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Environmental Technology Verification Report

Stormwater Source Area Treatment Device

BaySaver Technologies, Inc.
BaySaver Separation System, Model 10K

Prepared by

NSF International

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

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Ann Arbor, Michigan 48105

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

September 2005

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 BaySaver Technologies, Inc. BaySaver Separation System, Model 10K 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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Abbreviations and Acronyms

ASI	Analytical Services, Inc.
BMP	best management practice
cfs	Cubic feet per second
EMC	Event mean concentration
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ft^2	Square feet
ft^3	Cubic feet
gal	Gallon
gpm	Gallon per minute
hr	Hour
in.	Inch
kg	Kilogram
L	Liters
lb	Pound
NRMRL	National Risk Management Research Laboratory
mg/L	Milligram per liter
mm	millimeters
NSF	NSF International, formerly known as National Sanitation Foundation
O&M	Operations and maintenance
PBM	Practical Best Management, LLC
PCG	Paragon Consulting Group
QA	Quality assurance
QC	Quality control
SOL	Sum of the loads
SOP	Standard Operating Procedure
TCLP	Toxicity Characteristic Leaching Procedure
TO	Testing Organization (Paragon Consulting Group)
USGS	United States Geological Survey
VO	Verification Organization (NSF)
WQPC	Water Quality Protection Center

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 BaySaver Technologies, Inc. BaySaver Model 10K (BaySaver), a stormwater treatment device designed to remove sediments and floating particles 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 BaySaver 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
- BaySaver Technologies, Inc. (BaySaver)

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 Management 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 WQPC activities. In addition, EPA provides financial support for operation of the Center 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; and
- Post verification report 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@epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Branch
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;
- Prepare the verification report; and,
- Coordinate with EPA to approve the verification report.

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
(734) 769-8010

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 BaySaver 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

BaySaver Technologies, Inc. of Mount Airy, Maryland, is the vendor of the BaySaver, 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.

The key contact for BaySaver is:

Mr. Austin Meyermann,	Director of Operations
(301) 829-6470	email: ameyermann@baysaver.com

BaySaver Technologies, Inc.
1302 Rising Ridge Road
Mount Airy, Maryland 21771

1.2.6 Verification Testing Site

The BaySaver was located within right-of-way on the west side of Fifth Street in Griffin, Georgia. A private contractor, Site Engineering, Inc, installed the system.

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 BaySaver is a device that removes sediment and floatable particles from stormwater. The BaySaver is comprised of two pre-cast concrete manholes and a high-density polyethylene BaySaver Separator Unit. The primary manhole is set in-line with the storm drainpipe, and the storage manhole is offset to either side. The two manholes, which must be watertight, provide the retention time and storage capacity necessary to remove the target pollutants from the influent water. The BaySaver acts as a flow control device, diverting the influent water to the flow path that will result in the most efficient pollutant removal. A schematic of the BaySaver is in Figure 2-1.

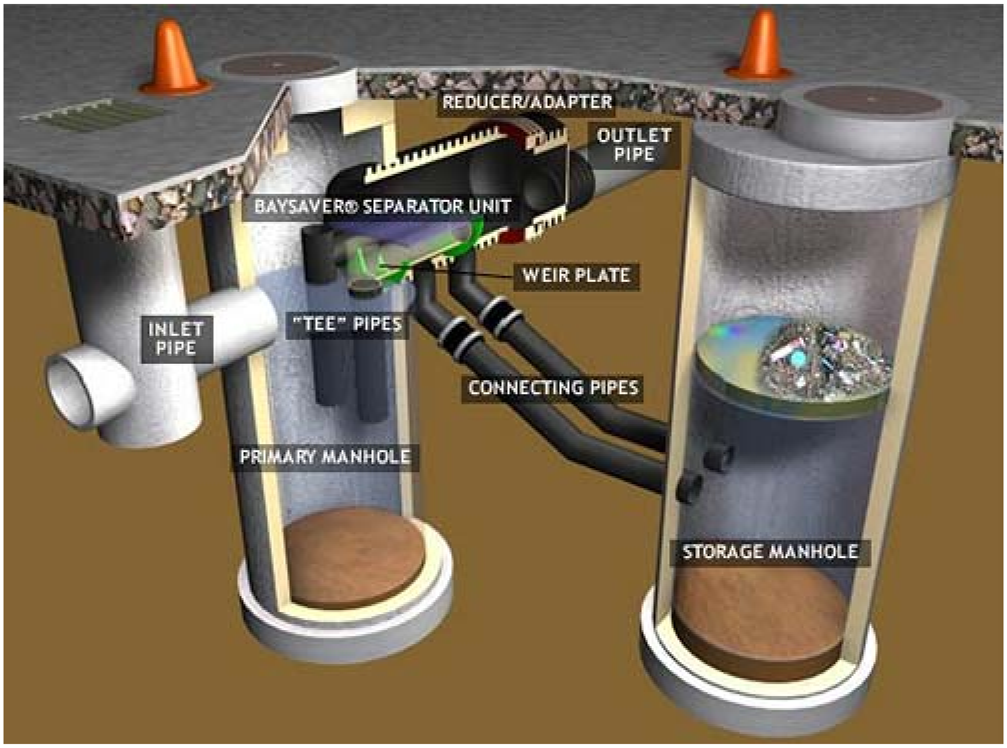

Figure 2-1. Schematic of the BaySaver.

The primary manhole removes and retains coarse sediments from the influent water in an eight-foot deep sump. A portion of the influent flow is skimmed from the surface of the primary manhole by the BaySaver and conveyed into the storage manhole. This water enters and exits the off-line storage manhole at an elevation below the water surface and above the floor of the structure, allowing both flotation and sedimentation to occur. The fine sediments and floatables entrained in this water are retained in the storage manhole.

The BaySaver limits the flow through the storage manhole by allowing excess water to pass directly from the primary manhole to the outfall. During higher-intensity storms (usually two-year events), the BaySaver draws water from the center of the primary manhole, approximately four feet below the water surface, and discharges it to the outfall. At the same time, it continues to skim the surface water and treat it through the storage manhole. Extremely high flows are conveyed by the separator unit directly to the outfall, and bypass the storage manhole completely. More detailed information about the operation of the BaySaver, as well as isometric drawings of the system, can be found in the BaySaver Separation System Technical and Design Manual (Appendix A).

The storage manhole stores fine sediments, oils, and floatables off-line, and the internal bypass minimizes the risk of re-suspending and discharging these contaminants. Additionally, the system is designed to minimize the volume of water that must be removed during routine maintenance, which results in lower disposal fees.

2.2 Product Specifications

BaySaver Model 10K:

- Housing construction/dimensions – two 10-ft diameter concrete manholes
- Maximum treatment capacity – 21.8 cfs
- Peak design capacity – 100 cfs
- Sediment storage – 11.6 yd^3
- Sediment chamber size – 10 ft diameter x 8 ft deep
- Floatables storage – 1,740 gal

2.3 Operation and Maintenance

The BaySaver must be maintained for continued effectiveness. Maintenance is performed using a vacuum truck or similar equipment when sediment levels reach two feet in either manhole. Access to the contaminant storage is available through 30-in. manhole covers in each structure, and the entire floor of each structure should be visible from the surface. Maintenance can be performed and inspected without confined space entry.

The maintenance procedure typically takes from three to five hours. BaySaver recommends removing all water, debris, oils, and sediment from the storage manhole using a vacuum truck or other equipment. Then, using a high-pressure hose, the storage manhole should be cleaned and the cleaning water removed using the vacuum truck. The two structures should then be filled with clean water.

2.4 Technology Application and Limitations

The BaySaver is flexible in terms of the flow it can treat. Baysaver offers units designed with a maximum treatment flow ranging from 1.1 to 21.8 cfs, or a peak design capacity ranging from 8.5 to 100 cfs. BaySaver also offers custom-designed units based on site-specific conditions.

The BaySaver can be used to treat stormwater runoff in a wide variety of sites throughout the United States. For jurisdictional authorities, the system offers solids and debris removal and improved water quality. The BaySaver 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.

The BaySaver works primarily as a settling device. The large capacity of the BaySaver manholes decreases the velocity of the entering stormwater, promoting solids to settle and floating debris and hydrocarbons to float to the water surface.

2.5 Performance Claim

According to the vendor, the BaySaver will provide a total suspended solids concentration net removal efficiency ranging between 60 to 80%, and will remove a significant portion of the free oils entering the system.

Chapter 3
Test Site Description

3.1 Location and Land Use

The BaySaver is located within the City of Griffin right-of-way, along Third Street, just north of the southwest corner of the intersection of Third Street and Taylor Street at 33° 14’ 49.4880” latitude and 84° 15’ 26.4960” 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 BaySaver and adjacent features, while Figure 3-2 identifies the drainage basin, the location of the unit, and the surface contours of the basin. The drainage basin consists of approximately 10 acres. An estimated 75% of the basin is impervious and includes about 100 linear feet of storm sewer along with approximately six storm inlets. No detention areas or open ditches are located within the drainage basin. No open ditches are located upstream of the BaySaver installation location.

The majority of the drainage basin consists of paved roadways, parking areas and buildings. A barbeque restaurant, school facilities, a bank, an automotive service business, and residences are located in the drainage basin. Small portions of the drainage basin are either landscaped sections or lawns. Moderate to heavy traffic volume runs along Taylor Street, but no major storage or use of hazardous materials or chemicals exists in the area. None of the stormwater runoff from the basin was pretreated prior to entering the BaySaver.

The nearest receiving water is Grape Creek, which is located approximately two-thirds of a mile east of the BaySaver. All water, either treated or bypass, flows via pipe flow in an easterly direction approximately 1,100 feet 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 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 area.

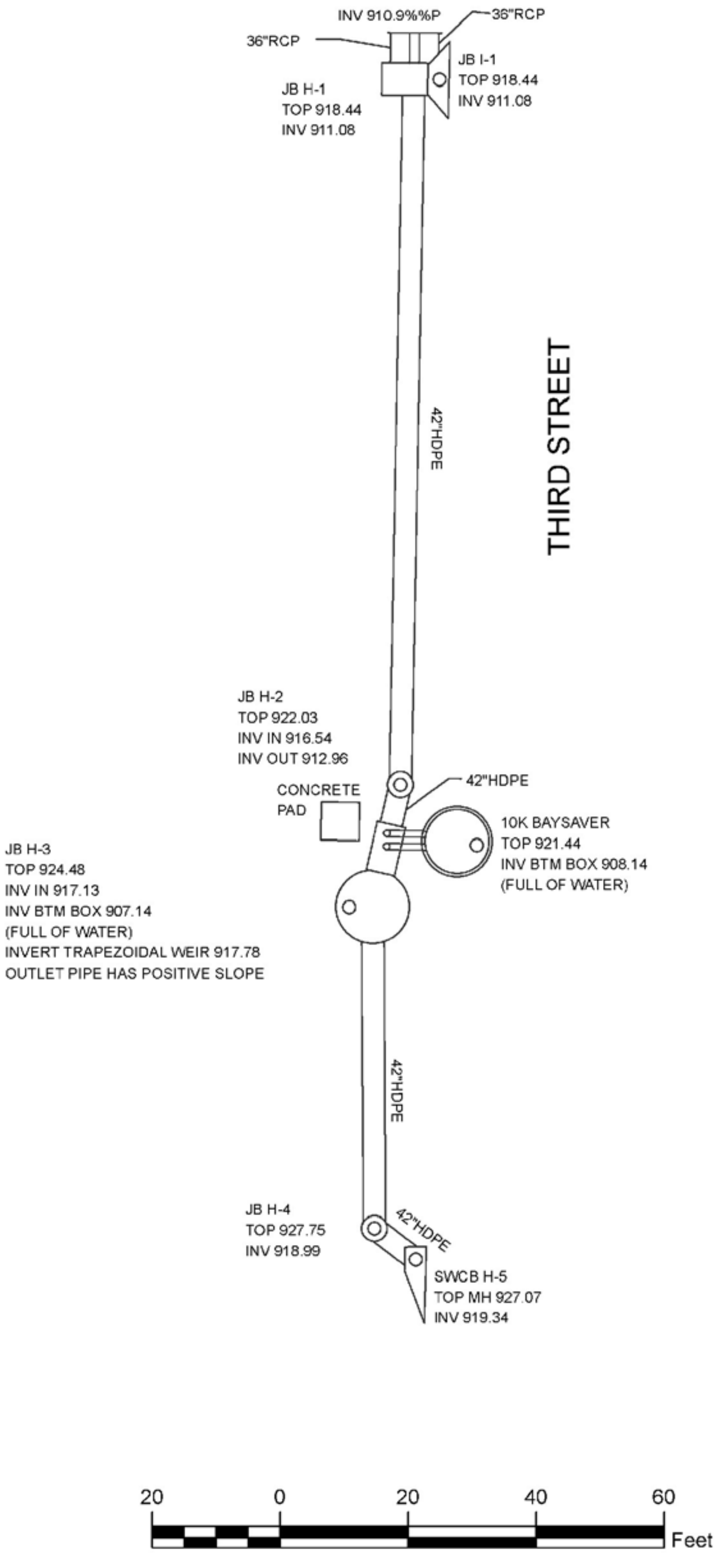

Figure 3-1. As-built drawing for the BaySaver installation.

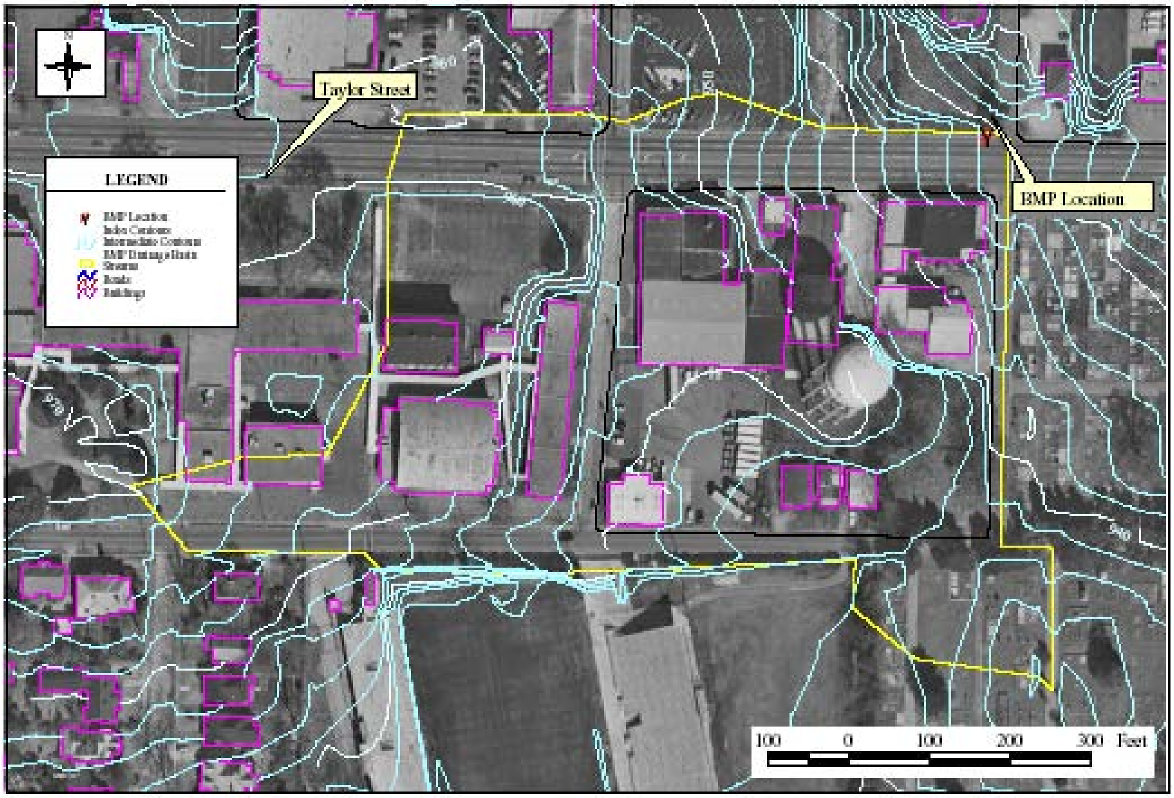

Figure 3-2. Drainage basin map for the BaySaver installation.

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 BaySaver unit. All water, either treated or bypass, flows via pipe flow in an easterly direction approximately 1,100 ft through storm pipe and ultimately flows into Grape Creek.

3.4 Rainfall and Peak Flow Calculations

The rainfall amounts for the 1, 2, 10, and 25-yr storms for the drainage area are presented in Table 3-1. 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 6.07-min time of concentration was determined for the basin, generating a peak runoff of 82.47 cfs for the 25-yr storm event. The rational method was used to calculate the peak flows for the device, since the drainage basin is just over ten acres. 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
6.07 min	0.31	0.42	0.65	0.76
30 min	0.53	1.19	1.81	2.10
1 hr	0.72	1.61	2.40	2.77
2 hr	1.00	2.00	2.98	3.46
12 hr	1.80	3.12	4.44	5.16

Source: NOAA, 2000

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

Duration	1-yr	2-yr	10-yr	25-yr
30 min	1.05	2.38	3.61	4.20
1 hr	0.72	1.61	2.40	2.77
2 hr	0.50	1.00	1.49	1.73
12 hr	0.11	0.26	0.37	0.43
24 hr	0.07	0.14	0.20	0.23

Table 3-3. Peak Flow Calculations (cfs)

Duration	1-yr	2-yr	10-yr	25-yr
30 min	9.56	21.66	32.86	38.23
1 hr	7.10	14.65	21.85	25.21
2 hr	4.55	9.10	13.56	15.75
12 hr	1.00	2.37	3.37	3.91
24 hr	0.64	1.27	1.82	2.09

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

Duration	1-yr	2-yr	10-yr	25-yr
6.07 min	33.68	45.78	70.72	82.47

3.5 BaySaver Installation

The construction contractor utilized to complete the construction work associated with the installation of the Bay Saver device was determined by a competitive bidding process, and was monitored by the City of Griffin as part of the TEA-21 project. The bid opening took place on March 11, 2002. Site Engineering, Inc. of Atlanta, Georgia the selected contractor. The installation of the BaySaver, Inc. device was initiated in April, 2002 and completed in July 2002. No major issues were noted during the installation process.

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 BaySaver unit. This plan, *Environmental Technology Verification Test Plan For Baysaver Inc., The BaySaver Separation System, TEA-21 Project Area***,** *City of Griffin, Spalding County, Georgia,* NSF, June 2003, is presented in Appendix B with all attachments. An overview of the key procedures used for this verification is presented below.

4.1 Sampling Locations

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

4.1.1 Influent

This sampling and monitoring site was selected to characterize the untreated stormwater from the entire basin. A velocity/stage meter and sampler suction tubing were located in the inlet pipe, upstream from the BaySaver so that potential changes in flow characteristics caused by the treatment device would not affect the velocity measurements.

4.1.2 Effluent

This sampling and monitoring site was selected to characterize the stormwater treated by the BaySaver. A velocity/stage meter and sampler suction tubing, connected to the automated sampling equipment, were located in the pipe downstream from the BaySaver. This location measured all of the water discharged from the system including any water that bypassed the storage manhole or the primary manhole.

4.1.3 Rain Gauge

A rain gauge was located at the effluent sampler location to monitor the depth of precipitation from storm events. The data were used to characterize the events to determine if the requirements for a qualified storm event had been achieved.

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 DTU II data logger;
- Sample Containers: Two 1.9-L glass bottles 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	0.02	SM 4500-P B,E
Total Kjeldahl nitrogen (TKN)	mg/L as N	0.4	EPA 351.3
Nitrate and 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	0.5	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* procedures; 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 March 2003, several trial events were monitored and the equipment tested and calibrated. Verification testing began in March 2003, and ended in November 2004. As defined in the test plan, "qualified" storm events met the following requirements:

- The total rainfall depth for the event, measured at the site rain gauge, 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 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.

- 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. Samples were removed from the sampler, split and capped after the event by PCG personnel. Samples were preserved per method requirements and analyzed within the holding times allowed by the methods. Particle size and SSC samples were shipped to the USGS sediment laboratory, while 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 results showed undetected hydrocarbon concentrations. When this change was made, the TO changed to a single four-gallon polyethylene sample container.

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 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 reached 0.5 in. to provide sufficient depth for sample collection.

5.1.1 Flow Data Evaluation

Table 5-2 summarizes the flow volumes and peak discharge rates for the inlet and outlet for each of the qualified events. A sizable difference was observed between the inlet and outlet flow during most storm events. Difficulties in gauging water depth and velocity in an open channel can result in flow measurement discrepancies in stormwater studies. For this installation, the open-channel flow was measured using area-velocity flow monitors, which measure water depth and velocity and calculate flow based on the diameter of the pipe. The depth gauge measures the pressure of the water and converts this to a depth. In spite of the TO's frequent inspections and calibrations of the flow probes, the depth readings, and subsequent calculated flow, are prone to error. The inlet and outlet pipes for the BaySaver unit in Griffin, Georgia are 42 in. in diameter. For pipes this large, a relatively minor difference in depth readings can translate into a sizable difference in flow.

The BaySaver does not have an external bypass mechanism, so the calculated inlet and outlet event volumes should be the same, and a comparison of the calculated inlet and outlet volumes can be used to ensure both flow monitors worked properly. The BaySaver manholes retain a certain amount of water between events, but since this retained volume is constant between events, the net runoff volume into the unit should equal the net runoff volume exiting the unit.

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)	Inlet Runoff Volume (gal)	Inlet Peak Discharge Rate (gpm)	Outlet Runoff Volume (gal)	Outlet Peak Discharge Rate (gpm)
1	3/5/03	19:45	3/5/03	22:35	0.32	2:50	46,100	3,520	16,400	1,180
2	3/15/03	0:55	3/15/03	3:40	0.48	2:45	51,900	1,050	30,100	725
3	11/27/03	15:50	11/27/03	21:20	0.67	4:30	74,400	386	60,500	595
4	12/13/03	14:50	12/13/03	21:15	0.46	6:25	43,800	466	56,700	468
5	5/12/04	17:05	5/12/04	20:20	0.52	3:15	20,500	313	47,000	620
6	5/18/04	15:05	5/18/04	16:55	1.16	1:50	34,300	1,500	64,700	6,400
7	6/12/04	23:55	6/13/04	6:30	0.97	6:35	22,400	394	63,300	719
8	6/14/04	11:35	6/14/04	21:55	0.43	10:20	16,100	661	56,800	840
9	6/27/04	18:25	6/27/04	22:00	0.79	3:35	20,900	1,420	68,800	1,460
10	6/28/04	22:40	6/29/04	0:35	0.51	1:55	24,800	1,150	63,300	1,310
11	6/30/04	19:25	6/30/04	22:40	1.13	3:15	66,400	2,220	114,000	3,690
12	8/10/04	11:25	8/10/04	16:35	0.71	5:10	55,800	366	99,100	678
13	8/21/04	15:35	8/21/04	17:20	0.29	1:45	7,140	327	21,000	955
14	10/29/04	18:50	10/29/04	22:20	0.36	3:30	15,100	610	30,700	1,480
15	11/12/04	1:50	11/12/04	14:15	1.16	12:25	17,600	295	91,500	1,640

The test plan indicates that the sum of loads value be calculated by multiplying inlet analytical concentrations with inlet flow measurements and outlet flow concentrations with outlet flow measurements. Utilizing this method when flow measurements are unequal can result in the differences in the recorded flow volumes having a large impact the SOL load reduction efficiency calculation. To eliminate this possible bias, a standard practice for ETV reports is to use either the inlet or outlet flow volumes in the SOL calculation. This approach is discussed further later in this section.

The depth, velocity and flow data were evaluated to assess whether the differences were based on an unusual trend or occurrence that would identify one set of data to be more reliable than the other. Both flow monitors were calibrated regularly, and both appeared to function properly during every qualified storm event.

Flow rate is very sensitive to depth in large diameter pipes, such as the 42-in. diameter inlet and outlet pipes in this system. A small error in depth measurement can result in large errors in flow rate and calculated runoff volume. In an equilibrium flow condition in this system, based on the inlet and outlet pipe slopes (approximately 3.5% and 1.5%, respectively), the inlet would be expected to have a slightly lower water level (approximately 0.2 to 0.4 in. at the depth and flow range observed during the 2004 events) compared to the outlet.

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

Event No.	Peak Discharge Rate (gpm)		Runoff Volume (gal)		Runoff Coefficient (dimensionless)[1]	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
1	3,520	1,180	46,100	16,400	0.53	0.19
2	1,050	725	51,900	30,100	0.40	0.23
3	386	595	74,400	60,500	0.41	0.33
4	466	468	43,800	56,700	0.35	0.45
5	313	620	20,500	47,000	0.15	0.33
6	1,500	6,400	34,300	64,700	0.11	0.21
7	394	719	22,400	63,300	0.09	0.24
8	661	840	16,100	56,800	0.09	0.33
9	1,420	1,460	20,900	68,800	0.10	0.32
10	1,150	1,310	24,800	63,300	0.18	0.46
11	2,220	3,690	66,400	114,000	0.22	0.37
12	366	678	55,800	99,100	0.29	0.51
13	327	955	7,140	21,000	0.09	0.27
14	610	1,480	15,100	30,700	0.15	0.31
15	295	1,640	17,600	91,500	0.06	0.29

1. Runoff coefficient calculated using a drainage area of 435,600 ft^2 (10 acres).

There was no consistent trend during the 2003 events to explain the differences in volumes for the 2003 data. However, for the 2004 events, the inlet water level reading tended to read approximately one inch lower than the correlating outlet reading. Based on the standard Manning formula, an inlet level reading one inch lower than the outlet pipe level would result in a recorded inlet flow rate approximately 50 to 200 gpm lower than the equivalent outlet flow rate in the range of inlet levels typically observed during the 2004 events. This difference appears to be the primary reason for the differences in the inlet and outlet flows and runoff volumes.

In spite of identifying the likely source of the differences in the inlet and outlet flows and runoff volumes, there were no specific trends observed in the data sets (inlet and outlet depths, velocities and flows) to clearly identify either the inlet or outlet data as the preferred data.

A number of flow and drainage models have been developed to predict flow conditions within a given drainage basin. A common means for determining the runoff for minor hydraulic structures in urban areas is the rational formula, which estimates runoff as a function of rainfall depth, and the drainage area size and imperviousness. While this formula provides only estimates of runoff volume, given the sometimes large discrepancy between inlet and outlet volumes, the formula can provide an indication of which recorded volume makes the most sense for the drainage basin and recorded precipitation. The VO conducted an evaluation of the flow volumes based on the rational formula by calculating runoff coefficients for the inlet and outlet volumes for each storm event. The runoff coefficients shown in Figure 5-2 were calculated using the following equation:

$$C = \frac{Q}{IA} \tag{5-1}$$

where:

C = Runoff Coefficient (dimensionless)
Q = Total Flow Volume (ft^3)
I = Rainfall Depth (ft)
A = Drainage Basin Area (ft^2)

Calculating the inlet and outlet runoff coefficient based on the recorded inlet and outlet flow measurements and rainfall depth can give an indication as to which set of runoff data is more reliable. Common runoff coefficients for single-family residential or light industrial areas, similar to the BaySaver drainage area, range from 0.3 to 0.8 (Merritt, 1976). While the calculated runoff coefficients at the test site are lower than the anticipated range, it is apparent that the inlet coefficient values for the 2003 events and the outlet coefficient values for the 2004 values are closer to the anticipated coefficient range. Therefore, the inlet flow volumes for the 2003 storm events and the outlet flow volumes for the 2004 storm events were used in the SOL calculation.

The runoff volume issue is discussed further in Section 5.2.2

5.1.2 Sample Aliquot Distribution

The differences in flow measurements between inlet and outlet samples also impacted the number and distribution of sample aliquots across the hydrograph. The protocol indicates a minimum number of samples aliquots that need to be collected on the rising limb, peak, and falling limb of the hydrograph.

During Event 8 (June 14, 2004), for example, the flow meters measured 16,100 gallons entering the BaySaver and 56,800 gallons leaving the system. Each composite sample is comprised of individual aliquots taken at regular intervals based on flow pacing. For Event 8, the inlet sample is comprised of 30 aliquots, six (20% of the inlet volume) of which were taken on the rising limb of the hydrograph (during the first 20 min of the storm). This sample is compared with an outlet sample made up of 90 aliquots, seven of which were taken from the rising leg of the hydrograph, representing less than eight percent of this sample by volume. Event 8 has two peaks. The inlet sample is divided fairly evenly: of 30 aliquots, six are on the first rising limb, one at the first peak, nine on the first falling limb, eight on the second rising limb, one at the second peak, and five on the second falling limb. The outlet sample, though, is heavily weighted toward the first falling leg and the second rising leg. A total of 48 of the 90 aliquots are taken from the falling leg of the first peak, while 29 are taken from the rising leg of the second peak. No aliquots are taken from the falling limb of the second peak. Similar circumstances arose during events 6 (May 18, 2004), 7 (June 12, 2004), and 11 (June 30, 2004).

The protocol does not specify that the number or distribution of sample aliquots for the inlet and outlet match. Instead, the protocol specifies that a representative composite sample consist of flow-proportional aliquots collected over certain intervals over the duration of the runoff event. The TO tried to pace the rate of inlet and outlet sample collection to achieve a degree of equivalency between the sample aliquots, but during many cases, this was not achieved. The composite samples were still considered representative for events where the number or distribution of inlet and outlet sample aliquots differed so long as the protocol criteria were met.

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:

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

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

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 11 to 260 mg/L, the outlet concentrations ranged from 12 to 110 mg/L, and the efficiency ratio ranged from –620 to 94%. Events with large negative efficiency ratios had very low (less than 30 mg/L) inlet TSS concentrations. The SSC inlet concentrations ranged 26 to 2,700 mg/L, the outlet concentrations ranged from 21 to 230 mg/L, and the efficiency ratio ranged from -140 to 98%.

The inlet SSC concentrations for the first four events are dramatically higher than the inlet SSC concentrations for the last eleven events. Between these events, the TO encountered frequent difficulties with the inlet auto sampler becoming obstructed or plugged, or blowing fuses on the auto sampler. On April 26, 2004, after the BaySaver inlet auto sampler failed to sample several events, the TO reported that the intake port had created an obstruction in the pipe sufficient to cause a two-inch deep accumulation of sediment around the intake port at the bottom of the pipe. The TO had to modify the test apparatus location to compensate for the difficulties inherent in stormwater sampling and particularly prevalent at this test site in order to successfully sample storm events. The TO moved the intake port approximately ten inches to the side of the pipe invert to prevent it from accumulating sediment. After this modification was made, the auto sampler was able to successfully sample storm events without blowing fuses during storm events. However, since the sample intake port was no longer at the bottom of the pipe, this modification may have resulted in the collection of samples during 2004 events that did not contain some of the heavier solids concentrations moving along the bottom of the pipe. Conversely, a buildup of solids near the sample intake screen observed by the TO could have resulted in a disproportionate amount of the heavier solids being collected in the samples during the 2003 events. A review of the sediment analytical data shows that the inlet SSC concentrations decreased significantly after this change was made. The inlet solids concentration was lower than the corresponding outlet solids concentration in more than 60% of the 2004 events. This in turn yielded negative sediment removal efficiencies for most of the 2004 storm events, as shown in Table 5-3. No significant sediment accumulation or modifications to the sampling setup was required on the outlet sampler, and the outlet sediment data remained fairly steady throughout the verification period.

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	3/5/03	190	12	94	2,700	230	91
2	3/15/03	11	79	-620	710	56	92
3	11/27/03	30	16	47	830	21	97
4	12/13/03	18	30	-67	1,100	26	98
5	5/12/04	26	26	0	48	57	-19
6	5/18/04	40	54	-35	68	81	-19
7	6/12/04	46	63	-37	54	74	-37
8	6/14/04	38	47	-24	33	55	-67
9	6/27/04	18	42	-130	26	62	-140
10	6/28/04	22	32	-45	44	110	-140
11	6/30/04	26	28	-7.7	42	35	17
12	8/10/04	25	24	4.0	30	27	10
13	8/21/04	18	38	-110	41	44	-7.3
14	10/29/04	260	110	57	180	61	65
15	11/12/04	56	33	41	94	46	51

Nutrients: The inlet and outlet sample concentrations and calculated efficiency ratios for nutrients are summarized in Table 5-4. Total phosphorus inlet concentrations ranged from 0.07 to 0.47 mg/L (as P), and the EMC ranged from –38 to 85%. TKN inlet concentrations ranged from 0.4 to 4.4 mg/L (as N), and the EMC ranged from –38 to 85%. Total nitrate inlet concentrations ranged from 0.10 to 1.7 mg/L (as N), and the EMC ranged from –280 to 55%. Total nitrite inlet and outlet concentrations were near or below method detection limits, such that a minor difference in concentration could result in a very significant calculated percent removal difference. This should be taken into consideration if using the EMC data to project the BaySaver’s actual nitrite treatment capability.

Metals: The inlet and outlet sample concentrations and calculated efficiency ratios for metals are summarized in Table 5-5. Total cadmium inlet and outlet concentrations were near or below the method detection limits such that a minor difference in concentration could result in a very significant calculated% removal difference. Total copper inlet concentrations ranged from 0.006 to 0.030 mg/L, and the EMC reductions ranged from -200 to 50%. Total lead inlet concentrations ranged from 0.020 to 0.140 mg/L, and the EMC reductions ranged from -550 to 97%. Total zinc inlet concentrations ranged from 0.06 to 0.19 mg/L, and the EMC reductions ranged from –170 to 43%. Many of the large negative EMC values occur when the inlet and outlet metals concentrations are close to the method detection limits.

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

Event No.	Date	Total phosphorus (as P) Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	TKN (as N) Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Total nitrate (as N) Inlet (mg/L)	Outlet (mg/L)	Reduction (%)	Total nitrite (as N) Inlet (mg/L)	Outlet (mg/L)	Reduction (%)
1	3/5/03	0.70	0.15	79	4.4	1.3	70	0.10	0.10	0	<0.01	<0.01	ND
2	3/15/03	0.07	0.09	-29	0.5	0.9	-80	0.46	0.62	-35	<0.01	<0.01	ND
3	11/27/03	0.13	0.11	15	0.8	0.7	13	NA	NA	ND	NA	NA	ND
4	12/13/03	0.21	0.12	43	2.6	1.4	46	NA	NA	ND	NA	NA	ND
5	5/12/04	0.13	0.17	-31	1.3	1.7	-31	0.46	0.33	28	0.02	0.02	0
6	5/18/04	0.47	0.22	53	1.9	1.1	42	0.51	0.32	37	0.02	0.02	0
7	6/12/04	0.25	0.21	16	1.8	1.3	28	0.81	0.44	46	0.04	0.02	50
8	6/14/04	0.17	0.18	-5.9	0.5	0.6	-20	0.27	0.33	-22	0.02	0.02	0
9	6/27/04	0.08	0.11	-38	0.4	0.9	-130	1.5	1.2	18	<0.01	<0.01	ND
10	6/28/04	0.08	0.07	13	1.3	1.0	23	0.36	1.4	-280	<0.01	0.01	ND
11	6/30/04	0.25	0.25	0	1.0	0.8	20	0.18	0.06	67	<0.01	<0.01	ND
12	8/10/04	0.19	0.20	-5.3	1.2	2.6	-120	0.22	0.21	4.5	<0.01	<0.01	ND
13	8/21/04	0.16	0.17	-6.3	2.1	1.4	33	0.41	0.81	-98	0.03	0.02	33
14	10/29/04	0.13	0.02	85	1.0	0.8	20	0.30	0.23	23	0.02	**<0.01**	75
15	11/12/04	0.18	0.11	39	1.5	0.9	40	1.7	0.75	55	0.02	**<0.01**	75

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 Metals

		Total cadmium			Total copper			Total lead			Total zinc		
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 (%)
1	3/5/03	<0.01	<0.01	ND	<0.01	<0.01	ND	0.03	**<0.002**	97	0.08	0.06	25
2	3/15/03	<0.01	<0.01	ND	0.01	0.03	-200	0.02	0.13	-550	0.14	0.38	-170
3	11/27/03	0.0007	**<0.0005**	57	0.02	0.01	50	0.06	0.04	33	0.14	0.08	43
4	12/13/03	0.0006	**<0.0005**	50	0.02	0.02	0	0.05	0.03	40	0.16	0.10	38
5	5/12/04	<0.0005	0.001	ND	0.01	0.02	-100	0.02	0.08	-300	0.11	0.21	-91
6	5/18/04	0.002	0.0008	60	0.03	0.04	-33	0.12	0.25	-110	0.19	0.20	-5.3
7	6/12/04	0.001	0.0009	10	0.03	0.03	0	0.14	0.22	-57	0.38	0.26	32
8	6/14/04	<0.0005	<0.0005	ND	0.02	0.02	0	0.06	0.09	-50	0.14	0.15	-7.1
9	6/27/04	<0.0005	<0.0005	ND	0.006	0.013	-120	0.03	0.09	-200	0.06	0.09	-50
10	6/28/04	0.0006	0.0005	17	0.008	0.01	-25	0.06	0.09	-50	0.09	0.09	0
11	6/30/04	<0.0005	<0.0005	ND	0.01	0.01	0	0.02	0.03	-50	0.06	0.07	-17
12	8/10/04	<0.0005	0.0005	ND	0.009	0.009	0	0.02	0.03	-50	0.08	0.09	-13
13	8/21/04	<0.0005	<0.0005	ND	0.02	0.02	0	0.06	0.11	-83	0.14	0.16	-14
14	10/29/04	<0.0005	<0.0005	ND	0.01	0.01	0	0.02	0.04	-100	0.08	0.08	0
15	11/12/04	<0.0005	<0.0005	ND	0.02	0.02	0	0.10	0.09	10	0.17	0.10	41

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 Outlet Load = (Outlet EMC_1)(Flow $Volume_1$) +
(Outlet EMC_2)(Flow $Volume_2$) + (Outlet EMC_n)(Flow $Volume_n$)

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

n= number of qualified sampling events

As shown in Equation 5-3, the SOL is calculated using flow volume data. Ideally, the SOL would be calculated by multiplying the inlet EMC by the inlet volume and the outlet EMC by the outlet volume. As discussed in Section 5.1.1, a large discrepancy was observed in the inlet and outlet flow volume, such that use of both the inlet and outlet volume data in the SOL calculations would skew the results. The use of the rational formula does not provide definitive indication that the selected volume alternative is indeed the most reasonable for the site. To demonstrate the impact of using different volume calculations at each location, four possible combinations of the SOL results are presented in Table 5-6 using:

- inlet volumes only;
- outlet volumes only;
- inlet volumes for inlet SOL and outlet volumes for outlet SOL; and
- inlet volumes for 2003 events and outlet volumes for 2004 events.

Table 5-6. Sediment Sum of Loads Efficiencies Calculated Using Various Flow Volumes

	SOL Removal Efficiency (%)								
Flow Location	**TSS**	**SSC**	**TKN**	**Phosphorus**	**Nitrate**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Utilized method[1]	33	82	31	27	16	23	-15	-56	9.1
Inlet only	48	89	29	34	6	31	-14	-55	-1.8
Outlet only	26	78	29	22	17	22	-13	-55	5.0
Inlet and outlet	6.3	83	35	31	19	31	-14	-55	-1.8

1. Utilized method uses inlet volumes for 2003 SOL calculations and outlet volumes for 2004 calculations.

The data demonstrates that using the either only the inlet or outlet volumes had a modest impact on the resulting SOL calculations. Therefore, in spite of the sizable differences between inlet and outlet flow calculations, the data can still be utilized in a way that provides a meaningful representation of the performance of the BaySaver during the 15 qualified events.

Sediment: Table 5-7 summarizes results for the SOL calculations for TSS and SSC. The TSS analytical procedure tends to measure only the lighter, finer particles in a sample, while the SSC analytical procedure measures both lighter, finer sediment and heavier, coarser sediment. The SOL analyses indicate a TSS reduction of 33% and SSC reduction of 82%. The large discrepancy in TSS versus SSC SOL is based on the difference in testing methodology between TSS and SSC, and the high SSC inlet concentrations reported during the first four storm events (see Section 5.2.1). Approximately 40% of the total calculated SSC mass is attributable to the first storm event, when the inlet auto sampler was collecting a high proportion of sediment, as measured by the SSC analytical procedure. The TSS analytical procedure tends to measure only the finer particles in a sample, while the SSC analytical procedure measures all of the sediment (fine and coarse) in the sample. Since stormwater BMP systems are generally more effective at treating coarse sediment, the SSC SOL tends to show higher removal efficiency.

Nutrients: The SOL data for nutrients are summarized in Table 5-8. Total phosphorus was reduced by 27%, nitrate was reduced by 16%, and TKN was reduced by 31%. The nitrite inlet and outlet concentrations were near or below the method detection limits during each event, which prevented a representative SOL reduction value from being calculated.

Metals: The SOL data for metals are summarized in Table 5-9. Total copper was reduced by -15%, total lead was reduced by –56%, and total zinc was reduced by 9.1%. Total cadmium was reduced by 23%; however, as discussed in Section 5.2.1, the cadmium inlet and outlet concentrations being near or below the method detection limits should be taken into consideration in projecting the BaySaver’s actual cadmium treatment capability.

Table 5-7. Sediment Sum of Loads Results

Event No.	Date	Runoff Volume (gallons)	TSS Inlet (lb)	TSS Outlet (lb)	SSC Inlet (lb)	SSC Outlet (lb)
1	3/5/03	46,100	72.3	4.61	1,020	88.0
2	3/15/03	51,900	4.76	34.2	309	24.2
3	11/27/03	74,400	117	9.92	517	13.0
4	12/13/03	43,800	6.57	11.0	417	9.49
5	5/12/04	47,000	10.2	10.2	18.8	22.3
6	5/18/04	64,700	21.6	29.1	36.7	43.7
7	6/12/04	63,300	24.3	33.2	28.5	39.1
8	6/14/04	56,800	18.0	22.3	15.6	26.0
9	6/27/04	68,800	10.3	24.1	14.9	35.6
10	6/28/04	63,300	11.6	16.9	23.2	55.9
11	6/30/04	114,000	24.7	26.6	39.9	33.3
12	8/10/04	99,100	20.7	19.8	24.8	22.3
13	8/21/04	21,000	3.15	6.65	7.18	7.70
14	10/29/04	30,700	67.6	28.9	45.0	15.6
15	11/12/04	91,500	42.7	25.2	71.7	35.1
Sum of the loads			**455**	**303**	**2,590**	**471**
Removal efficiency (%)			**33**		**82**	

Table 5-8. Nutrients Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	TKN Inlet (lb)	TKN Outlet (lb)	Phosphorus Inlet (lb)	Phosphorus Outlet (lb)	Nitrate Inlet (lb)	Nitrate Outlet (lb)
1	3/5/03	46,100	1.69	0.50	0.27	0.06	0.04	0.04
2	3/15/03	51,900	0.22	0.39	0.03	0.04	0.20	0.27
3	11/27/03	74,400	0.50	0.43	0.08	0.07	ND	ND
4	12/13/03	43,800	0.95	0.51	0.08	0.04	ND	ND
5	5/12/04	47,000	0.51	0.67	0.05	0.07	0.18	0.13
6	5/18/04	64,700	1.02	0.59	0.25	0.12	0.28	0.17
7	6/12/04	63,300	0.95	0.69	0.13	0.11	0.43	0.23
8	6/14/04	56,800	0.24	0.28	0.08	0.09	0.13	0.16
9	6/27/04	68,800	0.23	0.52	0.05	0.06	0.83	0.68
10	6/28/04	63,300	0.69	0.53	0.04	0.04	0.19	0.73
11	6/30/04	114,000	0.95	0.76	0.24	0.24	0.17	0.06
12	8/10/04	99,100	0.99	2.15	0.16	0.17	0.18	0.17
13	8/21/04	21,000	0.37	0.25	0.03	0.03	0.07	0.14
14	10/29/04	30,700	0.26	0.20	0.03	0.01	0.08	0.06
15	11/12/04	91,500	1.14	0.69	0.14	0.08	1.27	0.57
Sum of the loads			**10.7**	**9.15**	**1.65**	**1.21**	**4.05**	**3.41**
Removal efficiency (%)			**14**		**27**		**16**	

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. Metals Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Total Copper		Total Lead		Total Zinc	
			Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)
1	3/5/03	46,100	ND	ND	0.012	**0.00038**	0.031	0.023
2	3/15/03	51,900	0.0043	0.013	0.0087	0.056	0.061	0.16
3	11/27/03	74,400	0.012	0.0062	0.037	0.025	0.087	0.050
4	12/13/03	43,800	0.0073	0.0073	0.018	0.011	0.058	0.037
5	5/12/04	47,000	0.0039	0.0078	0.0078	0.031	0.043	0.082
6	5/18/04	64,700	0.016	0.022	0.065	0.13	0.10	0.11
7	6/12/04	63,300	0.016	0.016	0.074	0.12	0.20	0.14
8	6/14/04	56,800	0.009	0.009	0.028	0.04	0.070	0.070
9	6/27/04	68,800	0.0034	0.0075	0.017	0.052	0.034	0.052
10	6/28/04	63,300	0.0042	0.0053	0.032	0.047	0.047	0.047
11	6/30/04	114,000	0.0095	0.0095	0.019	0.029	0.057	0.067
12	8/10/04	99,100	0.0074	0.0074	0.017	0.025	0.066	0.074
13	8/21/04	21,000	0.0035	0.0035	0.011	0.019	0.025	0.028
14	10/29/04	30,700	0.0026	0.0026	0.005	0.010	0.072	0.020
15	11/12/04	91,500	0.015	0.015	0.076	0.069	0.13	0.076
Sum of the Loads			**0.12**	**0.13**	**0.43**	**0.67**	**1.1**	**1.0**
Removal Efficiency (%)			**-14**		**-56**		**9.1**	

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 5-10. The first four events had a very high proportion of sand in the inlet samples compared with the last eleven events. This is attributable to the location of the inlet sample intake port explained in Section 5.2.2. The BaySaver reduced the percentage of sand in the outlet sample for all 15 events. The outlet had a higher proportion of silt than the inlet, indicating that the BaySaver 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 the majority of the sediment removed was of the larger particle size.

Table 5-10. Particle Size Distribution Analysis Results

			Sand (>62.5 µm)		Silt (<62.5 µm)		Sand SOL		Silt SOL	
Event No.	Date	Runoff volume (gal)	Inlet (%)	Outlet (%)	Inlet (%)	Outlet (%)	Inlet (lb)	Outlet (lb)	Inlet (lb)	Outlet (lb)
1	3/5/03	46,100	97.6	45.3	2.4	54.7	1,000	40	25	48
2	3/15/03	51,900	95.5	10.6	4.5	89.4	300	2.6	14	22
3	11/27/03	74,400	96.5	9.2	3.5	90.8	500	1.2	18	12
4	12/13/03	43,800	96.7	6.3	3.3	93.7	390	0.6	13	8.9
5	5/12/04	47,000	34.8	16.6	65.2	83.4	6.5	3.7	12	19
6	5/18/04	64,700	40.4	33.9	59.6	66.1	15	15	22	29
7	6/12/04	63,300	42.4	16.1	57.6	83.9	12	6.3	16	33
8	6/14/04	56,800	14.6	13.6	85.4	86.4	2.3	3.5	13	23
9	6/27/04	68,800	41.7	17.2	58.3	82.8	6.2	6.1	8.7	29
10	6/28/04	63,300	52.5	3.1	47.5	96.9	12	1.7	11	54
11	6/30/04	114,000	30.7	21.4	69.3	78.6	12	7.1	28	26
12	8/10/04	99,100	47.1	44.4	52.9	55.6	12	9.9	13	12
13	8/21/04	21,000	42.0	17.9	58.0	82.1	3.0	1.4	4.2	6.3
14	10/29/04	30,700	51.7	35.9	48.3	64.1	23	5.6	22	10
15	11/12/04	91,500	44.7	28.9	55.3	71.1	32	10.1	40	25
				Sum of the loads			**2,300**	**120**	**260**	**360**
				Removal efficiency (%)			**95**		**-38**	

5.4 TCLP Analysis

At the end of the verification program, the BaySaver manholes were pumped of liquids and retained sediments (see Chapter 7). A representative composite sample of the sediment removed from the manholes was sent to the laboratory for TCLP metals analysis. These results shown in Table 5-11 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. The solids collected in the BaySaver were taken to the local municipal landfill for disposal, in accordance with and as allowed by local and state regulations.

Table 5-11. TCLP Results for Cleanout Solids

Parameter	TCLP Result (mg/L)	Regulatory Hazardous Waste Limit (mg/L)
Arsenic	<0.2	5.0
Barium	0.7	100
Cadmium	0.02	1.0
Chromium	<0.01	5.0
Copper	0.14	NA
Lead	1.7	5.0
Mercury	<0.005	0.2
Nickel	0.06	NA
Selenium	<0.5	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 and zinc in the outlet blank sample, and TKN and phosphorus in the inlet blank sample. TSS and nitrate-nitrite nitrogen concentrations were below detection limits in both the inlet and outlet blank samples.

After reviewing the analytical data, the TO hypothesized that the TKN, phosphorous and zinc contribution could have resulted from incomplete rinsing of the sample containers following decontamination procedures that utilized a detergent that contains these compounds. On July 25, 2003, the TO repeated decontamination procedures, including a thorough rinsing of the sample containers, 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 and TKN slightly above the detection level in the outlet blank sample. These results show that an acceptable level of contaminant control in field procedures was achieved.

Table 6-1. Field Blank Analytical Data Summary

		May 9, 2003		**July 25, 2003**	
Parameter	**Units**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
Nitrite-nitrite nitrogen	mg/L as N	<0.1	<0.1	NA	NA
Phosphorus	mg/L as P	0.56	<0.02	NA	NA
TKN	mg/L as N	1.2	0.7	<0.4	0.5
TSS	mg/L	<5	<5	NA	NA
Total cadmium	mg/L	<0.0005	<0.0005	NA	NA
Total copper	mg/L	<0.004	<0.004	NA	NA
Total lead	mg/L	<0.005	<0.005	NA	NA
Total zinc	mg/L	<0.004	0.005	0.02	<0.02

NA: Not analyzed

6.1.2 Replicates (Precision)

Precision measurements were performed by the collection and analysis of duplicate samples. The relative percent 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

Field precision: Field duplicates were collected to monitor the overall precision of the sample collection and analysis procedures. 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 RPD data show an acceptable level of precision, with a few parameters outside generally accepted limits. Below is a discussion on the results from selected parameters.

Nitrate and Nitrite: Nitrite replicates were all below detection limits. The RPD values for nitrate indicate a relatively low precision (high RPD values). The poorer precision for the inlet samples could be due to the sample handling and splitting procedures, or sampling handling for analysis, or a combination of factors. It appears that the low precision is most prevalent in the nitrates, and does not appear in other parameters.

TKN: In general, TKN concentrations were consistent, and RPDs were within moderate ranges, with the exception of the inlet sample on the second duplicate event, where the second replicate was close to the detection limit.

TSS: TSS showed good precision, with the RPD values ranging from 6 to 30%.

Phosphorus: The RPD for the inlet and outlet samples for the third duplicate were high, showing low precision for these samples. For the third duplicate, the first replicate was two to three times the concentration of the replicates for the other two duplicate events, attributing to the high RPD value.

Metals: In general, metals showed good precision. Replicates with higher RPD values occurred when the samples were near the laboratory detection limit.

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.

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

			Duplicate 1			**Duplicate 2**			**Duplicate 3**		
Parameter	**Units**		**Rep 1a**	**Rep 1b**	**RPD**	**Rep 2a**	**Rep 2b**	**RPD**	**Rep 3a**	**Rep 3b**	**RPD**
Nitrite	mg/L as N	Inlet	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0
		Outlet	<0.01	<0.01	0	0.01	**<0.005**	67	<0.01	<0.01	0
Nitrate	mg/L as N	Inlet	1.45	0.19	154	0.36	2.26	145	0.18	0.28	43
		Outlet	1.19	1.19	0	1.38	2.82	69	0.06	0.2	108
Phosphorus	mg/L as P	Inlet	0.08	0.08	0	0.08	0.08	0	0.25	0.13	63
		Outlet	0.11	0.1	10	0.07	0.07	0	0.25	0.06	123
TKN	mg/L as N	Inlet	0.4	0.6	40	1.3	0.4	106	1	0.7	35
		Outlet	0.9	0.8	12	1	1.1	10	0.8	0.6	29
TSS	mg/L	Inlet	18	14	25	22	24	9	26	30	14
		Outlet	42	36	15	32	30	6	28	38	30
Cadmium	mg/L	Inlet	<0.001	<0.001	0	0.0006	**<0.0003**	67	<0.001	<0.001	0
		Outlet	<0.001	<0.001	0	<0.001	<0.001	0	<0.001	<0.001	0
Copper	mg/L	Inlet	0.006	0.009	40	0.008	0.007	13	0.01	0.01	0
		Outlet	0.013	0.015	14	0.01	0.009	11	0.01	0.004	86
Lead	mg/L	Inlet	0.026	0.05	63	0.064	0.067	5	0.02	0.06	100
		Outlet	0.091	0.12	27	0.091	0.09	1	0.03	0.02	40
Zinc	mg/L	Inlet	0.06	0.061	2	0.086	0.095	10	0.06	0.1	50
		Outlet	0.092	0.086	7	0.086	0.1	15	0.07	0.05	33

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

The laboratory control data show that the laboratory maintained good precision throughout the course of the study, with most of the parameters falling within acceptable limits. The laboratories analyzed laboratory control samples as part of their ongoing analysis process. The laboratory control samples were reviewed, and all methods were found to be in control (within established laboratory precision limits). Laboratory procedures, calibrations, and data were audited and found to be in accordance with the published methods and good laboratory practice.

The field and analytical precision data combined suggest that the variability and insolubility of pollutant loadings in stormwater and the difficulty of collecting representative stormwater samples are the likely cause of poor precision, and apart from the field sample splitting procedures for inlet samples, the verification program maintained high precision.

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

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	29	112	130	95	11	83 - 135
Chromium	29	101	111	92	4.6	85 - 115
Nitrite	25	105	109	102	2.0	97 - 112
Nitrate	25	98	102	92	2.7	88 - 107
Phosphorus	31	104	110	93	4.2	91 - 115
Lead	29	105	118	96	4.2	85 - 115
TKN	29	93	110	72	11	67 - 126
TSS	29	97	103	91	3.0	89 - 109
Zinc	29	104	119	98	4.5	85 - 115

6.1.3 Accuracy

Method accuracy was determined and monitored using a combination of matrix spike/matrix spike duplicates (MS/MSD) and laboratory control samples (known concentration in blank water). The MS/MSD data are evaluated by calculating the percent recovery based on the measured result of the spiked sample and the calculated “true” value of the spiked sample (measured sample result plus spiked amount). Laboratory control data are evaluated by comparing the measured concentration in the control sample with the known true value of the control sample, and calculating the percent recovery. Accuracy was in control throughout the verification test. Tables 6-4 and 6-5 summarize the matrix spikes and lab control sample recovery data, respectively.

Table 6-4. Laboratory MS/MSD Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	30	104	125	87	9.9	80 - 120
Copper	30	107	129	92	10	80 - 120
Nitrite	26	104	110	95	3.5	75 - 125
Nitrate	26	99	120	89	5.9	75 - 125
Phosphorus	32	106	120	95	5.0	80 - 120
Lead	30	104	118	92	6.4	80 - 120
TKN	30	88	119	62	15	75 - 125
TSS	30	108	318	70	43	75 - 125
Zinc	30	108	318	70	43	80 - 120

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 6-5. Laboratory Control Sample Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)	Objective (%)
Cadmium	29	112	130	95	11	83 - 135
Chromium	29	101	111	92	4.6	85 - 115
Nitrite	25	105	109	102	2.0	97 - 112
Nitrate	25	98	102	92	2.7	88 - 107
Phosphorus	31	104	110	93	4.2	91 - 115
Lead	29	105	118	96	4.2	85 - 115
TKN	29	93	110	72	11	67 - 126
TSS	29	97	103	91	3.0	89 - 109
Zinc	29	104	119	98	4.5	85 - 115

6.1.4 Representativeness

The field procedures were designed to ensure that representative samples were collected of both inlet and outlet 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.

As described in Chapter 5, the inlet and outlet flow and volume data did not correlate. The BaySaver is designed so that all of the water entering through the inlet eventually passes through the outlet, so the inlet and outlet volumes should have been the same. This was not the case. A review of the hydrographs and the depth, velocity and flow data did not clearly identify one set of data as being more representative than the other. When the characteristics of the drainage basin and the rain depth were input into the rational formula and compared against the recorded flow data, the inlet flow volumes for the first four events and the outlet volumes for the last eleven events appeared to be most representative of the actual flow measurements.

The flow values are multiplied by the constituent analytical concentrations in order to determine the sum of loads efficiency of the BaySaver for each measured constituent. In spite of the large differences between recorded inlet and outlet flow volumes, different combinations of inlet and outlet flow volumes in the sum of loads calculations yielded only minor differences in the calculated sum of loads efficiency.

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.

Completeness was calculated by the following equation:

$$\text{Percent Completeness} = (V / T) \times 100\% \tag{6-3}$$

where:

V = Number of measurements that are valid.
T = Total number of measurements planned in the test.

The goal for this data quality objective was to achieve minimum 80% completeness for flow and analytical data. The data quality objective was exceeded, with discrepancies noted below:

- The flow data is 100% complete for all of the monitored events.

- Two sets of nitrate and nitrite samples (from events 3 and 4) were not analyzed by the analytical laboratory because the 48-hr hold times had been exceeded.

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

Chapter 7
Operations and Maintenance Activities

7.1 System Operation and Maintenance

Operation of a properly installed BaySaver consists of periodic inspection and maintenance. BaySaver's Technical and Design Manual indicates that maintenance is required once two feet of sediment have accumulated on the floor of either manhole. Typical maintenance consists of removing and disposing of the water, sediment, and pollutants accumulated in the manholes. The manholes may be accessed through 30-in. manhole covers, and the accumulated materials may be removed with a vacuum truck. BaySaver indicates this procedure typically takes two to four hours.

The BaySaver was maintained in December 2002, prior to testing. A second maintenance event was conducted on November 30, 2004, under the supervision of PCG and NSF. The City of Griffin provided a vacuum truck and operating personnel. Floating debris and a hydrocarbon sheen were visible inside both manholes. Water was decanted from the sediment in both manholes so that the sediment layer could be visually examined. The primary manhole contained approximately 3,000 gallons of debris and water and approximately two feet of accumulated sediment, while the storage manhole contained approximately 1,200 gallons of water and approximately two inches of accumulated sediment. The maintenance event took approximately 2.5 hr, and no significant issues were noted.

While conducting verification testing, the TO noticed that during extended dry-weather periods, the water level in the manholes would fall below the outlet elevations, indicating a possible leak. Apparently, a joint between the BaySaver separation unit and the concrete manholes was not watertight. On December 3, 2003, this issues was corrected by entering the concrete manhole and regrouting the seams.

The VO conducted numerous maintenance activities associated with the auto samplers, and the inlet auto sampler in particular, throughout the verification period. As discussed in Chapter 5, the inlet sample intake port appeared to obstruct the pipe, allowing for sediment to collect and preventing the auto sampler from functioning properly. This situation was corrected by moving the inlet sample port approximately ten inches to the side of the inlet pipe invert. This modification proved to be successful in allowing the auto sampler to function during storm events, but a review of the sediment analytical data shows that the inlet SSC concentrations decreased dramatically after this change was made. As discussed in Section 5.2.2, the inlet TSS and SSC concentrations were lower than the corresponding outlet solids concentration in more than 60% of the 2004 events. This in turn yielded negative removal efficiencies for most of the 2004 storm events.

Chapter 8
Vendor-Supplied Information

The following information is the evaluation and opinion of the vendor, BaySaver Technologies, Inc. This information has not been verified and does not necessarily represent the findings or conclusions of the Testing Organization or Verification Organization.

Stormwater device performance analysis is a complex endeavor. Some of these experimental requirements are prone, like any other complex process analysis projects, to unforeseen technical difficulties. It is our opinion that as a result of the technical difficulties encountered during this study and the corrective actions that followed, the results derived from this report do not accurately or reliably verify the performance of the verified BaySaver Separation System, Model 10K.

After careful data review, it became evident that this Griffin study unfortunately had serious problems with the solids sampling and analytical procedures. These problems made the solids analysis data asymmetric and difficult, if not impossible, to correlate and draw valid conclusions from, especially from an overall performance verification perspective. Given that solids removal is the pivotal parameter in stormwater BMP performance analysis, these problems make the results derived from this report of limited intrinsic value.

It is important to note that neither the testing organization nor verification organization analyzed the testing outcomes from the perspective BaySaver did, so our specific conclusions may not be mentioned explicitly in this verification report. Since this project collected copious amounts of data, BaySaver concentrated on the most salient and relevant discrepancies, and not on a statistical analysis of relevance, since it was not deemed essential for the purpose of this comment section.

8.1 TSS and SSC Data

BaySaver believes that the Total TSS data suffers fundamental inaccuracies. As shown in Table 5-3, the inlet TSS concentrations for the 2003 storm events are one to two orders of magnitude lower than the corresponding SSC concentrations. As explained in greater detail in Chapter 5 of this report, the TSS analytical procedure captures only a fraction of the total particles in the sample while the SSC procedure captures all of the particles in the sample.

Data presented in a USGS study (Grey et. al., 2000) indicates that TSS and SSC numbers had, on average, the same order of magnitude when 3,250 TSS and SSC data points were analyzed. Therefore, the difference encountered in this study appears to be extraordinary. The outlet TSS determinations for 2003 are higher than the inlet concentrations 50% of the time, and there is no explanation for this trend. For the 2004 storm events, this large difference between TSS and SSC diminished. BaySaver believes this change in the inlet solids concentration data was caused by the corrective action taken to solve the inlet sample tube clogging. At the same time this well intended measure generated a fundamental error in the TSS and SSC inlet data for the rest of the test as discussed next.

8.2 Sampling Procedure

Prior to the first storm event sampled in 2004, the inlet sample tube was moved from the pipe invert approximately 10 in. along the inside of the 42 in. HDPE pipe to avoid solids clogging of the sample tube. The outlet sampling tube remained in the same location, at the invert, for the duration of the test. While this action resolved the inlet sampling tube-clogging issue, BaySaver believes it also affected the inlet TSS and SSC data in a fundamental way, making it asymmetric with respect to the outlet data. By moving the inlet sample port up 10 in., this elevated the sample drawing point approximately 2.5 in. above the invert. Since heavier solids tend to travel along the bottom of the pipe, this biased the sampling towards sampling the smaller, lighter particles. At the same time, the outlet sampler continued to capture the solids traveling along the invert. BaySaver believes this greatly contributed to the tendency towards higher solids readings in the outlet than in the inlet. This anticipated effect is indeed reflected in the negative solids removal efficiencies shown in Table 5-3. This anticipated discrepancy is corroborated in the dramatic change in particle sizes between 2003 and 2004 when the inlet sample location was changed shown in Table 5-10.

8.3 Conclusions

Based on the above observations, BaySaver concludes that:

- The 2004 inlet/outlet solids concentration data cannot be used to obtain accurate solids removal efficiencies. The solids generation characteristic associated with the BaySaver BMP during most of the 2004 storm events is not consistent with mass conservation principles.

- The TSS data determinations for 2003 appear to have extraordinary deviations with respect to the corresponding SSC data and there is no fundamental explanation to account for these discrepancies.

- The reader is encouraged to read this report in light of our observations and to contact BaySaver and the verification organization to discuss the data and results derived from this project. It is our goal to keep contributing to the field of stormwater treatment technology and to make future testing efforts fruitful.

Chapter 9
References

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Appendices