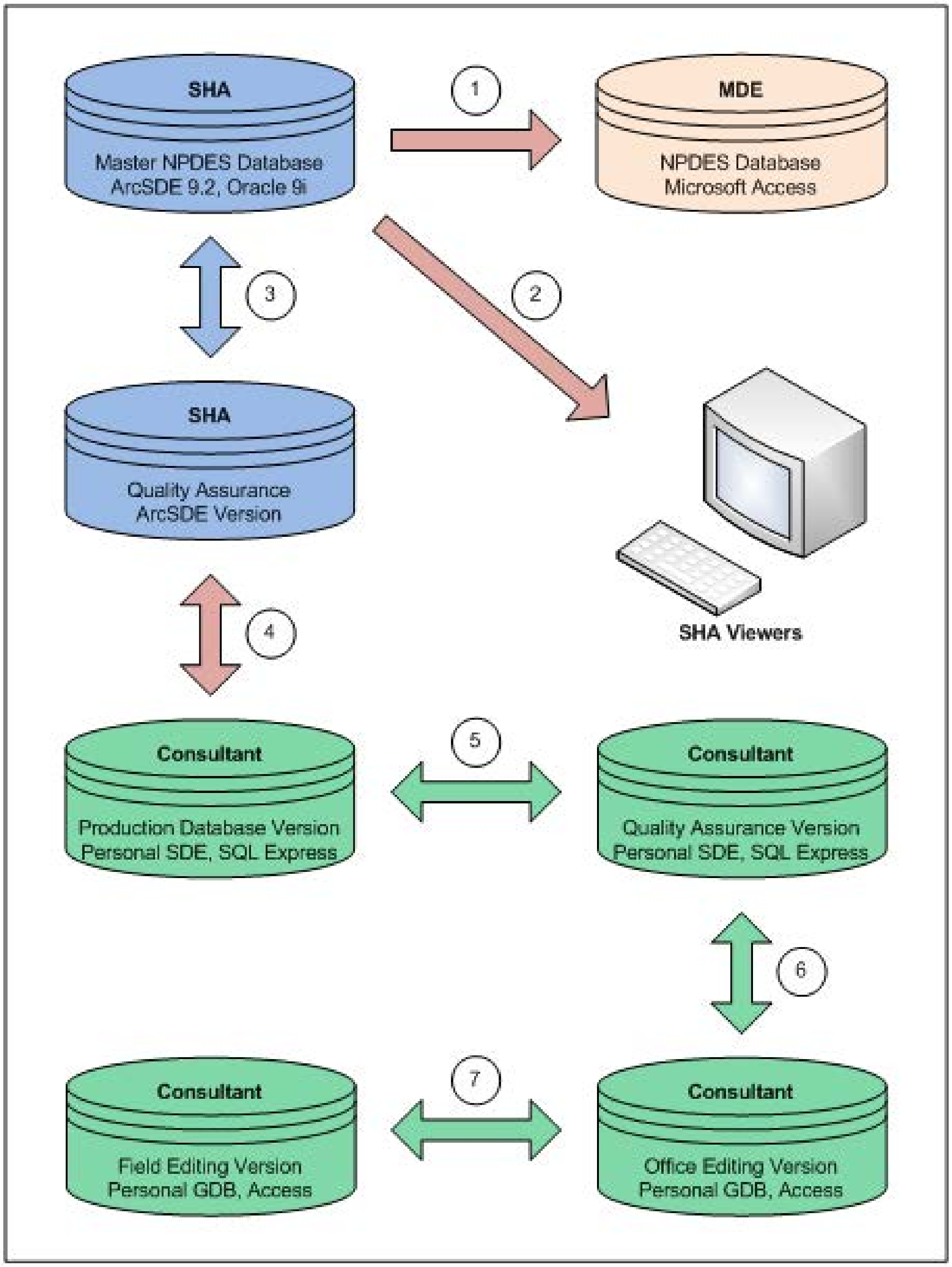


Figure 6.1 – Data Management Architecture and Process (6.2)

6.2.1 Process 1

The master geodatabase is managed by SHA using ArcSDE 9.2 and an Oracle 10g back end data engine. Consumers of the data are MDE and data viewers within SHA. MDE receives the data on a yearly basis in conjunction with the annual report using Process 1. Process 1 is described in detail in section 6.8.

6.2.2 Process 2 and 3

Data is made available to SHA viewers using Process 2, the NPDES Viewing Application. This is a web-based application using ArcGIS Server 9.2 and provides extensive viewing, reporting, and querying capabilities to SHA staff. The NPDES Viewing Application is described in Section 6.6.

The following sections describe the remaining processes, dedicated to the sharing and synchronizing of data between SHA and the engineering consulting firms that update the NPDES data.

6.2.3 Process 4 - Checking out Data from SHA to Consultants

Consulting firms are utilized to perform large scale updates to the NPDES data, including bringing the infrastructure data up to date using contract drawings and field work. Also, consultants perform the required inspections of BMPs to ensure that they are working as desired. To check the data out to a consultant, SHA first creates a version of the master database using the geographic extents of the area that the consultant is going to work within. This may be a County, watershed, or other geographic area. Using the versioning tools, SHA extracts the area into a versioned database. This database will be the version that is supplied to the consultant, but will also be the location where the consultant's version is synchronized back and checked for quality control prior to checking back into the master database.

With SHA's Quality Assurance database in place, SHA then provides the consultant with a copy of the versioned geodatabase. This Process number 4 on Figure 6.1 can be performed in a number of manners, depending on the technical capabilities of the consulting firm. The simplest method is to provide a personal geodatabase to the consultant via ftp, CD, or portable hard drive. If the consultant has Enterprise ArcSDE, then a replication process can be setup between the consultant and SHA. This may require special dispensation regarding SHA firewalls, which has not been addressed in this document. It is assumed that communication in Process 4 both from SHA and back to SHA will be via personal geodatabase, without the benefit of replication.

6.2.4 Process 5 - Consultant Production Database

When the consultant receives the personal database from SHA, the consultant will load the data into their ArcSDE environment. It is assumed for this process that the consultant is using personal SDE with SQL Server Express. However, if the consultant has enterprise ArcSDE, then similar processes can be performed.

With the data loaded into SDE, the consultant is recommended to produce a version for quality control. It is from this quality control version that the consultant produces individual personal geodatabases for editing within the office. As office edits are completed on a regular basis, they should be synchronized back to the quality assurance version. The consultant is required to run quality assurance checks on the data to be sure that it has been accurately defined and populated. When the data has passed quality assurance tests, the data is synchronized back to the production database. This database should be final and ready to be synchronized back to SHA. No edits should be performed on the production database. Process step 5 is performed using standard tools for database versioning within the SDE environment.

6.2.5 Process 6 and 7 – Consultant In-House Data Processing

Process step 6 to generate the office editing personal geodatabase is performed using…

6.3 Office Editing Tools

The SHA NPDES geodatabase utilizes the capabilities of relationship classes and domains that are inherent in the ESRI geodatabase model. These capabilities allow for a high level of quality to be achieved due to their inherent nature. Using an ESRI geodatabase model does complicate the process of editing the data using strict ArcGIS tools. For this reason, SHA has developed a series of tools to facilitate the editing of the data. Primarily, there is an office editing toolset and a field editing toolset. The purpose of the tools is to assist the user in editing of attribute information and navigating the table structure established in the schema. The user must be familiar with the basics of ArcGIS data editing in order to perform spatial manipulation of the data. The following section describes the use of the office and field editing toolsets.

6.3.1 Office Editing Environment Preparation

Office Editor system requirements:

- ArcEditor+ 9.2 sp3
    - .Net support install option
- .Net Framework 2.0
- ArcSDE 9.2 sp3
    - Versioned geodatabase

Editing of the NPDES geodatabase requires the use of either ArcEditor 9.2 or ArcInfo 9.2. The user should ensure that they are using one of these versions of ESRI ArcGIS software.

Before using any of the tools, the data needs to be added to the map along with the provided layer files.

The user can then add the personal geodatabase provided for editing to the ArcGIS environment. The map legend should mimic the following the legend in Figure 6.2.

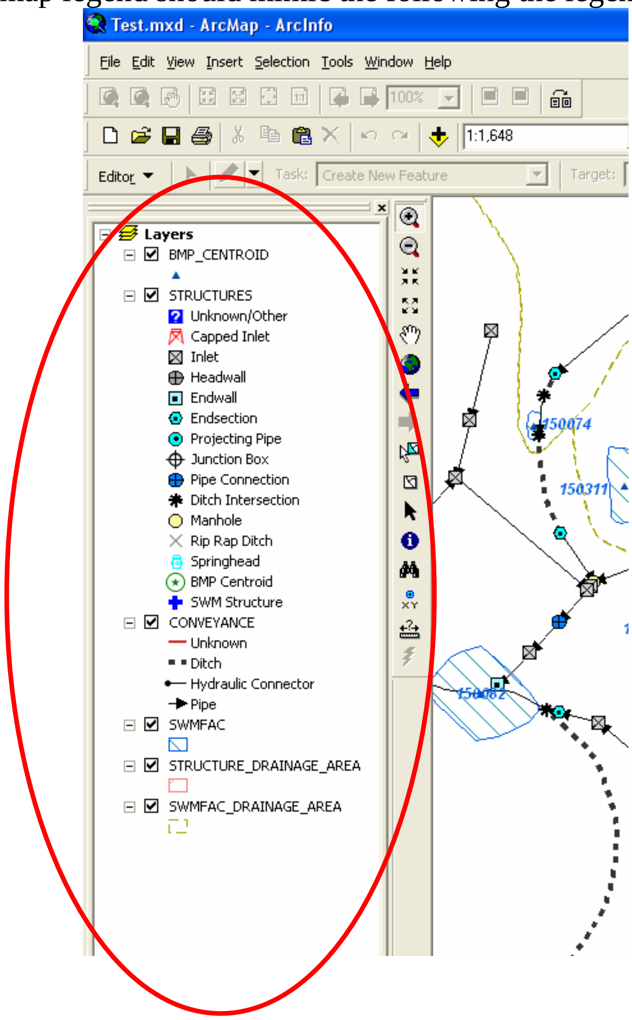


Figure 6.2 – ArcGIS view after personal geodatabase has been added

This map can be saved and used for all edits. To simplify the editing process, it is recommended that the user set the selectable layers as follows:

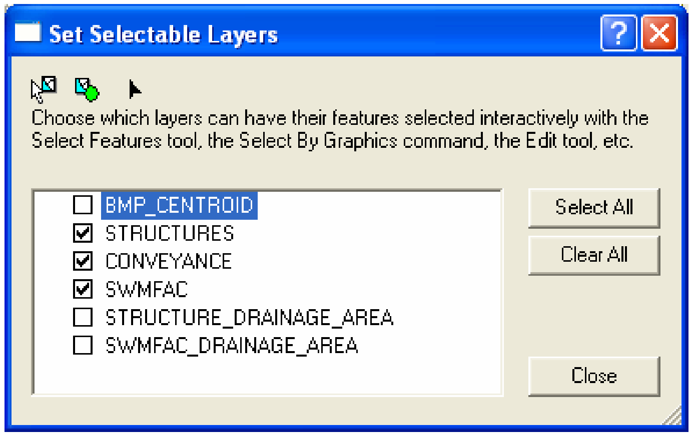


Figure 6.3 – Layer set to be selectable in the ArcGIS environment

6.3.2 Office Editing Toolset

With the office editing tools turned on, the following group of icons will be added to the ArcGIS toolbar as shown below.

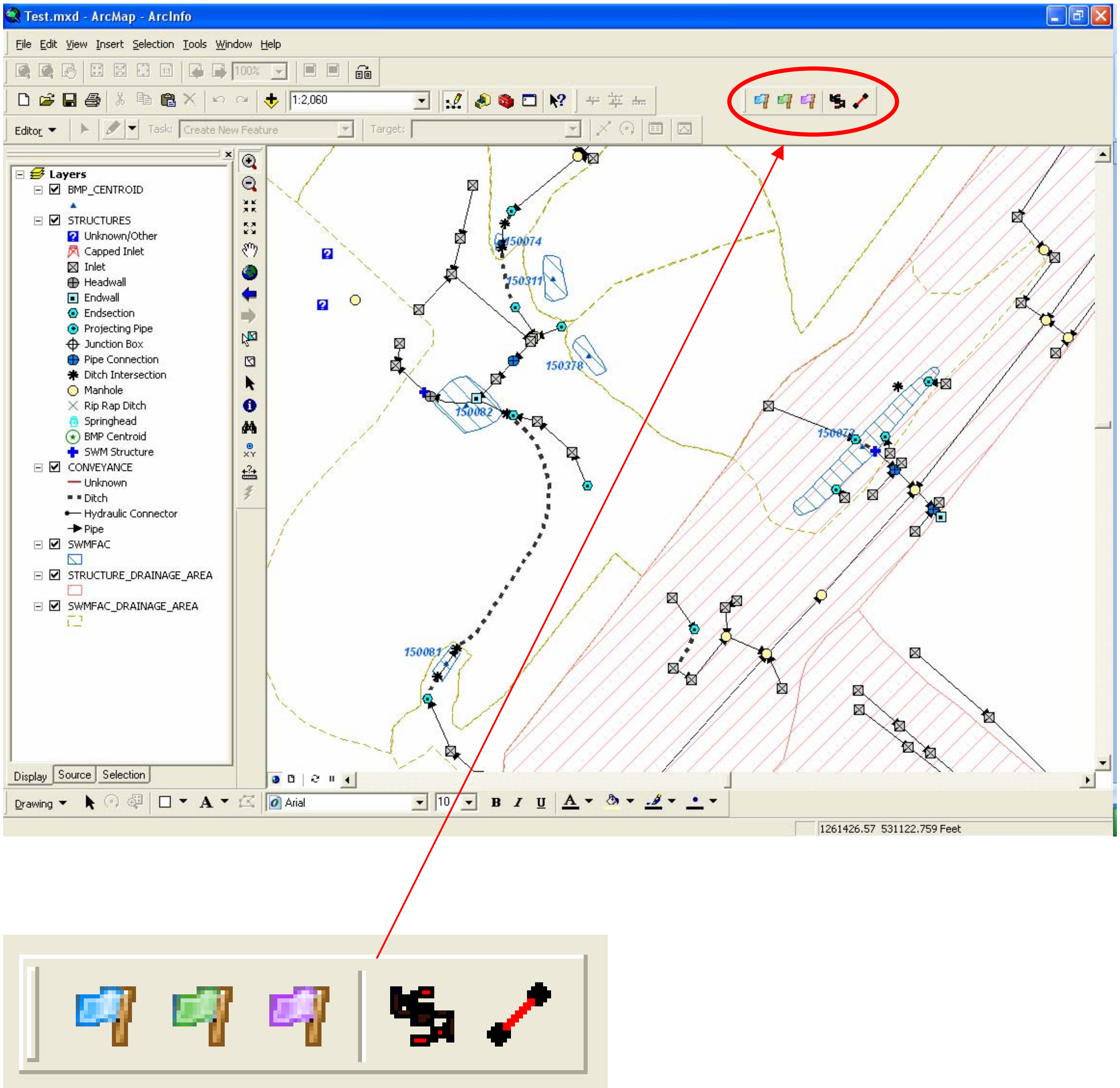


Figure 6.4 – Icons that are added to the toolbar when editing geodatabase

The first three tools indicated by flag icons are used to edit attributes of different primary features. The first icon, a blue flag is used to edit Structure Features. The second, a green flag is used for editing stormwater management facilities, or BMPs. The final icon, a purple flag, is used to edit pipes and ditches, otherwise known as conveyances.

The tools are for performing graphic editing actions. The first is a “Flip Pipe” tool. The last is used for creating conveyances.

6.3.3 Editing Structure Attributes

Structure features represent manholes, inlets, outfalls, risers, and other similar point features. In the stormwater infrastructure network, they allow for inflow of stormwater, outflow of stormwater, a connection in the network, or some form of flow control.

When the user is ready to edit the attributes of one of these point features, the user should select the Structures layer in the Table of Contents. The user should then select the one feature in the map area that it is desired to edit. The tool does not work with multiple features selected.

By pressing the Edit Structure Tool, represented by the blue flag, a window will open for the user with all of the attributes related to that structure represented.

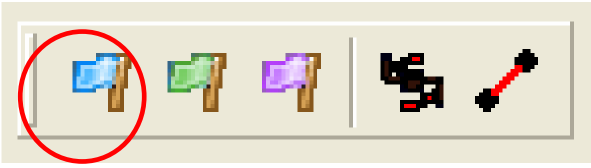


Figure 6.5 – The blue flag icon (Edit Structure Tool) is used when editing structures

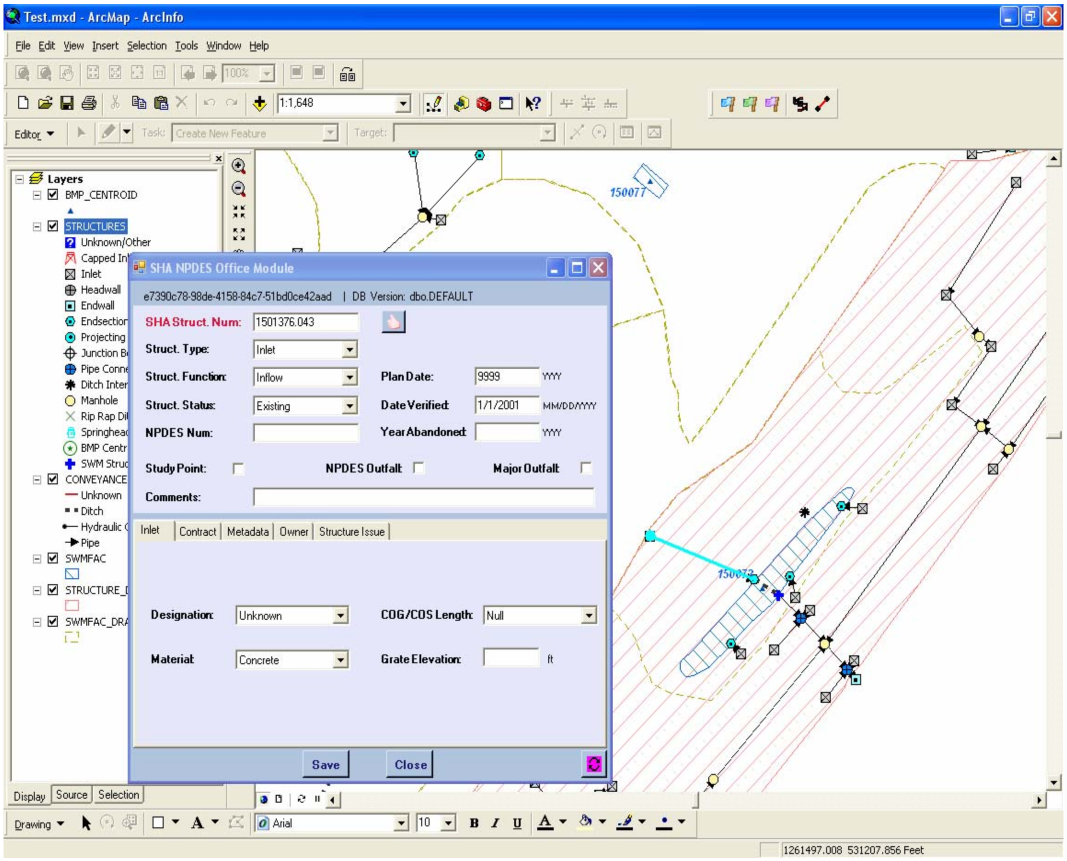
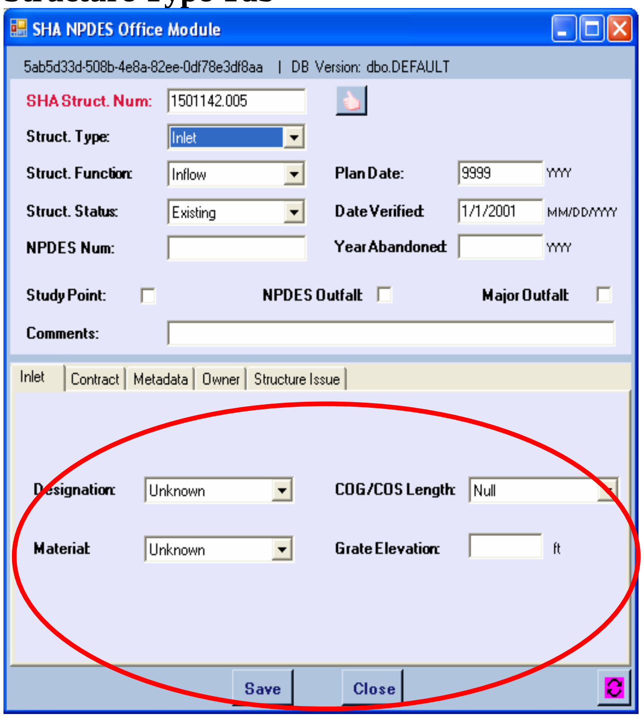


Figure 6.6 – Screen shot of the digital form that appears when editing a structure inventory record.

The top half of the form (Figure 6.6) represents standard attributes that are common to all structures. For a full description of attributes, the user should review Chapter 2, Source Identification.

The bottom half of the form is driven by tabs which relate to different tables in the geodatabase schema, such as INLET, CONTRACT, and OWNER tables.

Structure Type Tab



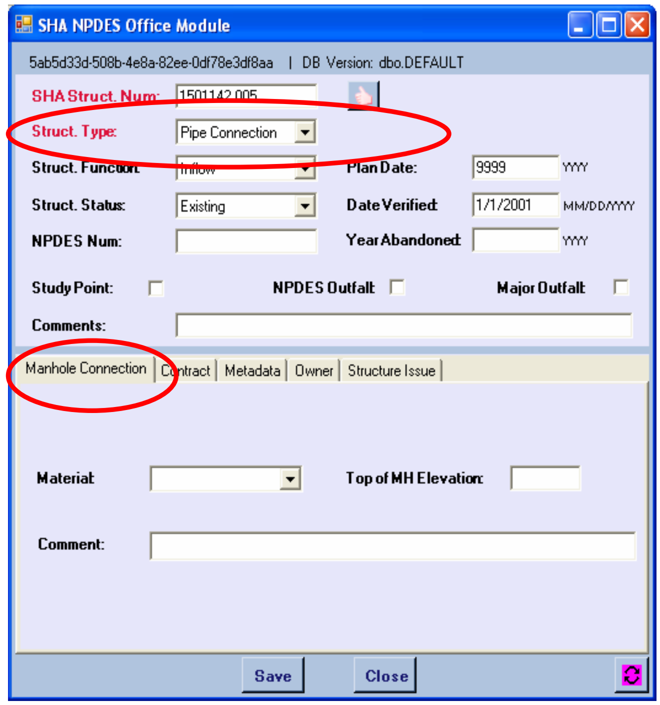


Figure 6.7 – Figure on the right is the structure type tab that is used to input structure type attributes such as an inlet as seen in the figure. The figure on the right represents a structure type pipe connection structure attribute tab.

The first tab is associated with the Structure Type. If the user changes the Structure Type in the top part of the form, the tab will change also. The attributes displayed in the lower part of the form with the Structure Type are unique to that specific structure type.

If the Structure Type is changed in the upper part of the form, the text will change to red, indicating that on saving the form, the old structure type record will be deleted and a new one created.

Contract Tab (Figure 6.8)

The Contract tab below indicates the contract drawing under which the feature was modified into its current form.

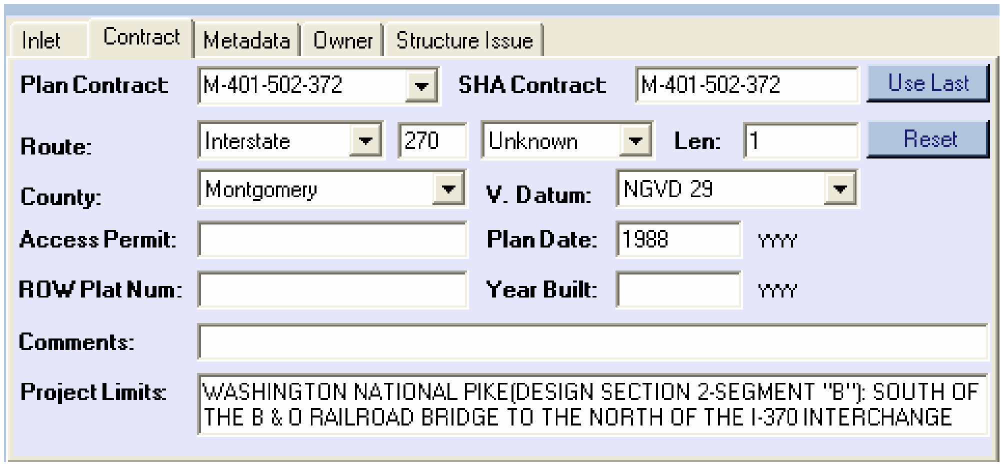


Figure 6.8 – Attributes to be filled in for the contract information per feature in the database

To associate a contract with the current feature, the user can select from the existing contract list using the pull down as seen in Figure 6.9 or create a new contract.

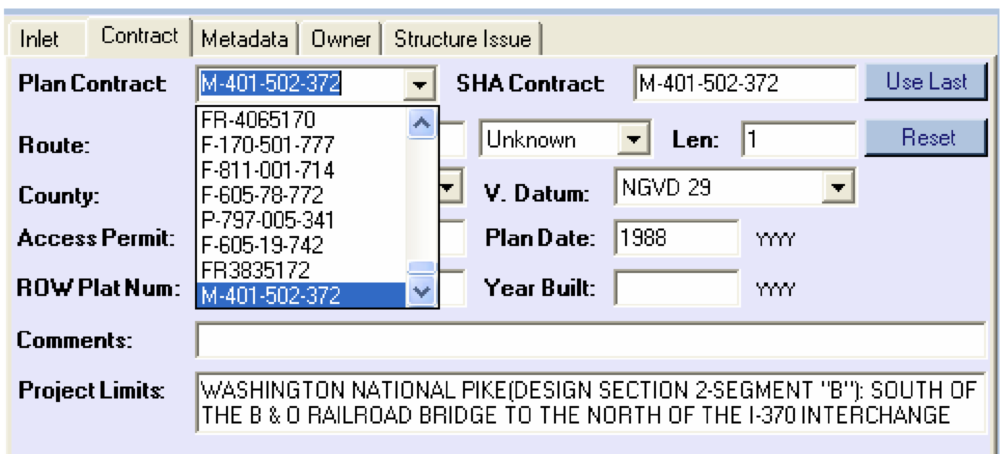


Figure 6.9 – Contracts that exist in the geodatabase CONTRACT table can be selected by using the pull down on the form

Selecting an existing contract can be achieved by scrolling through the list or starting to type the plan contract number in the list box. Typing the number will start a dynamic search.

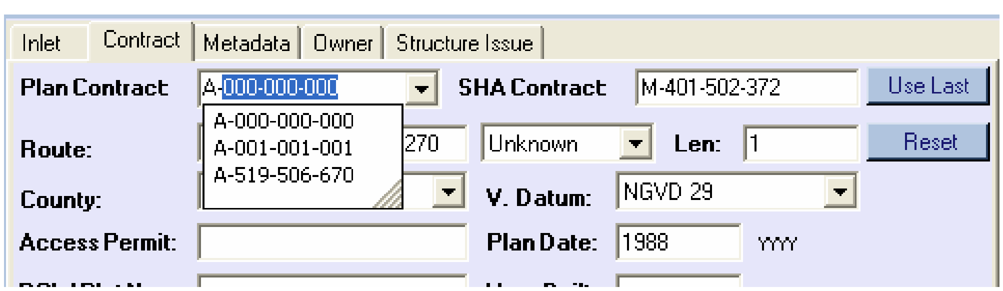


Figure 6.10 – New contracts can also be added when selecting a contract for a storm drain feature by typing in the new contract number in the form

Should the user type in a contract number that does not exist in the CONTRACT table, upon saving, it will create a new contract entry in the contract table with attributes selected. An example of a completed contract record is seen in Figure 6.11

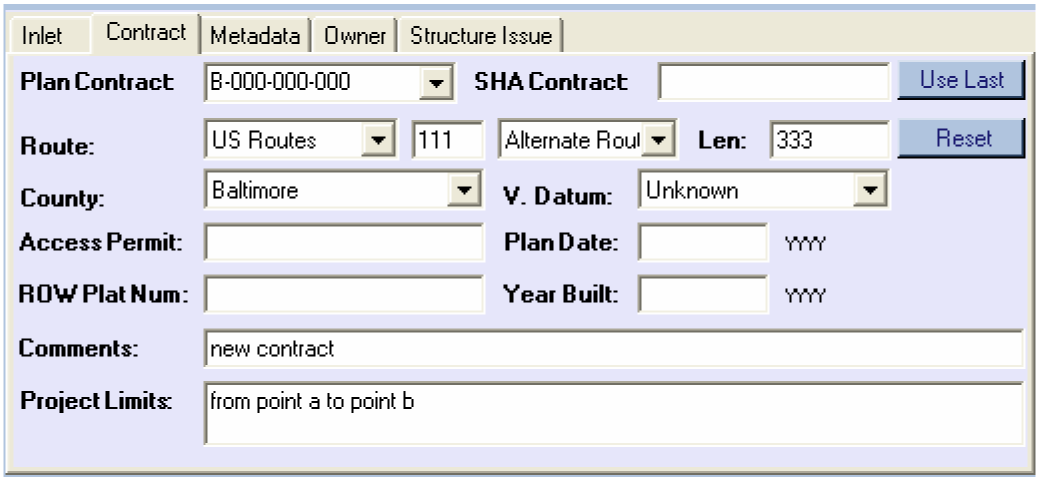


Figure 6.11 – Contract information associated with contract number in Plan Contract box

This contract is now added to the list and can be associated with any structure.

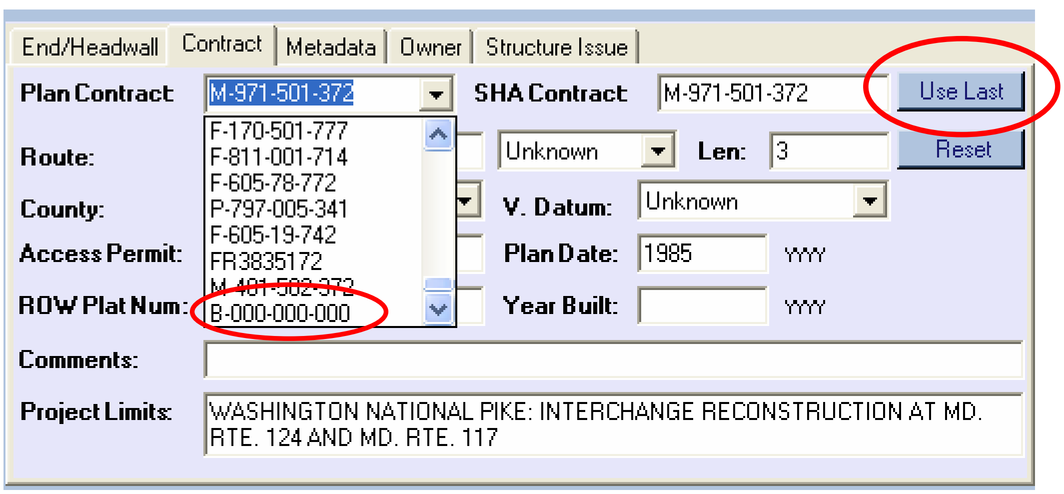


Figure 6.12 – The last contract assigned to a feature can be selected for the next feature inventoried by using the "Use Last" button

On both Contract and Metadata tabs, there is a "Use Last" button. Every time the edit window opens or the new selection is made, if there is contract/metadata associated with the selected feature, it is stored. If the next selected structure does not have contract/metadata associated with it, "Use Last" button will use the previously stored contract/metadata record. This simplifies the data entry process for multiple features that have the same Contract or Metadata. The "Use Last" button is circled in red for the contract form in Figure 6.11.

Metadata Tab
The Metadata tab (Figure 6.13) allows for the input of information about when the feature was edited, who was the editor, and the primary source of edits.

The default date for new features being inventoried is the current day, and all other information must be populated to save the record. Once the new information is entered and saved, the metadata is checked against the existing metadata records. If the record for that particular metadata already exists, then the application will assign the proper metadata identifier otherwise a new metadata identifier will be created. This will ensure that the three metadata field combinations are not duplicated in the database.

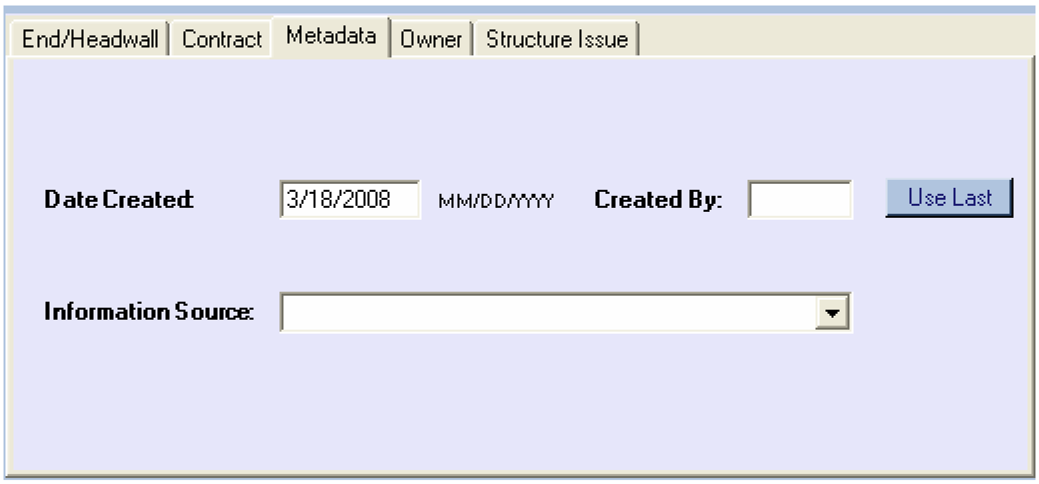


Figure 6.13 – Metadata attributes that are required to be completed prior to saving a record

Owner Tab
The Owner tab (Figure 6.14) allows for the input of information about existing owners of the storm drain features. It can also be used to create new owner or edit existing owner information.

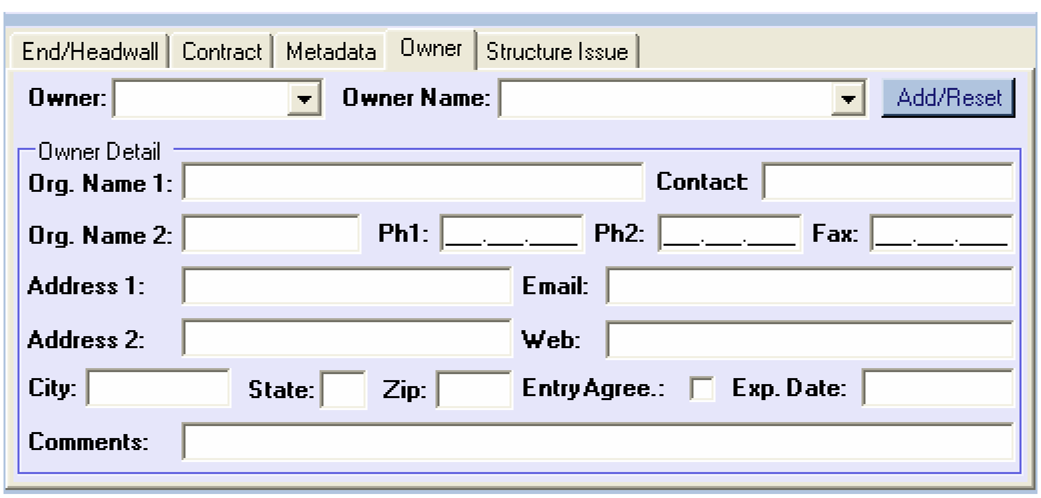


Figure 6.14 – Owner attributes that are completed for each feature inventoried

Depending on which owner type is selected (Figure 6.15), different owners are displayed (Figure 6.16).

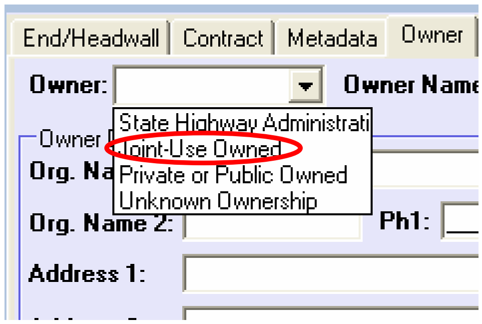


Figure 6.15 – Different type of owner can be selected per feature inventoried

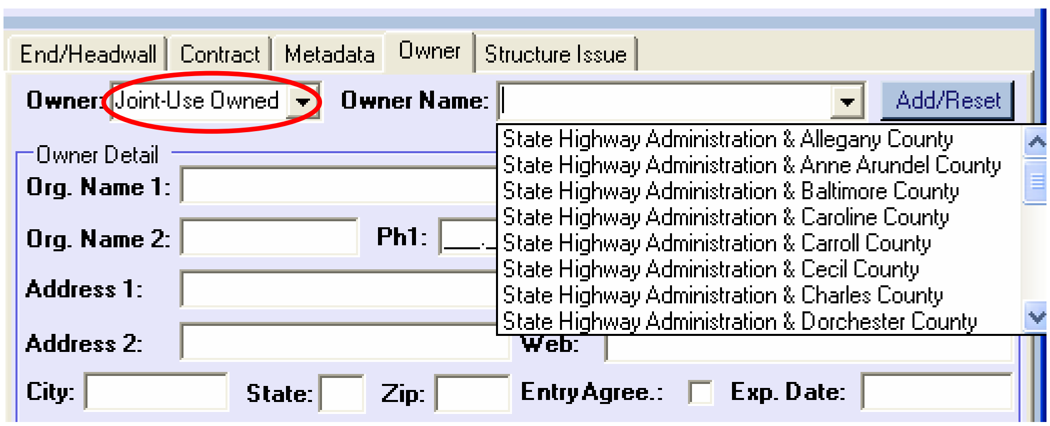


Figure 6.16 – In the example for Joint-Use Owned, the associated pre-populated Owner Names are displayed to be selected

Once a particular owner has been selected, the associated information can be edited in Figure 6.17.

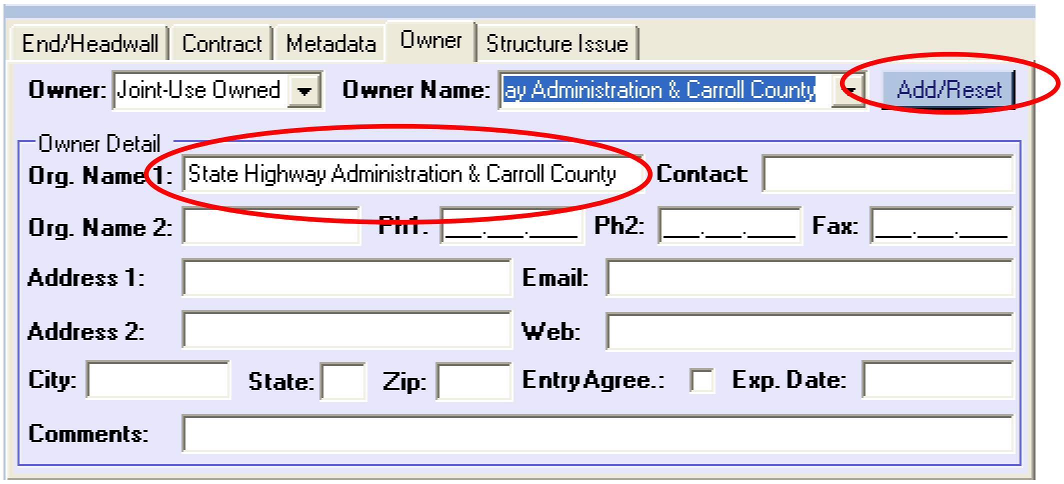


Figure 6.17 – Once the Owner Name is selected then the associated information about the owner is displayed

To create a new owner, user **must** click on the "Add/Reset" button, even if there is no owner currently displayed.

Structure Issue Tab

The final tab titled Structure Issue (Figure 6.18) describes any issues that are known to exist for the selected structure.

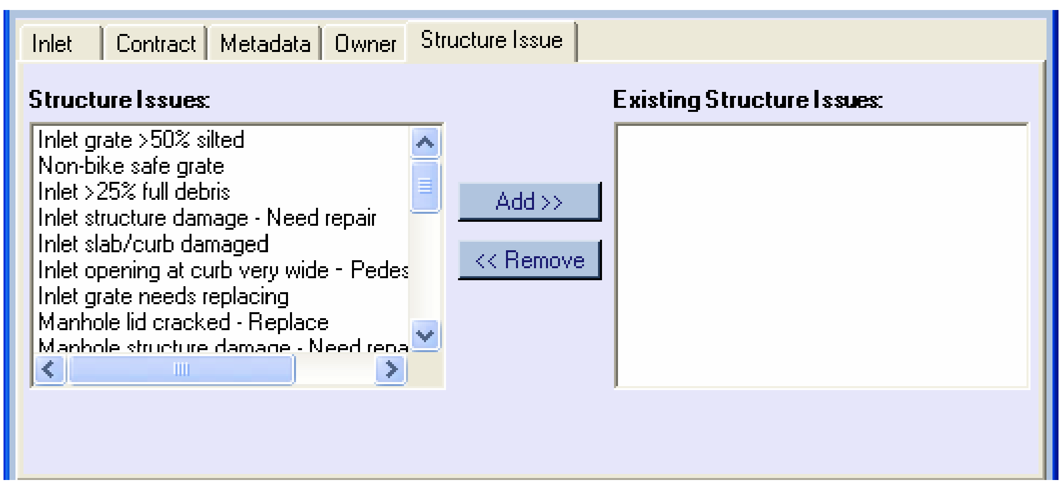


Figure 6.18 – Structure issues are pulled from a domain value and used to describe issues related to storm drain structures

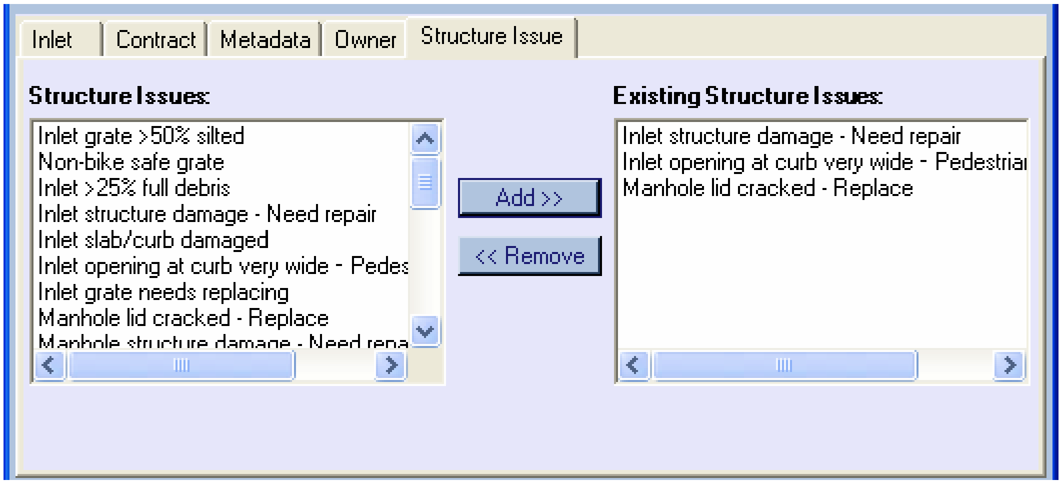


Figure 6.19 – Structure issues are selected and displayed when the ADD button is used. These issues can also be removed if needed.

New issues can be added or existing ones deleted as needed (Figure 6.19). (Double clicking on the structure issue on the left adds it to the existing structure issues list, unless it is already in the list. Similarly, double clicking on the existing structure issue removes it from the list.)

If at any time the user wishes to reset the entire form to the original data, the button circled in red in Figure 6.20 resets the form.

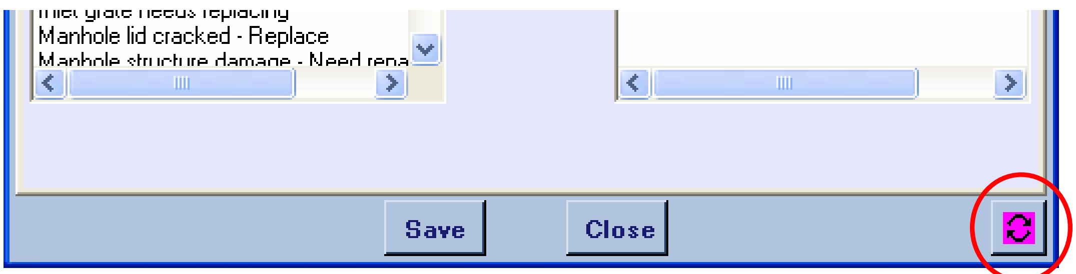


Figure 6.20 – The structure issues form can be reset with the selection of the button circled in red on the form.

6.3.4 Creating a New Structure

To create a new structure, the user will use standard ArcMap editing tools circled in Figure 6.21.

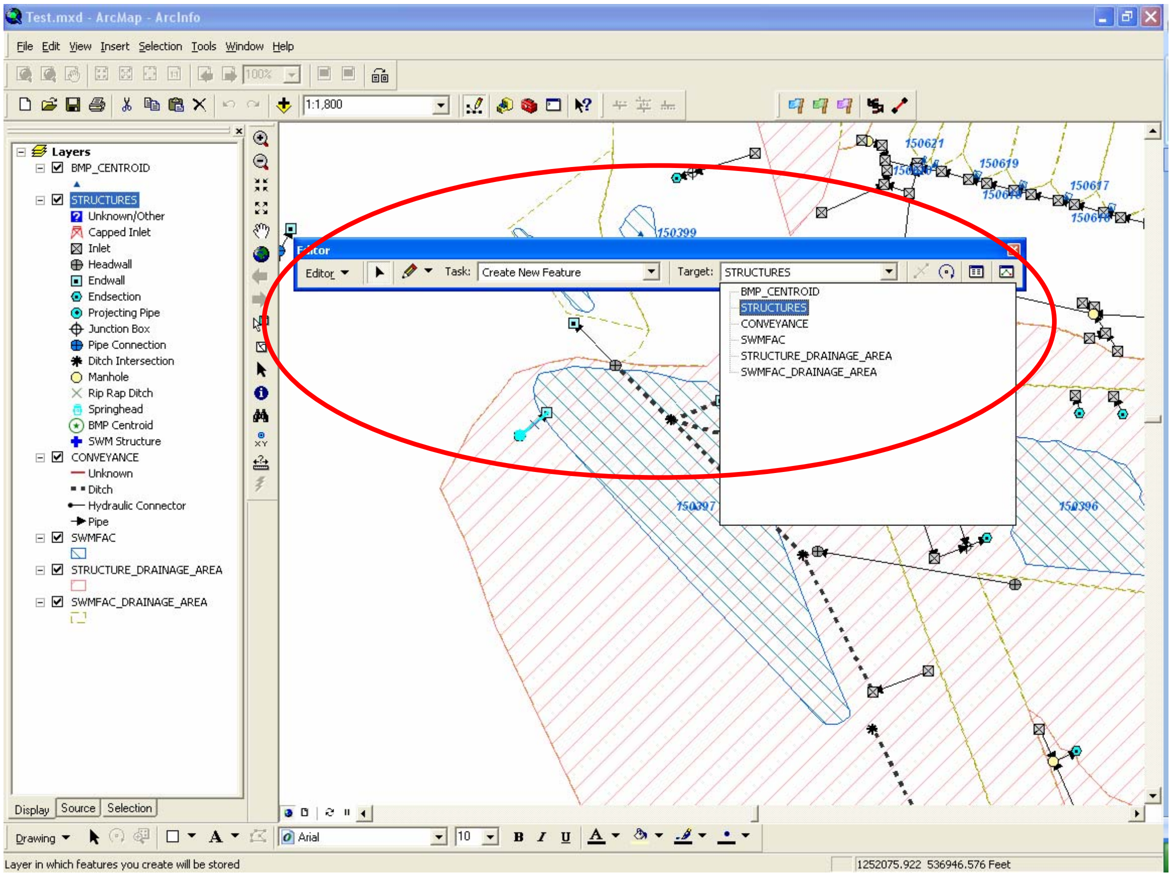


Figure 6.21 – Standard ArcMap editing tools used to edits and create storm drain features

Once a new point feature is created (with the edit session closed), the user can open the edit feature form and enter all the information pertaining to the new structure as seen in Figure 6.22.

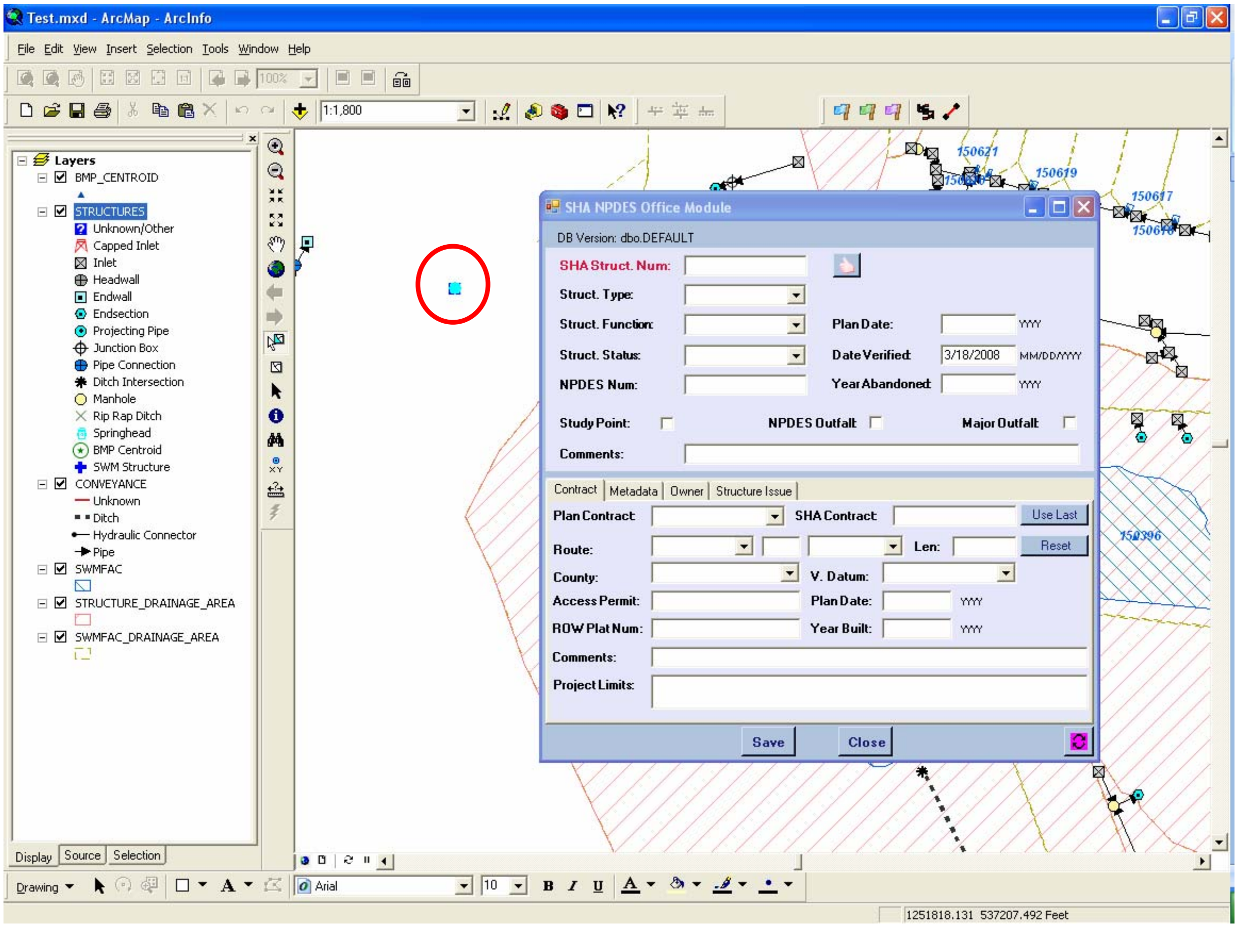


Figure 6.22 – The point feature circled in red was created using standard ArcMap editing tools. Once the feature is created and the edit session closed the attribute information for the feature can be entered.

One of the first things the user must do is assign SHA structure number to the new structure. The SHA structure number is a seven digit and three digit combination number that indicates the system and structure number that is unique to the subject structure. (See Chapter 2 for full description of the SHA Structure Number.) The user must be sure the new structure number fits the current system numbering schema and standards. After the user enters the number, they can click on the “Check SHA Number” button (thumbs up button in Figure 2.23). This checks to see if the number exists or is available but does not check compliance with current system numbering.

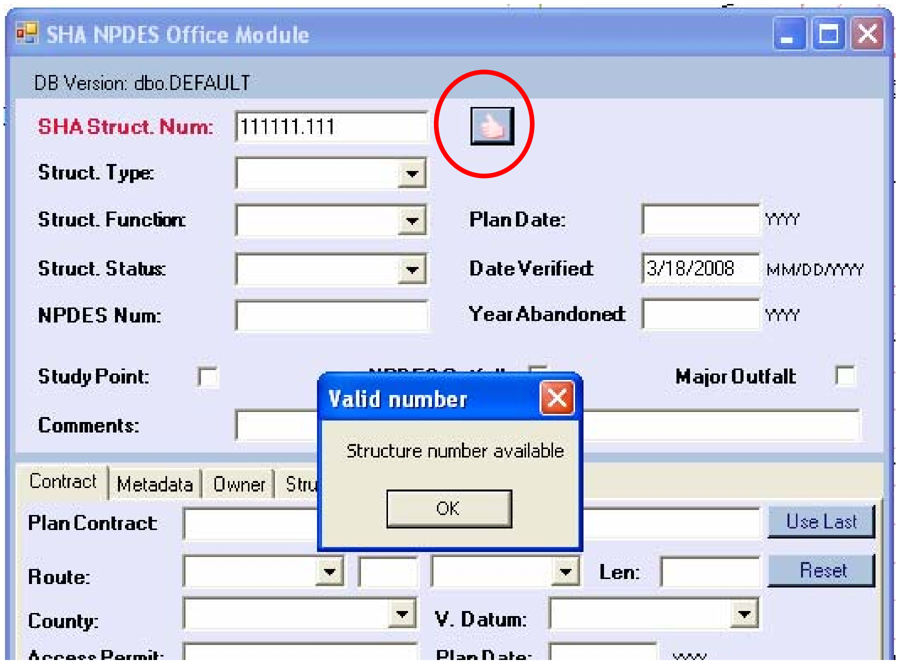


Figure 6.23 – The thumbs up button next to the structure number will check to see if the structure number entered is a valid number so that duplicate values are not created and so that the number is in the proper format according to SHA standards

After the check is performed, the user can enter and save all the information about the new structure.

6.3.5 Editing BMP Attributes

Best Management Practices (BMPs), also known as stormwater management facilities, are ponds and other structures that treat stormwater and are represented by polygons. When the user is ready to edit the attributes of one of these polygon features, the user should select the SWMFAC layer in the Table of Contents. The user should then select the one feature in the map area that it is desired to edit. The tool does not work with multiple features selected.

By pressing the Edit SWMFAC Tool, represented by the green flag (Figure 6.24), a window will open for the user with all of the attributes related to that BMP (Figure 6.25).

Figure 6.24 – The green flag will allow the use to enter BMP inventory data

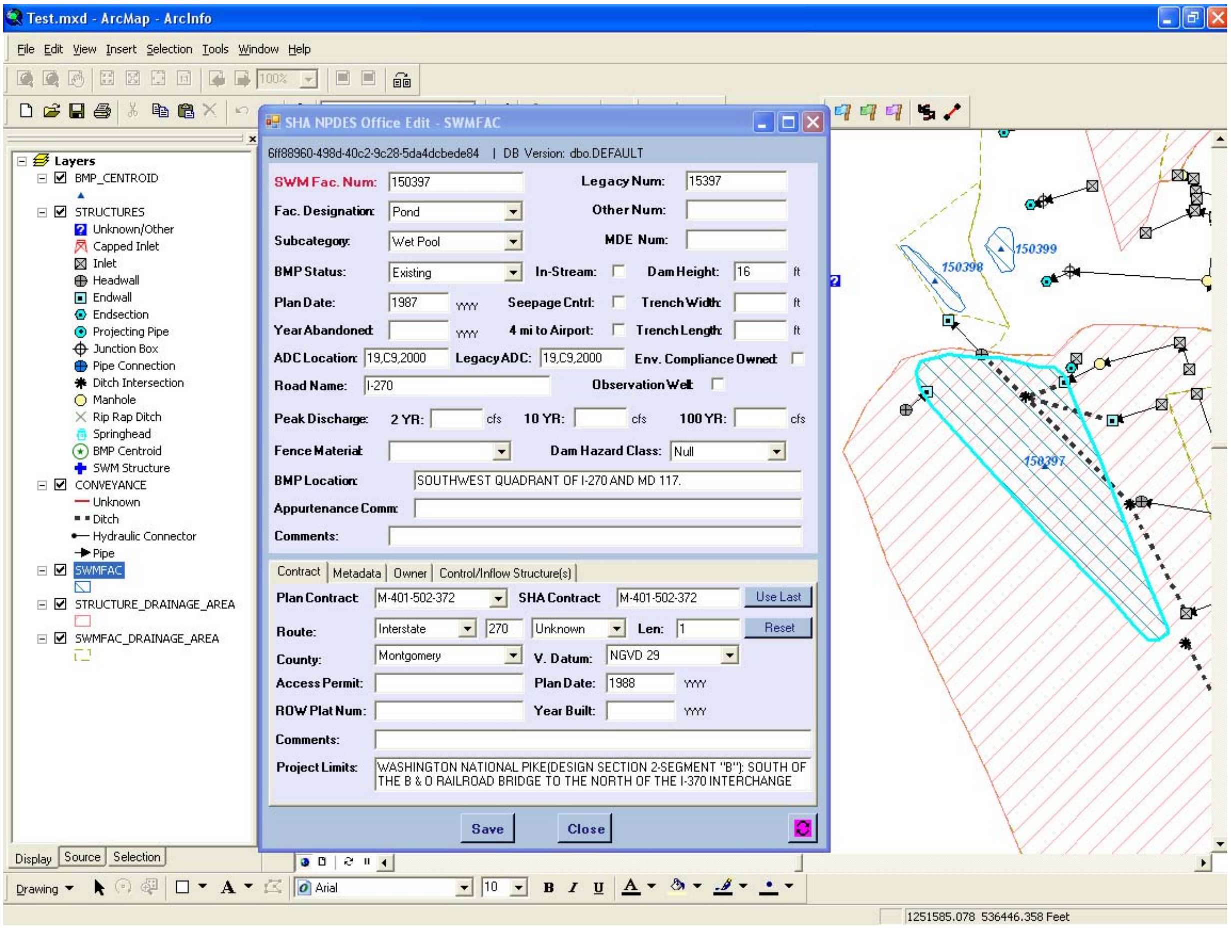


Figure 6.25 – The form is the BMP inventory form that will be completed for BMP feature records

This form (Figure 6.25) contains all the attributes associated with the selected SWMFAC feature inventory and related information, such as Contract, Metadata, Owner and Control/Inflow Structures. There is a separate form for entering inspection information.

Depending on which facility designation is selected, the list of facility subcategories will change. Figure 6.26 is an example of Pond designation subcategories.

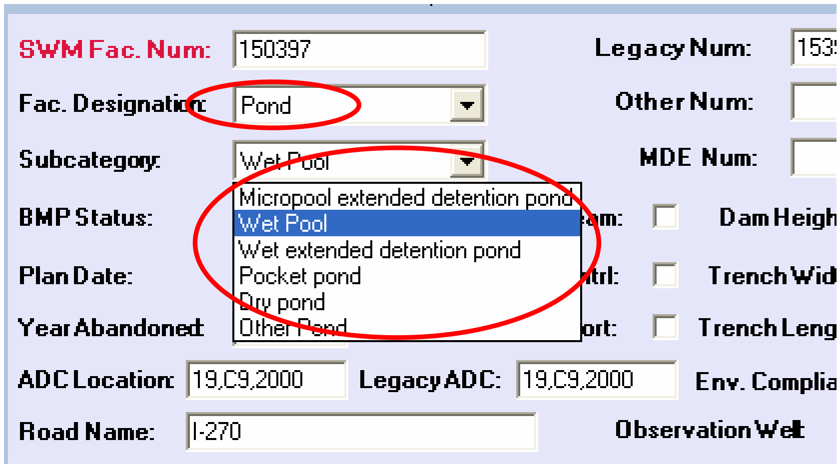


Figure 6.26 – There is an assigned group of subcategories associated with facility designation. These subcategories will update when different facility designation types are selected.

The observation well depth in the BMP inventory form is only visible if observation well is checked in the top part of the form. When observation well exists in a BMP the associated box in Figure 6.27 is checked and a depth can then be entered.

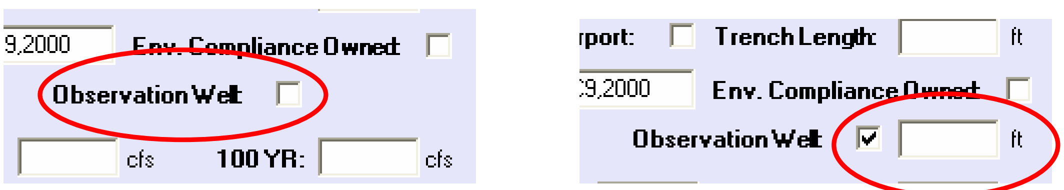


Figure 6.27 – Observation well and well depth fields

Control Structure and Inflow Tab

Similar to the Structures form, the lower half of the BMP form contains information related to other tables. The Contract, Metadata, and Owner tabs function the exact same way as with the Structures Attribute Editing. Unique to BMPs is the Control/Inflow Structures tab (Figure 6.28). This tab defines the structure numbers of those features that flow into the BMP, as well as defines the control structure for the BMP.

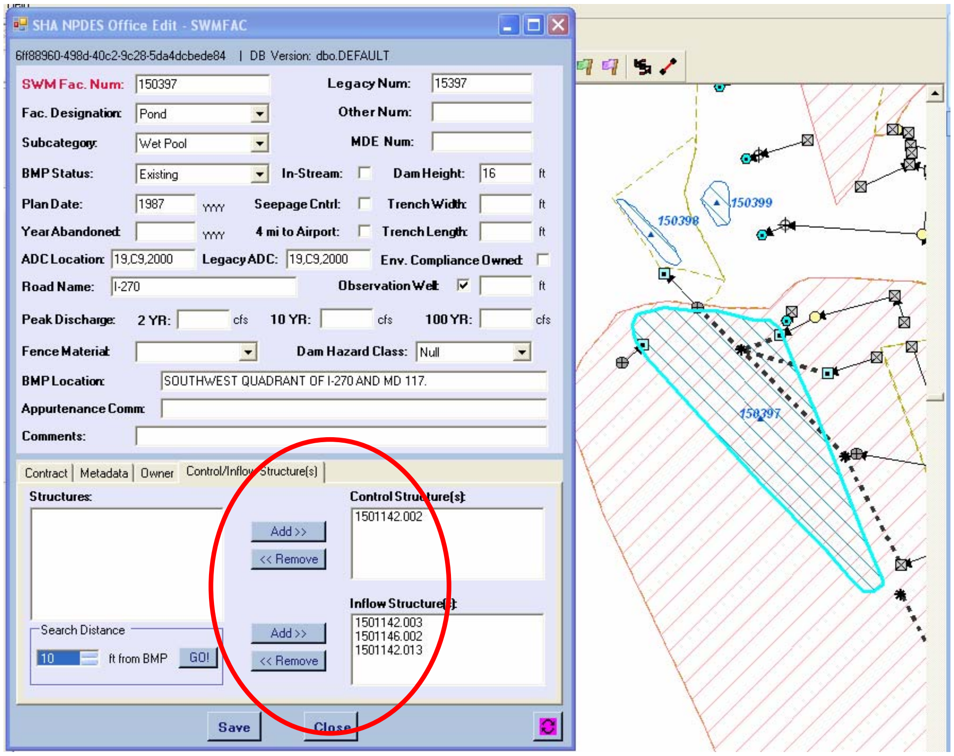


Figure 6.28 – The control structure and inflow structure point features are selected for each BMP using this form.

When an existing BMP is created the control structure and inflow structures are selected using this tab (Figure 6.28). If a BMP's control structure or inflow structures need to be updated or completed this tab is also used. To assist in making a selection of new structures, the user can use the "Buffer" tool provided. Clicking on the "Go" button will perform a spatial search within the specified buffer distance and select those features in the map. It will also list the selected features in the "Structures" list (Figure 6.29).

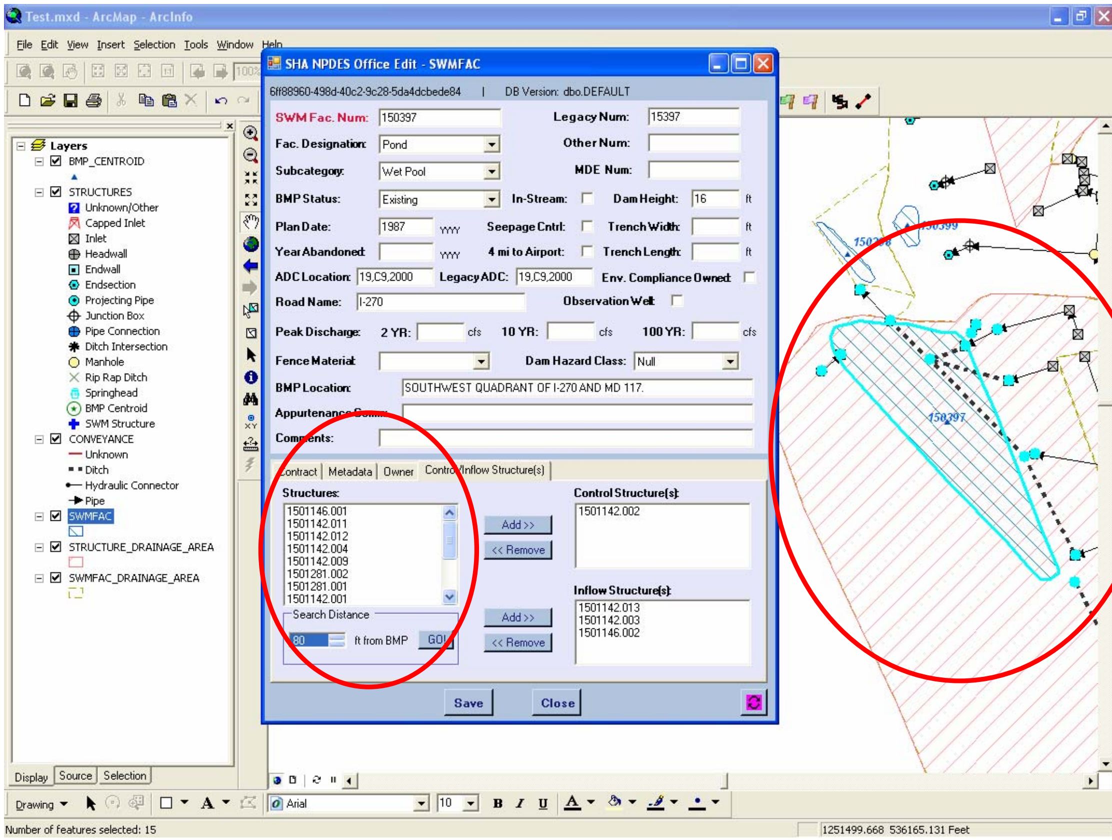


Figure 6.29 – List of structure are presented within a user defined buffer of the BMP outline

If the user clicks on a particular Structure in the Structures list, that feature will be selected on the map, making it easy for the user to decide if the appropriate structure has been selected (Figure 6.30). Also, if it is an existing Control or Inflow structure of the selected BMP, it will be selected in the appropriate list (Figure 6.30).

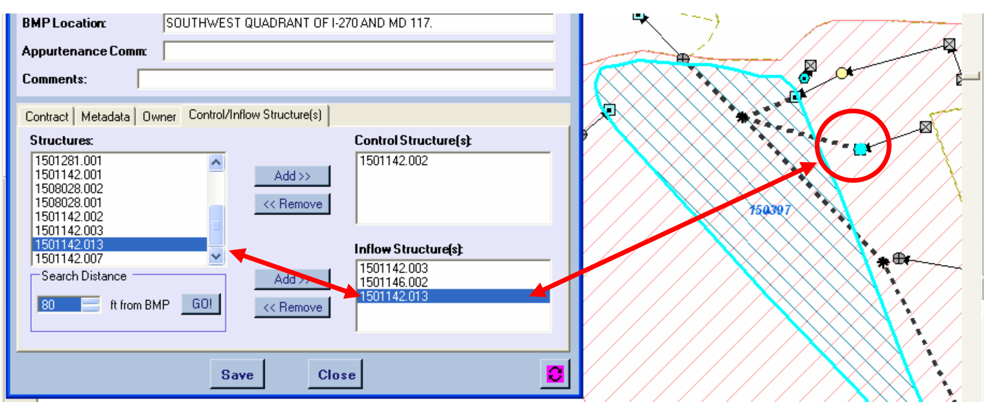


Figure 6.30 – For ease of selecting control structure and inflow structure the application will highlight in the ArcMap view the structure selected. Once the structure is confirmed to be a control or inflow structure, it is placed accordingly.

6.3.6 Editing Conveyance Attributes

Conveyances, also known as pipes, ditches, and hydraulic connectors are the linear features that convey stormwater within a storm drain system. When the user is ready to edit the attributes of one of these arc features, the user should select the Conveyance layer in the Table of Contents. The user should then select the one feature in the map area that it is desired to edit. The tool does not work with multiple features selected.

By pressing the Edit Conveyance Tool, represented by the purple flag (Figure 6.30), a window will open for the user with all of the attributes related to the conveyance represented.

Figure 6.30 – The purple flag will allow the use to enter conveyance inventory data

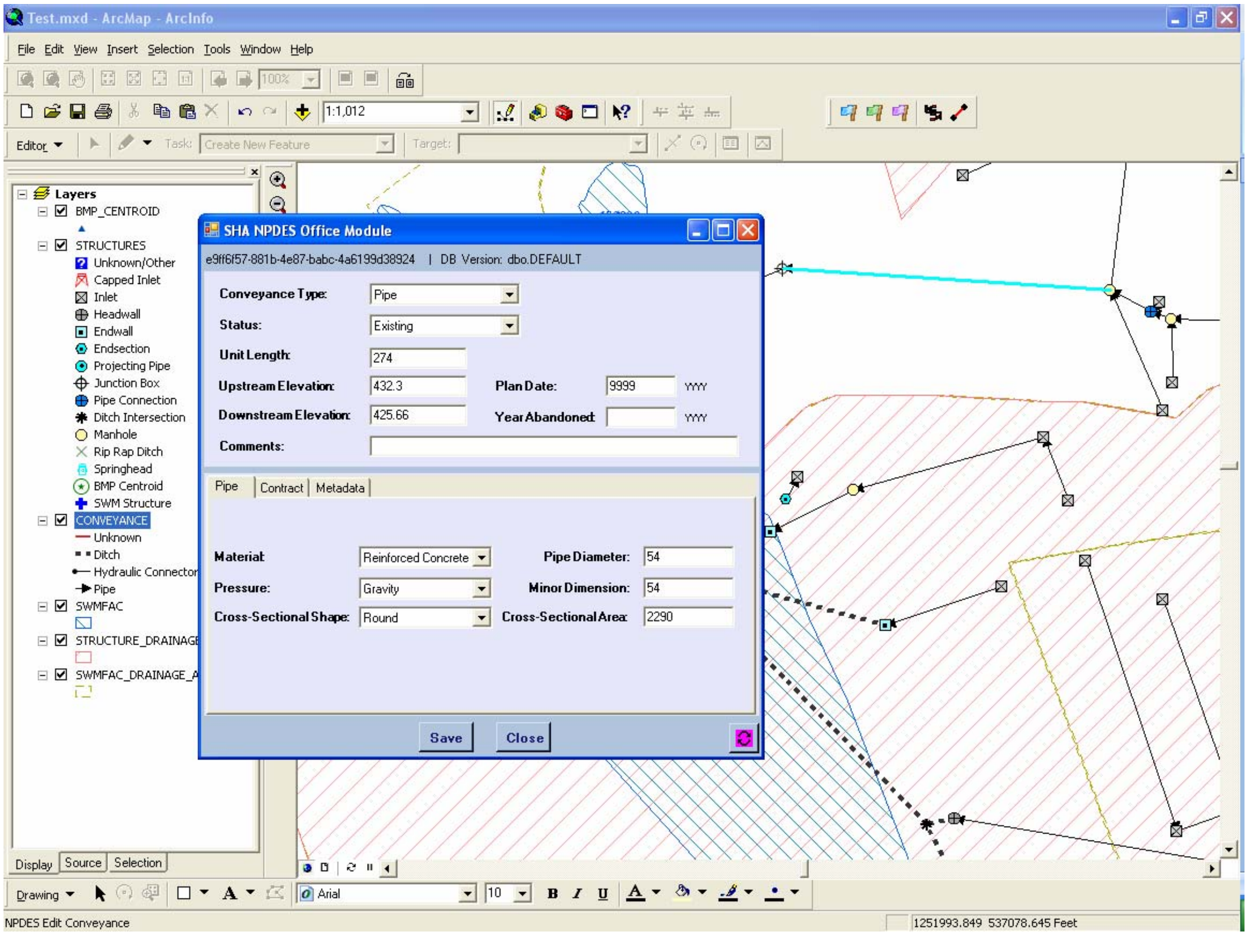


Figure 6.31 – Conveyance inventory form for a pipe

All of the attribute information related to the conveyance can be edited from this form (Figure 6.31). Similar to the Structures Form, the first tab will change depending on the conveyance type selected. Hydraulic connectors are imaginary connections between outfalls and control structures for ponds. They do not have any special attributes associated with them as seen in Figure 6.32.

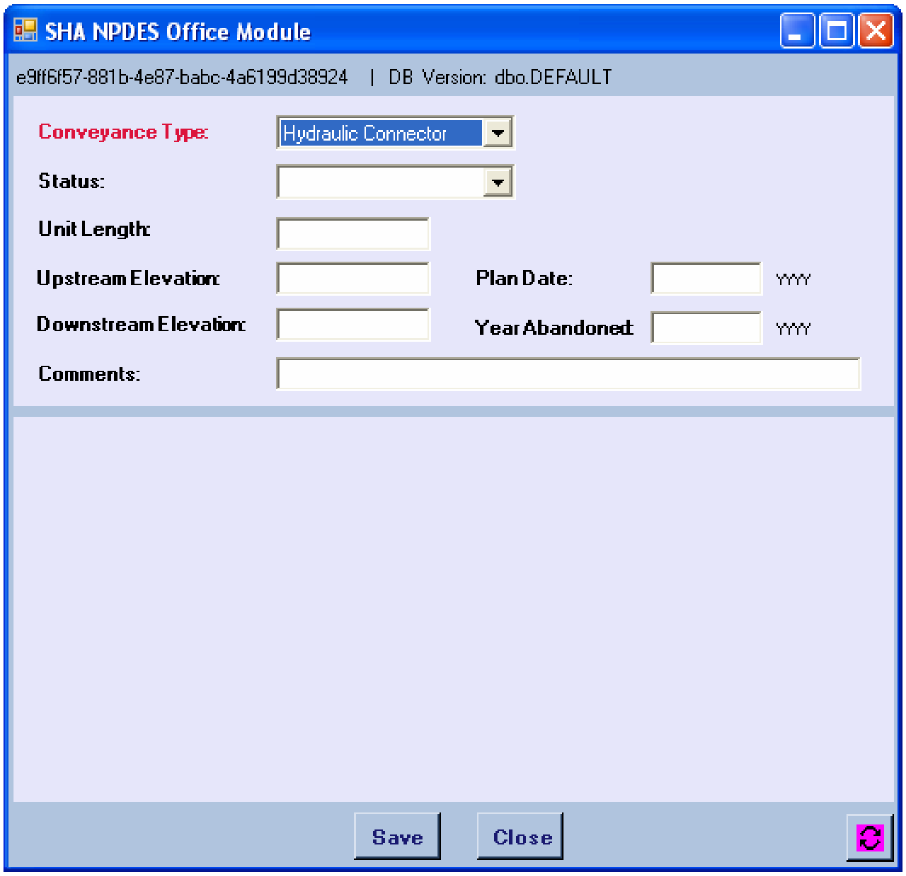


Figure 6.32 – Hydraulic connector inventory form

6.3.7 Flip Pipe Tool

The flip pipe tool is designed to reverse the direction of the pipe when the user discovers a mistake. The user selects the subject pipe and then clicks the icon (Figure 6.33) for the flip pipe tool to execute.

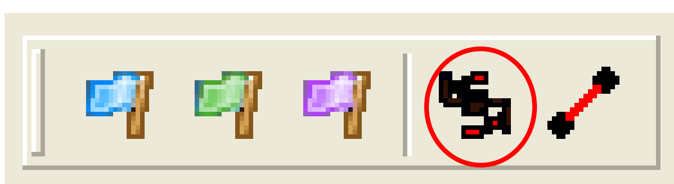
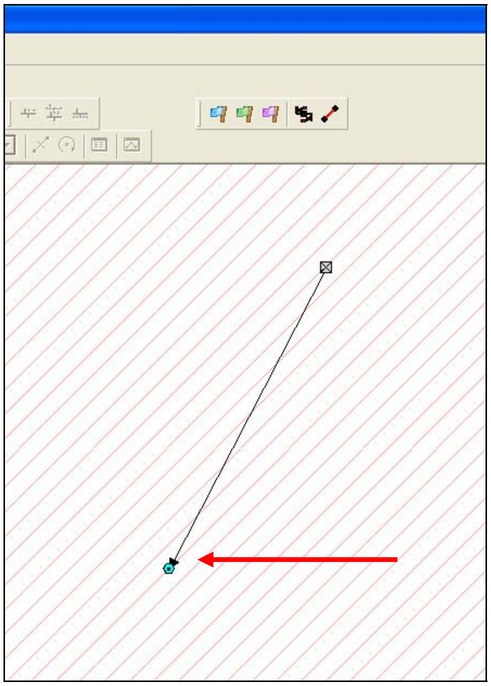


Figure 6.33 – Flip pipe tool button

Execution of the tool revises the upstream structure and downstream structure field in the CONVEYANCE table in the database and reverses the direction of the arc (Figure 6.34).



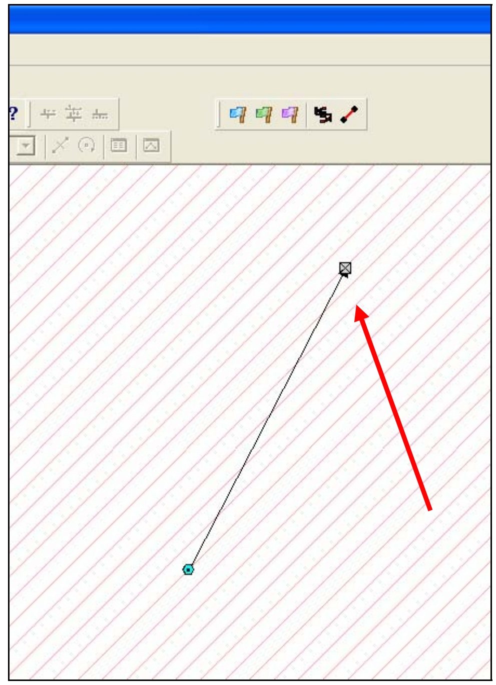


Figure 6.34 – The flip pipe tool will reverse the flow direction of the conveyance

6.3.8 Create Conveyance

The create conveyance tool (Figure 6.35) is designed to create the arc between two selected structures. The user must select the Conveyance Layer in the Table of contents and then select first the upstream, and then the downstream nodes that are to be connected by the conveyance. Selecting the icon for the create conveyance tool then creates the appropriate record in the database and creates the arc feature. If the feature is a ditch, standard ArcGIS editing tools should be used to adjust the geometry to fit contours and/or aerial photography.

Figure 6.35 – The create conveyance tool can only be used when the upstream and downstream structures are created

6.4 Field Editing Tools

6.4.1 Overview and requirements

The following section describes the Field Editing Tool (FET), its intended use, when and how it should be applied, installation requirements and how it integrates with ESRI's enterprise architecture. FET's design expedites all the field collection activities required to maintain full NPDES compliance. It enables users to quickly and accurately collect the following datasets::

- BMP (Stormwater Management Facilities)
- Conveyances (SDOIP)
- Structures (IDDE)

FET is intended to be used for specific field-related tasks. It allows users to perform specific field activates, including the following:

- Inventory
- Inspection
- GPS Location
- Image Capture

FET components plug in to ESRI capabilities and, as such, it leverages all of the following ESRI technologies:

- Personal GeoDatabase Model (Microsoft Access)
- Disconnected data editing (check in/check out)
- Replication (Versioning)

It is beyond the scope of this document to detail all the integration options; rather, it is left to the consultants to choose an integration methodology that best suits their needs. Please review figure 6.1 for scenarios and tips to integrate FET with ArcGIS.

FET requires the following software components prior to installation:

- ArcEngine Runtime 9.2 service pack 3
- ArcEngine License
- Microsoft .Net 2.0

The following software components are required if you should choose to adopt the proposed integration strategy as posited in section 6.2:

- ArcGIS

- ArcEditor or ArcInfo License
- Personal ArcSDE
- Microsoft SQL Express

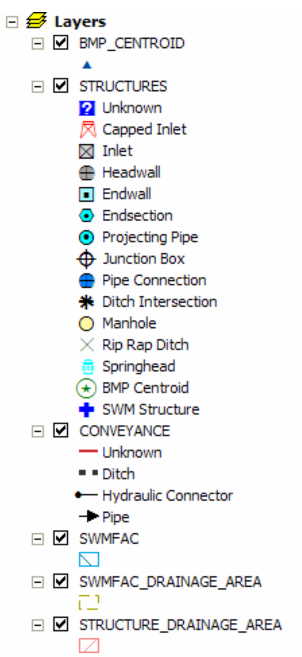
*Note: Personal ArcSDE and Microsoft SQL Express are bundled with ArcGIS at the ArcEditor License level. Please contact your ESRI sales representative for particulars.

FET is designed specifically to leverage Toughbook technology and as such requires that piece of hardware. Additionally, field crews are required to use a GPS device for spatially locating and inventorying all features. FET supports the following GPS connections and signal protocols:

- Bluetooth
- Serial
- NMEA

6.4.2 Loading data into FET

FET is a map-centric tool and as such requires a map document be pre-authored prior to its use. At a minimum the map document needs to reference all the feature classes in the NPDES data model. Of these, only the Structures, Conveyance and SWMFAC layers are mandatory and directly edited within FET. Supplied with FET is the layer symbology SHA has adopted for use throughout the NPDES program. Figure xx shows the table of contents for a typical FET-ready map document. FET supports any ESRI-compliant ancillary data source, including arterial imagery, road centerlines, points of interest and hydrologic features. Do not include these layers directly in the NPDES data model; rather, reference them as external data sources.



As previously mentioned, FET is architected to leverage ESRI's disconnected data editing technology. As such, all data must first be registered with an instance of ArcSDE prior to use within FET. It is beyond the scope of the document to enumerate all the possible ArcGIS configurations that FET supports but described below is one likely implementation strategy.

These are the necessary steps to follow when preparing data for use in FET. The intent is not to provide an exhaustive list of steps but to provide an overview of the steps and any special considerations.

- ArcSDE Personal
- Microsoft Access Personal GeoDatabase
- ArcGIS licensed at the ArcEditor level

Prerequisites to using data within FET:

- Distributed Geodatabase Toolbar added to ArcMap
- Unedited NPDES GeoDatabase Model
- Versioned GeoDatabase
- Proper Permissions

Figure 6.36 shows a check in/check out replica created using ArcGIS. Note the use of Microsoft Access; FET expects this format. Also note that “advanced options” has been toggled. Toggling “advanced options” is mandatory because it is used later in the process.

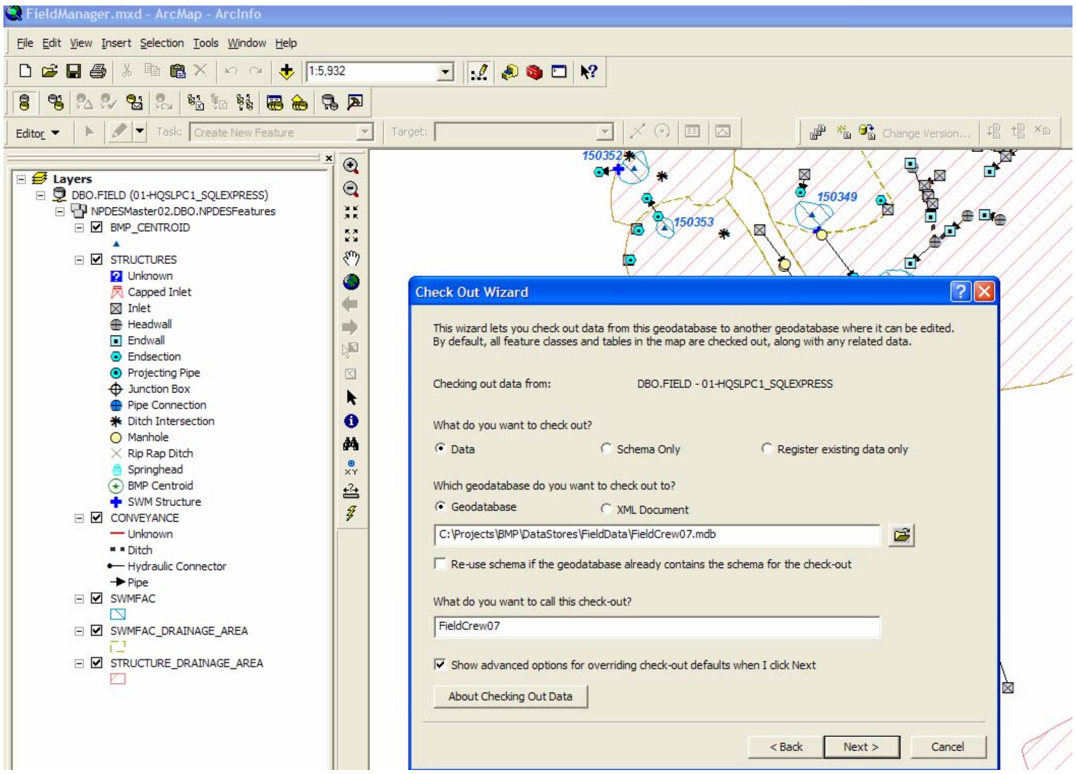


Figure 6.36

Figure 6.37 shows the second form one sees while creating a check in/check out replica. Note that extract related data is toggled and the spatial extent is set to current map extent. Both options are required as well as setting explicitly overriding the default settings for both the Contract and Owner tables. These tables serve as lookups and as such should be pre-populated prior to creating the check in/check out replica.

Override the default settings for the following tables by setting the check out option to “All Records”:

- Contract
- Owner

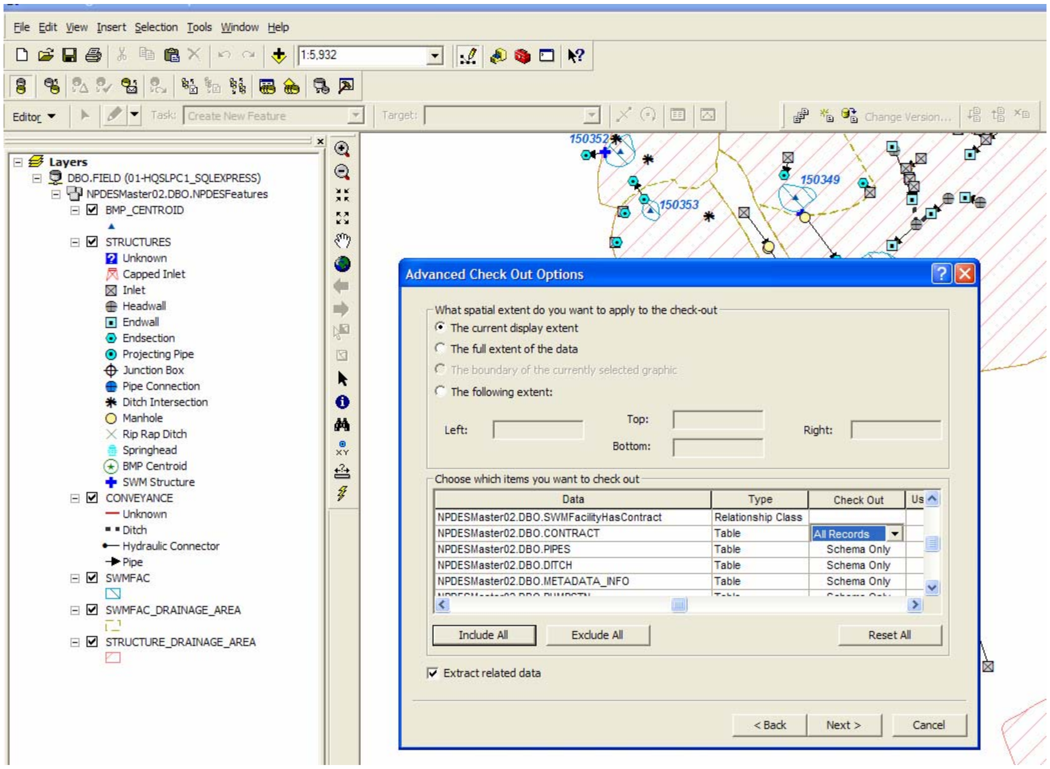


Figure 6.37

Figure 6.38 shows Owner table check out option set to “All Records” as required. (figure on next page)

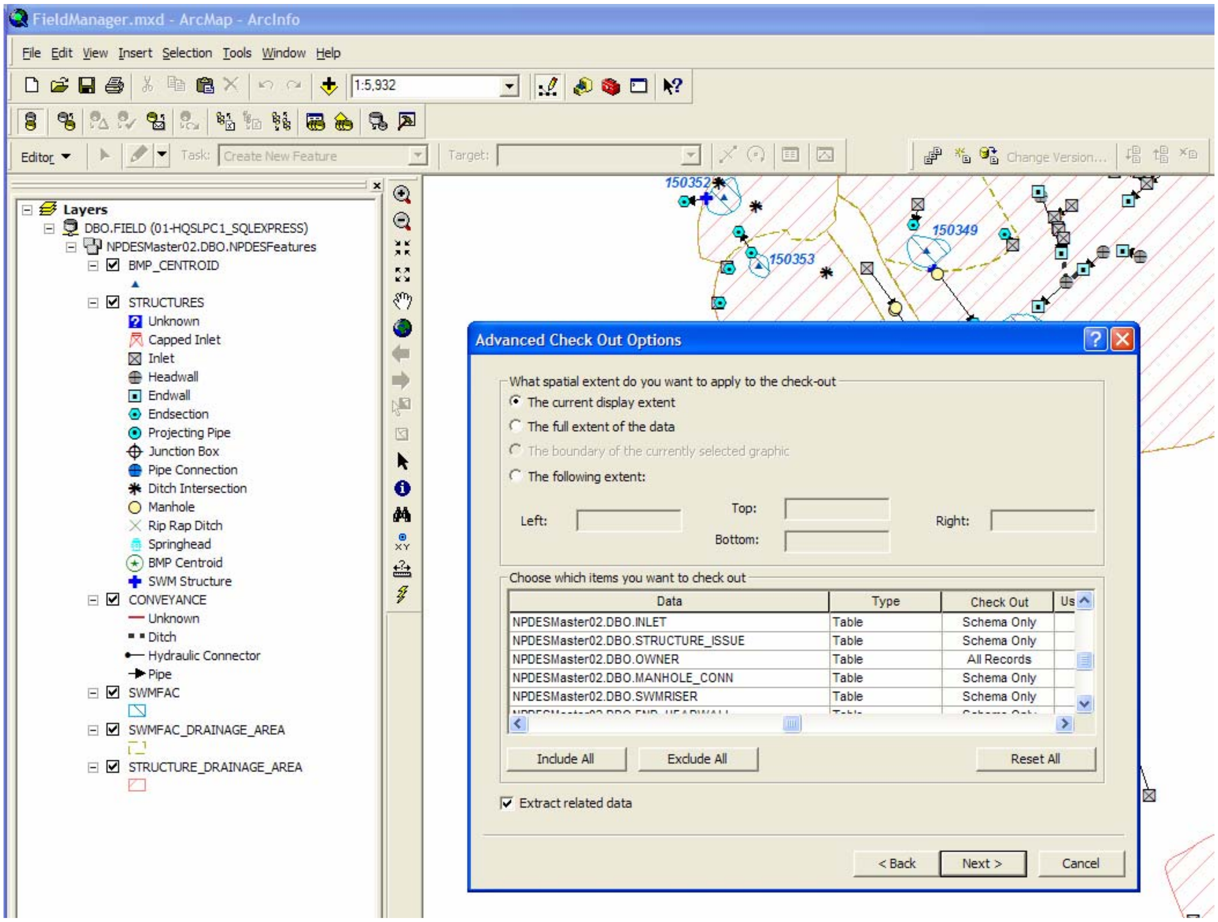


Figure 6.38

Figure 6.39 illustrates form three of the check in/check out replica process. The user simply accepts the default values presented on this form. (Figure 6.39 on next page)

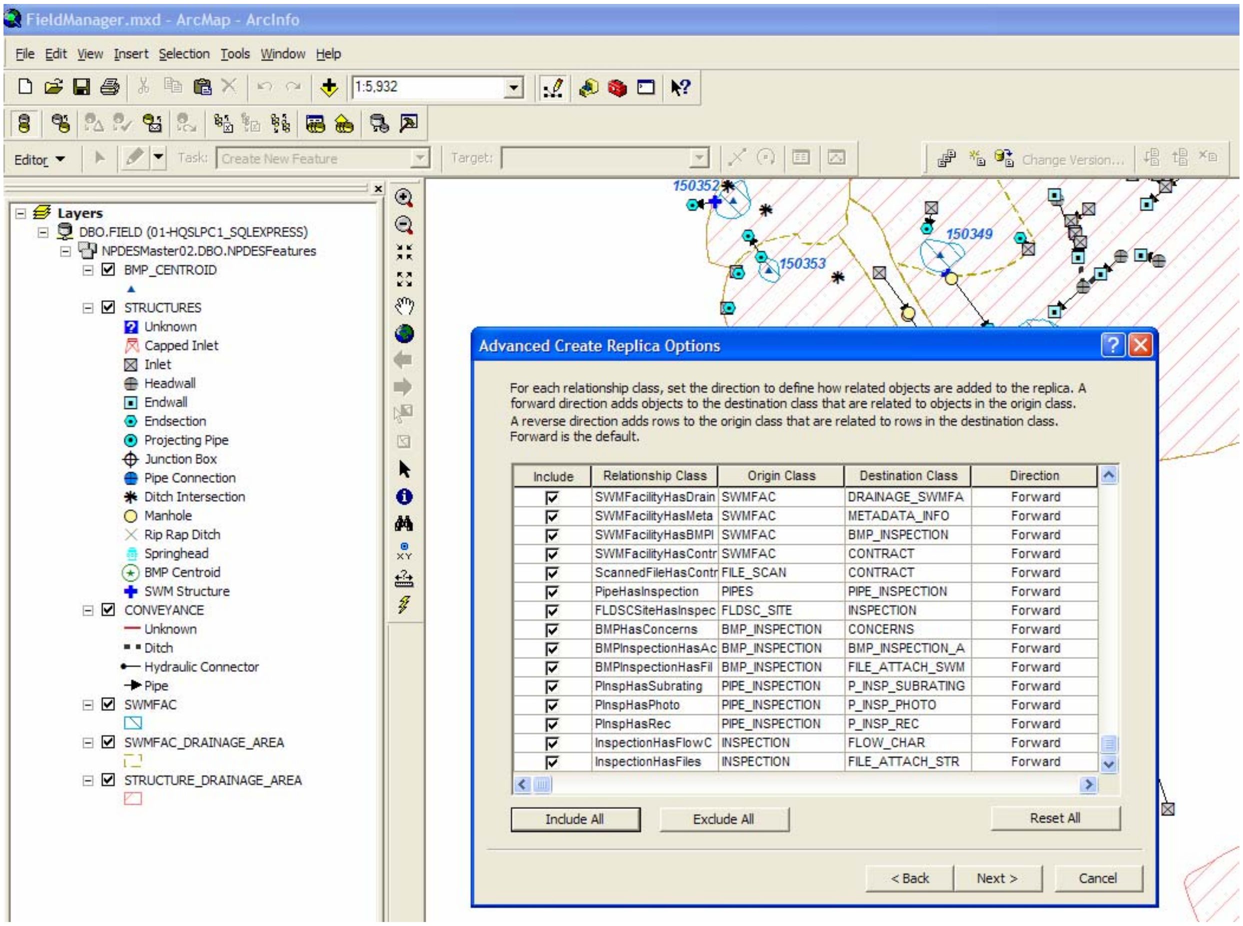


Figure 6.39

Figure 6.40 illustrates the final step in the check in/check out replica process. While no required, it is suggested that the user opt to have ArcGIS create a map document that is wired to the disconnected data set. Toggling this option is beneficial in two ways:

- All symbol sets are preserved
- Data sources are wired correctly

Additionally, all map documents should be created with relative data paths, so as to alleviate the need to rewire data sources prior to incorporating into FET. (Figure 6.40 on next page)

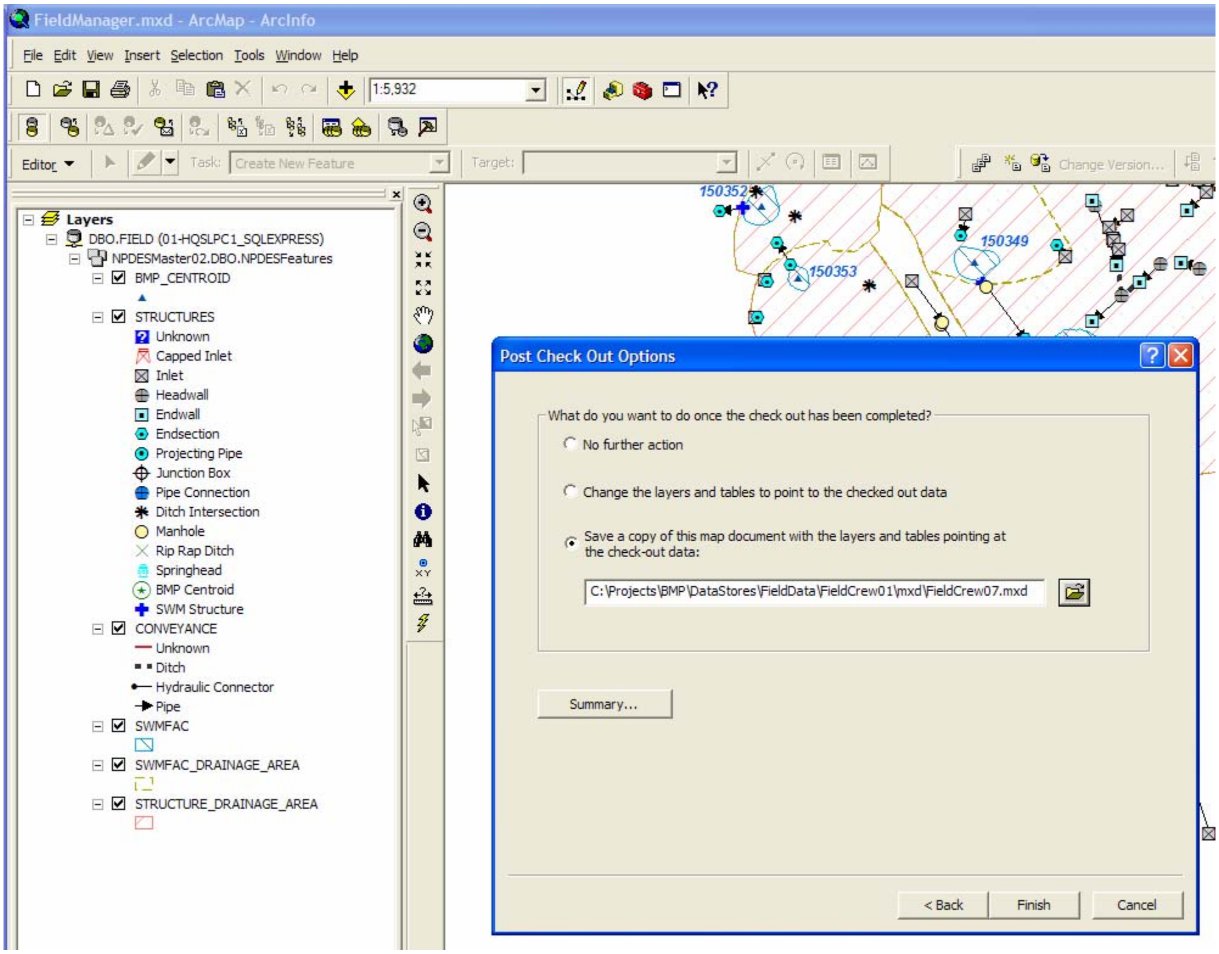


Figure 6.40

Figure 6.41 shows the final stage of the check in/check out replica process. The result of the process includes the following: (figure on next page)

- ArcMap Document (mxd)
- Personal GeoDatabase
- Correct symbology
- NPDES GeoDatabase Model

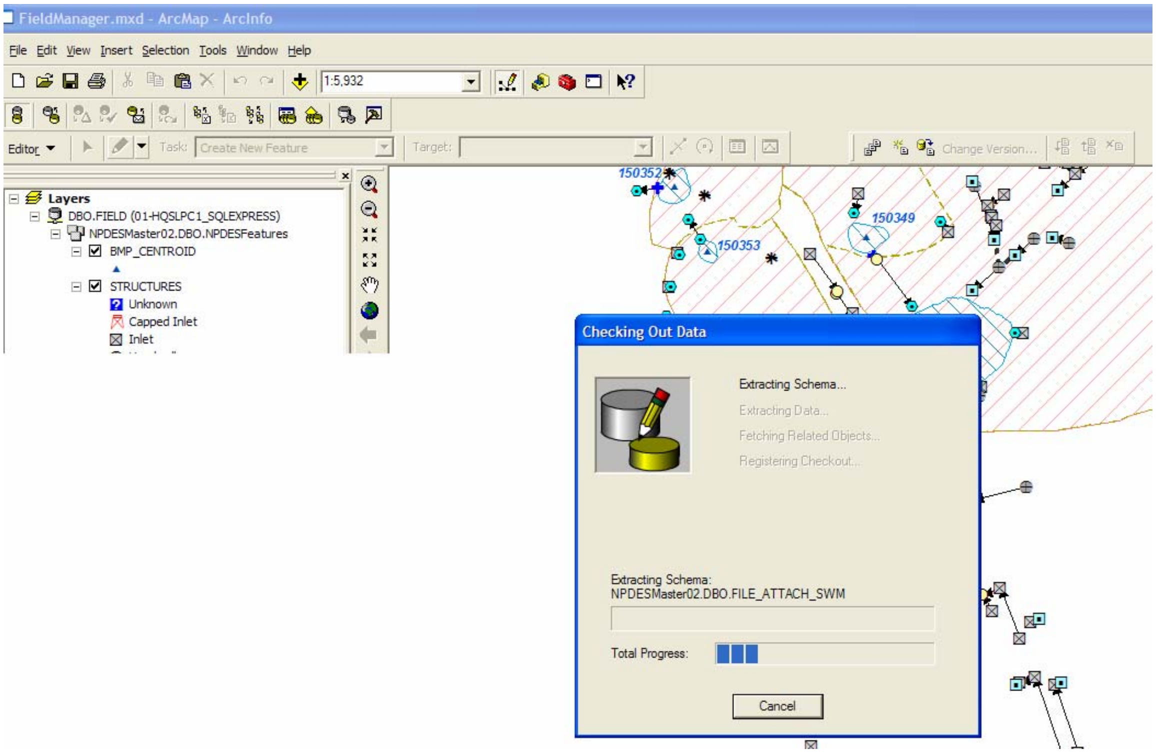


Figure 6.41

6.4.2.1Network Structure

While not mandatory, anyone using FET should adopt a strict folder naming convention and structure. Adopting such standards will enable both field and office crews to maintain large datasets that are being created and edited by both field and office personnel.

Figure 6.42 illustrates the suggested network structure to adopt for both field and office hardware.

The following items are required to complete field work:

- ArcMap Document
- Disconnected NPDES Personal GeoDatabase

It is suggested that the following items are used to complete field work when available:

- Field Images
- Scanned Contract

Note that Figure 6.43 illustrates the suggested data structure for a field toughbook intended for use in the Montgomery County area. If the suggested data structure is adopted, the field crew in the scenario simply needs to copy the Montgomery folder from the network prior to leaving for the day.

6.4.3 Application Tool & Status Bars

FET is an interactive tool used to assist field crews with their data gathering tasks. FET is designed specifically to encapsulate business rules and standard operating procedures field crews should be following. If used properly, it should make field staff more productive, enhance data quality, cut start-up time and serve as a mechanism to integrate with ESRI architecture.

FET can be used to accomplish the following activities:

- Inventory
- Inspection
- Location
- Mapping
- Image Inventory

Below are sections detailing how field-related task can easily be accomplished using FET.

FET has a number of components, forms, toolbars, tools and status bars that are also explained in detail.

Figure 6.44 shows FET's main toolbar. Each item on the toolbar has a tool tip indicating its intended use. Using this toolbar, users can navigate to a number of different functional areas, including:

- Map Window
- Inventory Windows
- Inspection Windows
- GPS Window
- User Setting Window
- Contract Window
- Owner Window
- Help Window
- Layout Configurations

Figure 6.44

Each of these items on the main toolbar is described in detail in the remaining sections of this document.
The main status bar in FET is shown in Figure 6.45. It is used to show feedback to users whenever FET is running.

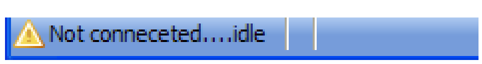


Figure 6.45

Figure 6.46 illustrates FET feedback as it regards to GPS- relevant activities. At a minimum, the status bar always displays GPS connection, tracking and locating activities.

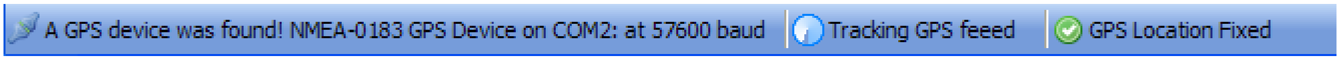


Figure 6.46

6.4.4 Mapping Interface

Figure 6.47 illustrates the embedded mapping interface of FET. FET is a map-centric tool and as such requires a map document be loaded prior accomplishing other tasks. As previously mentioned, all NPDES data sources must be preconfigured specifically for use within FET. FET, does, however, allow for external data sources as long as they remain external.

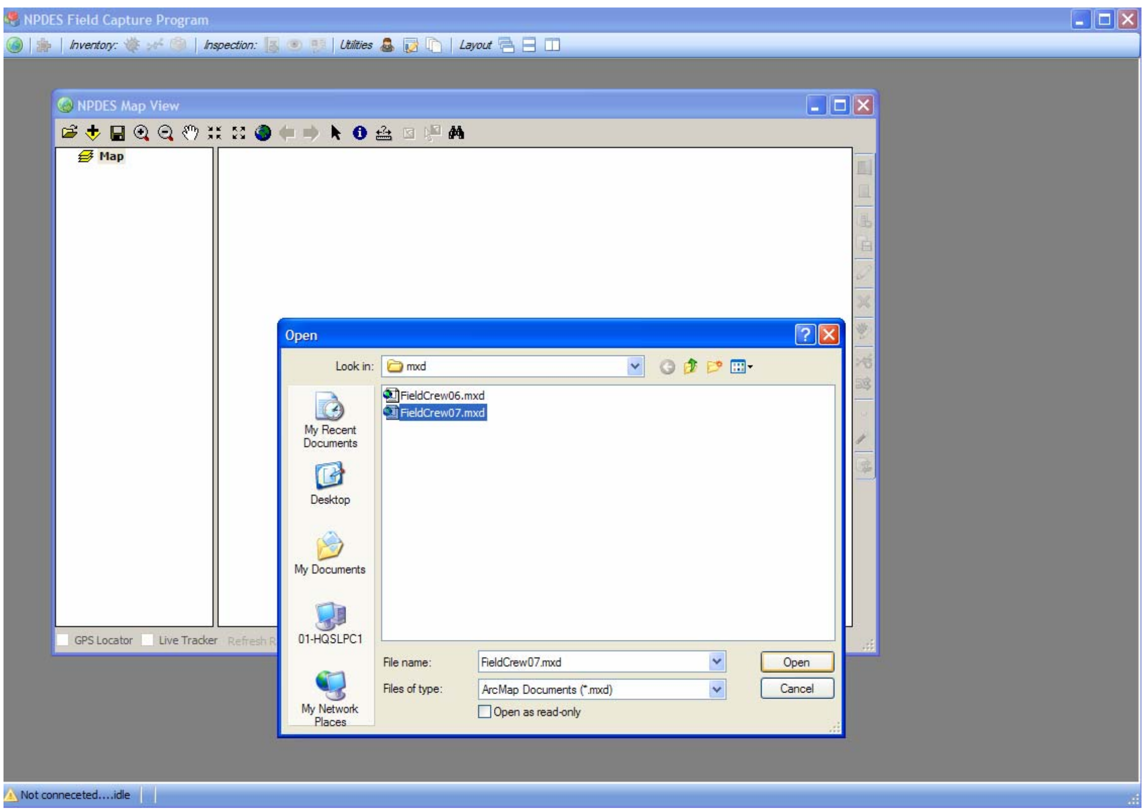


Figure 6.47

Figure 6.48 illustrates loading a map document into FET. Users are required to load a Map document for each FET session. Note the disabled state of most tools because an active layer has yet to be set.

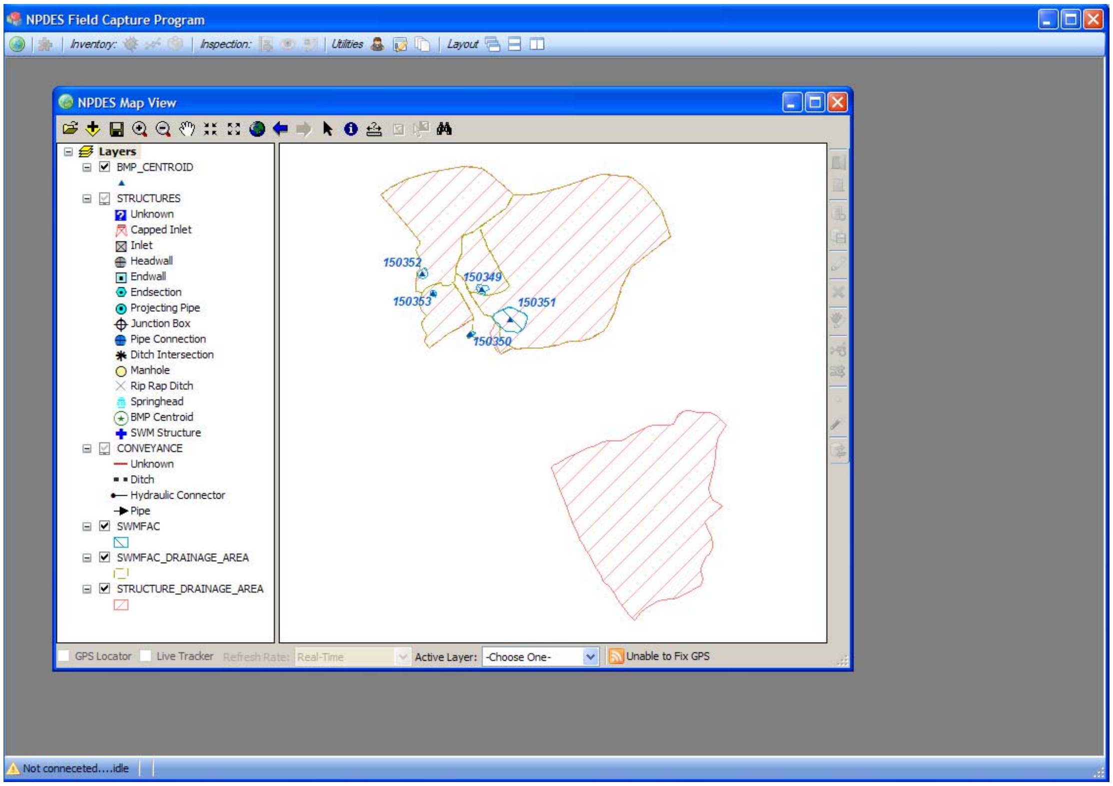


Figure 6.48

6.4.4.1 Interactive Map Toolbar

The FET mapping window contains a number of toolbars which the user can interact with to complete their work. The interactive mapping toolbar (Figure 6.49) enables users to accomplish a number of tasks, including the following
:

- Load a map document
- Load other related data sources
- Save a map document
- Navigational Tools
    - Zoom in
    - Zoom out
    - Pan
    - Zoom in to center
    - Zoom out to center
    - Zoom to full map extent
    - Go back to previous extent
    - Go to next extent
    - Select elements
    - Identify
    - Measure
    - Clear selected map features

- Select map features
- Search for map features
-

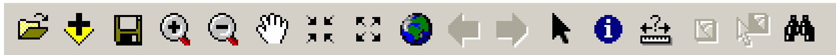


Figure 6.49

6.4.4.2 Map Information Toolbar

As previously stated, FET is a map-centric solution and the Map Information toolbar (Figure 6.50) illustrates that fact more than any other. It enables users to accomplish a host of tasks, including the following:

- Toggle GPS Locator mode
- Toggle Live Tracker mode
- Set Live Tracker update rate
- Activate a layer

The toolbar also serves as a status indicator for the following items:

- Current GPS fix
- X/Y location (MD State Plane 83 Feet)

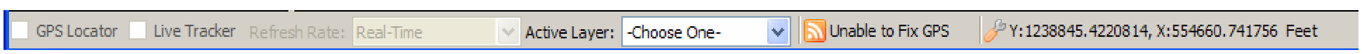


Figure 6.50

The user is required to interact with this toolbar occasionally throughout a session. It hosts a number of relevant features, least of which is setting the current active layer. Once a user sets an active layer, FET responds by setting dependant modes throughout the application. The following is a simple illustration of this built-in feature.

1. Active layer selected (Ex. Structures)
2. Any previous map selection cleared
3. Select map features button on interactive map toolbar enabled
4. Appropriate tools enabled on FET's main toolbar

Figure 6.51 shows the map information toolbar during a session of FET.

Figure 6.51

6.4.4.3 Geometry Tools

As its name implies, the Geometry Tools toolbar (Figure 6.52) – located to the right of the map- is used to interact with spatial features. Its state is dependant on the current active layer and whether an edit session has been initiated. The toolbar provides for the following functions:

- Open Edit
- Close Edit
- Cancel Edits
- Save Edits
- Delete Selected
- New BMP
- New
- Flip Conveyance
- Reverse upstream/downstream structure
- Update system
- New Structure
- Relocate

Figure 6.52

The geometry toolbar works in unison with all other toolbars, toggling between states to maintain editing integrity.

6.4.4.4 GPS Toolbar

The GPS toolbar (Figure 6.53) is used in conjunction with the geometry toolbar during the creation of features. This toolbar acts both to gather user input and to show feedback for the GPS-related activities. Included on this toolbar are the following inputs:

- GPS Override (manual input via mouse)
- GPS Accuracy settings
    - High (90 readings)
    - Medium (60 readings)
    - Low (30 readings)
- Cancel GPS acquisition tool
- Re-initiate GPS acquisition process tool
- GPS acquisition progress bar

Figure 6.53

The map information toolbar must indicate a fixed GPS signal prior to feature creation. If a fix is not established, an appropriate subset of the GPS tools will be displayed.

Figure 6.54 illustrates an edit session in progress and a structure location being acquired with high accuracy as indicated on the GPS toolbar. Note as GPS reads are received, the map interface updates until said accuracy is reached, after which the average of all readings is established and the appropriate feature placed.

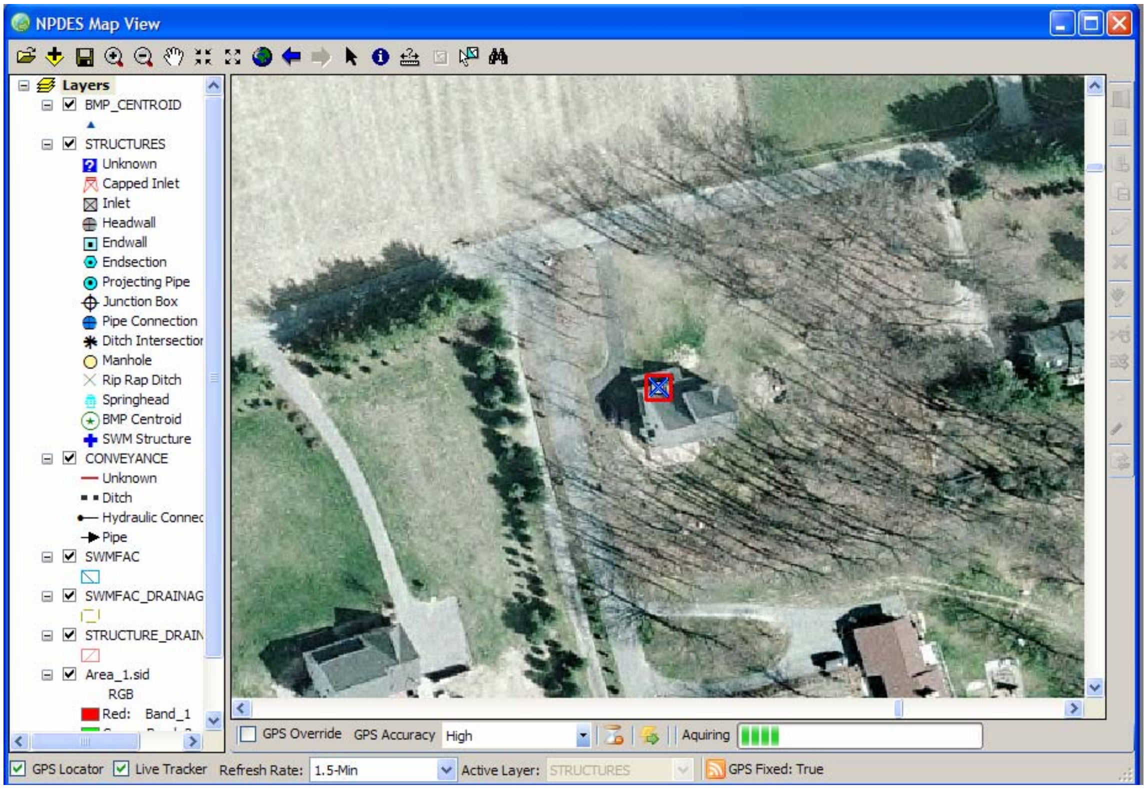


Figure 6.54

6.4.5 Inventory Interfaces

There are two main tasks consultant field crews must accomplish on a daily basis, inventories and inspections. FET is designed to encapsulate most, if not all, of the activities and business rules established for these tasks. Users will quickly notice FET's inventory and inspection interface have been consistently designed and behave in a similar fashion. This was done intentionally and should help ease the learning-curve for field crews and other staff using FET. Use FETs inventory interfaces to record field-data for the each of the following features:

- BMP
- Conveyance
- Structure

Using FET should relieve consultant staff from editing the NPDES database directly. It encapsulates the data-editing process via a number of forms. Each form is composed of required inputs that must be completed prior to FET performing a save operation.

6.4.5.1 BMP (Stormwater Management Facility)

As previously noted, all of FET's toolbars are linked to present only the appropriate tools and allow particular actions given the system's current state. Figure 6.55 illustrates how FET's toolbar are linked. The current state of the application is as follows:

- Active Layer: SWMFAC
- Select and clear map features enabled
- No edit session opened
- SWMFAC Inventory enabled
- SWMFAC Inspection enabled

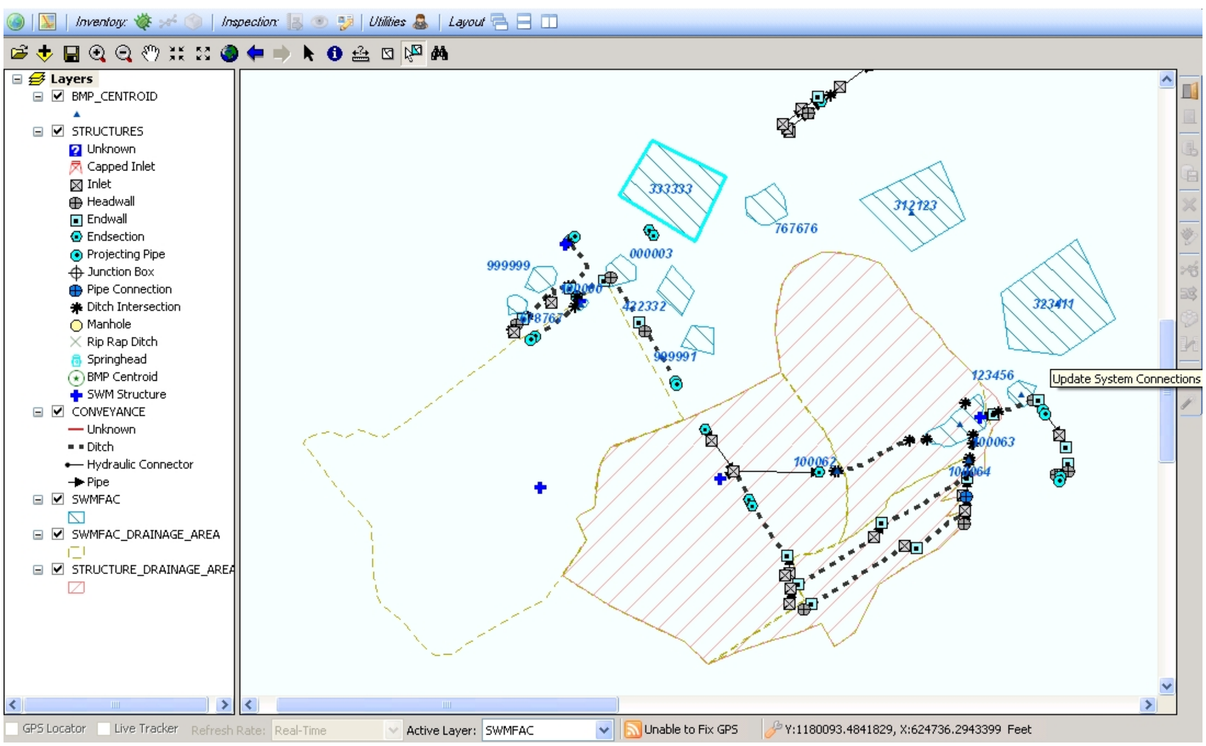


Figure 6.55

The figure below (Figure 6.56) shows the SWMFAC Inventory dialog. The user can select stormwater management facility types across the top of the inventory to further narrow their search of which features are selected.

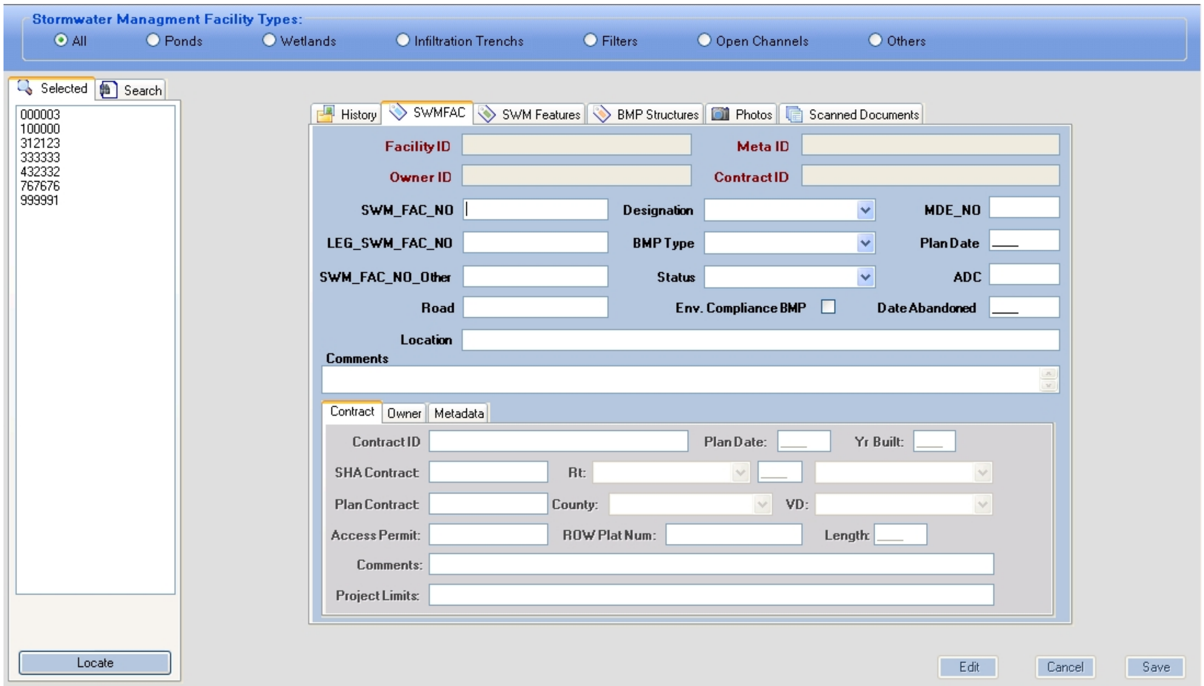


Figure 6.56

The SWMFAC tab (Figure 6.57) on the Inventory dialog displays attribute information related to any highlighted features under the selected tab. Certain data is required by the field crews in order to save information on a facility.

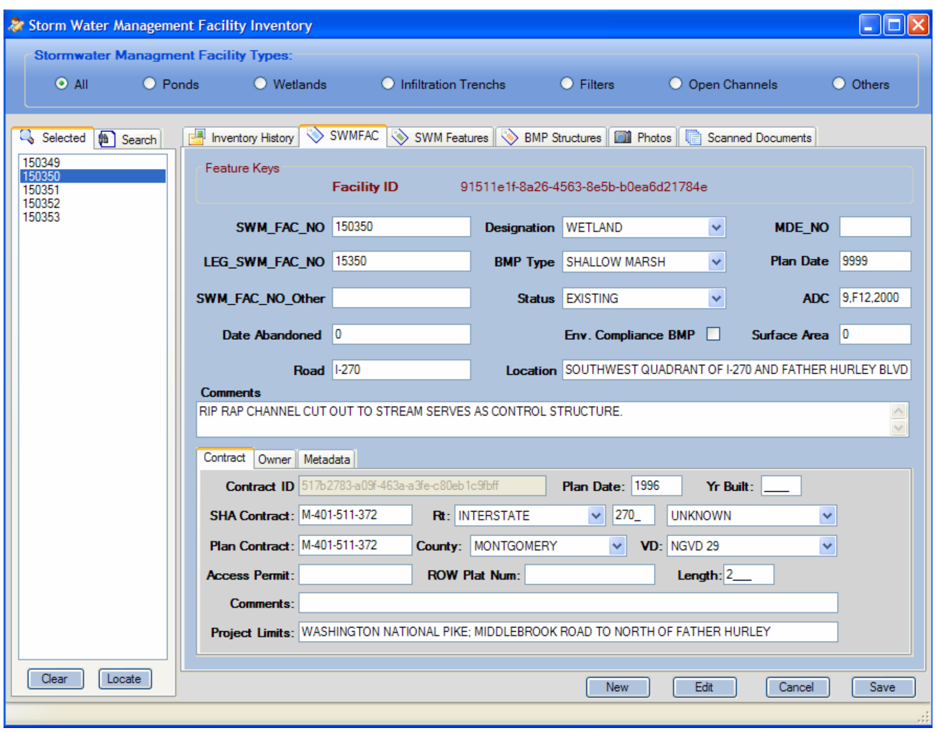


Figure 6.57

Figure 6.58, the SWM Features tab, contains information pertaining to whether the facility is an in stream BMP, the height of the dam, trench depth, etc.

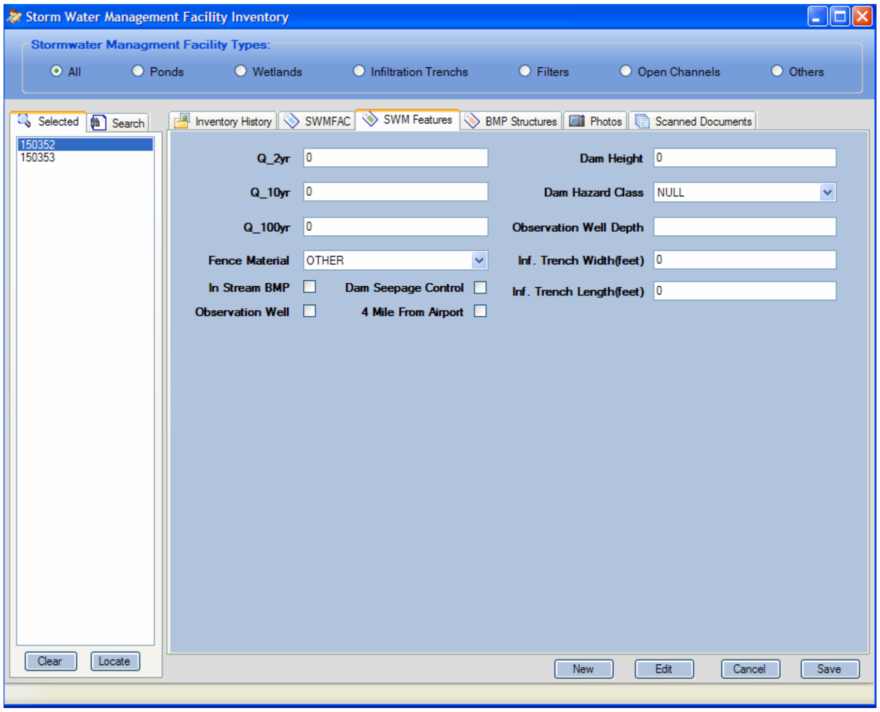


Figure 6.58

The following figure (6.59) shows related structures to the facility. The user can apply a spatial filter to search for structures within a certain distant from the selected facility. This tab also lists the inflow structure(s).

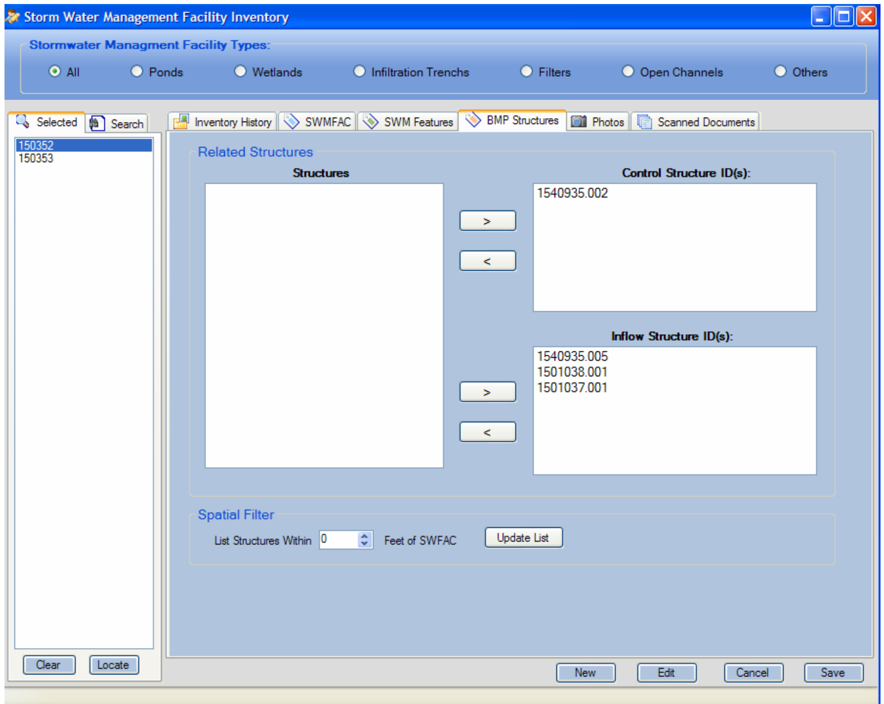


Figure 6.59

The user can view the facilities and related structures by highlighting the facility and/or structures in the BMP Structures tab as shown in figure 6.60.

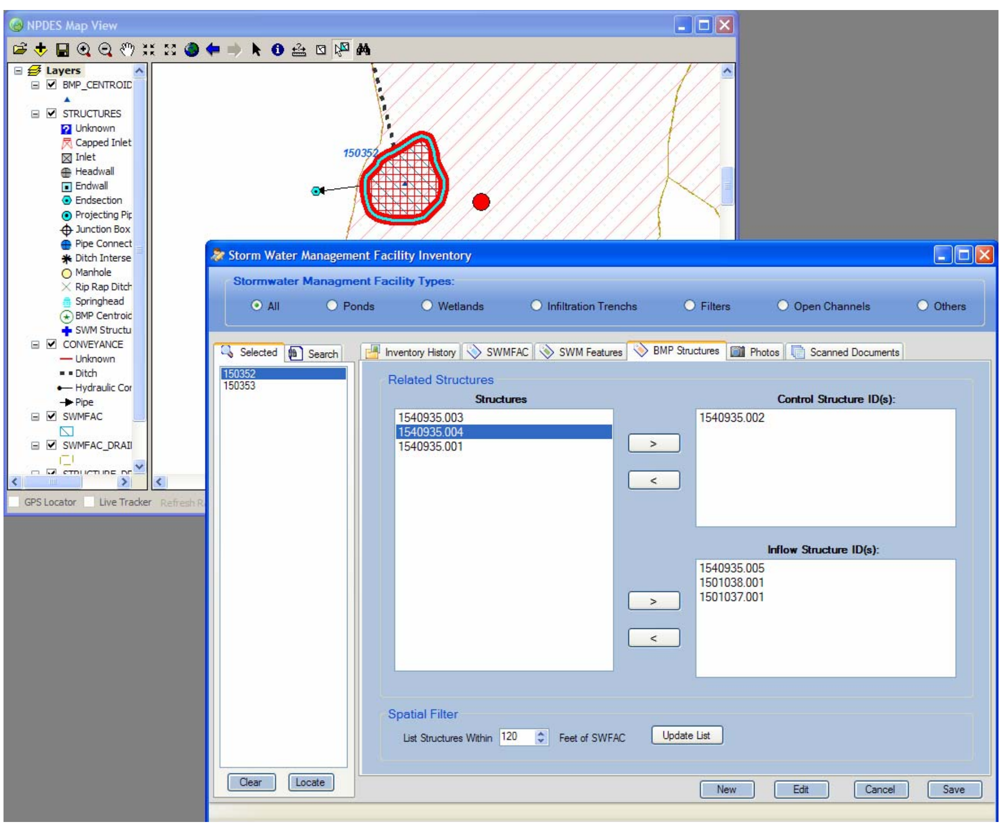


Figure 6.60

The Photos tab in Figure 6.61 allows the field crew to load pictures related to the facility they are inspecting. The crew can load multiple photographs and add comments to each photo.

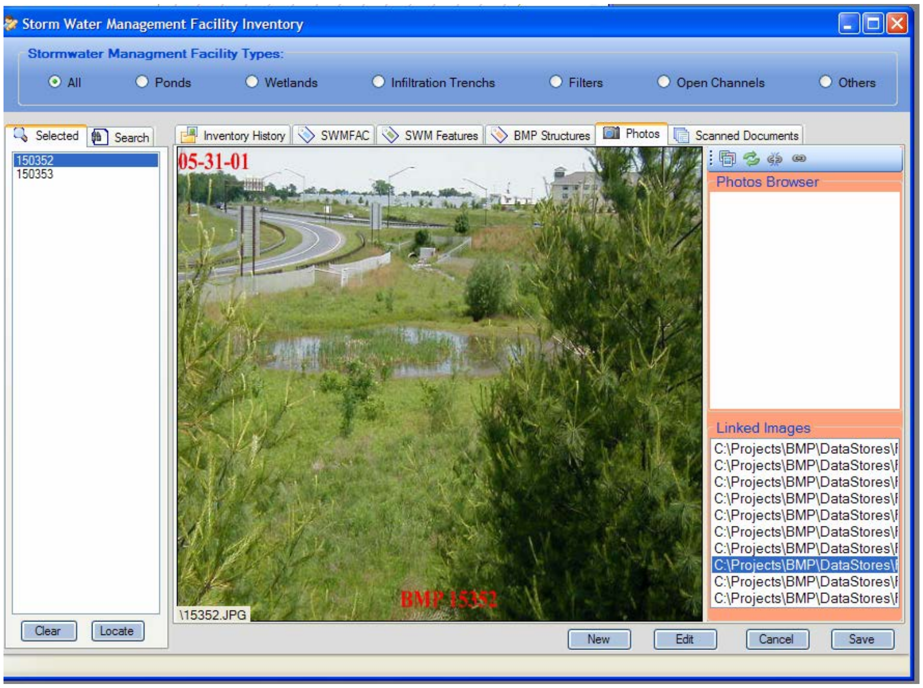


Figure 6.61 – Facility Inventory Photos

6.4.5.2 Conveyance (SDOIP)

The following figure (6.62) shows Inventory form that is associated with the conveyance layer once that layer is activated in the map view and has features selected. The Inventory History lists related structures, pipe or ditch data, and metadata information.

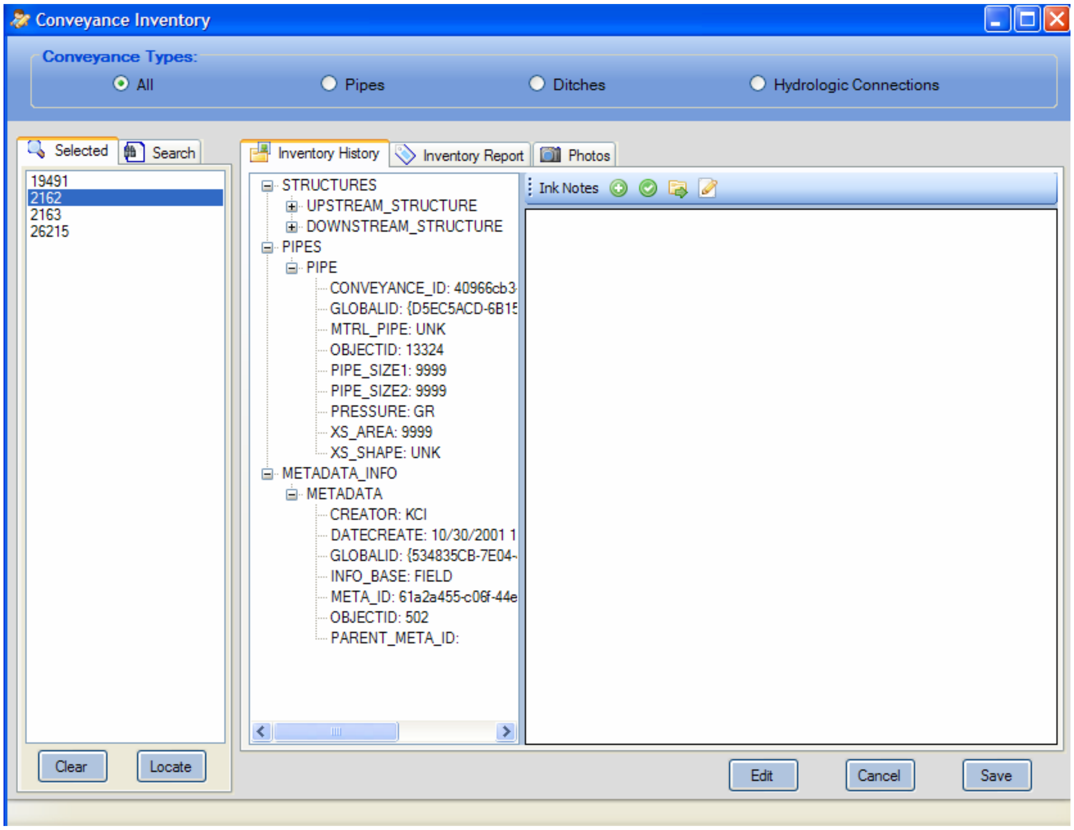


Figure 6.62 – Conveyance Inventory History

The Inventory Report (Figure 6.63) contains attribute information for the selected conveyance. The third tab on the bottom of the form will change based on whether the conveyance is a pipe or ditch.

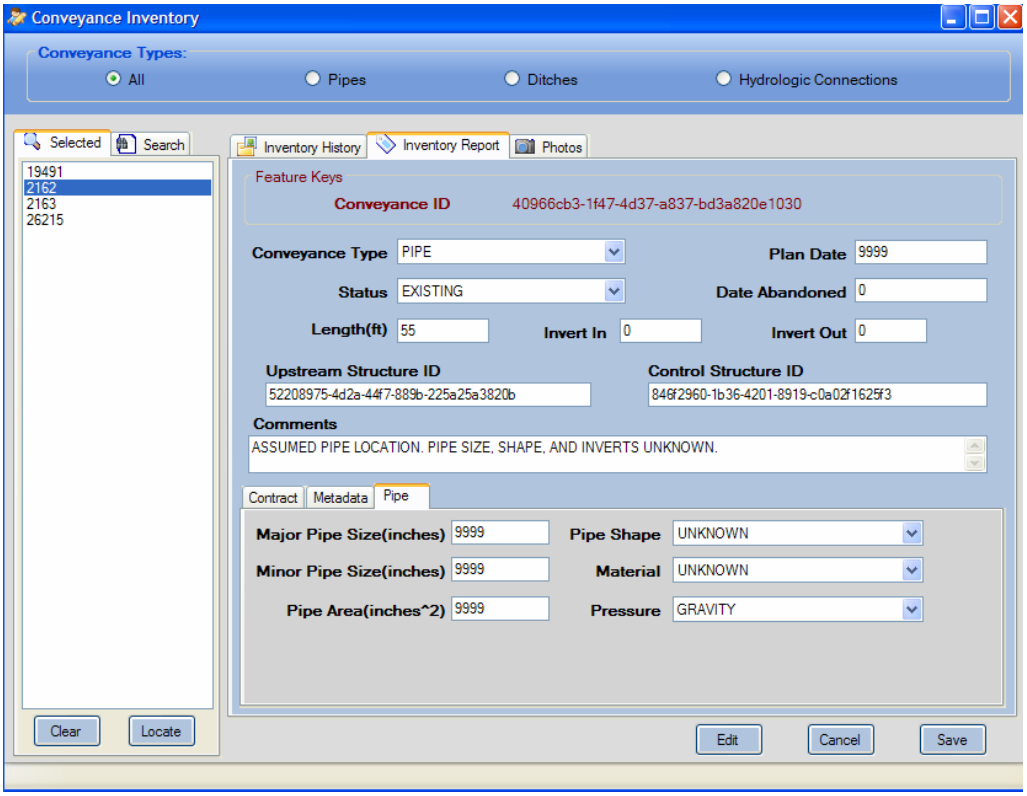


Figure 6.63 – Conveyance Inventory Report

6.4.5.3 Structure (IDDE)

The following figure (6.64) shows Inventory form that is associated with the structure layer once that layer is activated in the map view and features have been selected. Across the top of the dialog, the user can choose between different structure types that will filter the selected list.

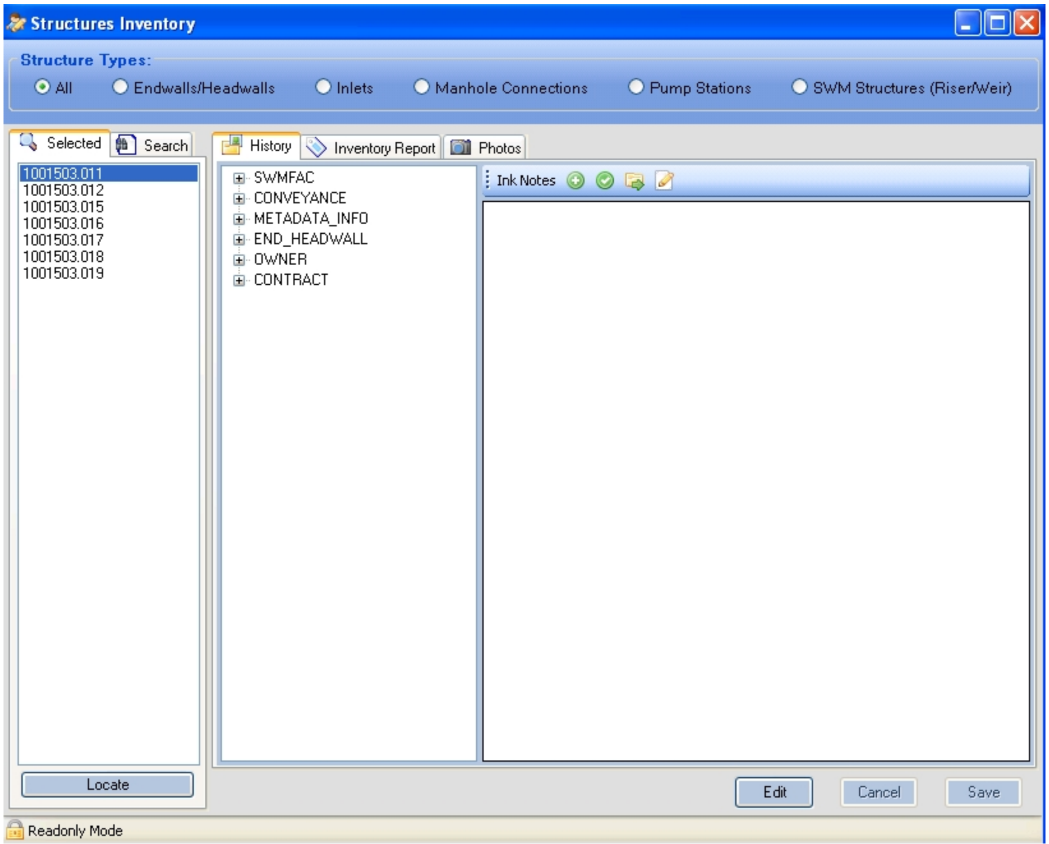


Figure 6.64 – Structures History

The next figure (6.65) is the Inventory Report containing attribute information for the selected structure. The last tab on the bottom of the form will change based on whether the structure is a endwall/headwall, inlet, manhole, pump station or a riser/weir.

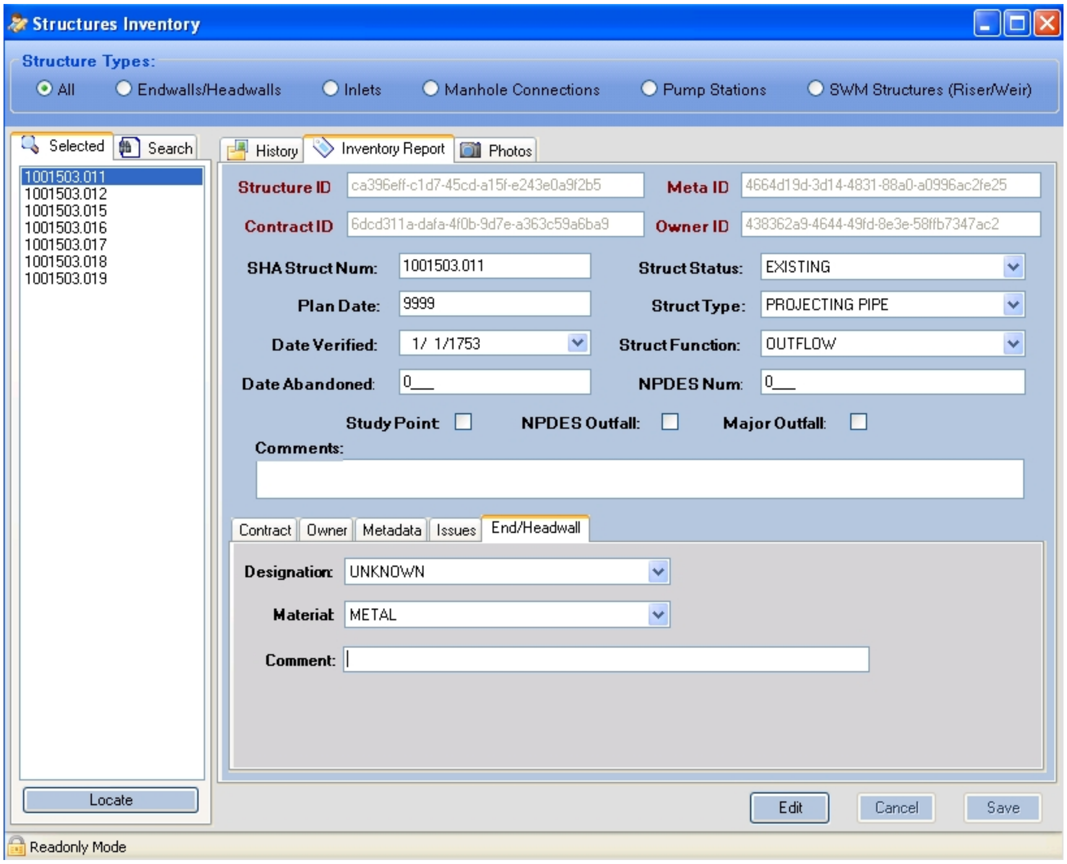


Figure 6.65 – Structures Inventory Report

6.4.6 Inspection Interfaces

6.4.6.1 BMP (Stormwater Management Facility)

Figure 6.66 is a graphic showing the Inspection form for facilities. Once a facility is selected on the left, the field crew can click New and begin capturing information for that feature. The first tab is History which contains BMP, contract, owner, and metadata information.

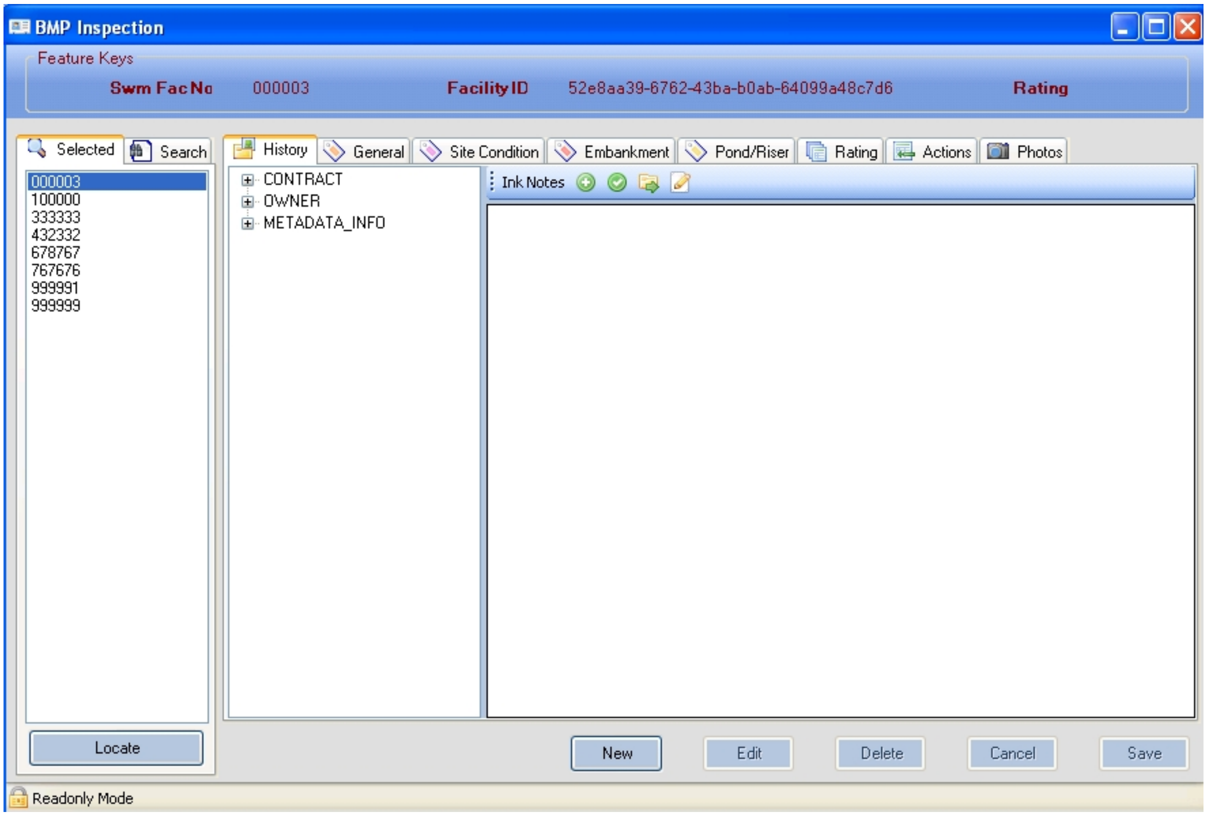


Figure 6.66 – BMP Inspections History

Figure 6.67 contains inspection date, type, location, SHA response, comments, whether the feature is a occupational hazard, context, etc.

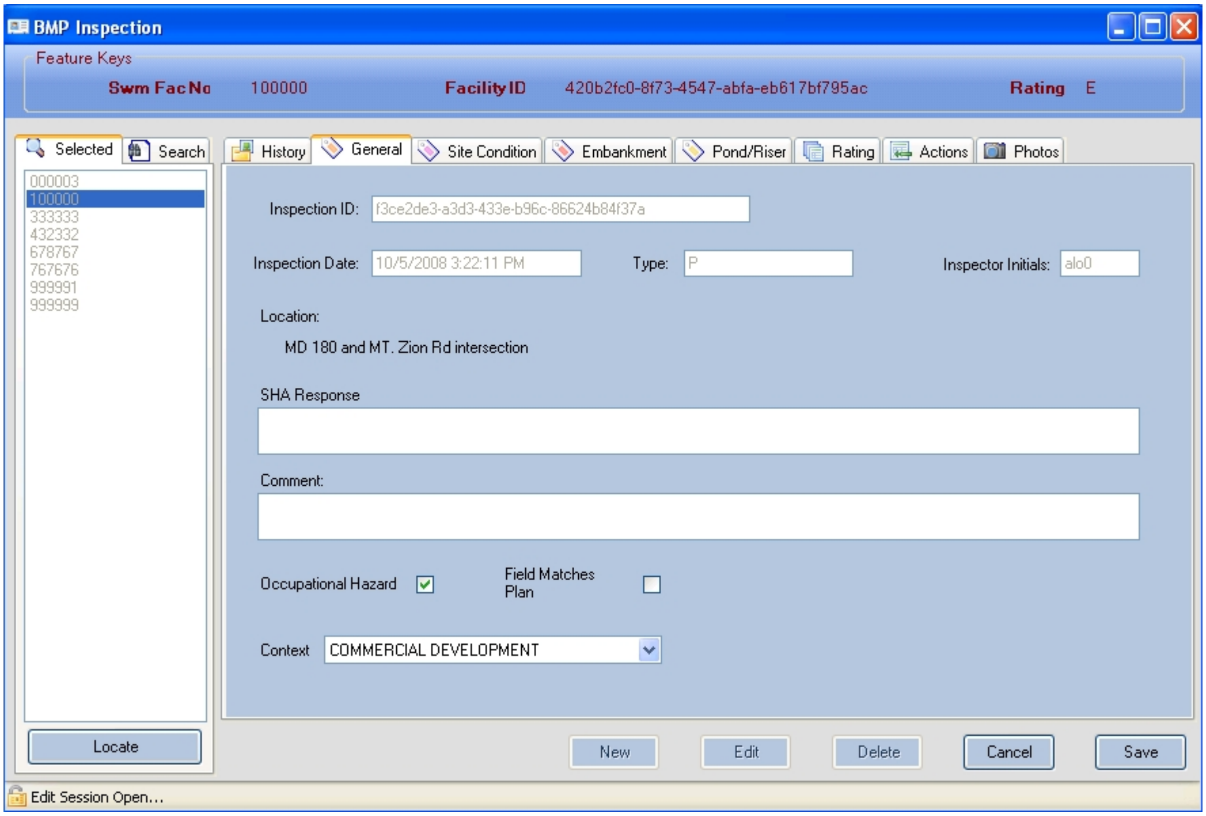


Figure 6.67 – BMP Inspections General

Figures 6.68 through 6.70 display site condition, embankment, pond/riser ratings from 0 – 5 and NR. Figure 6.71 contains the overall rating for the facility.

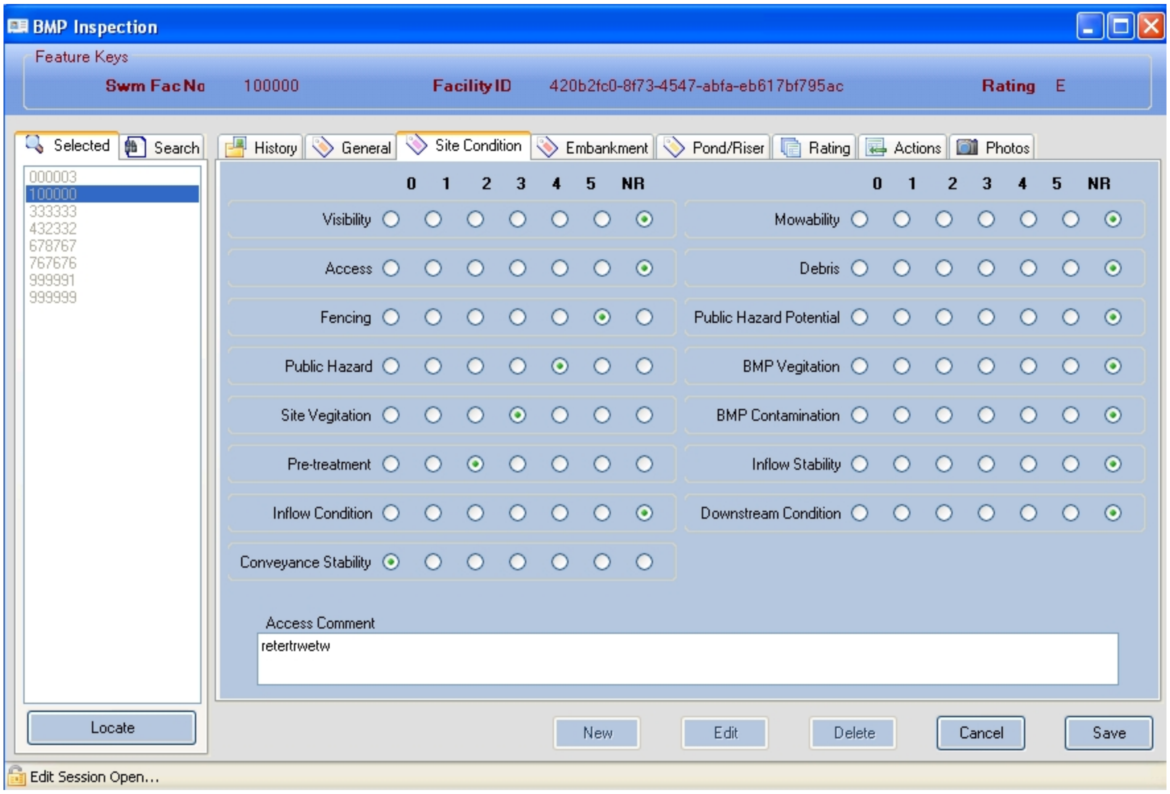


Figure 6.68 – BMP Inspections Site Condition

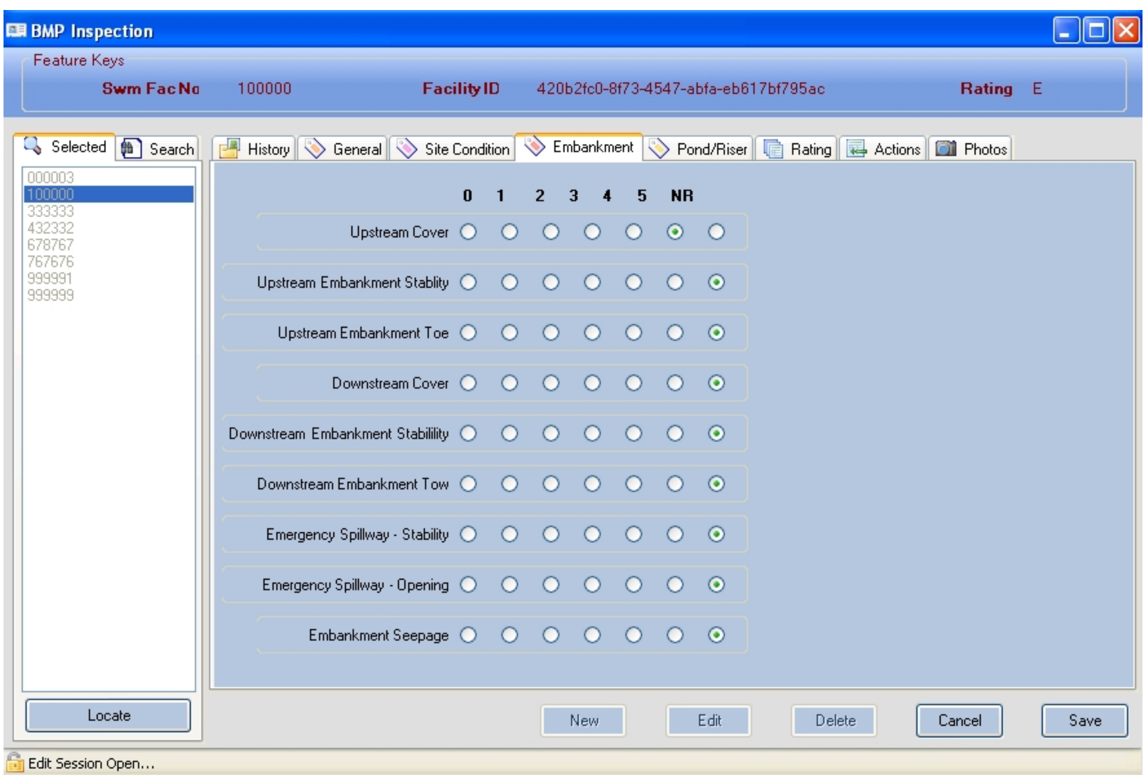


Figure 6.69 – BMP Inspections Embankment

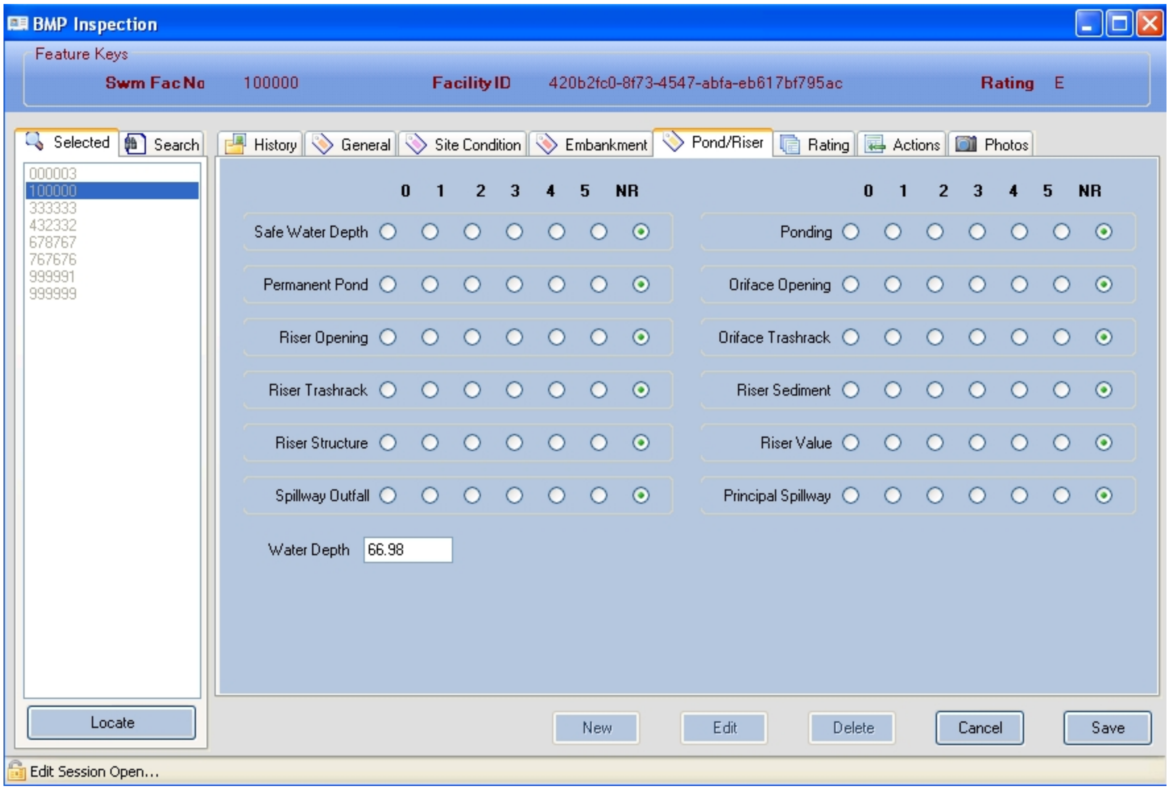


Figure 6.70 – BMP Inspections Pond/Riser

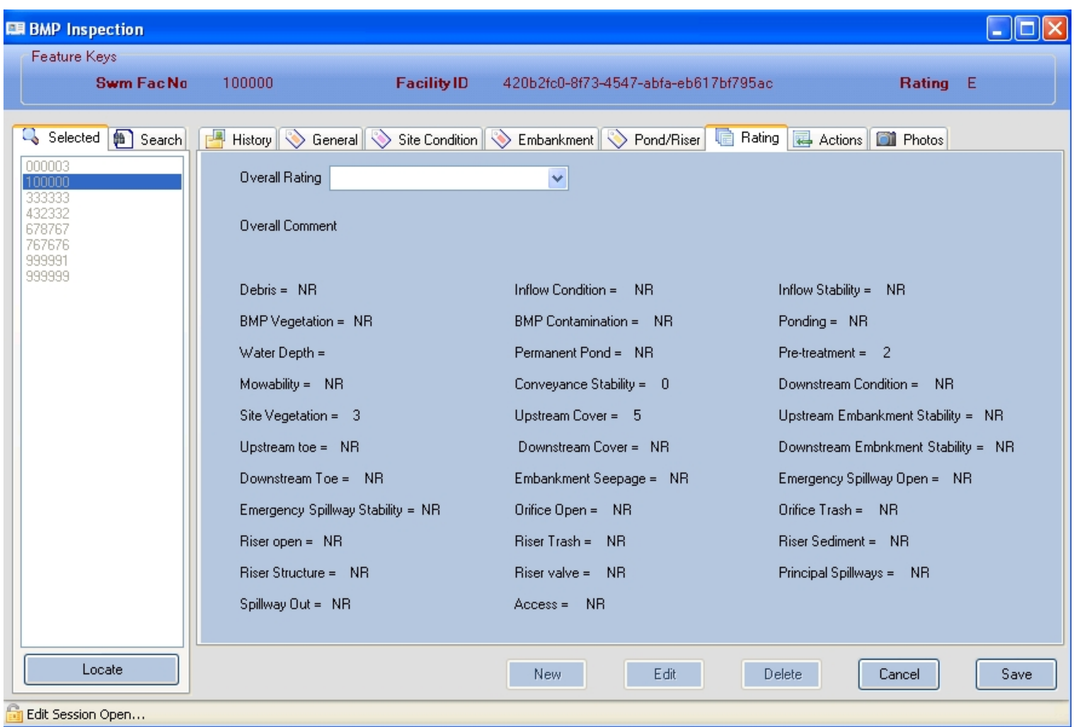


Figure 6.71 – BMP Inspections Rating

The Actions tab, shown in Figure 6.72, allows the field crew to choose an Action Type from the text box, then choose a Location. Once the action type and location are highlighted, the user can add or remove them from the Action/Location area.

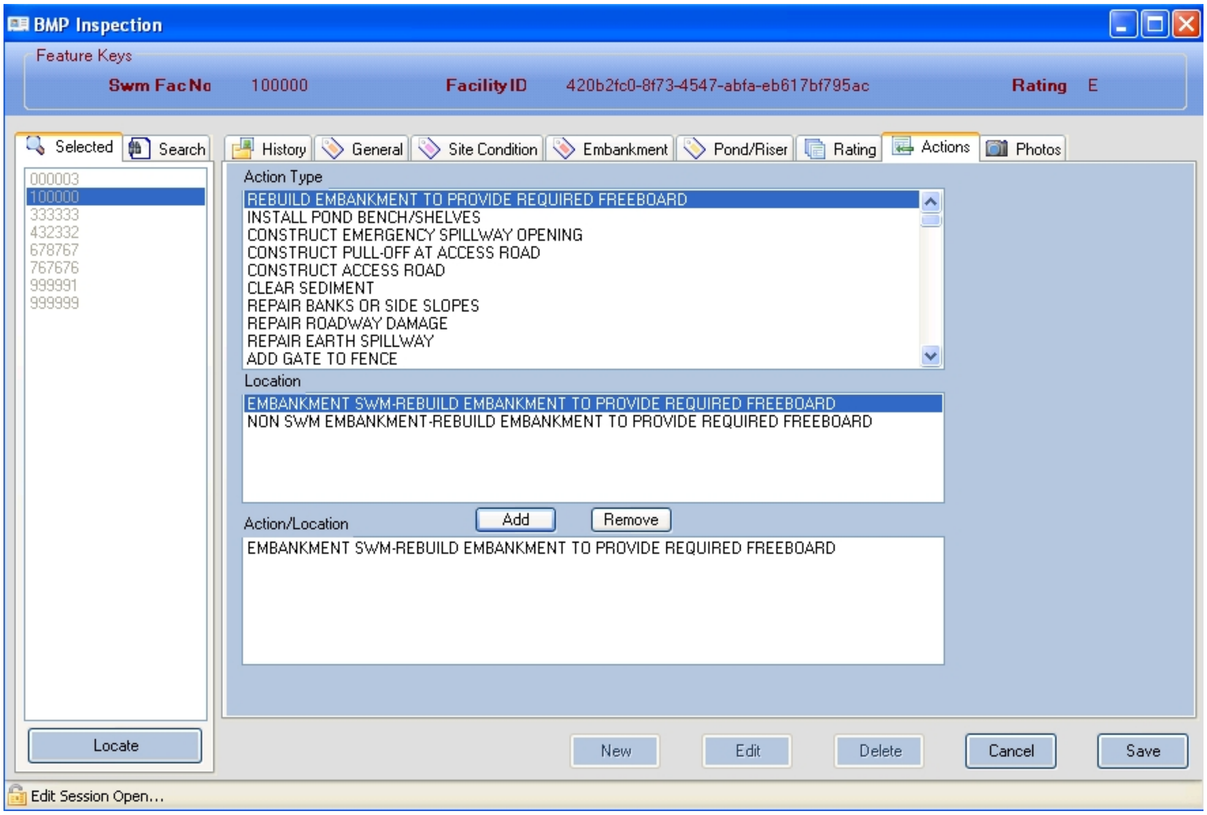


Figure 6.72 – BMP Inspections Actions

6.4.6.2 Conveyance (SDOIP)

After selecting conveyances in the Map View, the user can click the New Storm Drain Inspection button to bring up the form shown below in figure 6.73. The form lists all the selected conveyances and their histories. The history includes contract, structures, pipes, metadata, and pipe inspection information.

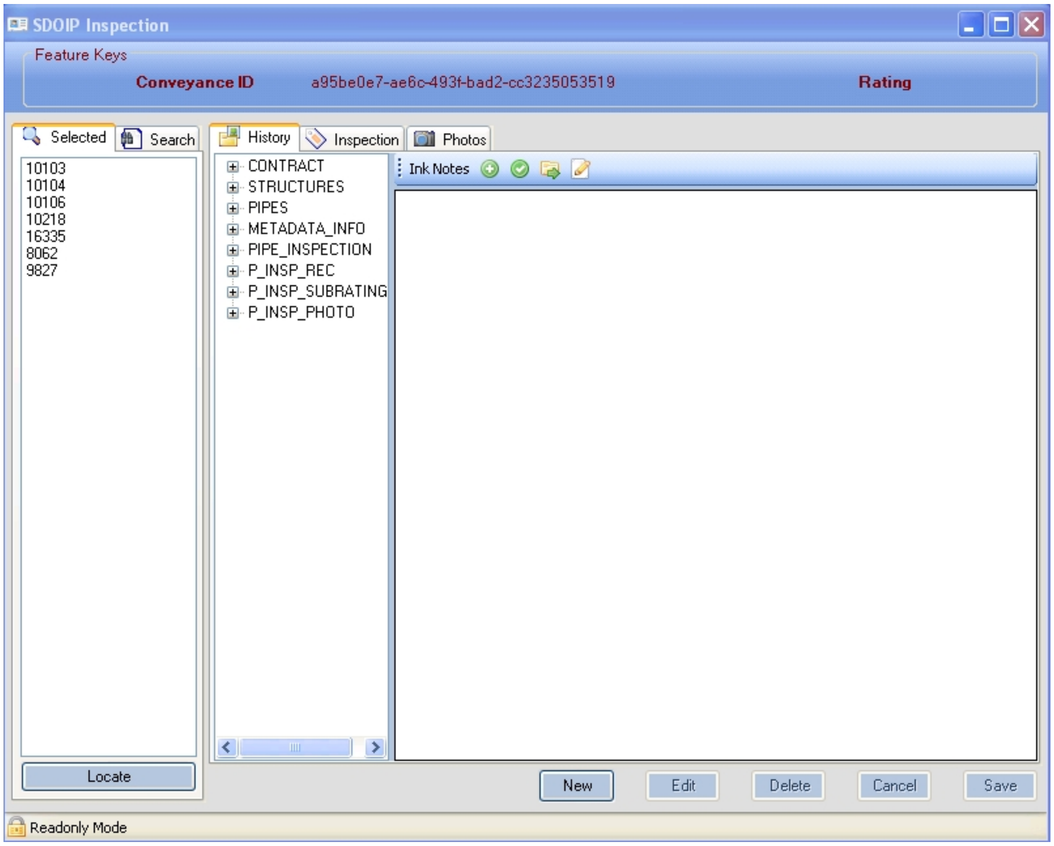


Figure 6.73 – Conveyance Inspection History

The final two tabs on the conveyance inspection form is Inspection and Photos (Figure 6.74). The Inspection tab contains pipe information, such as size, material, inspection date, ratings, and comments. The Photo tab allows the crew to load photos taken in the field or review photos related to a pervious inspection.

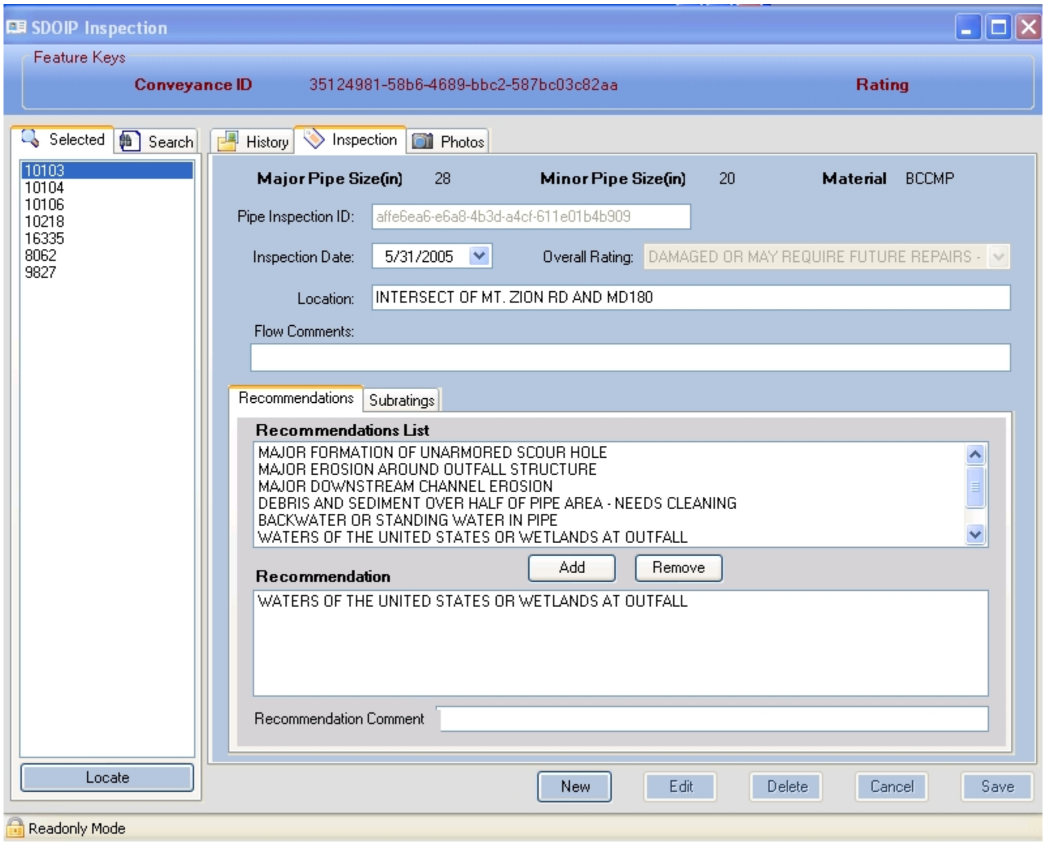


Figure 6.74 – Conveyance Inspection

6.4.6.3 Structure (IDDE)

Figure 6.75 shows a new Inspection being performed at the highlighted structure shown on the left side of the graphic. Once the field crew clicks New at the bottom of the screen, an edit session begins and the user can now add inspection information related to the selected structure.

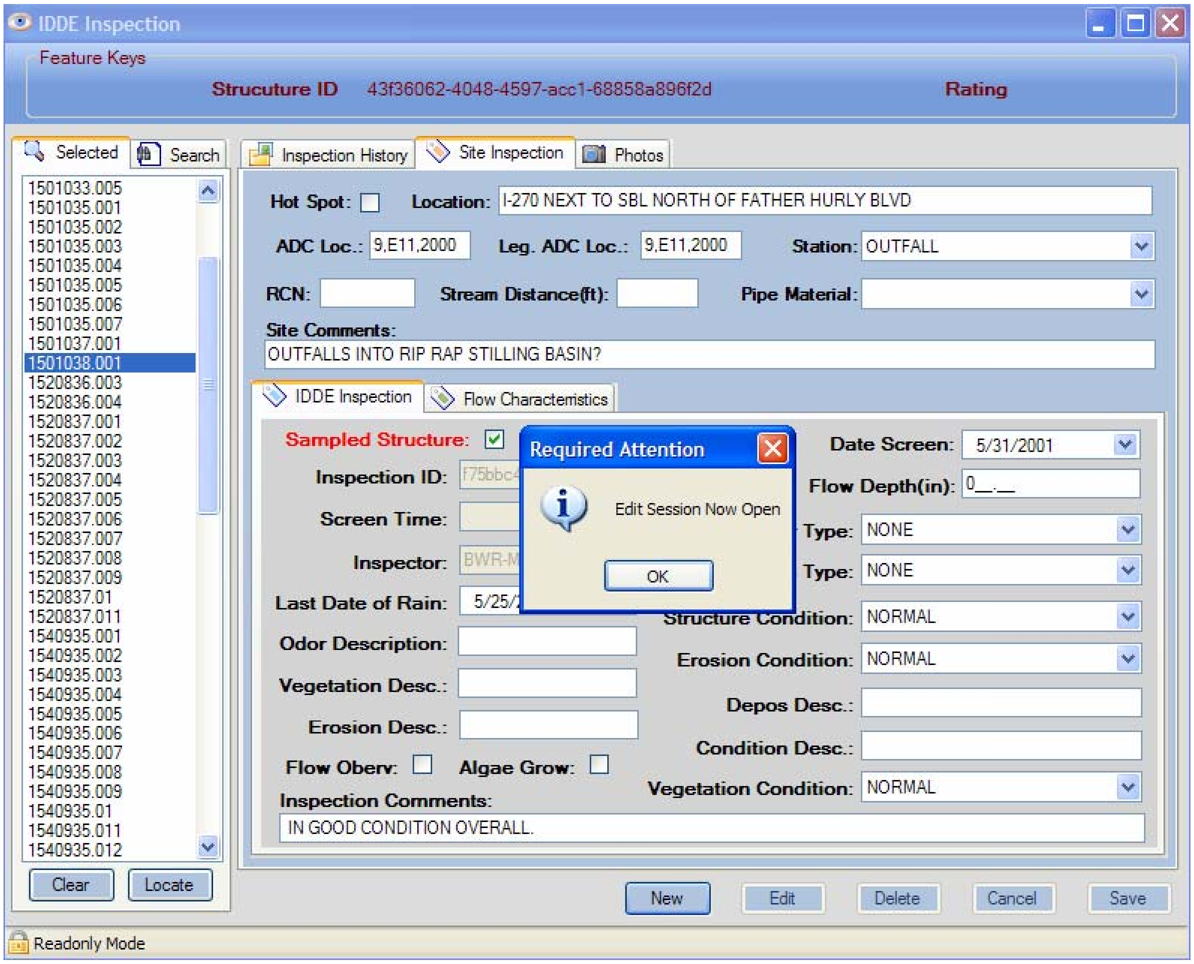


Figure 6.75

The next figure (6.76) shows the different attribute information field crews can collect during the Site Inspection.

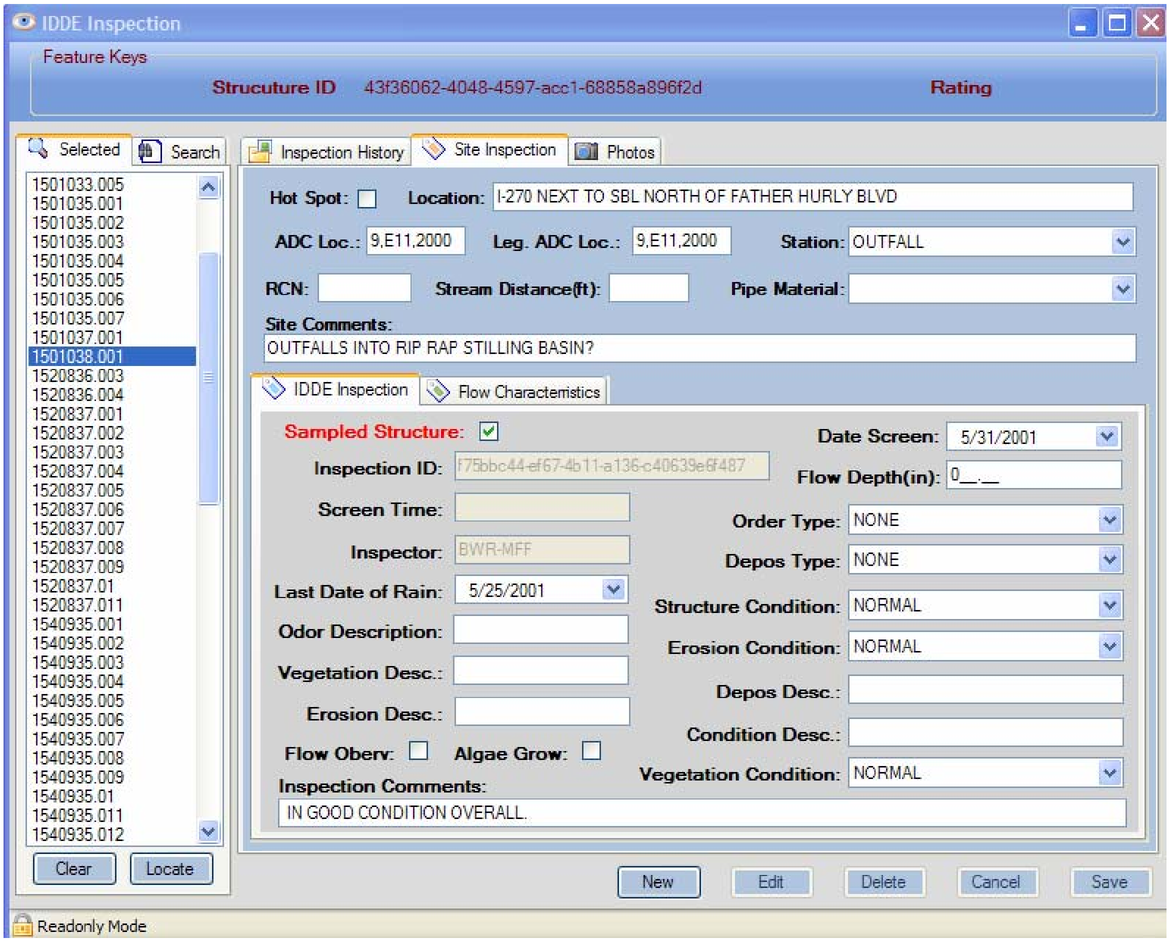


Figure 6.76

Once the field crew creates an inspection, a new tab is added to the Inspection dialog called the Structure Locator shown in Figure 6.77. The user can click on the upstream/downstream conveyance to zoom to the structure.

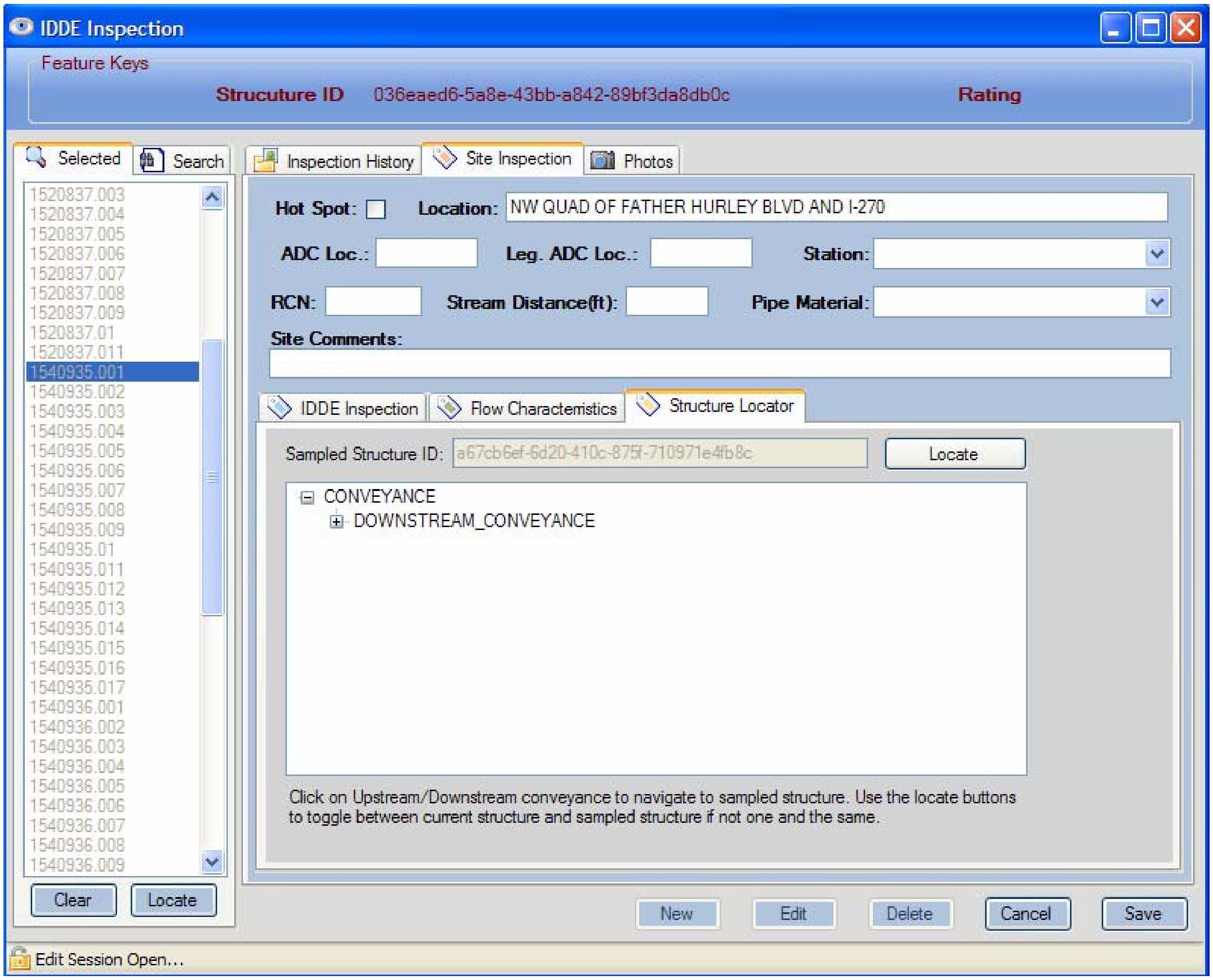


Figure 6.77

The final figure for the structures inventory shown below is an example of how the structure locator interacts with the map display. The user can toggle between the upstream or downstream conveyance as shown highlighted in red in figure 6.78.

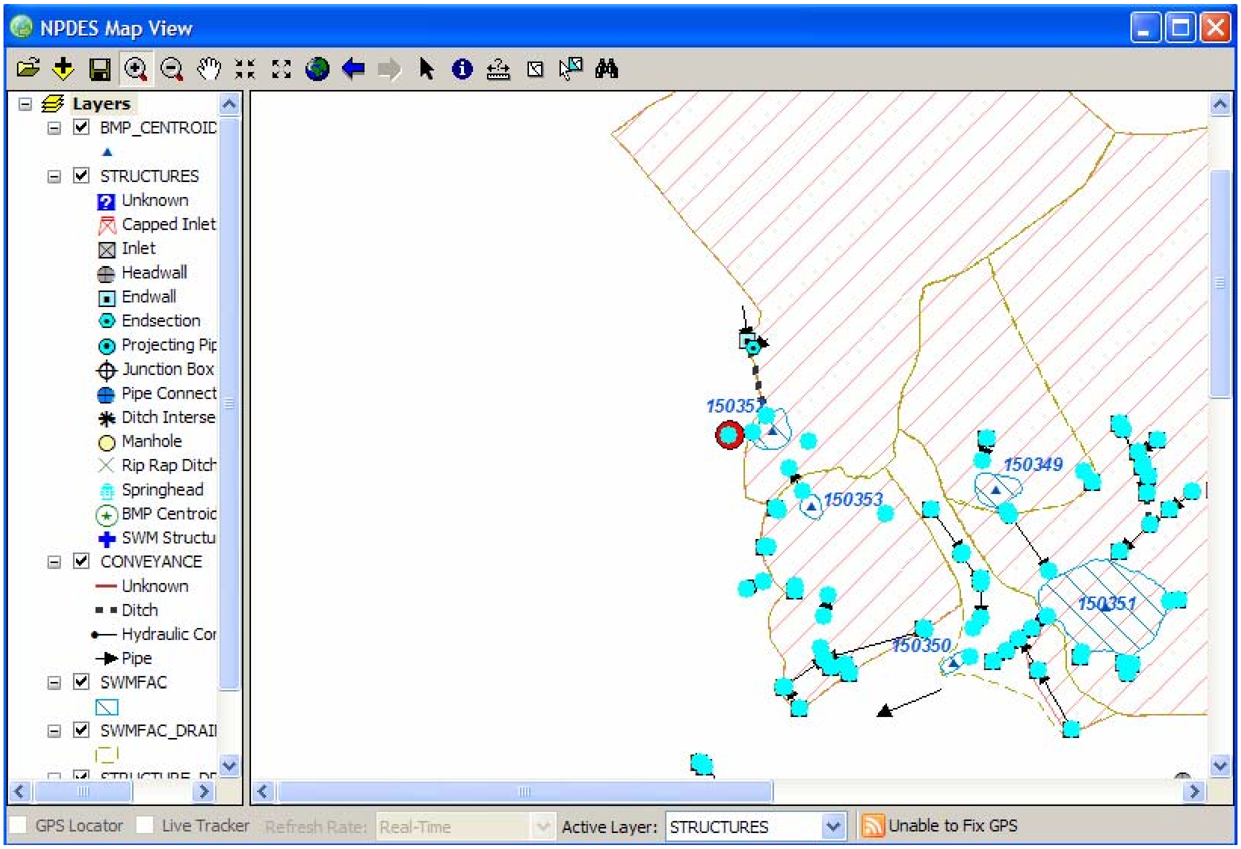


Figure 6.78

6.4.7 GPS Interface

Figure 6.79 shows the GPS Controller dialog used to connect the application with the GPS receiver. The user can click the Detect button, which will then scan the active ports on the toughbook machine. Once it finds the port being used with the receiver, the bottom left part of the dialog will switch to "Found device….connected status". The user can also view which satellites they are locked on and their signal strength. The GPS Properties tab displays baud rate and other GPS settings.

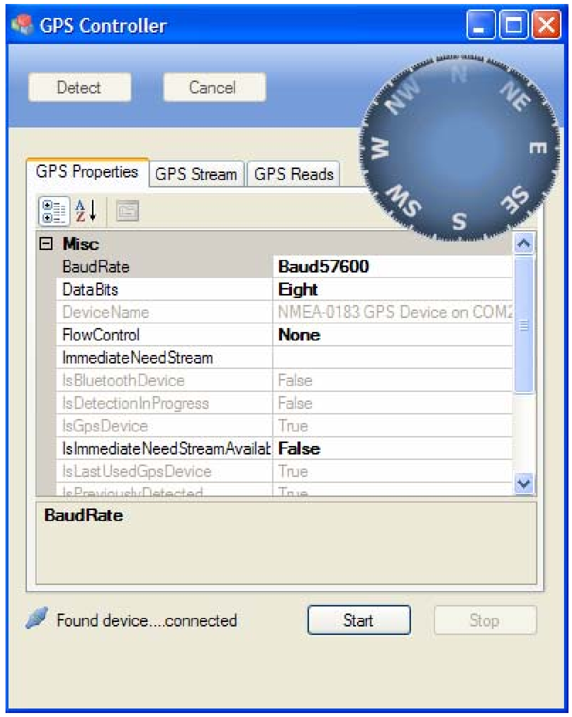


Figure 6.79

Figure 6.80 shows the GPS Stream tab on the GPS Controller dialog.

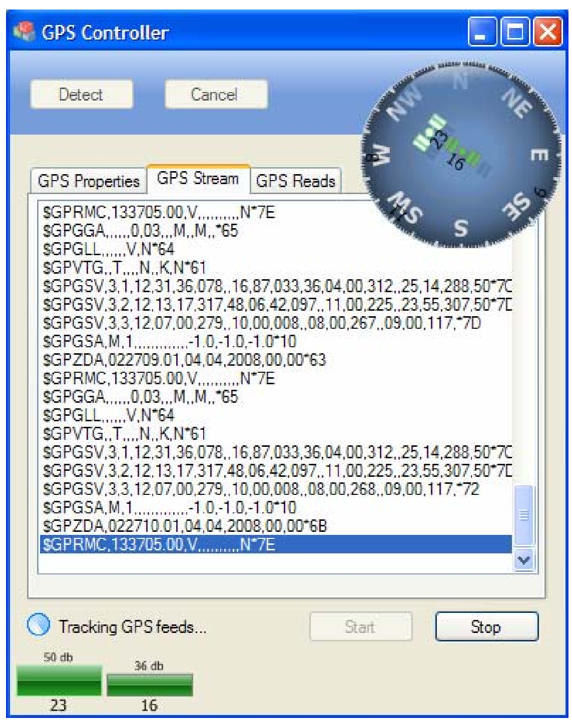


Figure 6.80

Figure 6.81 shows the GPS Reads tab on the GPS Controller dialog. This allows the user to view the current location and displays the x,y coordinates, status, gps quality, etc.

Figure 6.81

6.4.8 User Settings

Figure 6.82 shows the environmental settings that need configured prior to the field crews first use of the application. Once the correct paths, inspector initials, and company code are set and saved, the environment settings will not need to be configured again.

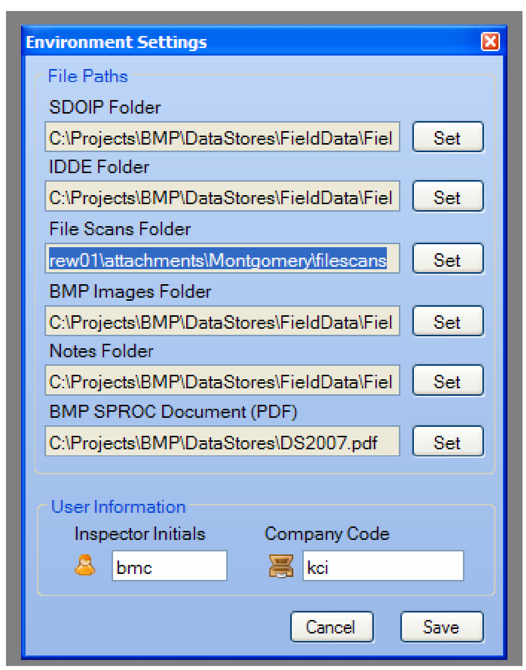


Figure 6.82

6.5 Special Spatial Editing

6.6 NPDES Viewer

6.7 Quality Assurance/Quality Control

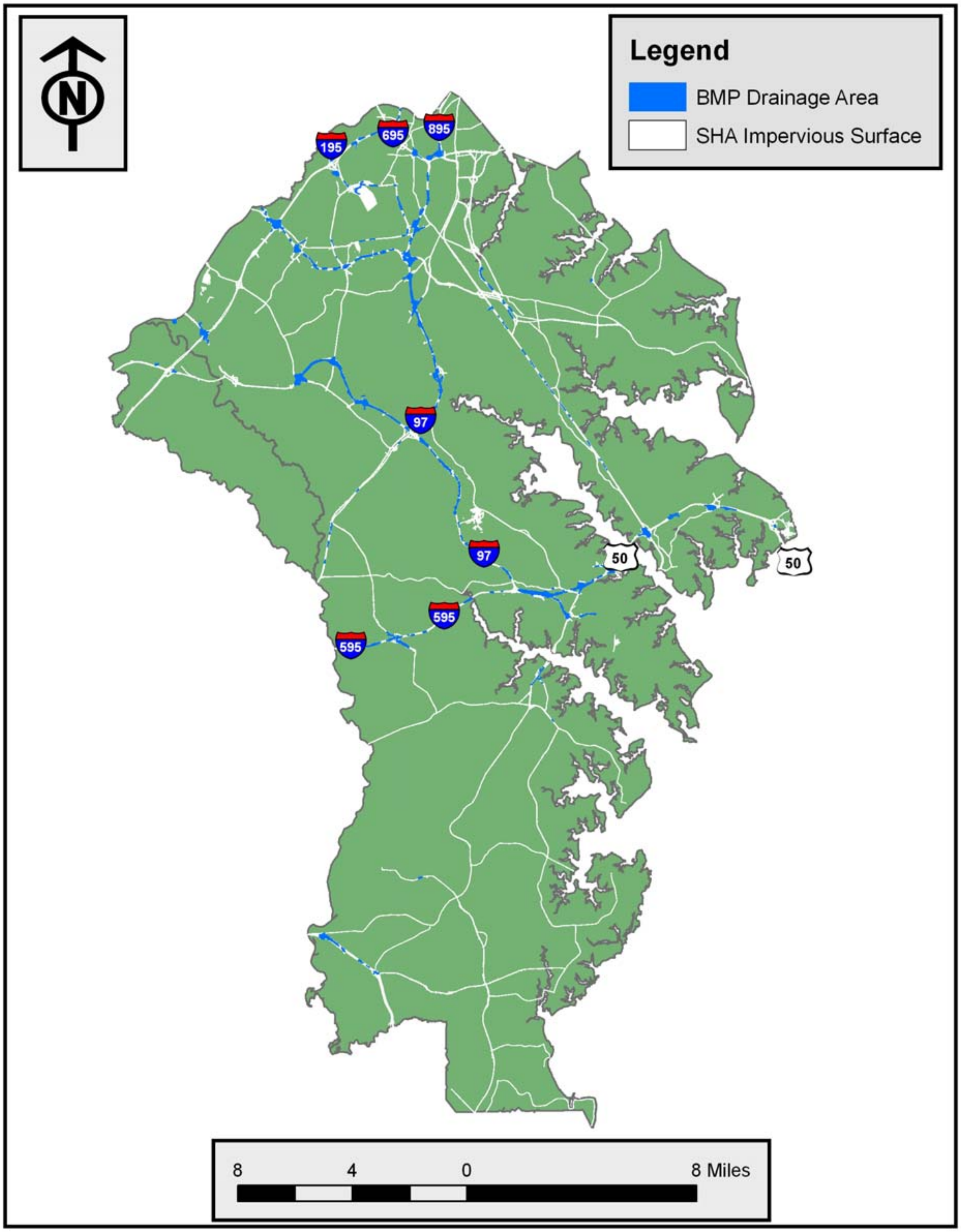
6.8 MDE Data Export

APPENDIX D:

Examples of Impervious Layers

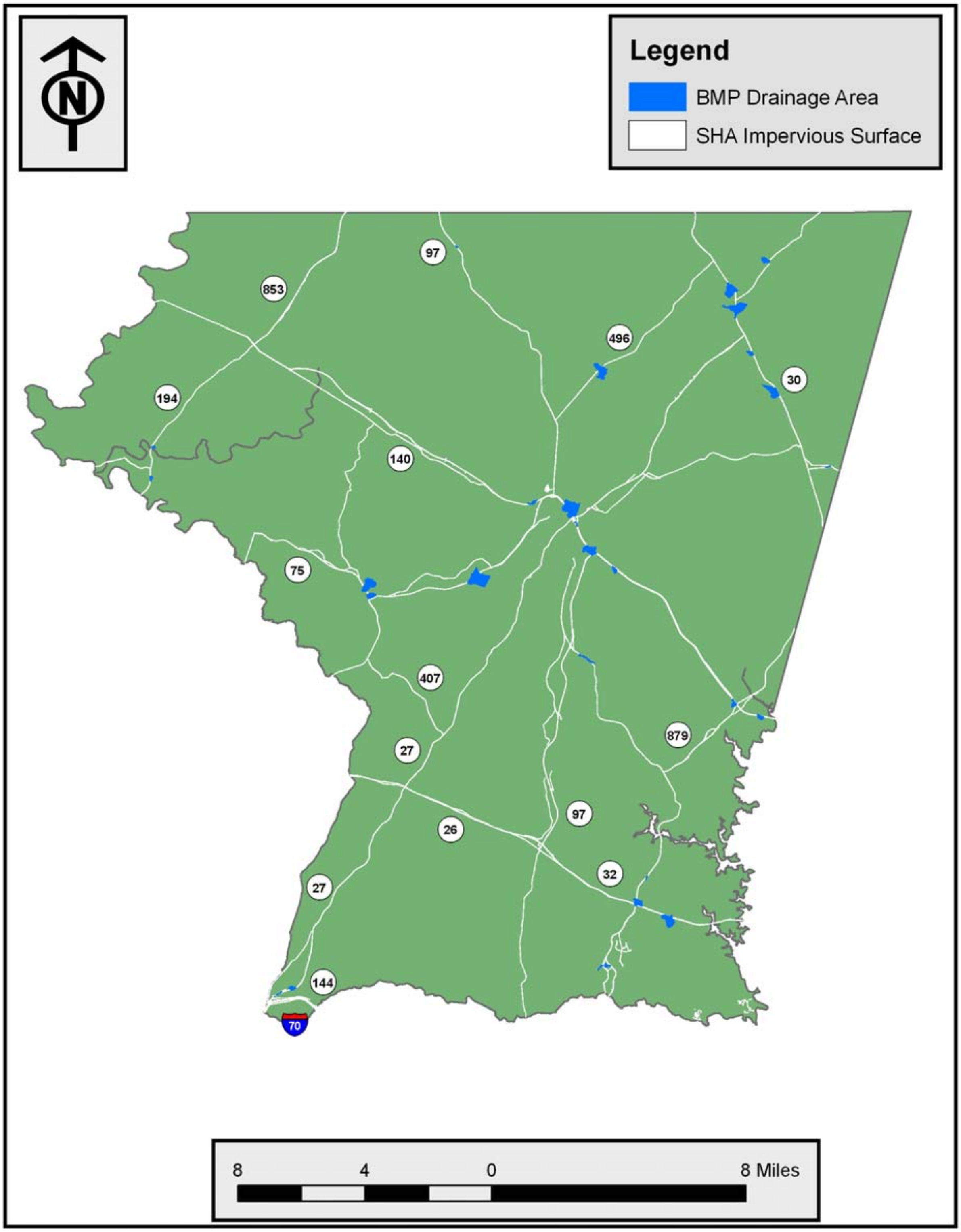
Anne Arundel County
Carroll County
Charles County
Frederick County
Montgomery County

EXAMPLES OF IMPERVIOUS SURFACES



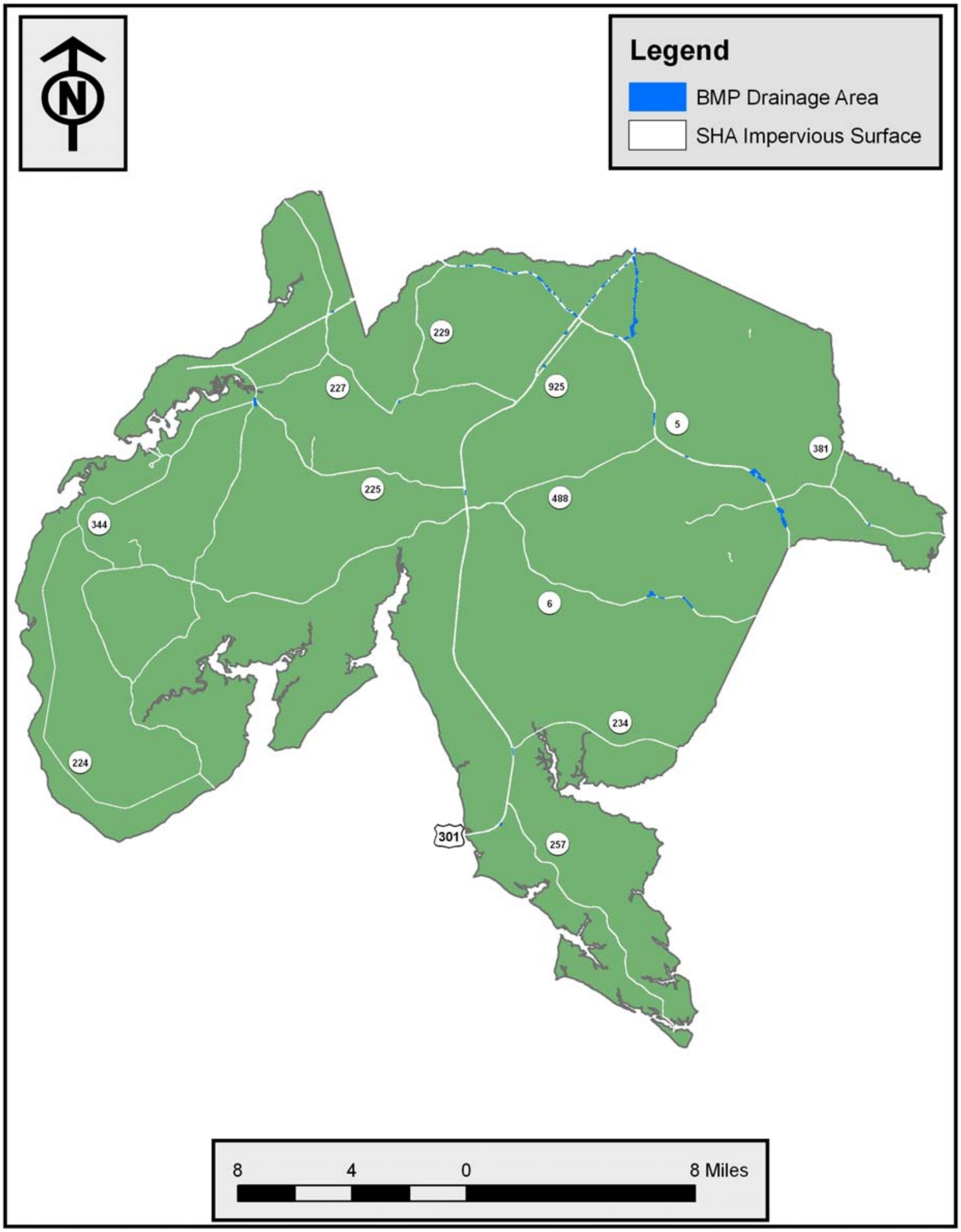
SHA-OWNED IMPERVIOUS SURFACES IN ANNE ARUNDEL COUNTY

EXAMPLES OF IMPERVIOUS SURFACES



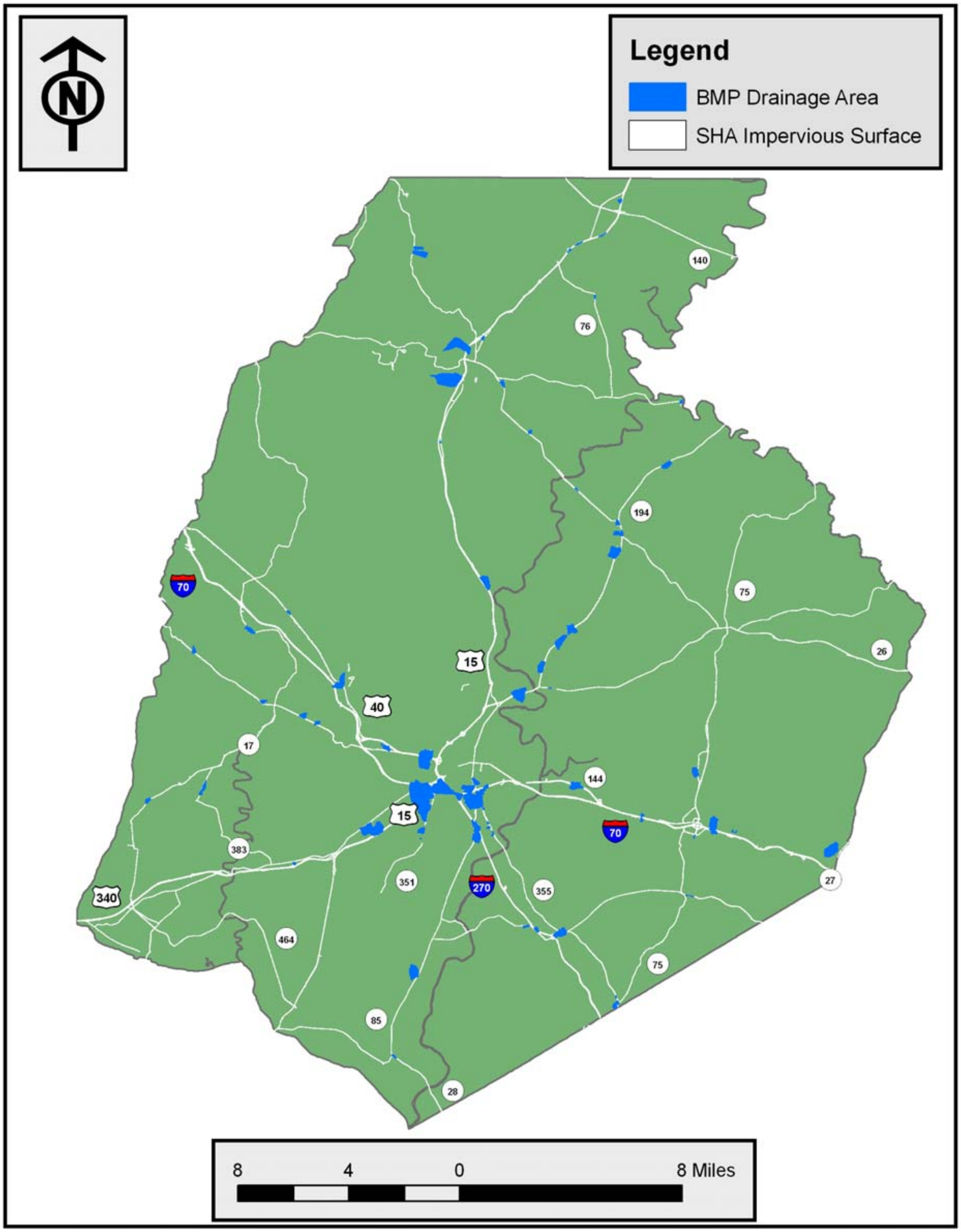
SHA-OWNED IMPERVIOUS SURFACES IN CARROLL COUNTY

EXAMPLES OF IMPERVIOUS SURFACES



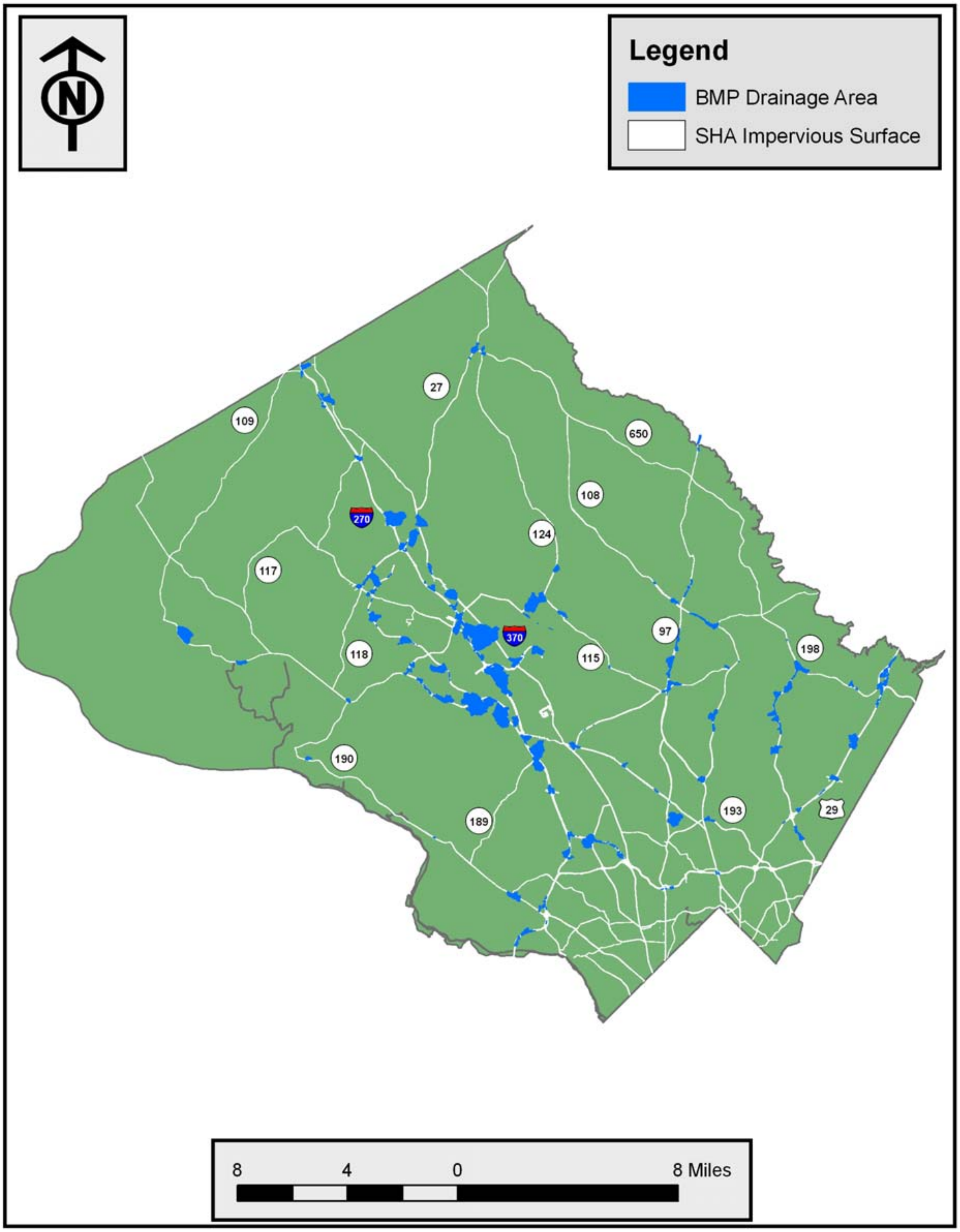
SHA-OWNED IMPERVIOUS SURFACES IN CHARLES COUNTY

EXAMPLES OF IMPERVIOUS SURFACES



SHA OWNED IMPERVIOUS SURFACES IN FREDERICK COUNTY

EXAMPLES OF IMPERVIOUS SURFACES



SHA-OWNED IMPERVIOUS SURFACES IN MONTGOMERY COUNTY

EXAMPLES OF IMPERVIOUS SURFACES

APPENDIX E:

Grass Swale Pollutant Removal Efficiency Studies – Part III

Progress Report
October 6, 2008

Progress Report: Grass Swale Pollutant Removal Efficiency Studies

Field Evaluation of Hydrologic and Water Quality Benefits of Grass Swales with Check Dams for Managing Highway Runoff.

Project Duration: August 2006 – August 2008

Project Sponsor: Karen Coffman
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Report Date: October 6, 2008

Table of Contents

Table of Contents…………………………………………………………………..5
Executive Summary ………………………………………………………………….iv
Chapter 1
INTRODUCTION……………………………………………………………. …8

Chapter 2 LITERATURE REVIEW……………………………………………..8
2.1 Stormwater Runoff Characterization……………………………………...14
2.1.1 Total Suspended Solids (TSS)…………………………………..15
2.1.2 Nutrients………………………………………………………15
2.1.3 Chloride...10
2.1.4 Heavy Metal…………………………………………………10
2.2 Grass Swale Mechanisms……………………………………………..11
2.3 Grass Swale Performance…………………….......................................11
2.3.1 Total Suspended Solids (TSS)…………………………………12
2.3.2 Nutrients……………………………………………………….16
2.3.3 Chloride……………………………………………………..17
2.3.4 Heavy Metals…………………………………………………..18
2.4 Performance of Grass Swale with Check Dams…………………………20
2.5 Grass Swale Specification Design for Pollution Control…...……………22
2.6 Pollutant Mass Loads during Rain Events………………….…………24
2.7 Toxicity of Urban Highway Runoff with Respect to Storm Duration…...25

Chapter 3 METHODOLOGY……………………………………………..27
3.1 Site Description……………………………………………………..27
3.2 Monitoring Equipment and Protocol…………………………………….32
3.3 Analytical Methodology & Procedures………………………………….33
3.3.1 Total suspended Solids (TSS)………………………………….34
3.3.2 Phosphorus……………………………………………………..34
3.3.3 Nitrite……………………………………………………….....34
3.3.4 Nitrate and Chloride……………………………………………35
3.3.5 Total Kjeldahl Nitrogen (TKN)………………………………..35
3.3.6 Metals : Copper, Lead, Zinc, Cadmium………………………..35
3.4 Quality Assuarance (QA) and Quality Control (QC)……………………36
3.5 Flow Calculation…………………………………………………………36
3.6 Hydrology Data Evaluation and Calculations……………………………38
3.6.1 Infiltration through the Swale………………………………….39
3.6.2 Total Grass Swale Discharge, Q_{swale} (Effective Flow)………...41
3.6.3 Total Storm Volume……………………………………………...42
3.7 Pollutant Data Evaluation and Calculations……………………………..42
3.7.1 Total Mass Load………………………………………………43
3.7.2 Event Mean Concentration (EMC)…………………………….43
3.7.3 Effective Event Mean Concentration (E-EMC)………………..44

3.8 Statistical Analysis……………………………………………………….44
3.8.1 Overall Statistical Analysis Procedure…………………………45
3.8.2 Dixon-Thompson Test for Outliers……………………………47
3.8.3 Wilcoxon-Mann-Whitney U Test…………………………...48
3.9 Swale Performance Plots…………………………………………...49

Chapter 4 RESULTS AND DISCUSSION…………………………………51
4.1 Field Sampling Description……………………………………...51
4.2 Hydrology Comparison………………………………………………53
4.2.1 Storm Event Characterization…………………………………53
4.2.2 Flow with Respect to Time…………………………………….58
4.2.3 Peak Flows and Lag Time……………………………………...62
4.2.4 Total Volume…………………………………………………..67
4.3 Pollutant Observations and Outliers………………………………..70
4.4 Wilcoxon-Mann-Whitney U Test and Pollutant Removal……………….75
4.5 Total Suspended Solids (TSS)…………………...……………………80
4.5.1 Total Suspended Solids (TSS) Comparison……………………81
4.6 Nutrients (Total Phosphorus (TP), Nitrite, Nitrate, TKN)……………….83
4.6.1 Total Phosphorus ……………………………………………...84
4.6.1a Total Phosphorus Comparison………………………..85
4.6.2 Nitrate, Nitrite, TKN…………………………………………..86
4.6.2a Nutrients (Nitrite, Nitrate, TKN) Comparison………..90
4.7 Chloride……………………………………………………………….92
4.7.1 Chloride Comparison…………………………………………..93
4.8 Metals (Zinc, Lead, Copper, Cadmium)………………………………94
4.8.1 Zinc…………………………………………………………….95
4.8.1a Zinc Comparison……………………………………...96
4.8.2 Lead…………………………………………………………….97
4.8.2a Lead Comparison…………………………………….98
4.8.3 Copper and Cadmium………………………………………….99
4.8.3a Copper and Cadmium Comparison………………….100

Chapter 5 CONCLUSION…………………………………………………103

Appendix A E-EMC for All Storm Events……………………………….....111

Appendix B EMC for All Storm Events…………………………………114

References……………………………………………………………….......117

Executive Summary

Managing highway runoff is a complex storm water management problem. This research is a input/output field study specifically looks into the hydrologic and water quality benefits of having grass swales with an additional pre-treatment area and incorporation of check dams for managing highway runoff at Maryland Route 32 highway. These swales manage the hydrology of the stormwater by increasing the lag time (2-3 hours), reducing the overall average peak (32-44%) and reducing the total runoff volume (4-46%). The overall mass pollutant loads are reduced for TSS (38-62%), nitrate (92-95%), nitrite (54-71%), lead (78-82%), copper (56-70%) and zinc (67-79%). On the other hand, TKN (-120 to 44%), TP (-5 to 40%) and chloride (-61 to -4%) show mass increased. Compare to previous study, swales with check dams do not show any significant improvement over swales without check dams. However, a check dam swale with a pretreatment area has higher reduction of the overall mass pollutants removal for all pollutants except for TSS.

Chapter 1

INTRODUCTION

Non-point source pollution occurs when rainfall or snowmelt runs over land or through the ground and picks up pollutants and deposits them into streams, lakes or groundwater. According to the U.S Environmental Protection Agency (EPA), non-point source pollution is the leading cause of water quality problems (USEPA 1994). Non-point sources include overland runoff from agricultural, industrial, urban areas, construction sites, roads, parking lots and other open spaces. Furthermore, Novontny and Harvey (1994) noted out that almost 50% of the total water pollution in the developed world comes from non-point source pollution.

Highway stormwater runoff is one of the significant sources of runoff pollution potentially impacting receiving water ecosystems due to the disperse nature of the pollutant pathways. Besides that, development of highways causes increase in impervious areas and indirectly reduces vegetation. Vegetation such as trees, shrubs and wetlands, intercept and store significant amounts of precipitation and reduce the erosive forces of rain and runoff. Therefore, due to more impervious surfaces, soil compaction and vegetation removal, the movement of water through the environment and the water quality will be altered. Eventually, a variety of problems may develop such as increased flooding, increased sedimentation and erosion of the receiving water body. In one study by the American Forests (1998), conversion of forest to impervious cover resulted in an estimated 1.2 billion cubic feet (29%) increase in runoff during a peak storm event and replacing this lost of stormwater retention capacity with reservoirs and other engineered systems would cost about $2.4 billion ($2 per cubic foot).

Currently, the Maryland State Highway administration (SHA) is exploring the use of Low Impact Development (LID) technologies for addressing complex stormwater management challenges. LID practices are innovative engineered systems that are design to manage stormwater by replicating the site's predevelopment hydrologic regime, incorporating design techniques that infiltrate evapotranspirate and reuse runoff (USEPA 2007).

LID technologies that have been used in many SHA designs include grass swales and grass filter strips. Swales are shallow vegetated channels that convey stormwater and grass filter strips are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Both system remove pollutants by filtration through grass and infiltration through soil prior to discharge to a downstream drainage system or receiving waters. According to Lee et al. (1998), major pollutant removal mechanisms in vegetative controls are sedimentation of suspended solids, infiltration and adsorption to plant and soil surfaces. Indirectly, from the hydrological aspect, grass swales help to reduce runoff velocities and reduce runoff peaks. However, one of the challenges associated with filter strips is the difficulty to maintain sheet flow since it is frequently dominated by concentrated flow, which results in little or no treatment of stormwater runoff. Therefore, in recent stormwater manuals, filter strips are considered as a beneficial technique for stormwater volume reduction rather than as a pretreatment practice on some of the sites (MDE 2000). Moreover, in order to increase the detention time of the water on the swales, check dams are often installed within the grass swale. This will allow more time for the water to infiltrate.

Figure 1. Grass swale with filter strip located on Maryland Route 32

Swales are relatively easy to design and maintain, and aesthetically appealing, especially for highway use. For some sites, it could be the most cost effective treatment technique. Figure 1 shows an example of grass swale with filter strip. The major difference between swales and other stormwater treatment practices such as gutters and detention ponds are the method used to size the treatment. Most of the stormwater treatment practices are sized by volume of runoff but swales on the other hand are design based on flow rate. For flood control purposes, it is required that the stormwater practice are able to reduce the peak flows for at least 10 year storm events (Claytor and Schueler 1996) and for channel protection, the stormwater practice needs to be design to reduce the peak flows for at least 1.5-year to 2-year storms (Schueler 1987, Rosgen 1996). A project to specifically study the effects of grass swale drainage by Kercher et al. (1983) measured a significant decrease in runoff from the swales in comparison to curb and gutter system. This is an advantage since less area is needed for the downstream stormwater detention ponds. Among the thirteen rain events that were monitored, the grass swale area only produced runoff during three events compared to every event by the curb and gutter area. In the same report, it was indicated that they could save AU$6100 if they construct and maintain the grass swale. The traditional curb and gutter system would cost AU$13,000 (net present value over 25 years).

Pollutant removals by swales are considered site specific and swale performance is highly depends on grass cover (type, density), type of soil, runoff quality and channel design. Yousef et al. (1987) recommended that grassed swales should be regarded as primary stormwater treatment facilities that convey stormwater to secondary treatments such as detention basins and wetlands. Currently, the information on water quality improvements for swales is limited and inconsistent as a result of the complexity of swale operation. In general, swales are effective in removing large particles such as suspended solids but during intense storms, settled particles are potentially subject to resuspension, resulting in net export of pollutants, especially for nutrients (Yu et al. 2001).

This research project site has been constructed on Maryland Route 32 near Savage, Maryland that consists of two individual swales with different designs but nearly identical roadway drainage areas. The monitoring location is the same as the previous study by Stagge

2006 where two swales are constructed in the median of a four-lane (two in each direction) limited access highway which receives runoff laterally from the southbound roadway lanes. The first swale has a sloped grass pretreatment area adjacent to the roadway and the second swale was identically constructed but without the pretreatment area. On each of these swales, two vegetated check dams were installed. Both swales convey to an inlet where water flow and quality measurements are made. Comparison between input vs output is done by having direct as the input and swales as the output. Ten target pollutants that are considered as being most problematic from highway runoff are monitored, specifically total suspended solids (TSS), nitrate-N, nitrite-N, total Kjeldahl nitrogen (TKN), total phosphorus (TP), chloride (Cl), copper (Cu), lead (Pb), zinc (Zn), and cadmium (Cd). In total, 24 storm events were analyzed over a period of 2 years. Since both swales convey to an inlet where water flow and quality measurements are made, input vis- a-vis output study is done by having direct as the input and swales as the output. A goal of sampling one storm event per month was established.

Stagge (2006) investigated 22 storm events over a period of 1.5 years, with 18 storm events containing associated pollutants data. His results showed significant peak reduction (50-53%), delay of the peak flow (33-34 min) and reduction of total runoff volume (46-54%). Statistically, the grass swales exhibited significant removals, represented by the Event Mean Concentration (EMC) of total suspended solids (41-52%), nitrite (56-66%), zinc (30-40%), lead (3-11%), copper (6-28%) and cadmium. Cadmium removal is difficult to quantify since most of the effluents are below the detection limit. On the other hand, nutrients such as nitrate, TKN and total phosphorus exhibited variable removal capabilities ranging from -1% to 60%. The negative sign shows that the swales are actually exporting the pollutant into the runoff. The swales also exported chloride at a significant level (216 – 499 mg/L). Stagge (2006) concluded that the pretreatment grass filter strip shows no significant water quantity or quality improvement and that the swale itself is the most important treatment mechanism.

The focus of this study is to investigate the effectiveness of vegetated check dams on swale performance. This study has four objectives. First is to study the overall efficiency of grass swales with native check dams on roadway runoff pollutant removal and peak runoff reduction. Second, is to examine at the effect of the shallow sloped grass pre-treatment area adjacent to the grass swale. Third, is to compare the effectiveness of swales with native check dams with swales that do not have any check dams. Research regarding the effectiveness of swales without check dams was previously completed at the same site by Stagge (2006). Fourth, is to provide a comprehensive literature review on grass swale performance.

In order to reach those objectives, two hypotheses are made. First, the pretreatment area prior to the grass swale is helping by slowing runoff velocities, providing more infiltration into underlying soils and filtering out sediment and other pollutions. Second, by having check dams within the grass swales, temporary ponding areas within swale will be created, runoff velocity will be reduced and indirectly, the retention time will be increased and eventually promote more infiltration through the soil and filtration through the grass swale.

In short, this research will quantify the importance of the pretreatment area prior to the grass swale and the importance of having check dams within the grass swales. It will then assist the SHA in providing the best management practices adjacent to their highways in order to manage stormwater runoff.

Chapter 2

LITERATURE REVIEW

2.1 Stormwater Runoff Characterization

Highway runoff consists of major water quality constituents that are summarized in Table 2-1 together with their common expected concentration. According to the National Cooperative Highway Research Program (NCHRP 1999), the primary source for total suspended solids is pavement wear and vehicle maintenance. Roadside fertilizer application contributes to the amount of phosphorus, nitrate, nitrite and TKN in stormwater runoff. Most chloride source comes from deicing salts, especially during winter. Tire wear, bearing wear and lubricating oil and grease are the primary sources for copper, lead and cadmium, while zinc comes from metal plating, engine parts and brake lining wear.

Table 2-1. Summary of the primary constituents of stormwater runoff and the typical expected concentration.

Constituent	Expected Concentration	Sources
Total Suspended Solids (TSS)	45 - 798 mg/L	Barrett et al. (1995)
Nitrate (total as N)	0.013 - 2.5 mg/L	Barrett et al. (1995)
Nitrite (total as N)	0.306 - 1.4 mg/L	Barrett et al. (1995)
TKN	0.355 - 55.0 mg/L	Barrett et al. (1995)
Chloride	20 - 400 mg/L	Kaushal et al. (2005)
Phosphorus	0.113 - 0.998 mg/L	Barrett et al. (1995)
Copper (Cu)	5 - 200 ug/L	Davis et al. (2001)
Lead (Pb)	5 - 200 ug/L	Davis et al. (2001)
Zinc (Zn)	20 - 5000 ug/L	Davis et al. (2001)
Cadmium	< 12 ug/L	Davis et al. (2001)

APPENDIX 3-A2.1.1 TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids consist of particles that are suspended in water and can be separated from water by a filtration process. Sources for TSS in highway runoff include soil erosion, the road surface, pavement wear, vehicles, and atmospheric deposition. TSS is an important water quality parameter because as TSS increases, the turbidity of the water will increase and eventually block penetration of sunlight into the water. This will eventually increase the temperature of water and decrease the levels of dissolved oxygen. In other words, the photosynthesis process will be interrupted due to less sunlight. Therefore, less oxygen is produced for aquatic organisms. According to the U.S Environmental Protection Agency, TSS in any water body should not exceed 30 mg/L, which is the same as the regulation that applies to most of the municipal wastewater treatment plants (DEQ 2007).

APPENDIX 3-B2.1.2 NUTRIENTS

Nitrogen and phosphorus are the two nutrients that are a major concern in stormwater runoff. Nitrogen is derived from decomposing organic matter, animal waste, fertilizers and atmospheric deposition. With the exception of atmospheric deposition, phosphorus comes from the same sources (Schueler 1994). Excess nutrients in water can accelerate algae production in the water bodies, known as eutrophication. Eventually, these algae die, sink to the bottom and decompose. Decomposition will decrease the amount of oxygen in water due to its oxygen consumption.

2.1.3 Chloride

Chloride is a negatively charged ion that can be found in deicing chemicals that are applied on highways during the winter season to manage ice and snow problems. Common deicing chemical compounds include sodium chloride ($NaCl$), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). These compounds leave residues of chloride ions on the highway surface (TFHRC 2007). Water with elevated amounts of chloride can affect some aquatic life. For example, some fishes can only tolerate salt levels as low as 400 mg/L (Hanes et al. 1970).

2.1.4 Heavy Metals

The sources of heavy metals in highway runoff are mainly ordinary wear of brakes, tires and vehicle parts. According to the study done at Milwaukee and Cincinnati by Sansalone et al. (1995), the amount of heavy metals in the environment has changed through out the years. For example, the EMC values for lead in Milwaukee in the late 1970s and early 1980s are much higher compared to the EMC values for lead in Cincinnati in 1995. The decrease was due to leaded gasoline that was banned by the government in 1995. On the other hand, the EMC values for zinc in Cincinnati in 1995 are much higher compare to the zinc in Milwaukee in the late 1970s and early 1980s due to the increased use of galvanized and corrosion resistant automobile parts containing plating that includes Zn, and the used of Zn in the manufacture of tires. These two places are comparable since both have an urban setting and similar traffic volumes.

Since heavy metals have toxic effects on aquatic life and humans, the Maryland Department of the Environment (MDE 2005) establishes aquatic toxicity limits that should be used as a guideline for toxicity levels. Four heavy metals that will be monitored in this project are zinc, copper, lead, and cadmium. The acute toxicity limits for zinc, lead, copper and cadmium are 120 µg/L, 65 µg/L, 13 µg/L and 2 µg/L, respectively (MDE 2005).

2.2 Grass Swale Mechanisms

Highway runoff seeps through the swale and soil through infiltration, percolation and filtration. However, those processes are complicated since they depend on the condition of the soils (permeability, hydraulic conductivity, moisture) and type of grass. The water quality constituents are either dissolved or particulate bound. Particulate pollutants such as total suspended solids usually can be removed by physical processes such as filtration by the grass. The dissolved pollutants, such as metals, can be removed by biological means, adsorption and phytoremediation.

Phytoremediation is a set of processes that uses plants to remove contamination in groundwater, surface water and leachate (FRTR 2008). Therefore, a grass swale can act as a media for phytoextraction to occur. In order for phytoextraction to occur, the contaminant must be bioavailable. The contaminant should exist as free ions, soluble complexes or adsorbed to inorganic soil constituents at ion exchange sites. For example, some metals such as zinc and cadmium exist in exchangeable, readily bioavailable form but some metals such as lead occur as soil precipitates (less bioavailable forms) (USEPA 2008).

2.3 Grass Swale Performance

This section focuses on grass swale performance towards removing pollutants. Typically, grass swales performance depends on the swale design, swale length, flow rate, particle size distribution and seasons. The study that compares the performance of grass swales that includes check dams and grass swales without check dams will be discussed separately in Section 2.4.

2.3.1 Total suspended solid (TSS)

Deletic (2005) summarized that efficiency of grassed areas in sediment removal depends on the grass type (density and thickness of grass blades), terrain characteristics (slope, size and length in the flow direction), soil type (infiltration capacity, roughness), sediment characteristics (size and density of particles), and rainfall characteristics (intensity and duration). Most of the literatures shows that grass swales are very efficient in removing total suspended solids, with Event Mean Concentration (EMC) removals reported as 69% (Deletic and Fletcher 2006), 85% (Barrett et al. 1998), 79-98% (Backstrom 2002a) and 41-52% (Stagge 2006).

Furthermore, Deletic and Fletcher (2006) discussed the results of controlled field tests on a grass filter strip in Aberdeen, Scotland (5 m long with average longitudinal slope of 7.8%) and a grass swale in Brisbane, Australia (65 m long with average longitudinal slope of 1.6%). In both studies, TSS concentrations were recorded along the grass for artificial inflow of water and sediment of different flow rates and sediment concentrations. The study in Aberdeen focused more toward the performance of the grass filter strips relative to different sediment particle size ranges from 0-0.58, 5.8-22, 22-57 and 57-180 μm along the strip. Inflow and outflow concentrations were recorded for one hour. The result shows that the TSS concentration decreased along the grass strip in the form of an exponential decay, with the smallest particles size having the lowest sediment concentration (Figure 2-1).

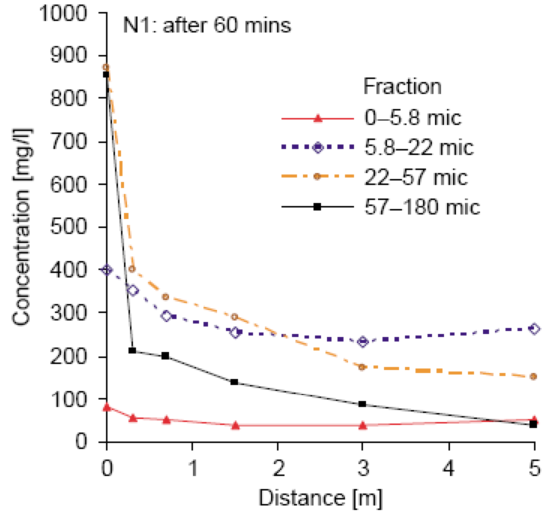

Figure 2-1. Concentration of four composite sediment fractions along the Aberdeen grass strip 60 min after the experiment started (Deletic and Fletcher 2006) (mic = µm).

In other words, swales trapped larger particles more efficiently than smaller particles especially if the vegetation is thin. This phenomenon can be seen in the simulated runoff event study by Backstrom 2003 (Figure 2-2) where particles larger than 25 µm were retained in the swale while particles range between 9 to 15 µm were easily transported out of the swale.

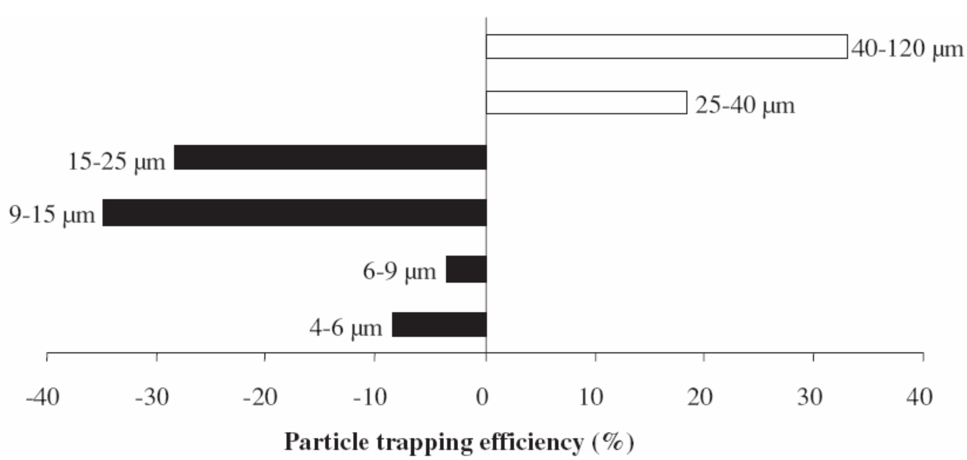

Figure 2-2. Particle trapping efficiencies observed at the Sodra Hamnleden site (Backstrom 2003).

The study in Brisbane placed more emphasis on treatment performance for TSS, total phosphorus (TP) and total nitrogen (TN). The results indicate that the form of the exponential decay is a function of flow. The higher the flow rate, the less sediment is deposited. With higher flow rates, less time is available for filtration to occur and therefore, less deposition to occur. This phenomenon is shown in Figure 2-3.

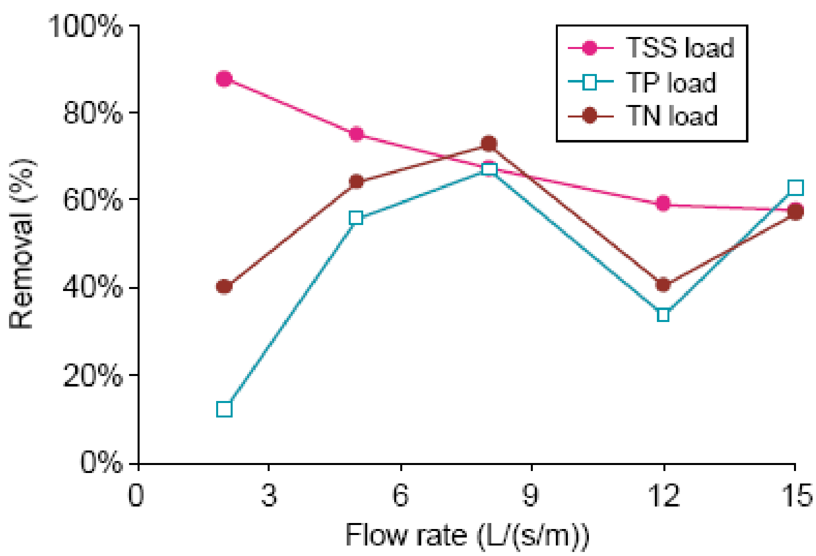

Figure 2-3. Removal of TSS, TP and TN load percent as a function of flow rate; the Brisbane swale (Deletic and Fletcher 2006).

Furthermore, TSS removal is also a function of influent suspended solids concentrations (Backstrom 2003). The study was done on 110 m long grass swale located along the roadside at Sodra Hamnleden, Lulea, Sweden. It seems that no significant removal occurred in the swale when the influent concentrations of TSS were below approximately 40 mg/L. This agrees with Ellis (1999) since she also found out that small reduction of TSS occurred if the inflow concentration was below 30 to 40 mg/L. The results of Backstrom (2003) are compared to two other studies in Figure 2-4. From the figure, results of Lorant (1992) and Backstrom (1998) shows that swales were effective (removal efficiencies more than 50%) when influent suspended solids concentrations are above 100 mg/L. The Backstrom (1998) was done on a 70 m long trapezoidal swale in a residential area in Sweden while the study in 2003 was done a 110 m long triangular swale along the roadside. Although the influent loading rate is truly site specific, the influent water quality is still an important site condition that influences the pollutant removal performance (Barrett et al. 1998).

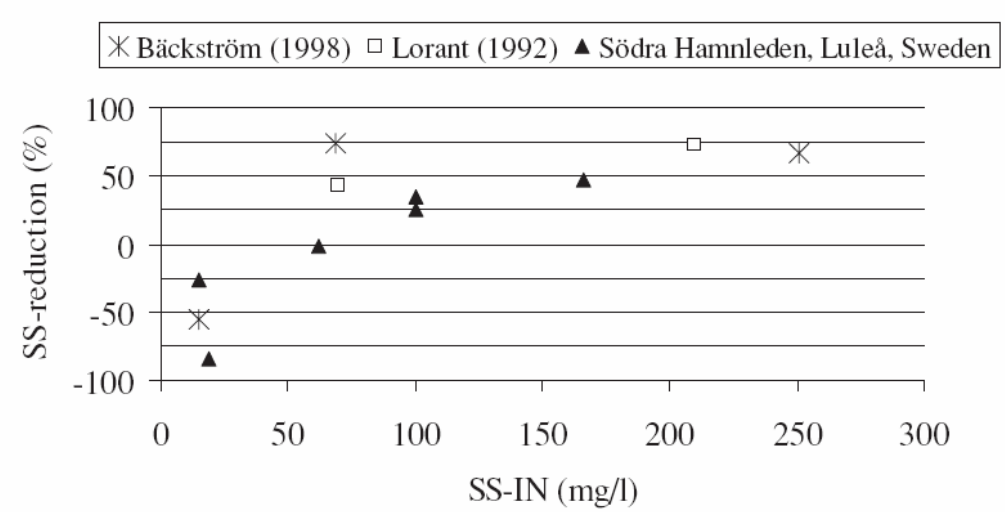

Figure 2-4. Reduction in Suspended Solids (SS) concentration at different influent SS concentrations for three different studies (Backstrom 2003).

Seasonal effects also play an important role in swale removal efficiencies for TSS. According to Walsh et al. (1997), during growing season, the combined filtering capacity of the dead and live grasses in the swale helps to remove more suspended solids compared to the dormant season. Besides that, Soderlund (1972) found that during winter season, less suspended solids were trapped in a vegetated waterway compared to warmer seasons. The change was from 75% reduction to only 30% reduction. This phenomenon occurs due to the swale being covered by the snow and therefore, flow resistance and filtering effects are lower compared to the rest of the seasons.

2.3.2 Nutrients (nitrate-N, nitrite-N, total Kjeldhl nitrogen (TKN), total phosphorus (TP))

The removal of nutrients by swales varies widely. In some cases, swales tend to export the nutrients into the runoff. This phenomenon occurred due to the vegetation itself or fertilization that contributes to nutrient loads, particularly after mowing (Patron 1998). Furthermore, nitrogen removal itself is a function of denitrification, biostorage (plant and animal uptake) and changes in soil storage (Deletic et al., 2006). Phosphorus removal is highly depends on physical processes that includes infiltration, deposition and filtration since phosphorus is considered as particle-bound pollutants (Barrett et al., 1998; Rose et al., 2003).

In a study by Barrett et al. (1998), two grassed areas along a busy motorway in Austin, Texas was monitored. Following are the characteristics of the grassed area: 15.8 m and 17.2 m cross-section length, 1055 m and 356 m centerline length, 9.4 and 12.1% cross-section slopes, and 1.7 and 0.73% centerline slopes. Measured pollutant reductions were similar for both sites, which were 31-61% for total phosphorus and total nitrogen. Stagge (2006) on the other hand, obtained variable removal capabilities ranging from -1% to 60% for nutrients such as nitrate, TKN and total phosphorus.

Another study of swales adjacent to a highway in Florida by Yousef et al. (1987) reports lower removal efficiencies than Barrett et al. (1998). It recorded that TP removal efficiency was 25 and 30% for swales at Maitland and EPCOT, respectively. In the same study, nitrogen removal is also low; averaging 11 and -7% respectively. The poor performance for soluble materials is due to the relatively high hydraulic loading in these study sites and therefore, the swales has less time for infiltration, filtration and deposition of the pollutants to occur. However, having a high infiltration rate can allow a significant impact on the removal efficiencies since Krecher et al. (1983) measured removal rates over

99% for total phosphorus (TP), total kjeldahl nitrogen (TKN) and total nitrate (TN). The grass swale received stormwater from a residential subdivision in Florida.

From Figure 2-3, it is clearly shown that removal of TN and TP for the grass swale in Brisbane is not flow-dependent compared to the TSS removal in the same study. However, this is not the case for natural conditions specifically for TP, since according to Ball et al. (1998), most of TP will be attached to fine sediment. Therefore, the higher the flow rate, the harder the pollutant to be removed from the swale and vice versa. In other words, to enhance the physical removal processes for phosphorus, dense vegetation should be used so that the orthophosphate that is already bound to the suspended sediment within the stormwater will be removed by the physical processes. On the other hand, the results of TN in Figure 2-3 are more acceptable since TN is often found to be in more soluble form in nature (Deletic et al. 2006).

2.3.3 Chloride (Cl)

Currently, there is no literature that compares the removal of chloride by grass swales. However, chloride is still a major source of pollutant in stormwater runoff especially during snow events and the snow-melting seasons. This agrees with results obtained by Stagge (2006) where chloride was actually being exported at a significant level (216 – 499 mg/L) by the swales, especially during the winter season and snow-melting season. Chloride adversely affects soil fertility by impacting soil structure and water transport through the soil (Marsalek 2003). This agrees with Amrhein et al. (1992) where sodium ions (Na^+) may replace Ca^{2+} and Mg^{2+} cations and leach out trace metals that may contaminate the groundwater.

2.3.4 Heavy metals (copper (Cu), lead (Pb), zinc (Zn) and cadmium (Cd))

Unlike organic compounds, the removal of metals from runoff is important since they are not degraded in the natural environment. According to the study by Sansalone et al. (1997), metals in urban roadway stormwater are either in the dissolved form or particulate bound. Metals that are mainly in dissolved form are Zn, Cd, and Cu while Pb is mainly particulate bound.

Kayhanian et al. (2007) analyzed highway runoff quality in California and concluded that generally, large proportions of most metals are bound to particulate matter in runoff. Lead has the highest proportion present as particulates (83%). This agrees with Sansalone et al. (1997) where lead was found mainly particulate bound. Arsenic, cadmium, chromium and zinc are between 60 and 65% in the particulate fraction and followed by copper and nickel between 50 and 55%. Therefore, lead, cadmium, chromium and zinc are expected to be highly removed since at least 50% of these metals can be effectively removed from runoff by targeting the particulate fraction. The colloidal binding effect will also help to enhance the removal. Colloidal binding is defined as the process where the metals complex or bind with inorganic or organic components of the suspended solids or natural organic matter. The complexation can affect the movement of the metals in the environment. For example, zinc usually had a higher removal tendency compared to copper since colloidal binding for zinc is lower than copper (Jensen et al. 1999). In other words, it is easier to remove zinc because copper has a high affinity to bound to dissolved organic complexes and colloids. Elliott et al. (1986) and Narwal and Singh (1995) also observed greater sorption affinity for Cu than for Zn on different types of mineral soils with varying amounts of organic compounds under acidic conditions. They also found out that increased levels of organic compounds limited the mobility of both metals, especially Cu.

Furthermore, Yousef et al. (1987) indicates that the removal of metals by swales will be greater for species that are present as charged ions. In this case, adsorption onto particles is the important removal mechanism. The particles are subsequently removed by sedimentation.

The metals EMC values vary between each study. For example, Barrett et al. (1998) measured reductions of 68-93% for Zn and Fe; 68-93% for Pb. Stagge (2006) obtained lower reduction, between 30-40% for Zn, 3-11% for Pb and 6-28% for Cu. Kretcher et al. (1983) measured a removal rate over 99% for Pb. The high reduction was due to high infiltration rates on the site. The study at the Sodra Hamnleden site (Backstrom 2002b), also had Zn as the highest removal rates. However, the swale at Sodra Hamnleden site acted as a source for Cu, Pb and Zn during low influent concentration events. Specifically for Cu, the concentrations of total and dissolved copper were lower in the road runoff compared with swale runoff for all events. The EMC values for dissolved copper were two to four times higher in swale runoff than in road runoff. In this case, a pool of colloidal copper must had accumulated in the swale prior to the research and was released from the swale during the study. Again, this result reinforces the fact that Cu had a high tendency to bind with organic matter in the soils and tends to be released throughout time.

Seasoned variations also affect the removal efficiency of metals by grass swales. The study by Backstrom (2003) at three grassed swales in central Lulea, Sweden during the melt period (March-April) 2000 indicates that total metals are retained to a large degree in a snow-covered swale (78-99% removal). The results of the study are in Table 2-2.

Table 2-2. pH, suspended solids (SS) and metal concentrations in snow and snowmelt in 3 roadside swales in Lulea (March-April 2000) (Backstrom 2003).

				Total			Dissolved		
		pH	SS (mg/l)	Cu (μg/l)	Pb (μg/l)	Zn (μg/l)	Cu (μg/l)	Pb (μg/l)	Zn (μg/l)
Site A Bodenv.	Snow	6.91	1,800	214	212	525	4.78	0.177	13.6
2000–03–29	Melt water	6.89	13	15.3	2.44	33.4	7.00	0.105	18.0
	Reduction	–	99%	93%	99%	94%	–46%	41%	–32%
Site B Hertsöv.	Snow	6.69	1,000	83.7	55.9	275	1.43	0.137	13.5
2000–04–10	Melt water	6.70	12	5.00	1.93	60.5	1.84	0.097	56.7
	Reduction	–	99%	94%	97%	78%	–29%	29%	–320%
Site C Lulsundet	Snow	6.99	5,400	520	189	1240	2.00	0.143	6.37
2000–04–10	Melt water	7.03	240	21.9	7.43	72.8	3.28	0.090	16.0
	Reduction	–	96%	96%	96%	94%	–64%	37%	–151%

2.4 Performance of Grass Swale with Check Dams

Addition of check dams on grass swales could attenuate the runoff flow, provide ponding behind the check dams and further enhance infiltration and settling by temporarily blocking the flow of water. These will eventually promote pollutant removals. At this point, very limited information is available looking at the effects of check dams on swale performance.

A study by Kaighn and Yu (1996) shows that pollutant removal was impacted more by the presence of check dams rather than changes in slope. The study was done between grass swales with check dams and grass swales without check dams, but having equal length and having different slopes. Yousef et al. (1985) also agrees that incorporating check dams in swale design would have a significant impact on pollutant removal performance.

Furthermore, the study by Yu et al. (2001) consists of field tests on grass swales in Taiwan and Virginia. In Taiwan, the swale is 30 m long with a 1% longitudinal slope. It has a midpoint triangular weir that acts as check dam. The test was done with and without the midpoint check dam by using synthetic runoff. In Virginia, the swale is 274.5 m long, 3% longitudinal slope and check dams at 175 m and 237.5 m from swale inlet. The swale is known as Goose Creek swale (GC) and it receives runoff from State Route 7. The results of both sites are listed in Table 2-3.

Table 2-3. Pollutant mass removal for total suspended solids (TSS), chemical oxygen demand (COD), Total nitrogen (TN) and Total Phosphorus (TP) (Yu et al. 2001).

		Length	Mass Removal (%)			
	Experiment	(m)	TSS	COD	TN	TP
TA	check dam	15	75.2	55.7	24.2	41.2
	outlet	30	69.7	62.9	20.9	76.9
TB	check dam	15	74.4	48.0	13.6	34.0
	outlet	30	86.3	45.6	23.1	58.1
TC	outlet	30	47.7	33.9	20.0	50.3
TD	outlet	30	67.2	42.7	13.8	28.8
GC	upper	238	29.7	NT	NT	73.4
GC	lower	99	97.2	NT	NT	96.8
GC	entire swale	274.5	94.0	NT	NT	98.6

Note: "T" designates Taiwan Swale; "GC" designates Virginia Swale; NT = not tested.

From Table 2-3, four scenarios (TA, TB, TC and TD) were tested on the Taiwan swale. TA and TC were conducted at a higher flow rate (4.0 x 10^{-3} m^3/s) and TB and TC are conducted at lower flow rate (0.9 x 10^{-3} m^3/s). For both flow rates, the mass removal at the outlet with the check dam is higher compared to the outlet without any check dam. However, the lower flow rate scenario produced higher mass removal since the detention time is almost double compared to the higher flow rate. This shows that the check dam helps to remove the pollutants since it increased the detention time and allowed more time for the runoff to be filtered by the grass and infiltrate into the soils that eventually reduced the runoff volume.

For the results from the Virginia swale, it seems that the lower section and the entire swale showed better performance compared to the upper section. This shows that the length of the swale and the amount of check dams play an important role in increasing mass removals.

Besides that, the Virginia swale was also able to infiltrate larger volumes of runoff compared to other swales. With the presence of two check dams and the long swale, complete captured events will occur for storms less than approximately 12.7 mm total precipitation. However, for a shorter swale (30 m), complete captured events will occur from storms with less than 5 and 7 mm total precipitation (Kaighn and Yu 1996).

2.5 Grass swale specification design for pollution control

There are a few important parameters of grass swale that could help to increase the performance of the swale. Those parameters are: swale length, slope, flow velocity and residence time. Moreover, from Section 2.4, it is clearly shown that by incorporating check dams in the grass swale design, it will help to increase the swale performance. Ferguson (1998) proposed some empirical design criteria such as the water velocity should be less than 0.15 m/s, swale length should be at least 60 m and residence time in the swale should be at least 9 minutes. Furthermore, Yu et al. (2001) combined results of eight studies in the literature to demonstrate the theoretical relationship between swale design characteristics and pollutant removal of TSS and TP (Urban Best Management Practices 1994, 1996; Yu et al. 1994; Kaighn and Yu 1996). Both pollutants were chosen since usually regulations are written in terms of sediment and phosphorus removal.

Figure 2-5 shows that the rate of removal reaches a plateau when swales are longer than approximately 75 m regardless of slope. However, having a maximum longitudinal slope of 3% will produce removal efficiency more than 50%. In Figure 2-6, TP shows no trend between length and slope. This reemphasis the fact that swales generally are not considered efficient for nutrients removal.

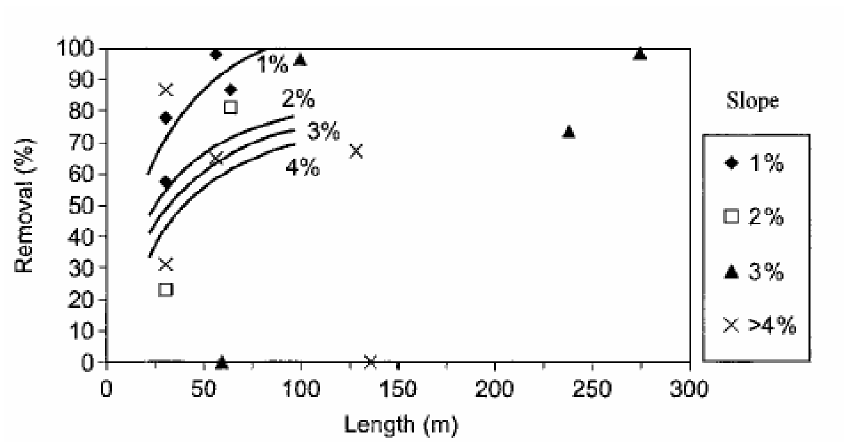

Figure 2-5 The relationship between swale total suspended solids removal efficiency, length and slope (Yu et al. 2001). *Curves are meant to show estimated trends.

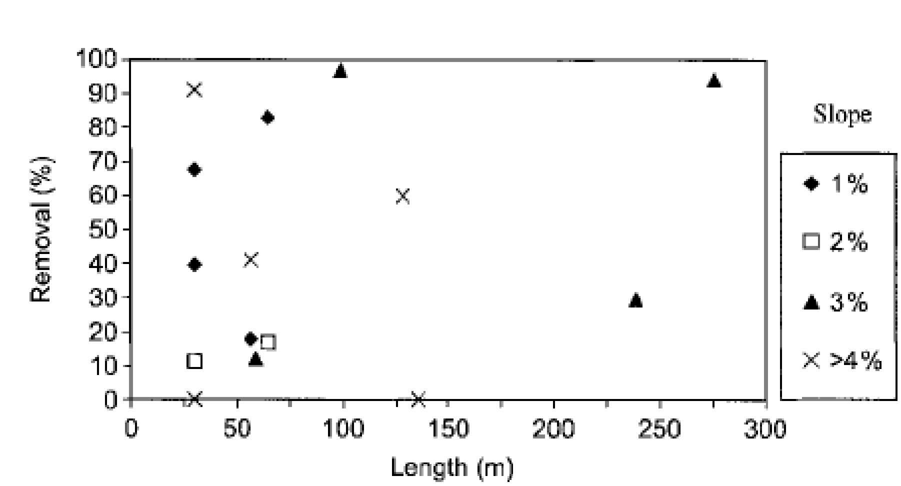

Figure 2-6 Relationship between swale total phosphorus removal efficiency, length and slope (Yu et al. 2001).

Regarding the residence time factor, there is no clear break point time at which the swale will perform the best, but we do know that the particle trapping efficiencies increased exponentially with residence time (Yu et al. 2001).

Interestingly, the ratio between swale area and contributing impervious area could also predict the removal (%) for suspended solids and zinc. The results combination from the full-scale study at Sodra Hamnleden, together with results from three roadside grassed swales in USA (Barrett et al. 1998) and Canada (Lorant 1992) concluded that the ratio should approach 1 in order to have high pollutant removals (>75%) for suspended solids and zinc (Backstrom 2003).

2.6 Pollutant mass loads during rain events.

Pollutant mass loads are another parameter that is more useful than pollutant concentration (EMCs), since it gives more insight on the long-term performance of a grassed swale area rather than each individual event. For example, at the Sondra Hamnleden site, the overall mass load reduction for suspended solids was 70% even though negative removals were observed during several rain events (Table 2-4). The calculations are based on four rain events with a total precipitation of 47.4 mm. Copper and zinc had a lower overall mass load reduction compared to suspended solids, which are 34% and 66%, respectively.

Table 2-4. Total mass flows of water and pollutants at Sodra Hamnleden site (Backstrom 2003).

	Water	Suspended solids	Copper		Zinc	
	(m^3)	(kg)	Total (g)	Dissolved (g)	Total (g)	Dissolved (g)
From road to swale	19	2.1	0.56	0.11	2.2	0.59
From swale to recipient	8.7	0.63	0.37	0.15	0.73	0.20
Load reduction (%)	54	70	34	−27	66	66

2.7 Toxicity of urban highway runoff with respect to storm duration.

It is important to know the toxicity of urban highway runoff with respect to storm duration, especially to the aquatic species in the receiving water body. Kayhanian et al (2008) indicated that toxicity varies throughout the storm events for both freshwater and marine species toxicity tests. In the same study, Kayhanian et al (2008) found that generally the concentrations of dissolved and total copper and zinc are substantially higher during the early portion of the runoff, which correlates well with the observed first flush toxicity effects. Furthermore, Kayhanian et al (2008) identifies a method published by USEPA called Toxicity Identification Evaluations (TIEs) which basically identifies toxicity in water. The results for TIEs in this study indicated that copper and zinc are the primary cause of toxicity in about 90% of the samples evaluated with these procedures. In some cases, the greatest degree of toxicity was observed during the early stages of a storm event when lower runoff volume was discharged. The study also found out that in most cases, more than 40% of the toxicity was associated with the first 20% of discharged runoff volume and on average, 90% of the toxicity was observed during the first 30% of storm duration.

The study by Stagge (2006) shows that although the input runoff shows high initial concentrations of zinc and copper, when analyzed in terms of first flush mass delivery, it is nearly constant for both metals. This suggests that dissolved zinc and copper are the predominant species initially and therefore, both metals do not exhibit first flush trends.

Chapter 3
METHODOLOGY

3.1 Site Description

The research site has been constructed on Maryland Route 32 near Savage, Maryland – Exit 38A (I-95N). It is located just south of the Vollmerhausen Road over pass (Figure 3-1). The site consists of two individual swales with different designs but nearly identical roadway drainage areas. The monitoring location is the same as the previous study by Stagge (2006), where the two swales are constructed in the median of a four-lane (two in each direction) limited access highway which receives runoff laterally from the southbound roadway lanes (Figure 3-2). The only condition that differs from Stagge's (2006) study is that two check dams are installed within each of the swales.

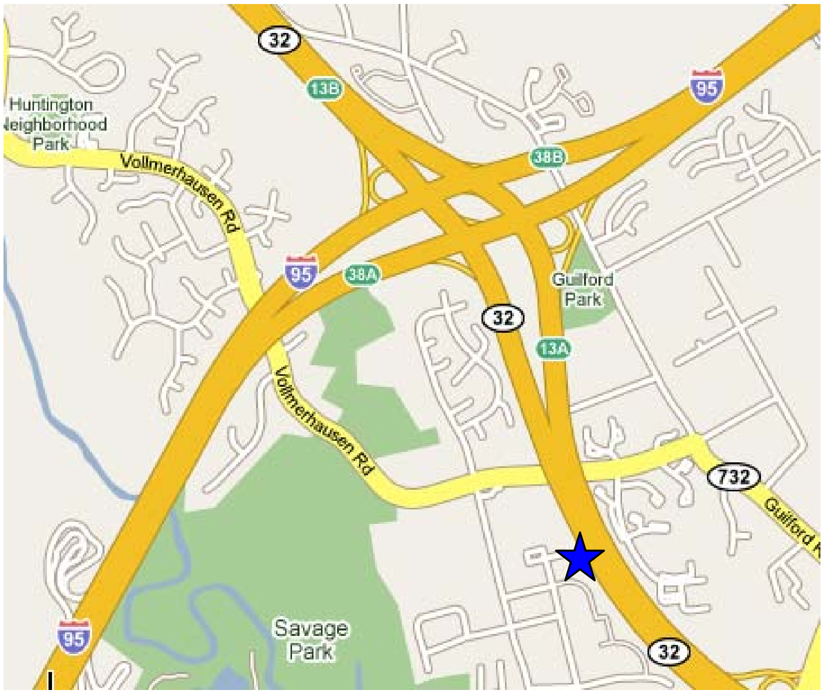

Figure 3-1. Route 32 grass swale research site (credit to: www.maps.google.com).

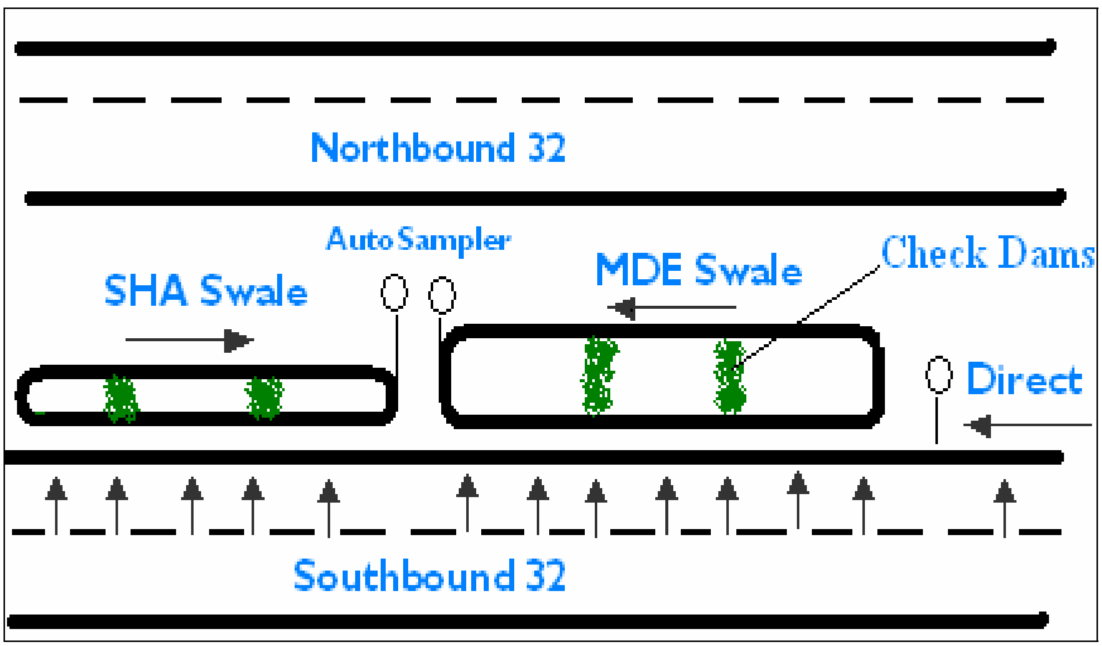

Figure 3-2. Diagram of site layout (Maryland Route 32). The arrows represent the highway runoff.

Each check dam was installed using three staggered row of Panicum Virgatum 'Heavy Metal', a sturdy plant that will remain standing either in heavy rain or snow. There were planted 12 inches (0.31 m) on center with 26 plants total. All check dams were constructed with identical cross-section design with a 2 ft (0.61 m) bottom width and side slopes of 3:1 and 4:1 on either side of the swale. Each check dams is 3 feet wide. Figure 3-3 shows typical sections of the check dams that were installed on the swales.

The vegetation covers that were used for the grass swale and the pretreatment area consist of 90% tall fescue, 5% Kentucky bluegrass and 5% perennial ryegrass. The top soils of the swales had an organic content between 1.5-10% by weight and a pH value between 6.0 and 7.5. The grading distribution of the soil (by weight) is 20-75% sand (2.0-0.05 mm), 10-60% silt (0.050-0.002 mm) and 5-30% clay (less than 0.002 mm).

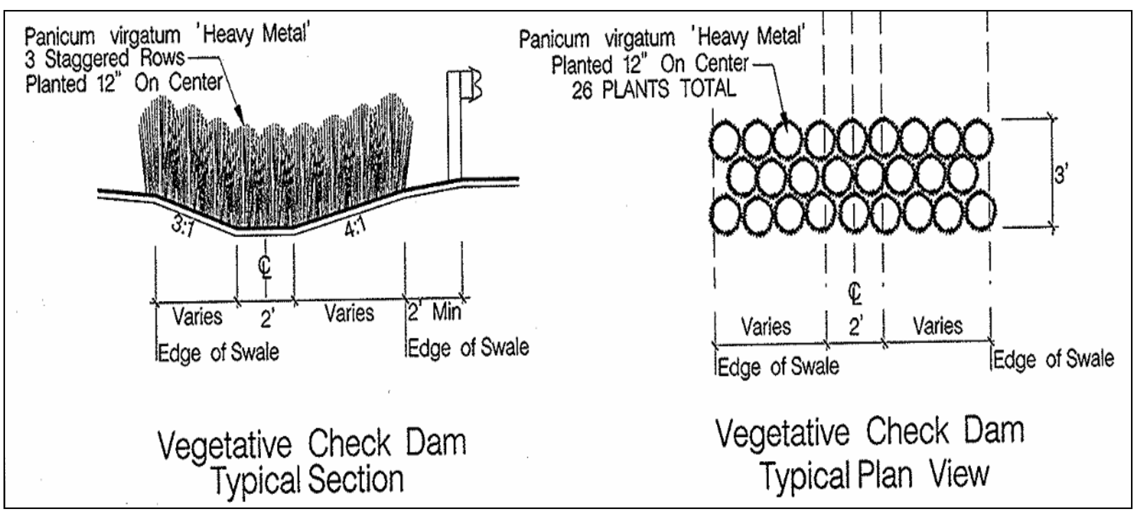

Figure 3-3. Vegetative check dam typical section (Maryland Route 32).

The first swale is constructed based on Maryland Department of the Environment (MDE) guidelines, with a sloped filter strip between the roadway and the swale channel. The filter strip is 15.2 m wide with a 6% slope on the southern side of the MDE swale. The distance between the two check dams on MDE swale is about 60.5 m (199 ft).

The second swale, to the north, known as the SHA swale was identically constructed but without the pretreatment area. The distance between the two check dams on the SHA swale is about 59.8 m (196 ft).

The third sampling area is a concrete channel that collects runoff sample directly from the highway located south of the swales. By having this third sampling point, instantaneous flow input and water quality from the highway surface can be obtained for comparing performance purposes.

All three sampling points had essentially identical roadway drainage areas. Specific design characteristics for those sampling points are listed in Table 3-1. These characteristics are similar with Stagge (2006) except for swale area for the SHA. Both grass swale area were checked and it seems that the swale area for SHA is 0.312 ha instead of 0.169 had. Therefore, the new area is used for all the calculations. Figure 3.4 – 3.6 present photos of the swales with check dams.

Table 3-1. Design characteristics for three sampled channels.

	Direct	SHA Swale with Check Dams	MDE Swale with Check Dams
Roadway Area (ha)	0.271	0.224	0.225
Swale Area (ha),A_S	0	0.312	0.431
Total Area (ha),A_T	0.271	0.393	0.656
Channel Material	Concrete	Grass	Grass
Channel Slope	0.2%	1.6%	1.2%

Channel Length (m)	168	198	137
Pretreatment Slope	-	-	6%
Pretreatment Width (m)	-	-	15.2 (from roadway to channel center)

Figure 3-4. Vegetated Check Dams on SHA Swale, Maryland Route 32 (August 2007)

Figure 3-5. Vegetated Check Dams on MDE Swale, Maryland Route 32

(October 2007).

Figure 3-6. Close up of Vegetated Check Dams on MDE Swale, Maryland Route 32 (after storm event) (December 2007).

3.2 Monitoring Equipment and Protocol

Sampling occurs at a 125^o V-notch wooden weir located at the end of each swale and the concrete channel. The flow rates were recorded by ISCO Model 6712 Portable Samplers and rainfall data was recorded by an ISCO 674 Tipping Bucket Rain Gauge with 0.0254 cm sensitivity in 2 minutes increments. Details of the sampler can be found in Stagge (2006). Table 3-2 indicates the sampling time for each sampling point with an emphasis on collecting more samples in the early portion of the storm event. However, the direct sampling was lengthened accordingly since there are a few hours of time lag before grassed swales trigger due to initial abstraction and infiltration.

Table 3-2. Sampling times for storm events at Route. 32

	Time Frame	
Sample	**Direct**	**Both Swales**
1	zero minutes	zero minutes
2	20 minutes	20 minutes
3	40 minutes	40 minutes
4	1 hour	1 hour
5	1 hr 20 min	1 hr 20 min
6	2 hr	1 hr 40 min
7	2 hr 40 min	2 hr
8	3 hr 20 min	2 hr 20 min
9	4 hr 20 min	2 hr 40 min
10	5 hr 20 min	3 hr 40 min
11	6 hr 20 min	4 hr 40 min
12	8 hr	6 hr

In August 2007, the housing of the portable sampler for the SHA swale was hit in an accident and the new housing was installed on site in September 2007. However, in order to avoid another accident, both samplers (SHA swale and MDE swale) were installed closer towards the southbound lanes of Route 32 rather than the northbound lanes. Nonetheless, this does not affect sampling data.

All samples were collected within 24 hours of a storm event and transported to the Environmental Engineering Laboratory, College Park, MD. TSS and nutrients analyses are immediately processed; 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. Metal digestion was completed within two weeks and analyses were carried out within 6 months.

3.3 Analytical Methodology & Procedures

All analyses were performed according to Standard Methods (APHA et al. 1995). Tables 3.3 summarize the analytical methods that were used to determine the pollutant concentration from highway runoff on Route 32 during storm events and the detection limit of each method. Further details can be found in Stagge (2006).

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

Pollutant	Standard Method (APHA et al. 1995)	Detection Limit (mg/L)
Total Suspended Solids (TSS)	2540 D	1
Total Phosphorus	4500-P	0.24
Total Kjeldahl Nitrogen (TKN)	4500-N_{0rg}	0.14
Copper	3030 E	0.002
Lead	3030 E	0.002
Cadmium	3030 E	0.002
Zinc	3030 E	0.0025
Chloride	Dionex DX-100 ion chromatograph	2
Nitrate	Dionex DX-100 ion chromatograph	0.1 as N
Nitrite	4500-NO_2^- B	0.01 as N

3.3.1 Total Suspended Solids (TSS)

Standard Method Section 2540 D (APHA et al. 1995) was used to analyze TSS. Glass-fiber filters with 47 mm diameter (Pall Corporation) and the aluminum dish were pre-weighed. 70 mL from each sample were filtered through the glass fiber filter, placed on the aluminum dish and left to dry in the oven for 24 hours (103^o – 105^o). Then, both the dried filter and the aluminum dish were weighed again to determine the total suspended solids.

3.3.2 Phosphorus

Standard Method Section 4500-P (APHA et al. 1995) was used. This analysis consists of two parts: 1) Persulfate Digestion Method 2) Stannous Chloride Method. The first part is critical since it converts all forms of phosphorus into dissolved orthophosphate. The second part determines the concentration of the dissolved orthophosphate by a colorimetric method. Ammonium molybdate was used since it reacts under acid conditions to form molybdophosphoric acid. It was then reduced by stannous chloride to intensely colored molybdenum blue. Finally, the intensity of the blue colored molybdenum was measured using a Shimadzu model UV160U spectrophotometer at 690 nm. Samples absorbances were compared against absorbance obtained from the standard concentrations of 0.24, 1.2 and 3 mg/L as P. All standards were prepared by using 1000 mg/L stock solution (Fisher Scientific).

3.3.3 Nitrite

Standard Method Section 4500-NO_2^- B (APHA et al. 1995) was used. It is a colometric method where a reddish purple azo dye color develops upon mixing the filtered samples with the indicating reagent. The absorbance of each sample was measured spectrophotometrically (Shimadzu model UV160U) at 543 nm. Samples absorbances were compared against absorbance obtained from the standard concentrations of 0.02, 0.08, 0.12, 0.24 mg/L as N. All standards were prepared by using 1000 mg/L stock solution (Fisher Scientific).

3.3.4 Nitrate and Chloride

Both analyses were performed using a Dionex ion chromatograph (model DX-100) via injection of 5 mL of sample into a 1.3 mM sodium carbonate/1.5 mM sodium bicarbonate eluent. Samples were compared against standard concentrations of 0.2, 0.4, 1.0, 1.4, 2.0

mg/L as N and 1, 3, 5, 8 mg/L Cl^-. All standards were prepared by using 1000 mg/L stock solution of nitrate and chloride.

3.3.5 Total Kjeldahl Nitrogen (TKN)

Standard Method Section 4500-N_{org} (APHA et al. 1995) was used. The Kjeldahl method determines nitrogen in the trinegative state and the term "Kjeldahl nitrogen" was applied to the results because ammonia nitrogen was not removed in the initial phase of the analysis. Three main steps were involved: 1) digestion of the sample 2) distillation of the digested sample 3) titration of the distilled sample. .

3.3.6 Cadmium, Copper, Lead and Zinc

Standard Method Section 3030 E (APHA et al. 1995) was used. First, 100 mL samples were digested using nitric acid digestion. Then, cadmium, copper and lead were analyzed on the furnace module of a Perkin Elmer Model 5100 ZL (Zeeman Furnace Module) atomic absorption spectrophotometer. Zinc was analyzed on the flame module of the same instrument. Standard concentrations that were used for the furnace model range from 4 μg/L to 50 μL and for the flame model range from 0.05 mg/L to 0.7 mg/L.

3.4 Quality Assurance (QA) and Quality Control (QC)

All glassware was acid washed with 0.1 M HNO_3 and cleaned using deionized water. Field blanks were collected once every 4 monitored storms in order to make sure that no contamination occurred on site that can affect the samples. Blanks were created by pouring deionized water in a cleaned bottle at the time of sample collection and the exact same analyses were run on the field blanks for all pollutants. Results of those blanks were low enough to be considered negligible for the samples.

In order to check the calibration curves for all of the analyses, standard concentrations were checked regularly. In cases where the data were below the method detection limit (MDL) (Table 3.3), the constituent will be indicated as having less than the detection limits when listed and if any statistical procedures are involved; half of the detection limit is used. This agrees with the US EPA recommendation where if less than 15 percent of all samples are nondetected, the MDL/2 approach should be used; but these simple substitution methods tend to perform poorly in statistical test when the nondetect percentage is substantial (Gilliom and Helsel 1986).

3.5 *Flow Calculation*

Swale flows were monitored by using a bubble flow meter that records the depth behind a thin wooden plate V-notch weir at each sampling point. For accuracy purposes, the bubbler modules were zeroed before every storm to ensure the same datum was used for every storm. Usually the height measurement showed minimal variation with time. The sampler is triggered when the water behind the weir reaches 0.1 ft. At that point, the sampler will be enabled, flow measurement will be recorded and samples will be collected. According to ASTM standards (2001), the flow rate over a triangular weir is determined by:

$$Q = \frac{8}{15}(2g)^{1/2} C_e \tan(\frac{\theta}{2})(H_e)^{5/2} \qquad (3\text{-}1)$$

where C_e = discharge coefficient

H_e = effective head

g = gravity

= angle of the V-notch

Effective head, $H_{e,}$ is the measured water head above the weir notch (in meters) plus adjustment for the combined effects of viscosity and surface tension for water at ordinary temperatures (4 to 30^{o}C). In this study, the adjustment is considered negligible and therefore can be neglected since the angle of the V-notch is large (ASTM 2001). Each V-notch weir angle is 125^{o} and a C_e value of 0.585 (ASTM 2001) was used for all calculations. With that, equation 3-1 simplifies to be:

$$Q_{weir} = 2.65H_e^{5/2} \qquad (3\text{-}2)$$

The design criteria (ASTM 2001) recommend measuring the head, H_e at a distance of 4 times the maximum head in order to eliminate the drawdown effect and to ensure that the velocity head is negligible. Due to physical limitations, the location of the bubble line where the head was measured is located exactly adjacent to the weir. Therefore, Stagge (2006) developed a relationship between head at the weir, H_{weir} and H_e by using Bernauli's equation and the physical geometry of the weir opening. As a result, the calculated flow through the weir is:

$$Q = 2.65(1.2276H_{weir})^{5/2} \qquad (3\text{-}3)$$

By using the method of estimating the total percentage error of a flow measured by a V-notch in ASTM 2001, Stagge (2006) found that the estimated error for this study is 3%.

3.6 Hydrology Data Evaluation and Calculations

A mass balance and a flow balance around the swale are used as tools to accurately model the hydrology and pollutant concentrations within the swales. Both mass and flow input output varies with respect to time. The flow balance and mass balance are pictured in Figure 3-7.

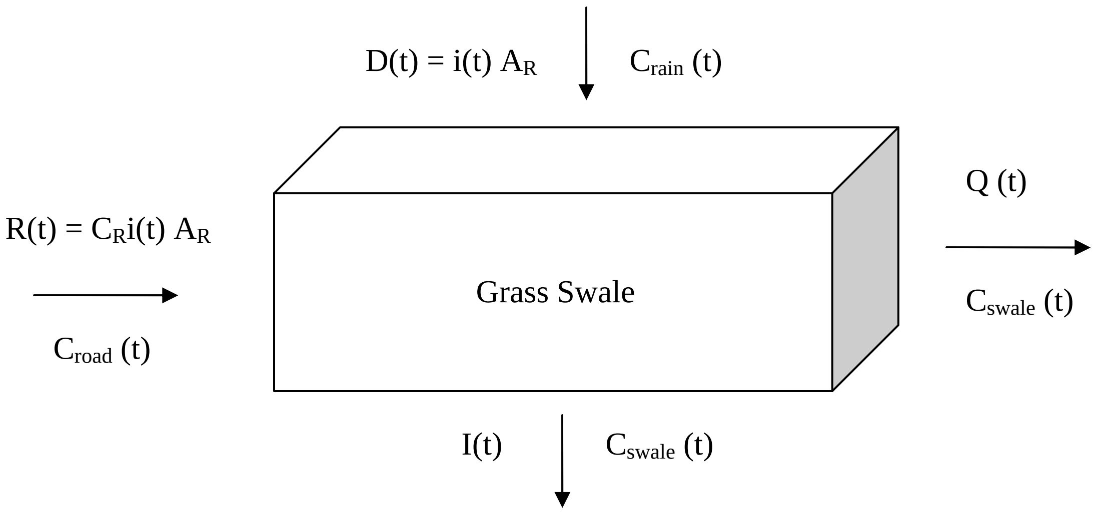

Figure 3-7. Grass swale mass and flow balance model.

where,

$D(t)$ = Flow from rainfall directly into swale (L/s)

$Q(t)$ = Flow leaving the swale (L/s)

$I(t)$ = Infiltration into the swale media (L/s)

$R(t)$ = Runoff from the highway (L/s)

C_R = Highway runoff coefficient

$i(t)$ = Rainfall intensity (m/hr)

A_R = Drainage area of the roadway surface (m^2)

$C_{rain}(t)$, $C_{road}(t)$, $C_{swale}(t)$ = Pollutant concentration in the rainfall, roadway flow and swale

From Figure 3-7, the flow balance (Equation 3-4) around the swale is derived:

$$R(t) + D(t) - I(t) = Q(t) \tag{3-4}$$

APPENDIX 3-C*3.6.1* INFILTRATION THROUGH THE SWALE

In this study, one of the swale inputs is from direct precipitation of rainfall on the swale. For comparison purposes, it is important to exclude the rainfall on the swale from the discharge of the swale. Without subtracting the rainfall on the swale, there will be differences in the input flows for each channel due to the differences in total drainage area causes by the additional area of the swales. By excluding the rainfall, direct comparison can be made between the quality and quantity of the highway runoff collected at the three sampling points since we are assuming that the grass swale receives water only from roadway surfaces. Therefore, we need to take into account how much water from the rainfall infiltrates into the ground and how much becomes runoff that goes out as the flow of the swale. Infiltration through the swale will start soon after the rain starts, up to the point where the ground is saturated. At that point, any rainfall that falls on the swale will become overland flow. This phenomenon is called saturation-excess overland flow and can be derived from the Horton equation. The amount of water that infiltrates into the ground is called the maximum infiltration capacity, given by the Horton equation (Hornberger et al. 1998):

$$f_{\max} = f_c + (f_o - f_c)e^{-t/K} \qquad (3\text{-}5)$$

where,

f_{max} = maximum infiltration capacity of the soil

f_o = initial infiltration capacity

f_c = final infiltration capacity

t = elapsed time from start of rainfall

K = decay time constant

In this study, the maximum infiltration capacity of the soil, f_{max} is obtained from the relationship between the total rainfall depth for 23 storm events and duration of the storms. These events are shown in Figure 3-8. Among these 23 storm events, only 13 events produced flow from the swales and the remaining 10 events are considered complete captured events since no swale flow was produced. Complete captured events also indirectly indicate that all rainfall infiltrates into the swale. Therefore, the relationship between the rainfall depth and duration for the complete captured events will provide the threshold amount of rainfall that can be infiltrated into the swale (f_{max}). Any rainfall above the threshold will be considered as overland flow which eventually will be part of the swale flow that needs to be excluded from the discharge of the swales. Details about this relationship will be discussed further in Section 4.2.1.

APPENDIX 3-D3.6.2 TOTAL GRASS SWALE DISCHARGE, Q_{SWALE} (EFFECTIVE FLOW)

The grass swales discharge consists of the direct rainfall on the swale and the runoff from the highway. However, the direct rainfall will only be part of the discharge after the cumulative rain depth for that specific storm reaches the maximum infiltration capacity of the soil, f_{max} calculated from Equation 3-6. The additional rain after that point is assumed as overland flow (L/s) which is calculated by:

$$Q_{overlandflow} = i(t) * A_s \qquad (3\text{-}6)$$

The swale area, A_s for SHA is 0.312 ha and for MDE is 0.431 ha. Since the rainfall is continuous and the rain gauge reading is collected every 2 minutes, it is hard to calculate the instantaneous rainfall flow at a specific moment. Therefore, $Q_{overlandflow}$ is calculated by using a moving average flow where the rainfall (i(t)) is combined into 10 minutes intervals. In other words, the i(t) is the average rainfall intensity for every 10 minutes. By this way, it also helps to smooth the hydrograph.

Typically, there is a lag time between the peak of the rain and the peak flow of the swale. This is because the rainfall and the highway runoff need time to travel through the swale before it reaches the weir, and from a few observations of the storms, it takes about 10 minutes for the water to travel through the swale and reaches the weir. In other words, the travel time is assumed to be 10 minutes. Therefore, the $Q_{overlandflow}$ is lagged for 10 minutes before being subtracted from the flow calculated by the weir from Equation 3-1. The result is called the total grass swale discharge, Q_{swale}:

$$Q_{swale} = Q_{weir} - Q_{overlandflow} \tag{3-7}$$

This method only allows comparison of inflow and outflow with respect to time but it does not allow any instantaneous analysis of infiltration. Besides, the threshold line for infiltration capacity obtained is only valid for the duration of storms that are covered in this study (up to 12 hours). For simplification purposes, Q_{swale} will be referred as Effective Flow in the discussion later.

APPENDIX 3-E*3.6.3* TOTAL STORM VOLUME

The total storm volume for the direct runoff and the swales are calculated by integrating the flow over the storm duration:

$$V_{direct} = \int_0^{T_d} Q_{weir}(t)dt \tag{3-8}$$

$$V_{swale} = \int_0^{T_d} Q_{swale}(t)dt \tag{3-9}$$

Where V represents the total volume (L) and T_d represent the duration of the storm event.

3.7 Pollutant Data Evaluation and Calculations

The mass balance around the grass swale is important in order to evaluate the water quality of the highway runoff. The mass balance includes pollutant concentration as a function of time (Figure 3-7, Equation 3-4):

$$R(t)C_{road}(t) + D(t)C_{rain}(t) - I(t)C_{swale}(t) + T(t) = Q(t)C_{swale}(t) \qquad (3\text{-}10)$$

The term T(t) represents the grass swale treatment term that includes the sum of processes that occurs within the grass swale, such as sedimentation, filtration, absorption and resuspention of sediments or pollutants. A positive T(t) indicates an export of pollutants but a negative T(t) indicates removal of pollutants. For simplification, the pollutant concentration from the rainfall is assumed to be negligible compared to the pollutant from the roadway surface. Equation 3-10 is therefore simplified to:

$$R(t)C_{road}(t) - I(t)C_{swale}(t) + T(t) = Q(t)C_{swale}(t) \qquad (3\text{-}11)$$

APPENDIX 3-F*3.6.1* TOTAL MASS LOAD

The total mass in the flow that is leaving the sampling points is calculated as:

$$M = \int_0^{T_d} Q_{weir} C\,dt \qquad (3\text{-}12)$$

Where C represent the pollutant concentration either in swale flow or from the roadway. By taking the integral for each term in Equation 3-12, the total mass measured leaving the swale is:

$$M_{swale} = M_{road} - M_{infiltration} + M_{treatment} \qquad (3\text{-}13)$$

APPENDIX 3-G*3.6.2* EVENT MEAN CONCENTRATION (EMC)

Event mean concentration is a statistical parameter representing the flow-weighted average of a desired water quality parameter during a single storm event (Wanielista and Yousef 1993). The concept behind this parameter is as if all runoff from the drainage area were collected in a large tank during a storm, the pollutant concentration in this tank would correspond to the EMC. In this study, sequential discrete samples are collected; the EMCs values are determined by calculating the cumulative mass of pollutant and dividing it by the volume of runoff (area under the hydrograph):

$$EMC = \frac{\int_0^{Td} CQ_{weir}\,dt}{\int_o^{Td} Q_{weir}\,dt} \tag{3-14}$$

Pollutant concentrations among various events are compared by using the EMC since it represents a single mean concentration. Both data from the current research and the previous research by Stagge (2006) will be compared using this parameter in order to see the benefits of having check dams on the swales.

APPENDIX 3-H*3.6.3* EFFECTIVE EVENT MEAN CONCENTRATION (E-EMC)

Normalization of the event mean concentration is done in order to take into account the dilution effect of the rainfall onto the highway runoff. It is simply done by dividing the mass of the swale with the total volume of the swale after eliminating the excess rainfall:

$$E - EMC = \frac{Mass_{swale}}{Volume_{swale} - Volume_{rainfall}} = \frac{\int_0^{Td} Q_{weir}(t) C_{swale}\,dt}{\int_0^{Td} Q_{swale}(t)\,dt} \tag{3-15}$$

Both EMC and E-EMC are important because EMC shows the actual field-based pollutant concentration that will impact the receiving water body while E-EMC describes the true removal capability of the swale by taking into consideration the dilution effects.

Since the direct channel has no impervious area, no dilution took place. Therefore, swale E-EMCs can be compared to the direct channel EMCs for water quality comparison purposes. Differences between the two represent the treatment process, T(t) of the swale.

3.7 Statistical Analysis

Statistical analyses are very important to clarify three hypotheses that are made for the study which are:

1st Hypothesis: Either grass swale with check dams is making statistically significant improvement on the hydrology or the water quality.

2nd Hypothesis: The inclusion of grass pretreatment area prior to the grass swale makes statistically significant difference in the hydrology or the water quality.

3rd Hypothesis: Either grass swale with check dams is making statistically significant improvement on the hydrology or the water quality compared to grass swales without check dams (Stagge 2006).

All data collected from the direct concrete channel are considered input and all data collected from the SHA and MDE swales are considered output. Direct comparisons are made since the highway drainage areas of the three sampling points are identical and all rainfall that falls directly on the swales is eliminated from the calculation. Comparisons are made between input and output in order to clarify whether the data collected fulfill the three hypotheses mentioned above.

3.7.1 *Overall Statistical Analysis Procedure*

Two tests are used to clarify the hypotheses: Dixon-Thompson Test and Mann-Whitney U Test. These tests are considered paired tests, where the values for each input and output for each storm event are paired in order to see the performance of the swales. Similar with Stagge (2006), all data collected from each storm events are considered as random populations and the data that can be compared in these tests consist of total mass, EMC, E-EMC, peak flow and total volume. Each of the tests will be further explain in Sections 3.7.2 – 3.7.4.

Table 3-4 summaries the list of tests performed to the paired variables, the purpose of each test and the hypothesis of each test.

Table 3-4. Summary of the statistical tests used to identify outliers and significant different between two populations.

Step	Test & Purpose	Hypothesis
1	***Dixon-Thompson Test*** - Identify and possibly remove outliers for both A_{CD} and B_{CD} (McCuen 2003)	H_o: All points are from the same population. H_a: The most extreme point is not from the same population.

2	**Wilcoxon-Mann-Whitney Signed-Ranks Test** - Determine if both data came from the same population. (Siegal and Castellan1988)	H_o: $\mu_{SHA\text{-}CD} = \mu_{DIRECT}$ H_a: $\mu_{SHA\text{-}CD} \neq \mu_{DIRECT}$ H_o: $\mu_{MDE\text{-}CD} = \mu_{DIRECT}$ H_a: $\mu_{MDE\text{-}CD} \neq \mu_{DIRECT}$ H_o: $\mu_{SHA\text{-}CD} = \mu_{MDE\text{-}CD}$ H_a: $\mu_{SHA\text{-}CD} \neq \mu_{MDE\text{-}CD}$ H_o: $\mu_{SHA\text{-}CD} = \mu_{SHA}$ H_a: $\mu_{SHA\text{-}CD} \neq \mu_{SHA}$ H_o: $\mu_{MDE\text{-}CD} = \mu_{MDE}$ H_a: $\mu_{MDE\text{-}CD} \neq \mu_{MDE}$

The first step is important for justification of the assumptions used for the second test. The information will be helpful if decisions need to be made on which test is more applicable in case of disagreement in the analyses. The second step compares the performance between the swales with check dams and also between the swales without any check dams from Stagge (2006). Further explanation on why these tests are chosen can be found in Stagge (2006).

3.7.2 *Dixon-Thompson Test for outliers*

The Dixon-Thompson test is used for detecting outliers on the extreme; either the highest or the lowest value. This test is suitable when the sample size (n) is between 3 to 25 observations. The data is ranked in ascending order, and then based on the sample size the tau (τ) statistic for the highest value or the lowest value is computed. The equations used to compute the tau statistic are tabulated in Table 3.5.

Table 3.5 Equations for calculating outliers in Dixon-Thompson Test (McCuen 2003).

Sample size, n	Highest Value Outliers Test	Lowest Value Outliers Test
3 to 7	$\tau = \frac{X_n - X_{n-1}}{X_n - X_1}$	$\tau = \frac{X_2 - X_1}{X_n - X_1}$
8 to 10	$\tau = \frac{X_n - X_{n-1}}{X_n - X_2}$	$\tau = \frac{X_2 - X_1}{X_{n-1} - X_1}$
11 to 13	$\tau = \frac{X_n - X_{n-2}}{X_n - X_2}$	$\tau = \frac{X_3 - X_1}{X_{n-1} - X_1}$
14 to 25	$\tau = \frac{X_n - X_{n-2}}{X_n - X_3}$	$\tau = \frac{X_3 - X_1}{X_{n-2} - X_1}$

The tau is then compared to a critical value (α) at 5% level of significance in McCuen (2003). If the tau is less than the critical value, the null hypothesis is not rejected and that point is not considered as an outlier. If the tau is more than the critical value, the null hypothesis is rejected and that point is considered as a candidate outlier. However, the outlier candidate can only be removed from the data set in this study if there is some physical reason for the abnormally high or low value, such as an abnormally intense storm. If the point is considered as an outlier, it is then removed from the data set and all subsequent calculations.

3.7.3 *Wilcoxon-Mann-Whitney U Test*

Wilcoxon-Mann-Whitney U Test is a nonparametric test that was used in order to evaluate the significant difference between two populations. Table 3.4 list five main cases that are being evaluated. Below are the steps for the test:

1) Determine the value of *m, n and N*. The number of cases in the smaller group is *m* (denoted X); the number of cases in the larger group is *n* (denoted Y); total cases is *N*. Alpha (α) is set to be 5%.

2) Data from both groups are combined and sorted from lowest to largest, being careful that the identity of the data is retained and then these data are ranked in increasing order (1 to the score that is algebraically lowest). An average of the tied ranks is assigned for any tied observations.

3) Determine the sum of ranks in group X, W_x.

4) For large samples, m>10, n>10, the sampling distribution W_x approaches a normal distribution, with mean, variance and significant z value calculated as :

$$Mean = \frac{m(N+1)}{2} \tag{3-16}$$

$$Variance = \frac{mn(N+1)}{12} \tag{3-17}$$

$$z = \frac{W_x \pm 0.5 - Mean}{\sqrt{Variance}} \tag{3-18}$$

5) If m<10 and n<10, the probabilities associated with the significant value, W_x is listed in the table in Siegal and Castellan (1988).

The critical value for the standard normal distribution (z) is found in the statistic table for a 5% level of significance. If the z calculated is larger than the critical z, the null hypothesis is rejected; both data came from different populations and therefore it implies that the grass, the pretreatment area, or the check dams are either successfully improving the hydrology and water quality parameter of the runoff or making the hydrology and water quality worse.

The statistical data such as the mean and the median for the direct and the swales will determines the significant difference of the swales for better or for worse.

3.8 Swale Performance Plots

Two types of plots are frequently used in this study: time based plots and probability plots. The time based plots are used for plotting rainfall, flow rates and constituent concentrations. These plots provide a better understanding of each specific storm event since the plots show delays in peak flow, delay of peak concentrations and differences in performance among the three sampling points.

On the other hand, probability plots are used to compare the distribution of the input (Direct) and the output (MDE-CD Swale and SHA-CD Swales). Comparisons will also be made between the data for current study and the data by Stagge (2006). Probability plots for peak flows and each pollutant were created by ranking the average value for each event from largest to smallest. The plotting position for each value on the probability scale, *p* was determined as:

$$P = \frac{i - \alpha}{(n + 1 - 2\alpha)} \qquad (3\text{-}19)$$

where i represents the smallest number in sample of size n and α represents a constant that describes the plotting position function, selected as α =3/8 (Cunnane 1978). Therefore, for this study, the plotting position function for the probability plots is:

$$P = \frac{i - 0.375}{N + 0.25} \qquad (3\text{-}20)$$

The best fit line for the data can be drawn and these lines are compared in order to draw conclusions for the swales performance. The x-axis will represent the probability and the y-axis will represent either flow or constituent concentration. All complete flow captured events, are plotted separately along the horizontal axis and therefore those data will not be considered in the best fit line.

Chapter 4

Results and Discussion

4.1 Field Sampling Description

Twenty four storm events have been sampled and analyzed throughout the research duration, August 2006 to July 2008. One of the events (2/25/2007) was a snow event and therefore no rainfall data were collected. Among those 24 storms, 10 storms were considered completely captured where no flow output was measured from the swales. Tables 4-1 summarize all storm events.

Table 4-1. Rainfall depth and storm duration for Rt. 32 storm events. Storms with complete capture are shown in bold.

Date	*Total Rainfall (cm)*	*Duration (hr)*
4/4/2007	1.02	5.3
5/12/2007	**0.43**	**6.3**
5/16/2007	1.83	1.7
6/3/2007	2.26	10.3
7/4/2007	1.65	6.0
9/11/2007	**0.51**	**2.5**
10/19/2007	**1.17**	**11.0**
10/24/2007	**0.69**	**11.5**
11/13/2007	**0.23**	**1.3**
12/2/2007	1.24	11.5
12/14/2007	2.06	8.3
1/10/2008	**0.23**	**6.5**
2/1/2008	2.24	12.0
3/4/2008	1.73	10.0
3/16/2008	1.02	6.6
4/3/2008	1.52	8.5
4/26/2008	1.07	6
5/16/2008	1.8	6.9
6/3/2008	1.4	8.2
6/10/2008	**0.51**	**0.17**

6/16/2008	**0.91**	**3.3**
6/30/2008	**0.2**	**0.67**
7/5/2008	**0.1**	**0.17**

In some cases, there were issues in getting a full complete pollutant data due to technical problems on site and problems with laboratory equipment. Problems that occurred on site include check dam grass dying, check dam mowing, and a broken weir.

In August 2007, the housing of the portable sampler for the SHA swale was destroyed in an accident and the new housing was installed on site in September 2007. Since this is the second accident on site (first time was when Stagge (2006) was working on the site), both samplers (SHA swale and MDE swale) were installed closer to the southbound lanes of Route 32 rather than the northbound lanes. Nonetheless, this does not affect sampling data. In April 2008, the batteries for the SHA and MDE swales failed to pump water from the weir and thus, pollutant data are unavailable for the SHA swale on 4/3/2008 and the MDE swale on 4/26/2008. After replacing the batteries, no further sampling problems arose. Regarding the check dams, on 6/3/2007, the check dams were accidently mowed by State Highway Administration highway workers, and new check dams were installed on 7/1/2007.

Besides issues, full sets of pollutant data were not able to be obtained for certain storms due to technical problems with lab instrumentation. The Dionex ion chromatograph malfunctioned for the storms that occurred between 12/2/2008 and 4/3/2008. Due to that, nitrate analyses could not be done since samples must be analyzed within a week. Samples for chloride on the other hand, can be stored for a long time before being analyzed.

4.2 Hydrology Comparison

4.2.1 Storm Event Characterization

Storm trends in Maryland were analyzed by Kreeb (2003) at 15 stations within the state. Kreeb (2003) rainfall volume and duration data were collected from 10,352 storm events. Table 4-2 represents the frequency of storm events that were collected from those 15 stations.

Table 4-2. Frequency of storm events for 15 storm station in Maryland (Kreeb 2003).

	Rainfall Depth (cm)					
Event Duration	0.0254 - 0.254	0.255 - 0.635	0.636 - 1.27	1.28 - 2.54	> 2.54	***Sum(%)***
0 - 2 hr	0.2857	0.0214	0.0167	0.0043	0.0008	32.89
2 - 3 hr	0.0164	0.0257	0.0221	0.0089	0.0025	7.56
3 - 4 hr	0.0085	0.0223	0.0198	0.0083	0.0038	6.27
4 - 7 hr	0.0099	0.0351	0.0475	0.0221	0.0087	12.33
7 - 13 hr	0.0058	0.0337	0.0629	0.0528	0.0266	18.18
13- 24 hr	0.0024	0.007	0.0397	0.0611	0.0515	16.17
> 24 hr	0	0.0009	0.0043	0.0172	0.0435	6.59
Sum (%)	32.87	14.61	21.3	17.47	13.74	100

From Table 4-2, 33% of storms in Maryland are expected to have duration between 0 - 2 hours and only 6% of storms have 3 – 4 hours duration. Moreover, 33% of storm depths are between 0.0254 – 0.254 cm and only 14% of storms are more than 2.54 cm deep. This information is important for our research since it can be use as a bench mark in order to see whether the storm events sampled are a representative of storms that occurred in Maryland. Results of the frequency of storm events that were sampled on site are tabulated in Table 4-3. The data from Table 4-2 and 4-3 were further compared in Figures 4-1 and 4-2. Figure 4-1 compares the frequency of storms vis-a-vis the rainfall depth (cm) and Figure 4-2 compares the frequencies of storms vis-a-vis the duration (hr).

Table 4-3. Frequency of storm events for 23 storm events sampled at Rt 32, Maryland.

	Rainfall Depth (cm)					
Event Duration	0.0254 - 0.254	0.255 - 0.635	0.636 - 1.27	1.28 - 2.54	> 2.54	***Sum (%)***
0 - 2 hr	0.1304	0.0435	0	0.0435	0	21.74
2 - 3 hr	0	0.0435	0	0	0	4.35
3 - 4 hr	0	0	0.0435	0	0	4.35
4 - 7 hr	0.0435	0.0435	0.1304	0.0870	0	30.43
7 - 13 hr	0	0	0.1304	0.2609	0	39.13
13- 24 hr	0	0	0	0	0	0
> 24 hr	0	0	0	0	0	0
Sum (%)	17.39	13.04	30.43	39.13	0	100

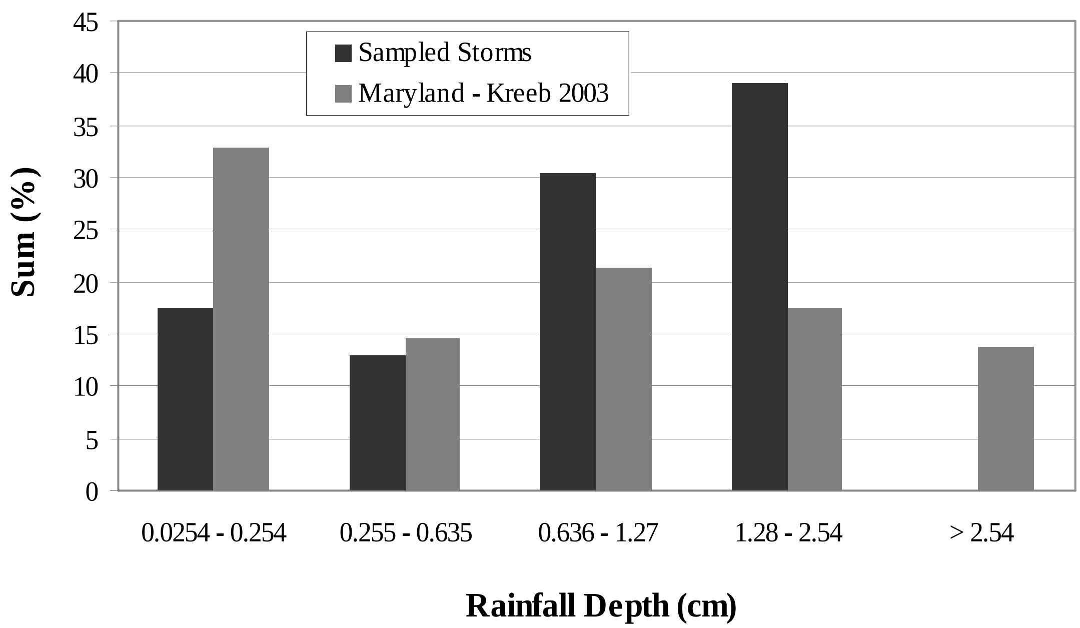

Figure 4-1 Rainfall Depth Distribution for Maryland (Kreeb 2003) and monitored Rt. 32 Storm Events.

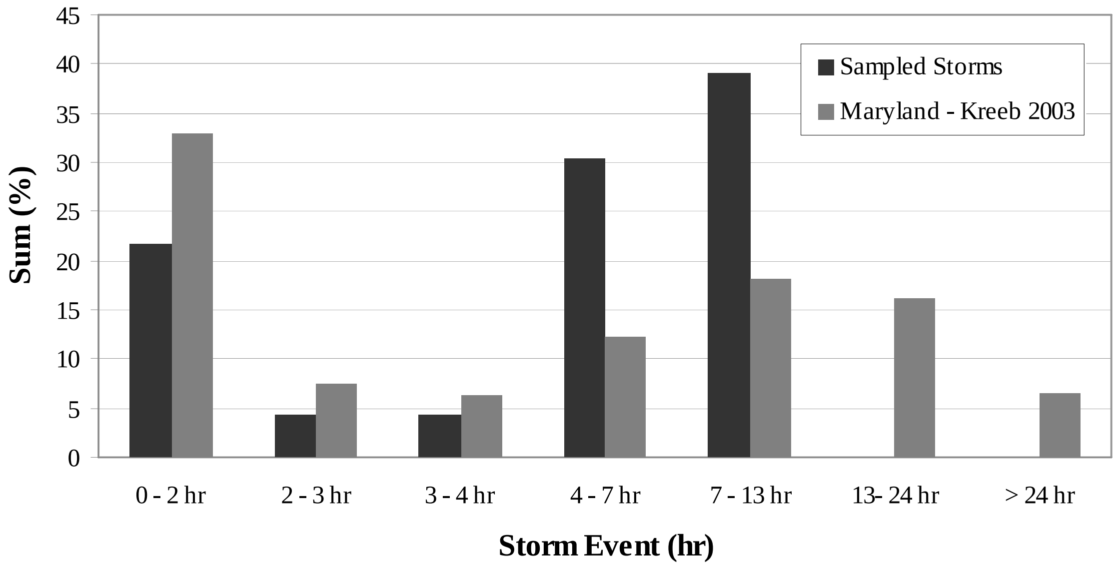

Figure 4-2. Storm duration distribution for Maryland (Kreeb 2003) and monitored Rt. 32 storm events.

From Figures 4-1 and 4-2, no specific trends are obtained but it is clearly seen that all storms sampled at Rt. 32, are less than 2.54 cm and the storm duration is not more than 13 hours. Compared to the Kreeb (2003) data, storms sampled on site were dominated by rainfall between 1.28 – 1.54 cm and 7 - 13 hours duration; both 39%. The results do not match well due to the fewer number of storm events sampled compared to the large number storm events sampled by Kreeb.

The rainfall for the 24 events ranged from 2.3 cm (0.9 inch) to as low as 0.1 cm (0.04 inch). Out of these 24 events, 10 were considered complete captured events. A complete captured event tends to occur when the rain is less than 1.2 cm (0.46 inch). This threshold is similar to the finding by Yu et al. (2001) on 275 m long swale in Virginia where complete captured events occurred for storms less than approximately 1.27 cm (0.5 inch). The swale also has two check dams but it is much longer compared to the SHA-CD swale (198 m) and

MDE swale (137 m). This shows that the length of the swale does not help to increase the capacity to infiltrates more water.

A graph of total rainfall depth at different rainfall durations is drawn from data listed in Table 4-1 (Figure 4-3). For this graph, complete captured storms and storms with discharge flow are clearly distinguished. Therefore a relationship between total rainfall and storm duration for the complete captured events can be obtained by linear regression between these two variables.

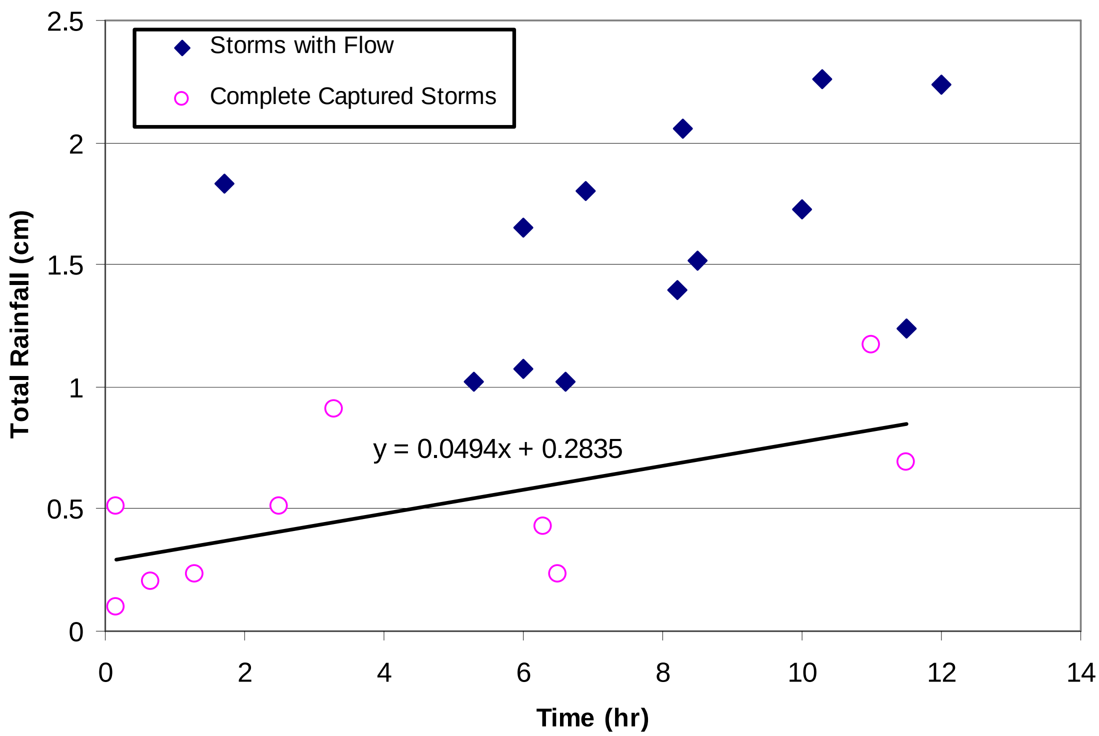

Figure 4-3. Total Rainfall Depth versus Duration. Plot showing completely captured storm events as empty circle (○) and storms with discharge as filled diamond (♦).

The best fit for the linear regression is:

$$Y = 0.0494X + 0.2835 \tag{4-1}$$

where Y represents the total rainfall depth (cm) and X represents the duration of the storm (hr). Therefore, for each storm, Y represents the threshold amount of how much rainfall that will infiltrate into the swale. In other words, Y represents the maximum infiltration capacity of the soil, f_{max}. Table 4-4 summarizes the f_{max} for each of the storm events. The water that infiltrates into the ground may increase the water table and eventually reappears as surface flow. Therefore, any rainfall above the threshold will be considered as overland flow which eventually will be part of the swale flow that needs to be excluded from the swale discharge.

Table 4-4. Maximum infiltration capacity (f_{max}) for each storm events. Complete captured events are in bold.

Date	Maximum Infiltration Capacity (cm)
4/4/2007	0.55
5/12/2007	**0.59**
5/16/2007	0.37
6/3/2007	0.79
7/4/2007	0.58
9/11/2007	**0.41**
10/19/2007	**0.83**
10/24/2007	**0.85**
11/13/2007	**0.35**
12/2/2007	0.85
12/14/2007	0.70
1/10/2008	**0.60**
2/1/2008	0.88
3/4/2008	0.78
3/16/2008	0.61
4/3/2008	0.70
4/26/2008	0.58
5/16/2008	0.62
6/3/2008	0.69
6/10/2008	**0.29**
6/16/2008	**0.45**
6/30/2008	**0.32**
7/5/2008	**0.29**

Compare to Stagge (2006), the threshold line for infiltration capacity was:

$$Y = 0.07X + 0.35 \qquad (4\text{-}2)$$

All units and variables are defined similar with the current study but the duration storms that are covered in this study are up to 30 hours compared to 12 hours for the current study. The maximum infiltration capacity of the soil, f_{max} will be higher in this case. For example, for 6 hours storm event, the f_{max} obtained will be 0.75 cm for the previous study and 0.58 cm for the current study. Having a higher infiltration capacity will allow more water to infiltrate and eventually helps to reduce the runoff volume. Besides that, this also shows that the maximum infiltration capacity depends on the duration storms covered by the study.

4.2.2 Flow with respect to time

Hydrographs were created to observe the effectiveness of the grass swales in reducing the peak flow of each event and the time delay between both initial flow and flow from both swales. The hyetograph is incorporated onto the hydrograph. A hyetograph from the April 4, 2007 event is shown in Figure 4-4.

From the hydrograph, it can be seen that the direct channel flow mirrors the rainfall hyetograph (Figure 4-4). High peaks in effective flow for the direct channel correspond to high peaks in rainfall. The effective flow used in the graph is the flow after excluding the overland flow from the calculated flow at the weir (Equation 3-7). Further explanation regarding the effective flow is presented in Section 3.6.2. In most of the events, significant runoff flows reduction was noted through the swales.

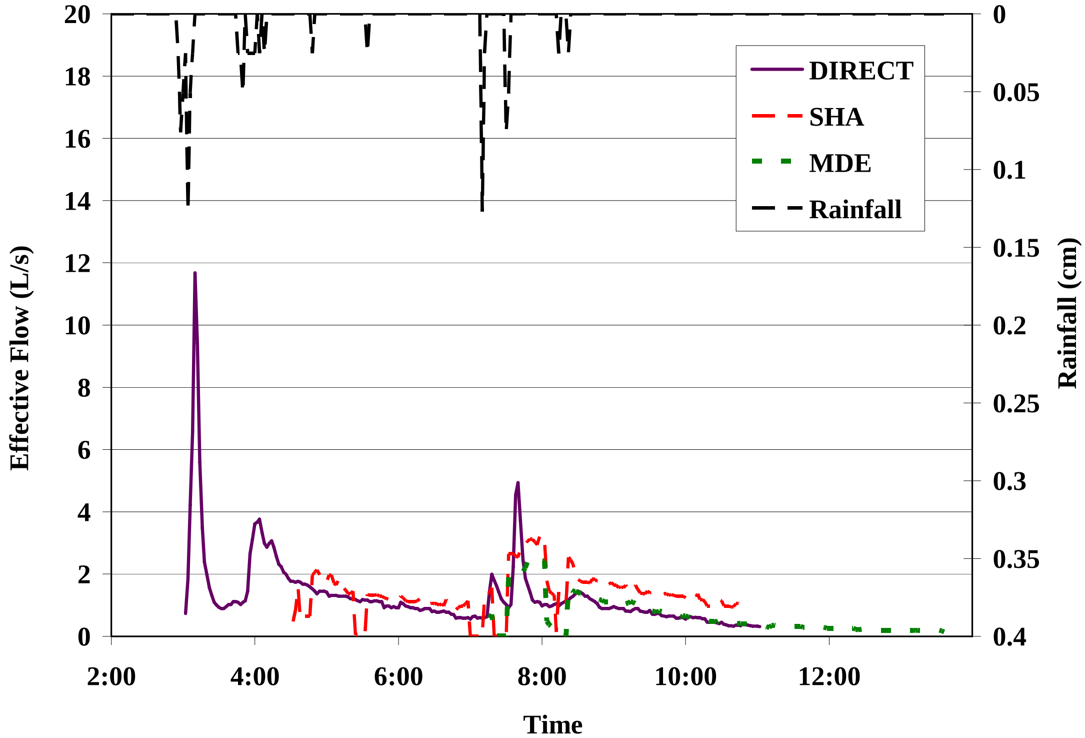

Figure 4-4. Effective Flow for 4/4/07 Storm Event at Rt. 32 Swales

In the event of 4 April 2007 (Figure 4-4), the peak flow from the direct was 11.7 L/s and was reduced to 2.6 L/s (MDE) and 3.2 L/s (SHA). Comparing both swales, runoff from the SHA swale for this particular event reached the outlet earlier, apparently due to less contact time in the swale. The peak flow for the MDE swale and the SHA swale was delayed for about 4.5 hours and 1.8 hours, respectively. However, having a secondary peak in the middle of the event can complicate the performance analysis, since it could affect the infiltration capacities of the swales.

Another type of flow behavior exhibited during storms is complete capture events. This phenomenon occurs when the rainfall intensity is small and not enough to produce flow through the swales, but flow still occurs through the direct channel, as demonstrated in Figure 4-5. In this event, the rainfall was 0.91 cm (0.36 inch) and lasted for about 3.3 hours.

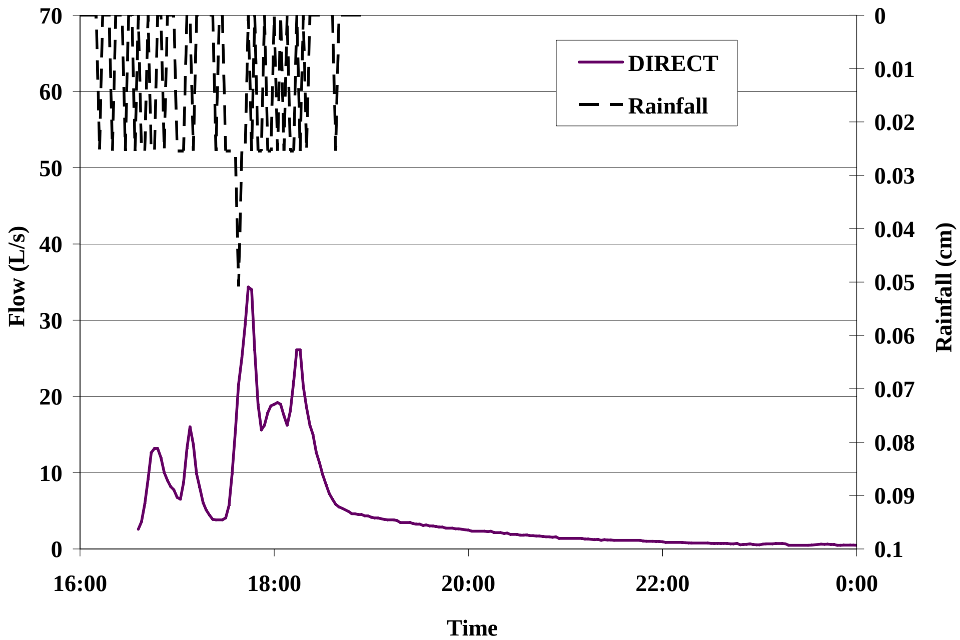

Figure 4-5. Direct Flow for 6/16/08 Storm Event at Rt. 32 Swales (Complete - Capture).

The second largest rain event out of the 23 events occurred on 12/14/07 (Figure 4-6), which was 2.1 cm (0.81 inch) and lasted for about 9 hours. In this event, the SHA swale did not function as expected. It did not reduce the flow but instead it had more flow than the direct and a higher peak discharge. A few secondary peaks in the middle of the event, starting around 1:00 am seemed to contribute to this phenomenon. By comparing this event to the event on 4/4/07 (Figure 4-4), similar phenomena are actually occurring. Around 8 am on 4/4/07, a second peak occurred and from that point, the SHA swale had more flow than the direct. Flows from the surrounding area may contribute to the swale flow at high event intensity. Furthermore, in both events, the MDE swale did not help much to reduce the flow.

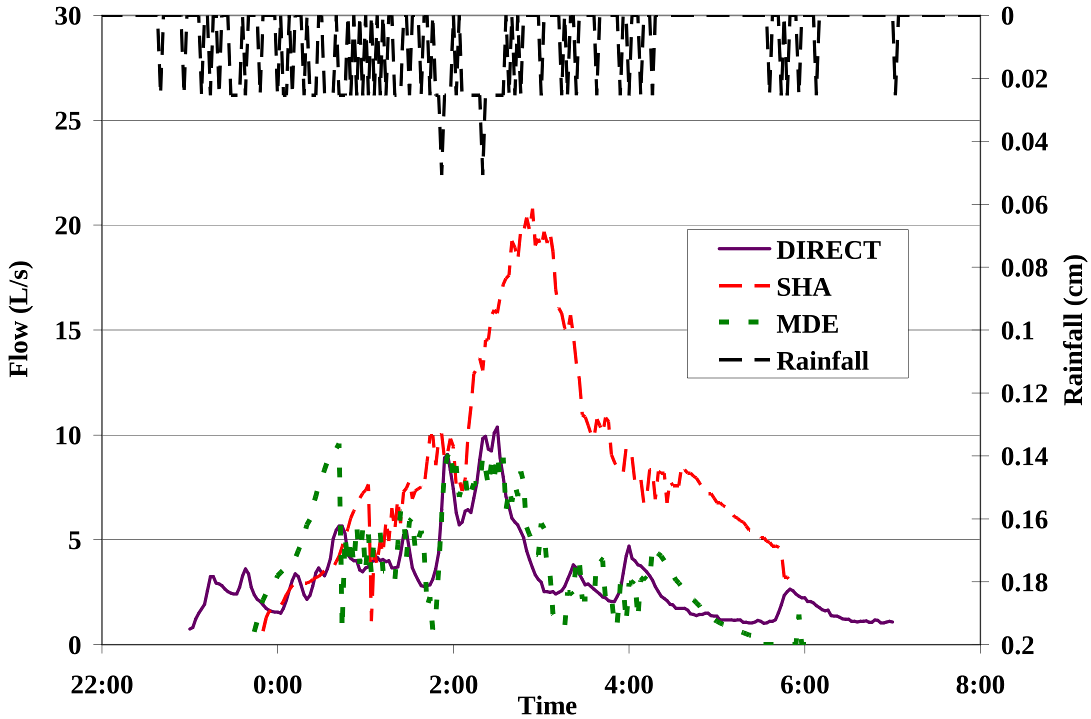

Figure 4-6. Effective Flow for 12/14/07 Storm Event at Rt. 32 Swales.

In the event of snow, the grass swales did not perform as they would for rain. The output produced more flow than the input because when the snow started to accumulate, the ground was freezing. When the rain started, the snow that covered the swales melted, flowing through the swale together with the runoff. Figure 4-7 shows this phenomenon. This phenomenon agrees with the finding of Soderlund (1972), where due to the swale being covered by snow, flow resistance and filtering effects are much lower compared to the rest of the seasons. Therefore, water tends to just flow on the swale instead of infiltrating into the soil.

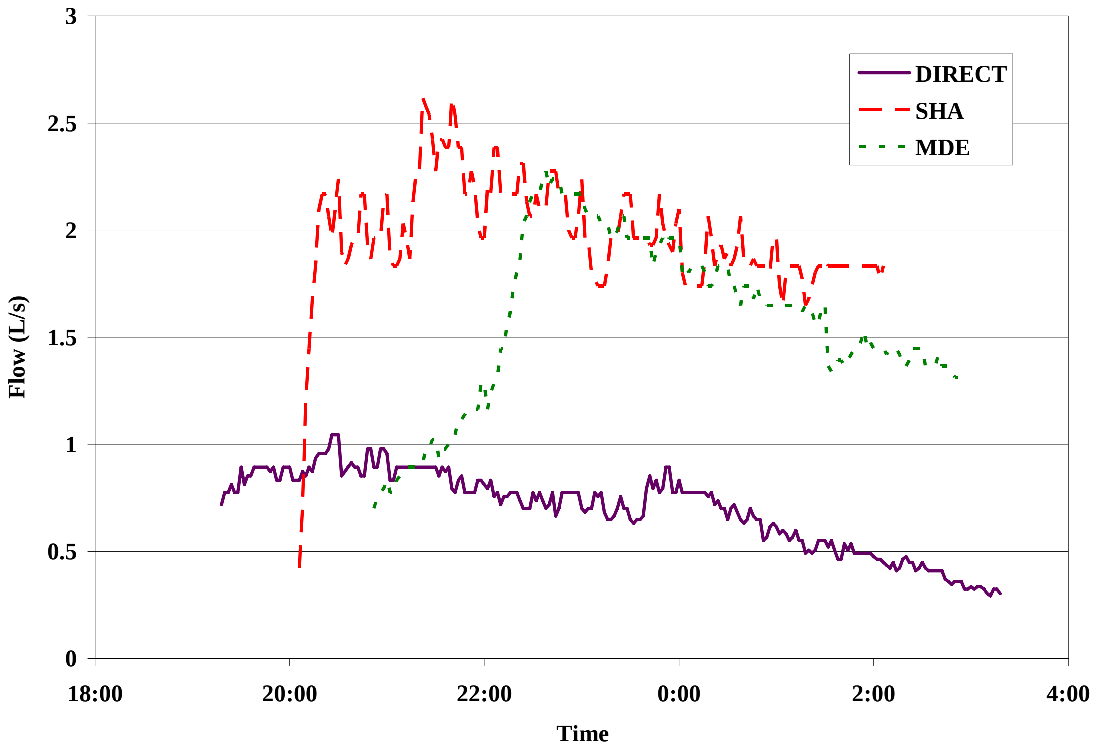

Figure 4-7. Flow for 2/25/07 Rain/Snowmelt Event at Rt. 32 Swales

4.2.3 Peak Flows and Lag Time

In order to have a better understanding on the overall performance of the swales specifically looking at the hydrology aspect, effective peak flows probability plots were synthesized by ranking the effective peak flows observed from each monitoring point from largest to smallest (Figure 4-8). Table 4-5 summarizes the effective peak flows for all storm events, including lag times.

Table 4-5. Summary of effective peak flow, effective volume and lag time for each storm events.

	Peak Flow (L/s)			Effective Volume (L)			Lag Time (hr)	
Storm event	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**SHA**	**MDE**
2/25/2007	1.05	3.20	3.00	20020	42600	34100	0.82	1.58
4/4/2007	11.67	2.60	2.28	33800	29300	14700	1.83	4.50

5/12/2007	3.70			11400				
5/16/2007	55.00	9.00	8.90	32800	31600	14300	0.15	0.20
6/3/2007	22.00	10.00	6.70	53200	27900	14000	5.40	5.50
7/4/2007	52.00	24.00	11.00	41500	27200	34300	0.47	0.47
9/11/2007	8.00			7830				
10/19/2007	26.00			25600				
10/24/2007	8.00			25400				
11/13/2007	1.10			3460				
12/2/2007	23.00	7.00	10.00	67700	27500	21200	5.37	5.60
12/14/2007	10.00	21.00	10.00	86700	183000	85300	0.83	1.07
1/10/2008	1.00			1580				
2/1/2008	18.00	12.00	9.00	97200	142000	75400	0.67	0.70
3/4/2008	30.00	13.00	12.00	55800	114000	42500	1.10	1.30
3/16/2008	8.00	3.00	3.00	36300	23900	6100	0.90	1.30
4/3/2008	6.00		3.00	63000		9420		4.97
4/26/2008	5.40	0.60		25000	6410		2.17	
5/16/2008	32.00	14.00	9.00	317000	82500	29200	1.50	1.68
6/3/2008	37.00	3.00	2.00	51700	9350	2670	3.17	5.72
6/10/2008	40.00			7110				
6/16/2008	9.00			29100				
6/30/2008	4.00			5910				
7/5/2008	1.00			820				

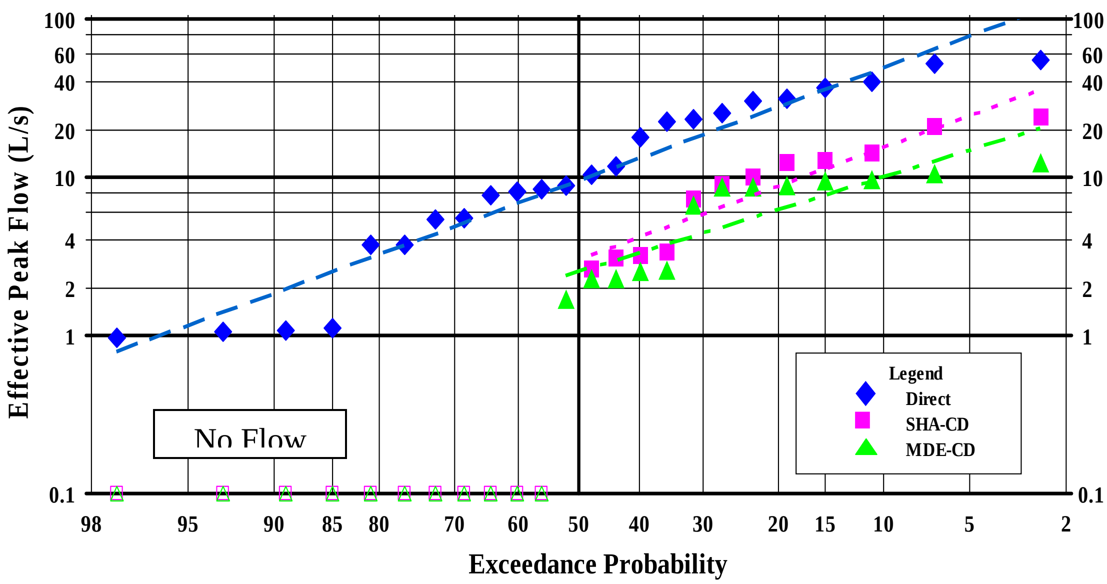

Figure 4-8. Probability plot for Effective Peak Flow at Rt. 32 Swales

The lag time listed in Table 4-5 is the time difference between the starting point of the direct flow and that of the swales. Having a longer lag time shows that the swales are actually slowing down the runoff and this allows more filtration and infiltration to occur within the swale. The average time for the SHA swale to start receiving flows at the weir is about 2 hours and the average time for the MDE swale is about 3 hours. Statistically there is no significant difference in performance for both swales. Having check dams helps to retain water longer on the swales.

Furthermore Figure 4-8 shows that the effective peak flow median values for the Direct, SHA and MDE are about 9.5 L/s, 1.6 L/s and 2.0 L/s, respectively. Each point on the plot was obtained from the effective peak flow for the swales and the direct for every storm event. There is a reduction of the effective peak flow median between the direct and the swales but statistically there are no significant improvement between the reduction of peak flow between the direct and the swales. There is also no significant difference in performance between those two swales either. This might be due to the nature of the statistic test where zero values (complete-captured events) are not incorporated in the calculations.

The average peak reduction by the swales is between 61% for SHA-CD swale and 68 % for MDE-CD swale. The Stagge (2006) study showed a lower percentage of peak reduction, 50 – 53%. This shows that the check dams on the swales do provide extra time to allow the runoff to infiltrate into the soil and further reduce the peak flow. Besides that, having a pre-treatment area allows the peak to spread out and further reduce the peak flows.

In most cases, the swales do not help much in reducing the total volume of the storm but swales definitely helps to reduce the effective peak flow which eventually helps the downstream water body. This phenomenon can be seen in Figure 4-9 where all flows for 6/3/07 storm were ranked from highest to lowest with 6 minutes increments. The total rainfall for this event was 2.26 cm that last for 10 hours. The graph shows that if the stormwater is not treated by the swales, the flow that will enter the river/stream will be about 17 L/s but with check dams swale (SHA-CD), the river/stream will only be impacted with 10 L/s. Even better, the check dams swale with the pre-treatment area (MDE-CD) is able to reduce the flow to about 6 L/s.

From the literature, in order to reduce the erosion in a water body such as a river, a maximum flow velocity of 4 – 5 ft/s (2-yr storm event) is recommended because that is considered a non-erosive flow (Claytor and Schuler 1996). Since this is a velocity, the area or size of the water body would eventually determine whether the flow that enters the river would erode the river bank or not. For example, a reduced peak flow of 17 L/s might not harm the larger river but might still be harmful for the smaller river. Therefore, whether or not the reduction of peak flow could help to reduce the erosion in the water body downstream is dependable on the size of the water body downstream.

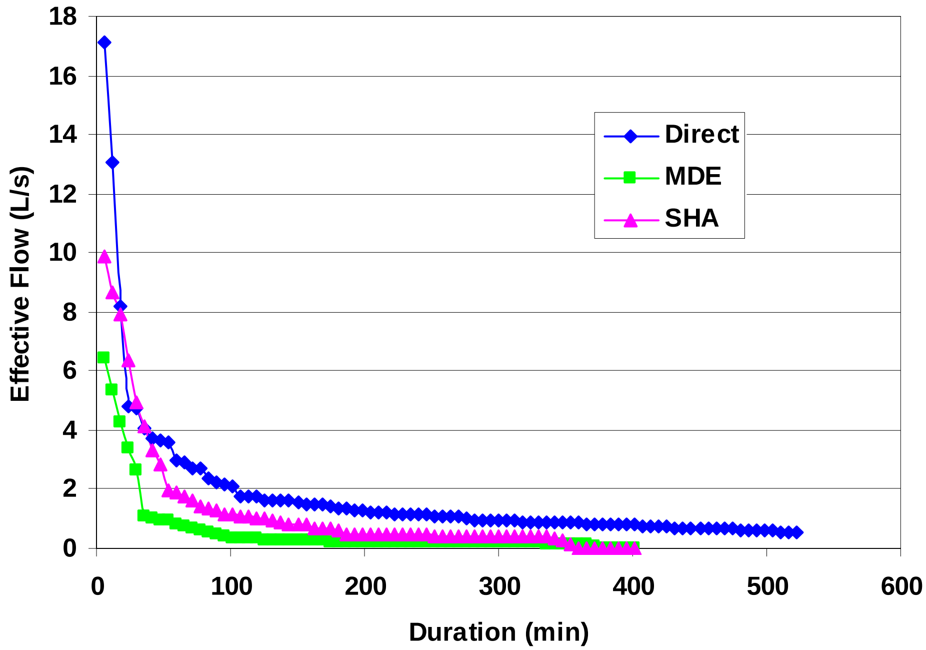

Figure 4-9. Effective Flow for storm sampled on 6/3/07 at Rt. 32 versus Storm Duration

Moreover, the combinations of all flow data for 23 rainfall events are plotted against the storm duration in increments of 6 min in Figure 4-10. It further clarify that through out the research, the swales did help to reduce the effective peak flows and the results show that the swale with a pretreatment area (MDE) performs better than the swale without pretreatment (SHA). The highest peak flow for Direct, SHA and MDE are 51 L/s, 20 L/s and 11 L/s respectively. Having extra area to infiltrate the water clearly helps in reducing the peak flows and indirectly reducing the volume. Lower peak flow eventually helps to reduce river bank erosion.

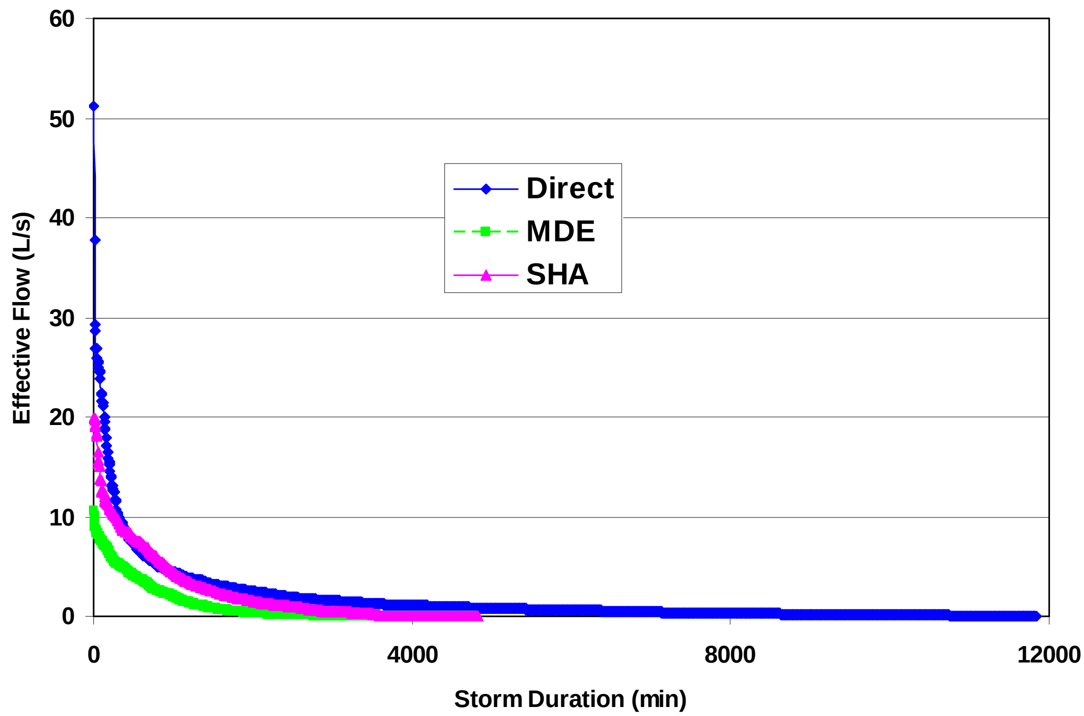

Figure 4-10. Cumulative Effective Flow for all 24 events sampled at Rt. 32 versus Storm Duration

4.2.4 Total volume

Total volume for each event is calculated using Equations 3.9 and 3.10. Table 4-5 provides the effective volume for all 24 events. The effective volume is basically the total volume leaving the swale after removing the excess rainfall that becomes overland flow. From the probability plot of total volume (Figure 4-11), it is shown that the swales do not help significantly reduce the volume.

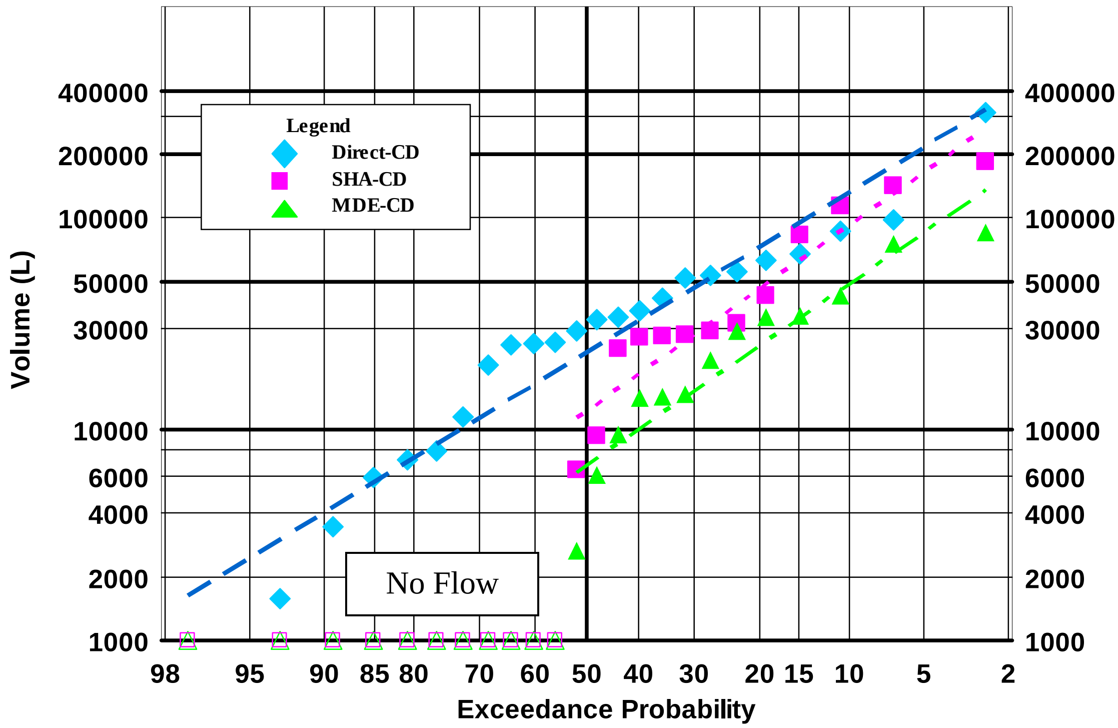

Figure 4-11. Total Volume for each sampling point at Rt. 32 for 24 events.

The median volume for the Direct is about 31000 L, SHA-CD swale is 29000 L and MDE-CD swale is 21000L. The SHA-CD swale is only capable to reduce 6% of the median volume but MDE-CD is capable to reduce 32% of the median volume. Having an extra area to infiltrate the water helps in reducing the volume but the difference is not statistically significant.

There were 4 storm events that produced more volume through the swales than the direct runoff (2/25/2007, 12/14/2007, 2/1/2008 and 3/4/2008). The first event (2/25/2007) was due to the snow melt on the swales, but the three other events are basically long duration rainfall events (more than 8 hours) with rainfall more than 1.7 cm (0.7 inch). An example of one of the other three events is given in Figure 4-12. This is the second largest storm event with 2.1 cm (0.8 inch) total rainfall that occurred for 8.3 hours.

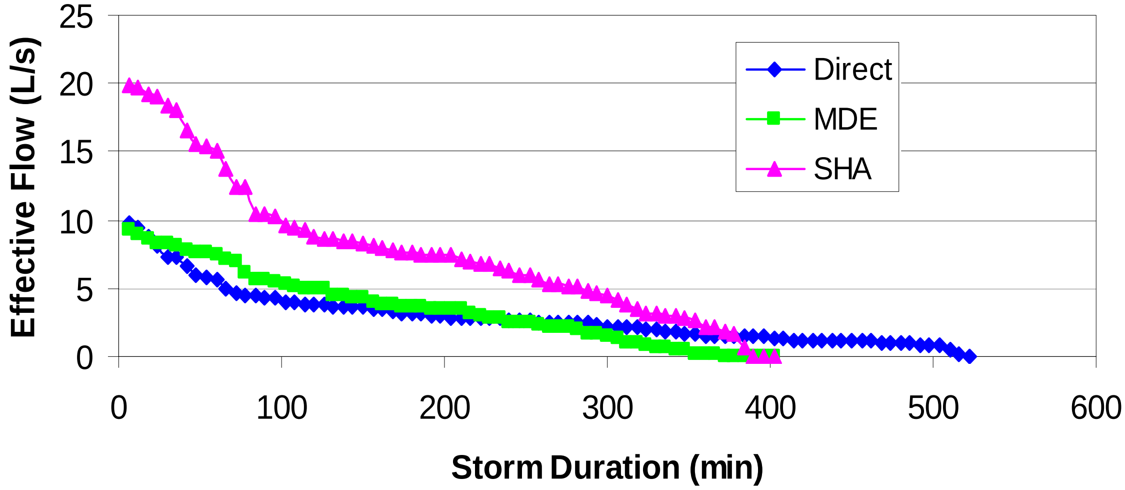

Figure 4 – 12 Cumulative Effective Flow versus Storm Duration at Rt. 32 (12/14/07)

Furthermore, the phenomenon in Figure 4 – 12 shows that the swale might have obtained more input from surrounding areas or there might be some portion of the storm that has high intensity within a short period. Therefore, the water just flows through the swale instead of infiltrating into the swale. The fact that the largest storm event with 2.6 cm (0.9 inch) total rainfall that occurs for about 10.3 hours did not produce more volume through the swales than the direct input might be due to the fact that it occurs in the middle of summer; the soil is dry and able to infiltrate/absorb more runoff since the antecedent dry period is longer. Having big storms back to back could also contribute to higher water table and therefore less runoff could infiltrates into the ground.

Comparing to the reduction of total volume with Stagge (2006), without check dams, the reduction of total volume was 46-54% but with check dams installed, the reduction is 28% for SHA-CD and 64% for MDE-CD. The SHA-CD did show any improvement of the hydrology because the check dams were not fully matured to act as usefull check dams. As seasons change, the check dams dries up and is not able to retain water longer on the swales.

Overall, although statistically the MDE-CD and SHA-CD do not show any significant improvement in hydrology, the MDE-CD swale clearly shows a better performance in lag time, reducing mean peak flows, total peak flows and volume compare to SHA-CD. Besides that, the MDE-CD reduces more total volume compare to MDE (without check dams). This shows that swale with pretreatment area perform better when check dams is incorporated in the system and it is beneficial for stormwater volume reduction; similar with the finding in the recent stormwater manuals (MDE 2000). It is not showing statistically just because the zero data for complete captured being excluded.

4.3 Pollutant Observations and Outliers

Ten pollutants were analyzed for all storms. Each storm has different pollutant concentration shapes with time, but the patterns are similar. Higher concentrations tend to occur at the beginning of the storm and when high intensity of rainfall occurred within a short time. The differences are due to variability in input flows and input pollutant concentrations. This phenomenon can be clearly seen in the Figure 4-13 and Figure 4-14 where two of the pollutant analyzed on the 12/2/07 shows high concentration at the beginning of the storm event and another peak at around 12.00 am when rainfall starts to peak again.

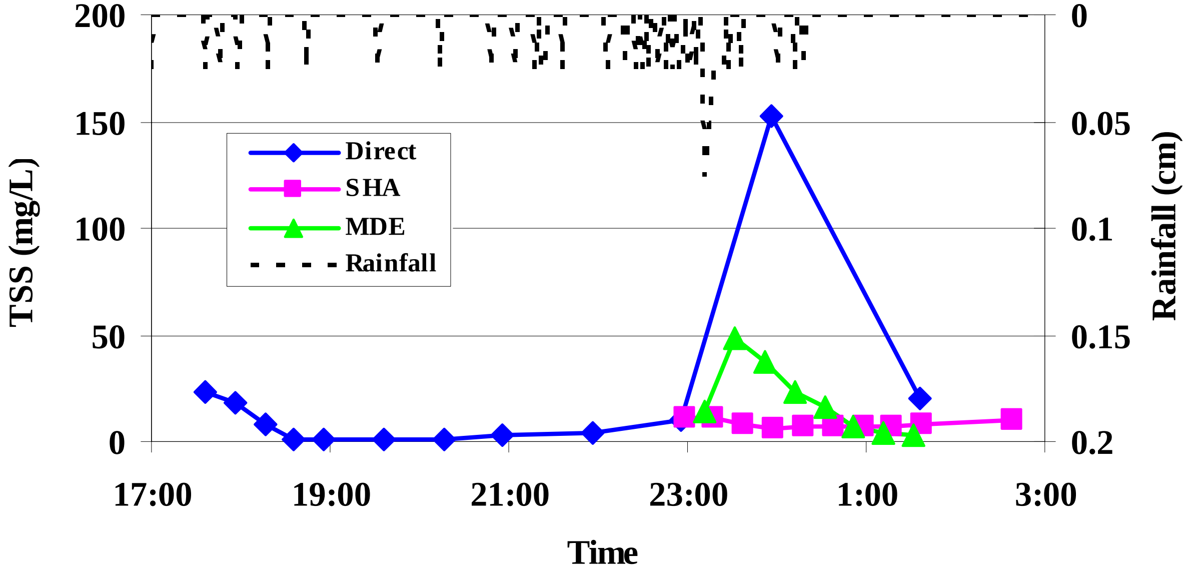

Figure 4-13. TSS Concentrations (12/2/07) at Rt. 32 Swales

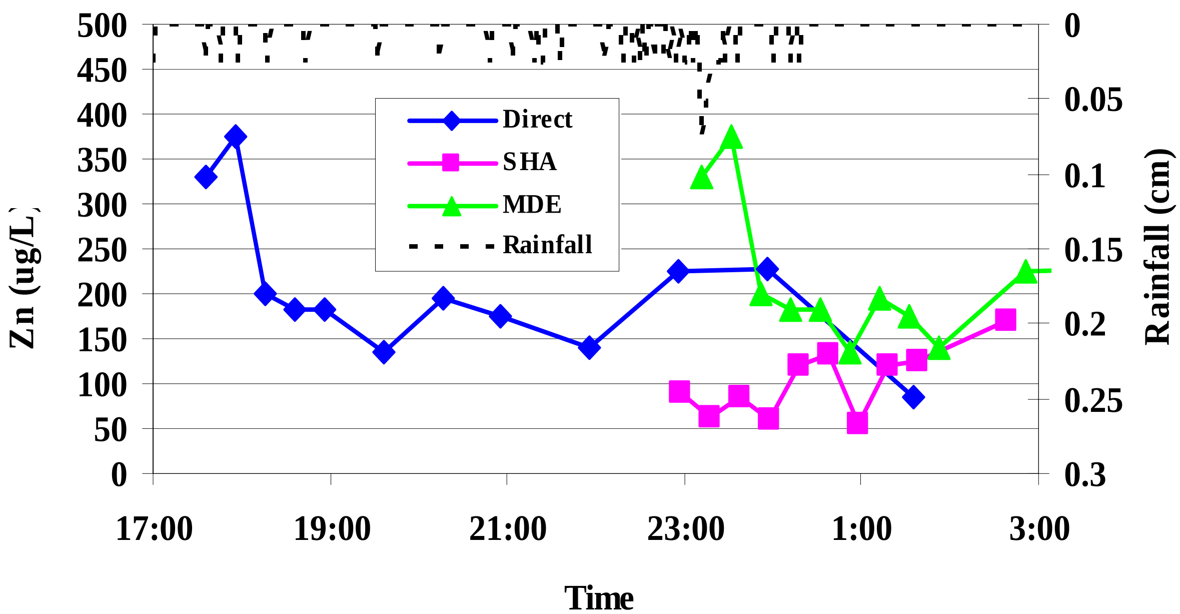

Figure 4-14. Zinc Concentrations (12/2/07) at Rt. 32 Swales

In order to analyze these data, parameters such as the Effective Event Mean Concentration (E-EMC) and total mass pollutant removal are used to quantify and compare the effects of having grass swales with check dams to treat highway runoff. Furthermore, the Event Mean Concentration (EMC) is used to quantify and compare the performance of grass swales with check dams and without check dams (Stagge 2006). Comparison is not done by using Effective Event Mean Concentration because Stagge (2006) had used a different way to incorporate the effect of rainfall dilution in the runoff, which he defines as Normalized Event Mean Concentration (N-EMC). N-EMC and E-EMC use the similar concepts where total mass leaving the swale is divided by total volume leaving the swale without rainfall on the swale. The difference between the two is the way total volume is calculated. Total volume for N-EMC is calculated as total volume of runoff leaving the swale minus the total volume of rainfall landing on the swale area during the storm event. On the other hand, the total volume for E-EMC is calculated as total volume of runoff leaving the swale minus the total saturated excess overland flow. The saturated excess overland flow only occurs after the rainfall reaches the maximum infiltration capacity of the soil (Equation 3-5).

The E-EMC's for each pollutant are determined using Equation 3-17. This equation takes into account the dilution effect of the rainfall by dividing the pollutant mass discharge of the swale with the total volume of the swale after eliminating the excess rainfall. Table 4-6 in Appendix A summarizes the E-EMCs for each pollutant for each storm event. Table 4-7 in Appendix B summarizes the EMC for each pollutant for each storm event. Both EMC and E-EMC are important because EMC shows the actual field-based pollutant concentration that will impact the receiving water body while E-EMC describes the true removal capability of the swale by taking into consideration the dilution effects.

The entire E-EMC data set is further checked using the Dixon-Thompson test in order to find any outliers at the extreme ends (highest and lowest values). Extreme events can create problems in data analysis. For example, an extremely large value can cause the sample mean and standard deviation to be much larger than the population values. However, statistically proven outliers from the sample should not be eliminated unless there is a physical reason that supports the decision to be eliminated. Table 4-8 lists all statistically proven outliers found in the study. These outliers are only at the higher end and no outliers are detected at the lower ends. Besides that, no outliers are detected for cadmium since most of them are below the detection limits.

Since the storm events are considered random, data may naturally have unusual high values. For example, high values for chloride on 2/25/2007 were due to a snow event and on 4/26/2008, there was an unusual high pollutant load occurred on the SHA swale since this swale posses high end outliers for all pollutant except for chloride and TKN. Therefore, if the value was actually measured, then such a value should not be discarded from the sample (Davis and McCuen 2005). None of the statistically proven outliers were discarded since there is no specific reason that shows that those concentrations were wrong. Since these high values are kept for further calculation, a nonparametric statistical method is more suitable for the data analysis rather than parametric statistical method. Therefore, a nonparametric test (Mann Whitney U Test) is used as a statistical tool to evaluate the significant improvement of having grass swales with check dams in improving the stormwater runoff at Rt. 32.

Table 4-8. Statistically proven outliers using Dixon-Thompson Test for 24 events at Rt. 32

Constituent	Event Date	Outliers	Source
TSS	7/4/2007	350 mg/L	*MDE*
	9/11/2007	600 mg/L	*Direct*

	4/26/2007	180 mg/L	*SHA*
Nitrate	4/26/2008	7.20 mg-N/L	*SHA*
Nitrite	5/12/2007	0.35 mg-N/L	*Direct*
	4/26/2008	0.38 mg-N/L	*SHA*
TKN	4/26/2008	4.10 mg/L	*Direct*
	6/3/2008	13 mg/L	*SHA*
	6/3/2008	19 mg/L	*MDE*
TP	7/4/2007	1.06 mg-P/L	*MDE*
	3/4/2008	0.63 mg-P/L	*Direct*
	4/26/2008	3.40 mg-P/L	*SHA*
Cl	2/25/2007	7400 mg/L	*Direct*
	2/25/2007	5000 mg/L	*SHA*
	4/4/2007	6100 mg/L	*MDE*
Pb	10/19/2007	560 µg/L	*Direct*
	4/26/2008	500 µg/L	*SHA*
Cu	3/16/2008	240 µg/L	*MDE*
	4/26/2008	500 µg/L	*SHA*
Zn	5/1/6/2007	2070 µg/L	*Direct*
	4/26/2008	850 µg/L	*SHA*

All E-EMC values were then used to construct the probability plots. All complete captured storm events resulted pollutant loads equal to zero and for these cases, a symbols with no fill is indicated on the plots. On most of the plots the water quality target for each constituent is drawn as a dashed line along the y-axis.

Another important parameter is the total mass pollutant removal. It represents the total pollutant load throughout the sampling duration and the differences between the Direct total pollutant load and the swales total pollutant load will represent the effect of swales. This parameter will be more useful than E-EMC when dealing with complete capture events. In Equation 3-13, the total mass formula involves integrating mass and concentration together over time. Therefore, zero flow results in zero mass. In other words, all storms are legitimate to be included in calculations of total mass reduction and this is useful for knowledge about long-term pollutant loadings.

Finally, the most popular way of quantifying the effects of pollutant removal by grass swales is by using the percentage of pollutant concentration reduction. However, the results maybe misleading since this parameter is highly dependent on the input concentrations.

4.4 Mann Whitney U Test and Pollutant Removal

The Mann Whitney U Test is a nonparametric test that was used to evaluate any significant difference between two populations. The Mann Whitney U Test is used for five main aspects of this study:

1) To examine any significant difference between the Direct and SHA-CD swale.

2) To examine any significant difference between the Direct and MDE-CD swale.

3) To examine any significant difference between the SHA-CD swale and MDE-CD swale.

4) To examine any significant difference between the SHA-CD swale and SHA swale (without check dams).

5) To examine any significant difference between the MDE-CD swale and MDE swale (without check dams).

A significant level of 5% was chosen and Table 4-10, summarizes the findings from the tests. From the table, P (critical) represents the 5% probability of rejecting the null hypothesis and P (calculated) is the calculated rejected probability. The cross (X) indicates that the rejected probability is more than the critical probability and the null hypothesis is accepted (there is no difference between both populations); it is also in bold. The check (√) indicates that the calculated rejected probability is less than the critical probability, the null hypothesis is rejected and the difference is significant between those two populations.

Next, in order to know whether the result designates a significant removal or significant export, other statistical parameters such as the mass, mean and median % removal are examined. The E-EMC varies over a wide range for each pollutant. The difference between the input and output E-EMC represents the ability of the grass swale and check dams to reduce the pollutant levels. The median and percent removals based on the median for each pollutant are presented in Table 4-10. The overall mass pollutant removals for each pollutant at the Rt. 32 Swales are presented in Table 4 -11.

Table 4-9. Wilcoxon Mann Whitney U Test (5% level of significant) for all pollutants.

		P(calculated)	P(critical)	Significant difference in population means
TSS	**Direct / SHA - CD**	**0.0202**	**0.05**	√
	Direct / MDE-CD	0.2912	0.05	X
	SHA-CD / MDE-CD	**0.0294**	**0.05**	√
	SHA / SHA -CD	0.2451	0.05	X
	MDE / MDE - CD	**0.0039**	**0.05**	√
Nitrate	Direct / SHA - CD	0.3372	0.05	X
	Direct / MDE-CD	0.3594	0.05	X
	SHA-CD / MDE-CD	0.2778	0.05	X
	SHA / SHA -CD	**0.0179**	**0.05**	√
	MDE / MDE - CD	**0.0317**	**0.05**	√
Nitrite	Direct / SHA - CD	0.123	0.05	X
	Direct / MDE-CD	**0.0019**	**0.05**	√
	SHA-CD / MDE-CD	0.1685	0.05	X
	SHA / SHA -CD	**0.0188**	**0.05**	√
	MDE / MDE - CD	0.0985	0.05	X
TKN	**Direct / SHA - CD**	**0.0084**	**0.05**	√
	Direct / MDE-CD	0.0749	0.05	X
	SHA-CD / MDE-CD	0.2296	0.05	X
	SHA / SHA -CD	**0.0188**	**0.05**	√
	MDE / MDE - CD	**0.0143**	**0.05**	√
TP	**Direct / SHA - CD**	**0**	**0.05**	√
	Direct / MDE-CD	0.2946	0.05	X

	SHA-CD / MDE-CD	0.1292	0.05	X
	SHA / SHA -CD	0.2236	0.05	X
	MDE / MDE - CD	0.0548	0.05	X
Chloride	**Direct / SHA - CD**	**0.018**	**0.05**	√
	Direct / MDE-CD	**0.0005**	**0.05**	√
	SHA-CD / MDE-CD	0.2119	0.05	X
	SHA / SHA -CD	0.0694	0.05	X
	MDE / MDE - CD	0.3264	0.05	X
Lead	Direct / SHA - CD	0.409	0.05	X
	Direct / MDE-CD	0.1446	0.05	X
	SHA-CD / MDE-CD	0.0869	0.05	X
	SHA / SHA -CD	0.3859	0.05	X
	MDE / MDE - CD	0.1038	0.05	X

Table 4-9. Wilcoxon Mann Whitney Test (5% level of significant) cont'd

		P(calculated)	P(critical)	Sig Significant difference in population means
Copper	Direct / SHA - CD	0.3336	0.05	X
	Direct / MDE-CD	0.2266	0.05	X
	SHA-CD / MDE-CD	0.0749	0.05	X
	SHA / SHA -CD	0.3859	0.05	X
	MDE / MDE - CD	0.0934	0.05	X
Zinc	**Direct / SHA - CD**	0	0.05	√
	Direct / MDE-CD	0	0.05	√
	SHA-CD / MDE-CD	0	0.05	√
	SHA / SHA -CD	0.0026	0.05	√
	MDE / MDE - CD	0.0019	0.05	√

Table 4-10. Median and percent removal based on E-EMC median for each pollutant at the Rt. 32 Swales.

	TSS (mg/L)			Nitrate (mg/L)			Nitrite (mg/L)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Median	60	5	9	0.7	0	0	0.06	0.01	0.02
% Removal		92	85		100	100		83	67

	TKN (mg/L)			TP (mg/L)			Cl (mg/L)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Median	0.55	0.42	0.20	0.22	0.25	0.2	20.00	50	100
% Removal		24	63		-14	9		-150	-400

	Lead (ug/L)			Copper (ug/L)			Zinc (ug/L)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Median	20	8	15	50	8	13	248	75	76
% Removal		60	25		84	74		70	69

Cadmium (ug/L)

	Direct	SHA	MDE
Median	<2	<2	<2
% Removal		-	-

Table 4-11. Overall mass pollutant removal for each pollutant at the Rt. 32 Swales.

	TSS (g)			Nitrate (g)			Nitrite (g)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Total Mass	68000	26000	42000	370	30	17	47	21	14
% Removal		62	38		92	95		55	70

	TKN (g)			TP (g)			Cl (g)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Total Mass	470	1000	260	210	220	130	290000	460000	300000
% Removal		-113	45		-5	38		-59	-3

	Lead (mg)			Copper (mg)			Zinc (mg)		
	Direct	SHA	MDE	Direct	SHA	MDE	Direct	SHA	MDE
Total Mass	51000	11000	9000	53000	23000	16000	280000	93000	59000
% Removal		78	82		57	70		67	79

	Cadmium (mg)		
	Direct	SHA	MDE
Total Mass	1200	690	380
% Removal		43	68

As mentioned above, characteristics of each storm event varies and therefore, the use of fractional mean E-EMC percent removal in runoff management has several drawbacks because it is not giving a clear picture on what is happening on the site. For example, high percent pollutant removal does not necessarily indicate an effective treatment practice because this parameter also depends on the input, and vice versa. However, having a negative value for percent removal shows that the swale is exporting the pollutant into the runoff. This phenomenon can be seen for total phosphorus and chloride for the mean E-EMC percent removal for both swales and TKN, total phosphorus and chloride for the mass percent removal specifically only for the SHA-CD swale. The swale performance for each constituent will be discussed in the next sections.

4.4 Total Suspended Solids (TSS)

The water quality goal for TSS is selected to be 30 mg/L since that is the minimum USA National Standards for secondary wastewater treatment (Metcalf and Eddy Inc., 2004).

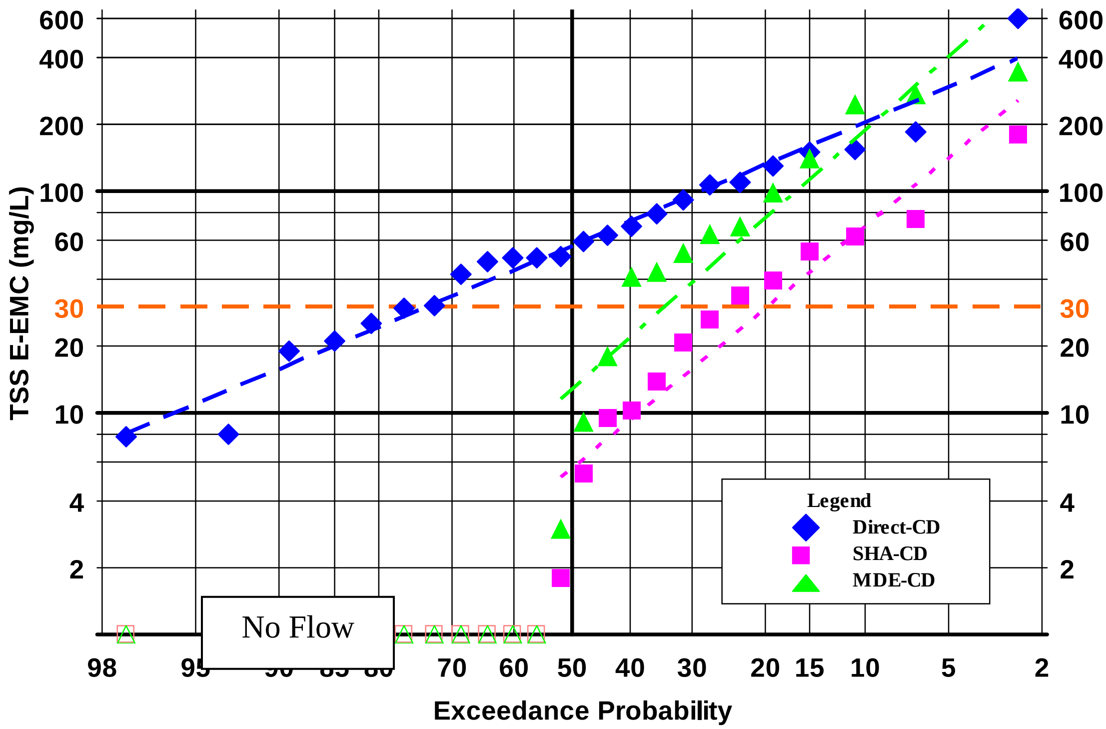

Figure 4-15. Probability plot for TSS E-EMCs at Rt. 32 Swales.

From Figure 4-15, the inflow concentration will theoretically exceed 30 mg/L during 75% of the storm events but with check dam swales, the MDE swale exceeded 30 mg/L TSS during only 35% of storm events and the SHA exceeded 30 mg/L TSS only during 25% of storm events. Summary statistics for the E-EMC from Table 4-10 shows clear difference between the median values for direct (60 mg/L), SHA (5 mg/L) and MDE (9 mg/L). The percent removals for SHA-CD swale is 92% but the percent removals for MDE-CD swale is only

85%. Statistically, only effluent TSS from the SHA-CD swale was determined to be different from the Direct and also statistically, there is a significant difference between the performances of both swales. (Table 4-9).

Since there is a significant difference between both swales, and SHA-CD works better, it shows that having a pretreatment area adjacent to the MDE swale is actually exporting more TSS into the runoff possibly due to sediment mobilized from the extra area of the pretreatment area. Although only SHA-CD is considered significantly different, the removals of both swales are similar with previous findings such as 79-98% (Backstrom 2003), 65%-98% (Schueler 1994), and 85-87% (Barrett et al. 1998). All those findings are from grass swale without check dams.

4.4.1 Total Suspended Solids (TSS) Comparison.

According to Yu et al. (2001), the mass removal at the swale outlet with check dams is higher compared to the outlet without any check dams. In the same study in Taiwan, a 30 m grass swale with one check dam in the middle produced 70% TSS mass removal at a constant flow of 4×10^{-3} m^3/s and 86% TSS mass removal at a constant flow of 0.9×10^{-3} m^3/s. At another site in Virginia with a 275 m length grass swale with two check dams produced about 94% TSS mass removal.

In the current research, for 24 storm events, Direct, SHA-CD and MDE-CD received 68 kg, 26 kg and 42 kg of TSS respectively (including complete captured events). This shows that a significant amount of TSS is transported by the MDE-CD swale compared to the SHA-CD swale. The total mass removal percentage for SHA-CD is 62% but, for MDE-CD it is only 38%. These values are smaller than those reported in the literature, due to not having a constant flow if compared to the Taiwan swale and due to a shorter swale compared to the

Virginia swale (198 m for SHA-CD and 137 m for MDE-CD swale). In order to provide a better comparison, current findings are compared to the previous study by Stagge (2006) by using the probability plot in Figure 4-16.

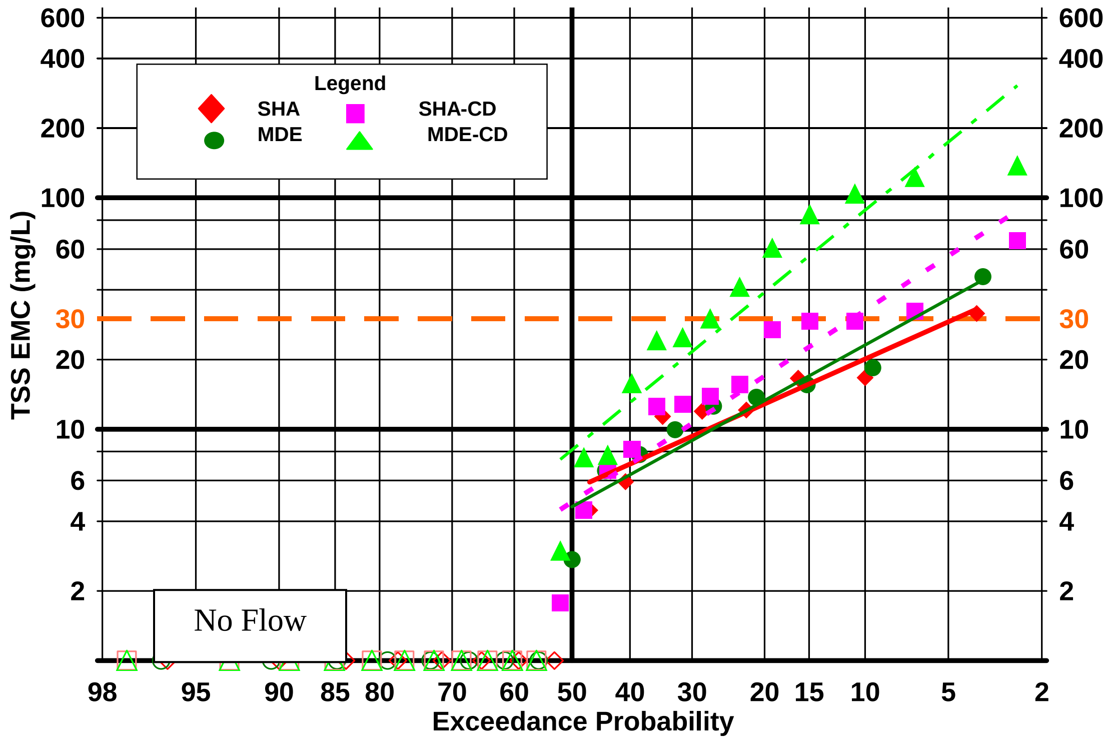

Figure 4-16. Probability plot for TSS EMCs at Rt. 32 Swales (Current study vs Stagge (2006)).

In the previous study, (without the check dams), both swales behaved similarly for TSS removal (Figure 4-14). However, in the current study (with check dams), there is a statistically significant difference between both swales. There is also significant difference between the performance of the MDE swale and the MDE-CD swale. No significant difference was found between the performance of the SHA swale and the SHA-CD swale. The MDE swale performs better without any check dams. It exceeded the water quality target only for 5% of storm events, but with the check dams it exceeded for about 25% of storm events. Besides that, previously, the total suspended solid mass was significantly reduced by the swales: 84% SHA and 73% MDE. Compare to the current finding, the total suspended solid mass was reduced only 62% SHA-CD and only 38% for MDE-CD.

In short, grass swales with check dams are capable of both reducing the total mass and the E-EMC for total suspended solids. This shows that the swales are dependent on sedimentation, filtration and infiltration process. The addition of a pretreatment area does not significantly improve the swale performance, in fact appears to degrade performance. Inclusion of check dams also does not help to significantly improve the performance of SHA-CD swale compared to SHA swale. Inclusion of check dams and pretreatment area on the swales are not appears to be necessary since the performance is worst in treating TSS.

4.5 Nutrients (Total Phosphorus (TP), Nitrite, Nitrate, TKN)

Nitrogen and phosphorus are two nutrients that are a major concern in stormwater runoff. Excess nitrogen in water bodies cause accelerated algal production and high amounts of phosphorus in runoff can produce problems at water treatment plants since it may interfere with the coagulation process (USEPA 2006). The effluent water quality goal for phosphorus is set to be 0.1 mg-P/L and 1 mg-N/L for nitrite by the National Water Quality Criteria (WQC) (USEPA 2006). Nitrate on the other hand, the excellent water quality in the Potomac River Basin is 0.2 mg-N/L. WQC was not used as the guide line for nitrate because the target is 10 mg-N/L which is too high for surface water but normal for human consume. A TKN criterion was not reported in the WQC.

4.5.1 Total Phosphorus (TP)

Unfortunately, from the probability plot (Figure 4-17), it is clearly shown that the swales are not helping towards meeting the goal and worst, all swales discharges exceeded the goal. Both swales tend to export phosphorus into the runoff. The SHA swale with check dams tends to export more phosphorus than the MDE swale with check dams. Statistically, the difference between the Direct and the SHA-CD swale is significant but neither performance between the direct and the MDE-CD swale nor between the SHA-CD swale and MDE-CD swale is significant. The mean E-EMC values for of each sampling points: Direct, SHA-CD and MDE-CD are 0.22, 0.25 and 0.20 mg/L respectively. The mean E-EMC removal of total phosphorus was found to be -14% for SHA and 9% for MDE. The removal is low compared to 31 to 61% by Barrett et al. (1998) and over 99% by Krecher et al. (19983) due to high infiltration rates.

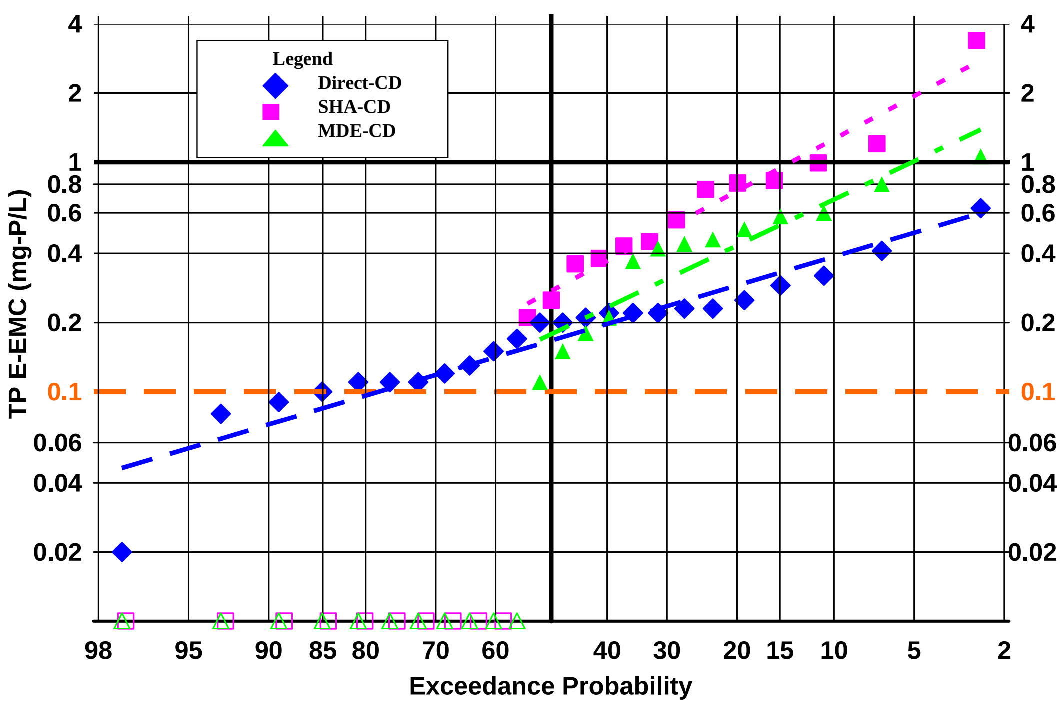

Figure 4-17. Probability plot for TP E-EMCs at Rt. 32 Swales.

In terms of total pollutant mass, the total phosphorus input loading is 213 g, SHA-CD is 224 g and MDE-CD 128 g. The total pollutant mass percent removal is -5% (SHA-CD) and 40% (MDE-CD). Statistically, the SHA-CD swale significantly exports phosphorus and having an extra pretreatment area does not help to significantly improve to reduce the phosphorus. Since phosphorus is considered as particulate bound, phosphorus removal is highly depends on physical processes such as infiltration, deposition and filtration (Barrett et al. 1998, Rose et al., 2003). Therefore, phosphorus might have been accumulating in the SHA-CD swale and leaches from time to time to cause the export of phosphorus. Length of the swale might not be the cause of the export since Yu et al. (2001) managed to obtained mass removal for about 99% for a 275 m long check dams swale and about 80% mass removal for 30 m long check dams swale.

4.5.1.1 Total Phosphorus Comparison

Figure 4-18 and statistical data from Table 4-9 shows that addition of check dams on the swale does not show any significant improvement to the water quality for phosphorus content. 50% of storm events will still exceed the water quality target of 0.1 mg-P/L.

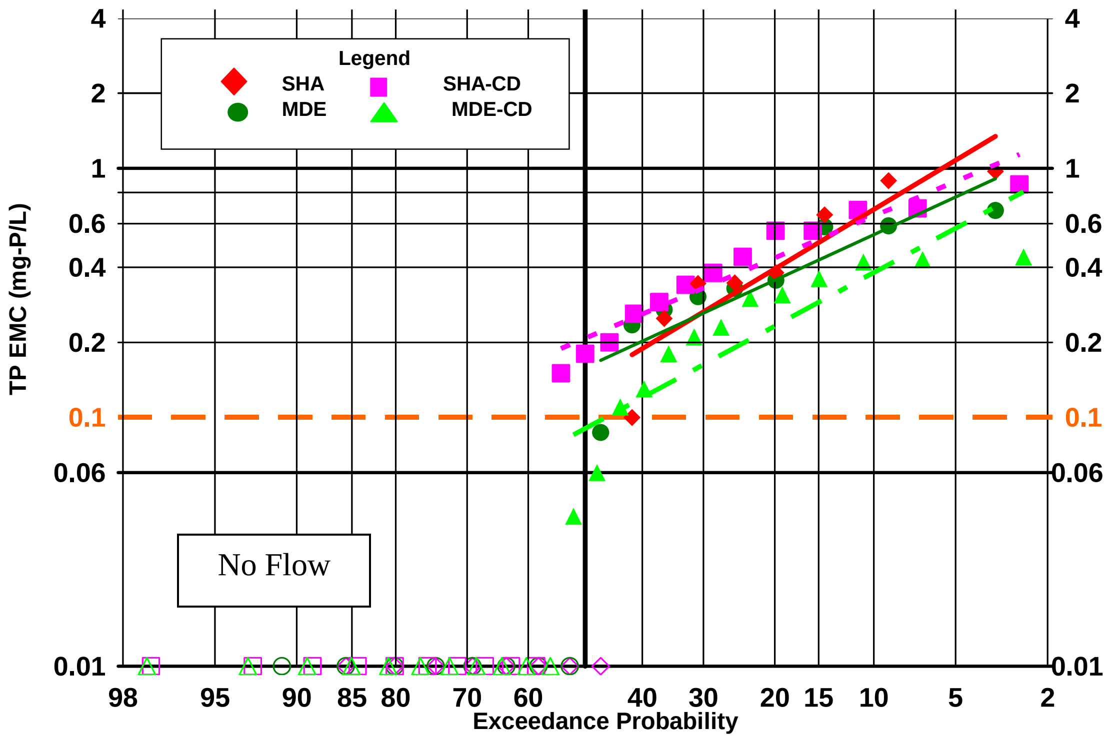

Figure 4-18 Probability plot for TP EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

4.5.2 Nitrate, Nitrite and TKN

The probability plots shows that all of the effluent data for nitrate and nitrite meet the selected target limit (Figure 4-19, 4-21). There is no significant difference between the Direct and the swales for nitrate but there is a significant difference between the Direct and MDE-CD swale for nitrite. However, without grass swales, about 95% of the storm events exceeded the target limits but with grass swales, less than 30% of the storm events exceeded the target limits. The total mass pollutant loading for nitrite are 47 g (Direct), 21 g (SHA-CD) and 14 g (MDE-CD). The MDE-CD swale significantly reduces the total mass by 71%. In the nitrogen cycle, under aerobic condition, nitrite becomes an electron acceptor in the biodecompostion reactions of soil organic matter. In other words, nitrite is easily rapidly oxidized to nitrate under aerobic condition. Therefore, having an extra pretreatment area might allow extra time for aerobic conditions to occur in the soil and therefore could enhance the removal of nitrite.

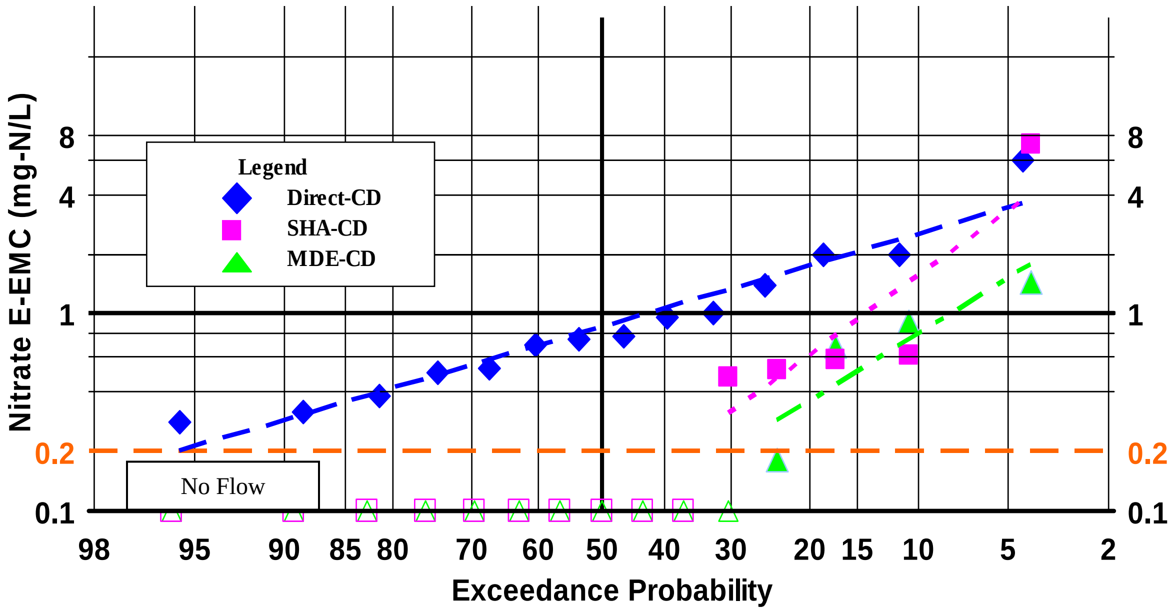

Figure 4-19. Probability plot for Nitrate E-EMCs at Rt. 32 Swales

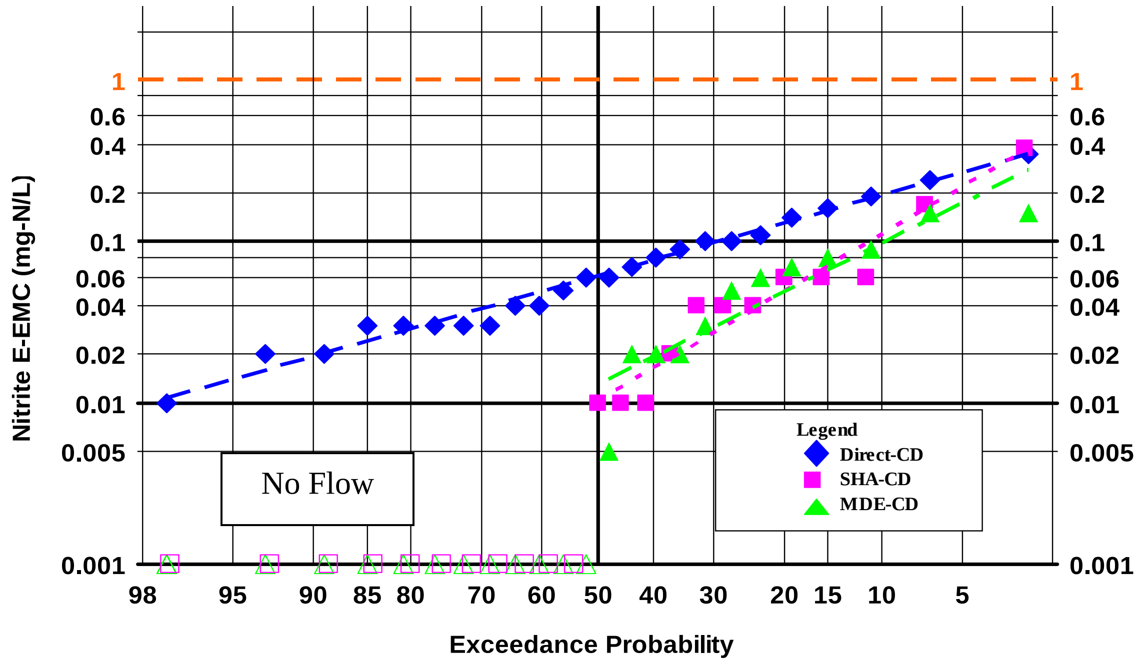

Figure 4-20. Probability plot for Nitrite E-EMCs at Rt. 32 Swales

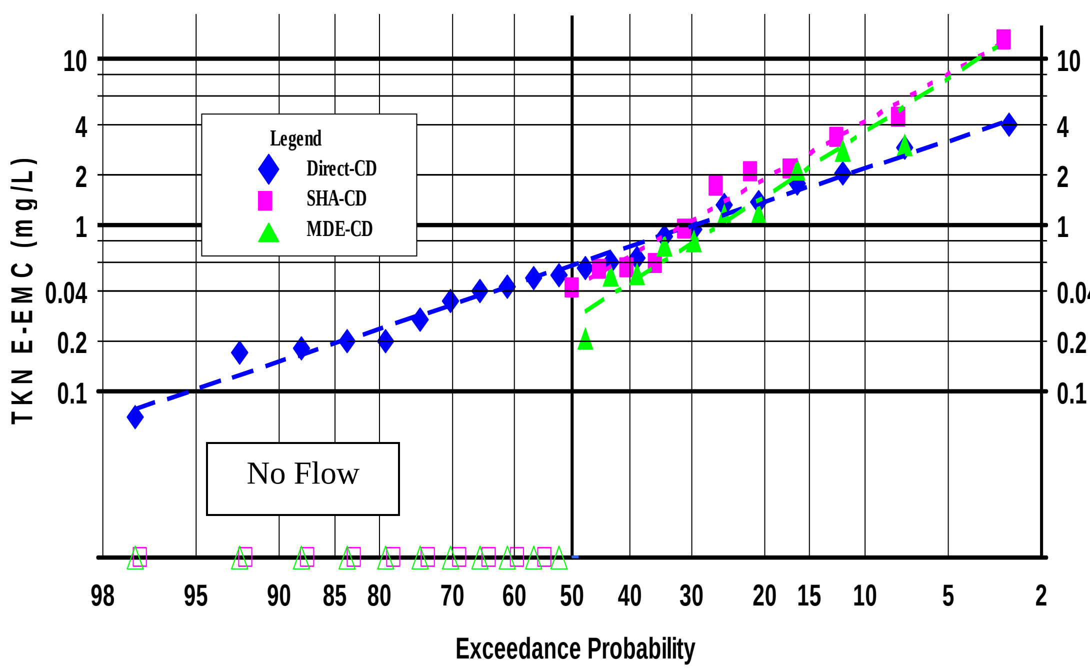

Figure 4-21. Probability plot for TKN E-EMCs at Rt. 32 Swales.

For TKN, the median E-EMC % removal in Table 4-10 shows that SHA-CD swale is able to remove 24% of TKN and MDE-CD swale is able to remove 63% of the TKN. However, looking at the overall total mass pollutant removal, the SHA-CD swale is actually exporting 562 g of TKN (-119%) and MDE-CD helps to reduce the TKN by 206 g (44%). Statistically, only the Direct and the SHA-CD swale show significant TKN being reduced by the swale. In this case the median E-EMC % removal and the total mass pollutant % removal for SHA-CD swale provide different conclusion but we can see clearly see from the probability plot (Figure 4-21) that the SHA-CD swale is exporting TKN. This might happen due to the fact that SHA-CD is longer than MDE-CD swale and therefore, more nitrogen from the grass is contributing to the additional mass in the runoff.

Besides that, literature reports mixed results for nutrients removal by grass swale. In some cases, swales tend to export the nutrients into the runoff due to a few factors such as fertilization, mowing, changing of season. For example, Barrett et al. (1998) reports nitrogen removal ranging from 11 to -7% but Krecher et al. (1983) measured removal rates over 99% for total phosphorus, TKN and total nitrate due to high infiltration rates.

Forms of nutrients fluctuate readily with different oxidation characteristics, sediment loads and within the overall environment itself (NCHRP 2006). Since there is no significant difference between the MDE-CD swale and the SHA-CD swale, having an extra pretreatment area is not necessary.

4.5.2a Nutrients (Total Phosphorus (TP), Nitrite, Nitrate, TKN) Comparison

All swales with check dam’s shows significant difference compare to the swales without any check dams (Stagge 2006) except for the comparison between MDE and MDE-

CD swale for nitrite. Most of the trend lines for the swale with check dams are lower than the line for the swale without any check dams (Figures 4-22 to 4-24). That shows that check dams helped both swales to reduce nutrients concentrations. On the other hand, having an extra pretreatment area for the MDE swale does not show any significant benefits.

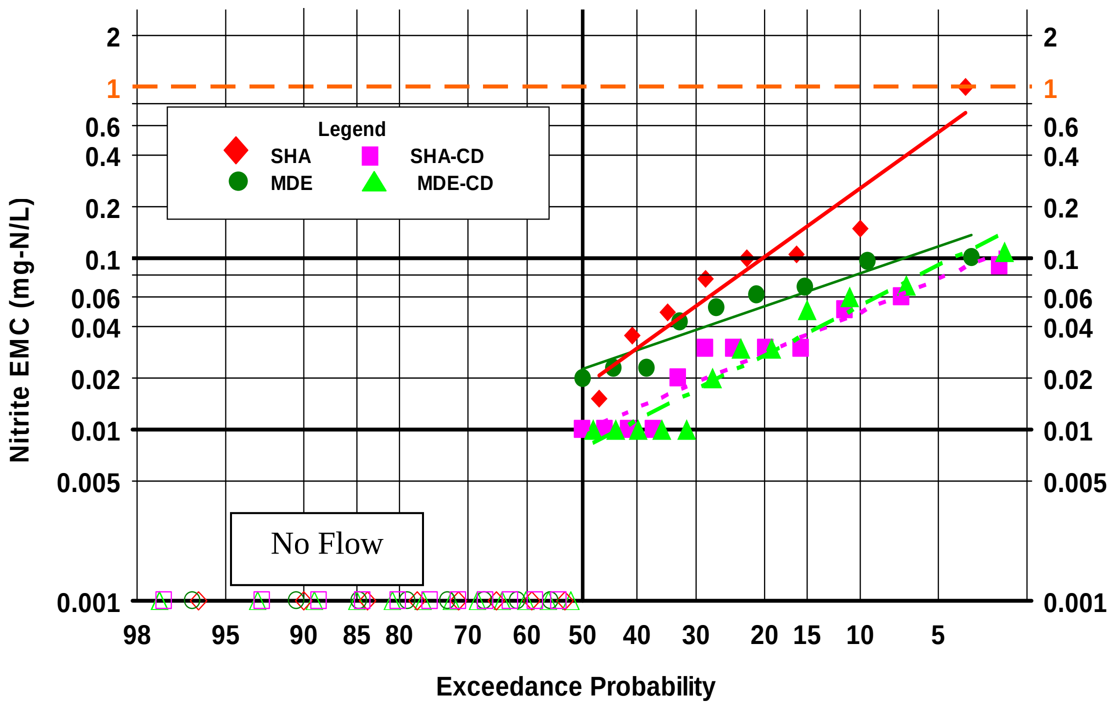

Figure 4-22. Probability plot for Nitrite EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

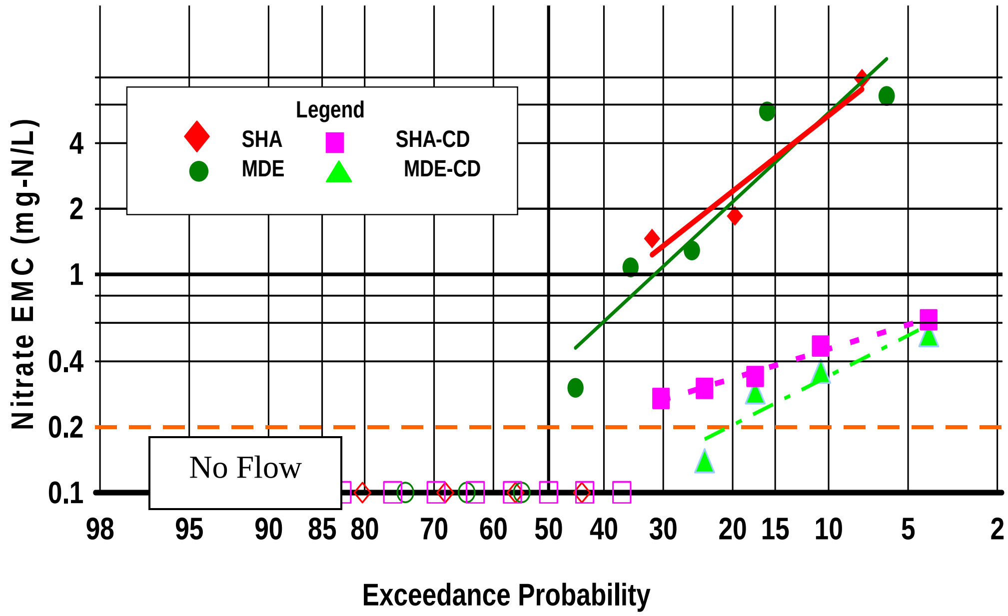

Figure 4-23. Probability plot for Nitrate EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

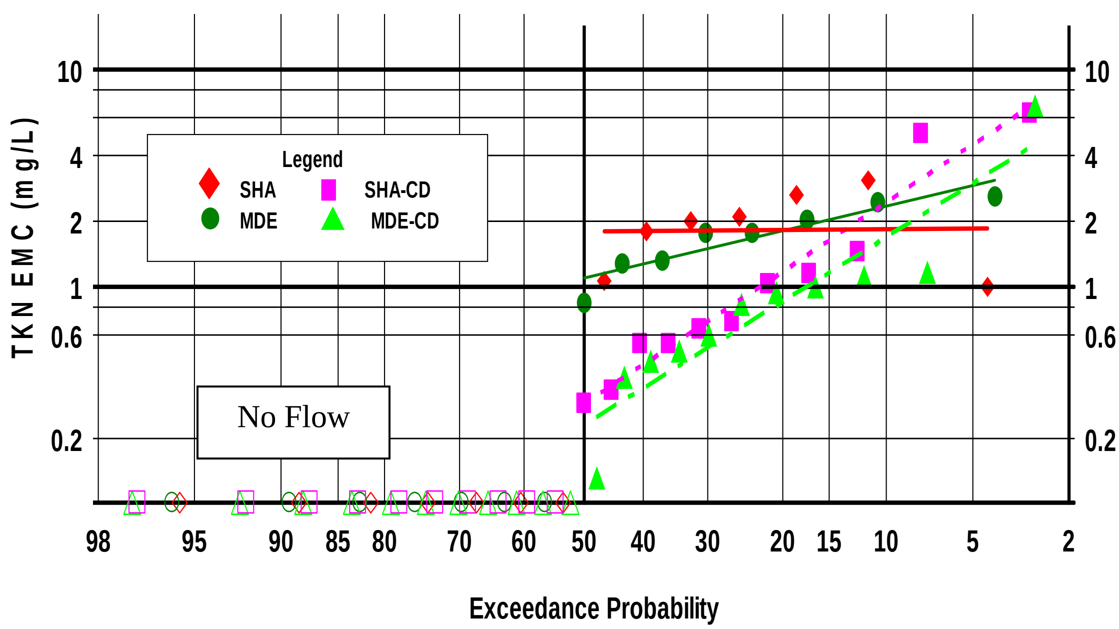

Figure 4-24. Probability plot for TKN EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

This finding agrees with Yu et al (2001), who examined a grass swale with check dams and without check dams but having equal length and different slopes. The study with flow rate 4 x 10^{-3} m^3/s shows % mass removal for total nitrogen and total phosphorus to be 21% and 77 % for the grass swale with check dams compared to 20% and 50% for that swale without any check dams. With that, it appears that the addition of check dams on grass swales could attenuate the runoff flow, increase the detention time and further enhance infiltration.

Comparing to Stagge (2006), the removal for nitrate, nitrite and TKN in the current study is higher (Table 4-10). Stagge (2006) had a significant N-EMC removals of nitrite (56-66%) and exhibited variable removal capabilities ranging from -1% to 60% for nitrate, TKN and total phosphorus.

4.6 Chloride

According to the World Health Organization (WHO) guideline for drinking water, the levels of chloride in water supplies should not exceed 250 mg/L (Radojevic and Bashkin 2006). Therefore the effluent water quality goal is set to be 250 mg/L (Figure 4-25)

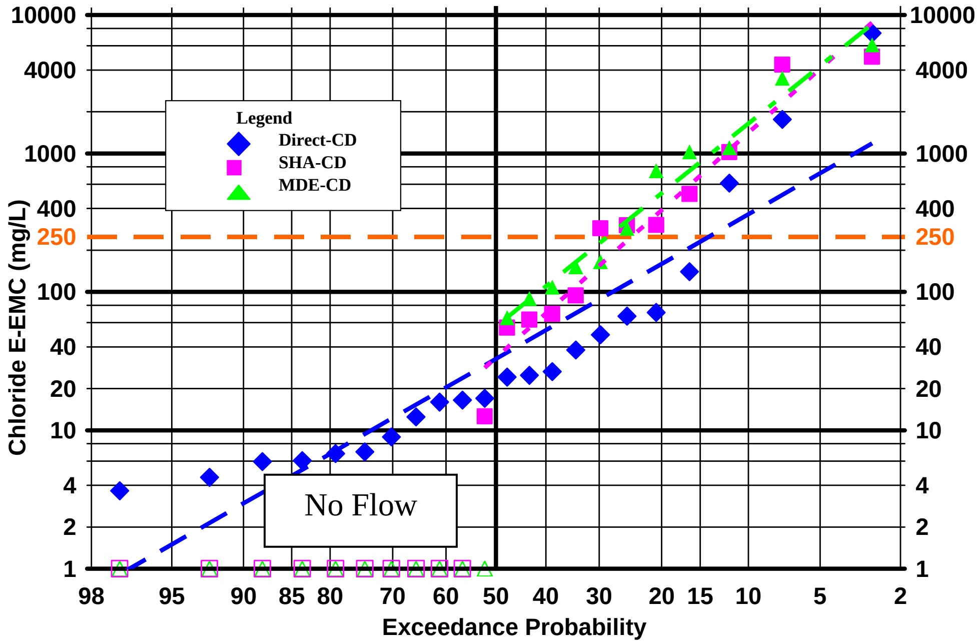

Figure 4-25. Probability plot for Chloride E-EMCs at Rt. 32 Swales.

From the plot, it is clearly seen that there is a significant export of chloride by the swales. However, no significant difference between swales obtained. The significant chloride export apparently comes from the application of de-icing reagents on the highway during snow seasons. Throughout time, the salt slowly dilutes out in every storm event. The total mass pollutant load for chloride is 29 kg (Direct), 46 kg (SHA) and 30 kg (MDE). Therefore the total mass % removal will be -60% (SHA-CD) and -4% (MDE-CD). The negative sign indicates export. Referring to the water quality target, the swales tend to exceed the target for about 30% of storm events compared to the direct only 15% of the storm events.

4.6.1 Chloride Comparison

It seems that the current chloride loading is a lot more than the previous study especially at the higher ends.

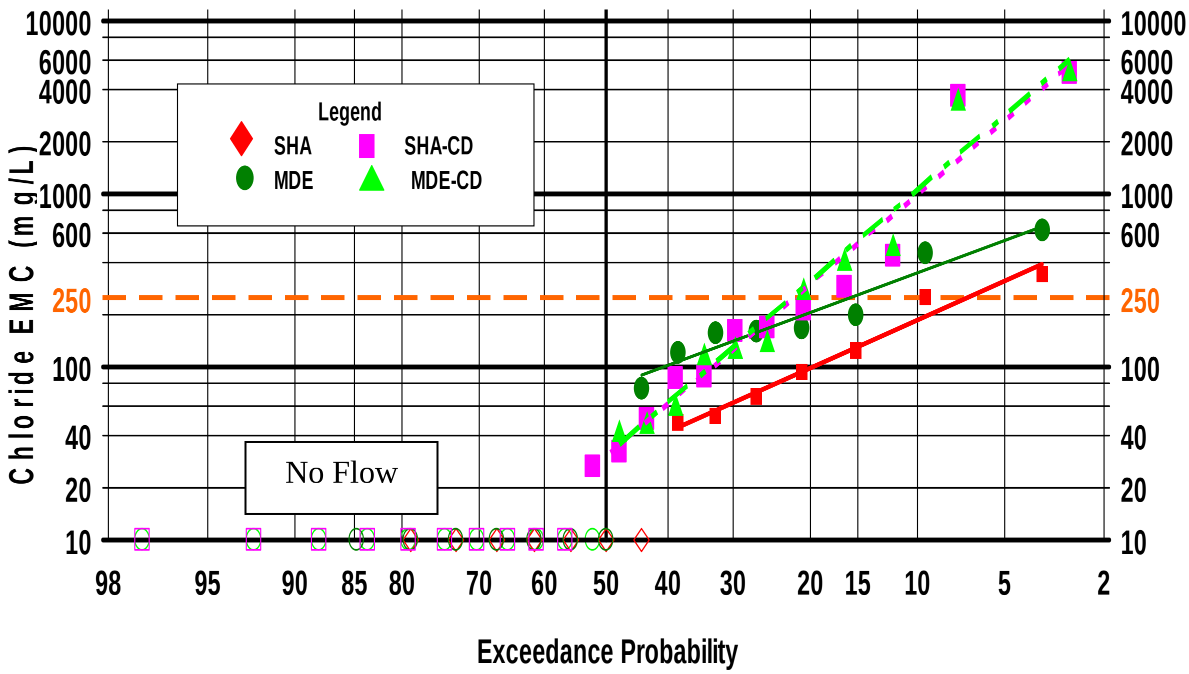

Figure 4-26. Probability plot for Chloride EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

Statistically, having check dams on the swale does not help to reduce the chloride. Instead, the non-exceedance probabilities to the target value (250 mg/L) for the swales chloride concentrations had increased to 30% compared to only 8% (SHA) and 15 % (MDE).

4.7 Metals (Zinc, Lead, Copper, Cadmium)

Monitoring metal concentrations in the runoff is important because heavy metals have toxic effects on aquatic life and humans. The acute and chronic aquatic toxicity limits established by the Maryland Department of the Environment (MDE 2005) are used as guidelines.

4.7.1 Zinc

Among these four metals, zinc generally has the highest concentration and is found primarily in dissolved form (Dean et al. 2005). The acute toxicity limit for zinc is 120 µg/L (MDE 2005). Figure 4-27 shows that 92% of storm events will produce highway runoff that exceeds the limit. However, after treatment with check-dam swales, only 30% of storm events for SHA-CD swale exceeded the limit of 120 µg/L and only 40% of storm events for MDE-CD swale exceeded 120 µg/L. There are significant statistical improvements in the water quality from the swale and between the swale.

The median E-EMC % removal for the SHA-CD is 70% and for MDE-CD is 69%. In terms of total mass pollutant loading the values are 284 g (Direct), 93 g (SHA-CD) and 59 g (MDE-CD). Therefore, the total mass pollutant % removal are 67% (SHA-CD) and 79% (MDE-CD). The swales performance emphasis should be placed on overall effluent water quality (i.e, total mass pollutant); therefore the MDE-CD swale seems to perform better than the SHA-CD swale since the total mass load reduction is larger. The median E-EMC % removal and total mass pollutant removal for this study falls within previous literature findings such as Barrett et al. (1998, 68-93%), Backstrom (2003, 78-94%) and the total mass load reduction by Backstrom (2003) is about 66%. Zinc is expected to be removed highly since at least 50% of this metal can be effectively removed from runoff by targeting the particulate fraction (Sansalone et al. 1997).

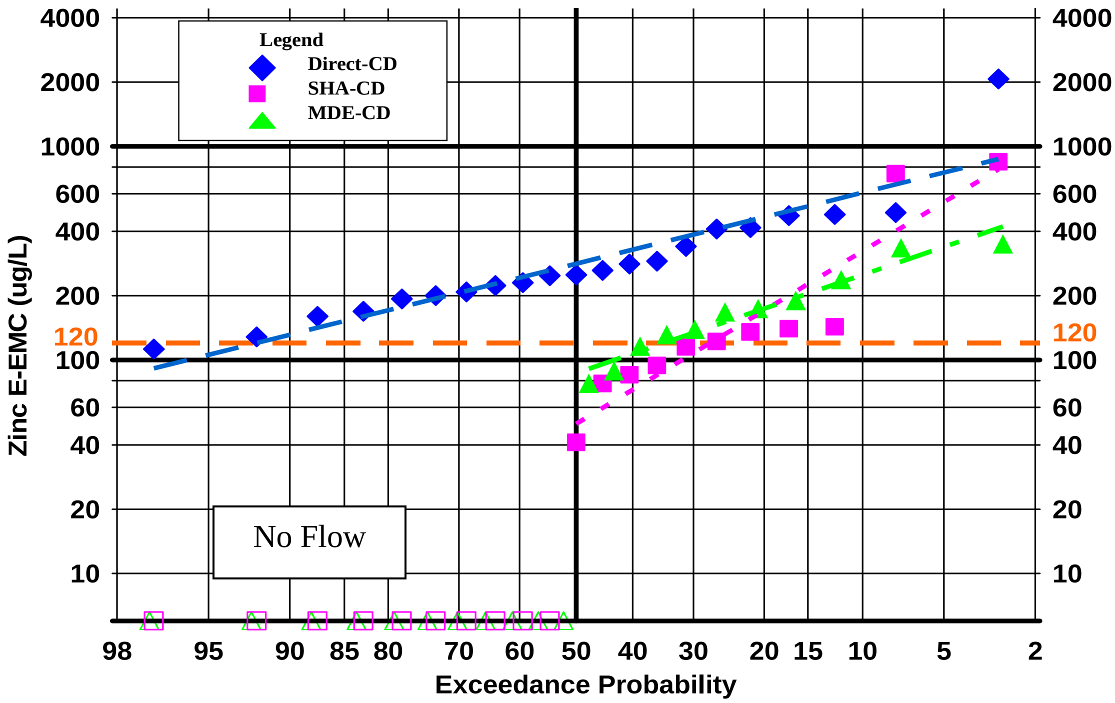

Figure 4-27. Probability plot for Zinc E-EMCs at Rt. 32 Swales.

4.7.1a Zinc Comparison

Statistically, there is a significant difference between the performance of grass swales with check dams and without any check dams but it is not clearly seen in Figure 4-28. The current and previous study still exceeds the water quality target for about 20% of storm events. However, there is a big difference in terms of significant removals based on the E-EMC zinc. Previously without check dams, it was reduce by 30%-40%, but with installation of check dams, the removal is 79%-81%.

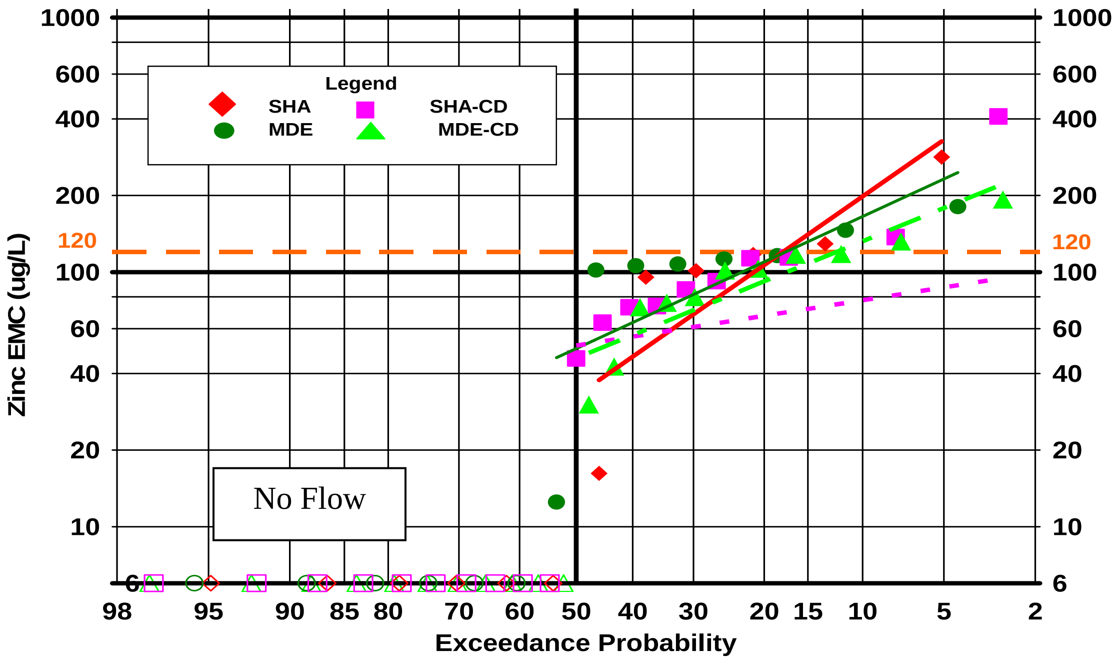

Figure 4-28. Probability plot for Zinc EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

4.7.2 Lead

The acute toxicity limit for lead is 65 µg/L (MDE 2005) and 20% of storm events exceeded this limit (Figure 4-29). With treatment from the check dam swales, the limit is exceeded for only about 12% of storm events for SHA-CD and only about 7% of storm events for MDE-CD. Although there is a slight different in the performance, it is not significantly different statistically. The total mass pollutant load for lead is: 51 g (Direct), 11 g (SHA-CD) and 9 g (MDE-CD).

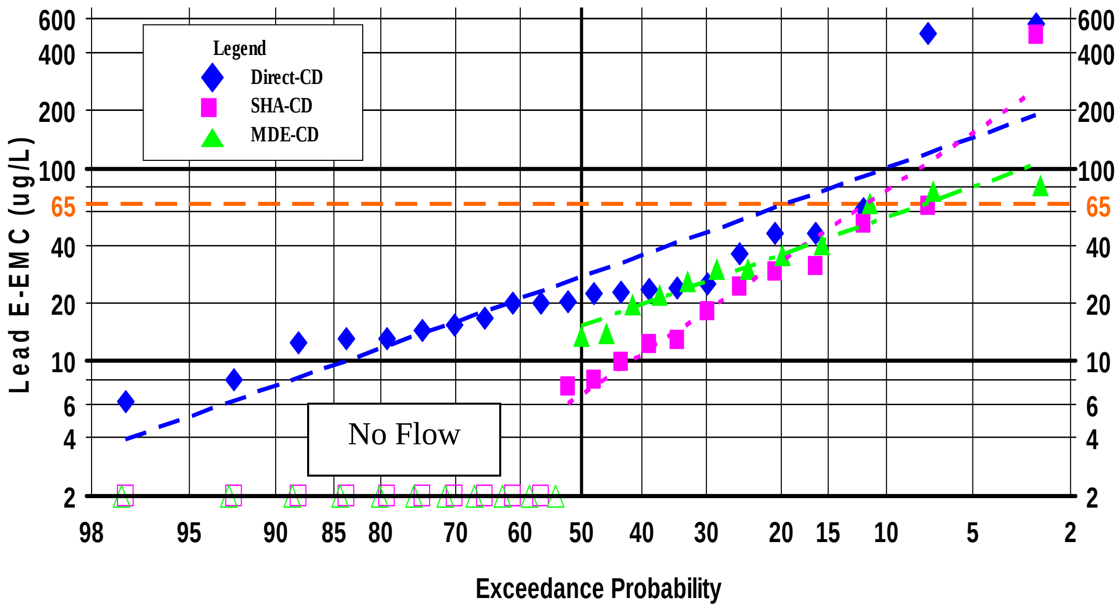

Figure 4-29. Probability plot for Lead E-EMCs at Rt. 32 Swales.

4.7.2a Lead Comparison

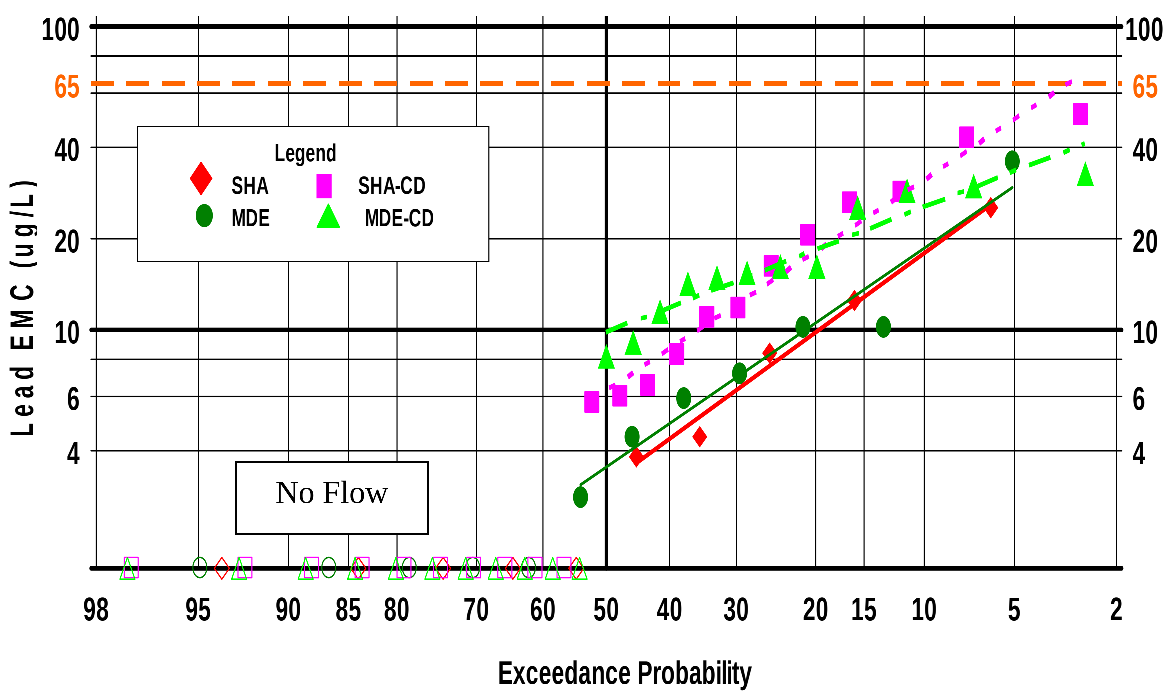

Figure 4-30. Probability plot for Lead EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

None of the data from the current study or the previous study exceed the acute toxicity limit of 65 µg/L. Although the performance of the swales with check dams look worst than without any check dams since the trend line appears above the previous study trend line, indeed no statistically significance difference was found.

4.7.3 Copper and Cadmium

The results for copper (Figure 4-31) shows that both swales help to reduce the number of storm events that will exceed the copper acute toxicity limit of 13 µg/L (MDE 2005), from 90% of the storm events to about 45%-50% storm events. This fact does not confirm that it helps to improve the water quality since statistically, there are no difference found between the direct and the swales. The reduction was also mainly due to no-flow event.

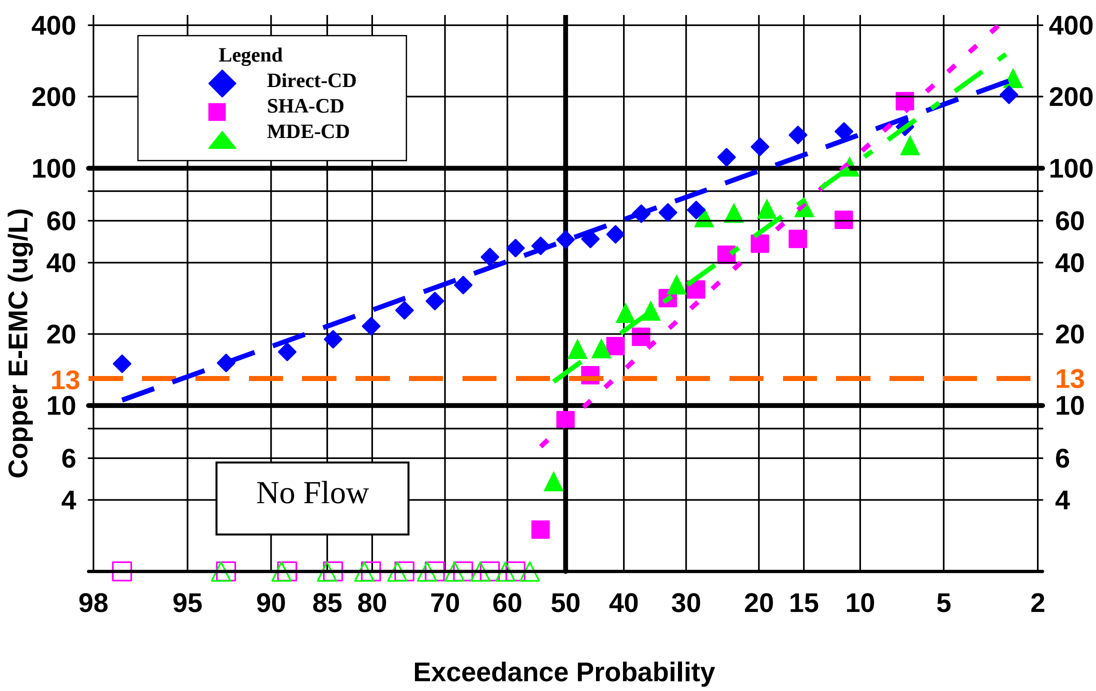

Figure 4-31. Probability plot for Copper E-EMCs at Rt. 32 Swales.

The acute toxicity limit for cadmium is 2 µg/L (MDE 2005). Most of the data are below the detection limit and therefore, no statistical analysis can be done. There are a few occasion where the swale produce high amount of cadmium for uncertain reasons (Figure 4-32).

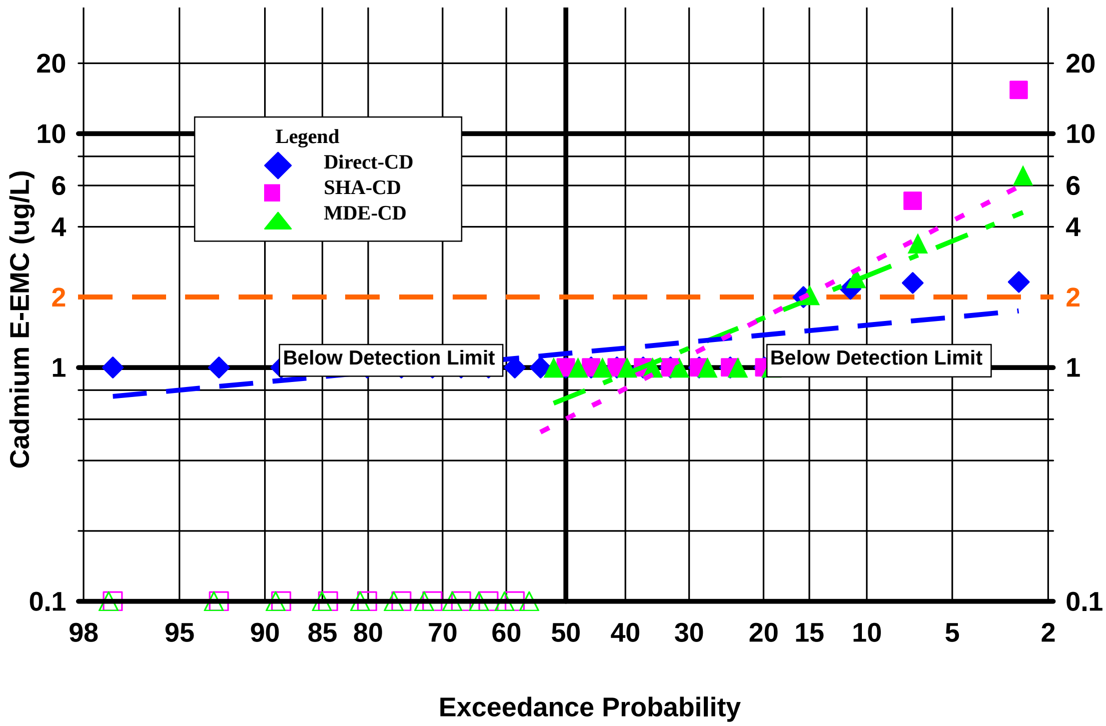

Figure 4-32. Probability plot for Cadmium E-EMCs at Rt. 32 Swales.

4.7.3a Copper and Cadmium Comparison

Check dams do not help to reduce the amount of copper in the stormwater runoff since it still exceed the acute toxicity limit for about 40% of the storm events (Figure 4-33). Cadmium comparison could not be done since all data from the previous study in below detection limits (Figure 4-34).

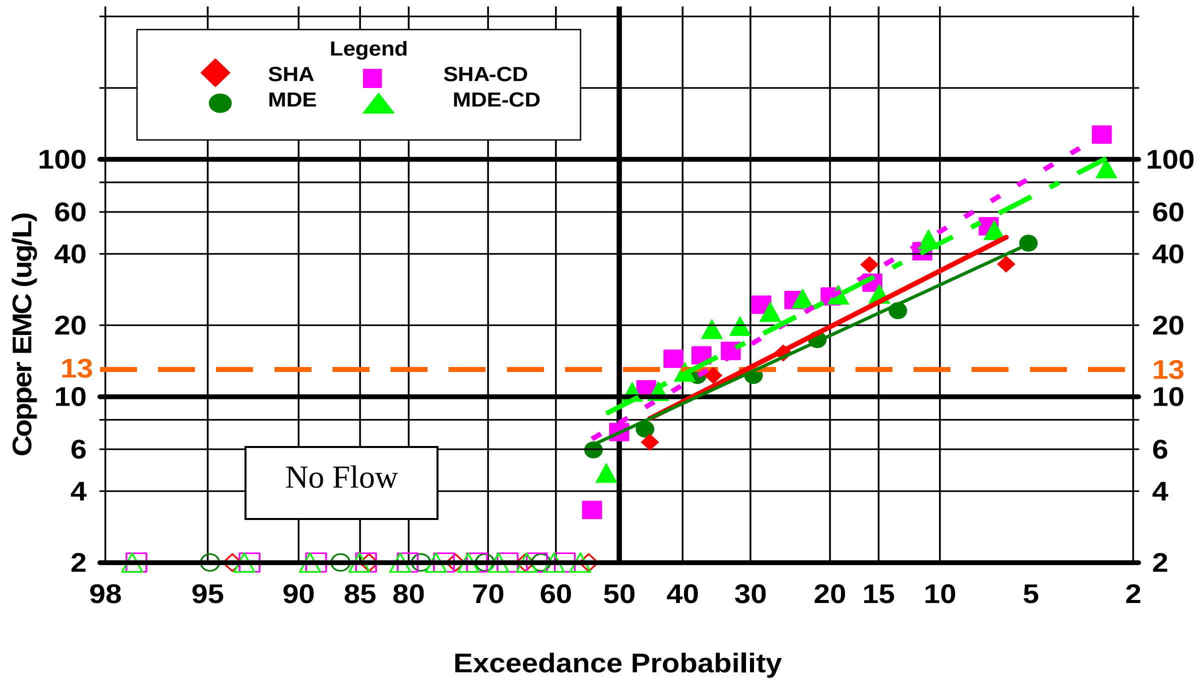

Figure 4-33. Probability plot for Copper EMCs at Rt. 32 Swales.

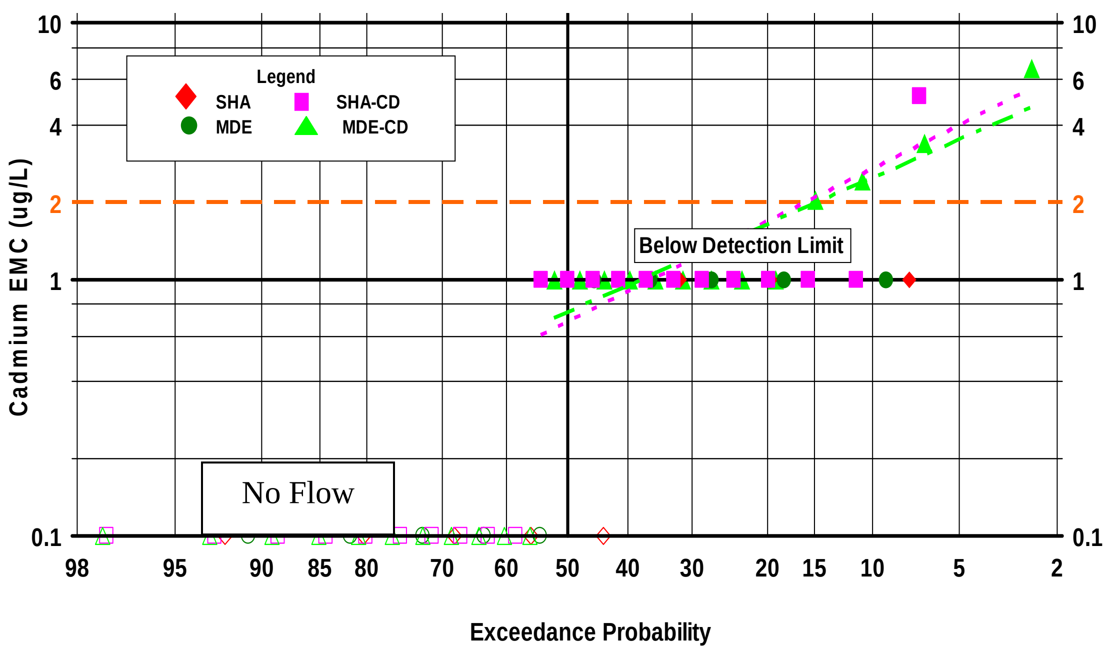

Figure 4-34. Probability plot for Cadmium EMCs at Rt. 32 Swales.
(Current study vs Stagge (2006))

In short, the only metals that shows statistically significant improvement when compared to the Direct is zinc. This might be due to high suspended solids and organic content within the grass. Zinc is easier to be removed compared to copper because copper has a high affinity to bound to organic complexes and zinc is mainly in dissolved form.

On the other hand, all pollutants shows positive mass removals, lead (78% SHA-CD, 82% MDE-CD), copper (56% SHA-CD, 70% MDE-CD) and zinc (67% SHA-CD, 79% MDE-CD). Mass removal shows significant removal compare to the concentration reduction. It implies that, the swale infiltration mechanism helps to reduce metals better by infiltration of the runoff rather than filtering the metals. This makes sense since most of the metal exists in dissolved form except for lead. Besides that, there are no significant metal removals by having check dams on the swales.

Chapter 5

CONCLUSION

The Maryland State Highway Administration (SHA) promotes the use of Low Impact Development (LID) technologies for addressing complex stormwater management challenges specifically dealing with highway runoff. This research was supported specifically to look into the hydrologic and water quality benefits of having grass swales with additional pre-treatment area and incorporation of check dams for managing highway runoff. Previously, similar study was done by Stagge (2006) looking at the same aspects but without check dams on the swales. Since both research projects were conducted at the same site, it allows direct comparison in order to see any improvement resulting from having check dams installed.

The research site was constructed in the median of a four-lane (two in each direction) limited access highway, Maryland Route 32 near Savage, Maryland. The site consists of two swales (MDE-CD and SHA-CD) with different designs but nearly identical roadway drainage area. The only condition that is different than the previous study by Stagge (2006) is that two vegetated check dams are installed within each of the swales. The vegetated check dams were constructed of Panicum Virgatum 'Heavy Metal', a sturdy plant that will remain standing either in heavy rain or snow. The swale that has the pre-treatment area adjacent to the roadway is known as MDE-CD (swale area: 0.431 ha, length: 137m) and the second swale without the pre-treatment area is known as SHA-CD (swale area: 0.312 ha, length: 198 m). Both swales convey to an inlet where water flow and quality measurements are made. Comparison between input and output is done by having the direct runoff as the input and the swales as the output. Ten target pollutants that are considered as being most problematic from highway runoff are monitored, specifically total suspended solids (TSS), nitrate-N, nitrite-N, total Kjeldahl nitrogen (TKN), total phosphorus (TP), chloride (Cl), copper (Cu), lead (Pb), zinc (Zn), and cadmium (Cd).

In total, 24 storm events were analyzed over a period of about 2 years. Among those 24 storms, 10 were completely captured where no flow output was measured from the swales. To evaluate the performance of the swale, two hypotheses are made. First, the pretreatment area prior to the grass swale is helping by slowing down the runoff velocities, providing more infiltration into underlying soils and filtering out sediment and other pollutions. Second, by having check dams within the grass swales, temporary ponding areas within the swales will be created, runoff velocity will be reduced and the retention time will be increased and eventually promote more infiltration through the soil and filtration through the grass swale will occur.

In order to clarify those hypotheses, several aspects of the hydrology such as peak flow, lag time and total effective volume were used to determine the effects of using grass swales with check dams treating the highway runoff. For water quality purposes, the pollutants concentrations were evaluated using the overall total mass loading on the swales and the effective event mean concentration (E-EMC), which allow a comparison between the flows weighted mean concentrations without the dilution effects of excess rainfall on the grass swale area.

It appears that the average time for SHA-CD swale to start receiving flows at the weir is about 2 hours after the Direct starts colleting samples and the average time for the MDE-CD swale is about 3 hours after the Direct starts collecting samples. Having check dams helps to detain water longer on the swales and will further enhance the filtration and infiltration process. Furthermore, the overall average peak reduction by the swales is between 61-68% and compares to Stagge (2006) study; he had a lower percentage of peak reduction of 50-53%. This shows that the check dams on the swales do provide extra time to allow the runoff infiltrates into the soil and further reduce the peak flow. Throughout the study, the highest peak flow obtained for the Direct is 51 L/s and the highest peak flow obtained for SHA-CD and MDE-CD were 20 L/s and 11 L/s respectively. Having extra area to infiltrate the water clearly helps in reducing the peak flows. The effectiveness of having a pre-treatment area is further emphasized when the result of the mean volume for MDE-CD swale (4400 L) is lesser than the Direct (31000L) and the SHA-CD swale (7900 L).

Compare to the reduction of total volume with Stagge (2006), without check dams, the reduction of total volume is between 46-54% but with check dams installed, the reduction is actually lower than before which is between 28-64 %. Many factors could contribute to this fact that SHA-CD did not perform as well as the MDE-CD and as well as the swale without check dams. One of the factors might be due to the check dams installed were not fully matured to act as a useful check dams. As seasons change, it dries up and not able to detain water longer on the swales.

Generally, the study shows that swale is not design to detain the runoff but to slow down the runoff by using the vegetation. MDE-CD swale does shows that the pretreatment area is beneficial for stormwater volume and peak reduction and increase in lag time, similar with the finding in the recent stormwater manuals (MDE 2000).

Considering at the water quality benefits, most of the overall mass pollutant loadingsexhibit positive reduction, but mixed results are obtained for the mean E-EMCs.

Reduction of E-EMCs were more difficult to prove statistically because this comparison only includes those storms with measurable flow, while overall mass reduction allows comparison that includes all complete captured storm events. Therefore, the overall mass reduction can give a better sense of the performance of the swales and it is put more weight in placed on this criterion.

The overall mass loading reduction for TSS shows that the SHA-CD swale is able to reduce 62% of the mass and MDE-CD swale is able to reduce 38% of the mass. Suggesting that the swales are capable of filtering out the suspended solids from the highway runoff. Compare to the mean E-EMCs, only SHA-CD swale shows different statistically compare to the Direct. This suggests that the filtration capacity is better in SHA-CD swale due to the longer swale and the extra area on MDE-CD is not helping to reduce the TSS significantly.

For nutrients, the SHA-CD swale shows positive overall mass loading reduction for nitrate (92%) and nitrite (54%) but a negative overall mass loading reduction for TKN (-120%) and TP (-5%). The MDE-CD swale on the other hand, shows positive overall mass loading reduction for all nutrients: nitrate (95%), nitrite (71%), TKN (44%) and TP (40%). While the E-EMC data showed statistically significant increase in nitrite (-2%) for the comparison between the Direct and the MDE-CD, in TKN (-148%) and TP (-172%) for the comparison between the Direct and the SHA-CD. The variability in nutrients removal suggests that the grass swales efficiency are affected by several factors such as seasonal effects, release of organic matter, mowing, different oxidation characteristics and input of sediment loads. These factors contribute to the removal efficiency due to the nature of the nutrients itself. For example, phosphorus, which highly depends on physical processes (due to being particulate bound) such as infiltration, deposition and filtration will be more easily to be removed if the TSS is high because it will tend to bond on the surface of the TSS and then being filtered by the grass.

Chloride shows significant increase in the swales E-EMC compared to the direct (SHA-CD: -388% and MDE-CD: -633%). Also overall mass loading increase was noted for both swale (SHA-CD:-61% and MDE-CD:-4%). This clearly shows significant chloride export by the swales apparently due to the application of de-icing reagents during the snow seasons and throughout time, the salts accumulated in the swales during the winter season slowly diluting out in every event.

Metals were all significantly removed by the swales in terms of the overall total mass. Lead shows the highest removal (SHA-CD: 78% and MDE-CD: 82%) followed by zinc (SHA-CD: 67% and MDE-CD: 79%) and copper (SHA-CD: 56% and MDE-Cd: 70%). The reduction of cadmium could not be obtained since most of the cadmium concentrations are below detection limit. However, only zinc appears to demonstrate a significante decrease in the swales E-EMC compared to the direct (SHA-CD: 57% and MDE-CD: 79%). From the literature, both zinc and copper are mostly in dissolved form but zinc has a higher tendency to be removed compare to copper because copper has a high affinity to bound to organic complexes. Lead on the other hand mostly particulate bounds and therefore the removal is the highest since the vegetation and the suspended solids are capable to adsorb the metals from the runoff; indirectly reduce the concentration.

All in all, the swale data do not show any significant improvement by including check dams. No consistent significant difference obtained. Looking at the overall total mass reduction, it seems that the MDE-CD swale tend to have a higher % reduction compare to SHA-CD except for TSS. This shows that the pre-treatment area did help to remove the total mass of the pollutants and the length of the swale does not affect the removal efficiencies. Although the SHA-CD is longer than MDE-CD it does not plays a big impact on the removal capability. Yu et al. (2001) shows that the rate of removal reaches a plateau when swales are longer than approximately 75 m regardless of slope. The inconsistency obtained for the removal of the mean E-EMCs concentration indicates that, the total mass reduction gives a better picture because it is a total value and not an average value. Since the swales are capable of reducing the total pollutant mass, we can conclude that the infiltration mechanism works better to improve the highway runoff rather than infiltration mechanism since it does not significantly improve the concentration of the pollutants.

In conclusion, the first hypotheses of this study is confirmed where the pretreatment area prior to the grass swale is helping by reducing the runoff velocity, provide more time for filtration, sedimentation and absorption of the pollutants and increase the infiltration capacity into underlying soils. However, the second hypothesis is not confirmed since no significant difference in the performance of swales with check dams was found in comparison to those without check dams.

Overall, this study shows that the grass swale is a beneficial technology that helps to manage highway runoff. However, there are areas of improvements that could be done for further research:

1) From the experimental aspect, a larger set of data could provide better understanding of the swales. A better distribution of storm events sampled could also provide a better understanding in terms of hydrology and water quality for high/low/moderate intensity storms. Furthermore, a better understanding about

metal speciation could also help since this allow better understanding of the removal mechanisms in grass swales.

2) Looking at the performance of having different kind of check dams on the swales (vegetated check dams vis-a-vis riprap or wood logs) is another aspect. Vegetated check dams have a disadvantage of being effected by seasons, mowing and the maturity of the plant itself. But having check dams made from rocks or wood logs could ensure better performance for all seasons and more water can be detained to increase the infiltration and filtration time within the swales. The number of check dams installed in a swale will also be another good aspect to look into.
3) Improve the design of the swales by maintaining shallow slopes, having soils that promote infiltration, and having denser grass/thicker vegetation since it is known that filtration and sedimentation are the main mechanisms of the swales. Besides that, having a layer or soil that has high organic matter could also help to increase the performance of particulate bound pollutants, but it needs to be carefully done because it might increase the nutrients in the grass. The grass for the pre-treatment area should also be fully developed so that less debris/washout from the extra area affects the water quality.
4) Measure infiltration rates on site (e.g., with a double-ring infiltrometer). Since infiltration capacity was deduced from the linear regression best fit, having the actuall measurements on site would help to clarify the method that was used in this research. Besides that, annual check for the soil parameters (grain size distribution, hydraulic conductivity, bulk density) could also helps to maintain the performance of the swale.

APPENDIX A

E-EMC for All Storm events

	TSS (mg/L)			Nitrate (mg-N/L)			Nitrite (mg-N/L)			TKN (mg/L)			TP (mg/L)		
Storm event	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**
2/25/2007	8	2	3	NA	NA	NA	0.09	0.06	0.05	0.40	0.54	0.50	0.32	0.56	0.44
4/4/2007	130	5	9	NA	NA	NA	0.05	0.06	0.09	1.40	1.80	1.00	0.40	0.45	0.37
5/12/2007	42	NF	NF	6.00	NF	NF	0.40	NF	NF	1.80	NF	NF	0.15	NF	NF
5/16/2007	184	53	276	NA	NA	NA	0.10	0.20	0.20	2.00	2.10	3.10	0.13	0.81	0.80
6/3/2007	70	14	53	1.00	0.50	0.20	0.03	0.04	0.00	0.40	0.60	0.80	0.22	0.76	0.46
7/4/2007	110	63	346	1.40	0.60	0.90	0.02	0.04	0.07	0.60	2.10	2.80	0.22	1.20	1.10
9/11/2007	600	NF	NF	2.00	NF	NF	0.24	NF	NF	0.35	NF	NF	0.23	NF	NF
10/19/2007	63	NF	NF	2.00	NF	NF	0.04	NF	NF	0.20	NF	NF	0.22	NF	NF
10/24/2007	48	NF	NF	1.00	NF	NF	0.10	NF	NF	0.17	NF	NF	0.41	NF	NF
11/13/2007	8	NF	NF	0.50	NF	NF	0.14	NF	NF	0.55	NF	NF	0.17	NF	NF
12/2/2007	50	10	41	NA	NA	NA	0.03	0.00	0.20	0.50	0.40	0.50	<0.1	0.25	0.58
12/14/2007	79	40	140	NA	NA	NA	0.02	0.01	0.02	NA	NA	NA	0.29	0.83	0.18
1/10/2008	21	NF	NF	NA	NF	NF	0.19	NF	NF	0.48	NF	NF	0.23	NF	NF
2/1/2008	91	34	99	NA	NA	NA	0.03	0.04	0.02	0.27	4.40	0.21	0.25	0.43	0.21
3/4/2008	150	75	248	NA	NA	NA	0.06	0.01	0.02	0.20	0.55	0.81	0.63	1.00	0.42
3/16/2008	59	21	64	NA	NA	NA	0.04	0.02	0.08	0.90	1.00	2.20	0.21	0.36	0.60
4/3/2008	30	NA	69	NA	NA	NA	0.01	NA	0.03	0.07	NA	1.20	0.20	NA	0.51
4/26/2008	50	181	NF	0.80	7.00	NF	0.08	0.38	NF	4.10	3.40	NF	0.12	3.39	NF
5/16/2008	25	10	18	0.30	0.50	0.70	0.03	0.01	0.00	NA	NA	NA	<0.1	0.21	0.11
6/3/2008	31	26	43	0.70	0.60	1.40	0.03	0.06	0.06	0.60	13.00	19.00	<0.1	0.38	0.15
6/10/2008	154	NF	NF	0.40	NF	NF	0.07	NF	NF	1.00	NF	0.11	0.11	NF	NF
6/16/2008	19	NF	NF	0.30	NF	NF	0.06	NF	NF	0.20	NF	NF	0.11	NF	NF
6/30/2008	107	NF	NF	0.50	NF	NF	0.11	NF	NF	1.30	NF	NF	0.10	NF	NF
7/5/2008	50	NF	NF	0.70	NF	NF	0.16	NF	NF	3.00	NF	NF	0.11	NF	NF

**NA = Data Not Available, NF = No Flow

	Cl (mg/L)			Lead (ug/L)			Copper (ug/L)			Zinc (ug/L)			Cadmium (ug/L)		
Storm event	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**
2/25/2007	7400	5000	3500	20.00	8.00	14.00	15.00	3.00	4.80	160.00	140.00	190.00	2.00	<2.0	<2.0
4/4/2007	610	4400	6100	61.00	31.00	30.00	32.00	18.00	25.00	420.00	140.00	90.00	<2.0	<2.0	<2.0
5/12/2007	140	NF	NF	24.00	NF	NF	65.00	NF	NF	290.00	NF	NF	2.30	NF	NF
5/16/2007	17	300	750	500.00	52.00	76.00	143.00	48.00	69.00	2000.00	750.00	350.00	2.30	5.20	6.60
6/3/2007	67	94	150	46.00	18.00	20.00	25.00	28.00	25.00	NA	NA	NA	<2.0	<2.0	<2.0
7/4/2007	50	69	108	16.00	12.00	41.00	42.00	31.00	68.00	NA	NA	NA	<2.0	<2.0	<2.0
9/11/2007	16	NF	NF	NA	NF	NF	NA	NF	NF	NA	NF	NF	NA	NF	NF
10/19/2007	17	NF	NF	560.00	NF	NF	50.00	NF	NF	490.00	NF	NF	<2.0	NF	NF
10/24/2007	25	NF	NF	13.00	NF	NF	47.00	NF	NF	200.00	NF	NF	<2.0	NF	NF
11/13/2007	38	NF	NF	8.00	NF	NF	19.00	NF	NF	230.00	NF	NF	<2.0	NF	NF
12/2/2007	7	63	65	17.00	64.00	22.00	15.00	13.00	18.00	190.00	120.00	140.00	<2.0	<2.0	<2.0
12/14/2007	NA	NA	NA	6.00	8.00	14.00	17.00	9.00	17.00	250.00	80.00	130.00	<2.0	<2.0	<2.0
1/10/2008	9	NF	NF	46.00	NF	NF	46.00	NF	NF	340.00	NF	NF	<2.0	NF	NF
2/1/2008	70	290	290	NA	NA	NA	50.00	20.00	32.00	410.00	143.00	170.00	<2.0	<2.0	<2.0
3/4/2008	1760	510	1030	23.00	13.00	66.00	150.00	61.00	102.00	480.00	85.00	240.00	<2.0	<2.0	2.40
3/16/2008	27.00	300.00	1100.00	14.00	10.00	30.00	64.00	190.00	240.00	260.00	40.00	78.00	<2.0	<2.0	<2.0
4/3/2008	NA	NA	NA	13.00	NA	26.00	123.00	NA	125.00	220.00	NA	340.00	<2.0	NA	3.40
4/26/2008	24	1020	NF	24.00	500.00	NF	53.00	480.00	NF	210.00	850.00	NF	<2.0	5.40	NF
5/16/2008	13.00	13.00	90.00	23.00	29.00	36.00	28.00	43.00	65.00	130.00	120.00	170.00	<2.0	2.00	<2.0
6/3/2008	5.00	55.00	166.00	12.00	24.00	81.00	22.00	50.00	62.00	110.00	90.00	120.00	<2.0	<2.0	2.00
6/10/2008	6.00	NF	NF	20.00	NF	NF	111.00	NF	NF	280.00	NF	NF	2.20	NF	NF
6/16/2008	6.00	NF	NF	20.00	NF	NF	67.00	NF	NF	250.00	NF	NF	<2.0	NF	NF
6/30/2008	4.00	NF	NF	25.00	NF	NF	204.00	NF	NF	470.00	NF	NF	<2.0	NF	NF
7/5/2008	7.00	NF	NF	35.00	NF	NF	140.00	NF	NF	170.00	NF	NF	<2.0	NF	NF

**NA = Data Not Available, NF = No Flow

Appendix B

EMC for All Storm Events

	TSS (mg/L)			Nitrate (mg-N/L)			Nitrite (mg-N/L)			TKN (mg/L)			TP (mg/L)		
Storm event	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**
2/25/2007	8	2	3	NA	NA	NA	0.09	0.06	0.05	0.40	0.54	0.50	0.32	0.56	0.44
4/4/2007	129	5	8	NA	NA	NA	0.05	0.05	0.07	1.40	1.45	1.00	0.40	0.38	0.31
5/12/2007	42	NF	NF	6.00	NF	NF	0.40	NF	NF	1.80	NF	NF	0.15	NF	NF
5/16/2007	184	29	104	NA	NA	NA	0.10	0.09	0.06	2.00	1.15	1.16	0.13	0.44	0.30
6/3/2007	70	13	41	1.00	0.50	0.20	0.03	0.03	0.00	0.40	0.54	0.60	0.22	0.69	0.36
7/4/2007	110	29	138	1.40	0.60	0.90	0.02	0.02	0.03	0.60	1.03	1.11	0.22	0.56	0.42
9/11/2007	600	NF	NF	2.00	NF	NF	0.24	NF	NF	0.35	NF	NF	0.23	NF	NF
10/19/2007	63	NF	NF	2.00	NF	NF	0.04	NF	NF	0.20	NF	NF	0.22	NF	NF
10/24/2007	48	NF	NF	1.00	NF	NF	0.10	NF	NF	0.17	NF	NF	0.41	NF	NF
11/13/2007	8	NF	NF	0.50	NF	NF	0.14	NF	NF	0.55	NF	NF	0.17	NF	NF
12/2/2007	50	10	30	NA	NA	NA	0.03	0.00	0.11	0.50	0.33	0.38	<0.1	0.20	0.43
12/14/2007	79	32	85	NA	NA	NA	0.02	0.01	0.01	NA	NA	NA	0.29	0.68	0.11
1/10/2008	21	NF	NF	NA	NF	NF	0.19	NF	NF	0.48	NF	NF	0.23	NF	NF
2/1/2008	91	27	61	NA	NA	NA	0.03	0.03	0.01	0.27	5.02	0.13	0.25	0.34	0.13
3/4/2008	150	65	123	NA	NA	NA	0.06	0.01	0.01	0.20	0.63	0.93	0.63	0.86	0.21
3/16/2008	59	14	25	NA	NA	NA	0.04	0.01	0.03	0.90	0.69	0.83	0.21	0.26	0.23
4/3/2008	30	NA	24	NA	NA	NA	0.01	NA	0.01	0.07	NA	0.45	0.20	NA	0.18
4/26/2008	50	16	NF	0.80	0.62	NF	0.08	0.03	NF	4.10	0.29	NF	0.12	0.29	NF
5/16/2008	25	7	8	0.30	0.34	0.29	0.03	0.01	0.00	NA	NA	NA	<0.1	0.15	0.04
6/3/2008	31	13	15	0.70	0.30	0.53	0.03	0.03	0.02	0.60	6.27	6.77	<0.1	0.18	0.06
6/10/2008	154	NF	NF	0.40	NF	NF	0.07	NF	NF	1.00	NF	NF	0.11	NF	NF
6/16/2008	19	NF	NF	0.30	NF	NF	0.06	NF	NF	0.20	NF	NF	0.11	NF	NF
6/30/2008	107	NF	NF	0.50	NF	NF	0.11	NF	NF	1.30	NF	NF	0.10	NF	NF
7/5/2008	50	NF	NF	0.70	NF	NF	0.16	NF	NF	3.00	NF	NF	0.11	NF	NF

**NA = Data Not Available, NF = No Flow

	Cl (mg/L)			Lead (ug/L)			Copper (ug/L)			Zinc (ug/L)			Cadmium (ug/L)		
Storm event	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**	**Direct**	**SHA**	**MDE**
2/25/2007	7400	5000	3500	20.00	8.00	14.00	15.00	3.00	4.80	160.00	140.00	190.00	2.00	<2.0	<2.0
4/4/2007	610	3680	5170	61.00	26.00	25.00	32.00	15.00	11.00	420.00	113.00	76.00	<2.0	<2.0	<2.0
5/12/2007	140	NF	NF	24.00	NF	NF	65.00	NF	NF	290.00	NF	NF	2.30	NF	NF
5/16/2007	17	167	284	500.00	28.00	29.00	143.00	26.00	26.00	2000.00	410.00	130.00	2.30	2.83	2.51
6/3/2007	67	85	119	46.00	16.00	15.00	25.00	26.00	19.00	NA	NA	NA	<2.0	<2.0	<2.0
7/4/2007	50	33	43	16.00	6.00	16.00	42.00	14.00	27.00	NA	NA	NA	<2.0	<2.0	<2.0
9/11/2007	16	NF	NF	NA	NF	NF	NA	NF	NF	NA	NF	NF	NA	NF	NF
10/19/2007	17	NF	NF	560.00	NF	NF	50.00	NF	NF	490.00	NF	NF	<2.0	NF	NF
10/24/2007	25	NF	NF	13.00	NF	NF	47.00	NF	NF	200.00	NF	NF	<2.0	NF	NF
11/13/2007	38	NF	NF	8.00	NF	NF	19.00	NF	NF	230.00	NF	NF	<2.0	NF	NF
12/2/2007	7	50	47	17.00	51.00	16.00	15.00	11.00	13.00	190.00	92.00	102.00	<2.0	<2.0	<2.0
12/14/2007	NA	NA	NA	6.00	6.00	8.00	17.00	7.00	11.00	250.00	63.00	80.00	<2.0	<2.0	<2.0
1/10/2008	9	NF	NF	46.00	NF	NF	46.00	NF	NF	340.00	NF	NF	<2.0	NF	NF
2/1/2008	70	290	140	NA	NA	NA	50.00	16.00	20.00	410.00	114.00	103.00	<2.0	<2.0	<2.0
3/4/2008	1760	440	510	23.00	11.00	33.00	150.00	52.00	51.00	480.00	74.00	118.00	<2.0	<2.0	<2.0
3/16/2008	27.00	213.00	423.00	14.00	7.00	12.00	64.00	127.00	92.00	260.00	30.00	30.00	<2.0	<2.0	<2.0
4/3/2008	NA	NA	NA	13.00	NA	9.00	123.00	NA	46.00	220.00	NA	117.00	<2.0	NA	<2.0
4/26/2008	24	88	NF	24.00	43.00	NF	53.00	41.00	NF	210.00	73.00	NF	<2.0	<2.0	NF
5/16/2008	13.00	9.00	38.00	23.00	21.00	15.00	28.00	30.00	27.00	130.00	85.00	73.00	<2.0	2.00	<2.0
6/3/2008	5.00	27.00	61.00	12.00	12.00	30.00	22.00	24.00	23.00	110.00	46.00	43.00	<2.0	<2.0	2.00
6/10/2008	6.00	NF	NF	20.00	NF	NF	111.00	NF	NF	280.00	NF	NF	2.20	NF	NF
6/16/2008	6.00	NF	NF	20.00	NF	NF	67.00	NF	NF	250.00	NF	NF	<2.0	NF	NF
6/30/2008	4.00	NF	NF	25.00	NF	NF	204.00	NF	NF	470.00	NF	NF	<2.0	NF	NF
7/5/2008	7.00	NF	NF	35.00	NF	NF	140.00	NF	NF	170.00	NF	NF	<2.0	NF	NF

**NA = Data Not Available, NF = No Flow

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APPENDIX F:

Underground Stormwater Management Thermal Mitigation Studies

Progress Report
October 6, 2008

Progress Report: Underground Stormwater Management Thermal Mitigation Studies

Project Duration: August 2006 – August 2008

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October 6, 2008

TABLE OF CONTENTS

LIST OF FIGURES **6**

LIST OF TABLES **7**

EXECUTIVE SUMMARY **8**

1 INTRODUCTION **9**

2 BACKGROUND **13**

2.1 Urbanization and land development 13
2.2 Imperviousness and its Impacts on Runoff Quantity and Quality 13
2.3 Effects of Imperviousness on Stream Ecosystem 13
2.4 Issue of Stream Warming 14
2.4.1 Response of stream biota to stream warming *16*
2.4.1.1 Temperature Sensitivity of Trout 16
2.4.1.2 Temperature Requirements of Trout 17
2.4.2 Thermal Enhancement of Streams by Stormwater Runoff *18*
2.5 Best Management Practices 19
2.6 Thermal Impact Study of BMPs 20
2.6.1 Runoff Temperature Mitigation Wetponds and Wetlands *20*
2.6.2 Runoff Temperature Mitigation of Bioretention Facilities *23*
2.6.3 Thermal Impact of Other BMPs *23*
2.6.4 Underground Stormwater Storage Facility *23*
2.6.5 Summary of Performance of various BMPs in Temperature Mitigation *24*
2.7 Thermal Impact Study of Underground Stormwater Storage BMP 24
2.7.1 Heat transfer Mechanism in Underground Storage Facility *24*
2.8 Modeling of Thermal Mitigation in BMPs 26
2.9 Research Direction 27

3 METHODOLOGY **28**

3.1 Site Description 28
3.2 Monitoring and Sampling 31
3.3 Data Collection 34
3.4 Data Quality Assurance and Quality Check 35
3.4.1 Rainfall Data *35*
3.4.2 Flow Data *35*
3.4.2.1 Simulation of Runoff 35
3.5 Data Analyses 38
3.5.1 Event Mean Temperature *38*
3.5.2 Exceedence of Threshold Temperature *39*
3.6 Heat transfer Model 39
3.6.1 Model formulation *39*
3.6.2 Implementation and Programming *43*
3.6.3 Model Evaluation *44*

4 RESEARCH PROGRESS **45**

4.1 Field Study 45
4.1.1 Event Characterization *45*

4.1.2 General Observations ... 48
4.1.3 Analysis of Storms of Different Temperature Ranges ... 51
4.1.4 Maximum, Minimum and Mean Monthly Temperatures ... 51
4.1.5 Exceedence of Threshold Temperature ... 54
4.1.6 Time of Exposure and Volume Analysis ... 55
4.2 Model ... 62
5 SUMMARY ... 64
6 REFERENCES ... 65

LIST OF FIGURES

Figure 1-1. Schematic diagram showing the transfer of heat to stormwater runoff....................... 10
Figure 2-1. Sensitivity of Brook trout population to percentage watershed imperviousness......... 14
Figure 2-2. Effect of development on six headwater stream temperatures in Maryland 15
Figure 2-3. Current and historical distribution of Brook trout in Maryland 17
Figure 3-1. Map location of I-83 study sites BMP 3007 and BMP 3008 29
Figure 3-2. Study site BMP 3007 behind the noisewall along I-83 NB.. 30
Figure 3-3. Study site BMP 3008 along I-83 NB... 30
Figure 3-4. Inlet I-43 of BMP 3008 along I-83 NB 31
Figure 3-5. Flow and conductivity sensors installed in the 122 cm (48 *in.*) underground conveyance pipe 33
Figure 3-6. Set up of instruments at the site 33
Figure 3-7. Rain gauge and air temperature sensor installed at the site... 34
Figure 3-8. Plot of simulated and observed inflow at a. Inlet 1 b. Inlet 2 and c. Observed Outflow of BMP 3007 on April 28, 2008 37
Figure 3-9. Schematic diagram of heat transfer in the storage pipe and air.................................. 41
Figure 3-10. Schematic representation of underground system and model design....................... 43
Figure 4-1. Plot of flow, temperature and conductivity of BMP 3007 on June 30, 2008 storm 50
Figure 4-2. Flow-weighted mean monthly temperatures for BMP 3007 53
Figure 4-3. a. Time-based and b. Volume-based plots of inflow and outflow temperatures of BMP 3007 in March 2008 56
Figure 4-4. a. Time-based and b. Volume-based plots of inflow and outflow temperatures of BMP 3007 in June 2008 57
Figure 4-5. a. Time-based and b. Volume-based plots of inflow and outflow temperatures of BMP 3007 in July 2008 58
Figure 4-6a. Proportion of monthly inflow and outflow volumes exceeding 14oC threshold temperature.. 59
Figure 4-6b. Proportion of monthly inflow and outflow volumes exceeding 17oC threshold temperature.. 60
Figure 4-6c. Proportion of monthly inflow and outflow volumes exceeding 20^{o}C threshold temperature.. 60

LIST OF TABLES

Table 2-1. Summary of temperature requirements and regimes for trout 18
Table 2-2. Summary of BMP Temperature Performance in Maryland 22
Table 3-1. Drainage characteristics of BMP 3007 and BMP 3008 31
Table 3-3. Constants and parameters used in the heat transfer model.. 42
Table 4-1. Rainfall data for Timonium site from February until August 2008 45
Table 4-2. Rainfall data recorded at the I-83 site from February until July 2008 46
Table 4-3. Total number and rainfall depths of events recorded in each month at 47
Timonium and events selected for the purpose of analysis 47
Table 4-4a. Summary of maximum, minimum, and flow-weighted mean monthly temperature at inlet and outlet of BMP 3007 52
Table 4-4b. Mean reduction of temperature in each month in BMP 3007 52

EXECUTIVE SUMMARY

As stormwater runoff contacts and is conveyed over asphalt roadways and access areas, heat is typically transferred from the asphalt to the runoff. The problem is especially acute in summer when ground temperatures are highest and when intense direct sunlight will greatly increase the temperature of the black-colored asphalt. The discharge of high-temperature water can have negative impacts on local streams receiving the runoff, raising stream temperatures, causing direct impact to aquatic organisms that cannot withstand higher temperature, and indirect impacts due to lower dissolved oxygen levels that occur in warmer waters. The underground storage and slow release facility is a versatile stormwater best management practice (BMP) for buffering high flows and mitigating temperature. Temperature reduction in underground storage BMPs, however, has not been quantified.

Stormwater runoff flows and temperatures into and out of two underground storage BMPs owned by Maryland SHA are being monitored. In the colder months (February, March, and April 2008), when the runoff temperature ranged between 5 and 15°C, small or no temperature reduction was observed. In the warmer months (June and July 2008), the inflow temperature ranged between 15 and 25°C. The mean temperature reduction during summer was about 1.5°C, but the reduction was not enough to cool the runoff below temperature thresholds. Outflow volumes violating the Maryland Class III standard of 20°C were observed during some monitoring periods. A heat-transfer model is being developed to predict the temperature reduction in the BMP based on input conditions. With supporting data and model, the impact of these BMPs in managing high temperature concerns in highway applications can be quantified for future design, analysis, and implementation.

INTRODUCTION

Over the past several centuries, forests have been cleared to satisfy the growing land demands of the burgeoning world population. Natural land covers have been replaced by large agricultural lands and urban areas. The world urban population is expected to almost double by 2050, increasing from 3.3 billion in 2007 to 6.4 billion in 2050 (United Nations 2008). Globally, the level of urbanization is expected to rise from 50% in 2008 to 70% in 2050 (United Nations 2008). The sustained increase in urbanization has resulted in large scale replacement of pervious land cover by impervious areas such as roads, driveways, sidewalks, parking lots, and rooftops. Replacement of the natural land cover by impervious surfaces and infrastructure has resulted in the "urban heat island effect." Many US cities have been found to have air temperatures 3.3 to 4.4°C (6 to 8°F) warmer than the surrounding rural regions (US Department of Energy, 1996).

Imperviousness impacts the quality and quantity of water from a watershed by reducing infiltration, increasing the runoff volume and pollutant loadings during storm events. Imperviousness is considered as a valuable indicator of the impacts of the land use changes in a watershed on aquatic systems (Schueler 1994). Hydrologic modification in a watershed associated with urbanization can affect physical, chemical and biological conditions of the receiving waters (Paul and Meyer 2001; Wang et al. 2003). Increased frequency of flooding and peak flow volumes, increased sediment loadings, loss of riparian habitat, changes in stream channel width and depth, decreased base flow, and increased stream temperature are some of the impacts of urban runoff on streams.

Stream warming due to urbanization has been a problem of growing concern in the recent years. In summer, the average stream temperature was found to increase by as much as 5 to 8°C in a watershed associated with urbanization (Pluhowski 1970). A study by Galli (1990) on thermal and dissolved oxygen impacts to aquatic life associated with urbanization in Maryland streams showed that the stream temperature increases by 0.14^{o}F for each one percent increase in watershed imperviousness. Connected imperviousness greater than 10% yielded demonstrable loss of aquatic system function (Schueler 1994; Booth and Jackson 1997; Wang et al. 2003). Sensitive species such Brook trout ceased to exist for upstream impervious cover beyond 2% (Boward et al. 1999).

Streams receiving urban stormwater runoff have been found to have elevated temperatures (Galli 1990; USEPA 1999; Walsh et al. 2003). Common urban impervious surfaces have high thermal capacity and absorb solar radiation. As stormwater runoff is conveyed over black asphalt roadways and access areas, heat is transferred to the runoff via conduction, thereby raising its temperature. Summer is the period of concern when ground temperatures are highest and when intense direct sunlight will greatly increase the temperature of the black-colored asphalt (Figure 1-1). Runoff temperatures from urban impervious areas as high as 29°C (82°F) have been measured in Dane County, Wisconsin (Roa-Espinosa et al. 2003). The discharge of warm runoff into local streams increases the ambient stream temperature, causing adverse effects on its ecosystems. Increase in stream temperature by heated runoff has been noted as a severe and prevalent problem in Maryland (Boward et al. 1999).

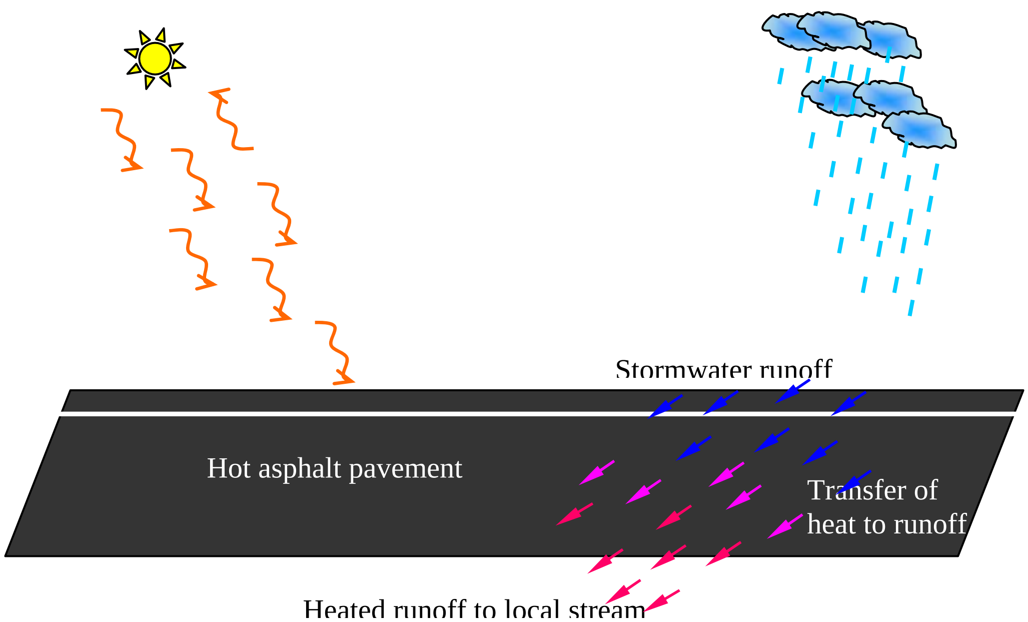


Figure 1-1. Schematic diagram showing the transfer of heat to stormwater runoff

Elevated water temperature levels can have negative impacts on the stream habitat. Biotic integrity and species diversity are severely impaired at higher water temperatures. Cold-water species such as trout are extremely sensitive to temperature and are stressed at higher temperatures. Cold-water streams are apparently the most ecologically sound at temperatures between 7 and 17ºC (Lyons and Wang 1996; Simonson 1996). The Maryland state Class III standard for natural trout waters and Class IV standard for recreational trout waters have been established as 20ºC (68ºF) and 24ºC (75ºF), respectively (USEPA 1988).

Increase in stream temperature has a direct impact on the dissolved oxygen level. At higher temperatures, the solubility of oxygen in water decreases, resulting in lower levels of dissolved oxygen. As temperature increases, the rise in the metabolic rate of aquatic organisms causes an increase in the demand for dissolved oxygen. Also, photosynthesis and plant growth increase with higher water temperatures. The consumption of oxygen by bacteria for decomposing dead plants further depletes the dissolved oxygen level in the stream (Paul and Meyer 2001).

Best management practices such as wetlands, dry detention ponds, grass swales, and sand filters are widely employed control measures for removing pollutants in urban stormwater runoff. Limited research has been done on the performance of these BMPs in reducing stormwater runoff temperature. Galli (1990) investigated the effects of stormwater BMPs, namely an infiltration facility, artificial wetland, extended detention dry pond, and wet pond, on stormwater runoff temperature, and found that these BMPs increased the outflow temperature. A thermal balance study on an on-stream wetpond in Ontario yielded similar results. Large surface area of the pond exposed to solar radiation and lack of surrounding vegetation resulted in the thermal enhancement of the pond during the dry-weather seasons (Van Buren et al. 2000a). Jones et al. (2007) performed a study on four bioretention facilities, a wetland and a wetpond located in trout-sensitive regions in North Carolina. The study revealed that the wetpond and wetland BMPs caused thermal enhancement of runoff, but the bioretention facility aided in cooling of the runoff.

Another versatile stormwater best management practice is an underground storage and slow release facility. These detention facilities attenuate peak flows. However, the knowledge of temperature mitigation in such underground storage BMPs is limited. In summer, the ambient temperature in underground storage facility is cooler than the surface (air) temperature and extended detention of the inflow runoff should aid in heat loss. Thus, it can be hypothesized that reduction in the temperature of incoming stormwater runoff should occur in an underground storage BMP. Hence, runoff discharged from the BMP into the receiving waters or streams will be at relatively lower temperatures.

In order to test the hypothesis, a thermal impact study was conducted in two underground storage BMPs in Timonium, Maryland. The objectives of this study were to quantify the impact of underground storage on the temperature of runoff from a highway and to develop a simple heat transfer model. In order to achieve these objectives, the first task was to setup and monitor stormwater runoff flows and temperatures into and out of two underground storage BMPs. Automated flow and temperature monitoring equipment was installed at the study sites. The data obtained were employed to quantify the temperature mitigation in the BMP and to develop the heat transfer model. The model, formulated as a differential equation, when solved numerically would predict the temperature of the runoff at the outlet of the facility. This will enable the determination of the efficacy of these BMPs in mitigating temperature of runoff. The impact of these BMPs in managing high temperature concerns in highway applications can hence be quantified for future design, analysis, and implementation.

BACKGROUND

Urbanization and land development

Impervious surfaces like, roads, driveways, parking lots, and rooftops have increased due to expanding urbanization. In 2002, urban land in the United States was lower than 3% of total land area, but housed 79% of the U.S. population (Lubowski et al. 2006). Urban and suburban land (residential, commercial, industrial, institutional, and extractive) constitute nearly 16% of Maryland and is concentrated in the Washington-Baltimore metropolitan area (Boward et al. 1999). Based on the 2000 Census, the population of Maryland has been projected to increase by 33% between 2000 and 2030 (US Census Bureau statistics). With the increase in population, urban sprawl is expected to further expand to accommodate the new population.

Imperviousness and its Impacts on Runoff Quantity and Quality

Watershed imperviousness imparts hydrologic modifications in the catchment; reduced infiltration, increased surface runoff, decreased lag time, increased peak flow volumes, and lower dry weather stream flow. Due to urbanization, increase in direct runoff to streams up to 5 times that of pre-urban periods has been witnessed in Long Island, New York (Seaburn 1970). In addition to the impact on water quantity, urbanization has an effect on the quality of the runoff. Impervious surfaces accumulate pollutants which are washed off during storm events and eventually delivered to the receiving waters. *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).

Effects of Imperviousness on Stream Ecosystem

The impact of watershed imperviousness on the stream ecosystem is manifold. Physical, chemical, and biological processes in the receiving waters are affected due to urbanization (Booth and Jackson 1997; Paul and Mayer 2001; Walsh et al. 2004). The term "urban stream syndrome" has been used to describe the consistently observed ecological degradation of streams draining urban land (Walsh et al. 2005). Urban-induced flashy hydrographs, decreased baseflow, channel instability, elevated levels of sediments, metals, nutrients, pesticides, fecal coliforms and other contaminants, stream warming, riparian deforestation, and decline in biodiversity in streams have been well documented by various researchers.

Urbanization is considered one of the more serious immediate threats to brook trout populations in Maryland. For a watershed impervious surface area of 0.5%, substantial reduction in brook trout population was observed, while for imperviousness greater than 4%, brook trout is expected to be completely eliminated (Butowski 2006). Figure 2-1 illustrates the extreme sensitivity of brook trout to imperviousness land cover in a watershed.

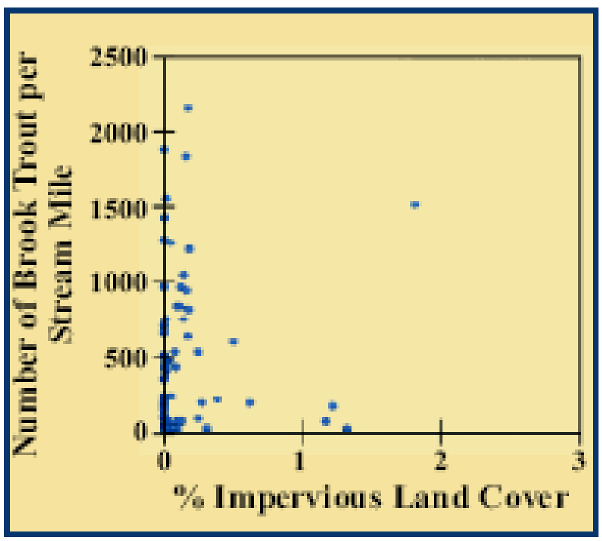


Figure 2-1. Sensitivity of Brook trout population to percentage watershed imperviousness (Source: Boward et al. 1999)

Stream Warming

Research studies have indicated that imperviousness has a direct impact on, and high correlation with, the stream temperature (Galli 1990; Booth and Jackson 1997; Schueler 2003; Wang et al. 2003). Stream temperature enhancement has been attributed to a range of urban factors, including the clearcutting of vegetation from streambanks, introduction of ponds and lakes, increased stormwater runoff to streams, and a reduction in the amount of ground-water inflow (Pluhowski 1970; USEPA

1999). Pluhowski (1970) observed 5-8°C increase in mean stream temperatures during summer in a study in Long Island, New York.

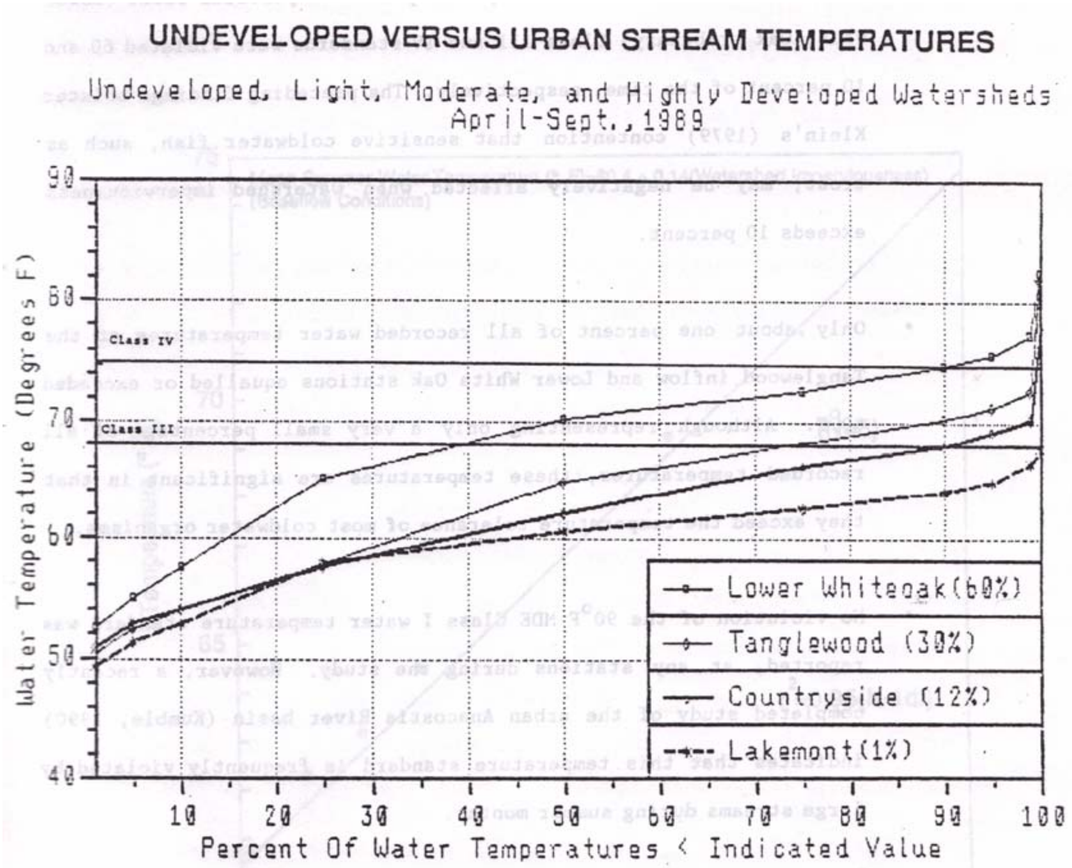


Figure 2-2. Effect of development on six headwater stream temperatures in Maryland (Source: Galli 1990)

Galli (1990) performed continuous water temperature monitoring in six headwater urban streams in the Piedmont portion of Maryland's Anacostia basin. The watershed imperviousness ranged between 0 and 60%. The study showed that the stream temperature increased by 0.14°F for each one percent increase in watershed imperviousness. The study findings on the effect of urbanization on stream temperature supported the work of Pluhowski (1970); urbanized Lower White Oak was typically 4-15°C warmer than undeveloped, forested Lakemont tributary (Figure 2-2). The study revealed that as the level of watershed imperviousness increased, the size of storm required to produce large fluctuations in stream temperature decreased. The streams became increasingly responsive to stormwater runoff inputs with the increase in watershed imperviousness. Study by

Wang et al. (2003) in trout streams in Wisconsin and Minnesota predicted 0.25°C increase in water temperature for each one percent increase in imperviousness.

Section 303(d) of the Clean Water Act addresses the thermal pollution of receiving waters. The section states that "*each State shall estimate for the waters identified as impaired the total maximum daily thermal load required to assure protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife*" (Federal Water Pollution Control Act, USEPA). Temperature Total Maximum Daily Loads (TMDLs) are being developed to protect the coldwater stream habitats, especially in the Pacific Northwest (Kieser et al. 2003).

Response of stream biota to stream warming

Many research studies on the effects of elevated stream temperature on aquatic biota have been conducted. Biotic integrity and species diversity are severely impaired at higher water temperatures. Fish growth, metabolic rate, egg maturation, spawning, incubation success, distribution and migration patterns, and resistance to diseases, parasites, and pollutants are influenced by temperature regimes (Armour 1991; Schueler 2003; Butowski 2006). Hogg and Williams (1996) observed that a 2-3.5°C water temperature increase in a stream in Ontario, Canada caused decrease in the total animal densities, smaller size and altered sex ratios in the stream invertebrates, and increase in the growth rates of amphipoda.

Temperature Sensitivity of Trout

When general temperature requirements are considered, fish can be grouped into coldwater, coolwater, or warmwater categories (Armour 1991). Increased water temperature may preclude temperature sensitive coldwater species such as salmon and trout. Alteration in thermal regimes can change the relative distribution and population of the species; coolwater and coldwater species may be completely extirpated and replaced by more tolerable species (USEPA 1999).

The comprehensive study on Maryland streams named Maryland Biological Stream Survey, conducted by the Maryland Department of Natural Resources from 1995 to 1997, showed that the streams most affected by urbanization are in the Baltimore-Washington Metropolitan portions of the Patapsco and Potomac Washington Metro river basins (Boward et al. 1999). The survey estimated the current brook trout population in Maryland streams to be about 300,000, which once numbered more than 3 million. The study cites that one of the most important reasons for the decrease in brook trout population is water temperature. Due to the clearing of trees for urban development, previously forested streams have been exposed to direct sunlight, combined with the input of heated runoff from impervious surfaces and warm water discharges from ponds and lakes. Consequently, only few streams have temperatures cool enough to support brook trout, particularly in the eastern half of the state (Boward et al. 1999). Figure 2-3 depicts the historic change in the population of brook trout in the state of Maryland.

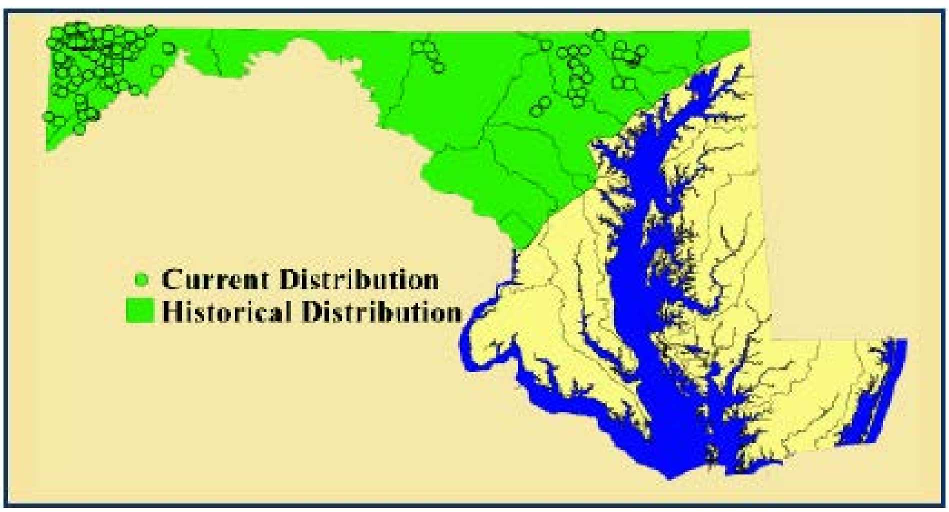


Figure 2-3. Current and historical distribution of Brook trout in Maryland (Source: Boward et al. 1999)

Temperature Requirements of Trout

Trout are adapted to cooler waters and may become stressed in thermally enhanced waters. Cold-water streams are apparently the most ecologically sound at temperatures between 7 and 17ºC (Lyons and Wang 1996; Simonson 1996). Baldwin (1951) identified 14^{o}C as optimal water temperature for brook trout. The upper lethal water temperature limit for hatchlings is 20^{o}C and approximately 25^{o}C for juveniles and adults. Brown trout have an optimum temperature range of 7 to 17ºC and become stressed at temperatures above 19ºC (Roa-Espinosa et al. 2003). Table 2-1 provides a summary of the temperature regimes for trout species.

Table 2-1. Summary of temperature requirements and regimes for trout

Requirement/Criteria	Temperature Range	Reference
Growth and survival	11 - 16ºC	Baldwin (1951); Raleigh (1982); Drake and Taylor (1996)
Optimal water temperature for brook trout	14ºC (Maximum 14.4ºC)	Baldwin (1951); (MacCrimmon and Campbell 1969)
Optimal water temperature for brown trout	7 - 17ºC	Roa-Espinosa et al. (2003)
Spawning of brook trout	19ºC	Hokanson (1973)
Egg maturation and development	4.5 – 11.5ºC	(MacCrimmon and Campbell 1969)
Upper lethal water temperature limit	20ºC (hatchlings); 25ºC (juveniles and adults)	(MacCrimmon and Campbell 1969)
Experimental LT50 (temperature at which 50% population survive) for trout	Brook : 25.2ºC. Brown: 26.2ºC Rainbow: 26.6ºC	Grande and Andersen (1991)
Maryland Class III standard for natural trout waters	20ºC	USEPA (1988)
Maryland Class IV standard for recreational trout waters	24ºC	USEPA (1988)
Maximum daily mean temperature (for brown trout)	22ºC	Ross and Hari (2007)
Maximum temperature for 100% survival exposure time (for brown trout)	1- minute: 28ºC 10-minutes: 26.5ºC 1-hour: 25ºC	Ross and Hari (2007)
Change in temperature at the beginning of storm event	≤ 7ºC	Ross and Hari (2007)
Maximum daily temperature in winter	≤ 12ºC	Ross and Hari (2007)

Procedures to evaluate the temperature regimes of salmon namely, maximum weekly temperature that should not be exceeded, short-term maximum survival temperature, upper and lower incipient temperatures, and lethality of exposure time based on the acclimation temperature have been proposed by Armour (1991). The Maryland state Class III standard for natural trout waters and Class IV standard for recreational trout waters have been established as 20ºC (68ºF) and 24ºC (75ºF), respectively (USEPA 1988). The U.S EPA has placed limitations on the daily and weekly average temperatures, and exposure times in marine and freshwater streams (USEPA 1988b).

Thermal Enhancement of Streams by Stormwater Runoff

Streams receiving storm runoff from urban impervious surfaces have been found to have elevated temperatures (Galli 1990; Booth and Jackson 1997; Boward et al. 1999; USEPA 1999; Walsh et al. 2003; Wang et al. 2003; Walsh et al. 2005). Stream warming due to heated runoff has been reported as a severe and prevalent problem in Maryland (Boward et al. 1999). Summer is a critical period when discharge of heated runoff can lead to a short-term spike in the stream temperature at the beginning of a storm (Ross and Hari 2007). This is because summer storms are usually characterized short heavy storms, typically more frequent in afternoon.

Best Management Practices

Low impact development strategies are often described as sustainable stormwater management practices and have been widely employed to remediate the impacts caused by strormwater runoff (USEPA 2000; Walsh et al. 2005; Bernhardt and Palmer 2007). Some of the widely employed best management practices (BMPs) to control pollution impacts of stormwater runoff are bioretention, grass swales, infiltration basins, wet/dry detention ponds, wetlands. Numerous studies have been performed in order to evaluate the performance of these BMPs in reducing the pollutant load of the stormwater runoff (USEPA 1999). However, the sensitivity of the BMPs in mitigating runoff temperature has not been thoroughly investigated. Generally, little or no consideration is placed towards temperature mitigation in the design aspects of the BMPs (Jones et al 2007).

Thermal Impact Study of BMPs

Thermal impact of the BMPs on urban stormwater runoff can be considered to be under-monitored and under-researched. Although the need for control measures to mitigate urban stormwater thermal enhancement have been emphasized, limited studies have investigated the performance of BMPs in reducing runoff temperature. Majority of such studies performed have focused on wetlands, wet and dry detention basins (Galli 1990; Van Buren et al 2000a; Sherwood 2001; Kieser et al. 2003), and few studies on infiltration and bioretention facilities (Galli 1990; Jones et al. 2007).

Runoff Temperature Mitigation Wetponds and Wetlands

Galli (1990) performed a study on four representative BMPs including an infiltration facility, artificial wetland, extensive detention dry pond, and a wetpond in Maryland. Inflow and outflow temperatures were monitored and violation of temperature standards during both baseflow and stormflow conditions was evaluated. The study revealed that none of the four monitored BMPs reduced the runoff temperature and in fact contributed to the increase in outflow temperature. The BMPs ranked in order of temperature mitigation performance were infiltration-dry pond, artificial wetland, extensive detention dry pond, and a wetpond. (See Table 2-2 showing the delta-T and standard violations). Based on the observed runoff temperatures, trout cannot be expected to survive at the outfall of any of the four BMPs.

Van Buren et al. (2000a) performed the thermal energy balance of an on-stream stormwater management pond in Kingston, Ontario. The pond received runoff inflows from a parking lot (12.6 *ha*) and a creek (4500 *ha*). During the dry-weather days, net radiation and heating of the baseflow owing to the large exposed surface area of the pond along with the lack of surrounding vegetation, resulted in increased pond temperature. During rainfall events, the parking lot runoff contributed to the thermal enhancement of the receiving waters and the thermal output was greater than the input. Also, the average surface water temperature was 3.6ºC higher than that at the pond bottom. The study illustrated that the per-area thermal energy contribution of the parking lot was 30 times higher than that of the upstream catchment area consisting of residential and forested land use.

Sherwood (2001) studied the effectiveness of a naturally vegetated stormwater detention basin in reducing the chemical loading and temperature of runoff from a residential development located in Monroe County in New York. The facility did not have a significant thermal impact on the runoff. During summer storms, the maximum inflow and outflow runoff temperatures were observed to be similar, the mean outflow temperature being 0.5°C (0.9°F) higher than the mean inflow temperature.

Table 2-2. Summary of BMP Temperature Performance in Maryland (Source: Galli 1990)

Table 16 Summary: BMP Temperature Performance1/

Parameter		BMP Type: Infiltration-Dry Pond	Extended Detention Wetland	Extended Detention Dry Pond	Wet Pond
Average Baseflow Delta-T (°F)		2.6	3.9	5.5	9.7
Maximum Baseflow Delta-T (°F)		7.6	8.7	9.7	15.1
Average Stormflow Delta-T (°F)		2.3	2.4	5.2	8.5
Maximum Stormflow Delta-T (°F)		5.0	7.8	11.2	14.0
Average Total Delta-T (°F)		2.5	3.2	5.3	1.1
Maximum Total Delta-T (°F)		7.6	8.7	10.9	9.1
Percent Baseflow	- Class III (68°F)	8	60	50	77
Violation of MDE	- Class IV (75°F)	1*	15	10	35
Temperature Stds.	- Class I (90°F)	0	0	0	0
Percent Stormflow	- Class III (68°F)	18	57	48	64
Violation of MDE	- Class IV (75°F)	0	5	15	25
Temperature Stds.	- Class I (90°F)	0	0	0	0
Maximum observed outflow water Temp (F)		77.7	80.8	81.9	82.6

1/ - Total Delta-T values shown represent combined baseflow and stormflow temperatures (i.e., all flow conditions).

* - Class IV violation result of defacto extended-detention control.

Runoff Temperature Mitigation of Bioretention Facilities

Recently, a thermal impact study was conducted on six BMPs located in trout sensitive regions in Western North Carolina (Jones et al. 2007). Four bioretention facilities, one wetland and a wetpond were monitored for inflow and outflow temperatures. The BMPs received stormwater runoff from asphalt parking lots with or without any shading by trees or vegetation. During the summer months, the mean effluent runoff temperature was significantly higher than the mean influent temperature in both wetland and wetpond. The water temperature remained above 21°C threshold in the deeper waters in the wetpond throughout the period. The outflow from the wetpond was warmer than that from the wetland ($p<0.05$). Unlike the wetland and wetpond, the bioretention facilities cooled the inflow runoff, although not below the 21°C threshold. Infiltration of runoff through the bioretention area aided in the loss of heat to the surrounding soil. Further, the study found that runoff conveyed through a buried metal pipe exhibited a temperature reduction of up to 6°C.

Thermal Impact of Other BMPs

Another LID practice, namely porous pavement, has been observed to provide some thermal mitigation (USEPA, unpublished). Temperature mitigation in rock cribs has been studied in Dane County (Roa-Espinosa 200). The field data indicated that the rock crib (volume 255 m^3) filled to capacity aided in effective mitigation of the runoff temperature until the initial volume of the crib was completely replaced by the runoff. The rock crib did not reduce inflow temperature after the volume was replaced.

Underground Stormwater Storage Facility

Underground storage and slow release facility is another versatile stormwater best management practice. In ultra-urban settings, where surface space is a constraint, underground detention systems provide best alternative to surface detention/retention ponds (Roberts 1997). These systems are mainly designed to address the quantitative aspect of stormwater runoff by attenuating peak flows. The outflow from underground storage facilities is controlled by orifice and/or weir combination. However, the ability of these facilities in reducing runoff temperature has not been probed.

Summary of Performance of various BMPs in Temperature Mitigation

Wetponds and wetlands have been found to serve as a source of thermal pollution in most of the studies. Large surface area of wetponds exposed to direct solar radiation and lack of shading result in increase in water temperature. Shading by vegetation and riparian buffers can help reduce temperature to some extent, but the outflow temperature might still be harmful to the receiving waters (Galli 1990; Van Buren et al. 2000a). Bioretention facilities and grass swales have the potential to reduce runoff temperature. With regards to design considerations, Jones et al (2007) pointed out that the bioretention facilities with inadequate depth and not designed to capture the first flush, may cause additional heating of the runoff. In general, stormwater BMPs promoting infiltration and providing sufficient shading to detained runoff can mitigate runoff temperature (Kieser et al. 2003). The performance of BMPs such as parallel pipe and baseflow diversion systems, multiple-port release wet ponds, sand and peat filters, and conveyance systems in mitigating temperature are yet to be evaluated (Galli 1990). No research study has reported the potential thermal mitigation in underground storage facilities.

Thermal Impact Study of Underground Stormwater Storage BMP

Underground storage systems are BMPs that have not been monitored for stormwater runoff temperature mitigation. Since these BMPs have been designed as slow release facilities, the runoff from highway is stored in the underground pipes for some period. During this detention period, the runoff can lose some heat by various heat transfer mechanisms. Hence, the BMP might be capable of reducing the temperature of urban storm runoff.

Heat transfer Mechanism in Underground Storage Facility

During summer storms, the runoff from highway and other impervious surface is typically heated up due to the convective transfer of heat from the hot impervious surface. The heated runoff flows into the underground pipes, where the ambient temperature is cooler than the high air temperature outside, specifically in summer. In case the underground storage pipes have some stored volume of water between storms, their temperature is expected to be same as the underground ambient temperature. The pipe buried underground is also expected to be at the surrounding soil temperature.

The runoff flowing into the underground system is expected to lose heat by three main mechanisms. Convective heat transfer in fluids is comprised of two mechanisms: diffusion (by random molecular motion) and advection (by bulk motion) (Incorpera and DeWitt 1990). As the heated runoff from highway flows into the system, it comes into contact with the pipe, surrounding air and already stored runoff if any, all at a lower temperature. A temperature gradient exists between the pipe wall and the inflow runoff. As runoff is conveyed through the pipe, convective heat transfer will occur between the pipe surface and the flowing water. If any water is stored in the pipe, the warmer inflow runoff mixes with the cooler stored water resulting in buffering of the temperature. The runoff will be cooled by the surrounding air as well. Some heat might be conducted through the pipe to the surrounding soil.

The detention time of runoff in the pipes will have an influence on the total heat transfer. Longer retention time will allow for further cooling of runoff. However, the retention time of runoff in the system depends on the volume received from the storm event. As more runoff flows in, the stored water flows out, and this may limit the net heat loss. The convective heat transfer flux is proportional to the temperature difference between the surface and fluid temperature. The proportionality constant, called the convective heat transfer, is a function of the nature of flow motion, and thermal properties of the material (Incorpera and DeWitt 1990). This suggests that the thermal conductivity of the pipe material will control the rate of heat transfer between the pipe and flowing runoff; higher the conductivity, greater the heat transfer and hence more reduction in the runoff temperature. The temperature of inflow runoff varies depending on the season. Hence a seasonal variation in temperature reduction in the BMP can occur.

Modeling of Thermal Mitigation in BMPs

Thermal enrichment of runoff passing over heated asphalt pavement is well established and has been modeled (Xie and James 1994; Van Buren et al. 2000b; Roa-Espinosa et al. 2003; Herb et al. 2006). Regression models for predicting stream temperatures as a function of watershed characteristics, land use, solar inputs, and inflows from upstream channel and/or runoff from a stormwater control have been developed (Huebner and Soutter 1994; Weatherbe 1995; Schroeter et al. 1996; Wehrly et al. 1998). Thermal Urban Runoff Model (TURM) was developed by the Dane County Land Conservation Department to predict the impact of urban development on stream temperature and tested successfully in the Token Creek watershed in Dane County, Wisconsin (Roa-espinosa et al. 2003).

Thermal impact of best management practices have been also been modeled. Van Buren et al. (2000a) modeled an on-stream stormwater management pond in Kingston, Ontario by thermal energy balance approach. Assuming the pond is in a completely mixed condition, the average pond temperature was estimated as a function of the thermal energy stored in the pond. A routine in the TURM model accounts for the gain or loss of heat from the passage of water through swales, detention basins, and rock cribs. TURM predicted that cooling of the runoff passing through rock crib and grass swales (Roa-espinosa et al. 2003). Herb et al. (2007) at the St. Anthony Falls Laboratory (Minnesota) developed hydro-thermal models to simulate temperature mitigation of surface runoff in wetland basins. The simulations predicted the wetland complex to reduce runoff temperature by 2.6 °C, on average for Minnesota climate conditions, compared to unmitigated runoff from an asphalt parking lot.

To summarize, many models have been developed to predict the runoff and stream temperatures. Thermal impact of BMPs has been modeled for limited types of BMPs. Since heat transfer models will measure the performance of the BMP in reducing runoff temperature, modeling the thermal impact of a BMP will yield useful information regarding the employment of BMPs for mitigating temperature of urban stormwater runoff for various imperviousness conditions.

Research Direction

While the need to control thermal pollution by storm runoff has been recognized in many research studies, limited studies have investigated the thermal sensitivity of BMPs. Wetponds and wetlands have been found to increase runoff temperatures while small reduction in temperature has been noticed in BMPs with infiltration. Evaluation of the thermal impact of the underground stormwater management facilities has not been performed. Through field study and modeling of the heat transfer in the system, the efficiency of the underground storage BMPs in mitigating stormwater runoff temperature can be quantified. This research will be a promising study towards managing thermally enriched stormwater runoff in urban areas. Results from this study will equip the urban stormwater planners and managers with the knowledge of thermal impact of underground storage systems which can serve as an effective stormwater management tool.

METHODOLOGY

Site Description

Several underground stormwater management facilities in Maryland were investigated to determine their suitability for inclusion in this study. The sites were evaluated based on the size of drainage area, percentage imperviousness, asphalt vis-à-vis concrete pavement, number of inflow points, accessibility of inlet and outlet points, and safety at the site. Two BMPs, BMP 3007 and BMP 3008, both located along I-83 northbound, north of Seminary Avenue in Baltimore County (Figures 3-1 to 3-4), were chosen for the study. Both the BMPs are located within the Maryland State Highway Authority right-of-way. A pavement sensor is located in I-695 at I-83 N, at a distance of approximately 3.22 *km* (2 miles) from the two BMPs. The sensor measurements include rainfall intensity, air temperature, pavement temperature and other weather parameters such as relative humidity, dew point, and wind speed and direction.

BMP 3007 and BMP 3008 were both modified to have two inflow points by blocking one inlet in each facility and redirecting the runoff into their respective downstream inlets. The drainage area to BMP 3007 is 1.07 *ha* (2.64 acres), of which 66% is impervious. BMP 3008 has a contributing drainage area of 1.23 *ha* (3.04 acres) and impervious fraction of 43%. The characteristics of the drainage areas of the two BMPs, including SCS curve number and time of concentration (T_c), are summarized in Table 3-1.

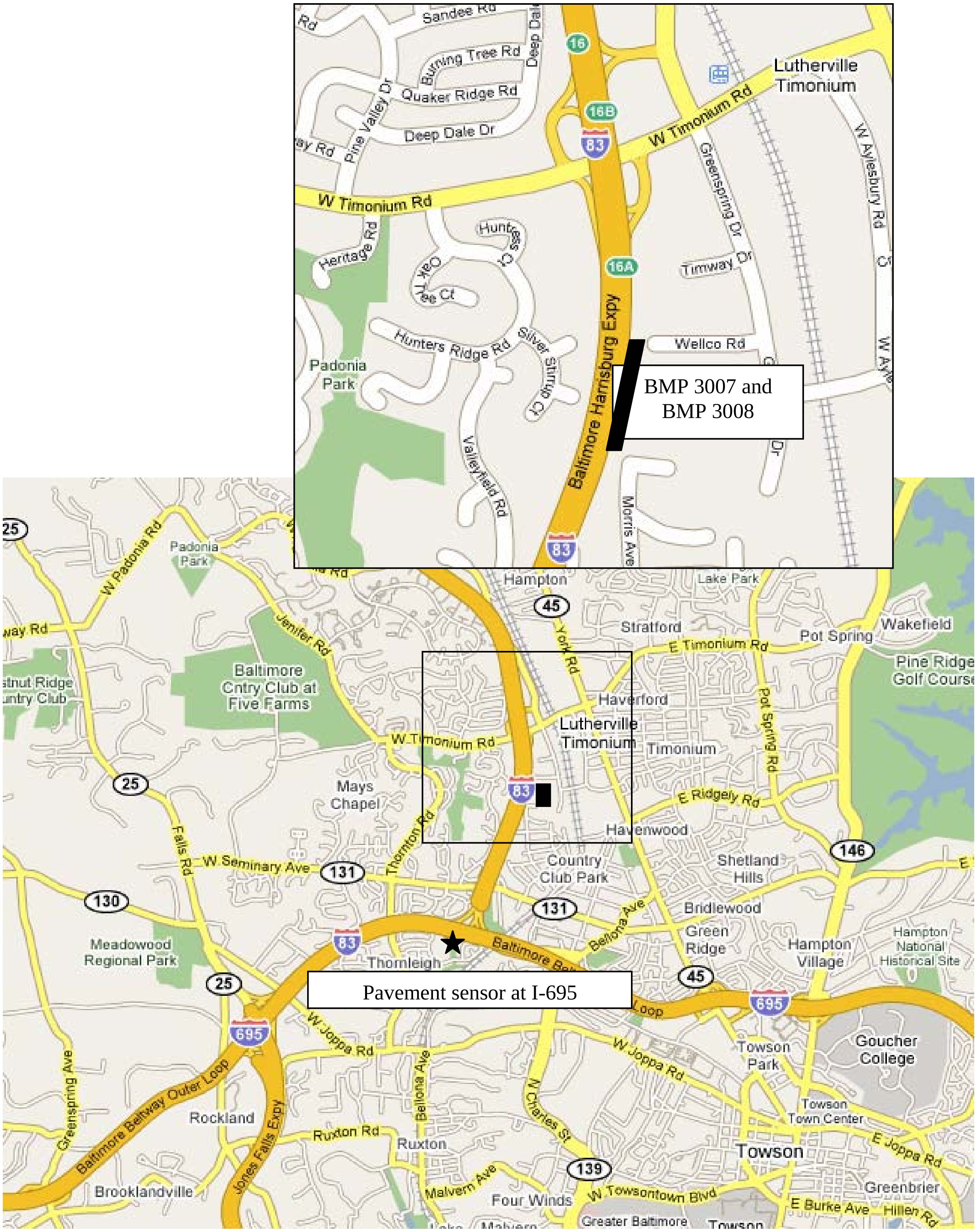


Figure 3-1. Map location of I-83 study sites BMP 3007 and BMP 3008
(Source: www.maps.google.com)

Figure 3-2. Study site BMP 3007 behind the noisewall along I-83 NB

Figure 3-3. Study site BMP 3008 along I-83 NB

Figure 3-4. Inlet I-43 of BMP 3008 along I-83 NB

Table 3-1. Drainage characteristics of BMP 3007 and BMP 3008

BMP	Structure Number (or Inlet)	Drainage Area (*ha*)	Curve Number	Tc (*hr*)	Impervious Area (*ha*)	% Impervious
3007	I 3-5	0.12	98	0.10	0.12	100%
	I 3-4			*blocked*		
	MH 3-3	0.95	62	0.10	0.58	61%
	Total	**1.07**	**66**		**0.70**	**66%**
3008	I 4-3	0.05	98	0.10	0.05	100%
	I 4-1			*blocked*		
	MH 4-3	1.18	81	0.38	0.48	41%
	Total	**1.23**	**82**		**0.53**	**43%**

The runoff from the highway flows into two inlet pipes of the BMP. In each BMP, the underground storage system consists of six HDPE pipes, each 122 *cm* (48 *in.*) in diameter. The outflow is controlled by a 3.8 *cm* (1.5 *in.*) orifice. The total length of pipes in BMP 3007 and BMP 3008 are 166 *m* (544 *ft*) and 188 *m* (616 *ft*) respectively, their corresponding storage capacities being 210 m^3 (7419 ft^3) and 236 m^3 (8316 ft^3).

Monitoring and Sampling

Monitoring equipment was installed in BMPs 3007 and 3008 in September 2007 to continuously measure and record flow depth, conductivity and temperature of stormwater runoff at the inflow and outlet points, air temperature, and rainfall depth. The sensors are manufactured by Global Water Instrumentation, Inc. (Gold River, CA). A Global Water FL16 flow logger was installed to record the stormwater runoff flow rate and temperature at the BMP inflow and outflow pipes. The probe has an operating temperature range of -40 to +85°C. The sensor works in depths as low as 1.9 *cm* (3/4 *in.*) and can be programmed to suit the pipe characteristics. Conductivity measurements were made using a conductivity sensor (WQ301) working over the range of 0-5000 microsiemens/cm. The sensors were placed in the underground conveyance pipes (Figure 3-5) and their loggers in a weather-proof box (Figures 3-6). A 15.2 *cm* (6 *in.*) tipping bucket rain gauge (RG 200) was installed to record the rainfall at the site at two minute intervals. The temperature sensor (WE700), capable of operating in the temperature range of -50 to +50°C, was installed to record air temperature. The air temperature sensor was mounted on a post and housed in a ventilated solar shield having high reflectiveness, low heat retention and low thermal conductivity in order to protect it from direct sunlight effects (Figure 3-7).

The conductivity sensor, air temperature sensor and rain gauge were connected to individual data loggers (GL500-2-1 USB model) capable of recording over 81,000 readings. The data logger can be programmed to sample at the desired interval from 1 second to multiple years. The instruments are battery powered and operate on a Windows-based software interface. The data stored in the logger's memory were retrieved by downloading as a file into a laptop.

Each probe was programmed to continuously record data at two-minute intervals. It was proposed to collect data for as many rainfall events as possible, placing importance on data obtained during late spring, summer, and early fall, when high temperatures are most critical.

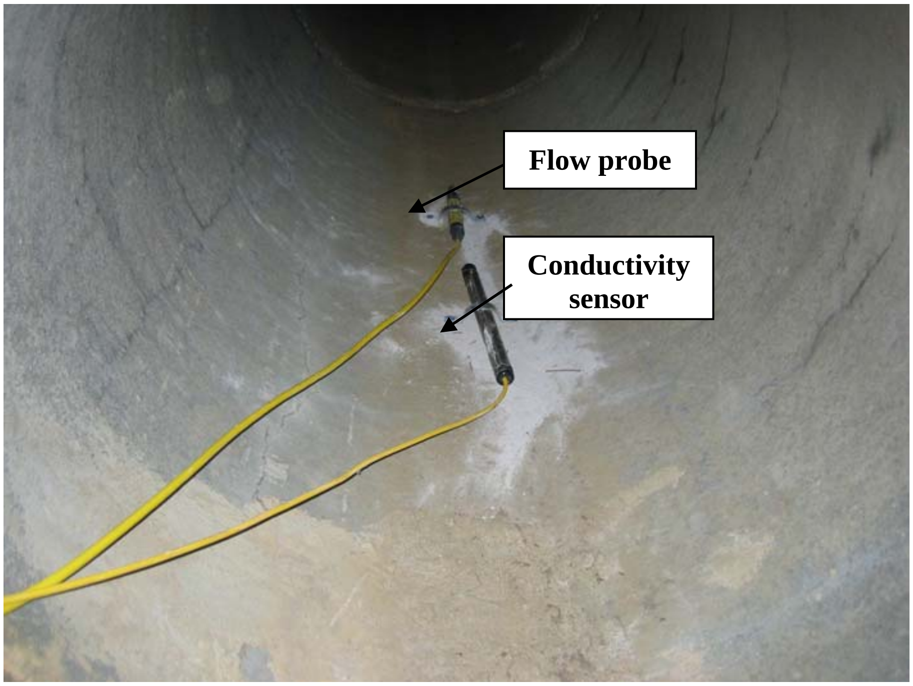


Figure 3-5. Flow and conductivity sensors installed in the 122 cm (48 *in.*) underground conveyance pipe

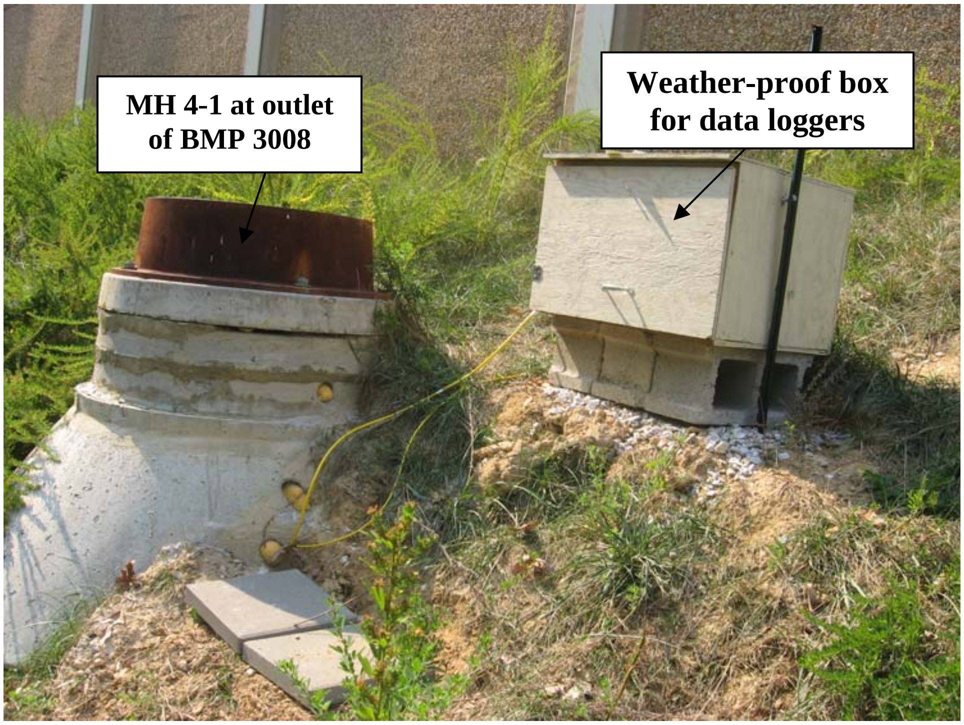


Figure 3-6. Set up of instruments at the site

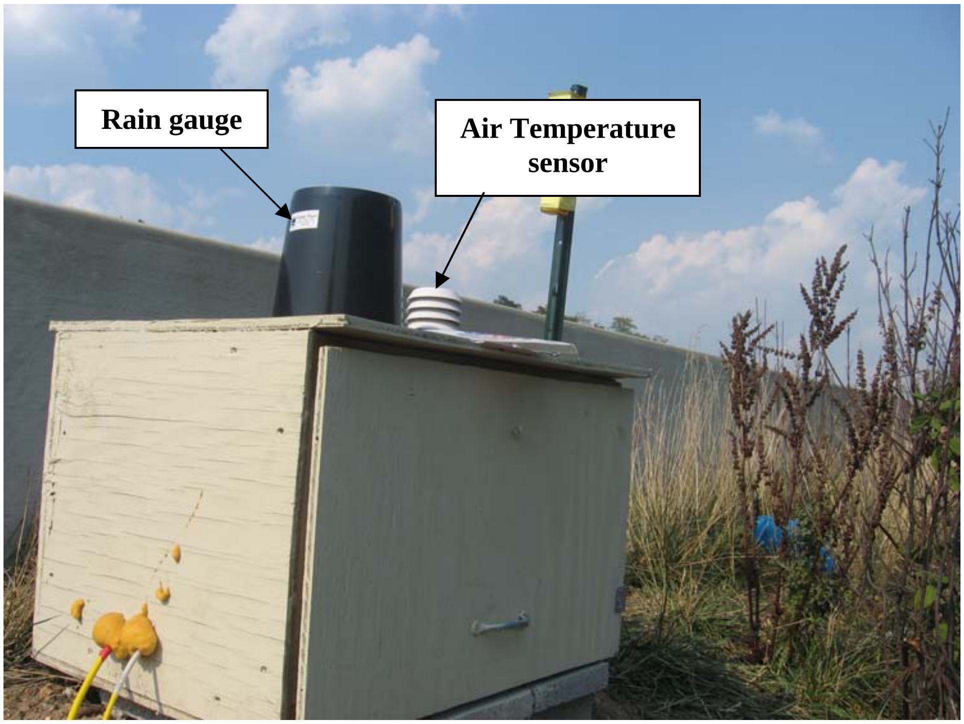


Figure 3-7. Rain gauge and air temperature sensor installed at the site

Data Collection

Runoff flow, temperature, and conductivity were monitored from the end of September 2007 through August 2008. Several initial installation problems occurred at the site. Rainfall data for the months September to November 2007 were lost due to calibration error in the rain gauge. Flow and temperature data were lost at the outlet of BMP 3008 due to malfunctioning of the flow probe for a short period. The probes at one inlet in each of the two BMPs did not record any flow during the storm events until December 2007. As a measure to capture most of the runoff from the highway, it was proposed to install weirs in the inlet pipes to increase the flow depth. The installation of weirs and replacement of non-functional units was completed in February 2008. In total, 75 events were recorded since equipment installation. However, due to the initial problems encountered at the site, it was necessary to exclude the data collected from September 2007 until the reinstallation in February 2008.

Data Quality Assurance and Quality Check

Rainfall Data

As a measure of quality check, rainfall depths recorded at the I-83 site were compared to the recordings at a weather station in Timonium, Maryland. The weather station, located at a distance of approximately 6 miles from the study site, measures rainfall rate, air temperature, and other weather parameters such as humidity, dew point, pressure, and wind speed at 5-minute increments. The data recorded at the weather station are accessible through the web (<*http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KMDTIMON1&month=10&day=19&year=2007*>). The total rainfall depth recordings at the site and the weather station were found to be in good agreement for most of the events.

Flow Data

The inflows observed at the inlets of the BMPs were found to be unrealistic. This was because the inflow into the system was much higher compared to the observed outflow, resulting in volume imbalance. Additionally, the inflows exceeded those reasonable for rainfall depth and drainage area. It is essential to achieve flow balance in the system to perform data analysis of any kind. It was thus necessary to simulate the runoff into the BMPs.

Simulation of Runoff

TR-55 was employed to simulate the runoff from the area draining each of the inlets based on the rainfall depth recorded at the study site (USDA 1986). Simulations using weighted curve number, computed based on cover type of the drainage area (See Table 3-1), produced small or no runoff for the range of rainfall recorded at the site. However, the probes installed in the inlet pipes had responded to these storm events. This suggested that a modification was required in the approach adopted to simulate runoff. It is reasonable to assume that runoff is generated from the impervious area only and the rainfall occurring over the grassy/pervious area is completely infiltrated for most common events. Based on this assumption, runoff to an inlet was computed using the fraction of impervious area as contributing drainage area and the corresponding curve number of 98 as input. Simulations were performed for a number of storm events and the simulated runoffs compared to the observed inflows.

The simulated flows matched the trend of the observed flow but were of significantly lower magnitudes. The simulated runoff and observed flow at the two inlets of BMP 3007 during an event on 4 May 2008 is shown for comparison in Figure 3-8. The simulated inflows and observed outflow at BMP 3007 during the same event is also shown in the figure. The simulated inflows and observed outflow yielded flow balance in the storage system for most of the storm events. This suggested that the approach adopted for simulating runoff was acceptable. Inflows to each inlet of the two BMPs were simulated using rainfall data for all the storm events and utilized for all data analyses.

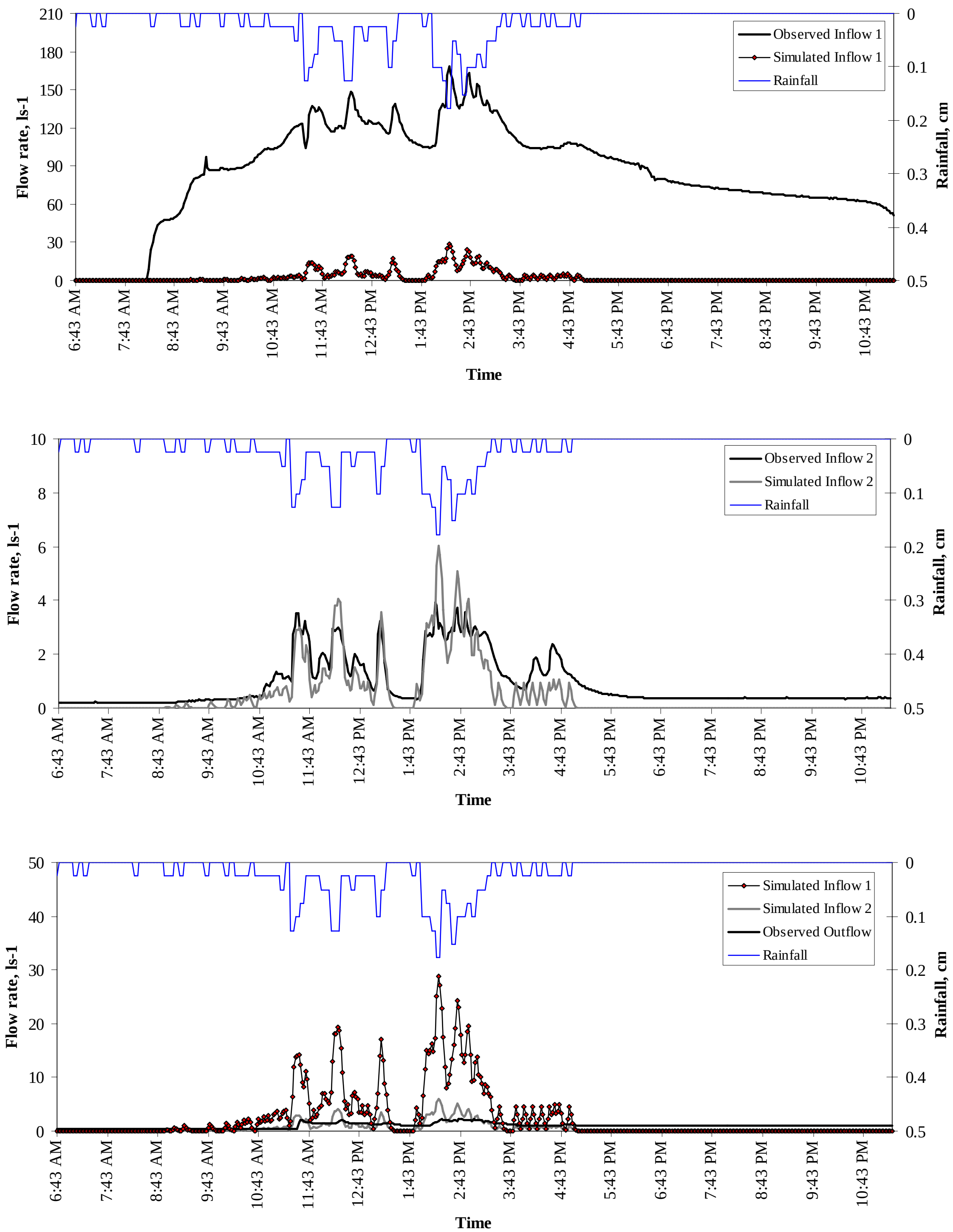


Figure 3-8. Plot of simulated and observed inflow at a. Inlet 1 b. Inlet 2 and c. Observed Outflow of BMP 3007 on April 28, 2008 (*Rainfall is plotted in 6-minute increments*)

Data Analyses

Complete data set for flow, temperature, and rainfall were available beginning February 2008. In total, 41 storm events occurred between February 22 and August 22, 2008 and were considered for data analyses.

Event Mean Temperature

For each storm event, the total thermal energy (E) present is calculated as:

$$E = \int_0^{T_d} QT\rho C_{pw} dt \quad (3\text{-}1)$$

where Q is the measured stormwater flow rate, T is the water temperature, ρ is the density of water and C_{pw} is the specific heat capacity of water. T_d is the duration of storm event. Substituting the flow and temperature observed at the inlets and outlet, the total thermal energy in and out can be obtained respectively.

The event mean temperature (EMT) is defined and calculated similarly as:

$$EMT = \frac{\int_0^{T_d} TQdt}{\int_0^{T_d} Qdt} \quad (3\text{-}2)$$

The EMT represents the temperature that would result if the entire storm event discharge were collected in one container. Since EMT weights discrete temperature measurements with flow volumes, EMT aids in the comparison of temperatures between inflow and outflow and among different events. By combining the events on a monthly (or seasonal) basis, the flow-weighted mean monthly (or seasonal) temperature can be computed for each month (or season). Additionally, peak input and output temperatures can be evaluated for each storm. The event mean temperature and peak temperature at the inlet and outlet are metrics employed to evaluate the reduction in temperature achieved in the underground system.

Exceedence of Threshold Temperature

The Maryland state water quality maximum temperature standard for wild reproducing trout stream designations (Maryland Department of the Environment, Use III, Natural Trout Water) has been established at 20ºC (Butowski et al. 2006). Baldwin (1951) identified 14^{o}C as optimal water temperature for brook trout. Brown trout have an optimum temperature range of 7 to 17ºC and become stressed at temperatures above 19ºC (Roa-Espinosa et al. 2003). In the present study, two temperature thresholds were considered, namely optimal water temperature for brook trout of 14^{o}C (63°F) and the Maryland State Class III temperature standard of 20°C (68°F). Volume of water and time exceeding these two temperature thresholds at the inlet and outlet are evaluated for each storm. This would demonstrate the possibility of the trout being subjected to stress if the runoff from highway and outflow from BMP were to be directly introduced into the stream. Also, an understanding of the performance of the system in abating temperature can be achieved.

Heat transfer Model

Model formulation

The impact of the underground storage BMP in mitigating stormwater runoff temperature can be estimated using a heat transfer model. The underground storage system consists of parallel pipes of diameter 122 *cm* (48 *in.*). For the purpose of modeling, the pipes are considered as a single storage pipe of 122 *cm*, and of length equal to the combined lengths of all pipes in the system. This pipe will be modeled as a set of completely mixed tank reactors (CSTR) in series. In this design, it is assumed that the water flowing in is instantaneously and completely mixed with the stored water and hence the temperature of water is uniform over the volume in a given CSTR.

For each CSTR, knowing the initial volume (V) of water stored, the equation below can be solved for θ (Figure 3-9):

$$V = \frac{R^2}{2}\left(\theta - \sin\theta\right)L \qquad (3\text{-}3)$$

The flow depth in the storage pipe can be calculated using:

$$h = R\left(1 - \cos\frac{\theta}{2}\right) \tag{3-4}$$

The outflow is calculated based on the flow depth assuming that it is controlled by a weir or orifice using:

$$Q_o = \frac{2}{3}C_d\sqrt{2gh^3} = \frac{2}{3}C_d\sqrt{2g}\left[R\left(1 - \cos\frac{\theta}{2}\right)\right]^{\frac{3}{2}} \tag{3-5}$$

or for orifice

$$Q_o = C_d a\sqrt{2gh} = C_d a\sqrt{2gR\left(1 - \cos\frac{\theta}{2}\right)} \tag{3-6}$$

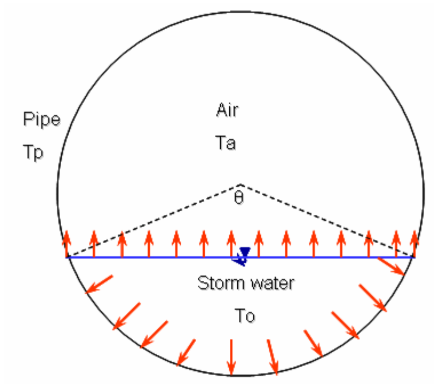
where R is the radius of the storage pipe (m), θ is the angle subtended by the water surface at the center of the pipe (radians), L is the length of one CSTR (m), h is the flow depth, which is the head over the weir or upstream head above the center of the orifice (m), C_d is the coefficient of discharge, a is the area of the orifice (m^2), d is the diameter of the orifice (m), and g is the acceleration due to gravity (ms^{-2}).

The storage in the pipe is calculated by solving the flow balance differential equation:

$$\frac{dV}{dt} = Q_{in1} + Q_{in2} - Q_0 \tag{3-7}$$

where Q_{in1} and Q_{in2} are the two inflow rates (m^3s^{-1}), and Q_0 is the computed outflow rate (m^3s^{-1}).

In the summer, the runoff flowing into the underground pipe is at a higher temperature compared to the water stored in the pipe, if any. Heat is transferred from the inflow water to the stored water by convection. As water flows through the pipe, heat will be transferred to the pipe walls from the runoff by convection. Some heat transfer might occur to surrounding air in the pipe. The heat transfer phenomenon occurring in the pipe is shown by a simple diagram in Figure 3-9. For simplicity, it is assumed that conduction of heat through the pipe wall and to the surrounding soil is negligible.



T_o = Temperature of stored water
T_a = Temperature of air
T_p = Temperature of pipe

Initial condition: $T_o = T_a = T_p$

Figure 3-9. Schematic diagram of heat transfer in the storage pipe and air

Taking into consideration these heat transfer terms, the heat balance for the system is given as:

$$\text{Heat energy stored} = \text{Heat in} - \text{Heat out} - \text{Heat loss} \qquad (3\text{-}8)$$

The heat loss term includes the heat transferred to the pipe wall and the surrounding air. Although, the heat loss to the air is likely to be very small due to the poor thermal conductivity of air, the water-air heat transfer term is taken into consideration.

The volume of water stored in the pipe is the control volume for performing the heat balance. The change in heat energy in the system per unit time can be expressed in the form of a differential equation as:

$$\frac{dE}{dt} = V_w \rho_w C_{pw} \frac{dT_o}{dt} = Q_{in1} \rho_w C_{pw} T_{in1} + Q_{in2} \rho_w C_{pw} T_{in2} - Q_o \rho_w C_{pw} T_o - U_a A_a (T_o - T_a) - U_p A_p (T_o - T_p)$$

(3-9)

where T is the temperature (°C), ρ_w is the density of water (kg m^{-3}), C_p is the specific heat capacity of water (J kg^{-1}°C^{-1}), U is the overall heat transfer coefficient (J s^{-1} m^{-2} °C^{-1}), A is the surface area in contact (m^2), and M is the mass (kg). Subscripts '*a*', '*p*' and '*w*' denote air, pipe and water, respectively.

The change in air and pipe temperature can be obtained by a heat balance on the surrounding air and that on the pipe:

$$M_a C_{pa} \frac{dT_a}{dt} = U_a A_a (T_o - T_a) \tag{3-10}$$

$$M_p C_{pp} \frac{dT_a}{dt} = U_p A_p (T_o - T_p) \tag{3-11}$$

where,

$$A_a = 2RL \sin\frac{\theta}{2} \tag{3-12}$$

$$A_p = R\theta L \tag{3-13}$$

$$M_a = \rho_a R^2 \left[\Pi - \frac{\theta - \sin\theta}{2}\right] L \tag{3-14}$$

$$M_p = \rho_p A_p k \tag{3-15}$$

Here, k is the thickness of the storage pipe (m). By solving the differential equations (3-9, 3-10 and 3-11) simultaneously by a numerical approach, the outflow temperature can be obtained along with the air and pipe temperature. The constants used in the above equations are listed in Table 3-3.

Table 3-3. Constants and parameters used in the heat transfer model

Parameter/Constant		Value	Units	Reference
Data	Q_i		m^3s^{-1}	
	T_i		°C	
Constants	g	9.8	ms^{-2}	Gibson (1952)
	ρ_w	1000	kg m^{-3}	Incorpera and DeWitt (1990)
	ρ_p	950	kg m^{-3}	Matweb
	ρ_a	1.247	kg m^{-3}	Incorpera and DeWitt (1990)
	C_{pw}	4186	J kg^{-1}°C^{-1}	Incorpera and DeWitt (1990)
	C_{pp}	2200	J kg^{-1}°C^{-1}	Matweb
	C_{pa}	1012	J kg^{-1}°C^{-1}	Incorpera and DeWitt (1990)

Implementation and Programming

Based on the CSTR-in-series design of the system, the pipe is divided into '*n*' number of CSTRs of equal lengths *L*. The first reactor in the series receives two inflows, as observed in the study sites. The outflow from the first reactor is the input to the second reactor and so on. The flow from one reactor to the successive one, except to the last, is assumed to be controlled by a weir. The outflow from last reactor is controlled by a 3.8 *cm* (1.5 *in.*) orifice, as existing in the study sites. A simple schematic of the underground storage system and the model design is shown in Figure 3-10.

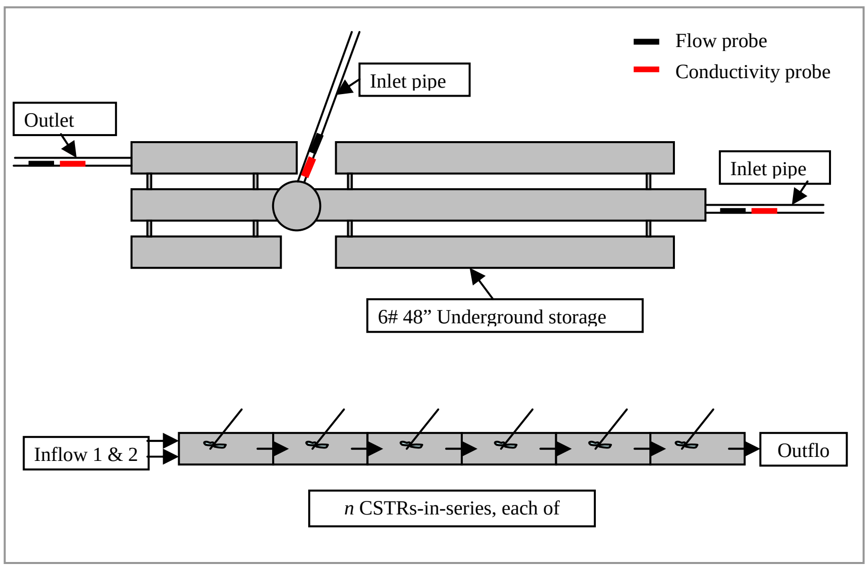


Figure 3-10. Schematic representation of underground system and model design

For each reactor, the volume and temperature differential equations, developed in the previous section, are solved numerically by the Runge-Kutta method in Matlab. Runoff inflow and temperature observed at the site and constants (discharge coefficients, density and thermal constants) are the inputs to the model. The model assumes that the stored water (if any), pipe wall and air have the same initial temperature, which is specified as an input. In the water balance module, the model computes the outflow rate and the storage in the system. In the second module of the code, the model predicts the temperature of runoff at the outlet as a function of time. The model results can hence be used to quantify the reduction in temperature of runoff.

Model Evaluation

Evaluation of the heat-transfer model is essential to determine the prediction accuracy of the model. The observed and model-predicted outflow temperature is compared for a number of events to determine whether the model underpredicts or overpredicts the temperature. The bias and relative bias in the model predictions can yield the level of prediction accuracy of the model.

RESEARCH PROGRESS

Field Study

Event Characterization

Totally, 43 storms comprising rainfall depths ranging from 0.15 to 4.72 *cm* (0.06 to 1.86 *in*.) were recorded at the study site from February through July 2008. The total rainfall depth and duration of each storm event are summarized in Table 4-1. The highest rainfall depth of 4.72 *cm* (1.86 *in*.) was recorded on 28 April, 2008. The duration of this event was about ten hours.

Table 4-1. Rainfall data for Timonium site from February until August 2008

Event Date	Rainfall Depth *cm* (*in.*)	Event Duration *hour*	Event Date	Rainfall Depth *cm* (*in.*)	Event Duration *hour*
2/26/2008	0.25 (0.10)	2.60	5/10/2008	0.46 (0.18)	5.03
2/26/2008	0.25 (0.10)	1.50	5/12/2008	4.72 (1.86)	26.63
3/4/2008	0.99 (0.39)	3.30	5/16/2008	1.19 (0.47)	9.53
3/5/2008	0.56 (0.22)	2.13	5/18/2008	0.18 (0.07)	1.17
3/5/2008	0.13 (0.05)	1.60	5/18/2008	0.25 (0.10)	0.40
3/7/2008	1.37 (0.54)	9.50	5/20/2008	0.53 (0.21)	2.73
3/8/2008	0.71 (0.28)	10.17	5/20/2008	0.56 (0.22)	1.13
3/16/2008	0.66 (0.26)	6.87	5/31/2008	1.09 (0.43)	3.77
3/18/2008	0.18 (0.07)*	2.90	6/3/2008	0.15 (0.06)*	0.97
3/19/2008	1.42 (0.56)	7.27	6/4/2008	0.99 (0.39)	2.60
3/20/2008	0.28 (0.11)	1.40	6/4/2008	0.84 (0.33)	0.97
4/1/2008	0.28 (0.11)	4.53	6/4/2008	0.10 (0.04)*	1.47
4/3/2008	1.47 (0.58)	12.27	6/10/2008	1.80 (0.71)	2.93
4/6/2008	0.58 (0.23)	5.57	6/28/2008	0.38 (0.15)	0.47
4/11/2008	0.48 (0.19)	0.70	6/29/2008	0.18 (0.07)*	0.13
4/13/2008	0.15 (0.06)*	1.30	6/30/2008	0.48 (0.19)	0.17
4/20/2008	0.53 (0.21)	0.93	7/6/2008	0.48 (0.19)	0.37
4/20/2008	4.17 (1.64)	3.53	7/9/2008	1.50 (0.59)	0.50
4/21/2008	0.76 (0.30)	1.13	7/13/2008	3.10 (1.22)	12.20
4/26/2008	0.64 (0.25)	4.03	7/23/2008	3.66(1.44)	5.10
4/28/2008	3.12 (1.23)	10.17	7/30/2008	0.99 (0.39)	0.30
5/9/2008	3.12 (1.23)	14.33			

* indicates events falling below the rainfall threshold value

As seen in Table 4-1, majority of the storm events are in the range of 0.25 to 1.5 *cm* (0.1 to 0.6 *in.*). Totally, only five events measuring rainfall depths greater than 2.54 *cm* (1 *in.*) were observed during the monitoring period. In summer, the storms were characterized by intense short-duration rainfall.

The volume-duration-frequency of the storm events included in the analyses was compared to the distribution of rainfall in 15 stations in Maryland (Kreeb and McCuen, 2003). The purpose of the comparison was to ensure that the rainfall data chosen for data analyses were representative of those expected in the state of Maryland. The study conducted for the 15 stations in Maryland was based on 10352 storms. Table 4-2 shows the frequency of storms events of given volume and duration at the study site. The statistics for the 15 stations in Maryland are also included in the table for comparison.

Table 4-2. Rainfall data recorded at the I-83 site from February until July 2008

		Rainfall Depth, *cm*					**Total**	
	Event Duration	0.025-0.254	0.255-0.635	0.636-1.270	1.271-2.540	2.540 <	Timonium, MD	15 Stations, MD*
	1 hr	0.0732	0.1220	0.0244	0.0244	0.0000	0.2439	0.3290
	2 hr	0.1463	0.0488	0.0244	0.0000	0.0000	0.2195	0.0756
	3 hr	0.0244	0.0488	0.0244	0.0244	0.0000	0.1220	0.0627
	4-6 hr	0.0000	0.0976	0.0488	0.0000	0.0244	0.1707	0.1234
	7-12 hr	0.0000	0.0000	0.0732	0.0488	0.0244	0.1463	0.1818
	13-24 hr	0.0000	0.0000	0.0000	0.0244	0.0488	0.0732	0.1616
	24< hr	0.0000	0.0000	0.0000	0.0000	0.0244	0.0244	0.0659
Total	Timonium, MD	0.2439	0.3171	0.1951	0.1220	0.1220	1.0000	1.0000
	15 Stations, MD*	0.3288	0.1461	0.2131	0.1747	0.1373	1.0000	

* (Table 3-5, Kreeb and McCuen, 2003)

On comparing the two frequency distributions, it can be observed that the percentage of storms of rainfall depth range of 0.255 to 0.635 *cm* is higher at Timonium than for the 15 stations in

Maryland. The 0.025- 0.254 rainfall depth range is 24% at Timonium compared to nearly 33% for the 15 stations. The other rainfall depth ranges are similar to each other. Taking into consideration the smaller sample size and sampling variation involved in the present study, it can be concluded that the rainfall data chosen for analysis adequately represents Maryland and is unbiased.

The two BMPs received very small volume of inflow during storm events measuring rainfall depths less than 0.25 *cm* (0.10 *in.*). However, the volume was not large enough to produce measurable outflow from the underground systems. Hence, a threshold rainfall depth value of 0.25 *cm* was fixed and only rainfall events equal to or more than the threshold value were considered for the analyses. During large storm events, outflow from the storage system continued for long periods, up to two days after the event. Smaller storm events of rainfall depth less than 0.25 *cm* occasionally occurred during these periods. Hence, such events, having rainfall depth less than the threshold depth and preceded by large storm events, were not eliminated. Totally five events were eliminated from the record of storm events, thereby reducing the storm sample size from 43 to 38 (Table 4-3). Runoff flows to the inlets were simulated for each of the selected storm event by the TR-55 method.

Table 4-3. Total number and rainfall depths of events recorded in each month at Timonium and events selected for the purpose of analysis

Month	Events		Events	
	Total	Total Rainfall Depth , cm	Above Threshold*	Total Rainfall Depth, cm
Feb-08	2	0.51	2	0.51
Mar-08	9	6.30	8	6.12
Apr-08	10	12.19	9	12.04
May-08	9	12.14	9	12.14
Jun-08	8	4.93	5	4.50
Jul-08	5	9.86	5	9.86
Total	43	45.92	38	45.16

*Includes storms below threshold but preceded by large storm events

General Observations

The general characteristics of flow, temperature, and conductivity during all the storm events are discussed in this section. A storm event is accompanied by a drop in the air temperature prior to the start of the event. After it begins to rain, it takes about 6 to 10 minutes (inlet 2 and inlet 1) for the runoff from the highway to flow into the underground facility. Since the pavement is warm at the beginning of the storm, an initial spike is observed in the inflow temperature. The inflow temperature gradually decreases as the storm progresses due to the cooling of the pavement. The average detention time of the inflow in the storage facility is between 10 and 20 minutes. The outflow temperature is more uniform compared to the inflow temperature and is observed to follow the trend of the inflow temperature until the inflow ceases.

The conductivity measurements support the start and stop of the inflow to the system. An initial spike is observed in inflow conductivity due to the first-flush phenomenon. The lag time between inflow and outflow conductivity peak is observed to be similar to that of temperature. The level of conductivity in the stormwater runoff is found to have seasonal variations. High levels of conductivity in the inflow runoff were measured during winter due to the use of salts to melt ice and snow on the highway. The concentration of salts in the runoff decreased in spring and a further decrease was observed in summer.

Another observation regarding the inflow temperatures was the effect of percent imperviousness. The fraction of impervious area in the drainage area of an inlet influenced the inflow temperatures at that inlet. In each BMP, higher inflow temperatures were recorded at the inlet drained by a larger fraction of impervious area than at the inlet having smaller impervious fraction for most of the events. Factors such as intensity, duration, and time of occurrence of the storm event also have an effect on the inflow temperature. The time of the day determines the air temperature and the pavement temperature and hence influences the runoff temperature. However, detailed analysis of the influence of these factors on temperature has not been performed in the current study.

The general observations are illustrated for the June 30, 2008 storm (Figure 4-1). The total rainfall depth recorded during this event was 0.48 *cm* (0.19 *in.*). The total duration of the event was 10 minutes. The air temperature dropped by over 10°C about before the event occurred. BMP 3007 received inflow six minutes after it began to rain. The highest inflow temperature of 21.7°C (71°F) was recorded during this event. The inflow temperature gradually reduced as the event progressed. Outflow from the system was observed six minutes after the runoff inflow began. The lag between peak inflow and outflow temperatures was around ten minutes. The outflow temperature remained lower than the two inflow temperatures throughout the event and then gradually approached the ambient underground temperature. High inflow runoff conductivity was measured when the inflow began and then gradually decreased to almost zero conductivity. This is because the salts on the highway are washed-off during the first few minutes of the storm.

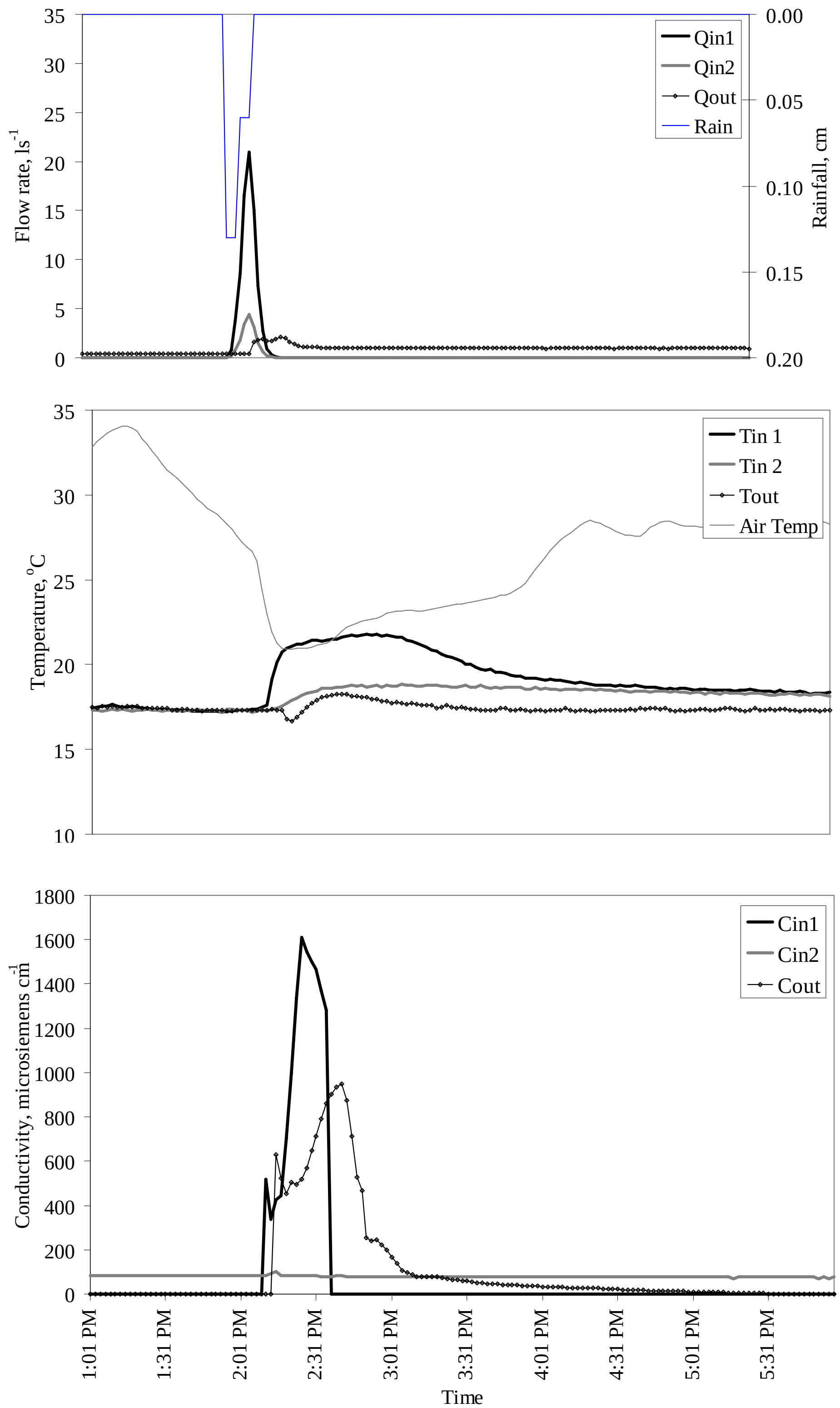


Figure 4-1. Plot of flow, temperature and conductivity of BMP 3007 on June 30, 2008 storm (Flow, temperature and conductivity measurements are plotted at two-minute intervals and rainfall is plotted at six-minute intervals)

Analysis of Storms of Different Temperature Ranges

During the monitoring period, the inflow and outflow runoff temperatures exhibited a seasonal variation. The inflow temperature ranged between 3.0 and 11.0°C (37 and 50°F) during the months of February and March 2008. The outflow temperature showed small or no difference from the inflow temperature during these months. The inflow temperature increased in the following months and very high inflow temperatures were observed in June and July 2008. Some reduction in the temperature was observed during the warmer periods.

Maximum, Minimum and Mean Monthly Temperatures

The maximum, minimum, and flow-weighted mean inflow and outflow temperatures were computed for each storm. In order to depict the overall temperature reduction achieved in the underground storage BMP, the storm events were combined on a monthly basis. The computed monthly temperatures along with the monthly rainfall depths are summarized in Table 4-4a. The difference (ΔT) between the flow-weighted mean monthly inflow and outflow temperatures is a measure of the temperature reduction achieved in a particular month. Hence, a positive ΔT would suggest that the underground storage BMP aids in the reduction of the runoff temperature. However, it is required to determine if the temperature reduction achieved in the BMP is significant enough to prove the effectiveness of the BMP.

Figures 4-2 shows the flow-weighted mean monthly inflow and outflow temperatures computed for the monitoring period. The optimum temperature ranges for brook trout and brown trout, and the MDE Class III temperature level are shown in the figure. In Figure 4-2, there is a clear trend of increasing monthly mean temperatures from February through August. While little or no difference exists between the mean inflow and outflow temperatures for the months February to May, some difference is exhibited for the months of June and July.

Table 4-4a. Summary of maximum, minimum, and flow-weighted mean monthly temperature at inlet and outlet of BMP 3007

Month	Number of events	Inlet 1 Temperature			Inlet 2 Temperature			Inflow Temperature*			Outflow Temperature		
		Maximum	Minimum	EMT	Maximum	Minimum	EMT	Maximum	Minimum	EMT	Maximum	Minimum	EMT
		°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
Feb-08	2	5.0	3.3	4.7	5.5	5.2	5.4	5.5	3.3	4.8	5.1	3.9	5.0
Mar-08	8	9.5	4.7	7.5	10.1	5.5	7.6	10.1	4.7	7.5	10.7	5.3	7.6
Apr-08	9	14.0	4.9	11.4	13.3	5.8	11.0	14.1	4.9	11.4	14.1	5.1	9.7
May-08	9	14.5	8.8	11.6	16.2	8.2	11.5	16.2	8.2	11.6	15.5	9.0	11.5
Jun-08	5	21.5	14.3	16.3	19.7	11.3	14.8	21.5	11.3	16.0	18.3	8.3	15.5
Jul-08	5	24.1	18.7	21.0	21.2	17.3	20.0	24.1	17.3	20.8	22.4	16.5	19.4
Total	38												

*Inlet 1 and Inlet 2 combined

Table 4-4b. Mean reduction of temperature in each month in BMP 3007

Month	**EMT in**	**EMT out**	**ΔT = EMT in – EMT out**
	°C	**°C**	**°C**
Feb-08	4.8	5.0	-0.2
Mar-08	7.5	7.6	-0.1
Apr-08	11.4	9.7	1.7
May-08	11.6	11.5	0.1
Jun-08	16.0	15.5	0.5
Jul-08	20.8	19.4	1.4

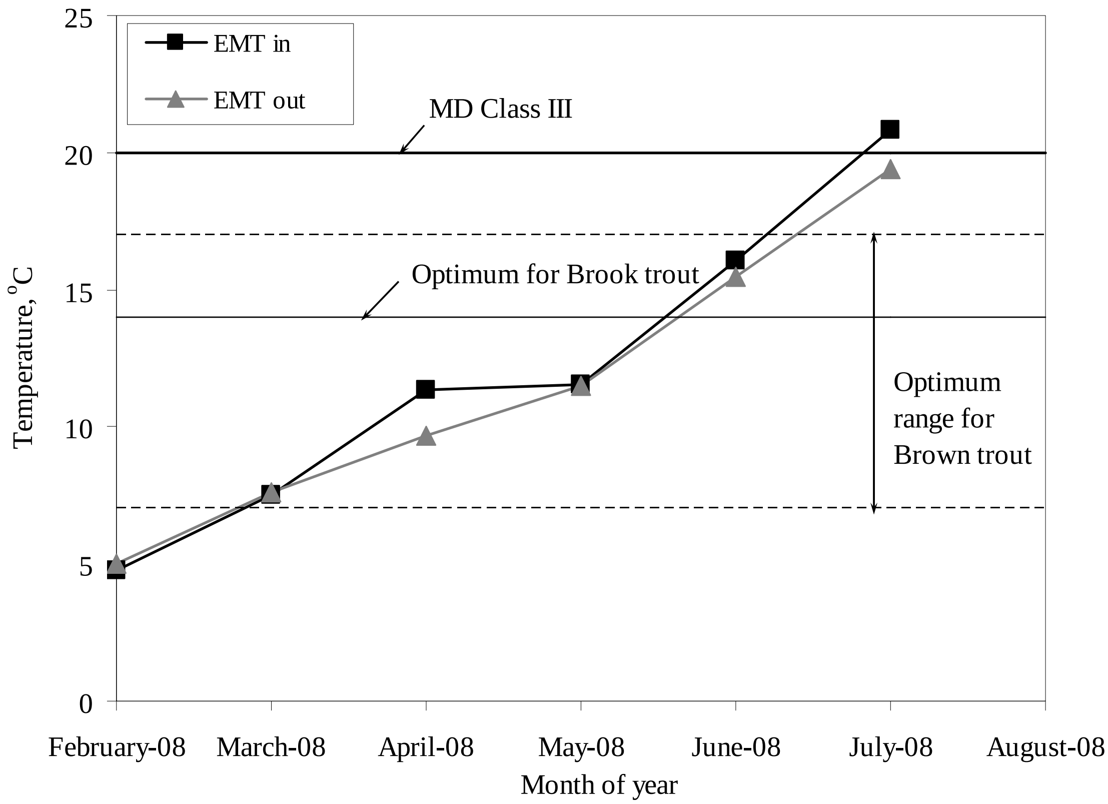


Figure 4-2. Flow-weighted mean monthly temperatures for BMP 3007

In Table 4-4a, it can be seen that the mean temperature of outflow runoff is slightly higher than that of inflow during February and March, resulting in a negative ΔT. The ΔT for the months April and May are small and positive (Table 4-4b). It can be hypothesized that during colder months, the air temperature is lower than the ambient underground temperature. Hence, little or no reduction in temperature might occur. It was observed that the air temperature was approximately 7°C (45°F) or less and the ambient underground temperature around 4.5°C (40°F) in February and early March. The inflow temperature ranged between 3.0 and 7.0°C (37 and 45°F). In most of the events, the outflow temperature was at least higher 0.3°C greater than the inflow temperature during the major part of the storm. Thus, the computed mean outflow EMT was greater than that of inflow. Since the ΔT values for these months are small, they can be considered to be insignificant. Also, the observed inflow and outflow temperatures fall within the optimum temperature range for survival of trouts. This suggests that although the BMP is not effective in reducing the temperature during colder months, the outflow temperatures are not detrimental to the trout.

Inflow and outflow temperatures exceeding the two threshold temperatures were recorded during summer (Table 4-4). In June, the flow-weighted mean temperature at the inlet and outlet were 16°C (60.9°F) and 15.5°C (59.8°F) respectively. Thus, the mean temperature reduction was around 0.5°C, which may not be very significant. Both mean inflow and outflow temperatures exceed the optimum temperature of 14°C for brook trout but are lower than the MDE Class III threshold (Figure 4-2).

A further increase in inflow temperature levels was observed in July. During this month, the inflow temperature ranged between 17°C and 24°C (63°F and 75°F). The high temperature range is because the majority of the storm events occurred in late afternoon when the air and pavement temperatures are very high. The highest inflow temperature of 24°C (75°F) was observed in the 13 July, 2008 storm. The flow-weighted mean inflow and outflow temperatures were computed as 21.7°C (71°F) and 19.7°C (67°F) respectively for this month. The mean temperature reduction of 2°C can be considered significant. However, the mean outflow temperature surpassed the 14°C optimum temperature threshold and is only 0.3°C less than the MDE Class III threshold (Figure 4-2).

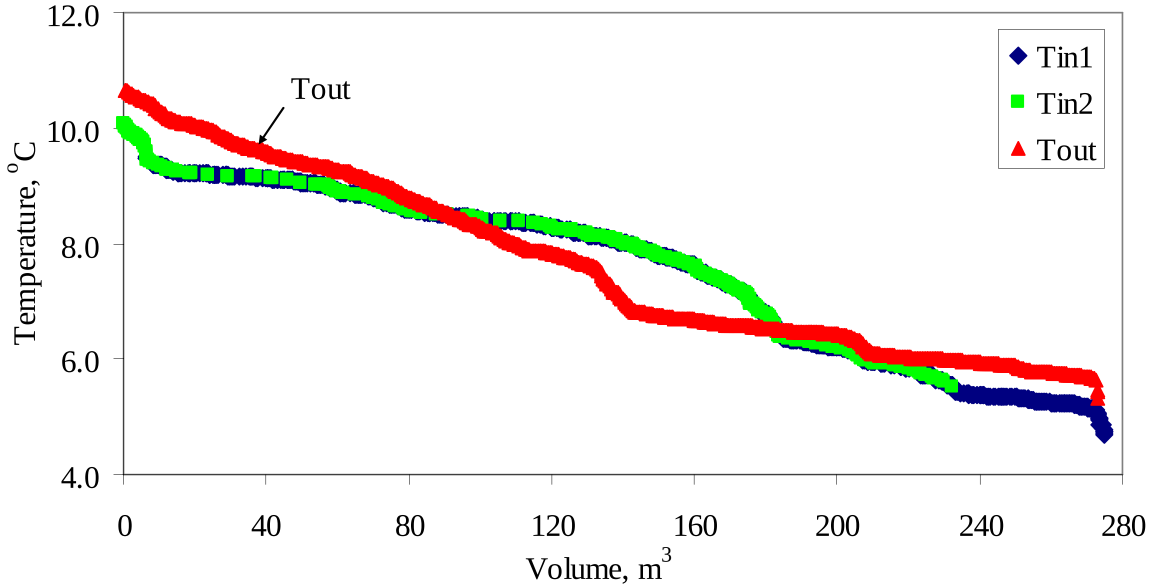
Exceedence of Threshold Temperature

As mentioned earlier, two temperature thresholds, namely optimal water temperature for brook trout of 14°C (63°F) and the Maryland State Class III temperature standard of 20°C (68°F), are considered for evaluating the performance of the BMP. In some occasions, the upper limit of the optimum temperature range for brown trout, 17°C, was exceeded. Hence, the 17°C limit was considered as an additional check to evaluate the BMP. Table 4-4a and Figure 4-2 clearly show instances of outflow temperature levels capable of stressing trout during summer.

The exposure of trout to the inflow and outflow temperatures and their exposure volume were computed for each storm event. For ease of representation, the time and volume of inflow and outflow water exceeding the two temperature thresholds are shown on a monthly-basis. Since summer is the period of interest, more emphasis is placed on summer storms.

Time of Exposure and Volume Analysis

Firstly, the results of the analysis performed on storms recorded in a colder month are presented. Inflows to and outflows from BMP 3007 from eight storm events in the month of March were combined to perform the analysis. BMP 3007 received inflow for nearly 50 hours during March. Figure 4-3a is a time-based plot of the inflow and outflow temperatures. As can be seen in Figure 4-3a, the outflow temperature was at least 0.5^oC higher than the inflow temperature during most of the month. While the maximum outflow temperature was 10.7^oC, the maximum inflow temperature was 10.1^oC. The combined volume of flow to inlet 1 and inlet 2 from the eight storms was 275 m^3. Of this, almost 90 m^3 outflow volume was nearly 0.6^oC higher than the inflow volume for the temperature range 10.7 to 9^oC (Figure 4-3b). The inflow temperature was cooled almost 2^oC in the lower temperature ranges. However, it is evident that both inflow and outflow temperatures lie well within the optimum temperature ranges of the trout species. Although the reduction in temperature is not considerable, if the inflow or the outflow volume were to be introduced to the stream, no stress is expected to occur.



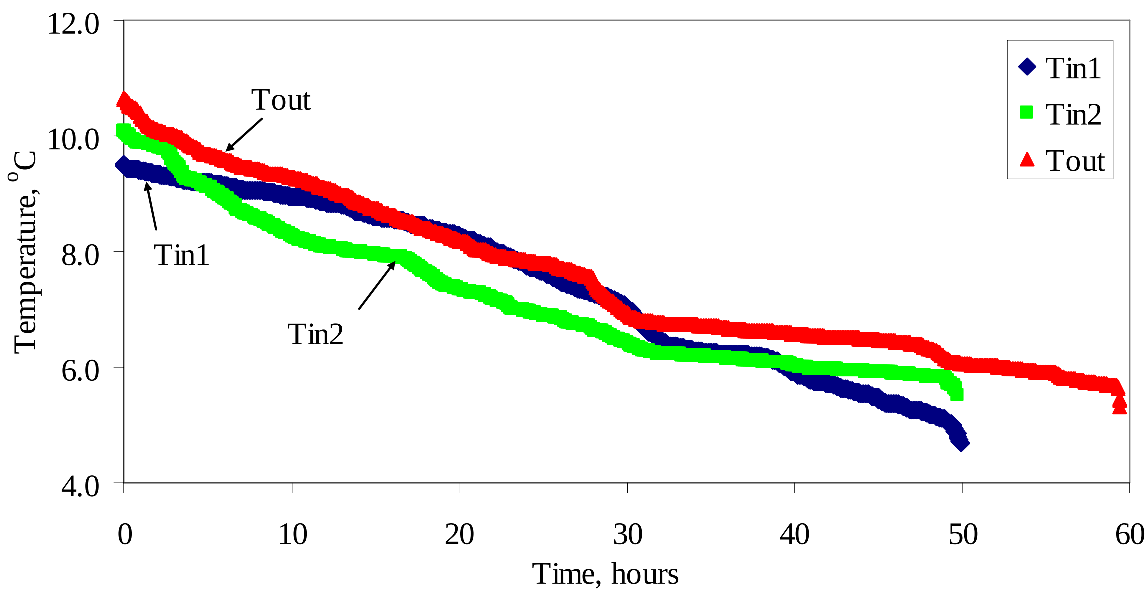


Figure 4-3. a. Time-based and **b.** Volume-based plots of inflow and outflow temperatures of BMP 3007 in March 2008

The inflow temperature range increased in the following months. Summer (June and July) 2008 was a period of concern since high inflow temperatures were recorded during this period. The monthly flow and temperature for the month of June 2008 are shown in Figure 4-4. BMP 3007 received runoff for nearly ten hours from the five storms that occurred during this month. About 14

m^3 of the total runoff volume exhibited temperature greater than 20°C (68°F) for a period of nearly 45 minutes. The storage system cooled this volume by at least 2°C. Runoff measuring temperature in the range 16 to 14°C was cooled by less than one degree. The inflow and outflow volumes were at the same temperature for most of the period in this month.

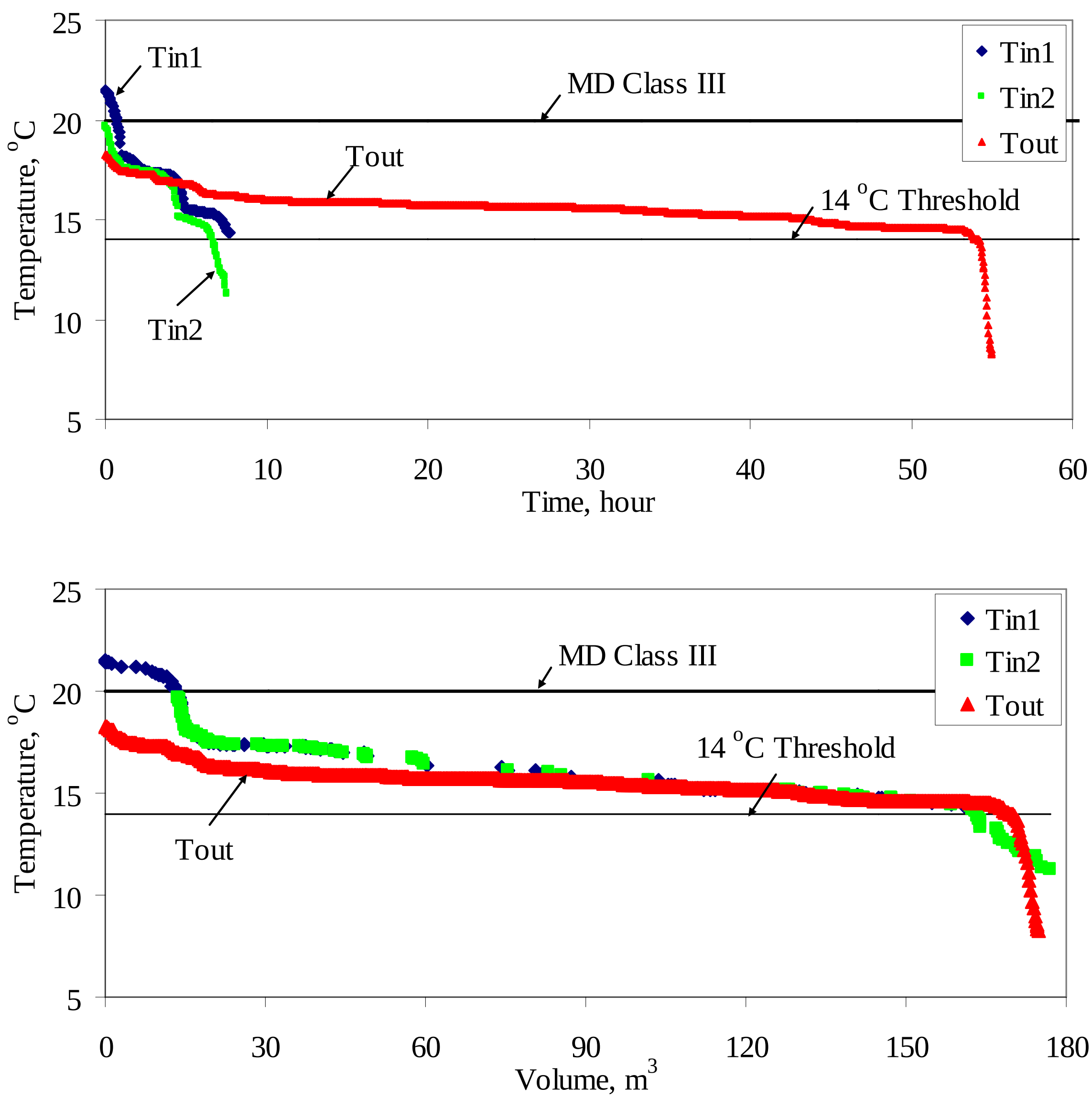


Figure 4-4. a. Time-based and **b.** Volume-based plots of inflow and outflow temperatures of BMP 3007 in June 2008

July was a hotter month; air temperature measured close to 32°C (90°F) before most events. Three storm events measuring rainfall depth greater than one inch occurred during the afternoon periods in this month. Runoff at the two inflow points exhibited temperature in the range 24 to 20°C (75 to 68°F) for nearly 18 hours (Figure 4-5). During this period, the outflow temperature was cooled by nearly 2°C, and remained above the 20°C threshold.

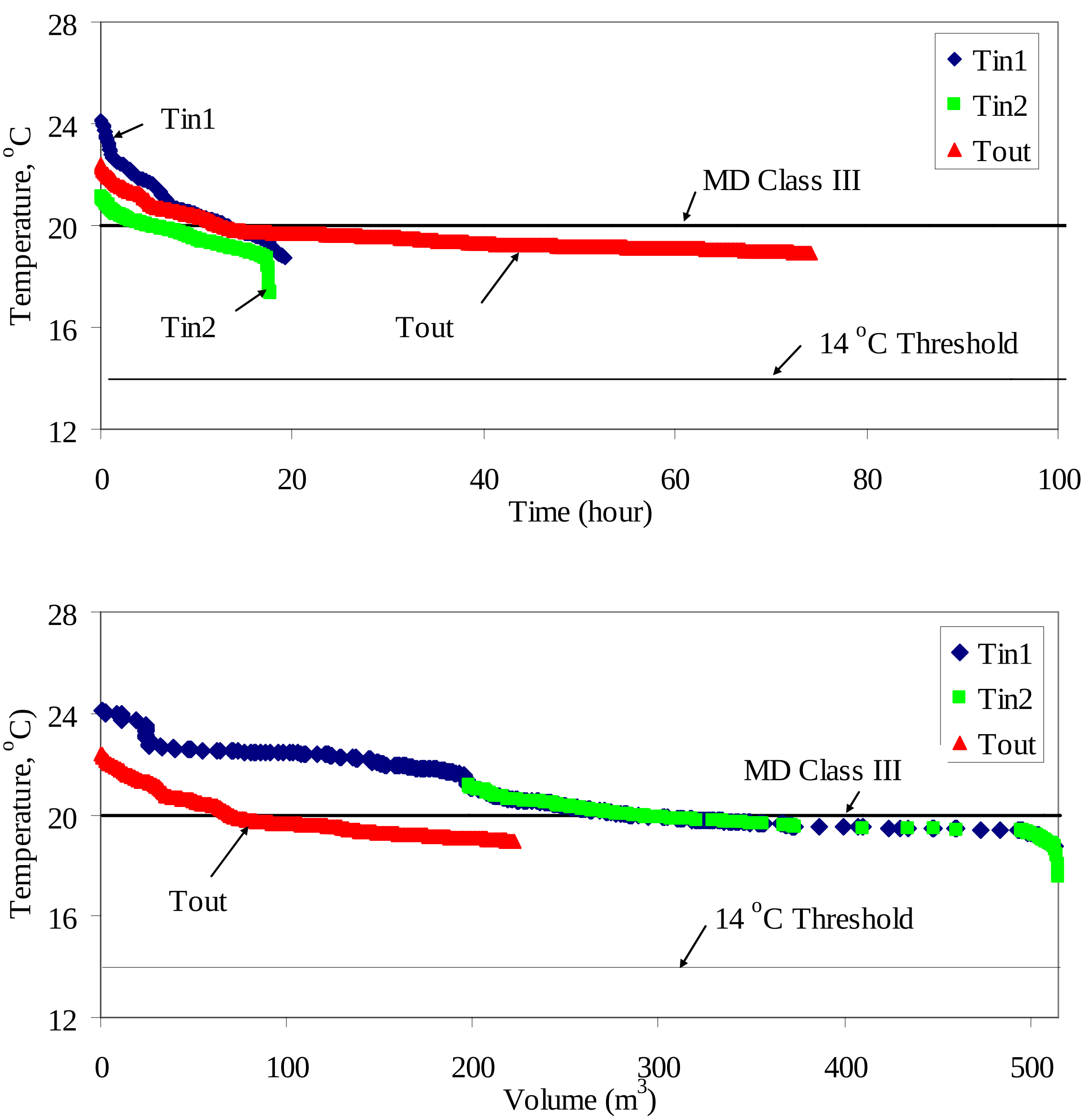


Figure 4-5. **a.** Time-based and **b.** Volume-based plots of inflow and outflow temperatures of BMP 3007 in July 2008

In order to evaluate the overall performance of the BMP during each month, proportions of the total monthly inflow and outflow volumes exceeding the temperature thresholds of 14°C, 17°C, and 20°C were computed and are shown in Figure 4-6. As seen in the figure, inflow and outflow temperatures did not exceed the three temperature threshold limits in February, March, and April. In May, less than 2% of the inflow volume was at a temperature greater than 14°C but lower than 17°C. The BMP did not aid in the cooling of this inflow volume. Thus, 2% of the outflow volume exceeded the 14°C threshold (Figure 4-6a). The months from February through May did not produce inflow temperatures more than 16°C.

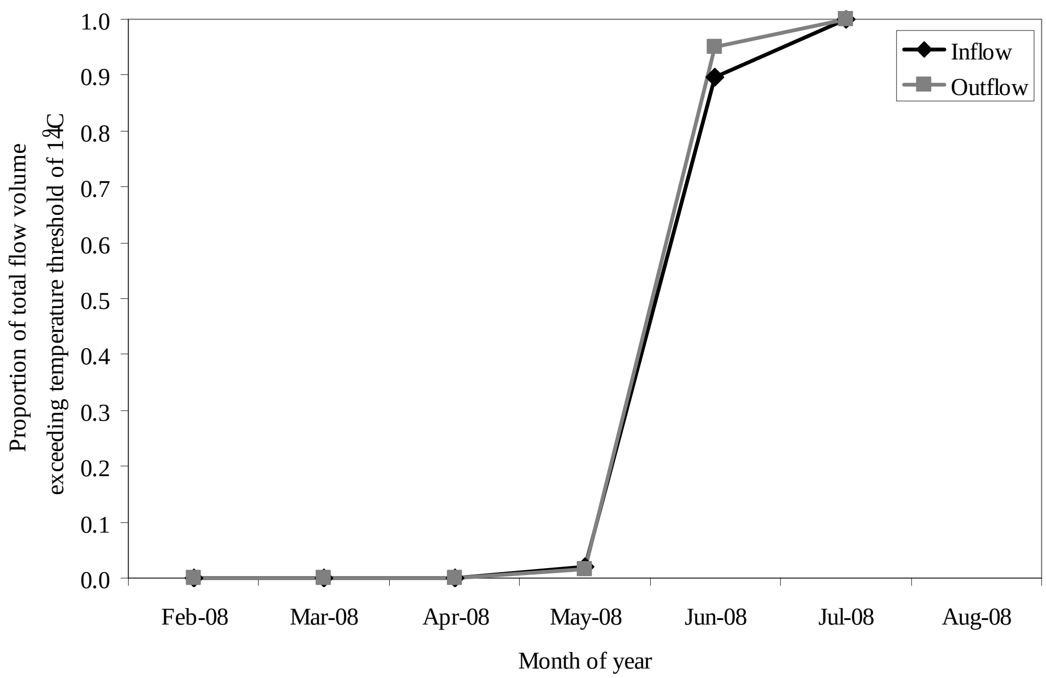


Figure 4-6a. Proportion of monthly inflow and outflow volumes exceeding 14oC threshold temperature

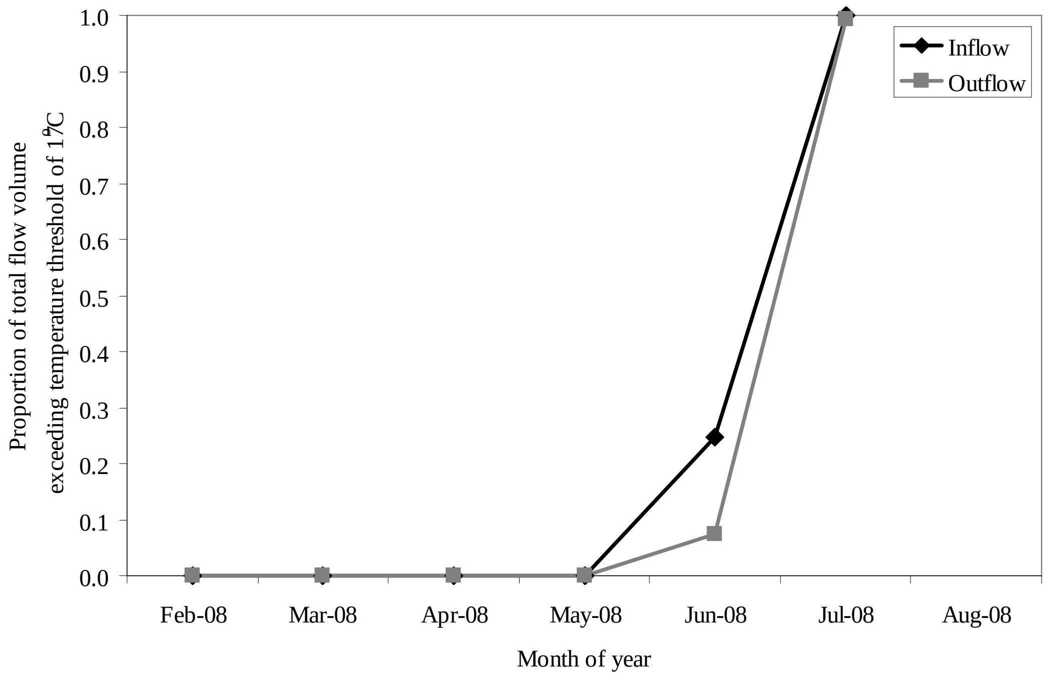


Figure 4-6b. Proportion of monthly inflow and outflow volumes exceeding 17oC threshold temperature

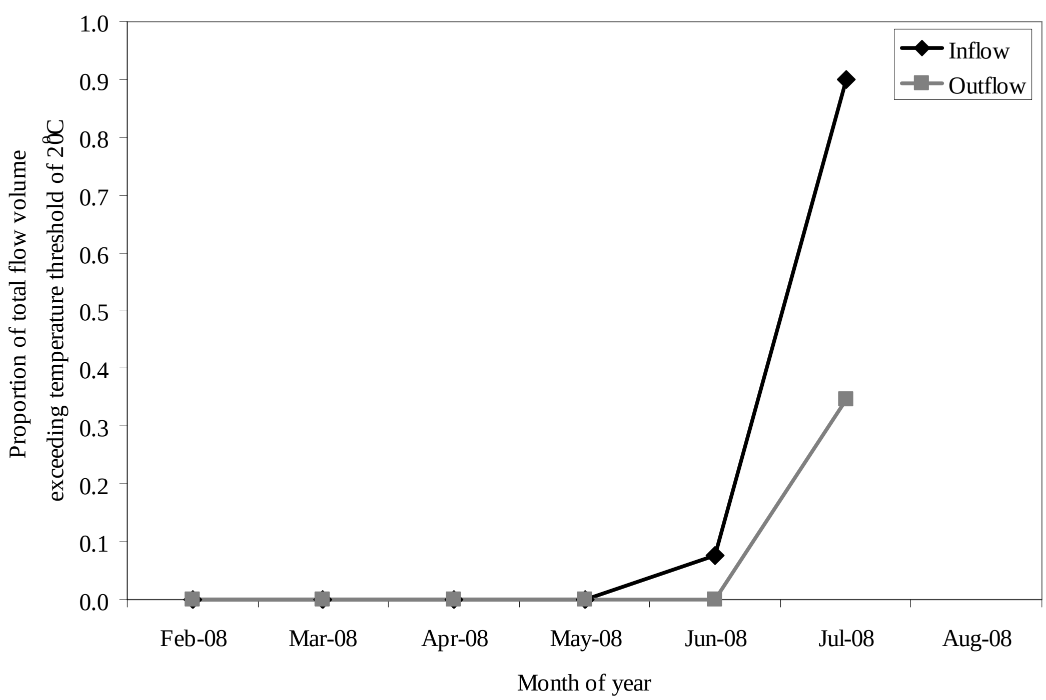


Figure 4-6c. Proportion of monthly inflow and outflow volumes exceeding 20°C threshold temperature

In the month of June, more than 95% of inflow volume exceeded the 14°C threshold, of which less than 5% of this volume was cooled to temperature below 14°C. Nearly 25% of the total inflow volume was at a temperature above 17°C. However, after passing through the BMP, less than 10% volume exceeded the 17°C threshold (Figure 4-6b). The conveyance of the runoff through the BMP enabled cooling of all of the 10% inflow volume having temperature greater than 20°C (Figure 4-6c). These results indicate that the underground storage reduces higher temperatures more effectively than lower temperature ranges. However, the detention of water does not completely cool off the runoff to desirable levels.

High-temperature flows capable of stressing trout were observed in July 2008. The inflow temperature was in the range of 17- 25°C in this month. This is evident in Figure 4-6, as 100% of the total inflow volume exceeded the 14°C and the 17°C thresholds. There was no reduction in temperature of this inflow volume. However, significant exceedence reduction occurred at 20°C. While almost 90% of the inflow volume exceeded the 20°C threshold, only 30% of the total outflow volume was found to be greater than 20°C.

Based on the time of exposure and volume analysis, it can be observed that during the cooler months (March and April 2008), the inflow volumes did not violate the 14, 17, and 20°C threshold. In May, less than 10% runoff volume exhibited temperatures greater between 14°C and 17°C. This volume exited the system without much reduction in temperature. This may be because the ambient underground temperature is nearly the same as the runoff temperature. Therefore, the heat loss to the surrounding air and pipe can be considered to be insignificant. Any heat transfer that is expected to occur would be by mixing of the runoff. Thus, little or no cooling would occur.

As it gets warmer, the temperature of runoff from the highway also increases. The warmer months (June and July) exhibited runoff temperature in the range 17 to 24°C (62 to 75°F). The ambient temperature in the underground pipes was usually maximum of 14°C (58°F), which is lower than the runoff temperature range. Some heat transfer can be expected to occur due to this difference in temperature. Any water stored from the antecedent event will be in equilibrium with the ambient underground temperature. Therefore, the mixing of the runoff and cooler stored volume of water will result in buffering the temperature. Depending on the detention time in the system, reduction in temperature will occur. As runoff flows through the system, it will lose some heat to the surrounding cooler air and pipe.

Most events in summer produced runoff temperatures lethal to trout. If the underground system were absent, the warm runoff flowing into the local stream would be expected to increase the ambient stream temperature. Temperature reduction between 2 and 3^{o}C was achieved during summer. Although this reduction in temperature occurred, it was not sufficient to meet the temperature standards. Some proportion of the flow from the system was still higher than the threshold.

Model

Simulations were performed for a number of storm events considering the underground storage system as an n-CSTR model. The simulated flow rate and observed temperature at the inlet of BMP 3007 were given as the inputs to the model. The flow module of the model involves a number of parameters, such as the number of CSTRs (n), and flow coefficients for the outlet of each CSTR, which are required to be calibrated. The simulations performed so far have not yielded satisfactory predictions of the flow from the system. Since the model-predicted outflow does not match the observed data, it is not possible to perform the heat balance of the system.

If the system were to be considered as 1-CSTR, the outflow temperature predicted by the model was almost twice the magnitude of the observed temperature. This error is suggestive of a wrong model structure in the flow modeling. The n-CSTR model might be a better representation of the behavior of the storage system. However, the simulations have yielded some useful results regarding the possible heat transfer in the system. The 1-CSTR simulations revealed that the temperature of the air and pipe do not change significantly from their initial conditions during the period of inflow. This is because of the coefficients of convective heat transfer for these materials are small. This suggests that in the underground system, the heat loss to surrounding air and pipe may be minor.

At present, the model coefficients require calibration to accurately predict the observed flow from the system. The coding for the temperature balance in n-CSTR model is complete. Once volume balance is achieved for the n-CSTR model, the heat transfer in the system can be simulated.

SUMMARY

The data collected so far have yielded a qualitative and quantitative understanding of the performance of the BMP in mitigating temperature. The inflow temperature is dependent on the air temperature, intensity, duration and time of occurrence of storm, and percent impervious area. Flow and temperature data from February through July 2008 have been analyzed. The data analysis shows that there is minor temperature reduction in the cooler months (February, March, and April). In summer, when the underground temperature is significantly less than air temperature, the BMP has some impact on the temperature. However, violation of the temperature standards has been observed during summer. Data for the months August and September are yet to be analyzed. Conclusions on the effectiveness of the underground stormwater management facility can be made only after complete analysis is performed. At this stage, the heat transfer model requires further work to yield better results.

Data collected at the study sites, in combination with the model results, will enable evaluation of the efficiency of the underground storage systems in reducing the temperature of the stormwater runoff. A detailed analysis on the reduction in temperature of runoff from highways for varying storm intensities and duration occurring in different seasons will provide useful information regarding the impact of these underground storage BMPs in temperature mitigation.

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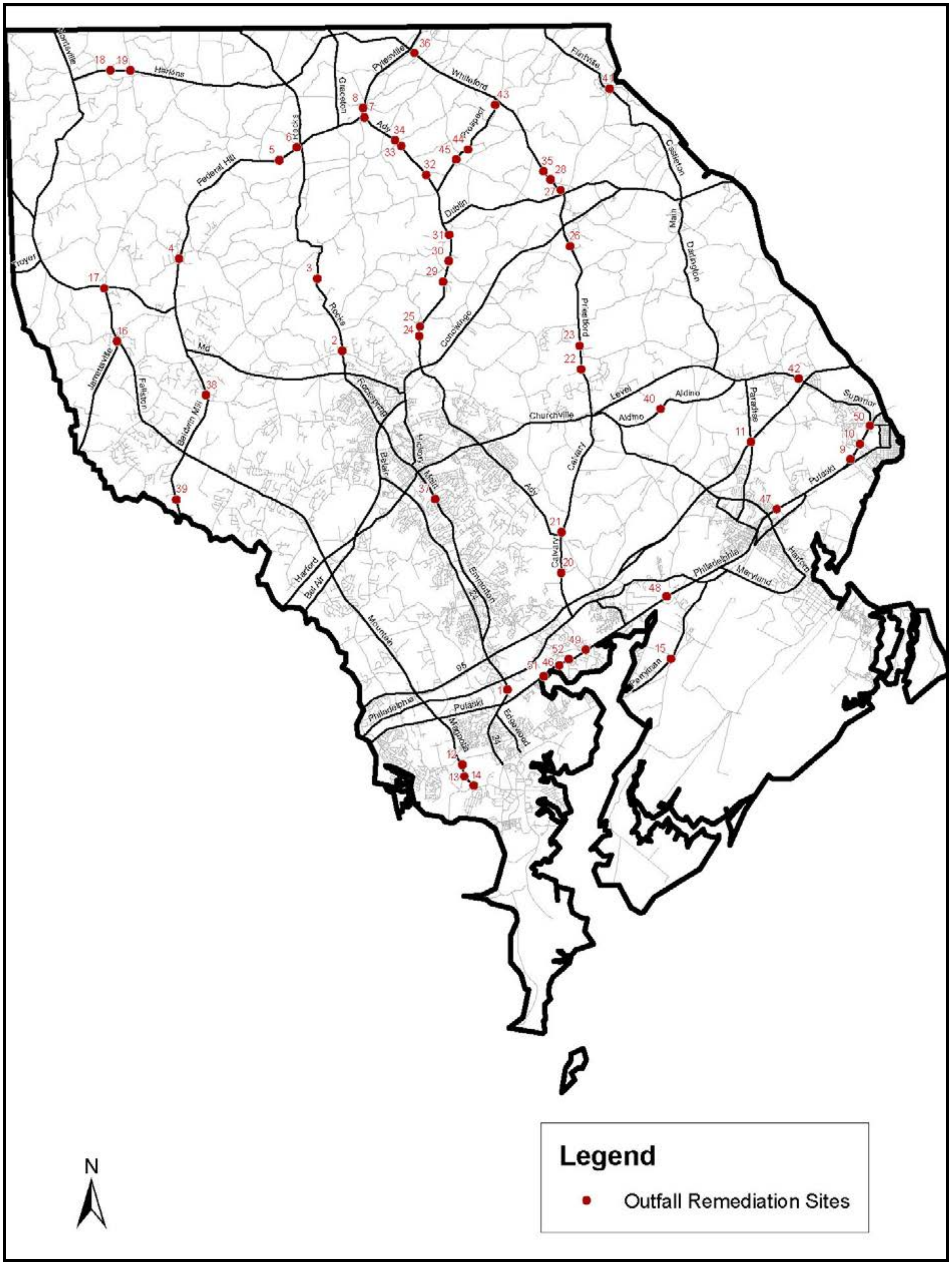
APPENDIX G:

Storm Drain Outfall Inspection & Remediation Program – Remediation Sites

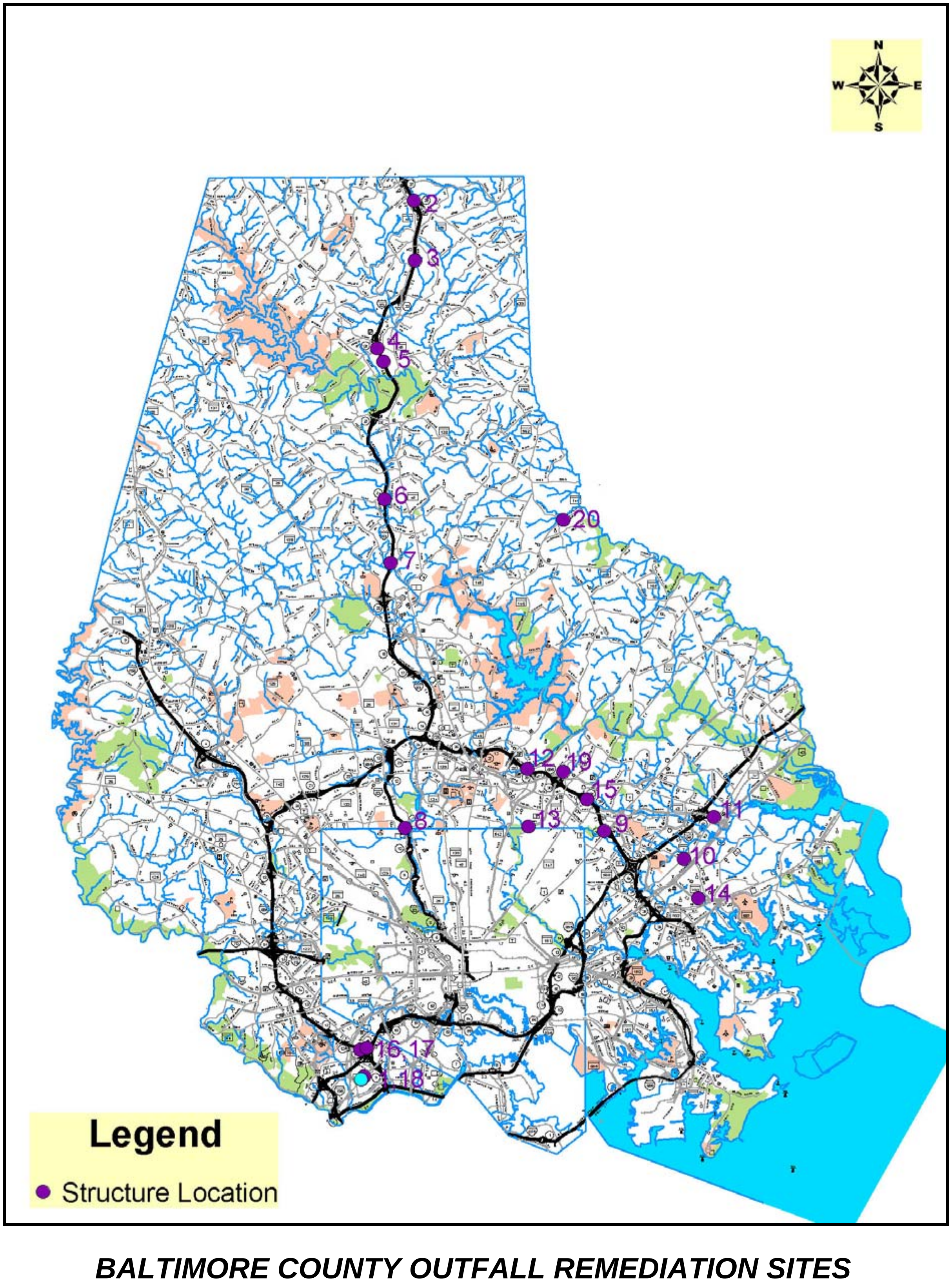
Harford County
Baltimore County



HARFORD COUNTY OUTFALL REMEDIATION SITES

Map Location No.	Pipe number	Rating	Location	Pipe type	upstrm_str
1	1200054	4	MD 24 APPROX 500' NORTH OF PULASKI/EMMORTON CONNECT	24" HDPE	1200027.002
2	1200158	4	MD 24 NW OF INTERSECTION W/ JARRETTSVLLE RD	18" RCP	1200121.002
3	1200188	4	MD 24 - 3222 ROCKS ROAD	54" x 36" CMP	1200161.002
4	1201449	4	MD 165 APPROX 7500' NORTHEAST OF NORRISVILLE ROAD	18" CMP	1200305.002
5	1201636	4	MD 165 APPROX 4000' WEST OF ROCKS ROAD	24" CMP	1200327.002
6	1201639	4	MD 165 300' NORTHWEST OF OLD PYLESVILLE ROAD	30" RCP	1200331.002
7	1200617	4	MD 543 APPROX. 45' NORTH OF OLD PYLESVILLE ROAD	18" CMP	1200346.002
8	1201649	4	MD 165 APPROX 1200' NORTH OF ADY ROAD	30" RCP	1200348.002
9	1202535	4	US 40 APPROX 1200' NORTHEAST OF OLD POST SPLIT	15" CMP	1200554.002
10	1201580	4	US 40 APPROX 570' SOUTHWEST OF LEWIS LANE	15" CMP	1200561.002
11	1201794	4	MD 462 @ I-95 SOUTH OF BRIDGE	24" CMP	1200656.002
12	1200543	4	MD 152 APPROX 55' SOUTHEST OF FORT HOYLE ROAD	15" CMP	1201000.002
13	1200545	4	MD 152 APPROX 430' SOUTHWEST OF FORT HOYLE ROAD	15" CMP	1201001.002
14	1200547	4	MD 152 APPROX 700' SOUTHWEST OF FORT HOYLE	18" CMP	1201002.002
15	1200030	4	MD 159 APPROX 570' SOUTHWEST OF CANNING HOUSE ROAD	12" CMP	1201105.002
16	1201032	4	MD 146 @ MD 152	30" RCP	1201177.002
17	1021040	4	MD 146 - 500' SOUTH OF MD23	24" CMP	1201182.002
18	1021075	5	MD 136 APPROX 40' EAST OF ISLAND BRANCH ROAD	21" CMP	1201204.002
19	1201080	5	MD 136 APPROX 100' WEST OF CAREA RD	12" RCP	1201209.002
20	1201084	4	MD 136 1/4 MILE NORTH OF GOAT HILL ROAD	18" CMP	1201241.002
21	1201088	4	MD 136 - 500' NORTH OF MD 543	12" PVC	1201245.002
22	1200999	4	MD 136 150' NORTH OF E MEDICAL HALL ROAD	18" CMP	1201268.002
23	1201009	4	MD 136 APPROX 3000' SOUTHEAST OF PALMER VIEW DRIVE	36" CMP	1201274.002
24	1200671	4	MD 543 APPROX. 3030' NORTH OF SLADE LANE	15" CMP	1201303.002
25	1200866	4	MD 543 APPROX. 820' SOUTHWEST OF CHESTNUT HILL ROAD	15" CMP	1201305.002
26	1200958	4	MD 136 350' SOUTHEAST OF POPLAR GROVE ROAD	18" CMP	1201320.002
27	1201106	4	MD 136 APPROX. 1190' SOUTHEAST OF DEERFIELD ROAD	36" CMP	1201326.002
28	1201107	4	MD 136 APPROX. 400' NORTHWEST OF DEERFIELD ROAD	15" CMP	1201327.002
29	1200681	4	MD 543 APPROX. 1490' NORTH OF SMITHSON DRIVE	42" CMP	1201344.002
30	1200687	4	MD 543 APPROX. 1600' NORTH OF EAST WALTERS MILL ROAD	24" CMP	1201350.002
31	1200699	4	MD 543 APPROX 360' NORTHWEST OF BRINEGAR ROAD	18" CMP	1201357.002
32	1200710	4	MD 543 APPROX. 420' SOUTHEAST OF DOYLE ROAD	18" CMP	1201368.002
33	1200719	4	MD 543 APPROX. 560' SOUTHEAST OF HEAPS ROAD	48" RCP	1201377.002
34	1200720	5	MD 543 APPROX 40' SOUTHEAST OF HEAPS ROAD	18" RCP	1201378.002
35	1201109	4	MD 136 APPROX 2100' NORTHWEST OF DEERFIELD ROAD	24" CMP	1201385.002
36	1201121	4	MD 136 1000' SOUTH OF MD165 INTERSECTION	24" RCP	1201408.002
37	1201266	4	MD 924 100' SOUTH OF VICTORY LANE	30" CMP	1201431.002
38	1201669	4	MD 165 APPROX 7800' SOUTHWEST OF EAST-WEST HIGHWAY	49"x33" CMP	1201473.002
39	1201678	4	MD 165 APPROX 8000' SOUTH OF FALLSTON ROAD	18" CMP	1201493.002
40	1201763	4	MD 156 APPROX. 2165' SOUTHWEST OF TIMOTHY ROAD	12" CMP	1201523.002
41	1201710	4	MD 623 APPROX 200' NORTHEAST OF PADDRICK ROAD	24" RCP	1201538.002
42	1201630	4	MD 155 APPROX. 980' NORTHWEST OF I-95	36" RCP	1201570.002
43	1201911	4	MD 646 APPROX 730' SOUTH OF WHITEFORD ROAD	36" RCP	1201627.002
44	1201919	4	MD 646 APPROX 1300' NORHTEAST OF BAY DRIVE	18" RCP	1201635.002
45	1201833	4	MD 646 APPROX 1100' SOUTHWEST OF BAY DRIVE	36" RCP	1201638.002
46	1202563	4	US 40 APPROX 1160' SOUTHWEST OF OTTER POINT ROAD	24" RCP	1201661.002
47	1202793	4	US 40 WEST OF BEARDS HILL ROAD	15" CMP	1201696.002
48	1202783	4	US 40 APPROX 1000' SOUTHWEST OF SPESUTIA ROAD	15" RCP	1201673.002
49	1202648	5	US 40 APPROX 640' NORTHEAST OF LONG BAR HARBOR ROAD	18" RCP	1201683.002
50	1203106	4	US 40 SOUTHWEST OF OTSEGO STREET	18" RCP	1201706.002
51	1202640	5	US 40 APPROX 4000' SOUTHWEST OF OTTER POINT ROAD	24" CMP	1201724.002
52	1202566	4	US 40 APPROX 470' SOUTHWEST OF OTTER POINT ROAD	30" RCP	1201727.002

TABLE OF HARFORD COUNTY SITES



BALTIMORE COUNTY OUTFALL REMEDIATION SITES

Map Location No.	Pipe Number	Rating	Location	Pipe Type	upstrm_str
1	303971	4	US ALT 1- Across From CNR Lighting	36" RCP	301136.005
2	310715	4	I-83 NBL at MD439	24" CMP	301242.004
3	310766	4	I-83 SBL Before Exit 33	30" CMP	301259.002
4	310614	4	I-83 SBL- SW Ramp Exit 31	30" RCP	301300.002
5	310609	4	I-83 NBL at Mile 30	36" RCP	301304.002
6	310818	4	I-83 at Belfast Road NW Quad	18" RCP	301343.010
7	310879	4	I-83 NBL- One Mile Past Shawan Road Exit	36" RCP	301373.002
8	311241	4	I-83 SBL at Baltimore City/County line	24" RCP	301868.002
9	309265	3	US 1 at 695 Ramp	24" RCP	302056.002
10	309475	4	MD 7 EBL Past King Avenue	24" CMP	302151.003
11	309448	4	MD 43 EBL at MD 7	24" RCP	302161.002
12	304505	4	I-695 West Ramp	24" CMP	302274.002
13	304352	4	MD41	18" RCP	302346.002
14	304015	4	MD 700 North Bound Lane, by Windsor House Apts.	15" CMP	302407.004
15	307505	4	MD147/ I-695- NE Quad.	24" RCP	302632.002
16	313630	5	I-695/ I-95 Interchange	36" RCP	302984.002
17	313633	4	I-695/ I-95 Interchange	18" CMP	302993.004
18	303973	4	US-1 ALT- Across From Kangaroo Coach	28" CMP	320719.002
19	304390	3	MD41 north of Satyr Hill Rd.	30" CMP	321018.002
20	304988	4	MD 146 at 15041	18" CMP	321308.002

TABLE OF BALTIMORE COUNTY SITES

APPENDIX H:

Illicit Discharge Screening Reports

Carroll County

CARROLL COUNTY ILLICIT DISCHARGE INSPECTION
BCS 2005-06C: NPDES SERVICES STATEWIDE
WINTER 2008

Submitted to:
Karen Coffman
Highway Hydraulics Division
Maryland State Highway Administration
707 N. Calvert St.
Baltimore, Maryland 21202

Prepared by:

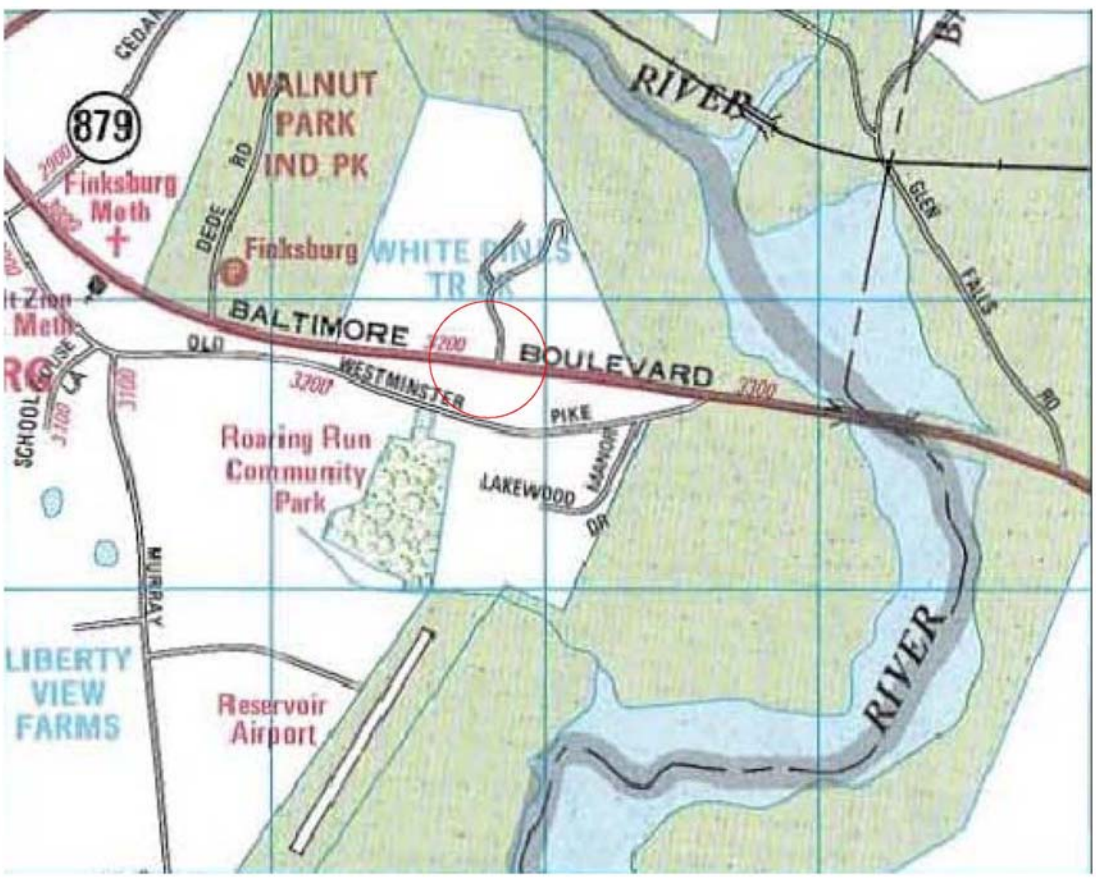
GREENMAN-PEDERSEN, INC.

CHESAPEAKE ENVIRONMENTAL MANAGEMENT, INC.

Illicit Connection #1

On March 3, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, a PVC pipe was found discharging into an inlet alongside MD 140. Later that year on December 18, illicit discharge inspectors visited the furthest downstream structure from that inlet, as part of a screening of all outfalls 36" or greater. There was no flow at the outfall at that time.

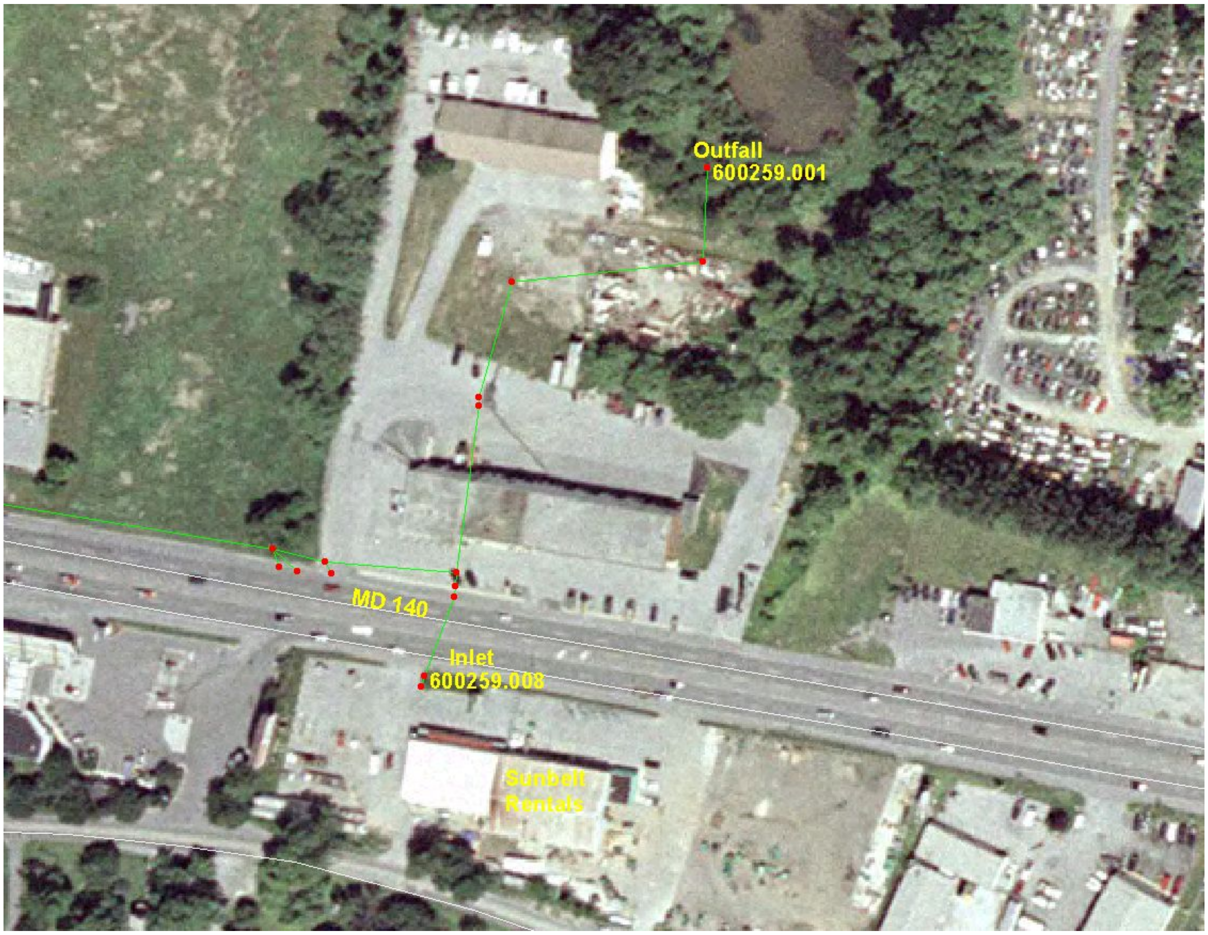
On February 7, 2008, inspectors revisited the site to investigate a potential illicit discharge. At the time of visit, a small yet constant amount of flow was trickling from the PVC pipe. A sample was gathered from the low flow at the pipe. The sample was somewhat cloudy and grey, and resulted in a minor detection of detergents (.10). Although the pipe is coming from the east direction along MD 140, its upstream end could not be found. In the vicinity, inspectors observed a washing area for heavy equipment at "Sunbelt Rentals." The drainage system for the washing bay was not apparent. Sunbelt Rentals is located at 3201 Baltimore Blvd. The structure number of the SHA inlet in question is 0600259.008. It is recommended that SHA continue monitoring the system to determine if there is an illicit connection.



Carroll County ADC Map 26, page 30.

PVC pipe discharging to SHA inlet along MD140.

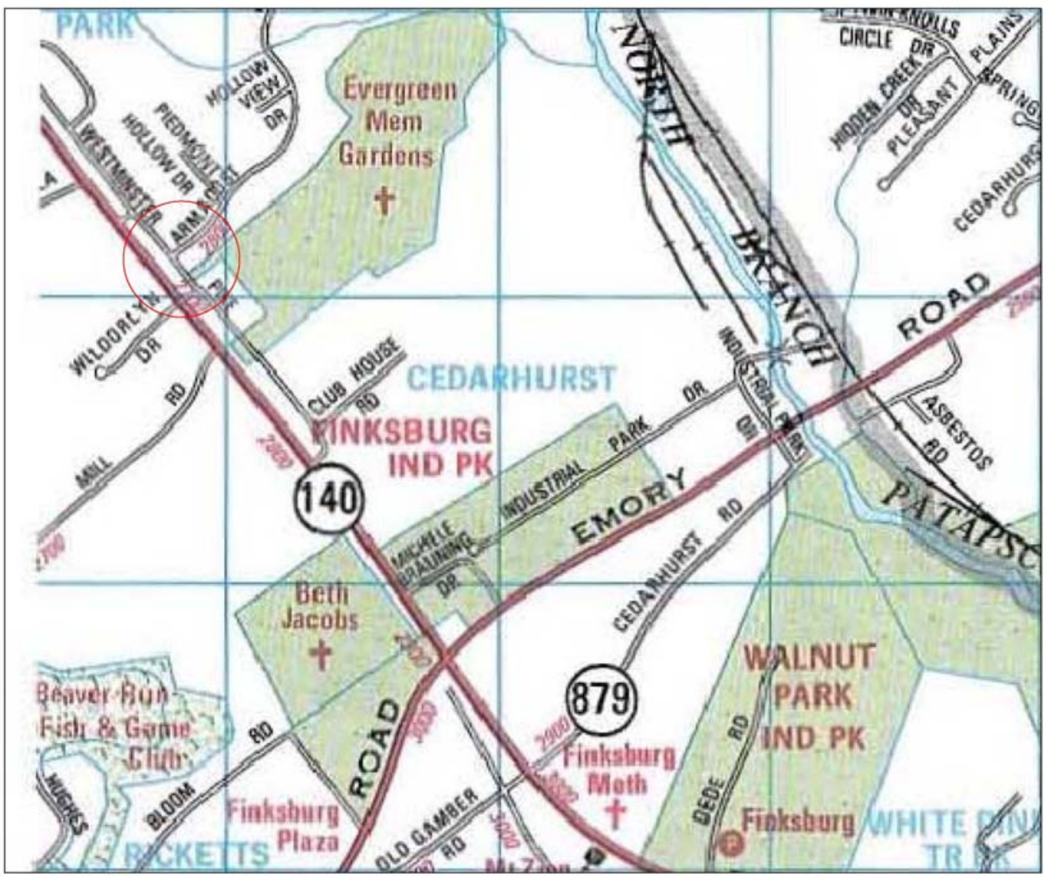
Downstream SHA structure #0600259.001.


Outfall
600259.001
MD 140
Inlet
600259.008
Sunbelt
Rentals

Illicit Connection #2

On March 28, 2007, while verifying Maryland State Highway Administration (MDSHA) stormwater structures in Carroll County, a garden hose was found pointing in the direction of a culvert inflow point. The opposite end of the culvert is a SHA outfall numbered 0600270.002. There was no flow from the hose at the time, and most of the hose was buried approximately 1" beneath the ground surface. The hose was coming from the direction of a private swimming pool.

On February 8, 2008, illicit discharge inspectors visited the site to identify the illicit connection. Pulling the hose up from the ground it was revealed that the hose could be directly attached to the swimming pool. At this time, the homeowner engaged the inspectors. The homeowner explained that the hose is used to drain the swimming pool, although this practice had not taken place recently. The address of the home is 2801 Armacost Avenue.



Carroll County Map 26, page 30.

Garden hose leading to swimming pool at 2801 Armacost Ave.

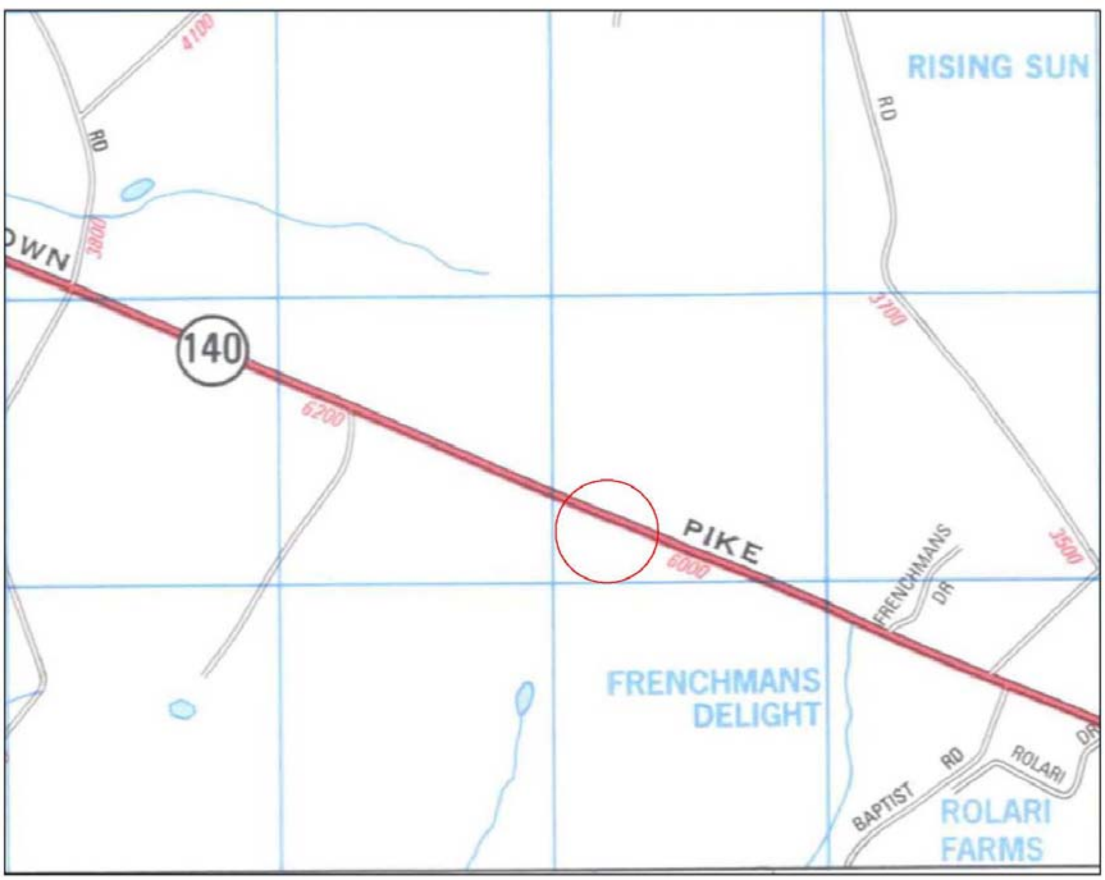
Downstream SHA structure #0600270.002.


ARMACOST
House
#2801
Hose connection
600270.005
Outfall
600270.002
MD 140
OLD WESTMINSTER

Illicit Connection #3

On May 15, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, surveyors observed raw sewage seeping from the ground into a roadside ditch. The ditch runs alongside Taneytown Pike (MD 140) and leads to SHA outfall # 0600412.002. Shortly downstream from the culvert the ditch connects to perennial waters.

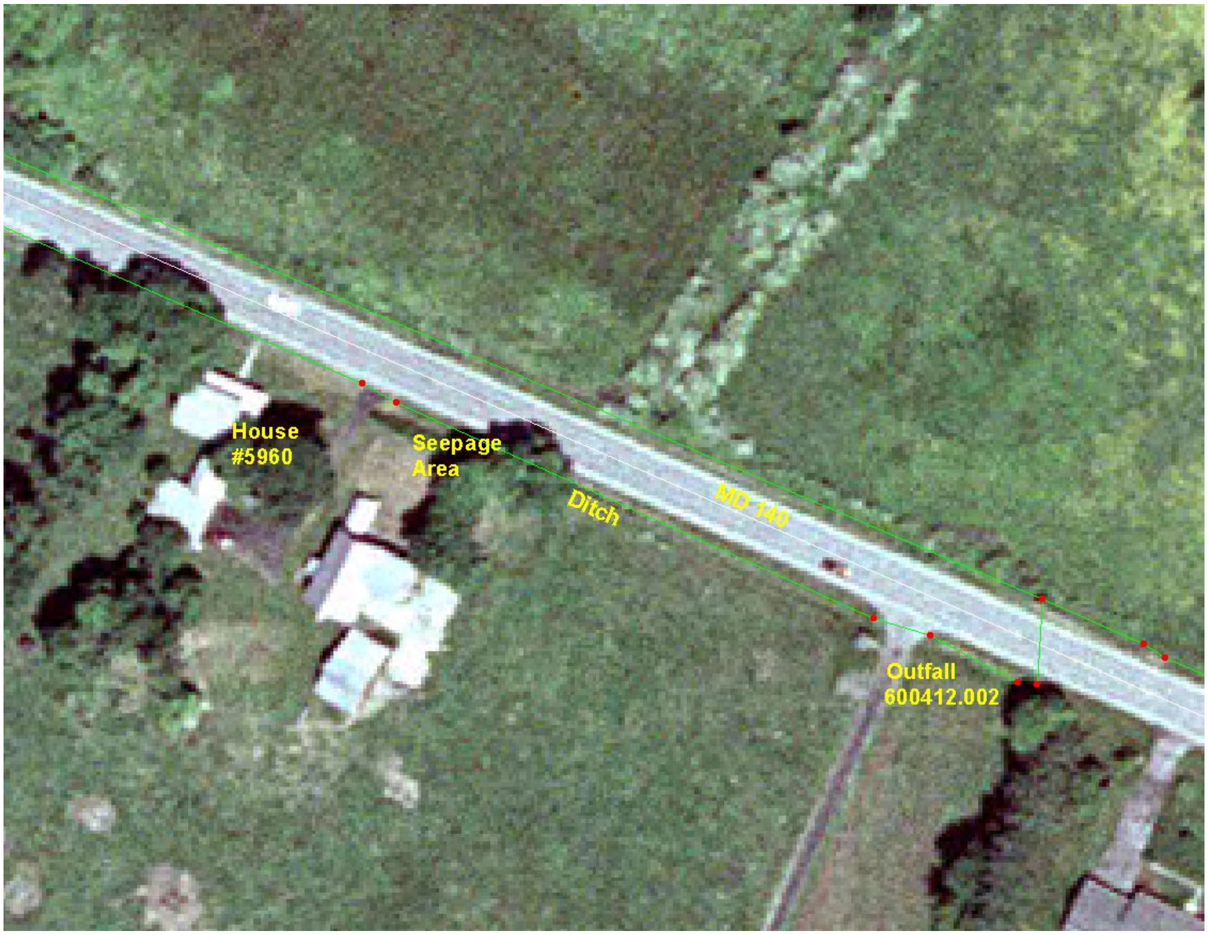
On February 7, 2008, illicit discharge inspectors revisited the site to verify the illicit connection. Again, raw sewage was found seeping into the roadside ditch. Inspectors observed the seepage from several locations. Sewage odor was apparent, and excessive vegetation was noted in the area of the seepage. Inspectors dug into the slope of the ditch and excessive amounts of sewage oozed from the ground. This problem area is located in front of an outbuilding next to the residence at 5960 Taneytown Pike.



Carroll County ADC Map 1, page 5.

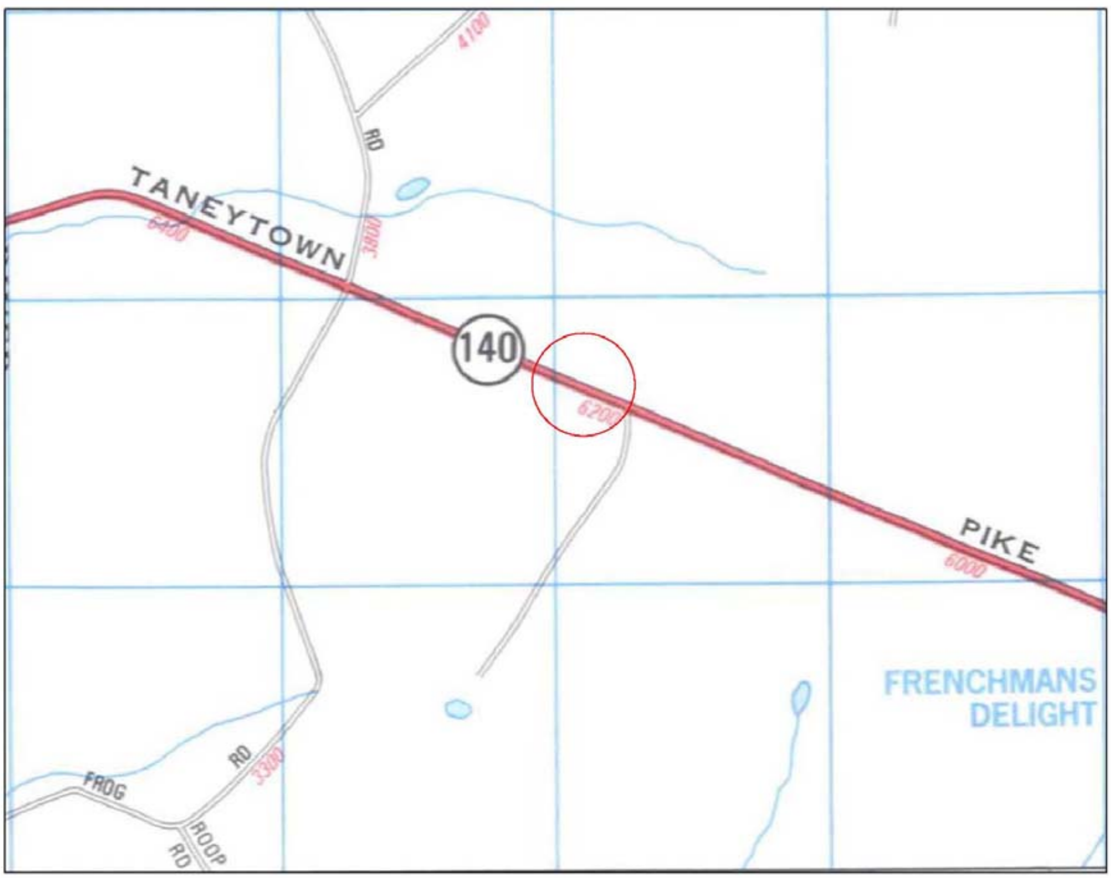
Raw sewage seeping into roadside ditch at 5960 Taneytown Pike.

Downstream SHA structure #0600412.002.


House
#5960
Seepage
Area
Ditch
MD 140
Outfall
600412.002

Illicit Connection #4

On April 16, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, a PVC pipe was found connecting to drainage systems along MD 140. The pipe is visibly connected to the house at 6155 Taneytown Pike. On February 7, 2008, illicit discharge inspectors revisited the site to investigate a potential illicit discharge. There was a drip from the PVC pipe at the time of visit, deemed to little to sample from. The downstream SHA outfall is numbered 0600413.004. It is recommended that the SHA continue monitoring the outfall to identify any illicit connection.



Carroll County ADC Map 1, page 5.

PVC pipe discharging to SHA drainage at 6155 Taneytown Pike.

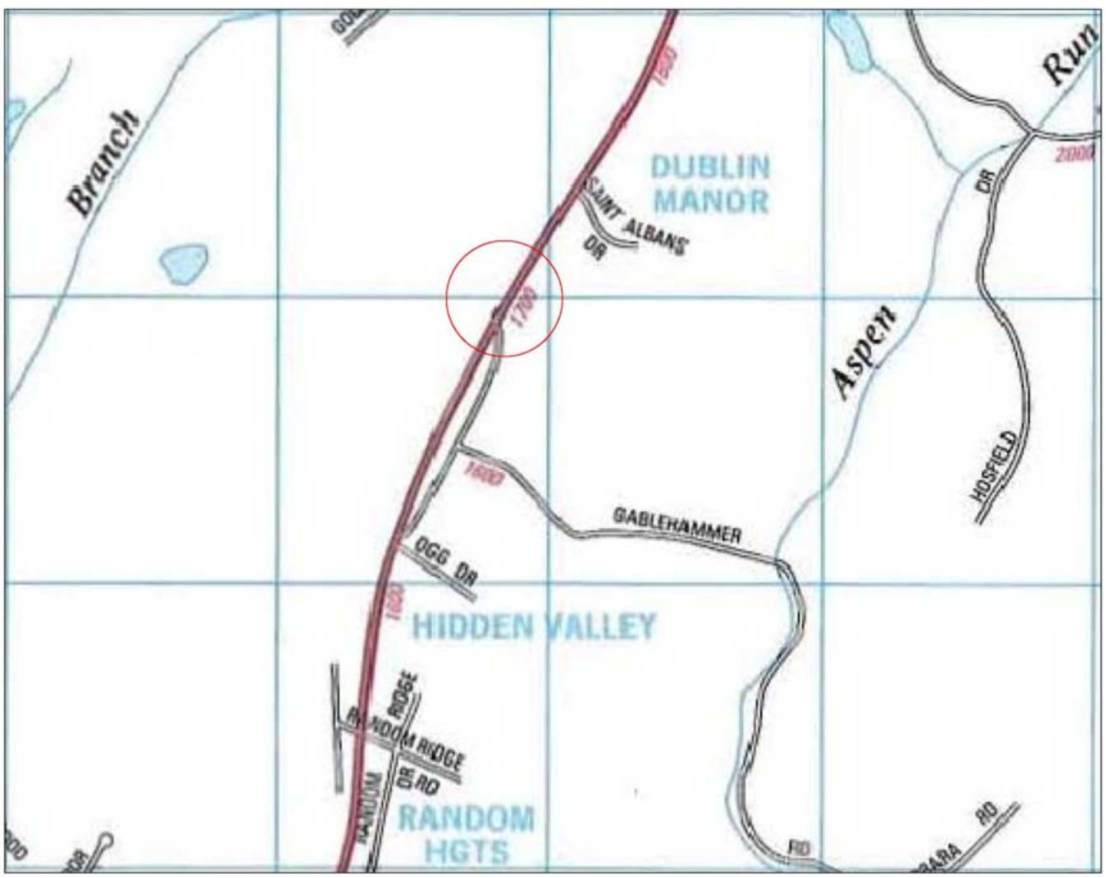
Downstream SHA structure #0600413.004.


MD 140
Outfall
600413.004
Pipe
connection
House
#6155

Illicit Connection #5

On July 13, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, a PVC pipe near outfall # 0600632.001 was identified as a potential illicit discharge source point. The pipe is associated with the residence at 1709 Manchester Road (MD 27).

On February 2, 2008, the site was revisited to verify an illicit connection. Although there was no flow at the time of visit, indications of recent flow from the PVC pipe were identified. There was a rancid odor coming from the pipe, and wastewater appeared to be pooling within the SHA culvert immediately downstream from the pipe. It is recommended that SHA continue monitoring the site to verify the illicit connection.



Carroll County ADC Map 13, page 17.

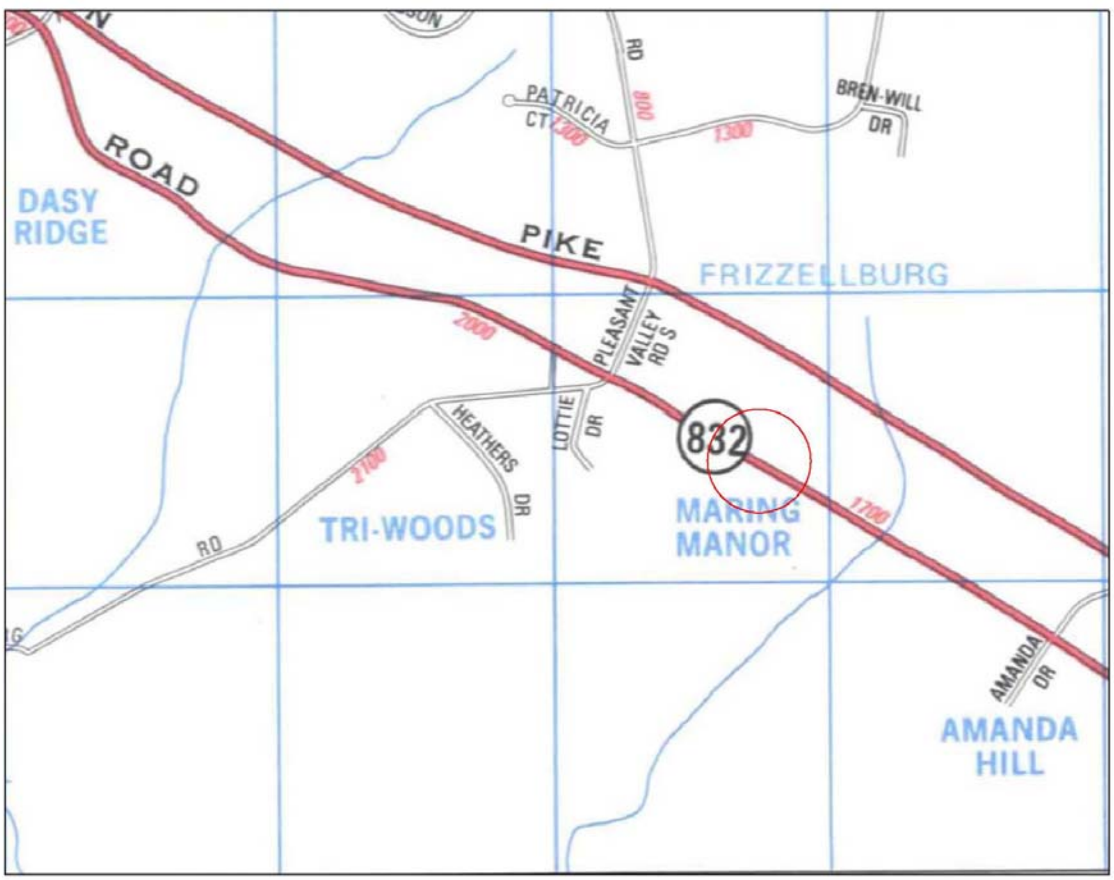
PVC pipe discharging to SHA culvert at 1709 Manchester Road.

SHA structure #0600632.001.

Illicit Connection #6

On September 19, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, a rancid, sludgy substance was found standing in the pipe at outfall # 0601142.001 along MD 832. Surveyors noticed a PVC pipe connected to the SHA inlet directly upstream from the outfall, but it was not flowing at the time.

On February 8, 2008, illicit discharge inspectors visited the outfall to verify an illicit connection. Again, there was no flow at the outfall, or at the PVC pipe. Inspectors searched the property at 1836 Old Taneytown Road to try to locate the upstream end of the PVC pipe, but no connection could be found. To determine if there is an illicit flow, it is recommended that SHA continue to monitor the outfall.



Carroll County ADC Map 11, page 15.

PVC pipe discharging to SHA inlet, at 1836 Taneytown Pike.

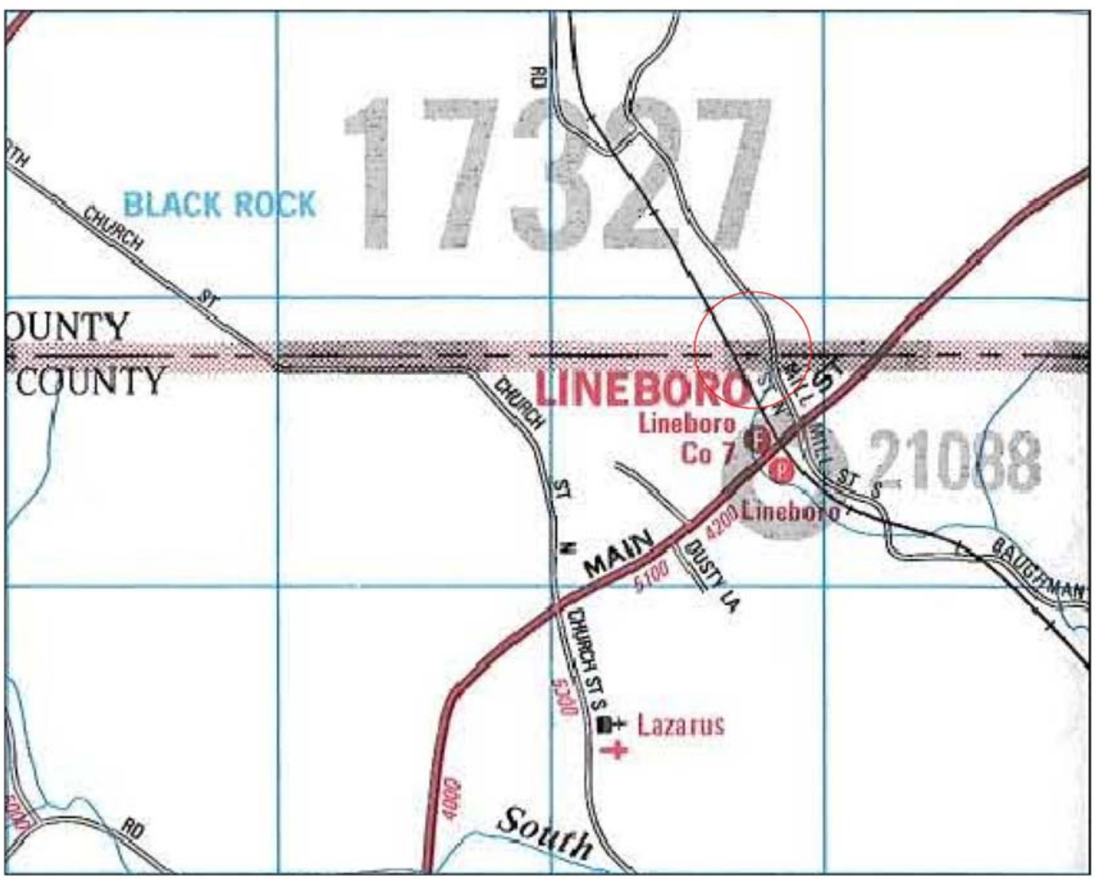
Downstream SHA outfall #0601142.001


House
#1836
MD 832
Inlet
601142.002
Outfall
601142.001

Illicit Connection #7

On September 27, 2007, while verifying Maryland State Highway Administration (MDSHA) owned stormwater structures in Carroll County, a HDPE pipe was found to be discharging laundry wastewater directly into a perennial stream. At the time of visitation, surveyors observed a foamy discharge coming from the pipe and a sweet smell associated with detergents in laundry wastewater.

Illicit discharge inspectors revisited the site on December 27, 2007 and February 7, 2008. There was no flow at the HDPE pipe during either of these visits, but indications of illicit discharge from the pipe were still evident. The pipe leads in the direction of house # 5310 on Mill Street North in Lineboro. Directly downstream from the pipe, the channel is identified as a tributary to Gunpowder Falls. Since this illicit connection originates from beyond SHA right-of-way, it is necessary that SHA coordinate with the neighboring jurisdiction to address the issue.



Carroll County ADC Map 6, page 10.

HDPE pipe located in the backyard at 5310 Mill Street North.

HDPE pipe discharging directly to perennial stream.


House
#5310
Location of
HDPE pipe
MILL ST. NORTH
MD 86

APPENDIX I:

Long Draught Branch Chemical & Physical Monitoring Annual Report

2008

Long Draught Branch Chemical & Physical Monitoring Annual Report 2008

October 2008

LimnoTech
Water | Environment | Scientists | Engineers

1.0 INTRODUCTION

The Long Draught Branch Restoration Project was initiated by the MDSHA to assess and restore/stabilize the degraded conditions of the stream channel from Clopper Road (MD 117) to the location of the Gaithersburg stormwater management facility. Long Draught Branch has deteriorated greatly due to channel straightening, piping, floodplain encroachments, damming, lining with stone, bark armoring, past poor land-use practices, and more recent urbanization. The intent of the project was to conduct chemical, physical, and, biological monitoring over a period of three years to determine the effectiveness of the restoration efforts of the Long Draught Branch Stream Restoration Project. Please refer to Section H1 of SHA's 2008 NPDES Report to the Maryland Department of the Environment for the current status of the construction document development.

2.0 CHEMICAL MONITORING

2.1 Objectives

Monitoring the chemical water quality pre- and post-restoration is an important tool to (1) characterize base line conditions prior to restoration and (2) gauge the success of restoration efforts in improving water quality.

The original intent of the project was that chemical water quality monitoring would occur in two phases:

Phase CHEM 1 (pre-restoration) was initiated November 2006. The goal of this effort was to conduct baseline characterization of the stream reach. While construction is underway, monitoring would stop and resume after the construction was completed.

Phase CHEM 2 would have continued chemical monitoring post-stream bank restoration and stabilization. The goal of this effort was to provide data to help determine the effectiveness of the NPDES stormwater management program and progress toward improving water quality.

2.2 Site Locations

Water quality monitoring was conducted at two sites within the stream reach: one above and one below the restoration site. The upstream site was located at the downstream end of the Clopper Road crossing of Long Draught Branch near Firstfield Road. The downstream site was located at the foot bridge crossing upstream of the City of Gaithersburg stormwater management facility (on Rabbitt Road west of Quince Orchard Road) (Figure 2.1). Continuous flow was recorded at the upstream monitoring site. The flow meter was attached to the downstream side of the culvert at the Clopper Road crossing (MD 107 culvert).

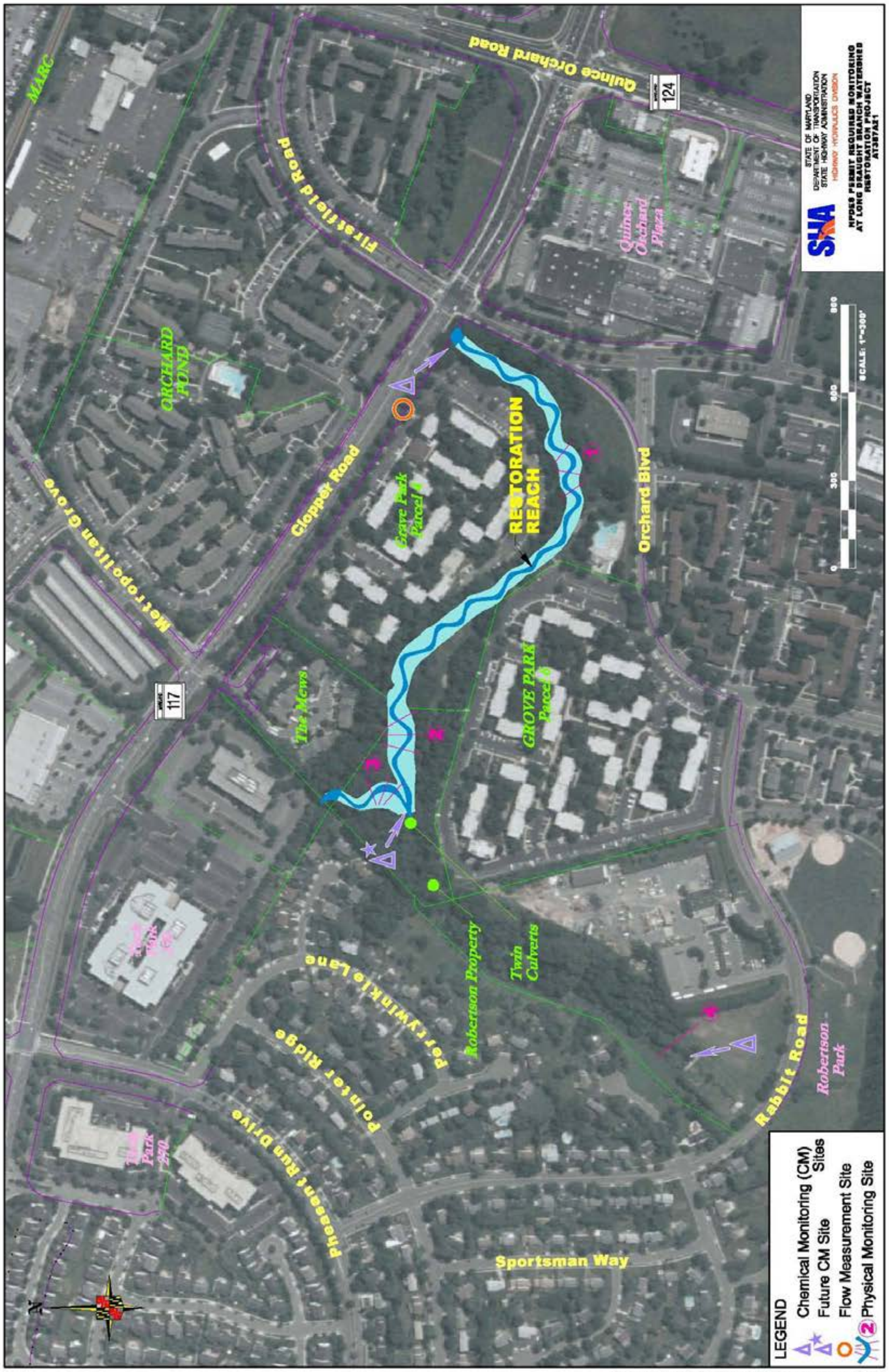


Figure 2.1: Long Draught Branch Monitoring Locations

Sample Types and Sampling Frequency

Chemical water quality monitoring occurred monthly, with at least three sampling events occurring per quarter (based on calendar year) during storm events as well as selected dry-weather periods. A qualifying storm event was defined as rainfall over 0.1 of an inch occurring after there has been no significant (> 0.1 inch) rainfall within 72 hours. To allow for the collection of sufficient data to characterize the impacts of stormwater discharges, baseflow samples were collected during dry weather approximately once per quarter in lieu of a wet weather event. Dry weather was defined as less than 0.1 inch having fallen within the previous 72-hour period.

2.3 Sample Collection Procedures

Samples were collected using manual grab methods following the protocols *EPA NPDES Stormwater Sampling Guidance* (1992). Samples were collected while facing upstream to minimize contamination from the sampler or field equipment and are transferred to lab provided sample containers (except Oil & Grease and E. coli, which were sampled directly into the sample container per recommendations in EPA 1992). All samples were placed in coolers with ice and transported to the laboratory for analysis. In addition to water samples, field measurements of water temperature and pH were measured during the collection of samples using a hand held meter. Samples were analyzed according the methods approved in 40 CFR Part 146 by GPL Laboratories of Frederick, MD and Fredericktown Labs (E. coli) of Myersville, MD.

Figure 2.2: Continuous water level meter at upstream monitoring site

A meter (Teledyne Isco 4110 Ultrasonic Flow Logger), attached to the downstream side of the culvert at the Clopper Road crossing (MD 107 culvert) recorded water level continuously at 15-minute intervals (Figure 2.2). In conjunction with sampling events, the LimnoTech team also conducted flow measurements using a Marsh McBirney portable Flowmeter.

Rainfall data was provided by the Montgomery County, MD Department of Environmental Protection. Rainfall data is collected via a tipping bucket rain gauge at a weather station located adjacent to the Yard Trim Composting Facility Dickerson, MD.

2.4 Sample Documentation

Sampling field sheets and sample labels were completed for each event. Information recorded on field forms included the sampling field crew, sampling location, date and time of sample collection, number and volume of samples collected, sample identification numbers, preservatives used, as well as, weather and physical conditions.

Chain of custody forms were initiated by the sampling crew in the field and remain with the samples at all times. The chain of custody form includes the sample identification number, sample date and time, description, sample type, sample preservative, and analyses required.

2.5 Analytical Parameters

Targeted pollutants for monitoring include:

-Biochemical Oxygen Demand (BOD5)

-Total Lead

-Total Kjeldahl Nitrogen (TKN)

-Total Copper

-Nitrate plus Nitrite

-Total Zinc

-Total Suspended Solids

-Total Phosphorus

-Total Petroleum Hydrocarbons

-Oil and Grease

-Escherichia coli

-Ammonia (added March 2007)

-Orthophoshate (added March 2007)

2.6 Data Management Procedures

Water quality data are stored in a Microsoft Access database, designed by LimnoTech for this project. Water level data, rainfall data, and flow measurements are tracked via Excel spreadsheets.

3.0 RESULTS

Between November 2006 and August 2008, LimnoTech sampled 7 storm events and 13 baseflow periods. Flow weighted EMCs were calculated for all storm events utilizing both "0" (EMC (0)) and the detection limit (EMC(dt)) for discrete samples recorded as less than the detection limit.

3.1 Comparison of Storm and Base Flow Pollutant Concentrations

Storm- and baseflow concentrations of the targeted constituents were compared based on visual representation of the data and the use of Mann-Whitney U test, a nonparametric analogue of the two-sample t-test. Statistical significance was assessed based on an alpha level of 0.05. Summary data for all pollutants is located in Appendix A.

Medians of stormwater concentrations and baseflow concentrations based on this sampling period are presented in Table 3.1. Most parameters (BOD, e. coli, total phosphorus, total suspended solids, zinc and orthophosphate) had significantly higher concentrations during storm flow. Nitrate/nitrite; however, had significantly higher concentration during baseflow, which may indicate dry weather inputs/ wet weather dilution.

Table 3.1: EMC medians and Mann-Whitney test statistics for baseflow and stormflow at Long Draught Branch monitoring sites, years 2007-2008. Significant differences noted in bold.

		Baseflow	Stormflow	Test statistic
BOD (mg/L)	EMC (0)	2.0	6.9	**0.000**
	EMC (dt)	2.0	6.9	**0.000**
	EMC (0)	0.0	0.0	**0.037**
Total Copper (ug/L)	EMC (dt)	10	10	**0.037**
	EMC (0)	54	1101	**0.020**
e.coli (col/100 mL)	EMC (dt)	54	1101	**0.020**
	EMC (0)	0	0	0.580
Total Lead (ug/L)	EMC (dt)	10	10	0.580
	EMC (0)	1.200	0.798	**0.003**
Nitrate/Nitrite (mg/L)	EMC (dt)	1.200	0.798	**0.003**
	EMC (0)	0.52	1.11	**0.000**
Nitrogen, Total Kjeldahl (mg/L)	EMC (dt)	0.52	1.205	**0.000**
	EMC (0)	5.4	5.1	0.268
Oil & Grease (mg/L)	EMC (dt)	5.4	5.4	1.000
	EMC (0)	0.036	0.119	**0.001**
Total Phosphorus (mg/L)*	EMC (dt)	0.036	0.119	**0.001**
	EMC (0)	5.0	7.0	**0.008**
TSS (mg/L)*	EMC (dt)	5.0	7.3	**0.021**
	EMC (0)	5.2	3.9	0.552
TPH (mg/L)	EMC (dt)	5.3	5.4	0.609
	EMC (0)	27.1	44	**0.008**
Zinc (ug/L)	EMC (dt)	27.1	44	**0.008**
	EMC (0)	0.10	0.19	0.300
Ammonia (mg/L)	EMC (dt)	0.10	0.21	0.112

Table 3.1: EMC medians and Mann-Whitney test statistics for baseflow and stormflow at Long Draught Branch monitoring sites, years 2007-2008. Significant differences noted in bold.

		Baseflow	Stormflow	Test statistic
Orthophosphate (mg/L)	EMC (0)	0.020	0.025	0.065
	EMC (dt)	0.020	0.031	**0.049**

Table 3.2: Detection limits

Parameter	Detection Limit
BOD (mg/L)	2.0
Nitrogen, Total Kjeldahl (mg/L)	0.10
Nitrate/Nitrite (mg/L)	0.050
Total Phosphorus (mg/L)	0.020
TSS (mg/L)	5.0
Total Copper (ug/L)	10.0
Total Lead (ug/L)	10.0
Zinc (ug/L)	20.0
TPH (mg/L)	5.0-6.1
Oil & Grease (mg/L)	5.0-6.1
e.coli (col/100 mL)	1
Ammonia (mg/L)	0.10
Orthophosphate (mg/L)	0.020

3.2 Comparison of upstream vs. downstream concentrations

Upstream vs. downstream concentrations of the targeted constituents were compared based on visual representation of the data and the use of paired t-test (Table 3.3). Statistical significance was assessed based on an alpha level of 0.05. For most parameters, both during storm flow and baseflow, the upstream and downstream concentrations did not differ significantly. The only significant relationships included: BOD being significantly higher upstream during storm events and TKN being significantly higher upstream during baseflow events.

Table 3.3: *EMC means and paired T-test for Long Draught Branch upstream and DS monitoring sites. Discrete samples less than detection limit calculated as 0 , EMC(dt) shown, EMC(dt) shown in where different. Significant differences noted in bold. N= Baseflow (13 events), Stormflow (7 events) unless otherwise noted.*

		Baseflow	Stormflow
BOD (mg/L)	Upstream	2.5 (2.6)	15.0
	Downstream	2.0 (3.0)	12.2
	p	*0.288(0.239)*	***0.018***
Total Copper (ug/L)	Upstream	0 (10.0)	10.7 (16.4)
	Downstream	0 (10.0)	8.9 (14.6)
	p		*0.267*
e.coli (col/100 mL)*	Upstream	522	951
	Downstream	221	8648
	p	*0.41*	*0.40*
Total Lead (ug/L)	Upstream	0.0 (10.0)	0.6 (10.1)
	Downstream	0.0 (10.0)	1.1(10.6)
	p		*0.356*
Nitrate/Nitrite (mg/L)	Upstream	1.448	0.860
	Downstream	1.296	0.801
	p	*0.630*	*0.397*
Nitrogen, Total Kjeldahl (mg/L)	Upstream	0.62	1.31
	Downstream	0.48	1.57
	p	***0.034***	*0.099*
Oil & Grease (mg/L)	Upstream	3.5 (5.5)	7.0 (8.9)
	Downstream	7.7 (9.0)	2.3 (5.4)
	p	*0.242 (0.277)*	*0.235 (0.281)*
Total Phosphorus (mg/L)**	Upstream	0.055 (0.058)	0.147
	Downstream	0.081 (0.082)	0.169
	p	*0.455 (0.481)*	*0.397*
TSS (mg/L)**	Upstream	3.1(5.4)	10.9 (11.3)
	Downstream	4.7(6.3)	27.5 (27.7)
	p	*0.4 00(0.249)*	*0.270*
TPH (mg/L)	Upstream	3.1 (5.4)	9.3 (11.6)
	Downstream	4.7(6.7)	2.3(5.4)
	p	0.363 (0.356)	0.328 (0.261)
Zinc (ug/L)	Upstream	30.5 (36.6)	88.7
	Downstream	22.9(32.1)	69.7
	p	*0.445(0.354)*	*0.270*
Ammonia (mg/L)***	Upstream	0.27 (0.29)	0.30 (0.31)
	Downstream	0.17 (0.19)	0.32 (0.33)
	p	*0.328 (0.375)*	*0.396*
Orthophosphate (mg/L)****	Upstream	0.016 (0.022)	0.056 (0.060)
	Downstream	0.017(0.023)	0.074 (0.079)
	p	*0.278*	*0.538 (0.485)*

** 3 storm events, 5 baseflow events*
*** 6 baseflow events*
**** 9 baseflow, 6 storm events*
***** 10 baseflow, 6 storm events*

3.3 Development of discharge rating curve

Water level/stage was continuously monitored via the meter located at the downstream end of the Clopper Rd. crossing. Water levels can be converted to flow rates (Figure 3.1) based on a theoretical rating curve developed for this site (Figure 3.2). The stage-discharge rating curve was developed using Manning's equation (water levels of 1.2 -2.53 ft.) and regression based on the HEC-RAS results for varying flood sizes presented in MHSA (2005) (for water levels between 2.67 and 5.4 ft.), with the assumption of no flow at > 1.2 ft. The Manning's equation used a culvert width of 8 ft. and assumed a 0.04 *n* value. The LimnoTech team used flow measurements manually taken during each sampling event to refine and validate this rating curve (Table 3.2).

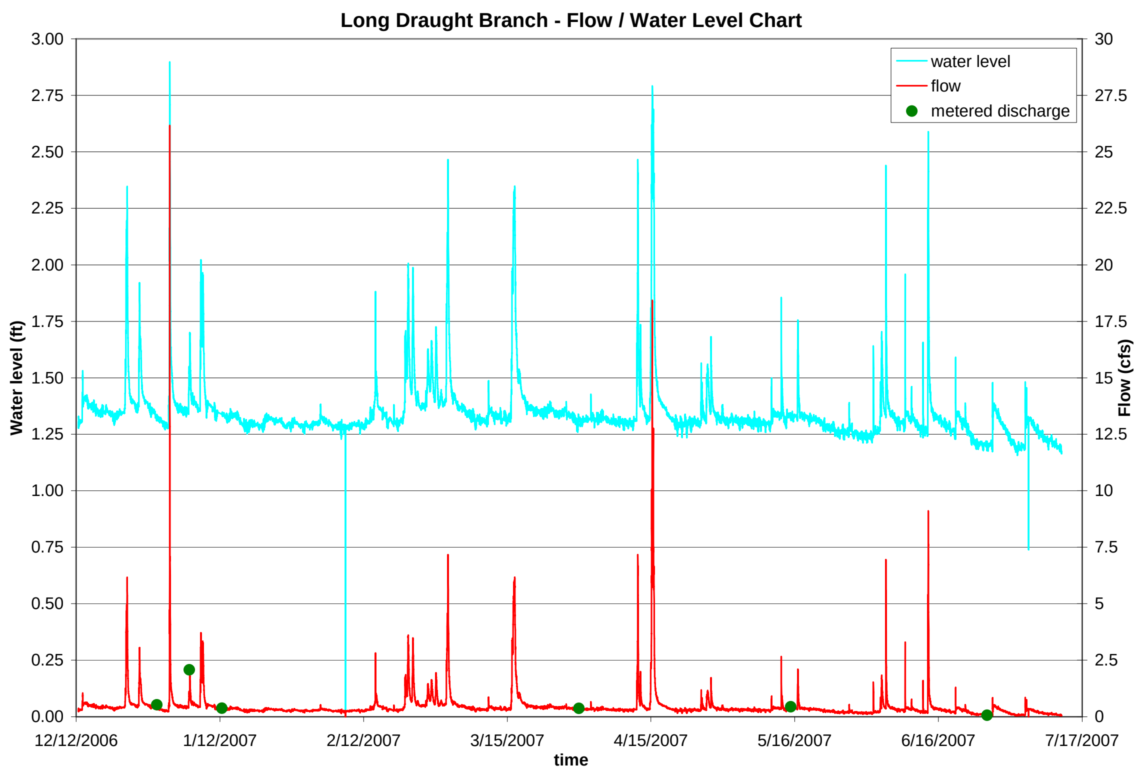


Figure 3.1: Long Draught Branch water level and discharge (cfs) at upstream monitoring site

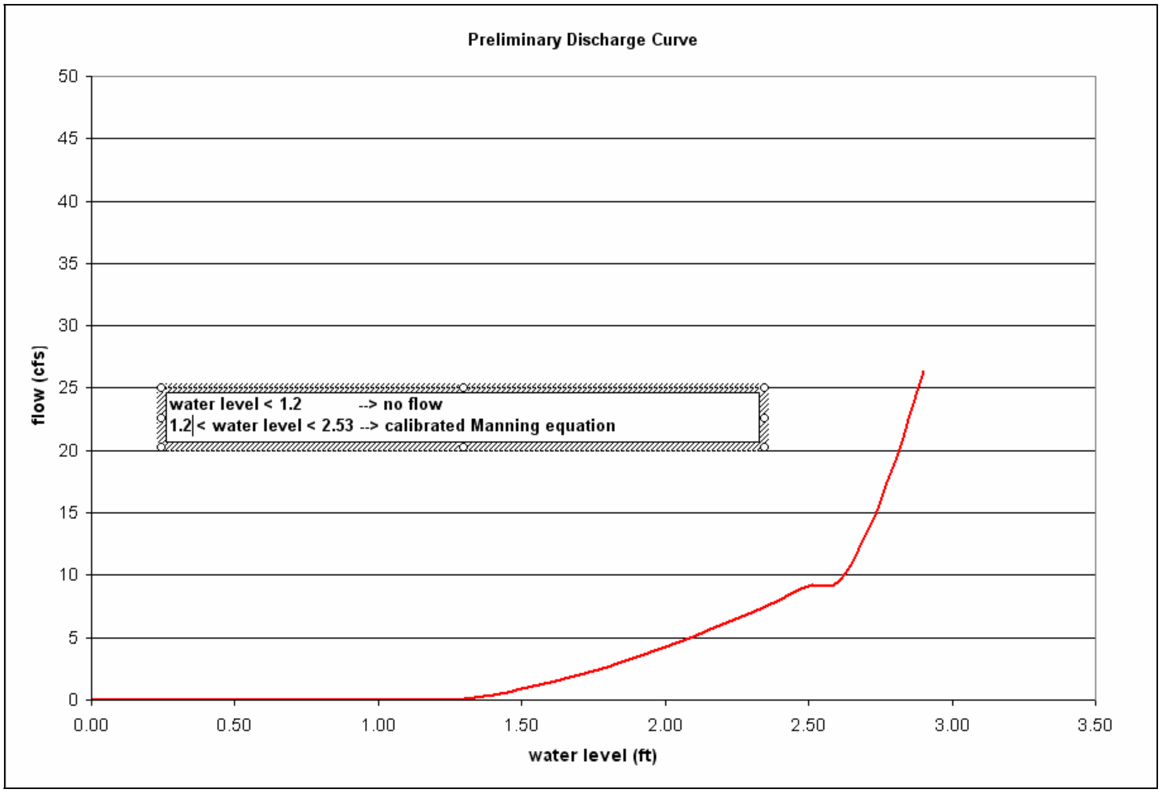


Figure 3.2: Stage-Discharge rating curve for Long Draught Branch

Table 3.2: Discharge measurements taken during sampling events

	Water level (ft)	Discharge (cfs)
12/29/2006 9:56	1.33	0.524
1/5/2007 9:51	1.53	2.072
1/12/2007 11:00	1.34	0.3735
3/30/2007 11:01	1.31	0.3692
5/16/2007 3:27	1.45	0.44
6/26/2007 11:57	1.21	0.07
7/19/2007 2:35	1.20	-0.80
8/16/2007 12:17	1.26	-0.056
1/4/2008 11:15	1.26	0.01325
1/29/2008 3:40	1.32	0.144
2/29/2008 11:20	1.32	0.413
5/20/2008 10:30	1.57	3.862
5/20/2008 11:50	1.70	1.482

*meter installed 12/12/2006
** at low water levels, backflow conditions may impact flow measurement

4.0 Physical Monitoring

4.1 Objectives

Physical monitoring was intended to classify three discrete site or stations within the Long Draught Branch project reaches per the stream classification system devised by Dave Rosgen. Particular stream types developed by Mr. Rosgen speak to a level of stability in geometric terms of plan and profile. Analyzing and categorizing certain ratios provides an adequate language to describe the stream morphology is progressing in a degrading, aggrading, or no-change condition. This work was to be performed both pre and post construction to determine if physical benefits had been established as one of the goals of the project.

Figure 4.1: Upstream view of Site 2

4.2 Site Locations

Three reaches were selected to be monitored both pre and post construction. Please refer to Figure 2.1 on page 2 of this report for the site locations. Site 1 is located approximately 400 feet southwest of the MD 117 culvert over Long Draught Branch. Site 2 is approximately 1,500 feet due west of the same culvert and about 200 feet upstream of the low head dam structure of the existing stormwater management control. Site 3 is on the tributary and is approximately 150 feet south of the storm drain outfall.

4.3 Methods

Rosgen Level I and II assessments were performed to classify the sites cross sectional geometry, profile, and channel bed composition. From these measurements, various ratios are developed to better understand the geomorphologic dynamics. The channel forming or "bankfull" discharge is selected to determine the storm flow access to the overbank areas.

Figure 4.2: Upstream View of Site 3 (Trib)

In urban systems such as seen at Long Draught Branch and greater Gaithersburg, channel forming discharge implies a competency or efficiency of sediment transport and the related associated stream flow. With multiple storm water retention and detention ponds and facilities upstream of the project site, limited sediment supply is being provided at the top of the reach. Additionally, the available material of the reach in the bed and banks of Long Draught have been determined to be modern sediments deposited on the historic floodplain. The current channel is cutting through these fine sediments comprised of silts, clays and sands.

On November 2, 2007, Dr. Dorothy Merritts assessed the Long Draught Branch stream valley within and beyond the project reach. Her assessment of the thickness of these modern sediments varied from as much as 5 feet to 3 feet at varying points in the valley. All of these sediments at these depths were determined to be deposited since approximately 1750.

Therefore, with the increased volume and flashy nature of urban storm flows, high shear stress on material that tends to smaller gravel and sand is a poor condition for determining channel forming or “bankfull” discharge, depths and widths.

The features that were sought comprised of vegetative features at lower, near active channel locations, subtle riffle features that imply stability within incised and steep banks, and sorting of the gravels and sands in an armoring manner. These elevations were identified at the three sites.

Two riffle sections and one pool section were performed were recognizable features were identified. On Site 1 all were identified and measured. On Sites 2 and 3, the degrading nature of the channel made riffles more difficult to identify given that these sites were generally comprised of pools at cut banks. Only 1 riffle was measured at each of these sites.

Sinuosity was measured from land survey data developed for the construction document development. Approximately 12 “bankfull” widths were spanned both upstream and down to cover the 25 width site reaches.

Sieve analysis was performed to characterize the gradations of the channel bed material. Sieve sizes of 2, 4, 8, 16, 31.5 and 63 millimeters were used. The segregated samples were then weighed and analyzed to determine the percent compositions per sieve. The mean diameters were developed from those measurements.

4.4 RESULTS

Please refer to Appendix B for all field sheets and assessment of the sections, profile and sieve data.

Generally, the assessment shows wide and rectangular riffle sections with relatively low entrenchment ratios. Width/depth ratios are as high as 40 with entrenchment ratios generally 1.5 ± 0.45. Site 3 (Trib) was more narrow with lower width/depth ratios but similar entrenchment ratios. The tributary is mostly confined with high banks with exposed tree roots and fallen trees across the active channel.

Slopes varied because of the base level drop of the active channel bed. Site 1, being at the most upstream site of this assessment, has not experienced the full head cut that is working headward through the project reach. Slope was 0.81% for the site reach. Site 2 is within the changing nature of the existing stormwater structure. Severe erosion is working on the south end of the low head concrete wall of the stormwater structure. The downstream end of Site 2 appears to be dropping with each storm event. Slope was measured at 1.13%. The slope on Site 3 (Trib) is towards the downstream end with the significant base level drop already occurring and traveling upstream. This may change with the precarious nature of the existing concrete stormwater structure.

Channel bed material for all three reaches resulted in D_{50} of 13, 9.7 and 6.9 mm respectively. Significant amounts of sand are present.

Based on the assessment performed, all three reaches classify as F4 streams per the Rosgen classification system, although few of the sections fit one of the classifications for all variables. Sinuosity is very low and more characteristic of an A or B stream type. Entrenchment on some sections is more in line with a B channel type.

F type streams are more associated with depositional soils associated with stream downcutting. This seems to characterize all three sites with the depositional nature of the floodplains confirmed by Dr. Merritts.

Given the design intent of developing a C4 stream type, this would be consistent with the evolutionary nature of F streams eroding downward then laterally to establish a more appropriate access to the floodplain. With the current status of the construction project, the stream will continue to erode and transport associated nutrients with mobilized bank material until a stable form can be established. This will have significant water quality impacts over time. With the precarious nature of the existing structure, this could evolve rapidly with a catastrophic failure in a large storm event.

5.0 LITERATURE

EPA. 1992. NPDES Storm Water Sampling Guidance. United State Environmental Protection Agency, Office of Water. Report EPA 833-8-92-001, July 1992.

MSHA. 2005. Long Draught Branch Restoration/Stabilization Semi-Final Design Report, SHA Project No: MO357121. Maryland State Highway Administration, Highway Hydraulics Division. November 2005.

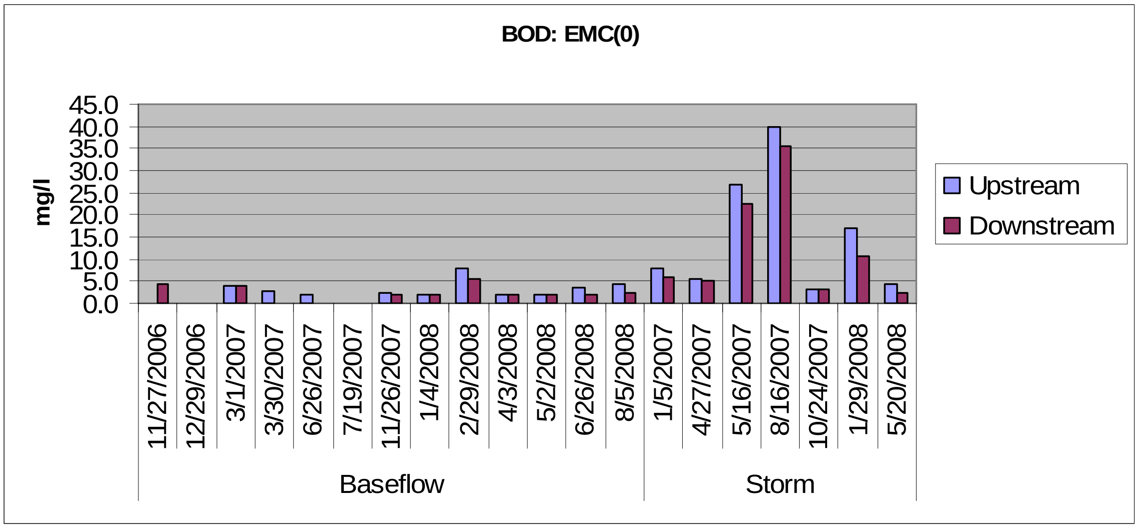
Rosgen, Dave. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

APPENDIX A:

Pollutant Summary Information

Biological Oxygen Demand (mg/l)

Date	Station Name	Storm/ Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	2.0	0.0	2.0
11/27/2006	Downstream	Baseflow	2.0	4.2	4.2
12/29/2006	Upstream	Baseflow	2.0	0.0	2.0
12/29/2006	Downstream	Baseflow	2.0	0.0	2.0
3/1/2007	Upstream	Baseflow	2.0	3.9	3.9
3/1/2007	Downstream	Baseflow	2.0	3.8	3.8
3/30/2007	Upstream	Baseflow	2.0	2.8	2.8
3/30/2007	Downstream	Baseflow	2.0	0.0	2.0
6/26/2007	Upstream	Baseflow	2.0	2.1	2.1
6/26/2007	Downstream	Baseflow	2.0	0.0	2.0
7/19/2007	Upstream	Baseflow	2.0	0.0	2.0
7/19/2007	Downstream	Baseflow	2.0	0.0	2.0
11/26/2007	Upstream	Baseflow	2.0	2.3	2.3
11/26/2007	Downstream	Baseflow	2.0	2.0	2.0
1/4/2008	Upstream	Baseflow	2.0	2.0	2.0
1/4/2008	Downstream	Baseflow	2.0	2.0	2.0
2/29/2008	Upstream	Baseflow	2.0	7.8	7.8
2/29/2008	Downstream	Baseflow	2.0	5.4	5.4
4/3/2008	Upstream	Baseflow	2.0	2.0	2.0
4/3/2008	Downstream	Baseflow	2.0	2.0	2.0
5/2/2008	Upstream	Baseflow	2.0	2.0	2.0
5/2/2008	Downstream	Baseflow	2.0	2.0	2.0
6/26/2008	Upstream	Baseflow	2.0	3.6	3.6
6/26/2008	Downstream	Baseflow	2.0	2.0	2.0
8/5/2008	Upstream	Baseflow	2.0	4.3	4.3
8/5/2008	Downstream	Baseflow	2.0	2.2	2.2
1/5/2007	Upstream	Storm	2.0	7.9	7.9
1/5/2007	Downstream	Storm	2.0	5.8	5.8
4/27/2007	Upstream	Storm	2.0	5.7	5.7
4/27/2007	Downstream	Storm	2.0	5.1	5.1
5/16/2007	Upstream	Storm	2.0	27.0	27.0
5/16/2007	Downstream	Storm	2.0	22.4	22.4
8/16/2007	Upstream	Storm	2.0	40.0	40.0
8/16/2007	Downstream	Storm	2.0	35.6	35.6
10/24/2007	Upstream	Storm	2.0	3.2	3.1
10/24/2007	Downstream	Storm	2.0	3.1	3.1
1/29/2008	Upstream	Storm	2.0	17.1	17.1
1/29/2008	Downstream	Storm	2.0	10.6	10.6
5/20/2008	Upstream	Storm	2.0	4.3	4.3
5/20/2008	Downstream	Storm	2.0	2.5	2.5


BOD: EMC(0)
mg/l
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
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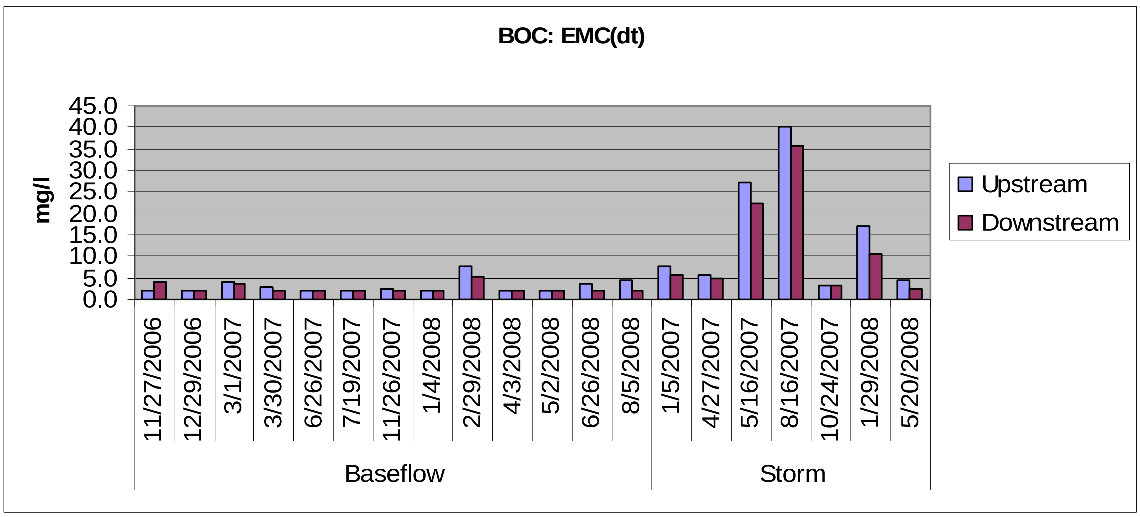
Baseflow
Storm
Upstream
Downstream


BOC: EMC(dt)
mg/l
45.0
40.0
35.0
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11/27/2006
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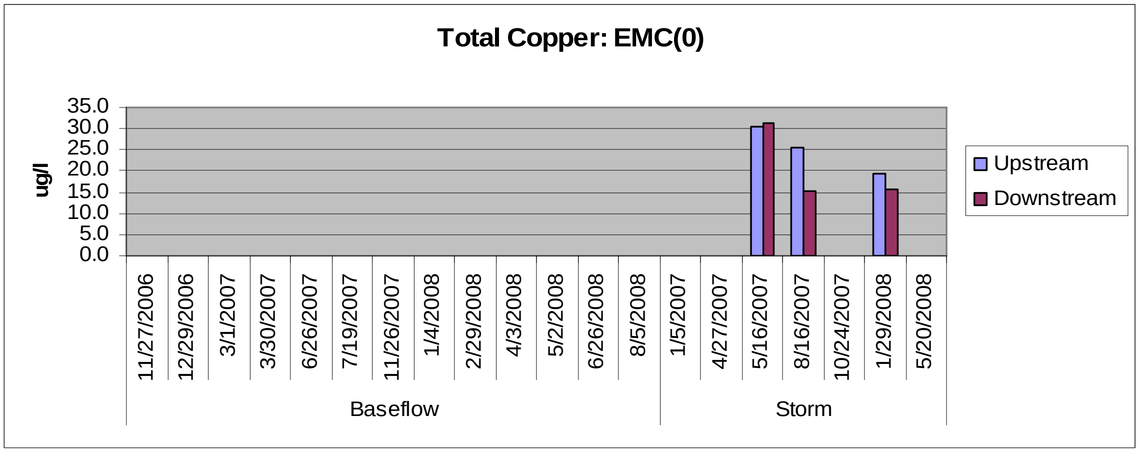
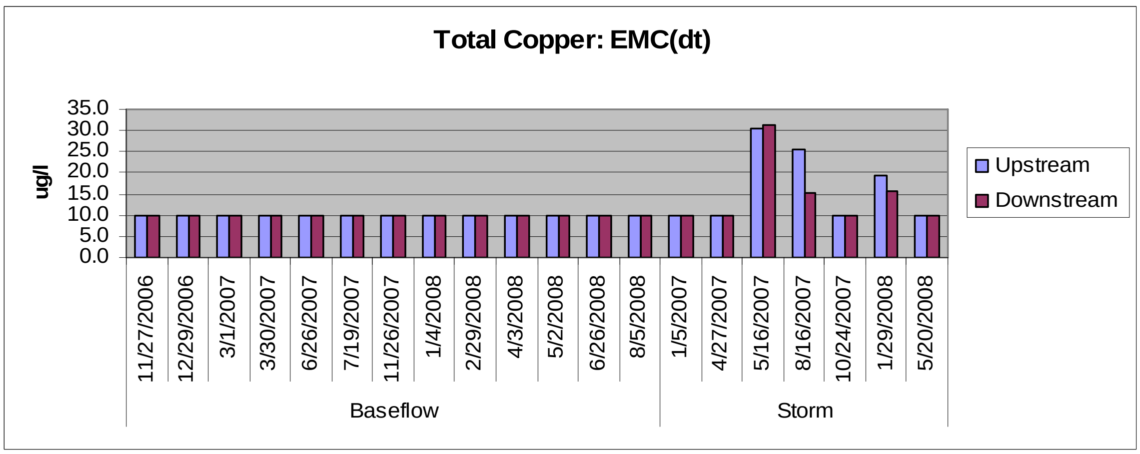
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Total Copper (ug/l):

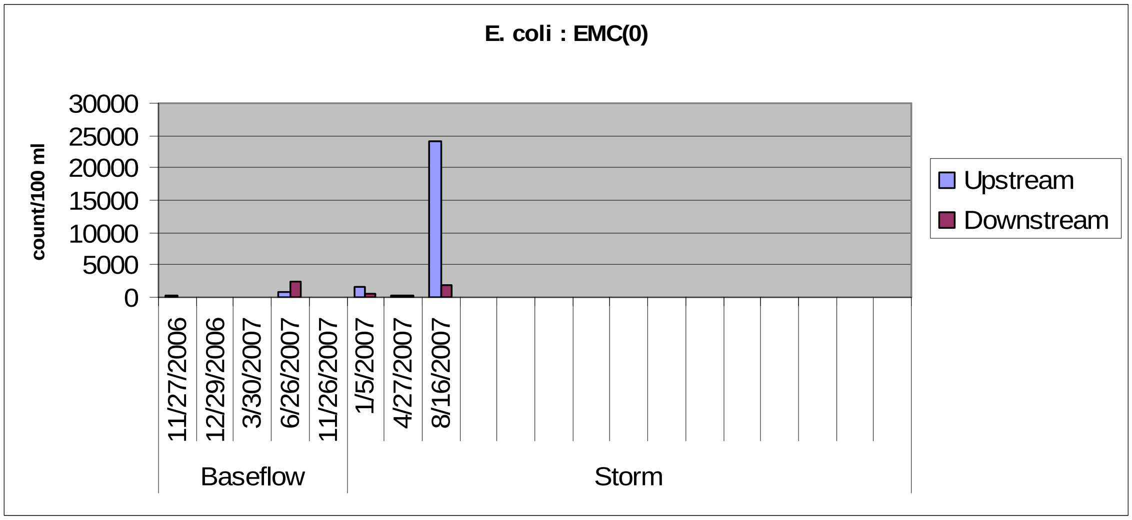
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	10.0	0.0	10.0
11/27/2006	Downstream	Baseflow	10.0	0.0	10.0
12/29/2006	Upstream	Baseflow	10.0	0.0	10.0
12/29/2006	Downstream	Baseflow	10.0	0.0	10.0
3/1/2007	Upstream	Baseflow	10.0	0.0	10.0
3/1/2007	Downstream	Baseflow	10.0	0.0	10.0
3/30/2007	Upstream	Baseflow	10.0	0.0	10.0
3/30/2007	Downstream	Baseflow	10.0	0.0	10.0
6/26/2007	Upstream	Baseflow	10.0	0.0	10.0
6/26/2007	Downstream	Baseflow	10.0	0.0	10.0
7/19/2007	Upstream	Baseflow	10.0	0.0	10.0
7/19/2007	Downstream	Baseflow	10.0	0.0	10.0
11/26/2007	Upstream	Baseflow	10.0	0.0	10.0
11/26/2007	Downstream	Baseflow	10.0	0.0	10.0
1/4/2008	Upstream	Baseflow	10.0	0.0	10.0
1/4/2008	Downstream	Baseflow	10.0	0.0	10.0
2/29/2008	Upstream	Baseflow	10.0	0.0	10.0
2/29/2008	Downstream	Baseflow	10.0	0.0	10.0
4/3/2008	Upstream	Baseflow	10.0	0.0	10.0
4/3/2008	Downstream	Baseflow	10.0	0.0	10.0
5/2/2008	Upstream	Baseflow	10.0	0.0	10.0
5/2/2008	Downstream	Baseflow	10.0	0.0	10.0
6/26/2008	Upstream	Baseflow	10.0	0.0	10.0
6/26/2008	Downstream	Baseflow	10.0	0.0	10.0
8/5/2008	Upstream	Baseflow	10.0	0.0	10.0
8/5/2008	Downstream	Baseflow	10.0	0.0	10.0
1/5/2007	Upstream	Storm	10.0	0.0	10.0
1/5/2007	Downstream	Storm	10.0	0.0	10.0
4/27/2007	Upstream	Storm	0.0	0.0	10.0
4/27/2007	Downstream	Storm	10.0	0.0	10.0
5/16/2007	Upstream	Storm	10.0	30.4	30.4
5/16/2007	Downstream	Storm	10.0	31.4	31.4
8/16/2007	Upstream	Storm	10.0	25.3	25.3
8/16/2007	Downstream	Storm	10.0	15.0	15.0
10/24/2007	Upstream	Storm	10.0	0.0	10.0
10/24/2007	Downstream	Storm	10.0	0.0	10.0
1/29/2008	Upstream	Storm	10.0	19.3	19.3
1/29/2008	Downstream	Storm	10.0	15.6	15.6
5/20/2008	Upstream	Storm	10.0	0.0	10.0
5/20/2008	Downstream	Storm	10.0	0.0	10.0

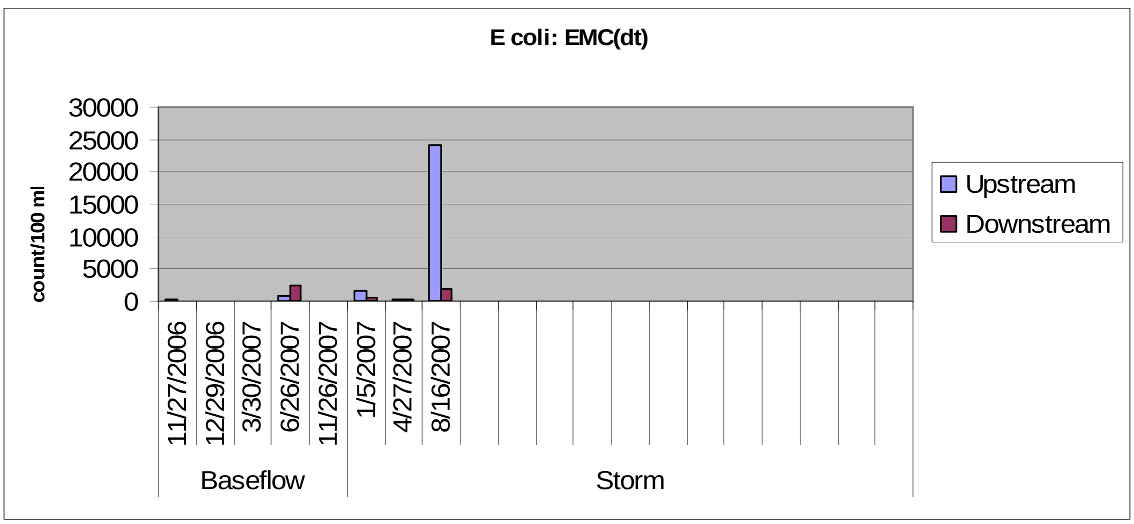

Total Copper: EMC(0)
ug/l
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


Total Copper: EMC(dt)
ug/l
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

E. coli (count/100 ml):

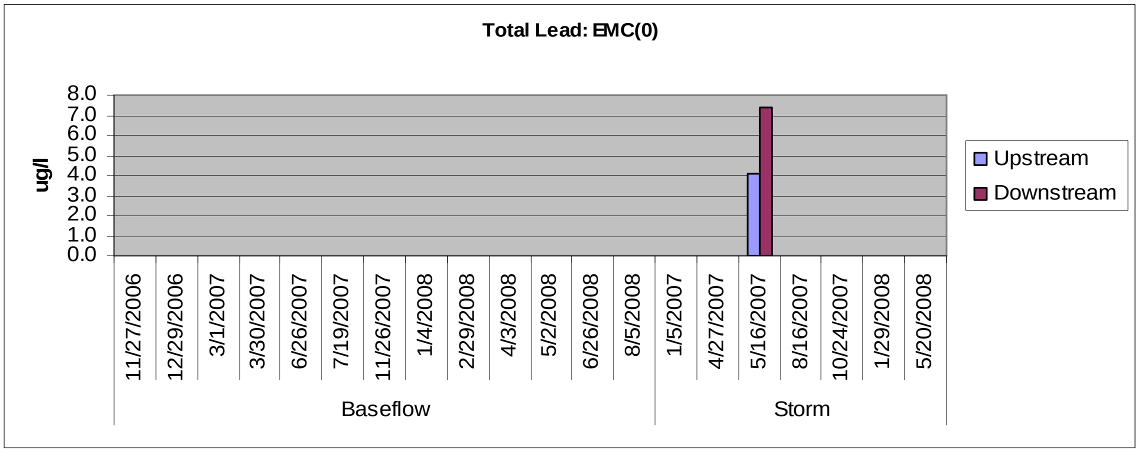
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Downstream	Baseflow	1	199	199
12/29/2006	Downstream	Baseflow	1	56	56
3/30/2007	Downstream	Baseflow	1	20	20
6/26/2007	Downstream	Baseflow	1	816	816
11/26/2007	Downstream	Baseflow	1	17	17
1/5/2007	Downstream	Storm	1	1553	1553
4/27/2007	Downstream	Storm	1	201	201
8/16/2007	Downstream	Storm	1	24190	24190
11/27/2006	Upstream	Baseflow	1	51	51
12/29/2006	Upstream	Baseflow	1	78	78
3/30/2007	Upstream	Baseflow	1	52	52
6/26/2007	Upstream	Baseflow	1	2419	2419
11/26/2007	Upstream	Baseflow	1	10	10
1/5/2007	Upstream	Storm	1	649	649
4/27/2007	Upstream	Storm	1	201	201
8/16/2007	Upstream	Storm	1	2002	2002

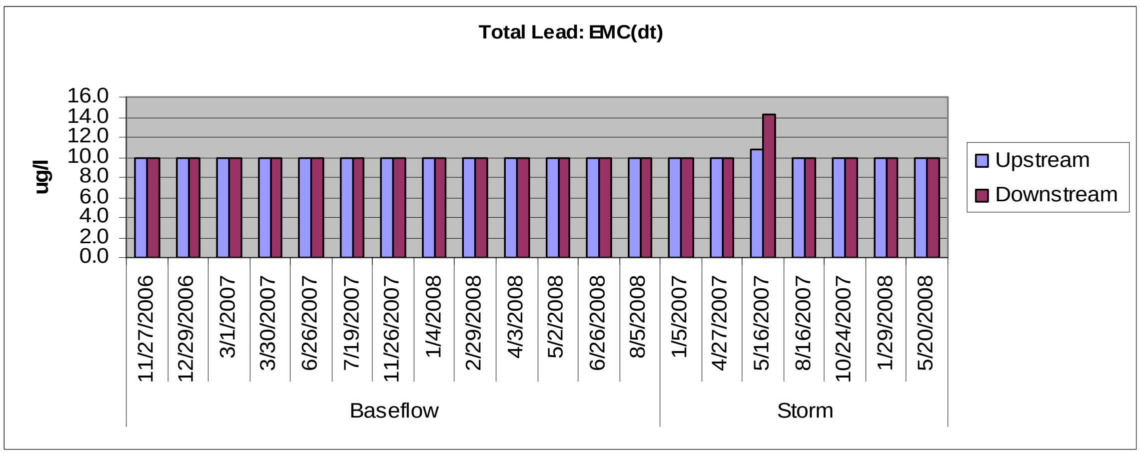

E. coli : EMC(0)
count/100 ml
30000
25000
20000
15000
10000
5000
0
11/27/2006
12/29/2006
3/30/2007
6/26/2007
11/26/2007
1/5/2007
4/27/2007
8/16/2007
Baseflow
Storm
Upstream
Downstream


E coli: EMC(dt)
count/100 ml
30000
25000
20000
15000
10000
5000
0
11/27/2006
12/29/2006
3/30/2007
6/26/2007
11/26/2007
1/5/2007
4/27/2007
8/16/2007
Baseflow
Storm
Upstream
Downstream

Total Lead (ug/l):

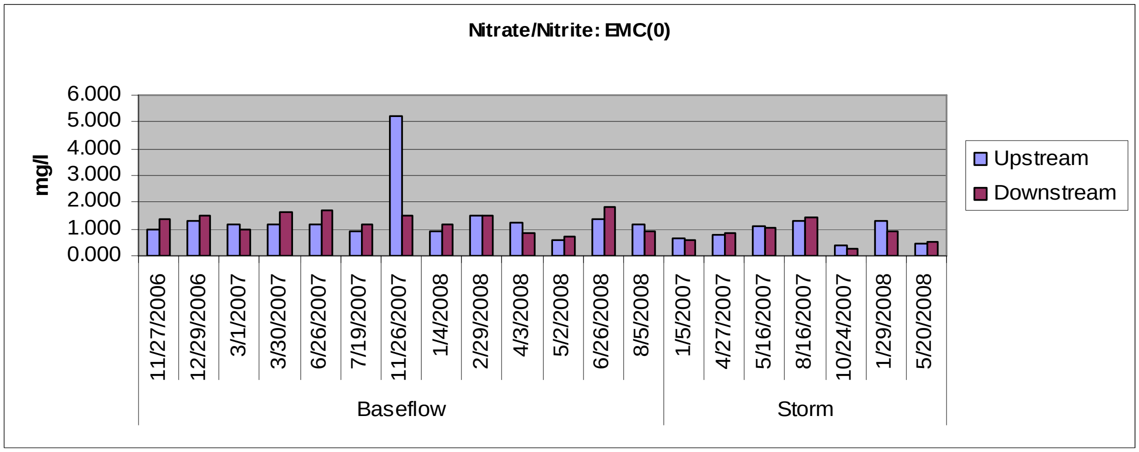
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	10.0	0.0	10.0
11/27/2006	Downstream	Baseflow	10.0	0.0	10.0
12/29/2006	Upstream	Baseflow	10.0	0.0	10.0
12/29/2006	Downstream	Baseflow	10.0	0.0	10.0
3/1/2007	Upstream	Baseflow	10.0	0.0	10.0
3/1/2007	Downstream	Baseflow	10.0	0.0	10.0
3/30/2007	Upstream	Baseflow	10.0	0.0	10.0
3/30/2007	Downstream	Baseflow	10.0	0.0	10.0
6/26/2007	Upstream	Baseflow	10.0	0.0	10.0
6/26/2007	Downstream	Baseflow	10.0	0.0	10.0
7/19/2007	Upstream	Baseflow	10.0	0.0	10.0
7/19/2007	Downstream	Baseflow	10.0	0.0	10.0
11/26/2007	Upstream	Baseflow	10.0	0.0	10.0
11/26/2007	Downstream	Baseflow	10.0	0.0	10.0
1/4/2008	Upstream	Baseflow	10.0	0.0	10.0
1/4/2008	Downstream	Baseflow	10.0	0.0	10.0
2/29/2008	Upstream	Baseflow	10.0	0.0	10.0
2/29/2008	Downstream	Baseflow	10.0	0.0	10.0
4/3/2008	Upstream	Baseflow	10.0	0.0	10.0
4/3/2008	Downstream	Baseflow	10.0	0.0	10.0
5/2/2008	Upstream	Baseflow	10.0	0.0	10.0
5/2/2008	Downstream	Baseflow	10.0	0.0	10.0
6/26/2008	Upstream	Baseflow	10.0	0.0	10.0
6/26/2008	Downstream	Baseflow	10.0	0.0	10.0
8/5/2008	Upstream	Baseflow	10.0	0.0	10.0
8/5/2008	Downstream	Baseflow	10.0	0.0	10.0
1/5/2007	Upstream	Storm	10.0	0.0	10.0
1/5/2007	Downstream	Storm	10.0	0.0	10.0
4/27/2007	Upstream	Storm	10.0	0.0	10.0
4/27/2007	Downstream	Storm	10.0	0.0	10.0
5/16/2007	Upstream	Storm	10.0	4.1	10.7
5/16/2007	Downstream	Storm	10.0	7.4	14.3
8/16/2007	Upstream	Storm	10.0	0.0	10.0
8/16/2007	Downstream	Storm	10.0	0.0	10.0
10/24/2007	Upstream	Storm	10.0	0.0	10.0
10/24/2007	Downstream	Storm	10.0	0.0	10.0
1/29/2008	Upstream	Storm	10.0	0.0	10.0
1/29/2008	Downstream	Storm	10.0	0.0	10.0
5/20/2008	Upstream	Storm	10.0	0.0	10.0
5/20/2008	Downstream	Storm	10.0	0.0	10.0

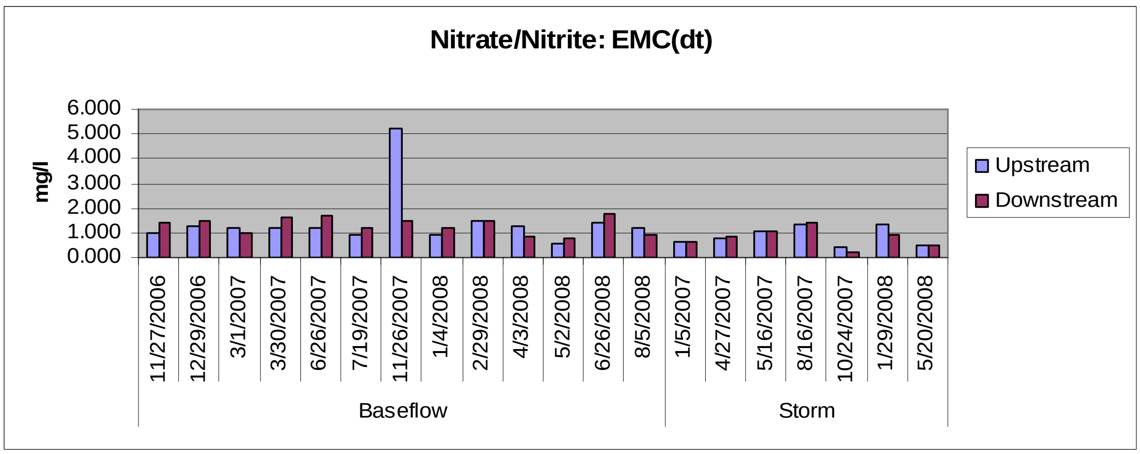

Total Lead: EMC(0)
ug/l
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm


Total Lead: EMC(dt)
ug/l
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm

Nitrate/Nitrite (mg/l):

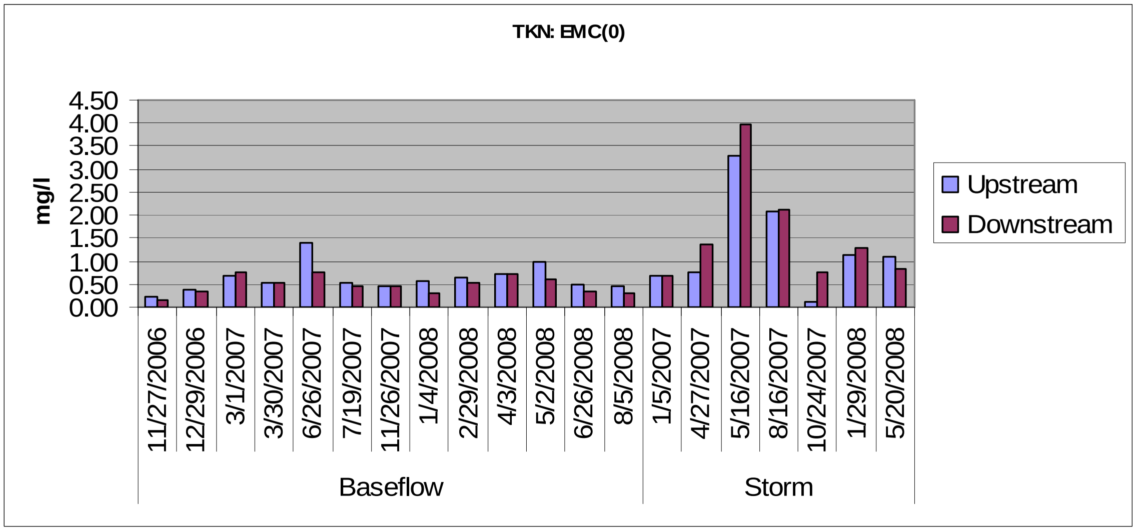
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
1/5/2007	Upstream	Storm	0.050	0.633	0.633
1/5/2007	Downstream	Storm	0.050	0.615	0.615
4/27/2007	Upstream	Storm	0.050	0.771	0.771
4/27/2007	Downstream	Storm	0.050	0.824	0.824
5/16/2007	Upstream	Storm	0.050	1.080	1.080
5/16/2007	Downstream	Storm	0.050	1.043	1.043
8/16/2007	Upstream	Storm	0.050	1.328	1.328
8/16/2007	Downstream	Storm	0.050	1.427	1.427
10/24/2007	Upstream	Storm	0.050	0.390	0.390
10/24/2007	Downstream	Storm	0.050	0.233	0.233
1/29/2008	Upstream	Storm	0.050	1.334	1.334
1/29/2008	Downstream	Storm	0.050	0.940	0.940
5/20/2008	Upstream	Storm	0.050	0.483	0.483
5/20/2008	Downstream	Storm	0.050	0.528	0.528
11/27/2006	Upstream	Baseflow	0.050	1.000	1.000
11/27/2006	Downstream	Baseflow	0.050	1.400	1.400
12/29/2006	Upstream	Baseflow	0.050	1.300	1.300
12/29/2006	Downstream	Baseflow	0.050	1.500	1.500
3/1/2007	Upstream	Baseflow	0.050	1.200	1.200
3/1/2007	Downstream	Baseflow	0.050	0.960	0.960
3/30/2007	Upstream	Baseflow	0.050	1.200	1.200
3/30/2007	Downstream	Baseflow	0.050	1.600	1.600
6/26/2007	Upstream	Baseflow	0.050	1.200	1.200
6/26/2007	Downstream	Baseflow	0.050	1.700	1.700
7/19/2007	Upstream	Baseflow	0.050	0.890	0.890
7/19/2007	Downstream	Baseflow	0.050	1.200	1.200
11/26/2007	Upstream	Baseflow	0.500	5.200	5.200
11/26/2007	Downstream	Baseflow	0.050	1.500	1.500
1/4/2008	Upstream	Baseflow	0.050	0.920	0.920
1/4/2008	Downstream	Baseflow	0.050	1.200	1.200
2/29/2008	Upstream	Baseflow	0.050	1.500	1.500
2/29/2008	Downstream	Baseflow	0.050	1.500	1.500
4/3/2008	Upstream	Baseflow	0.050	1.250	1.250
4/3/2008	Downstream	Baseflow	0.050	0.850	0.850
5/2/2008	Upstream	Baseflow	0.050	0.560	0.560
5/2/2008	Downstream	Baseflow	0.050	0.750	0.750
6/26/2008	Upstream	Baseflow	0.050	1.400	1.400
6/26/2008	Downstream	Baseflow	0.050	1.800	1.800
8/5/2008	Upstream	Baseflow	0.050	1.200	1.200
8/5/2008	Downstream	Baseflow	0.050	0.890	0.890

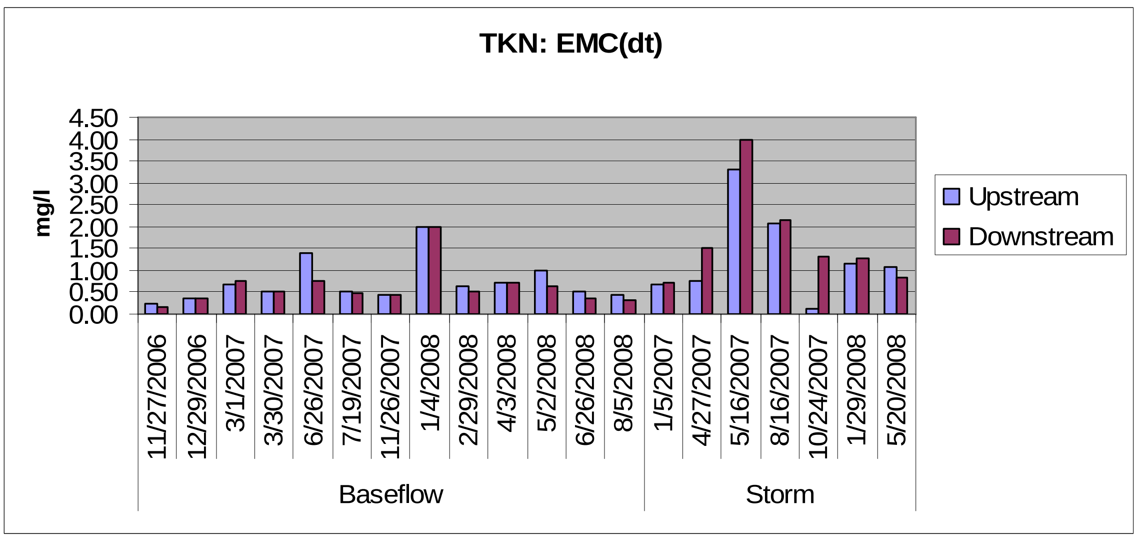

Nitrate/Nitrite: EMC(0)
mg/l
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm


Nitrate/Nitrite: EMC(dt)
mg/l
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm

TKN (mg/l):

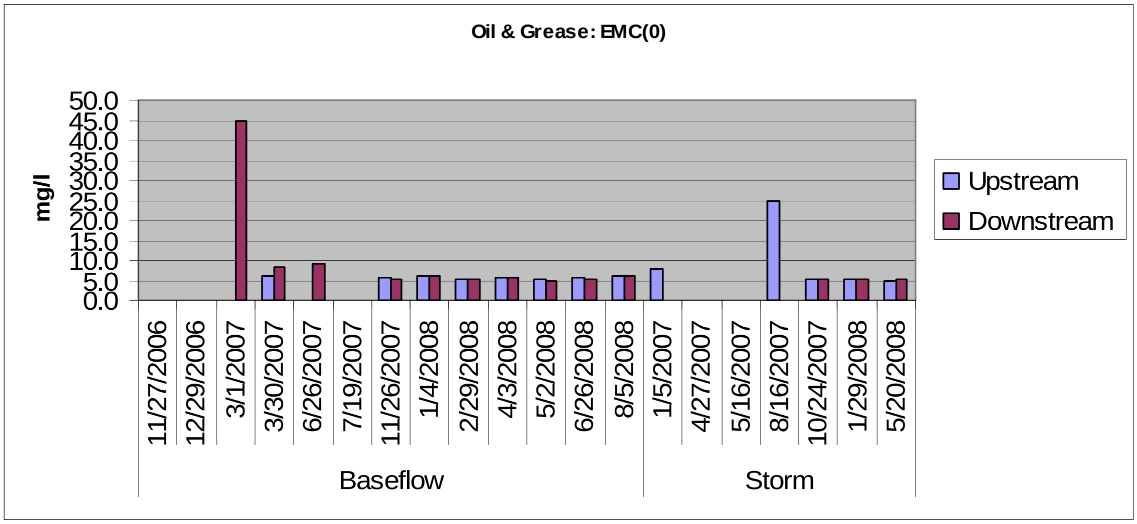
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	0.10	0.23	0.23
11/27/2006	Downstream	Baseflow	0.10	0.17	0.17
12/29/2006	Upstream	Baseflow	0.10	0.37	0.37
12/29/2006	Downstream	Baseflow	0.10	0.34	0.34
3/1/2007	Upstream	Baseflow	0.10	0.67	0.67
3/1/2007	Downstream	Baseflow	0.10	0.77	0.77
3/30/2007	Upstream	Baseflow	0.10	0.53	0.53
3/30/2007	Downstream	Baseflow	0.10	0.53	0.53
6/26/2007	Upstream	Baseflow	0.10	1.41	1.41
6/26/2007	Downstream	Baseflow	0.10	0.74	0.74
7/19/2007	Upstream	Baseflow	0.10	0.52	0.52
7/19/2007	Downstream	Baseflow	0.10	0.46	0.46
11/26/2007	Upstream	Baseflow	0.10	0.44	0.44
11/26/2007	Downstream	Baseflow	0.10	0.44	0.44
1/4/2008	Upstream	Baseflow	0.10	0.57	0.57
1/4/2008	Downstream	Baseflow	0.10	0.32	0.32
2/29/2008	Upstream	Baseflow	0.10	0.64	0.64
2/29/2008	Downstream	Baseflow	0.10	0.52	0.52
4/3/2008	Upstream	Baseflow	0.10	0.71	0.71
4/3/2008	Downstream	Baseflow	0.10	0.71	0.71
5/2/2008	Upstream	Baseflow	0.10	1.00	1.00
5/2/2008	Downstream	Baseflow	0.10	0.62	0.62
6/26/2008	Upstream	Baseflow	0.10	0.51	0.51
6/26/2008	Downstream	Baseflow	0.10	0.35	0.35
8/5/2008	Upstream	Baseflow	0.10	0.44	0.44
8/5/2008	Downstream	Baseflow	0.10	0.32	0.32
1/5/2007	Upstream	Storm	0.10	0.67	0.67
1/5/2007	Downstream	Storm	0.10	0.70	0.70
4/27/2007	Upstream	Storm	0.10	0.77	0.77
4/27/2007	Downstream	Storm	0.10	1.35	1.50
5/16/2007	Upstream	Storm	0.10	3.30	3.30
5/16/2007	Downstream	Storm	0.10	3.96	3.96
8/16/2007	Upstream	Storm	0.10	2.09	2.09
8/16/2007	Downstream	Storm	0.10	2.14	2.14
10/24/2007	Upstream	Storm	0.10	0.10	0.10
10/24/2007	Downstream	Storm	0.10	0.75	1.30
1/29/2008	Upstream	Storm	0.10	1.14	1.14
1/29/2008	Downstream	Storm	0.10	1.27	1.27
5/20/2008	Upstream	Storm	0.10	1.08	1.08
5/20/2008	Downstream	Storm	0.10	0.84	0.84


TKN: EMC(0)
mg/l
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm

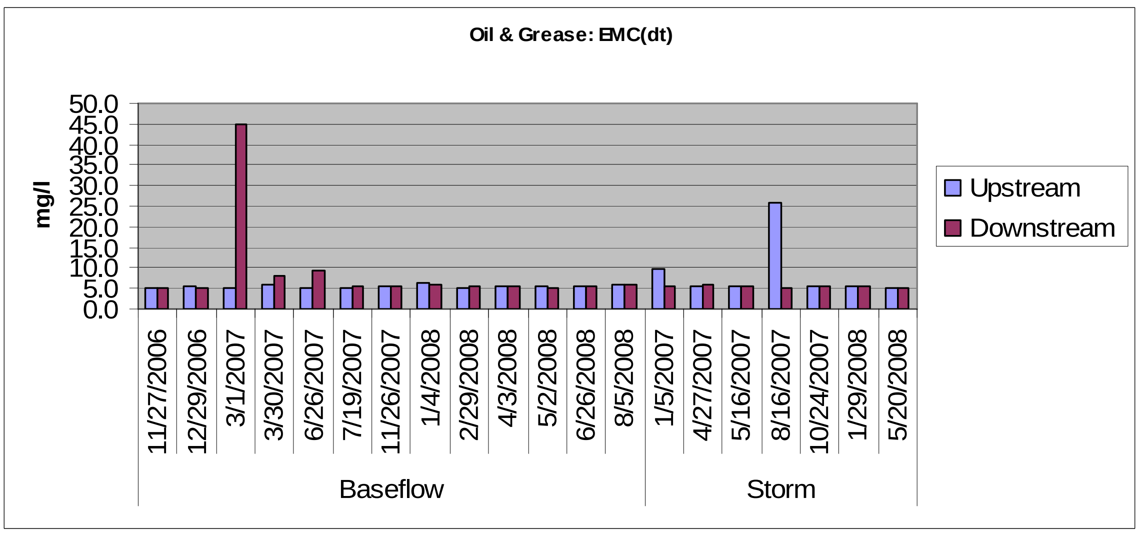

TKN: EMC(dt)
mg/l
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Upstream
Downstream
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm

Oil and Grease (mg/l):

Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	5.0	0.0	5.0
11/27/2006	Downstream	Baseflow	5.0	0.0	5.0
12/29/2006	Upstream	Baseflow	5.3	0.0	5.3
12/29/2006	Downstream	Baseflow	5.0	0.0	5.0
3/1/2007	Upstream	Baseflow	5.1	0.0	5.1
3/1/2007	Downstream	Baseflow	5.3	45.0	45.0
3/30/2007	Upstream	Baseflow	5.0	5.9	5.9
3/30/2007	Downstream	Baseflow	5.0	8.1	8.1
6/26/2007	Upstream	Baseflow	5.0	0.0	5.0
6/26/2007	Downstream	Baseflow	5.6	9.3	9.3
7/19/2007	Upstream	Baseflow	5.2	0.0	5.2
7/19/2007	Downstream	Baseflow	5.4	0.0	5.4
11/26/2007	Upstream	Baseflow	5.6	5.6	5.6
11/26/2007	Downstream	Baseflow	5.3	5.4	5.4
1/4/2008	Upstream	Baseflow	6.3	6.3	6.3
1/4/2008	Downstream	Baseflow	5.9	5.9	5.9
2/29/2008	Upstream	Baseflow	5.1	5.1	5.1
2/29/2008	Downstream	Baseflow	5.3	5.3	5.3
4/3/2008	Upstream	Baseflow	5.6	5.6	5.6
4/3/2008	Downstream	Baseflow	5.6	5.6	5.6
5/2/2008	Upstream	Baseflow	5.3	5.3	5.3
5/2/2008	Downstream	Baseflow	5.0	5.0	5.0
6/26/2008	Upstream	Baseflow	5.6	5.6	5.6
6/26/2008	Downstream	Baseflow	5.3	5.3	5.3
8/5/2008	Upstream	Baseflow	6.1	6.1	6.1
8/5/2008	Downstream	Baseflow	6.1	6.1	6.1
1/5/2007	Upstream	Storm	5.0	8.0	9.6
1/5/2007	Downstream	Storm	5.5	0.0	5.7
4/27/2007	Upstream	Storm	5.4	0.0	5.5
4/27/2007	Downstream	Storm	5.7	0.0	5.7
5/16/2007	Upstream	Storm	5.3	0.0	5.3
5/16/2007	Downstream	Storm	5.4	0.0	5.3
8/16/2007	Upstream	Storm	5.0	24.9	26.0
8/16/2007	Downstream	Storm	5.0	0.0	5.0
10/24/2007	Upstream	Storm	5.3	5.4	5.4
10/24/2007	Downstream	Storm	5.3	5.3	5.3
1/29/2008	Upstream	Storm	5.4	5.4	5.4
1/29/2008	Downstream	Storm	5.4	5.4	5.4
5/20/2008	Upstream	Storm	5.0	5.0	5.0
5/20/2008	Downstream	Storm	5.0	5.2	5.2



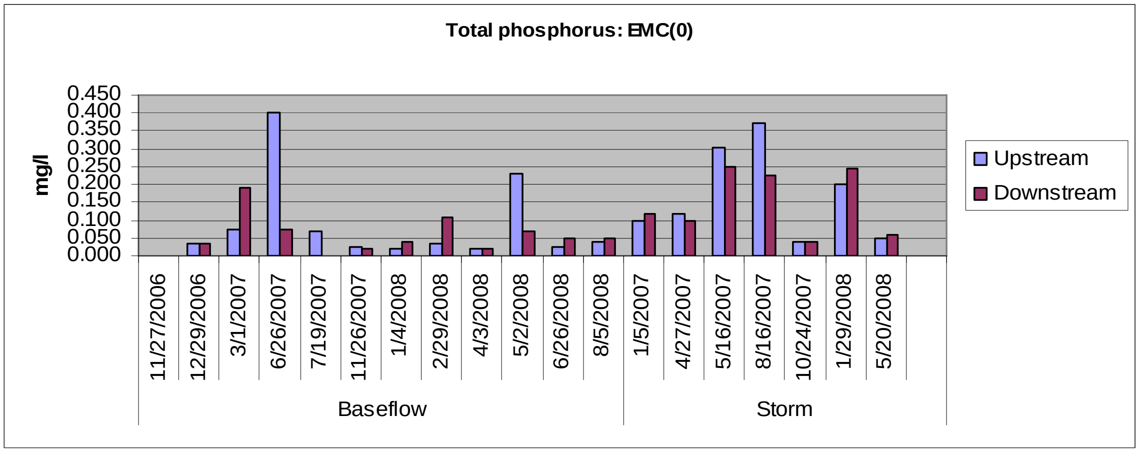
Oil & Grease: EMC(0)
mg/l
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

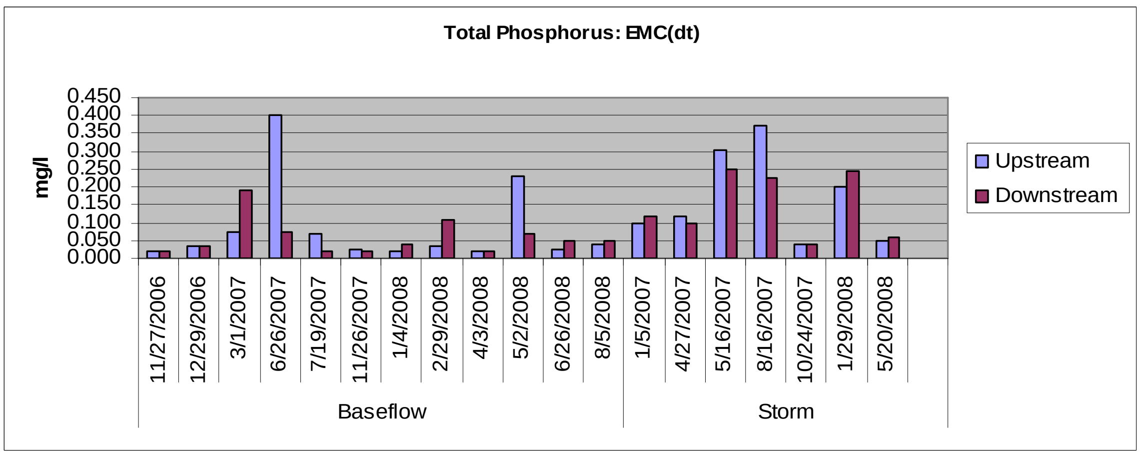


Oil & Grease: EMC(dt)
mg/l
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Total Phosphorus (mg/l):

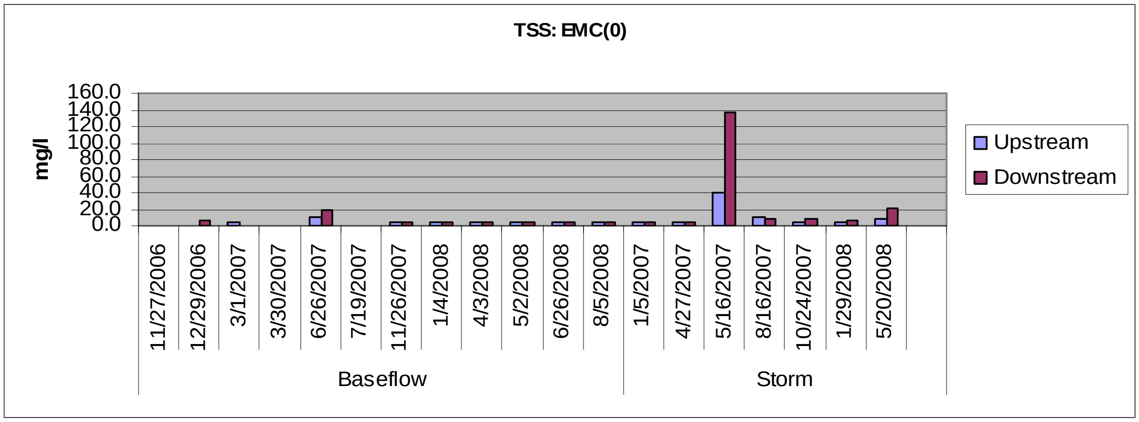
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
1/5/2007	Upstream	Storm	0.020	0.117	0.117
1/5/2007	Downstream	Storm	0.020	0.096	0.096
4/27/2007	Upstream	Storm	0.020	0.099	0.099
4/27/2007	Downstream	Storm	0.020	0.120	0.120
5/16/2007	Upstream	Storm	0.020	0.250	0.250
5/16/2007	Downstream	Storm	0.020	0.304	0.304
8/16/2007	Upstream	Storm	0.020	0.227	0.227
8/16/2007	Downstream	Storm	0.020	0.371	0.371
10/24/2007	Upstream	Storm	0.020	0.037	0.037
10/24/2007	Downstream	Storm	0.020	0.040	0.040
1/29/2008	Upstream	Storm	0.020	0.243	0.243
1/29/2008	Downstream	Storm	0.020	0.200	0.200
5/20/2008	Upstream	Storm	0.020	0.058	0.058
5/20/2008	Downstream	Storm	0.020	0.050	0.050
11/27/2006	Upstream	Baseflow	0.020	0.000	0.020
11/27/2006	Downstream	Baseflow	0.020	0.000	0.020
12/29/2006	Upstream	Baseflow	0.020	0.036	0.036
12/29/2006	Downstream	Baseflow	0.020	0.035	0.035
3/1/2007	Upstream	Baseflow	0.020	0.190	0.190
3/1/2007	Downstream	Baseflow	0.020	0.072	0.072
6/26/2007	Upstream	Baseflow	0.020	0.075	0.075
6/26/2007	Downstream	Baseflow	0.020	0.400	0.400
7/19/2007	Upstream	Baseflow	0.020	0.000	0.020
7/19/2007	Downstream	Baseflow	0.020	0.070	0.070
11/26/2007	Upstream	Baseflow	0.020	0.020	0.020
11/26/2007	Downstream	Baseflow	0.020	0.023	0.023
1/4/2008	Upstream	Baseflow	0.020	0.037	0.037
1/4/2008	Downstream	Baseflow	0.020	0.020	0.020
2/29/2008	Upstream	Baseflow	0.020	0.110	0.110
2/29/2008	Downstream	Baseflow	0.020	0.033	0.033
4/3/2008	Upstream	Baseflow	0.020	0.022	0.022
4/3/2008	Downstream	Baseflow	0.020	0.020	0.020
5/2/2008	Upstream	Baseflow	0.020	0.068	0.068
5/2/2008	Downstream	Baseflow	0.020	0.230	0.230
6/26/2008	Upstream	Baseflow	0.020	0.049	0.049
6/26/2008	Downstream	Baseflow	0.020	0.025	0.025
8/5/2008	Upstream	Baseflow	0.020	0.048	0.048
8/5/2008	Downstream	Baseflow	0.020	0.040	0.040

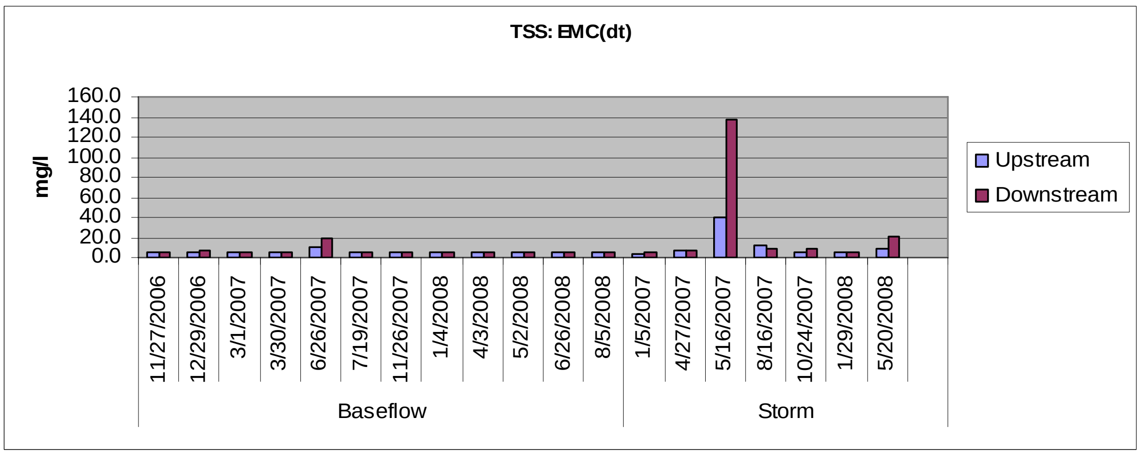

Total phosphorus: EMC(0)
mg/l
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
11/27/2006
12/29/2006
3/1/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


Total Phosphorus: EMC(dt)
mg/l
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
11/27/2006
12/29/2006
3/1/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Total suspended solids (mg/l):

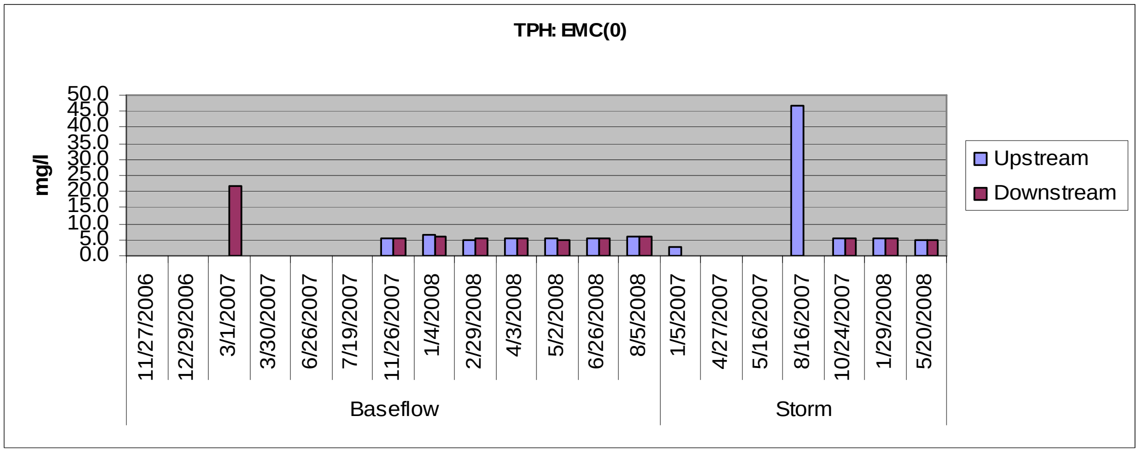
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	5.0	0.0	5.0
11/27/2006	Downstream	Baseflow	5.0	0.0	5.0
12/29/2006	Upstream	Baseflow	5.0	0.0	5.0
12/29/2006	Downstream	Baseflow	5.0	7.0	7.0
3/1/2007	Upstream	Baseflow	5.0	5.0	5.0
3/1/2007	Downstream	Baseflow	5.0	0.0	5.0
3/30/2007	Upstream	Baseflow	5.0	0.0	5.0
3/30/2007	Downstream	Baseflow	5.0	0.0	5.0
6/26/2007	Upstream	Baseflow	5.0	10.0	10.0
6/26/2007	Downstream	Baseflow	5.0	19.0	19.0
7/19/2007	Upstream	Baseflow	5.0	0.0	5.0
7/19/2007	Downstream	Baseflow	5.0	0.0	5.0
11/26/2007	Upstream	Baseflow	5.0	5.0	5.0
11/26/2007	Downstream	Baseflow	5.0	5.0	5.0
1/4/2008	Upstream	Baseflow	5.0	5.0	5.0
1/4/2008	Downstream	Baseflow	5.0	5.0	5.0
4/3/2008	Upstream	Baseflow	5.0	5.0	5.0
4/3/2008	Downstream	Baseflow	5.0	5.0	5.0
5/2/2008	Upstream	Baseflow	5.0	5.0	5.0
5/2/2008	Downstream	Baseflow	5.0	5.0	5.0
6/26/2008	Upstream	Baseflow	5.0	5.0	5.0
6/26/2008	Downstream	Baseflow	5.0	5.0	5.0
8/5/2008	Upstream	Baseflow	5.0	5.0	5.0
8/5/2008	Downstream	Baseflow	5.0	5.0	5.0
1/5/2007	Upstream	Storm	5.0	3.5	6.0
1/5/2007	Downstream	Storm	5.0	4.5	4.5
4/27/2007	Upstream	Storm	5.1	3.8	6.3
4/27/2007	Downstream	Storm	5.0	5.1	6.5
5/16/2007	Upstream	Storm	5.0	39.7	39.7
5/16/2007	Downstream	Storm	5.0	137.4	137.4
8/16/2007	Upstream	Storm	5.0	11.5	11.5
8/16/2007	Downstream	Storm	5.0	9.1	9.1
10/24/2007	Upstream	Storm	5.0	5.0	5.0
10/24/2007	Downstream	Storm	5.0	9.0	9.0
1/29/2008	Upstream	Storm	5.0	5.0	5.0
1/29/2008	Downstream	Storm	5.0	6.0	6.0
5/20/2008	Upstream	Storm	5.0	8.0	8.0
5/20/2008	Downstream	Storm	5.0	21.4	21.4

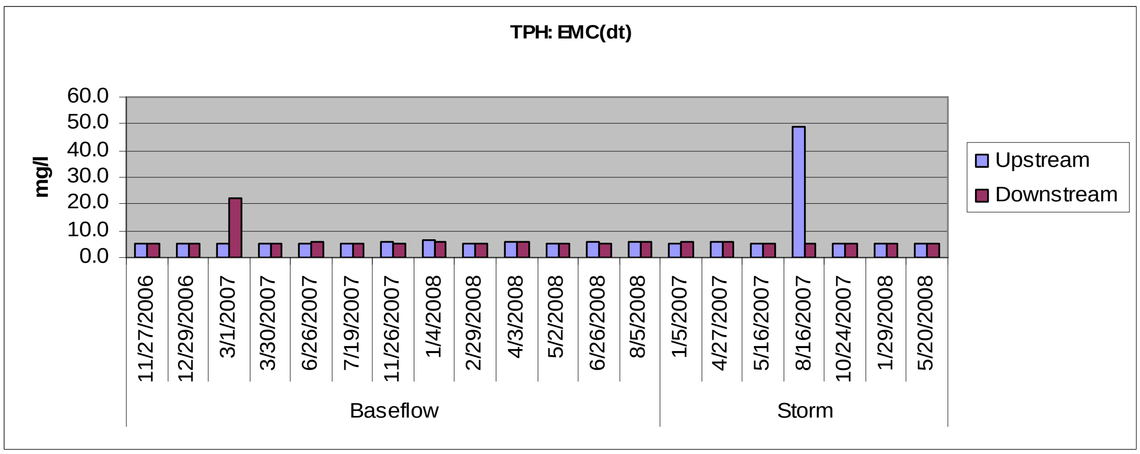

TSS: EMC(0)
mg/l
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


TSS: EMC(dt)
mg/l
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

TPH (mg/l):

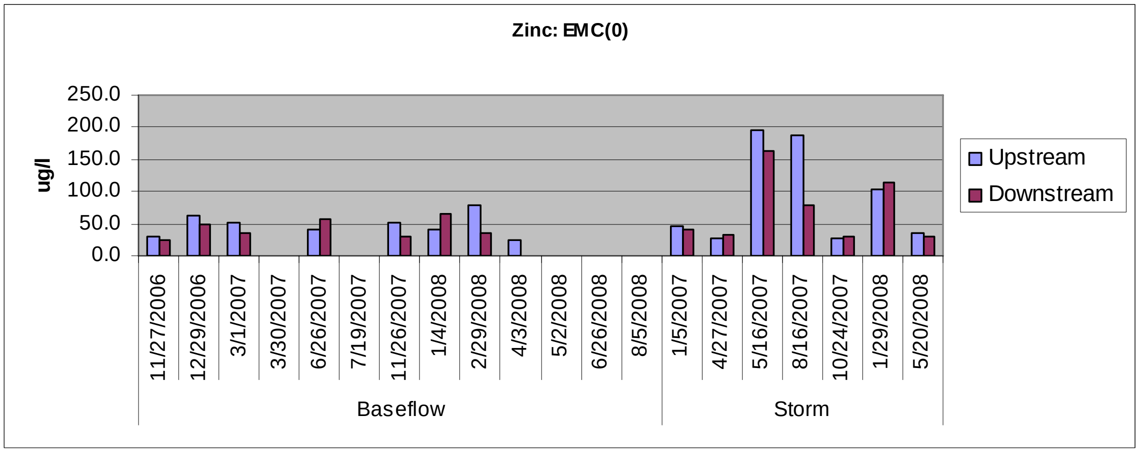
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	5.0	0.0	5.0
11/27/2006	Downstream	Baseflow	5.0	0.0	5.0
12/29/2006	Upstream	Baseflow	5.3	0.0	5.3
12/29/2006	Downstream	Baseflow	5.0	0.0	5.0
3/1/2007	Upstream	Baseflow	5.3	0.0	5.3
3/1/2007	Downstream	Baseflow	5.1	22.0	22.0
3/30/2007	Upstream	Baseflow	5.0	0.0	5.0
3/30/2007	Downstream	Baseflow	5.0	0.0	5.0
6/26/2007	Upstream	Baseflow	5.0	0.0	5.0
6/26/2007	Downstream	Baseflow	5.6	0.0	5.6
7/19/2007	Upstream	Baseflow	5.2	0.0	5.2
7/19/2007	Downstream	Baseflow	5.4	0.0	5.4
11/26/2007	Upstream	Baseflow	5.6	5.6	5.6
11/26/2007	Downstream	Baseflow	5.3	5.3	5.3
1/4/2008	Upstream	Baseflow	6.3	6.3	6.3
1/4/2008	Downstream	Baseflow	5.9	5.9	5.9
2/29/2008	Upstream	Baseflow	5.1	5.1	5.1
2/29/2008	Downstream	Baseflow	5.3	5.3	5.3
4/3/2008	Upstream	Baseflow	5.6	5.6	5.6
4/3/2008	Downstream	Baseflow	5.6	5.6	5.6
5/2/2008	Upstream	Baseflow	5.3	5.3	5.3
5/2/2008	Downstream	Baseflow	5.0	5.0	5.0
6/26/2008	Upstream	Baseflow	5.6	5.6	5.6
6/26/2008	Downstream	Baseflow	5.3	5.3	5.3
8/5/2008	Upstream	Baseflow	6.1	6.1	6.1
8/5/2008	Downstream	Baseflow	6.1	6.1	6.1
1/5/2007	Upstream	Storm	5.0	2.7	5.5
1/5/2007	Downstream	Storm	5.5	0.0	5.7
4/27/2007	Upstream	Storm	5.5	0.0	5.6
4/27/2007	Downstream	Storm	5.7	0.0	5.7
5/16/2007	Upstream	Storm	5.3	0.0	5.3
5/16/2007	Downstream	Storm	5.3	0.0	5.3
8/16/2007	Upstream	Storm	5.0	46.5	49.0
8/16/2007	Downstream	Storm	5.0	0.0	5.0
10/24/2007	Upstream	Storm	5.3	5.4	5.4
10/24/2007	Downstream	Storm	5.3	5.3	5.3
1/29/2008	Upstream	Storm	5.4	5.4	5.4
1/29/2008	Downstream	Storm	5.4	5.4	5.4
5/20/2008	Upstream	Storm	5.0	5.0	5.0
5/20/2008	Downstream	Storm	5.1	5.2	5.2

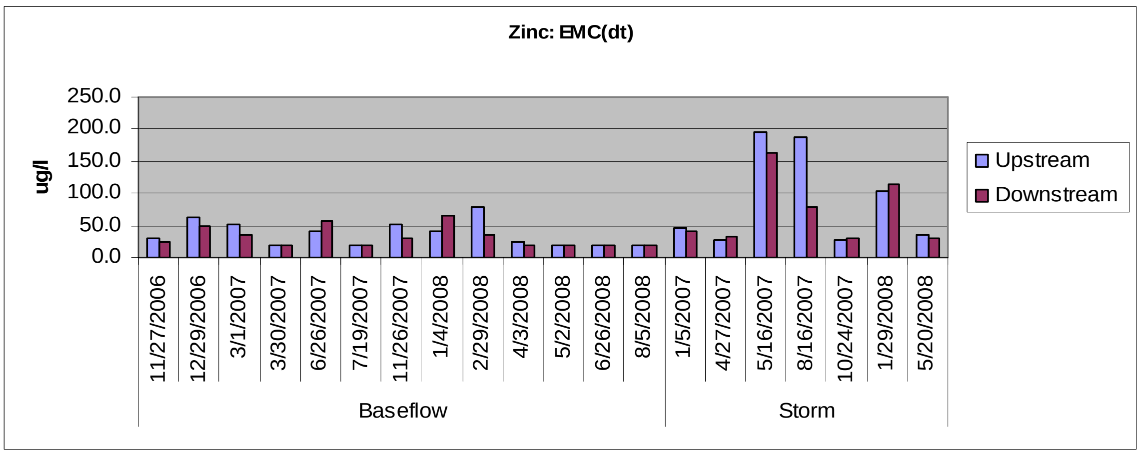

TPH: EMC(0)
mg/l
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


TPH: EMC(dt)
mg/l
60.0
50.0
40.0
30.0
20.0
10.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Zinc (ug/l):

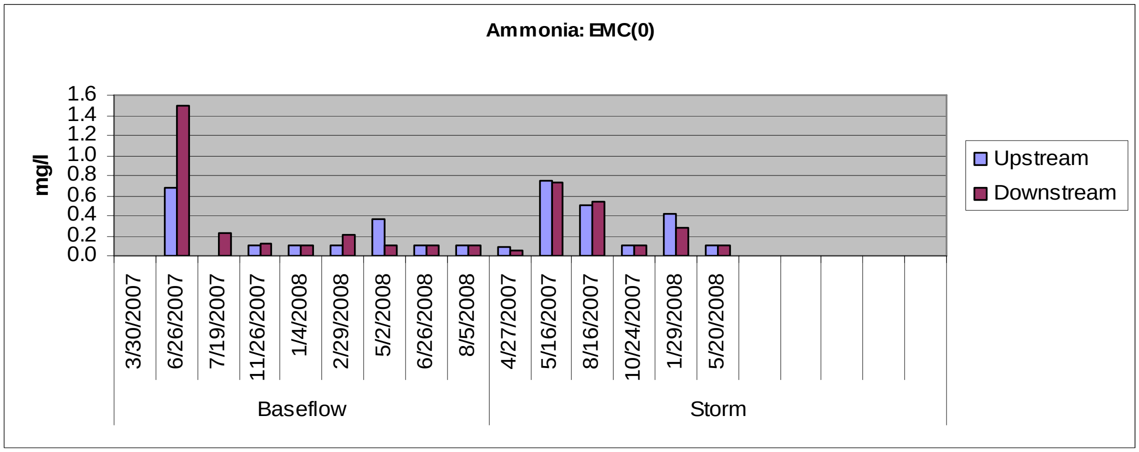
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
11/27/2006	Upstream	Baseflow	20.0	29.3	29.3
11/27/2006	Downstream	Baseflow	20.0	24.8	24.8
12/29/2006	Upstream	Baseflow	20.0	62.4	62.4
12/29/2006	Downstream	Baseflow	20.0	48.1	48.1
3/1/2007	Upstream	Baseflow	20.0	50.95	50.95
3/1/2007	Downstream	Baseflow	20.0	36.3	36.3
3/30/2007	Upstream	Baseflow	20.0	20.0	20.0
3/30/2007	Downstream	Baseflow	20.0	0.0	20.0
6/26/2007	Upstream	Baseflow	20.0	40.7	40.7
6/26/2007	Downstream	Baseflow	20.0	57.3	57.3
7/19/2007	Upstream	Baseflow	20.0	0.0	20.0
7/19/2007	Downstream	Baseflow	20.0	0.0	20.0
11/26/2007	Upstream	Baseflow	20.0	50.3	50.3
11/26/2007	Downstream	Baseflow	20.0	30.6	30.6
1/4/2008	Upstream	Baseflow	20.0	39.8	39.8
1/4/2008	Downstream	Baseflow	20.0	65.3	65.3
2/29/2008	Upstream	Baseflow	20.0	78.7	78.7
2/29/2008	Downstream	Baseflow	20.0	34.6	34.6
4/3/2008	Upstream	Baseflow	20.0	23.8	23.8
4/3/2008	Downstream	Baseflow	20.0	0.0	20.0
5/2/2008	Upstream	Baseflow	20.0	0.0	20.0
5/2/2008	Downstream	Baseflow	20.0	0.0	20.0
6/26/2008	Upstream	Baseflow	20.0	0.0	20.0
6/26/2008	Downstream	Baseflow	20.0	0.0	20.0
8/5/2008	Upstream	Baseflow	20.0	0.0	20.0
8/5/2008	Downstream	Baseflow	20.0	0.0	20.0
1/5/2007	Upstream	Storm	20.0	46.3	46.3
1/5/2007	Downstream	Storm	20.0	41.7	41.7
4/27/2007	Upstream	Storm	20.0	28.4	28.4
4/27/2007	Downstream	Storm	20.0	32.3	32.3
5/16/2007	Upstream	Storm	20.0	194.8	194.8
5/16/2007	Downstream	Storm	20.0	161.7	161.7
8/16/2007	Upstream	Storm	20.0	187.3	187.3
8/16/2007	Downstream	Storm	20.0	80.2	80.2
10/24/2007	Upstream	Storm	20.0	26.8	26.8
10/24/2007	Downstream	Storm	20.0	28.7	28.7
1/29/2008	Upstream	Storm	20.0	102.5	102.5
1/29/2008	Downstream	Storm	20.0	114.9	114.9
5/20/2008	Upstream	Storm	20.0	35.0	35.0
5/20/2008	Downstream	Storm	20.0	28.6	28.6

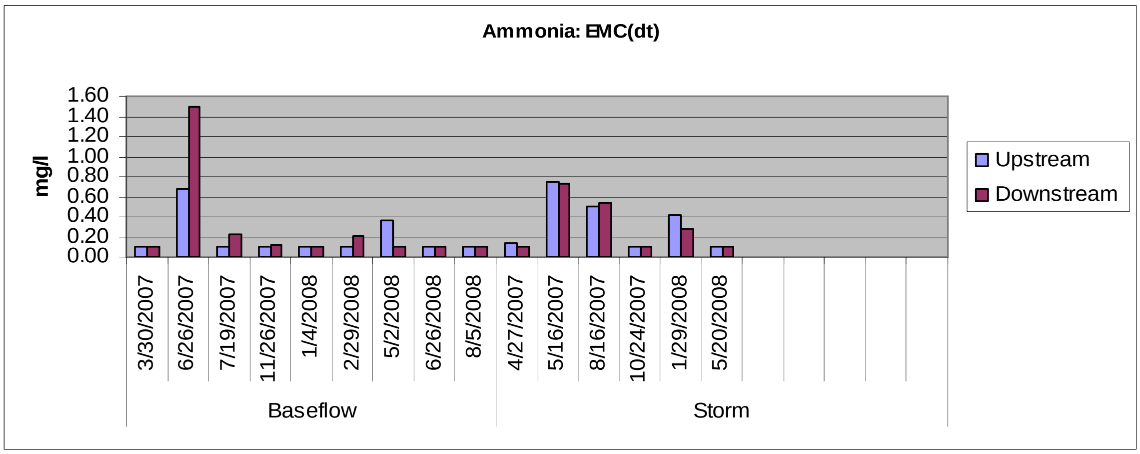

Zinc: EMC(0)
ug/l
250.0
200.0
150.0
100.0
50.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


Zinc: EMC(dt)
ug/l
250.0
200.0
150.0
100.0
50.0
0.0
11/27/2006
12/29/2006
3/1/2007
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
1/5/2007
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Ammonia (mg/l)

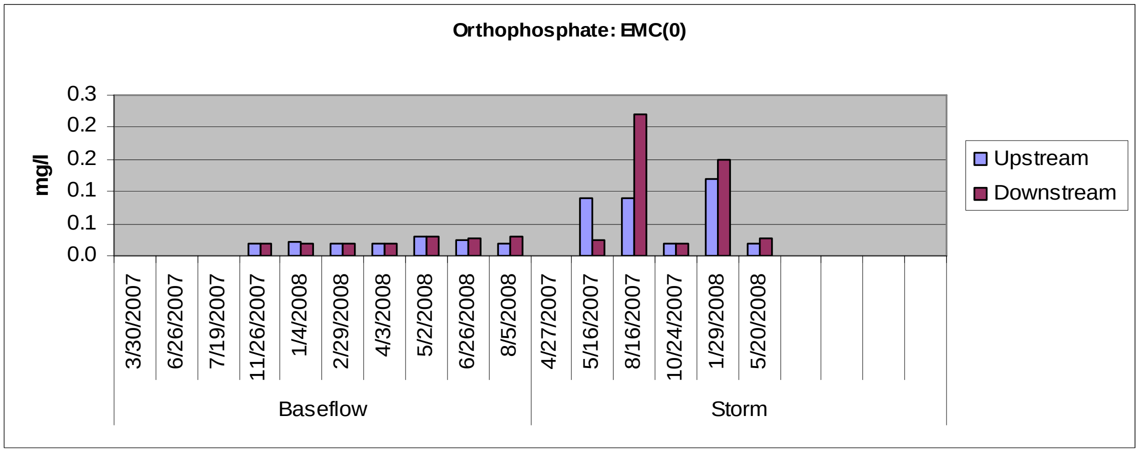
Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
3/30/2007	Upstream	Baseflow	0.10	0.00	0.10
3/30/2007	Downstream	Baseflow	0.10	0.00	0.10
6/26/2007	Upstream	Baseflow	0.10	1.50	1.50
6/26/2007	Downstream	Baseflow	0.10	0.68	0.68
7/19/2007	Upstream	Baseflow	0.10	0.23	0.23
7/19/2007	Downstream	Baseflow	0.10	0.00	0.10
11/26/2007	Upstream	Baseflow	0.10	0.13	0.13
11/26/2007	Downstream	Baseflow	0.10	0.10	0.10
1/4/2008	Upstream	Baseflow	0.10	0.10	0.10
1/4/2008	Downstream	Baseflow	0.10	0.10	0.10
2/29/2008	Upstream	Baseflow	0.10	0.21	0.21
2/29/2008	Downstream	Baseflow	0.10	0.10	0.10
5/2/2008	Upstream	Baseflow	0.10	0.10	0.10
5/2/2008	Downstream	Baseflow	0.10	0.36	0.36
6/26/2008	Upstream	Baseflow	0.10	0.10	0.10
6/26/2008	Downstream	Baseflow	0.10	0.10	0.10
8/5/2008	Upstream	Baseflow	0.10	0.10	0.10
8/5/2008	Downstream	Baseflow	0.10	0.10	0.10
4/27/2007	Upstream	Storm	0.10	0.06	0.11
4/27/2007	Downstream	Storm	0.10	0.09	0.14
5/16/2007	Upstream	Storm	0.10	0.73	0.73
5/16/2007	Downstream	Storm	0.10	0.74	0.74
8/16/2007	Upstream	Storm	0.10	0.54	0.54
8/16/2007	Downstream	Storm	0.10	0.50	0.50
10/24/2007	Upstream	Storm	0.10	0.10	0.10
10/24/2007	Downstream	Storm	0.10	0.10	0.10
1/29/2008	Upstream	Storm	0.10	0.27	0.27
1/29/2008	Downstream	Storm	0.10	0.41	0.41
5/20/2008	Upstream	Storm	0.10	0.10	0.10
5/20/2008	Downstream	Storm	0.10	0.10	0.10

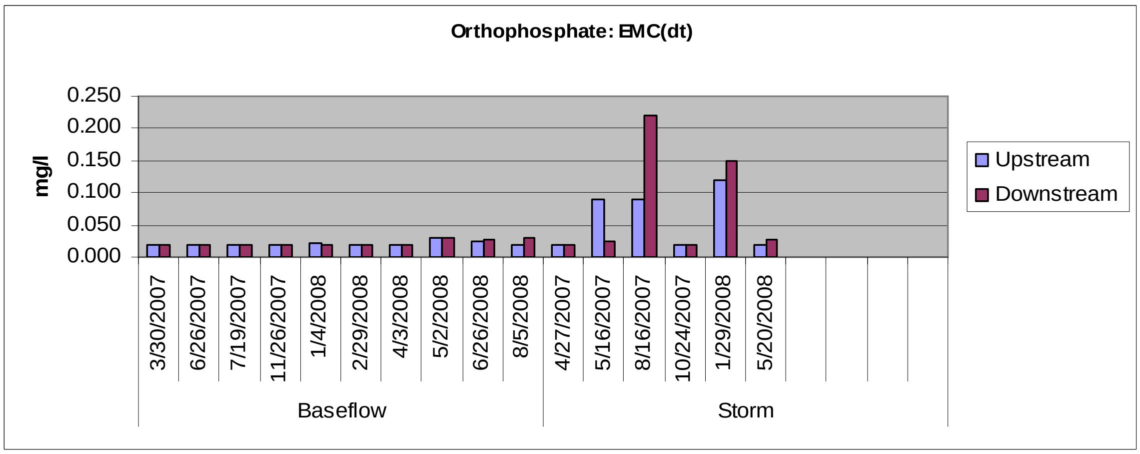

Ammonia: EMC(0)
mg/l
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
5/2/2008
6/26/2008
8/5/2008
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream


Ammonia: EMC(dt)
mg/l
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
5/2/2008
6/26/2008
8/5/2008
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm
Upstream
Downstream

Orthophosphate (mg/l):

Date	Station Name	Storm/Baseflow	dt	EMC(0)	EMC(dt)
3/30/2007	Upstream	Baseflow	0.020	0.000	0.020
3/30/2007	Downstream	Baseflow	0.020	0.000	0.020
6/26/2007	Upstream	Baseflow	0.020	0.000	0.020
6/26/2007	Downstream	Baseflow	0.020	0.000	0.020
7/19/2007	Upstream	Baseflow	0.020	0.000	0.020
7/19/2007	Downstream	Baseflow	0.020	0.000	0.020
11/26/2007	Upstream	Baseflow	0.020	0.020	0.020
11/26/2007	Downstream	Baseflow	0.020	0.020	0.020
1/4/2008	Upstream	Baseflow	0.020	0.021	0.021
1/4/2008	Downstream	Baseflow	0.020	0.020	0.020
2/29/2008	Upstream	Baseflow	0.020	0.020	0.020
2/29/2008	Downstream	Baseflow	0.020	0.020	0.020
4/3/2008	Upstream	Baseflow	0.020	0.020	0.020
4/3/2008	Downstream	Baseflow	0.020	0.020	0.020
5/2/2008	Upstream	Baseflow	0.030	0.030	0.030
5/2/2008	Downstream	Baseflow	0.030	0.030	0.030
6/26/2008	Upstream	Baseflow	0.020	0.024	0.024
6/26/2008	Downstream	Baseflow	0.020	0.027	0.027
8/5/2008	Upstream	Baseflow	0.020	0.020	0.020
8/5/2008	Downstream	Baseflow	0.020	0.031	0.031
4/27/2007	Upstream	Storm	0.020	0.000	0.020
4/27/2007	Downstream	Storm	0.020	0.000	0.020
5/16/2007	Upstream	Storm	0.020	0.089	0.089
5/16/2007	Downstream	Storm	0.020	0.025	0.035
8/16/2007	Upstream	Storm	0.020	0.089	0.089
8/16/2007	Downstream	Storm	0.020	0.221	0.221
10/24/2007	Upstream	Storm	0.020	0.020	0.020
10/24/2007	Downstream	Storm	0.020	0.020	0.020
1/29/2008	Upstream	Storm	0.020	0.120	0.120
1/29/2008	Downstream	Storm	0.020	0.150	0.150
5/20/2008	Upstream	Storm	0.020	0.020	0.020
5/20/2008	Downstream	Storm	0.020	0.026	0.026


Orthophosphate: EMC(0)
mg/l
0.3
0.2
0.2
0.1
0.1
0.0
Upstream
Downstream
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm


Orthophosphate: EMC(dt)
mg/l
0.250
0.200
0.150
0.100
0.050
0.000
Upstream
Downstream
3/30/2007
6/26/2007
7/19/2007
11/26/2007
1/4/2008
2/29/2008
4/3/2008
5/2/2008
6/26/2008
8/5/2008
4/27/2007
5/16/2007
8/16/2007
10/24/2007
1/29/2008
5/20/2008
Baseflow
Storm

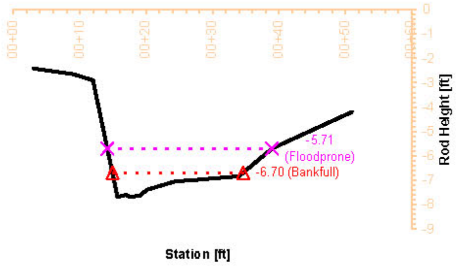
APPENDIX B:

Physical Monitoring Field Data Sheets

Site 1

Long Draught

Site 1-Riffle (Sta. 15.8)



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Results		Classification Possibilities
max depth:	0.99 ft	
avg depth:	0.46 ft	
entrenchment:	1.26	A, F, G
width/depth ratio:	42.50	D
hydraulic radius:	0.45 ft	
bankfull discharge:	19.94 ft³/s	
floodprone discharge:	130.90 ft³/s	
avg. velocity	2.19 ft/s	
slope	0.81%	D, C, E, F
Sinuosity	1.09	A
Avg. shear stress at bankfull stage:	0.228 lb/ft²	
Most Probable Classification ➔		**F** 4

Benchmark		Bankfull	-6.70	Floodprone	-5.71
Elevation		Rod Height [ft]	6.70	Rod Height [ft]	
Benchmark		channel slope	0.81%		
Rod Height		manning's 'n'	0.036		

			Bankfull			Floodprone		
Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
Total			**20.23 ft**	**9.11 ft²**	**19.68 ft**	**25.94 ft**	**31.12 ft²**	**24.79 ft**
3.00	2.42	-2.42	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
9.00	2.65	-2.65	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
12.00	2.90	-2.90	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
15.70	7.69	**-7.69**	1.25 ft	0.38 ft²	0.76 ft	2.50 ft	1.51 ft²	1.53 ft
17.00	7.60	**-7.60**	1.30 ft	1.23 ft²	1.30 ft	1.30 ft	2.52 ft²	1.30 ft
17.50	7.68	**-7.68**	0.51 ft	0.47 ft²	0.50 ft	0.51 ft	0.97 ft²	0.50 ft
19.00	7.64	**-7.64**	1.50 ft	1.44 ft²	1.50 ft	1.50 ft	2.93 ft²	1.50 ft
20.20	7.39	**-7.39**	1.23 ft	0.98 ft²	1.20 ft	1.23 ft	2.17 ft²	1.20 ft
24.40	7.05	**-7.05**	4.21 ft	2.18 ft²	4.20 ft	4.21 ft	6.34 ft²	4.20 ft
27.50	6.99	**-6.99**	3.10 ft	0.99 ft²	3.10 ft	3.10 ft	4.06 ft²	3.10 ft
34.00	6.84	**-6.84**	6.50 ft	1.40 ft²	6.50 ft	6.50 ft	7.83 ft²	6.50 ft
39.00	5.70	-5.70	0.63 ft	0.04 ft²	0.61 ft	5.08 ft	2.80 ft²	4.96 ft
51.00	4.20	-4.20	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 1-Riffle (Sta. 65.4)

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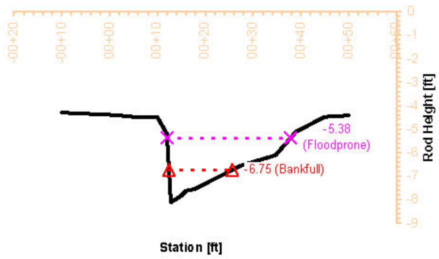


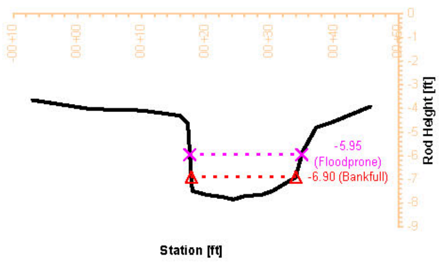
	Results	Classification Possibilities
max depth:	1.37 ft	
avg depth:	0.65 ft	
entrenchment	1.95	B
width/depth ratio:	20.31	B, C, F
hydraulic radius:	0.60 ft	
bankfull discharge:	**22.79 ft³/s**	
floodprone discharge:	**168.61 ft³/s**	
avg. velocity	2.65 ft/s	
slope	0.81%	D, C, E, F
Sinuosity	1.09	A
Avg. shear stress at bankfull stage:	0.303 lb/ft²	
Most Probable Classification ➔	**F**	4

Benchmark		Bankfull	-6.75	Floodprone	-5.38
Elevation		Rod Height [ft]	6.75	Rod Height [ft]	
Benchmark		channel slope	0.81%		
Rod Height		manning's 'n'	0.036		

				Bankfull			Floodprone		
	Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
Total				**14.35 ft**	**8.60 ft²**	**13.22 ft**	**28.11 ft**	**37.41 ft²**	**25.83 ft**
	-10.00	4.30	-4.30	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	1.00	4.40	-4.40	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	6.00	4.50	-4.50	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	10.00	4.50	-4.50	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	12.00	5.20	-5.20	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	12.80	8.12	**-8.12**	1.42 ft	0.26 ft²	0.38 ft	2.84 ft	1.03 ft²	0.75 ft
	15.00	7.84	**-7.84**	2.22 ft	2.71 ft²	2.20 ft	2.22 ft	5.72 ft²	2.20 ft
	16.00	7.63	**-7.63**	1.02 ft	0.99 ft²	1.00 ft	1.02 ft	2.36 ft²	1.00 ft
	17.70	7.56	**-7.56**	1.70 ft	1.44 ft²	1.70 ft	1.70 ft	3.77 ft²	1.70 ft
	23.00	7.02	**-7.02**	5.33 ft	2.86 ft²	5.30 ft	5.33 ft	10.12 ft²	5.30 ft
	27.60	6.55	-6.55	2.66 ft	0.36 ft²	2.64 ft	4.62 ft	6.46 ft²	4.60 ft
	34.70	6.12	-6.12	0.00 ft	0.00 ft²	0.00 ft	7.11 ft	6.78 ft²	7.10 ft
	39.00	5.12	-5.12	0.00 ft	0.00 ft²	0.00 ft	3.27 ft	1.18 ft²	3.18 ft
	45.00	4.48	-4.48	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	50.00	4.42	-4.42	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught

Site 1-Pool



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Results		*Classification Possibilities*
max depth:	0.95 ft	
avg depth:	0.67 ft	
entrenchment:	1.07	*A, F, G*
width/depth ratio:	24.31	*B, C, F*
hydraulic radius:	0.65 ft	
bankfull discharge:	**30.28 ft³/s**	
floodprone discharge:	**125.61 ft³/s**	
avg. velocity	2.79 ft/s	
slope	0.81%	*D, C, E, F*
Sinuosity	1.09	*A*
Avg. shear stress at bankfull stage:	0.327 lb/ft²	
Most Probable Classification →		4

Benchmark		*Bankfull*	-6.90	Floodprone	-5.95
Elevation		*Rod Height [ft]*	6.90	Rod Height [ft]	
Benchmark		*channel slope*	0.81%		
Rod Height		*manning's 'n'*	0.036		

				Bankfull			***Floodprone***	
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
Total			***16.79 ft***	***10.87 ft²***	***16.25 ft***	***19.13 ft***	***26.88 ft²***	***17.45 ft***
-7.00	3.65	-3.65	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
2.00	4.03	-4.03	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
10.00	4.09	-4.09	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
16.00	4.31	-4.31	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
17.20	4.62	-4.62	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
17.90	7.49	**-7.49**	0.61 ft	0.04 ft²	0.14 ft	1.59 ft	0.29 ft²	0.38 ft
20.20	7.66	**-7.66**	2.31 ft	1.55 ft²	2.30 ft	2.31 ft	3.74 ft²	2.30 ft
22.50	7.74	**-7.74**	2.30 ft	1.84 ft²	2.30 ft	2.30 ft	4.03 ft²	2.30 ft
24.30	7.85	**-7.85**	1.80 ft	1.61 ft²	1.80 ft	1.80 ft	3.32 ft²	1.80 ft
26.00	7.71	**-7.71**	1.71 ft	1.50 ft²	1.70 ft	1.71 ft	3.11 ft²	1.70 ft
28.70	7.65	**-7.65**	2.70 ft	2.11 ft²	2.70 ft	2.70 ft	4.67 ft²	2.70 ft
30.40	7.49	**-7.49**	1.71 ft	1.14 ft²	1.70 ft	1.71 ft	2.75 ft²	1.70 ft
34.00	6.91	**-6.91**	3.65 ft	1.08 ft²	3.60 ft	3.65 ft	4.50 ft²	3.60 ft
35.10	5.83	-5.83	0.01 ft	0.00 ft²	0.01 ft	1.37 ft	0.47 ft²	0.98 ft
37.20	4.80	-4.80	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
39.60	4.59	-4.59	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
45.60	3.93	-3.93	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 1

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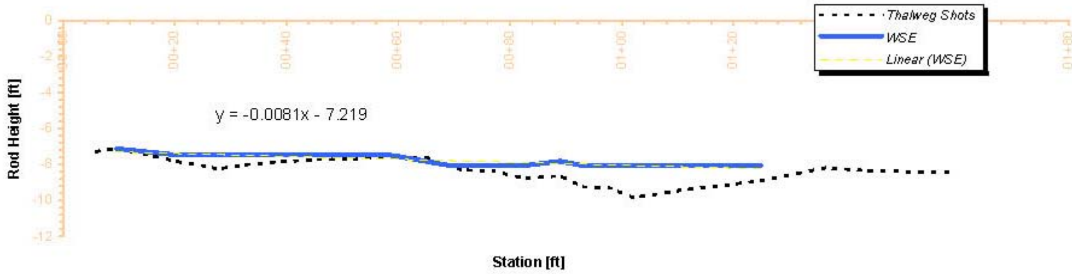

Benchmark Elevation	
Benchmark Rod Height	

Station [ft]	Rod Height [ft]		Bankfull RH	WSE depth	RH		
6.00	7.28	-7.28					
9.50	7.11	-7.11		0	7.11	9.50	-7.11
16.00	7.50	-7.50					
19.30	7.77	-7.77		0.34	7.43	19.30	-7.43
25.90	8.12	-8.12					
27.60	8.25	-8.25					
32.80	8.01	-8.01					
37.80	7.86	-7.86					
45.00	7.73	-7.73					
52.00	7.68	-7.68		0.22	7.46	52.00	-7.46
59.00	7.55	-7.55		0.06	7.49	59.00	-7.49
62.00	7.57	-7.57					
65.40	7.65	-7.65					
68.50	8.02	-8.02		0	8.02	68.50	-8.02
71.40	8.30	-8.30		0.24	8.06	71.40	-8.06
77.00	8.35	-8.35		0.3	8.05	77.00	-8.05
82.70	8.77	-8.77		0.72	8.05	82.70	-8.05
89.00	8.62	-8.62		0.8	7.82	89.00	-7.82
93.00	9.24	-9.24		1.18	8.06	93.00	-8.06
98.10	9.31	-9.31		1.25	8.06	98.10	-8.06
102.00	9.85	-9.85		1.8	8.05	102.00	-8.05
110.40	9.44	-9.44		1.4	8.04	110.40	-8.04
119.00	9.12	-9.12		1.05	8.07	119.00	-8.07
125.00	8.90	-8.90		0.85	8.05	125.00	-8.05
136.40	8.17	-8.17		0.1	8.07	136.40	-8.07
144.00	8.34	-8.34		0.1	8.24	144.00	-8.24
159.00	8.44	-8.44					

Long Draught

Site 1

Sieve Size (mm)	Sieve Weight (kg)	Sieve & Sample Weight (kg)	Retained on Sieve (kg)		Passing Sieve	
0	**0.4**	**4.16**	4	21%	---	---
2	**0.52**	**2.17**	2	9%	21%	21%
4	**0.56**	**2.45**	2	11%	9%	30%
8	**0.6**	**2.98**	2	13%	11%	41%
16	**0.59**	**3.66**	3	17%	13%	54%
31.5	**0.61**	**4.32**	4	21%	17%	72%
63	**0.61**	**1.92**	1	7%	21%	93%
					7%	100%

total wt retained in sieves: 18

Note:

Enter sieve size that passed 100% of sample.

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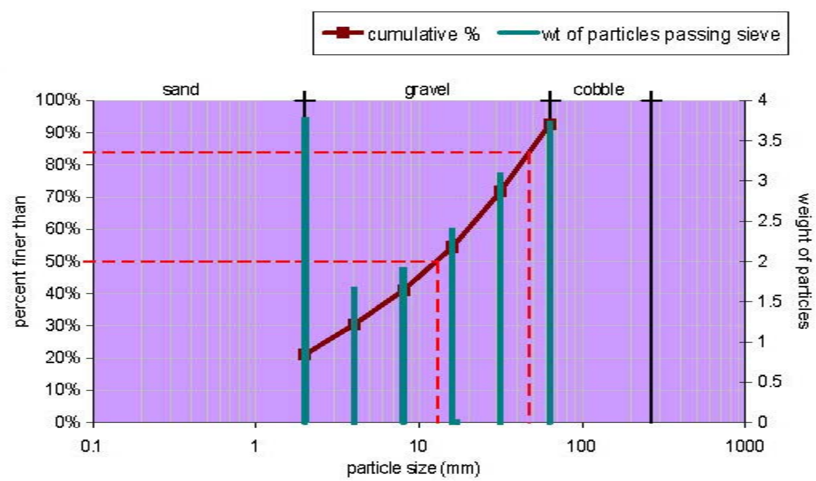
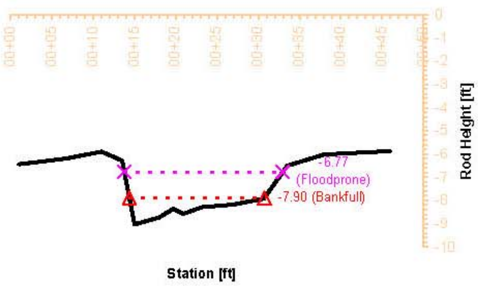


Size (mm)			
D16	---	D65	24
D35	5.4	D84	47
D50	13	D95	63

Site 2

Long Draught

Site 2-Riffle (Sta. 50+00)



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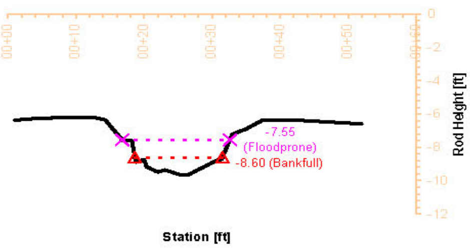
Results		Classification Possibilities
max depth:	1.13 ft	
avg depth:	0.50 ft	
entrenchment:	1.17	A, F, G
width/depth ratio:	32.86	B, C, F
hydraulic radius:	0.48 ft	
bankfull discharge:	**21.82 ft³/s**	
floodprone discharge:	**151.75 ft³/s**	
avg. velocity	2.68 ft/s	
slope	1.13%	D, C, E, F
Sinuosity	1.05	A
Avg. shear stress at bankfull stage:	0.335 lb/ft²	
Most Probable Classification ➔		**C** 4

Benchmark		Bankfull	-7.90	Floodprone	-6.77
Elevation		Rod Height [ft]	7.90	Rod Height [ft]	
Benchmark		channel slope	1.13%		
Rod Height		manning's 'n'	0.036		

			Bankfull			Floodprone		
Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
Total			**17.13 ft**	**8.14 ft²**	**16.36 ft**	**20.93 ft**	**28.25 ft²**	**19.22 ft**
1.00	6.44	-6.44	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
6.70	6.20	-6.20	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
11.00	5.89	-5.89	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
13.50	6.29	-6.29	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
15.00	9.03	**-9.03**	1.29 ft	0.35 ft²	0.62 ft	2.58 ft	1.40 ft²	1.24 ft
18.00	8.73	**-8.73**	3.01 ft	2.94 ft²	3.00 ft	3.01 ft	6.33 ft²	3.00 ft
19.70	8.37	**-8.37**	1.74 ft	1.11 ft²	1.70 ft	1.74 ft	3.03 ft²	1.70 ft
20.90	8.58	**-8.58**	1.22 ft	0.69 ft²	1.20 ft	1.22 ft	2.05 ft²	1.20 ft
23.20	8.29	**-8.29**	2.32 ft	1.23 ft²	2.30 ft	2.32 ft	3.83 ft²	2.30 ft
27.00	8.18	**-8.18**	3.80 ft	1.27 ft²	3.80 ft	3.80 ft	5.57 ft²	3.80 ft
30.70	7.92	**-7.92**	3.71 ft	0.55 ft²	3.70 ft	3.71 ft	4.74 ft²	3.70 ft
33.50	6.51	-6.51	0.04 ft	0.00 ft²	0.04 ft	2.56 ft	1.31 ft²	2.28 ft
38.00	6.02	-6.02	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
46.00	5.87	-5.87	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 2-Pool



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Baltimore, MD 21228
410.728.2900

ver 2.1

Results		Classification Possibilities
max depth:	1.05 ft	
avg depth:	0.61 ft	
entrenchment	1.23	A, F, G
width/depth ratio:	21.23	B, C, F
hydraulic radius:	0.58 ft	
bankfull discharge:	**23.82 ft³/s**	
floodprone discharge:	**109.02 ft³/s**	
avg. velocity	3.06 ft/s	
slope	1.13%	D, C, E, F
Sinuosity	1.05	A
Avg. shear stress at bankfull stage:	0.409 lb/ft²	#VALUE!
Most Probable Classification →		**C** 4

Benchmark Elevation		Bankfull	-8.60	Floodprone	-7.55
Benchmark Rod Height		Rod Height [ft]	8.60	Rod Height [ft]	
		channel slope	1.13%		
		manning's 'n'	0.036		

Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Bankfull Wetted Perimeter	Bankfull Cross Sectional Area	Bankfull Top Width	Floodprone Wetted Perimeter	Floodprone Cross Sectional Area	Floodprone Top Width
Total			**13.45 ft**	**7.79 ft²**	**12.86 ft**	**17.50 ft**	**21.56 ft²**	**15.84 ft**
1.00	6.37	-6.37	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
4.00	6.28	-6.28	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
9.00	6.20	-6.20	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
13.00	6.23	-6.23	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
14.30	6.36	-6.36	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
16.90	7.60	-7.60	0.00 ft	0.00 ft²	0.00 ft	0.12 ft	0.00 ft²	0.10 ft
18.20	7.59	-7.59	0.00 ft	0.00 ft²	0.00 ft	1.30 ft	0.06 ft²	1.30 ft
18.80	8.89	**-8.89**	0.32 ft	0.02 ft²	0.13 ft	1.43 ft	0.41 ft²	0.60 ft
20.00	8.73	**-8.73**	1.21 ft	0.25 ft²	1.20 ft	1.21 ft	1.51 ft²	1.20 ft
20.40	9.17	**-9.17**	0.59 ft	0.14 ft²	0.40 ft	0.59 ft	0.56 ft²	0.40 ft
22.00	9.48	**-9.48**	1.63 ft	1.16 ft²	1.60 ft	1.63 ft	2.84 ft²	1.60 ft
23.10	9.36	**-9.36**	1.11 ft	0.90 ft²	1.10 ft	1.11 ft	2.06 ft²	1.10 ft
25.30	9.65	**-9.65**	2.22 ft	1.99 ft²	2.20 ft	2.22 ft	4.30 ft²	2.20 ft
26.50	9.65	**-9.65**	1.20 ft	0.63 ft²	1.20 ft	1.20 ft	1.26 ft²	1.20 ft
30.70	8.78	**-8.78**	4.29 ft	2.58 ft²	4.20 ft	4.29 ft	6.99 ft²	4.20 ft
31.40	8.72	**-8.72**	0.70 ft	0.11 ft²	0.70 ft	0.70 ft	0.84 ft²	0.70 ft
33.00	7.21	-7.21	0.17 ft	0.01 ft²	0.13 ft	1.70 ft	0.73 ft²	1.24 ft
35.00	6.90	-6.90	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
37.50	6.36	-6.36	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
43.00	6.38	-6.38	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
52.00	6.59	-6.59	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 2

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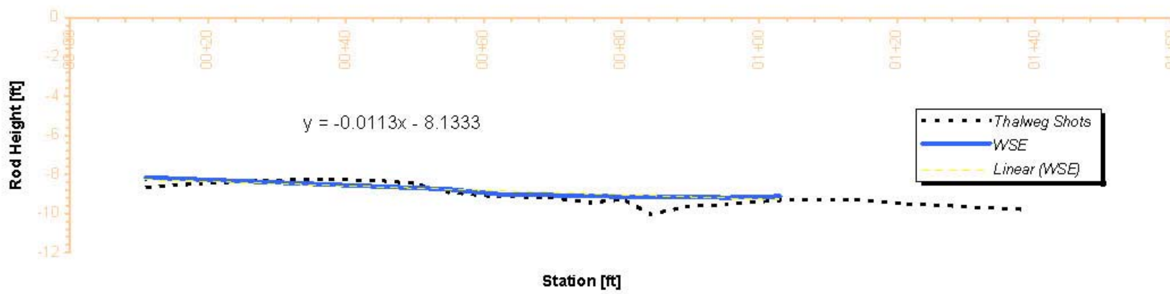

Benchmark Elevation	
Benchmark Rod Height	

Station [ft]	Rod Height [ft]		Bankfull RH	WSE depth	RH		
11.00	8.15	-8.15		0	8.15	11.00	-8.15
11.00	8.66	-8.66					
19.00	8.45	-8.45					
27.70	8.32	-8.32					
36.70	8.23	-8.23					
45.50	8.33	-8.33					
50.00	8.46	-8.46					
54.70	8.90	-8.90		0.15	8.75	54.70	-8.75
62.00	9.14	-9.14		0.14	9.00	62.00	-9.00
69.50	9.16	-9.16					
75.50	9.44	-9.44					
80.30	9.27	-9.27		0.14	9.13	80.30	-9.13
84.30	10.04	-10.04		0.9	9.14	84.30	-9.14
89.50	9.64	-9.64		0.5	9.14	89.50	-9.14
95.20	9.53	-9.53		0.35	9.18	95.20	-9.18
103.00	9.31	-9.31		0.2	9.11	103.00	-9.11
113.50	9.28	-9.28		0.1	9.18	113.50	-9.18
121.50	9.49	-9.49					
138.00	9.79	-9.79					

Long Draught

Site 2

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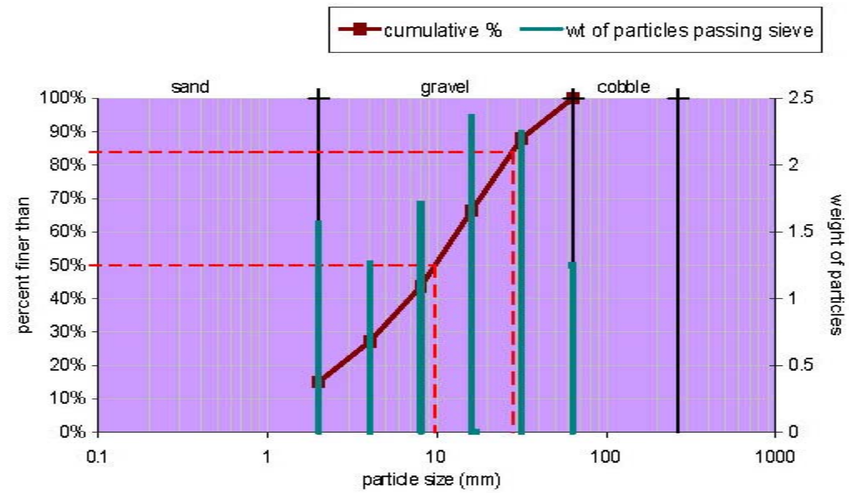
Sieve Size (mm)	Sieve Weight (kg)	Sieve & Sample Weight (kg)	Retained on Sieve (kg)	Retained on Sieve	Passing Sieve	Passing Sieve
0	**1.8**	**3.36**	2	15%	---	---
2	**0.48**	**1.74**	1	12%	15%	15%
4	**0.5**	**2.21**	2	16%	12%	27%
8	**0.58**	**2.94**	2	23%	16%	44%
16	**0.58**	**2.82**	2	22%	23%	66%
31.5	**0.62**	**1.87**	1	12%	22%	88%
63	**0.61**	**0.61**			12%	100%

total wt retained in sieves: 10

Note:



	Size (mm)		
D16	#NUM!	D65	15
D35	5.6	D84	28
D50	9.7	D95	32

Site 3

Long Draught

Site 3 (Trib) -Riffle (Sta. 68.5)

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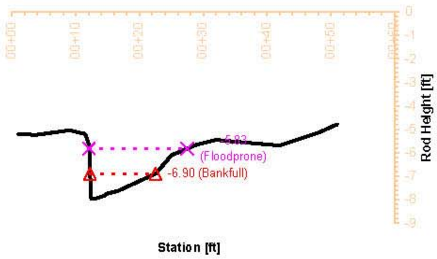
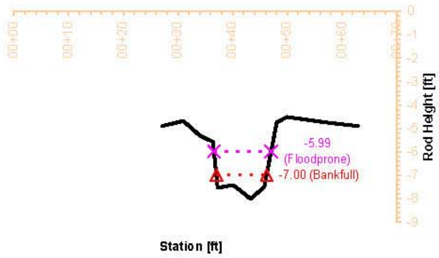


	Results	Classification Possibilities
max depth:	1.07 ft	
avg depth:	0.59 ft	
entrenchment:	1.50	B
width/depth ratio:	17.36	B, C, F
hydraulic radius:	0.54 ft	
bankfull discharge:	**4.24 ft³/s**	
floodprone discharge:	**21.53 ft³/s**	
avg. velocity	0.70 ft/s	
slope	0.07%	D, C, E, F
Sinuosity	1.20	A
Avg. shear stress at bankfull stage:	0.022 lb/ft²	
Most Probable Classification →	**F**	4

Benchmark		*Bankfull*	-6.90	Floodprone	-5.83
Elevation		*Rod Height [ft]*	6.90	Rod Height [ft]	
Benchmark		*channel slope*	0.07%		
Rod Height		*manning's 'n'*	0.036		

Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Bankfull Wetted Perimeter	Bankfull Cross Sectional Area	Bankfull Top Width	Floodprone Wetted Perimeter	Floodprone Cross Sectional Area	Floodprone Top Width
Total			**11.23 ft**	**6.06 ft²**	**10.26 ft**	**17.42 ft**	**19.15 ft²**	**15.37 ft**
1.00	5.23	-5.23	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
4.00	5.24	-5.24	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
9.00	5.05	-5.05	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
11.50	5.21	-5.21	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
12.10	5.67	-5.67	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
12.40	7.94	**-7.94**	1.05 ft	0.07 ft²	0.14 ft	2.13 ft	0.29 ft²	0.28 ft
13.00	7.97	**-7.97**	0.60 ft	0.63 ft²	0.60 ft	0.60 ft	1.28 ft²	0.60 ft
14.40	7.84	**-7.84**	1.41 ft	1.41 ft²	1.40 ft	1.41 ft	2.91 ft²	1.40 ft
15.00	7.74	**-7.74**	0.61 ft	0.53 ft²	0.60 ft	0.61 ft	1.18 ft²	0.60 ft
16.60	7.63	**-7.63**	1.60 ft	1.26 ft²	1.60 ft	1.60 ft	2.97 ft²	1.60 ft
20.00	7.21	**-7.21**	3.43 ft	1.77 ft²	3.40 ft	3.43 ft	5.41 ft²	3.40 ft
22.60	6.89	-6.89	2.54 ft	0.39 ft²	2.52 ft	2.62 ft	3.17 ft²	2.60 ft
25.00	6.11	-6.11	0.00 ft	0.00 ft²	0.00 ft	2.52 ft	1.61 ft²	2.40 ft
29.00	5.66	-5.66	0.00 ft	0.00 ft²	0.00 ft	2.50 ft	0.35 ft²	2.49 ft
32.00	5.46	-5.46	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
42.00	5.70	-5.70	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
48.00	5.16	-5.16	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
51.00	4.80	-4.80	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 3 (Trib) -Pool (Sta. 28)



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Results		Classification Possibilities
max depth:	1.01 ft	
avg depth:	0.62 ft	
entrenchment:	1.14	A, F, G
width/depth ratio:	14.82	B, C, F
hydraulic radius:	0.58 ft	
bankfull discharge:	**4.14 ft³/s**	
floodprone discharge:	**19.28 ft³/s**	
avg. velocity	0.73 ft/s	
slope	0.07%	D, C, E, F
Sinuosity	1.20	A
Avg. shear stress at bankfull stage:	0.023 lb/ft²	
Most Probable Classification ➔		**F** 4

Benchmark		Bankfull	-7.00	Floodprone	-5.99
Elevation		Rod Height [ft]	7.00	Rod Height [ft]	
Benchmark		channel slope	0.07%		
Rod Height		manning's 'n'	0.036		

	Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Bankfull Wetted Perimeter	Bankfull Cross Sectional Area	Bankfull Top Width	Floodprone Wetted Perimeter	Floodprone Cross Sectional Area	Floodprone Top Width
Total				**9.85 ft**	**5.67 ft²**	**9.17 ft**	**12.28 ft**	**15.59 ft²**	**10.47 ft**
	27.10	4.91	-4.91	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	31.00	4.69	-4.69	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	34.00	5.31	-5.31	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	36.40	5.58	-5.58	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	37.30	7.54	**-7.54**	0.59 ft	0.07 ft²	0.25 ft	1.71 ft	0.55 ft²	0.71 ft
	40.00	7.42	**-7.42**	2.70 ft	1.30 ft²	2.70 ft	2.70 ft	4.02 ft²	2.70 ft
	40.60	7.50	**-7.50**	0.61 ft	0.28 ft²	0.60 ft	0.61 ft	0.88 ft²	0.60 ft
	43.30	8.01	**-8.01**	2.75 ft	2.04 ft²	2.70 ft	2.75 ft	4.77 ft²	2.70 ft
	45.80	7.50	**-7.50**	2.55 ft	1.89 ft²	2.50 ft	2.55 ft	4.41 ft²	2.50 ft
	48.10	4.75	-4.75	0.65 ft	0.10 ft²	0.42 ft	1.97 ft	0.95 ft²	1.26 ft
	50.00	4.52	-4.52	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	57.00	4.75	-4.75	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft
	63.00	4.91	-4.91	0.00 ft	0.00 ft²	0.00 ft	0.00 ft	0.00 ft²	0.00 ft

Long Draught
Site 3 (Trib)

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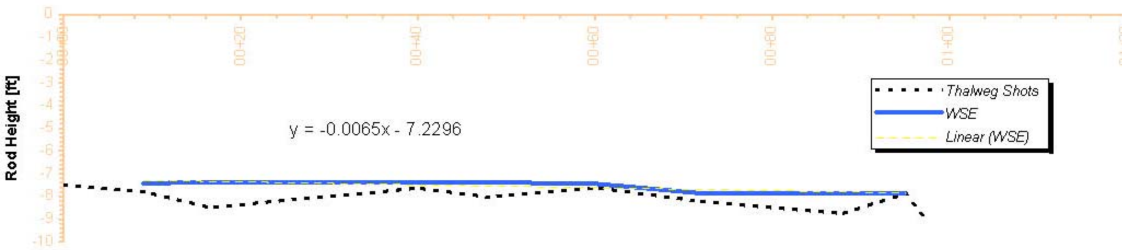

Benchmark Elevation	
Benchmark Rod Height	

Station [ft]	Rod Height [ft]		Bankfull RH	WSE depth	RH		
0.00	7.48	-7.48		0.21	7.27	0.00	-7.27
9.00	7.78	-7.78		0.35	7.43	9.00	-7.43
16.40	8.49	-8.49		1.12	7.37	16.40	-7.37
40.00	7.63	-7.63		0.24	7.39	40.00	-7.39
48.00	8.03	-8.03		0.65	7.38	48.00	-7.38
60.00	7.61	-7.61		0.17	7.44	60.00	-7.44
72.00	8.22	-8.22		0.36	7.86	72.00	-7.86
88.00	8.76	-8.76		0.89	7.87	88.00	-7.87
95.00	7.87	-7.87		0	7.87	95.00	-7.87
97.00	8.80	-8.80		0.68	8.12	97.00	-8.12

Long Draught
Site 3 (Trib)

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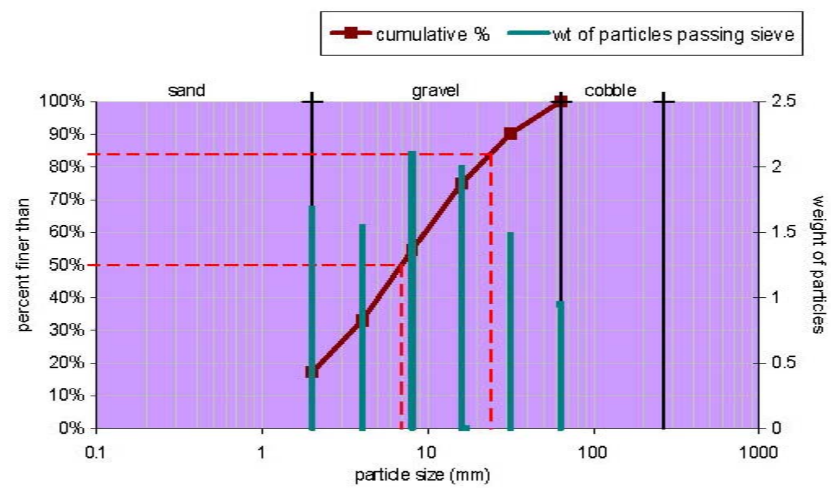
Sieve Size (mm)	Sieve Weight (kg)	Sieve & Sample Weight (kg)	Retained on Sieve (kg)		Passing Sieve	
0	**1.8**	**3.48**	2	17%	---	---
2	**0.48**	**2.02**	2	16%	17%	17%
4	**0.5**	**2.6**	2	22%	16%	33%
8	**0.54**	**2.53**	2	20%	22%	55%
16	**0.58**	**2.06**	1	15%	20%	75%
31.5	**0.58**	**1.53**	1	10%	15%	90%
63					10%	100%

total wt retained in sieves: 10

Note:



Size (mm)			
D16	---	D65	11
D35	4.3	D84	24
D50	6.9	D95	32

APPENDIX I:

Long Draught Branch Pre-Construction Biological Monitoring

October 2004

Site Summary for SHA Restoration Site: Long Draught Branch

Long Draught Branch is a 1st order stream at the locations sampled with MBSS methods (Figure A9). The stream sampled is a tributary to Seneca Creek, which flows into the Potomac River. This stream is located within Piedmont Physiographic Region as is part the Potomac-Washington Metro River Basin

General Comments

The restoration and control 75 meter transects sampled on Long Draught Branch were located upstream of Clopper Lace. The two sample sites had similar biological and physical attributes. Sampling was conducted in 2004 before any restoration work had been conducted.

Physical Habitat

Data from the restoration and control sites on Long Draught Branch is located in Table A9.

Overall, the physical habitat was very similar at the restoration and control sites on Long Draught Branch.

MPHI

Long Draught Branch is located within the Potomac-Washington Metro River Basin, which extends from Piscataway Creek in Prince George's County to the Little Monocacy River in Southern Frederick County. This basin lies within the Piedmont and Coastal Plain Physiographic Regions. Long Draught Branch is located within the Piedmont Physiographic Region. Figure A9 shows 1995-1997 MBSS sample sites within the Potomac-Washington Metro Basin.

The 2004 MPHI scores for the restoration site (26.30) and the control site (37.34) were both lower than the average score for all 1st order Non-Coastal Plain MBSS stream sites (54.74).

Fish Data

Two fish species (483 individuals) were collected from the restoration site and three fish species (191 individuals) were collected from the control site in 2004. The average Fish IBI score for all non-coastal 1st order streams sampled by the MBSS was 2.8. The 2004 fish IBI scores at the restoration and control sites (1.44) were both lower than the non-coastal plain average for 1st order streams (Table A9).

Table A9. Physical habitat and fish data from SHA sample sites on Long Draught Branch.

Presence/Absence, Landuse, and Stream Characters	Pre-Restoration Site 2004	Control Site 2004
Wetland		
Deciduous	X	X
Coniferous	X	X
Residential	X	X
Commercial	X	X
Cropland		
Meandering	X	
Braided		
Channelized	X	
Straight		
Riffle	X	X
Run/Glide	X	X
Deep Pool		X
Shallow Pool	X	X
Boulder		
Cobble	X	X
Bedrock		
Gravel	X	X
Sand	X	X
Silt/Clay	X	X
Concrete/Gabion		
Rootwad	X	
Undercut Bank	X	X
Overhead Cover	X	X
Human Refuse	X	X
Emergent Vegetation		
Submergent Vegetation		X
Floating Vegetation		X
Storm Drain		
Effluent Discharge		

			Coastal Plain Averages
Fish IBI	1.44	1.44	3.28
Habitat IBI	26.30	37.34	54.74

Habitat Metrics and Quantitative Variables	Pre-Restoration Site 2004	Control Site 2004
Number of Rootwads	3	1
Number of Woody Debris	3	1
Instream Habitat	13	14
Epifaunal Substrate	10	7
Velocity/Depth Diversity	7	13
Pool/Glide/Eddy Quality	7	12
Riffle/Run Quality	6	8
Channel Alteration	15	15
Bank Stability	08	17
Embeddedness	45	40
Channel Flow Status	90	90
Shading	75	75
Riparian Buffer Width	00	18
Buffer Type	Bare Soil	Mowed Lawn
Adjacent Land Cover	Parking Lot	Paved Road
Remoteness	01	01
Aesthetic Rating	06	08
Mean Wetted Width (m)	2.3	2.2
Mean Thalweg Depth (cm)	16.0	15.0
Maximum Depth (cm)	42.0	51.0
Mean Thalweg Velocity (m/sec)	17.0	19.0

Fish Data		
Blacknose dace	390	158
Golden shiner	0	1
Mosquitofish	93	32
Total Number of Fish	483	191
Number of Species	2	3
Biomass (g)	486	261

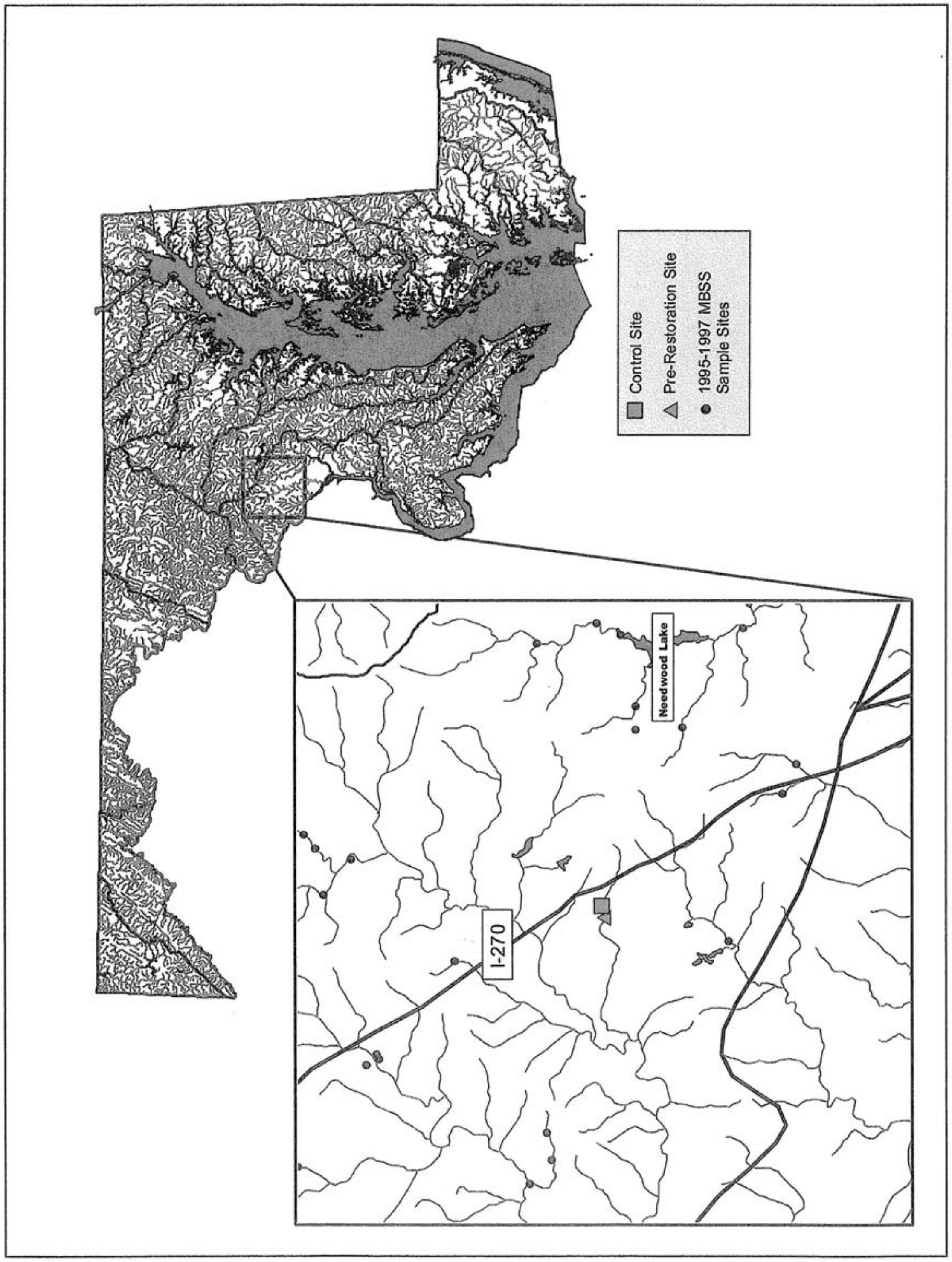


Figure A9. Pre-restoration and Control sample site locations Long Draught Branch.

Table Long Draught Branch 1. Numbers of benthic macroinvertebrates collected in Course Particulate Organic Matter (CPOM) samples from Long Draught Branch on 12 October 2004.

Functional Feeding Group	Control	Restoration
Shredders	0	0
Plecoptera		
Other		
Scrapers		
Gastropoda	2	56
Trichoptera		
Other		
Filtering Collectors		
Trichoptera	3	56
Diptera		
Other		1
Gathering Collectors		
Oligochaetes		
Diptera	33	81
Other		2
Predators		
Diptera	4	7
Other	2	4
Other Macroinvertebrates	0	0

Table Long Draught Branch 2. Data summary of benthic macroinvertebrates collected in D-frame and CPOM samples on 12 October 2004 at stations in Long Draught Branch. For CPOM community, shredder/total = number of benthic macroinvertebrates in shredder functional feeding group to total number collected. For riffle community: taxa richness = total number of taxa recognized; total. EPT taxa = total number of recognized taxa of Ephemeroptera, Plecoptera, and Trichoptera; Ephemeroptera taxa = number of mayfly taxa; Diptera taxa = number of "true" fly taxa (including midges); % Ephemeroptera = percent mayflies nymphs; % Tanytarsini = percent of Tanytarsini midges to total fauna; intolerant taxa = number of taxa considered to be sensitive to perturbation - Hilsenhoff values 0 - 3 (*Hilsenhoff, 1987*); % tolerant = percent of sample considered tolerant of perturbation - Hilsenhoff values 7 - 10 (*Hilsenhoff, 1987*); % collector gatherers = percent of sample that feeds on detrital deposits or loose surface films; * = sample size < 100.

	CPOM COMMUNITY		RIFFLE COMMUNITY		
Metric	Control	Restoration	Control	Lower Restoration	Middle Restoration
Prop. Shredders/Total	0.0%*	0.0%			
Taxa Richness			18	18	21
Total EPT Taxa			2	3	2
Ephemeroptera taxa			0	1	0
Diptera taxa			4	5	6
% Ephemeroptera			0.0%	0.4%	0.0%
% Tanytarsini			0.0%	0.0%	0.8%
Intolerant taxa			2	1	2
% Tolerant			24.4	13.2%	28.6%
% Collector gatherers			36.2%	9.4%	19.9%

Table Long Draught Branch 3. Numbers of macroinvertebrates collected in benthic samples by combining 9 D-frame aquatic net samplings (total sampling area approximately 1 m²) at sites in Long Draught Branch on 12 October 2004. Insect quantities represent numbers of larvae or nymphs unless designated otherwise by a P for pupa or A for adult. The first number is a total, followed by the number of individuals in a particular life stage, if other than larva or nymph. * = Specimens were either too small, damaged, or in an inappropriate life stage for further identification. ** = Not included in calculations.

Taxon Station	Control	Lower Restoration	Middle Restoration
Turbellaria			
Phygocata sp.	17	8	15
Nematoda	2		1
Enopla			
Hoplonemertea	27	7	6
Annelida			
Oligochaeta			
Lumbricidae		4	3
Lumbriculidae	11	3	22
Naididae	4	2	2
Tubificidae	1	1	10
Mollusca			
Gastropoda			
Ancylidae			
Ferrissia sp.	2	3	3
Physidae		1	2
Planorbidae	4		7
Sphaeriidae	1	7	8
Crustaceae			
'Hydracarina'	1		
Insecta			
Ephemeroptera			
Baetidae			
Baetis sp.		1	
Odonata			
Calopterygidae			
Calopteryx sp.	1	2	3
Coenagrionidae	1		1
Trichoptera			
Hydropsychidae	9	29	29
Cheumatopsyche sp.	9	87	73
Diplectrona modesta			
Hydropsyche sp.	1	40	21
Diptera			
Chironomidae	4	1	
Tanypodinae	10	14	15
Diamesinae			
Orthocladinae	15	8	9
Chironominae	9	6	3
Tanytarsinii			2
Empididae			
Chelifera sp.			
Hemerodromia sp.	6	10	5
Tipulidae			
Limonia sp.		1	
Tipula sp.			1

Table Long Draught Branch 4. Numbers of benthic macroinvertebrates collected in Course Particulate Organic Matter (CPOM) samples from Long Draught Branch on 30 March 2005.

Functional Feeding Group	Control	Restoration
Shredders	0	0
Plecoptera		
Other		
Scrapers	0	
Gastropoda		2
Trichoptera		
Other		
Filtering Collectors		
Trichoptera		2
Diptera		
Other	1	
Gathering Collectors		
Oligochaetes	16	25
Diptera		12
Other		1
Predators	0	
Diptera		11
Other		
Other Macroinvertebrates	0	25

Table Long Draught Branch 5. Data summary of benthic macroinvertebrates collected in D-frame and CPOM samples on 30 March 2005 at stations in Long Draught Branch. For CPOM community, shredder/total = number of benthic macroinvertebrates in shredder functional feeding group to total number collected. For riffle community: taxa richness = total number of taxa recognized; total. EPT taxa = total number of recognized taxa of Ephemeroptera, Plecoptera, and Trichoptera; Ephemeroptera taxa = number of mayfly taxa; Diptera taxa = number of "true" fly taxa (including midges); % Ephemeroptera = percent mayflies nymphs; % Tanytarsini = percent of Tanytarsini midges to total fauna; intolerant taxa = number of taxa considered to be sensitive to perturbation - Hilsenhoff values 0 - 3 (*Hilsenhoff, 1987*); % tolerant = percent of sample considered tolerant of perturbation - Hilsenhoff values 7 - 10 (*Hilsenhoff, 1987*); % collector gatherers = percent of sample that feeds on detrital deposits or loose surface films; * = sample size < 100.

	CPOM COMMUNITY		RIFFLE COMMUNITY		
Metric	Control	Restoration	Control	Lower Restoration	Middle Restoration
Prop. Shredders/Total	0.0%*	0.0%*			
Taxa Richness			16	14	14
Total EPT Taxa			3	3	3
Ephemeroptera taxa			0	0	0
Diptera taxa			4	4	5
% Ephemeroptera			0.0%	0.0%	00%
% Tanytarsini			0.0%	0.0%	0.0%
Intolerant taxa			1	0	0
% Tolerant			69.9%	54.7%	52.2%
% Collector gatherers			71.5%	43.3%	62.0%

Table Long Draught Branch 6. Numbers of macroinvertebrates collected in benthic samples by combining 9 D-frame aquatic net samplings (total sampling area approximately 1 m²) at sites in Long Draught Branch on 30 March 2005. Insect quantities represent numbers of larvae or nymphs unless designated otherwise by a P for pupa or A for adult. The first number is a total, followed by the number of individuals in a particular life stage, if other than larva or nymph. * = Specimens were either too small, damaged, or in an inappropriate life stage for further identification. ** = Not included in calculations.

Taxa Site	Control	Lower Restoration	Middle Restoration
Turbellaria			
Phygocata sp.	20		
Nematoda		1	2
Enopla			
Hoplonemertea	1		
Annelida			
Oligochaeta	3		4
Lumbriculidae	83	59	84
Naididae	20	1	
Tubificidae	13	27	15
Hirudinea			
Glossiphoniidae			
Helobdella sp.			1
Pelycepoda			
Sphaeriidae	1	1	1
Crustaceae			
'Hydracarina'			
Diplopoda			
Orconectes sp.		1	
Insecta			
Collembola	1		
Odonata			
Calopterygidae			
Calopteryx sp.		2	
Coenagrionidae			
Enallagma sp.	1		
Trichoptera			
Hydropsychidae	4	5	2
Cheumatopsyche sp.	4	71	51
Hydropsyche betteni	6	5	3
H. cuanis		2	3
H. sp.			1
Symphytopsyche sp.	2	2	3
Coleoptera			
Elmidae			
Stenelmis sp.	1		1

Table Long Draught Branch 6. (*Continued*)

Taxa Site	Control	Lower Restoration	Middle Restoration
Diptera			
Chironomidae			2
Tanypodinae	13	22	23
Diamesinae			
Orthocladinae	14		34
Chironominae	4		13
Tanytarsinii			
Empididae			
Chelifera sp.			
Hemerodromia sp.	2	1	1
Tipulidae			
Limonia sp.			
Tipula sp.		1	1

APPENDIX J:

Industrial NPDES Capital Improvement Summary

INDUSTRIAL NPDES CAPITAL IMPROVEMENTS

INDUSTRIAL NPDES CAPITAL IMPROVEMENTS

DISTRICT	FACILITY	ITEM	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
1	Berlin	Fuel Canopy & Drainage - New		X						
		Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff								O
	Cambridge	AST - Removal and Remediation			X					
		Oil Water Separator - Connection to Public Sewer System						U		
		Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff								O
	Princess Anne	Oil Water Separator Upgrade					N			
		AST - Removal and Remediation						U		
		Berm/Swale to Divert Site Runoff								O
	Salisbury	Washbay - Retrofit				U	U	U		
	Snow Hill	Oil Water Separator - Connection to Public Sewer System			X					
2	Centreville	Oil Water Separator Upgrade			X					
	Chestertown	Washbay - Retrofit				U	U	U		
		Oil Water Separator Upgrade						O		
	Denton	Oil Water Separator Upgrade			X					
		Material Storage Bin Structure - New							O	
		Fuel Canopy Downspout/Outfall - Retrofit								O
		Brine Operations - Retrofit/Repair								O
		Water Quality BMP								O
	Easton	Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff								O
	Elkton	Material Storage Bin Structure - New	X							
		Riprap Channel Construction for Erosion Control							O	
	Millington	Fuel Canopy & Drainage - New							O	
	Stevensville	Salt Contamination Remediation/ Site Redevelopment				U	U	U		
3	Fairland	Material Storage Bin Structure - New						U		
		Stabalize Discharge Point and Improve Drainage Coverage							O	
		SWM Infiltration Trench Retrofit								O
	Gaithersburg	Oil Water Separator Repair		X						
		Material Storage Bin Structure - New						O		
		Fuel Canopy Downspout/Oufall - Retrofit							O	
		Berm/Swale to Divert Site Runoff							O	
		Brine Operations - Retrofit/Repair								O
	Kensington	Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff								O
	Laurel	Material Storage Bin Structure - New						U		
	Marlboro	AST - Removal & Remediation						U		
		Inlet Grit Chamber - New						O		
		SWM Infiltration Basian Retrofit								O
	Metro/Landover	Material Storage Bin Structure - New							O	
		Fuel Canopy & Drainage - New								O
		Berm/Swale to Divert Site Runoff								O

Note: X = Completed N = No Longer Necessary
U = Underway O = Pending

INDUSTRIAL NPDES CAPITAL IMPROVEMENTS

DISTRICT	FACILITY	ITEM	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
4	Churchville	Oil Water Separator Upgrade			X					
		Plumbing - Connect to Oil Water Separator			X					
		Fuel Canopy Downspout/Oufall - Retrofit					X			
	Golden Ring	Riprap Channel Construction for Erosion Control						O		
	Hereford	Oil Water Separator Upgrade	X							
		Washbay Treatment System Upgrade					U	X		
		Material Storage Bin Structure - New						U		
		Berm/Swale to Divert Site Runoff								O
	Owings Mills	Oil Water Separator - Connection to Public Sewer System			X					
		Material Storage Bin Structure - New							O	
5	Annapolis	Erosion Stabalization				U	U	U		
		Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff							O	
		Water Quality BMP								O
	Glen Burnie	Dewatering Structure - New		X						
		Fuel Canopy Downspout/Oufall - Retrofit		X						
		Bioretention Retrofit			U	U	U	U		
		Material Storage Bin Structure - New							O	
	Hanover Complex	Oil Water Separator Upgrade			X					
		Oil Water Separator - Connection to Public Sewer System						U		
	LaPlata	Oil Water Separator - Connection to Public Sewer System			X					
		Material Storage Bin Structure - New							O	
	Leonardtown	Oil Water Separator Upgrade	X							
		Washbay Treatment System Upgrade				U	X			
		Material Storage Bin Structure - New							O	
		Berm/Swale to Divert Site Runoff								O
	Prince Frederick	Oil Water Separator - Connection to Public Sewer System		X						
		Fuel Canopy Downspout/Oufall - Retrofit		X						
		Washbay - Retrofit				U	X			
		Inlet Sediment Trap							O	
		Riprap Channel for Erosion and Sediment Control							O	
		Water Quality BMP								O

Note: X = Completed
U = Underway
N = No Longer Necessary
O = Pending

INDUSTRIAL NPDES CAPITAL IMPROVEMENTS

DISTRICT	FACILITY	ITEM	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
6	**Frostburg**	Material Storage Bin Structure - New							O	
		Water Quality BMP								O
	Hagerstown	Washbay - Retrofit				U	U			
		Fuel Canopy Downspout/Oufall - Retrofit							O	
	Hancock	Fuel Canopy & Drainage - New							O	
		Storm Drain System - New Construction							O	
		Water Quality BMP								O
	Keysers Ridge	Oil Water Separator Upgrade			X					
		Washbay - Retrofit				U	U	U		
		Oil Water Separator - Connection to Public Sewer System							O	
		Fuel Canopy Downspout/Oufall - Retrofit							O	
		Water Quality BMP					O	U		
	LaVale	Washbay - Retrofit				U	U	U		
		Fuel Canopy Downspout/Oufall - Retrofit							O	
	Oakland	Fuel Canopy Downspout/Oufall - Retrofit					X			
		Material Storage Bin Structure - New							O	
		Inlet Sediment Trap							O	
		Water Quality BMP								O
7	**Dayton**	N/A								
	Frederick	Material Storage Bin Structure - New							O	
	Thurmont	Oil Water Separator Upgrade					N			
		Water Quality BMP								O
	Westminster	N/A								

Note: X = Completed
U = Underway
N = No Longer Necessary
O = Pending

INDUSTRIAL NPDES CAPITAL IMPROVEMENTS

APPENDIX K:

GIS Standard Procedures Chapter 7: BMP Assessment Guidelines for Maintenance and Remediation

Draft October 2008

Chapter 7

Best Management Practice Assessment Guidelines for Maintenance and Remediation

October 2008

Table of Contents

7.1 INTRODUCTION 7

7.2 FIELD PREPARATION 8

7.2.1 Pre-Field Investigation 8
7.2.1.1 SHA Response Rating System 8
7.2.1.2 Additional Inspection Information 9
7.2.2 Review/Analysis of Inspection Information 10
7.2.2.1 Issues which may Preclude a Site Visit 11
7.2.3 Weather conditions 11
7.2.4 Other Reasons to Delay a Site Visit 12

7.3 FIELD OPERATIONS 13

7.3.1 Equipment 13
7.3.2 Inspection Criteria – Re-inspect Known Deficiencies 13
7.3.3 Inspection Criteria – Inspect for Other Deficiencies 14
7.3.4 Digital Photograph Data 14

7.4 ANALYSIS 17

7.4.1 Assessment of Facility Function 17
7.4.2 Recommendations 18
7.4.2.1 Recommendations for Infiltration Trenches 18
7.4.3 Common Recommendations 19
7.4.3.1 Recommendations to Stabilize an Eroded Embankment or Ditch 20
7.4.3.2 Recommendations to Remove Trees or other Excess Vegetation 20
7.4.3.3 Recommendations to Repair a Separated Pipe or Endwall 21
7.4.4 Recommendations for Ponds and Basins 21
7.4.4.1 Recommendations to Unblock Low Flow Device 21
7.4.4.2 Recommendations to Remove Sediment from a Pond or Basin 23
7.4.5 Recommendations for Infiltration Trenches 23
7.4.5.1 Recommendations for Replacing a Saturated Trench 23
7.4.5.2 Recommendations for Installing an Observation Well 24

7.5 MAINTENANCE REPORTS 26

7.5.1 Types of BMP Reports 26
7.5.1.1 Minor/Major Maintenance Report 26
7.5.1.2 Infiltration Trenches 27
7.5.1.3. Retrofit Recommendation Report 27
7.5.1.4. No Maintenance Required Report 27
7.5.2 Deliverables 28
7.5.2.1 BMP Reports - Paper Copies 28
7.5.3 QA/QC 29

List of Tables

Chapter 7

Assessment Guidelines for Maintenance and Remediation

7.1 INTRODUCTION

This chapter describes the procedure for field assessment of Best Management Practices (BMPs) previously designated as needing maintenance during the field inventory inspection. After the routine cyclical inspections and database updates, final performance ratings and level of functionality are evaluated. All BMPs with major deficiencies that require more that minor maintenance undertake detailed assessment to determine specific causes of deficiencies and to develop a remedial action plan. The determination of the need for further assessment is described in Chapter 3 of this manual. The procedures outlined in this chapter will assist SHA and those who work with SHA with decisions on maintenance, repair, and retrofit of SWM facilities.

The objective of these Assessment Guidelines are to document the methodologies to be used in the field for inspecting BMP facilities so that they can be maintained, repaired or reconstructed in order to comply with the original Stormwater Management approval and NPDES permit conditions. This document provides standardization to assist trained inspection personnel to inspect BMP facilities statewide, to identify and to assess the causes of the deficiencies, and to recommend repairs with relatively consistent results. The intent is not to be a comprehensive resource manual; therefore, other resources should be consulted in conjunction with this document. These Guidelines provide information on field preparation, data management of collected information and development of remediation reports and work orders for maintenance/ construction crew.

7.2 FIELD PREPARATION

The main component of the Remedial Assessment is the field inspection to identify the source of facility deficiencies. The process is initiated when a Remedial Inspection Team receives an assignment of a set number of facilities, which have been previously determined to need a more comprehensive assessment. The Remedial Inspection Team will be provided with a list of facilities, usually within the same County and located within a reasonably close proximity to each other. Other relevant information may also be provided for the facilities to help with the inspection, including location maps, As-Built plans and the Initial Inspection Reports. The information will be provided by a representative from the SHA Highway Hydraulics Division (HHD) who will distribute and organize information for the Remedial Inspection Team and will be the point of contact for all questions concerning these facilities.

7.2.1 Pre-Field Investigation

The objective of the pre-field investigation is to review the existing information provided to the Remedial Inspection Team in order to have a more thorough understanding of the function of each facility to be inspected and to be aware of the deficiencies that were previously identified. The most important piece of information is the Initial Inspection Report which summarizes the existing facilities conditions at the time of the initial inspection and includes a Performance Rating for each facility. Each stormwater BMP facility is given a condition rating based on observations by the Initial Inspection Team (Rating scale from A-E). A rating of “C” usually means maintenance is required. However prior to assigning facilities to a Remedial Inspection Team for inspection and preparation of a work order, SHA office personnel will review all facilities and develop an SHA rating. The criteria used for the SHA rating will based upon information included in the Initial Inspection Report, any pictures provided and any other information available. Based upon this review, an SHA Response Rating will be assigned to each facility, and this rating will determine whether the facility is assigned to a Remedial Inspection Team.

7.2.1.1 SHA Response Rating System

Each stormwater BMP facility is given a condition rating by SHA office personnel who maintain the database (Rating scale from I-VI). The SHA office rating system is based on organizing the BMPs rated by the initial inspection teams in a consistent manner in order to address the deficiencies noted at each facility. Table 7.1 shown below provides a brief description for each rating category. In general, BMPs designated in the “III” category are considered as having significant problems which can be addressed by a construction crew utilizing heavy equipment. These facilities are the ones that are assigned to a consultant to perform a Remedial Assessment in order to prepare the work order for the maintenance of the facility.

Table 7.1 – SHA Rating Table

SHA		

Response Rating	Category	Explanation
I	No Maintenance Needed Response Required	No Maintenance Needed
II	Minor Maintenance	Perform routine maintenance to sustain BMP performance. Can be performed with typical maintenance crew.
III	Major Maintenance	Maintenance or repair is needed to return the site to original functionality within the existing footprint of the facility. Remediation is more significant than just routine maintenance and will likely require heavy equipment mobilization, construction material and possible Maintenance of Traffic.
IV	Retrofit	Retrofit design and construction is required since the BMP cannot be returned to its original functionality within its existing footprint. It involves reconstruction of the facility from one to another type of BMP.
V	Immediate Response	Public safety hazards exist that require immediate correction.
VI	Abandonment	BMP is not maintainable and will not provide sufficient benefit to justify retrofit.

7.2.1.2 Additional Inspection Information

As stated in the previous Section, an initial inventory and assessment has been conducted for all the known SHA-owned BMPs in the particular County. From this inventory, a BMP database has been created to organize information from the design and inspection of all the inspected BMPs. The database may include photos, as-built drawings, and a Location Map for the facility in addition to the Initial Inspection Report. This information is used by the Remedial Inspection Team to prepare for further inspect their designated BMPs. Prior to the field investigation, all information provided to the Remedial Inspection Team should be reviewed to get a better understanding of the facilities.

Additional information, not necessarily stored in the GIS database, could include aerial mapping, topography, construction plans, etc. This information may be provided to the Remedial Inspection Team and should also be reviewed for a more complete understanding of the area to be inspected. The inspection team may also request supplemental information that may be available, but has not yet been provided, if they feel that it is necessary to properly prepare for the field investigation. The information available will help identify potential safety issues such as site access, road hazards, and BMP locations. Based on potential conditions, the inspection crew can prepare appropriately for the field investigation. Availability of data varies among the individual counties. Below is a brief listing and description of some of the information that may be provided to the Remedial Inspection Team.

The **Initial Inspection Report** summarizes the existing facilities conditions at the time of the initial inspection, inspection rating, facility type, the general location, and why the facility warrants maintenance or a retrofit. Special attention should be made to the comments section of the report. This will provide the concerns the previous inspector had with the BMP and will be of special interest in the current Assessment. If the Initial Inspection Report contains outdated, inconsistent, or erroneous data, the questionable data shall be identified and reported to the HHD contact after performing the Remedial Assessment.

GIS location maps are also available for all BMPs that are currently in the inventory. Location maps usually include roads, aerial topography, and storm drain systems. The primary purpose of this information is to locate the facility. An ADC Map can be used to supplement this information to organize the facilities based upon the road network layout and to plan the logistics of the field trip.

Most **As-Built plans** are provided for the BMP facilities, and the plans provide muc valuable information. First, the plans sheets usually include a label which provides the facility type. It is important to know the design facility type for each BMP facility to properly identify and determine how it is functioning, or if it has failed. Secondly, the As-Built plans show the location of the BMP and the location of structures, inflow and outflow points, and outfalls to be inspected. This helps the Remedial Inspection Team locate all facility structures even if the facility is overgrown with vegetation. Finally, the detail and grading sheets should be used to determine if the facility was properly constructed, which is also helpful in determining why the facility has failed. If As-Built plans are not provided, further investigation into the SHA archives is usually beneficial.

Site photographs are also available and can be helpful in identifying the site during the field visit. Photos can provide landmarks and identifiers that plans sheets do not provide. Photos of the BMP sites are not always provided so further inquiry may be needed.

7.2.2 Review/Analysis of Inspection Information

Once all of the information is compiled for the targeted sites, it is critical that the reason for the BMP re-inspection is determined. The Initial Inspection Report should be reviewed to determine the issues identified that are requiring the Remedial Assessment. Issues which have been noted on the Initial Inspection Report need to be addressed by the team that re-inspects the BMP. Even if the facility is functioning as designed, the items documented in the Initial Inspection Report need to be addressed within the Remedial Assessment Report. Other problems with the facility may be found during the second inspection; however, the original issues found by the initial inspection need to be addressed and evaluated in the Remedial Assessment. This will be discussed in more detail in Section 7.3.2.

The Remedial Inspection Team should have a general idea of where the BMPs are located before visiting the sites. A well planned route should be prepared to maximize the number of sites that can be visited during the field day. Plan sheets, location maps, and any available previous photographs should be used to help identify the facility in the field. ADC maps can also be used to provide more information for locating BMPs and for planning routes for inspecting several BMP sites in a field day.

7.2.2.1 Issues which may Preclude a Site Visit

There may be instances when the Remedial Inspection Team determines that a site visit is unnecessary after a thorough review of the inspection information. This usually will occur when it can be determined that the facility to be inspected is not owned by SHA or if it can be determined that the facility is functioning as designed based upon the inspection information. In most cases, the SHA ownership of the facility is clear; however, there are cases where the ownership must be investigated further. If the information available is unclear, additional right-of-way plats or memorandum-of-understanding (MOU) may be needed to be acquired to verify ownership of the BMP. If it is determined that a facility is not the responsibility of SHA, then the HHD representative needs to be notified so the BMP can be removed from the database.

Information provided in the Initial Inspection Report should be compared to the as-built plans to verify the facility type and for a better understanding of how the facility was constructed and how the facility should function. If it is determined that the facility was misidentified during the original inspection, a second inspection may not be necessary. For example, a facility may originally be identified as an infiltration basin which may be considered to have failed due to standing water in the facility. But if the As-built plans identify the facility as an extended detention pond which should have standing water, the facility may be functioning properly. Below in Table 7.2 is a list of common facility misidentifications, with recommendations on how to proceed in each circumstance.

Table 7.2 – Common Facility Misidentifications

Facility Type (Initial Inspection Report)	Facility Type (As-Built Plans)	Analysis - Recommendation
Dry Extended Detention Pond	Wet Pond	If ponding is noted as a failure in the Initial Inspection Report, then the facility may be functioning as designed
Infiltration Basin	Wet Pond	If ponding is noted as a failure in the Initial Inspection Report, then the facility may be functioning as designed
Infiltration Trench	Outlet Protection	Non-BMP - should be removed from database
Wet/Dry Pond	E&SC Pond/Trap	Non-BMP - should be removed from database
SHA BMP	Private BMP	Non-SHA BMP - should be removed from database
SHA BMP - Wetland/Pond	Natural Wetland/Pond	Non-BMP - should be removed from database

If any of these issues occur, then a site visit may not be required. The canceling of a second inspection is on a case by case basis and should be discussed with the HHD contact.

7.2.3 Weather conditions

The inspector should be monitor rainfall events prior to the inspection of the facilities. Inspection days should be scheduled to avoid inspection of facilities after a significant rainfall event, which could impair the inspection. A precipitation event is usually considered significant if 0.5” or more of rain falls within a 24 hour period. The Remedial Inspection Team should also consider the intensity and duration of the precipitation event(s) before inspecting BMPs.

Certain facilities are designed to dewater over a designed period of time, which is 72 hours for most infiltration trenches. Detention and extended detention ponds are also designed to dewater after a specified period of time, usually 12 to 24 hours.

Adverse weather conditions can delay the scheduling of site visits. If facilities are not dewatered, the inspector will not be able to visually inspect pipe outfalls or riser structures which may be under water. For this reason, it is always important to schedule field visits with consideration for the weather, to ensure that the site can be properly inspected and that a follow-up visit will not be necessary.

7.2.4 Other Reasons to Delay a Site Visit

Finally, other than for weather, there are additional reasons to delay visiting in order to perform a thorough inspection. For instance, the inspectors may have incomplete information on the facility and may not be able to perform an in-depth site analysis. The inspector should not visit a site unless they have a clear understanding of the problems previously noted with the facility in the Initial Inspection Report and a clear understanding of how the facility and all of its components function. The As-built plans will usually provide the necessary information, but they may not be provided initially or may not be available. However, the Remedial Assessment Team should check for this information before conducting a site visit.

Finally, as mentioned previously, the inspector should not visit a facility until SHA ownership is verified. If SHA ownership is questionable, the inspection team should wait until enough information is received that can determine if it is SHA property. Verifying SHA ownership prior to visiting the site will prevent wasting effort on the part of the Remedial Inspection Team and ultimately for other SHA personnel.

7.3 FIELD OPERATIONS

The main component of the Remedial Assessment is the field inspection to identify the source of facility deficiencies.

7.3.1 Equipment

As part of planning for the field inspection, the proper equipment must be used to ensure that comprehensive field inspections are performed. A Field Equipment List has already been compiled for the initial inspections and can be found in Chapter 3, Section 3.3.1. The required field equipment is essential for conducting field inspections, and much of it will be necessary to complete the Remedial Assessment. The digital camera is used to document existing field conditions for the maintenance reports. Proper field attire and a safety vest are required due to the overgrowth of brush at the facilities and the proximity of the facilities next to busy interstates and highways. Measuring tapes are used to measure the size of pipes, areas needed to be repaired, and the depth of water in observation wells.

Additional equipment may also be helpful when performing the Remedial Assessment. Hip waders may be a necessary to properly inspect facilities with standing water and to check the extent of a pipe blockage. Bolt cutters or a wrench may be necessary to cut locks or remove the top from an observation well to an infiltration trench to get a measurement of the water level within the trench. Other types of equipment may also be necessary depending on the likely problems encountered at each facility. The Remedial Inspection team should have a proper understanding of the likely field conditions to be encountered so that they can bring the proper equipment. Finally, the inspectors should always go out in the field with at least two inspectors and a cell phone.

7.3.2 Inspection Criteria – Re-inspect Known Deficiencies

As explained in the previous section, each facility that is to be assessed has been inspected previously and deficiencies have been identified on the Initial Inspection report. Before the field visit, these items should be reviewed and understood so that the Remedial Assessment inspectors can gauge the extent of the deficiency observed in the field during the Initial Inspection and are prepared to investigate potential solutions. Therefore, the first and primary component of all Remedial Assessments is to investigate the known facility deficiencies, re-assess the problem at the time of the new inspection, and to determine the actions needed to fix the problem.

The deficiencies identified in the Initial Inspection report are usually related to the function of the facility, structural damage to an inflow pipe or riser structure or problems associated with erosion or sedimentation. The first type of problem relates to the overall function of the facility and can only be addressed by inspecting the facility as a whole. One such problem concerns facilities with standing water. When an infiltration basin or dry pond is observed to have standing water, this is normally caused by a blockage of a dewatering pipe or sedimentation along the bottom of a basin. The exact cause of the problem is not easy to observe since the source of the problem could be several feet under water. Identifying and addressing this type of problem requires a full facility inspection and employing engineering judgment to identify the source of the problem and recommend appropriate solutions.

Structural deficiencies and erosion problems are easier to locate and identify the source of the problem. Usually there will be a pipe separation or damage to a structure due to either poor construction or eventual deterioration over time. Structural problems are easily addressed through repair or replacement of the deficient structure. However, care should be taken to properly identify the source of the failure. Pipe separation at a poorly constructed endwall may be indicative of more separation along the entire length of pipe. Enough information should be gathered during the assessment to ensure that the whole problem has been addressed. Erosion in the facility is also a localized problem that should be sufficiently inspected and addressed. Sometime the solution is as simple as filling in the erosive spot and reseeding the area. Other times a slope may need to be regraded and stabilization matting placed to hold the slope until the vegetation establishes. The scope of the repairs varies from facility to facility and proper engineering judgment should be employed when making a recommendation for addressing erosion.

7.3.3 Inspection Criteria – Inspect for Other Deficiencies

After the known deficiencies which were identified by the Initial Inspection have been investigated in the field, the inspection team will re-evaluate the condition of the entire facility by completing a qualitative inspection of the BMP. This inspection will include investigating all components of the facility to identify any additional deficiencies within the facility that may have been missed by the initial inspection or may have developed since the initial inspection. All deficiencies should be noted, and proper repairs should be considered while in the field. Any additional investigation or information that is necessary to properly repair the deficiency should be made.

7.3.4 Digital Photograph Data

Photographs are taken at each inspection site to document the existing conditions of the SWM facility at the time of the Remedial Inspection and should include any damage that may need to be repaired in order to maintain the facility. However, since extensive photographs should have been taken during the Initial Inspection, it is not required that standard photographs be taken at each facility. Instead, it is recommended that photographs be taken at each feature and structure of the facility which may be documented in the BMP report for each facility, and will provide general support for the findings of the Remedial Inspection. Some of these facility features are the following: an overall picture of the facility; inflow and outflow points to the facility including any outfall channel protection; any other facility structures (such as berms between a forebay and the main facility); any major erosion or other damage to facility; any excessive debris or trash; and any other obstructions to flow at the inflow and outflow points. Of these photos, the most important are those which show any damage that needs to be repaired since these photos will be the most relevant for the maintenance crews which will need to maintain the facility. In addition, the photos can be marked-up using Power Point or other applications to specifically identify the repair work that needs to be performed.

One special feature that should be photographed at all facilities where repairs are recommended, are those features related to access of the facility for maintenance vehicles. These photographs should document any maintenance access roads which were constructed to provide access to the facility and which may be used for any current repairs. If no maintenance access road exists, than the most likely access point to the facility should be determined and photographs should be taken to document any obstructions to access. These obstructions can include roadside curbs, guard rail, steep slopes, heavy vegetation and any other obstacle for which the maintenance crew should be aware of prior to going to the site. Pictures of several access points may be required for larger facilities for which maintenance work would be required in different areas separated by large obstructions such as permanent pools. Pictures of the site can also help with determining a Maintenance of Traffic recommendations, which may be necessary for site access from a state roadway.

Additionally, since the time between inspections may be several years, other issues may arise between inspections which should be documented with pictures. Any changes to the surrounding area or access may have an impact on the maintenance of the facility. Evidence of human or natural impacts may be photographed if it helps demonstrate the source of some facility problems. One example may be sedimentation in a facility caused by upstream development. Identifying the source of a problem better demonstrates whether the recommended maintenance activity will correct the deficiency or whether the same problem will occur again in the future.

Finally, due to the large volume of photos that are usually taken during a day of field inspection, it is recommended that the inspector keep track of where each photo is taken. There are several ways to do this, including noting each picture on the as-built plans used in the field and then organizing the photographs by facility once the inspector returns to the office. Using the file name to identify where the photo was taken is another way to identify each photo. Naming conventions have been developed for the Initial Inspections and can be found in Chapter 3, Section 3.9 of the NPDES Program Manual.

7.4 ANALYSIS

The following discusses the procedures in interpreting the information gathered from the Field Investigation in order to make recommendations and prepare maintenance reports. The goal of the inspections is to determine if the facility is working properly. If the facility is not working properly, the inspection should determine why the facility is not functioning and how can it be fixed. Although the condition of the facility will be analyzed throughout the maintenance process, primarily the Remedial Assessment Team will analyze the information collected in the field for each facility to determine whether work needs to be performed to maintain the facility, and the extent of the maintenance work. The analysis includes interpreting the data collected in the field with the known function of the facility as shown on the plans and other design information.

7.4.1 Assessment of Facility Function

Sometimes the function of the facility is not clear after the field inspection. If the facility type and function are not clearly defined on the plans, additional information may be needed to complete the analysis. As an example, some As-Built plans refer to a facility as water quality check dams, which is not a standard facility type. Additional information usually includes reviewing the original stormwater management report to confirm how the facility was intended to function. Frequently, the stormwater management report is unavailable, and the intended function of the facility may remain unclear. Under these conditions, the Remedial Assessment Team needs to exercise engineering judgment to determine the intended function of the facility. (For the water quality check dams, the Team may need to evaluate them under grass channel credit criteria). The Remedial Assessment Team needs to determine the best recommendation to maintain functionality. The Remedial Assessment Team should consider several factors including actual treatment provided (even if it is not the same type of facility as was designed – basin acting as a pond), cost of repairs, aesthetics of the existing facility and any other relevant factors.

If the source of a facility failure cannot be determined in the field, some basic in-house research and computations may be needed. This may include developing drainage areas to a facility and measuring the impervious area treated, through the analysis of existing plans, details and aerial topography. If it can be verified, the stormwater management report should be used to check if the BMP is currently treating the same amount of drainage and impervious area as when the facility was designed and constructed. If it is necessary to retrieve the stormwater management report to verify the design of the facility, a request should be made to retrieve it from the SHA archives. The original stormwater management report, As-Built plans and detail sheets can give clues as to why the facility failed (i.e. poor design, poor construction or changes to drainage area since BMP was constructed). With better information regarding the original design, sources of failure are easier to identify, and proper recommendations for repairing the facility can be made.

7.4.2 Recommendations

During the analysis process, the recommendations should always be considered. There are four main types of recommendations: No Maintenance Required, Minor/Major Maintenance Required (to repair Facility), Retrofit of the Facility is Required or Abandonment of the Facility is Required since the deficiencies cannot be corrected through simple maintenance.

7.4.2.1 Recommendations for Infiltration Trenches

There are three types of recommendations for infiltration trenches: Maintain, Abandon or Retrofit. Because most of the facility is underground, most problems associated with the facility are not readily observable. Therefore, when an infiltration trench has failed due to high levels of water within the observation well, a general recommendation to replace the media is sometimes made. But maintenance may not always be the best option, such as when there are several facilities constructed in a series and all have failed. Under these circumstances, it may be more cost effective to retrofit one facility instead of rebuilding several failed facilities.

Therefore, there are three standard recommendations for infiltration trenches: maintain the facility, abandon the facility, or retrofit the facility. Maintenance of the facility is the most likely recommendation. It can require the media to be replaced in-kind, when the water level in the observation well is greater than 50%. Other maintenance recommendations for trenches can include replacing broken observation wells, clearing of invasive vegetation and repairing erosion around the media. Maintenance of a facility is usually the best option, since the facility can be restored and the cost is significantly less than a retrofit design.

Abandonment of a facility is sometimes recommended when an infiltration trench has failed. Some trenches provide treatment for small impervious areas (< 0.50 Ac.). Under these circumstances, it is not cost effective to maintain the facility. Instead, the facility can be abandoned, and the loss of water quality treatment can be compensated through a retrofit project. Abandonment of infiltration trenches is only recommended where it can be demonstrated that the impervious area treated is small, the cost of maintenance is significant, and it is likely that the maintenance will not provide a long-term solution.

The final recommendation for infiltration trenches is retrofit of the facility. This recommendation is always the last option because of the significant costs associated with a retrofit design. Retrofits should only be recommended after a thorough analysis of the existing infiltration trench site has determined that the trench cannot be maintained at the current location. One such instance would be a trench constructed for a small drainage area, but which is located along a roadside ditch which receives a large volume of runoff. This can occur when several trenches are constructed in a series, and the last trench receives a larger runoff volume than what it was designed for. The retrofit recommendation should include an analysis of the existing site to determine if additional impervious areas can be treated through a retrofit. These additional impervious areas are used to offset any loss of water quality as a result of abandoning other stormwater management facilities. In some instance, if the stormwater management facility treats less than 0.5 acres of impervious area, then the facility should be considered for abandonment. Abandonment should be considered based on several factors, including the costs for a retrofit design, the amount of impervious area that the existing facility treats and site constraints which may impact a retrofit design.

7.4.3 Common Recommendations

When a facility is in good condition or very bad condition, there is not much that needs to be recommended. For facilities which are in good condition, a recommendation of No Maintenance can be made. This recommendation is appropriate when the original problems identified by the Initial Inspection Report have already been corrected or there was a misidentification of the problem. For facilities which are in very bad condition, a Retrofit design can be recommended. When recommending a facility for Retrofit, a general recommendation can be made which describes the most appropriate facility design for the site conditions, but does not provide any detailed information. The detailed retrofit design will be prepared by others at a later date.

When facilities are in bad condition, but can be repaired without an extensive redesign, then Minor or Major Maintenance should be recommended. When Maintenance is required, there are some common problems that are associated with all facilities. These problems include erosion within a facility and along slopes, excessive vegetation within a facility and structural problems such as separation of pipes and endwalls. Many of these problems are common and require consistent recommendations for maintenance. One example is when the low flow device has clogged. Depending on the type of low flow device being employed there can be several types of solutions proposed to alleviate the problem. These solutions include the addition of a trash rack to protect the low flow orifice, replacing a failed low flow structure, and/or removing sediment and debris which is clogging the low flow structure or orifice.

Another common problem is excess trash, debris and vegetation within the facility. Removal of trash and debris is a relatively simple recommendation, but can be problematic if the amount of trash and debris is minimal and there are no other recommendations for the facility. The Remedial Assessment Team should use proper judgment to determine the impact of trash and debris on the facility, and if it justifies sending a work crew to the site to clean it up. Overgrowth of vegetation can also cause problems, especially along embankments and inflow/outflow channels. The removal of this vegetation would be recommended to improve the functionality of the facility.

Recommendations should also consider site access and should provide the contractor with recommended areas to access the site. Thought should be given as to how heavy or light vehicles can access the facility. Preference should be given to areas which avoid removal of guardrails or fences, minimize travel down steep slopes or which may remain completely within the SHA right-of-way. When determining the best location for site access, Maintenance of Traffic should also be considered and recommendations made when applicable.

Any required permits should also be considered when recommending maintenance for a facility. This includes sediment and erosion control permits if the maintenance work will disturb over 5,000 SF and wetlands or waterways construction permits if the work may impact wetlands or adjacent streams. The permit requirements and limitations on the maintenance should be determined for each facility which is recommended for maintenance. The next few sections provide common problems that occur regularly in stormwater management facilities with recommended approaches for the maintenance of each facility.

7.4.3.1 Recommendations to Stabilize an Eroded Embankment or Ditch

One of the most common problems with any facility is erosion along an unstable channel or embankment (see below). When soils are not properly compacted during construction or the vegetation does not establish along a slope or channel, erosion can occur. If not addressed, the erosion can continue to get worse and lead to highly unstable banks and sediment deposition within facilities which reduce the capacity.

A typical method for stabilizing eroded slopes or channels is to first remove an unconsolidated sediment deposits or to begin to regrade the area. Borrow material may need to be provided in order to grade the area to proper elevations. Any borrow material will need to be properly placed and compacted. It is recommended that once slopes and channels have been compacted to within 2”-4” of final grades, stabilization matting and topsoil should be placed to meet final grades, and the area should be seeded. If conditions warrant, sod should be placed on steep slopes or other areas where stabilization needs to be more quickly established.

7.4.3.2 Recommendations to Remove Trees or other Excess Vegetation

Another common problem with many facilities is when trees or vegetation, which have grown over time, interfere with the proper function of a facility (see below). In some instances, trees or bushes can grow adjacent to riser structures partially blocking low flow pipes and weirs. Occasionally, trees will grow within the media of an infiltration trench or along a pond embankment. Usually the vegetation will only become a problem after many years of growth. However, in order to avoid future issues, the team should recommend vegetation removal whenever there is a potential for impacting a facility.

7.4.3.3 Recommendations to Repair a Separated Pipe or Endwall

Another common problem is when inflow pipes have become separated from an existing endwall or pipe joint, or when the inflow structure has become undermined. This problem, if not addressed, can lead to greater instability. Usually the existing pipe or structure does not need to be replaced, but can be reattached and any gaps can be sealed with mortar. If the condition of the pipe or end section is too degraded, then the recommendation should be for replacement of the pipe or end section. Undermining of the pipe or structure usually occurs when water flows underneath through a gap at the separation. When the separation is fixed, proper bedding material should be installed, and any dislodged outfall protection should be reset or replaced to design grades.

Finally, some pipes cannot be replaced or reset without great expense, such as large pipes located under a permanent pool of water. A more feasible recommendation would be to provide grouting in the partial separation to seal any gaps and to provide a temporary solution. The report should note the structural integrity of the pipe system and should recommend further monitoring of the problem for worsening conditions. However, any potential emergency situation should be addressed as soon as possible.

7.4.4 Recommendations for Ponds and Basins

7.4.4.1 Recommendations to Unblock Low Flow Device

One of the most common problems with ponds and basins is excessive ponding due to a blockage of the low flow pipe or orifice (see below). If the low flow pipe is blocked, ponding can be as deep as 10 feet or more, depending on the elevation of the next highest weir control within the riser structure. Water levels to these depths interfere with the pond function. In order to restore the facility to its proper function, the pond needs to be dewatered and the low flow pipe needs to be cleaned or repaired.

A recommendation for dewatering a blocked facility needs to provide the contractor with adequate information for pumping operations and for maintaining sediment and erosion control practices. The instructions for pumping should be specific to the site, should include pump sizing and the anticipated time to dewater the facility. Typical pumping instructions should recommend use of a 2”-3” Dri-Prime pump which can pump at a rate of 100-200 gpm up to a head of 15’. Dewatering time will depend on the pump capacity specified and the volume of water that needs to be pumped from the facility. A 2”-pump can dewater 1 Ac-ft of water, which should be the maximum for most facilities, within 24 hours. The volume of water can be determined by calculating from the grading shown on the As-Built plans or can be determined from a SWM Report, if one is available. The instructions should provide for pumping from the surface of the pond where the water is cleaner.

Sediment and erosion control features should include filtration of pumped water through portable sediment tanks or dirt bags, whichever is more appropriate, to a stable downstream outlet. Pumping into the riser structure through a weir opening or top of structure may be one option. If it is not an option, the pump hose can outlet over an earthen embankment to the outflow channel. If the pond embankment is an active roadway, then other options may need to be explored.

Once the pond had been dewatered, the damage or blockage to the low flow pipe or orifice will need to be addressed. Since the extent of damage to the low flow pipe may be unknown, recommendations should be based on correcting any design deficiencies with the low flow structure. This usually entails adding a trash rack for larger detention pipes which may have been blocked, or calling for repairs and replacement of a perforated low flow pipe. The team should analyze the existing design as shown on the As-built plans, determine the likely problem causing the blockage, and propose an appropriate solution to prevent the problem from reoccurring.

7.4.4.2 Recommendations to Remove Sediment from a Pond or Basin

Another problem with ponds and basins is excessive sedimentation within the facility. Sedimentation is usually associated with eroded embankments or inflow channels, but some sources of sedimentation can be from offsite areas. First, the inspector needs to identify the source of sedimentation and determine if it is still active. If it is active, the recommendations should include methods for addressing the source, such as stabilizing eroded slopes or inflow channels. Once the source has been addressed, the recommendations should address removing excess sedimentation and restoring the original design volume to the facility. As-Built plans should be referenced and used to determine the original facility grades if it there is uncertainty. Finally, some of the material may be reused on-site. But if the material cannot be used to stabilize eroded areas, then the recommendations should be to dispose of the excess material off-site and at an MDE approved facility.

7.4.5 Recommendations for Infiltration Trenches

7.4.5.1 Recommendations for Replacing a Saturated Trench

One of the most common problems with infiltration trenches is excessive ponding within the stone media. Since the infiltration trench media is underground, the primary information measured from an initial inspection is the depth of water within an observation well. When the water level is greater than 50% of the well depth, the facility is considered to have failed. There can be many reasons for a trench failure including a high groundwater table, poor drainage in the surrounding soils, poor construction of the trench or internal blockage within the facility due to sedimentation. If there are no indications that the facility was improperly designed or constructed, it is assumed that the facility has become blocked due to sedimentation.

The most feasible method for correcting a blocked infiltration trench is to replace the stone media. The recommendation in the report should indicate that the media should be excavated and replaced in-kind. The contractor should have material to replace the media on-site at the time of the excavation. If the excavated media is not covered with sediment as a result of a blockage, then it can be reused. The on-site inspector should be alerted to look for other indicators that may have caused the failure, so that the contractor can receive proper instructions to correct the trench deficiencies. The contractor should not blindly replace the media, because there may be indications of a high water table or poor drainage in the surrounding soils which caused the failure. In this situation, the contractor should place the excavated material back in the trench and abandon the site. The inspector should then notify HHD that the facility could not be maintained and was therefore abandoned. The recommendation report must clearly reflect all of these steps, where appropriate, so that the trench media can be replaced when it is feasible or the trench will need to be abandoned.

7.4.5.2 Recommendations for Installing an Observation Well

Another common problem with infiltration trenches is the lack of an observation well. Sometimes the observation well was not installed during the original construction, or it was improperly installed and cannot be located at the time of inspection. When an observation well cannot be located, the inspector cannot measure water levels within the infiltration trench to determine if the trench has failed. If there are no other indications that the trench has failed, than the Maintenance Report should recommend that a new observation well be installed within the infiltration trench to be utilized for future maintenance inspections.

The recommendations should include instructions to install a new observation well and should provide a detail, usually based on the As-Built plan, for the installation. The report should also recommend that the inspector monitor the media removed in order to install the well, since there may be indicators that the trench has failed that were not visible from the surface. If there are indicators of sedimentation or failure, during the observation well installation, then the inspector should be instructed to follow similar steps as outlined in the previous section.

7.5 MAINTENANCE REPORTS

The recommendations for each facility are summarized in a Maintenance Report. The Maintenance Report is to be submitted in a standardized format as outlined in this Section.

7.5.1 Types of BMP Reports

There are three basic types of BMP Reports that can be submitted for each facility: a Minor/Major Maintenance Report, a No Maintenance Required Report and a Retrofit Report. Each type of report consists of different information. Depending on type of BMP further information may need to be provided beyond the standard report.

7.5.1.1 Minor/Major Maintenance Report

The main type of BMP Report is the Minor/Major Maintenance Report. This report is prepared for any facility in which maintenance work is required to address facility inadequacies. The primary purpose is to provide recommendations for maintaining a facility in the form of a work order for a work crew to utilize to make the repairs. Major Maintenance work for a facility is distinguished as repairs that will require the contractor to mobilize heavy equipment and which may require MOT. All other maintenance work can be considered as Minor Maintenance. Although the naming conventions are different, both types of reports for recommended repairs will follow the same standardized format. At a minimum, each standard report should include the following items:

a. BMP Maintenance Report – this is a Word document which provides textual information summarizing the inspection and the recommendations
b. Maintenance Report Work Order – this is an Excel document which provides a “punchlist” of items that the work crew will need to complete to repair the facility
c. Location of Work drawing – this is an image file (which can be a PDF, Power Point or other document) that shows where each individual work item, shown on the work order, is located within the facility. The number shown on the work order item should correspond to the call-out on the drawing. This document is not required and may not be included when the location of work is obvious and easily located.
d. Location Map - this is an image file (usually a JPEG document) which provides the work crew with adequate information to locate the facility in the field. This map is usually provided to the Inspection Team with the initial project information.
e. Cost Estimate - this is an Excel document which is used by SHA to assess the cost of the standard repairs that are recommended. The cost estimate is based on the labor costs, equipment costs, and material costs necessary to complete the work. This type of cost estimate is usually referred to as a time plus materials estimate.
f. As-Built Plan Sheets/ Detail Sheets – these are the scanned images (usually TIFF images) provided to the Inspection Team with the initial project information which can be provided, when available, as additional detailed information for the work crew. If As-built plans are not available with these details, CADD drawings may need to be developed to illustrate for

the work crew how to install items such as infiltration trenches (providing depths, widths and materials) or trash racks.

Refer to Appendix Section ‘A’ for a copy of a sample Standard Maintenance Report.

In addition, there is supplemental information which may be included in a Maintenance Report to help clarify the recommendations or constraints for making the repairs. They are as follows:

7.5.1.2 Infiltration Trenches

Maintenance Reports for Infiltration Trenches include additional information specific to this type of facility. Since there are three standard recommendations for infiltration trenches, a standard Infiltration Rating worksheet was created to summarize the facility and to support the recommendation. The Infiltration Rating contains relevant information about the trench, including the impervious area treated by the trench, the depth of the water in the observation well and the recommendation for the facility. The Infiltration Rating worksheet is included with the Standard Maintenance Report for all infiltration trenches. Refer to Appendix Section ‘A’ for a copy of a sample Infiltration Rating worksheet

The Infiltration Rating worksheet will precede the Standard Maintenance Report within a submittal. It is linked to an Investigation Summary sheet which summarizes the credit or debit recommended for each watershed. This summary helps the Remedial Inspection Team to determine the best recommendation for each facility.

7.5.1.3 Retrofit Recommendation Report

In many instances, the stormwater management facility cannot be restored to its original function by performance of routine maintenance. These instances are more thoroughly described in the preceding Sections. When a facility is recommended to be retrofitted, the report is less detailed than for maintenance. The report will still include a Location Map and a Word document summarizing the inspection and recommendations. The recommendations should include potential retrofit facility types and possible relocations for a new facility. In addition, the report should explore options for treating additional impervious areas, where possible. The Retrofit Recommendation Report will become a source of information for determining which facilities to include in any future retrofit design project.

7.5.1.4 No Maintenance Required Report

In other instances, the Remedial Inspection team will determine that there are no problems that need to be addressed at a particular facility. These instances are more thoroughly described in the preceding Sections. The most likely reason this occurs is the Initial Inspection Team misidentifies a problem which is more clearly shown on the As-Built plans, which may not have been available at the time of the Initial Inspection. If this occurs, it is important to create a No Maintenance Inspection Report to be submitted and stored within the database. This creates a permanent record which will address the maintenance recommendations from the Initial

Inspection Report. Without this record, there could be uncertainty concerning the need to address the issues identified in the Initial Inspection Report.

7.5.2 Deliverables

Once several BMP facilities have been inspected, analyzed and recommendation reports have been developed, thought should be given to the deliverables. Individual BMP Facility Reports should be compiled into an Overall BMP Report to be submitted to SHA. The Overall BMP Report should be organized based upon facilities located in a common location (same road or area) and facilities with common recommendations (Maintenance Reports or No Maintenance Required). Sometimes, depending on the requirements of work crews, several Overall BMP Reports may need to be prepared for one group of facilities provided to the Remedial Inspection Team to be inspected. This usually occurs when some, but not all of the facilities have been inspected. When the work crews have a limited backlog of facilities to maintain, SHA may request that the Remedial Inspection Team submit BMP Facility Reports for

All information to be submitted is to be delivered in a standardized format. This is important so that an accurate BMP inspection database can be maintained. Each submittal shall contain several BMP Facility Reports and shall be submitted with paper copies and with an electronic copy. Paper copies of the maintenance reports are submitted so that the document can be provided to the contractor who will perform the recommended work. Electronic copies of the reports are archived in the BMP database for proper documentation of the Remedial Assessment and recommendations.

7.5.2.1 BMP Reports

Paper Copies

Each paper copy of the maintenance reports is recommended to be bound in a three ring binder. This format allows for any updates to the recommendations, where updated sheets can be easily replaced within the report. This format also allows the work to be split between several work crews. Several facilities in one report can be removed and given to different work crews since each individual facility report can be maintained independently.

The paper copy of the Overall BMP Report shall include a title sheet within the front binder cover identifying the report and supplying relevant information such as the date of submittal and the County where the facilities are located. A table listing of each facility within the report should also be included.

Three hard copies are required of each maintenance report. One copy shall be for the contractor performing the work, one shall be for the inspector overseeing the work and one shall be kept as an archive record. The first two copies of the maintenance report shall consist of all the necessary information except for the cost estimate. The third copy of the maintenance report shall include the cost estimate. A cost estimate is not required for retrofits.

Electronic Copies

In addition to delivering hard copies of the reports, an electronic copy of each report shall also be submitted. For Pond/ Basin reports, all information which pertains to each individual BMP shall have all of its components (text, maintenance action sheet, cost estimate, plan sheets, etc.) combined in a single PDF document with the sheets in the same order as the sheets that were submitted for the hard copy submittal. Photographs are to remain in color and any 11x17 plan/ detail sheets are to be kept at the same size in the PDF document. The file name shall be "Report" and the bmp identification number (i.e. Report_BMP_15234.pdf)

Infiltration trench/ check dam reports shall have the county initials, trench/ check dam report, and the date of the hard copy submittal as the file name (i.e AA_Trench_Report_7-06-2007.pdf). If the trench/ check dam report contains BMPs from various counties the file name shall either include all the county initials or "Various _Counties" shall replace the county name. Infiltration trench and check dam watershed summary spread sheets shall be submitted in Microsoft Excel format so that data can be easily transferred to a master summary sheet. These files shall have the watershed name, trenches/ check dams, and the date of the hard copy submittal as the file name (i.e. Patapsco_River_trenches_7-06-2007.xls).

All electronic files shall be copied to a CD and shall be submitted at the same time that the hard copies of the reports are delivered.

7.5.3 QA/QC

Quality Assurance and Control shall be followed throughout the Assessment process to reduce errors. It shall be the duty of the Remedial Assessment Team to follow proper QA/QC procedures as it is not the responsibility of SHA to review the reports for content errors.

APPENDIX L:

ALP Environmental Survey

October 2008

SHA INTRAnet Maryland Department of Transportation Advanced Leadership Program (ALP) This List: ALP Env

SHA Intranet > Deputy Administrator for Finance, Information Technology & Administration > Advanced Leadership P
Respond to this Survey

ALP Environmental Survey: Respond to this Survey

1. In which office or district do you work? *

Office of the Deputy Administrator/Chief Engineer – Operations

2. Where do you live? *

3. What is your age group? *

4. What is your highest level of education attained? *

5. Do you see the condition of the environment in general as getting better, staying the same or getting w

- Getting Better
- Staying the Same
- Getting Worse
- Not Sure

6. In general, would you say that State Highway Administration now does about the right amount for the to do less? *

- Does Right Amount
- Needs to do More
- Needs to do Less
- Not Sure

7. Compared to other issues and concerns, how you would assess the importance of the environment to y

- Extremely Important
- Very Important
- Somewhat Important
- Not That Important
- Not Sure

8. How important is it to you that Maryland considers alternative energy sources? *

- Extremely Important
- Very Important
- Somewhat Important
- Not That Important
- Not Sure

9. My own actions contribute to global warming and other environmental problems such as water and air

- Strongly Agree
- Mostly Agree
- Mostly Disagree
- Strongly Disagree
- Not Sure

10. Changing my own behavior will help reduce the impacts of global warming and other environmental p

- Strongly Agree
- Mostly Agree
- Mostly Disagree
- Strongly Disagree
- Not Sure

11. When you go shopping and are thinking about which products to buy, how often do you think about tl environment? *

- Frequently decide based on environmental impact
- Occasionally decide based on environmental impact
- Decide on other factors (cost or personal preference for a particular brand)
- Not sure

12. What mode of transportation do you use to get to work? *

- SHA-assigned vehicle
- Personal vehicle
- Mass transit
- Bike/walk
- Carpool
- Taxi
- Motorcycle

13. During the past year, when you commute by car for SHA business, how often do you carpool? *

- Always
- Most of the time

- Sometimes
- Never
- SHA travel is not required

14. When purchasing a vehicle, do you consider environmental impacts as part of your decision?

- Yes
- No

15. Which activities do you consistently practice? (The following activities will improve gas mileage) Che

- Remove excess weight in vehicle
- Properly inflated tires
- Drive at a constant speed
- Routine vehicle maintenance
- Avoid unnecessary idling
- Anticipate driving conditions to avoid unnecessary braking
- Combine trips
- Avoid using air conditioner whenever possible
- Avoid driving with windows open above 50 mph

16. Of the above activities that you identified, do you also practice these activities when using a State/co

- All
- Most
- Some
- None
- I do not drive State/company vehicles

17. Do you unnecessarily use a State vehicle to meet the minimum mileage requirements in order to justi

- Yes
- No
- I do not have a State/company vehicle assigned to me

18. Which of the following use electricity when "off" but still plugged in (known as Phantom Load)? Chec

- Curling iron
- TV
- Computer
- Coffee maker
- Microwave
- Toaster
- Stereo
- Oven

- ☐ Power adapter with no "off" switch
- ☐ Cell phone charger

19. Do you turn your computer monitor off when not in use?

- ○ Always
- ○ Most of the time
- ○ Sometimes
- ○ Never

20. At work do you turn off the lights when a room is not in use?

- ○ Always
- ○ Most of the time
- ○ Sometimes
- ○ Never

21. At home do you turn off the lights when a room is not in use? *

- ○ Always
- ○ Most of the time
- ○ Sometimes
- ○ Never

22. Do you recycle? *

- ○ Always
- ○ Most of the time
- ○ Sometimes
- ○ Never

23. If so, what do you recycle? Please check all that apply.

- ☐ Paper
- ☐ Plastic
- ☐ Cans
- ☐ Glass
- ☐ Batteries
- ☐ Yard waste
- ☐ Organic/kitchen waste
- ☐ Specify your own value:

24. If you do not recycle, why?

- ☐ Not convenient

- [ ] Not sure what can be recycled
- [ ] Don't have a habit of recycling
- [ ] Not sure of real benefit and how it will make a difference to the environment
- [ ] Specify your own value:

25. Which of the following do you practice to conserve energy? Check all that apply.

- [ ] Close blinds during the day in the summer
- [ ] Use Energy Star products
- [ ] Use energy efficient light bulbs
- [ ] Wrap water heater in blanket
- [ ] Insulate attic
- [ ] Use less hot water (shorter showers)
- [ ] Turn water heater thermostat down
- [ ] Use programmable thermostat
- [ ] Use solar power
- [ ] Don't run dishwasher unless it's full
- [ ] Change filters in furnace/air conditioner
- [ ] Use ceiling fans

26. Check any of the following waste reduction activities that you practice:

- [ ] Use reusable water bottles
- [ ] Use a reusable coffee mug at work
- [ ] Use reusable containers for food instead of plastic or foil
- [ ] Wash and reuse plastic bags
- [ ] Use cloth shopping bags instead of plastic or paper
- [ ] Buy food in bulk to save packaging
- [ ] Use rechargeable batteries
- [ ] Specify your own value:

27. Which group accounts for the most negative impact on the environment? *

- ○ Industry
- ○ Government
- ○ Farmers
- ○ Individual people

28. What motivates you (or would motivate you) to take personal actions to improve the environment? C

- [ ] Saves money/cost-effective
- [ ] Moral obligation to future generations/sustainability

- [ ] Peer pressure/It's become popular
- [ ] It makes me feel good/empowered to make a difference
- [ ] Have seen destruction of local environment
- [ ] Concerned about pollution effects on human health
- [ ] Influenced by media
- [ ] Not sure
- [ ] Specify your own value:

29. What prevents you from taking additional steps or actions to address environmental problems? *

- [ ] My actions won't make a difference
- [ ] Set in my ways
- [ ] Don't know enough/don't have enough information
- [ ] Inconvenient
- [ ] Too expensive
- [ ] Don't think it is a problem
- [ ] Not sure
- [ ] Specify your own value:

30. Would you volunteer some of your personal time to improve the environment locally? *

- ○ Yes
- ○ No
- ○ Not sure

31. What environmentally friendly practices does your work unit already undertake?

32. How can we be more environmentally friendly at SHA?

APPENDIX M:

Long Draught Branch Alternative Analysis and Correspondence

August 2008

LDB Alternative Analysis and Correspondence

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

State Highway Administration
Maryland Department of Transportation

John D. Porcari, *Secretary*
Neil J. Pedersen, *Administrator*

August 5, 2008

Ms. Andi Cunabaugh, Chief
Regulatory Services Coordination Office
Water Management Administration - Mailstop - 430
Maryland Department of the Environment
Montgomery Business Park
1800 Washington Boulevard
Baltimore, Maryland 21230

Attn: Mr. Steve Hurt, McCormick Taylor

RE: MD 117: Long Draught Branch Stream Restoration
SHA Project No. **MO280A21** (formerly MO357A21)
MDE Tracking No.: 200661425

Dear Ms. Cunabaugh:

As you know, the Maryland Department of Natural Resources (DNR) submitted comments to your office in a memorandum dated March 14, 2008 expressing their concerns regarding the Maryland State Highway Administration's (SHA) approach to the restoration of the subject stream. This memo also requests an interagency meeting, which was held on July 16, 2008. Some of the concerns have been addressed at the meeting. This letter and attached documents include direct responses to the outstanding comments and those expressed at the meeting.

It is our understanding that DNR has two specific concerns. These are the loss of riparian forest, as proposed in the current design plans, and SHA stream restoration design policy. Attached documents summarize the project alternatives considered from the project inception through the development of the final design plans. Some of these options were presented at the pre application meeting with some of the agencies' representatives in December 2005 and the Alternative No. 4 was concurred. It is our opinion that Alternate 4 is the preferred design option when permanent forest loss, costs, water quality, sustainability, and overall benefit to the watershed are considered.

As the design proceeded with the selected alternative, some of the information for the other options was not formally compiled and presented. Subsequent to the meeting on July 16, 2008, the additional information was complied for the previously considered options in order to define and compare the riparian impacts as requested.

My telephone number/toll-free number is ______________________
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.marylandroads.com

Cunabaugh
Long Draught Branch Restoration
MO280A21
Page 2 of 2

SHA has been actively cooperating with the City of Gaithersburg that is in full support of this project (see attached letter). SHA has committed funds and is prepared to implement these plans during the 2008/2009 construction season in order to forestall a cataclysmic failure of the damaged dam.

Worth reiterating is the fact that SHA has no plan or policy to promote the wholesale grading of floodplains and riparian forest for the purpose of removing 'legacy' or 'pre-settlement' sediments. With agencies' approval, SHA has and will continue to make thoughtful and judicious design decisions in specific situations where hydraulic engineering constraints dictate.

If you have any question or comments, please do not hesitate to contact Veronica Piskor at 410 545-8631.

Sincerely,

Sonal Sanghavi, Director
Office of Environmental Design

Enclosures

SS/vrp

CC: Greg Golden, DNR
Steve Elinsky, USACOE
Bill Schultz, USFWS
Barbara Rudnick, EPA
Kirk McClelland, SHA - OHD
Raja Veeramachaneni, SHA – OPPE
Karuna Pujara, SHA - HHD
Dana Havlik, SHA – HHD
Juliet Healy, SHA - PPD
David Black, RKK
Drew Altland, Landstudies

Long Draught Branch – Alternatives Analysis
Design Constraints, Stability Considerations and Level of Impact

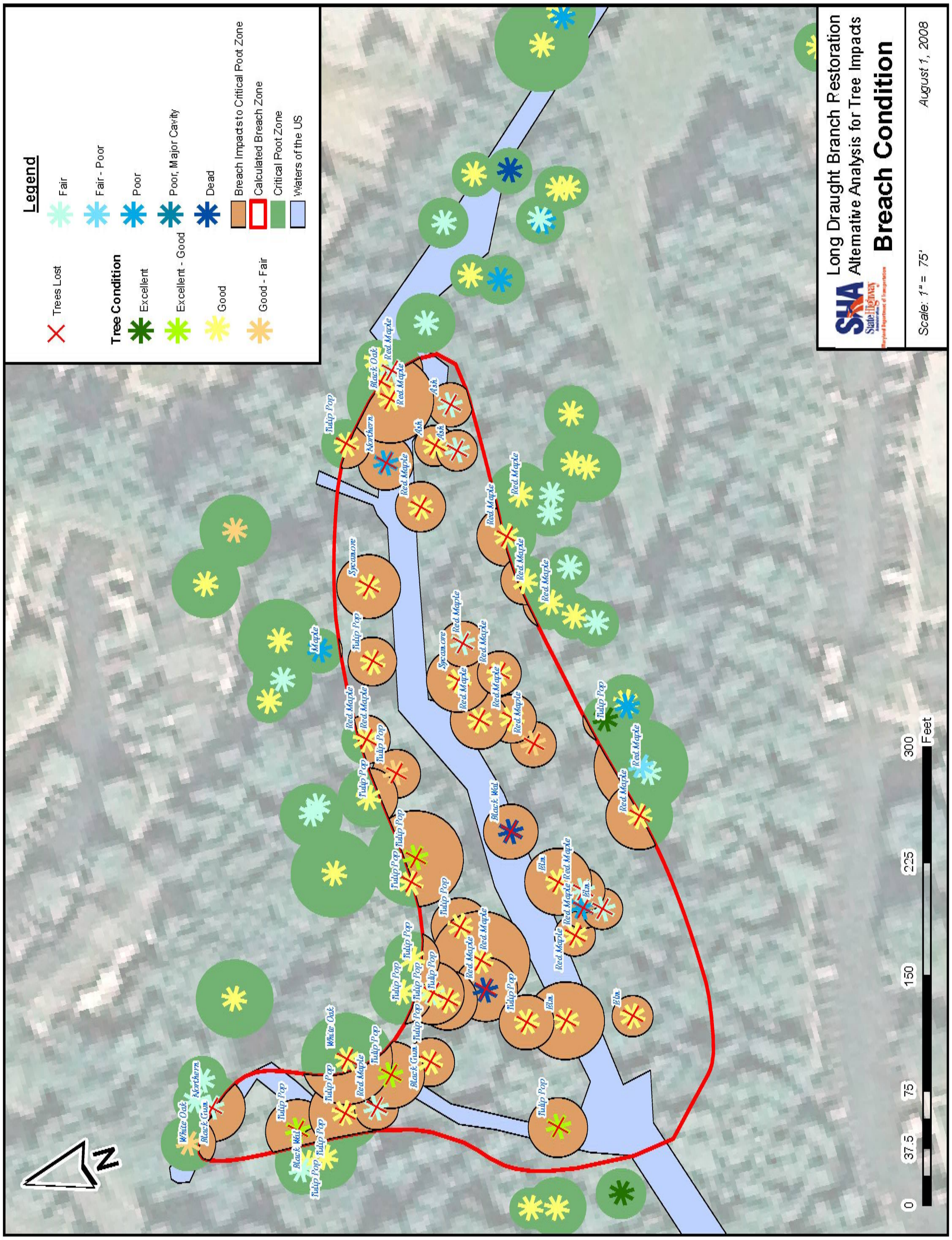
The State Highway Administration began studying Long Draught Branch, downstream of MD 117, in 2004 for channel protection needs associated with the proposed Phase II of the roadway widening project. After preliminary studies revealed the failing downstream dam and the fact that channel protection would be required in the upper reach, MDE's Sediment and Stormwater Plan Review Division agreed with SHA's plan to perform stream restoration along this 2,300 foot reach for both channel protection and water quality requirements for the roadway project. To this end, SHA developed four design alternatives to present to the reviewing agencies during a pre-application meeting in the field. These alternatives are presented below and shown on the attached graphics. The attached Summary Table shows some of the design considerations for all four alternatives.

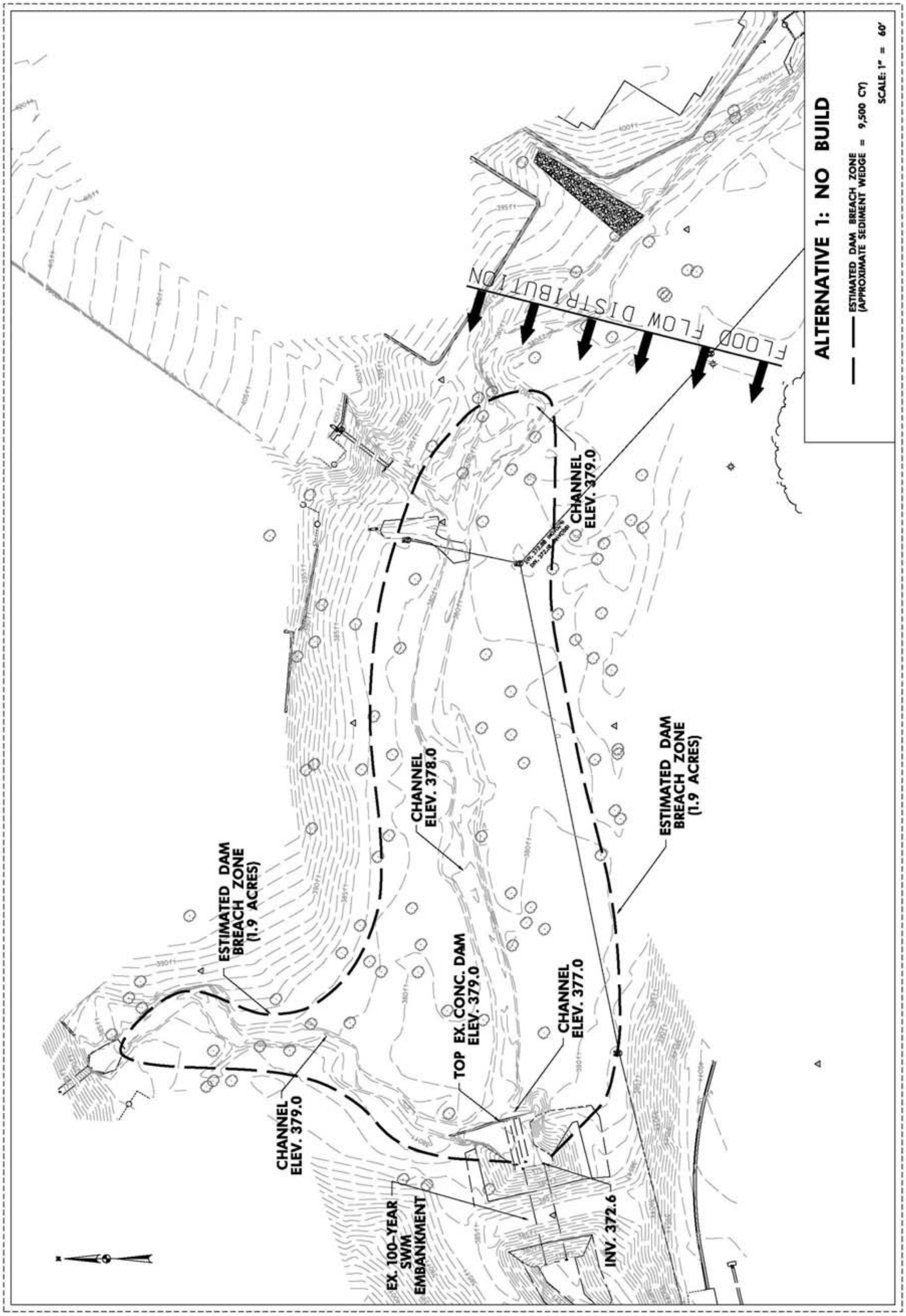
<u>Alternative 1 – No build option for lower reach</u>:

This alternative involves restoration of 1300 feet of the upper reach starting at MD 117 and avoids all stabilization and/or restoration efforts on the lower 945 foot reach of Long Draught Branch (LDB), including the unnamed tributary in its entirety, thereby not addressing the concrete dam breach. Based on its current condition, it is highly probable that over some unknown time period the dam will breach and cease to provide a grade control for the upstream streambed composed of fine sediments that are stored behind the 6-foot high concrete dam. The attached drawing for Alternate 1 shows the immediate zone of influence once the dam breaches and the nick point migrates upstream under flood flow conditions. The volume of fine sediment that has been deposited in this zone as a direct influence of the dam has been estimated to be 9,500 cubic yards, which equates to approximately 12,000 tons of sediment.

Based on the research by Zhou, Donnelly and Middleton (*Dam Removal and Sediment Movement: A Practical Modeling Approach published June 2004*), the transport capacity of these fine sediments under dam breach conditions at 303 cubic feet per second (representing 2-year storm peak discharge) is approximately 10 lb per cubic foot. Multiplying transport capacity by the LDB 2-year peak discharge yields an erosion rate of 3,030 lbs per second. Therefore, according to the research by Zhou et al, if the 2-year peak discharge were maintained for 2.2 hours under dam breach conditions, then 12,000 tons of sediment could potentially be removed from the site during one fairly routine event. This zone of influence on LDB, shown on the attached drawing for Alternate 1, is estimated to span <u>1.9 acres</u>, including <u>47 trees</u> greater than 18" DBH within this zone. The SHA design team understands that the conditions analyzed by Zhou et al are likely to vary from that of LDB, but use this example to demonstrate the seriousness of the breach impacts. Even if the LDB erosion rate and stored sediment volume estimate is half of what has been stated above (i.e. 6,000 tons of sediment removed in 4.4 hours), the impact of the breach is still highly significant to downstream environments and the forested areas currently within the erosion zone.

This alternative includes the restoration of LDB from Sta. 0+00 to Sta. 13+00, as is proposed in the submitted construction documents. At Sta. 13+00, the proposed channel and existing channel closely match in plan and profile making it possible to end the restoration at this point.


Legend
Trees Lost
Tree Condition
Excellent
Excellent - Good
Good
Good - Fair
Fair
Fair - Poor
Poor
Poor, Major Cavity
Dead
Breach Impacts to Critical Root Zone
Calculated Breach Zone
Critical Root Zone
Waters of the US
Long Draught Branch Restoration
Alternative Analysis for Tree Impacts
Breach Condition
Scale: 1" = 75'
August 1, 2008
0 37.5 75 150 225 300
Feet

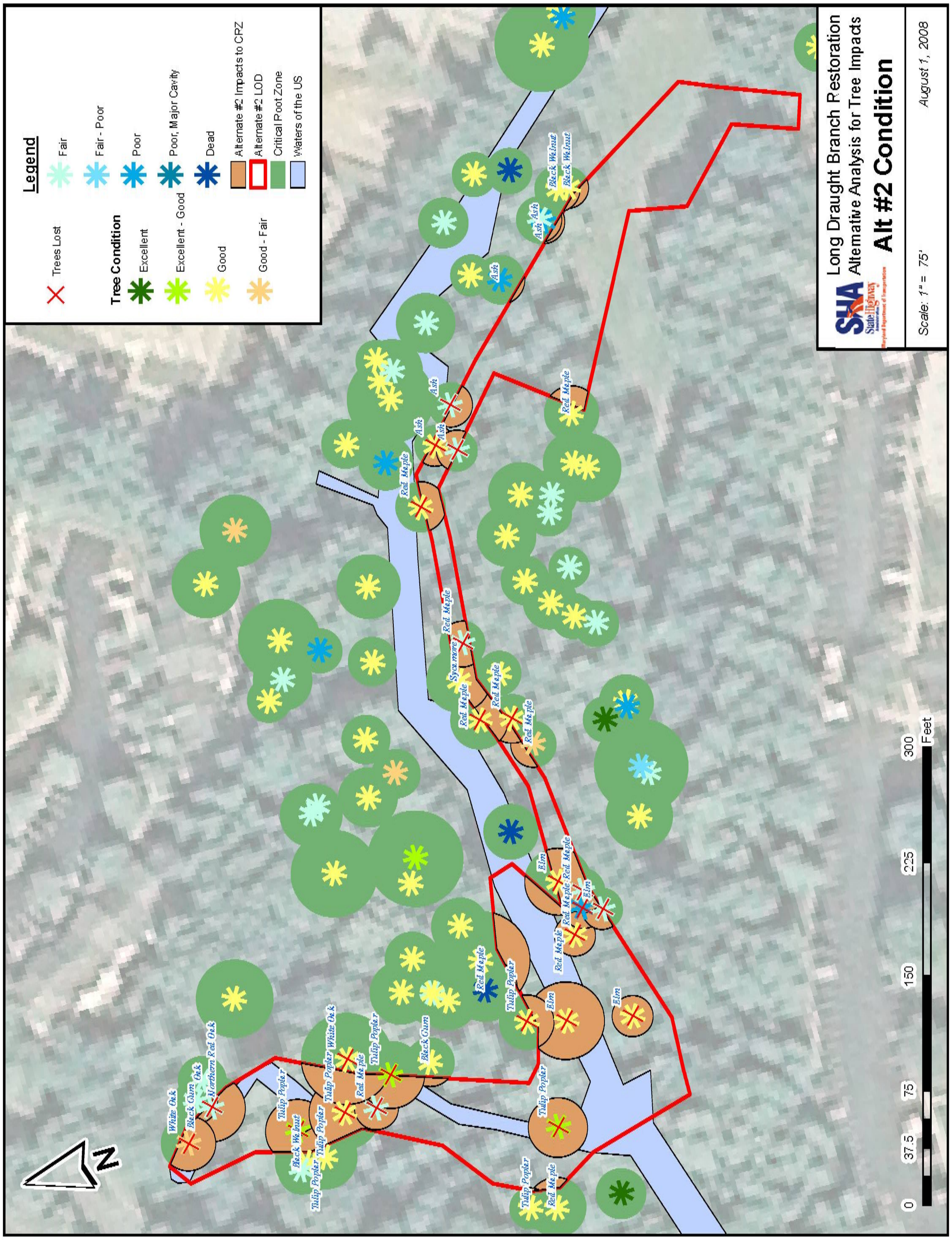

ALTERNATIVE 1: NO BUILD
ESTIMATED DAM BREACH ZONE
(APPROXIMATE SEDIMENT WEDGE = 9,500 CY)
SCALE: 1" = 60'
FLOOD FLOW DISTRIBUTION
CHANNEL ELEV. 379.0
ESTIMATED DAM BREACH ZONE (1.9 ACRES)
CHANNEL ELEV. 378.0
ESTIMATED DAM BREACH ZONE (1.9 ACRES)
TOP EX. CONC. DAM ELEV. 379.0
CHANNEL ELEV. 377.0
CHANNEL ELEV. 379.0
EX. 100-YEAR SWM EMBANKMENT
INV. 372.6

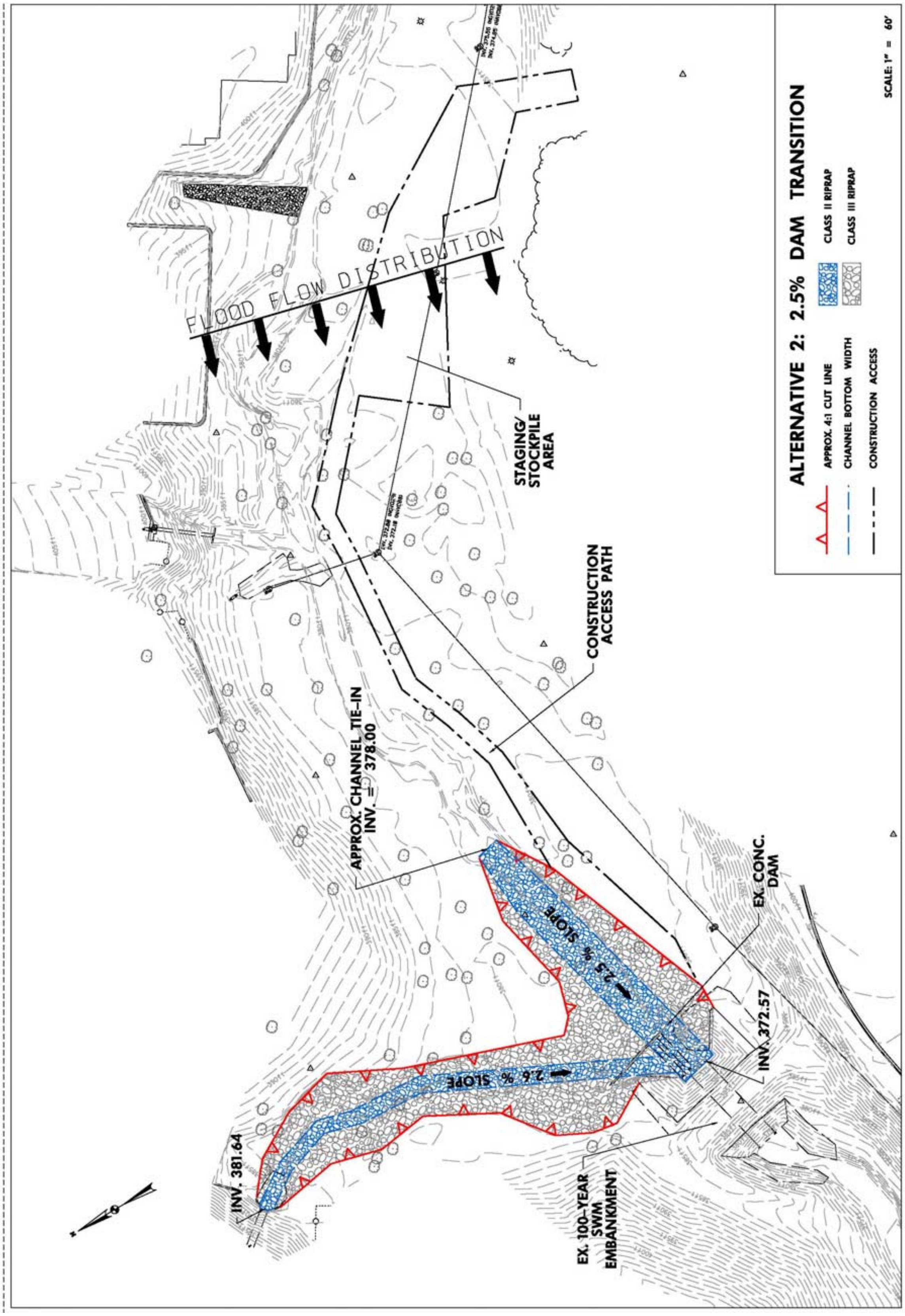
<u>Alternative 2 – Stream stabilization with 214-foot transition for the lower reach option</u>:

This alternative includes removal of the concrete dam and transitions the 6-foot vertical drop at the upstream channel slope of 2.5 percent. The approximate transitional reach length is 214 feet, as shown on the attached drawing for Alternate 2. The bottom width of the transition channel is 27 feet to match the existing apron width at the channel entrance to the twin 7.5 foot by 11.5 foot culvert opening of the 100-year storm SWM embankment. The side slopes of this transition channel that tie the bottom of the channel back up to existing ground have been set at a 4 horizontal to 1 vertical slope. The unnamed tributary has been set at a 2.6 percent channel slope and the channel bottom width has been set at 12 feet, which is the approximate width of the existing channel. The side slopes of the tributary have also been set at a 4 horizontal to 1 vertical slope. The area or footprint of grading and rock stabilization in the 214-foot reach, NOT including construction access and erosion control measures, is 0.60 acres. The volume of sediment to be removed within the 214-foot reach alternative is 1,025 cubic yards to get to grade and another 2,475 cubic yards to install riprap. It is important to note that 0.60 acres of stabilization will need to be completely armored with riprap in the streambed, channel banks and a portion of the flood prone area, and therefore will not permit vegetative establishment in this zone. In other words there would be a <u>0.60 acre permanent loss of forested area</u> associated with this option. The total construction disturbance for the lower 214-foot reach will impact 1.11 acres and <u>23 trees</u> greater than 18" DBH. Additionally, stability of placed riprap is of significant concern due to the underlying unconsolidated material behind the dam. If the stones can not be placed on stable ground then profile adjustment of the transition reach is likely to occur. This can result in a major channel head cut.

The SHA design team believes this design alternative to be unstable and has major concerns in relations to long-term stability as well as function with this strategy from the engineering perspective. These stability concerns stem from the steep slopes required to drop flood flow discharges from elevation 380 (current floodplain surface upstream of dam) to elevation 372.6 (invert of 100-year SWM embankment culvert) over a short distance of 214 feet. At a location that is approximately 850 feet upstream of the 100-year SWM culvert, flood flows from the upper project reach begin to spread laterally due to the flattening of the valley slope created by the deposition of sediment collected behind the concrete SWM dam. According to the existing conditions HEC-RAS model analysis, the water surface elevation (WSEL) at RS 1110 is 382.84 to 384.86 for the 2-year to 100-year storms, respectively. The stream bank height or floodplain surface elevation at RS 1110 is 382, yielding flood flow depths of 0.84 feet to 2.86 feet flow down the filled in floodplain surface for the 2-year to 100-year storms, respectively. As flood flows approach and spill over the riprap armoring of the 214-foot transition reach, failure in the armoring layer is expected over time, as shear stress over the 4:1 riprap slope will achieve nearly 8 lbs per square foot for a test case depth of 0.5 feet. The shear stress for 0.84 feet and 2.86 feet depth of flow would be even higher. The time for failure will be dependent upon future rainfall patterns, but the SHA design team expects stability issues to develop in the near-term with this alternative. Therefore this alternative is not recommended.

This alternative does include the restoration of LDB from Sta. 0+00 to Sta. 13+00, as is proposed in the submitted construction documents. At Sta. 13+00, the proposed channel and existing channel closely match in plan and profile making it possible to end the restoration at this point. Note that a reach of approximately 735 feet in length between Sta. 13+00 and the 214-foot transition reach will remain unrestored / not stabilized.


Legend
Trees Lost
Tree Condition
Excellent
Excellent - Good
Good
Good - Fair
Fair
Fair - Poor
Poor
Poor, Major Cavity
Dead
Alternate #2 Impacts to CPZ
Alternate #2 LOD
Critical Root Zone
Waters of the US
Long Draught Branch Restoration
Alternative Analysis for Tree Impacts
Alt #2 Condition
Scale: 1" = 75'
August 1, 2008
0
37.5
75
150
225
300
Feet
N


ALTERNATIVE 2: 2.5% DAM TRANSITION
APPROX. 4:1 CUT LINE
CHANNEL BOTTOM WIDTH
CONSTRUCTION ACCESS
CLASS II RIPRAP
CLASS III RIPRAP
SCALE: 1" = 60'
FLOOD FLOW DISTRIBUTION
STAGING/ STOCKPILE AREA
CONSTRUCTION ACCESS PATH
APPROX. CHANNEL TIE-IN INV. = 378.00
EX. CONC. DAM
INV. 372.57
2.5 % SLOPE
2.6 % SLOPE
INV. 381.64
EX. 100-YEAR SWM EMBANKMENT

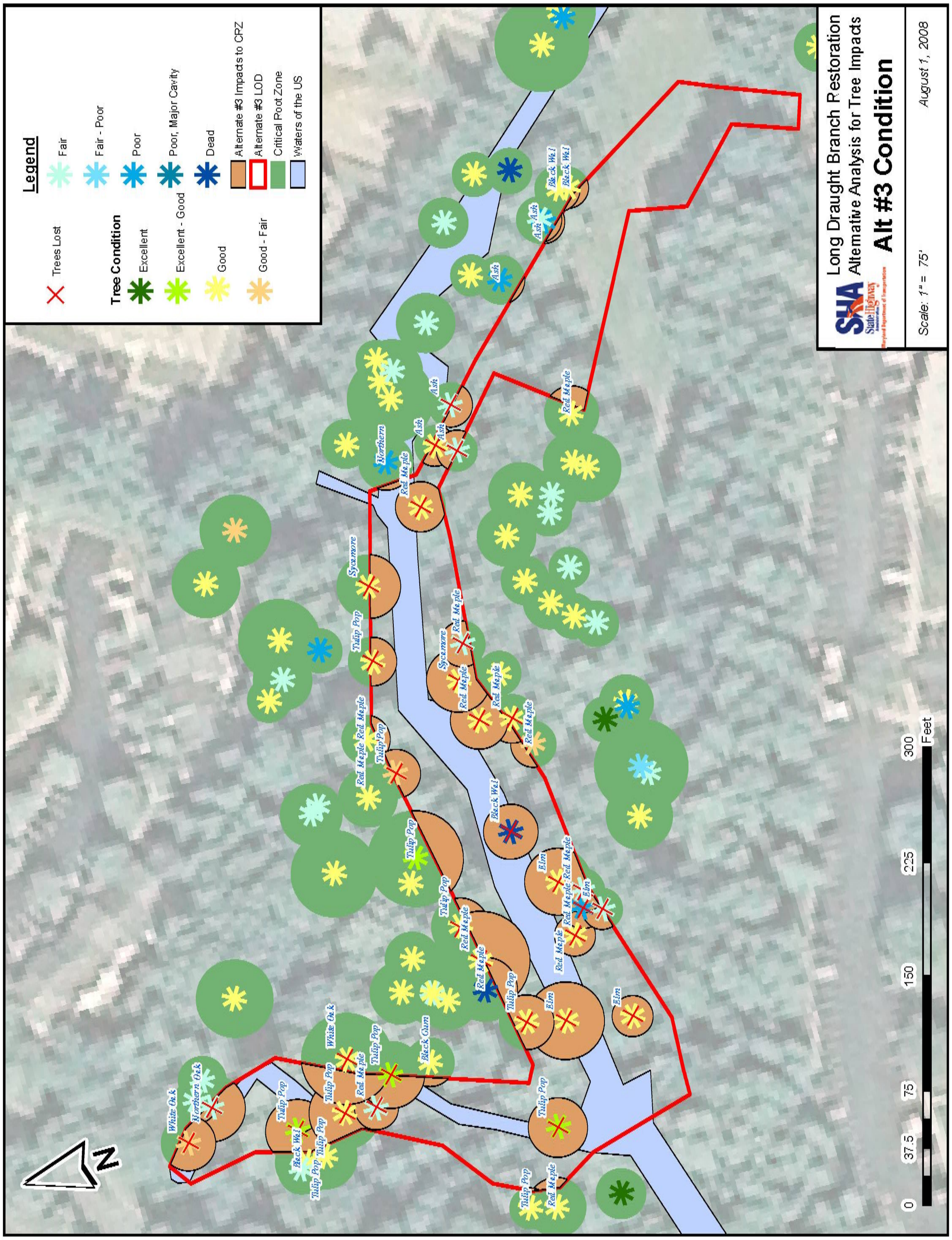
<u>**Alternative 3 – Stream stabilization with 478-foot transition for the lower reach option**</u>:

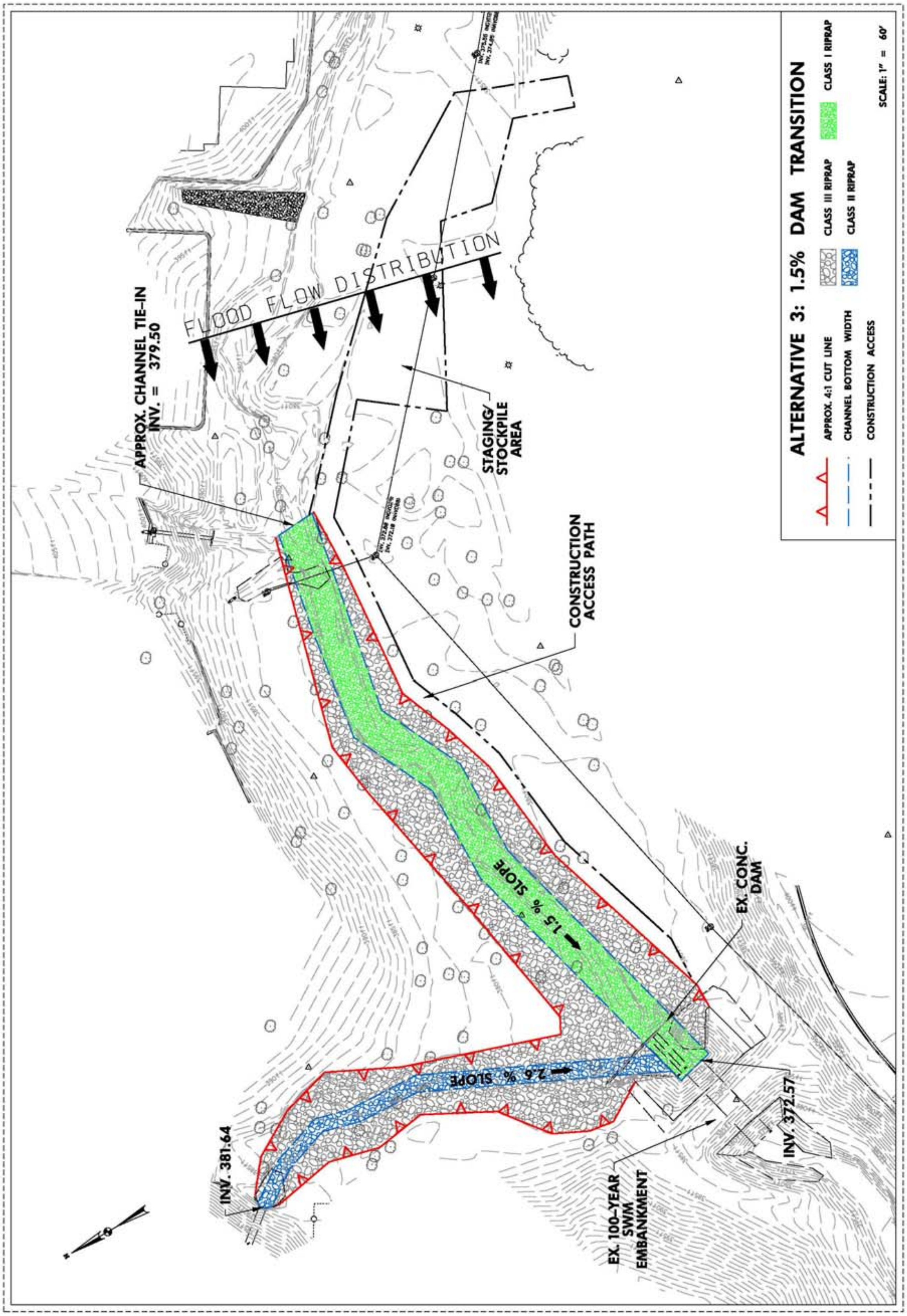
This alternative includes removal of the concrete dam and transitions the 6-foot vertical drop at the upstream channel slope of 1.5 percent. The approximate length of the transition reach is 478 feet, as shown on the attached drawing for Alternate 3. The bottom width of the transition channel is 27 foot wide to match the existing apron width at the channel entrance to the twin 7.5 foot by 11.5 foot culvert opening of the 100-year storm SWM embankment. The side slopes of this transition channel that tie the bottom of the channel back up to existing ground have been set at a 4 horizontal to 1 vertical slope. The unnamed tributary has been set at a 2.6 percent channel slope and the channel bottom width has been set at 12 feet. The side slopes of the tributary have also been set at a 4 horizontal to 1 vertical slope. The area or footprint of grading in the 478-foot reach, NOT including construction access and erosion control measures, is 1.03 acres. The volume of sediment to be removed within the 478-foot reach is 2,200 cubic yards to get to grade and another 3,846 cubic yards to install riprap. Based on computations it is expected that stabilization 1.03 acres of stabilization will need to be completely armored with riprap and therefore not permit vegetative establishment in this zone. In other words there would be a <u>1.03 acre permanent loss of forested area</u>. The total construction disturbance for the lower 478-foot reach will impact 1.50 acres and <u>30 trees</u> greater than 18” DBH.

The SHA design team believes this design alternative to be unstable and has major concerns in relations to long-term stability and function with this strategy. These stability concerns stem from the steep slopes required drop flood flow discharges from elevation 380 (current floodplain surface upstream of dam) to elevation 372.6 (invert of 100-year SWM embankment culvert) over a distance of 478 feet. As described in Alternative 2, at a location that is approximately 850 feet upstream of the 100-year SWM culvert, flood flows from the upper project reach begin to spread laterally due to the flattening of the valley slope created by the deposition of sediment collected behind the concrete SWM dam. According to the existing conditions HEC-RAS model analysis, the WSEL at RS 1110 is 382.84 to 384.86 for the 2-year to 100-year storms, respectively. The stream bank height or floodplain surface elevation at RS 1110 is 382, yielding flood flow depths of 0.84 feet to 2.86 feet flow down the filled in floodplain surface for the 2-year to 100-year storms, respectively. As flood flows approach and spill over the riprap armoring of the 478-foot transition reach, failure in the armoring layer is expected over time, as shear stress over the 4:1 riprap slope will achieve nearly 8 lbs per square foot for a chosen depth of 0.5 feet. Since the HEC-RAS model is showing flow depths of up to 2.86 feet entering this riprap slope, we believe failure of riprap over fine infill sediments is eminent.

SHA considered various side slopes to reduce the shear stress and the required riprap size, however, the foot print of the incised channel and associated tree impact greatly increases with flatter bank slopes. SHA design team expects stability issues to develop with this alternative, therefore this design option is not recommended.

This alternative does include the restoration of LDB from Sta. 0+00 to Sta. 13+00, as is proposed in the submitted construction documents. At Sta. 13+00, the proposed channel and existing channel closely match in plan and profile making it possible to end the restoration at this point. Note that a reach of approximately 475 feet in length between Sta. 13+00 and the 478-foot transition reach will remain unrestored / not stabilized.


Legend
Trees Lost
Tree Condition
Excellent
Excellent - Good
Good
Good - Fair
Fair
Fair - Poor
Poor
Poor, Major Cavity
Dead
Alternate #3 Impacts to CPZ
Alternate #3 LOD
Critical Root Zone
Waters of the US
Long Draught Branch Restoration
Alternative Analysis for Tree Impacts
Alt #3 Condition
Scale: 1" = 75'
August 1, 2008
0 37.5 75 150 225 300
Feet


ALTERNATIVE 3: 1.5% DAM TRANSITION
APPROX. 4:1 CUT LINE
CHANNEL BOTTOM WIDTH
CONSTRUCTION ACCESS
CLASS III RIPRAP
CLASS II RIPRAP
CLASS I RIPRAP
SCALE: 1" = 60'
FLOOD FLOW DISTRIBUTION
APPROX. CHANNEL TIE-IN
INV. = 379.50
STAGING/
STOCKPILE
AREA
CONSTRUCTION
ACCESS PATH
EX. CONC.
DAM
1.5 % SLOPE
2.6 % SLOPE
INV. 381.64
INV. 372.57
EX. 100-YEAR
SWM
EMBANKMENT

Alternative 4 (Preferred) – Stream restoration with 770-foot transition reach option:

This alternative serves to remove the concrete dam and transition the 6-foot vertical drop at the upstream channel slope of 0.8 percent and an approximate reach length of 770 feet, as shown on the attached drawing for Alternate 4, and in the submitted construction documents. This alternative includes the complete restoration of LDB from Sta. 0+00 to Sta. 23+00 and the tributary from Sta. 100+00 to Sta. 22+78, as is proposed in the submitted construction documents.

For Alternative 4, the width of the restored floodplain varies from approximately 55 feet to 90 feet at the confluence of the tributary. By removing the concrete dam and a significant portion of the wedge of sediment that has deposited behind the dam, this alternative is able to re-create a 2,300-foot reach with a consistent valley slope of approximately 0.9 percent. This establishment of a consistent valley slope throughout the entire LDB restoration project length provides the best opportunity to convey low flow and flood flows at uniform slopes and eliminates quick or abrupt vertical changes in elevation that typically carry high energy, stress and velocity. The drop over the dam from the invert of the 100-year embankment culvert to the top of the concrete dam and the filled in floodplain is approximately 6 feet. This recommended alternative serves to distribute the 6-foot vertical drop over an approximate 770-foot reach thereby eliminating hotspots of extreme energy that would be created in the above alternatives as flood flow spill over existing nick points, steep streambeds created on top of fine infill sediments, and/or 4:1 (or similar) grading on the channel side slopes.

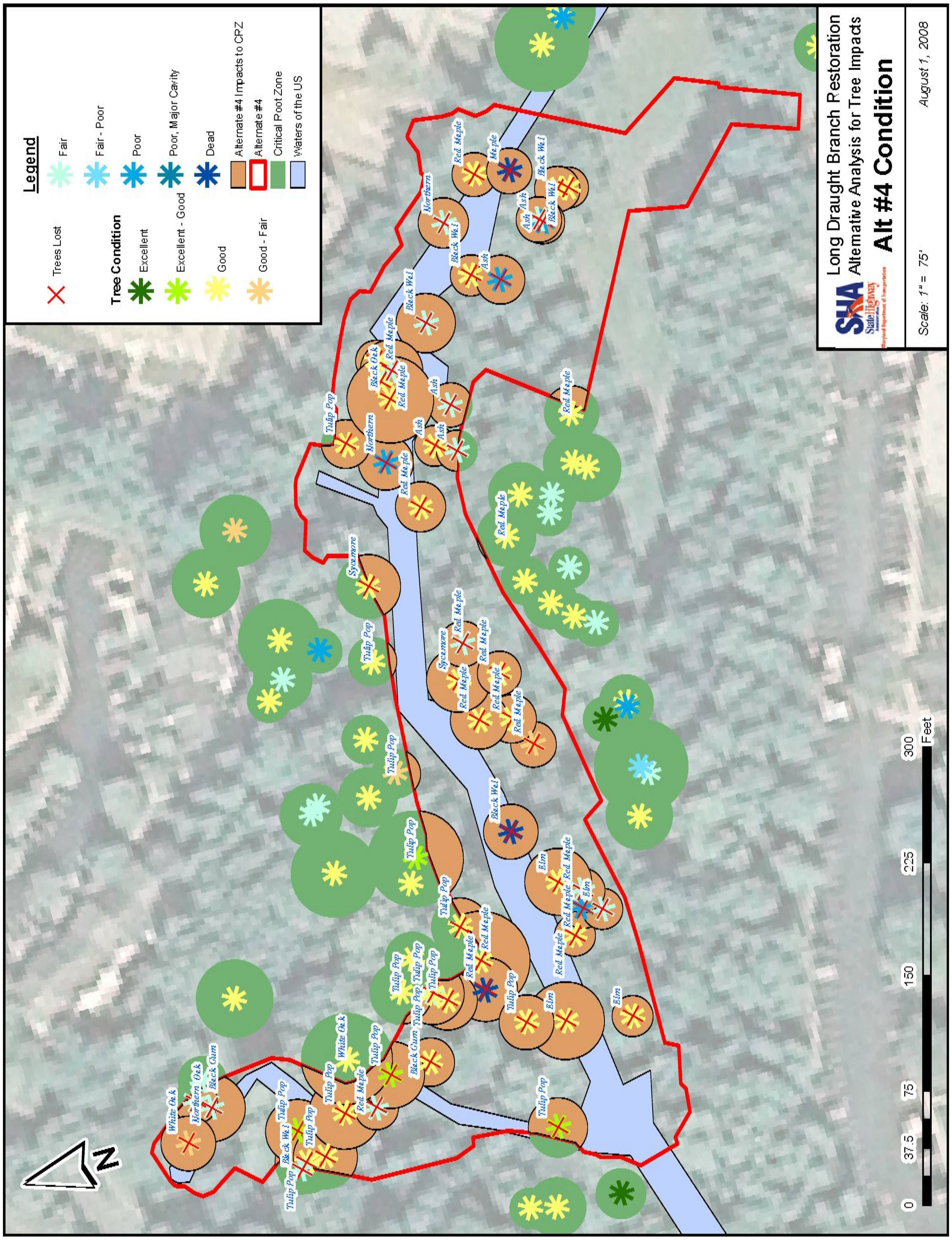
The footprint of grading in the 770-foot reach, not including construction access and erosion control measures, is 2.08 acres. The volume of sediment to be removed within the 770-foot reach is 8,925 cubic yards to get to grade and another 1,210 cubic yards to install imported streambed gravel and outfall/inlet protection in the active channel area. Within the 2.08 acres of grading in the 770-foot reach, this alternative will serve to create approximately 0.99 acres of riparian wetlands, 0.35 acres of waters of the US, and will be completely re-vegetated with exception of the small active channel area. In the existing conditions there exist only 0.03 acres of wetlands in the 770-foot reach. The total construction disturbance for the lower 770-foot reach will impact 2.36 acres and 54 trees greater than 18" DBH.

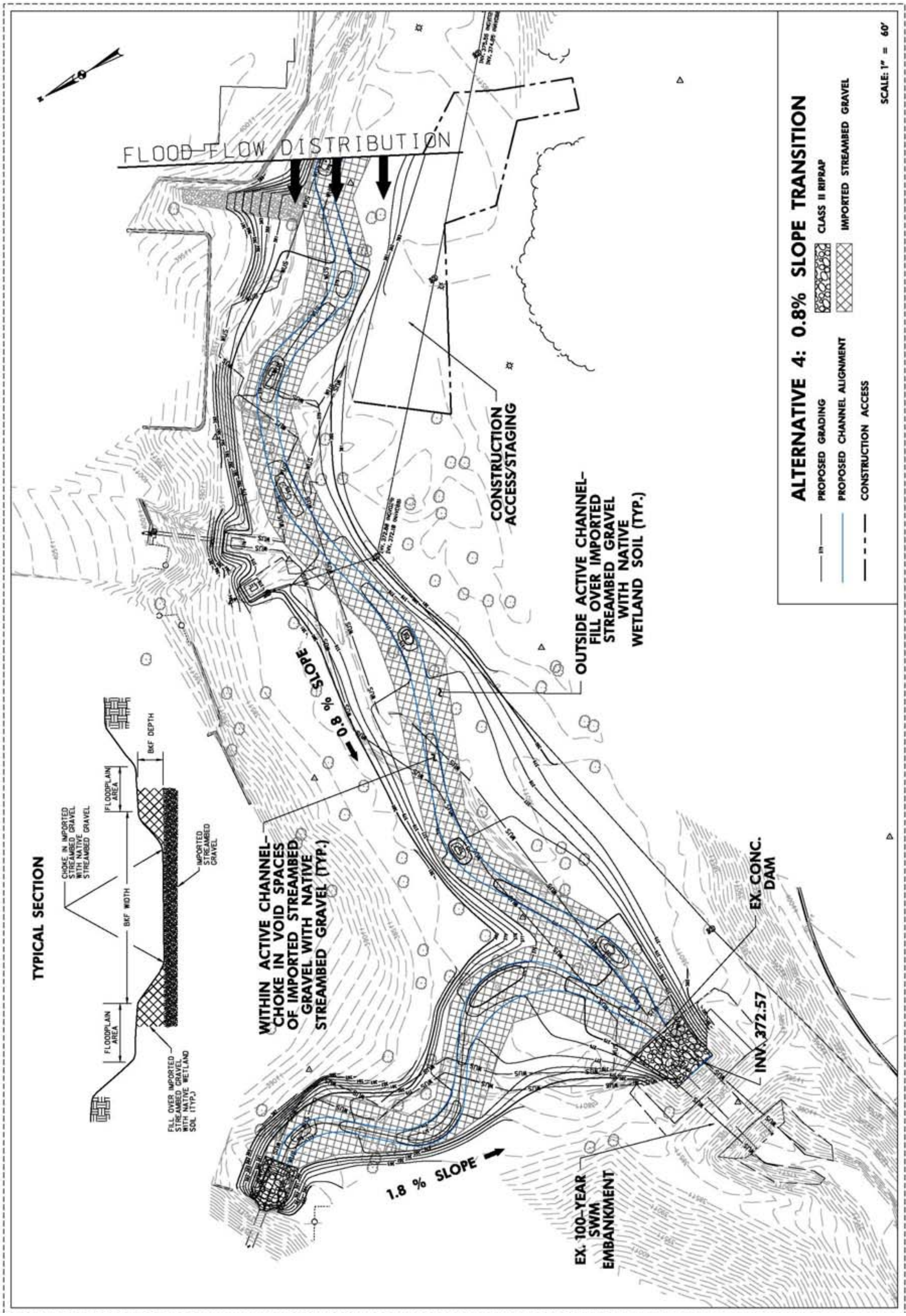
In the upper project reach above the influence of the existing concrete dam, establishment of a low level wider floodplain replanted with dense riparian vegetation will create a condition where all flows are conveyed at lower depths and velocities under uniform flow conditions. The reduction in velocity yields a direct increase in residence time for low flows and thus nutrient processing in the riparian wetland floodplain. Residence time is further increased in this design alternative by introducing additional roughness throughout the floodway by the establishment of dense wetland vegetation that directly interacts with all discharges greater than 12 cubic feet per second.

In the lower 770-foot reach the argument could be made that residence time is increasing due to the increase in slope created by removing the failing concrete dam and the deposition of sediment stored upstream of the dam. However, the removal of floodplain sediments also provides a significant increase in the floodplain storage throughout the restoration site. The increase in floodplain storage created by this alternative's proposed grading plan serves to attenuate peak flow storm events within a well-developed riparian wetland zone. Hydrologic analysis incorporating the increased storage area in the reach routing component of the TR-20 model shows decreases in peak discharges for all analyzed flow events at the outlet of the existing 100-year SWM embankment when comparing pre- vs. post-restoration conditions despite increasing the lower reach slope by removing the sediment wedge. The hydrologic modeling shows a reduction in discharge of 5, 19, 28 and 36 cubic feet per second for the 2-, 10-, 50- and 100-year storm events, respectively, from pre- to post-restoration conditions. This discharge reduction equates to a 1.4, 3.0, 3.2 and 3.4 percent decreases in discharges for the 2-, 10-, 50- and 100-year storm events, respectively, exiting the project reach at the watershed scale.

Therefore, according to the SHA's hydrologic and hydraulic analysis, Alternative 4 serves to directly increase residence time within approximately 1,530 feet (upper reach) of the 2,300 foot reach on LDB project reach. Furthermore, the increase in floodplain storage in a riparian wetland zone reduces the watershed's peak storm event discharges exiting the restoration site at the existing 100-year SWM dam. Since the extent of benefit created by this restoration approach is currently unknown, the SHA has committed to visual, chemical, biological, and physical monitoring of this alternative to document the level of environmental benefit.

It has been recognized that this alternative does not preserve as many trees as the Alternatives 1, 2 or 3 during construction. Even though the above alternatives initially preserve additional trees, we question the sustainability of Alternatives 1, 2 and 3 and believe many more trees will be lost over time. SHA feels that Alternative 4 and the associated tree impacts are necessary to construct a restoration project that provides the best opportunity for long-term stability. However, SHA has made cognizant efforts during the design of this option to reduce the impacts of the riparian buffer. It may not have been apparent to the reviewing agencies; however, between the Final Review and PS&E submittals, the LOD and floodplain grading limits were altered to protect and preserve additional trees. The results of this past avoidance and minimization effort saved an additional seven (7) trees (two red maple and five tulip poplar) in good to excellent condition with a range of 19" to 42" DBH. Since the area within its LOD is greatest for Alternative 4, SHA has applied all methods of reducing tree loss and added tree protection mechanisms where ever practical and where ever long-term restoration design success is not compromised. Additionally, the entire reach, with the exception of the active channel, will be planted with 894 1 to 1½" caliper trees and 2,323 shrubs, as well as livestake plantings on the stream banks. Since the stability of banks and tree stand are dynamic in the stream environment, a designated specialist will be available during the construction to further avoid tree impacts, if the opportunity exits, with minor modification of grading plan.


Legend
Trees Lost
Tree Condition
Excellent
Excellent - Good
Good
Good - Fair
Fair
Fair - Poor
Poor
Poor, Major Cavity
Dead
Alternate #4 Impacts to CPZ
Alternate #4
Critical Root Zone
Waters of the US
Long Draught Branch Restoration
Alternative Analysis for Tree Impacts
Alt #4 Condition
Scale: 1" = 75'
August 1, 2008
0
37.5
75
150
225
300
Feet


ALTERNATIVE 4: 0.8% SLOPE TRANSITION
PROPOSED GRADING
PROPOSED CHANNEL ALIGNMENT
CONSTRUCTION ACCESS
CLASS II RIPRAP
IMPORTED STREAMBED GRAVEL
SCALE: 1" = 60'
FLOOD FLOW DISTRIBUTION
CONSTRUCTION ACCESS/STAGING
OUTSIDE ACTIVE CHANNEL- FILL OVER IMPORTED STREAMBED GRAVEL WITH NATIVE WETLAND SOIL (TYP.)
WITHIN ACTIVE CHANNEL- CHOKE IN VOID SPACES OF IMPORTED STREAMBED GRAVEL WITH NATIVE STREAMBED GRAVEL (TYP.)
0.8 % SLOPE
1.8 % SLOPE
EX. CONC. DAM
INV. 372.57
EX. 100-YEAR SWM EMBANKMENT
TYPICAL SECTION
CHOKE IN IMPORTED STREAMBED GRAVEL WITH NATIVE STREAMBED GRAVEL
FLOODPLAIN AREA
BKF WIDTH
FLOODPLAIN AREA
BKF DEPTH
IMPORTED STREAMBED GRAVEL
FILL OVER IMPORTED STREAMBED GRAVEL WITH NATIVE WETLAND SOIL (TYP.)

Conclusion:

Based on SHA's assessment and analyses of the site hydrology, hydraulics, and geomorphic setting, we believe that Alternatives 1, 2 and 3 would not provide the best opportunity for long-term stability and will very likely fail within the near-term. Therefore, SHA can not recommend pursuing Alternatives 1, 2 or 3, based on sound engineering judgment. Despite the temporary tree impacts associated with Alternative 4, the project, as designed, will maximize the environmental benefits associated with the dam removal, riparian wetland and forest buffer creation as well as the future stability of the entire project reach.

Finally, it is worth mentioning, that the watershed served by Long Draught Branch is extremely over managed by the in-stream stormwater management facilities. Therefore, the hydraulic behavior of this stream is unlike other natural streams. This adds complexity in the modeling, however, based on the known SWM effects on waterways, it is expected that the stream will be subjected to prolonged peak flows after the major rainfall events. Because of this and other constrains mentioned above, the Alternative 4 has been selected as the most appropriate design option for this reach.

SUMMARY TABLE – ALL ALTERNATIVES

ALTERNATIVE	DESCRIPTION	ENGINEERING CONSIDERATIONS	COST	LIMIT OF DISTURBANCE (ACRES)	TREE IMPACT (EACH)	PERMANENT FOREST LOSS[1] (ACRES)	TEMPORARY IMPACT WETLANDS (AC) / STREAM (AC)	PROPOSED WETLANDS CREATION (ACRES)	MEETS PROJECT GOALS[2] AND OBJECTIVES[3]
1 No- build of lower reach (potential dam breach)	Restoration of 1300 feet of the upper reach starting at MD 117, no restoration efforts on the lower 945 foot reach. No failed in-stream dam removal or reconstruction.	• Eminent threat catastrophic dam failure. • Headcut migration leading to valley destruction. • Higher yields of sediment/nutrient loads. • Local government needs to address TMDL. • May impact upstream restoration efforts in future.	$876,510	1.9	41	1.9 Loss followed by long-term regeneration likely to include many invasive species.	0.002 / 0.38	0	PARTIAL Due to upper reach restoration
2 Lower reach stabilization 214' transition reach	Restoration of 1300 feet of the upper reach starting at MD 117. Removal of the failed concrete dam and construction of 214' at 2.5% slope transition reach using Class II and III riprap within the channel, & along the 4:1 banks.	• Extreme energy/stress leading to near-term failure. • Floodplain flow over 4:1 side slope promote high risk. • Riprap armoring creates permanent loss of forest and habitat = 0.60 acres. • Poor aesthetic value. • Does not match local government expectation. • High cost for little environmental benefit.	$1,117,710	1.11	23	0.60	0 / 0.18	0	PARTIAL
3 Lower reach stabilization 478' transition reach	Restoration of 1300 feet of the upper reach starting at MD 117. Removal of the failed concrete dam and construction of 478' at 1.5% slope. Class I, II and III riprap along the entire length of the channel, & along the 4:1 banks.	• Extreme energy/stress leading to near-term failure. • Floodplain flow over 4:1 side slope promote high risk. • Riprap armoring creates permanent loss of forest and habitat = 1.03 acres. • Poor aesthetic value. • Does not match local government expectation. • High cost for little environmental benefit	$1,293,010	1.50	30	1.03	0 / 0.32	0	PARTIAL
4 Lower reach restoration 770' transition reach (Preferred)	Restoration of entire project reach spanning 2300 feet of LDB. Removal of the failed dam and construction of 770' transition reach at 0.8% slope, creating approx. 55'- 90' floodway area and 10' wide low flow channel within a riparian wetland floodplain.	• Reduces energy/stress to extent practical in project reach. • The total LOD is completely vegetatively stabilized. • Creates approx. 2.6 acres of riparian floodplain wetlands. • Imported streambed gravel is not exposed as streambed is choked in with native gravel and floodplain area is filled over with native wetland soil & coir fiber matting. • Reduces residence time in upper 1530 foot restoration reach. • Reduces peak storm event discharges exiting restoration site by increasing flood storage zone in riparian wetlands.	$1,221,980	2.36	54 Reduced from original 61	0 Replanted riparian buffer includes 894 - 1.5" caliper B&B trees	0.03 / 0.48	2.6	ALL

[1] Permanent Forest Loss equates to the area of riprap outside of the stream channel that could not be planted with trees.

[2] SHA PROJECT GOALS:

1. Improve surface water quality by:
   - Reestablishing stream connection to the floodplain
   - Creating riparian wetlands to promote treatment of incoming watershed nutrient loads
   - Removing source of sediment and nutrients by creating stable stream channel
2. Improve ground water quality by:
   - Creating dense vegetated floodplain to provide up-take of phosphorus and promote de-nitrification of groundwater
   - Enhancing groundwater recharge in the floodplain

[3] SHA PROJECT OBJECTIVES:

1. Remove the failed in-stream SWM facility to prevent the catastrophic breach
2. Stabilize existing infrastructure impacts: storm drain outfalls , pedestrian bridge , sanitary crossings, parking lot slopes
3. Provide storm water pretreatment at storm drain outfalls before discharging to the channel
4. Stabilize stream banks to minimize further erosion and sediment transport
5. Restore existing stream channel and floodplain to their stable form and create an effective riparian buffer

	Alternatives								Existing Forest			
	Breach		Alternative 2: 214' Transitional Reach		Alternative 3: 478' Transitional Reach		Alternative 4: 770' Transitional Reach		All of Forest Stands 2 & 3		All Trees Assessed	
Existing Trees Permanently Impacted	47		23		30		54		108		173	
Trees Saved w/ CRZ[1] Impacted	14		18		20		8		n/a		n/a	
Total Sum of DBH[2] (Perm. Impacted)	1,162 inches		547 inches		737 inches		1,263 inches		2,609 inches		4,148 inches	
Alternative 'LOD' Area	1.90 acres		1.11 acres		1.50 acres		2.36 acres					
Health of Existing Trees Permanently Impacted	# of Trees	% of Total Lost	# of Trees	% of Total Lost	# of Trees	% of Total Lost	# of Trees	% of Total Lost				
· *Excellent*	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	2.78%	7	4.05%
· *Excellent - Good*	4	8.51%	3	13.04%	3	10.00%	3	5.56%	4	3.70%	5	2.89%
· *Good*	28	59.57%	11	47.83%	16	53.33%	28	51.85%	61	56.48%	103	59.54%
· *Good - Fair*	2	4.26%	1	4.35%	2	6.67%	2	3.70%	4	3.70%	5	2.89%
· *Fair*	9	19.15%	7	30.43%	7	23.33%	14	25.93%	24	22.22%	35	20.23%
· *Fair - Poor*	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.93%	1	0.58%
· *Poor*	2	4.26%	1	4.35%	1	3.33%	4	7.41%	8	7.41%	12	6.94%
· *Poor, Major Cavity*	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	1.16%
· *Dead*	2	4.26%	0	0.00%	1	3.33%	3	5.56%	3	2.78%	3	1.73%
DBH of Existing Trees Permanently Impacted												
· *18 inch to 21 inch*	22		11		13		28		51		82	
· *22 inch to 25 inch*	6		4		6		8		19		38	
· *26 inch to 31 inch*	14		6		8		15		27		34	
· *32 inch to 38 inch*	2		1		1		2		6		11	
· *39 inch to 50 inch*	3		1		2		1		5		8	
· *Maximum*	43 inches		40 inches		43 inches		43 inches		43 inches		50 inches	
· *Minimum*	18 inches		18 inches		18 inches		18 inches		18 inches		17 inches	
· *Average*	25 inches		24 inches		25 inches		23 inches		24 inches		24 inches	
· *Median*	24 inches		22 inches		24 inches		21 inches		22 inches		22 inches	

TREE HEALTH DEFINITIONS:

Excellent: Healthy specimen tree; no visible defects; well-formed crown; few minor dead branches acceptable

Good: Healthy tree; very minor defects/decay acceptable with callous forming/complete; well-formed crown; few minor/major dead branches acceptable

Fair: Health questionable; structurally sound tree; defects present that do not affect structural integrity; minor/major dead branches may be present; crown not broken out but not necessarily well formed or even

Poor: May be structurally unsound; may be dead or dying; may contain significant decay; may have broken or missing top/crown; may have heavy lean; significant health problems

NOTES:

- Trees assessed within and contigous to the project limits were 18" DBH and higher.
- Entire assessment identified three distinct forest stands. All scenarios only involve impacts to Forest Stands 2 and 3.

[1] *'CRZ' = Critical Root Zone (Trees are considered permanently removed when more than 1/3 of CRZ is impacted. "Additional Trees" shown had less than 1/3 CRZ impacted and are therefore <u>not</u> assumed to be removed)*

[2] *'DBH' = Diameter at Breast Height*

August 5, 2008

Gaithersburg
A CHARACTER COUNTS! CITY

August 1, 2008

Karuna Pujara, Chief
Highway Hydraulics Division
707 N. Calvert Street
Baltimore, MD 21202

Re: SHA Long Draught Stream Restoration Project

Dear Ms. Pujara,

The City of Gaithersburg remains very supportive of the proposed State Highway Administration (SHA) Long Draught Branch Restoration Project, and is hopeful it will go forward once it clears the remaining regulatory hurdles. Importantly, this project will correct an area that was identified in our 2002 Stream Assessment as being one of the top ten candidate restoration sites within our municipal limits.

We understand that the impacts to the stream will be substantial. At first we had grave concerns about minimizing these impacts; however, after analyzing the Conceptual Design Report which summarizes the full scope of the failing outfalls and structures in jeopardy along this stream channel, we feel that it is both necessary and the best approach to adopt a comprehensive strategy to repair the existing damage and to minimize the potential for future degradation of Long Draught Branch.

This full scale restoration project would preclude the need for several piecemeal restoration projects that are required to repair individual failing outfalls, to stabilize the apartment complex's parking lot, pool, and bridge, and to remove and stabilize a failed online stormwater management (SWM) structure. The cumulative effects of those individual projects would likely be similar to the impacts associated with this comprehensive project. It should also be noted that over nine thousand cubic yards of sediment and debris have accumulated upstream of the failed SWM structure. Without this restoration project, there is a serious possibility that an existing headcut in the dam will cause this accumulated sediment and debris to wash downstream. Consequently, this failure would threaten a downstream culvert and SWM structure and contribute sediment into Clopper Lake, which has Total Maximum Daily Load (TMDL) standards for phosphorous and sediment.

The City has spent considerable time and resources working with SHA and the adjacent property owners to gain access for this work, which will not only allow for construction, but for continued maintenance once the project is completed. Our environmental staff has also reviewed the forest impacts and the replacement plantings for this project, and has found them to be acceptable. While these impacts are significant, the continued loss of the mature trees after each storm will have a similar net effect if the stream channel is not stabilized.

City of Gaithersburg • 31 South Summit Avenue, Gaithersburg, Maryland 20877-2098
301-258-6300 • FAX 301-948-6149 • TTY 301-258-6430 • cityhall@gaithersburgmd.gov • www.gaithersburgmd.gov

Ms. Karuna Pujara
Page Two
August 1, 2008

This project has the support of the City of Gaithersburg and we believe that only a full scale restoration will allow Long Draft Branch to become more stable and to function in a more natural manner. We appreciate that your staff and engineers have worked closely with us during the preliminary design of this project, as it has resulted in a true partnership between state and local government.

If you should have any questions or wish to further discuss this project, please feel free to contact me at 301-258-6310.

Sincerely,

James D. Arnoult

James D. Arnoult
Acting City Manager

cc: Mayor and City Council

REGULATORY AGENCY RESPONSES

LDB Alternative Analysis and Correspondence

MARYLAND DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard● Baltimore, Maryland 21230
410-537-3000 ● 1-800-633-6101 ● http://www.mde.state.md.us/wetlands

MDE

Martin O' Malley
Governor

Anthony G. Brown
Lt. Governor

Shari T. Wilson
Secretary

Robert M. Summers
Deputy Secretary

October 14, 2008

Mr. Todd Nichols
Maryland Department of Transportation
State Highway Administration
707 North Calvert Street
Baltimore, MD 21202

Attn: Ms. Veronica Piskor

Application Number: 200661425 / 06-NT-0007
Project: MD SHA Contract No. MO357 / MD 117: Phase 2,
Long Draught Branch Stream Restoration

The Nontidal Wetlands and Waterways Division of the Water Management Administration is continuing our review of the revised application for the above referenced project, and the additional information that has been provided in association with the application, including a Memorandum from Bill Schultz, USFWS dated March 10, 2008; and correspondence from Jeff Horan, MD DNR dated September 18, 2008.

As stated previously (correspondence dated December 9, 2007), and also expressed by USFWS and MD DNR, the removal of the forested floodplain adjacent to the lower reaches of the stream is problematic. Based upon the consensus of the reviewing natural resource agencies, we request that SHA either remove this area from the proposed scope of work for the project, or develop an alternative design approach which protects the forested buffer throughout this area to the maximum extent possible.

Please contact me by phone at (410) 662-7400 or by email at smhurt@mccormicktaylor.com with any questions or comments.

Sincerely,

Steve Hurt

Steve Hurt on behalf of WMA,
Nontidal Wetlands and Waterways Division

Cc: (via email)
Mr. Sean McKewen, WMA Nontidal Division Regional Chief
Mr. William Seiger, WMA Nontidal Division Chief Engineer
Mr. Greg Golden, MD DNR
Mr. Steve Elinski, US Army Corps of Engineers

TTY Users 1-800-735-2258
Via Maryland Relay Service

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt. Governor*
John R. Griffin, *Secretary*
Eric Schwaab, *Deputy Secretary*

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By: Date:

September 18, 2008

Kirk McClelland
Maryland State Highway Administration
Office of Highway Development
707 N. Calvert Street
Baltimore, MD 21202

Subject: Long Draught Branch

Dear Mr. McClelland: Kirk

Thank you for meeting with us in the field on August 7, 2008 to tour and discuss the Long Draught Branch stream project in Gaithersburg. We have greatly appreciated the extended opportunity to discuss the objectives and design of this proposed project with you and your staff. SHA should be commended for their commitment to address all agency comments through a coordinated review process. We concur with the assessment that there are opportunities to stabilize and enhance the Long Draught Branch stream system in the project reach and its surrounding areas. However, we cannot support the project as proposed because of the conflicts with current State goals and policies regarding stream and riparian zone management. Concerns leading to our position had been presented by both MDDNR and Maryland Department of the Environment (MDE) to MDSHA on several occasions during the interagency coordination of the project review. This position remains following our recent tour and detailed discussions. However, early in the project review, MDDNR should have been more clear about the degree of our opposition to key components of the project as proposed.

Initial reports and presentations by SHA consultants working on the Long Draught Branch project had, to some degree, provided justification for the project based on the removal of "legacy" sediment in the project reach. Valley dredging as a means of retrofitting storm runoff water quality problems is not generally endorsed by MDDNR due to policies regarding in-stream stormwater management, valley management, and because of the lack of data to support such an approach for runoff water quality treatment. We also have significant concerns about impacting the ecosystem function in the relatively intact, although degraded, riparian zone and forested buffer.

In response to MDDNR and MDE concerns, the project focus has been fine tuned to a certain degree to emphasize the removal of the existing in-stream dam structure at the downstream end of the project reach. While our review concurs that the removal of the dam structure is justified, the extent of the proposed vegetation removal and valley grading through the reach is inconsistent with long standing environmental

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review policy related to riparian impact minimization. Dam removals, profile transitions, and grade control projects in other similar settings have been accomplished by MDSHA and others with less disturbance than indicated by the project plans. Similarly, our review has indicated that there are opportunities to address localized stream bank and tributary outfall stability problems with lower levels of disturbance than proposed by the current proposed design.

MDDNR shares the interest of the City of Gaithersburg and MDSHA in removing the concrete dam structure at the downstream end of the project reach, bank stabilization in several locations, vegetation enhancement, and storm drain outfall retrofits. However, we do not support the current proposal because of the associated unnecessary impacts to Long Draught Branch and its riparian corridor. Our experiences with other projects suggest that other alternatives are available to meet the project objectives related to stability, safety, and water quality. We recognize this major change in project objectives may impact the decisions to move forward with any project in Long Draught Branch at this time.

We look forward to coordinating with MDSHA on this project should alternative proposals with less impact to the existing riparian corridor and stream channel of Long Draught Branch be put forward. If you have questions regarding these comments, please contact Greg Golden of my staff at ggolden@dnr.state.md.us.

Sincerely,

Jeff Horan, Director
Watershed Services

cc: Steve Hurt, McCormick Taylor for MDE
Bill Schultz, USFWS
Steve Elinsky, USACE
Barbara Rudnick, EPA
Sean Smith, DNR
Greg Golden, DNR

Date: March 10, 2008

Memorandum

To: Veronica Piskor, Susan Ridenour, Steve Elinky, Steve Hurt, Greg Golden

From: Bill Schultz, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service

Subject: Long Draught Branch Restoration

The U.S. Fish and Wildlife Service (Service) re-visited Long Draught Branch with a stream geomorphologist from the Maryland Department of Natural Resources. The geomorphologist did not understand the logic of removing the riparian forest, lowering the floodplain by two to four feet, armoring the stream channel with rip-rap, and replanting trees on the graded area. This individual believes that the remaining riparian forest is needed to maintain stream stability and biological function. The Non-tidal Wetlands and Waterways Division of the Maryland Department of the Environment is also opposed to the removal of this forest. The Service has evaluated this project further and agrees with the Department of Natural Resources and Maryland Department of the Environment. The forest needs to be preserved which will require a radical alteration of the project proposal.

The most significant problem with Long Draught Branch involves a five-foot high dam at the downstream end of the project area. This dam has raised the stream invert by five feet and has trapped approximately 11,600 tons of sediment behind it. Presently, the stream is starting to head-cut around the south end of the dam. The Service realizes that this head-cut has to be stopped before it reaches the stream channel. The Maryland State Highway Administration (SHA) consultant proposes to remove this accumulated sediment. This would involve the removal of a two to four-foot deep, by 60-foot wide, by 2,400-foot long swath of sediment along the stream channel. The consultants also propose to remove a two-foot deep, by 60-foot wide, by 400- foot long sediment accumulation along a tributary located at the downstream end of the project area. Sediment removal is one option. However, it requires removal of numerous mature trees, the grading down of the floodplain, and the total armoring of the stream channel with nine-inch long rip-rap. The stream will be turned into an engineered floodway. The Service believes a more moderate approach could provide an opportunity for creative engineering and an opportunity to save the riparian forest.

The Service recommends that a stream weir be located 10 to 30 feet downstream of the dam. The weir would probably need to be constructed with Class III rock. Class I rock and nine-inch long rip-rap could be place between the dam and weir to break up the energy of the water and to hold the dam and head-cut in place. This would leave the lower 1,000-foot long riparian forest intact and provide for a more natural looking stream valley. The consultant should also re-design the upper 1,600-foot stream segment to reduce the need for the proposed quantities of rip-rap. The Service believes the stream could be stabilized with less rip-rap.

The Service is asking that the existing downstream bed elevation be maintained so the existing riparian forest can be preserved. It is unnecessary to destroy the riparian habitat. The Service agrees with the apprehensions expressed by the Maryland Department of the Environment and Maryland Department of Natural Resources. We recommend less engineering and the preservation of more of the existing habitat. The Service is requesting a meeting with SHA, the Corps of Engineers, the Department of the Environment, and the Department of Natural Resources. Wetland permits may be denied unless this project is modified to reduce environmental impacts.

LDB Alternative Analysis and Correspondence