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# Sediment Control Log Performance, Design, and Decision Matrix for Field Applications

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16. Abstract (Limit: 250 words)

Significant time and money are currently being expended in the purchase and installation of sediment control logs. These logs often fail because of poorly understood performance limits and improper installation. This project investigated the performance limits by determining the flow and sediment removal characteristics of different types of logs. The physical characteristics and flow rates per project area were evaluated with twelve different logs. The densities and flow rate of materials in these logs varied between 0.035 gm/cm$^3$ and 1508 ft /min for wood fiber to 0.269 gm/cm$^3$ and 208 ft/min for compost. Flow rates were predicted using a power function of density with fair accuracy ($r^2$=0.64) and predicted with good accuracy using saturated conductivity ($r^2$=0.87) or capillary moisture content ($r^2$=0.81). A sediment flume was constructed and used to evaluate sediment removal and failure rates. One log with three replicates of each type of material was tested. There was a positive, power function relationship between percent finer and mean log capture ($r^2$ = 0.91). Field information was collected and used in conjunction with hydraulic and sediment data to develop selection guidelines for sediment control logs. Educational materials were prepared for workshops.

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# SEDIMENT CONTROL LOG PERFORMANCE, DESIGN, AND DECISION MATRIX FOR FIELD APPLICATIONS

## FINAL REPORT

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# EXECUTIVE SUMMARY

Sediment control logs (SCLs) are one of the most popular practices used to reduce sediment loads from construction sites. They are designed and installed to provide perimeter control, inlet ring protection, slurry filters and ditch checks. Successful use of SCLs under these diverse conditions requires careful considerations of characteristics of both the site and the logs themselves. By using the appropriate logs at the proper locations, the material cost for purchasing logs, the labor costs for installation, user costs for site inspection and supervision and the life-cycle costs will all be reduced. The project goal is therefore to improve the selection of SCLs and their implementation in designing sediment control plans. This goal is achieved by collecting data on the hydraulic and sediment response of different types of logs and by integrating this information with site conditions to improve SCL selection.

The physical characteristics and flow rates per project area were evaluated for twelve different logs that vary by fiber fill and containment fill. An important component of the project was to tie hydraulic response and sediment removal of SCLs to more easily measurable physical characteristics. Measured physical characteristics include the density, volumetric pore space, saturated moisture content, saturated conductivity, capillary moisture content, percent finer (by mass) for d = 2 mm and percent finer by d = 25.4 mm. Physical characteristics varied substantially among the logs. The densities varied between 0.035 gm/cm$^3$ for wood-fiber to 0.269 gm/cm$^3$ for compost materials.

Flow rates of clean water for the twelve SCLs were measured in a hydraulic flume located in the Biosystems and Agricultural Engineering Building at the University of Minnesota. Three different flow rates corresponding to three different ponded depths were used. The first two depths correspond to approximately 1/3 and 2/3 of the log height. The third depth is nearly equal to the overtopping depth. The flow rate for each of these depths was divided by the projected area to obtain the flow rate per projected area. The overtopping flow rate was of greatest interest to the project, and three replicates were used for this depth. Flow rates of different materials varied between 208 ft/min (63 m/min) for compost to 1508 ft/min (459 m/min) for wood fiber. These flow rates were predicted using a power function of density with fair accuracy ($r^2$=0.64) and predicted with good accuracy using saturated conductivity ($r^2$=0.87) or capillary moisture content ($r^2$=0.81).

A sediment flume was constructed for the project in Biosystems and Agricultural Engineering Building at the University of Minnesota. This flume was used to evaluate sediment removal and failure rates. A subset of the five logs was used for the sediment-flume experiments. This subset was chosen to capture the measured range in the hydraulic response and to represent a variety of log materials. Three replicates were used for each log. Sediment removal was assessed using the capture of sediment in the log itself and total effectiveness that includes deposition upstream of the log. Median log capture varied between 1.4 % for rock to 15.5% for straw materials. Median total effectiveness varied among materials between 72% for wood fiber to 92% for compost. There was a positive, power function relationship between percent finer of d=2 mm and mean log capture ($r^2$ = 0.91).

Sediment deposition within the log itself reduces its effectiveness as a sediment control practice. The functional longevity of logs is defined from the point of installation to a point when they are no longer

acting as a sediment control device. They are no longer an effective device when the water depth overtops them. Estimates of log longevity were initially assessed using the rate of change in the upstream water height behind logs caused by sediment deposition within the logs. These longevity estimates varied between 2.2 hours for rock material to 8.7 hours for wood compost. Since flow rates differ among logs, and larger flow rates have greater influx of sediment, an alternative estimate of longevity was obtained by using a ratio of a normalized increase rate of water height and a normalized flow rate. This analysis suggests that straw material was plugged twice as fast as coconut fiber, wood fiber and compost material and four times faster than the rock material.

Field guidelines for selecting SCLs were obtained by integrating measured hydraulic and sediment response of logs with a simple representation of runoff for given site characteristics. The hydraulic flume data were simplified into three categories of different flow rates and upslope flow depths. The maximum runoff flow rate before the log was overtopped was defined using these flow rates and upslope depths. The corresponding maximum watershed area for this flow rate was obtained using NRCS TR-55 model. Acceptable SCLs were defined using watershed area, basin slope and ditch slope. Different tables were developed when SCLs were used as ditch checks and perimeter control for 0.5-year and 2-year events. The guidelines for longevity used the estimates obtained by the normalized values of the sediment flume experiments.

Educational material was prepared as part of the project for use in the Erosion and Stormwater Management Certification workshops. An important component of this material was combining observations from the field with the information gained directly from the project itself. Field information was particularly important in the development of materials on installation and maintenance. The educational material has sections of introduction, basic functions and failures, clean water flow experiments, sediment laden flow experiments, selection tools, installation, maintenance and conclusion.

# CHAPTER 1: INTRODUCTION

## 1.1 OVERVIEW

Sediment control logs (SCLs) are one of the most popular, versatile and adaptable practices to reduce sediment loads from construction sites. They are designed and installed to provide perimeter control, inlet ring protection, slurry filters and ditch checks. Successful use of SCLs under these diverse conditions requires careful considerations of characteristics of both the site and the logs themselves. The runoff volume, peak flow rate, sediment load and corresponding particle size distribution are important site characteristics. Factors that impact these characteristics include drainage area, slope steepness, soil type, land cover and properties of the storm. Important log characteristics are volumetric flow rate through them, the ponded water depth behind them and the sediment removal rate within them. These characteristics are a function of the type of materials used in the log, the type of casing and packing-related properties such as density and porosity.

Currently, many of the sediment control logs fail because their performance limits are poorly defined and not related to functional longevity and they are installed in inappropriate locations. By using the appropriate logs at the proper locations, the material cost for purchasing logs, the labor costs for installation, user costs for site inspection and supervision and the life-cycle costs will all be reduced. Resources invested to protect the environment from construction activities will protect the environment.

The overall goal of this project is to improve the selection of SCLs. This goal is achieved by collecting data on the hydraulic and sediment response of different types of logs and by developing tools to select the appropriate logs for their conditions. The project is focused on providing information that can be used by field practitioners. While not part of the study, this research can also be used to quantify and rate the effectiveness of new logs that have different fiber fill densities. The work has the potential to be developed into an American Society for Testing and Materials ( ASTM )standard.

## 1.2 PROJECT OBJECTIVES

The specific objectives of the projects are to:

(1) Determine hydraulic characteristics of SCLs constructed from different media and encasement fabrics,

(2) Evaluate the removal efficiency of sediment for these logs and the impact of trapped sediment on the hydraulic characteristics,

(3) Develop design guidelines for selection of sediment control logs based on the log and watershed characteristics and

(4) Coalesce the selection guidelines into a format that can be used by field practitioners for amending or upgrading the device.

The description of activities is divided into chapters that summarize previous research, experimental methods and results for characterizing the hydraulic parameters of different sediment control logs, experimental methods and results for characterizing the sediment response of the logs, and a description of the design tool. The supporting materials to train field practitioners on how to select the sediment control log for their site is included in the chapter on the development of the design tool. Because of time and cost limitations of the project, the use and performance of sediment control logs in ditches is not considered in the study.

# CHAPTER 2: REVIEW OF PREVIOUS STUDIES

## 2.1 INTRODUCTION

An important component of the study was to review previously published studies related to the performance of sediment control logs. The review of literature provides insight into appropriate designs of equipment and instrumentation for sediment logs as well possible methods for data analysis. It is also useful in identifying possible duplication of existing information.

The review is divided into data collected in laboratory settings and data collected in field settings. Studies that rely on smaller scale apparatus are included in the discussion of laboratory studies. For each study, a brief description is given on the experimental methods, type of data analysis, and conclusions drawn from the study.

## 2.2 SMALL-SCALE AND LABORATORY STUDIES

### 2.2.1 Overview

The scale and laboratory studies cover relevant research and methods from 1995 to 2013. Publishers of these studies include committees such as American Society for Testing and Materials (ASTM) and researchers at universities. A wide range of sediment control practices is covered, including geotextile silt fences, compost berms, and sediment control logs comprised of a variety of media. Many of these studies also address the impact of adding flocculants to these control measures.

Research in this section is often conducted in flumes or small-scale field studies. As such, they provide rigorous information from controlled environments under different slopes, flows, loadings, soil types, and other variables. Additionally, a few of the studies reviewed examined the potential release and removal efficiency of additional pollutants such as nutrients and metals. Studies in these controlled environments also allow for longevity studies of sediment control practices and their removal efficiency over time. Removal efficiencies of sediment and other analytes are generally dependent on the flow rates, sediment size, and the porosity and type of media.

### 2.2.2 ASTM Standard on Determining Characteristics of Silt Fences

In 2004, the American Society for Testing and Materials (ASTM) published a standard method for determining filtering efficiency and flow rate of geotextile silt fences. Their testing method uses a flume with a volumetric flow container of 75 L (20 gallons). It also utilizes a customized drill for stirring, a desiccator, and a vacuum pump. Simulations of different storm events and different soil compositions are possible. Sediment removal is found by measuring suspended solids after filtration through the geotextile materials. Flow through rate is obtained by measuring how long it takes for water to pass through the materials.

For the standard testing method, a geotextile is first stretched taut across the opening of a flume that is set to an 8% slope. The geotextile is pre-wetted by running one test with 50 L (13 gallons) of sediment-free water. The sediment-laden flows are obtained by mixing 0.15 kg (0.33 lb) of air-dried site-specific soil in 50 L of untreated water. The particle sizes are smaller than 2 mm. The solution is stirred in the 75 L (19.8 gallons) container for at least 1 min to obtain a uniform mixture. , A depth-integrated suspended-solids sample is obtained from the mixture. After washing, desiccating, and weighing a filter disk, the sample is filtered using a vacuum-driven filter disk to obtain a mass. The suspended solids concentration is computed by dividing the mass of the residue on the filter by the sample volume. The sediment-laden mixture is released in the flume over a duration less than 10 seconds. The time required for the water to flow through the geotextile is recorded and all of the filtrate that passes through the geotextile is collected. If not all water has passed through the geotextile after 25 min, the distance from the geotextile to the edge of the water behind the geotextile is recorded. The filtering efficiency is calculated using the mass passed through the filter and the amount behind the geotextile. The flow rate is calculated by timing how long it took for the water to flow past the geotextile. If not all water passed through the geotextile in 25 min, then a formula is available that accounts for the storage behind the geotextile.

The ASTM standard has been available for use for approximately twenty-five years. Potential problems include human error in timing the water flow rate, pouring the solution into the flume, and attaching the geotextile across the opening consistently and correctly. It is, however, a relatively simple method that is fairly easy to replicate. The method is versatile in testing different geotextiles and different types of soil.

### 2.2.3 Headloss through Compost Filter Berms

Büyüksönmez et al. (2012) studied the behavior of flow through compost berms. Maximum flow rates of different masses and compost sizes were determined prior to their structural failure. They also developed relationships to predict the loss of head as a function of flow rate per unit width, the median size of the compost, and the dimensions of the berm. This work included the consideration of the sediment load head loss.

Compost was obtained from a city-operated recycling center in San Diego. The sieving method of Legee and Thompson (1997) was used to determine the size of the compost material. The median diameter ($D_{50}$) was defined from the sieve data. Two flumes were used to perform the experiments; one flume used was 12 m long and the other was 1.52 m (60 in) long.

Three types of runs were performed corresponding to uniform compost material with sediment-free inflow (U), sediment-free inflow with mixed sizes of compost material (M), and sediment-laden inflow with mixed sizes of compost material (MS). A single sieve size was used to obtain a uniform-sized compost for the U runs. Two mixtures of compost particles sizes were used. Mass of compost making up the berm was varied, and berm dimensions were measured and recorded. The flow was slowly increased until inflow and outflow were constant, and the velocity was recorded at this point. Then, flow was increased until the berm failed structurally due to toe erosion and collapse, and the flow rate at failure was recorded.

Experiments for sediment-laden flows were performed with a constant flow rate of 0.33 L $s^{-1}$ to prevent failure of the berm from occurring. When inflow and outflow had become equal to each other, sediments were added to the flow so that the sediment concentration of the flow was 1,000 mg $L^{-1}$. The water depths upstream and downstream of the berm were recorded, and the TSS concentration upstream and downstream of the berm was determined.

*Uniform (U) Experiment:* As expected, smaller compost particles with smaller pore space had a greater resistance to flow resulting in increased head loss. Structural failure of the berm occurred with lower flows (0.26 to 0.45 lps) for smaller particle sizes; whereas structural failure occurred with flow rates of 1.20 to 3.91 lps for larger particle sizes. The relationship between head loss and flow rate is described in the equation $H_L/F_L = \alpha {Q_w}^{\beta}$ where $H_L$ is head loss (cm), $F_L$ is hydraulic flow length through the buffer (cm), $Q_w$ is the flow rate per unit width (lps/cm), and $\alpha$ and $\beta$ are derived from the $D_{50}$ particle size of the compost. The definitions of $\alpha$ and $\beta$ are as:

$$\alpha = 0.24 D_{50}^{-0.48} \tag{2.1}$$

$$\beta = 0.31 D_{50}^{0.44} \tag{2.2}$$

*Mixed (M) Experiments:* The results from the mixed experiments follow similar trends as those from the uniform experiments. Specifically, they follow the same phenomenon in which smaller particle sizes result in higher loss of head than larger sizes. This is again attributed to the smaller pore sizes in the compost for smaller particles. The power law function described above for the uniform experiments, along with separate definitions for $\alpha$ and $\beta$, relate head loss to flow rate for the mixed experiments. The definitions of $\alpha$ and $\beta$ are as:

$$\alpha = 0.24 D_{50}^{-0.45} \tag{2.3}$$

$$\beta = 0.34 D_{50}^{0.42} \tag{2.4}$$

*Mixed with Sediment (MS) Experiments:* When sediment was added to the flow, the depth of the water upstream increased over time corresponding to a larger head loss. Sediment particles trapped in the compost berm reduced the volume of available pore space for the flow of water.

Büyüksönmez et al.'s (2012) relationships allow the designer to vary the size of compost material to prevent failure of the berms. Smaller compost particle sizes were detrimental increased head losses and also were more likely to be clogged. A potential weakness of this study is that it only represents results from a flume in a laboratory experiment, and did not extend its investigation to field-scale experiments. Therefore, the applicability of the equations to field-scale settings should be used cautiously.

### 2.2.4 Turbidity Reduction for a Geotextile Silt France

Campos et al. (2010) tested the effectiveness of a geotextile silt fence to reduce turbidity from construction sites in Brazil. Two slurries created from local soils were run through the geotextile fabric in a flume for different runoff conditions. Their experiment tested instantaneous filtration as well as the overall performance for different flow rates. They found that the silt fence reduced turbidity and achieved the best results with the lowest flow-through rates.

The flume was constructed with the dimensions: 1.25 m (49 in) length, 0.85 m (33 in) width, 0.30 m (12 in) sidewall height and a grade of 14%. The geotextile was a non-woven fabric. Only one type of geotextile was used for this experiment. It is the most commonly used material at the highway construction site from which the soils were collected.

The two soil slurries were created using topsoil from a highway construction site in Sao Paulo. One slurry was made with a sandy clay soil and the second with a sandy loam soil. Both soils were dried and sieved through a 2 mm (0.07 in) screen and then combined with water in a tank at the top of the flume to make the slurry. The sandy clay slurry had a ratio of 450 g (0.99 lb) dried soil to 200 L (52 gallons) water. The sandy loam slurry had a ratio of 400 g (0.99 lb) dried soil to 200 L water.

Two series of test runs were conducted – one for each slurry. Each series had seven cycles in which runoff events were simulated. The flume and all other materials were cleaned between each series and the tested geotextile fence was replaced. Each run started as soon as the 200 L slurry was released into the flume and concluded once there was no water remaining behind the silt fence or seven hours had passed. To test instantaneous filtration, samples were collected on timed intervals from the pool behind the geotextile and from the effluent downstream of the silt fence, in paired sets. The samples collected were analyzed for turbidity.

Three metrics were used to test the performance of the geotextile silt fence: percent instantaneous turbidity reduction, flow through rate, and percent overall turbidity reduction. The percentage of instantaneous turbidity reduction ($T_{IR}$) was defined as:

$$T_{IR} = 100 \left(\frac{T_F - T_G}{T_F}\right) \qquad 2.5$$

where $T_F$ is the turbidity in the pool upstream of the fence (NTU) and $T_G$ is the turbidity of the effluent downstream of the fence. The flow through rate (q) was defined as:

$$q = \frac{\Delta V}{(t_{n+1} - t_n)\, A_s} \qquad 2.6$$

where ΔV is the volume of runoff passing through the geotextile fence at each time interval, $t_{n+1}$ and $t_n$ are the timed intervals of each run, and $A_S$ is the area of the textile that is submerged. Overall turbidity reduction ($T_R$) as a percentage is defined as

$$T_R = 100\left(\frac{T_{up} - T_{down}}{T_{up}}\right) \qquad 2.7$$

where $T_{up}$ is the turbidity of the slurry before it is released into the flume (NTU) and $T_{down}$ is the turbidity of the effluent after thorough mixing (NTU).

The geotextile silt fence significantly reduced the instantaneous turbidity for both slurries, especially between the first and fourth hour. They observed up to 99.8% turbidity reduction in the sandy clay slurry and up to 99.9% reduction in the sandy loam slurry between the samples upstream and downstream of the silt fence. The range of instantaneous reduction percentages is 56.0% to 99.8% for the sandy clay slurry and 86.1% to 99.9% for the sandy loam slurry, after the first 30 minutes of each run. After the first 30 minutes, the best filtration was achieved during the lowest flow through rates.

The overall turbidity reduction ranged from 55.9% to 84.1% for the sandy clay slurry, between the third and seventh runs. For the sandy loam slurry, these results ranged from 59.0% to 67.6%. The global turbidity reduction during the third run ranged between 55.9% for the sandy clay slurry to 84.1% for the sandy loam slurry, demonstrating that the tested control significantly affects reduction results.

Flow rates decreased after the 4th and 5th runs for the sandy clay and sandy loam slurries, respectively, likely because of clogging and accumulation of sediment upstream of the geotextile. The flow through rate on average was 15 $m^3/m^2$/day between the third and seventh runs for both slurries. The maximum flow through rate was 237.40 $m^3/m^2$/day.

One limitation of this study is that the flume and geotextile set up represent optimal operating field conditions. The results assume that all runoff is captured and retained by the silt fence. Results are not applicable if fences are overtopped, undercut or flanked that can occur in the field. Also, this study is aimed specifically at one construction site; soil slurries and the geotextile used are collected from and representative of that site. There is no investigation of turbidity reduction performance using other common silt fence materials or soils with other compositions.

### 2.2.5 Evaluation of Compost Biofilters

Gharabagi et al. (2007) completed lab tests on three different types of compost biofilters. Lab experiments tested flow through capacities, leaking of harmful chemicals, the sediment removal efficiency with and without Polyacrylamide polymers, and longevity. A flume was used to test for flow through capacity and chemicals released from the different types of compost. A channel was excavated in the field to test sediment removal efficiency and longevity.

The material inside the compost biofilters was a composite of yard waste, “including twigs, bark, and woodchips” (Gharabagi et al., 2007). Three different compost types were used, which were processed from three different facilities in Ontario, Canada. The Region of Peel composting facility composts yard and organic wastes. The Region of Waterloo composter receives yard and wood chip waste. The type of compost received at Alltreat Farms was not provided. All three different compost types had a void space between 60% and 70%.

For the flow through capacity and chemical analysis portions of the study, a 1.5-meter (5 ft) long, by 0.69-meter (2.2 ft) wide, and 0.3-meter (0.98 ft) deep flume was used. Eight-inch (20 cm) diameter compost biofilters were placed perpendicular to flow across the flume. Trials were completed in triplicate for each type of compost. Biofilters were also tested to ensure they did not release harmful chemicals. Water flowing through biofilters were tested for pH, TSS, turbidity, conductivity, total Kjeldahl Nitrogen, total phosphorus, and total carbon.

Sediment removal efficiency was tested in the field within excavated channels at the Guelph Turf Grass Institute in Ontario, Canada. Two channels were dug, each 10 meters long (32 ft) and 1.2 meters (3.9 ft) wide. Sod was removed and the final channel was topped with plastic sheeting. Flow rates were set to 0.5 (0.1), 1 (0.2), and 2 (0.5) L/second (gallon/second). Equal flows across the flume were ensured by using a 1.2-meter (3.9 ft) wide weir at the inlet. Sediment was added from a peristaltic pump after being mixed with water by a sump pump. Each trial was run for 50 minutes. The first 10 minutes had clean water flowing through the system. The remaining 40 minutes had the sediment-laden flows. Samples were taken after the 40-minute sediment-laden flows. Eight-inch (20 cm) and 18-inch (46 cm) diameter biofilters were used.

To measure flow, a compost biofilter was tightly fitted and secured in the flume. Water flowed through the flume but did not rise over the biofilter. A ruler was used to measure the water height upstream and downstream of the biofilter. Different depths at 5 mm (0.19 in) to 10 mm (0.39 in) increments were measured by increasing or decreasing the water flow in the flume.

The chemicals released from the biofilters were measured from water downstream of the biofilter in 500 mL jars. Samples were collected at one-minute increments for the first 5 minutes and then at minutes 10, 20, and 30. To ensure equal flows. a biofilter wrapped in plastic was placed upstream of the biofilter to be tested. Water from the tap entered the flume behind this wrapped biofilter. Once a steady state of water was reached, the wrapped biofilter was taken out and the flume pump was engaged. Conductivity and pH were measured with probes. Turbidity was measured with a HACH 2100P Turbidimeter. Total suspended solids were measured by collecting sediment on a 0.45-micron filter paper and subtracting the dried weight from the wet weight.

To test for the impact of polymers, a variety of test methods and modifications were conducted due to the difficulty of measuring the change in polymer amount as it moves through the system. Methods employed included a hydrometer and test jars. Polymers were tested at ranges of 5 to 500 mg/L.

Testing biofilter longevity required repeated flow through measurements of the 8-inch and 18-inch biofilters with sediment-spiked water containing fine to coarse particles. Biofilters were stacked horizontally in channel with Alltreat compost located the furthest downstream and Peel compost the furthest upstream.

Flow through tests found that all three compost-type biofilters had a similar response. As flow rates increased, the upstream flow depth also increased. The compost from the Peel Region, which included organic and yard waste, was denser. Therefore, flow through the biofilter was lower than the other two compost types. The hydraulic conductivity for all three types was between 1.51 (0.59) to 1.85 (0.72) cm/s (in/s).

Clean water tests showed a high release of particles during the first minute of the test. The denser compost particles corresponding to the Peel Region compost had the highest release of particles. Initial TSS concentrations for biofilters ranged from approximately 160 to 320 mg/L. After 30 minutes, TSS approached zero. For turbidity, all compost types behaved similarly and approached zero NTUs after approximately 10 minutes.

Conductivity responses varied among the three compost types, with a change in measurements observed in all treatments within the first 10 minutes. The US EPA's acute short-term exposure level of 860 mg/L chlorides was only measured during minute 1 of the Peel Region compost (Gharabagi et al., 2007, p. 39). pH readings were approximately neutral and stabilized after the first 10 minutes. Total Kjeldahl Nitrogen (TKN) ranged from approximately 9 to 13 mg/L during the first minute of the study. By 10 minutes of the study, TKN measurements approached zero and stabilized. Total phosphorus was flushed more quickly from the system, after approximately 5 minutes. Initial concentrations for the three treatments ranged from approximately 1.1 to 2.3 mg/L TP. Total organic carbon (TOC) levels were high at the start of the clean water flush, ranging between 33 to 106 mg/L TOC. This is likely due to the high carbon content of composted material. Total organic carbon stabilized after approximately 5 minutes and approached zero after 30 minutes.

Sediment removal efficiency was significantly affected by biofilter size and number of biofilters used in a group. Eight-inch (20 cm) biofilters in groups of 5 had 20-40% removal efficiency. Groups of 10 biofilters had 40 to 60% removal efficiency and groups of 15 biofilters had the highest efficiency ranging from 60 to 80%. Adding polymers to the biofilters resulted in a 93% sediment removal rate at 5 mg/L polymer. Regarding biofilter longevity, sediment removal efficiency decreased quickly over the first set of trials and then leveled off. As the number of trials increased, sediment removal efficiency increased for medium and coarse silts but decreased for clay-sized particles. The 18-inch (46 cm) diameter biofilter had a greater longevity than the 8-inch diameter sock, this is likely due to a larger area and volume of filtering material in the biofilter. The 18-inch biofilter started with an approximate 62% sediment removal efficiency, which dropped to approximately 43% after over 30 trials.

The applicability of several biofilters to a setting using a single set needs to be considered. Results presented in this paper may be more applicable to projects with required, redundant BMPs. One benefit of this paper was the thorough research of compost particle size and source. This paper demonstrates that different compost compositions can have measurable impacts on flow, TSS, turbidity, TKN, TP, and TOC.

### 2.2.6 Silt Fence Testing for Eagle River Flats

Henry and Hunnewell. (1995) assessed the performance of various types of silt fence to remove sediment for the Eagle River Flats in Alaska, where remediation was required to remove sediment containing white phosphorus. The remediation process allowed the sediment to settle out of suspension in a settling pond before having the water flow through a silt fence. The majority of the sediment was removed by the settling pond. The silt fence was installed as a back-up practice. The silt fence needed to retain particles larger or equal to 0.1 mm because white phosphorus particles of this size has been shown to be harmful to wildlife in the area.

Sediment used in the study were from the Eagle River Flats settling ponds. This sediment is a glacially derived silt. Silt fences tested were Texel F-300 (nonwoven polyester), Texel Geo 9 (nonwoven polyester), Amoco L17811 (nonwoven polypropylene), and Amoco 4551 (nonwoven polypropylene). These fences were evaluated using two types of tests. Part I involved following accepted engineering test methods outlined in ASTM D5141, *Standard Test Method for Determining Filtering Efficiency and Flow Rate of a Geotextile for Silt Fence Application Using Site-Specific Soil*. Part II was designed to test geotextile materials in a way that would emulate field conditions. In both Part I and Part II, the accuracy of the measurement methods was assessed by mixing in a blender 150 g (0.33 lb) of dry soil with 500 mL (0.13 gallon) of water. Then 49.5 L (13 gallons) of water was added, and the mixture was stirred. Samples were collected while water was stirred. The sampled TSS were found to be within 2% of the known TSS values.

To test each geotextile in Part I, water with a known level of TSS was released to the flume following the methods in ASTM D5141. The only adjustments to those methods were that soil was mixed in a blender before being added to the water to break apart soil particles; agitation of the soil-water mixture was not continued during the release of the water into the flume; and three 50 mL (0.01 gallon) samples taken using a PVC Coliwasa water sampler rather than taking a depth-integrated sample. For each geotextile, three replicate tests were performed.

For the Part II tests, conditions were more specific to the field conditions at the Eagle River Flats site. Only the Texel Geo 9 geotextile was tested; three replications of the test were performed on this geotextile, and the results were compared to the results of three tests without any geotextile. Adjustments to the ASTM D5141 procedure to simulate field conditions were as follows: TSS was $2.0 \times 10^5$ mg/L, which is 67 times greater than the recommended level; salinity of the water was 4.5 ppt rather than fresh water; an impermeable gate was installed in the flume to allow the soil to settle out of the mixture for approximately two hours before releasing the water to the geotextile; and the slope of the flume was set at 1%; geotextile was scraped with a spatula to increase water flow. Additionally, the ability of the geotextile to remove particles of 0.1 mm or larger was tested by sieving the soil-water after the flume test was complete.

Filtering efficiency, or the percent of soil particles retained by the silt fence, was calculated for Part I experiments. For Part II experiments, the TSS of the sediment-laden water was compared to the TSS of the water behind the gate in the flume to quantify removal of TSS (for tests both with and without a geotextile present).

Results from Part I experiments indicate that the Texel F-300 and the Texel Geo 9 geotextiles performed well, but the Amoco L17811 and Amoco 4551 geotextiles performed poorly. Specifically, average filtering efficiency for the Texel F-300 and the Texel Geo 9 geotextiles was 69.6% and 72.8%, respectively. For the Amoco L17811 and Amoco 4551 geotextiles the average filtering efficiencies were 58.7% and 45.5%. Part II experiments show that the Texel Geo 9 geotextile had a filtering efficiency of 99% and reduced final TSS values by a factor of 10. It was also found that scraping the geotextile with a spatula approximately 15 minutes after the water-soil mixture is released to the geotextile promotes increased water flow rate. However, it was also found to decrease the amount of soil that the geotextile retained.

It was concluded that the Texel Geo 9 would be the best option for use at the Eagle River Flats, and that it effectively retains particles that are 0.075 mm or larger.  They also recommended that the quantity of soil larger than 0.1 mm that is not retained by the silt fence should be monitored, that the silt fence should be inspected for damage; that extra replacement silt fence should be available; that the silt fence should be back-flushed with water to promote water flow through it; and that the soil on the upstream side of the silt-fence should be kept lower than half the height of the fence.

### 2.2.7 Comparison of Compost Filter Media and Silt Fence

Keener et al. (2006) evaluated the flow through rate, sediment removal efficiency and design capacity of Filtrexx Silt Soxx$^{TM}$ (SS) compared to a standard silt fence. A flume was built out of MDO plywood with dimensions 2 ft (0.6 m) wide, 3 ft (0.9 m) sidewalls and 8 ft (2.4 m) length and mounted on a frame that allowed for a 10- or 20-degree slope. Fixtures were built into the base that allowed an 8 in SS, 12 in SS or 24 in silt fence to be mounted on the base. For the clean water studies, a 40-gallon tank was used to supply water that was pumped into the flume. For the sediment-laden water a 170-gallon (151 L) tank was used. For tests requiring more than 150 gallons (567 L) of sediment laden water, the test was interrupted for 2.5 to 3.5 minutes while the tank was refilled.

SS fabric and materials came from Filtrexx International and were the standard 8-inch (20 cm) and 12 (30 cm) inch products made of HDPE plastic with 3/8 in (0.95 cm) knitted mesh. These were filled with compost material which was composed of yard trimmings in two sizes – a fine grade of < 1/8 inch (0.31 cm) in size and a coarse grade with the overs from screening with a 3/8 inch (0.95 cm) trommel screen. Particle sizes were determined using a roto-top shaker and standard ASTM size sieves ranging from 0.5 inch (1.2 cm) to 0.0661 inch (0.16 cm). The SS compost was filled to Filtrexx defined tension and was filled horizontally for clean water tests and vertically for sediment laden water tests. A ¾ in. plug was inserted after filling to contain the compost.

The silt fence had a height of 24 in (60 cm) and was installed with 6-inch (15 cm) buried, as is the normal application at sites.  Therefore 18 inches (45 cm) of fence was extended above and perpendicular to the bottom of the flume.

The clean water test analyzed flow through for SS 8 inch (20 cm) fine grade, 8 inch (20 cm) coarse grade, 12 inch (30 cm) fine grade and 12 inch (30 cm) coarse grade, with three fixed flows for slopes of both 10 and 20 degrees. The test duration was until the depth behind the fence stabilized or 30 minutes elapsed. A flow rate for failure by overtopping was also determined by increasing flow until they overtopped the sediment control device. Flow rates were taken at ½ min intervals using a flow meter. Each test was replicated 3 times for a total of 120 tests run.

The sediment laden water test analyzed flow through for SS 8 in (20 cm) coarse grade and 12 in (30 cm) coarse grade, as well as the silt fence. Again, 3 flow rates were tested for each device on a 10-degree slope, plus an overtop flow rate was tested. The sediment-laden water was made by adding 6.4388 kg (14.1 lb) of air dried Wooster silt loam soil (particle size less than 2000 micron) to 170 gallons (643 L) of water where it was hand stirred and circulated using a pump. The sediment content of the water in front of the control device and the outflow from the control device was measured by taking water samples at 10-minute intervals during the test, which were then oven dried and weighed. The tests were replicated 3 times for a total of 29 tests run.

*Clean Water Test.* Compost sizes for the SS sleeves were air dried until they contained less than 20% moisture and then were screened. The fine grade contained 8% > ½ inch (1.3 cm) and 82% < 5/16 inch (0.8 cm). The coarse grade contained 27% > ½ inch and 58% > 5/16 inch. Steady state flow was determined to occur after 3-4 minutes so the tests were run for 7 minutes. The average flow rate was based on the flow measurements taken at 5, 5.5, 6, 6.5, and 7 minutes. For output flow rate, $q_0$, SS 8 inch and 12 inch both gave similar results at a given water depth so the data for both was pooled. Results showed that flow rates can be defined as a power function of water depth ($d_f$). A theoretical analysis determined $q_0 = (C)\ d_f^{1.5}$ and the regression equations determined the following scaling coefficients as C= 1.054, C=1.313 and C=1.20 for SS fine grade, SS coarse grade and silt fence, respectively. Overall the flow rate for the SS fine grade was 16% of the silt fence flow and the SS coarse grade was 75% of that observed for the silt fence. It was also observed that the 20-degree slope caused slightly higher flow rates than the 10-degree slope at the same water depth, but no statistical analysis was done on these results.

*Slurry Test*: Wooster silt loam was added to water to create a 1.0% by mass of sediment laden runoff. For these tests, only the coarse grade compost was used in the SS sleeves. The water depth behind the devices was measured over 30 minutes for flow rates of 2, 4, 5 and 15 (overtop test) gpm. The pond depth was measured every 5 minutes during the 30-minute test and it was discovered that the depth behind the silt fence increased more quickly than it did behind the 12 in SS. Because the depth was changing over time for this test, due to particles from the slurry being caught in or on the filtration devices, flow rate as a function of pond depth was described by a power function. The exponents used were 0.698 for silt fence and 1.0 for SS. A set of relationships was developed to predict how long the devices would take to be overtopped. The average sediment removal efficiency was determined to be higher for silt fence than 8-inch SS, but only slightly larger for 12-inch SS. Overall, both SS and SF were approximately 30 - 50% efficient at trapping solids.

Flow rates for the clean water tests showed that there was much less flow through SS, particularly for those containing the fine compost, than the silt fence. The opposite trend was observed for the slurry test where the lower flow rate was observed for the silt fence. This difference could be consequence of natural variability in packing the SS sleeve or the impact of particles clogged the devices.

### 2.2.8 Compost Filter Socks

Faucette et al. (2009b) studied the effectiveness of compost filter socks in removing:

- Fine sediment particles of clay and silt;
- Inorganic nitrogen, $NH_4$-N and $NO_3^-$-N;
- Coliform bacteria and *E. Coli*;
- Typical stormwater metals Cd, Cr, Cu, Ni, Pb, and Zn; and
- Petroleum hydrocarbons of motor oil, diesel fuel, and gasoline.

Each analyte group was analyzed in a separate experiment as to not confound results on each group studied. Experiments were conducted in constructed box chambers composed of bare Hatboro silt loam (Ap horizon) or bare concrete. Chambers were 100 cm (39 in) long by 35.56 cm (14 in) wide and 25 cm (9.8 in) deep. Experiments in each group were performed in triplicate with a control of bare soil or concrete. In addition, a specific flocculant was added to each study group to determine its impact on pollutant removal. Compost filter socks were constructed by Filtrexx International. The compost material was enclosed by a 3.2 mm (0.12 in) diamond-shaped mesh composed of photodegradable polypropylene. The compost filter socks were snugly situated at the downslope end of the chamber, near the drainpipe. Chamber corners and the interface between the concrete and sock were packed with compost filter material. Each pollutant in the experiment was at a “worst-case scenario” level. Fine sediment particle testing was completed on bare soils. Inorganic nitrogen, in the form of fertilizer, was added at a rate of 202 Kg/h (445 lb/h). For bacteria testing, 10 Kg/m2 (0.2 lb/ft2) of fresh bovine manure slurry was applied. Stormwater metals were applied at 15 ppm in a 500 mL solution. Petroleum hydrocarbons were each added in 100 mL volumes.

Simulated rainfall fell approximately 2.6 m (8.5 ft) to reach chambers for 30 minutes at intensities ranging from 9.57 (3.8) to 11.19 (4.4) cm/h (in/h). Cups placed along the perimeter of the chambers collected data on rainfall intensity. Experiment water from chambers was collected from drains at the bottom of a 10% slope. Runoff was calculated for 30-40 minutes by collecting water draining into containers. Total suspended solids were calculated by filtering and oven-drying samples. Turbidity was measured using a LaMotte 2020 Turbidimeter. Sediment particle sizes were analyzed by a laser scattering particle diameter frequency distribution analyzer. Inorganic nitrogen was measured by a Lachat. Bacteria was analyzed using Colilert Defined Substrate Technology and Quanti-Tray/2000 analysis. Metals were analyzed from soils at 2.54 cm (1 in) depth and were analyzed separately for aqueous and solid phases using inductively coupled plasma optical emission spectrometry. If elements were below the detection limit, atomic absorption spectroscopy was used. Petroleum hydrocarbons were analyzed using EPA Method 8015B and EPA Method 1664. Statistical analysis compared the difference in means between the control and the treatment at the $P < 0.05$ significance level.

The compost filter socks removed 65% and 66% of clay and silt particles. However, the removal efficiency between the compost filter sock and the control was not statistically significant. The compost filter sock removed 17% of $NH_4$-N and 11% of $NO_3^-$-N, but removal rates were again not statistically significant different than that obtained for the control. A nitrogen-specific flocculant increased $NH_4$-N removal to 27% but did not affect $NO_3^-$-N. The removal percent for coliform bacteria and *E. Coli* were high, at 74% and 75%. Adding a bacteria-targeting flocculant increased removal efficiencies of both to 99% and was significantly different than the control. The compost filter sock removed a range of metals, from 37% to 71%. The reduction was significant for all metals except chromium. Adding a metal-targeting flocculant increased removal percentages to 47% to 73%. With the flocculant, the removal efficiency was significant for all metals compared to the control. The compost filter sock removed 84% of motor oil and 43% of gasoline alone. Authors posit that statistically significant removal rates of bacteria, metals, and petroleum hydrocarbons were due to the high sediment removal rate, high surface area, and cation exchange-capacity of the compost filter socks.

### 2.2.9 Performance of Compost Filtration with Natural Sorbents

Faucette et al. (2013) built off of their 2009 work on compost filter socks, adding filter socks with natural sorbents. The two treatments were tested against a control for removal of:

- Soluble phosphorus;
- Inorganic nitrogen, $NH_4$-N and $NO_3^-$-N;
- Bacteria, *E. coli* and *Enterococcus faecium*; and
- Motor oil.

As with the 2009 study, each analyte group was analyzed in a separate experiment. The experiment

(see Section 2.2.8). Experiments in each group were performed in triplicate. Unlike the 2009 study, controls of bare concrete and soil were only tested in the beginning of the experiment to confirm that all runoff and analytes ran through the system. Also, unlike the 2009 study, runoff events were simulated until the compost filter socks without natural sorbents and with natural sorbents both reached a greater than 25% removal efficiency or until 25 trials were completed. Similar to the 2009 study, a specific flocculant was added to each study group to determine its impact on pollutant removal. Soluble phosphorus (P2O5) was tested at 2 mg/L (. Inorganic nitrogen was tested at 1.0 mg/L and 2.0 mg/L for $NH_4$-N and $NO_3^-$-N, respectively. For fecal bacteria, cultures were obtained from the USDA Millner culture collection and prepared to a concentration of 30,000 colony forming units/100 mL. Motor oil was applied at 35.7 mg/L. In between each experiment, chambers were rinsed with deionized water.

Compost filter socks were constructed by Filtrexx International and had the same mesh specifications as the 2009 study. The filter is “derived from land clearing and yard debris organic materials” and is composed of 17% media <2 mm (0.07 in), 27% media is between 2 mm (0.07 in) and 9.5 mm (0.37 in) and 56% media >9.5 mm (0.37 in) and no media over 25 mm (0.98 in). The compost filter socks were snugly situated at the downslope end of the chamber, near the drainpipe. Chamber corners and the interface between the concrete and sock were packed with compost filter material.

Runoff was generated by pouring 15 L, at an increment of 1 L per minute, of pollutant-spiked water into each chamber. The water source for all analyte groups, except bacteria, was tap water. Unchlorinated well water was sourced for the bacteria study. Orthophosphorus and inorganic nitrogen were analyzed with a Lachat analyzer. Bacteria were spiral plated as aliquots on agar, incubated, and colonies were counted. For motor oil, runoff was collected in a 2L container with 100 mL hexane. The hexane was decanted off and the remaining motor oil was dried and weighed. Statistical analysis compared the difference in means for the filter sock with natural sorbents and without natural sorbents at the $P < 0.05$ level.

Soluble phosphorus was significantly different between treatments, with the filter sock containing natural sorbents performing more strongly (mean 34% removal). However, the removal ability of the filter socks with the natural sorbents decreased over the 8 trial period conducted. There was no significant difference in inorganic nitrogen removal for the two treatments. However, the filter sock with natural sorbents removed a mean 54% $NH_4$-N while the filter sock without sorbents removed a mean of 31% over 25 trials. Similarly, the filter sock with natural sorbents removed higher percentages of $NO_3^-$-N compared to the filter sock without, 11% mean removal and 9% mean removal, respectively. Motor oil removal was very high, 99% mean removal efficiency for both treatments. For bacteria, the filter sock with natural sorbents performed significantly better than the filter sock without. For *E. coli*, the filter sock with natural sorbents removed a mean 85%, compared to the 4% for the filter sock without sorbents. For *Enterococcus*, the filter sock with natural sorbents had a removal efficiency of 65%, compared to 23% for the filter sock without sorbents. Bacteria experiments had 25 trials.

## 2.3 FIELD STUDIES

### 2.3.1 Overview

The research in this section is based on field studies. Primary goals were to develop consistent and reproducible methods to quantify performance of erosion control devices directly applicable to real world conditions. A common theme in most of the studies is the importance and difficulty of proper product installation for reliable and repeatable performance. It is a practical impossibility to attain a perfect installation of a device (Beighley and Valdes 2009). The prevalence of this issue indicates the need to further look at developing methods that mitigate installation difficulties. Another common observation is that the effectiveness of devices depends on local conditions and that a combination or “treatment train” may be the best option for many situations.

Two ASTM methods apply to field or full-scale testing of sediment retention devices, ASTM 7208 for ditch check applications and 7351 for sheet flow applications. It was found that many of the full-scale studies were modeled after one of these two methods. These standards are discussed first.

### 2.3.2 ASTM Standard for Ditch Checks

ASTM 7208 (2014) describe an experimental procedure to evaluate temporary ditch check performance. Ditch checks protect earthen channels by slowing and/or ponding runoff to encourage sedimentation, and thereby reducing soil particle transport downstream, by trapping soil particles upstream of structure, and by decreasing soil erosion.

This method uses test channels of trapezoidal cross-section with a 0.61 m bottom width, 2:1 side slope ratios and a minimum length of 18.3 m (60 ft) long. They are at a slope of approximately 5% and are plated with a minimum of 45 cm (17.7 in) of compacted soil veneer. Before testing, the soil is loosened in the test area to a depth of 10 cm (4 in). Ditch checks are placed perpendicular to the flow and are long enough so the flow does not escape around the ends. The system is designed to minimize turbulence in the delivery of water to the test channel with minimal turbulence. A probe is used to measure velocity in a three point pattern. Testing is performed with a target flow of 0.085 $m^3/s$ for 30 minutes or until a ditch check is dislodged. Testing is replicated at least three times for each type of ditch check. Soil lost or gained in the test is evened out to pre-test conditions before the next test is performed. Before testing, channel surface elevations are recorded at 9 cross sections points along the channel and immediately before and after the ditch check. As soon as a steady state flow condition is reached water surface elevations velocity measurements are taken at the centerpoint of each cross section. At the end of the test, channel elevations are recorded at the same locations as the pre-test.

The collected data are used to calculate total discharge, velocity, flow depth, energy slope (EGL), cut areas (Ct), fill areas (Ft), Clopper Soil Loss Index (CSLI) and Soil Aggradation Index (SAI). The EGL is calculated by $EGL= WSE + v^2/2g$ where WSE is the slope of water surface; v is the average water velocity, and g is the acceleration of gravity. The CLSI and SAI are used to define the performance of the ditch checks compared to a bare soil test. Equations for calculating CLSI and SAI are $CSLI = (Ct/ At) X 100$ and $SAI= (Ft/ At) X 100$, where At is wetted channel area.

### 2.3.3 Evaluation of Alabama DOT Ditch Check Practices

Zech and Fang (2014) tested the performance of a wattle ditch check with seven different installations. Improvement of performance over control was determined based on velocity reduction, impoundment length, and structural integrity.

The methodology of this experiment was based on ASTM 7208. The channel was designed with a top width of 4 m (13 ft) and a bottom width of 1.2 m (3.9 ft) with 3:1 side-slope ratios. The depth of the channel was 0.5 m (1.6 ft) and was 12 m (39 ft) long. The channel had a steel plated section 7.5 m (24.6 ft118) long followed by an earthen section 4.6 m (15 ft) long. The channel slope was 5%. The earthen section was raked and compacted. A constant flow of 16 L/s of clean water was run for a duration of 30 minutes. A 50 cm (20 in) diameter, 6 m (20 ft) long wheat straw wattle with synthetic netting was installed in seven different configurations: (1) Downstream Staking, (2) Teepee Staking, (3) Downstream Staking w/Trenching, (4) Teepee Staking w/8 oz. FF and Trenching, (5) Downstream Staking w/FF, (6) Teepee Staking w/8 oz. FF and (7) Teepee Staking w/8 oz. FF + Staples. Each configuration, including the no wattle control, was tested 3 times.

At eight cross-sectional locations, six upstream and two downstream of ditch check, water depth and velocity were measured at three points, one foot apart, mid-channel. Once a steady state was achieved, the distance from the upstream face of the wattle to the hydraulic jump was also recorded (length of subcritical flow). From the data collected average water velocity, depth and the slope of the energy grade line (EGL) were calculated. A multiple regression model was used to evaluate the effect the installment configurations had on the length of subcritical flow.

The authors noted that from their hydraulic evaluation of the of the tests' results, evaluating performance based solely on EGL slope reduction may lead to improper conclusions, especially if the EGL crosses the hydraulic jump. They evaluated ditch checks performance based on subcritical flow length. From the multiple regression model of subcritical flow length, it was concluded that 1) the staking pattern does not significantly affect the performance of the installation, (2) trenching the wattle has a significantly detrimental effect on performance and (3) underlying and stapling significantly improve performance by increasing the subcritical flow length. They noted that there was excessive undercutting and piping occurring at the interface of the wattle and channel bottom with staking only. This lead to a decrease in subcritical flow length. Stapling and filter fabric underlay both had mitigating effects on the undercutting. Another noteworthy observation was that trenching significantly increased piping and thus decreased subcritical flow length even more than staking alone.

When the results of this study were discussed at a working group meeting, ALDOT (Alabama Department of Transportation) representatives stated that it was unlikely that contractors would be willing to include stapling to secure the wattle to the ground. Thus, even though stapling was shown to increase performance, it may not be realistic to expect it to be implemented in the field.

### 2.3.4 Evaluations of Wattle Ditch Checks

Donald et al. (2014) examined the effect of different wattle materials, densities, and dimensions on overall hydraulic performance wattle ditch checks. The aim of the paper was to provide a method to determine the in-field performance of wattle ditch checks for these differing properties.

Donald et al. modified ASTM 7208 for their study. They used the same channels and prepared in the same manner as that done by Zech and Fang (2014). A tiered flow regime of 16, 32, and 48 L/s of clean water was used for a duration of 10 min each for a total 30-min test duration. Eight different wattles were tested and each wattle was installed in the same manner so the wattles could be evaluated regardless of composition properties. Each wattle was tested three times. The wattles were installed with wooden stakes with an underlay of filter fiber secured by sod pins.

As in Zech and Fang (2014), eight cross-sectional locations, six upstream and two downstream of ditch check were identified. Water depth and velocity were measured at three points on the cross-section, 0.3 m (1 ft.) apart, mid-channel. Once a steady state was achieved, the distance from the upstream face of the wattle to the hydraulic jump was also recorded (length of subcritical flow). From the data collected average water velocity, depth and the slope of the energy grade line (EGL) were calculated. From the eight different wattles, three independent groups were formed based on material (1) excelsior wattle (EW), (2) wheat straw wattle (WW), and (3) synthetic wattle (SW). An analysis of the ratio of hydraulic performance to the density of each wattle for each flow tier was performed with a one-way analysis of variance (ANOVA) test to determine if these different wattle groups performed similarly. The impoundment depth at the cross-section immediately upstream of the wattle was used to measure hydraulic performance. A least significant difference (LSD) post hoc test was used to determine which groups were statistically significantly different from each other.

The researchers found that there were significant differences in depth to density ratios between all 3 groups under low flow conditions. Therefore, it was the material fill that controlled runoff depth behind the wattles.  For medium and high flow, the excelsior and wheat wattles performed similarly and were not different, therefore wattle density was the controlling factor for runoff depth. The synthetic wattle was significantly different from the other two groups for all three flow tiers.  This was due to its much higher absorption capabilities, resulting in larger impoundments of subcritical flow. Using these results, the researchers felt that when considering wheat straw or excelsior products, practitioners should be able to choose a product to meet their ditch check needs based on the manufacturer's specified density. For synthetic materials, it is important to understand how the material is affected by flow.

### 2.3.5 ASTM Standard for Sediment Retention Device

The purpose of ASTM-D7351 (2013) is to evaluate the sediment retaining ability of Sediment Retention Devices (SRDs) when exposed to “sheet” runoff of sediment-laden water. This method was first written in 2007 and was revised in 2013. SRDs are installed to reduce runoff transport of eroded soil from disturbed sites by trapping and settling the suspended soil. Sediment laden flows through, over, above and/or under a SRD. The amount of sediment in the water is measured both up and downstream of the device.

The testing area for this standard has an installation zone of soil compacted to 90±3% of Standard Proctor density, at a soil moisture within ±3 % of optimum moisture content per ASTM D 698. Soil depth is in excess of the depth of installation. The installation zone width is wide enough to completely contain the SRD. Impermeable areas are constructed immediately preceding and following the installation zone. The retention zone, the area above the installation, is a 3:1 slope surface (at least 5 m long) immediately below a mixer tank and spreads the discharge to the width of the SRD installation. The SRD should be installed according to manufacturer's recommendations, perpendicular to the flow and secured appropriately.

A collection tank is placed at a lower grade than the installation zone, at the bottom of the impermeable area. The mixing tank and collection tank are both positioned on scales which allows monitoring of the weight of the sediment laden water going into and out of the SRD installation zone. Sediment-laden runoff is created by combining and agitating water and soil in the mixing tank during the test.  A flow rate of 90 kg/min (198 lb/min) is discharged from a mixture of 2270 kg (2.5 ton) of water and 136 kg (299 lb) of soil for 30 minutes. This is accomplished by recording the mixing tank weight every 5 minutes and adjusting the flow valve as appropriate. This flow simulates sheet flow from a slope measuring 6.1 m wide by 30 m (98 ft.) long exposed to the peak 30 min of a 100 mm (4 in) per hour rainfall hydrograph. The weight of the collection tank is recorded and grab samples are taken every five minutes as runoff passes through the SRD and enters the tank. Grab samples are also taken every 5 minutes at the mouth of the discharge from the mixing tank.

Each grab sample is filtered or dried to determine solids fraction, weighted solids fraction (solids fraction x time interval/total-test-time) and total solids fraction ($F_{st}$). The total mass collected ($M_T$) is defined the total mass (kg) of water and sediment collected in the receiving tank, plus the combined sediment/water mixture mass (kg) of the grab samples. These values are used to determine soil retention percentage ($T_r$) defined as

$$T_R \quad 100\left(1-\frac{M_T\,F_{st}}{136\,kg}\right) \tag{2.8}$$

### 2.3.6 Evaluation of Slope Interrupter Practices

Beighley and Valdes (2009) created steep sloped bare soil conditions representative of most construction sites and used these conditions to compare the performance of two devices with contrasting treatment technologies. The main components of the experiment were a tilting soil bed (3 m x 10 m) and a Norton Ladder Rainfall Simulator. The top 10-15 cm (4-6 in) of soil of the bed was replaced before each test with a sandy loam soil typically found in southern California. The soil was then compacted to a mean density of 1.5 g/cm3 (94 lb/ft3). The slope of the bed was 3H:1V and the testing area was 2 m (6.6 ft.) width and 8 m (26 ft.) long. A metal flume was attached to the end of the bed. Runoff discharged from the flume into a graduated collection tank. Two slope interrupter practices were tested: a 20 cm (7.9 in) diameter fiber roll filled with rice-straw (FR) and a 20 cm (7.9 in) diameter geo-roll consisting of perforated tubing wrapped in filter fabric with an attachment apron (GR). These practices were installed according to manufacturer's recommended specifications. Each device was tested in triplicate.

Simulated rainfall was applied 2.5 m (8 ft.) above the soil surface designed to mimic a 1 hr, 10-year coastal California storm. Rainfall intensity was 5 mm/hr (0.19 in/hr) for 30 min, 50 mm/hr (1.9 in/hr) for 40 min followed by 5 mm/hr (0.19 in/hr) for 30 min. Total rainfall was 38 mm (1.5 in) and total duration was 100 min. Every 5 min runoff volumes were recorded and runoff samples were collected.

Average sediment concentration and particle size were determined from the runoff samples. The average flow rate for each time interval was calculated using the interval runoff volume plus the runoff sample volume. Soil-retention efficiencies percentage ($T_r$) were calculated by

$$T_R = 100\left(\frac{\sum_{i=1}^{k}\left(S_{NT,i}-S_{T,i}\right)}{\sum_{i=1}^{k}S_{NT,i}}\right) \tag{2.9}$$

where *i* corresponds to the time of measured sediment export; k is the number of time observations; and $S_{NT,i}$ and $S_{T,i}$ are the masses of dry soil exported at the *i*th time for the no treatment NT and treatment (FR and GR) experiments, respectively.

Beighley and Valdes examined the Rational Method and NRCS-CN runoff curve number method for estimating peak flow and runoff. The C coefficients for the Rational Method were estimated to be 0.81 and 0.69 (water only), and CN runoff values were 96 and 94 (water only).

The geo roll performed slightly better than the fiber roll in this experiment. Reduction in parameters compared to no-treatment for FR and GR respectively were 37% and 41% of total runoff, 89% and 94% of sediment export, 33% and 35% of peak discharge rates, and 75% and 85% of peak sediment concentrations. No-treatment sediment concentrations are strongly related to discharge (R=0.88). Runoff began after about 2.5 mm (0.09 in) of rainfall or 20-25 minutes into the test for no treatment with about a 5 minutes lag time behind that for the practice tests.

### 2.3.7 Assessment of Compost Filter Socks and Conventional Practices

Faucette et al. (2009a) compared 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 based on a 24-hour, five-year return runoff event to help practitioners in choosing an appropriate BMP for their project. The testing ground was graded to a 10% slope exposing a semi-compacted subsoil (Bt horizon) to simulate land disturbing and grading conditions. A 1.0 m (3.3 ft) wide by 4.8 m (16 ft) long plot area was created with fifteen-cm (6-in) high stainless steel borders which were trenched 7.5 cm (3 in) into the soil. Long border extensions 60-cm (2-ft) tall by 90-cm (3-ft) were installed on each side of the plot base to contain water ponding behind sediment control treatments. Prior to each simulated rainfall event, a removable flume was installed at the base of each plot to collect runoff. Six SRD treatments plus control (no device) were tested: 20 and 30-cm (8 and 12-in) compost filter sock, 20 and 30-cm (8 and 12-in) compost filter sock plus polymer, mulch filter berm, straw bale. All devices were installed at the toe of the slope per manufacturer or government agency specifications.

A Norton Rainfall Simulator was used to generate a (4.5-in) rainfall event based on cultivated agricultural land bare soil within the B hydrologic soil group (CN = 86). This event represents that of a 24-hour 5-year return storm based on historical rainfall records. The following data were generated from the storm water runoff samples and analysis: 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). Water samples were taken every 5 minutes after runoff started coming out of the flume aperture.

All compost filter socks showed a significant increase in sediment removal efficiency (total solids, total suspended solids, P factor in USLE) over straw bales and mulch filter berms, however the difference between differing diameters of compost filter socks was not significant. Turbidity in all of the compost sock treatments was lower than the bare soil and the compost socks with polymer added had significantly lower turbidity than the compost socks alone.

### 2.3.8 Evaluation of Practices for Concentrated Flow

Garcia et. al. (2015) developed and tested a method for evaluating sediment control devices in typical Illinois weather and soil conditions. It served as a guide to the IDOT (Illinois Department of Transportation) for the installation and maintenance of sediment reduction devices (SRDs) and provides data that can help assess the usefulness of specific products for IDOT projects.

The test channel simulated the typical channel profile found in construction sites and roadside ditches and was approximately 3 m (9.8 ft) wide at the upstream end and 7.9 m (26 ft) at the downstream end, 61 m (200 ft) in length with a 4 % slope and 2(H):1(V) side slopes. The top 10 cm (3.9 in) of soil in the bed was first loosened and then compacted in the installation area. Water was supplied from a detention pond and was pumped for 30 minutes at flow rates of 5, 7.5, and 10 l/s into the 11 m (36 ft) discharge zone which was stabilized with a turf reinforcement mat (TRM) and vegetation. The discharge then went through a wire into the 50 m (164 ft) 2 testing zone. Every 5 minutes grab samples were collected from the upstream and downstream sides of each ditch check. Three ditch check products were tested: Sediment Logs, GeoRidge plastic berms, and Triangular Silt Dikes. Each product was installed in a series of two in the testing zone in accordance with the manufacturer's recommendations. The wetted channel area upstream of the product for 2 m (6.5 ft) in length was scanned with a laser distance meter before and after triplicate tests were run for each product and flow rate. For each flow rate the channel was prepared anew.

Total solids concentration (TSC) and turbidity were determined for each grab sample. Total soil loss was computed with the average TSC value over each 5-minute period after steady-state was achieved. The total volume of retained sediment was computed using the surface scans for the downstream ditch check. Comparisons of product performance were made with a Welch's t test.

The Triangular Silt Dikes performed better than the other two ditch checks and had significantly lower total soil loss. The Triangular Silt Dikes also had consistently lower volume of accumulated sediment than the other two while the GeoRidge plastic berms had consistently lower volume of accumulated sediment than the sediment logs. In general, there was no relationship shown between flow rate and average sediment concentration. None of the products failed and undercutting was only seen with the sediment logs at the higher flow rates. The author established a relationship between TSC and turbidity and proposed that turbidity could be used as a quick estimate of TSC in the field.

### 2.3.9 Response of Practices Under Standardized Conditions

Thiesen and Spittle (2006) used a standardized large-scale method for testing different sediment retention devices (SRD). Their method is a modification of ASTM 7351. The testing area is comprised of an installation area in between impermeable retention and collection areas. The installation zone is 1.5 m (4.9 ft) wide with compacted soil subgrade the same as used for the sediment. The compacted soil is reconstructed after each test.

The SRDs were installed in the center of the installation zone to a width that extended beyond the retention zone to ensure no runoff escaped around the ends. Six SRDs were tested between 2003 -

2004: Fiber Filtration Tube, Sliced Silt Fence, Triangular Silt Dike, Excelsior Fiber Roll, Straw Wattle, Static Silt Fence. A second round of testing was done in 2004 to assess the benefits of more than one SRD in a series as would be found in steep slope or low flow applications. In this round a parabolic sandy loam bed channel was configured to 15.2 m (50 ft) long and 2.1 m (6.9 ft) wide with a 2% gradient and gentle side slopes. The discharge quantity was increased by 50% so the discharge was released at the same rate for 45 minutes. One device was installed across the channel 4.6 m below the hydraulic discharge point and a second device was installed 7.6 m (25 ft) downstream of the first. All devices were installed perpendicular to the flow and trenched to a depth of 16 mm (0.63 in).  Soil retention effectiveness for each SRD was assessed by their respective % soil retentions. In the second round of testing, ease of installation, flow rate, filtration, installation stability, and turbidity of the water entering and exiting the test channel were observed in addition to the initial set of parameters.

Soil retention effectiveness for the six SRDs in the first round were as follows: Fiber Filtration Tube 94%, Sliced Silt Fence 90%, Triangular Silt Dike 86%, Excelsior Fiber Roll 54%, Straw Wattle 54%, Static Silt Fence 49%. The Fiber Filtration Tube outperformed the others Straw/Coconut Fiber Roll, Compost Sock, Straw Wattle, Excelsior Fiber Roll) in the second round as well with 98% soil retention and turbidity of 300 NTU (next lowest was 4500). The second round of studies showed that a second device did increase performance for all of the devices tested. From their observations the authors also noted that the fiber filtration tubes, straw wattles and excelsior fiber rolls were easier to install than the compost socks and straw/coconut fiber rolls.

### 2.3.10 Assessment of Practice in Georgia

Troxel (2013) evaluated different types of sediment control devices (SCDs) and included a life-cycle assessment.  Life-cycle analysis (LCA) to determine the environmental impacts of each sediment control device was performed using GaBi software version 6.0 by PE INTERNATIONAL.  This analysis is beyond the scope of this project and is not included here.

Evaluation of different types of SCMs was done following ASTM 7351 method using a channel slope of approximately 21 degrees.  The soil was red to reddish brown sandy clay. For device installation, the SCD was installed generally centered in the installation zone so that there was equal space in front and behind the SCD.  The SCDs tested were: (1) Silt fence - type A (ErosionTech ET-GA-A), (2) High-flow silt fence - type C (ErosionTech ET-GA-C), (3) Compost sock, 12” Filtrexx® silt sock and 18” Filtrexx® silt sock, (4)Straw bale and (5) Mulch berms. The SCDs were installed to Georgia Soil and Water Conservation Commission (GSWCC) specifications. Special attention was paid to ensuring that the runoff didn’t bypass the SCD. To that end, wing walls were attached to form a 45 degree inner angle with the barrier wall in the installation zone upstream of the SCD for all three-dimensional SCDs. For the 12-inch compost sock and straw bale tests bentonite clay was used to backfill both wing walls. Mulch and loose compost were used to backfill the wing walls during the mulch berm and 18-inch tests respectively. Cylinder filter tests were performed to determine nutrient and metal retention by the SCDs. Sample material from the SCDs was compacted into long acrylic cylinders to field density. Initial nutrient concentrations in the SCD material was determined and nutrient and metal capturing ability was measured by filtering water with known nutrient or metal concentrations through the SCD.

Turbidity was measured in up and downstream samples. Total suspended solids and total dissolved solids were measured only in downstream samples and total solids was measured only in upstream samples. From these sample analyses and data collected during testing, the weight of the soil and water mixture retained, flow-through rate, TSS reduction, turbidity reduction, TDS reduction and SCD removal efficiency were calculated.

The silt fences had the best performance in TSS and turbidity removal efficiency with straw bales performing the worst, though all of the SCDs had relatively high sediment retention. The reduction range for TSS was 91% - 98% and for turbidity was 50% - 93%. There was a strong relationship between TSS and turbidity with most of the devices.  Compost, mulch and straw were tested for nutrient and metal retention. Mulch berms performed significantly higher (56%) than straw (32.5%) and compost (6.4%) in the removal of nitrogen.  Phosphorus removal was quite low in all devices and in fact, straw bales increased phosphorus significantly. Mulch and compost performed well in removing metals (80%-94% removal) straw had a more moderate performance (26%-48%).

The author pointed out several weaknesses or limitations in the ASTM 7351 method including:

- Large soil loading during the test
- Large range of grain sizes that are acceptable for use
- Soil type selected for use may not represent the soil that would erode during a storm
- Difficulty in eliminating edge effects with the method as specified

# CHAPTER 3: EVALUATION OF HYDRAULIC CHARACTERISTICS

## 3.1 OVERVIEW OF ACTIVITIES

Understanding the hydraulic characteristics of sediment control logs is of fundamental importance in determining whether they are appropriate for given set of site conditions and, if they are, in selecting the best log. The hydraulic characteristic of greatest interest is the volumetric flow rate through the log. These flow rates were measured using the flume located in the Biosystems and Agricultural Engineering Laboratory at the University of Minnesota.

An important component of the study is to tie hydraulic response and sediment removal of logs to more easily measurable physical characteristics. A variety of different physical characteristics was used to investigate possible relationships. The physical characteristics are first summarized in this chapter. The hydraulic flume experiments and analysis are then presented. Detailed descriptions of the experimental methods for measuring physical characteristics are given in Appendix A.

## 3.2 PHYSICAL CHARACTERISTICS OF SEDIMENT CONTROL LOGS

A summary of sediment control logs used in this study is given in Table 1. Visual differences between the different types of logs can be seen in Figs. 1 through 4. These logs are shown mounted in the hydraulic flume. Details of the methods to measure the diameter, density and volumetric void space are given in Appendix A. Another set of densities was measured for the conditions of the hydraulic flume.

Figure 1 Sediment Control Log with Straw (S1, Western Excelsior Straw)

Table 1 Overview of Sediment Control Logs.

| Source | Log Type | Label | Fill | Average diameter mm (in) | Density g/cm$^3$ (lb/ft$^3$ ) | Percent volumetric pore space |
|---|---|---|---|---|---|---|
| Brock White | American Excelsior | S2 | Straw | 200 (7.9) | 0.089 (5.56) | 69.3 |
| Brock White | Coir | C | Coconut Fiber | 302 (11.9) | 0.078 (4.87) | 87.8 |
| Brock White | American Excelsior | W2 | Wood Fiber | 193 (7.6) | 0.035 (2.18) | 95.0 |
| Lawn and Driveway Services Western Excelsior | Western Excelsior logs | W1 | Wood Fiber | 185 (7.3) | 0.067 (4.18) | 85.5 |
| Lawn and Driveway Services Western Excelsior | Excelsior Straw Log | S1 | Straw | 195 (7.7) | 0.042 (2.62) | 78.3 |
| Western Excelsior | Burlap W | W3 | Wood Fiber | 233 (9.2) | 0.057 (3.56) | 88.9 |
| Western Excelsior | Burlap Straw | S3 | Straw | 241 (9.5) | 0.089 (5.56) | 77.7 |
| Pautz Construction | Curb log | WC | Wood Chips | 233 (9.2) | 0.152 (9.49) | 74.9 |
| Ramy Turf | Eco-Guard White | WC White | Compost Heavy | 193 (7.6) | 0.269 (18.5) | 62.6 |
| Ramy Turf | Eco-Guard Red | WC Red | Compost Medium | 185 (7.3) | 0.214 (13.4) | 62.8 |
| Ramy Turf | Eco-Guard Blue | WC Blue | Compost light | 182 (7.2) | 0.181 (11.3) | 69.2 |
| Menards | River Pebble | R | Rock | 152 (6.0) | NA[1] | 42.3 |

[1] Unable to collect data.

As shown in Table 1, the densities vary considerably among different types of logs. They ranged from a minimum of 0.035 g cm$^{-3}$ (2.18 lb ft$^{-3}$) to a maximum of 0.269 g cm$^{-3}$ (18.5 lb ft$^{-3}$). Percent volumetric pore spaces generally varied inversely with density. Logs with small densities have larger pore spaces than logs with larger densities.

Figure 2 Sediment Control Log with Wood Chips (WC Red, Eco-Guard Compost ).

Figure 3 Sediment Control Log with Coconut (C, Coir Coconut Fiber).

Additional physical characteristics are given in Table 2. Ambient moisture content was determined from the difference in mass of a sample of the log media before and after drying at 75°C. Capillary moisture was determined by weighing a log section before soaking the log overnight. The mass was determined after the log was allowed to be drip dried. The mass was converted to volume using the density of water. The capillary moisture content corresponds to the amount of water stored in smaller pore space corresponding to capillary potentials greater than that of gravity. It is a measure of the number of small pores in the logs.

Figure 4 Sediment Control Log with River Pebble Rocks.

Table 2 Physical Characteristics of Sediment Control Log.

| **Log Type** | **Label** | **Saturated moisture content (by mass)** | **Ambient moisture content (by mass)** | **Saturated Conductivity mm/s (in/s)** | **Capillary moisture content (by vol)** | **% Finer for d=2 mm** | **%Finer for d=25.4 mm** |
|---|---|---|---|---|---|---|---|
| American Excelsior | S2 | 79.6% | 12.5% | 21.0 (0.83) | 18.5 | 72.5% | 98.1% |
| Coir | C | 64.6% | 10.2% | 252.8 (9.9) | 8.3 | 7.3% | 8.6% |
| American Excelsior | W2 | 67.6% | 13.5% | 1921.2 (75.6) | 5.2 | 12.2% | 15.4% |
| Western Excelsior logs | W1 | 72.8% | 6.3% | 403.6 (15.9) | 13.8 | 7.9% | 49.0% |
| Excel Straw Log | S1 | 83.3% | 11.9% | 261.2 (10.3) | 12.1 | NA[1] | NA[1] |
| Burlap W | W3 | 71.7% | 7.4% | 617.1 (24.3) | 10.7 | 64.2% | 71.1% |
| Burlap Straw | S3 | 77.3% | 22.7% | 64.4 (2.5) | 26.3 | NA[1] | NA[1] |
| Curb log | WC | 56.3% | 5.6% | NA[1] | NA[1] | 19.2% | 98.4% |
| Eco-Guard White | WC White | 50.9% | 10.2% | NA[1] | NA[1] | 29.7% | 98.7% |
| Eco-Guard Red | WC Red | 57.3% | 10.2% | 45.4 (1.8) | 20.1 | 59.1% | 98.9% |
| Eco-Guard Blue | WC Blue | 55.8% | 9.6% | 54.8 (2.2) | 22.6 | 63.4% | 99.0% |
| River Pebble | R | 3.02% | NA[1] | 263.5 (10.4) | NA[1] | 0.1% | 99.9% |

[1] Unable to collect reliable data.

Particle size distributions were obtained using standard sieve analysis. These results are shown in Figure 5. The percent finer values corresponding to the d= 2 mm and d=25.4 mm are also given in Table 2. There is a wide range of size distributions. The coconut and wood fibers of W1 and W2 consist of large size materials; whereas other materials, such as wood chips of Eco-Guard, are composed of smaller size particles. The particle size distribution for S1 (S3 is the same fill material) was not reliably measured.

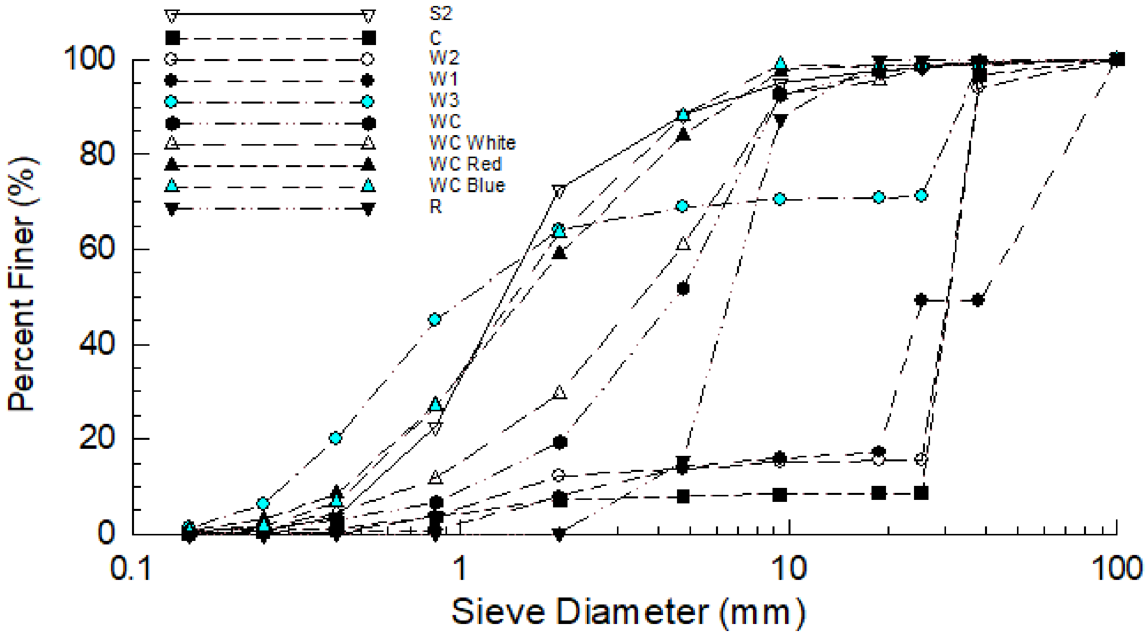

Figure 5 Particle Size Distributions of the Different Materials in Sediment Control Logs.

The measured saturated conductivities for different logs are also reported in Table 2. In comparison to the other physical parameters, saturated conductivity was the most time-consuming characteristic to measure. The permeameter constructed by Dr. Gary Feyereisen was modified and used for this study. The permeameter and conductivity chamber filled with sediment-log material are shown in Figure 6. The chamber has a length of 35.5 in (0.9 m) and an inside diameter of 6 in (0.15 m). Water potentials were measured at the bottom and top of the testing chamber. The volumetric flow rates were measured for these water potentials. By using the length of the chamber, the saturated conductivity is obtained from Darcy's equation.

The measured saturated conductivities varied substantially among the different types of logs. Smaller conductivities were general obtained for logs with large capillary moisture contents and larger conductivities with small capillary moisture content. Large capillary moisture contents correspond to a larger number of small pores.

Figure 6 Permeameter (left photo) and Conductivity Chamber (Coir, right photo).

## 3.3 HYDRAULIC FLUME EXPERIMENTS

The hydraulic flume located in the Biosystems and Agricultural Laboratory was used to study the flow rates through different sediment control logs.  The flume is shown in Figure 7. The overall length of the flume is approximately 45 ft (13.7 m). The logs were located 8 ft (2.4 m) upstream from the end of the flume. The sediment-control log was placed into the structure shown in Figure 8. Foam and sealants were used to ensure that the flow was through the log itself and not around it. More details about the setup procedures are given in the standard operating procedures in Appendix A.

Figure 7 Hydraulic Flume in the Biosystems and Agricultural Engineering Laboratory.

The experimental procedures use three different flow rates corresponding to three different ponded depths upstream of the log. The first two depths correspond to approximately 1/3 and 2/3 of the depth to the top of the log. The third depth is nearly equal to the overtopping depth. The flow rate for each of these depths is divided by the projected area to obtain the flow rate per projected area. Three replicates were used to determine the flow rate corresponding to the overtopping depth. The average of these replicates is given in Table 3. Since our primary interest is the performance of the logs for relatively large runoff events, only a single replicate was used for the smaller flow depths. The flow rate and depth for each of the logs are given in Table 3. The density of the logs in the log holder was also determined for each run. For the rock log and the Burlap Straw log, the flow rates were difficult to measure for the lowest ponded depth and therefore were not recorded.

Changes in flow rates for the three flow depths are shown in Fig. 9. The left-sided figure is for the rock and straw logs. Changes in flow rates with depths for the other logs are shown in the right-sided figure. Generally, the rocks, straw and wood fiber have rapid changes in flow rates with ponded depths. The flow rates for the wood-chip-compost and coconut fiber don’t respond as quickly to changes in ponded depths. These trends are likely related to density. The flow rates don’t change as rapidly for the logs with larger density. The rock density cannot be as easily compared to densities of the other material.

Figure 8 Frame Attachment and Log Holder for Flume Studies.

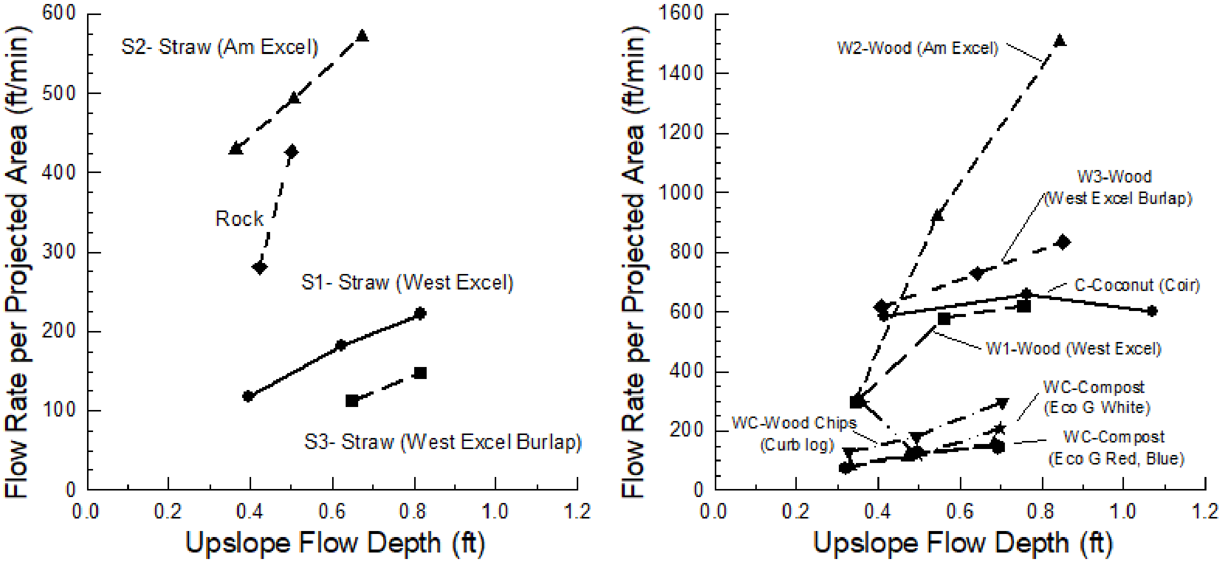

Figure 9 Change in Flow Rate with Ponded Flow Depth. Trends for straw fiber and rock fills are given in the left-sided figure and other materials are given in the right-sided figure.

**Table 3 Summary of Flume Data.**

| Log Type | Label | Density Flume g/cm$^3$ (lb/ft$^3$) | First Depth | | | Second Depth | | | Third Depth | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **h** cm (ft) | **Q** m$^3$/min (gpm) | **q** m/min (ft/min) | **h** cm (ft) | **Q** m$^3$/min (gpm) | **q** m/min (ft/min) | **h** cm (ft) | **Q** m$^3$/min (gpm) | **q** m/min (ft/min) |
| American Excelsior | S2 | 0.070 (4.36) | 12.1 (0.396) | 0.02 (5.53) | 35.9 (117.7) | 19.0 (0.624) | 0.07 (19.57) | 55.5 (182) | 24.9 (0.818) | 0.133 (35.34) | 67.7 (222) |
| Coir | C | 0.077 (4.8) | 12.7 (0.416) | 0.11 (28.80) | 178.4 (585.4) | 23.3 (0.764) | 0.35 (93.41) | 200 (657) | 32.6 (1.071) | 0.506 (133.89) | 182.6 (599) |
| American Excelsior | W2 | 0.035 (2.18) | 10.5 (0.346) | 0.04 (10.38) | 90.9 (298.3) | 16.5 (0.543) | 0.30 (78.42) | 280 (919) | 25.7 (0.844) | 0.946 (250.00) | 459 (1508) |
| Aspen Excelsior logs | W1 | 0.067 (4.18) | 10.5 (0.346) | 0.037 (9.85) | 90.7 (297.7) | 17.1 (0.560) | 0.20 (52.03) | 176 (576) | 22.9$^*$ (0.75) | 0.335$^*$ (88.5) | 189$^*$ (620) |
| Excel Straw Log | S1 | 0.040 (2.5) | 11.1 (0.364) | 0.061 (16.32) | 131.0 (429.8) | 15.4 (0.505) | 0.14 (37.30) | 150 (493) | 20.5 (0.672) | 0.26 (68.79) | 174 (572) |
| Burlap W | W3 | 0.050 (3.12) | 12.4 (0.407) | 0.115 (30.49) | 187.9 (616.4) | 19.5 (0.641) | 0.31 (81.51) | 221 (728) | 25.9 (0.852) | 0.53 (141.33) | 254 (834) |
| Burlap Straw | S3 | 0.087 (5.43) | - | - | - | 19.8 (0.649) | 0.05 (12.70) | 34.1 (112) | 24.8 (0.816) | 0.088 (23.42) | 45.1 (148) |
| Curb log | WC | 0.150 (9.36) | 10.0 (0.329) | 0.013 (3.64) | 39.8 (130.5) | 15.0 (0.493) | 0.05 (12.82) | 54.9 (180) | 21.4 (0.702) | 0.144 (38.17) | 90.8 (298) |
| Eco-Guard White | WC White | 0.228 (14.2) | 11.1 (0.363) | 0.032 (8.57) | 89.5 (293.5) | 15.2 (0.498) | 0.03 (8.72) | 35.7 (117) | 21.2 (0.698) | 0.099 (26.39) | 63.4 (208) |
| Eco-Guard Red | WC Red | 0.184 (11.5) | 9.72 (0.319) | 0.007 (2.00) | 22.7 (74.6) | 15.1 (0.494) | 0.03 (9.08) | 39.0 (128) | 21.0 (0.692) | 0.083 (21.93) | 44.2 (145) |
| Eco-Guard Blue | WC Blue | 0.183 (11.4) | 10.1 (0.331) | 0.009 (2.38) | 24.9 (81.6) | 14.4 (0.472) | 0.03 (7.43) | 33.8 (111) | 20.8 (0.685) | 0.073 (19.39) | 47.8 (157) |
| River Pebble | R | 1.170 (73.0) | - | - | - | 12.9 (0.422) | 0.06 (15.04) | 85.6 (281) | 15.2 (0.501) | 0.120 (31.82) | 130 (427) |

$^*$Flow rate corresponds to the log height and not overtopping depth.

To evaluate trends in flow rates and the physical characteristics of the logs, only the flow rates corresponding to the overtopping depth are used. Trends with densities (using density given in Table 3), saturated conductivities and capillary moisture contents are shown in Figure 10, and trends with percent finer values for d=2 mm (0.07 in) and volumetric pore space are given in Figure 11. Power relationships between flow rates and separately with density, saturated conductivities and capillary moisture contents represent the data with good accuracy. All of the power relationships have coefficients of determination greater than R$^2$=0.6. The best relationship was obtained using the saturated conductivity.

However since this characteristic requires time consuming to measure, the relationship with the capillary moisture content is likely of greater value for this study.

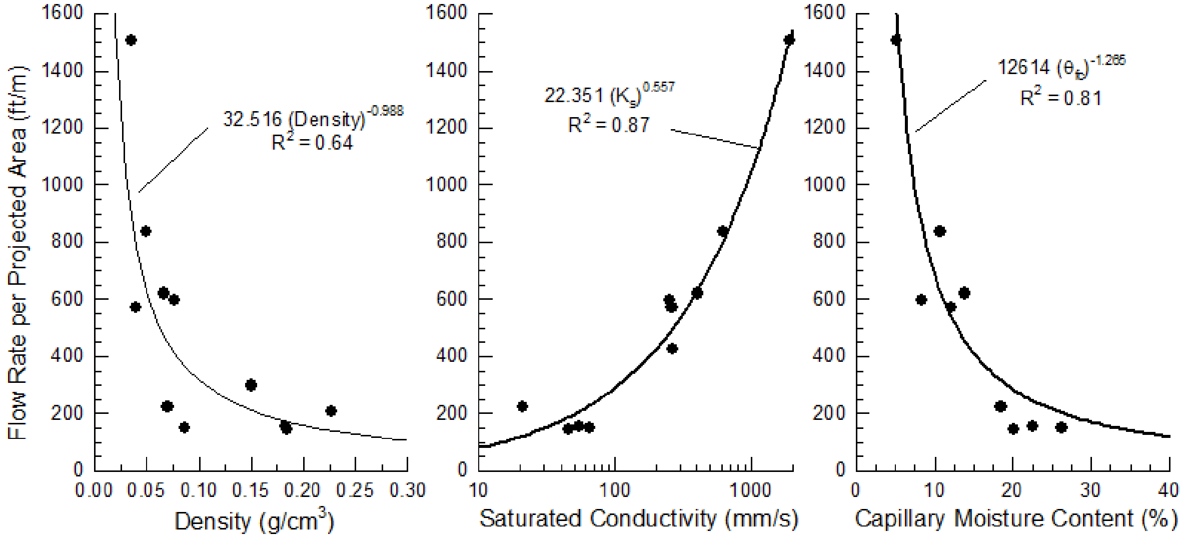

**Figure 10 Trends in Flow Rates with Density, Saturated Conductivity and Capillary Moisture Content.**

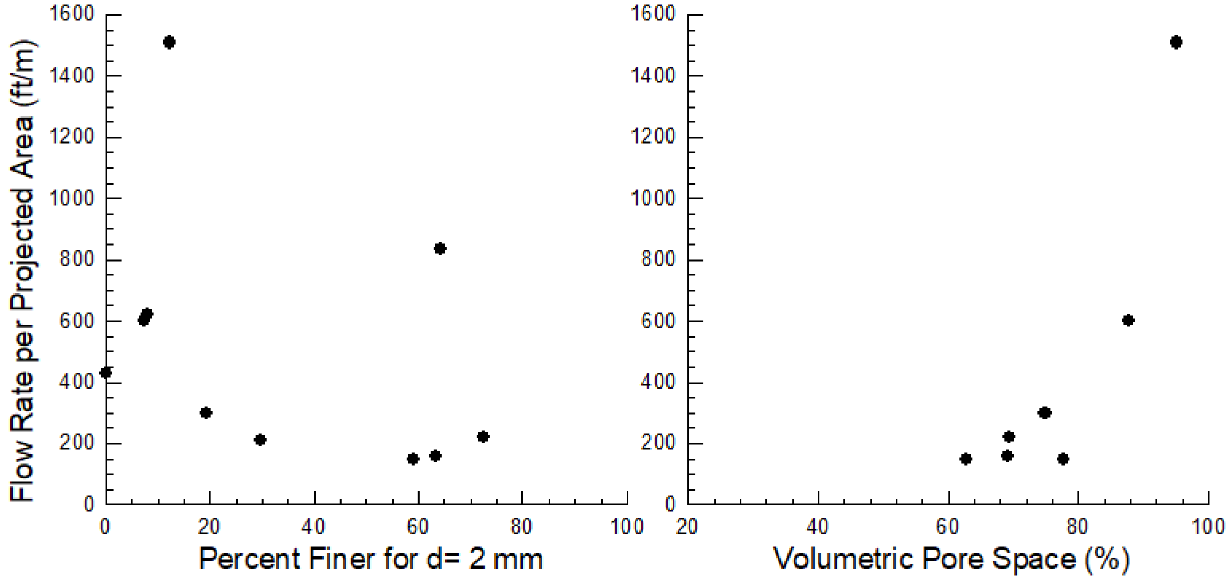

**Figure 11 Trends in Flow Rates with Percent Finer for d= 2 mm and Volumetric Pore Space.**

## 3.4 SUMMARY

The physical characteristics and the flow rate of 12 different types of sediment-control logs were measured as part of the project. These characteristics are summarized in Tables 1 and 2. They were measured to evaluate whether relatively simple measure can be used to represent hydraulic and sediment responses. Some of the physical characteristics, such as density, are relatively easy to determine whereas other characteristics, such as saturated conductivity, require much more effort. Physical characteristics varied substantially among the logs. For example, the densities varied between 0.035 gm/cm$^3$ (2.18 lb/ft$^3$) for wood-fiber to 0.269 gm/cm$^3$ (18.5 lb/ft$^3$) for compost materials.

Flow rates through the different logs were determined using the hydraulic flume located in the Biosystems and Agricultural Engineering Laboratory. Three flow rates were obtained for equally spaced ponded depths, where the largest depth corresponds to the overtopping depth. Three replicates of the same type of log were used to determine the flow rate for the largest depth. Only a single log was used for the other two depths. Changes in flow rates with depth varied substantially among the different logs. The flow rates of different materials varied between 208 ft/min (63.4 m/min) for compost to 1508 ft /min (459.6 m/min) for wood fiber. Flow rates were predicted using a power function of density with fair accuracy ($r^2$=0.64) and predicted with good accuracy using saturated conductivity ($r^2$=0.87) or capillary moisture content ($r^2$=0.81).

# CHAPTER 4: EVALUATION OF THE REMOVAL EFFICIENCIES

## 4.1 OVERVIEW OF ACTIVITIES

In addition to the hydraulic response, the impact of the sediment control logs on the removal of sediment and the longevity of the logs are important in selecting the best logs for a set of site conditions. These important attributes are evaluated in this chapter using a flume with sediment-laden flows and field observations.

Methods and analysis of data collected with a sediment flume will be discussed. Field observations are then summarized. Both sets of information are valuable in making recommendations on appropriate sediment control logs.

## 4.2 SEDIMENT FLUME EXPERIMENTS

The sediment flume located in the Biosystems and Agricultural Laboratory was used to study the flow rates through representative sediment control logs. A subset of the logs discussed in Chapter 3 was used for the sediment-flume experiments. This subset was chosen to capture the different type of hydraulic response discussed in Chapter 3 and to represent the type of material used in the logs. The representative sediment control logs tested in the sediment flume are given in Table 4. Logs of each material type were tested in triplicate in the sediment flume.

Table 4 Representative Sediment Control Logs Tested in Sediment Flume.

| **Source** | **Log Type** | **Label** | **Fill** |
|---|---|---|---|
| Brock White | Coir | C | Coconut Fiber |
| Brock White | American Excelsior | S2 | Straw |
| Lawn and Driveway Services Western Excelsior | Western Excelsior | W1 | Wood Fiber |
| Ramy Turf | Eco-Guard White | WC White | Wood Compost |
| Menards | River Pebble | R | Rock |

A sediment flume was constructed for this project and is shown in Figure 12. The flume is 96 inches (2.4 m) long, 5.75 inches (0.14 m) high, and 19.25 inches (0.48 m) wide with an adjustable slope set to 6%. Sediment control logs were placed at the end of the sediment flume. To simulate the sediment log placed on soil, a 6-inch-wide (0.15 m) and 19.25-inch-long (0.48 m) erosion control blanket was laid underneath the sediment control log in the bottom of the flume. As needed, small foam pieces were inserted in any gaps between the log and flume wall to prevent water bypass. A holder was lowered on top of the log, as needed, to secure it in place. Care was taken not to compress the log. The mounting of the sediment control logs is shown in Figure 13.

Figure 12 Sediment Flume in the Biosystems and Agricultural Engineering Laboratory.

Figure 13 Facing Downstream, Log Holder for Sediment Flume Studies.

All logs were tested with flows corresponding to one-half of the log height. Table 5 shows the flow rates used in the experiments. Logs were allowed to saturate in the flume prior to the start of the experiment. Prior to the experiment after the flow had stabilized, the hydraulic jump was measured. During the experiment, sediment was added at a concentration of 2 g/L (0.12 lb/ft3). The sediment used was a sandy loam, with 68% sand and 32% fines. Sediment delivery rates were measured at the pre- and post-experiment to determine total sediment delivered. Water samples, flow rates, and water heights were measured four times through the experiment, every three minutes. Water samples were collected through a funnel into clean 1 liter HDPE Nalgene bottles.

Table 5 Average flow rates of each log type.

| Log Type | Label | Fill | Average Flows (gal/min) |
|---|---|---|---|
| Coir | C1C | Coconut Fiber | 27.3[3] |
| American Excelsior | S2 | Straw | 14.0[4] |
| Western Excelsior | W1 | Wood Fiber | 28.0 |
| Eco-Guard White | WC White | Wood Compost | 6.19 |
| River Pebble | R | Rock | 10.2[5] |

[3] Flow rates for log C1C were only averaged for pre-experiment through minute 9, as the sediment feeder started to run out of sediment after minute 9.

[4] No post-experiment flow rate taken for log C1C or S2.

[5] No post-experiment flow rates taken for all rock logs

Sediment not captured in the flume or log was measured after the experiment run. Water samples collected in the Nalgene bottles were weighed, transferred to pre-weighed beakers, and dried to determine the weight of soil in the sample. Sediment remaining in the bottom of the flume was scraped into pre-weighed trays. The erosion control blanket and any foam pieces were rinsed lightly, and their contents squeezed into the tray. Trays and water samples were oven dried. Final weights of sediment were determined after two consecutive same weights of the sample. Additional details of the experimental procedures are given in Appendix A.

Two major analyses were performed on the experiment data collected, removal efficiency and an assessment of the longevity. Log capture was calculated by subtracting the sum of $\text{Sediment}_{\text{Out}}$ and $\text{Sediment}_{\text{Settled}}$ from $\text{Sediment}_{\text{In}}$. $\text{Sediment}_{\text{In}}$ is the average sediment input, as determined from the pre- and post-experiment measurements of mass of sediment delivered in one minute by the sediment feeder. Sediment$_{Settled}$ encompasses the sediment collected from the flume bed, foam, and erosion control blanket. Sediment$_{Out}$ is sediment volume discharged over the length of the experiment. This was determined by calculating the concentration of sediment in each sample, multiplying it by the flow rate, and then multiplying the result by 3 minutes to obtain a sediment weight discharged during that time. Figures 15, 16, 17, 18, and 19 show the sediment weights collected in discharge samples, as plotted with experiment run time for the coir, straw, wood fiber, wood compost, and rock logs respectively. These sediment weight data points were combined to obtain the total sediment volume discharged over the entire experimental run.

The total effectiveness of the log was obtained by dividing the sum of sediment deposited upstream of the log and captured in the log by Sediment$_{In}$. Log capture was computed as percentage, by dividing the mass of sediment captured in the log by Sediment$_{In}$. The log capture and total effectiveness percentages are reported in Table 6.

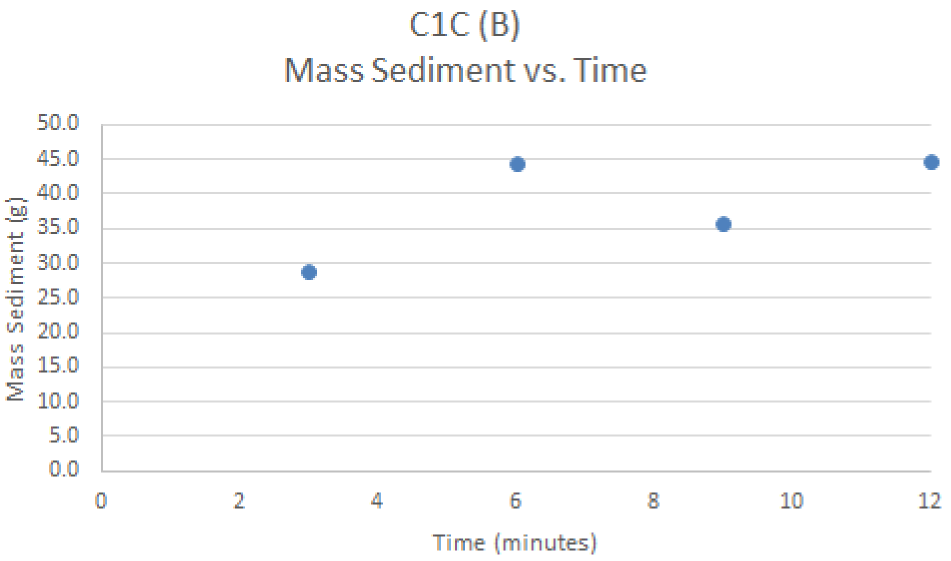

**Figure 14 Mass sediment discharged over time for the median log capture coconut fiber log, C1C (B).**

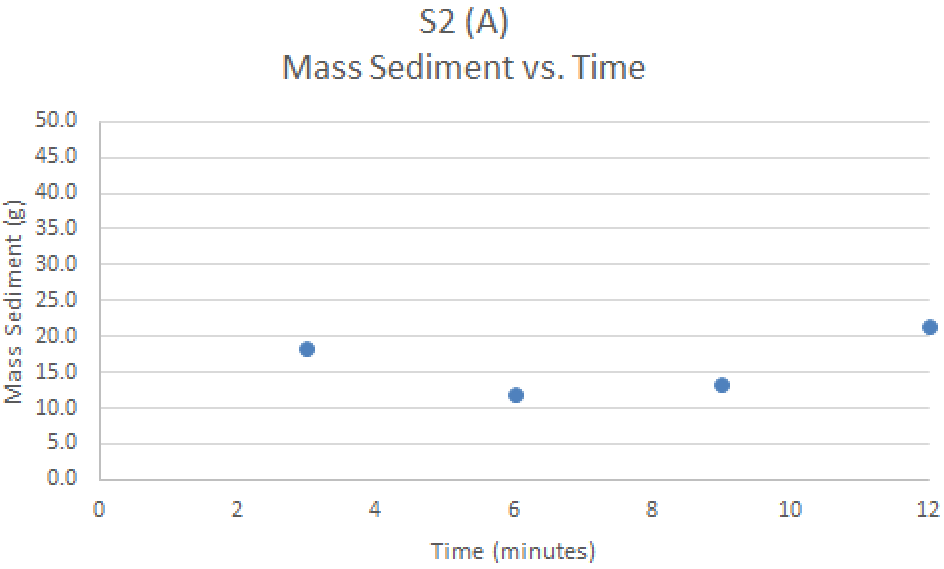

**Figure 15 Mass sediment discharged over time for the median log capture straw log, S2 (A).**

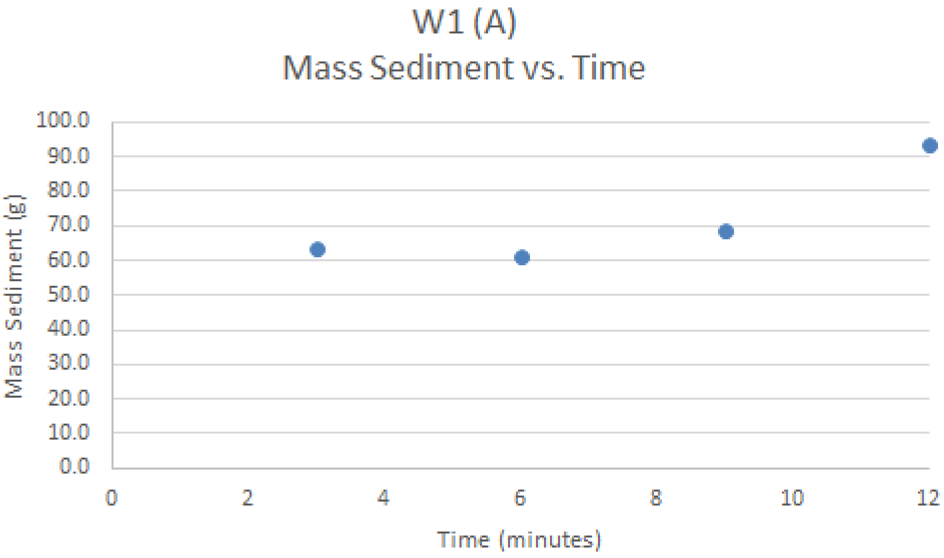

**Figure 16 Mass sediment discharged over time for one of the two median wood fiber logs, W1 (A). Four replicates were completed on the wood fiber logs. Note the mass sediment scale is double than the rest, as the sediment pass through was higher than other logs tested**

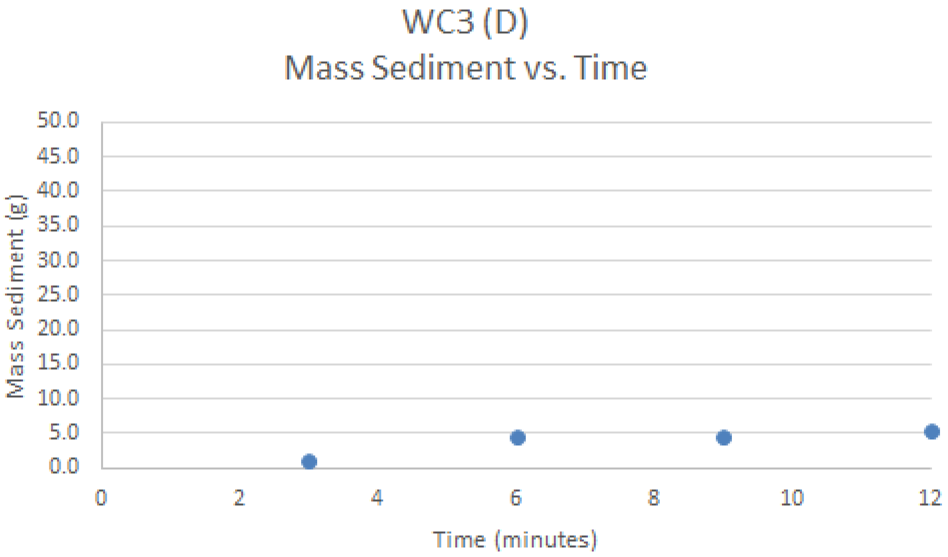

Figure 17 Mass sediment discharged over time for one of the two median wood compost logs, WC3 (D). WC3 (E) also had a log capture of 15%.

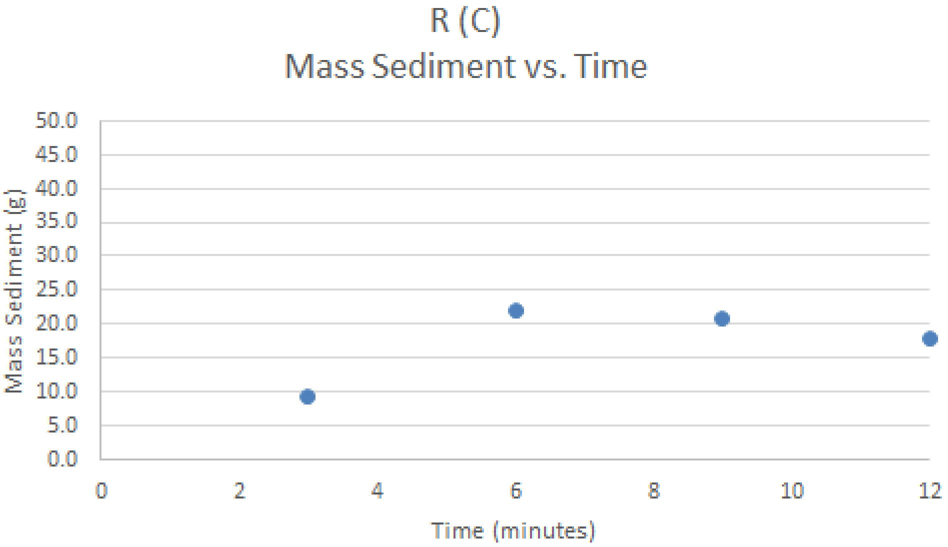

Figure 18 Mass sediment discharged over time for the median log capture rock log, R (C).

**Table 6 Summary of Sediment Removal Efficiency. The alpha identifier in parentheses after the label name refers to the replicate piece of the log taken from the whole log.**

| Log Type | Fill | Label | Log Capture (%) | Median Log Capture (%) | Total Effectiveness (%) | Median Total Effectiveness (%) |
|---|---|---|---|---|---|---|
| Coir | Coconut Fiber | C1C (A)[6] | 27 | 7.2 | 89 | 85 |
| | | C1C (B) | 7.2 | | 85 | |
| | | C1C (C)[7] | 7.0 | | 81 | |
| American Excelsior | Straw | S2 (A) | 12 | 15.5 | 82 | 85 |
| | | S2 (C) | 19 | | 92 | |
| | | S2 (D) | 54 | | 88 | |
| | | S2 (E) | -2.5 | | 73 | |
| Western Excelsior | Wood Fiber | W1 (A) | 15 | 15 | 76 | 72 |
| | | W1 (B) | 6.4 | | 72 | |
| | | W1 (C) | 39 | | 72 | |
| Eco-Guard White | Wood Compost | WC3 (C) | 32 | 15 | 92 | 92 |
| | | WC3 (D) | 15 | | 94 | |
| | | WC3 (E) | 15 | | 91 | |
| River Pebble | Rock | R (A) | 8.2 | 1.4 | 93 | 82 |
| | | R (B) | -3.7 | | 81 | |
| | | R (C) | 1.4 | | 82 | |

[6] Post-experiment measurement of sediment delivered in one minute not available. Sediment feeder ran out of sediment during post-experiment measurement.

[7] Calculations based on a 10.5-minute experiment duration. Experiment feeder ran out of sediment.

Three log types, straw, wood fiber, and wood compost had very similar median log captures at 15.5%, 15%, and 15%. Coconut fiber and rock were much lower at 7.2% and 1.4%, respectively. However, the median total sediment removal efficiencies, which include the sedimentation capture upstream of the log, show that wood compost is better at preventing sediment pass through, with a median of 92% total efficiency. Coconut fiber and straw logs had a median total efficiency of 85%. Rock had a median total efficiency at 82%. Wood fiber logs were the least efficient at 72%. The flow rates in Table 6 indicate the wood compost log, while having a higher total efficiency, also has the lowest flow rate, suggesting that more of the sediment capture could be occurring from sedimentation and slower water movement. The coir is able to achieve both a high flow rate and high efficiency. The wood fiber achieves a high flow rate with a lower efficiency. The wood compost achieves a low flow rate with a higher efficiency.

There was no significant relationship between mean percent sediment trap efficiency and log density, volumetric pore space, saturated conductivity, or percent fines. This is likely due to the few number of data points (n=5) or (n=4) for parameters where data collection is still ongoing. There is a potential relationship between log density and mean sediment trap efficiency. Refer to Figure 20 below. The density for the rock log outstanding at this time and will help determine the relationship between these two parameters once collected.

There was also no significant relationship between mean log capture and log density, volumetric pore space, saturated conductivity, and percent finer (d=25.4). However, there was a positive, power function relationship between percent finer (d=2) and mean log capture. This relationship likely exists because logs with fine-size material likely have less macropores and therefore can more effectively slow and capture incoming sediment. Refer to Figure 21 below.

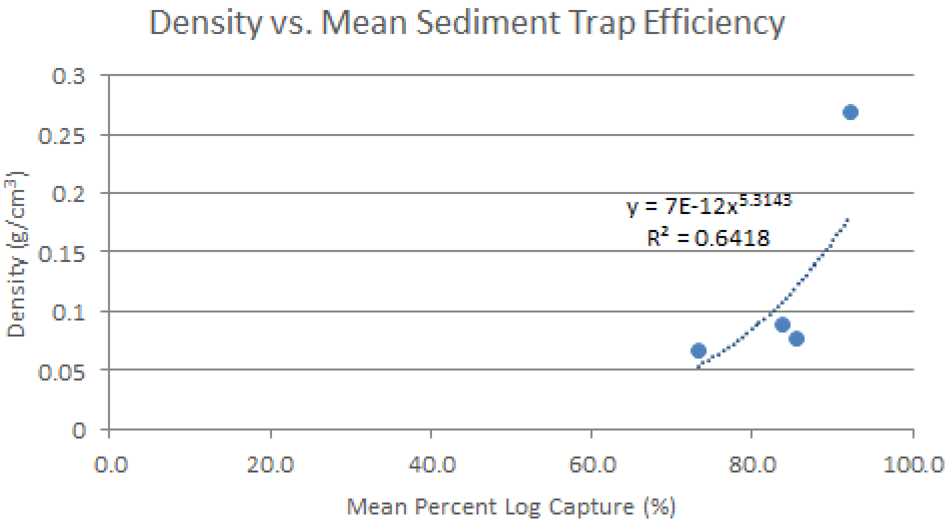

**Figure 19 Relationship between log density and mean sediment trap efficiency.**

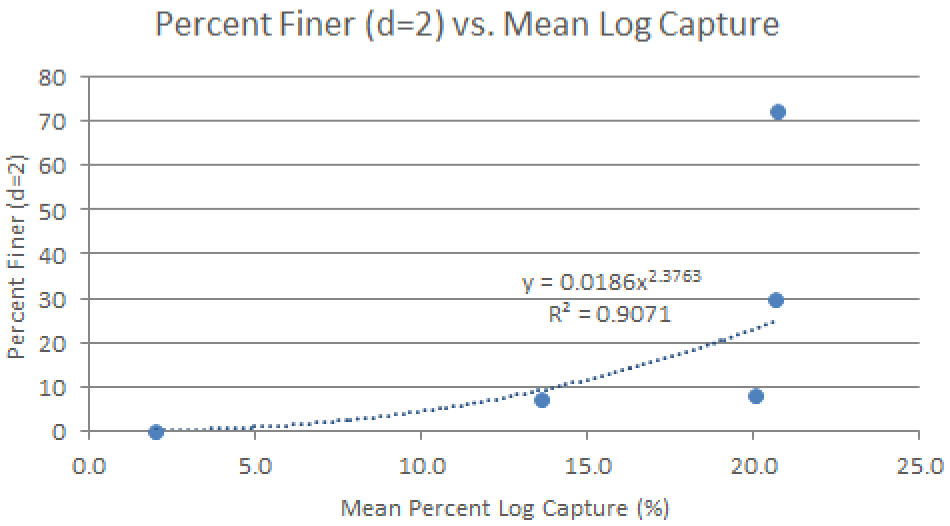

**Figure 20 Relationship between percent finer (d=2) and mean log capture.**

While the flume experiments were not run to an overtopping failure condition, the rate of change in the upstream water height can be used as a surrogate for log longevity or log failure due to overtopping. The longevity was therefore evaluated by considering the time required for upstream height of the water to reach the top of the sediment control log. A linear relationship was used to represent the change in upstream head over time. This equation allowed the number of hours to failure to be computed. The upstream height of the water was multiplied by the flow to obtain q (feet/second). To obtain the hydraulic conductivity, k, q was divided by difference of upstream head from downstream head over the width of the log.

All logs had a positive linear relationship between experiment duration and height of water upstream of the sediment control log., that is, as the experiment progressed, the head of water above the log raised as flow paths through the log became clogged with sediment. Refer to Figures 22-26 below.

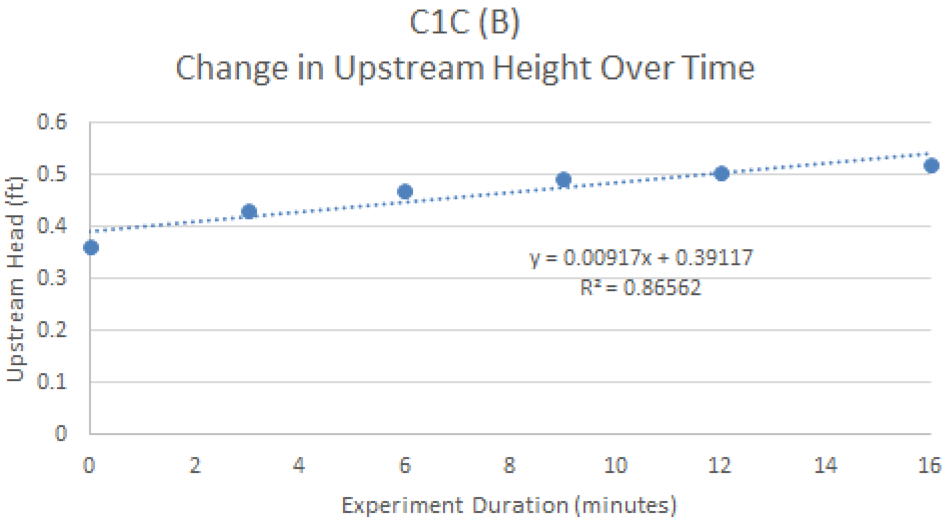

Figure 21 Increase in upstream water height during experiment for coconut fiber log, C1C (B).

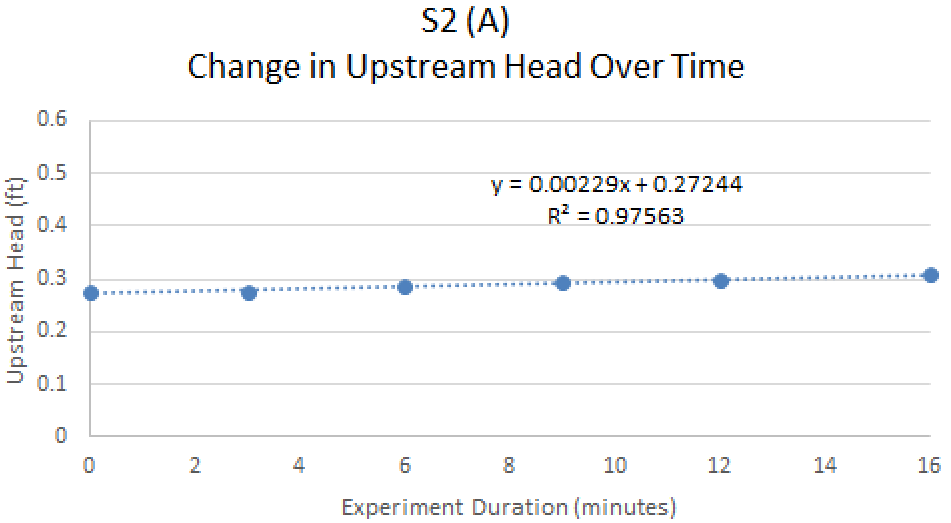

Figure 22 Increase in upstream water height during experiment for straw log, S2 (A).

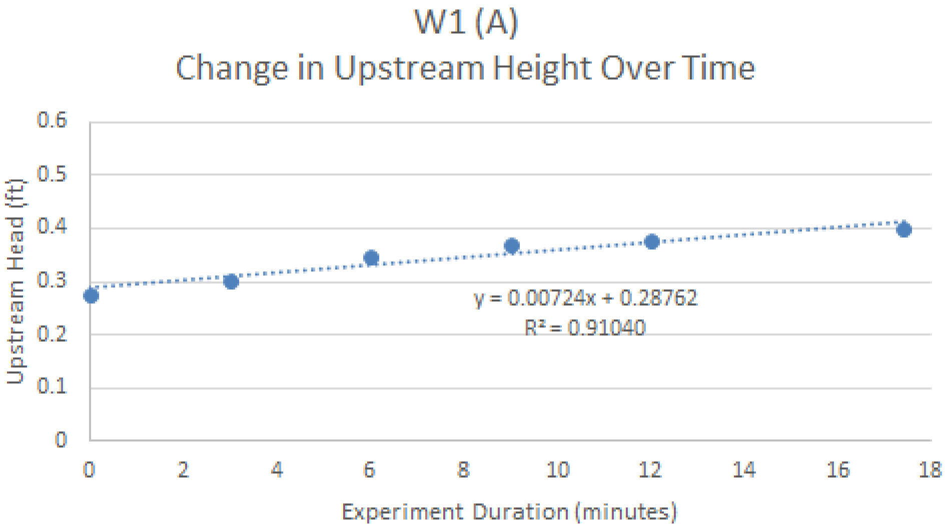

Figure 23 Increase in upstream water height during experiment for wood fiber log, W1 (A).

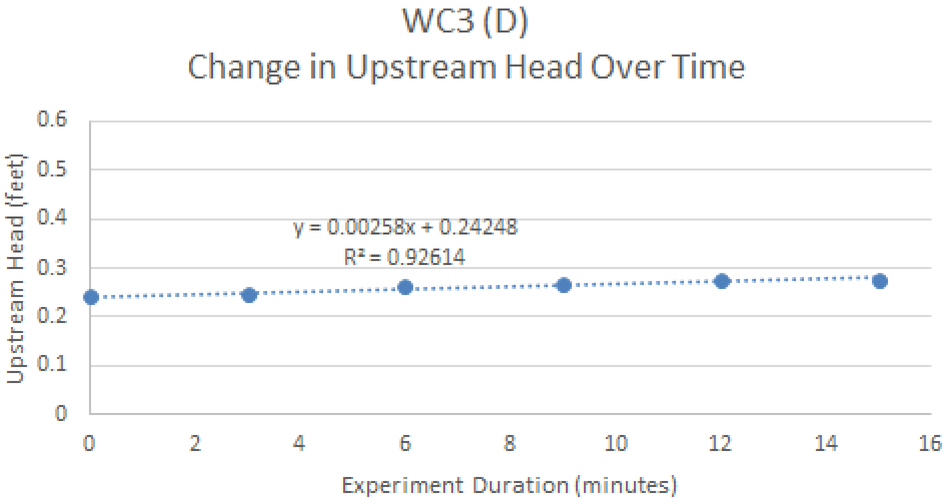

Figure 24 Increase in upstream water height during experiment for wood compost log, WC3 (D).

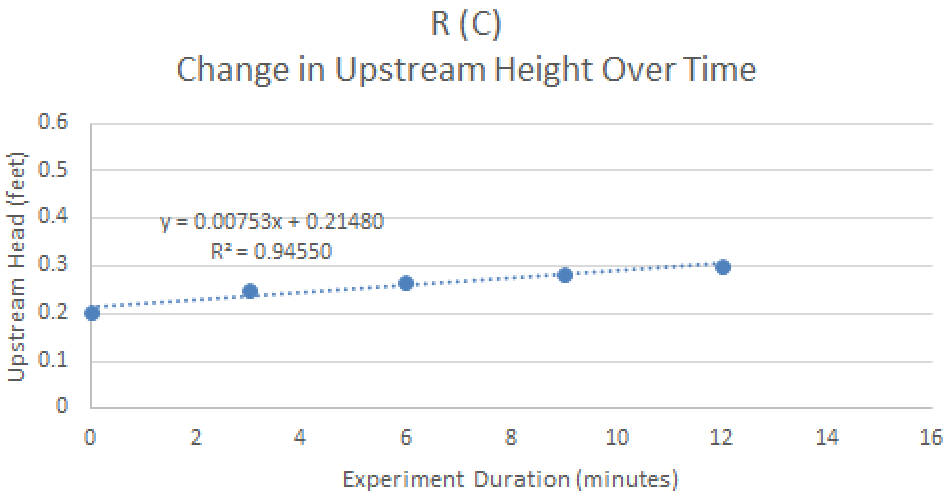

**Figure 25 Increase in upstream water height during experiment for rock log, R (C).**

A summary of log longevity based on the rate of upstream water change is given in Table 7. Log failure varied by log type, with the wood compost log and straw log having the greatest predicted longevity and wood fiber, rock and coconut fiber having the shortest longevity at flows initially one-half of its height, as indicated by the rate of water increase during the test period. Data in Table 7 have also been extrapolated to estimate an average longevity in hours of test flow until overtopping. However, wood compost logs also had the highest variability, as demonstrated by the highest standard deviation of all the log types.

**Table 7 Estimates of Log Longevity Using Rate of Change in Water Height.**

| Log Type | Label | Fill | Rate of Overtopping centimeter per hour (inches per hour) | Average Longevity (hours) | Standard Deviation of Longevity |
|---|---|---|---|---|---|
| Coir | C1C | Coconut Fiber | 16.7 (6.6) | 4.0[8] | 1.7 |
| American Excelsior | S2 | Straw | 4.06 (1.6) | 5.7[9] | 2.0 |
| Western Excelsior | W1 | Wood Fiber | 13.2 (5.2) | 3.3 | 0.98 |
| Eco-Guard White | WC White | Wood Compost | 4.8 (1.9) | 8.7 | 4.8 |
| River Pebble | R | Rock | 13.7 (5.4) | 2.2[10] | 0.090 |

[8] For log C1C (C), k was only calculated through minute 9, as the sediment feeder started to run out of sediment after minute 9.
[9] For log S2 (E), k was only calculated through minute 12; a post-experiment flow measurement was not taken.
[10] For all rock logs, R (A), R (B), and R (C), k was calculated through minute 12; no post-experiment flows were taken.

In addition to longevity estimates obtained by using the rate of change in water height, better estimates can be obtained by also considering the flow rate through the different types of logs. This analysis was done by normalizing our data points such that the flow rates are divided by the lowest product flow rate and the longevity upstream water level change with time is divided by the lowest value. Another estimate of longevity can be obtained by comparing the normalized water level change divided by the normalized flow. Table 8 shows the normalized longevity of logs. These values suggest that combining flow rates and water level changes from clogging, the straw log will plug approximately twice as fast as the coir, wood fiber, and wood compost, and the rock log will plug approximately half as fast as coir, wood fiber, and wood compost.

Table 8 Normalized Longevity of Logs the Incorporate the Flow Rates.

| **Log Type** | **Label** | **Fill** | **Normalized Flow** | **Normalized Water Increase** | **Normalized Water Increase / Normalized Flow** |
|---|---|---|---|---|---|
| Coir | C1C | Coconut Fiber | 4.41 | 4.00 | 1.10 |
| American Excelsior | S2 | Straw | 2.26 | 1.00 | 2.26 |
| Western Excelsior | W1 | Wood Fiber | 4.52 | 3.16 | 1.43 |
| Eco-Guard White | WC White | Wood Compost | 1.00 | 1.13 | 0.89 |
| River Pebble | R | Rock | 1.65 | 3.29 | 0.50 |

Another approach of considering longevity is to consider the change in hydraulic conductivity (k). These changes are summarized in Figures 27 through 31. Hydraulic conductivity decreased in all log types in all replicates. The relationship between k and experiment duration was described by polynomials, with a relatively more rapid decrease k initially and slower rate near the end of the runs. The observed trends suggest that flow has a non-zero minimum flow rate that will be sustained over time. A simple definition of longevity corresponding to no flow conditions is of little value. A possible definition is to define longevity when the long term “clogged” flow rate is approximately half of the clear water flow rate.

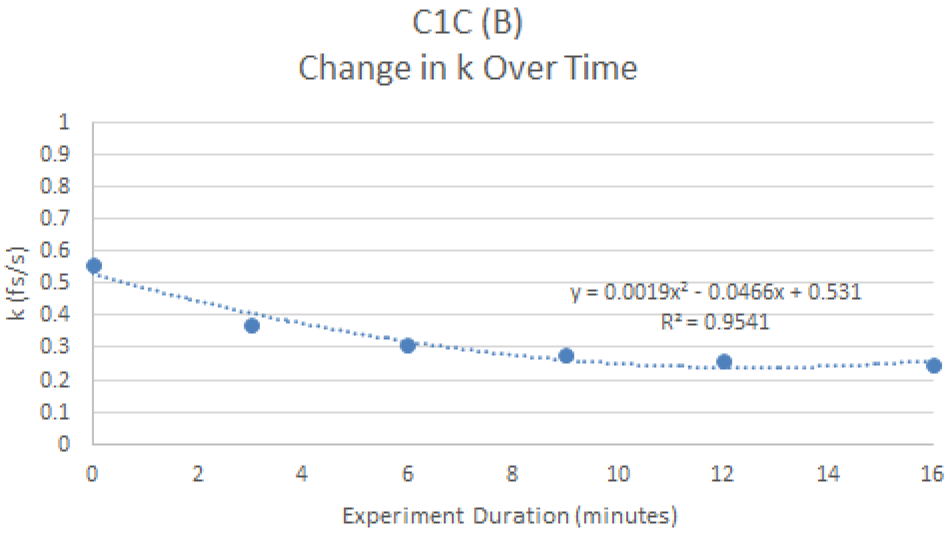

Figure 26 Decrease in k over time for coconut fiber log, C1C (B).

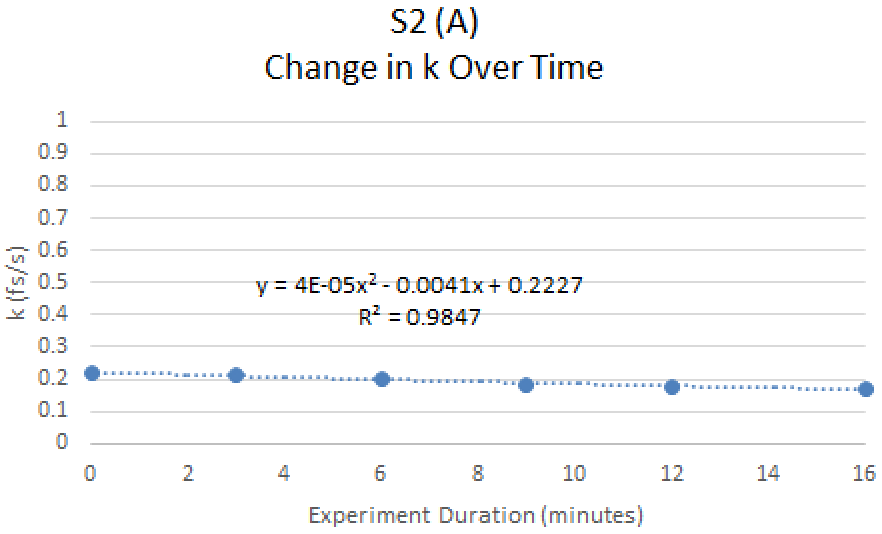

Figure 27 Decrease in k over time for straw log, S2 (A).

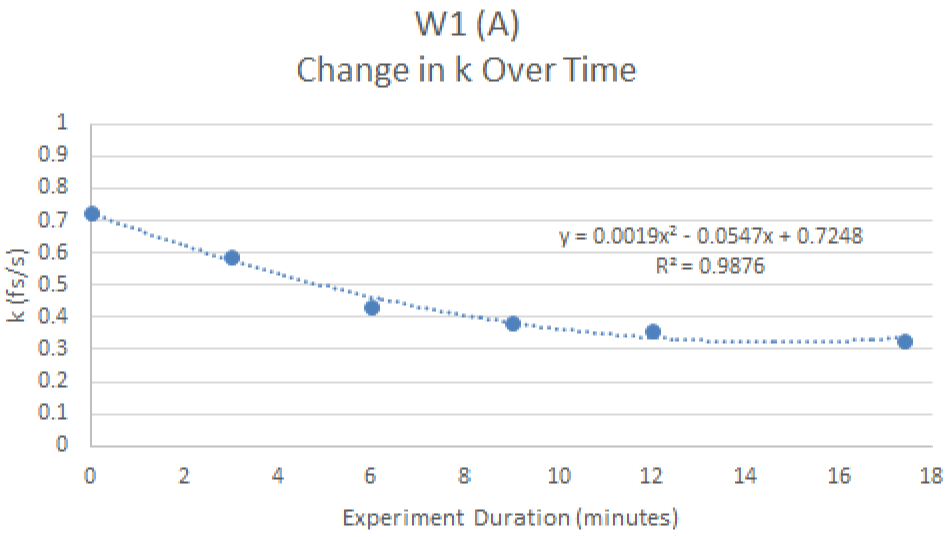

Figure 28 Decrease in k over time for wood fiber log, W1 (A).

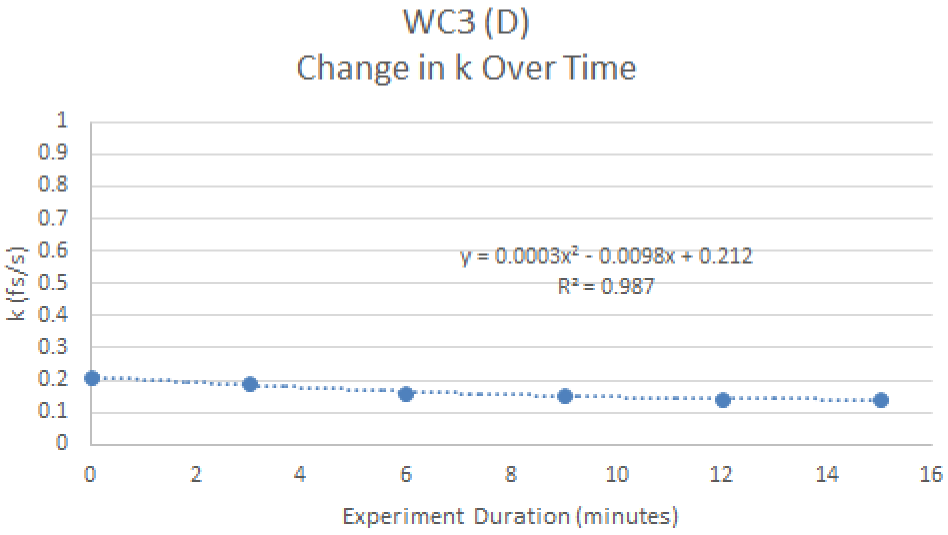

Figure 29 Decrease in k over time for wood compost log, WC3 (D).

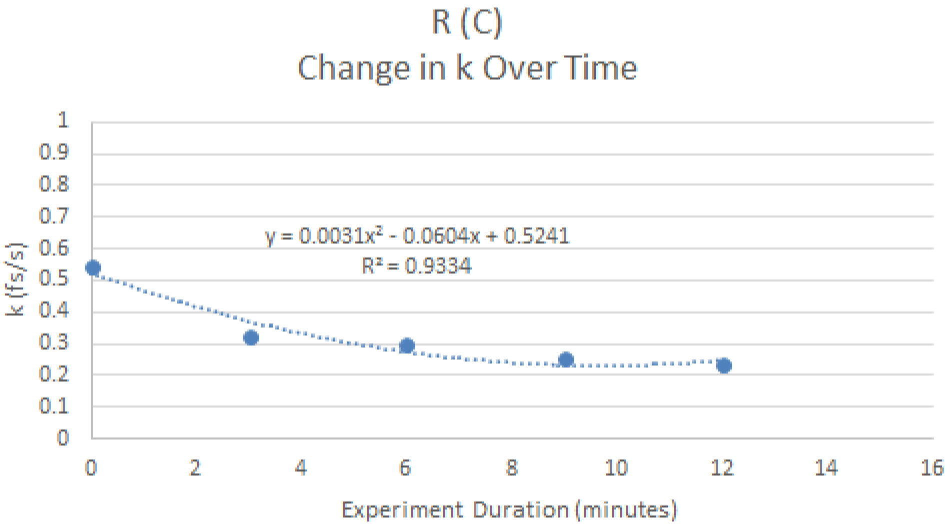

**Figure 30 Decrease in k over time for rock log, R (C).**

## 4.3 FIELD OBSERVATIONS

As part of the project activities, field-installed sediment control logs were observed for their erosion control function in a variety of scenarios. Sediment control logs were observed in the Twin Cities Metro this fall. Three major causes of log failure were observed: incorrect installation, incorrect log selection, and lack of maintenance. First, incorrect installation methods were observed at many sites. An example of this type of problem is shown in Figure 32. The product here was correct for the site but an installation error caused failure in the field. Second, the logs used were inappropriate for the site soils, slopes, and flows. Refer to Figure 33 from an example of this type of problem. Lastly, a couple instances of incorrect maintenance resulted in ineffective erosion control. Refer to Figure 34 below.

Figure 31 Product installation error allowing flow to go around the product.

**Figure 32 Product chosen could not handle the flow at this location. Another sediment control log that could withstand higher flows would be a more appropriate choice.**

**Figure 33 Product required maintenance prior to its current state. Replacement at the time of the photo is required to continue controlling erosion at the site.**

## 4.4 SUMMARY

Sediment removal and failure rates by clogging the SCLs were evaluated using a sediment flume was constructed for the project. A subset of the five logs was used for the sediment-flume experiments. This subset was chosen to represent the variety of log materials used for the hydraulic flume experiments discussed in Chapter 3. Three replicates were used for each log. Sediment removal was assessed using the capture of sediment in the log itself and total effectiveness that includes deposition upstream of the log. Median log capture varied between 1.4 % for rock to 15.5% for straw materials. Median total effectiveness varied among materials between 72% for wood fiber to 92% for compost. There was a positive, power function relationship between percent finer of d=2 mm (0.4 in) and mean log capture ($r^2$ = 0.91).

Estimates of log longevity by clogging were assessed using the rate of increase in ponded water depth behind the logs. This rate is related to sediment deposition within the logs. Longevity estimates using the changing ponded depth varied between 2.2 hours for rock material to 8.7 hours for wood compost. Since flow rates differ among logs, and larger flow rates have greater influx of sediment, an alternative estimate of longevity was obtained by using a ratio normalized increase rate of water height and a normalized flow rate.  This analysis suggests that straw material plug twice as fast as coconut fiber, wood fiber and compost material and four times faster than the rock material.

Although the work done in the laboratory using hydraulic and sediment flumes is useful, the failure of sediment control logs in the field is often a consequence of incorrect installation or improper maintenance.  The effective use of sediment control logs is not only dependent on understanding the response of the logs but also providing training opportunities for proper installation and maintenance.

# CHAPTER 5: DESIGN SELECTION TOOLS AND EDUCATIONAL MATERIALS

## 5.1 OVERVIEW OF ACTIVITIES

This chapter integrates the experimental results and field observations to provide design guidance for the selection of sediment control logs for stormwater management. The measured hydraulic and sediment response of sediment control logs have been combined with site characteristics to assess the best log under different conditions. These results are summarized in simple to use table.

The results of the research needs to be presented in a format that is useful for field practitioners. The educational materials developed for future workshops offered by the Erosion and Stormwater Management Certification Program are also summarized in this chapter. Issues related to installation and maintenance are summarized as part of the educational materials.

## 5.2 HYDROLOGY BACKGROUND

### 5.2.1 Summary of Hydraulic Flume Data

For purposes of selection tool, the hydraulic flume data have been summarized in Table 9. Here the flow rates and upslope flow depths have been simplified into three main categories.

Table 9 Summary of Flume Data for Design Selection Tool.

| Filter Material | Clean Water Flow Rate, cms (cfs) | Upslope flow depth, m (ft) |
|---|---|---|
| Coconut Fiber | 0.02 (0.1667) | 0.15 (0.5) |
| Straw | 0.0009 (0.033) | 0.18 (0.6) |
| Wood Fiber | 0.02 (0.1667) | 0.15 (0.5) |
| Wood Compost | 0.0009 (0.033).11 | 0.15 (0.5) |
| Rock | 0.003 (0.1167) | 0.13 (0.4) |

### 5.2.2 Consideration of Flow Rates

One of the important design features of a SCL (sediment control log) is the required length for given watershed area or the maximum watershed area for a given SCL length. The approach used for the design selection tool is discussed in this section. The underlying framework assumes that the drainage area, curve number, slope steepness and surface roughness are known or can be estimated for the watershed.

Let's consider the runoff to a SCL with an inflow rate per projected area (***q***) determined by watershed characteristics and an outflow rate per projected (***q'***) defined by the SCL characteristics. The outflow rate per projected area is defined as

$$q' = \frac{Q_{out}}{H\,L} = \frac{Q}{H\,L} \qquad 5.1$$

where q' is the outflow rate per projected area of the SCL, $Q_{out}$ is the volumetric outflow rate, H is the height of the SCL corresponding to the log diameter, and L is the length. The value of q' can be estimated for our different logs by dividing the flow rate in Table 9 by the corresponding product of the height of Table 9 and a given log length. For steady-state conditions, the outflow rate is equal to inflow rate, that is, $Q=Q_{out} = Q_{in}$. For a given inflow rate, the required length of the SCL is then solved as

$$L = \frac{Q_{in}}{q'\,H} \qquad 5.2$$

We can define an effective rainfall excess intensity ($i_e$) as the inflow rate divided by the watershed area ($A_w$), that is,

$$i_e = \frac{Q_{in}}{A_w} \qquad 5.3$$

or alternatively, we can determine the watershed area for a specified SCL length (L) as

$$A_w = \frac{Q}{i_e} = \frac{q'(H\,L)}{i_e} \qquad 5.4$$

where Eq. 5.1 has been used and where q' and H for different logs is given in Table 3 and L is specified by base on site conditions. The effective rainfall excess intensity needs to be estimated using hydrologic prediction methods, which for our application is obtained using the SCS TR-55 (SCS, 1986).

### 5.2.3 Estimation of Runoff Depth

To estimate runoff from storm rainfall, the design tool uses the NRCS runoff curve number (CN) method as indicated in TR-55 (SCS, 1986). This approach is consistent with those given in Minnesota State DOT guideline (manual). Determination of CN depends on the watershed characteristics, such as soil and land cover conditions.

Runoff depth (in) can be determined using the following equation:

$$Z = \frac{(P-0.2S)^2}{(P+0.8S)} \quad for\ P > 0.2\,S \quad and\ Z = 0 \quad for\ P < 0.2\,S \qquad 5.5$$

where $Z$ is the runoff depth (in) for a rainfall depth of P (in), and S is the maximum potential maximum retention (in). $S$ is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by the following equation.

$$S = \frac{1000}{CN} - 10 \qquad 5.6$$

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). TR-55 provides a flow chart for selecting the appropriate figure or table for determining runoff curve numbers (USDA, 1986).

## 5.3 SEDIMENT LOG SELECTION TOOL

The findings from the previous tasks have been synthesized into a design guide for better use and application of different sediment control log products. Sediment contro l logs are typically used in two different situations, ditch checks and parameter controls, and these are each addressed with different design guidance.

### 5.3.1 Ditch Checks

The TR-55 hydrologic model was used to evaluate different site conditions that would contribute rainfall-runoff into a ditch system that uses sediment control logs or bio-logs. The model was used to calculate an “allowable area” for different groups of sediment control log products when used as ditch checks. Since the length of the SCL is known from the width of the ditch, the watershed area can be computed directly from Equation 5.4. A watershed area greater than that computed by Equation 5.4 contributes more runoff resulting in overtopping and failure of the SCL.

The site conditions evaluated in the model included land cover conditions of grass and bare soil. The site conditions evaluated also considered two overall basin slopes of 1% and 4%, and two ditch slopes of 1% and 4%. The site conditions were evaluated for a typical 2-year 24-hour storm event of 2.4 inches. An additional case of a half-year (50% probability) 24-hour storm condition was also evaluated for the bare soil conditions. The selection tool for these cases is shown in Tables 10 and 11.

The reported allowable area includes an adjustment for clogging (50% flow rate reduction) and an adjustment for the effective filtration surface area of the log (66% reduction from the full diameter) which accounts for installation, sedimentation, and manufacturing variability. Combined together, these result in a factor of safety of 5 from the tested clean water flow rate.

The sediment control logs with slower flow rates were found to have higher sediment removal efficiencies. If sediment removal is a prime goal of the installation, using the slowest flow rate possible for your given site is advisable.

**Table 10 Ditch Check Selection Tool for 2-year 24-hour storm event.**

| Sediment Control Log Flow Rate | Cover Type | Basin Slope | Ditch Slope | Allowable area (ac) |
|---|---|---|---|---|
| Straw, Compost<br>0.033 cfs | Grass | 1% | 1% | 0.052 |
| | | | 4% | 0.043 |
| | | 4% | 1% | 0.050 |
| | | | 4% | 0.041 |
| | Bare | 1% | 1% | 0.004 |
| | | | 4% | 0.004 |
| | | 4% | 1% | 0.004 |
| | | | 4% | 0.004 |
| Rock<br>0.1167cfs | Grass | 1% | 1% | 0.149 |
| | | | 4% | 0.127 |
| | | 4% | 1% | 0.141 |
| | | | 4% | 0.117 |
| | Bare | 1% | 1% | 0.016 |
| | | | 4% | 0.016 |
| | | 4% | 1% | 0.016 |
| | | | 4% | 0.016 |
| Wood Fiber, Coir<br>0.1667cfs | Grass | 1% | 1% | 0.202 |
| | | | 4% | 0.173 |
| | | 4% | 1% | 0.189 |
| | | | 4% | 0.158 |
| | Bare | 1% | 1% | 0.022 |
| | | | 4% | 0.022 |
| | | 4% | 1% | 0.022 |
| | | | 4% | 0.022 |

Table 11 Ditch Check Selection Tool for 0.5-year 24-hour storm event.

| Sediment Control Log Type | Cover Type | Basin Slope | Ditch Slope | Allowable area (ac) |
|---|---|---|---|---|
| Straw, Compost<br>0.033 cfs | Bare | 1% | 1% | 0.088 |
|  |  |  | 4% | 0.071 |
|  |  | 4% | 1% | 0.086 |
|  |  |  | 4% | 0.070 |
| Rock<br>0.1167cfs | Bare | 1% | 1% | 0.243 |
|  |  |  | 4% | 0.200 |
|  |  | 4% | 1% | 0.238 |
|  |  |  | 4% | 0.193 |
| Wood Fiber, Coir<br>0.1667cfs | Bare | 1% | 1% | 0.326 |
|  |  |  | 4% | 0.268 |
|  |  | 4% | 1% | 0.317 |
|  |  |  | 4% | 0.258 |

### 5.3.2 Perimeter Control

The TR-55 calculations were also used to approximate the shallow concentrated flow occurring along a basin perimeter. Here the flow per unit widths were computed using a wide ditch. The combination of variables and the computational approach is the same as those to for the ditch checks. For perimeter control, the allowable area was computed per 100 feet of sediment control log (SCL). The results are shown in Tables 12 and 13.

**Table 12 Perimeter Control Selection Tool for 2-year 24-hour storm event.**

| Sediment Control Log Flow Rate | Cover Type | Basin Slope | Ditch Slope | Allowable area (ac) per 100 LF of SCL |
|---|---|---|---|---|
| Straw, Compost | Grass | 1% | 1% | 0.648 |
| | | | 4% | 0.541 |
| | | 4% | 1% | 0.624 |
| | | | 4% | 0.513 |
| | Bare | 1% | 1% | 0.055 |
| | | | 4% | 0.055 |
| | | 4% | 1% | 0.055 |
| | | | 4% | 0.055 |
| Rock | Grass | 1% | 1% | 1.862 |
| | | | 4% | 1.585 |
| | | 4% | 1% | 1.759 |
| | | | 4% | 1.466 |
| | Bare | 1% | 1% | 0.195 |
| | | | 4% | 0.195 |
| | | 4% | 1% | 0.195 |
| | | | 4% | 0.195 |
| Wood Fiber, Coir | Grass | 1% | 1% | 2.520 |
| | | | 4% | 2.160 |
| | | 4% | 1% | 2.368 |
| | | | 4% | 1.980 |
| | Bare | 1% | 1% | 0.278 |
| | | | 4% | 0.278 |
| | | 4% | 1% | 0.278 |
| | | | 4% | 0.278 |

Table 13 Perimeter Control Selection Tool for 0.5-year 24-hour storm event.

| Sediment Control Log Type | Cover Type | Basin Slope | Ditch Slope | Allowable area (ac) per 100 LF of SCL |
|---|---|---|---|---|
| Straw, Compost | Bare | 1% | 1% | 1.096 |
| | | | 4% | 0.889 |
| | | 4% | 1% | 1.079 |
| | | | 4% | 0.869 |
| Rock | Bare | 1% | 1% | 3.040 |
| | | | 4% | 2.493 |
| | | 4% | 1% | 2.969 |
| | | | 4% | 2.409 |
| Wood Fiber, Coir | Bare | 1% | 1% | 4.071 |
| | | | 4% | 3.350 |
| | | 4% | 1% | 3.964 |
| | | | 4% | 3.224 |

## 5.4 DEVELOPMENT OF EDUCATIONAL MATERIALS

The presentation materials were prepared as part of the projects for use in the Erosion and Stormwater Management Certification workshops. This content will be primary provided in the Construction. Site Management and Stormwater Pollution Prevention Plan Designer courses. The training material will be presented primarily by lecture using visuals. The lecture is divided into the following component parts of introduction, basic functions and failures, clean water flow experiments, sediment laden flow experiments, Selection tools, installation, maintenance and conclusion. These components are discussed in more detail below.

### 5.4.1 Introduction

This component of the presentation explains the importance of improving our understanding of biologs and of providing tools to better select products for a given site.

### 5.4.2 Basic Functions and Failures

This component of the presentation describes the filtering and settling processes of biologs. It also outlines the common ways these products fail, including installation errors, or exceeding the product capacity for flow, or by not maintaining the products. The latter source of failure also results in exceeding the product capacity for flow.

### 5.4.3 Clean Water Flow Experiments

This component of the presentation explains the basic filter materials that were tested and presents a simple representation of the flow rates determined in the experiments from Chapter 3.

### 5.4.4 Sediment Laden Flow Experiments

This component of the presentation explains the testing that was done using sediment laden flow and presents a simple representation of the flow rates determined in the experiments from Chapter 4.

### 5.4.5 Selection Tools

The tables and graphs are presented in the training materials in much the same format as given in Tables 1 through 13. The training materials include a conversion grid of square feet to acreage to assist the audience in understanding the scale of the allowable area. An example of the use is also discussed in the lecture

### 5.4.6 Installation

The use of these product selection tools will help to more appropriately place the products in locations where they will be most effective. This guide should help to limit the number of overtopping failures occurring with sediment control logs, but it will not limit the number of failures occurring from improper installation. Research being conducted at Auburn University in Alabama suggests that the best installation can be achieved by the following procedure:

1. Place a light duty wood fiber erosion control blanket strip, 20 cm or 8 inches in width, at the designed location
2. Place the sediment control log on top of the blanket strip
3. Place wire staples through the upstream edge of the sediment control log and through the blanket strip
4. Drive a wood stake into the soil behind the sediment control log at an upstream angle to further secure the sediment control log.

The installation described above will be done using one or more of the visuals in Figures is shown in two visuals, presented below as Figures 1 and 2.

The use of these product selection tools will help to more appropriately place the products in locations where they will be most effective. This guide should help to limit the number of overtopping failures occurring with sediment control logs, but it will not limit the number of failures occurring from improper installation. Research being conducted at Auburn University in Alabama suggests that the best installation can be achieved by the following procedure:

1. Place a light duty wood fiber erosion control blanket strip, 20 cm or 8 inches in width, at the designed location
2. Place the sediment control log on top of the blanket strip

3. Place wire staples through the upstream edge of the sediment control log and through the blanket strip
4. Drive a wood stake into the soil behind the sediment control log at an upstream angle to further secure the sediment control log.

The installation described above is shown in Figures 34 through 37.

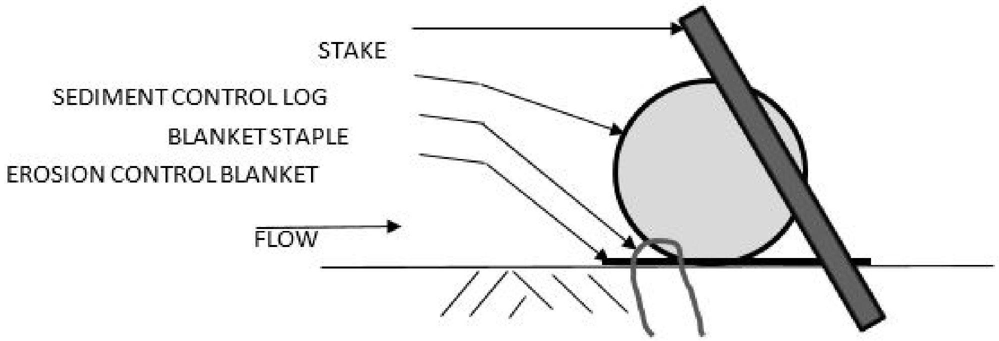

Figure 34 A concept detail of sediment control log installation.

Figure 35 Sediment Control log installed using a wood fiber blanket foundation and staples placed at the leading edge.  Traditional angled wood stakes are also placed along the downstream edge.

Figure 36 The end of a wood chip compost sediment control log installed using a wood fiber blanket foundation and staples placed along the leading edge. A traditional angled wood stake is also used along the downstream edge.

**Figure 37 A partial installation of a wood compost sediment control log along a perimeter. The foundational blanket extending past the log will offer some protection in case of overtopping.**

### 5.4.7 Maintenance

The use of these product selection tools will not eliminate or reduce the need for maintenance of the SCLs. SCLs trap sediment as a primary function, and the trapped sediment will need to be removed for continued performance of the installation. Straw and compost, while being the most effective at sediment trapping, will have the shortest longevity and need maintenance and replacement sooner than other sediment control logs. Coir has the longest longevity, on the order of 4 times the life of the straw and compost logs. Wood fiber and rock sediment control logs fall into the middle range of product longevity. The exact length of time before maintenance is required will depend on the precipitation, soils, site cover, and other factors and cannot be estimated in general at this time.

The longevity discussion has been simplified for the training materials. The normalization of the data for comparison of products is still done, but the products have been ordered from fastest to plug to slowest to plug, and the all the products have been normalized to the fastest plugging product. This is shown in Table 14.

Table 14 Normalized Sediment Control Log Maintenance

| Sediment Control Log Type | Normalized Life Expectancy |
|---|---|
| Straw | 1 |
| Wood Fiber | 1.6 |
| Coir | 2 |
| Wood Compost | 2.5 |
| Rock | 4.5 |

This is an estimate of how long the products will last compared to each other, considering the flow rate reduction with sediment capture and accounting for different flow rates of the products. This does not consider the fiber bio-degradation. This is meant to be a relative decision making comparison, and the units of "life" are not provided in days or weeks or hours. The actual life would depend on the soil and erosion rates for the specific site.

## 5.5 SUMMARY

A simple selection tool was developed to assist practitioners in their selection of sediment control logs. This tool summarized the flow rates for clean water through SCL into three simple categories. The maximum runoff flow rate before the log was overtopped was defined using log flow rates and upslope depths. The corresponding maximum watershed area for this flow rate was obtained using NRCS TR-55 model. Acceptable SCLs were defined using watershed area, basin slope and ditch slope. Different tables were developed for ditch checks and perimeter control for 0.5 year and 2-year events. The guidelines for longevity used the estimates obtained by the normalized values of the sediment flume experiments.

Educational materials were also developed. Longevity estimates obtained as part of the collected experimental data are embedded into these materials. Installation and maintenance are also included in presentations. The education materials will be used as part of the Erosion and Stormwater Management Certification workshops offered in the winter of 2018 and 2019.

# CHAPTER 6: CONCLUSIONS

Sediment control logs (SCLs) are widely used to reduce sediment loads from construction sites. This project collected and analyzed data to improve the selection of these logs for diverse site conditions. Simple tools and educational material were developed so that the research can be readily used by practitioners.

A hydraulic flume located in Biosystems and Agricultural Engineering Building at the University of Minnesota were used to measure the flow characteristics of twelve SCLs. The overtopping flow rate was of greatest interest to the project, and three replicates were used for this depth. Flow rates of different materials varied between 208 ft/min (63 m/min) for compost to 1508 ft/min (459 m/min) for wood fiber. In addition to the hydraulic flow data, physical characteristics were determined to relate the hydraulic response to more easily measurable physical characteristics. Measured flow rates were predicted using a power function of density with fair accuracy ($r^2$=0.64) and predicted with good accuracy using saturated conductivity ($r^2$=0.87) or capillary moisture content ($r^2$=0.81).

To evaluate the effectiveness of SCLs for sediment removal, a sediment flume was constructed as part of this project and is located in the Biosystems and Agricultural Engineering Building at the University of Minnesota. A subset of the five logs was used in this flume. Median capture of sediment in the log itself varied between 1.4 % for rock to 15.5% for straw materials. The total effectiveness was assessed by including deposition behind the log. The median removal that included this deposition varied between 72% for wood fiber to 92% for compost. There was a positive, power function relationship between percent finer of d=2 mm and mean log capture ($r^2$ = 0.91). Estimates of log longevity were assessed using the rate of change in the upstream water height behind logs caused by sediment deposition within the logs. These longevity estimates varied between 2.2 hours for rock material to 8.7 hours for wood compost. Since flow rates differ among logs, and larger flow rates have greater influx of sediment, an alternative estimate of longevity was obtained by using a ratio of a normalized increase rate of water height and a normalized flow rate. This analysis suggests that straw material was plugged twice as fast as coconut fiber, wood fiber and compost material and four times faster than the rock material.

Field guidelines for practitioners were obtained by combining the measured hydraulic and sediment response of logs with site characteristics. To simplify, the SCLs were divided into three categories of different flow rates and upslope flow depths. The maximum runoff flow rate before overtopping was used to select the log for a given set of watershed conditions. Guidelines for longevity used the estimates obtained by the normalized values of the sediment flume experiments. The field guidelines were integrated into the educational activities of the Erosion and Stormwater Management Certification workshops. The educational materials are incorporated field observations important for installation and maintenance.

The research data of this study were limited to measurements collected using laboratory flumes. The selection of SCLs could be further improved by collecting field data. Since collecting field data is difficult, only a relatively few observations are needed to verify the laboratory results. It is recommended that additional research is conducted to expand the tool developed for this project to consider other erosion and sediment control practices.  Of particular importance is the effectiveness of multiple practices at construction sites used in a series as a treatment train.

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# APPENDIX A

## DETAIL DESCRIPTION OF EXPERIMENTAL METHODS

## Determining Index Nominal Diameter, Nominal Length, and Volume Density of a Sediment Control Retention Fiber Roll

*Purpose:* This document outlines the procedure for determining index nominal diameter, nominal length, and volume density of a sediment control retention fiber roll for the Erosion Control and Stormwater Management (Sediment Control Log) Project. The method is adapted from ASTM technical committee Work Item #: WK39691. At the time of this writing, the ASTM method is not an ASTM standard.

*Materials:* Label, Pen, Sediment control log to be tested, Data sheet, Sheet plastic, Flexible measuring tape, Calculator or Excel, Specimen tub, Calibrated scale with a +/- 50 g accuracy, Submerging tub, Tap water.

*Preparation of Sediment Control Log:*

1. Ensure sediment control log is not distorted or irregular. Compare sediment control log to other sediment control logs of its type.
2. Label the sediment control log with:
    a. Product manufacturer;
    b. Product name, style or product number;
    c. Unique product number; and
    d. Date sampled.
3. Record the following information on the data sheet:
    a. Test location (eg, BAE room 14);
    b. Date and time;
    c. Operator(s);
    d. Product manufacturer;
    e. Product name, style, or product number;
    f. Unique product number; and
    g. A statement of any departure from the testing procedures.
4. For all measurements of length, circumference, and density, include three significant figures.

*Dry measurements of the sediment control log:*

1. Ensure the sample has not been exposed to rain or water (other than ambient humidity) for at least 24 hours at ambient conditions. Determine and record the mass of the sample, in grams. After one additional hour, determine and record the mass of the sample again. If the mass of the sample did not change, proceed to step 3 below. If the mass of the sample changed, continue to determine and record the mass of the sample every hour until two consecutive mass measurements are the same.
2. Report the average ambient temperature and humidity along with the total conditioning time for the sample.
3. Lay down the tarp set on the floor that is isolated from any sources of moisture other than humidity present in the air. Set straightened sediment control log on plastic sheeting.
4. Measure the nominal length of the sample using a right-angle projection from the tip of the unit with no compression or stretching. Record this value as *L* in centimeters.
5. Measure the circumference. Locate and mark cross sections at a minimum of three evenly spaced points, not exceeding 60 cm apart along the length of the sample. Measure the circumference at each cross section using a flexible tape measure. Measurement points should be taken at least 30 cm away from the ends of the sediment control log at locations where the log is in contact with the table or floor in a resting state. Record these values as $C_1$, $C_2$,...$C_x$ in centimeters.

6. Determine and record the mass of the clean and dry specimen tub on a calibrated balance to the nearest 50 g. Record this value as $M_{tub.}$ Place the sample in the sample tub along with any fibers collected during handling and determine the mass of the tub with the sample. Place the sample in the tub along with any fibers collected during handling and determine the mass of the tub with the sample to the nearest 250 g.
7. Calculate nominal diameter in centimeters at each cross section of the sample,
8. Calculate the sample average nominal diameter, in centimeters, as the average of all nominal diameters at all cross sections.
9. Calculate the mass, $M$, in grams, of the sample
10. Calculate the volume density as the ratio of the mass per volum,

*Wet measurements of the sediment control log:*

1. Completely wet the sample by submerging in water for at least 8 hours.
2. After removal from the water, allow the product to drain freely for 5 minutes. Verify water is no longer draining from the product; some products may take more than five minutes to drain.
3. Lay down a sheet of plastic on a long table or floor that is isolated from any sources of moisture other than humidity present in the air. Set straightened sediment control log on plastic sheeting.
4. Measure the nominal length of the sample using a right angle projection from the tip of the unit with no compression or stretching. Record this value as $L$ in centimeters.
5. Measure the circumference. Locate and mark cross sections at a minimum of three evenly spaced points, not exceeding 60 cm apart along the length of the sample. Measure the circumference at each cross section using a flexible tape measure. Measurement points should be taken at least 30 cm away from the ends of the sediment control log at locations where the log is in contact with the table or floor in a resting state. Record these values as $C_1$, $C_2$,...$C_x$ in centimeters.
6. Calculate nominal diameter in centimeters at each cross section of the sample.
7. Calculate the sample average nominal diameter, in centimeters, as the average of all nominal diameters at all cross sections.

**Determining Volume and Pore Space of Sediment Control Log Material**

*Purpose*: This document describes the method for determining the volume of material in a sediment control log for the Erosion Control and Stormwater Management (Sediment Control Log) Project, and the subsequent calculation of pore space in said log.

*Materials*: 3 L beaker, 250 mL graduated cylinder, 2.5 L of deionized water, Round wire mesh the same diameter as the beaker, 2 lb weight, Sediment control log material to be tested, Pipette, Saran Wrap, Rubber band, Pen, Google Spreadsheet for data entry, Calculator or Excel, Calibrated scale, and Oven safe trays.

*Notes*: This experiment will take several days and may require coming in on weekends to weigh samples and record oven temperatures. Plan work time accordingly. This experiment requires three replicates. The directions are written for one replicate but the steps must be completed three times total in one session, testing the material from the same log.

*Procedure*:

1. Go into room 315. Turn on the blue oven and adjust the heat to approximately 75°C. The oven temperature should be no lower than 65°C and no higher than 80°C.

2. Record temperature, humidity, date, and time on Google Drive Spreadsheet. Use the NOAA website for Falcon Heights, MN.
3. Carefully open one end of the sediment control log and remove material with as little disturbance to the log as possible.
4. Calculate the weight (g) of material needed in a 2 L (2 L = 2,000 $cm^3$) volume using the density of the material and the equation for density.
5. Don gloves. Place the 3 L beaker on the scale. Tare the scale. Carefully add the calculated weight of material into the beaker. To reach the correct weight in a 2 L volume, it may be necessary to use your hands to compact the material to the desired density. Be careful to not disturb the structure of the material. Record the initial weight of the sample.
6. Fill the 250 mL graduated cylinder with deionized water to exactly 250 mL. Use a pipette if necessary. Carefully and uniformly pour the water into the beaker containing the material. Avoid splashing onto the insides walls of the beaker. Continue refilling the cylinder and pouring deionized into the material until the water line reaches 2 L on the beaker. Record the initial volume of deionized water added on the spreadsheet.
7. After 10 minutes, re-check water line. If more water is needed to reach the 2 L mark, add more and record additional water volume.

### Determining Flow Through Rates of Sediment Control Log Material

*Purpose*: This document describes the method for determining the flow through rates of sediment logs at low, medium and high water levels for the Erosion Control and Stormwater Management (Sediment Control Log) Project.

*Materials*: Flume, Log holder, Foam pieces, Log holder bracket, Weather stripping, Butyl tape, Gorilla tape, PVC top piece to keep log from floating, Point gauge. Shimmies, 50 gallon barrel with calibration scale, Timer amd Flume log runs data sheet.

*Notes*: Three different sections of each log should be tested. Before testing begins, the slope of the flume and location of the frame in the flume should be measured.

*General Procedures:*

Before testing begins, the slope of the flume and location of the frame in the flume should be measured. Slope is determined by the rise (y)/run (x). Where y is calculated by subtracting the height of the flume bed at each end and x is calculated by using the formula for the hypotenuse of a triangle: $a^2+b^2=c^2$ . In this case a=y calculated above, b=x and c = the length of the flume, so to solve for x: $x^2=c^2-y^2$. Currently x=43 ft, y=0.23 ft, and the slope is 0.005. The frame is located 9.24 ft from the end of the flume. The length of the flume is 43’ not including the green head box.

*Log Section*

1. Cut a log section to match the length of the log holder.
2. Add or take out material to ensure a snug fit in the holder.
3. Sausage the ends and secure each end with a zip tie.
4. Measure and record date, log label, section number, weight, length and three circumferences approximately equally spaced along the length.

*Frame Attachment*

1. Place frame into flume and seal edges to flume with butyl tape making sure not to leave and spaces along the cracks.
2. Tape over the butyl tape with Gorilla tape paying special attention to the corners. Make sure the tape is laid flat to the flume in all places.

*Log Holder Placement*

1. Place weather stripping along the three edges of the log holder that contact the frame.
2. Place foam in a hollow circle in the ends of the holder. Place the log in the holder and put additional foam on the bottom of the holder at the ends if needed to eliminate any space between the log and holder.
3. Place holder in frame and secure by wedging the shimmies between the holder and the frame blocks. Make sure the bottom weather stripping is even with the lower lip of the frame.
4. Measure the log height (LH) with the point gauge and subtract the frame bottom height (FH) and holder thickness (HT) to get the actual height of the log. LH = LHh- FH-HT
5. Place the PVC top on the log and secure in place with the nuts attached to the threaded poles. Place weights on top of the whole top apparatus to ensure that it doesn't get pushed up.

*Flow Measurement*

1. Calculate 1/3 & 2/3 height of log (LH). Add the flume bottom (FB, measured in front of the frame), the frame bottom thickness (FT), and the holder thickness (HT) to each as well as the LH to get the height needed on the point gauge to bring water to log 1/3, 2/3 and full height (1/3 FLH, 2/3 FLH, FLH) . FLH= LH+FB+FT+HT
2. Turn on pump. Watch the initial water flow to the frame and look for leaks under the frame. Also watch the initial flow into the log for any indication of leaks around the log. Bring water level up until it is just below over-topping the log. Let the log saturate for 15 min or longer until the water level does not change significantly at a constant flow rate.
3. Set point gauge to the lowest height (1/3 FLH) in front of the frame. Adjust flow until the water level in front of the frame is approximately the same height as the point gauge and does not significantly change.
4. Record date, time, log and section label, water temperature and water level height (with the point gauge).
5. Measure the flow by recording flow rate from the appropriate meter (paddle or magnetic depending on which pump is used) or, if the flow is too low (under 40 gal/min), use the calibrated 50 gallon drum to time flow to 19" and 21" marks (see below). Repeat measurement 2 – 3 times. Calculate flow rate by dividing the number of gallons reached at each mark by the time in minutes.
6. Put a visible tag with the log label on top of the log lid and take a picture of the back and front of the log, upload to the Google Drive picture folder.
7. Repeat steps 2-3 for the medium (2/3) and over-top heights.
8. Repeat steps above procedure for the other two log replicates but only for the over-top height.

*Calibrating the 50 gallon drum*

1. Draw a scale on the inside of the drum every 2 inches from 15-24 inches.
2. Estimate volume for every 2 inches using the formula for volume of a cylinder $v=\pi r^2 h$
3. To verify the volumes, the weight of water is used.
4. Place drum on a scale, fill with water and weigh at each of the 2” marks.
5. Convert the weight into gallons (1 gallon = ~ 8.34 lbs water), adjusting for the water temperature.
6. Use these volumes to determine flow rate under low flow conditions.

**Determining the Performance of Sediment Control Logs in Removing Sediment from Simulated Runoff**

*Purpose*: This document describes the method for determining the sediment removal performance of sediment control logs for the Erosion Control and Stormwater Management (Sediment Control Log) Project.

*Materials*: Flume, Sediment feeder, Sediment control logs, Erosion control blanket, Foam pieces, PVC top piece to keep log from floating, Point gauge, 5 gallon bucket with calibration scale, Pre-weighed Sampling bottles, Large Funnel, Pre-weighed metal soil cans, Pre-weighed 2 L glass beakers, Timer, Sediment feeder calibration curve, Squeegee, Data sheet.

*Notes*: Three different sections of each log should be tested.

*General Procedures:*

Before testing begins, the slope of the flume and location of the frame in the flume should be measured. Slope is determined by the rise (y)/run (x). Where y is calculated by subtracting the height of the flume bed at each end and x is calculated by using the formula for the hypotenuse of a triangle: $a^2+b^2=c^2$ . In this case a=y calculated above, b=x and c = the length of the flume, so to solve for x: $x^2=c^2-y^2$. Currently x= 95.8 in , y=5.75 in, and the slope is 6%. The logs are located 13.5 inches from the end of the flume.The length of the flume is 96 in.

*Log Section*

1. Cut a log section to match the width of the flume.
2. Add or take out material to ensure a snug fit in the holder.
3. Close each end weaving with a zip tie.
4. Measure and record date, log label, section number, weight, length and three circumferences approximately equally spaced along the length.

*Calibrating 5 gallon bucket*

1. Tare a 5 gallon bucket on the scale.
2. Fill the bucket with 5 gallons of water using the conversion: 1 gallon = ~ 8.34 lbs water, adjusting for the water temperature.
3. Mark the 5 gallon level on the inside of the bucket

*Flow Measurement*

1. Cut a piece of erosion control blanket 6 in wide and long enough to fit the width of the flume. Place the blanket piece in the flume and set the sediment control log on top. The log should be snug with the sides of the flume. Insert small pieces of foam in the cracks between the log and flume to ensure there will be no seepage around the sides. Put the top on and tighten to where the top is resting towards the back side of the log with no space between but without putting downward pressure on the log. Measure the height between the top and the bottom of the bar it is secured to and record on the datasheet. Stand a board perpendicular to the log touching the back side and measure the distance from the end of the flume (before spout) to the front of the board. Record this on the datasheet. Using the point gauge, measure the log height and flume bottom. Calculate the actual log height by subtracting the flume bottom measurement from the measured log height. Take ½ the actual log height and add flume bottom height for ½ log height to be used in step 2. Record the heights on the datasheet.
2. The flume should initially be set up to return the water back into the pumping tank. Put the splash board on the flume underneath the sediment feeder and turn the pump on. Adjust the flow until the water level is approximately ½ of the log height. Make sure the hose is positioned so the flow is coming out centered. Check the flow from behind the log to make sure it is not going under or around the log. If flow is going under, lower the top to put more pressure on the log. Add weights to the stabilizing bar if necessary to keep the log pressed down. Record the weight added, re-measure and record the distance between the top and the stabilizing bar. If water is going around the sides, add more foam to the front or back ends of the log.
3. Allow the log material to saturate (15-30 min depending on the type of material) and the water level to stabilize. When the water level has stabilized, measure the flow rate by timing how long it takes to fill the 5 gallon bucket. Time the flow 2 times to ensure accuracy. Calculate the flow rate by dividing the gallons by time in minutes. Using the point gauge, measure water level immediately in front of the log. Measure the water level in 3 places across the back of the log to make sure the flow is spread evenly. Measure the hydraulic jump (where the flow meets the back water) distance from the log and from the wind block board. Record the flow rate, water temperature, water levels and hydraulic jump distance on the datasheet.
4. Calculate how many grams of sediment per minute is need by using the equation **g/min = Flow (gal/min)*3.785 (liters/gal)*2 gram/liter** (assuming 2 g/liter soil desired). Using the sediment feeder calibration curve, calculate how many RPM is required to achieve the desired amount of soil per minute (equation **RPM = (g/min +37.783)/1.694)**
5. Divert the flow coming out of the flume to the outside and then remove the splash board.
6. Calculate how much sediment will be needed for the 12 minute run (g/min x 12 min). Load and prime the sediment feeder (capturing the sediment in a cup and returning it to the feeder) with enough sediment plus extra for the entire run. Set the feeder to the desired RPM. Put up the cardboard wind block on top of the flume.
7. Run the feeder for one minute, collecting the soil in one of the pre-weighed soil cans. Do not allow the sediment to fall into the flume. Weigh the can and determine the soil weight.
8. Turn on sediment feeder and start a timer for 12 minutes.
9. Every 3 Minutes and again at the end of the run:

    - Take a water sample by inserting the funnel into the sampling bottle and collecting the water coming off the end of the flume. Remove the bottle from the stream before it is completely full.
    - Measure the height of the water level in front and in back of the log
    - Measure the flow rate by timing 5 gallons with the calibrated bucket.

10. At the end of the run (after last data collection at 12 min), collect the soil coming out of the feeder for one minute in one of the pre-weighed soil cans. Turn the water pump off. Weigh the can and determine the soil weight.
11. Weigh the water samples, record weight and transfer them into a pre-weighed glass beaker, rinsing the container to ensure the transfer of all of the sediment. Put in oven between 75-90 degrees C until dry (weight no longer changes). When dry, weigh the beaker and calculate the soil weight by subtracting the beaker weight.
12. After the water has drained from the flume, remove the log and blanket. Scrape the sediment on the flume bottom with a shovel or squeegee into a bucket. Rinse the remaining sediment into the bucket with as little water as possible. Pour the sludge onto a metal tray, rinsing out the bucket with as little water as possible. Put tray into the oven between 75-90 degrees C until dry (the weight no longer changes) and record weight. Calculate the soil weight and record.