August 2005
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Environmental Technology Verification Report

Stormwater Source Area Treatment Device

The Stormwater Management StormFilter® using Perlite Filter Media

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

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Ann Arbor, Michigan 48105

Under a cooperative agreement with the U.S. Environmental Protection Agency

Raymond Frederick, Project Officer
ETV Water Quality Protection Center
National Risk Management Research Laboratory
Water Supply and Water Resources Division
U.S. Environmental Protection Agency
Edison, New Jersey

August 2005

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency **NSF International**

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**STORMWATER TREATMENT TECHNOLOGY**	
APPLICATION:	**SUSPENDED SOLIDS AND ROADWAY POLLUTANT TREATMENT**	
TECHNOLOGY NAME:	**THE STORMWATER MANAGEMENT STORMFILTER® USING PERLITE FILTER MEDIA**	
TEST LOCATION:	**GRIFFIN, GEORGIA**	
COMPANY:	**STORMWATER MANAGEMENT, INC.**	
ADDRESS:	**12021-B NE Airport Way** **Portland, Oregon 97220**	PHONE: **(800) 548-4667** FAX: **(503) 240-9553**
WEB SITE:	**http://www.stormwaterinc.com**	
EMAIL:	**mail@stormwaterinc.com**	

NSF International (NSF), in cooperation with the U.S. Environmental Protection Agency (EPA), operates the Water Quality Protection Center (WQPC), one of six centers under the Environmental Technology Verification (ETV) Program. The WQPC recently evaluated the performance of the Stormwater Management StormFilter® (StormFilter), with perlite filter media, manufactured by Stormwater Management, Inc. (SMI). The StormFilter was installed in a city-owned right-of-way near downtown Griffin, Georgia. Paragon Consulting Group (PCG) performed the testing.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups, which consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

TECHNOLOGY DESCRIPTION

The following description of the StormFilter was provided by the vendor and does not represent verified information.

The StormFilter consists of an inlet bay, flow spreader, cartridge bay, overflow baffle, and outlet bay, housed in an 18-ft long by 8-ft wide pre-cast concrete vault. The inlet bay serves as a grit chamber and provides for flow transition into the cartridge bay. The flow spreader traps floatables, oil, and surface scum. This StormFilter was designed to treat stormwater at a maximum flow rate of 495 gpm (1.1 cfs). Flows greater than the maximum flow rate would overflow a baffle between the cartridge bay and the outlet bay, bypassing the filter media.

The StormFilter contains filter cartridges that contain media designed to remove specific pollutants. In this test, the cartridges were filled with perlite filter media, which traps particulates and adsorbs materials such as petroleum hydrocarbons, suspended solids, and pollutants such as nutrients and metals that commonly bind to sediment particles. Water in the cartridge bay infiltrates the filter media to a tube in the center of the filter cartridge. When the center tube fills, a float valve opens and a check valve on top of the filter cartridge closes, creating a siphon that draws water through the filter media. The filtered water drains into a manifold under the filter cartridges and to the outlet bay, where it exits the system through the discharge pipe. The system resets when the cartridge bay is drained and the siphon is broken. Air pulled into the filters when the siphon breaks helps to scrub solids from the filter, cleaning the filters and preventing the filter cartridges from clogging.

The vendor claims that the treatment system can remove 50% to 90% of the suspended solids in stormwater, as well as 25% to 60% of total phosphorus, depending on site characteristics, pollutant loading, and sediment particle size. The vendor's claims are outlined in greater detail in the verification report.

VERIFICATION TESTING DESCRIPTION

Methods and Procedures

The test methods and procedures used during the study are described in the *Environmental Technology Verification Test Plan For The Stormwater Management StormFilter, TEA-21 Project Area***,** *City of Griffin, Spalding County, Georgia,* (June 2003). The City of Griffin requires that all storm drain systems be designed to pass peak flows from a 25-yr event without causing surface flooding. For the StormFilter drainage basin, a 25-yr storm event would have a 1.47-min time of concentration and would generate a peak runoff of 4.93 cfs. The rational method was used to calculate the peak flows to the system.

Verification testing consisted of collecting data during a minimum of 15 qualified events that met the following criteria:

- The total rainfall depth for the event, measured at the site, was 0.2 in. (5 mm) or greater;
- Flow through the treatment device was successfully measured and recorded over the duration of the runoff period;
- A flow-proportional composite sample was successfully collected for both the influent and effluent over the duration of the runoff event;
- Each composite sample was comprised of a minimum of five aliquots, including at least two aliquots on the rising limb of the runoff hydrograph, at least one aliquot near the peak, and at least two aliquots on the falling limb of the runoff hydrograph; and
- There was a minimum of six hours between qualified sampling events.

Automated sample monitoring and collection devices were installed and programmed to collect composite samples from the influent and effluent during qualified flow events. In addition to the flow and analytical data, operation and maintenance (O&M) data were recorded. Samples were analyzed for the following parameters:

Sediments

- total suspended solids (TSS)
- suspended sediment concentration (SSC)
- particle size distribution

Metals

- total and dissolved cadmium, lead, copper and zinc

Nutrients

- total and dissolved phosphorus
- total Kjeldahl nitrogen (TKN)
- total nitrate
- total nitrite

The test plan included total petroleum hydrocarbon (TPH) and polynuclear aromatic hydrocarbon (PAH) analyses in the suite of analytical parameters. Samples were initially analyzed for TPH and PAH along with the sediment, metals, and nutrient parameters. TPH and PAH concentrations were below detection limits for every event. In December 2003, SMI, NSF, PCG, and EPA agreed to eliminate the hydrocarbon analyses from the sampling plan since these analyses were always below detection limits.

VERIFICATION OF PERFORMANCE

The following is a summary of the verified data gathered during the course of verification testing. Verification testing of the StormFilter lasted approximately 11 months. A significant number of storm events that met the qualification criteria were not sampled due to issues with the automated sampling equipment and power supply, including blown fuses, power surges and interruptions, or sample tube clogging. A total of 15 storm events were successfully sampled.

Test Results

The precipitation data for the rain events are summarized in Table 1. The peak flow rates exceeded the StormFilter's rated flow capacity during several events, indicating the likelihood that some bypass occurred during storm events with peak flows exceeding the StormFilter's rated flow capacity.

Table 1. Rainfall Data Summary

Event number	Start date	Start time	Rainfall amount (in.)	Rainfall duration (hr:min)	Peak Discharge Rate (gal)[1]	Runoff volume (gpm)[1]
1	7/21/03	18:30	0.49	0:40	362	7,730
2	7/22/03	15:00	0.22	0:55	398	7,090
3	7/23/03	17:40	0.33	1:05	572	8,650
4	8/1/03	16:25	1.73	4:15	1,040	38,200
5	8/6/03	14:40	0.76	1:30	881	18,400
6	1/17/04	21:15	0.44	4:40	175	10,700
7	2/2/04	10:35	0.33	8:10	21.7	2,910
8	4/12/04	19:30	0.31	0:35	778	10,000
9	4/30/04	18:05	0.74	6:40	296	14,100
10	5/12/04	17:10	0.52	2:00	431	10,400
11	5/18/04	15:10	1.24	0:50	879	25,600
12	6/14/04	11:35	0.43	0:35	838	9,180
13	6/25/04	13:10	0.46	6:20	282	6,270
14	6/27/04	18:25	0.82	2:45	959	22,600
15	6/28/04	22:40	0.59	1:35	975	16,900

1. Runoff volume and peak discharge rate measured at the outlet of the StormFilter. See the verification report for further details.

The monitoring results were evaluated using event mean concentration (EMC), or efficiency ratio comparison, and sum of loads (SOL) comparisons. The EMC evaluates treatment efficiency on a percentage basis by dividing the effluent concentration by the influent concentration and multiplying the quotient by 100. The EMC was calculated for each analytical parameter and each individual storm event. The SOL comparison evaluates the treatment efficiency on a percentage basis by comparing the sum of the influent and effluent loads (the parameter concentration multiplied by the precipitation volume) for all storm events. The calculation is made by subtracting from one the quotient of the total effluent load divided by the total influent load, and multiplying by 100. SOL results can be summarized on an overall basis since the loading calculation takes into account both the concentration and volume of runoff from each event. The analytical data ranges, EMC range, and SOL reduction values are shown in Table 2.

Table 2. Analytical Data, EMC Range, and SOL Reduction Results

Parameter	Units	Inlet Range	Outlet Range	EMC Range (%)	SOL Reduction (%)
TSS	mg/L	90 – 410	12 – 110	24 – 69	50
SSC	mg/L	120 – 430	55 – 200	20 – 61	50
Total phosphorus	mg/L as P	0.13 – 0.38	0.05 – 0.19	11 – 68	50
Dissolved phosphorus	mg/L as P	<0.02 – 0.23	<0.02 – 0.07	0 – 96	42
TKN	mg/L as N	<0.4 – 2.5	<0.4 – 1.3	0 – 67	24
Total nitrate	mg/L as N	0.37 – 1.1	0.27 – 1.9	-170 – 30	-13
Total nitrite	mg/L as N	<0.01 – 0.04	<0.01 – 0.03	0 – 75	36
Total cadmium	mg/L	<0.0005 – 0.001	<0.0005 – <0.0005	50 – 75	70
Total copper	mg/L	<0.004 – 0.02	<0.004 – 0.02	0 – 65	34
Total lead	mg/L	0.02 – 0.07	0.009 – 0.04	0 – 67	37
Total zinc	mg/L	0.07 –0.23	0.04 –0.10	30 – 67	52
Dissolved cadmium	mg/L	<0.0005 – <0.0005	<0.0005 – <0.0005	ND	ND
Dissolved copper	mg/L	<0.004 – 0.008	<0.004 – 0.006	0 – 67	-44
Dissolved lead	mg/L	<0.005 – 0.02	<0.005 – 0.02	-50 – 75	-3.5
Dissolved zinc	mg/L	0.02 –0.14	0.01 –0.10	-67 – 75	21

ND: Not determined.

Based on the SOL evaluation method, TSS, SSC and total phosphorus reductions met the vendor's performance claim. The StormFilter was also able to remove some nutrients, total metals, and dissolved zinc.

A particle size distribution procedure known as "sand-silt split" was conducted on samples as part of the SSC analysis. The sand-silt split procedure quantifies the percentage (by weight) of particles greater than 62.5 µm (defined as sand) and less than 62.5 µm (defined as silt). The percentage of silt in the inlet ranged from 73% to 99%, while the percentage of silt in the outlet ranged from 97% to 99%. This data was incorporated into the SOL calculation, revealing the reduction in the SSC sand fraction was 95% and the reduction in the SSC silt fraction was 42%.

System Operation

The StormFilter was installed by a subcontractor, under the supervision of PCG. No issues were noted during the installation.

The StormFilter was cleaned in February 2003, and inspected in August 2003, January 2004, May 2004, and December 2004. During the December 2004 inspection, the filter chamber contained sediment at depths ranging from one to four inches. The filters were covered in sediment and organic detritus, but appeared not to be clogged. A composite sample of the sediment was collected and analyzed for Toxicity Characteristic Leachate Procedure metals, and the sediment was found to be non-hazardous.

Quality Assurance/Quality Control

NSF personnel completed a technical systems audit during testing to ensure that the testing was in compliance with the test plan. NSF also completed a data quality audit of at least 10% of the test data to ensure that the reported data represented the data generated during testing. In addition to QA/QC audits performed by NSF, EPA personnel conducted an audit of NSF's QA Management Program.

Original signed by:
Sally Gutierrez *10/3/05*
Sally Gutierrez Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original signed by:
Robert Ferguson *10/5/05*
Robert Ferguson Date
Vice President
Water Systems
NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the *ETV Verification Protocol, Stormwater Source Area Treatment Technologies Draft 4.1, March 2002,* the verification statement, and the verification report (NSF Report Number 05/23/WQPC-WWF) are available from:

ETV Water Quality Protection Center Program Manager (hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140

NSF website: http://www.nsf.org/etv (electronic copy)
EPA website: http://www.epa.gov/etv (electronic copy)
Appendices are not included in the verification report, but are available from NSF upon request.

The accompanying notice is an integral part of this verification statement.

Notice

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center (WQPC), operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and EPA and recommended for public release. Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use or certification by NSF.

Foreword

The following is the final report on an Environmental Technology Verification (ETV) test performed for NSF International (NSF) and the United States Environmental Protection Agency (EPA). The verification test for the Stormwater Management, Inc. StormFilter® using Perlite filter media was conducted at a testing site in Griffin, Georgia, maintained by the City of Griffin Public Works and Stormwater Department.

The EPA is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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Tables

Abbreviations and Acronyms

ASI	Analytical Services, Inc.
BMP	best management practice
cfs	Cubic feet per second
DTU	Data transfer unit
EMC	Event mean concentration
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ft^2	Square feet
ft^3	Cubic feet
g	Gram
gal	Gallon
gpm	Gallon per minute
HDPE	High density polyethylene
hr	Hour
in	Inch
kg	Kilogram
L	Liter
lb	Pound
NRMRL	National Risk Management Research Laboratory
mg/L	Milligram per liter
min	Minute
mm	Millimeter
NSF	NSF International, formerly known as National Sanitation Foundation
O&M	Operations and maintenance
PCG	Paragon Consulting Group
QA	Quality assurance
QC	Quality control
SMI	Stormwater Management, Inc. (vendor)
SOL	Sum of the loads
SOP	Standard Operating Procedure
TCLP	Toxicity Characteristic Leachate Procedure
TO	Testing Organization (Paragon Consulting Group)
µm	Micron
USGS	United States Geological Survey
VO	Verification Organization (NSF)
WQPC	Water Quality Protection Center
yd^3	Cubic yard
yr	Year

Chapter 1
Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups, which consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory (as appropriate) testing, collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF), in cooperation with the EPA, operates the Water Quality Protection Center (WQPC). The WQPC evaluated the performance of the Stormwater Management StormFilter® using perlite filter media (StormFilter), a stormwater treatment device designed to remove sediments and pollutants from wet weather runoff.

It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or "accepted" by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the Testing Organization (TO).

1.2 Testing Participants and Responsibilities

The ETV testing of the StormFilter was a cooperative effort among the following participants:

- U.S. Environmental Protection Agency
- NSF International
- Paragon Consulting Group, Inc. (PCG)
- Analytical Services, Inc. (ASI)
- United States Geological Survey (USGS) Sediment Laboratory
- Stormwater Management, Inc. (SMI)

The following is a brief description of each ETV participant and their roles and responsibilities.

1.2.1 U.S. Environmental Protection Agency

The EPA Office of Research and Development, through the Urban Watershed Branch, Water Supply and Water Resources Division, National Risk Management Research Laboratory (NRMRL), provides administrative, technical, and quality assurance guidance and oversight on all ETV Water Quality Protection Center activities. In addition, EPA provides financial support for operation of the WQPC and partial support for the cost of testing for this verification. EPA's responsibilities include:

- Review and approval of the test plan;
- Review and approval of verification report;
- Review and approval of verification statement; and
- Post verification report and statement on the EPA website.

The key EPA contact for this program is:

Mr. Ray Frederick, ETV WQPC Project Officer
(732) 321-6627 email: Frederick.Ray@epamail.epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Research Laboratory
2890 Woodbridge Avenue (MS-104)
Edison, New Jersey 08837-3679

1.2.2 Verification Organization

NSF is the verification organization (VO) administering the WQPC in partnership with EPA. NSF is a not-for-profit testing and certification organization dedicated to public health, safety, and protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in development of consensus standards for the protection of public health and the environment. NSF also provides testing and certification services to ensure that products bearing the NSF name, logo and/or mark meet those standards.

NSF personnel provided technical oversight of the verification process. NSF provided review of the test plan and was responsible for the preparation of the verification report. NSF contracted with Scherger Associates to provide technical advice and to assist with preparation of the verification report. NSF's responsibilities as the VO include:

- Review and comment on the test plan;
- Review quality systems of all parties involved with the TO, and qualify the TO;
- Oversee TO activities related to the technology evaluation and associated laboratory testing;
- Conduct an on-site audit of test procedures;
- Provide quality assurance/quality control (QA/QC) review and support for the TO;
- Oversee the development of the verification report and verification statement; and,
- Coordinate with EPA to approve the verification report and verification statement.

Key contacts at NSF are:

Mr. Thomas Stevens, P.E., (734) 769-5347	Program Manager email: stevenst@nsf.org
Mr. Patrick Davison, (734) 913-5719	Project Coordinator email: davison@nsf.org

NSF International
789 North Dixboro Road
Ann Arbor, Michigan 48105

Mr. Dale A. Scherger, P.E., (734) 213-8150	Technical Consultant email: daleres@aol.com

Scherger Associates
3017 Rumsey Drive
Ann Arbor, Michigan 48105

1.2.3 Testing Organization

The TO for the verification testing was Paragon Consulting Group, Inc. (PCG) of Griffin, Georgia. The TO was responsible for ensuring that the testing location and conditions allowed for the verification testing to meet its stated objectives. The TO prepared the test plan; oversaw the testing; and managed the data generated by the testing. TO employees set test conditions, and measured and recorded data during the testing. The TO's Project Manager provided project oversight.

PCG had primary responsibility for all verification testing, including:

- Coordinate all testing and observations of the StormFilter in accordance with the test plan;
- Contract with the analytical laboratory, contractors and any other subcontractors necessary for implementation of the test plan;
- Provide needed logistical support to subcontractors, as well as establishing a communication network, and scheduling and coordinating the activities for the verification testing; and
- Manage data generated during the verification testing.

The key contact for the TO is:

Ms. Courtney Nolan, P.E., (770) 412-7700	Project Manager email: cnolan@pcgeng.com

Paragon Consulting Group
118 North Expressway
Griffin, Georgia 30223

1.2.4 Analytical Laboratories

Analytical Services, Inc. (ASI), located in Norcross, Georgia, analyzed the samples collected during the verification test.

The key ASI contact is:

Ms. Christin Ford
(770) 734-4200 email: cford@ASI.com

Analytical Services, Inc.
110 Technology Parkway
Norcross, Georgia 30092

USGS Kentucky District Sediment Laboratory analyzed the suspended sediment concentration (SSC) samples.

The key USGS laboratory contact is:

Ms. Elizabeth A. Shreve, Laboratory Chief
(502) 493-1916 email: eashreve@usgs.gov

United States Geological Survey, Water Resources Division
Northeastern Region, Kentucky District Sediment Laboratory
9818 Bluegrass Parkway
Louisville, Kentucky 40299

1.2.5 Vendor

Stormwater Management, Inc. of Portland, Oregon is the vendor of the StormFilter, and was responsible for supplying a field-ready system. Vendor responsibilities include:

- Provide the technology and ancillary equipment required for the verification testing;
- Provide technical support during the installation and operation of the technology, including the designation of a representative to ensure the technology is functioning as intended;
- Provide descriptive details about the capabilities and intended function of the technology;
- Review and approve the test plan; and
- Review and comment on the draft verification report and draft verification statement.

The key contact for SMI is:

Mr. James Lenhart, P.E., Senior Vice President
(800) 548-5667 email: jiml@stormwaterinc.com

Stormwater Management, Inc.
12021-B NE Airport Way
Portland, Oregon 97220

1.2.6 *Verification Testing Site*

The StormFilter was located within right-of-way on the west side of Fifth Street in Griffin, Georgia. The key contact for City of Griffin Public Works and Stormwater Department is:

Mr. Brant Keller Ph.D., Director
(770) 229-6424 email: bkeller@cityofgriffin.com

Public Works and Stormwater Department
City of Griffin
134 North Hill Street
Griffin, Georgia 30224

Chapter 2
Technology Description

The following technology description was supplied by the vendor and does not represent verified information.

2.1 Treatment System Description

The components installed at this testing site included a StormFilter and a StormGate™ high flow bypass structure (StormGate). The StormGate was installed upstream of the StormFilter and included a field-adjustable weir, which was set to divert continuous flows up to 495 gpm (1.1 cfs) to the StormFilter. Continuous flows greater than 495 gpm would bypass the StormFilter at the StormGate and discharge to the overflow pipe that reconnected with the storm sewer system downstream of the StormFilter. The performance of the StormGate was not included as part of this verification. Additional technical information on the StormGate is provided in Section 2.2.1.

The StormFilter is designed to remove sediments, metals, and other roadway pollutants from stormwater. The StormFilter under test was designed to treat storm water with a maximum continuous flow rate of 495 gpm. Flows entering the StormFilter that exceeded the design flow rate would bypass the filter cartridges via the high-flow bypass weir in the StormFilter. The unit consisted of an energy dissipater, cartridge bay, flow spreader, high-flow bypass weir, and outlet bay, all housed in a 18-ft long by 8-ft wide pre-cast concrete vault. The flow spreader provided for the trapping of floatables, oil, and surface scum. The unit also included 33 filter cartridges filled with perlite filter media, installed inline with the storm drain lines. The cartridge bay provided for sediment storage capacity of 1.9 yd^3. A schematic of the StormFilter and a detail of the filter cartridge are shown in Figures 2-1 and 2-2.

Additional equipment specifications, test site descriptions, testing requirements, sampling procedures, and analytical methods were detailed in the *Environmental Technology Verification Test Plan for the Stormwater Management StormFilter®, TEA 21 Project Area, City of Griffin, Spalding County, Georgia* June, 2003. The test plan is included in Appendix B.

2.2 Filtration Process

The filtration process works by percolating storm water through a series of filter cartridges filled with perlite filter media, which traps particulates and pollutants such as phosphorus, nitrogen, and metals that commonly bind to sediment particles. The perlite media can also adsorb materials such as petroleum hydrocarbons and dissolved constituents present in the stormwater. A diagram identifying the filter cartridge components is shown in Figure 2-2.

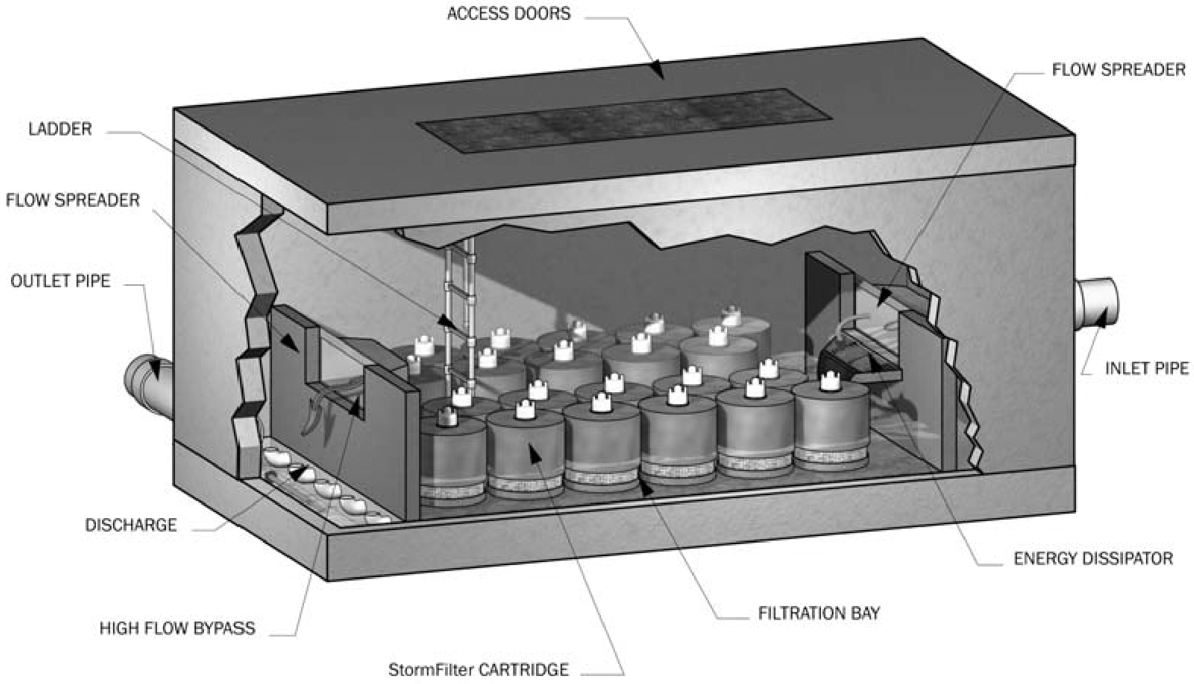

Figure 2-1. Schematic drawing of a typical StormFilter system.

Stormwater enters the cartridge bay through the flow spreader, where it ponds. Air in the cartridge is displaced by the water and purged from beneath the filter hood through the one-way check valve located on top of the cap. The water infiltrates through the filter media and into the center tube. Once the center tube fills with water, a float valve opens and the water in the center tube flows into the under-drain manifold, located beneath the filter cartridge. This causes the check valve to close, initiating a siphon that draws stormwater through the filter. The siphon continues until the water surface elevation drops to the elevation of the hood's scrubbing regulators. When the siphon begins to break air is quickly drawn beneath the hood, causing high-energy turbulence between the inner surface of the hood and the outer surface of the filter. This turbulence agitates the surface of the filter, releasing accumulated sediments on the surface, flushing them from beneath the hood, and allowing them to settle to the vault floor. This surface-cleaning mechanism maintains the permeability of the filter surface and enhances the overall performance and longevity of the system. When the water drains, the float valve closes and the system resets.

The StormFilter is equipped with an internal overflow baffle designed to bypass flows and prevent catch basin backup and surface flooding. The bypass flow is discharged through the outlet pipe along with the treated water.

2.2.1 StormGate

The StormGate is a system installed upstream of the StormFilter. It is designed to bypass high-energy flows that exceed a treatment system's design capacity. The StormGate is provided as a complete manhole or vault unit that installs directly into an existing sewer system. A schematic of a typical StormGate is shown in Figure 2-3.

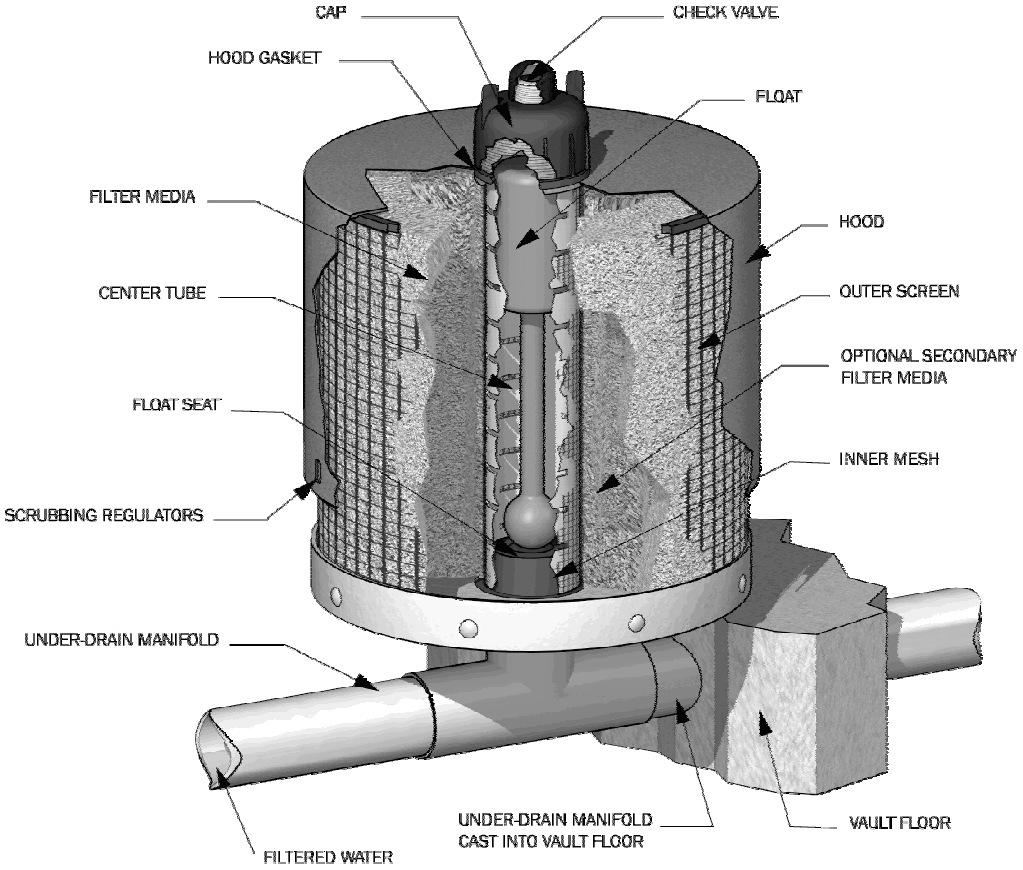

Figure 2-2. Schematic drawing of a StormFilter cartridge.

High flows can reduce the effectiveness of water quality facilities by resuspending sediments and flushing captured floatables, which causes a concentrated pulse of pollutants to be sent to downstream waterways. To minimize the occurrence of pulsing, a high-flow bypass can be installed upstream of water quality or pretreatment facilities to direct the high flow away from the treatment system. The StormGate uses a field-adjustable weir to direct polluted low flows to stormwater treatment systems, while allowing extreme flows to bypass the systems. The StormGate provides tighter control over system hydraulics than other high-flow bypass methods, as changes can be made to the weir elevation once actual field elevations are established or if future design flows change.

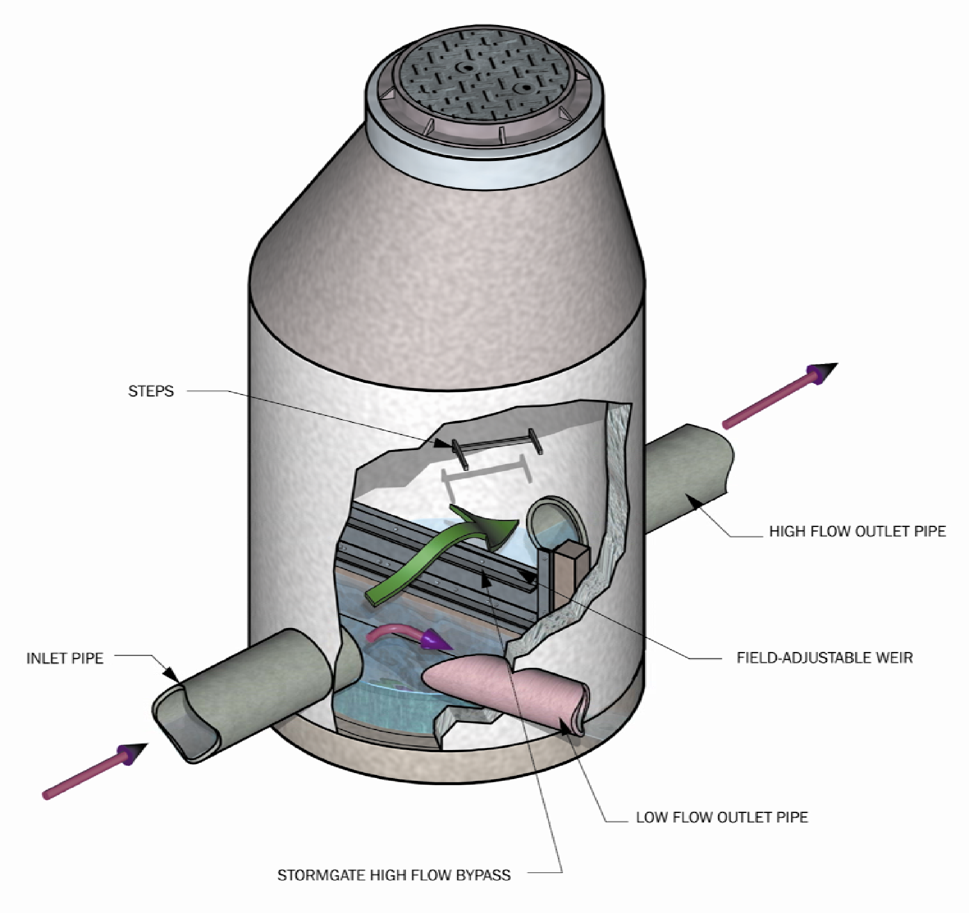

Figure 2-3. Schematic of the StormGate.

2.3 Technology Application and Limitations

The StormFilter is being used to treat stormwater runoff in a wide variety of sites throughout the United States. The StormFilter typically requires 2.3 ft of head differential between the inlet and outlet.

The StormFilter may be used for development, roadways, and specialized applications. Typical development applications include parking lots, commercial and industrial sites, and high-density and single-family housing. Typical development applications also include maintenance, transportation and port facilities. Typical roadway applications include arterial roads, freeways, bridge decks, and light rail and transit facilities. For specialized applications, laboratory evaluation of the water is normally required to establish the operational parameters.

2.4 Operations and Maintenance

The StormFilter requires minimal routine maintenance. SMI recommends that the system be maintained once per year. The rate at which the system collects pollutants will depend more on site activities than the size of the unit.

SMI recommends that the StormFilter device be inspected between six to nine months following the previous maintenance or original installation, generally late in the rainy season. Maintenance typically includes cartridge replacement or exchange and should take place during dry weather conditions. Maintenance may also involve disposal of materials that require consideration of regulatory guidelines.

It is important to check the condition of the StormFilter following major storm events to check for damage caused by high flows and to check for high sediment accumulation, which may be caused by localized erosion in the drainage area. It may be necessary to adjust maintenance activity scheduling depending on the actual operating conditions encountered by the system.

During inspection, loose debris and trash can be removed using a pole with a grapple or net on the end if system performance appears to be hindered. Cleanout of the StormFilter is best accomplished with the use of mobile vactor equipment. Approximately three to four inches of sediment on the vault floor warrants full cleaning of the StormFilter. The cartridges are completely plugged if they remain submerged after an extended time during dry weather conditions. However, the inspector should insure that the cartridges are not submerged due to backwater conditions caused by high groundwater, plugged pipes, or high hydraulic grade lines. Completely plugged cartridges can also be associated with heavy oil and grease loading from animal and vegetable fats or petroleum hydrocarbons, which warrants source control measures.

The media should be replaced when the white perlite media becomes darkened to the point of almost being black. A square nose shovel or vacuum truck should be used to remove accumulated sediments after cartridge removal.

It is important to note that the drainage structures and system upstream of the treatment device should also be maintained to ensure maximum function of the SMI devices.

2.5 Performance Claim

According to SMI, the performance of the StormFilter varies with regards to pollutant loading, variability in contaminate concentrations, environmental conditions, regional soil variation, flow rate through the cartridge, and media type. As flow rate is decreased through the cartridge, performance typically increases at removal of TSS, nutrients, and metals.

2.5.1 TSS

SMI expected the StormFilter to achieve a net removal efficiency ranging between 50% to 90% depending upon the site characteristics and pollutant loading. TSS removal performance is expected to increase with increases in the loading of sand. As TSS becomes finer, performance will decrease. TSS concentrations less than 40 mg/L have presented difficulties in quantifying performance.

1. Laboratory experiments have indicated that a single StormFilter cartridge operating at 15 gpm using a coarse perlite media achieves TSS removal efficiency of 79% with a 95%

confidence limit of 78% and 80%, respectively, for a sandy loam material comprised of 55% sand, 45% silt, and 5% clay (USDA) by mass, using simulated stormwater.

2. Laboratory experiments have indicated that a single StormFilter cartridge operating at 15 gpm using a coarse perlite media achieves TSS removal efficiency of 77% with a 95% confidence limit of 76 and 77%, respectively, for a manufactured SIL-CO-SIL 106 material comprised of 20% sand and 80% silt (USDA) by mass, using simulated stormwater.

3. Field and laboratory experiments have indicated that a single StormFilter cartridge operating at 15 gpm using CSF leaf media had a TSS removal efficiency of 73% with 95% confidence limits of 68% and 79%, respectively.

2.5.2 Metals

Metals are measured as both total metals and soluble metals. Total metals are the sum of dissolved metals and those metals associated with particulates. Soluble metals are commonly defined as those metals that pass through a 0.45-µm filter. Frequently, the soluble metals are cationic form in that they posses a net positive charge.

Typically, performance claims are given for dissolved metals because total metals are associated with particulate matter that is difficult to quantify. For removal of dissolved metals via cation exchange, SMI recommends use of the zeolite or CSF® media.

At this time, no performance claims for the removal of metals can be made for perlite. Metals removal will be tied closely to site conditions and the removal of TSS.

2.5.3 Nutrients

Nutrients are typically removed via attachment to sediment particles. CSF leaf media is not recommended for the removal of soluble phosphorus or nitrogen. Nutrients maybe removed by perlite and perlite mixtures (perlite/zeolite/granular activated carbon) and are recommended for nutrient sensitive waters.

Total phosphorus reduction claims are not usually provided using CSF leaf media due to its organic nature. Perlite and perlite mixtures are capable of removing between 25% and 60% total phosphorus.

2.5.4 Oil and Grease

The system performs best when oil and grease loadings are less than 25 mg/L with measured removal rates between 40% to 70%. Oil and grease concentrations that exceed 15 mg/L on a consistent basis may need to incorporate additional oil and grease control measures to aid removal and protect media longevity.

Chapter 3
Test Site Description

3.1 Location and Land Use

The StormFilter is located within the City of Griffin right-of-way, along the eastern side of Fifth Street, just north of the southeast corner of the intersection of Fifth Street and Taylor Street at 33° 14’ 51.5040” latitude and 84° 15’ 37.4040” longitude. These coordinates are based on Arcview’s Global Information System (GIS) utilizing state plane coordinates.

Figure 3-1 is an as-built drawing of the StormFilter and adjacent features, while Figure 3-2 identifies the drainage basin, the location of the unit, and the surface contours of the drainage basin. The drainage basin consists of approximately 0.7 acres. An estimated 85% of the drainage basin is impervious and includes about 45 linear feet of storm sewer pipe and one storm inlet. No detention areas or open ditches are located within the drainage basin. No open ditches are located upstream of the StormFilter installation location.

The majority of the drainage basin consists of paved roadways, parking areas and various retail and commercial buildings. An unpaved church parking lot within the drainage basin provided a considerable sediment contribution to the stormwater. Small portions of the drainage basin are either landscaped sections or are lawns. Moderate to heavy traffic volume runs along Taylor Street, but no major storage or use of hazardous materials or chemicals exists in the drainage basin. None of the stormwater runoff from the drainage basin was pretreated prior to entering the StormFilter.

The nearest receiving water is Grape Creek, which is located approximately two-thirds of a mile east of the StormFilter. All water, either treated or bypass, flows via pipe flow in an easterly direction approximately 800 ft through storm pipe and ultimately flows into Grape Creek.

Griffin has many local ordinances to aid in stormwater management improvement and implement pollution control measures. Such ordinances include establishment of the Stormwater Utility, Soil Erosion and Sediment Control, buffer width, and land disturbance requirements. Copies of the existing ordinances are included in Attachment E of the test plan.

3.2 Contaminant Sources and Site Maintenance

The main pollutant sources within the drainage basin are created by vehicular traffic, typical urban commercial land use, and atmospheric deposition. Trash and debris accumulate on the surface and enter the stormwater system through large openings in the street inlets, sized to accommodate the large storm flows that can occur in this part of Georgia. The storm sewer catch basins do not have sumps. There are no other stormwater best management practices (BMPs) within the drainage basin.

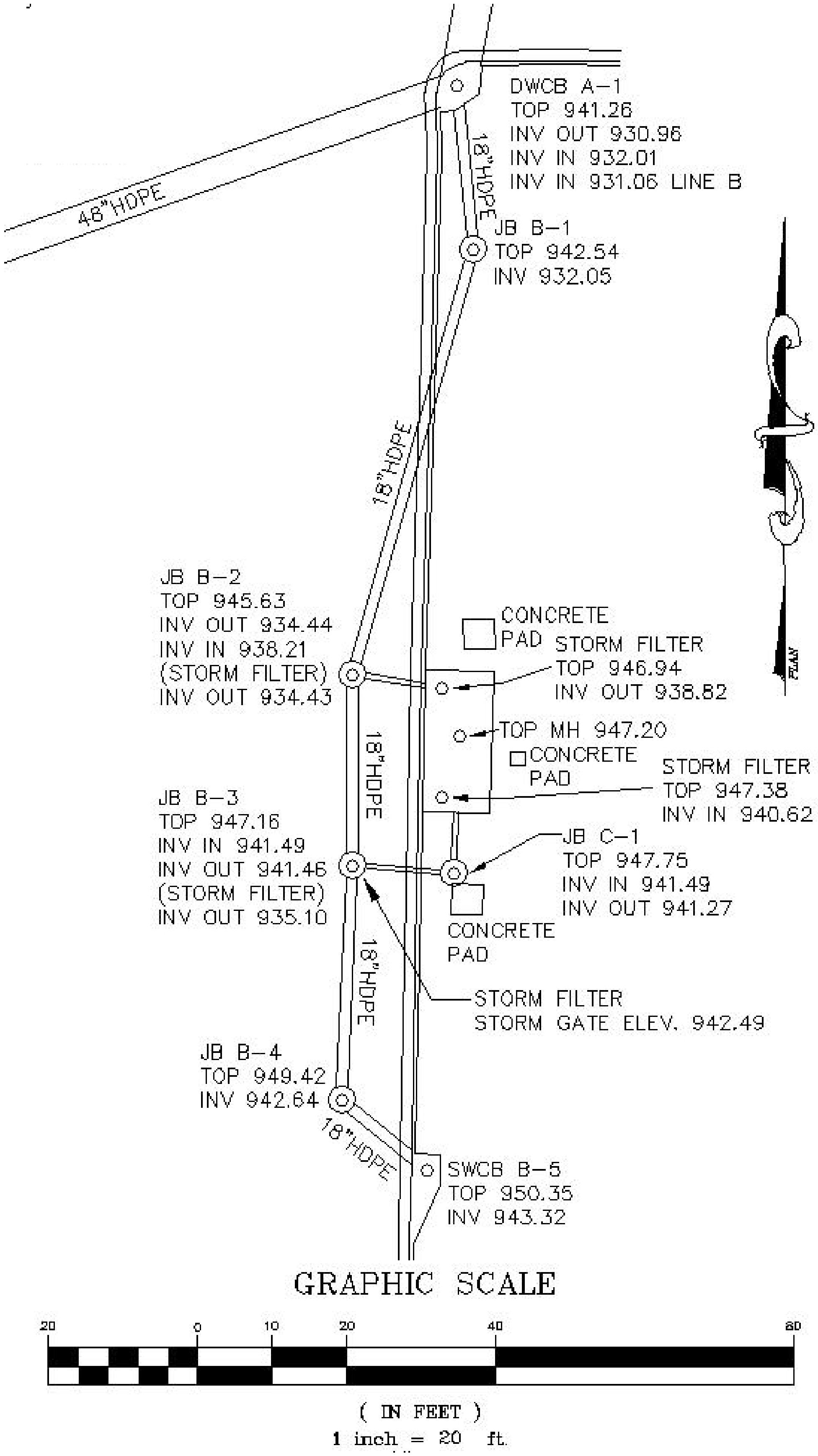

Figure 3-1. As-built drawing for the StormFilter installation.

Figure 3-2. Drainage basin map for the StormFilter installation.

No planned or on-going maintenance activities are in place for the area of the installation, such as street sweeping or catch basin cleaning. Because Taylor Street is a State Highway, the Georgia Department of Transportation is responsible for maintenance activities along the road. According to Griffin Public Works Department personnel, if such activities were performed, Griffin would either be involved with the actions, or at least informed that the activities are to take place. Such maintenance activities are typically only performed during emergencies.

3.3 Stormwater Conveyance System and Receiving Water

As previously discussed, the nearest receiving water is Grape Creek, which is located approximately two-thirds of a mile east of the StormFilter unit. All water, either treated or bypass, flows via pipe flow in an easterly direction approximately 800 ft through storm pipe and ultimately flows into Grape Creek.

3.4 Rainfall and Peak Flow Calculations

The rainfall amounts for the one-, two-, ten-, and twenty-five year storms for the drainage area are presented in Table 3-1. The protocol specifies that a value for the 6-month storm be presented, however, these data were not available. Table 3-2 presents the intensities in inches per hour calculated for the given rainfall depths. These data were utilized to generate the peak flows shown in Table 3-3. Table 3-4 presents the peak flow calculated using the time of concentration for the drainage basin.

Griffin requires that all storm drain systems be designed to accommodate the 25-yr storm. A 1.47-min time of concentration was determined for the basin, generating a peak runoff of 4.93 cfs for the 25-yr storm event. The rational method was used to calculate the peak flows for the StormFilter. The rationale for these calculations was discussed in the test plan.

Table 3-1. Rainfall Depth (in.)

Duration	1-yr	2-yr	10-yr	25-yr
30 min	0.99	1.19	1.58	1.81
1 hr	1.36	1.61	2.10	2.40
2 hr	1.68	2.00	2.62	2.98
12 hr	2.67	3.12	3.96	4.44
24 hr	2.87	3.36	4.32	4.80

Source: NOAA, 2000

Table 3-2. Intensities (in./hr)

Duration	1-yr	2-yr	10-yr	25-yr
30 min	1.99	2.38	3.16	3.61
1 hr	1.36	1.61	2.10	2.40
2 hr	0.84	1.00	1.31	1.49
12 hr	0.22	0.26	0.33	0.37
24 hr	0.12	0.14	0.18	0.20

Table 3-3. Peak Flow Calculations (cfs)

Duration	1-yr	2-yr	10-yr	25-yr
30 min	1.26	1.51	2.01	2.29
1 hr	0.86	1.02	1.33	1.52
2 hr	0.53	0.64	0.83	0.95
12 hr	0.14	0.17	0.21	0.23
24 hr	0.08	0.09	0.11	0.13

Table 3-4. Peak Flow Calculations (cfs) Using Time of Concentration

Duration	1-year	2-year	10-year	25-year
30 min	2.71	3.19	4.31	4.93

3.5 StormFilter Installation

The construction contractor utilized to complete the construction work associated with the installation of the StormFilter device was determined by bid. Site Engineering, Inc. of Atlanta, Georgia was the selected contractor. Installation activities began in April, 2002. Installation consisted of installing the StormFilter and StormGate into the existing storm sewer infrastructure. The StormFilter and StormGate were delivered and installed in May, 2002. SMI personnel were at the site during installation to ensure that the device was installed correctly. Construction activities were completed in July, 2002.

Chapter 4
Sampling Procedures and Analytical Methods

Descriptions of the sampling locations and methods used during verification testing are summarized in this section. The test plan presents the details on the approach used to verify the StormFilter. An overview of the key procedures used for this verification is presented below.

4.1 Sampling Locations

Three locations in the test site storm sewer system were selected as sampling and monitoring sites to determine the treatment capability of the StormFilter.

4.1.1 Upstream

This monitoring site was selected to monitor the stormwater flow rates entering into the StormGate. A velocity/stage meter was located in the influent pipe, upstream from the StormGate, so that potential backwater effects of the treatment device would not affect the velocity measurements. The upstream monitoring location was selected only to evaluate flow conditions, and did not include the ability to collect samples.

4.1.2 Influent

This sampling and monitoring site was selected to characterize the untreated stormwater diverted to the StormFilter by the StormGate. A velocity/stage meter and sampler suction tubing were located in the influent pipe, upstream from the StormFilter.

4.1.3 Effluent

This sampling and monitoring site was selected to characterize the stormwater exiting the StormFilter. A velocity/stage meter and sampler suction tubing, connected to the automated sampling equipment, were located in the pipe downstream from the StormFilter.

4.1.4 Rain Gauge

A rain gauge was located adjacent to the drainage area to monitor the depth of precipitation from storm events. The data were used to characterize the events to determine if they met the requirements for a qualified storm event.

4.2 Monitoring Equipment

The specific equipment used for monitoring flow, sampling water quality, and measuring rainfall for the upstream and downstream monitoring points is listed below:

- Sampler: American Sigma 900MAX automatic sampler with a data transfer unit (DTU II) data logger;

- Sample Containers: Two 1.9-L glass and six polyethylene bottles; or one four-gallon polyethylene container;
- Flow Monitors: American Sigma Area/Velocity Flow Monitors; and
- Rain Gauge: American Sigma Tipping Bucket Model 2149.

4.3 Constituents Analyzed

The list of constituents analyzed in the stormwater samples is shown in Table 4-1.

Table 4-1. Constituent List for Water Quality Monitoring

Parameter	Reporting Units	Method Detection Limit	Method[1]
Total suspended solids (TSS)	mg/L	5	EPA 160.2
Suspended sediment concentration (SSC)	mg/L	0.5	ASTM D3977-97
Total phosphorus	mg/L as P	0.016	EPA 365.1
Dissolved phosphorus	mg/L as P	0.02	SM 4500P B,E
Total Kjeldahl nitrogen (TKN)	mg/L as N	0.10	EPA 351.3
Nitrate + nitrite nitrogen	mg/L as N	0.02	EPA 9056
Total zinc	µg/L	4	EPA 200.7
Total lead	µg/L	5	EPA 200.7
Total copper	µg/L	4	EPA 200.7
Total cadmium	µg/L	0.07	EPA 7131
Dissolved zinc	µg/L	4	EPA 200.7
Dissolved lead	µg/L	5	EPA 200.7
Dissolved copper	µg/L	4	EPA 200.7
Dissolved cadmium	µg/L	0.07	EPA 7131
Sand-silt split	NA	NA	Fishman *et al*

[1] EPA: *EPA Methods and Guidance for the Analysis of Water* procedures; ASTM: American Society of Testing and Materials procedures; SM: *Standard Methods for the Examination of Water and Wastewater;* Fishman et al.: *Approved Inorganic and Organic Methods for the Analysis of Water and Fluvial Sediment* procedures; NA: *Not applicable*.

4.4 Sampling Schedule

The monitoring equipment was installed in August 2002. From September 2002 through June 2003, several trial events were monitored and the equipment tested and calibrated. Verification testing began in July 2003, and ended in June 2004. As defined in the test plan, “qualified” storm events met the following requirements:

1. The total rainfall depth for the event, measured at the site rain gauge, was 0.2 in. (5 mm) or greater.

2. Flow through the treatment device was successfully measured and recorded over the duration of the runoff period.

3. A flow-proportional composite sample was successfully collected for both the influent and effluent over the duration of the runoff event.

4. Each composite sample collected was comprised of a minimum of five aliquots, including at least two aliquots on the rising limb of the runoff hydrograph, at least one aliquot near the peak, and at least two aliquots on the falling limb.

5. There was a minimum of six hours between qualified sampling events.

4.5 Field Procedures for Sample Handling and Preservation

Water samples were collected with Sigma automatic samplers programmed to collect aliquots during each sample cycle. A peristaltic pump on the sampler pumped water from the sampling location through Teflon™-lined sample tubing to the pump head where water passed through silicone tubing and into the sample collection bottles. After qualified events, samples were removed from the sampler, split and capped by PCG personnel. Samples were preserved per method requirements and analyzed within the holding times allowed by the methods, except as noted in Chapter 6. Samples for particle size and SSC determination were shipped to the USGS sediment laboratory. All other samples were shipped to ASI for analysis. Custody was maintained according to the laboratory's sample handling procedures. To establish the necessary documentation to trace sample possession from the time of collection, field forms and lab forms (see Attachment G of the test plan) were completed and accompanied each sample.

The test plan included sampling and analysis for oil and grease (total petroleum hydrocarbons and polynuclear aromatic hydrocarbons). For events sampled before December 2003, the autosampling equipment was programmed to place the first two aliquots in the glass sample containers, and to composite the subsequent aliquots in the polyethylene sample containers. In December 2003, the TO, VO, vendor, and EPA agreed to discontinue oil and grease analyses after all analytical data reported no detectable hydrocarbon concentrations. When this change was made, the TO changed to the single four-gallon polyethylene sample container, and a sample splitting procedure that included vigorously stirring the sample with a stirring rod attached to a drill, and pouring off directly into the sample containers shipped to the laboratories.

Chapter 5
Monitoring Results and Discussion

Precipitation and stormwater flow records were evaluated to verify that the storm events met the qualified event requirements. The qualified event data is summarized in this chapter. The monitoring results related to contaminant reduction over the events are reported in two formats:

1. Efficiency ratio comparison, which evaluates the effectiveness of the system on an event mean concentration (EMC) basis.

2. Sum of loads (SOL) comparison, which evaluates the effectiveness of the system on a constituent mass (concentration times volume) basis.

5.1 Storm Event Data

Table 5-1 summarizes the storm data for the qualified events. Detailed information on each storm's runoff hydrograph and the rain depth distribution over the event period are included in Appendix C. The sample collection starting times for the inlet and outlet samples, as well as the number of sample aliquots collected, varied from event to event. The samplers were activated when the respective velocity meters sensed flow in the pipes, and the depth had reached 0.5 in. providing sufficient depth for a sample to be collected.

5.1.1 Flow Data Evaluation

With perfect measurements, the inlet and outlet volumes should be exactly the same, and the upstream volume should also be the same so long as the StormGate did not allow high flows to bypass the StormFilter. Table 5-2 summarizes the flow volumes and peak discharge rates for the three monitoring locations for each of the qualified events. A sizable difference was observed between the inlet, outlet and upstream flow volumes during most storm events. According to the flow monitor manufacturer, area velocity sensors work best when installed in sites with normalized flow, free of turbulence caused by obstructions, vertical drops, or pipe bends. When practical, sensors should be installed at a minimum distance of five times the maximum expected level upstream from an obstruction and ten times the expected level downstream from an obstruction. The flow monitors were calibrated at irregular intervals throughout the course of the study and consistently produced data with discrepancies as noted below.

Upstream: The upstream flow monitoring location provided data on the total flow entering into the StormGate. The flow monitor was installed in an 18-in. high-density polyethylene (HDPE) pipe upstream of the StormGate. This pipe had a straight run of approximately 30 ft with an average slope of approximately 3.8%, and the sensor was installed in a location free of obstructions. The upstream flow monitor failed to record data during events 7 and 8, and the depth probe readings were biased approximately two inches high during events 9 and 13, but appeared to function properly during the other qualified events. In general, the upstream volume data was similar to the outlet volume data and higher than the inlet volume data.

Table 5-1. Summary of Events Monitored for Verification Testing

Event No.	Start Date	Start Time	End Date	End Time	Rainfall Amount (in)	Rainfall Duration (hr:min)
1	7/21/03	18:30	7/21/03	19:10	0.49	0:40
2	7/22/03	15:00	7/22/03	15:55	0.22	0:55
3	7/23/03	17:40	7/23/03	18:45	0.33	1:05
4	8/1/03	16:25	7/31/03	20:40	1.73	4:15
5	8/6/04	14:40	8/6/03	16:10	0.76	1:30
6	1/17/04	21:15	1/18/04	1:55	0.44	4:40
7	2/2/04	10:35	2/2/04	18:45	0.33	8:10
8	4/12/04	19:30	4/12/04	20:05	0.31	0:35
9	4/30/04	18:05	4/30/04	0:45	0.74	6:40
10	5/12/04	17:10	5/12/04	19:10	0.52	2:00
11	5/18/04	15:10	5/18/04	16:00	1.24	0:50
12	6/14/04	11:35	6/14/04	12:10	0.43	0:35
13	6/25/04	13:10	6/25/04	19:40	0.46	6:20
14	6/27/04	18:25	6/27/04	21:10	0.82	2:45
15	6/28/04	22:40	6/29/04	0:15	0.59	1:35

The upstream peak runoff intensity was generally higher than the inlet peak runoff intensity and lower than the outlet peak runoff intensity. The upstream flow monitor's water elevation data were also used to evaluate whether the water elevation exceeded the StormGate weir elevation with respect to the invert elevation of the pipe where flow was monitored (approximately 10.5 in.), which would indicate a bypass condition. Events 1, 4 and 11 had inlet peak runoff intensities greater than the design flow of the StormFilter (495 gpm). During these events, the peak water level elevation at the upstream monitoring location reached 6.1 in., 8.1 in, and 10.2 in., respectively. Due to turbulence and a possibility of slight water elevation measurement inaccuracies, it is likely that some bypass occurred at the StormGate during these events.

Table 5-2. Peak Discharge Rate and Runoff Volume Summary

			Peak runoff intensity (gpm)			Flow volume (gal)		
No.	**Date**	**Rainfall (in)**	**Upstream**	**Inlet**	**Outlet**	**Upstream**	**Inlet**	**Outlet**
1	7/21/03	0.49	711	349	362	7,020	3,860	7,730
2	7/22/03	0.22	332	103	398	5,390	1,610	7,090
3	7/23/03	0.33	537	304	572	5,770	2,230	8,650
4	7/31/03	1.84	1,710	515	1,040	27,100	12,400	38,200
5	8/7/03	0.76	393	347	881	8,120	5,810	18,400
6	1/17/04	0.44	94.7	49.5	175	5,710	2,610	10,700
7	2/2/04	0.33	NR	68.6	21.7	NR	1,100	2,910
8	4/13/04	0.31	NR	191	778	NR	2,510	10,000
9	4/30/04	0.74	273	120	296	18,200	3,850	14,100
10	5/12/04	0.52	129	293	431	7,280	5,130	10,400
11	5/18/04	1.24	651	591	879	18,500	17,000	25,600
12	6/14/04	0.43	193	155	838	6,270	2,190	9,180
13	6/25/04	0.46	180	110	282	16,500	2,100	6,270
14	6/27/04	0.82	425	342	959	17,100	5,840	22,600
15	6/28/04	0.59	357	233	975	12,700	4,500	16,900

Inlet: The inlet flow monitoring location provided data on the flow diverted from the StormGate and entering the StormFilter. The flow monitor was installed in an 8-in. pipe that ran from the StormGate to junction box JB C-1 (refer to Figure 3-1). This pipe had a straight run of approximately 10 ft with an average slope of approximately -0.3%. This pipe was sized to handle an maximum flow rate (without head) approximately equivalent to the 495-gpm design flow of the StormFilter. The short pipe run prevented sensor installation in a location free of obstructions. The inlet flow and peak runoff intensity data were consistently lower than both the upstream and outlet data. This flow probe was used primarily to activate the inlet autosampler, rather than to accurately gauge the volume and intensity of the flow. The inlet autosampler was programmed to collect aliquots at intervals lower than the downstream sampler to account for the lower recorded water volume. During event 11, the depth probe read a depth of 50 in., which is likely attributable to a probe malfunction, possibly under full-pipe conditions, but appeared to function consistently during the other events.

Outlet: The outlet flow monitoring location provided data on the flow exiting the StormFilter. The flow monitor was installed in an 8-in. pipe that ran from the StormFilter to junction box JB B-2 (refer to Figure 3-1). This pipe had a straight run of approximately 8 ft with an average slope of approximately 7.6%. The short pipe run prevented sensor installation in a location free of obstructions. However, the StormFilter's outlet bay is designed to minimize turbulence, so it is likely that the flow in this pipe was sufficiently quiescent for flow monitoring. The outlet flow data were similar to the upstream flow data and higher than the inlet flow data. The outlet peak runoff intensity data were generally higher than both the inlet and upstream data. This may indicate that either the StormFilter can treat water in excess of its design capacity, or water was bypassing filtration by flowing over the weir located between the filter chamber and outlet chamber.

Conclusion: The inlet monitoring location was not a valid monitoring point for accurately measuring flow. The flow volume data from the upstream and outlet monitoring locations were generally similar, and differences were attributable either to the StormFilter treating water in excess of its rated capacity, water bypassing the StormFilter cartridges by flowing over the internal weir between the cartridge chamber and outlet chamber, or flow measurement error. The upstream monitor experienced two events where no data were collected and two events where the depth readings were biased high, but reliable data for the other events. Therefore, the outlet volume data appear to be more reliable than the inlet volume data for sum of loads calculations.

5.2 Monitoring Results: Performance Parameters

5.2.1 Concentration Efficiency Ratio

The concentration efficiency ratio reflects the treatment capability of the device using the event mean concentration (EMC) data obtained for each runoff event. The concentration efficiency ratios are calculated by:

$$\text{Efficiency ratio} = 100 \times (1-[\text{EMC}_{\text{effluent}}/\text{EMC}_{\text{influent}}]) \qquad (5\text{-}2)$$

The influent and effluent sample concentrations and calculated efficiency ratios are summarized by analytical parameter categories: sediments (TSS and SSC), nutrients (total phosphorus, TKN, nitrates, and nitrites), and total and dissolved metals (cadmium, copper, lead, and zinc).

Sediments: The inlet and outlet sample concentrations and calculated efficiency ratios for sediments are summarized in Table 5-3. The TSS inlet concentrations ranged from 90 to 410 mg/L, the outlet concentrations ranged from 36 to 150 mg/L, and the efficiency ratio ranged from 24% to 69%. The SSC inlet concentrations ranged 110 to 430 mg/L, the outlet concentrations ranged from 55 to 200 mg/L, and the efficiency ratio ranged from 20% to 61%.

The results show a similarity between inlet TSS and SSC concentrations. Both the TSS and SSC analytical parameters measure sediment concentrations in water; however, the TSS analytical procedure requires the analyst to draw an aliquot from the sample container, while the SSC procedure requires use of the entire contents of the sample container. If a sample contains a high concentration of settleable (large particle size or high density) solids, acquiring a representative aliquot from the sample container is very difficult. Therefore a disproportionate amount of the settled solids may be left in the container, and the reported TSS concentration would be lower than SSC. Since this phenomenon was not observed during this study, it appears that the sediment loading consisted primarily of sediments with small particle size. This observation correlates with the particle size distribution data summarized in Section 5.3.

Table 5-3. Monitoring Results and Efficiency Ratios for Sediment Parameters

		TSS			**SSC**		
Event No.	**Date**	**Inlet (mg/L)**	**Outlet (mg/L)**	**Reduction (%)**	**Inlet (mg/L)**	**Outlet (mg/L)**	**Reduction (%)**
1	7/21/03	90	44	51	130	77	41
2	7/22/03	98	74	24	120	78	33
3	7/23/03	170	90	47	230	130	42
4	8/1/03	160	75	53	220	99	55
5	8/6/03	230	120	48	280	160	43
6	1/17/04	96	38	60	120	55	53
7	2/2/04	120	36	69	NA	NA	NA
8	4/12/04	270	150	43	340	200	42
9	4/30/04	170	72	57	180	77	57
10	5/12/04	99	56	43	180	78	57
11	5/18/04	410	150	64	430	170	61
12	6/14/04	130	74	43	160	99	40
13	6/25/04	180	110	37	170	87	47
14	6/27/04	130	100	25	110	90	20
15	6/28/04	120J	84J	28	160	87	47

NA: Not analyzed due to insufficient collected sample volume.
J: Estimated concentration, samples analyzed one day outside hold time.

Nutrients: The inlet and outlet sample concentrations and calculated efficiency ratios are summarized in Table 5-4. Total phosphorus inlet concentrations ranged from 0.13 to 0.38 mg/L (as P), and the EMC reduction ranged from 11% to 85%. Dissolved phosphorus concentrations were near or below the method detection limits. TKN inlet concentrations ranged from <0.4 to 2.5 mg/L (as N), and the EMC reduction ranged from 0% to 67%. Total nitrate inlet concentrations ranged from 0.21 to 1.14 mg/L (as N), and the EMC ranged from -170% to 33%. Total nitrite inlet and outlet concentrations were near or below method detection limits.

Metals: The data for inlet and outlet sample concentrations and calculated efficiency ratios for total metals are in Table 5-5, and dissolved metals are in Table 5-6. Total and dissolved cadmium inlet and outlet concentrations were near or below the method detection limits. Total copper inlet concentrations ranged from <0.004 to 0.02 mg/L, and the EMC reduction ranged from 0% to 65%. Dissolved copper inlet concentrations ranged from <0.004 to 0.008 mg/L, and the EMC reduction ranged from 0% to 67%. Total lead inlet concentrations ranged from 0.02 to 0.07 mg/L, and the EMC reduction ranged from 0% to 75%. Dissolved lead inlet concentrations ranged from <0.005 to 0.02 mg/L, and the EMC reduction ranged from –50% to 75%. Total zinc inlet concentrations ranged from 0.07 to 0.23 mg/L, and the EMC reduction ranged from 30% to 70%. Dissolved zinc inlet concentrations ranged from 0.02 to 0.14 mg/L, and the EMC reduction ranged from –67% to 75%.

Table 5-4. Monitoring Results and Efficiency Ratios for Nutrients

		Total phosphorus (as P)			Dissolved phosphorus (as P)			Total Kjeldahl nitrogen (as N)			Total nitrate (as N)			Total nitrite (as N)		
Event No.	Date	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)
1	7/21/03	0.14	0.08	43	<0.02	<0.02	ND	0.4	**0.2**	50	0.59	0.65	-10	0.03	0.02	33
2	7/22/03	0.13	0.11	15	0.04	**0.01**	75	0.4	**0.2**	50	1.1	0.80	29	0.03	0.02	33
3	7/23/03	0.18	0.16	11	<0.02	<0.02	ND	<0.4	<0.4	ND	0.62	0.59	5	0.02	**0.005**	75
4	8/1/03	0.38	0.12	68	<0.02	0.02	ND	<0.4	<0.4	ND	0.21	0.27	-29	<0.01	<0.01	ND
5	8/6/04	0.23	0.16	30	<0.02	<0.02	ND	1.2	0.9	25	0.49	0.50	-2	0.02	**0.005**	75
6	1/17/04	0.34	0.05	85	0.23	**0.01**	96	1.7	1.3	24	0.71	0.50	30	<0.01	0.02	ND
7	2/2/04	0.27	0.23	15	0.06	0.04	33	1.2	0.9	25	0.37	0.56	-51	0.03	0.03	0
8	4/12/04	0.30	0.19	37	0.08	0.07	13	2.5	1.5	40	0.67	0.48	28	0.03	0.02	33
9	4/30/04	0.22	0.08	64	0.03	**0.01**	67	0.6	**0.2**	67	NA	NA	NA	NA	NA	NA
10	5/12/04	0.18	0.11	39	<0.02	<0.02	ND	1.5	1.2	20	0.51	0.69	-35	0.02	0.02	0
11	5/18/04	0.30	0.19	37	0.05	0.05	0	1.8	1.4	22	0.73	0.62	15	0.04	0.02	50
12	6/14/04	0.26	0.15	42	0.04	0.03	25	0.7	0.5	29	0.93	0.71	24	0.03	0.02	33
13	6/25/04	0.19	0.09	53	0.07	0.04	43	1.5	1.3	13	NA	NA	NA	NA	NA	NA
14	6/27/04	0.18	0.09	50	0.06	0.04	33	0.9	0.8	11	1.1	0.76	33	0.01	**0.005**	50
15	6/28/04	0.13	0.11	15	<0.02	<0.02	ND	1.0	1.0	0	0.68	1.9	-170	0.01	0.01	0

NA: Not analyzed due to expiration of hold time.
ND: Not determinable.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

Table 5-5. Monitoring Results and Efficiency Ratios for Total Metals

	Total Cadmium			Total Copper			Total Lead			Total Zinc		
Event No.	Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)
1	<0.0005	<0.0005	ND	0.02	0.007	65	0.02	0.009	55	0.11	0.04	64
2	<0.0005	<0.0005	ND	0.01	0.007	30	0.04	0.01	75	0.09	0.06	33
3	<0.0005	<0.0005	ND	0.02	0.009	55	0.04	0.04	0	0.09	0.06	33
4	<0.0005	<0.0005	ND	0.01	0.01	0	0.03	0.02	33	0.08	0.05	38
5	<0.0005	<0.0005	ND	0.01	0.009	10	0.05	0.04	20	0.10	0.06	40
6	0.0005	**0.00025**	50	0.01	0.007	30	0.02	0.02	0	0.21	0.10	52
7	0.0006	**0.00025**	58	0.01	0.007	46	0.03	0.02	29	0.13	0.08	41
8	<0.0005	<0.0005	ND	0.02	0.01	50	0.05	0.04	20	0.18	0.09	50
9	<0.0005	<0.0005	ND	0.01	0.006	40	0.03	0.01	67	0.15	0.05	67
10	<0.0005	<0.0005	ND	0.02	0.02	0	0.03	0.01	67	0.19	0.07	63
11	0.0010	**0.00025**	75	0.02	0.009	55	0.07	0.03	57	0.23	0.07	70
12	<0.0005	<0.0005	ND	0.004	**0.002**	50	0.03	0.02	33	0.10	0.07	30
13	<0.0005	<0.0005	ND	0.01	0.008	20	0.03	0.02	33	0.12	0.07	42
14	<0.0005	<0.0005	ND	0.009	0.005	44	0.03	0.03	0	0.08	0.04	50
15	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.03	0.01	67	0.07	0.04	43

ND: Not determinable.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

Table 5-6. Monitoring Results and Efficiency Ratios for Dissolved Metals

	Dissolved Cadmium			Dissolved Copper			Dissolved Lead			Dissolved Zinc		
Event No.	Inlet mg/L	Outlet mg/L	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)	Inlet mg/L	Outlet mg/L	Reduction (%)
1	<0.0005	<0.0005	ND	<0.004	0.006	ND	<0.005	<0.005	ND	0.04	0.01	75
2	<0.0005	<0.0005	ND	<0.004	0.006	ND	<0.005	<0.005	ND	0.03	0.05	-67
3	<0.0005	<0.0005	ND	<0.004	<0.004	ND	<0.005	<0.005	ND	0.02	0.02	0
4	<0.0005	<0.0005	ND	<0.004	0.006	ND	<0.005	<0.005	ND	0.02	0.02	0
5	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.008	0.01	-25	0.03	0.03	0
6	<0.0005	<0.0005	ND	0.006	**0.002**	67	0.01	**0.0025**	75	0.14	0.04	71
7	<0.0005	<0.0005	ND	0.007	0.005	29	0.02	0.009	55	0.11	0.09	16
8	<0.0005	<0.0005	ND	0.008	0.006	25	<0.005	<0.005	ND	0.05	0.03	40
9	<0.0005	<0.0005	ND	<0.004	<0.004	ND	<0.005	<0.005	ND	0.06	0.03	50
10	<0.0005	<0.0005	ND	0.005	0.005	0	<0.005	<0.005	ND	0.06	0.04	33
11	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.01	0.009	10	0.03	0.04	-33
12	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.008	0.009	-13	0.09	0.10	-11
13	<0.0005	<0.0005	ND	<0.004	<0.004	ND	<0.005	0.007	ND	0.13	0.09	31
14	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.01	0.02	-50	0.06	0.05	17
15	<0.0005	<0.0005	ND	<0.004	<0.004	ND	0.01	0.008	20	0.03	0.04	-33

ND: Not determinable.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

5.2.2 *Sum of Loads*

The sum of loads (SOL) is the sum of the% load reduction efficiencies for all the events, and provides a measure of the overall performance efficiency for the events sampled during the monitoring period. The load reduction efficiency is calculated using the following equation:

$$\% \text{ Load Reduction Efficiency} = 100 \times (1 - (A / B)) \qquad (5\text{-}3)$$

where:

A = Sum of Effluent Load = (Effluent EMC_1)(Flow $Volume_1$) + (Effluent EMC_2)(Flow $Volume_2$) + (Effluent EMC_n)(Flow $Volume_n$)

B = Sum of Influent Load = (Influent EMC_1)(Flow $Volume_1$) + (Effluent EMC_2)(Flow $Volume_2$) + (Effluent EMC_n)(Flow $Volume_n$)

n= number of qualified sampling events

As noted in Section 5.1.1, the outlet monitoring location provided the most representative flow data, so the SOL calculation was made using the outlet volumes for both the inlet and outlet data.

Sediment: Table 5-7 summarizes results for the SOL calculations for TSS and SSC. The SOL analyses indicate a 50% reduction for both TSS and SSC.

As noted in Section 5.1.1, the outlet monitoring location provided the most representative flow data, so the SOL calculation was made using the outlet volumes for both the inlet and outlet data. As a point of comparison, if the inlet volume data were used to calculate the sediment SOL, the result would be a 54% reduction in TSS and a 53% reduction in SSC. Similarly, calculating sediment SOL using the upstream volume data results in a 50% reduction in TSS and a 51% reduction in SSC. This demonstrates that using the different volumes had little impact on the resulting SOL calculations. For this reason, the loads for metals and nutrients are calculated using only the outlet volumes.

Nutrients: The SOL data for nutrients are summarized in Table 5-8. The total phosphorus load was reduced by 50%, dissolved phosphorous was reduced by 42%, nitrate was reduced by -13%, TKN was reduced by 24%, and nitrite was reduced by 36%. The nitrate SOL reduction was heavily influenced by event 15. When this data point is removed, the SOL reduction for nitrate increases to 15%.

Metals: The SOL data for total and dissolved metals are summarized in Tables 5-9 and 5-10, respectively. The total cadmium load was reduced by 70%, however, most influent and effluent sample concentrations were near or below method detection limits. Total copper was reduced by 34%, total lead was reduced by 37%, and total zinc was reduced by 52%. Dissolved cadmium was not detected, dissolved copper was reduced by –44% (although most analytical data was near or below the analytical detection limit), dissolved lead was reduced by –3.5%, and dissolved zinc was reduced by 21%.

Table 5-7. Sediment Sum of Loads Results

			TSS Loading		SSC Loading	
Event No.	Date	Runoff Volume (gal)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)
1	7/21/03	7,730	5.8	2.8	8.4	5.0
2	7/22/03	7,090	5.8	4.4	6.9	4.6
3	7/23/03	8,650	12	6.5	17	9.6
4	8/1/03	38,200	51	24	70	32
5	8/6/03	18,400	35	18	42	24
6	1/17/04	10,700	8.6	3.4	10	4.9
7	2/2/04	2,910	2.8	0.87	NA	NA
8	4/12/04	10,000	22	13	28	16
9	4/30/04	14,100	20	8.5	21	9.1
10	5/12/04	10,400	8.6	4.9	16	6.8
11	5/18/04	25,600	87	31	92	36
12	6/14/04	9,180	9.9	5.7	13	7.6
13	6/25/04	6,270	9.5	6.0	8.6	4.5
14	6/27/04	22,600	25	19	21	17
15	6/28/04	16,900	16J	12J	23	12
Sum of the Loads			**320**	**160**	**380**	**190**
Removal Efficiency (%)			**50**		**50**	

NA: Not analyzed due to insufficient collected sample volume.
J: Estimated weight, TSS samples analyzed one day outside hold time.

Table 5-8. Nutrients Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Total Phosphorus		Dissolved Phosphorus		TKN		Total Nitrate		Total Nitrite	
			Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)
1	7/21/03	7,730	0.009	0.005	ND	ND	0.03	**0.01**	0.038	0.042	0.0019	0.0013
2	7/22/03	7,090	0.008	0.007	0.002	**0.001**	0.02	**0.01**	0.066	0.047	0.0018	0.0012
3	7/23/03	8,650	0.013	0.012	ND	ND	ND	ND	ND	ND	0.0014	**0.0004**
4	8/1/03	38,200	0.12	0.038	**0.003**	0.006	ND	ND	0.067	0.086	ND	ND
5	8/6/04	18,400	0.035	0.025	ND	ND	0.18	0.14	ND	ND	0.0031	**0.0008**
6	1/17/04	10,700	0.030	0.004	0.021	**0.001**	0.15	0.12	0.063	0.045	**0.0004**	0.0018
7	2/2/04	2,910	0.007	0.006	0.001	0.001	0.03	0.02	0.009	0.014	0.0007	0.0007
8	4/12/04	10,000	0.025	0.016	0.006	0.006	0.21	0.13	0.056	0.040	0.0025	0.0017
9	4/30/04	14,100	0.026	0.009	0.004	**0.001**	0.07	**0.02**	NA	NA	NA	NA
10	5/12/04	10,400	0.016	0.010	ND	ND	0.13	0.10	0.044	0.060	0.0017	0.0017
11	5/18/04	25,600	0.064	0.041	0.011	0.011	0.38	0.30	ND	ND	0.0085	0.0043
12	6/14/04	9,180	0.020	0.011	0.003	0.002	0.08	0.04	ND	ND	0.0023	0.0015
13	6/25/04	6,270	0.010	0.005	0.004	0.002	0.08	0.07	NA	NA	NA	NA
14	6/27/04	22,600	0.034	0.017	0.011	0.008	0.17	0.15	0.21	0.14	0.0019	**0.0009**
15	6/28/04	16,900	0.018	0.015	ND	ND	0.14	0.14	0.096	0.26	0.0014	0.0014
Sum of the Loads			**0.44**	**0.22**	**0.066**	**0.038**	**1.6**	**1.2**	**0.65**	**0.74**	**0.028**	**0.018**
Removal Efficiency (%)			**50**		**42**		**24**		**-13**		**36**	

NA: Not analyzed due to expiration of hold time.
ND: Not determined because both inlet and outlet samples were below detection limits.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL reduction.

Table 5-9. Total Metals Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Total Cadmium		Total Copper		Total Lead		Total Zinc	
			Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)
1	7/21/03	7,730	ND	ND	0.59	0.20	0.59	0.26	3.2	1.2
2	7/22/03	7,090	ND	ND	0.27	0.19	1.1	0.27	2.4	1.6
3	7/23/03	8,650	ND	ND	0.65	0.29	1.3	1.31	2.9	2.0
4	8/1/03	38,200	ND	ND	1.4	1.4	4.3	2.9	12	7.2
5	8/6/04	18,400	ND	ND	0.70	0.63	3.5	2.8	7.0	4.2
6	1/17/04	10,700	0.020	**0.010**	0.40	0.28	0.81	0.81	8.5	4.0
7	2/2/04	2,910	0.007	**0.003**	0.14	0.08	0.31	0.22	1.4	0.85
8	4/12/04	10,000	ND	ND	0.76	0.38	1.9	1.51	6.8	3.4
9	4/30/04	14,100	ND	ND	0.53	0.32	1.6	0.53	8.0	2.7
10	5/12/04	10,400	ND	ND	0.79	0.79	1.2	0.39	7.5	2.8
11	5/18/04	25,600	0.097	**0.024**	1.9	0.87	6.8	2.9	22	6.8
12	6/14/04	9,180	ND	ND	0.14	**0.07**	1.0	0.69	3.5	2.4
13	6/25/04	6,270	ND	ND	0.24	0.19	0.71	0.47	2.8	1.7
14	6/27/04	22,600	ND	ND	0.77	0.43	2.1	2.40	6.8	3.7
15	6/28/04	16,900	ND	ND	ND	ND	1.8	0.83	4.3	2.8
Sum of the Loads			**0.12**	**0.037**	**9.4**	**6.2**	**29**	**18**	**99**	**47**
Removal Efficiency (%)			**70**		**34**		**37**		**52**	

ND: Not determined because both inlet and outlet samples were below detection limits.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL reduction.

Table 5-10. Dissolved Metals Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Dissolved Cadmium		Dissolved Copper		Dissolved Lead		Dissolved Zinc	
			Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)	Inlet (g)	Outlet (g)
1	7/21/03	7,730	ND	ND	**0.059**	0.18	ND	ND	1.2	0.29
2	7/22/03	7,090	ND	ND	**0.054**	0.16	ND	ND	0.81	1.3
3	7/23/03	8,650	ND	ND	ND	ND	ND	ND	0.65	0.65
4	8/1/03	38,200	ND	ND	**0.29**	0.87	ND	ND	2.9	2.9
5	8/6/04	18,400	ND	ND	ND	ND	0.56	0.70	2.1	2.1
6	1/17/04	10,700	ND	ND	0.24	**0.081**	0.40	**0.10**	5.7	1.6
7	2/2/04	2,900	ND	ND	0.077	0.055	0.22	0.10	1.2	1.0
8	4/12/04	10,000	ND	ND	0.30	0.23	ND	ND	1.9	1.1
9	4/30/04	14,100	ND	ND	ND	ND	ND	ND	3.2	1.6
10	5/12/04	10,400	ND	ND	0.20	0.20	ND	ND	2.4	1.6
11	5/18/04	25,600	ND	ND	ND	ND	0.97	0.87	2.9	3.9
12	6/14/04	9,180	ND	ND	ND	ND	0.28	0.31	3.1	3.5
13	6/25/04	6,270	ND	ND	ND	ND	**0.06**	0.17	3.1	2.1
14	6/27/04	22,600	ND	ND	ND	ND	1.0	1.5	5.2	3.9
15	6/28/04	16,900	ND	ND	ND	ND	0.64	0.51	1.9	2.6
Sum of the Loads			**ND**	**ND**	**1.2**	**1.8**	**4.2**	**4.3**	**38**	**30**
Removal Efficiency (%)			**ND**		**-44**		**-3.5**		**21**	

ND: Not determined because both inlet and outlet samples were below detection limits.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL reduction.

5.3 Particle Size Distribution

Particle size distribution analysis was conducted as part of the SSC analysis by the USGS laboratory. The SSC method includes a “sand/silt split” analysis determined the percentage of sediment (by weight) larger than 62.5 µm (defined as sand) and less than 62.5 µm (defined as silt). The particle size distribution results are summarized in Table 5-11. The inlet samples had a high proportion of fine sediment. During most events, the proportion of larger particles decreased during treatment, which indicates the StormFilter removed a higher proportion of larger particles.

The SOL can be recalculated for SSC concentrations and “sand/silt split” data to determine the proportion of sand and silt removed during treatment. This evaluation shows that 95% of “sand” and 42% of “silt” was removed.

Table 5-11. Particle Size Distribution Analysis Results

			Sand (>62.5 um)		Silt (<62.5 um)		Sand SOL		Silt SOL	
Event No.[1]	Date	Volume (gal)	Inlet (%)	Outlet (%)	Inlet (%)	Outlet (%)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)
1	7/21/03	7,730	2.4	1.1	97.6	98.9	0.20	0.06	8.17	4.91
2	7/22/03	7,090	19.2	1.1	80.8	99.0	1.33	0.05	5.59	4.56
3	7/23/03	8,650	7.1	0.7	92.9	99.3	1.18	0.07	15.4	9.53
4	8/1/03	38,200	27.2	2.3	72.8	97.7	19.0	0.73	50.8	30.8
5	8/6/03	18,400	11.7	0.7	88.3	99.3	4.94	0.17	37.4	23.8
6	1/17/04	5,710	8.2	1.2	91.8	98.8	0.45	0.03	5.07	2.59
8	4/12/04	10,000	9.4	0.9	90.6	99.1	2.64	0.15	25.5	16.2
9	4/30/04	14,100	8.3	2.3	91.7	97.7	1.77	0.21	19.5	8.84
10	5/12/04	10,400	13.3	1.5	86.7	98.5	2.09	0.10	13.6	6.66
11	5/18/04	25,600	21.1	1.7	78.9	98.3	19.5	0.62	72.7	35.7
12	6/14/04	9,180	10.6	1.0	89.4	99.0	1.33	0.08	11.2	7.50
13	6/25/04	6,270	8.1	4.1	91.9	95.9	0.70	0.19	7.93	4.36
14	6/27/04	22,600	0.8	1.8	99.2	98.2	0.19	0.31	24.1	16.7
15	6/28/04	16,900	10.6	3.1	89.4	96.9	2.45	0.38	20.7	11.9
				Sum of the loads			**58.1**	**3.15**	**319**	**186**
				Removal efficiency (%)			**95**		**42**	

[1] Sand/silt split analysis not conducted for event 7 due to insufficient collected sample volume.

5.4 TCLP Analysis

At the end of the verification program, the StormFilter was evaluated to estimate the volume of retained sediments in the filter chamber (see Chapter 7). A representative composite sample of the sediments removed from the filter chamber was sent to the laboratory for TCLP metals analysis. The results, shown in Table 5-12, indicate that any metals present in the solids were not leachable and the sediment was not hazardous. Therefore, it could be disposed of in a standard Subtitle D solid waste landfill or other appropriate disposal location.

Table 5-12. TCLP Results for Cleanout Solids

Parameter	TCLP Result (mg/L)	Regulatory Hazardous Waste Limit (mg/L)
Arsenic	<0.2	5.0
Barium	0.6	100
Cadmium	<0.01	1.0
Chromium	<0.01	5.0
Copper	<0.02	NA
Lead	<0.1	5.0
Mercury	<0.002	0.2
Nickel	<0.02	NA
Selenium	<0.2	1.0

NA: Not applicable.

Chapter 6
QA/QC Results and Summary

The Quality Assurance Project Plan (QAPP) in the test plan identified critical measurements and established several QA/QC objectives. The verification test procedures and data collection followed the QAPP. QA/QC summary results are reported in this section, and the full laboratory QA/QC results and supporting documents are presented in Appendix D.

6.1 Laboratory/Analytical Data QA/QC

6.1.1 Bias (Field Blanks)

Field blanks were collected at both the inlet and outlet samplers to evaluate the potential for sample contamination through the automatic sampler, sample collection bottles, splitters, and filtering devices. The field blank was collected on May 9, 2003, allowing PCG to review the results early in the monitoring schedule.

Results for the field blanks are shown in Table 6-1. The data identified detectable concentrations of TKN, total zinc, and dissolved zinc in the inlet sample, and total and dissolved zinc in the outlet sample, while other compounds were below detection limits in both the inlet and outlet samples.

After reviewing the analytical data, the TO hypothesized that the TKN and zinc contribution could have resulted from incomplete rinsing of the sample containers. On July 25 and 30, 2003, the TO repeated decontamination procedures and collected additional samples to analyze for those constituents identified during the May sampling event. The data showed a residual concentration of total zinc in the inlet blank sample. These results show that an acceptable level of contaminant control in field procedures was achieved.

6.1.2 Replicates (Precision)

Precision measurements were performed by the collection and analysis of duplicate samples. The relative% difference (RPD) recorded from the sample analyses was calculated to evaluate precision. RPD is calculated using the following formula:

$$\%RPD = \left(\frac{|x_1 - x_2|}{\bar{x}} \right) \times 100\% \tag{6-1}$$

where:
x_1 = Concentration of compound in sample
x_2 = Concentration of compound in duplicate
$\bar{x}$ = Mean value of x_1 and x_2

The RPD data show an acceptable level field of precision, with a few parameters outside generally accepted limits. In most circumstances where the RPD values are high, the concentrations were near or below method detection limits.

Table 6-1. Field Blank Analytical Data Summary

Parameter	Units	April 23, 2003 Inlet	April 23, 2003 Outlet	July 25, 2003 Inlet	July 25, 2003 Outlet	July 30, 2003 Inlet	July 30, 2003 Outlet
Nitrite-nitrite nitrogen	mg/L as N	<0.1	<0.1	NA	NA	NA	NA
Total phosphorus	mg/L as P	<0.02	<0.02	NA	NA	NA	NA
TKN	mg/L as N	0.7	<0.4	<0.4	0.5	NA	NA
TSS	mg/L	<5	<5	NA	NA	NA	NA
Total cadmium	mg/L	<0.0005	<0.0005	NA	NA	NA	NA
Total copper	mg/L	<0.004	<0.004	NA	NA	NA	NA
Total lead	mg/L	<0.005	<0.005	NA	NA	NA	NA
Total zinc	mg/L	0.08	0.04	0.02	<0.02	NA	NA
Dissolved cadmium	mg/L	<0.0005	<0.0005	NA	NA	NA	NA
Dissolved copper	mg/L	<0.004	<0.004	NA	NA	NA	NA
Dissolved lead	mg/L	<0.005	<0.005	NA	NA	NA	NA
Dissolved zinc	mg/L	0.06	0.13	NA	NA	NA	<0.004

NA: Not analyzed

Field precision: Field duplicates were collected to monitor the overall precision of the sample collection procedures, including sample splitting. Duplicate inlet and outlet samples were collected during three different storm events to evaluate precision in the sampling process and analysis. The duplicate samples were processed, delivered to the laboratory, and analyzed in the same manner as the regular samples. Summaries of the field duplicate data are presented in Table 6-2. The data show several sample pairs with a high RPD. For many of these samples, the sample concentrations were near or below method detection limits, creating a condition where a slight measurement deviation can cause a large RPD value.

Laboratory precision: ASI analyzed duplicate samples from aliquots drawn from the same sample container as part of their QA/QC program. Summaries of the laboratory duplicate data are presented in Table 6-3. The laboratory also analyzed the relative percent difference (RPD) on matrix spike/matrix spike duplicate (MS/MSD) samples, summarized in Table 6-4. The data show that laboratory precision was generally maintained throughout the course of the project.

6.1.3 Accuracy

Method accuracy was determined and monitored using a combination of MS/MSD and laboratory control samples (known concentration in blank water). The MS/MSD data are evaluated by calculating the deviation from perfect recovery (100%), while laboratory control data are evaluated by calculating the absolute value of deviation from the laboratory control concentration. Tables 6-5 and 6-6 summarize the matrix spikes and lab control sample recovery data, respectively. The matrix spikes and lab control samples remained within targeted objectives throughout the study, with the exception of two cadmium samples and one TSS sample.

Table 6-2. Field Duplicate Sample Relative Percent Difference Data Summary

			Event 12			Event 13			Event 14		
Analyte	**Units**	**Loc**	**Rep 1**	**Rep 2**	**RPD**	**Rep 1**	**Rep 2**	**RPD**	**Rep 1**	**Rep 2**	**RPD**
TSS	mg/L	inlet	130	119	**8.8**	182	179	**1.7**	133	120	**10**
		outlet	74	74	**0**	114	146	**25**	100	92	**8.3**
Total nitrate	mg/L as N	inlet	0.93	0.94	**1.1**	NA	NA	**ND**	1.14	1.13	**0.9**
		outlet	0.71	0.72	**1.4**	NA	NA	**ND**	0.76	0.76	**0**
Total nitrite	mg/L as N	inlet	0.03	0.03	**0**	NA	NA	**ND**	0.01	0.02	**67**
		outlet	0.02	0.03	**40**	NA	NA	**ND**	<0.01	<0.01	**ND**
TKN	mg/L as N	inlet	0.7	0.5	**33**	1.5	1.7	**13**	0.9	1.7	**62**
		outlet	0.5	0.6	**18**	1.3	1.3	**0**	0.8	1.0	**22**
Total phosphorus	mg/L as P	inlet	0.26	0.15	**54**	0.19	0.20	**5.1**	0.18	0.09	**67**
		outlet	0.15	0.19	**24**	0.09	0.10	**11**	0.09	0.16	**56**
Dissolved phosphorus	mg/L as P	inlet	0.04	0.03	**29**	0.07	0.08	**13**	0.06	0.03	**67**
		outlet	0.03	0.03	**0**	0.04	0.03	**29**	0.04	0.03	**29**
Total cadmium	mg/L	inlet	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**
		outlet	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**
Total copper	mg/L	inlet	0.004	**0.002**	**67**	0.01	0.01	**0**	0.009	0.010	**11**
		outlet	**0.002**	0.005	**86**	0.008	0.007	**13**	0.005	0.006	**18**
Total lead	mg/L	inlet	0.03	0.02	**40**	0.03	0.04	**29**	0.025	0.036	**36**
		outlet	0.02	0.03	**40**	0.02	0.03	**40**	0.028	0.029	**3.5**
Total zinc	mg/L	inlet	0.10	0.06	**50**	0.12	0.12	**0**	0.080	0.079	**1.3**
		outlet	0.07	0.10	**35**	0.07	0.07	**0**	0.043	0.042	**2.4**
Dissolved cadmium	mg/L	inlet	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**
		outlet	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**	<0.0005	<0.0005	**ND**
Dissolved copper	mg/L	inlet	<0.004	<0.004	**ND**	<0.004	<0.004	**ND**	<0.004	<0.004	**ND**
		outlet	<0.004	<0.004	**ND**	<0.004	<0.004	**ND**	**0.002**	0.004	**67**
Dissolved lead	mg/L	inlet	0.008	0.01	**22**	**0.0025**	0.008	**105**	0.012	0.012	**0**
		outlet	0.009	0.009	**0**	0.007	0.01	**35**	0.018	0.019	**5.4**
Dissolved zinc	mg/L	inlet	0.09	0.06	**40**	0.13	0.13	**0**	0.061	0.055	**10**
		outlet	0.10	0.07	**35**	0.09	0.11	**20**	0.046	0.079	**53**

Rep values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate RPD.

The balance used for TSS analyses was calibrated routinely with weights that were NIST traceable. The laboratory maintained calibration records. The temperature of the drying oven was also monitored using a thermometer that was calibrated with an NIST traceable thermometer.

Table 6-3. Laboratory Duplicate Sample Relative Percent Difference Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Nitrite	24	1.6	29	0	6.1	0 - 25
Nitrate	24	5.0	67	0	14	0 - 25
Phosphorus	32	4.4	43	0	7.8	0 - 30
TKN	36	8.7	48	0	9.5	0 - 25
TSS	30	10	67	0	15	0 - 30

Table 6-4. Laboratory MS/MSD RPD Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	13	5.2	19	0	4.9	0 - 25
Copper	14	1.1	3	0	1.0	0 - 25
Nitrite	12	0.2	1	0	0.4	0 - 25
Nitrate	12	0.0	0	0	0.0	0 - 25
Phosphorus	10	1.2	3	0	1.3	0 - 30
Lead	14	0.9	3	0	0.9	0 - 25
TKN	11	7.5	16	0	6.8	0 - 25
TSS	9	4.6	16	0	4.9	0 - 30
Zinc	13	1.1	4	0	1.0	0 - 25

Table 6-5. Laboratory MS/MSD Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	30	88	124	14	31	80 - 120
Copper	30	107	118	99	6.4	80 - 120
Nitrite	28	103	112	93	4.3	75 - 125
Nitrate	28	99	120	89	6.2	75 - 125
Phosphorus	34	103	109	84	6.2	70 - 130
Lead	32	100	112	82	8	80 - 120
TKN	36	90	113	60	13	75 - 125
TSS	34	102	118	70	10.5	75 - 125
Zinc	30	102	115	88	6.7	80 - 120

Table 6-6. Laboratory Control Sample Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	16	107	129	83	12	80 - 120
Copper	16	100	110	95	4.0	80 - 120
Nitrite	14	105	112	102	2.8	75 - 125
Nitrate	14	98	104	95	2.7	75 - 125
Phosphorus	17	105	110	100	3.2	70 - 130
Lead	16	102	107	97	2.5	80 - 120
TKN	19	93	120	74	12	75 - 125
TSS	16	99	103	92	3.0	75 - 125
Zinc	16	102	105	99	2.0	80 - 120

6.1.4 Representativeness

The field procedures were designed to ensure that representative samples were collected of both influent and effluent stormwater. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. The challenge in sampling stormwater is obtaining representative samples. The data indicated that while individual sample variability might occur, the long-term trend in the data was representative of the concentrations in the stormwater, and redundant methods of evaluating key constituent loadings in the stormwater were utilized to compensate for the variability of the laboratory data.

The laboratories used standard analytical methods, with written SOPs for each method, to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed to verify that standard procedures were being followed. The use of standard methodology, supported by proper quality control information and audits, ensured that the analytical data were representative of actual stormwater conditions.

6.1.5 Completeness

Completeness is a measure of the number of valid samples and measurements that are obtained during a test period. Completeness will be measured by tracking the number of valid data results against the specified requirements of the test plan. The goal for this data quality objective was to achieve 80% completeness for flow and analytical data. The data quality objective was exceeded, with discrepancies noted below:

- The flow data (15 events, three monitoring locations per event) is complete for all of the monitored events, except for 5 missing data sets: from the upstream flow monitor for events 7 and 8, biased upstream data for events 9 and 13, and an incorrect inlet water level data reading for event 11. This resulted in the flow data being 89% complete.
- SSC data were not analyzed from event 7 due to insufficient sample volume collected.

- Two sets of nitrate and nitrite samples (from events 6 and 7) were not analyzed by the analytical laboratory because the 48-hr hold times had been exceeded.

- TSS analytical for the event 15 were analyzed one day outside the 7-day hold time. The data was reported as an estimated concentration.

These issues are appropriately flagged in the analytical reports and the data used in the final evaluation of the StormFilter device.

Chapter 7
Operations and Maintenance Activities

7.1 System Operation and Maintenance

SMI recommends initially scheduling one minor inspection and one major maintenance activity per year for a typical installation. A minor maintenance activity and inspection consists of visually inspecting the unit and removing trash and debris. During this activity, the need for major maintenance should be determined. A major maintenance consists of pumping accumulated sediment and water from the vault and replacing the filter cartridges. SMI indicates that the sedimentation rate is the primary factor for determining maintenance frequency, and that a maintenance schedule should be based on site-specific sedimentation conditions.

Installation of the StormFilter was completed in July 2002. In the fall of 2002, the sampling equipment was installed, and several shakedown events were sampled. ETV monitoring of the system began in the spring of 2003. The StormFilter was cleaned in February 2003, and inspected in August 2003, January 2004, May 2004, and December 2004.

A major maintenance procedure was conducted on the StormFilter on February 18-20, 2003, by SMI personnel, supervised by TO personnel. A local industrial service company with a Vactor truck. Maintenance consisted of dewatering the influent and cartridge bays, removing the spent filter media and accumulated sediment from the vault, replacing the filter cartridges, and inspecting the StormFilter components for damage. The plastic filter cartridge components from the spent filter cartridges were shipped back to SMI for cleaning, repair, and reuse. During the maintenance, SMI personnel repaired a damaged coupling that caused one filter cartridge in the middle of the vault to become dislodged.

A minor maintenance and inspection on the StormFilter was conducted on December 1, 2004, by SMI personnel, supervised by the TO and VO. The accumulated sediment in the inlet and filter chambers was measured in ten discrete locations, in accordance with a SOP prepared by SMI. In the inlet chamber, approximately 4.75 in. of accumulated sediment was observed. In the filter chamber, the accumulated sediment depth ranged from 0 to 3.5 in., and averaged approximately 2.6 in. There were no structural or operational issues with the StormFilter noted during the inspection.

Chapter 8
References

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6. United States Environmental Protection Agency. *Methods and Guidance for Analysis of Water*, EPA 821-C-99-008, Office of Water, Washington, DC, 1999.

Appendices

A	**StormFilter Design and O&M Guidelines**
B	**Verification Test Plan**
C	**Event Hydrographs and Rain Distribution**
D	**Analytical Data Reports with QC**