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EVALUATING INLET SEDIMENT TRAPS

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Biography

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Benton Ruzowicz, Technical Specialist – Mr. Ruzowicz provides technical assistance to land disturbers, local governments, and erosion and sediment control professionals around the State on erosion and sedimentation control issues and the appropriate use of urban BMP's. He also provides technical plan reviews on behalf of the Districts in the Metro Atlanta area as well as technical support to all plan reviewers throughout the State. Ben also helps oversee the State's education and certification program for people involved in land disturbing activities in which there have been over 75.000 people certified.

Jay Sprague, Lab Director – Mr. Sprague supervises a staff of technicians, directs all site operations and testing, and is responsible for implementation of TRI's Quality Systems throughout all lab operations. Mr. Sprague's background includes developing markets and technologies associated with agricultural and erosion and sediment control products.

Abstract

In 2010, the Georgia Soil and Water Conservation Commission (GSWCC) received funding to revise the Manual for Erosion and Sediment Control in Georgia. One of the parameters was to incorporate new BMP's into the Manual. This was done by characterizing full-scale, installed performance of commonly used best management practices (BMPs) for sediment control at storm water manhole and curb inlets. Some of the specific BMPs tested included what the GSWCC refers to as inlet sediment traps, or inlet protection. Inlet sediment traps are commonly site-built and comprised of one or more generic components, such as stone, open-cell concrete blocks, fence posts, and/or wire fabric, or they may be pre-manufactured products such as geotextiles (silt fence), sediment retention fiber rolls (SRFRs) or proprietary 3-D structures. Critical elements of inlet sediment traps are their ability to: (a.) slow and/or pond concentrated runoff to encourage sedimentation, thereby reducing soil particle transport into the inlet, and (b.) trap soil particles upstream of an inlet.

Recognizing that the actual performance of BMPs is system or installation dependent, the GSWCC determined that a large-scale test that could incorporate full-scale "as installed" conditions would be the best evaluation procedure. To this end, the GSWCC selected a large-scale test procedure that generally conformed to ASTM D 7351, with a modification to present a concentrated flow, rather than sheet flow, to an area inlet. The procedure includes an inlet area comprised of an approximate 24-inch x 24-inch opening simulating a manhole inlet positioned at the center of an approximate 96-inch x 96-inch containment area. The BMPs tested were installed adjacent to the opening and exposed to simulated (concentrated) runoff. The measurement of sediment that passes through, over, and/or under the BMP compared to the amount in the upstream flow is used to quantify the effectiveness of the BMP in retaining sediments while allowing continued seepage. The measurement of water that passes through, over, and/or under the BMP compared to the amount of the upstream flow is used to quantify the effectiveness of the BMP in allowing continued seepage.

The test results appear to establish appropriate baseline performance characteristics for standard BMPs used in either unpaved or paved applications. The results of the testing reported herein strongly suggest that in both paved and unpaved applications, it is possible to differentiate between BMPs that provide maximum sediment retention and those providing maximum seepage. This may facilitate separate application-specific specifications for BMP systems.

Keywords: sediment trap, inlet protection, BMP, inlet testing, GSWCC, ASTM D 7351

1 Background

The Georgia Soil and Water Conservation Commission (GSWCC) testing program described herein was intended to characterize full-scale, installed performance of commonly used best management practices (BMPs) for sediment control at storm water manhole and curb inlets. The specific BMPs tested included what the GSWCC refers to as inlet sediment traps, or inlet protection. Inlet sediment traps are commonly site-built and comprised of one or more generic components, such as stone, open-cell concrete blocks, fence posts, and/or wire fabric, or they may be pre-manufactured products such as geotextiles (silt fence), sediment retention fiber rolls (SRFRs) or proprietary 3-D structures. Critical elements of inlet sediment traps are their ability to: (a.) slow and/or pond concentrated runoff to encourage sedimentation, thereby reducing soil particle transport into the inlet, and (b.) trap soil particles upstream of an inlet. This testing served as a "baseline" for qualification of future sediment barriers. Additionally, the "index properties" of the tested materials were verified and documented to go along with their associated performance properties. Together the index and performance data facilitates the correlation of performance to certain easily measured properties of the sediment barrier components, and it "bench-marks" the performance of a given product to specific index properties.

The testing protocol was a modification of an existing standard test method – ASTM D 7351 – which was fully documented for potential standardization, so that future sediment traps can be subjected to the same protocol and be easily and reliably compared to the results of this program.

2 Overview of Test Procedures for Inlet Sediment Traps

2.1 Basic Index Tests for "Bench-marking" of Components of Tested Systems

Inlet sediment traps are commonly site-built and comprised of one or more generic components, such as stone, open-cell concrete blocks, fence posts, and/or wire fabric, or they may be pre-manufactured products such as geotextiles, sediment retention fiber rolls (SRFRs) or proprietary 3-D structures. While generic components can typically be characterized by reference to a specification, type, or size, pre-manufactured products will usually need to be uniquely characterized for a few basic component properties that are routinely measured in the manufacturer's own QC lab.

2.1.1 Basic Mechanical Index Properties of 2-Dimensional Systems

A basic knowledge of the size, shape, and strength characteristics of components and products is essential to BMP selection and to assuring construction or manufacturing consistency. Tensile strength is a primary quality control property measured on most Inlet BMP components. Arguably, tensile strength may be important if an Inlet BMP is subject to the weight of sediments or the pressures associated with impounding runoff. ASTM D4632, "Standard Test Method for Grab Breaking Load and Elongation of Geosynthetics" is most commonly used for geotextile components.

2.1.2 Basic Mechanical Index Properties of 3-Dimensional Sediment Barriers

Many inlet sediment trap systems are 3-dimensional products (i.e. wattles, bales, etc.). As there are no standard index test methods yet available for these products, non-standard procedures are currently used to measure such things as density (or unit weight per length) and circumference.

2.1.3 Basic Hydraulic Index Properties

The most unique thing about inlet sediment trap systems is that, typically, for them to be very effective in retaining sediment they must also impound most of the runoff. Conversely, for them to freely pass runoff, they have to be allowed to pass a significant amount of sediment. Neither of these extremes is usually preferred, so the user has to determine the proper balance of retaining sediment while permitting seepage. Thus, a basic knowledge of the hydraulic properties that characterize the openings and flow capacity of the sediment trap components is essential to product selection and to manufacturing consistency.

2.1.3.1 Permittivity (a.k.a. Water Flow Rate) – Permittivity is a geotextile term that relates to the vertical clear water flow capacity of the material. It is often reported as gallons per minute per square foot of material and uses clear water. The standard test method is ASTM D4491, "Standard Test Methods for Water Permeability of Geotextiles by Permittivity".

2.1.3.2 Apparent Opening Size (AOS) – The measure of the approximate largest (d85) size opening in a geotextile is called apparent opening size (AOS). The standard test method is ASTM D4751, "Standard Test Method for Measuring the Apparent Opening Size of Geosynthetics".

2.1.3.3 Percent Open Area (POA) – While the AOS is a good indicator of a geotextile's ability to retain sediments when the geotextile has lots of varying sized openings – such as with a nonwoven geotextile – a woven geotextile can have a few larger openings and a lot of very small ones making it prone to clogging even though the AOS test may indicate that it has relatively large openings. To make sure it has enough openings, the overall percent of open area can be determined using a light box. Though this test is not standardized by ASTM for geotextiles, there is a Corps of Engineers protocol that has been successfully used for decades.

2.1.4 *Basic Durability Index Property* – UV Resistance

Another unique thing about sediment trap systems is that, typically, they are exposed to the degrading effects of sunlight for extended periods. The ultraviolet portion of sunlight degrades plastics. Thus, since these systems often include geotextile components that are composed of polymeric materials, their ability to resist degradation when exposed to ultraviolet light is commonly documented via lab testing. The most common standard accelerated lab test, ASTM D4355, which uses a Xenon Arc light source, includes 500 hrs or more of continuous exposure. Unfortunately, because of the length of time and associated costs associated with this testing, it is not practical as either a QC test or a "bench-mark" test.

2.2 Full-scale Performance Testing of *Sediment Traps in Inlet Protection Applications*

As noted earlier, the actual performance of BMPs is system or installation dependent. Therefore a large-scale test that can incorporate full-scale "as installed" conditions is the ideal evaluation procedure. One of the testing protocols that are under development focuses on inlet sediment trap applications. Performance testing associated with this application can be accomplished using the ASTM D 7351 protocol and equipment, but discharging the initial sediment laden water as concentrated flow to a simulated inlet instead of as sheet flow to a toe-of-slope installation.

3 Products Tested and Associated Index Properties

3.1 Test Matrix

Table 1 presents the inlet sediment trap systems tested along with a description of each.

Test	GSWCC Identification	BMP Type
Unpaved Surface Systems	Sd2-F	Filter Fabric on Support Frame
	Sd2-Bg	Block and Gravel Drop Inlet
	SCDOT Type B	SCDOT Type B
Paved Surface Systems	Sd2-P	Fabric-Wrapped 8-inch Blocks
	Sd2-P	Plastic Mesh-Wrapped #57 Stone

Table 1. Inlet Sediment Trap Systems Tested

3.2 Index Testing Results

Tables 2a thru 2e present a summary of index testing results for the products used in testing. Table 2f provides detailed properties of the geotextile used in all testing.

Index Property	Specification Value
Steel Fence Posts	GDOT
Wire Backing	GDOT
Type C Silt Fence	See Table 2f

Table 2a. GSWCC Sd2-F (Silt Fence on Support Frame) Inlet Sediment Trap Components

Index Property	Specification Value
8-inch Concrete Blocks	GDOT
Screened Stone (#57)	GDOT

Table 2b. GSWCC Sd2-Bg (Block and Gravel) Inlet Sediment Trap Components

Index Property	Specification Value
Steel Fence Posts	GDOT
Hardware Fabric Mesh	GDOT
Screened Stone (#57)	GDOT

Table 2c. SCDOT Type B (Stone + Support Frame) Inlet Sediment Trap Components

Index Property	Specification Value
Type C Silt Fence	See Table 2f
8-inch Concrete Blocks	GDOT

Table 2d. GSWCC Sd2-P (Fabric-Wrapped Blocks) Inlet Sediment Trap Components

Index Property	Specification Value
Type C Silt Fence	See Table 2f
Screened Stone (#57)	GDOT

Table 2e. GSWCC Sd2-P (Fabric-Wrapped Stone) Inlet Sediment Trap Components

Type C Silt Fence				Tested
Property	Units	Spec	Test	
Tensile	lb	260 x 180	D4632	364 x 201
Elong	%	40	D4632	21 x 15
AOS	mm	0.6	D4751	0.419
Flow	gpm/ft^2	70	GDT 87	203
POA	%	-	-	30

Table 2f. Specifications and Index Testing Results

4 Inlet Sediment Trap Performance Testing in accordance with ASTM D7351 Modified

4.1 Testing Overview

The large-scale testing reported herein was performed in general accordance with ASTM D 7351 modified to present the flow to an area inlet. For this testing, a simulated area inlet installation comprised of an approximate 24-inch x 24-inch opening simulating a manhole inlet positioned at the center of a containment area was used. The BMP was installed adjacent to the opening and exposed to simulated runoff. Sediment-laden water was piped and discharged into the fully contained area around the inlet opening and allowed to run up to and seep through, over, and/or under an installed inlet sediment trap BMP protecting the inlet. The amount (via water and soil weight) of sediment-laden flow was measured both upstream and downstream of the BMP. The measurement of sediment that passes through, over, and/or under the BMP compared to the amount in the upstream flow is used to quantify the effectiveness of the BMP in retaining sediments while allowing continued seepage. The measurement of water that passes through, over, and/or under the BMP compared to the amount of the upstream flow is used to quantify the effectiveness of the BMP in allowing continued seepage. A complete test on each installed BMP with each type of runoff included 3 repeat flows, or events, separated by not less than 4 hours. This test method is full-scale and therefore, appropriate as an indication of product performance, for general comparison of product capabilities, and for assessment of product installation techniques.

Figure 1. Test Setup

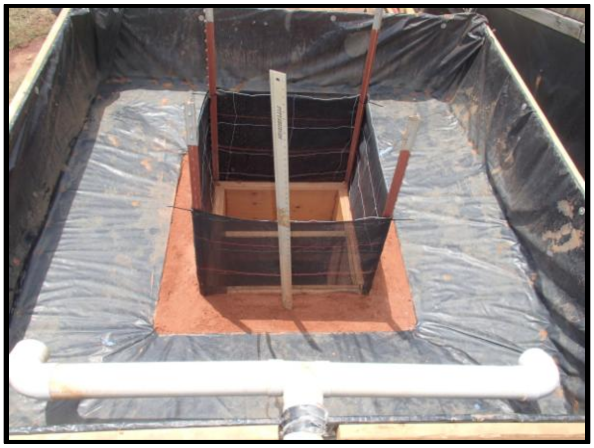

Figure 2. Closeup of a Typical Installation (shown is GSWCC Sd2-F)

4.2 Test Setup

The test procedure requires relatively large equipment to accomplish the full-scale testing of inlet sediment trap BMPs. The suggested system includes the following components:

- A tank with an internal paddle mixer device mounted on scales capable of holding/weighing 10,000 lb of sediment-laden water.
- A sufficient source of water and associated pumping equipment to repeatedly fill the mixing tank.
- A tank mounted on scales of sufficient volume to collect all runoff passing the BMP.

For this testing the setup presented concentrated flow to a simulated storm drain inlet located between the mixing and collection tanks. Sediment-laden water was conveyed by pipe and discharged into a fully contained area around the inlet. The simulated inlet includes a retention zone surrounding an installation zone. The installation zone is about 1.5 feet wide and encircles the inlet opening and is comprised of prepared soil subgrade to allow full-scale installation of the BMP to be tested. The discharged sediment-laden water is allowed to run up to and seep through, over, and/or under an installed BMP protecting the simulated inlet. The seepage migrates through the inlet opening and drains into the collection tank.

The test apparatus is shown in Figures 1 and 2. Pictures of each installed inlet sediment trap BMP are shown in Figures 2 thru 6.

4.3 Preparation of the Installation Zone and Inlet Sediment Trap BMP Installation

The initial installation zone subgrade soil is placed and compacted. Compaction is verified to be 90% (± 3%) of Proctor Standard density using ASTM D2937 (drive cylinder method). The soil is placed in lifts not exceeding 8 inches. Between tests, the top 4 inches (minimum) of soil are removed and replaced and compacted.

The inlet sediment trap BMP is installed in the installation zone which is comprised of the same soil used as sediment test soil. The soil depth is in excess of the depth of BMP installation and compacted to 90±3% of Standard Proctor maximum dry density, at a soil moisture within ±3% of optimum moisture content per ASTM D-698. The BMP length exposed to flow depends on whether an unpaved or paved application is being evaluated. In unpaved applications, the BMP completely surrounds the inlet opening. In paved applications, the BMP extends the full width of the retention zone (approx. 8 ft) along one side of the inlet opening. Because special effort is needed to seal where the BMP meets the wall, only about 7 ft of BMP is exposed to runoff.

Each inlet sediment trap was installed as directed by the GSWCC. For the tests reported herein, the installations were in accordance with the GSWCC's Manual for Erosion and Sediment Control in Georgia ("the Manual"). The BMPs tested are listed in Table 1.

Figure 3. Unpaved Test Setup –
GSWCC Sd2-Bg

Figure 4. Unpaved Test Setup – SCDOT
Type B

Figure 5. Paved Test Setup –
GSWCC Sd2-P (Pigs-In-A-Blanket)

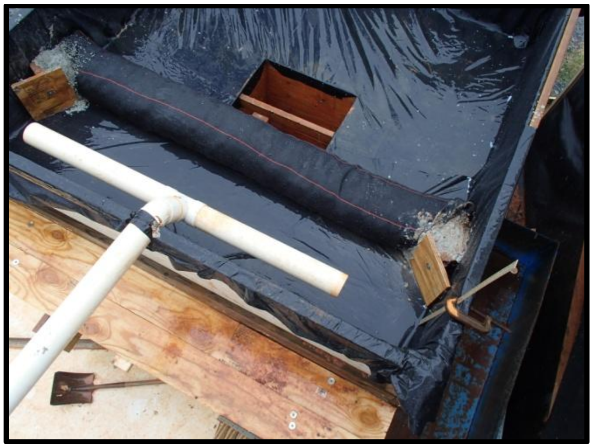

Figure 6. Paved Test Setup –
GSWCC Sd2-P (Wrapped Stone)

4.4 Specific Test Procedure

After the BMP is installed, a sediment-laden runoff is then created by combining water and soil in the mixing tank. Sediment-laden runoff was created by combining water and soil in the mixing tank and agitating during the test. 4000 lb of water and either 240 lb (dry weight) or 48 lb (dry weight) of sandy clay soil were combined to create the sediment-laden runoff of either 6% (60000 mg/L) or 1.2% (12000 mg/L), respectively. This amount of water and sediment simulates runoff from a hypothetical slope presenting the following “default” scenario:

- With and without an upstream toe-of-slope BMP in place;
- A 2-yr, 24-hr storm event (mid-Atlantic region of US) equal to a 4-inch rainfall;
- Approximately 25% of the storm would occur during the peak 30 minutes;
- 50% of the rainfall would infiltrate into the ground;
- A theoretical contributory area of 100 ft slope length by 16 ft wide;

Runoff and associated sediment were calculated using the Modified Universal Soil Loss Equation (MUSLE) as shown in D7351 which allows for calculating a storm-specific quantity of sediment.

Agitation is maintained and discharge is released evenly for 30 minutes. The quantity of released runoff is measured at 5-minute intervals by noting the reduction in weight in the mixing tank, adjusting the valve on the tank outlet to increase/decrease flow to stay as close as possible to the target (4240 lb / 30 min = 140 lb / min). For this testing, the discharge flow is introduced to allow it to flow up to and around the BMP. Retention observations, ponding depths, and associated times are recorded during the test.

Figure 7. Introduction of Initial Runoff to the Sd2-F BMP

Figure 8. Start of Second “Event” on Sd2-F BMP

Figure 9. Start of Third “Event” on Sd2-F BMP

Figure 10. End of Test after Third “Event” on Sd2-F BMP

As runoff passing the BMP system is collected, the weight and volume of the collection tank is recorded and grab samples are taken at 5 minute intervals. Cutoff time is the earlier of 90 minutes or when there is low-volume ponding and minimal discharge. Figures 7 thru 10 show a typical test in progress.

Grab samples are evaluated in a lab to determine turbidity using a Hach 2100 AN Turbidimeter and to determine percent dry solids content. Drying of collected sediments is accomplished in a forced air oven at 110°C for a minimum of 24 hours or until all moisture is driven off, whichever is greater. All weighing of sediments is done with laboratory scales accurate to ± 0.01 grams.

5 Test Results

Total sediment and associated runoff measured during the testing are the principle data used to determine the performance of the product tested. This data is entered into a spreadsheet (see appendix) that transforms the sediment concentration and collected runoff into the retention effectiveness values shown in Table 3. Graphs summarizing test data are shown in Figures 4 thru 6. Additionally, turbidity samples were taken to determine if any change in turbidity resulted from the measured short-term system performance. In both tests, modest differences in upstream (runoff) and downstream (short-term seepage) turbidity were found.

Table 4. Measures of Effectiveness

Test Series	Appli-cation	Setup	Performance Characteristic	%*	Time to Overtopping *
1	Unpaved	Sd2-F, Filter Fabric on Posts, 60000mg/L (3 replicate)	Soil Retention Effectiveness:	96.54	No overtopping
			Seepage Effectiveness:	71.92	
2	Unpaved	Unpaved Control, 60000mg/L	Soil Retention Effectiveness:	10.13	No overtopping
			Seepage Effectiveness:	98.53	
3	Unpaved	Unpaved Control, 12000mg/L	Soil Retention Effectiveness:	6.01	No overtopping
			Seepage Effectiveness:	99.61	
4	Unpaved	Sd2-F, Filter Fabric on Posts, 60000mg/L	Soil Retention Effectiveness:	98.84	No overtopping
			Seepage Effectiveness:	78.21	
5	Unpaved	Sd2-F, Filter Fabric on Posts, 12000mg/L	Soil Retention Effectiveness:	96.03	No overtopping
			Seepage Effectiveness:	70.04	
6	Unpaved	Sd2-Bg, Block & Gravel, 60000mg/L	Soil Retention Effectiveness:	80.13	No overtopping
			Seepage Effectiveness:	92.92	
7	Unpaved	Sd2-Bg, Block & Gravel, 12000mg/L	Soil Retention Effectiveness:	82.66	No overtopping
			Seepage Effectiveness:	92.13	
8	Unpaved	SCDOT Type B, Gravel + Mesh on Posts, 60000mg/L	Soil Retention Effectiveness:	81.67	No overtopping
			Seepage Effectiveness:	94.68	
9	Paved	Paved Control, 60000mg/L	Soil Retention Effectiveness:	2.50	No overtopping
			Seepage Effectiveness:	99.13	
10	Paved	Paved Control, 12000mg/L	Soil Retention Effectiveness:	3.43	No overtopping
			Seepage Effectiveness:	98.77	
11	Paved	Sd2-P, Fabric Wrapped Blocks, 60000mg/L	Soil Retention Effectiveness:	92.25	4:34
			Seepage Effectiveness:	90.35	
12	Paved	Sd2-P, Fabric Wrapped Blocks, 12000mg/L	Soil Retention Effectiveness:	91.42	14:33
			Seepage Effectiveness:	88.97	
13	Paved	Sd2-P, Fabric Wrapped Stone, 60000mg/L	Soil Retention Effectiveness:	77.04	2:45
			Seepage Effectiveness:	94.85	
14	Paved	Sd2-P, Fabric Wrapped Stone, 12000mg/L	Soil Retention Effectiveness:	90.32	10:48
			Seepage Effectiveness:	92.34	

*Average of 3 sequential tests on one setup.

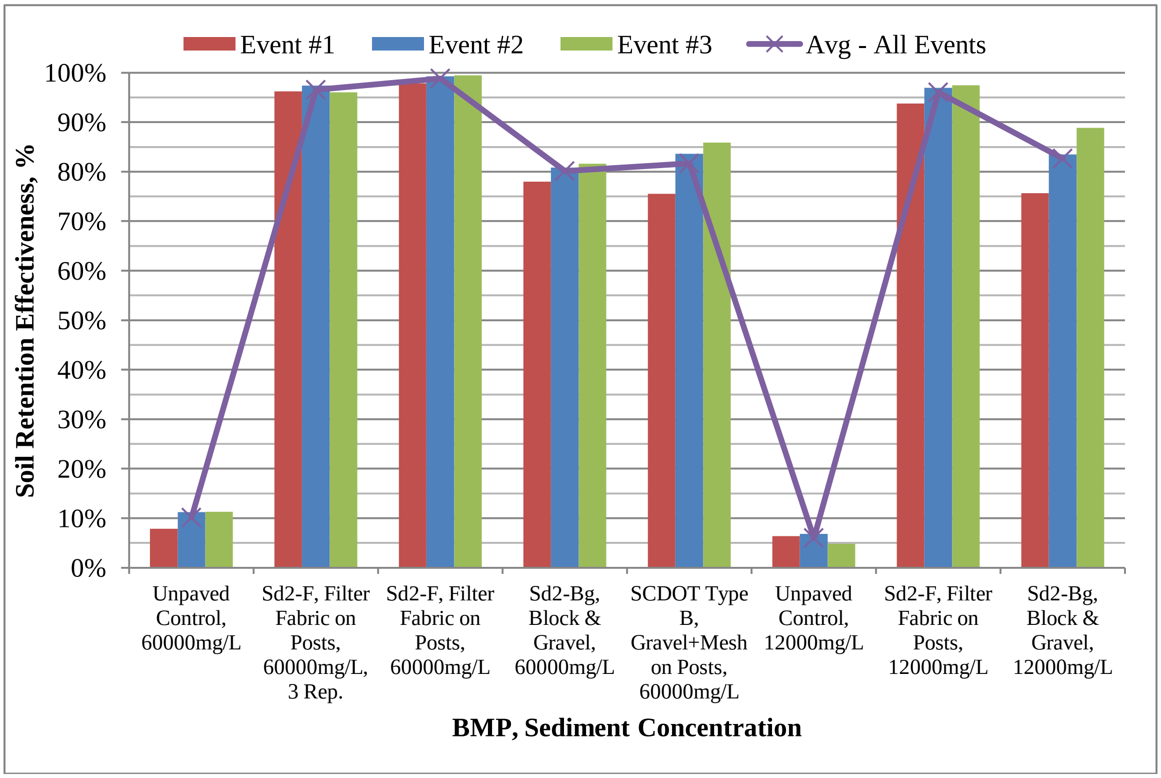

Figure 4. Unpaved Inlet Sediment Traps – Soil Retention Effectiveness

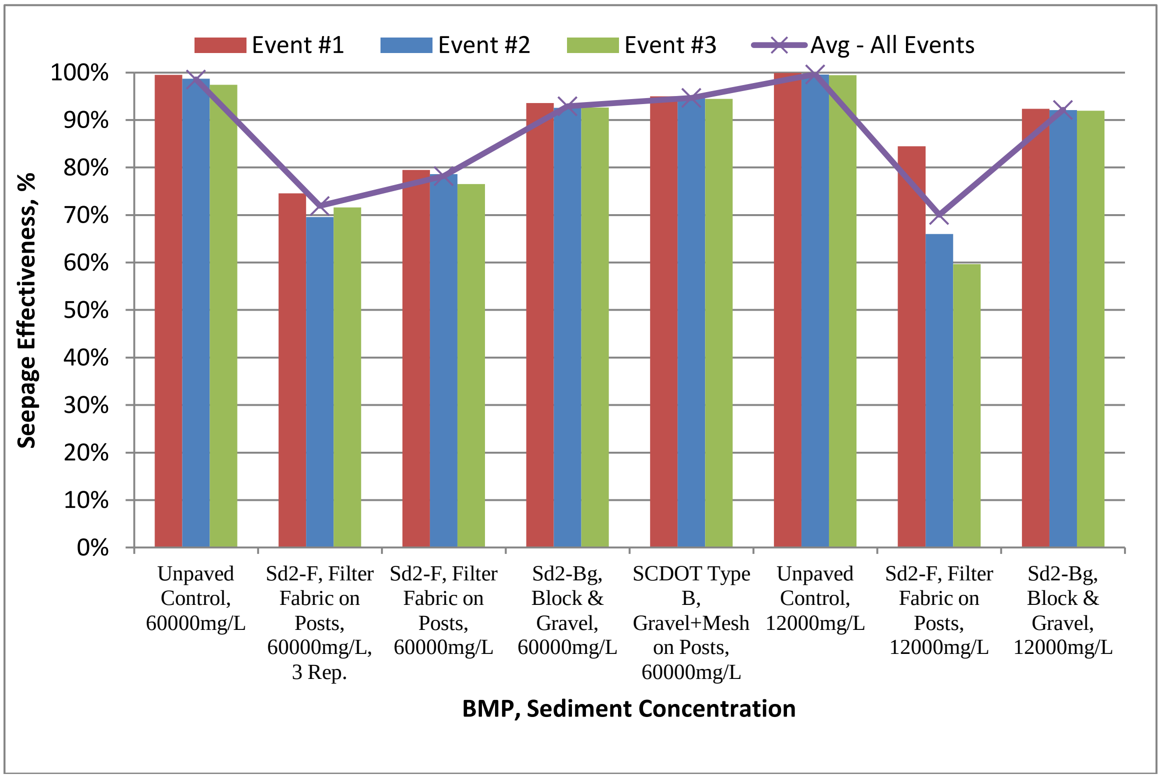

Figure 5. Unpaved Inlet Sediment Traps – Seepage Effectiveness

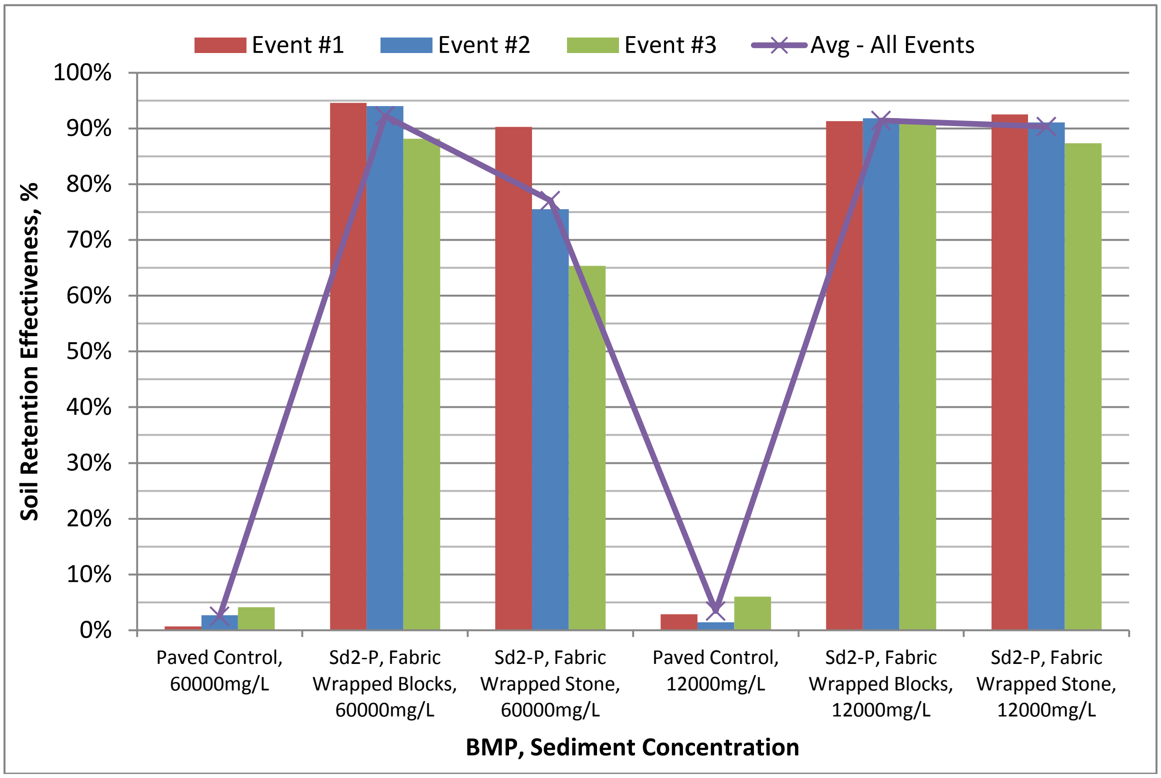

Figure 6. Paved Inlet Sediment Traps – Soil Retention Effectiveness

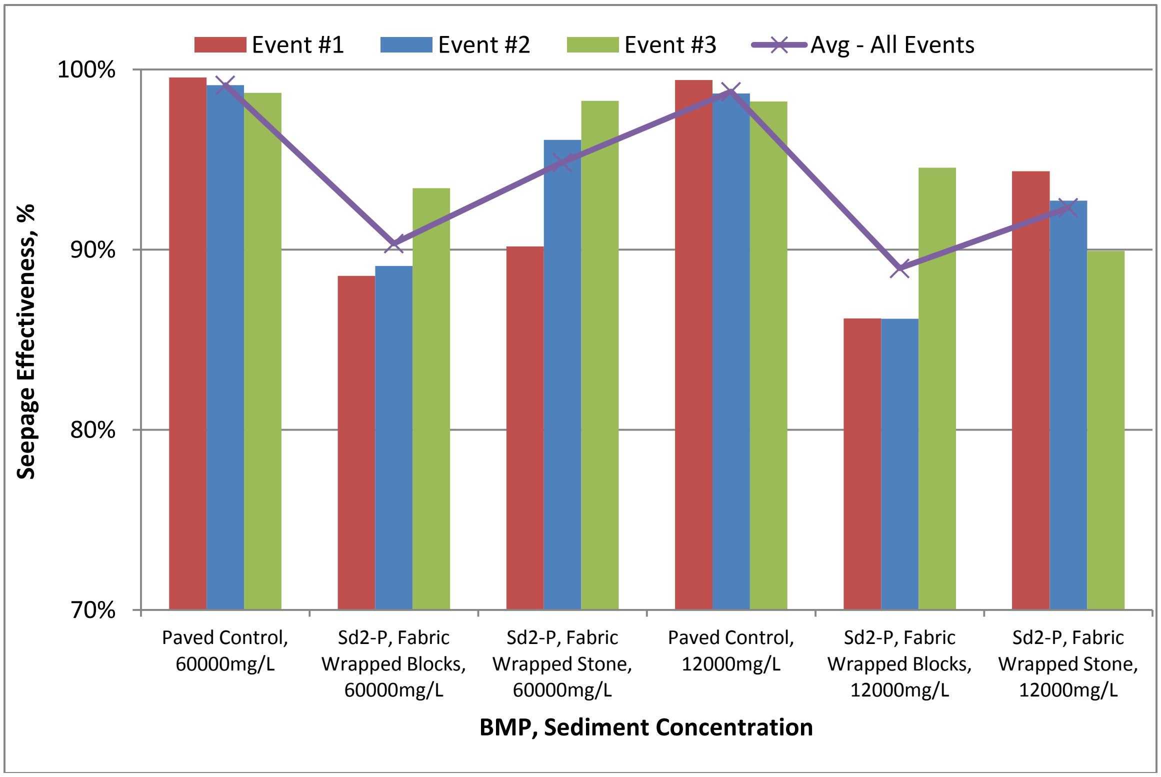

Figure 7. Paved Inlet Sediment Traps – Seepage Effectiveness

6 Discussion

The performance results for inlet sediment traps for unpaved applications are presented in Figures 4 and 5. The figures clearly establish that the filter fabric based BMP (Sd2-F) had the highest retention effectiveness along with the lowest seepage effectiveness. Conversely, the stone based BMP (Sd2-Bg) had the lowest retention effectiveness but the highest seepage effectiveness. These relationships were consistent for both levels of sediment concentration tested. It should also be noted that both BMPs tested vastly outperformed the controls in retention effectiveness but only modestly underperformed the controls in seepage effectiveness.

Figures 6 and 7 show that results are not so orderly for inlet sediment traps used in paved applications. This appears to be a result of the inevitability of overtopping that occurs as these low profile BMPs retain sediments and lose ponding volume. Both tested BMPs are filter fabric based, incorporating a filter fabric around a porous medium. The big difference being that the concrete block wrapped with fabric presents a very uniform height while the stone wrapped with fabric has a more irregular height. Thus, the stone wrapped system is susceptible to earlier overtopping occurring at low points which causes greater seepage and associated lower retention. This appears to explain why the fabric wrapped block system has higher retention effectiveness and lower seepage effectiveness than does the fabric wrapped stone. This is especially pronounced with the higher sediment concentration runoff condition. As with the unpaved applications, both BMPs tested vastly outperformed the controls in retention effectiveness but only modestly underperformed the controls in seepage effectiveness.

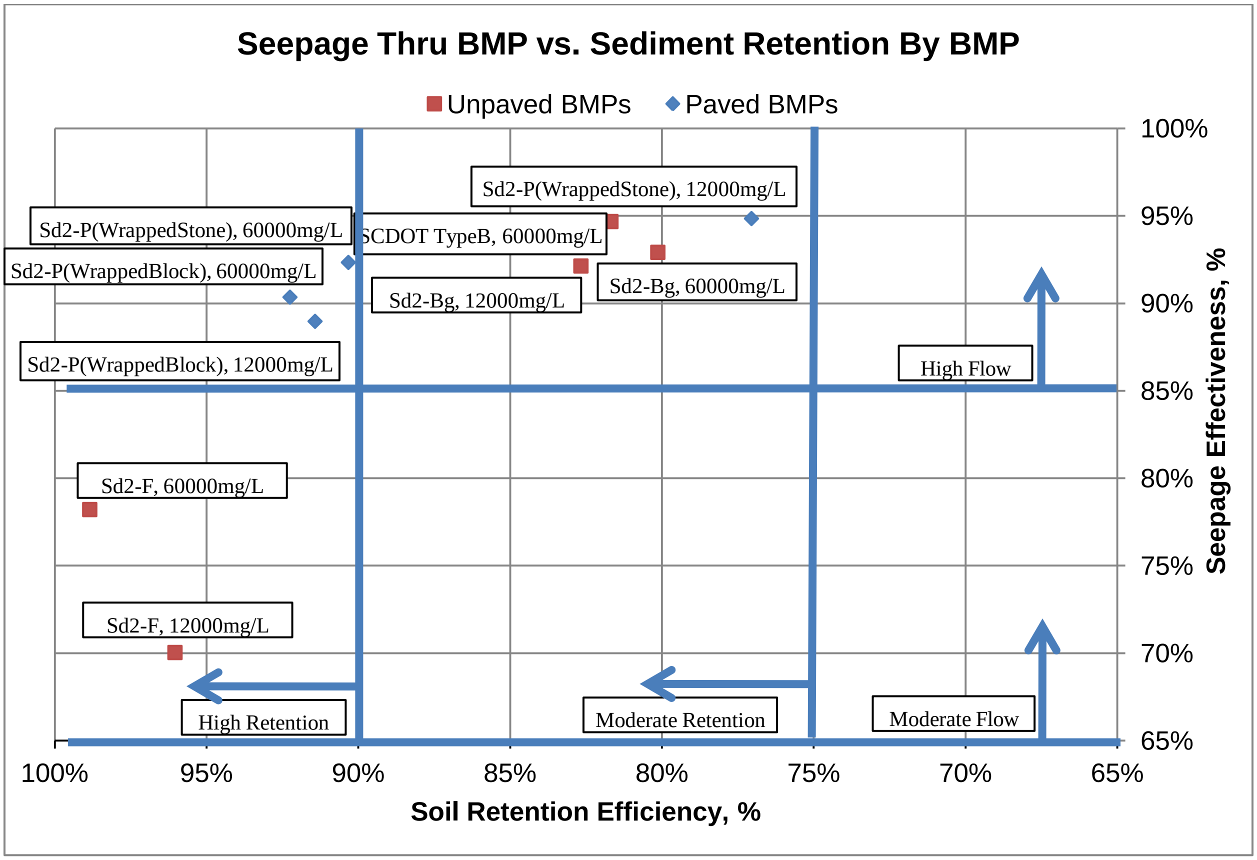

Figure 8. Summary of BMP Test Results

6 Conclusions and Recommendations

The test results presented herein appear to establish appropriate baseline performance characteristics for standard BMPs used in either unpaved or paved applications. For unpaved applications, the filter fabric based BMP (Sd2-F) provides maximum sediment retention while the stone based BMP (Sd2-Bg) provides maximum seepage. The Sd2-F system may be best used where sufficient ponding area is available, while the Sd2-Bg system should be preferred where ponding would cause a potential safety or property damage risk.

For paved applications, it appears that the more determinant height of concrete block assures maximum ponding prior to eventual overtopping. Thus, the so-called “pigs-in-a-blanket” – filter fabric wrapped blocks - would appear to be a more dependable choice for curb inlet protection (Sd2-P) based solely on retention and seepage effectiveness. Comparatively, especially when considering the 12000 mg/L tests, the “pigs-in-a-blanket” appears to provide maximum sediment retention while the fabric-wrapped stone provides maximum seepage. Still, consideration of cost and safety issues associated with the use of concrete blocks instead of stone is recommended.

Figure 8 summarizes the results of the testing reported herein and suggests that in both paved and unpaved applications, it is possible to differentiate between BMPs that provide maximum sediment retention and those providing maximum seepage. This may facilitate separate application-specific specifications for BMP systems.

Finally, results from testing with 60000 mg/L sediment concentration were very similar in most cases to testing with 12000 mg/L. Thus, as the lower concentration is more consistent with inlet flows downstream of toe-of-slope sediment barriers, testing only with 12000 mg/L sediment concentrations is recommended as sufficient to properly characterize inlet BMPs.

7 Acknowledgement

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