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Small-Scale Performance Evaluations of Geotextiles used in Silt Fence Applications

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SMALL-SCALE PERFORMANCE EVALUATIONS OF GEOTEXTILES USED IN SILT FENCE APPLICATIONS

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April 2019

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1. INTRODUCTION

Standard small-scale testing methodologies for evaluating the sediment removal capabilities of silt fence perimeter control installations have failed to adequately quantify realistic filtering and sediment retention efficiencies. Current small-scale testing methodologies do not address realistic stormwater runoff volumes or sediment loadings that in-field silt fence installations will most likely intercept during their life cycle. For example, ASTM D5141 *Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device* specifies that 75 L (20 gal.) of sediment-laden water be introduced during testing in less than 10 seconds (*ASTM 2011*). This method does not mimic realistic runoff conditions encounter in the field resulting from a 2-yr, 24-hr storm event, which is stipulated in the U.S. Environmental Protection Agency's Construction General Permit as the minimum design storm for determining the capacity requirement for all erosion and sediment control (ESC) practices (*USEPA 2017*). Cooke et al. (*2015*) identified that research regarding the efficiency of silt fence is lacking and that better science is needed to identify which factors influence the effectiveness of such devices. Thus, this study aims to improve the industries understanding of silt fence performance regarding sediment-laden flow rates by improving upon current small-scale testing standards by developing an improved testing technique that addresses these issues and provides in-field performance capabilities of common geotextile fabrics used in silt fence applications.

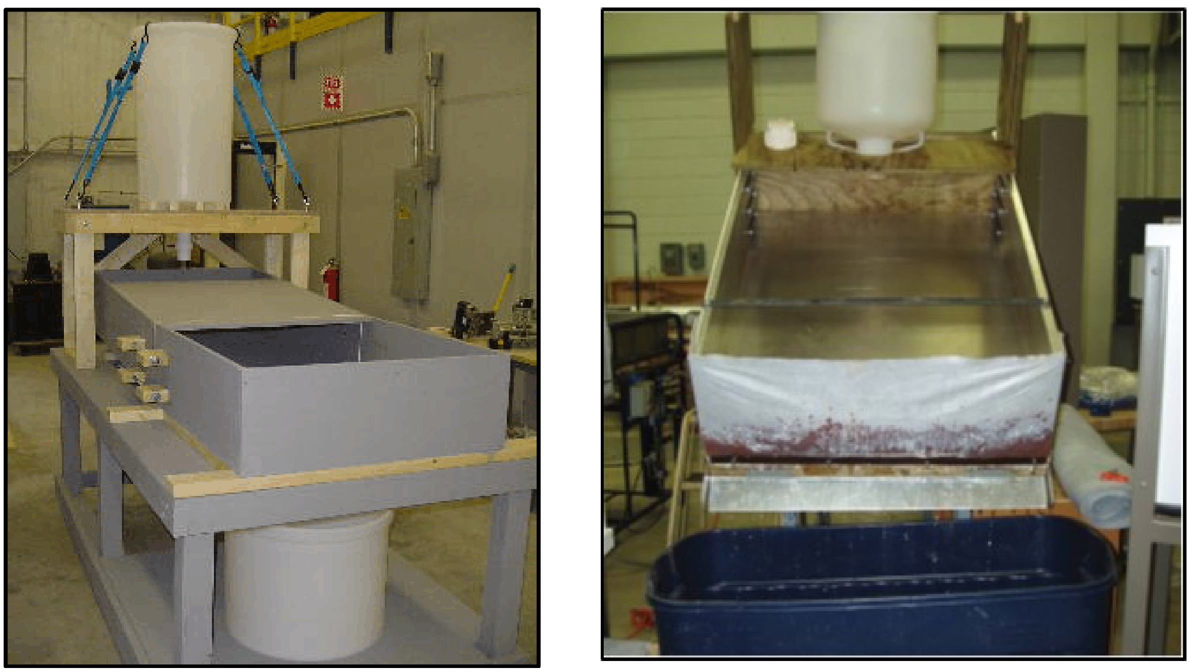
2. RESEARCH OBJECTIVE

The primary objective of this study is to better understand and compare flow rates, sediment retention capabilities, and water quality impacts associated with various geotextiles commonly used in silt fence applications. Specific tasks performed to satisfy the primary objective include: (1) design and construction of a small-scale sediment barrier (SB) testing apparatus, (2) development of a testing methodology that incorporates regionally specific design criteria and produces repeatable tests, (3) small-scale performance evaluations of various silt fence geotextiles, and (4) a proof-of-principle analysis for evaluating three-dimensional SB practices within the developed small-scale testing apparatus. Results obtained from this study can provide federal and state transportation agencies with improved geotextile performance capabilities that can enhance the design, implementation, and maintenance protocols associated with standard silt fence practices.

3. BACKGROUND

Determining the performance capabilities and effectiveness of various geotextile fabrics is challenging when evaluating in-field installations on construction sites. The challenge lies within uncontrollable weather patterns and inconsistent site conditions, making replicated field experiments difficult to perform (*McLaughlin et al. 2001*). To achieve replicable performance evaluations of geotextiles, several parameters need to be continuously monitored during installation and throughout the experimental process.

Currently, ASTM D5141 is the only ASTM recognized method for evaluating geotextile fabrics used in silt fence filtering applications. ASTM D5141 describes the procedures for conducting small-scale flume experiments to determine sediment removal efficiency and flow through rates of geotextile fabrics. The development of this test method was a direct result of the work done by Wyant (*1981*), where he evaluated multiple nonwoven geotextile fabrics within a laboratory setting. As shown in Figure 1(a), the test apparatus consists of a 49.2 in. (125 cm) long by 33.5 in. (85 cm) wide flume inclined with an 8% slope. Sediment-laden flow is introduced using a 20 gal. (75 L) container equipped with a mechanical stirrer to facilitate soil suspension. Wyant (*1981*) observed average sediment removal efficiencies of 92% for silty soil and 97% for sandy soil, with flow rates ranging from 0.0013 to 11.5 ft^3/ft^2/min (0.0004 to 3.5 m^3/m^2/min). Henry and Hunnewell (*1995*) also used this standard test method to evaluate nonwoven polyester and polypropylene geotextiles using dredged sediment that mainly consisted of silt and clay. Results indicated sediment removal efficiencies of 45.5% and 72.8%, respectively, with flow rates ranging from 0.206 to 0.085 ft^3/ft^2/min (0.063 to 0.026 m^3/m^2/min). Risse et al. (*2008*) performed sediment removal tests on the Silt-Saver® Belted Strand Retention Fence™ (BSRF) and the Georgia Soil and Water Conservation Commission Type-C silt fence using this standard test method, as well as a modified version. As shown in Figure 1(b), the modified version increased the slope of the flume from 8% to 58% to produce increased hydraulic head on the geotextile. Results indicated that under standard sediment loading conditions the BSRF and Type-C silt fence reduced turbidity by 61% and 46%, respectively, and had effluent flow rates of 0.0488 to 0.0276 ft^3/ft^2/min (0.0149 and 0.0084 m^3/m^2/min), respectively. Table 1 provides a summary of relevant studies reviewed pertaining to small-scale performance testing and major finding associated with each.



(a) standard testing (*Sprague 2006*) (b) modified testing (*Risse et al. 2008*)

Figure 1. ASTM D5141 test apparatus.

Table 1. Small-Scale Testing Literature Review Summary

Study	Test Type	Materials Tested	Major Findings
Wyant 1981	small-scale flume	15 geotextiles	development of ASTM D5141
Fisher and Jarrett 1984	small-scale constant head filter fabric test apparatus	6 geotextiles	geotextiles retained all sands, removed various amounts of coarse silt, and were ineffective at removing silt-clay
Crebbin 1988	small-scale flume	4 geotextiles	geotextile apparent opening size does not accurately predict filtering efficiency
Kouwen 1990	small-scale flume	geotextile fabrics	excessive ponding is due to geotextile blinding
Henry and Hunnewell 1995	ASTM D5141	nonwoven polyester and polypropylene geotextiles	Observed Flow Rates: 0.063 to 0.026 $m^3/m^{2/}$min Observed Sediment Removal Rates: 45.5 to 72.8%
Barrett et al. 1998	small-scale flume and field observation	various geotextile fabrics	Sediment removal is not achieved by filtration. Lab Results: TSS removal rates of 68 to 90%. Field Results: Little to no improvement in turbidity.
Britton et al. 2000	small-scale flume	tight and open weave geotextiles	increasing impoundment volume improves sediment removal
Keener et al. 2007	small-scale flume	silt fence and siltsoxx	siltsoxx's are less likely to overtop than silt fences
Risse et al. 2008	ASTM D5141 and Modified ASTM D5141 [conducted at UGA]	nonwoven BSRF and GDOT type-c	Turbidity Reduction: BSRF = 58 – 82% GDOT type-c= 25 – 58% Each had similar flow rates

A major limiting factor associated with these studies is the lack of realistic sediment and hydraulic loadings placed on geotextiles throughout the experiment. The loadings selected for these experiments do not mimic typical sediment-laden flows an in-field geotextile installation would intercept throughout its life cycle on a construction project. Additionally, the loading duration associated with these experiments only last approximately 10 seconds. This time limitation prevents the identification of performance changes of a geotextile the longer it is exposed to sediment-laden runoff.

4. MEANS AND MEHTODS

The testing methodology developed as part of this study improves upon current practices outlined within standard testing procedures and reviewed literature. The methodology aims at providing performance evaluations and analyses of geotextile fabrics while addressing limiting factors of published geotextile testing efforts. The developed testing protocol subjects SB geotextiles to typical stormwater loading conditions associated with central Alabama. The purpose of these geotextile experimental tests are to evaluate sediment retention capabilities, effluent flow rates, and water quality improvements. The geotextiles selected for testing consisted of two nonwoven fabrics (e.g., needle punched and spunbond) and three woven fabrics with varying weave configurations. In addition, a stacked sandbag configuration was evaluated to demonstrate a proof-of-principle for evaluating three-dimensional practices using the small-scale testing apparatus and presented methodology.

4.1 SMALL-SCALE TEST APPARATUS DESIGN

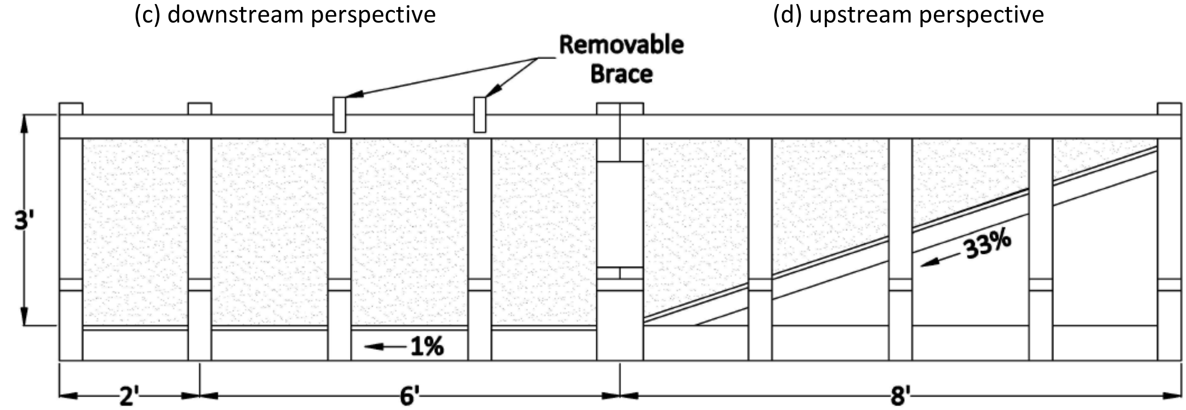
The small-scale SB testing apparatus was designed to evaluate geotextiles installed as perimeter control practices. The apparatus is constructed out of dimensional lumber and plywood with overall dimensions of 4 ft (1.2 m) wide, 16 ft (4.9 m) long, and height of 3 ft (0.9). The profile of the apparatus consists of a 3*H*:1*V* slope that transitions to a 1% slope, which mimics typical slopes associated with highway construction projects. When evaluating geotextiles using ASTM D5141, geotextiles are installed at the toe of an 8% slope, which limits the installations stormwater storage capacity due to the close proximity to the slope. To increase storage capabilities, geotextiles were installed 6 ft (1.8 m) from the toe of the 3*H*:1*V* slope within the small-scale testing apparatus. Flow is directed into the apparatus via an 8 ft (2.4 m) plywood sheet with 2 by 6 in. (5 by 15 cm) lumber borders that transition inflow from shallow concentrated to sheet flow. Figure 2 shows as-built pictures and details of the small-scale SB testing apparatus.

(a) test apparatus

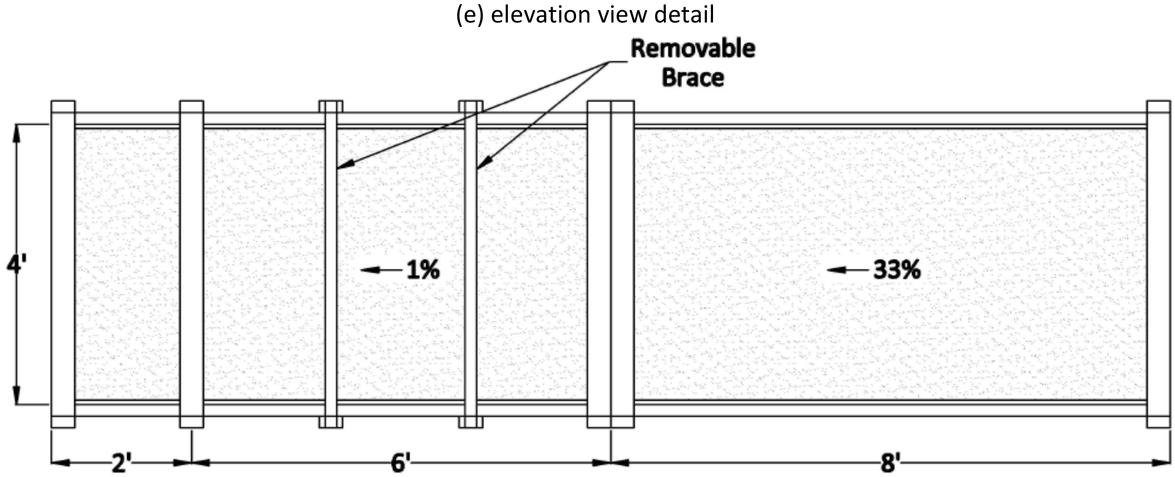
(b) sheet flow introduction

(c) downstream perspective

(d) upstream perspective



(e) elevation view detail



(f) plan view detail

Figure 2. Small-scale SB testing channel images and details.

To prevent flow from passing through joints of the small-scale apparatus during testing, a 0.006 in. (0.15 mm) thick polypropylene liner was placed inside the apparatus. Geotextiles were held in place using 2 by 4 in. (5 by 10 cm) lumber and wood screws. Flow bypass between the geotextile and polypropylene liner was prevented by sealing each installation with heavy-duty construction caulk during the installation process. After each evaluation was completed, the geotextile and dried caulk sealant were carefully removed to prevent damage to the liner. This process allowed a single liner to be used for multiple installations. However, if liner damage occurred during post-test geotextile or sediment removal, a new liner was installed. This method proved effective at preventing seepage, while also providing a means for collecting retained sediment.

4.2 Flow Introduction

Water introduction into the apparatus was designed to facilitate accurate flow rate monitoring throughout testing while also providing a means for easy flow rate adjustments. To achieve the desired flow control necessary during testing, a four-stage process was implemented. The setup consisted of a submersible 2 in. (5 cm) pump [Figure 3(a)], a 300-gallon (1,135 L) equalizing tank [Figure 3(b)], a 90° v-notch discharge weir plate for controlling apparatus inflow [Figure 3(c)], and two 4 in. (10 cm) discharge valves for controlling flow exiting the bottom of the tank [Figure 3(d)]. The submersible pump transported water from the onsite supply pond into the equalizing tank located upstream of the test apparatus. As water filled the tank and began to flow across the weir plate, discharge gate valves were adjusted until the desired water level within the tank was achieved. A custom scale and pressure head tube apparatus [Figure 3(e)] were installed adjacent to the tank to monitor water levels. The scale provided a correlation between water depth flowing across the weir plate and flow rate entering the apparatus. This method of water introduction and monitoring allows for a wide range of flow rates, which may vary based on regional rainfall events.

(a) submersible pump

(b) equalizing tank

(c) v-notch weir

(d) discharge gate valves

(e) flow rate monitoring

Figure 3. Water regulation system.

Silt fence installations are typically designed based on contributory area or maximum slope length above the installation. Within the state of Alabama, two area based design parameters are commonly used. The first method limits contributory area to 0.25 acre (0.10 ha) per 100 ft (30.5 m) of unreinforced silt fence. This design strategy is typically implemented on small residual projects where land disturbance is minimized. The second method limits contributory area to 0.50 acre (0.20 ha) per 100 ft (30.5 m) of reinforced silt fence. This design strategy is commonly applied on projects that have large land disturbance areas, such as highway construction, and was used to develop the theoretical drainage area during full-scale testing. Appling the same principles outlined in the full-scale testing methodology, a hydrograph was created for a 0.02 acre (0.008 ha) drainage area that would be intercepted by a 4 ft (1.2 m) section of silt fence. As shown in Figure 4, the average flow rate for the peak 30 minutes of a 2-yr, 24-hr design storm from a drainage area of 0.02 acre (0.008 ha) was calculated to be 0.04 ft^3/s (0.0011 m^3/s). This flow rate was applied during each 30-minute small-scale test.

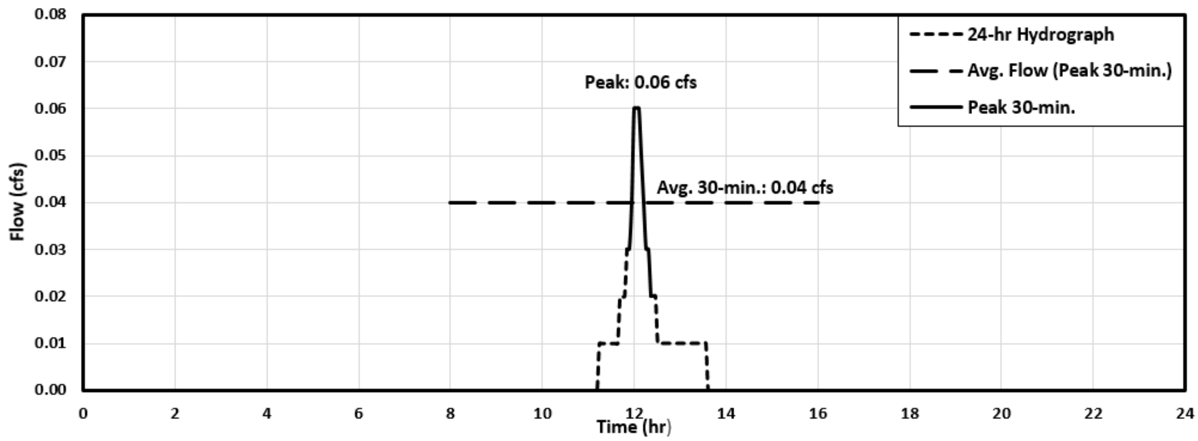


Figure 4. Hydrograph for 0.02 acre (0.008 ha) representative drainage area.

A summary of the drainage areas, flow rates, and runoff volumes applied during small-scale testing are shown in Table 2.

Table 2. Summary of Theoretical Flow Values for Small-Scale SB Testing

Design Drainage Area ac (ha)	Scaled-Down Drainage Area ac (ha)	Peak Flow ft^3/s (m^3/s)	Avg. Flow for 30 Min Peak ft^3/s (m^3/s)	Total Vol. 30 Min Test ft^3 (m^3)	Total Vol. 30 Min Test Gal (L)
0.50 (0.20)	0.02 (0.008)	0.06 (0.0017)	0.04 (0.0011)	72.0 (2.04)	592.4 (2,242)

Note: Average 2-year, 24-hour storm for Alabama = 4.43 inches. NRCS Type III rainfall distribution. Average CN = 88.5 for Alabama; 1 ac = 0.4 ha; 1 ft^3/s = 0.028 m^3/s; 1 ft^3 = 0.028 m^3; 1 gal = 3.79 L

4.3 Sediment Introduction

Sediment metering was achieved by manually feeding soil into the soil/water mixing trough built on the plywood flow introduction sheet [Figure 5(a)]. To maintain a consistent rate throughout testing, 5-gallon (3.79 L) buckets were pre-filled with the exact amount of soil to be introduced over a 2 minute duration. Workers would monitor a stopwatch while feeding soil from the buckets into the system so that one bucket of soil would be emptied every 2 minutes. Workers would position themselves beside the flow introduction sheet so that at the end of every 2-minute cycle, a new bucket of soil could be easily place over the mixing trough and soil feeding could continue without interruption [Figure 5(b)]. A mechanical means of soil introduction was available; however, soil texture caused particles to bridge together preventing soil from flowing from the hopper into the mechanical auger at a consistent rate.

(a) mixing trough

(b) sediment introduction

Figure 5. Sediment introduction system.

While peak and 30 minute average flows associated with full and small-scale contributory areas are different, the average flow per linear foot of silt fence remains constant (e.g., 0.01 cfs/LF). Nonetheless, the modified universal soil loss equation estimations associated with each contributory area change substantially per liner foot of silt fence due to total volume and flow rate variations. To maintain consistent sediment loading parameters per linear foot between full and small-scale tests, the calculated sediment load for full-scale testing was converted into sediment load per liner foot (e.g., 1127.8 lb. (511.6 kg) of soil per 20 ft (6.1 m) of silt fence= 56.4 lb./LF (83.8 kg/LM)). Using this loading rate and the width of the small-scale testing apparatus (i.e., 4 ft (1.2 m)), total sediment load was computed to be 225.6 lb. (102.3 kg) for small-scale testing. The targeted sediment load metering rate was calculated to be 7.5 lb./min. (3.3 kg/min.) over the 30 minute test duration. Based upon the flow and sediment introduction rates, the sediment introduction concentration was calculated to be 3.1 lb./ft^3 (50,000 mg/L) as flow enters the test apparatus, which is the same concentration applied during full-scale testing. As outlined by ASTM D5141 (*2011*), soil used during testing should be site-specific or representative of the location of implementation. Thus, soil used during testing was native to central Alabama and was classified as a sandy loam according to the United State Department of Agriculture (USDA) soil classification system.

4.4 Testing Regime

To assess the performance characteristics of geotextiles used in SB applications, a multiple iteration experimental testing regime was developed for small-scale testing. The developed regime requires that each geotextile be installed and sealed inside the testing apparatus and subjected to a constant sediment-laden flow of 30 minutes. After the test period, observation and data collection continued during dewatering for an additional 90 minutes to evaluate post-test performance. In total, observational and data collection lasted 120 minutes. To better understand performance capabilities and insure accurate reporting of geotextile properties, three installations and evaluations were conducted per geotextile. This repetitive approach provides a means for identifying inconsistencies between tests and implementing adjustments in subsequent geotextile evaluations if necessary. Figure 6 illustrates the small-scale testing regime implemented during geotextile evaluations.

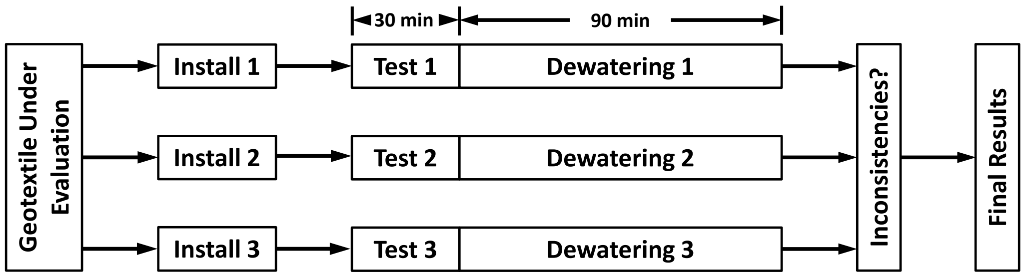


Figure 6. Small-scale testing regime.

4.5 DATA COLLECTION

Evaluations are based on observations and data collected throughout experiments. Hydraulic conductivity, sediment retention, and water quality data were collected for each experiment. These parameters are used to compare the performance of each geotextile tested.

4.5.1 Hydraulic Conductivity

Two Onset HOBO water level pressure transducers (U20-001-04) were deployed during testing to accurately measure impoundment depth within the apparatus throughout the duration of each experiment. One logger was installed along the floor of the test apparatus, upstream of the geotextile, to record water pressure as an impoundment formed [Figure 7]. The second logger was installed downstream of geotextile above the high water mark to record atmospheric pressure. Each logger was programed to take pressure and temperature measurements at 10 second intervals. Pressure data collected along the bottom of the impoundment was evaluated against atmospheric pressure data to calculate differential pressures over the course of each experiment. Using these pressures, corresponding time-variable water depths throughout each experiment were calculated using HOBO® software. Knowing the storage geometry of the test apparatus and time-variable water depth, retained time-variable flow volumes were calculated. These time-variable volumes were analyzed against the introductory flow to determine geotextile effluent flow rates.

Figure 7. Upstream water level logger installation location.

4.5.2 Sediment Retention

To accurately quantify sediment retained upstream for each experiment, dry soil weights were determined pre and post-tests. Soil used for testing was mechanically sieved to remove large rocks and organic debris then stored in a drying shed. Prior to testing, 5-gallon (3.79 L) buckets were filled with dried soil until the required weight per bucket was obtained. Soil samples were collected from several buckets and processed to determine an average moisture content of the air dried soil. Using the moisture content results, which were typically around 9%, dry soil weight prior to testing was determined. Upon test completion, retained sediment was removed from the test apparatus and placed on polypropylene sheets to sun dry [Figure 8(a)]. After sun drying, retained soil was loaded in galvanized washtubs and placed in large ovens to remove residual moisture. Post-test dry soil weight was obtained from oven dried soil to calculate sediment retention [Figure 8(b)].

(a) sun drying

(b) oven dried soil

Figure 8. Small-scale soil drying process.

4.5.3 Water Quality Sampling

Water sampling was conducted during each geotextile performance evaluation to analyze effects on water quality as flow passed through the system. Grab samples were collected in 8 oz. (236 mL) bottles by manually obtaining water samples from three locations: (1) along the surface of the upstream impoundment (i.e., SL2), (2) along the bottom of the impoundment via a sampling pump (i.e., SL3), and (3) downstream of the geotextile installation (i.e., SL4). Figure 9 illustrates the sample locations in relation to an installed geotextile. Over the course of each experiment, 12 grab samples were collected at each sampling location. During the initial 45 minutes of an experiment, grab samples were taken at five minutes intervals (i.e., 9 grab samples). The remaining three samples were collected at elapsed time durations of 60, 90, and 120 minutes. Grab samples were processed post-test in a laboratory to determine turbidity levels within the system oven the duration of the experiment.

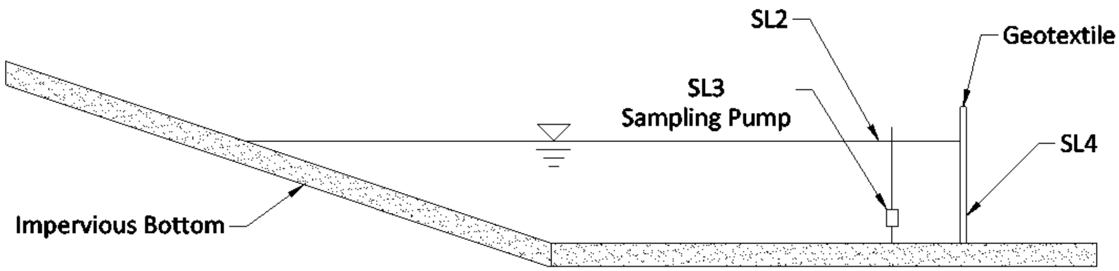


Figure 9. Small-scale SB grab sample locations.

4.6 METHODOLOGY COMPARISON

The standard method for evaluating geotextiles is outlined in ASTM D5141-11 *Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device*. This research effort aimed to improve upon the understanding of silt fence geotextile material subjected to realistic sediment-laden flows using this standard test methodology by mimicking realistic runoff conditions intercepted by SB practices. The parameters associated with the existing methodology and developed methodology are shown in Table 3 to provide a comparison between the methods.

Table 3. Comparison of ASTM D5141 and AU-ESCTF Small-Scale Testing Methodologies

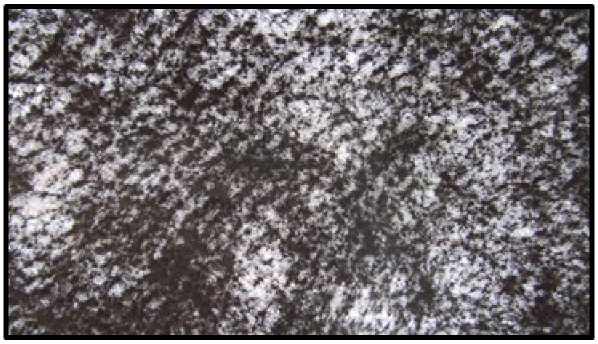
Study	Focus	Design Storm	Drainage Basin ac (ha)	Flow Rate ft^3/s (m^3/s)	Sediment Load lb. (kg)	Test Duration (min)
ASTM D5141 (2011)	Filtering Efficiency and Flow Rate	N/A	N/A	0.177 (0.005)	0.33 (0.15)	0.17
AU-ESCTF Small-Scale SB Testing	Sediment Retention, Flow Rate, and Water Quality	2-yr, 24-hr	0.02 (0.008)	0.04 (0.0011)	225.6 (102.3)	30

Note: 1 ac = 0.4 ha; 1 ft^3/s = 0.028 m^3/s; 1 lb. = 0.45 kg

5. GEOTEXTILE MATERIALS

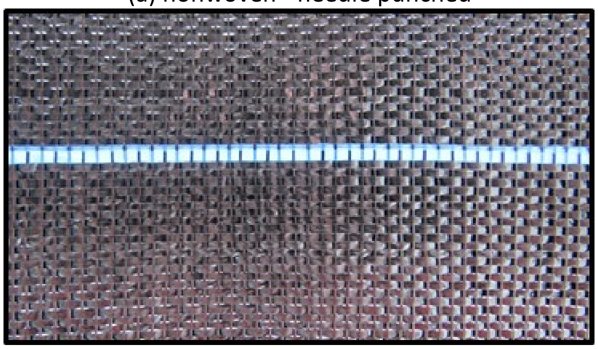
For this research effort, two nonwoven and three woven geotextiles were selected for evaluation. While all nonwoven geotextiles start out as a loosely connected synthetic polymer fibers, the method in which bonding occurred varies. The most common method for bonding is by mechanically entangling staple fibers or continuous filaments using heated rollers equipped with barbed needles. Geotextiles manufactured using this needle-punch process are typically black in color and have a felt-like consistency, as shown in Figure 10(a). Spunbonding is another popular method for bonding synthetic fibers. Manufacturing typically consist of jetting extruding filaments onto a collection belt and passing the matrix through heated rollers to bond the fibers. Finished products are typically gray in color with a smooth finish, as shown in Figure 10(b). Key differences between the two method is that spunbond products typically have reduced pore size openings and increased tensile strength when compared to needle-punched products (*U.S. Fabrics 2018*).

Woven geotextiles are manufactured in two basic structures: slit film and monofilament. Slit film geotextiles are manufactured by slitting polypropylene sheets into narrow flat strands of yarn and weaving them together to from a woven sheet. These types of geotextiles work well in geotechnical applications but do not perform well in filtering applications due to low permeability and increased clogging potential. Monofilament geotextiles are manufactured by extruding strands of polypropylene yarn and weaving them together to form strong, highly permeable products that are commonly used in filtering applications (*U.S. Fabrics 2018*). Three variations of monofilament geotextiles were evaluated during this study: wide filament – constant density [Figure 10(c)], narrow filament – constant density [Figure 10(d)], and narrow filament – variable density [Figure 10(e)]. Each of these geotextiles are better known within industry as Blue Stripe, Red Stripe, and Green Stripe, respectively, due to the colored filaments woven into each of the geotextiles. Green Stripe was the only fabric evaluated that incorporated a stage release design concept which allows effluent flow rates to increase as water depth increases. This is accomplished by reducing filament weave density within each horizontal zone of the geotextile. Figure 10(f) illustrates the locations of Zones B – E when installed in a field application, with Zone A being the portion of fabric trenched in the soil. The physical properties and published flow capabilities associated with each of these geotextiles are summarized in Table 4. Manufacture data sheets for each geotextile are provided in the appendix.

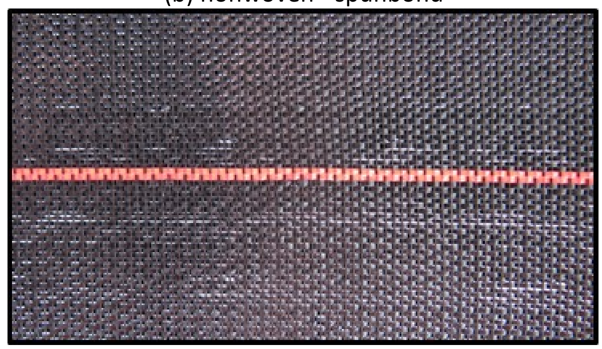


(a) nonwoven - needle punched

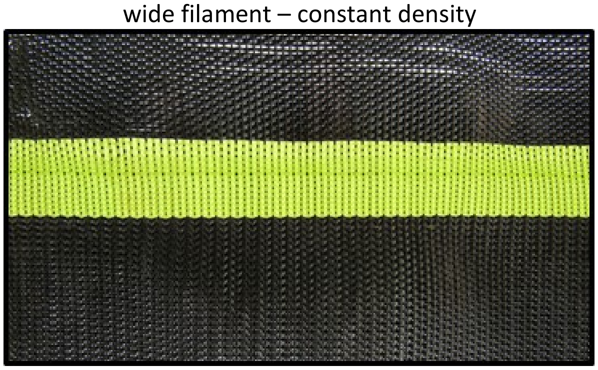
(b) nonwoven - spunbond



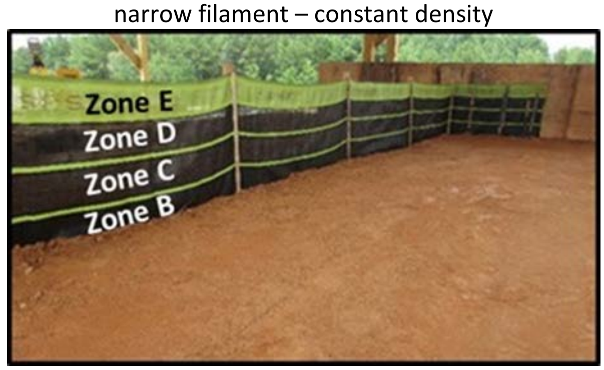
(c) woven monofilament – blue stripe
wide filament – constant density



(d) woven monofilament – red stripe
narrow filament – constant density



(e) woven monofilament – greed stripe
narrow filament – variable density



(f) green stripe – stage release zones

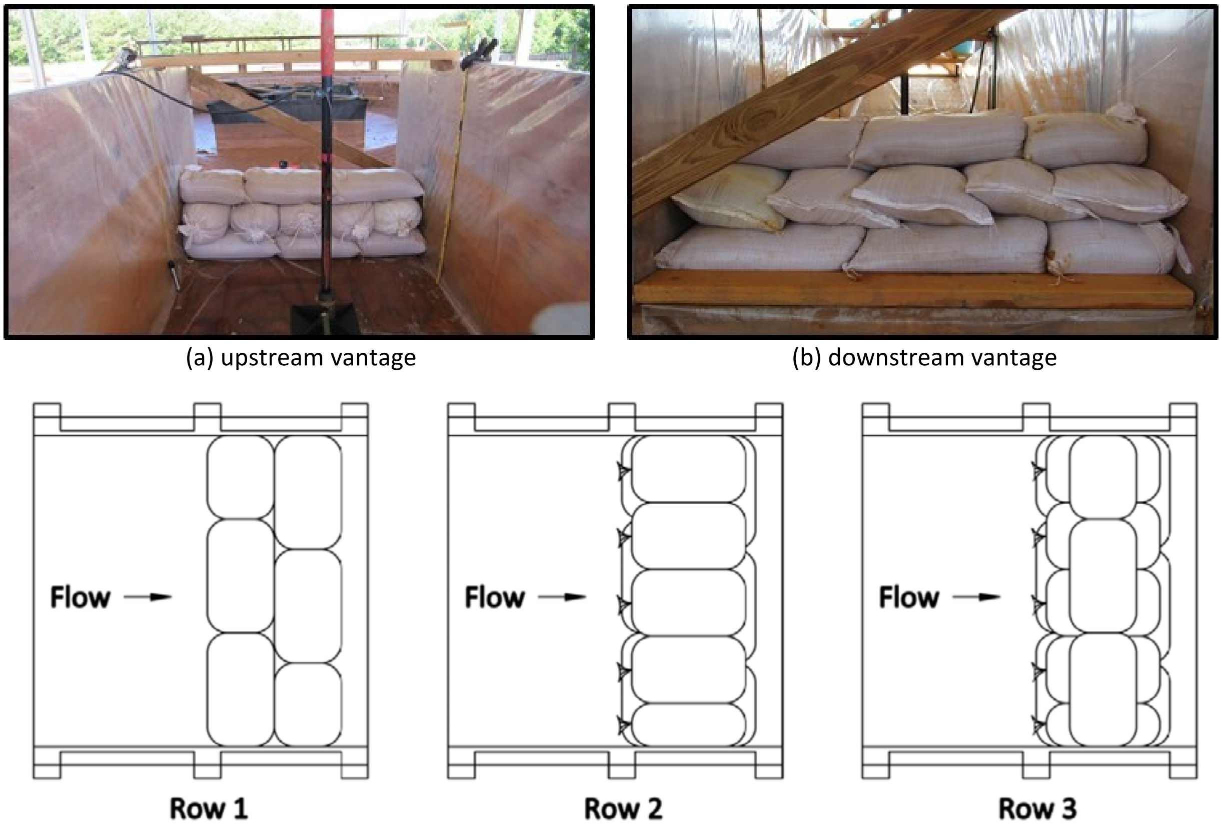
Figure 10. Geotextile materials evaluated.

Table 4. Geotextile Material Properties

Geotextile	Zone	Weight oz./yd^2 (g/m^2)	MD Filament Width in. (mm)	MD Density fila./in. (fila./cm)	XMD Density fila./in. (fila./cm)	AOS U.S. Sieve (mm)	Flow[a] gpm/ft^2 (lpm/m^2)
Nonwoven Needle-Punched (*Skaps 2018*)	n/a	3.5 (118.7)	n/a	n/a	n/a	50 (0.297)	150 (6,103)
Nonwoven Spunbond (*Silt Saver 2014*)	n/a	4.8 (162.7)	n/a	n/a	n/a	70 (0.210)	180 (7,324)
Woven Blue Stripe (*DDD 2015a*)	n/a	3.3 (111.9)	0.055 (1.4)	20 (8)	14 (5)	40 (0.420)	93 (3,784)
Woven Red Stripe (*DDD 2015b*)	n/a	5.6 (189.9)	0.040 (1.0)	28 (11)	18 (7)	30 (0.595)	95.5 (3,886)
Woven Green Stripe (*Silt Saver 2013*)	E[b]	5.2 (176.3)	0.030 (0.76)	24 (9)	20 (8)	20 (0.841)	324 (13,183)
	D[b]	6.2 (210.2)	0.030 (0.76)	28 (11)	20 (8)	20 (0.841)	235 (9,562)
	C[b]	6.7 (227.2)	0.030 (0.76)	32 (12)	20 (8)	20 (0.841)	210 (8,545)
	B[b]	7.3 (247.5)	0.030 (0.76)	36 (14)	20 (8)	40 (0.420)	141 (5,737)

Note: [a] =clear water flow rates determined using ASTM D4491; [b] = zone locations shown in Figure 10(f); n/a = not applicable; MD = Machine Direction; XMD = Cross Machine Direction; AOS = Apparent Opening Size; fila. = filament

In addition to the aforementioned geotextiles, a stacked sandbag configuration was installed and evaluated using the presented methodology. The installation consisted of stacking sandbags in alternating directions while also staggering abutment ends. These evaluations were conducted to compare the performance of a stacked sandbag configuration to various geotextiles while also demonstrating a proof-of-principle for evaluating three-dimensional products within the small-scale testing apparatus. Figure 11 illustrates the sandbag installation and associated schematic.



(a) upstream vantage (b) downstream vantage

(c) installation schematic

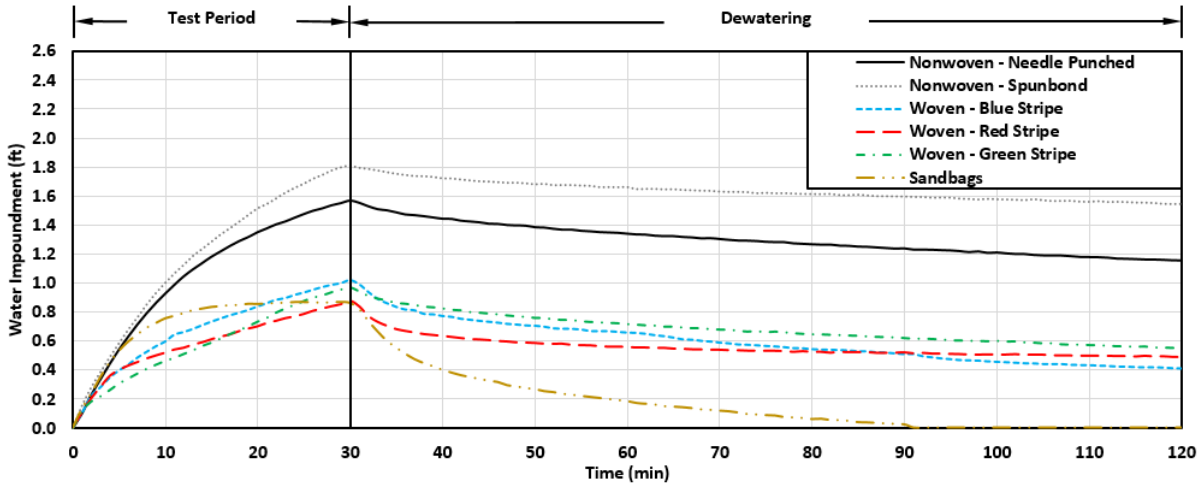
Figure 11. Small-scale sandbag installation details.

6. RESULTS AND DISCUSSION

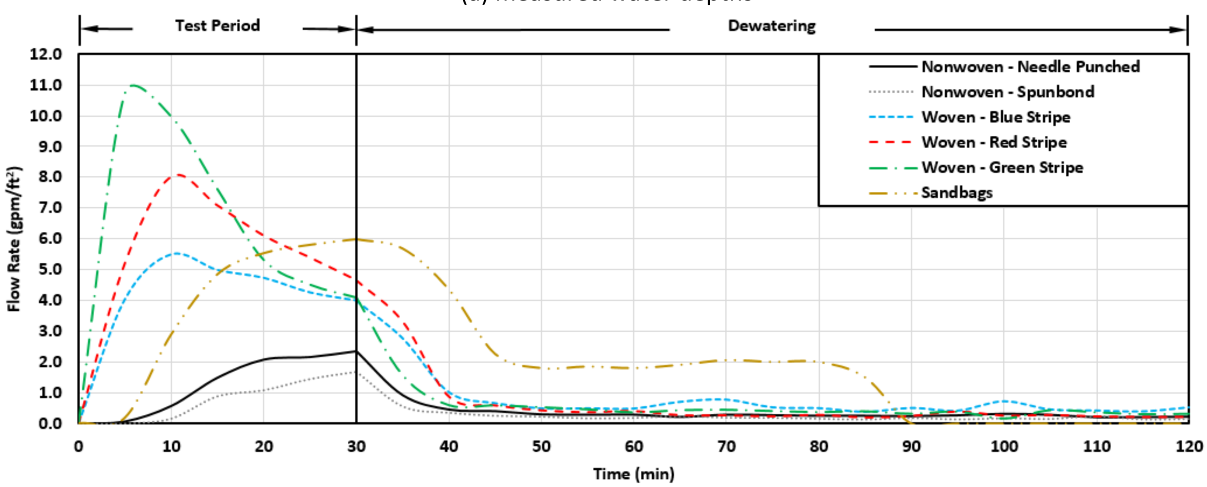
The following is a summary of the results and observations made from performance evaluations of five geotextile fabrics and a stacked sandbag configuration using a constant sheet flow of 0.04 cfs (0.0011 m^3/s) over a 30-minute duration.

6.1 HYDRAULIC EVALUATION

Hydraulic conductivity of the filtering component of a SB is a key parameter to determine during performance evaluations. Impoundment depth measurements obtained throughout each experiment provide a means for evaluating the hydraulic performance of each geotextile tested. Figure 12(a) shows average impoundment depths over three installations for each material evaluated and Figure 12(b) shows the calculated flow rates. From the plots, it is evident that nonwoven geotextiles impound considerably more volume than woven geotextiles. This is expected due to nonwoven geotextiles possessing reduced apparent opening size (AOS) when compared to woven monofilament geotextiles. When comparing the two nonwoven geotextiles, spunbond creates a slightly large impoundment than needle-punched. This increased impoundment resulted in spunbond effluent flows being reduce by 30% when compared to needle-punched.



(a) measured water depths



(b) calculated effluent flow rates per square foot of geotextile

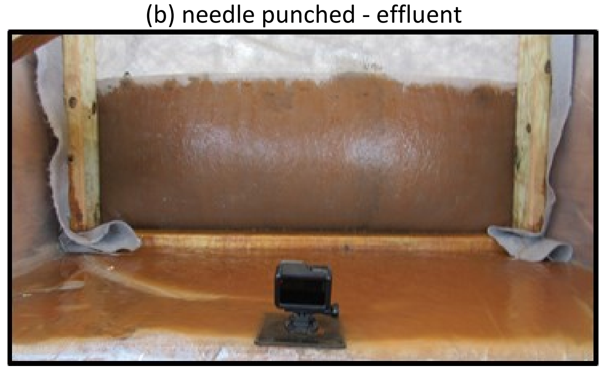
Figure 12. Small-scale hydraulic analyses.

Figure 13 shows hydraulic observations made during nonwoven geotextile testing.

(a) needle punched - impoundment

(b) needle punched - effluent

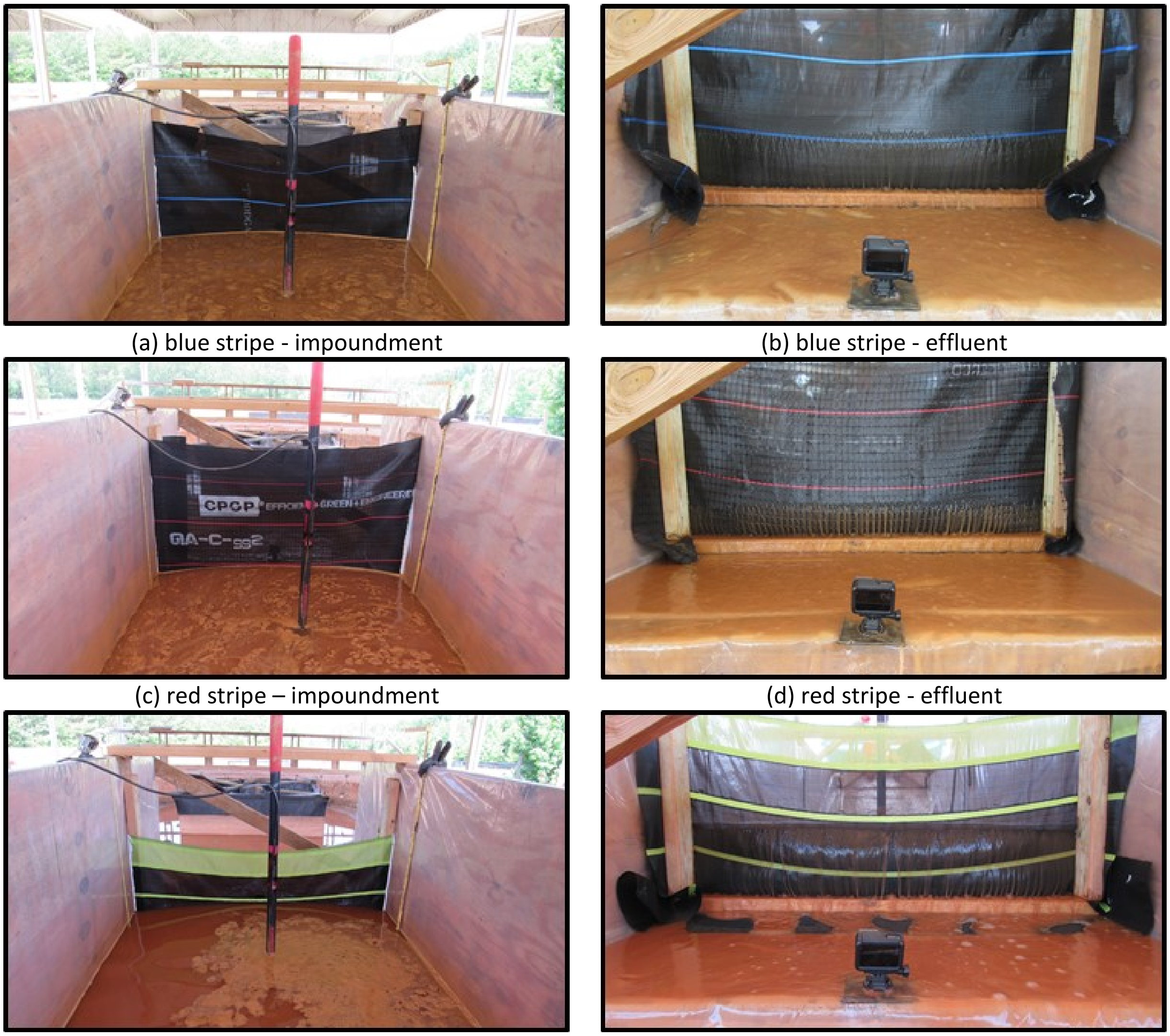
(c) spunbond – impoundment



(d) spunbond - effluent

Figure 13. Nonwoven geotextile hydraulic observations.

As shown in Table 4, filament density associated with each woven geotextile varies slightly. This change in filament density affects the quantity of pore opening per unit of surface area. Based on filament densities shown, blue stripe has the least quantity of pore opening at 280 pores/in.^{2} (40 pores/cm^2), red stripe has 504 pores/in.^{2} (77 pores/cm^2), and green stripe has the most at 720 pores/in.^{2} (112 pores/cm^2). These material properties suggest that effluent flow rates would be 2.5 times higher for green stripe when compared to blue stripe. To test this hypothesis, a single factor ANOVA was conducted on average effluent flow rates calculated over the 30-minute testing period. The test failed to find a significant difference between woven geotextile flow data. This statistical analysis suggest that while each woven geotextile tested is comprised of a distinct manufacturing design to control effluent flow, no significant flow variations occurred between woven geotextiles. In addition, each geotextile emitted similar effluent flows when subjected to sediment-laden runoff. Figure 14 shows the hydraulic observations made during woven geotextile testing.



(a) blue stripe - impoundment (b) blue stripe - effluent

(c) red stripe – impoundment (d) red stripe - effluent

(e) green stripe - impoundment (f) green stripe - effluent

Figure 14. Woven geotextile hydraulic observations.

Sandbag barriers are commonly used in ditch check and inlet protection applications, while their uses as a construction site perimeter control is less common. The installation configuration tested, which consisted of a rotated middle row, was based on ALDOT standard drawings for ditch checks and inlet protection that provides improved friction between bags while also minimized gap voids. As illustrated in Figure 15(a), the average maximum impoundment achieved during evaluations was 0.87 ft (0.27 m), which was lower than all geotextiles evaluated. Hydraulic observations made during testing indicated that sandbags did not provide a tight seal and flow passed through abutment gaps with minimal to no flow passing through the sand medium, as shown in Figure 15(b). Sandbags were the only practices to achieve complete dewatering during the observational period, which occurred 60 minutes into dewatering.


(a) maximum impoundment


(b) flow passing through abutment gaps

Figure 15. Sandbag hydraulic observations.

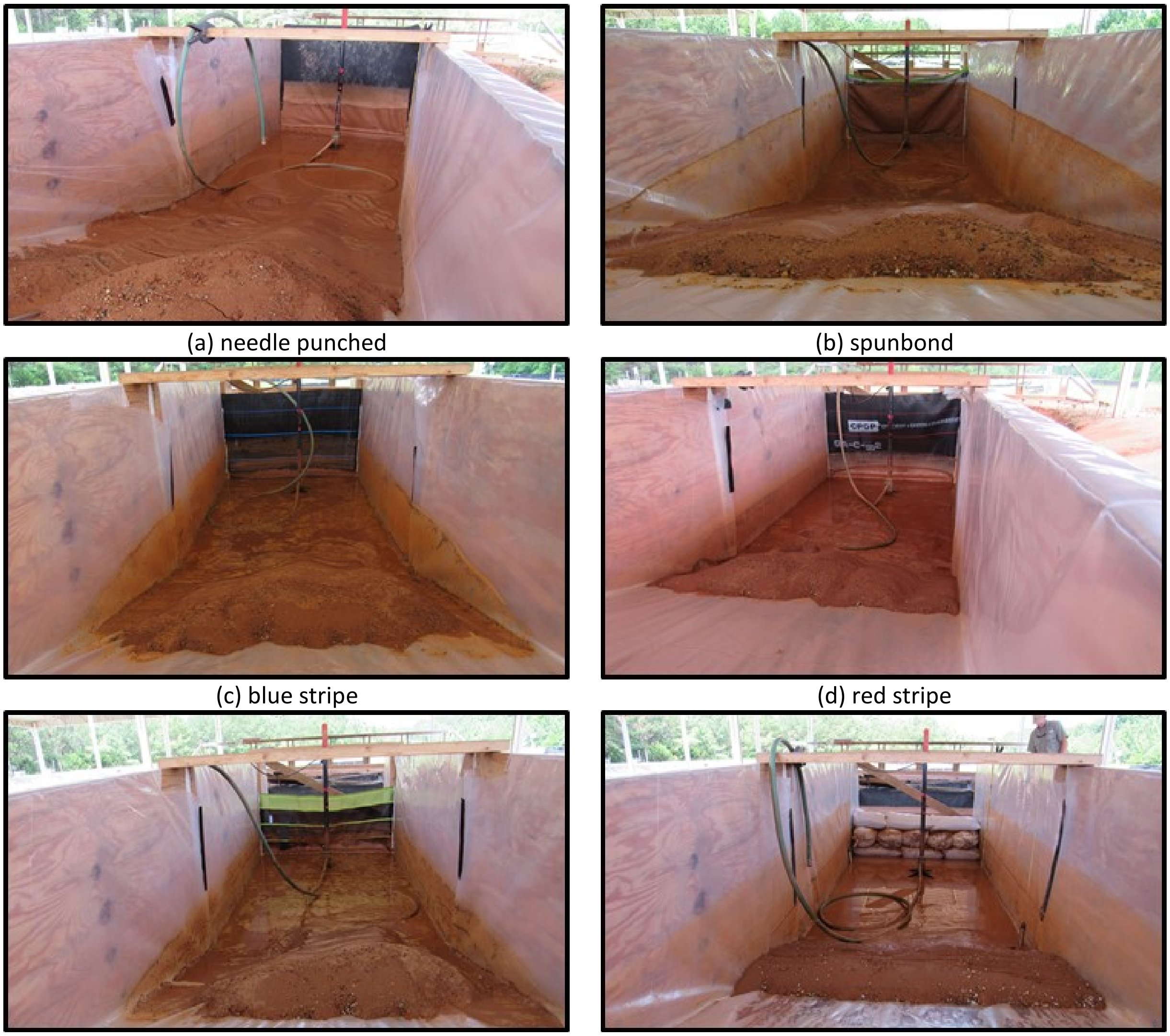
6.2 Sediment Retention Evaluation

Sediment retention indicates the percent of sediment removed from sediment-laden flow mainly through the process of sedimentation. Currently, ASTM D5141 does not specifically outline a process for differentiating the quantity of sediment removed by geotextile filtration and through the process of sedimentation. Implementation of the aforementioned small-scale sediment retention methodology has proved to an effective means for filling this evaluation gap. A complete summary of small-scale sediment retention results is provided in Table 5, along with maximum impoundment depths and effluent flow rates. Results obtained from needle-punched and spunbond geotextiles indicate average sediment retention rates of 97% and 98%, respectively. Of the geotextile types tested, nonwoven was the most effective and consistent at removing sediment through sedimentation. Woven geotextile results indicated that red, green, and blue stripe fabrics had average sediment retention rates of 94%, 93%, and 87%, respectively. Of all small-scale sediment retention evaluations, sandbag were the least effective with an average retention rate of 83%. Standard deviations of sediment retention results for green stripe, blue stripe, and the sandbag installations was 4%, 6%, and 8%, respectively. These deviations were greater than both nonwoven geotextiles and the red stripe geotextile (e.g., 1%). Figure 16 shows sediment deposition observations for each practices evaluated.

Table 5. Small-Scale Performance Results

Material		Install.	Sediment Retained	Max Depth ft (m)	Avg. Effluent Flow gpm/LF (lpm/LM)[a] Test Period	Avg. Effluent Flow gpm/LF (lpm/LM)[a] Dewatering	Avg. Effluent Flow gpm/ft² (lpm/m²)[b] Test Period	Avg. Effluent Flow gpm/ft² (lpm/m²)[b] Dewatering
Nonwoven Geotextiles	Needle Punched	I1	97%	1.54 (0.47)	1.94 (24.12)	0.54 (6.73)	1.49 (60.9)	0.48 (19.5)
		I2	96%	1.63 (0.50)	1.72 (21.34)	0.24 (2.94)	1.29 (52.4)	0.21 (8.5)
		I3	98%	1.55 (0.47)	1.96 (24.35)	0.24 (3.02)	1.59 (64.6)	0.22 (9.1)
		Avg.	**97%**	**1.57 (0.48)**	**1.88 (23.27)**	**0.34 (4.23)**	**1.46 (59.3)**	**0.30 (12.4)**
	Spunbond	I1	97%	1.85 (0.56)	1.35 (16.70)	0.31 (3.87)	0.86 (35.2)	0.18 (7.4)
		I2	98%	1.79 (0.55)	1.38 (17.16)	0.39 (4.79)	0.88 (35.8)	0.24 (9.9)
		I3	98%	1.79 (0.55)	1.29 (16.00)	0.28 (3.48)	0.87 (35.4)	0.22 (9.1)
		Avg.	**98%**	**1.81 (0.55)**	**1.34 (16.62)**	**0.33 (4.05)**	**0.87 (35.4)**	**0.22 (8.8)**
Woven Monofilament Geotextiles	Blue Stripe	I1	93%	0.97 (0.30)	3.33 (41.28)	0.49 (6.11)	5.25 (213.7)	0.96 (39.2)
		I2	86%	1.13 (0.34)	2.36 (29.22)	0.48 (5.95)	3.91 (159.2)	0.63 (25.8)
		I3	81%	0.98 (0.30)	3.07 (38.04)	0.34 (4.25)	4.57 (186.3)	0.51 (20.9)
		Avg.	**87%**	**1.03 (0.31)**	**2.92 (36.18)**	**0.44 (5.44)**	**4.57 (186.4)**	**0.70 (28.6)**
	Red Stripe	I1	93%	1.01 (0.31)	3.29 (40.82)	0.31 (3.87)	4.24 (172.8)	0.42 (17.0)
		I2	95%	0.81 (0.25)	2.69 (33.40)	0.30 (3.71)	7.19 (292.9)	0.55 (22.5)
		I3	94%	0.84 (0.26)	3.31 (41.05)	0.31 (3.79)	6.81 (277.3)	0.57 (23.2)
		Avg.	**94%**	**0.89 (0.27)**	**3.07 (38.11)**	**0.31 (3.79)**	**6.08 (247.7)**	**0.51 (20.9)**
	Green Stripe	I1	93%	1.04 (0.32)	3.16 (39.20)	0.40 (4.95)	5.61 (228.7)	0.54 (21.8)
		I2	90%	0.91 (0.28)	3.31 (41.05)	0.29 (3.63)	10.45 (425.7)	0.42 (17.0)
		I3	97%	0.98 (0.30)	3.25 (40.35)	0.31 (3.79)	4.78 (194.7)	0.38 (15.6)
		Avg.	**93%**	**0.98 (0.30)**	**3.19 (39.50)**	**0.33 (4.12)**	**6.95 (283.0)**	**0.45 (18.1)**
Sandbags		I1	74%	0.94 (0.29)	3.48 (43.14)	0.78 (9.61)	3.93 (159.9)	1.61 (65.5)
		I2	86%	0.83 (0.25)	3.61 (44.76)	0.77 (9.49)	4.52 (184.2)	2.82 (114.9)
		I3	89%	0.84 (0.26)	3.59 (44.53)	0.80 (9.87)	4.05 (164.9)	4.31 (175.6)
		Avg.	**83%**	**0.87 (0.27)**	**3.56 (44.14)**	**0.78 (9.66)**	**4.16 (169.7)**	**2.91 (118.7)**

Note: [a] = average effluent flow rate in gallon per minute per linear foot of geotextile (liter per minute per linear meter); [b] = average effluent flow rate in gallon per minute per square foot of geotextile; 1 ft = 0.3 m; 1ft^2 = 0.093 m^2; 1 gpm = 3.78 lpm



(a) needle punched (b) spunbond

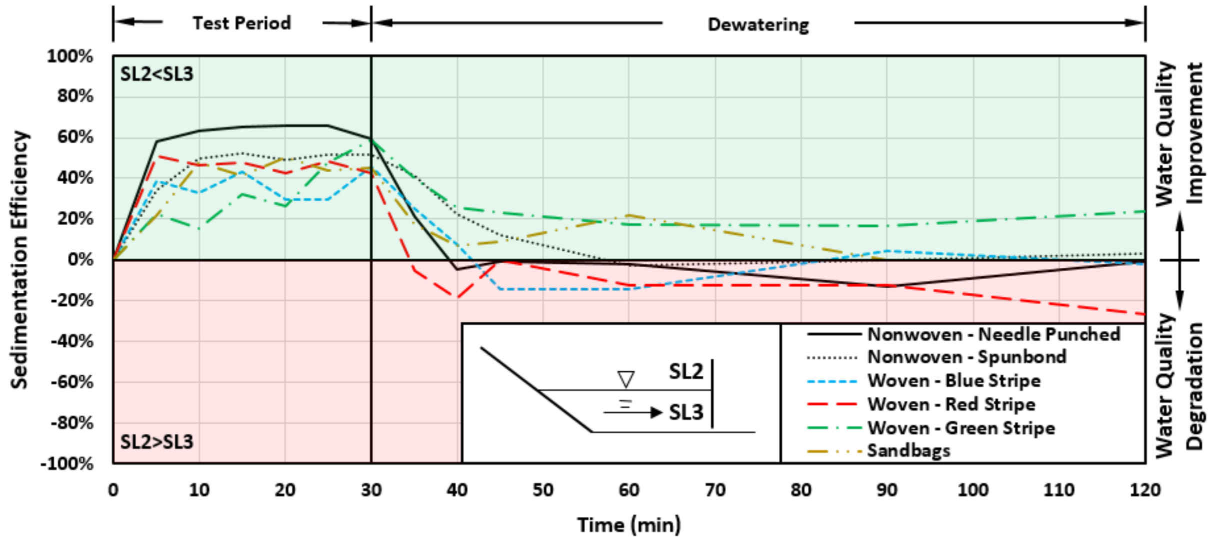
(c) blue stripe (d) red stripe

(e) green stripe (f) sandbags

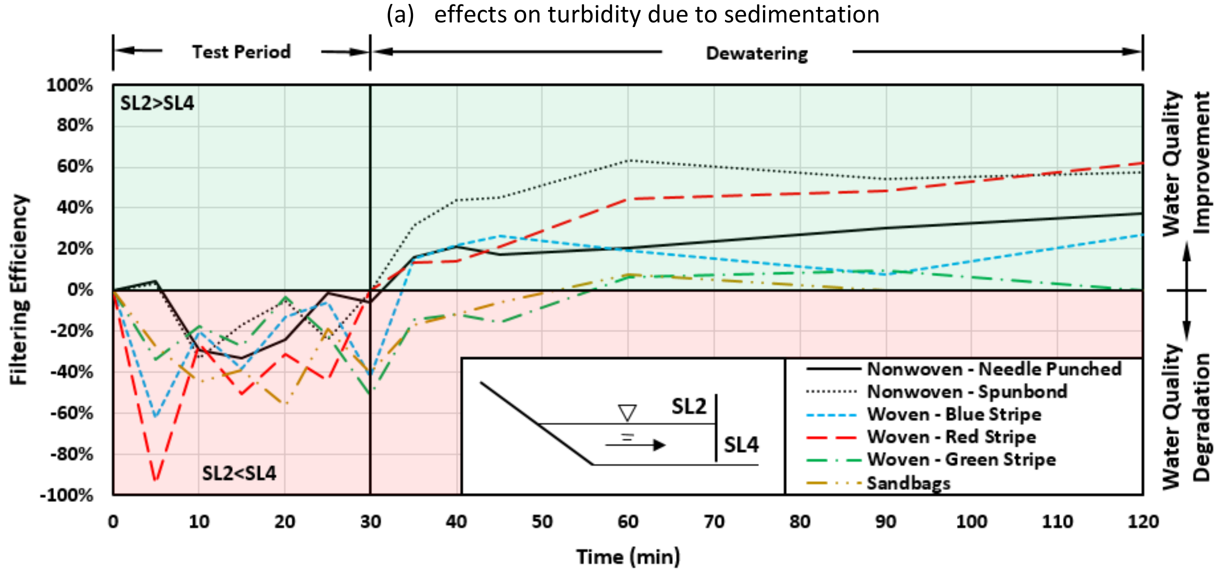
Figure 16. Small-scale sediment deposition observations.

6.3 WATER QUALITY EVALUATION

Turbidity readings obtained from grab samples gathered over the duration of each experiment were used to evaluate changes in water quality as flow progressed through the small-scale testing apparatus. To distinguish the extent individual mechanisms contribute to water quality improvements within the system, analyses were conducted on turbidity reductions due to sedimentation and material filtration. Water quality effects due to sedimentation were determined be comparing turbidity levels along the bottom of the impoundment (i.e., SL3) to those along the impoundment surface (i.e., SL2) at concurrent sampling times. Figure 17(a) illustrates time-variable sedimentation efficiencies for each material evaluated. Water quality effects due to material filtration were determined by comparing turbidity levels along the impoundment surface (i.e., SL2) to those downstream of the material installation (i.e., SL4) at concurrent sampling times. Turbidity levels along the impoundment surface were used to determine filtration efficiency because soil particles clog pore passages within the geotextile as tests progress and water depth increases, thus only allowing water along the surface of the impoundment to pass through the geotextile fabric. Time-variable filtering efficiencies are shown in Figure 17(b). Plotted results are reported as percent increase/decrease in turbidity for each material tested over the 120-minute evaluation period. Positive percentages (i.e., shaded green) indicate water quality improvements and negative percentages (i.e., shaded red) indicate degradation of water quality between respective sampling locations.



(a) effects on turbidity due to sedimentation



(b) effects on turbidity due to material filtration

Figure 17. Small-scale water quality analysis.

From the plots, it is evident that during the 30-minute test period, substantial reductions in turbidity (i.e., 34% to 63%) result from sedimentation while little to no improvements result from material filtration. Based on analyses of the sedimentation efficiency plot, nonwoven – needle punched was the most efficient by reducing turbidity an average of 63% during the test period. Green stripe was the least efficient with a 34% reduction; however, it was the most efficient during dewatering with a 24% reduction in turbidity due to sedimentation. Analyses of the filtering efficiency plot indicated that on average water quality degraded by 29%, thereby failing to improve water quality during the 30-minute test period. However, filtering efficiencies improve on average by 19% during dewatering. While these water quality improvements are desirable, effluent flow volumes during dewatering are substantially less than flows observed during the test period. These observations are a result of pore clogging, which minimizes effluent flow and prolongs impoundment retention time.

7. CONCLUSIONS

This study has provided a greater understanding of silt fence geotextile performance for controlling sediment and the need to improve upon the ASTM standard for evaluating the filtering efficiency and flow rate of the filtering component of sediment retention devices. The study included the design and construction of a small-scale SB testing apparatus capable of simulating a wide range of design storm scenarios. The apparatus was designed to accommodate various manufactured geotextiles and sediment control devices. The presented methodology outlines a means for selecting appropriate flow rates and sediment loads based on regionally specific design storms data. The developed procedure lends to dedicated and controlled testing that produces replicable experimental results. The small-scale testing apparatus and presented methodology provides researchers with an improved method to evaluate innovative geotextile fabrics and material configurations in a controlled environment that allows for better understanding of performance capabilities. Results of standardized performance based testing will lead to improved design guidance for practitioners and regulatory agencies to reference when selecting geotextiles to incorporate into their SB designs.

Under the developed testing regime, performance evaluations were conducted on two nonwoven geotextiles, three woven geotextiles, and a stacked sandbag installation. Data collection included: impoundment depth, sediment retention weights, and grab samples for water quality analyses. Each of these parameters were subsequently used to evaluate the performance capabilities of each material evaluated. Effluent flow rates observed during the test period for nonwoven geotextiles were on average 43% lower than woven materials, which resulted in extensive retention times for nonwoven materials. Sediment retention results indicated that on average nonwoven geotextiles (e.g., 97%) outperform woven geotextiles (e.g., 91%). Water quality analyses suggest that the primary means for turbidity reduction is sedimentation during the test period (e.g., 46%) and filtration during dewatering (e.g., 19%). This suggests that having adequate stormwater storage upstream of an installation is important to dissipate inflow energy, promote sedimentation, and minimize resuspension of particles. Finally, an evaluation of stacked sandbags established that performance capabilities of three-dimensional SB products can be determined using the small-scale SB testing apparatus. A comprehensive performance summary of materials evaluated as part of this study that ALDOT can easily reference is provided in Table 6.

Table 6. Comprehensive Performance Summary

Material	Sediment Retention	Avg. Effluent Flow (gpm/LF)[a]		Avg. Sedimentation Efficiency[b]		Avg. Filtration Efficiency[b]	
		Test Period	Dewatering	Test Period	Dewatering	Test Period	Dewatering
Needle Punched	97%	1.88	0.34	63%	0%	-15%	24%
Spunbond	98%	1.34	0.33	48%	13%	-13%	49%
Blue Stripe	87%	2.92	0.44	37%	1%	-30%	19%
Red Stripe	94%	3.07	0.31	46%	-13%	-41%	34%
Green Stripe	93%	3.19	0.33	34%	24%	-26%	-4%
Sandbags	83%	3.56	0.78	46%	14%	-41%	-7%

Note: [a] = average effluent flow rate in gallons per minute per linear foot of geotextile; [b] = positive percentages indicate water quality improvement, negative percentages indicate water quality degradation

8. ACKNOWLEDGEMENT

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APPENDIX

Geotextile Manufacture Data Sheets

Nonwoven – Needle Punched

SKAPS GT-135
NON-WOVEN GEOTEXTILE

SKAPS INDUSTRIES
335 Athena Drive,
Athens, GA 30601
Ph: (706)-354-3700
Fax: (706)-354-3737
Email: contact@skaps.com

SKAPS GT-135 is a needle-punched nonwoven geotextile made of 100% virgin polypropylene staple fibers, which are formed into a random network for dimensional stability. SKAPS GT-135 resists ultraviolet deterioration, rotting, biological degradation, naturally encountered alkalis and acids. Polypropylene is stable within the pH range of 2 to 13. SKAPS GT-135 is NTPEP certified and meets requirements as per AASHTO Standards and/or D.O.T. Standards.

SKAPS GT-135 conforms to the Minimum Average Roll Values (MARV) listed below:

PROPERTY	TEST METHOD	ENGLISH (MARV[2])	METRIC (MARV[2])
Grab Tensile Strength	ASTM D 4632	90 lbs.	0.401 kN
Grab Elongation	ASTM D 4632	50%	50%
Trapezoid Tear Strength	ASTM D 4533	40 lbs.	0.178 kN
CBR Puncture Resistance	ASTM D 6241	265 lbs	1.178 kN
Permittivity[4]	ASTM D 4491	2.0 sec^{-1}	2.0 sec^{-1}
Water Flow[4]	ASTM D 4491	150 gpm/ft^2	6095 $l/min/m^2$
Apparent Opening Size (AOS)[3&4]	ASTM D 4751	50 Std. U.S. Sieve	0.300 mm
UV Resistance	ASTM D 4355	70%/500 hrs.	70%/500 hrs.

PACKAGING

Roll Dimensions (W x L)	12.5 x 360 ft. 15 x 360 ft.	3.81 m x 109.8 m 4.6 m x 109.8 m
Area Per Roll	500 sq. yards 600 sq. yards	418.3 sq. meters 505.1 sq. meters
Estimated Roll Weight	130 lbs. 155 lbs.	59 kg 70 kg

NOTES:

1. The property values listed above are subject to change without notice.
2. Minimum Average Roll Values (MARV) is calculated as the average minus two standard deviations. Statistically, it yields approximately 97.5% degree of confidence that any samples taken from quality assurance testing will meet or exceed the values described above.
3. Maximum Average Roll Value (MaxARV)
4. At time of manufacturing. Handling may change these properties.

This information is provided for reference purposes only and is not intended as a warranty or guarantee. SKAPS assumes no liability in connection with the use of this information.

Nonwoven – Spunbond

SILT - SAVER®
EROSION & SEDIMENT CONTROL PRODUCTS
WWW.SILTSAVER.COM

PRODUCT DESCRIPTION FOR

Silt-Saver Fabric - BSRF PRIORITY 1

BSRF Priority 1 silt fence is a gray, continuous filament polyester, needlepunched, nonwoven fabric. BSRF Priority 1 conforms to the values in the following table:

FABRIC PROPERTY *			STANDARD VALUES
Fabric weight, oz/yd2		ASTM 5261	4.8 (min. 4.0)
Thickness, mils		ASTM 5199	39.4 (29.0 – 53.1)
Grab Strength, lbs.	MD	ASTM 4632	130 (min. 108)
	CD	ASTM 4632	105 (min. 83)
Grab Elongation, %	MD	ASTM 4632	65 (min. 50)
	CD	ASTM 4632	80 (min. 50)
Trapezoid Tear, lbs.	MD	ASTM 4533	49 (min. 36)
	CD	ASTM 4533	45 (min. 31.5)
Mullen Burst, psi		ASTM 3786	190 (min. 160)
Puncture Strength, lbs.		ASTM 4833	49 (min. 36)
Water Permeability, gpm/ft2 Vert		ASTM 4491	180 (min. 160)
AOS		ASTM 4751	70 mesh (212 microns)

* Material sampled and tested in accordance to Quality Assurance test methods. Copies of these test methods and procedures are available upon request.

Silt-Saver, Inc. * 1094 Culpepper Drive, Conyers, GA 30094
Phone 770-388-7818 * TOLL FREE 1-888-382-SILT (7458) * Fax 770-388-7640 * www.siltsaver.com

BNE/056160English Units
08/05/2014

Woven – Blue Stripe

DDD EROSION CONTROL, INC.

12/22/2017

This is to certify that the product & specification listed below as **DDDGA36-A (aka Alabama Type C silt fence)** and sold to Sunshine Supplies, is further manufactured & sold by DDD Erosion Control, Inc. of Ashburn, Georgia. The results below reflect the product style that is further manufactured by DDD Erosion Control, Inc. and sold to Sunshine Supplies & identified on our invoices to them. This product is manufactured with a black Mono / Tape Construction and with blue marker yarns. The specification also meets and exceeds the AASHTO M288 and ASTM D 6461 / D6461M specifications.

DDDGA36-A with Stakes Data Sheet

Georgia DOT Type A Silt Fence / Alabama Type C Silt Fence Fabric

PROPERTY	TEST METHOD	Georgia DOT Specifications	2015 TYPICAL TEST RESULTS ENGLISH
Mass Per Unit Area	ASTM D 5261		3.3 oz/sy
Grab Tensile Strength	ASTM D 4632	120 x 100 lbs	158 x 106 lbs
Elongation	ASTM D 4632	40 %max	16x14%
Puncture	ASTM D 4833		63 lbs
Trapezoidal Tear	ASTM D 4533		53 x 39lbs
Permittivity s^{-1}	ASTM D 4491		1.24 sec^{-1}
Bursting Strength, psi		175 psi	
AOS Sieve	ASTM D 4751	30 sieve	40 sieve
Water Flow Rate	ASTM D 4491	25 gpm/ft^2	93 gpm/ft^2
UV Resistance * Retained after 500 hrs.	ASTM D 4355	80% after 500 hours	80% after 500 hours
Hardwood Stakes	1 ½ x 1 ½ x48"	17 stakes	6' spacing
Roll Size Completed Product	3' x 96'		

***Test Results Provided By Golder Associates Inc. 2015**
The properties above are subject to change without notice.
At the time of manufacturing, handling, storage and shipping may change these properties.
Physical and hydraulic properties reported as minimum average roll values (MARV).
AOS reported as maximum avg. roll value.
*UV Testing Not provided by Golder Lab during this testing

2017 Verified

DDD Erosion Control, Inc. is a Woman Owned /Veteran Owned Small Business

1383 Industrial Drive * P.O. Box 694 * 229-567-0751 (P) * 229-567-0752 (F) * 3derosion.com *

Woven – Red Stripe

DDD EROSION CONTROL

Georgia DOT Type "C" Silt Fence Fabric

GA-CSA Data Sheet

DDD Erosion Controls' GA-CSA is a Georgia approved, high strength / highly durable, mono-mono silt fence fabric assembly designed for high water flow areas. The construction assembly allows for a poly-mesh netting to be sewn on the fabric making it a single unit and the netting has been tested and determined to be strong enough to replace the wire fencing that was in the original style of installation. The assembly has also allowed the state of Georgia through testing evidence to replace the original metal T-posts with 1 3/4" x 1 7/8" x 48" hardwood stakes, with 4' spacing of stakes. This assembly has not only reduced costs for the state of Georgia, but it has also become a favorite of installers, due to the ease of installation of one single assembled unit of GA-CSA, versus individual T-Posts/ Rolls of Wire Fencing/ Rolls of Fabric out on the job site. This product can be sold with the hardwood stakes attached to the fabric and netting or it is available for the installer to purchase with only the fabric and netting attached if metal posts are desired.

This product is also available in orange.

Fabric Style Only: DDDGA36-C

PROPERTY	TEST METHOD	TYPICAL TEST RESULTS ENGLISH
Grab Tensile Strength	ASTM D 4632	343 / 241 lbs
Elongation	ASTM D 4632	40 / 29 %
Puncture	ASTM D 4833	99.1 lbs
Mullen Burst	ASTM D 3786	398 psi
Trapezoidal Tear	ASTM D 4533	131 /106 lbs
Permittivity s^{-1}	ASTM D 4491	1.28
AOS Sieve	ASTM D 4751	30 sieve 0.344 Opening Size
Water Flow Rate	ASTM D 4491	95.5 gpm/ft^2
UV Resistance Retained after 500 hrs.*	ASTM D 4355	80% after 500 hours

- Test Results Are Provided From An Independent Testing Lab Golder Associates Inc / March 2015

The properties above are subject to change without notice.
At the time of manufacturing, handling, storage and shipping may change these properties.
Physical and hydraulic properties reported as typical roll values
AOS reported as maximum avg. roll value.
*UV Results Provided By In House Test Results, not by independent lab

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Woven – Green Stripe

TRI/Environmental, Inc.
A Texas Research International Company

Sediment Control Test Results

Client: SiltSaver
TRI Log #: 2278-03-21

Test Procedure: ASTM D 5141

Sample	Soil Type	Flow Rate per ASTM D 5141, gpm/ft^2	Max. Ht., in.	Flow Rate per Linear Foot, cfs	Flow Rate per 100 lf (1/4-acre for 110-ft slopes), cfs	Cumulative Flow Rate per 100 lf
Staged Release Silt Fence - Zone B	Silty Clay	0.845	7	0.0011	0.11	0.11
Staged Release Silt Fence - Zone C	Silty Clay	1.066	6	0.0012	0.12	0.23
Staged Release Silt Fence - Zone D	Silty Clay	*1.2*	6	0.0013	0.13	0.36
Staged Release Silt Fence - Zone E	Silty Clay	*1.6*	5	0.0015	0.15	0.51
		estimated based on percent increase in permittivity (see below)	24		Meets/Exceeds TDOT Peak Flow Req't? (see note below)	**yes**

Fence Zone	AOS		Permittivity		Tested Sample
	95% Opening		Falling Head		
	mm	Sieve #	sec^{-1}	gpm/ft^2	
E	0.786	#20	4.33	324	
D	0.818	#20	3.14	235	
C	0.829	#20	2.81	210	
B	0.364	#40	1.89	141	
A			2.89	216	
M288-06	0.6 max	#30	0.05 min	3.75 min	

NOTE: Peak flow requirement is 0.51 cfs for the 5-yr, 24-hr storm event and 1/4-acre area. (TDOT EPSC Device Certification Instructions - April 30, 2008). ASTM D5141 testing is based on a "low head" and, thus, the flow rates are considered conservative (low) as compared to actual flow when signifcant ponding occurs behind the fence.

Calculations & Report by: C. Joel Sprague, P.E.
Date: 23-Oct-13

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Engineering Large-scale Testing: Denver Downs Research Facility, Anderson, SC / 864-242-2220 / jsprague@tri-env.com