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Performance of compost filter socks and conventional sediment control barriers used for perimeter control on construction sites

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Abstract: The objective of this study was to compare the sediment removal efficiency, peak flow rate, and cost of straw bales, mulch filter berms, compost filter socks, and compost filter socks + polymer used as perimeter sediment control devices under high intensity/duration single storm event conditions to assist environmental regulators and design professionals in choosing an appropriate best management practice for their construction site or storm water pollution prevention plan. A simulated rainfall intensity/duration was chosen in order to produce a direct runoff (*Q*) per linear unit length of treatment equivalent to that generated in 24-hour 5-year return for north Georgia (11.25 cm [4.5 in]) using the maximum drainage area allowed for silt fence on a 10% slope. All sediment control treatments restricted peak runoff flow rates relative to the bare soil (control). All treatments discharged significantly lower total solids (concentration and load) than the bare soil, while all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale. Removal efficiency for total solid load ranged from 63.5% to 88.2%. Single-event P factor (soil loss ratio) was determined for all treatments and ranged from 0.118 to 0.365. All treatments were significantly lower than the bare soil, and all compost filter socks were significantly lower than the mulch filter berm. All treatments discharged significantly lower total suspended solids (concentration and load) than the bare soil, and all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale. Removal efficiency for total suspended solid load ranged from 60.4% to 89.5%. All compost filter socks had significantly lower turbidity relative to bare soil, and the addition of the polymer to the compost filter sock treatments had significantly lower turbidity relative to the compost filter socks without the polymer. Percent turbidity reduction ranged from 8.1 to 49.1. Total cost of installation was estimated for each sediment control device based on product + freight from distributor + staking materials + labor to install. Total cost for sediment control devices ranged from $1.75 to $2.87 per linear 30 cm (1 ft).

Key words: best management practices—compost filter socks—P factor—sediment control—straw bale—water quality

According to the US Environmental Protection Agency (USEPA), surface water sediment is the nation's leading source of water pollution. Sediment transport to surface waters also carries fertilizers, pesticides, fuels, heavy metals, and other contaminants and substances that attach to soil particles and are commonly spilled at construction sites (Risse and Faucette 2001). Due to Phase II enforcement of the National Pollutant Discharge Elimination System for storm water discharge from construction activities in 2003, evaluating the effectiveness and performance level of sediment control devices (SCDs) has never been more important. It is estimated that the national cost to society due to sedimentation of eroded soil is over $17 billion per year (Brady and Weil 1996).

Performance of Sediment Controls. As states begin to revise their erosion and sediment control and/or storm water management manuals to reflect new information and technology on best management practices (BMPs), many are requiring that erosion and sediment control practices meet a minimum performance standard (South Carolina Department of Transportation 2006). However, there is very little performance data in the research literature, despite a call for this information by environmental regulators and design professionals and the approval and inclusion of these new BMPs into state erosion control manuals. In addition, there is currently no standard test method for evaluating SCDs, and until a standard test method is developed, the best way to comparatively evaluate the performance of these BMPs are under side-by-side controlled research design scenarios. As performance information becomes available for sediment control BMPs, this information can be used to predict soil erosion and soil loss from construction sites. The Universal Soil Loss Equation and Revised Universal Soil Loss Equation have been widely used to empirically predict erosion rates from agricultural and construction sites. The support practice (P) factor within the equations can be used to account for sediment control management practices and their effect on soil loss when used in the landscape. Developing P factors for use within these equations will help design professionals to predict soil loss rates when employing these measures. Sadeghi et al. (2006) and Kelsey et al. (2006) have reported single event P factors for SCDs by determining the soil loss ratio of a specific management practice relative to a bare soil under the same controlled conditions.

As the industry standard BMP for perimeter control of sediment on construction sites, silt fence and straw bales have been evaluated for performance (Keener et al. 2007; Sadeghi et al. 2006; Faucette et al. 2005; Demars et al. 2000; Barrett et al. 1998). However, most emerging sediment perimeter control technologies are of a tubular, three dimensional

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construction as opposed to the planar construction of the silt fence. These new SCDs are designed to allow storm runoff to flow through at higher rates while the three-dimensional constructions of these sediment filters allow the filter itself to trap suspended solids from runoff reducing the need to pond water to achieve sediment removal through deposition. Less ponding and lower head pressure (due to higher hydraulic flow rates) may reduce the propensity for failure from undermining and overtopping in the field. Additionally, if sediment removal efficiency is a result of the performance of the filter—or filtration, instead of its ability to restrict flow and pond water, thereby relying solely on deposition—then the design capacity, spacing, and height for these new SCDs should be based on flow-through rate and not ponding rate. This may also reduce the necessary effective height of the SCD.

In a study conducted at the University of Georgia, Faucette et al. (2005) reported that on a 10% slope with hydromulch treated soils, mulch filter berms, relative to silt fence, reduced sediment loads by as much as 16% to 64%. At the University of Connecticut, Demars et al (2000) reported similarly that under a 1.91-cm (0.75-in) storm event, mulch berms, relative to silt fence and straw bales, reduced total sediment by 80% and 97%, respectively. Additionally, under an 11.2-cm (4.4-in) storm event, mulch berms reduced total sediment relative to straw bales and silt fence by 91% and 92%, respectively.

Kelsey et al. (2006) evaluated 30-cm (12-in) diameter wood fiber logs and 30-cm diameter straw wattles on a loam soil with a 12.5% slope using a design storm of 5 cm h^{-1} (2 in hr^{-1}) for 20 minutes, followed by 10 cm h^{-1} (4 in hr^{-1}) for 30 minutes, followed by 15 cm h^{-1} (6 in hr^{-1}) for 30 minutes. They reported total solid (TS) removal efficiency for the wood fiber logs and the straw wattle of 71% and 20%, respectively.

Theisen and Spittle (2006) evaluated 23-cm (9-in) diameter wood/synthetic fiber blended tubes, wood fiber logs, and straw wattles on a sandy loam soil with a 2% slope. All treatments were trenched 10 cm (4 in) into the soil. Their findings revealed the wood/synthetic fiber tubes reduced TS by 94% while the straw wattle and wood fiber logs both reduced TS by 54%.

Evaluating compost filter socks under bench scale conditions using simulated runoff with a total sediment concentration of 3,000 mg L^{-1} on a 3:1 slope, Faucette and Tyler (2006) reported a mean TS removal efficiency of 98%. Over three successive runoff events, suspended solids removal efficiency and turbidity (NTUs) reduction averaged 70% and 55%, respectively. In a study conducted by the USDA Agricultural Research Service, Sadeghi et al. (2006) reported that on a silt loam soil with a 3:1 slope under a rainfall intensity of 7.5 cm h^{-1} (3.0 in hr^{-1}) for a 30-minute duration, compost filter socks reduced turbidity by 61% and total suspended solids (TSS) by 78%, and silt fence reduced turbidity by 54% and TSS by 71%, relative to bare soil conditions. It should be noted that the aforementioned studies were all conducted under controlled environmental conditions—not active construction test sites.

Polymers may be used in conjunction with SCDs to target specific pollutants in storm water that are common to land-disturbing activities. Polymers that are anionic flocculants and coagulants are often used to reduce suspended solids and turbidity in sediment detention ponds and to temporarily stabilize disturbed soils. Hayes et al. (2005) found that polymers can reduce average turbidity on disturbed soils characteristic to construction sites. Sadeghi et al. (2006) found that by adding these anionic polymers to compost filter socks, the removal efficiency of TSS, with exposure concentrations of 61,000 mg L^{-1} under a single rainfall-runoff event, was increased to 97% and turbidity to 98%, relative to bare soil conditions. These new applications may be of critical importance on highly disturbed silt and clay soils (as these sediments typically stay in suspension longer and are more difficult to remove by SCD management practices), soils recently fertilized for vegetation establishment, or near total maximum daily load designated receiving waters.

Hydraulic flow rates can be useful when determining spacing and maximum allowable watershed drainage areas for these BMPs when creating erosion and sediment control or storm water pollution prevention plans. Additionally, the useful longevity of these technologies, or time to required maintenance, is also important information for environmental regulators, design professionals, and site inspectors. This becomes increasingly important as BMP maintenance is enforced by state agencies and becomes a significant cost to developers and contractors. Many state agencies require that sediment must be removed from the SCD once it accumulates to half the height of the device (Georgia Soil and Water Conservation Commission 2000; Kentucky Transportation Cabinet 2005; South Carolina Department of Transportation 2006; Wisconsin Department of Transportation 2005).

Research Objective. The objective of this study was to compare the sediment removal efficiency performance (TS, TSS, turbidity) and hydraulic flow-through rate of selected sediment barriers based on a 24-hour, five-year return runoff event in order to assist environmental regulators and design professionals in choosing an appropriate BMP for their construction site or erosion and sediment control plan. The authors hypothesized that the compost filter socks would have lower hydraulic flow-through rates and higher sediment removal efficiency than the straw bale and mulch filter berm.

Materials and Methods

Site Description. Research test plots were constructed at Spring Valley Farm in Athens/Clarke County, Georgia, at 33°57' N latitude and 83°19' W longitude (figure 1). The soil was originally classified as an eroded Pacolet sandy clay loam (USDA Soil Conservation Service 1968) and has a high soil erodibility factor (K value) of approximately 0.36 (Wischmeier and Smith 1978). The area receives an average annual rainfall of 1,215 mm, with January through March as the wettest period. The average annual high temperature for the area is 22°C, the average low is 11°C, with a mean annual temperature of 17°C (Weather Channel 2005).

The testing area was cleared of vegetation and graded to a 10% slope with a grading blade mounted skid steer, exposing a semi-compacted (from the skid steer) subsoil (Bt horizon) to simulate land disturbing and grading conditions. Test plot borders were installed to prevent cross contamination of plots (figure 2). Fifteen-cm (6-in) high stainless steel borders were trenched 7.5 cm (3 in) into the soil. The plots were sized to fit the effective rainfall distribution from the rainfall simulator, 1.0 m (3.3 ft) wide by 4.8 m (16 ft) long, for a total plot area of 4.8 m^2 (53 ft^2). To contain water ponding behind sediment control treatments, removable 60-cm (2-ft) tall by 90-cm (3-ft) long border extensions were installed on each side of the plot base and trenched 5 cm (2

Figure 1
Experimental test plots installed with sediment control device treatments.

Figure 2
Experimental test plot with flume and rainfall simulator system.

in) into the soil. To collect runoff, a removable flume was installed at the base of each plot prior to each simulated rainfall event (figure 2). To maintain the structure and integrity of the soil in the plot, a removable stainless steel border was carefully inserted at the base of each plot once the flume was removed after each storm event. The soil was carefully compacted around the removable flume and the removable border after each one was installed for use. See figure 1 and figure 2 for experimental site and plot design.

Treatment Description. Six SCD treatments were installed across the entire base-width of individual test plots. The control (bare soil) received no SCD. All treatments and the control were replicated in triplicate for a total of 21 test plots. See table 1 for a list of treatments, their design and effective heights, and installation detail summary. Design height is defined as the pre-installed height and diameter as reported by the manufacturer, effective height is the actual height of the SCD above the soil surface once installed and subjected to field runoff conditions.

The compost filter sock treatments are a tubular constructed device that uses mesh netting material to contain composted organic filter media that adheres to Filtrexx International specifications for SiltSoxx and FilterMedia (Filtrexx International 2007). Twenty-cm (8-in) and 30-cm (12-in) diameter compost filter socks were evaluated. Two additional treatments utilizing the 20-cm and 30-cm compost filter socks received a proprietary polyachrylamide polymer blend (Silt Stop 705) used to flocculate suspended solids and reduce turbidity (Applied Polymer Systems 2006) and potentially reduce total and suspended solids concentrations and loads passing through the compost filter sock system. The straw (wheat) bales are of rectangular construction, 35-cm (14-in) wide by 45-cm (18-in) high by 90-cm (36-in) long and adhere to California Department of Transportation specifications (Caltrans 2003). The mulch filter berm was composed of pine chips and constructed to 60-cm (24-in) wide and 30-cm (12-in) high according USEPA specifications for filter berms (USEPA 2006).

Treatment Installation. All installation procedures followed manufacturers' and/or government agency specifications. All compost filter socks were cut to a standard length of 1.2 m (4 ft) to allow the ends of the SCD to curl slightly upslope in order to prevent runoff from circumventing the SCD. All SCD treatments were installed at the toe of the slope and immediately upslope from the runoff collection flume. All compost filter socks were installed manually on top of the soil surface using 90-cm (36-in) wood stakes placed at the ends of the SCD (1.2 m) and inserted through the center of the SCD, according to manufacturer's specifications (Filtrexx International 2007). Loose compost FilterMedia was placed and compacted directly upslope of the device according to manufacturer's specifications (Filtrexx International 2007). The polymer was added to one 20-cm (8-in) and one

Table 1
Sediment control device treatments, installation specifications, and total cost.

Treatments	8-in compost filter sock	12-in compost filter sock	8-in compost filter sock + polymer	12-in compost filter sock + polymer	Mulch filter berm	Straw bale	Bare soil (control)
Diameter	8 in (20 cm)	12 in (30 cm)	8 in (20 cm)	12 in (30 cm)	24 in (60 cm)	NA	NA
Design height	8 in (20 cm)	12 in (30 cm)	8 in (20 cm)	12 in (30 cm)	12 in (30 cm)	14 in (35 cm) W x 18 in (45 cm) H x 36 in (90 cm) L	NA
Staked	At ends	At ends	At ends	At ends	No	2 per bale	NA
Cost per linear ft (30 cm)* (product only/ product installed)	$1.80/$1.80†	$2.40/$2.40†	$2.48/$2.48†	$2.74/$2.74†	$1.00/$1.75	$1.37/$2.87*	NA

* Installed cost includes cost of product + freight from distributor ($0.50 per linear ft [30 cm]) + stakes ($0.25 per stake) + labor ($0.25 per linear ft [30 cm]) for install.

† Compost filter socks installed by certified installer, cost provided from installer is all inclusive.

30-cm (12-in) compost filter sock treatment and applied directly to the soil surface at the base of the upslope side of the compost filter sock. The polymer was applied to the 20-cm compost filter sock treatment at 1.6 g per linear cm (1.75 oz per linear ft) and to the 30-cm compost filter sock treatment at 0.8 g per linear cm (0.88 oz per linear ft) (Filtrexx International 2007). Mulch filter berms were installed manually to the soil surface at the dimensions previously described according to USEPA specifications (USEPA 2006). Straw bales were manually secured to the soil surface using two 90-cm wood stakes per bale and abutted at the ends. It should be noted that while installation procedures explicitly followed specification guidelines, often installation guidelines are not adhered to in real-world applications resulting in greatly reduced performance.

Rainfall Simulator and Runoff Event. A Norton Rainfall Simulator with four variable speed V-jet oscillating nozzles originally obtained from the USDA Agricultural Research Service National Soil Erosion Research Lab, West Lafayette, Indiana, was used to simulate the rain event (figure 2). During the rain event, water pressure to the nozzles was maintained at 0.42 kg cm^{-2} (6 psi), according to manufacturer's specifications. Average TS, TSS, and turbidity of random water samples exiting the pump prior to entry into the rainfall simulator system were 8.0 mg L^{-1}, 6.7 mg L^{-1}, 8.3 NTUs, respectively.

A rainfall intensity/duration was chosen in order to produce a direct runoff (Q) per linear unit length of treatment on a 4.8-m^2 (53-ft^2) plot that has the equivalent Q per linear length of treatment as 7.25-cm (2.9-in) runoff on 232-m^2 (2,500-ft^2) watershed. This area was chosen to replicate the maximum spacing requirements for silt fence typically used for sediment control on disturbed soils for 10% slopes (15 m or 50 ft)(Georgia Soil and Water Conservation Commission 2000). This watershed area will generate 17,698 L (4,675 gal) of runoff, or 1,180 L (312 gal) per linear m of silt fence. Using the runoff curve number method and a Q of 7.5 cm (3.0 in) this would model a 11.25-cm (4.5-in) rainfall event based on cultivated agricultural land bare soil within the B hydrologic soil group (CN = 86). This models a 24-hour 5-year return storm based on historical rainfall records (US Soil Conservation Service 1986).

Runoff Sampling and Analysis. Sampling and analyses of storm water runoff included: rainfall duration, rainfall volume, time until start of runoff, time until steady state of runoff flow rate, runoff volume, peak runoff flow rate, TS concentration and load, TSS concentration and load, turbidity, single event P factor (soil loss ratio).

Runoff sampling procedures and calculation methods followed procedures used for the Water Erosion Prediction Project developed by the USDA National Soil Erosion Research Lab, which has been used in similar studies (Glanville et al. 2001; Faucette et al. 2005). Runoff samples were collected from a flume placed at the base of each plot. The first sample was taken once water began to "trickle" from the flume aperture, the point determined to be the start of runoff. After the first sample was collected, samples were taken every 5 minutes until the storm was finished. Sampling for runoff quantity and quality used one 500 mL (0.13 gal) Nalgene bottle per 5-minute interval sample, and "seconds-to-fill" bottle times were recorded to obtain runoff flow rates. The total volume of each runoff sample and the time over which it was collected was recorded.

A sub-sample from each 500-mL (0.13 gal) runoff/solids sample was weighed and oven dried at 105°C (221°F) until constant weight was achieved to determine the TS content. The TS were measured using methods 2540 B Total Solids Dried at 103°C (217°F) to 105°C (USEPA 1983). Total suspended solids were determined following methodology outlined by the USEPA (1999). Turbidity (NTUs) was measured using a LaMotte model 2020 turbidity meter. The peak runoff rate (once flow reached steady state conditions) was determined once runoff rates for three time adjacent samples were the same. The runoff rate (known volume per measured time) sampled at 5-minute intervals during the simulation was plotted, and the total runoff volume was calculated by summing the area under the runoff curve.

Total solids, TSS, and turbidity pollutographs were charted as a measure of concentration (NTU for turbidity) over time for the duration of the runoff event. Total solids and TSS loads were calculated by summing the average concentration of two time adjacent concentration samples multiplied by the average of the same two time adjacent samples for runoff volume. P factors (single event) were determined for each treatment using TS loads and were calculated as a single event soil loss ratio of the treatment relative to bare soil (control) (Sadeghi et al. 2006; Kelsey et al. 2006).

Cost Analysis. Total cost for each SCD treatment was determined. Cost was based on

Table 2
Average runoff, sediment, sediment removal efficiency, and P factors by treatment for a single runoff event.

Treatments	8-in (200 mm) compost filter sock	12-in (300 mm) compost filter sock	8-in (200 mm) compost filter sock + polymer	12-in (300 mm) compost filter sock + polymer	Mulch filter berm	Straw bale	Bare soil (control)
Peak flow rate (ml s^{-1} m^{-1})	79ab (0.37 gpm ft^{-1})	78ab (0.37 gpm ft^{-1})	87ab (0.41 gpm ft^{-1})	83ab (0.39 gpm ft^{-1})	98ab (0.47 gpm ft^{-1})	97ab (0.46 gpm ft^{-1})	108a (0.52 gpm ft^{-1})
Total runoff volume (L m^{-2})	157.9cb	135.9c	149.8cb	154.1cb	205.4ab	199.8ab	237.4a
TS concentration (mg L^{-1})	1,439.0de	1,659.4d	1,394.6de	1,176.6e	2,745.6b	2,118.8c	6,077.9a
TS removal efficiency (%)	76.3	72.7	77.1	80.7	54.8	65.1	0%
TS load (g m^{-2})	226.8de	217.3de	198.3de	170.2e	526.9b	414.6c	1,445.1a
TS load removal efficiency (%)	84.3	85.0	86.3	88.2	63.5	71.3	0%
P factor (single event)	0.157cd	0.150cd	0.137cd	0.118d	0.365b	0.287cb	1.0a
TSS concentration (mg L^{-1})	1,026.7cd	1,213.9c	1,028.4cd	718.3d	2,069.0b	1,964.0b	4,252.3a
TSS removal efficiency (%)	75.9	71.4	75.8	83.1	51.3	53.8	0%
TSS load (g m^{-2})	161.6cd	151.1cd	154.0cd	105.5d	397.1b	386.9b	1,004.0a
TSS load removal efficiency (%)	83.9	84.9	84.7	89.5	60.4	61.5	0%
Turbidity (NTU)	2,592c	2,934bc	1,847d	2,113d	3,334ab	3,201ab	3,628a
Turbidity reduction (%)	28.6	19.1	49.1	41.8	8.1	11.8	0%

Note: Values with same letters were not significantly different at $p \leq 0.05$ level.

a per linear 30 cm (1 ft) basis for initial product cost from vendor, freight delivery, staking materials, and labor to install. The addition of these four costs was used to determine the total cost. This only reflects the full cost of installation; future projects should quantify the life cycle cost for these products including maintenance, repair, removal, and disposal.

Statistical Analysis. Statistical Analysis Systems version 8.2 (SAS Institute 2001) was used for statistical analysis. Separation of means was determined by PROC GLM using Duncan's Multiple Range test to determine any significant differences between treatments ($p \leq 0.05$). Prior to means separation using Duncan's Multiple Range test, Type 1 Error was controlled for at the ≤ 0.05 level and any resultant $Pr > F$ values > 0.05 were not deemed to be significant.

Results and Discussion

Runoff Volume and Peak Flow Rate. Total runoff volume and peak flow rate from the control area was 237 L m^{-2} (8.3 ft^3 m^{-2}), 108 ml s^{-1} m^{-1} (0. 52 gpm ft^{-1}), respectively (table 2). Relative to the bare soil, all compost filter socks had lower runoff volume, likely due to greater soil infiltration resulting from the increased ponding created by flow restriction and/or from absorption by the compost. All sediment control treatments restricted peak runoff flow rates relative to the control, although none were significantly different. The mulch filter berm restricted flow rate by 9%, the straw bale restricted flow by 10%, the 8-in (200-mm) compost filter sock restricted flow by 19% to 27%, and the 12-in (300-mm) compost filter sock restricted flow by 23% to 28%. Typically the greater the flow restriction, the faster runoff will be detained, and hydraulic ponding and head pressure will result. Sediment control devices that have low flow rates should have higher effective construction heights, shorter slope spacing intervals, shorter slope lengths, or smaller contributing drainage areas. To reduce the incidence of in-field failure of SCDs, designers should consider the flow rate of the SCD in the planning process.

Total Solids Concentration and Load. Runoff TS concentration, TS load, and removal efficiency from bare soil were evaluated for sediment control treatments. The mean TS concentration and load for bare soil for the entire 3-hour rainfall-runoff event was 6,080 mg L^{-1} and 1,445 g m^{-2} (2.66 lb yd^{-3}), respectively. All treatments were significantly lower (concentration and load) than the bare soil, and all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale (table 2). Mean TS concentrations from the sediment control treatments ranged from 1,177 to 2,746 mg L^{-1}, and TS loads ranged from 170 to 527 g m^{-2} (0.31 to 0.97 lb yd^{-3}). Removal efficiency for TS load ranged from 63.5% to 88.2%. Kelsey et al. (2006) reported similar TS load removal efficiencies for excelsior fiber logs, 55.2% to 71.2%, but substantially lower removal efficiencies for straw wattles at 19.5% to 34.3%. Faucette et al. (2005) reported TS load removal efficiencies for mulch filter berms and silt fence on soils prior to vegetation establishment at 96% and 95%, respectively. See figure 3 for the 3-hour rainfall-runoff pollutograph for TS concentration over time between treatments.

Support Practice Factor. Single event support practice (P) factors used in the USLE and RUSLE can be used to help predict erosion rates from a given area where soil disturbance may exist. The lower the P factor value, the greater the potential sediment removal under a given set of environmental conditions, where a bare soil is equivalent to 1.0. It should be noted that P factors determined for multiple events, seasons, or for an annual basis will likely be higher. Single event P factors were determined for all treatments and ranged from 0.118 to 0.365 (table 2). All treatments were significantly lower than the bare soil, and all compost filter socks were significantly lower than the mulch filter berm. These values are similar to single event P factors reported by Sadeghi et al. (2006) for silt fence at 0.11 to 0.29, and for compost filter socks at 0.10 to 0.32, but were slightly higher than that reported for compost filter socks + polymer at 0.06 to 0.02. Faucette et al. (2005) reported single event P factors (as soil loss ratio) for mulch filter berms between 0.01 and 0.041 and for silt fence between 0.013 and 0.048 where sediment loads were between 53.3 and 308.5 kg per linear meter (35.6 and 206.1 lb per linear ft) of SCD. However, single event P factors reported by Kelsey et al. (2006) were substantially higher for straw wattles, at 0.66 to 0.81, and for excelsior fiber logs, at 0.29 to 0.45. Large variations in single-event P factors for similar products can be due to many reasons, including sediment concentration and load exposure, runoff flow rates, flow restriction, sediment accumulation, installation method, and incidence of failure. The development of standard test methodologies for these types of devices should help better determine single event P factors.

TSS Concentration and Load. Runoff TSS concentration, TSS load, and removal efficiencies were evaluated for all sediment control treatments. The mean TSS concentration and load for bare soil for the 3-hour rainfall-runoff event was 4,250 mg L^{-1} and 1,004 g m^{-2} (1.83 lb yd^{-3}), respectively. Runoff suspended solids accounted for 70% of the TS in the runoff. Typically, suspended solids are more difficult to remove from storm water runoff than the non-suspended solids fraction. Historically, sediment ponds and traps have been used to remove fine suspended solids instead of sediment control barriers such as silt fence (Fifield 2001). All treatments were significantly lower (concentration and load) than the bare soil, and all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale (table 2). Mean TSS concentrations from the sediment control treatments ranged from 718 to 2,069 mg L^{-1}, and TSS loads ranged from 106 to 397 g m^{-2} (0.23 to 0.86 lb yd^{-3}). Removal efficiency for TSS load ranged from 56.3% to 89.5%. Sadeghi et al. (2006) similarly reported under TSS loads of 182 to 247 g m^{-2} (0.33 to 0.45 lb yd^{-3}), removal efficiency for compost filter socks was 68.3% to 89.7%, compost filter sock + polymers was 94.0% to 98.2%, and silt fence was 71.5% to 89.1%. See figure 4 for the 3-hour rainfall-runoff pollutograph for TSS concentration between treatments.

Turbidity. Runoff turbidity and reduction efficiency relative to bare soil were determined for all sediment control treatments (table 2). Turbidity from bare soil under these rainfall-runoff and soil conditions was 3,630 NTUs. All compost filter socks had significantly lower turbidity relative to bare soil, and the addition of the polymer to the compost filter sock treatments had significantly lower turbidity relative to the compost filter socks without the polymer. Percent turbidity reduction ranged from 8.1 to 49.1. Although

Figure 3
Average total solids concentration passing through each sediment control treatment in five-minute intervals for three hours of rainfall-runoff.

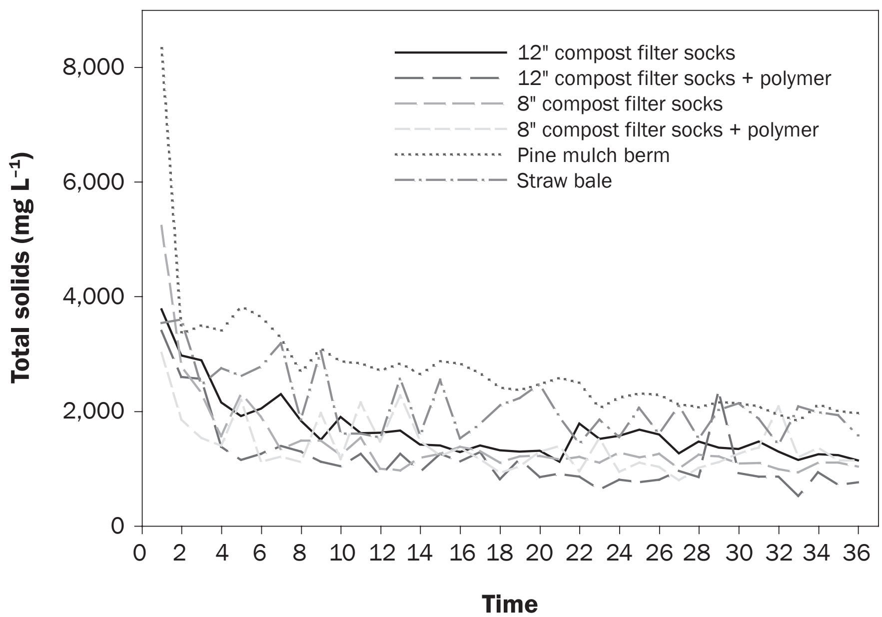
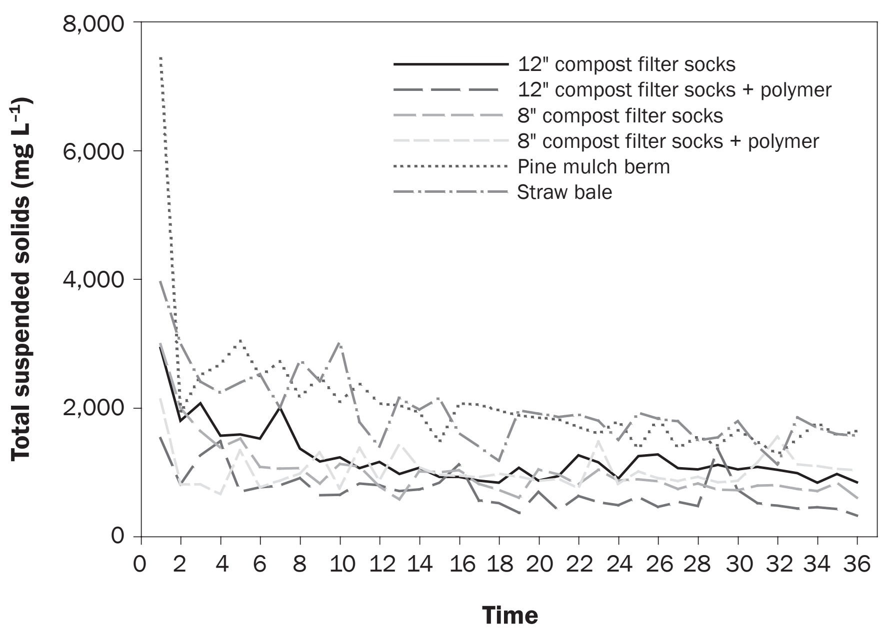


Figure 4
Average total suspended solids concentration passing through each sediment control treatment in five-minute intervals for three hours of rainfall-runoff.



not statistically correlated, there appeared to be a positive relationship between flow restriction and turbidity reduction. Sadeghi et al. (2006) used bench scale chambers and reported substantially higher turbidity reduction for compost filter socks at 52.5% to 77.8%, for compost filter sock + polymers at 79.2% to 98% and for silt fence at 44.8% to 76%.

Total Cost of Sediment Control Installation. The summary of SCD treatment cost per linear 30 cm (1 ft) is provided in table 1. Total cost was based on product + freight + staking materials + labor to install. Freight was assumed to be $0.50 per linear 30 cm of SCD. Installation procedure and staking requirements followed manufacturers' and/or government agency specifications. Wood stakes were specified by all SCD manufacturers and were available locally at $0.25 each. Staking cost was normalized on a per linear 30 cm basis according manufacturers' stake spacing specifications. Installation cost was assumed to be $0.25 per 30 cm. The addition of the polymer to the compost filter sock treatment was added to the cost of the compost filter sock treatment and normalized to a per linear 30 cm basis.

Product cost for all SCDs ranged from $1.00 to $2.87 per 30 cm (1 ft); however, once the total cost of installation was considered these sediment controls ranged from $1.75 to $2.87 per 30 cm (table 1).

Summary and Conclusions

Based on the specific single event rainfall-runoff and site-soil conditions used in this study, total runoff volume from the area of the control was 237 L m^{-2} (8.3 ft^3 m^{-2}), and the flow rate of the runoff was 108 mL s^{-1} m^{-1} (0. 52 gpm ft^{-1}). All sediment control treatments restricted peak runoff flow rates relative to the bare soil (control). The mean TS concentration and load for bare soil was 6,078 mg L^{-1} and 1,445 g m^{-2} (2.66 lb yd^{-3}), respectively. All treatments were significantly lower (concentration and load) than the bare soil, and all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale. Removal efficiency for TS load ranged from 63.5% to 88.2%. Single-event P factors (soil loss ratio) were determined for all treatments and ranged from 0.118 to 0.365. All treatments were significantly lower than the bare soil, and all compost filter socks were significantly lower than the mulch filter berm. The mean TSS concentration and load for bare soil for the entire runoff event was 4,252 mg L^{-1} and 1,004 g m^{-2} (1.83 lb yd^{-3}), respectively. Runoff suspended solids accounted for 70% of the TS in the runoff. All treatments were significantly lower (concentration and load) than the bare soil, and all compost sock treatments were significantly lower (concentration and load) than the mulch filter berm and straw bale. Removal efficiency for TSS load ranged from 60.4% to 89.5%. Turbidity from bare soil under these rainfall-runoff and soil conditions was 3,630 NTUs. All compost filter socks had significantly lower turbidity relative to bare soil, and the addition of the polymer to the compost filter sock treatments had significantly lower turbidity relative to the compost filter socks without the polymer. Percent turbidity reduction ranged from 8.1 to 49.1. Total cost of installation was estimated for each sediment control BMP. Total cost was based on product + freight from distributor + staking materials + labor to install. Total cost for sediment controls ranged from $1.75 to $2.87.

In conclusion, there was no significant difference in sediment removal efficiency between differing diameters of compost filter socks. However, there was a significant increase in sediment removal efficiency by all compost filter socks relative to straw bales and mulch filter berms and in turbidity reduction from the compost filter sock + polymer relative compost filter sock without a polymer. These results will assist design professionals in predicting erosion rates from construction sites when used with the USLE and RUSLE. Sediment control devices that have lower sediment removal efficiencies typically have less sediment accumulation and therefore may require less sediment removal maintenance after storm events. Unfortunately, these SCDs typically emit higher runoff sediment loads, thereby adversely affecting receiving water resources. When determining the cost of a SCD, additional required materials and installation should be included in the total cost, as this total cost can vary widely between sediment control practices.

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