Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-06/0-4572-1		

4. Title and Subtitle	5. Report Date
WATER QUALITY CHARACTERISTICS AND PERFORMANCE OF COMPOST FILTER BERMS	January 2005 Resubmitted: November 2005 Published: April 2006
	6. Performing Organization Code
7. Author(s) Beverly B. Storey, Aditya B. Raut Desai, Ming-Han Li, Harlow C. Landphair, and Timothy Kramer	8. Performing Organization Report No. Report 0-4572-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 0-4572
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Technical Report: September 2002-December 2004 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation, the Texas Commission on Environmental Quality, the Environmental Protection Agency, and the Federal Highway Administration.
Project Title: Characteristics of Compost Filter Berms
URL: http://tti.tamu.edu/documents/0-4572-1.pdf

16. Abstract

The Texas Department of Transportation, in conjunction with the Texas Commission on Environmental Quality and the Environmental Protection Agency, commissioned a study to examine the water quality impacts of compost leachate constituents and structural integrity of unseeded compost filter berms, seeded compost filter berms, and compost/mulch filter socks. Wood mulch filter berms, straw bales, and silt fence were tested comparatively. Three compost types were tested: dairy manure, biosolids, and yard waste. The berms and filter sock material used a mixture of 50 percent compost and 50 percent wood chips.

Studies were conducted with low velocity flows. Each of the alternatives was tested for two rounds consisting of three repetitions each round on both sand and clay soils. Results showed that the yard waste compost outperformed the dairy manure compost and biosolid compost in water quality characteristics and structural durability in performance. The berms that were seeded and left in place long term surpassed the unseeded berms in their ability to sustain overtopping and retain their structure.

17. Key Words	18. Distribution Statement
Compost, Compost Filter Berm, Compost Filter Sock, Storm Water, Sediment Control	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	119	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

WATER QUALITY CHARACTERISTICS AND PERFORMANCE OF COMPOST FILTER BERMS

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Project 0-4572
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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use. The researcher in charge of the project was Beverly B. Storey, RLA, Texas, #1996.

ACKNOWLEDGMENTS

The authors acknowledge individuals who contributed to and assisted with the research and preparation of this report. The authors would like to thank David Zwernemann, who served as the project director. A special thanks also to members of the Project Monitoring Committee who actively participated in the direction of the project. Numerous other TxDOT and Texas Commission on Environmental Quality (TCEQ) personnel also took time to provide insights and information that assisted in the completion of the project, and we sincerely appreciate their help.

Texas Transportation Institute staff that deserve recognition for their hard work in the installation of tests, assistance with data collection, and project support are Derrold Foster, Randy Eardley, Rodney Jackson, and Alex Ferrazas.

This project was conducted in cooperation with TxDOT, TCEQ, the Environmental Protection Agency, and FHWA.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1: INTRODUCTION

BACKGROUND

Implementation of the National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) requires that the Texas Department of Transportation (TxDOT) adopt a variety of storm water quality measures to meet Clean Water Act (CWA) requirements. Rules promulgated by the Edwards Aquifer Authority Act covering the area over the Edward's Aquifer address concerns for storm water pollutants entering this sensitive water body. In Texas alone, the state maintains over 79,000 miles of right-of-way and approximately 1600 active highway construction projects at any given time. TxDOT spent approximately $59 million on erosion and sediment control from February 2003 to February 2004, excluding maintenance or items that may have a dual purpose. Research was conducted to explore means of using environmentally friendly, recycled materials to reduce the costs of temporary storm water management systems while meeting water quality standards set by legislation. The recent focus has been on compost.

TxDOT undertook several pilot efforts in recent years that demonstrate the beneficial uses of compost in roadside applications. Specific uses of composted materials on roadsides include:

- erosion control,
- compost filter berms,
- compost filter socks, and
- as a soil amendment or mulch for vegetation establishment.

Results show compost to be a positive treatment. However, TxDOT, the Environmental Protection Agency (EPA), and the Texas Commission on Environmental Quality (TCEQ) were concerned that compost may have a negative water quality contribution through its leachate characteristics. Specific questions arose regarding possible eutrophication of receiving waters, a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae, or nutrient loading. Other concerns were in the:

- structural stability of the berms,
- proper placement in the right-of-way,

- longevity,
- relative performance of seeded versus unseeded berms, and
- relative performance and costs as compared to commonly used best management practices (BMPs) such as compost filter socks, silt fence, and straw bales.

OBJECTIVES

The project goal is intended to evaluate the following BMPs for use as temporary sediment controls: unseeded compost filter berms, seeded compost filter berms, wood mulch berms, compost and wood mulch filter socks, silt fence, and straw bales.

The specific objectives of the field and laboratory tests are as follows:

- Determine the water quality impact of composted materials – dairy manure, biosolids, and yard waste – when used as berms for temporary sediment control, whether as a filter berm or in a filter sock.
- Determine the water quality impact of wood mulch berms when used for temporary sediment control.
- Determine the water quality impact of seeded compost filter berms – dairy manure, biosolids, and yard waste – when used for temporary sediment control.
- Determine the structural stability of each type of compost filter berm, seeded compost filter berm, compost filter sock, and wood mulch berm.
- Evaluate the performance of silt fence and straw bales relative to compost filter berms.

Researchers studied several parameters, with a majority of the work focusing on the nutrients (phosphorous and nitrogen), bio-chemical oxygen demand (BOD), and dissolved oxygen (DO).

The water quality parameters of the collected samples that were analyzed are as listed in Table 1.1. The collected samples were analyzed, in accordance with the American Public Health Association (APHA) *Standard Methods for the Examination of Water and Wastewater* (*1*) to determine the parameters.

Table 1.1. Water Quality Parameters Analyzed.

Parameters	Units	Method of Analysis
Color	Color Units	APHA 2120
Turbidity	NTU	APHA 2130
Specific Conductance	$\mu S/cm^2$	APHA 2510
Total Suspended Solids (TSS)	g/l	APHA 2540 C
Total Dissolved Solids (TDS)	g/l	APHA 2540 D
Dissolved Oxygen	g/l	APHA 4500 O
pH	pH scale	APHA 4500 H
Alkalinity	mg/l as $CaCO_3$	APHA 2320
Anions Cl^-, SO_4^{2-}, NO_2^-, NO_3^-, PO_4^{3-}	mg/l	APHA 4500
Metals As, Cd, Co, Cr, Cu, Fe, Pb, Zn	mg/l; µg/l	APHA 3113 B
Biochemical Oxygen Demand BOD_5	mg/l	APHA 5210
Total and Fecal Coliform	MPN	APHA 9222

CHAPTER 2: LITERATURE REVIEW

INTRODUCTION

The 1987 amendment to the Clean Water Act established the Non-point Source Management Program, which mandated the control of storm water, erosion, and sediment at construction sites. The 1990 Coastal Zone Act Reauthorization Amendments (CZARA) established the Coastal Non-point Pollution Program. The Intermodal Transportation Efficiency Act of 1991 prompted the Federal Highway Administration (FHWA) to adopt the Erosion and Sediment Control Rules (23 CFR 65) in 1994 *(2)*. The EPA Phase I rules require construction sites greater than five acres to have construction permits and pollution prevention plans. The implementation of EPA Phase II rules in 2003 extended the permitting and pollution prevention plans requirement to smaller construction sites between one and five acres *(3)*.

EROSION

Non-point source (NPS) pollution occurs when a transport medium, such as water, moves pollutants from the land to a water body or into the groundwater supply. The EPA recognizes sediments and nutrients as the most common NPS pollutants. Sediments and nutrients released into the receiving waters as a result of soil erosion can become NPS pollution. Traditionally, it has been perceived that the impact of soil erosion is restricted mainly to agricultural runoff which has motivated major research endeavors in this field. In recent years, construction sites have attracted increased attention concerning soil erosion following the 1987 amendments to the CWA and CZARA *(2)*. These amendments regulate or permit the discharge or outfall of storm water into receiving water. Highway construction activity falls into the category of point source pollution as the storm water is directly discharged into receiving water or conveyance system.

The soil exposed by site disturbances, caused by construction and developmental activities, is susceptible to erosion *(4)*. Highway construction sites can increase the soil loss rates 10 to 20 times greater than those from agricultural lands, establishing them as potential sources of NPS pollution through soil erosion *(5)*. Techniques need to be devised to prevent erosion whenever a soil slope is exposed to rainfall or running water *(6)*. Some sites, like buildings, roadways, and developmental activities, need protection only during the construction phase, while sites with barren slopes are a source of continuing challenge. Wood residuals have effectively curbed damage to waterways by fine silt and clay particles (*6*).

Runoff from such sites could seriously threaten the quality of the receiving water and health of the residents in the surrounding areas (*7*). A 1999 study, conducted in Germany by Dierkes and Geiger, showed that the winter multi-lane divided highway runoff, when sampled at the edge of the pavement, displayed the highest frequency of severe toxicity (*8*). Erosion and fertilizer/herbicide runoff can greatly degrade the water quality in the surrounding areas (*2*).

The water quality parameters for highway runoff and urban runoff are generally similar, and hence both could use the same type of runoff control (*7*). The impact of highway storm water runoff, though not adverse when considered alone, could result in degradation of water quality when combined with runoff from other sources. Furthermore, the type of drainage system affects the quality of runoff (*7*).

A variety of particles of different sizes, textures, and compositions are present in urban runoff (*9, 10*). In urban environments, these solids may be considered important carriers of nutrients, metals, and toxic elements (*11*).

COMPOST APPLICATION IN EROSION AND SEDIMENT CONTROL

Departments of transportation (DOTs) have adopted a number of temporary and permanent control measures to address the problem of erosion control on highway construction projects. There are numerous products and materials available, both organic and synthetic. The incorporation of recycled organic materials, such as compost, on the roadside is relatively new. TxDOT's initial research study showed promise for using compost for erosion control. The research demonstrated that compost, when applied as a surface cover, could be as effective as some standard erosion control products in reducing sediment loss and establishing vegetation (*12*).

TxDOT has successfully used compost for vegetation establishment in the harshest of climatic and soil conditions along Texas roadways as well as for erosion control and moisture retention (*13*). The use of natural materials to reduce erosion has been well established with composted feed stocks (*6*). While successfully reducing pressure on landfills, the rapid increase in composting operations also has created a need for new markets that can utilize large amounts of composted materials (*14*).

The use of compost as a mulch blanket has gained increased attention due to its multiple benefits. The main advantage of using compost on highway right-of-way construction is protection against erosion and runoff, while providing an end use for recycled compost. This can be done at a reasonably low cost as compost becomes more widely used. Other benefits of using compost include stabilization of soil temperature and evaporation, as well as increased soil nutrient levels *(2)*.

Many states have emphasized reducing the quantity of materials entering landfills through recycling organic material. Composting facilities accomplish this reduction by preventing yard and garden trimmings, biosolids, and other organics from entering the landfill. States view compost use in erosion control on highway construction projects as a potential beneficial utilization of organic wastes.

A significant amount of research has been conducted to determine the impact of the surface application of composted organics on the reduction of soil erosion *(2)*. Persyn et al. showed that surface applied composted organics can reduce runoff rates, interrill (in the form of a sheet or thin layer) erosion rates, and interrill erodibility factors, and increase infiltration. The depth of the compost mulch application had no effect on the erosion control parameters like runoff and infiltration for vegetated treatments. However, an increase in infiltration and a decrease in runoff were observed in the case of unvegetated treatments *(2)*. Demars et al. reported that damage to waterways from silt and clay particles can be prevented effectively by use of mulch made from wood residuals *(6)*.

The mean interrill erosion rates displayed a trend similar to that of the mean runoff rates, with the topsoil and the control having the highest mean interrill erosion rates and the bio-industrial and yard waste treatments having the lowest. The mean interrill erosion rates for each treatment did not vary significantly with the different depths of the blanket applied or the vegetation *(14)*.

The application of composted organic material has the added benefit of facilitating the establishment of crop cover (grass swales). Vegetation can root and grow through the wood-residual mulch application, which reduces the amount of soil eroded *(6)*.

However, one downside of the application of composted organic material is the potential degradation of runoff water quality. Manures and composted material contain large amounts of nitrogen (N) and phosphorus (P) compounds. The nutrient-rich runoffs can enter the natural water bodies and cause eutrophication. Eutrophication is the word given to describe the effects that occur when a water body becomes rich in nutrients causing algal blooms and starving the water body of oxygen. Gilley et al. observed that there was a variation in nutrient concentrations in the runoff with soil type. Soils with larger clay content displayed greater adsorption of nutrients (*15*).

The total soil-P levels influence the total P in the runoff. The use of manure in excess of crop requirement increases the soil-P levels. The use of feed supplements or selected corn hybrids reduces the P content of manure. Manure with reduced P content decreases the amount of P accumulation in the soil, consequently reducing the P transport by overland flow. However, if there is a rainfall event immediately on application of the manure, the soil-P level had little effect on the P concentrations of the runoff (*15*).

Slopes greater than a 4:1 gradient with high likelihood of erosion potential are good candidates for use of compost filter berms. The berms are placed on slopes to intercept runoff. The runoff water flows through the berm, and sediment is filtered from the storm water (*16*). Berms allow soil particles to settle out by slowing the flow down. The process of reducing velocity allows for greater runoff infiltration into the soil as the water backs up behind the berm (*17*). Slope severity and the amount of expected rainfall govern the berm size and construction method (*16*). Compost berms are typically placed at the base of the slope with a second berm at mid-slope contours, perpendicular to the flow, and/or on the shoulder contour of steeper slopes for added protection. The particle size distribution of the compost is critical for use in filter berms as too many smaller size particles would reduce the rate of flow through the berm while too many larger size particles would render the berm ineffective for particle trapping (*18*). The trapezoidal shape of the berm allows maximum water penetration. The berm should be placed uncompacted on bare soil as soon as possible. Having vegetation or compost in front of or above the berms may protect them; however, vegetation should not be present under the berm (*16, 17*). Compost filter berms must never be constructed in runoff channels, ditches, or gullies (*16*). Backhoe, bulldozer, pneumatic blower, or grading blade may be used for the application and construction of compost berms; however, manual application is an option in small areas (*16*). Compost filter berms can be planted and seeded for permanent vegetation establishment at the time of application, or spread out and planted or seeded at the end of the project. Compost berms can be left at the site after construction is completed. The remaining composted material can be left in place or distributed as a soil amendment (*16, 17*, *19*).

A study conducted at San Diego State University reported that the use of berms reduced runoff volume by approximately 31 percent and off-site sediment delivery by 100 percent (*20*). The City of Eugene, Oregon, approved compost and mulch filter berms as effective alternatives to silt fence for erosion control and storm water protection (*21*).

FIRST FLUSH EFFECT

The concentrations of pollutants in the runoff are higher at the beginning of a runoff event. This phenomenon, called first flush, has been seen in many studies. First flush was most evident at high traffic density sites. The first flush effect was most pronounced for short duration storms, constant traffic volumes, and constant rainfall intensities. The vehicles provided a constant input of pollutant load during the storm event (*7*).

CHAPTER 3:
MATERIAL AND EXPERIMENTAL APPROACH

ON-SITE TESTING

Personnel conducted testing of erosion control devices at the TxDOT/Texas Transportation Institute (TTI) Hydraulics, Sedimentation, and Erosion Control Laboratory (HSECL) facility located at Texas A&M University's (TAMU) Riverside Campus.

Field data collections were done in accordance with an approved Quality Assurance Project Plan (QAPP). Testing procedures for water quality were consistent with current EPA 40 CFR 136 requirements.

Tests were carried out on the following cross-channel BMPs:

- dairy manure compost (DMC) berm,
- yard waste compost (YWC) berm,
- composted biosolids (CBS) berm,
- uncomposted wood chips (WC) berm,
- DMC filter sock,
- YWC filter sock,
- CBS filter sock,
- WC filter sock,
- straw bales, and
- silt fence.

The compost filter berms were tested in an unseeded and seeded condition. Water quality data were collected for each of the above applications with compost and wood mulch. The silt fence and straw bales were tested for their relative structural stability and total suspended solids.

Two types of soil were used in the tests, a fine sandy loam and a high plasticity index (PI) clay. These soils are typical of those found on highway rights-of-way in the state and are used for testing erosion control products for TxDOT's Approved Products List (APL).

Researchers took elevation measurements at various points in the testing basin upstream of the berm prior to every test to confirm the slope.

Experimental Setup

The experimental setup consisted of tests done:

- on unseeded berms, filter socks, straw bales, and silt fence:
    - 3 percent grade channel approximately 12 ft wide and 60 ft long, with a water reservoir at one end and the BMP placed at the other end as shown in Figure 3.1; and
- on the seeded berms:
    - six separate, at-grade channels – three at 3 percent grade and three at 7 percent grade – in which the berms were installed, seeded, and allowed to settle and grow vegetation for a period of 45 days prior to testing.

Compost

All compost mixtures used in the research project were in compliance with the quality standards set down in TxDOT Item 161 Compost. Berms were constructed and placed in accordance with TxDOT Special Specification 1011 Compost/Mulch Filter Berm. All compost berms and compost filter socks were comprised of a mixture of 50 percent compost and 50 percent wood chips in accordance with TxDOT specifications. Table 3.1 provides the relevant parameters of the compost used.

Table 3.1. Compost Properties.

PARAMETERS	UNITS	TXDOT[1]	DMC[2]	YWC[3]	CBS[4]	BRYAN[5]
pH		5.5-8.5	6.69	6.5	7.59	7.4
Specific Conductance	µS/cm	< 500	550	300	395	1870
Particle Size	<9.5 mm, dry weight basis	> 95	97.1	100	100	---
Moisture Content	%, wet weight basis	30-60	31.4	22.49	55.3	20.3
Organic Matter	%, dry weight basis	30-65	34.1	28.62	54	53.5
Stability		< 8	1.6	1	3	---
Maturity		> 80%	100	97	100	---
Nitrogen	%, wet weight basis		0.85	0.14	0.93	0.97
Phosphate	%, wet weight basis		2.20	0.02	0.34	2.15

1. TxDOT – TxDOT Specifications
2. DMC – Dairy Manure Compost (Organic Residual Reclamation, LLC, Dublin, Texas)
3. YWC – Yard Waste Compost (Garden Success, Inc., Houston, Texas)
4. CBS – Composted Biosolids (Garden-ville, San Antonio, Texas)
5. Bryan – Compost from Local Composting Facility
--- No Data Available

Tests on Unseeded Berms

The water quality tests were conducted as follows:

- All water quality tests were set up for two sets of three repetitions on two different soils.

- Each water quality test repetition was conducted for a 15-minute duration.
- The water flow rate was ~110 gallons per minute (gpm) where water filled the reservoir and over-flowed into the channel simulating a shallow, concentrated flow of ~ 0.25 cubic feet per second (cfs) similar to shallow, concentrated runoff.
- The tests were conducted separately with two soil types, sand and clay. It was planned to use two slopes, 3 percent and 7 percent, for each soil type during the testing. However, only a 3 percent slope was used as all the BMPs failed at 3 percent slope, making the use of 7 percent slope redundant.
- Three repetitions of the sheet flow water quality test were conducted using the same BMP in place.
- All berms (unseeded and seeded) were constructed according to TxDOT Special Specifications 1011 Compost/Mulch Filter Berm with base of 3.0 ft and a height of 1.5 ft and pre-wet before testing to simulate rainfall on the berm.

Four time-weighted samples were collected for each water quality test repetition. First infiltration and the time for each sample collection were noted. The samples were collected at a location (shown in Figure 3.1) downstream of the BMP structures 1, 7, 15, and 30 minutes from the time that the first infiltration was observed.

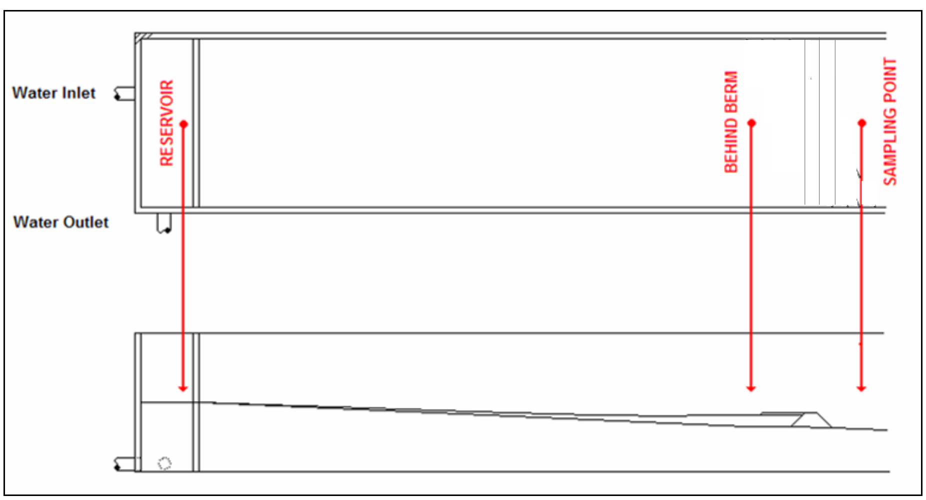

Figure 3.1. Sampling Location in Test Channel.

The ~0.25 cfs flow rate (Q) for this project was evaluated using the standard Rational Method of Q = CIA and backed out equivalent rainfall intensities (I) by varying runoff coefficient (C) and drainage area (A), comparing resultant rainfall intensities with the latest storm data produced by a research consortium of the U.S. Geological Survey (USGS), Texas Tech University, University of Houston and Lamar University. A component of this research determined storm depths for each Texas county for a 24-hour minimum time interval between storms and a non-exceedance probability of 0.90 (90 percent of storms will be of this rainfall depth or less). Figure 3.2 shows the water flowing in the test channel.

Figure 3.2. Flow in Test Channel.

The evaluation shows that the flow rate of 0.25 cfs is appropriate. The flow depth was not uniform across the test channel. The flow tended to concentrate toward the center one half to two thirds of the channel. This was due to the shallow swale configuration. The flow velocity observed during the testing was approximately 1 ft/sec when the water first reached the berm/sock.

In order to monitor the actual water quality during the tests, potable water was used. A sample was collected from the reservoir just before starting the test to determine the background concentrations of the contaminants present in the testing water. During the test, samples were also collected from behind the berm and at some distance downstream of the berm, before the water entered the receiving pond. Dissolved oxygen and temperature readings were taken on-site as they have a tendency to change with time.

If the berm did not fail after the second round of tests, a flow of up to ~0.35 cfs was used after taking the last water quality sample. This flow was sustained for 30 minutes or until berm failure.

Tests on Seeded Berms

The water quality tests were conducted on berms that were seeded in the same manner as the unseeded berms. However, samples were collected behind the berm, just after observing infiltration and after overtopping ceased. Upon completion of each set of flow tests (three repetitions), and assuming the structure maintained its integrity, multiple 30-minute continuous flow tests were conducted at flows up to 0.35 cfs. For the structural integrity tests, water was pumped into the reservoir in the channels at the same rate of up to 0.35 cfs. These tests used potable water. These tests were to document how long the BMP structure can sustain overtopping flow. A maximum of three continuous flows were conducted. If a structure sustained all three tests, no further tests were conducted. The time for the first infiltration, infiltration along the berm, and overtopping was noted in each case. The result section of this report presents the data.

Tests on Compost Filter Socks

The testing on the compost socks was done in the same manner as the unseeded berms except that the compost sock replaced the berm. The tests on the compost socks included two repetitions of ~110 gpm flow for 15 minutes. The socks were tested on both sand and clay soils. Socks were made of 12-inch diameter high density polyethylene as specified in TxDOT Special Specification for Temporary Erosion Control Device and filled using a pneumatic blower. The same method was used for the wood mulch sock; however, the sock was 18 inches in diameter as recommended by various TxDOT district personnel. Interviews with TxDOT personnel in different districts that have used the compost or wood mulch filter socks have concluded that the 18-inch minimum diameter of sock material had the most consistent positive results as the height was similar to that of silt fence material.

Tests on Wood Mulch Berms

Uncomposted wood mulch berms were installed according to TxDOT Special Specification 1011 Compost/Mulch Filter Berm. WC berms were tested on clay and sand soils. Water quality samples were collected in the same manner as with the compost filter berms.

Tests on Silt Fence and Straw Bales

Silt fence and straw bale materials were installed according to TxDOT Item 506 Temporary Erosion, Sedimentation, and Environmental Controls and TxDOT standard detail sheet EC(1)-93 for Temporary Erosion, Sediment, and Water Pollution Control Measures, Fenced and Baled Hay (see Appendices B and C). Water quality samples were collected and tested for total suspended solids and total dissolved solids only. Performance testing was conducted in the same manner as the compost berms and socks using the rate of up to 0.35 cfs as a test flow rate.

LABORATORY ANALYSIS

Samples were preserved as necessary and transported directly to the TAMU Civil Engineering Water Laboratory (EWRL), where the remaining tests were performed in a timely manner. Water tests were run for the parameters shown in Table 1.1.

The flowchart in Figure 3.3 outlines the timeline used for the laboratory analysis of the samples collected. Water samples were collected in 1 L cubi-containers and transported to the laboratory in a cooler at approximately 4°C, in accordance with *Standard Methods* (*1*). The samples were allowed to come to room temperature before conducting any tests.

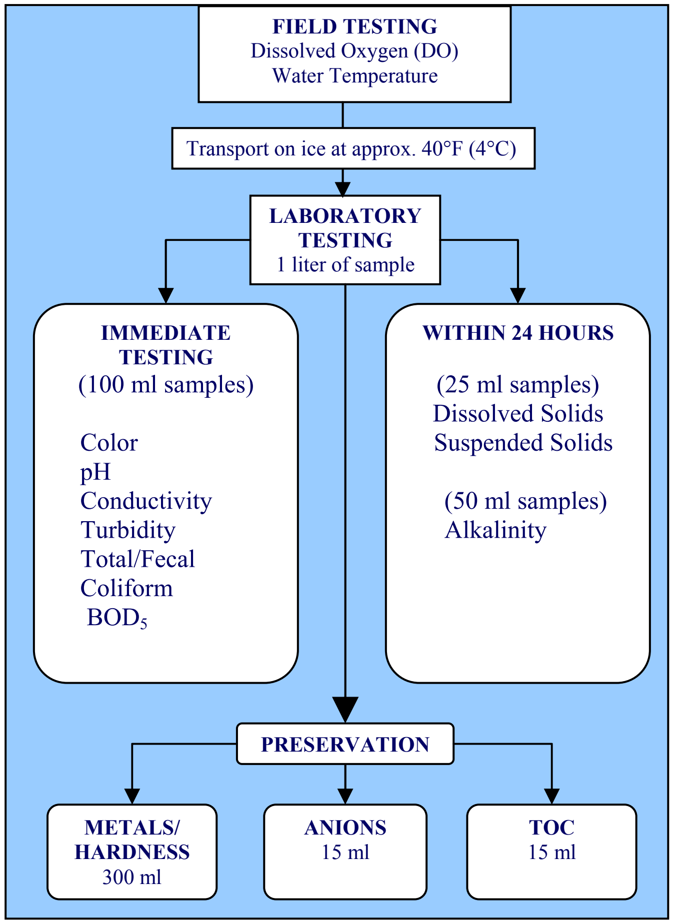

Figure 3.3. Sample Collection Timeline.

Temperature and dissolved oxygen were measured on-site right after the sample was obtained. The pH, color, turbidity, specific conductance, total suspended solids, total dissolved solids, total/fecal coliform, and 5-day biochemical oxygen demand (BOD_5) of the samples were analyzed immediately upon arrival at the laboratory. The rest of the sample was filtered through 1.5 micron Whatmann filters and stored in two 15 ml conical tubes for anion analysis using ion chromatography (IC), a 300 ml bottle for the heavy metal analysis using the atomic absorption spectroscopy and a 150 ml bottle for testing the alkalinity of the samples.

Temperature

The temperature of the samples was measured immediately upon collection of the sample. The temperature readings were taken using the DO-meter on-site as soon as the sample was grabbed. The results of the temperature readings were reported to the nearest 0.1°C.

Color

The sample was filtered through a 1.5 µm filter, and then the color was measured using the HACH 2100AN turbidimeter calibrated using a set of predefined standards. The color was reported on a scale of 0 to 500 color units (cu).

Turbidity

The nephelometric method was used in the laboratory analysis due to its precision, sensitivity, and application over a wide turbidity range. Turbidity was measured using a HACH 2100AN turbidimeter, and the measurement results were reported as nephelometric turbidity units (NTU). The turbidity meter was calibrated using a set of standard reference suspensions before analyzing any batch of samples.

Specific Conductance

The instrument used for measuring the specific conductance in the laboratory was a Corning conductivity-meter and a Corning probe. The equipment was calibrated using a standard potassium chloride solution that is commercially available. The results were reported in $\mu S/cm^2$ units.

Total Suspended Solids and Total Dissolved Solids

Before starting the test, the filters were washed with three successive 20 ml portions of reagent-grade water through the vacuum filtering apparatus. The washed filters were then placed in well labeled aluminum weighing dishes and kept in the oven for drying to measure the total suspended solids. A separate set of well labeled aluminum weighing dishes was kept in the oven for measuring the total dissolved solids. Before commencement of the test, the weighing dishes (with and without the filters) were removed from the oven and cooled in desiccators before weighing. The weights of the weighing dishes (with and without the filters) were recorded as B1 and B2, respectively. A 25 ml portion of the sample was measured using a pipette and deposited on the filter. Vacuum was applied, and the sample was allowed to pass through the filter. A 10 ml volume of the filtrate was pipetted into the weighing dishes (without the filter). The filters were removed from the filtering setup and placed in their respective weighing dishes. The dishes were then kept in the oven at 108°C to dry. On drying, the weighing dishes were removed from the oven, cooled in desiccators, and weighed. The weights of the weighing dishes (with and without the filters) were recorded as A1 and A2, respectively.

The total suspended solids were then calculated using the following formula:

$$mg \ total \ \ suspened \ \ solids \Big/ liter = \frac{(A1 - B1) \times 1000}{25}$$

The total dissolved solids were calculated using the formula:

$$mg \ total \ \ dissolved \ \ solids \Big/ liter = \frac{(A2 - B2) \times 1000}{10}$$

Dissolved Oxygen

The dissolved oxygen of the sample can change with time and temperature, so the DO of the sample was measured on-site immediately after the sample was collected. A field DO-meter (YSI model 51B) was used for measurement purposes along with a YSI model 5740 DO probe.

pH

The pH of the samples was measured using an Orion pH meter model 420A along with a ThermoOrion combination pH probe.

Alkalinity

For determining the alkalinity, 50 ml of the sample was titrated with 0.2 N sulfuric acid, and the pH decrease was noted for every 0.1 ml of acid added. The recorded data were entered in the online alkalinity calculator on the USGS website <http://or.water.usgs.gov/alk/>. This website also gave an estimated concentration of bicarbonates. The results were reported in mg/l as $CaCO_3$.

Anions

The anions such as sulfates, chlorides, nitrites, nitrates, and phosphates were measured by ion chromatography using the DX-80 ion analyzer. The DX-80 ion analyzer carries out isocratic ion analysis using suppressed conductivity detection. The ion analyzer was calibrated using a standard solution before the samples were run. PeakNet, the computer running chromatography software, compared the peak measured from the sample to that from the standards and converted the peak to a sample concentration. The sample was injected through a 0.25 µm filter to ensure that all suspended particles were removed. If high concentrations (beyond the calibration curve) were observed, the samples were diluted before analyzing. Each sample was run three times in order to ensure that there was no error in the readings. The results were reported in mg/l.

Heavy Metals

Heavy metals analyzed included As, Cd, Co, Cr, Co, Fe, Ni, Pb, and Zn. The samples were stored by preserving them at pH >2 using nitric acid. The analysis was done using atomic adsorption spectroscopy. The machine used for the analysis of metals in the sample was a Solaar M series AA spectrometer. The furnace method was used for the analysis as most of the metals were in trace concentrations (in the order of µg/L). Appropriate standards were created, and the machine was calibrated. An auto-sampler was used for the analysis.

BOD_5

The BOD test was performed in a specially designed bottle with a flared cap that forms a water seal to keep out air. The bottles were filled completely with samples, which must be near neutral pH and free of toxic materials. Since some of the samples had BODs much higher than the limited solubility of oxygen in water, two dilutions containing 25 ml and 50 ml of sample in a nutrient-containing, aerated "dilution water" were prepared. After an initial measurement of the DO (using YSI model 51B DO-meter and YSI 5905 BOD probe), the bottles were sealed and stored in a dark incubator at 20°C for 5 days. The bottles are kept in the dark because algae, which may be present in the sample, will produce oxygen when exposed to light. The DO is measured again after this incubation period. The measured difference in dissolved oxygen was multiplied by the appropriate dilution factors and reported as BOD. Samples which did not contain enough bacteria to carry out the BOD test were "seeded" by adding bacteria from another source.

Total and Fecal Coliform

Colilert™ analysis was used in conjunction with the QuantiTray system to enumerate both total coliform and fecal coliform. The trays were composed of individual pockets that were sealed with the sample and incubated at approximately 35°C for 24 hours. After incubation, the number of positive (yellow and fluorescent) individual pockets was counted and interpreted into a most probable number (MPN), for total and fecal coliform respectively, using a chart supplied by the manufacturer (IDEXX Laboratories, Inc., Westbrook, Maine). A 25 ml portion of the sample was diluted by adding 75 ml of buffer water to produce 100 ml of diluted sample for the Colilert™ analysis. The buffer water was composed of 1.25 ml stock phosphate buffer solution and 5.0 ml magnesium chloride solution (81.1 g $MgCl_2.6H_2O$ in 1 L of reagent-grade water) added to 1.0 L reagent-grade water. The buffer water was autoclaved at 121°C for 30 minutes and cooled prior to addition to ensure sterility.

CHAPTER 4:
RESULTS AND DISCUSSION

TESTING ON UNSEEDED BERMS

Dairy manure compost, yard waste compost, and composted biosolids were the three composts tested for water quality of the leachate. The berms consisting of these composts were tested on sand and clay soils at 3 percent slope. The majority of the berms failed within 15 minutes of the commencement of the flow as data in Table 4.1 shows. It was, therefore, decided that further testing on 7 percent slopes would be redundant. Due to the almost immediate failure of most of the berms, it was possible to acquire only one sample at 1 minute from infiltration.

Table 4.1. Performance of Unseeded Berms.

	Soil Type	1st Infiltration mm:ss	Failure mm:ss	Samples Collected mm:ss
DMC-1	Clay	3:05	5:25	2
DMC-2	Clay	5:04	8:00	2
DMC-3	Clay	5:29	7:44	3
YWC-1	Clay	3:56	No Failure	6
YWC-2	Clay	3:19	15:30	4
YWC-3	Clay	3.23	15:50	4
CBS-1	Clay	4:40	10:40	2
CBS-2	Clay	4:33	11:05	3
CBS-3	Clay	4:51	10:53	2
DMC-1	Sand	8:57	15:05	3
DMC-2	Sand	6:40	12:05	3
YWC-1	Sand	4:20	13:05	3
YWC-2	Sand	4:15	15:04	4
CBS-1	Sand	5:12	8:32	3
CBS-2	Sand	4:58	7:12	2

Structural Stability Testing on Unseeded Berms

No definite pattern was observed in the failure of the berms. Failure was not restricted to any particular location. The berms failed by different mechanisms. On clay soil, the primary mode of failure was breaking due to stresses caused in the berm resulting from the longitudinal displacement of the berm. Figures 4.1 to 4.4 illustrate the phenomenon of displacement. A white plastic sheet was secured in front of the berms to enable sample collection and for a visual comparison for photographs and video. The plastic did not interfere with the movement of the berms as it was not in direct contact with the berm.

Figure 4.1. Failure of the DMC Berm on Clay Due to Displacement (Round 1-1).

Figure 4.2. Failure of the DMC Berm on Clay Due to Displacement (Round 2-1).

Figure 4.3. No Traction between Clay Soil and CBS Berm Leading to Displacement of Berm.

Figure 4.4. Displacement Causing Stresses Leading to Failure of the YWC Berm.

Figure 4.4 shows the cracks caused by the stresses due to displacement. Displacement as great as 19 inches was observed in the case of the YWC berm. The displacement could be attributed to the lack of friction between the clay soil base and the berm.

Numerous approaches were tried to prevent failure of the berm on clay soils due to displacement. In one approach the berm was anchored in place by driving wooden stakes through the berm to try to provide some stability. As Figure 4.5 illustrates, the water eroded the compost material around the stake, leading to the ultimate failure of the berm.

Figure 4.5. Failure around the Stakes When the Berm Was Anchored.

Another approach was to lay the berm in a 2-inch deep trench cut out in the soil. This approach also turned out to be ineffective as the berm was displaced even after laying it in the trench. In the final approach, the berm was laid by compacting and tamping the compost in 6-inch thick layers. However, the tamping seemed to reduce the effective pore size of the berm, leading to decreased infiltration. Figure 4.6 shows the effect of tamping on the performance of the berm. The berm, ultimately, failed due to overtopping. Covering the berm with a retaining net was not tried as it would negate the primary advantage of ease of installation in practical application of the berms.

On the sandy soil, the primary mode of failure was undercutting of the soil beneath the berm. Substantial infiltration was observed through the soil under the berm in the case of sandy soil for all the berms. This indicated that the application of compost filter berms for sediment control is not suitable for sandy soils. Figure 4.7 shows dramatic berm failure on sand.

Figure 4.6. Compaction of the Berm Leading to Overtopping with Very Little Infiltration.

Figure 4.7. Failure of CBS Berm on Sand.

Water Quality Testing on Unseeded Berms

No surface water standards are set for storm water. The present assumption is that if a BMP is used, then the water quality requirements are met. The test flows used potable water. The water sample picked up a dark yellow color after passing through the berms. The dark yellow color was observed for the first 5 minutes after infiltration and gradually turned to a pale yellow color after 10 minutes of infiltration. The color increased from less than 50 behind the berm to over 400 after passing through the berm. Color makes water unpleasant for sight and affects the aesthetics, and is most often caused by dissolved matter from decaying organic materials.

Turbidity is caused by material suspended in water and is an indirect measure of total suspended solids. The turbidity data indicate that the turbidity of the water increases in the case of clay soil for all the berms. However, for the sandy soil the turbidity is reduced considerably in the case of DMC, CBS, and WC and increases in the case of YWC. In addition to depreciating the aesthetics, turbidity can also be a health concern as suspended matter can carry pathogens with it (22).

Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water. It is a measure of the dissociated salts present in the water. Specific conductance is a measure of the ability of water to conduct an electrical current. The specific conductivity results indicate that the least amount of specific conductivity of the leachate was observed in the case of YWC, while the conductivity for DMC was very high.

Suspended material causes sedimentation and can decrease the depth of the receiving water body. If there is a lot of biodegradable organic material in the sediment, it will become anaerobic and contribute to oxygen depletion. The TSS data indicate that none of the berms reduce the total suspended solids in the water. On the contrary, the berms increased the TSS in the water, with YWC berm adding the most TSS to the water. However, this is likely due to the fact that the berms were actually in the process of failing while the sample was being collected.

The TDS data exhibit that the least amount of dissolved solids were introduced in the water from the YWC, while the DMC, CBS, and WC introduced fairly large amounts of dissolved solids into the water. The TDS introduced in the water was considerably higher when testing the berm on sand as compared to when testing it on clay. This is concurrent with the specific conductivity results.

Dissolved oxygen levels below 5.0 mg/l can put aquatic life under severe stress. The dissolved oxygen level in the water dropped considerably after passing through the DMC, CBS, and YWC berms. However, there was a smaller drop in DO observed in the case of the WC berm. This could be attributed to the residence time of the water within the berm. The larger pores in the WC berm allow for the water to infiltrate through the berm quickly and reduce the residence time of the water inside the berm. The DO in some cases depleted close to the 5.0 mg/l, limit needed to support healthy populations of aquatic life. However, water samples collected downstream from the berm showed a rise in dissolved oxygen level to near pre-berm conditions as the water passed overland, indicating re-oxygenation.

Water having a pH of about 8.5 was used for testing. A pH range of 6.0 to 9.0 is favorable for aquatic ecosystems. This high pH can be accounted for by the fact that College Station relies on groundwater for its supply, which has a high carbonate concentration. A sudden drop in pH was observed after the water passed through the berm. The presence of organic acids may cause a drop in pH, which gives the compost an acidic nature.

The water used for testing had a considerable amount of alkalinity that was about 358 mg/l as $CaCO_3$ on average. The alkalinity was mostly due to the bicarbonates present in the water. The berms reduced the alkalinity of the water. The alkalinity results were not consistent enough to draw any definite conclusions. The compost is acidic and probably reduced the alkalinity due to its acidic nature.

The results of the sulphate analysis show that a large amount of sulfates were introduced into the water by the CBS. The DMC berm also introduced a large amount of sulfates into the water; however, the level was much less than that introduced by the CBS. The YWC and WC berms released a very small quantity of sulfates into the water. There was no appreciable difference in the results of the tests on sand as compared to the tests on clay.

The results from the chlorides test were not conclusive. However, it appears as if the DMC inputs a considerable amount of chlorides into the water when tested on sand.

Very little nitrites were observed in most of the samples as nitrites are very unstable and are immediately converted to nitrates. The nitrite results do not warrant any conclusions. However, it may be noted that in YWC on clay the nitrite level is very high, while the nitrate level is very low, so the total nitrogen in YWC on clay is consistent, only it exists as nitrites instead of nitrates.

The nitrate results indicated that the YWC and WC berms were the least contributors of nitrates in the water. The DMC and CBS berms introduced an incredibly large amount of nitrates into the water. This effect could be due to the fact that the samples were collected as the berm was failing. The nitrate anion NO_3^- is not adsorbed by soil and moves with infiltrating water.

Phosphates PO_4^{3-} is very toxic and subject to bioaccumulation. The DMC berm was the largest contributor of phosphates to the water. The WC, YWC, and CBS berms introduced very small amounts of phosphates into the water. Table A-13 shows the results of the phosphate concentration in the water.

The heavy metals results in Tables A-14 to A-20 show that the heavy metals in the leachate were not a source of concern. In fact, arsenic and lead levels were found to be below detectable limits of the machine.

The results presented in Table A-21 indicate that the berms introduced some amount of organic matter into the water. A large amount of organic matter seemed to be introduced into the water by the DMC and CBS berms when these berms were tested on the clay soil. However, the results are not very conclusive.

A considerable increase in the total coliform concentration was observed in the water after it passed through the berms. Results showed that the MPN/100 ml for the total coliforms was high for leachate through all the berms.

An increase in fecal coliform concentration also was observed in the water after it passed through the YWC and CBS. When the CBS berm was tested on clay soil, the MPN/100 ml of fecal coliform in the leachate was very high as compared to the rest of the test berms. No increase in fecal coliform was observed in the water after it passed through the DMC, implying that it had been disinfected.

TESTING ON SEEDED BERMS

Six berms were tested as seeded berms for structural stability and leachate constituent, as follows:

- three channels at 3 percent centerline grade:
    - one DMC berm, one YWC berm, and one CBS berm; and
- three channels at 7 percent centerline grade:
    - one DMC berm, one YWC berm, and one CBS berm.

All berms were installed on April 2, 2004, in six specially prepared channels. The berms were seeded with a grass seed mixture and irrigated to promote the growth of the vegetation. The first test flows on the berms were on May 17, 2004, approximately 45 days after installation. Three runs were conducted with flows of up to 0.35 cfs. Table 4.2 provides a comparison of the performance of the seeded berms.

Table 4.2. Performance of Seeded Berms.

	Slope %	1st Infiltration mm:ss	Infiltration along Berm mm:ss	Overtopping mm:ss
DMC-1	3	4:45	5:19	9:21
DMC-2	3	4:39	5:11	9:05
DMC-3	3	5:18	5:54	9:05
YWC-1	3	3:15	3:50	14:34
YWC-2	3	2:33	3:38	10:40
YWC-3	3	2:30	3:29	10:15
CBS-1	3	6:36	7:35	12:40
CBS-2	3	4:45	5:36	9:42
CBS-3	3	4:53	5:30	9:54
DMC-1	7	5:15	5:55	7:07
DMC-2	7	4:15	4:30	6:20
DMC-3	7	3:05	4:25	6:20
YWC-1	7	2:35	3:19	9:55
YWC-2	7	2:18	3:12	8:35
YWC-3	7	2:21	3:05	8:26
CBS-1	7	4:30	5:00	10:00
CBS-2	7	4:13	5:41	9:20
CBS-3	7	4:21	5:28	8:51

There was substantial growth of vegetation observed on the CBS and DMC berms as Figures 4.8 and 4.9 indicate. However, as Figure 4.10 shows, no growth was observed on the YWC berm after an initial sprouting. This could be explained by the lack of moisture retention capability of the YWC. The DMC and CBS also have a much more soil-like consistency as compared to the YWC which was coarser.

Figure 4.8. Composted Biosolids Berm before Starting the Structural Testing.

Figure 4.9. Dairy Manure Compost Berm before Starting the Structural Testing.

Figure 4.10. Yard Waste Compost Berm before Starting the Structural Testing.

Structural Testing on Seeded Berms

All of the seeded berms withstood all three test repetitions. Slight damage was observed, as Figures 4.11 and 4.12 indicate, in the case of DMC and CBS on the leading face where the vegetation was absent. The least damage was observed in the case of YWC as Figure 4.13 illustrates. The slope of the channel seemed to have no effect on berm performance. Overtopping was observed in the case of all the berms for both 3 percent and 7 percent slopes. However, there was insignificant damage to the structure of the berm due to overtopping. This performance of the seeded berm implies that the berms could be used as a runoff control method if installed and allowed to vegetate undisturbed prior to rainfall events. This would require scheduling and coordination with installation. Some of the TxDOT and TCEQ personnel interviewed said that they experienced good performance with the berms when seeded for as little as 7 days prior to rainfall events.

Figure 4.11. Composted Biosolids Berm Showing Minor Damages to the Leading Face.

Figure 4.12. Dairy Manure Compost Berm Showing Minor Damages to the Leading Face.

Figure 4.13. Yard Waste Compost Berm Showing No Damages to the Leading Face.

Water Quality Testing on Seeded Berms

A dark yellow color was imparted to the water when observing first infiltration. However, the color changed to pale yellow for the second sample, which was collected when overtopping had stopped. DMC had the maximum color input into the water, making the water look almost brown (however, there was very little turbidity or suspended solids) upon infiltration and changing to a pale brownish yellow color when overtopping had ceased. YWC imparted the least color to the water, making it look pale yellow which became almost colorless when overtopping had stopped. The point to note is that there was a visible reduction in color in samples taken upon first infiltration and stopping of overtopping. CBS performed intermediate to DMC and YWC as far as color was concerned.

The turbidity data and the total suspended solids data indicate that the three seeded berms (DMC, CBS, and YWC) brought about significant reduction in turbidity and total suspended solids. This reflects positively on the performance of the seeded berms as the turbidity was reduced below 15 NTU and total suspended solids were reduced below 0.05 g/L for all the seeded berms.

Table A-3 presents specific conductance results, while Table A-5 presents the TDS results. An interesting point to observe in these two tables is that the berms seem to bring about very little change of both specific conductance and total dissolved solids in the water initially during first infiltration. However, when the second sample is taken after the overtopping has stopped; a decrease in both the parameters is observed. This could be a form of first flush effect, with the berms actually removing dissolved solids from the water.

The dissolved oxygen level in the water, shown in Table A-6, dropped considerably after passing through the berm. This drop could be associated with the residence time of the water inside the berm and can be an indicator of the pore size of the berm available for the water to flow through. The table shows that the YWC berm had the least drop in dissolved oxygen and could be indicative of larger pores in the YWC berm, allowing the water to filter more freely through the berm. The DO in all cases was found to be less than 6.5 mg/l, which is less than the critical value for surface waters. However, as mentioned before, the dissolved oxygen level in the water rises back to approximately 7.8 mg/l after the water flows for some distance downstream of the berm.

Table A-7 shows a small drop in pH after passing through the berm initially, but the pH of the sample taken after overtopping had stopped is almost the same as the pH of the testing water. Alkalinity data presented in Table A-8 show a slight drop in the alkalinity which can again be attributed to the organic acids which have a tendency to reduce the alkalinity when they reduce the pH.

The results of the sulphate analysis presented in Table A-9 show that a large amount of sulfates were introduced into the water by the CBS. In fact, the CBS berm seemed to increase the sulfates in the water almost ten-fold. However, it may be noted that even after this large input the concentration of sulfates in the water was greatly below the National Primary Drinking Water Standards (NPDWS) (250 mg/L) and so should not be a source of concern. DMC and YWC berms input insignificant amounts of sulfates into the water.

The results from the chlorides test shown in Table A-10 indicate that the chloride concentration in the water was unaffected by the berms.

Nitrites were not detected in the samples, and hence there are no data presented for this parameter (Table A-11). The nitrate results in Table A-12 indicate that the YWC and CBS berms removed some nitrates from the water. This nitrate removal could be explained by the need to compensate for the nitrate uptake by the vegetation in the case of the CBS berm. In the case of the YWC compost berm this removal of nitrate could be accounted for by the very low concentration of nitrates in the YWC compost as Table 3.1 indicates. The DMC berm contributed to a significant increase in the nitrate concentration of water. However, this seems just like a first flush effect as the nitrate concentration in the sample taken after overtopping had stopped was below the concentration of nitrate in the water before passing through the berm. This increase should not be a source of concern as the maximum concentration of nitrates in the water after passing through the berm was below the concentration limit for nitrate in drinking water of 25 mg/l.

Table A-13 shows the results of the phosphate concentration in the water. The DMC berm contributed significant amounts of phosphates to the water. The CBS also introduced some phosphates into the water, but this amount was very small compared to DMC. The YWC berm introduced a very small amount of phosphates into the water.

The heavy metals results in Tables A-14 to A-20 show that the heavy metals in the leachate were not a source of concern. In fact, arsenic and lead levels were found to be below detectable limits of the machine.

The results presented in Table A-21 indicate that all the berms introduced very large amounts of organic matter into the water. This large influx of organic matter could explain the color in the water. The amount of organic matter introduced into the water decreased significantly for the sample taken after overtopping had stopped. This could explain the almost colorless sample for YWC after overtopping had stopped.

A slight increase in the total coliform concentration was observed in the water after it passed through the berms. There was a subsequent decrease in the total coliform concentration at the time of collection of the second sample when overtopping had stopped. A very small increase in fecal coliform was seen in the water after it passed through the seeded berms. The results presented in Tables A-22 and A-23 show that the MPN/100 ml for the total coliforms was high for leachate through all the berms.

TESTING ON COMPOST FILTER SOCKS

The tests on the compost filter socks included two repetitions of ~110 gpm flow for 15 minutes. The compost socks imparted a pale yellow color to the water, which was almost the same for all the socks on both clay and sand. Table A-1 indicates that no significant difference in color was observed for the three types of composts tested.

The turbidity data, presented in Table A-2, indicate a slight reduction in turbidity for tests on clay soil, while a significant decrease was observed for tests on sandy soil.

Table A-3 presents specific conductance results and shows a very nominal increase. The TSS data presented in Table A-4 indicate that the four types of compost socks introduced a smaller amount of TSS into the water than the unseeded berms. This could be attributed to the fact that the water was either overtopping (on clay) or under flowing (on sand) with respect to the sock and consequently introduced a lesser amount to suspended solids into the water. Most of the TSS seemed to be contributed by the channel bed; however there was some infiltration through the compost filter sock which contributed to the TDS.

The TDS results presented in Table A-5 indicate a significant influx of contaminants. The results for the dissolved oxygen, pH, and alkalinity in Tables A-6 to A-8 follow the same trend as the unseeded and seeded compost.

The results of the sulfate analysis presented in Table A-9 show that a large amount of sulfates were introduced into the water by the CBS which is concurrent to the sulfate data from the unseeded and seeded berms. The DMC sock seemed to introduce a relatively small amount of sulfates, while the WC and YWC socks had negligible contributions of sulfate to the water. The results from the chlorides test shown in Table A-10 indicate that there was some amount of chloride removal by all the berms.

A very small amount of nitrate seemed to enter the water after passing through any of the socks as seen in Table A-12; however, the amount that entered the water was insignificant. The phosphates results in Table A-13 indicate very clearly a high input of phosphates by the DMC sock, while the least input seemed to come from the WC and YWC socks. The concentration of phosphate in the water was less than that observed in the case of both unseeded and seeded berms.

The heavy metals results in Tables A-14 to A-20 show that the socks inputted insignificant amounts of heavy metals into the water. Arsenic and lead levels were found to be below detectable limits of the machine.

A small amount of organic matter seemed to be introduced into the water as Table A-21 shows. As Tables A-22 and A-23 show, a minute increase in the total coliform and fecal coliform concentration was observed in the water after it passed through the socks. However, the data for organic matter, total coliform, and fecal coliform are not conclusive.

TESTING ON SILT FENCE AND STRAW BALES

The TSS and TDS results for testing on silt fences and straw bales are presented in Table 4.3 and Table 4.4 respectively. In the case of the straw bales very little infiltration through the bales was observed as the water seemed to flow under the bales and not impede flow. When used on the clay soil the silt fence and straw bales reduced the TSS and spread the flow uniformly in the channel. However, they did not perform well on the sandy soil. Figure 4.14 and 4.15 show considerable scouring downstream of the straw bales and silt fences when used on sand. The results indicate a negligible change in the TDS in the water after crossing the silt fence or straw bales.

Table 4.3. TSS Results for Silt Fence and Straw Bales (g/l).

	Silt Fence						Straw Bales			
	Clay			Sand			Clay		Sand	
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 1	Run 2
Behind Berm	0.448	0.521	0.496	1.205	1.164	1.543	0.444	0.465	1.469	1.268
Sample 1	0.384	0.426	0.402	2.228	2.828	2.476	3.456	1.660	1.94	6.832
Sample 2	0.772	0.597	0.445	3.528	2.080	1.140	1.796	0.820	21.02	5.444
Sample 3	0.356	0.399	0.348	2.644	1.140	0.540	0.892	0.392	-----	-----
Sample 4	0.152	0.201	0.298	4.636	0.440	0.216	2.052	0.220	-----	-----

Table 4.4. TDS Results for Silt Fence and Straw Bales (g/l).

	Silt Fence						Straw Bales			
	Clay			Sand			Clay		Sand	
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 1	Run 2
Behind Berm	0.95	0.84	0.76	0.65	0.94	0.89	0.34	1.05	0.56	0.98
Sample 1	0.63	0.78	0.77	0.94	1.11	0.96	0.33	0.73	0.31	0.39
Sample 2	0.65	0.73	0.75	0.98	1.08	4.71	0.85	0.90	0.34	0.34
Sample 3	0.69	0.71	0.61	0.84	0.99	0.96	0.75	0.76	-----	-----
Sample 4	0.74	0.75	0.53	0.79	0.97	0.90	0.88	0.59	-----	-----

Figure 4.14. Scouring Downstream of the Silt Fence.

Figure 4.15. Scouring Downstream of the Straw Bales.

TESTING ON LOCALLY AVAILABLE COMPOST – FIRST FLUSH EFFECT

A set of trial runs was also conducted on locally acquired compost. The compost was a mixture of yard waste and bio-solids. However, the compost did not meet the TxDOT specifications. Testing was commenced within a week of laying the berm in the channel. The berm withstood the three rounds of water quality testing and three rounds of structural testing with minimal damage. The data from this testing is complete and have therefore been presented. Most of the parameters exhibited the effect of first flush. Figure 4.16 demonstrates the first flush effect in the three repetitions, where the color increases to over 500 cu and then reduces to 100 cu in 30 minutes.

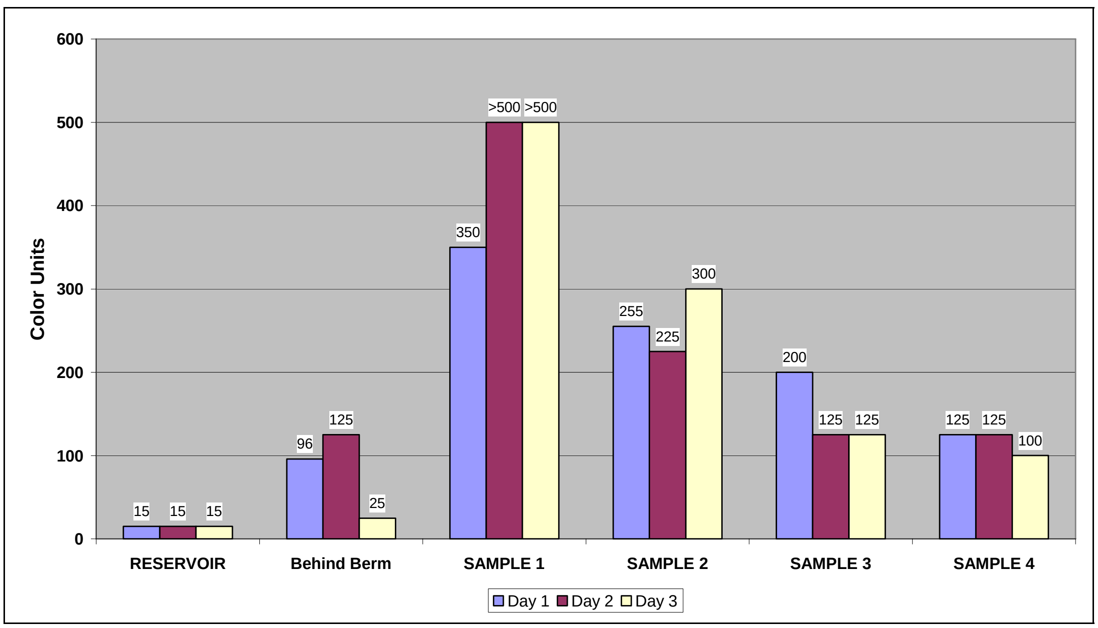

Figure 4.16. The Effect of First Flush Seen in the Trial Test.

The same effect can be seen in Figure 4.17 in the case of turbidity. The compost berm managed to reduce the turbidity of the water approximately 30 NTU from over 150 NTU behind the berm in 30 minutes. Figure 4.18 also shows the first flush effect, with the specific conductance of leachate approaching that of the original water during the 30-minute test duration.

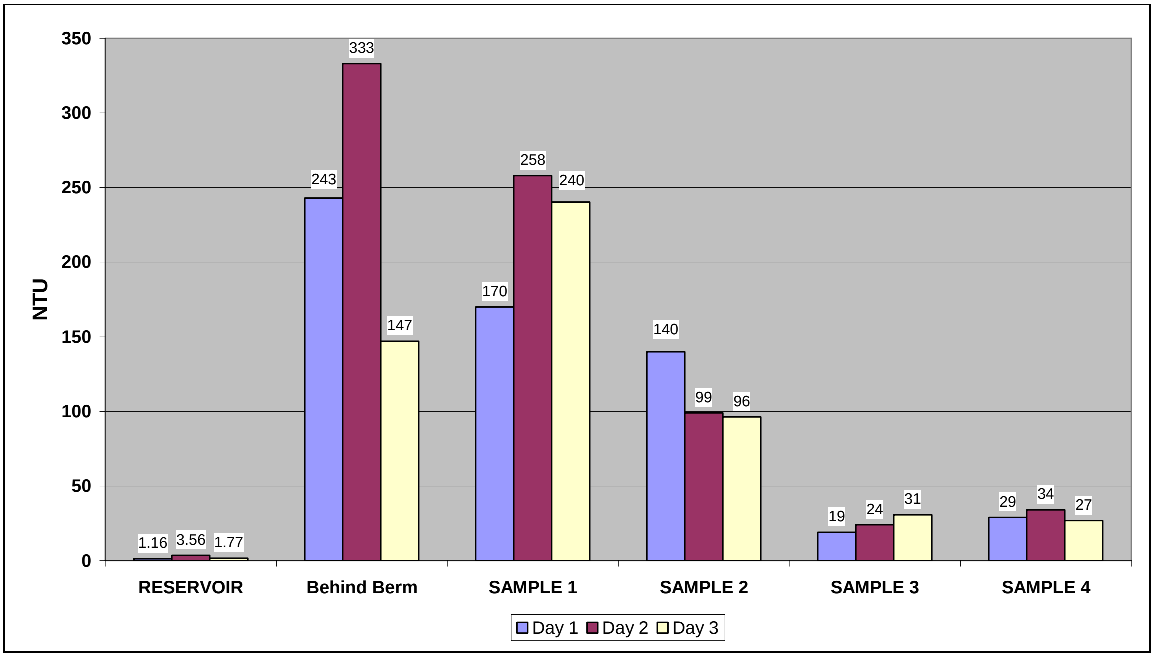

Figure 4.17. Turbidity – The Effect of First Flush Seen in the Trial Test.

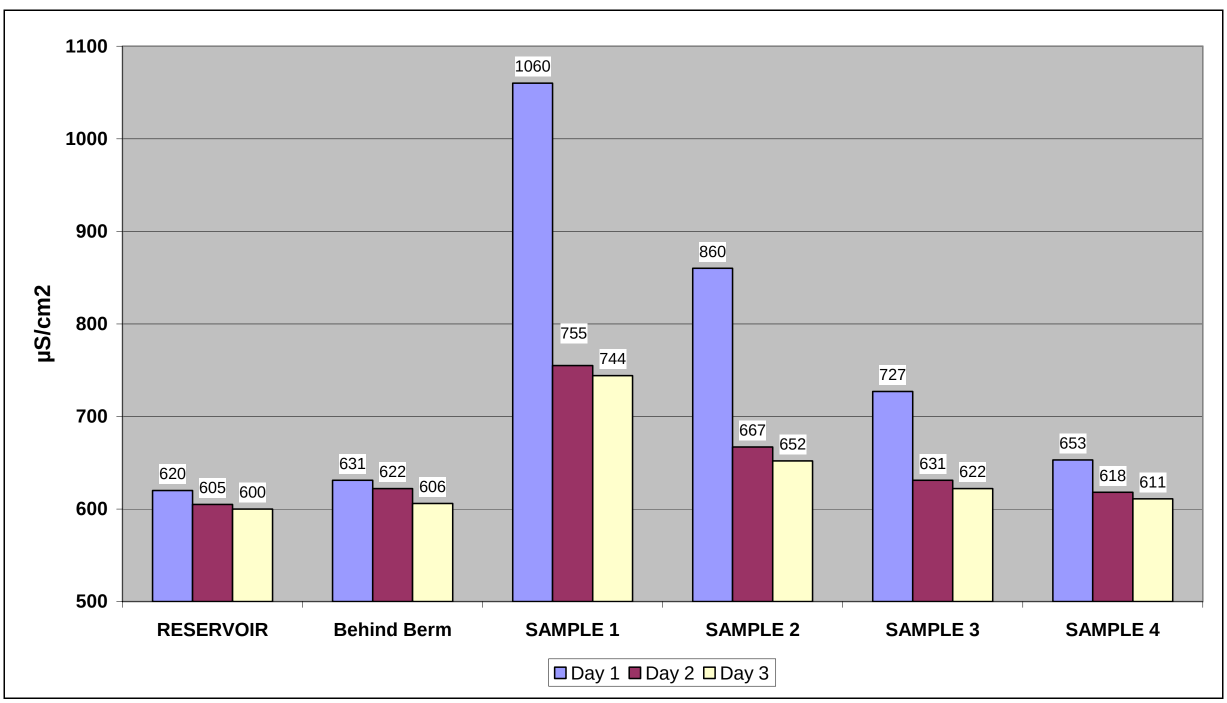

Figure 4.18. Specific Conductivity – The Effect of First Flush Seen in the Trial Test.

Figure 4.19 shows that the berm is effective in removing the total suspended solids from the water. The TSS of the leachate decreases quickly to approximately 0.047 from over 0.3 g/l in 30 minutes.

The total dissolved solids result in Figure 4.20 is similar to the specific conductivity result in Figure 4.18. Both the results distinctively demonstrate the first flush effect. In the first couple of minutes a large amount of TDS is contributed. However, after 30 minutes the water passed through the berm without picking up significant amounts of TDS.

In Figure 4.20 the dissolved oxygen decreased by approximately 1.43 g/l on average in the first 1 minute. Over the next 30 minutes the dissolved oxygen dropped by a further 0.67 g/l to reach approximately 5.8 g/l on average. The total average fall in dissolved oxygen was 2.1 g/l. However, the DO remained above 5.0 g/l.

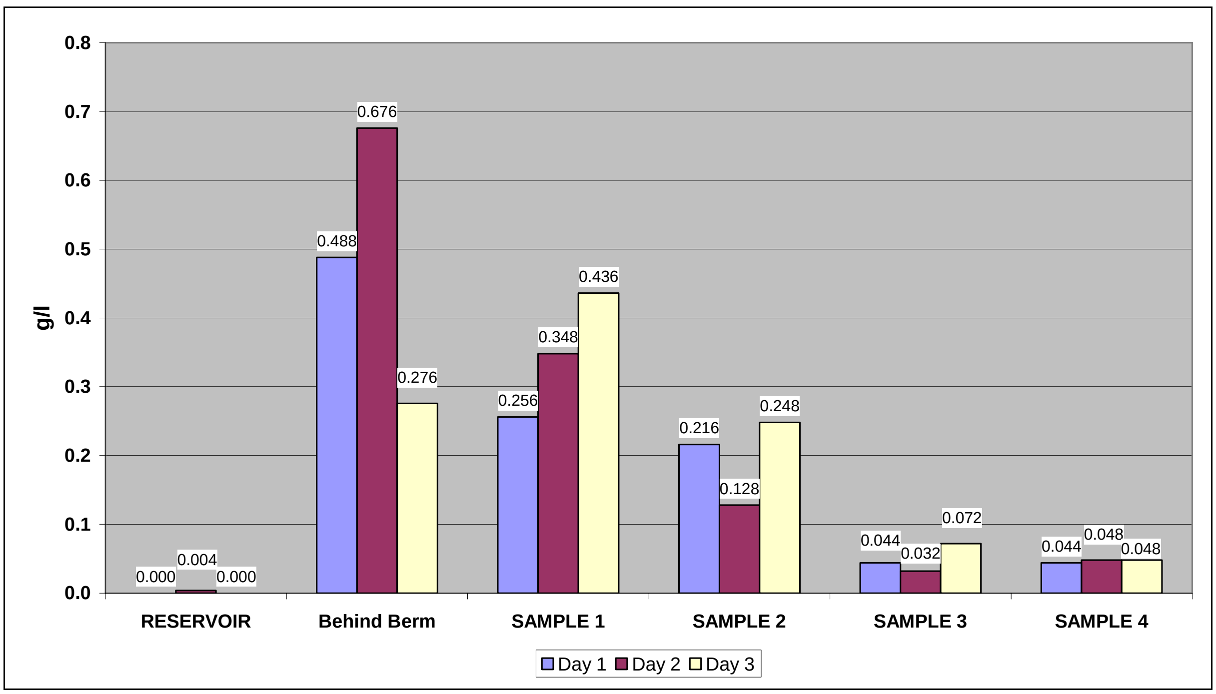

Figure 4.19. Total Suspended Solids – The Effect of First Flush Seen in the Trial Test.

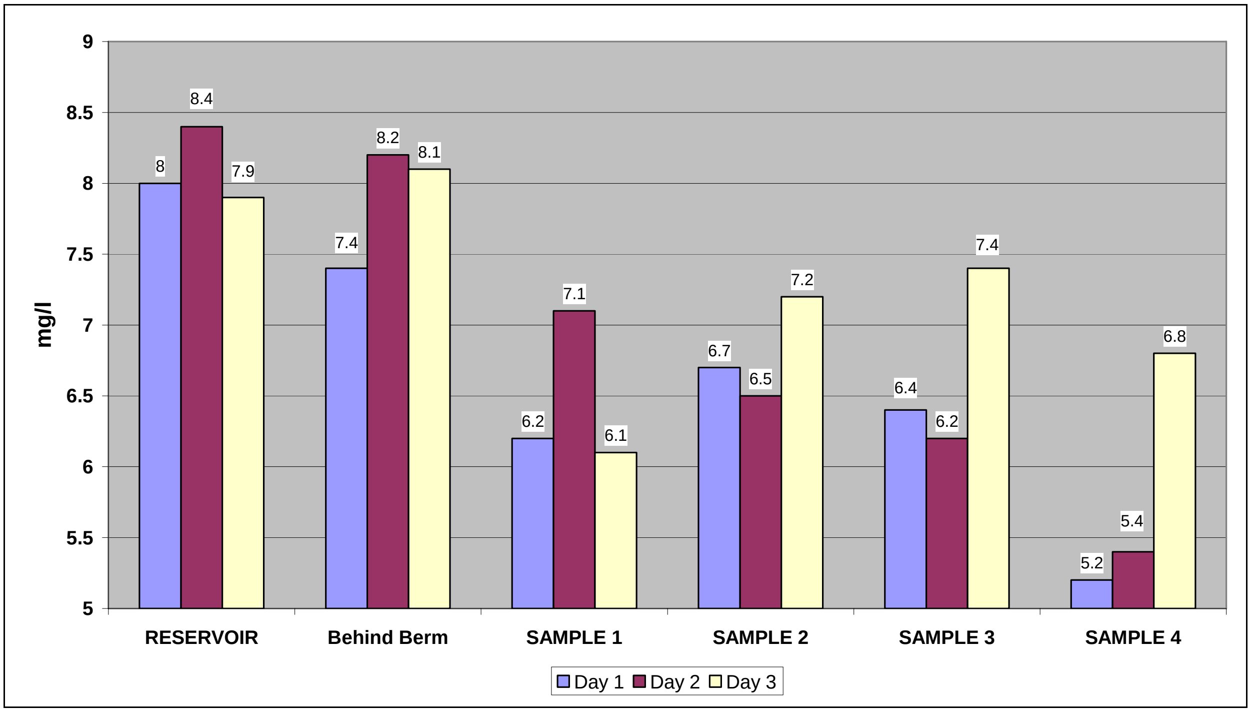

Figure 4.20. Dissolved Oxygen – The Effect of First Flush Seen in the Trial Test.

The water used for testing was potable water which had a pH of about 8.3. This pH is due to the fact that the water supplied in College Station is groundwater and has a large amount of carbonate concentration. Figure 4.21 shows that the pH of the water dropped suddenly after passing through the berm. However, the pH of the water passing through the berm increased with time. The drop in pH may be due to the acidic nature of the compost due to the presence of organic acids. The pH reducing capacity of the compost reduced with time as more volume of water passed through. Another interesting observation is that the pH reducing capacity of the compost reduced with each simulation run.

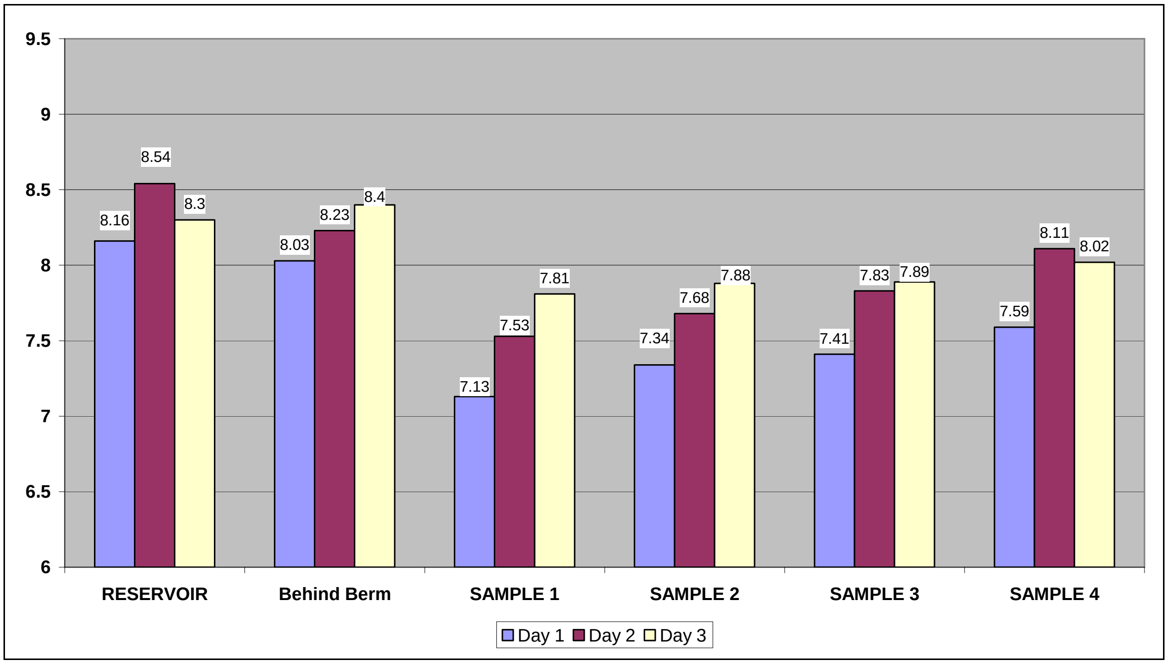

Figure 4.21. pH – The Effect of First Flush Seen in the Trial Test.

The sulfates results shown in Figure 4.22 indicate a pronounced first flush effect for the first run. The effect diminished with each run and was barely perceptible in the last run (third run). The decrease in the first flush effect was probably due to a washing effect, which reduced the concentration of sulfates in the berm compost.

The first flush effect is seen in Figure 4.23, displaying the chlorides results. The input water had a chloride concentration of about 65 mg/l. For the first run, there was a pronounced increase in concentration in the first 1 minute followed by a gradual decrease until the chloride concentration was almost the same as that in the input water. The effect of first flush reduced with each simulation run and was barely perceptible in the last run.

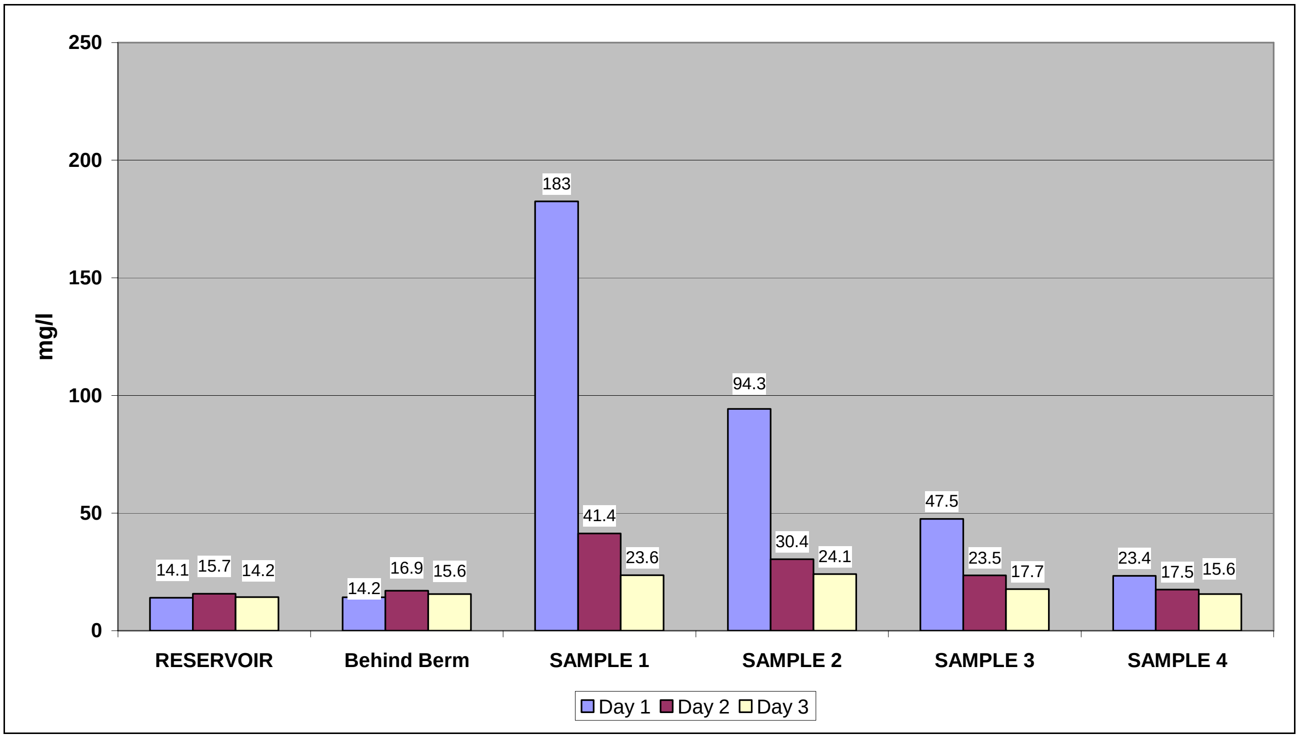

Figure 4.22. Sulfates (SO_4^{2-}) – The Effect of First Flush Seen in the Trial Test.

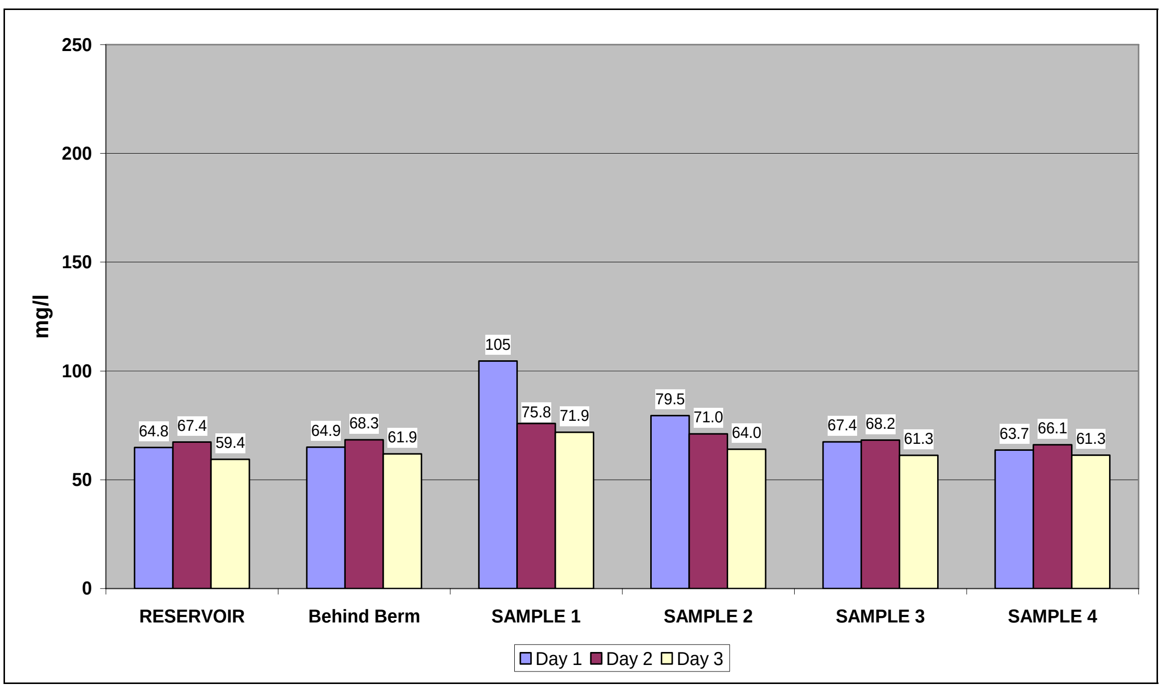

Figure 4.23. Chlorides (Cl^-) – The Effect of First Flush Seen in the Trial Test.

The nitrate results, presented in Figure 4.24, indicate that the water used for testing had a substantial nitrate concentration. The berm seemed to remove a considerable amount of nitrates from the water in the first run. The nitrate concentration increased in the next 30 minutes to 1 mg/l. The berm removed some amount of nitrate in the second and third runs.

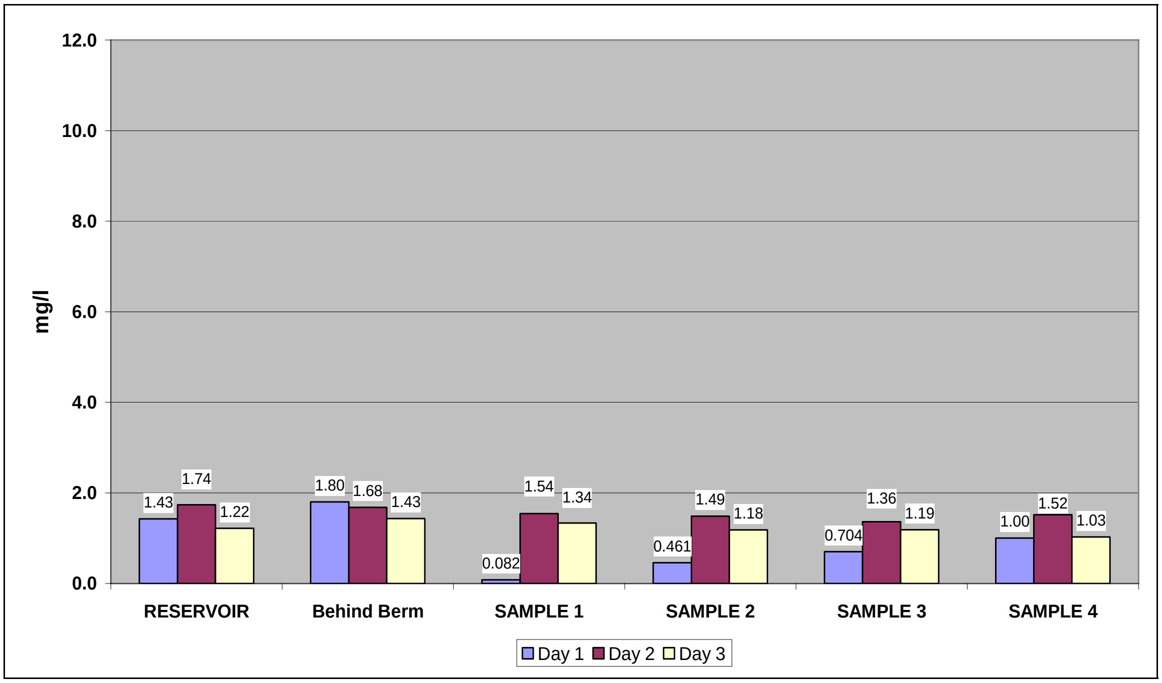

Figure 4.24. Nitrates as Nitrogen (NO_3^--N) – The Effect of First Flush Seen in the Trial Test.

The phosphate results presented in Figure 4.25 indicate the effect of first flush. There was no input of phosphates in the first minute for the first run. The amount of phosphates released into the water by the berm decreased over the 30-minute testing period. In the second run the amount of phosphates released by the berm was reduced to 0 mg/l within 30 minutes. The 5-day biochemical oxygen demand results presented in Figure 4.26 show a pronounced first flush effect in the first run which gradually diminishes with each run.

These results indicate that the berm releases a large load of contaminants for the first minute. The amount of contaminants released into the water reduced gradually over the 30-minute testing period after which time negligible pollutants are released into the water. Also, with each run the capacity of the berm to release pollutants into the water reduces considerably.

This can be explained by a washing effect that the water has over the berm. The water reduces the concentration of the contaminants in the berm by washing them away.

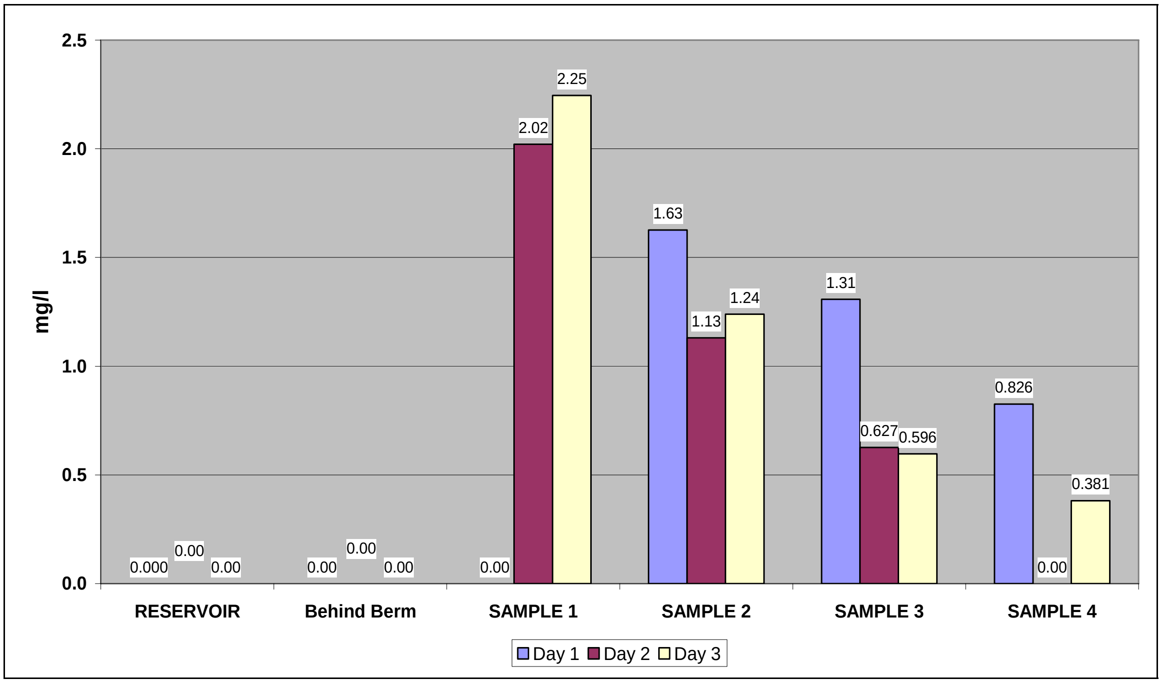

Figure 4.25. Phosphates (PO_4^{-3}) – The Effect of First Flush Seen in the Trial Test.

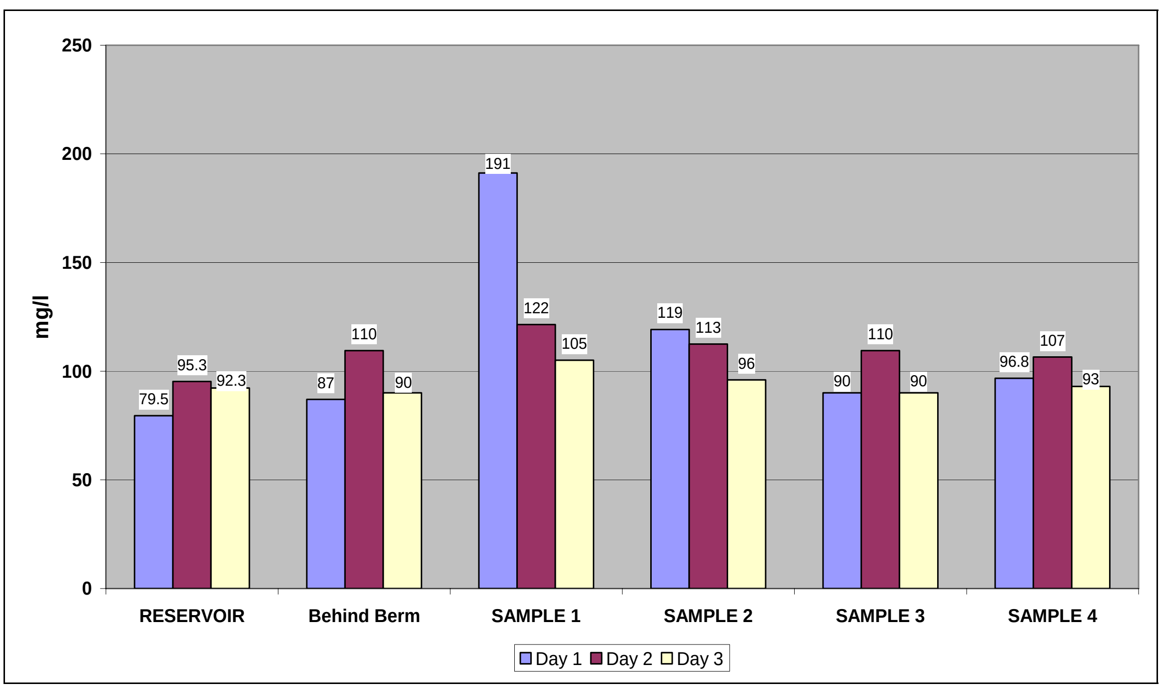

Figure 4.26. BOD_5 – The Effect of First Flush Seen in the Trial Test.

Another explanation for the pronounced first flush effect is the residence time of the water in the berm. For the first couple of minutes water is backing up behind the berm and the rate of infiltration is very slow. This gives the water ample time to remain in contact with the compost and extract contaminants. As the level of water backed up behind the berm rises, the water flows or infiltrates through the berm at a much faster rate. This increase in the flow rate does not provide the water enough time to contact the compost and extract contaminants.

DISCUSSION AND CONCLUSIONS

Unseeded Berms

Structural Stability

During the environmental quality testing of the unseeded berms a near 100 percent failure was observed. The berms performed better on clay than on sand, where the failure was mainly due to scouring of the sand underneath the berm. This result indicates that the use of compost filter berms on sandy soils is not practicable. The use of compost filter berms in concentrated flows is not recommended.

Unseeded Berm Repair

Repair of failed berms proved not to be a viable option. One of the "selling points" of compost filter berms was the ability to repair failed berms by filling in the dislodged materials. As demonstrated in testing, the replacement material inserted into the existing berms was quickly loosened and dislodged. This may be accounted for by the difference in moisture content, compaction, and residence time of repair material relative to the material in the existing berm. Each trial of berm repair failed.

Water Quality

The unseeded berms seem to contribute a significant amount of contaminants to the water. However, the data cannot be used to make conclusive remarks as the berms were failing when the samples were being collected. This being said, we can conclude that the berm may possibly have negative effects on the surrounding environment in the event of a failure. This would be an important deciding factor when considering the field application of compost berms. Also, the possibility of failure should be considered seriously when using these types of BMPs close to environmentally sensitive areas.

Seeded Berms

Structural Stability

For the seeded berms, the DMC and CBS promoted growth of vegetation. The YWC inhibited any growth on the berm after initial sprouting. This may be attributed to less soil like material in the large pores of the compost material. This may also be a contributing factor in the performance. However, all three types of seeded compost berms performed very well in the structural integrity testing with no failures. This difference in performance compared to unseeded berms may be due to the fact that the berms were allowed to establish themselves in place for approximately 45 days, so the compost in the berm had time to settle, and anchor to the soil. In addition to the simulated test flows, natural rainfall events at the HSECL during the test period of six months were over 32 inches, the third wettest year in recorded Texas history. Many factors may have contributed to the berms' performance.

Water Quality

The three types of berms (DMC, CBS, and YWC) proved to be highly efficient as sediment trapping devices by bringing about an almost complete removal of suspended solids. While YWC berm contributed the least contaminants to the water, DMC caused a considerable increase in the nutrient concentration in the water. The CBS berm was intermediate as far as contaminant input goes. Having said this, it may also be pointed out that the increase in the concentration of the nutrients in the water caused by these berms never increased to a level so as to warrant concern. The rest of the monitored parameters did not display any significant impact.

Compost Filter Socks

Structural Stability

The compost filter socks held in place during the flow tests. There was some concern about the water flowing under the socks; however, the socks did filter the water, slow the velocity, and redistribute the flow uniformly across the test channel as it passed through/under the filter sock.

Water Quality

The compost filter socks introduced a significantly higher amount of TSS compared to seeded berms. The capability of the compost filter socks for nutrient contribution was comparable to the seeded berms. Compost filter socks introduced negligible amounts of nutrients (nitrates and phosphates) into the water. There was no difference in the performance of the three composts (DMC, YWC, CBS) when used as a compost filter sock.

Straw Bales

The straw bales performed well in the test flows. They did well at retaining sediment behind the bales while not impeding the flow. In interviews with TxDOT district personnel, it was noted that performance of straw bales was tied to proper installation, proper placement, and maintenance. This can be said of all erosion and sediment control BMPs. Figures 4.27 and 4.28 show the performance of straw bales and silt fence.

Silt Fences

The silt fences performed better than the straw bales in the test flows. They retained the water and allowed the sediments to settle out. Silt fences performed better on clay soil compared to sand. This was mainly due to the fact that the silt fence could anchor firmly in the clay soil as opposed to sandy soil where a lot of undercutting was observed. In general it was observed that the silt fences were effective until overtopping was observed eventually resulting in failure of the silt fence.

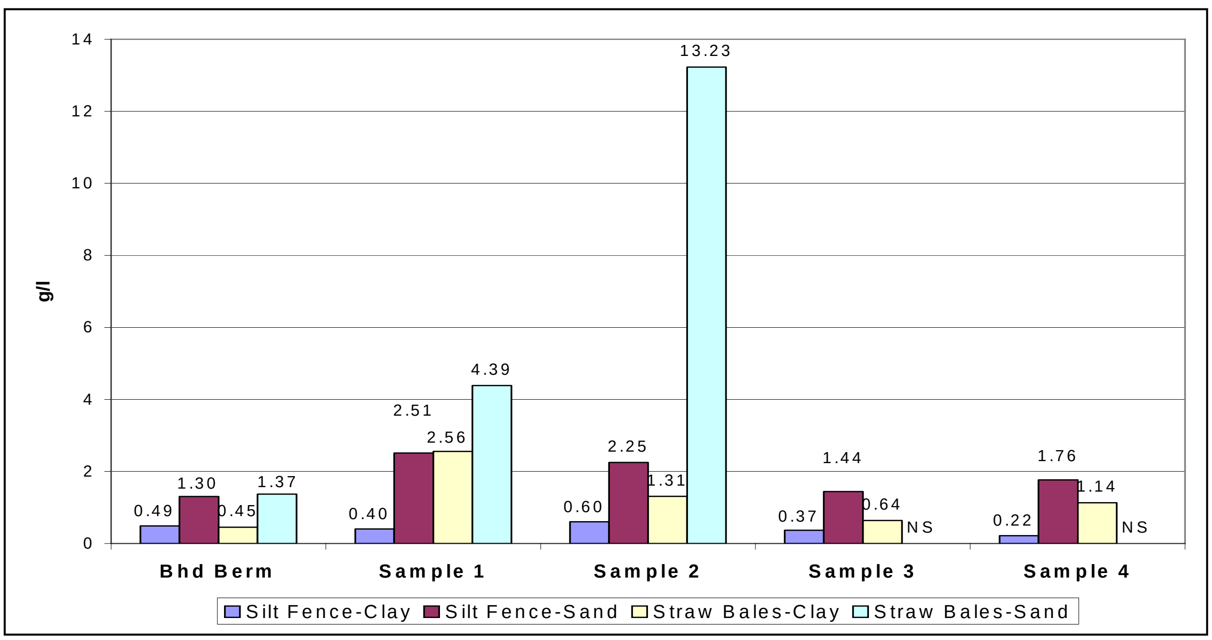

Figure 4.27. Total Suspended Solids Loading for Straw Bales and Silt Fence.

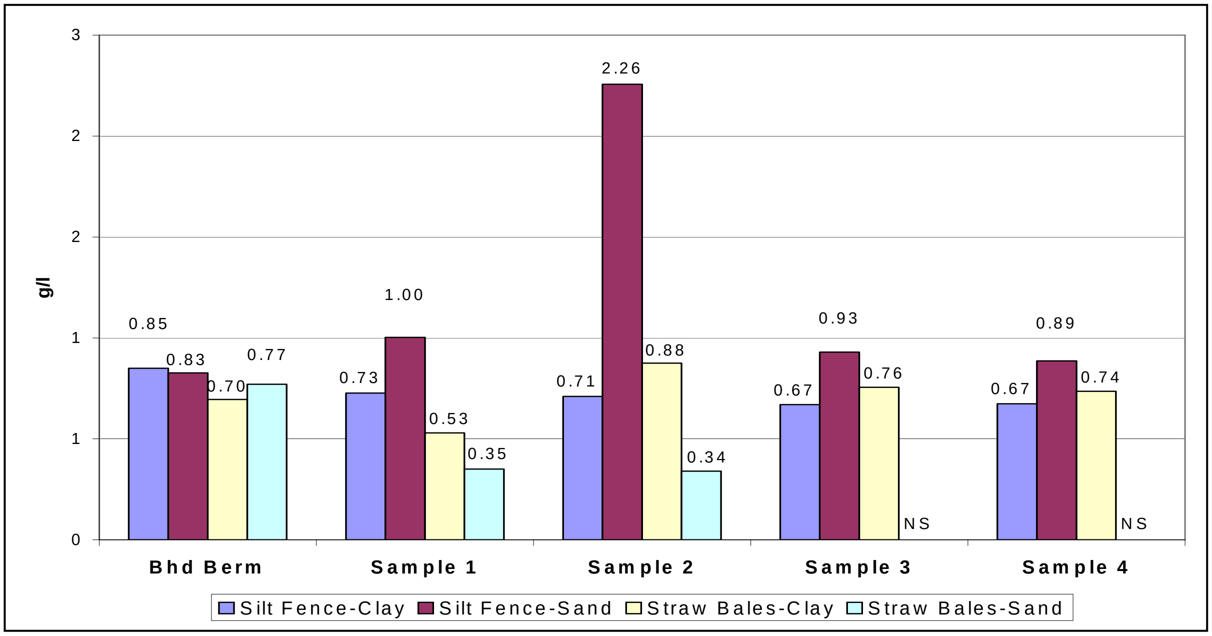

Figure 4.28. Total Disolved Solids Loading for Straw Bales and Silt Fence.

General Performance Discussion

The sediment trapping capability of the berms could not be deduced from the results due to failure during sample collection. A drop in dissolved oxygen was observed for all the berms. The YWC berm introduced the least amount of dissolved solids including sulfates, nitrates, and phosphates. The nutrients released by YWC were below the limits set for them respectively. The CBS and the DMC berm were equally unsatisfactory as both berms introduced substantial quantities of nutrients in the water, but again, berm failure occurred during sampling.

First Flush Discussion

The effect of first flush was evident from the tests on the locally available compost berm. There was a definite spike in the contaminants in the first few minutes of infiltration. The concentration dropped gradually over the 30-minute testing interval until negligible pollutants were released in the water. Also, with each run the capacity of the berm to release pollutants in the water reduces considerably. This can be explained by a washing effect that, by virtue of which, there is a reduction in the concentration of the contaminants in the berm. The marked first flush effect appears to be due to the residence time of the water in the berm. The more time that the water spent in the berm the more contaminants it dissolved from the compost.

Cost/Performance Evaluation

One of the benefits sought through the use of compost materials for erosion and sediment control is the ability to leave the compost and/or wood mulch in place after the BMP is no longer needed and final stabilization has been achieved. Manufacturers were reluctant to give cost data as they are directly tied to quantity. The costs associated with installation and removals were taken from the TxDOT statewide average low bid unit price data and are shown in Table 4.5. The costs reflect removal of the BMP; however, if the compost and wood mulch BMPs are not removed, the cost is reduced significantly. What is not directly reflected in Table 4.5 is the availability and transportation costs associated with compost. The research team had difficulty finding the three composts – dairy manure, biosolids, and yard waste – that not only met or exceeded the TxDOT specification for compost use, but also met the Seal of Testing Assurance (STA) certification requirements. Transportation costs ranged from $500 to $700 per compost type because so few suppliers were certified at the time of delivery. The list of STA certified facilities has grown throughout the project duration, and several facilities now exist across the state, thereby reducing the need for excessive transport costs.

The low cost associated with the silt fence is likely due to ready availability and familiarity of the BMP and standard use of this BMP in all types of construction activity. Straw bales were also used for the tests. The availability of straw bales is very regional. Many TxDOT districts have hay bales, but not much straw is produced. Straw is preferred to hay because it is a stronger, more durable part of the plant. TxDOT specifications refer to “hay bales” and do not reference straw or make any distinction between hay and straw.

Table 4.5. Average BMP Costs.

Item No.	BMP	Statewide Average Low Bid Unit Price		
		Installation	Remove & Replace	Remove
5012	TEMP SEDMT CONT FENCE	1.25 LF	1.07 LF	0.25 LF
1059	FILTER BERM COMPOST	2.15 LF	2.00 LF	1.17 LF
1034	FILTER BERM MULCH	3.50 LF	1.50 LF	3.00 LF
5003	BALED HAY FOR ERSN & SED CONT	10.25 EA	8.40 EA	5.12 EA

RECOMMENDATIONS

The performance of the seeded compost berms was very good. This may be attributed to two reasons: the establishment of vegetation on the berms and the residence time of the berm prior to testing. However, the YWC seeded berm outperformed the others in water quality and structural stability and did not have established visible vegetation present during testing. This may be attributed to a lesser quantity of fine, loose material in the compost as compared to the DMC and CBS.

The erosion and sediment control objective can be achieved by using filter socks filled with the compost materials and/or wood mulch and anchored in place according to TxDOT Specification 5046 Biodegradable Erosion Control Logs. From discussion with TxDOT personnel throughout the state, this seems to be the direction of compost and wood mulch use as sediment control BMPs. Further investigation using these socks could yield more conclusive results. The diameter of the filter sock seemed to have an impact on performance. The larger the diameter, the better the performance seemed to be. This may be attributed to the weight and height of the sock.

The use of the compost filter berms and socks in perimeter protection where sheet flow exists and where no direct stress would be exerted on the berm, should also be considered. Other possible applications may be used to shorten slope lengths by placing the BMP at mid-slope.

With the present berm placement recommendations, the practical use of the berm may cause concern in environmentally sensitive areas. If the berm fails, the effect is not the same as other BMPs, such as silt fence. Upon failure, not only will the accumulated sediment be distributed, but the compost from the berm will be carried with the velocity of flow and may eventually be transported to the receiving water body. The constituents in the compost could pollute the water bodies and the nutrients might lead to an accelerated eutrophication process. The compost debris could also have an adverse effect on the aesthetics of the surroundings. This may prove to be a risk to the surrounding ecosystem. Even if the berms were structurally stable, the mere possibility of its failure negates the practical application of the compost filter berms as sediment trapping devices in sensitive areas.

DRAFT SPECIFICATIONS AND INSTALLATION GUIDELINES

Specification

During the course of this project the specification for compost was revised and is now part of the 2004 TxDOT specification book as Item 161 Compost. Special Specification 5049 Biodegradable Erosion Control Logs is in place for the compost filter sock and mulch filter socks as well as Special Specification 1011 for Compost/Mulch Filter Berms. The aforementioned specifications are included in Appendix B. These are additional recommendations for use of compost filter berms and compost and wood mulch filter socks.

Installation Guidelines and Recommendations

Without further study to qualify why the seeded berms outperformed the unseeded berms, the specific structural capabilities of compost berms in concentrated flow situations, and given the conditions under which the research was conducted, the following is recommended.

1. Compost filter berm use should be avoided in high velocity, high volume, concentrated flows, i.e., ditches, channels, etc., and are not suitable for use as a check dam substitute.
2. Compost filter berms should not be used as the most downstream BMP or the last BMP before runoff enters receiving water. Another sediment capturing device should be present in the event of berm failure.
3. If failure occurs, replace compost filter berms with another suitable BMP. If damaged during construction, the berm should be replaced rather than repaired.
4. Compost filter berms may be used where sheet flow is anticipated as:
   a. perimeter protection,
   b. mid-slope sediment control, or
   c. toe-of-slope sediment control.
5. All compost filter berms should be seeded and placed as soon as possible to allow for vegetative growth and berm establishment prior to rainfall events.

Recommendations for compost filter sock use and placement are as follows:

1. Compost or wood mulch filter socks should generally be a minimum of 18 inches in diameter when used as a substitute for a BMP such as a silt fence as specified in Special Specification for Biodegradable Erosion Control Logs and placed and

used as written in the specification. However, sock diameter should be a site specific decision depending upon application.

2. The ratio of the mixture of compost and wood mulch may be changed to include a higher percentage of wood mulch to compost, up to 100 percent wood mulch.

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APPENDIX A:
WATER QUALITY TEST TABLES

Table A-1. Water Quality Test (Color).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0	NS	425	0	25	> 500	15	> 500	350	----	----	----
Dairy Manure Compost	0	NS	475	0	NS	450	10	> 500	400	10	> 500	375
Dairy Manure Compost	0	15	> 500	-----	-----	-----	10	> 500	475	10	> 500	410
Dairy Manure Sock	0	15	125	0	20	200	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0	10	175	0	10	120	-----	-----	-----	-----	-----	-----
Biosolids Compost	0	NS	350	0	35	450	5	> 500	310	----	----	----
Biosolids Compost	0	10	450	0	NS	500	20	> 500	380	10	> 500	425
Biosolids Compost	0	NS	400	-----	-----	-----	10	> 500	325	20	> 500	400
Biosolids Sock	0	10	200	0	25	225	-----	-----	-----	-----	-----	-----
Biosolids Sock	0	20	150	0	15	185	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0	15	> 500	0	25	> 500	35	> 500	460	----	----	----
Yard Waste Compost	0	5	225	0	35	475	5	> 500	425	5	> 500	425
Yard Waste Compost	0	15	500	-----	-----	-----	5	> 500	350	25	> 500	460
Yard Waste Sock	0	15	110	0	25	125	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0	25	150	0	10	175	-----	-----	-----	-----	-----	-----
Wood Chips	0	25	> 500	0	30	475	-----	-----	-----	-----	-----	-----
Wood Chips	0	15	350	0	35	> 500	-----	-----	-----	-----	-----	-----
Wood Chips	0	30	425	0	20	350	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0	25	125	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0	15	160	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0	20	130	-----	-----	-----	-----	-----	-----

--- ***Field test not conducted***
NS ***No sample collected***
ND ***Not detected by machine***

Table A-2. Water Quality Test (Turbidity – NTU).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	6.73	NS	350.33	0.592	1707	1334	152.37	125	6.21	----	----	----
Dairy Manure Compost	9.75	NS	2853.67	1.42	NS	1582	134.65	11.6	3.75	156.74	186	8.13
Dairy Manure Compost	3.67	378	4518	-----	-----	-----	140.62	54.1	5.95	162.13	76.3	12.5
Dairy Manure Sock	5.32	154	123	2.05	1090	250	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	2.76	176	140	1.26	568	354	-----	-----	-----	-----	-----	-----
Biosolids Compost	1.795	NS	3383.5	0.951	3453	546	85.65	22.4	6.45	----	----	----
Biosolids Compost	2.74	74.55	145.5	1.06	NS	4575	96.21	32.4	5.08	103.74	414	17.6
Biosolids Compost	1.057	NS	1816.5	-----	-----	-----	105.32	67.5	24.5	146.71	154	18
Biosolids Sock	0.56	93	112	0.876	758	473	-----	-----	-----	-----	-----	-----
Biosolids Sock	2.09	130	97.5	1.34	450	267	-----	-----	-----	-----	-----	-----
Yard Waste Compost	1.21	2.39	1499	0.849	3849	>10000	110.35	62.2	6.34	----	----	----
Yard Waste Compost	0.057	278	742	0.196	2991	3585	121.69	37.9	2.74	132.42	121	5.13
Yard Waste Compost	0.833	117	3072	-----	-----	-----	106.78	37.7	5.52	159.42	129	4.12
Yard Waste Sock	1.76	156	163	2.34	682	274	-----	-----	-----	-----	-----	-----
Yard Waste Sock	1.35	178	153	1.09	375	362	-----	-----	-----	-----	-----	-----
Wood Chips	0.946	143	136	1.23	1209	1029	-----	-----	-----	-----	-----	-----
Wood Chips	1.12	158	128	1.92	1302	1204	-----	-----	-----	-----	-----	-----
Wood Chips	1.05	173	162	0.76	972	972	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	1.16	659	256	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	1.05	732	229	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	1.21	528	203	-----	-----	-----	-----	-----	-----

--- ***Field test not conducted***
NS ***No sample collected***
ND ***Not detected by machine***

Table A-3. Water Quality Test (Specific Conductance – µS/cm^2).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	825$^{17.6}$	NS	1836$^{17.1}$	902$^{19.7}$	953$^{19.7}$	5770$^{19.7}$	872.2$^{19.7}$	1311$^{19.7}$	808$^{19.7}$	----	----	----
Dairy Manure Compost	827$^{17.9}$	NS	4150$^{17.2}$	941$^{19.7}$	NS	7920$^{19.7}$	826$^{19.7}$	844$^{19.7}$	683$^{19.7}$	899$^{19.6}$	1055$^{19.6}$	836
Dairy Manure Compost	848$^{18.5}$	834$^{18.5}$	2910$^{18.2}$	-----	-----	-----	905$^{19.7}$	1069$^{19.7}$	725$^{19.7}$	917$^{19.6}$	979$^{19.6}$	802
Dairy Manure Sock	894$^{18.5}$	895$^{18.5}$	1136$^{18.5}$	915$^{19.0}$	914$^{19.0}$	901$^{19.0}$	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	885	892	1083	902$^{19.0}$	927$^{19.0}$	1026$^{19.0}$	-----	-----	-----	-----	-----	-----
Biosolids Compost	947$^{19.8}$	NS	3630$^{20.0}$	976$^{19.7}$	979$^{19.7}$	5250$^{19.7}$	932$^{19.7}$	754$^{19.7}$	756$^{19.7}$	----	----	----
Biosolids Compost	904$^{19.9}$	906$^{19.9}$	6880$^{20.2}$	920$^{19.7}$	NS	8540$^{19.7}$	895$^{19.7}$	1040$^{19.7}$	739$^{19.7}$	936$^{19.5}$	1087$^{19.5}$	840
Biosolids Compost	927$^{20.1}$	NS	5530$^{20.1}$	-----	-----	-----	956$^{19.7}$	954$^{19.7}$	747$^{19.7}$	954$^{19.5}$	1095$^{19.5}$	805
Biosolids Sock	936$^{19.0}$	917$^{19.1}$	1228$^{19.1}$	919$^{19.1}$	932$^{19.1}$	1134$^{19.0}$	-----	-----	-----	-----	-----	-----
Biosolids Sock	920$^{19.1}$	903$^{19.0}$	1092$^{19.0}$	903$^{19.1}$	927$^{19.0}$	1007$^{19.1}$	-----	-----	-----	-----	-----	-----
Yard Waste Compost	926$^{19.3}$	945$^{19.3}$	895$^{19.3}$	897$^{19.7}$	907$^{19.7}$	1146$^{19.7}$	956$^{19.6}$	565$^{19.6}$	679$^{19.6}$	----	----	----
Yard Waste Compost	934$^{19.1}$	930$^{19.2}$	931$^{19.2}$	896$^{19.7}$	900$^{19.6}$	1095$^{19.7}$	937$^{19.6}$	787$^{19.6}$	708$^{19.6}$	952$^{19.7}$	833$^{19.7}$	784
Yard Waste Compost	925$^{19.2}$	923$^{19.1}$	1006$^{19.1}$	-----	-----	-----	913$^{19.6}$	650$^{19.6}$	698$^{19.6}$	940$^{19.7}$	827$^{19.7}$	763
Yard Waste Sock	921$^{19.5}$	905$^{19.6}$	953$^{19.7}$	928$^{19.8}$	903$^{19.8}$	976$^{19.9}$	-----	-----	-----	-----	-----	-----
Yard Waste Sock	897$^{19.6}$	928$^{19.7}$	946$^{19.7}$	895$^{19.8}$	912$^{19.7}$	934$^{19.7}$	-----	-----	-----	-----	-----	-----
Wood Chips	903$^{19.3}$	932$^{19.4}$	904$^{19.3}$	928$^{19.9}$	916$^{19.8}$	938$^{19.7}$	-----	-----	-----	-----	-----	-----
Wood Chips	932$^{19.3}$	917$^{19.3}$	879$^{19.3}$	916$^{19.2}$	927$^{19.2}$	965$^{19.1}$	-----	-----	-----	-----	-----	-----
Wood Chips	912$^{219.3}$	926$^{19.3}$	895$^{19.3}$	925$^{19.1}$	918$^{19.2}$	984$^{19.2}$	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	876$^{20.1}$	890$^{20.1}$	938$^{20.1}$	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	915$^{20.1}$	920$^{20.1}$	957$^{20.1}$	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	930$^{20.1}$	926$^{20.1}$	946$^{20.1}$	-----	-----	-----	-----	-----	-----

--- ***Field test not conducted***
NS ***No sample collected***
ND ***Not detected by machine***

Table A-4. Water Quality Test (Total Suspended Solids – TSS g/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0.012	NS	0.516	0.000	2.004	3.272	0.760	0.244	0.028	----	----	----
Dairy Manure Compost	0.100	NS	8.856	0.000	NS	6.284	0.640	0.200	0.012	0.540	0.312	0.056
Dairy Manure Compost	0.008	0.840	3.720	-----	-----	-----	0.850	0.144	0.044	0.760	0.136	0.044
Dairy Manure Sock	0.100	0.960	2.362	0.004	1.140	3.267	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.320	0.760	2.813	0.018	0.620	3.452	-----	-----	-----	-----	-----	-----
Biosolids Compost	0.000	NS	9.592	0.008	3.464	2.076	0.750	0.164	0.008	----	----	----
Biosolids Compost	0.000	0.260	4.576	0.036	NS	9.200	0.630	0.108	0.016	0.840	0.492	0.052
Biosolids Compost	0.000	NS	0.496	-----	-----	-----	0.540	0.204	0.092	0.670	0.216	0.032
Biosolids Sock	0.005	0.560	2.376	0.007	1.670	3.160	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.009	0.360	2.474	0.016	0.830	3.510	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0.008	0.476	1.464	0.008	4.232	9.376		0.156	0.020	----	----	----
Yard Waste Compost	0.008	0.056	0.72	0.004	3.240	5.660	0.160	0.108	0.008	0.290	0.172	0.032
Yard Waste Compost	0.004	0.240	3.548	-----	-----	-----	0.670	0.176	0.048	0.590	0.272	0.016
Yard Waste Sock	0.008	0.372	2.150	0.004	0.680	2.814	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.013	0.391	2.060	0.015	0.720	2.745	-----	-----	-----	-----	-----	-----
Wood Chips	0.005	0.468	2.276	0.015	0.472	2.819	-----	-----	-----	-----	-----	-----
Wood Chips	0.008	0.382	2.582	0.011	0.512	2.763	-----	-----	-----	-----	-----	-----
Wood Chips	0.012	0.412	2.108	0.009	0.528	2.932	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.015	0.653	1.865	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.004	0.539	1.674	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.008	0.489	1.954	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-5. Water Quality Test (Total Dissolved Solids – TDS g/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0.74	NS	2.06	0.70	1.09	5.36	0.94	1.47	0.66	----	----	----
Dairy Manure Compost	0.67	NS	4.98	0.00	NS	7.62	0.71	1.03	0.62	0.97	1.19	0.77
Dairy Manure Compost	0.65	0.90	1.90	-----	-----	-----	1.04	1.09	0.59	0.81	1.07	0.71
Dairy Manure Sock	0.65	0.68	2.01	0.71	1.04	4.31	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.71	0.76	2.79	0.64	0.97	4.19	-----	-----	-----	-----	-----	-----
Biosolids Compost	0.72	NS	3.63	0.73	0.83	5.6	0.92	0.7	0.68	----	----	----
Biosolids Compost	0.60	0.66	8.40	0.65	NS	9.83	0.98	0.98	0.54	0.94	1.01	0.71
Biosolids Compost	0.69	NS	6.26	-----	-----	-----	1.07	1.12	0.61	1.02	1.02	0.68
Biosolids Sock	0.63	0.68	4.16	0.74	0.92	4.71	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.69	0.65	4.53	0.64	0.85	3.14	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0.69	0.67	1.14	0.72	0.88	1.18	1.03	0.71	0.55	----	----	----
Yard Waste Compost	0.61	0.71	0.98	0.69	0.97	1.07	0.93	0.81	0.58	0.89	0.84	0.66
Yard Waste Compost	0.63	0.66	0.96	-----	-----	-----	0.95	0.89	0.63	1.12	0.82	0.65
Yard Waste Sock	0.73	0.69	1.37	0.68	0.94	1.83	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.64	0.73	1.12	0.71	0.89	1.57	-----	-----	-----	-----	-----	-----
Wood Chips	0.69	0.83	2.15	0.65	0.92	3.16	-----	-----	-----	-----	-----	-----
Wood Chips	0.67	0.71	3.27	0.68	0.89	2.78	-----	-----	-----	-----	-----	-----
Wood Chips	0.71	0.76	2.63	0.78	0.96	2.93	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.62	0.91	1.67	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.65	0.84	1.78	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.71	0.89	1.65	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-6. Water Quality Test (Dissolved Oxygen – DO g/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	7.9	NS	6	7.2	7	4.8	7.4	5.1	5.3	----	----	----
Dairy Manure Compost	7.7	NS	5.8	7.8	NS	5.6	7.7	5.2	5	7.5	6.4	5.6
Dairy Manure Compost	8.1	7.7	6.4	-----	-----	-----	8.1	5.4	5.5	7.6	4.8	5.9
Dairy Manure Sock	7.5	7.4	6.6	7.6	7.4	6.1	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	7.9	7.9	6.8	7.9	7.7	6.4	-----	-----	-----	-----	-----	-----
Biosolids Compost	7.4	NS	5.6	7.6	7.1	5.8	7.3	5.2	5.8	----	----	----
Biosolids Compost	7.9	7.3	6.3	7	NS	5	7.4	5.2	5.2	7.9	5.4	5.4
Biosolids Compost	7.5	NS	5.8	-----	-----	-----	8.2	5.8	5.7	7.6	5.1	5.4
Biosolids Sock	7.8	7.5	6.5	7.5	7.4	6.6	-----	-----	-----	-----	-----	-----
Biosolids Sock	7.9	8	6.8	7.8	7.6	6.3	-----	-----	-----	-----	-----	-----
Yard Waste Compost	6.8	6.5	5.3	8	7.5	6	7.9	5.8	5.6	----	----	----
Yard Waste Compost	7	6.7	5.6	7.6	7.1	5.4	7.3	5.6	6.2	8	6.1	6.4
Yard Waste Compost	6.9	6.6	5.6	-----	-----	-----	7.5	5.8	6	7.5	5.66	5.8
Yard Waste Sock	7.6	7.3	5.8	7.3	7.5	6.1	-----	-----	-----	-----	-----	-----
Yard Waste Sock	7.9	7.8	6.3	8.1	7.8	5.5	-----	-----	-----	-----	-----	-----
Wood Chips	7.5	7.6	6.7	7.9	6.5	6.7	-----	-----	-----	-----	-----	-----
Wood Chips	7.8	6.8	6.9	7.4	7.3	6.8	-----	-----	-----	-----	-----	-----
Wood Chips	7.6	6.9	7.1	7.6	7.1	6.6	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	7.8	7.5	6.5	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	8.1	7.7	6.6	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	6.9	6.5	5.9	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-7. Water Quality Test (pH).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	8.17	NS	7.46	8.73	8.6	7.62	8.34	7.72	7.96	-----	-----	-----
Dairy Manure Compost	8.20	NS	7.52	8.46	NS	7.39	7.93	7.73	9.02	8.04	7.8	8.03
Dairy Manure Compost	8.78	8.23	7.41	-----	-----	-----	8.16	7.69	7.98	8.56	7.77	8.1
Dairy Manure Sock	8.83	8.19	7.92	8.63	8.10	7.89	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	8.12	8.35	7.69	8.43	8.43	7.74	-----	-----	-----	-----	-----	-----
Biosolids Compost	8.42	NS	7.23	8.32	8.12	7.33	8.45	7.65	7.99	-----	-----	-----
Biosolids Compost	8.33	8.36	7.34	8.41	NS	7.81	7.93	7.56	7.95	8.47	7.88	8.19
Biosolids Compost	8.45	NS	7.39	-----	-----	-----	8.28	7.53	7.81	7.83	7.91	8.19
Biosolids Sock	8.23	8.24	7.69	8.21	8.04	7.93	-----	-----	-----	-----	-----	-----
Biosolids Sock	8.45	8.29	7.63	8.59	8.49	7.86	-----	-----	-----	-----	-----	-----
Yard Waste Compost	8.53	7.54	7.51	8.31	8.23	7.7	7.84	7.58	8.05	-----	-----	-----
Yard Waste Compost	8.23	8.59	7.63	8.46	8.39	7.59	8.48	7.75	8.1	7.94	7.91	8.31
Yard Waste Compost	8.63	8.55	7.52	-----	-----	-----	8.15	7.5	7.98	8.39	7.97	8.3
Yard Waste Sock	8.32	7.89	7.79	8.28	8.15	7.89	-----	-----	-----	-----	-----	-----
Yard Waste Sock	8.19	8.35	7.83	8.56	8.49	7.82	-----	-----	-----	-----	-----	-----
Wood Chips	8.57	8.29	7.88	8.62	7.83	7.47	-----	-----	-----	-----	-----	-----
Wood Chips	8.12	7.94	7.47	8.3	8.39	7.69	-----	-----	-----	-----	-----	-----
Wood Chips	8.21	8.54	7.93	8.18	8.42	7.92	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	8.7	8.4	7.57	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	8.1	8.0	7.31	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	8.5	8.3	7.44	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-8. Alkalinity (mg/l as $CaCO_3$).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	377.3	NS	419.6	324.5	381.1	449.1	373.9	368.2	351.9	----	----	----
Dairy Manure Compost	384.1	NS	307.4	386.7	NS	466.5	369.4	372.4	359.4	352.9	346.8	349.2
Dairy Manure Compost	371.9	378	378.1	-----	-----	-----	379.3	365.5	356.1	359.1	341.5	347.4
Dairy Manure Sock	356.9	375.3	347.1	352.5	363.6	325.4	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	368.5	378.9	333.8	364.3	367.8	327.9	-----	-----	-----	-----	-----	-----
Biosolids Compost	357.8	NS	389.6	365.8	376.9	276.2	361.3	372.6	356.4	----	----	----
Biosolids Compost	349.2	347.9	338.6	352.9	NS	182.4	352.9	357.8	351.2	354.2	347.2	345.6
Biosolids Compost	345.6	NS	336.8	-----	-----	-----	365.6	351.9	358.5	349.7	351.3	341.8
Biosolids Sock	356.7	357.8	325.6	365.2.4	371.8	312.5	-----	-----	-----	-----	-----	-----
Biosolids Sock	342.8	361.7	340.4	367.5	374.3	280.5	-----	-----	-----	-----	-----	-----
Yard Waste Compost	344.8	317.1	272.2	329.2	354.8	344.2	368.3	357.8	348.3	----	----	----
Yard Waste Compost	358.7	359.5	349.1	344.1	340.7	345.3	363.9	353.5	351.8	368.4	358.2	356.1
Yard Waste Compost	351	353.4	332.1	-----	-----	-----	352.9	359.2	358.2	373.4	361.7	351.4
Yard Waste Sock	358.9	345.7	325.6	362.3	373.8	311.3	-----	-----	-----	-----	-----	-----
Yard Waste Sock	361.3	350.1	331.7	374.5	379.5	306.7	-----	-----	-----	-----	-----	-----
Wood Chips	361.8	352.7	315.3	365.1	358.3	325.6	-----	-----	-----	-----	-----	-----
Wood Chips	358.5	347.8	321.6	361.6	353.2	329.1	-----	-----	-----	-----	-----	-----
Wood Chips	363.9	358.2	319.5	369.9	356.5	317.8	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	365.5	343.3	309.0	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	360.1	347.9	324.2	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	361.4	351.9	344.7	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-9. Water Quality Test (Sulfates – SO_4^{2-} mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	28.747	NS	101.51	15.546	14.075	609.47	17.261	38.5004	23.8721	----	----	----
Dairy Manure Compost	14.927	NS	285.733	15.493	NS	154.661	16.983	7.129	24.8988	16.943	17.4899	22.8117
Dairy Manure Compost	16.058	16.346	213.768	-----	-----	-----	16.592	21.98	16.3124	16.479	14.0239	20.9818
Dairy Manure Sock	13.892	16.467	56.732	16.729	15.481	79.271	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	17.385	16.51	61.153	15.994	15.016	76.285	-----	-----	-----	-----	-----	-----
Biosolids Compost	14.404	NS	972.268	21.943	23.833	1037.56	17.371	139.963	71.9763	----	----	----
Biosolids Compost	13.122	16.601	1308.32	19.331	NS	1214.43	16.033	89.8024	24.8529	16.934	130.212	40.5979
Biosolids Compost	11.093	NS	1195.23	-----	-----	-----	16.274	115.458	18.571	16.238	83.3256	28.6048
Biosolids Sock	16.35	16.671	328.554	20.448	16.256	206.183	-----	-----	-----	-----	-----	-----
Biosolids Sock	14.983	16.598	317.273	23.692	17.937	213.663	-----	-----	-----	-----	-----	-----
Yard Waste Compost	16.353	16.968	29.8397	19.716	19.976	22.701	16.473	8.7422	23.5831	----	----	----
Yard Waste Compost	16.546	16.2218	17.829	21.913	22.174	24.606	17.045	17.1527	17.4688	17.391	15.3381	22.1115
Yard Waste Compost	14.839	14.9143	28.7516	-----	-----	-----	16.845	9.5019	15.6093	16.942	16.3322	21.3083
Yard Waste Sock	13.775	16.029	17.286	19.827	18.367	20.167	-----	-----	-----	-----	-----	-----
Yard Waste Sock	14.833	16.327	17.925	20.683	18.274	19.583	-----	-----	-----	-----	-----	-----
Wood Chips	15.011	17.037	15.367	17.205	17.371	25.383	-----	-----	-----	-----	-----	-----
Wood Chips	15.935	16.938	26.237	16.604	16.836	29.422	-----	-----	-----	-----	-----	-----
Wood Chips	15.742	17.823	21.739	17.947	17.376	19.369	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	21.158	20.705	23.553	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	20.761	19.253	22.682	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	19.452	18.943	20.969	-----	-----	-----	-----	-----	-----

***---* Field test not conducted**
***NS* No sample collected**
***ND* Not detected by machine**

Table A-10. Water Quality Test (Chlorides – Cl^- mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	79.013	NS	0.000	65.264	67.522	654.287	66.748	58.6874	69.402	----	----	----
Dairy Manure Compost	79.554	NS	36.223	65.289	NS	211.69	65.432	8.7589	62.7314	67.859	68.3644	73.2883
Dairy Manure Compost	78.119	78.987	15.949	-----	-----	-----	65.943	61.5615	64.1222	68.774	74.1663	69.2612
Dairy Manure Sock	72.157	73.759	25.478	65.927	67.487	40.834	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	72.836	73.028	36.298	64.902	61.368	36.487	-----	-----	-----	-----	-----	-----
Biosolids Compost	66.361	NS	103.877	76.503	78.026	163.088	65.832	7.5299	63.772	----	----	----
Biosolids Compost	66.088	68.546	233.422	69.448	NS	221.726	66.023	60.7876	65.1216	69.381	66.9414	71.1268
Biosolids Compost	65.774	NS	192.956	-----	-----	-----	65.843	40.4548	65.7148	70.045	71.4031	68.2463
Biosolids Sock	68.028	69.875	41.363	72.92	75.983	47.384	-----	-----	-----	-----	-----	-----
Biosolids Sock	67.926	69.029	43.347	68.024	75.324	45.362	-----	-----	-----	-----	-----	-----
Yard Waste Compost	70.2234	71.6854	78.2779	67.883	67.322	100.622	66.034	33.0598	63.809	----	----	----
Yard Waste Compost	70.4016	70.9253	72.3936	68.897	68.683	96.486	65.948	71.2993	64.0331	69.398	73.9878	72.0165
Yard Waste Compost	67.7182	67.6534	77.9481	-----	-----	-----	65.745	60.9768	64.5869	67.348	74.5847	68.4763
Yard Waste Sock	67.836	70.938	45.794	68.973	67.934	53.982	-----	-----	-----	-----	-----	-----
Yard Waste Sock	68.037	71.438	46.368	68.003	68.934	50.327	-----	-----	-----	-----	-----	-----
Wood Chips	70.29	68.729	61.638	69.217	72.021	83.832	-----	-----	-----	-----	-----	-----
Wood Chips	65.038	71.927	65.238	71.230	70.739	82.023	-----	-----	-----	-----	-----	-----
Wood Chips	68.382	70.917	63.108	70.210	69.012	80.012	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	69.472	68.843	76.246	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	67.975	69.286	72.351	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	71.407	72.452	79.543	-----	-----	-----	-----	-----	-----

***---** Field test not conducted*
***NS** No sample collected*
***ND** Not detected by machine*

Table A-11. Water Quality Test (Nitrites – NO_2^- mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0.000	NS	483.513	0.000	0.000	5.660	0.000	0.000	0.000	-----	-----	-----
Dairy Manure Compost	0.000	NS	285.980	0.000	NS	1.875	0.000	0.000	0.000	0.000	0.000	0.000
Dairy Manure Compost	0.000	0.000	204.127	-----	-----	-----	0.000	0.000	0.000	0.000	0.000	0.000
Dairy Manure Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Biosolids Compost	0.000	NS	102.986	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----
Biosolids Compost	0.000	0.000	0.000	0.000	NS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biosolids Compost	0.000	NS	6.65	-----	-----	-----	0.000	0.000	0.000	0.000	0.000	0.000
Biosolids Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----
Yard Waste Compost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yard Waste Compost	0.000	0.000	0.000	-----	-----	-----	0.000	0.000	0.000	0.000	0.000	0.000
Yard Waste Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips	0.000	0.000	0.000	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.000	0.000	0.000	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-12. Water Quality Test (Nitrates – NO_3^- mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	2.243	NS	256.97	4.981	6.141	1935.6	4.208	35.1777	2.2291	----	----	----
Dairy Manure Compost	2.269	NS	68.181	4.766	NS	547.094	4.023	6.0402	1.3696	4.924	10.8998	2.4914
Dairy Manure Compost	3.774	4.05	37.414	-----	-----	-----	4.939	9.3237	1.3591	5.203	7.0314	1.5943
Dairy Manure Sock	3.044	4.538	14.398	4.389	7.478	9.387	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	2.945	3.823	12.469	3.293	6.989	9.028	-----	-----	-----	-----	-----	-----
Biosolids Compost	3.505	NS	425.908	5.985	6.677	1305.08	4.237	2.0887	1.147	----	----	----
Biosolids Compost	5.695	4.496	1514.27	3.357	NS	187.412	5.028	5.2723	1.1778	5.371	3.0374	0.191
Biosolids Compost	4.516	NS	1033.57	-----	-----	-----	4.738	3.827	0.9808	4.793	1.7251	0.4483
Biosolids Sock	3.183	4.578	6.549	4.903	6.943	7.838	-----	-----	-----	-----	-----	-----
Biosolids Sock	3.848	4.718	6.328	3.945	6.827	8.038	-----	-----	-----	-----	-----	-----
Yard Waste Compost	2.1288	2.3066	0.5249	7.488	4.642	8.712	3.908	0.8124	1.0203	----	----	----
Yard Waste Compost	2.1744	2.1888	2.2268	5.19	6.281	12.779	4.392	0.9132	1.078	4.738	0.9203	0.2413
Yard Waste Compost	1.8674	4.496	0.3854	-----	-----	-----	4.031	0.3487	0.8283	5.289	0.649	0.5755
Yard Waste Sock	1.948	3.294	4.289	5.932	5.738	6.92	-----	-----	-----	-----	-----	-----
Yard Waste Sock	2.083	3.167	4.938	5.483	5.839	7.283	-----	-----	-----	-----	-----	-----
Wood Chips	3.028	3.356	5.498	3.728	5.936	8.438	-----	-----	-----	-----	-----	-----
Wood Chips	2.937	3.563	5.909	2.934	6.062	9.034	-----	-----	-----	-----	-----	-----
Wood Chips	2.384	3.745	6.378	2.738	5.278	8.474	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	6.119	5.935	6.984	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	5.785	5.821	6.012	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	4.678	5.045	5.545	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-13. Water Quality Test (Phosphates – PO_4^{3-} mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0	NS	0	0.464	0.849	42.692	0.736	6.9181	4.479	----	----	----
Dairy Manure Compost	0	NS	22.369	0.448	NS	24.249	0.719	8.8524	4.1302	0.739	9.6035	5.6487
Dairy Manure Compost	0	0	14.33	-----	-----	-----	0.638	8.9204	3.1873	0.689	11.1929	5.1293
Dairy Manure Sock	0.523	0.703	5.025	0.593	0.828	5.893	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.59	0.699	4.904	0.682	0.911	7.278	-----	-----	-----	-----	-----	-----
Biosolids Compost	0.708	NS	4.982	0.833	0.593	3.657	0.589	2.4553	3.4325	----	----	----
Biosolids Compost	0.757	0.946	4.21	0.951	NS	4.013	0.693	6.3317	5.3637	0.482	5.0647	4.3129
Biosolids Compost	0.71	NS	4.294	-----	-----	-----	0.437	6.1827	5.5819	0.792	6.1077	4.9257
Biosolids Sock	0.498	0.845	2.382	0.501	0.478	2.94	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.522	0.829	2.943	0.589	0.593	2.736	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0.5883	0.4456	2.7445	0.737	0.616	2.13	0.482	0.5431	0.7828	----	----	----
Yard Waste Compost	0.5101	0.5395	1.6363	0.557	0.633	0.867	0.793	1.0762	0.6515	0.583	0.6412	0.4976
Yard Waste Compost	0.2494	0.3448	3.9253	-----	-----	-----	0.583	0.6438	0.4436	0.518	0.5355	0.5873
Yard Waste Sock	0.583	0.497	1.583	0.493	0.578	1.038	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.483	0.587	1.082	0.583	0.473	1.839	-----	-----	-----	-----	-----	-----
Wood Chips	0.483	0.439	1.849	0.438	0.574	1.398	-----	-----	-----	-----	-----	-----
Wood Chips	0.769	0.438	1.93	0.392	0.497	1.948	-----	-----	-----	-----	-----	-----
Wood Chips	0.693	0.59	2.019	0.598	0.589	1.091	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.645	0.651	1.483	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.583	0.602	1.497	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.596	0.615	1.483	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-14. Water Quality Test (Arsenic – As mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	ND	NS	ND	ND	ND	ND	ND	ND	ND	----	----	----
Dairy Manure Compost	ND	NS	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND
Dairy Manure Compost	ND	ND	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Dairy Manure Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Biosolids Compost	ND	NS	ND	ND	ND	ND	ND	ND	ND	----	----	----
Biosolids Compost	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND
Biosolids Compost	ND	NS	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Biosolids Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Biosolids Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Yard Waste Compost	ND	ND	ND	ND	ND	ND	ND	ND	ND	----	----	----
Yard Waste Compost	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Yard Waste Compost	ND	ND	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Yard Waste Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Yard Waste Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	ND	NS	ND	ND	ND	ND	ND	ND	ND	----	----	----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-15. Water Quality Test (Cadmium – Cd mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	9.0039	NS	8.8264	2.6134	2.2584	15.8087	0.5784	0.6016	0.3057	----	----	----
Dairy Manure Compost	1.9034	NS	6.9921	15.1578	NS	10.4241	0.8215	1.6075	0.4241	0.7293	0.7943	0.2934
Dairy Manure Compost	6.1637	2.3176	21.9034	-----	-----	-----	0.478	0.7791	0.3187	0.6292	0.9303	0.4322
Dairy Manure Sock	0.834	1.839	6.9382	0.9302	1.8393	4.2982	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.493	2.7392	8.2803	0.6328	2.6482	11.8309	-----	-----	-----	-----	-----	-----
Biosolids Compost	2.4359	NS	5.4536	0.833	0.593	3.657	0.7382	1.492		----	----	----
Biosolids Compost	6.4596	0.7199	18.5897	0.951	NS	4.013	0.5379	0.9203	0.5292	0.7293	0.8393	0.4182
Biosolids Compost	2.2584	NS	14.6252	-----	-----	-----	0.6839	0.6829	0.3638	0.6292	0.7592	0.3929
Biosolids Sock	0.9284	1.8392	5.7389	0.4839	2.1293	7.8403	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.8349	1.5938	6.4471	0.9437	1.9373	3.729	-----	-----	-----	-----	-----	-----
Yard Waste Compost	6.3974	2.9684	6.4004	3.3235	1.43	5.3353	0.582	0.8974	0.3057	----	----	----
Yard Waste Compost	0.5101	0.5395	1.6363	2.0809	0.7199	7.2288	0.7293	0.7791	0.3649	0.7293	0.6832	0.3892
Yard Waste Compost	1.7258	2.14	6.8738	-----	-----	-----	0.6292	0.8974	0.8383	0.6292	1.3784	0.4628
Yard Waste Sock	1.1729	1.839	5.9288	0.9874	1.9327	4.1738	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.7492	1.182	3.7288	0.8929	1.5739	2.3189	-----	-----	-----	-----	-----	-----
Wood Chips	0.9397	1.6379	2.9108	2.1093	3.2399	5.282	-----	-----	-----	-----	-----	-----
Wood Chips	0.8392	1.0282	4.2892	0.6389	2.7383	3.7292	-----	-----	-----	-----	-----	-----
Wood Chips	1.8293	2.9843	3.209	0.7739	2.1893	3.0839	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	1.037	2.144	3.264	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.961	1.875	2.918	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.947	1.381	2.811	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-16. Water Quality Test (Cobalt – Co mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	1.41667	NS	8.91667	0	0.58333	21.4167	2.7672	4.75	2.25	----	----	----
Dairy Manure Compost	2.25	NS	7.25	1.41667	NS	14.75	2.1536	2.25	1.41667	3.3829	2.8393	1.6437
Dairy Manure Compost	2.25	2.25	18.0833	-----	-----	-----	2.9367	3.08333	1.5983	1.0283	2.3893	2.3672
Dairy Manure Sock	3.0283	2.6373	5.7932	2.1823	2.7383	4.9208	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	1.2638	2.2819	6.1826	1.9302	3.1739	5.2839	-----	-----	-----	-----	-----	-----
Biosolids Compost	2.25	NS	8.08333	1.41667	4.75	7.25	3.1824	3.4782	1.9379	----	----	----
Biosolids Compost	1.41667	1.41667	16.4167	1.41667	NS	7.25	1.5983	3.1892	2.3902	2.9901	3.1927	2.4361
Biosolids Compost	4.75	NS	13.0833	-----	-----	-----	1.2839	2.6373	2.693	2.1982	2.6739	2.1251
Biosolids Sock	2.1839	2.7183	4.8292	1.8392	2.1893	3.7482	-----	-----	-----	-----	-----	-----
Biosolids Sock	2.9302	1.7382	5.1839	1.2839	3.1367	3.9278	-----	-----	-----	-----	-----	-----
Yard Waste Compost	3.975	8.91667	8.08333	2.25	3.08333	39.75	1.1728	0.58333	0.1092	----	----	----
Yard Waste Compost	2.25	1.41667	3.08333	3.08333	2.25	21.4167	0.9176	1.41667	0.0352	1.6473	2.1839	0.5027
Yard Waste Compost	2.25	0.58333	12.25	-----	-----	-----	1.5361	2.25	0.0726	1.9283	2.7383	0.0782
Yard Waste Sock	3.192	3.1983	3.2973	1.6282	2.6893	2.9373	-----	-----	-----	-----	-----	-----
Yard Waste Sock	1.8292	2.8291	3.9373	1.2738	3.1829	3.2748	-----	-----	-----	-----	-----	-----
Wood Chips	1.5373	2.9374	4.7829	1.9373	3.2893	3.8464	-----	-----	-----	-----	-----	-----
Wood Chips	2.4792	2.5281	4.9203	2.7384	2.9427	4.2993	-----	-----	-----	-----	-----	-----
Wood Chips	2.7364	3.9273	5.2783	2.0183	3.392	4.0446	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.676	3.028	3.256	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.312	2.594	2.899	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.02	2.304	2.705	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-17. Water Quality Test (Chromium – Cr mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	2.9349	NS	17.6931	2.2524	5.9121	18.4957	1.6493	5.2382	2.7811	----	----	----
Dairy Manure Compost	2.6286	NS	9.9652	1.5931	NS	12.2182	1.9374	12.8503	2.104	1.9203	9.0948	5.7282
Dairy Manure Compost	3.0123	5.1943	21.7064	-----	-----	-----	2.3443	10.8637	2.362	2.3849	13.4829	4.9733
Dairy Manure Sock	3.0289	5.7282	11.7384	2.5268	5.9202	11.3932	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	2.6373	5.1782	14.3738	2.7383	5.5829	16.8393	-----	-----	-----	-----	-----	-----
Biosolids Compost	10.1518	NS	21.7064	2.1706	12.3722	21.9036	2.8374	22.7483	9.7292	----	----	----
Biosolids Compost	10.797	5.0631	21.7064	1.8469	NS	21.7064	1.9373	24.8394	9.7349	1.9398	14.9382	6.8393
Biosolids Compost	11.0661	NS	21.7064	-----	-----	-----	2.8484	21.8393	7.849	2.6373	18.0303	5.0394
Biosolids Sock	3.2893	6.3392	17.9374	2.3728	5.3748	15.3839	-----	-----	-----	-----	-----	-----
Biosolids Sock	2.939	5.5392	19.0833	1.2784	5.1389	16.2383	-----	-----	-----	-----	-----	-----
Yard Waste Compost	1.6835	5.2382	21.7064	3.168	12.4502	21.7064	2.9183	16.1746	4.761	----	----	----
Yard Waste Compost	2.2524	4.8468	10.3415	2.8195	12.7688	21.7064	1.9373	21.7064	4.3804	2.7393	13.7484	6.0834
Yard Waste Compost	1.4494	4.297	21.7064	-----	-----	-----	1.7383	21.7064	4.3386	1.9308	16.7334	2.4043
Yard Waste Sock	2.1783	5.9303	15.8392	2.8391	4.9384	15.9374	-----	-----	-----	-----	-----	-----
Yard Waste Sock	2.1893	5.5383	15.4829	2.1829	5.3728	13.7382	-----	-----	-----	-----	-----	-----
Wood Chips	2.3874	5.3893	16.3843	2.0819	5.9744	13.8743	-----	-----	-----	-----	-----	-----
Wood Chips	2.9474	5.9374	17.0384	2.5474	5.9733	15.3494	-----	-----	-----	-----	-----	-----
Wood Chips	1.9373	5.2844	15.9748	2.0283	5.3938	16.2939	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.912	7.809	15.793	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.993	10.641	21.142	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	2.706	6.734	14.335	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-18. Water Quality Test (Copper – Cu mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	62.403	NS	125.056	40.3281	38.5846	166.338	35.832	100.563	59.2253	----	----	----
Dairy Manure Compost	48.3425	NS	125.281	35.4069	NS	193.531	43.8422	108.746	45.3055	37.2938	79.2938	41.7382
Dairy Manure Compost	32.5699	69.4613	192.519	-----	-----	-----	46.3739	108.637	47.2439	39.2941	85.3821	45.392
Dairy Manure Sock	43.9647	65.8329	123.948	33.8392	41.7438	134.748	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	45.2864	61.6397	115.643	37.4004	43.3539	137.392	-----	-----	-----	-----	-----	-----
Biosolids Compost	36.2224	NS	141.929	23.4475	26.5207	160.292	25.7329	103.049	45.382	----	----	----
Biosolids Compost	40.5249	39.8219	194.459	31.8637	NS	197.412	28.9203	99.4028	49.3729	31.9482	81.8392	43.9402
Biosolids Compost	31.282	NS	169.966	-----	-----	-----	30.2193	95.294	42.484	35.8532	85.3829	38.4924
Biosolids Sock	40.3974	43.7844	142.469	29.7364	40.3958	130.748	-----	-----	-----	-----	-----	-----
Biosolids Sock	41.7429	45.1825	145.839	26.8445	34.7294	138.495	-----	-----	-----	-----	-----	-----
Yard Waste Compost	43.0819	38.4159	59.3378	36.0537	24.3835	33.3822	24.8392	30.4576	16.3972	----	----	----
Yard Waste Compost	65.0745	31.8637	66.818	25.0584	33.0448	32.2293	35.8392	59.1129	43.0558	28.4722	56.4931	37.4829
Yard Waste Compost	41.7622	33.4384	76.0135	-----	-----	-----	31.9405	88.2461	35.8568	36.4829	49.3829	34.834
Yard Waste Sock	35.9302	43.7391	50.7382	34.7202	58.7782	45.3839	-----	-----	-----	-----	-----	-----
Yard Waste Sock	43.3922	37.8324	55.3839	28.4729	42.8492	49.4629	-----	-----	-----	-----	-----	-----
Wood Chips	35.8429	40.2839	45.8293	34.7291	36.8329	51.7739	-----	-----	-----	-----	-----	-----
Wood Chips	42.3822	39.9201	47.9385	31.8321	31.0394	50.283	-----	-----	-----	-----	-----	-----
Wood Chips	49.2973	35.7328	51.3803	41.3728	43.9923	49.293	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	30.29	26.845	32.942	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	31.477	37.376	43.246	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	35.908	45.138	50.912	-----	-----	-----	-----	-----	-----

--- ***Field test not conducted***
NS ***No sample collected***
ND ***Not detected by machine***

Table A-19. Water Quality Test (Iron – Fe mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	0.1530	NS	1.0156	0.0164	0.2356	0.9144	0.3722	1.3465	1.0028	----	----	----
Dairy Manure Compost	0.0204	NS	1.3812	0.0076	NS	0.8315	0.4812	1.6948	1.1038	0.4184	1.6871	1.6800
Dairy Manure Compost	0.0000	0.2350	3.8946	-----	-----	-----	0.5712	2.0054	1.6457	0.3157	2.6411	2.0548
Dairy Manure Sock	0.0150	0.3780	1.8540	0.0064	0.3486	1.1054	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	0.0210	0.2910	1.7560	0.0023	0.3157	1.2005	-----	-----	-----	-----	-----	-----
Biosolids Compost	0.0045	NS	1.5462	0.0058	0.4612	1.0045	0.5489	1.5644	1.2341	----	----	----
Biosolids Compost	0.0103	0.3165	1.8372	0.0043	NS	1.5461	0.4288	1.8943	1.5487	0.4185	1.4573	1.2045
Biosolids Compost	0.0085	NS	1.2563	-----	-----	-----	0.3119	1.6457	1.3355	0.3918	1.6451	1.7811
Biosolids Sock	0.0115	0.3456	1.5419	0.0085	0.3157	1.2154	-----	-----	-----	-----	-----	-----
Biosolids Sock	0.0125	0.2648	1.2943	0.0094	0.3512	1.1673	-----	-----	-----	-----	-----	-----
Yard Waste Compost	0.0000	0.1527	5.9943	0.0063	0.2346	1.0981	0.4728	2.5679	2.0064	----	----	----
Yard Waste Compost	0.0000	0.7191	2.7194	0.0012	0.4517	1.1224	0.3917	3.0015	2.5147	0.3112	2.0641	1.4644
Yard Waste Compost	0.0000	0.2458	5.0695	-----	-----	-----	0.4134	2.6490	2.3174	0.4554	3.1179	2.1875
Yard Waste Sock	0.0000	0.5681	4.6189	0.0015	0.4679	0.9785	-----	-----	-----	-----	-----	-----
Yard Waste Sock	0.0025	0.6423	5.1287	0.0086	0.4157	0.9756	-----	-----	-----	-----	-----	-----
Wood Chips	0.0098	0.3871	3.1648	0.0045	0.2991	0.9611	-----	-----	-----	-----	-----	-----
Wood Chips	0.0153	0.5971	4.0077	0.0067	0.4582	0.9468	-----	-----	-----	-----	-----	-----
Wood Chips	0.0124	0.6487	4.6581	0.0024	0.3519	0.9183	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.0071	0.3025	2.0110	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.0013	0.2375	1.9114	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	0.0052	0.2725	1.9956	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-20. Water Quality Test (Lead – Pb mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	ND	NS	ND	ND	ND	ND	ND	ND	ND	----	----	----
Dairy Manure Compost	ND	NS	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND
Dairy Manure Compost	ND	ND	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Dairy Manure Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Biosolids Compost	ND	NS	ND	ND	ND	ND	ND	ND	ND	----	----	----
Biosolids Compost	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND
Biosolids Compost	ND	NS	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Biosolids Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Biosolids Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Yard Waste Compost	ND	ND	ND	ND	ND	ND	ND	ND	ND	----	----	----
Yard Waste Compost	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Yard Waste Compost	ND	ND	ND	-----	-----	-----	ND	ND	ND	ND	ND	ND
Yard Waste Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Yard Waste Sock	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips	ND	ND	ND	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	ND	ND	ND	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	ND	ND	ND	-----	-----	-----	-----	-----	-----

---   Field test not conducted
NS   No sample collected
ND   Not detected by machine

Table A-21. Water Quality Test (BOD_5 mg/l).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	28.2	NS	>106.8	14.4	25.0	24.6	15.0	> 104.6	42.8	----	----	----
Dairy Manure Compost	26.4	NS	>106.8	13.2	NS	18.3	0.6	> 104.6	35.8	17.8	> 104.6	39.2
Dairy Manure Compost	26.4	19.0	>100.8	-----	-----	-----	19.0	> 104.6	31.6	35.0	> 104.6	35.7
Dairy Manure Sock	5.8	11.6	56.4	14.5	15.4	41.5	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	19.6	20.4	37.2	8.4	18.4	59.8	-----	-----	-----	-----	-----	-----
Biosolids Compost	1.2	NS	35.7	14.4	15.6	22.8	25.0	> 104.6	28.2	----	----	----
Biosolids Compost	0.0	0.9	>105.6	14.4	NS	25.2	16.6	> 104.6	35.4	31.0	> 104.6	25.7
Biosolids Compost	0.0	NS	>100.8	-----	-----	-----	28.7	> 104.6	30.6	15.4	> 104.6	19.8
Biosolids Sock	13.7	19.4	63.2	19.4	21.8	61.6	-----	-----	-----	-----	-----	-----
Biosolids Sock	9.6	15.6	23.7	6.2	16.8	49.8	-----	-----	-----	-----	-----	-----
Yard Waste Compost	16.8	9.8	37.1	14.4	9.6	30.8	13.2	> 104.6	14.4	----	----	----
Yard Waste Compost	9.8	12.3	12.0	10.6	14.4	18	17.9	> 104.6	15.8	27.0	> 104.6	9.6
Yard Waste Compost	15	12.3	32.8	-----	-----	-----	29.0	> 104.6	20.4	15.7	> 104.6	29.4
Yard Waste Sock	11.6	12.4	21.7	0.5	8.4	12.2	-----	-----	-----	-----	-----	-----
Yard Waste Sock	8.4	13.6	24.8	17.4	21.7	29.6	-----	-----	-----	-----	-----	-----
Wood Chips	16.8	21.6	24.8	12.8	10.4	12.8	-----	-----	-----	-----	-----	-----
Wood Chips	19.4	24.8	25.0	17.0	19.2	21	-----	-----	-----	-----	-----	-----
Wood Chips	14.6	18.0	20.6	13.6	7.6	15.4	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	12.5	18.9	21.5	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	11.59	18.2	21.1	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	12.67	19.3	22.3	-----	-----	-----	-----	-----	-----

--- Field test not conducted
NS No sample collected
ND Not detected by machine

Table A-22. Water Quality Test (Total Coliform – T-Coli MPN).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	<1	NS	<1	<1	25	3022	60.4	504.3	67.3	----	----	----
Dairy Manure Compost	<1	NS	<1	<1	NS	3022	100.6	683.2	55.3	80.1	500.1	61.4
Dairy Manure Compost	<1	50.6	<1	-----	-----	-----	75.4	592.6	72.5	50.6	802.1	59.2
Dairy Manure Sock	<1	40.4	45.6	<1	200.3	29.5	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	<1	15.6	61.2	<1	20.5	100.4	-----	-----	-----	-----	-----	-----
Biosolids Compost	383.6	NS	4044.4	<1	15.6	3481.6	32.8	1030	102.5	----	----	----
Biosolids Compost	4	2004.8	4044.4	<1	NS	4044.4	65.3	1503.2	80.6	32.8	1143.6	71.7
Biosolids Compost	383.6	NS	4044.4	-----	-----	-----	41.8	1309.4	90.5	50.4	1520.3	75.2
Biosolids Sock	<1	31.6	102.4	<1	10.6	20.4	-----	-----	-----	-----	-----	-----
Biosolids Sock	<1	100.5	1045.6	<1	25.8	38.4	-----	-----	-----	-----	-----	-----
Yard Waste Compost	< 1	< 1	3481.6	< 1	319.2	4044.4	42.8	103.5	15.9	----	----	----
Yard Waste Compost	4	< 1	172.8	108.8	79.6	1376.4	30.5	159.4	10.4	23.7	83.6	30.2
Yard Waste Compost	< 1	29.6	4044.4	-----	-----	-----	35.6	104.6	15.6	31.8	203.4	5.7
Yard Waste Sock	<1	<1	30.6	<1	<1	15.4	-----	-----	-----	-----	-----	-----
Yard Waste Sock	<1	<1	45.2	<1	<1	31.6	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	5	<1	<1	3	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	12.5	<1	<1	21.6	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	20.7	<1	<1	30.4	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	20.8	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	15.4	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	< 1	-----	-----	-----	-----	-----	-----

--- ***Field test not conducted***
NS ***No sample collected***
ND ***Not detected by machine***

Table A-23. Water Quality Test (Fecal Coliform – F-Coli MPN).

	Unseeded						Seeded					
	Clay			Sand			3%			7%		
	RES	Behind Berm	Sample	RES	Behind Berm	Sample	Behind Berm	After Infilt	After Stop	Behind Berm	After Infilt	After Stop
Dairy Manure Compost	<1	NS	<1	<1	<1	<1	<1	4	<1	----	----	----
Dairy Manure Compost	<1	NS	<1	<1	NS	<1	<1	12	<1	<1	15.2	<1
Dairy Manure Compost	<1	<1	<1	-----	-----	-----	<1	20	<1	<1	10.4	<1
Dairy Manure Sock	<1	<1	6	<1	<1	12	-----	-----	-----	-----	-----	-----
Dairy Manure Sock	<1	<1	2	<1	<1	35	-----	-----	-----	-----	-----	-----
Biosolids Compost	<1	NS	131.2	<1	<1	45.6	<1	5	<1	----	----	----
Biosolids Compost	<1	<1	4044.4	<1	NS	8	<1	14	<1	<1	3	<1
Biosolids Compost	<1	NS	4044.4	-----	-----	-----	<1	1	<1	<1	12.7	<1
Biosolids Sock	<1	<1	100.4	<1	<1	16	-----	-----	-----	-----	-----	-----
Biosolids Sock	<1	<1	250.3	<1	<1	3	-----	-----	-----	-----	-----	-----
Yard Waste Compost	<1	<1	4	<1	<1	168.4	<1	4	<1	----	----	----
Yard Waste Compost	4	<1	8	<1	<1	38	<1	7	<1	<1	1	<1
Yard Waste Compost	<1	<1	32.4	-----	-----	-----	<1	8	<1	<1	5	<1
Yard Waste Sock	<1	<1	<1	<1	<1	<1	-----	-----	-----	-----	-----	-----
Yard Waste Sock	<1	<1	<1	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	<1	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	<1	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips	<1	<1	<1	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	<1	-----	-----	-----	-----	-----	-----
Wood Chips Sock	-----	-----	-----	<1	<1	<1	-----	-----	-----	-----	-----	-----

---　Field test not conducted
NS　No sample collected
ND　Not detected by machine

APPENDIX B:
ITEM AND SPECIFICATION

ITEM 161
COMPOST

161.1. Description. Furnish and place compost as shown on the plans.

161.2. Materials. Furnish compost that has been produced by aerobic (biological) decomposition of organic matter and meets the requirements of Table 1. Compost feedstock may include, but is not limited to, leaves and yard trimmings, biosolids, food scraps, food-processing residuals, manure or other agricultural residuals, forest residues, bark, and paper. Ensure compost and wood chips do not contain any visible refuse, other physical contaminants, or any substance considered harmful to plant growth. Do not use materials that have been treated with chemical preservatives as a compost feedstock or as wood chips. Do not use mixed municipal solid waste compost. Provide compost meeting all applicable 40 CFR 503 standards for Class A biosolids and TCEQ health and safety regulations as defined in the TAC, Chapter 332, including the time and temperature standards in Subchapter B, Part 23. Meet the requirements of the United States Composting Council (USCC) Seal of Testing Assurance (STA) program. Before delivery of the compost, provide quality control (QC) documentation that includes the following:

- the feedstock by percentage in the final compost product,
- a statement that the compost meets federal and state health and safety regulations,
- a statement that the composting process has met time and temperature requirements,
- a copy of the producer's STA certification, and
- a copy of the lab analysis, performed by an STA-certified lab, verifying that the compost meets the requirements of Table 1.

When furnishing biosolids compost, also provide a copy of the current TCEQ compliance statement signed by the facility manager.

Provide a designated project stockpile of unblended compost for sampling and testing at the producer's site. The Department will take samples from each stockpile for quality assurance (QA). Make payment to the STA-certified lab chosen by the Department for the required QA testing. Submit lab invoices for passing QA tests to the Department for reimbursement.

Table 1
Physical Requirements for Compost

Property	Test Method	Requirement
Particle Size	TMECC[1] 02.02-B, "Sample Sieving for Aggregate Size Classification"	95% passing 5/8 in. 70% passing 3/8 in.
Heavy Metals Content	TMECC 04.06, "Heavy Metals and Hazardous Elements": 04.06-As, Arsenic 04.06-Cd, Cadmium 04.06-Cu, Copper 04.06-Pb, Lead 04.06-Hg, Mercury 04.06-Mo, Molybdenum 04.06-Ni, Nickel 04.06-Se, Selenium 04.06-Zn, Zinc	Pass
Soluble Salts	TMECC 04.10-A, "1:5 Slurry Method, Mass Basis"	5.0 dS/m maximum[2]
pH	TMECC 04.11-A, "1:5 Slurry pH"	5.5–8.5
Maturity	TMECC 05.05-A, "Germination and Root Elongation"	> 80%
Organic Matter Content	TMECC 05.07-A, "Loss-on-Ignition Organic Matter Method"	25–65% (dry mass)
Stability	TMECC 05.08-B, "Carbon Dioxide Evolution Rate"	8 or below
Fecal Coliform	TMECC 07.01-B, "Fecal Coliforms"	Pass

1. "Test Methods for the Examination of Composting and Compost," published by the United States Department of Agriculture and the USCC.
2. A soluble salt content up to 10.0 dS/m for compost used in compost manufactured topsoil will be acceptable.

Maintain compost in designated stockpiles at the producer's site until accepted by the Engineer. The Engineer reserves the right to sample compost at the jobsite.

A. Compost Manufactured Topsoil (CMT). CMT will consist of 75% topsoil blended with 25% compost measured by volume. Use CMT that is either blended on-site (BOS), blended in-place (BIP), or pre-blended (PB), as specified on the plans. Use topsoil conforming to Article 160.2, "Materials."

B. Erosion Control Compost (ECC). ECC will consist of 50% untreated wood chips blended with 50% compost measured by volume. Use wood chips less than or equal to 5 in. in length with 95% passing a 2-in. screen and less than 30% passing a 1-in. screen.

C. General Use Compost (GUC). GUC will consist of 100% compost.

161.3. Construction. Prepare the types of compost for use on the project and stockpile at the jobsite.

A. Compost Manufactured Topsoil (CMT). After excavation and embankment work is complete, remove and dispose of objectionable material from the topsoil before blending. Roll the CMT with a light corrugated drum.

1. Blended On-Site (BOS). Furnish topsoil. Topsoil may be salvaged from excavation and embankment areas, in accordance with Item 160, "Topsoil." Apply CMT to the depth shown on plans or apply compost in a uniform layer and incorporate into the in place topsoil to the depth shown on plans.

2. Blended In-Place (BIP). Apply compost in a uniform layer and incorporate into the existing in place topsoil to the depth shown on the plans.

3. Pre-blended (PB). Apply CMT in a uniform layer to the depth shown on the plans.

B. Erosion Control Compost (ECC). Use only on slopes 3:1 or flatter. After excavation and embankment work is complete, apply a 2-in. uniform layer, unless otherwise shown on the plans or as directed. When rolling is specified, use a light roller or other suitable equipment.

C. General Use Compost (GUC). Apply in a uniform layer as a top dressing on established vegetation to the depth shown on the plans. Do not bury existing vegetation. If using GUC as a backfill ingredient, in a planting soil mixture, for planting bed preparation, or as mulch, apply as shown on the plans.

161.4. Measurement. This Item will be measured by the 100-ft. station along the baseline of each roadbed, by the square yard complete in place, or by the cubic yard in vehicles at the point of delivery. For CMT (BOS and PB only) and ECC cubic yard measurement, the quantity will be the composite material, compost and topsoil or wood chips.

161.5. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Compost Manufactured Topsoil (BOS)," "Compost Manufactured Topsoil (BIP)," "Compost Manufactured Topsoil (PB)," "Compost Manufactured Topsoil (BOS or PB)," "Erosion Control Compost," and "General Use Compost" for the depth specified, except for measurement by the cubic yard. This price is full compensation for loading, hauling, stockpiling, blending, placing, rolling, sprinkling, equipment, labor, materials (including topsoil for CMT (BOS and PB only) and wood chips for ECC), tools, and incidentals. Costs associated with passing QA testing will be paid for in accordance with the requirements of Article 9.5, "Force Account," at invoice price with no add-ons.

SPECIAL SPECIFICATION
1011
Compost/Mulch Filter Berm

1. Description. Furnish, place and remove compost filter berms or mulch filter berms as shown on the plans.

2. Materials. Furnish compost in accordance with Item 161, “Compost.” Furnish untreated wood chips less than or equal to 5 in. in length with 95% passing a 2-in. screen and less than 30% passing a 1-in. screen.

A. Compost Filter Berm (CFB). Furnish CFB consisting of 50% wood chips blended with 50% compost measured by volume.

B. Mulch Filter Berm (MFB). Furnish MFB consisting of 100% wood chips.

3. Construction. Prepare the compost, wood chips, or both for use on the project and stockpile at the jobsite. Unless otherwise directed, construct a 1-1/2 ft. high by 3 ft. wide berm at locations shown on the plans.

4. Maintenance. Routinely inspect and maintain filter berm in a functional condition at all times. Correct deficiencies immediately. Install additional filter berm material as directed. Remove sediment after it has reached 1/3 of the height of the berm. Disperse filter berm or leave in place as directed.

5. Measurement. This Item will be measured by the cubic yard.

6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Compost Filter Berm” or “Mulch Filter Berm.” This price is full compensation for loading, hauling, stockpiling, blending, placing, maintaining, removing, equipment, labor, materials, tools and incidentals. Costs associated with passing Quality Assurance (QA) testing for compost will be paid for by force account at invoice price. Removal of accumulated sediment deposits will be measured and paid for under Item 506, “Temporary Erosion, Sedimentation and Environmental Controls.”

SPECIAL SPECIFICATION
5049
Biodegradable Erosion Control Logs

1. Description. Furnish, install, maintain, and remove biodegradable erosion control logs as shown on the plans or as directed.

2. Materials.

A. Core Material. Furnish core material that is biodegradable or recyclable. Except where specifically called out in plans, material may be compost, mulch, aspen excelsior wood fibers, chipped site vegetation, agricultural rice or wheat straw, coconut fiber, 100% recyclable fibers, or any other acceptable material. No more than 5% of the material is permitted to escape from the containment mesh. Furnish compost, meeting the requirements of Item 161, "Compost."

B. Containment Mesh. Furnish containment mesh that is 100% biodegradable, photodegradable or recyclable such as burlap, twine, UV photodegradable plastic, polyester, or any other acceptable material.

i. Furnish biodegradable or photodegradable containment mesh when log will remain in place as part of a vegetative system.

ii. Furnish recyclable containment mesh for temporary installations.

C. Size. Furnish biodegradable erosion control logs with diameters shown on the plans or as directed. Stuff containment mesh densely so logs do not deform.

3. Construction. Install biodegradable erosion control logs near the downstream perimeter of a disturbed area to intercept sediment from sheet flow. Incorporate the biodegradable erosion control logs into the erosion control measures used to control sediment in areas of higher flow. Install, align, and locate the biodegradable erosion control logs as specified below, as shown on the plans, or as directed.

A. Anchoring. Secure biodegradable erosion control logs in a method adequate to prevent displacement as a result of normal rain events and to the satisfaction of the Engineer and such that flow is not allowed under the logs.

B. Maintenance. Inspect and maintain the biodegradable erosion control logs in good condition (including staking, anchoring, etc.). Maintain the integrity of the control, including keeping the biodegradable erosion control logs free of accumulated silt, debris, etc., until permanent erosion control features are in place, or the disturbed area has been adequately stabilized. Perform in accordance with Section 506.4.C, "Installation, Maintenance and Removal Work.” Stabilize the areas damaged by the removal process using appropriate methods as approved.

Repair or replace damaged biodegradable erosion control logs as required and as directed. Temporarily remove and replace biodegradable erosion control logs as required to facilitate work. Remove sediment and debris when accumulation affects the performance of the devices, after a rain, and when directed. Dispose of sediment and debris at an approved site in a manner that will not contribute to additional siltation.

C. Removal. Remove biodegradable erosion control logs when directed.

4. Measurement. This Item will be measured by the linear foot along the centerline of the top of the control logs.

5. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Biodegradable Erosion Control Logs,” of the size specified. This price is full compensation for furnishing, placing, maintaining, temporarily removing and replacing as required to facilitate construction operations, and removing of the biodegradable erosion control logs and for all other materials, labor, tools, equipment, and incidentals.

Removing accumulated sediment deposits, as described under “Maintenance,” will be measured and paid for under Item 506, “Temporary Erosion, Sedimentation, and Environmental Controls.”

Stabilization (as described under “Maintenance”) will be measured and paid for under the various pertinent bid items.

ITEM 506
TEMPORARY EROSION, SEDIMENTATION, AND ENVIRONMENTAL CONTROLS

506.1. Description. Install, maintain, and remove erosion, sedimentation, and environmental control devices. Remove accumulated sediment and debris.

506.2. Materials.

A. Rock Filter Dams.

1. Aggregate. Furnish aggregate with hardness, durability, cleanliness, and resistance to crumbling, flaking, and eroding acceptable to the Engineer. Provide the following:

- **Types 1, 2, and 4 Rock Filter Dams.** Use 3 to 6 in. aggregate.
- **Type 3 Rock Filter Dams.** Use 4 to 8 in. aggregate.

2. Wire. Provide minimum 20 gauge galvanized wire for the steel wire mesh and tie wires for Types 2 and 3 rock filter dams. Type 4 dams require:

- a double-twisted, hexagonal weave with a nominal mesh opening of 2-1/2 in. x 3-1/4 in.;
- minimum 0.0866 in. steel wire for netting;
- minimum 0.1063 in. steel wire for selvages and corners; and
- minimum 0.0866 in. for binding or tie wire.

3. Sandbag Material. Furnish sandbags meeting Section 506.2.I, "Sandbags," except that any gradation of aggregate may be used to fill the sandbags.

B. Temporary Pipe Slope Drains. Provide corrugated metal pipe, polyvinyl chloride (PVC) pipe, flexible tubing, watertight connection bands, grommet materials, prefabricated fittings, and flared entrance sections that conform to the plans. Recycled and other materials meeting these requirements are allowed if approved. Furnish concrete in accordance with Item 432, "Riprap."

C. Baled Hay. Provide hay bales weighing at least 50 lb., composed entirely of vegetable matter, measuring 30 in. or longer, and bound with wire, nylon, or polypropylene string.

D. Temporary Paved Flumes. Furnish asphalt concrete, hydraulic cement concrete, or other comparable non-erodible material that conforms to the plans. Provide rock or rubble with a minimum diameter of 6 in. and a maximum volume of 1/2 cu. ft. for the construction of energy dissipaters.

E. Construction Exits. Provide materials that meet the details shown on the plans and this Section.

1. Rock Construction Exit. Provide crushed aggregate for long- and short-term construction exits. Furnish aggregates that are clean, hard, durable, and free from adherent coatings such as salt, alkali, dirt, clay, loam, shale, soft, or flaky materials and organic and injurious matter. Use 4- to 8-in. aggregate for Type 1 and 2- to 4-in. aggregate for Type 3.

2. Timber Construction Exit. Furnish No. 2 quality or better railroad ties and timbers for long-term construction exits, free of large and loose knots and treated to control rot. Fasten timbers with nuts and bolts or lag bolts, of at least 1/2 in. diameter, unless otherwise shown on the plans or allowed. For short-term exits, provide plywood or pressed wafer board at least 1/2 in. thick.

3. Foundation Course. Provide a foundation course consisting of flexible base, bituminous concrete, hydraulic cement concrete, or other materials as shown on the plans or directed.

F. Embankment for Erosion Control. Provide rock, loam, clay, topsoil, or other earth materials that will form a stable embankment to meet the intended use.

G. Pipe. Provide pipe outlet material in accordance with Item 556, "Pipe Underdrains," and details shown on the plans.

H. Construction Perimeter Fence.

1. Posts. Provide essentially straight wood or steel posts that are at least 60 in. long. Furnish soft wood posts with a minimum diameter of 3 in. or use 2 x 4 boards. Furnish hardwood posts with a minimum cross-section of 1-1/2 x 1-1/5 in. Furnish T- or L-shaped steel posts with a minimum weight of 1.3 lb. per foot.
2. Fence. Provide orange construction fencing as approved by the Engineer.
3. Fence Wire. Provide 12-1/2 gauge or larger galvanized smooth or twisted wire. Provide 16 gauge or larger tie wire.
4. Flagging. Provide brightly colored flagging that is fade-resistant and at least 3/4 in. wide to provide maximum visibility both day and night.
5. Staples. Provide staples with a crown at least 1/2 in. wide and legs at least 1/2 in. long.
6. Used Materials. Previously used materials meeting the applicable requirements may be used if accepted by the Engineer.
I. Sandbags. Provide sandbag material of polypropylene, polyethylene, or polyamide woven fabric with a minimum unit weight of 4 oz. per square yard, a Mullen burst-strength exceeding 300 psi, and an ultra-violet stability exceeding 70%. Use natural coarse sand or manufactured sand meeting the gradation given in Table 1 to fill sandbags. Filled sandbags must be 24 to 30 in. long, 16 to 18 in. wide, and 6 to 8 in. thick.

Table 1
Sand Gradation

Sieve #	Maximum Retained (% by Weight)
4	3%
100	80%
200	95%

J. Temporary Sediment Control Fence. Provide a net-reinforced fence using woven geo-textile fabric. Logos visible to the traveling public will not be allowed.
1. Fabric. Provide fabric materials in accordance with DMS-6230, "Temporary Sediment Control Fence Fabric."
2. Posts. Provide essentially straight wood or steel posts with a minimum length of 48 in., unless otherwise shown on the plans. Soft wood posts must be at least 3 in. in diameter or nominal 2 x 4 in. Hardwood posts must have a minimum cross-section of 1-1/2 x 1-1/2 in. T- or L-shaped steel posts must have a minimum weight of 1.3 lb. per foot.
3. Net Reinforcement. Provide net reinforcement of at least 12-1/2 gauge galvanized welded wire mesh, with a maximum opening size of 2 x 4 in., at least 24 in. wide, unless otherwise shown on the plans.
4. Staples. Provide staples with a crown at least 3/4 in. wide and legs 1/2 in. long.
5. Used Materials. Use recycled material meeting the applicable requirements if accepted by the Engineer.
506.3. Equipment. Provide a backhoe, front end loader, blade, scraper, bulldozer, or other equipment as required when "Earthwork for Erosion Control" is specified on the plans as a bid item.
506.4. Construction.
A. Contractor Responsibilities. Implement the Department's Storm Water Pollution Prevention Plan (SWP3) for the project site in accordance with the specific or general storm water permit requirements. Develop and implement an SWP3 for project-specific material supply plants within and outside of the Department's right of way in accordance with the specific or general

storm water permit requirements. Prevent water pollution from storm water associated with construction activity from entering any surface water or private property on or adjacent to the project site.

B. General.

1. Phasing. Implement control measures in the area to be disturbed before beginning construction, or as directed. Limit the disturbance to the area shown on the plans or as directed. If, in the opinion of the Engineer, the Contractor cannot control soil erosion and sedimentation resulting from construction operations, the Engineer will limit the disturbed area to that which the Contractor is able to control. Minimize disturbance to vegetation.

2. Maintenance. Immediately correct ineffective control measures. Implement additional controls as directed. Remove excavated material within the time requirements specified in the applicable storm water permit.

3. Stabilization. Stabilize disturbed areas where construction activities will be temporarily stopped in accordance with the applicable storm water permit. Establish a uniform vegetative cover. The project will not be accepted until a 70% density of existing adjacent undisturbed areas is obtained, unless otherwise shown on the plans. When shown on the plans, the Engineer may accept the project when adequate controls are in place that will control erosion, sedimentation, and water pollution until sufficient vegetative cover can be established.

4. Finished Work. Upon acceptance of vegetative cover, remove and dispose of all temporary control measures, temporary embankments, bridges, matting, falsework, piling, debris, or other obstructions placed during construction that are not a part of the finished work, or as directed.

5. Restricted Activities. Do not locate disposal areas, stockpiles, or haul roads in any wetland, water body, or streambed. Do not install temporary construction crossings in or across any water body without the prior approval of the appropriate resource agency and the Engineer. Restrict construction operations in any water body to the necessary areas as shown on the plans or applicable permit, or as directed. Use temporary bridges, timber mats, or other structurally sound and non-eroding material for stream crossings. Provide protected storage area for paints, chemicals, solvents, and fertilizers at an approved location. Keep paints, chemicals, solvents, and fertilizers off bare ground and provide shelter for stored chemicals.

C. Installation, Maintenance, and Removal Work. Perform work in accordance with the specific or general storm water permit. Install and maintain the integrity of temporary erosion and sedimentation control devices to accumulate silt and debris until earthwork construction and permanent erosion control features are in place or the disturbed area has been adequately stabilized as determined by the Engineer. If a device ceases to function as intended, repair or replace the device or portions thereof as necessary. Remove sediment, debris, and litter. When approved, sediments may be disposed of within embankments, or in the right of way in areas where the material will not contribute to further siltation. Dispose of removed material in accordance with federal, state, and local regulations. Remove devices upon approval or when directed. Upon removal, finish-grade and dress the area. Stabilize disturbed areas in accordance with the permit, and as shown on the plans or as directed. The Contractor retains ownership of stockpiled material and must remove it from the project when new installations or replacements are no longer required.

1. Rock Filter Dams for Erosion Control. Remove trees, brush, stumps, and other objectionable material that may interfere with the construction of rock filter dams. Place sandbags as a foundation when required or at the Contractor's option. For Types 1, 2, 3, and 5, place the aggregate to the lines, height, and slopes specified, without undue voids. For Types 2 and 3, place the aggregate on the mesh and then fold the mesh at the upstream side over the aggregate and secure it to itself on the downstream side with wire ties, or hog rings, or as directed. Place rock filter dams perpendicular to the flow of the stream or channel unless otherwise directed. Construct filter dams according to the following criteria, unless otherwise shown on the plans:

a. Type 1 (Non-reinforced).

(1) Height. At least 18 in. measured vertically from existing ground to top of filter dam.

(2) Top Width. At least 2 ft.

(3) Slopes. At most 2:1.

b. Type 2 (Reinforced).

(1) Height. At least 18 in. measured vertically from existing ground to top of filter dam.

(2) Top Width. At least 2 ft.

(3) Slopes. At most 2:1.

c. Type 3 (Reinforced).

(1) Height. At least 36 in. measured vertically from existing ground to top of filter dam.

(2) Top Width. At least 2 ft.

(3) Slopes. At most 2:1.

d. Type 4 (Sack Gabions). Unfold sack gabions and smooth out kinks and bends. For vertical filling, connect the sides by lacing in a single loop–double loop pattern on 4- to 5-in. spacing. At one end, pull the end lacing rod until tight, wrap around the end, and twist 4 times. At the filling end, fill with stone, pull the rod tight, cut the wire with approximately 6 in. remaining, and twist wires 4 times. For horizontal filling, place sack flat in a filling trough, fill with stone, and connect sides and secure ends as described above. Lift and place without damaging the gabion. Shape sack gabions to existing contours.

e. Type 5. Provide rock filter dams as shown on the plans.

2. Temporary Pipe Slope Drains. Install pipe with a slope as shown on the plans or as directed. Construct embankment for the drainage system in 8-in. lifts to the required elevations. Hand-tamp the soil around and under the entrance section to the top of the embankment as shown on the plans or as directed. Form the top of the embankment or earth dike over the pipe slope drain at least 1 ft. higher than the top of the inlet pipe at all points. Secure the pipe with hold-downs or hold-down grommets spaced a maximum of 10 ft. on center. Construct the energy dissipators or sediment traps as shown on the plans or as directed. Construct the sediment trap using concrete or rubble riprap in accordance with Item 432, "Riprap," when designated on the plans.

3. Baled Hay for Erosion and Sedimentation Control. Install hay bales at locations shown on the plans by embedding in the soil at least 4 in. and, where possible, approximately 1/2 the height of the bale, or as directed. Fill gaps between bales with hay.

4. Temporary Paved Flumes. Construct paved flumes as shown on the plans or as directed. Provide excavation and embankment (including compaction of the sub-grade) of material to the dimensions shown on the plans, unless otherwise indicated. Install a rock or rubble riprap energy dissipater, constructed from the materials specified above to a minimum depth of 9 in. at the flume outlet to the limits shown on the plans or as directed.

5. Construction Exits. When tracking conditions exist, prevent traffic from crossing or exiting the construction site or moving directly onto a public roadway, alley, sidewalk, parking area, or other right of way areas other than at the location of construction exits. Construct exits for either long- or short-term use.

a. Long-Term. Place the exit over a foundation course, if necessary. Grade the foundation course or compacted sub-grade to direct runoff from the construction exits to a sediment trap as shown on the plans or as directed. Construct exits with a width of at least 14 ft. for one-way and 20 ft. for two-way traffic for the full width of the exit, or as directed.
(1) Type 1. Construct to a depth of at least 8 in. using crushed aggregate as shown on the plans or as directed.
(2) Type 2. Construct using railroad ties and timbers as shown on the plans or as directed.
b. Short-Term.
(1) Type 3. Construct using crushed aggregate, plywood, or wafer board. This type of exit may be used for daily operations where long-term exits are not practical.
(2) Type 4. Construct as shown on the plans or as directed.
6. Earthwork for Erosion Control. Perform excavation and embankment operations to minimize erosion and to remove collected sediments from other erosion control devices.
a. Excavation and Embankment for Erosion Control.
Features. Place earth dikes, swales, or combinations of both along the low crown of daily lift placement, or as directed, to prevent runoff spillover. Place swales and dikes at other locations as shown on the plans or as directed to prevent runoff spillover or to divert runoff. Construct cuts with the low end blocked with undisturbed earth to prevent erosion of hillsides. Construct sediment traps at drainage structures in conjunction with other erosion control measures as shown on the plans or as directed. Where required, create a sediment basin providing 3,600 cu. ft. of storage per acre drained, or equivalent control measures for drainage locations that serve an area with 10 or more disturbed acres at one time, not including offsite areas.
b. Excavation of Sediment and Debris. Remove sediment and debris when accumulation affects the performance of the devices, after a rain, and when directed.
7. Construction Perimeter Fence. Construct, align, and locate fencing as shown on the plans or as directed.
a. Installation of Posts. Embed posts 18 in. deep or adequately anchor in rock, with a spacing of 8 to 10 ft.
b. Wire Attachment. Attach the top wire to the posts at least 3 ft. from the ground. Attach the lower wire midway between the ground and the top wire.
c. Flag Attachment. Attach flagging to both wire strands midway between each post. Use flagging at least 18 in. long. Tie flagging to the wire using a square knot.
8. Sandbags for Erosion Control. Construct a berm or dam of sandbags that will intercept sediment-laden storm water runoff from disturbed areas, create a retention pond, detain sediment, and release water in sheet flow. Fill each bag with sand so that at least the top 6 in. of the bag is unfilled to allow for proper tying of the open end. Place the sandbags with their tied ends in the same direction. Offset subsequent rows of sandbags 1/2 the length of the preceding row. Place a single layer of sandbags downstream as a secondary debris trap. Place additional sandbags as necessary or as directed for supplementary support to berms or dams of sandbags or earth.
9. Temporary Sediment-Control Fence. Provide temporary sediment-control fence near the downstream perimeter of a disturbed area to intercept sediment from sheet flow. Incorporate the fence into erosion-control measures used to control sediment in areas of higher flow. Install the fence as shown on the plans, as specified in this Section, or as directed.
a. Installation of Posts. Embed posts at least 18 in. deep, or adequately anchor, if in rock, with a spacing of 6 to 8 ft. and install on a slight angle toward the runoff source.

b. Fabric Anchoring. Dig trenches along the uphill side of the fence to anchor 6 to 8 in. of fabric. Provide a minimum trench cross-section of 6 x 6 in. Place the fabric against the side of the trench and align approximately 2 in. of fabric along the bottom in the upstream direction. Backfill the trench, then hand-tamp.
c. Fabric and Net Reinforcement Attachment. Unless otherwise shown under the plans, attach the reinforcement to wooden posts with staples, or to steel posts with T-clips, in at least 4 places equally spaced. Sewn vertical pockets may be used to attach reinforcement to end posts. Fasten the fabric to the top strand of reinforcement by hog rings or cord every 15 in. or less.
d. Fabric and Net Splices. Locate splices at a fence post with a minimum lap of 6 in. attached in at least 6 places equally spaced, unless otherwise shown under the plans. Do not locate splices in concentrated flow areas. Requirements for installation of used temporary sediment control fence include the following:

- fabric with minimal or no visible signs of biodegradation (weak fibers),
- fabric without excessive patching (more than 1 patch every 15 to 20 ft.),
- posts without bends, and
- backing without holes.

506.5. Measurement.
A. Rock Filter Dams. Installation or removal of rock filter dams will be measured by the foot or by the cubic yard. The measured volume will include sandbags, when used.
1. Linear Measurement. When rock filter dams are measured by the foot, measurement will be along the centerline of the top of the dam.
2. Volume Measurement. When rock filter dams are measured by the cubic yard, measurement will be based on the volume of rock computed by the method of average end areas.
a. Installation. Measurement will be made in final position.
b. Removal. Measurement will be made at the point of removal.
B. Temporary Pipe Slope Drains. Temporary pipe slope drains will be measured by the foot.
C. Baled Hay. Baled hay will be measured by each bale.
D. Temporary Paved Flumes. Temporary paved flumes will be measured by the square yard of surface area. The measured area will include the energy dissipater at the flume outlet.
E. Construction Exits. Construction exits will be measured by the square yard of surface area.
F. Earthwork for Erosion Control.
1. Equipment. Equipment use will be measured by the actual number of hours the equipment is operated.
2. Volume Measurement.
a. In Place.
(1) Excavation. Excavation will be measured by the cubic yard in its original position and the volume computed by the method of average end areas.
(2) Embankment. Embankment will be measured by the cubic yard in its final position by the method of average end areas. The volume of embankment will be determined between:

- the original ground surfaces or the surface upon that the embankment is to be constructed for the feature and
- the lines, grades and slopes of the accepted embankment for the feature.

b. In Vehicles. Excavation and embankment quantities will be combined and paid for under "Earthwork (Erosion and Sediment Control, In Vehicles)." Excavation will be measured by the cubic yard in vehicles at the point of removal. Embankment will be measured by the cubic yard in vehicles measured at the point of delivery. Shrinkage or swelling factors will not be considered in determining the calculated quantities.

G. Construction Perimeter Fence. Construction perimeter fence will be measured by the foot.

H. Sandbags for Erosion Control. Sandbags will be measured as each sandbag or by the foot along the top of sandbag berms or dams.

I. Temporary Sediment-Control Fence. Temporary sediment-control fence will be measured by the foot.

506.6. Payment. The following will not be paid for directly but are subsidiary to pertinent Items:

- erosion-control measures for Contractor project-specific locations (PSLs) inside and outside the right of way (such as construction and haul roads, field offices, equipment and supply areas, plants, and material sources);
- removal of litter;
- repair to devices and features damaged by Contractor operations;
- added measures and maintenance needed due to negligence, carelessness, lack of maintenance, and failure to install permanent controls;
- removal and reinstallation of devices and features needed for the convenience of the Contractor;
- finish grading and dressing upon removal of the device; and
- minor adjustments including but not limited to plumbing posts, reattaching fabric, minor grading to maintain slopes on an erosion embankment feature, or moving small numbers of sandbags.

The Contractor will be reimbursed in accordance with pertinent Items or Article 9.5, “Force Account,” for maintenance, repair, or reinstallation of devices and features when the need for additional control measures cannot be attributed to the above, as determined by the Engineer. Stabilization of disturbed areas will be paid for under pertinent Items. Furnishing and installing pipe for outfalls associated with sediment traps and ponds will not be paid for directly but are subsidiary to the excavation and embankment under this Item.

A. Rock Filter Dams. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid as follows:

1. Installation. Installation will be paid for as “Rock Filter Dams (Install)” of the type specified. This price is full compensation for furnishing and operating equipment, finish backfill and grading, lacing, proper disposal, labor, materials, tools, and incidentals.

2. Removal. Removal will be paid for as “Rock Filter Dams (Remove).” This price is full compensation for furnishing and operating equipment, proper disposal, labor, materials, tools, and incidentals. When the Engineer directs that the rock filter dam installation or portions thereof be replaced, payment will be made at the unit price bid for “Rock Filter Dams (Remove)” and for “Rock Filter Dams (Install)” of the type specified. This price is full compensation for furnishing and operating equipment, finish backfill and grading, lacing, proper disposal, labor, materials, tools, and incidentals

B. Temporary Pipe Slope Drains. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Temporary Pipe Slope Drains” of the size specified. This price is full compensation for furnishing materials, removal and disposal, furnishing and operating equipment, labor, tools, and incidentals. Removal of temporary pipe slope drains will not be paid for directly but is subsidiary to the installation Item. When the Engineer directs that the pipe slope drain installation or portions thereof be replaced, payment will be made at the unit price bid for “Temporary Pipe

Slope Drains" of the size specified, which is full compensation for the removal and reinstallation of the pipe drain. Earthwork required for the pipe slope drain installation, including construction of the sediment trap, will be measured and paid for under Section 506.5.F, "Earthwork for Erosion and Sediment Control." Riprap concrete or stone, when used as an energy dissipater or as a stabilized sediment trap, will be measured and paid for in accordance with Item 432, "Riprap."

C. Baled Hay. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Baled Hay." This price is full compensation for furnishing and placing bales, excavating trenches, removal and disposal, equipment, labor, tools, and incidentals. When the Engineer directs that the baled hay installation (or portions thereof) be replaced, payment will be made at the unit price bid for "Baled Hay," which is full compensation for removal and reinstallation of the baled hay.

D. Temporary Paved Flumes. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Temporary Paved Flume (Install)" or "Temporary Paved Flume (Remove)." This price is full compensation for furnishing and placing materials, removal and disposal, equipment, labor, tools, and incidentals. When the Engineer directs that the paved flume installation or portions thereof be replaced, payment will be made at the unit prices bid for "Temporary Paved Flume (Remove)" and "Temporary Paved Flume (Install)." These prices are full compensation for the removal and replacement of the paved flume and for equipment, labor, tools, and incidentals. Earthwork required for the paved flume installation, including construction of a sediment trap, will be measured and paid for under Section 506.5.F, "Earthwork for Erosion and Sediment Control."

E. Construction Exits. Contractor-required construction exits from off right of way locations or on right of way PSLs will not be paid for directly but are subsidiary to pertinent Items. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" for construction exits needed on right of way access to work areas required by the Department will be paid for at the unit price bid for "Construction Exits (Install)" of the type specified or "Construction Exits (Remove)." This price is full compensation for furnishing and placing materials, excavating, removal and disposal, cleaning vehicles, labor, tools, and incidentals. When the Engineer directs that a construction exit or portion thereof be removed and replaced, payment will be made at the unit prices bid for "Construction Exit (Remove)" and "Construction Exit (Install)" of the type specified. These prices are full compensation for the removal and replacement of the construction exit and for equipment, labor, tools, and incidentals. Construction of sediment traps used in conjunction with the construction exit will be measured and paid for under Section 506.5.F, "Earthwork for Erosion and Sediment Control."

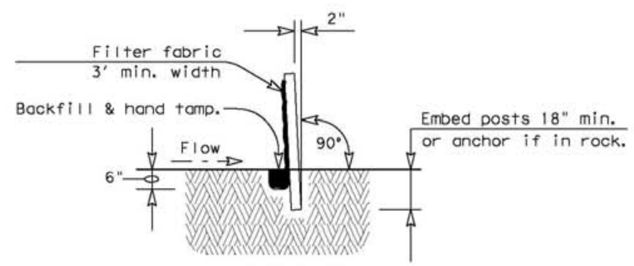
F. Earthwork for Erosion and Sediment Control. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Excavation (Erosion and Sediment Control, In Place)," "Embankment (Erosion and Sediment Control, In Place)," "Earthwork (Erosion and Sediment Control, In Vehicles)," "Dragline Work (Erosion and Sediment Control)," "Backhoe Work (Erosion and Sediment Control)," "Excavator Work (Erosion and Sediment Control)," "Front End Loader Work (Erosion and Sediment Control)," "Blading Work (Erosion and Sediment Control)," "Scraper Work (Erosion and Sediment Control)," or "Bulldozer Work (Erosion and Sediment Control)." This price is full compensation for excavation including removal of accumulated sediment in various erosion control installations as directed, hauling, and disposal of material not used elsewhere on the project; excavation for construction of erosion-control features; embankments including furnishing material from approved sources and construction of erosion-control features; sandbags; plywood; stage construction for curb inlets involved in curb-inlet sediment traps; and equipment, labor, tools, and incidentals. Earthwork needed to remove and obliterate erosion-control features will not be paid for directly but is subsidiary to pertinent Items unless otherwise shown on the plans. Sprinkling and rolling required by this Item will not be paid for directly, but will be subsidiary to this Item.

G. Construction Perimeter Fence. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Construction Perimeter Fence." This price is full compensation for furnishing and placing the fence; digging, fence posts, wire, and flagging; removal and disposal; and materials, equipment, labor, tools, and incidentals. Removal of construction perimeter fence will be not be paid for directly but is subsidiary to the installation Item. When the Engineer directs that the perimeter fence installation or portions thereof be removed and replaced, payment will be made at the unit price bid for "Construction Perimeter Fence," which is full compensation for the removal and reinstallation of the construction perimeter fence.

H. Sandbags for Erosion Control. Sandbags will be paid for at the unit price bid for "Sandbags for Erosion Control" (of the height specified when measurement is by the foot). This price is full compensation for materials, placing sandbags, removal and disposal, equipment, labor, tools, and incidentals. Removal of sandbags will not be paid for directly but is subsidiary to the installation Item. When the Engineer directs that the sandbag installation or portions thereof be replaced, payment will be made at the unit price bid for "Sandbags for Erosion Control," which is full compensation for the reinstallation of the sandbags.

I. Temporary Sediment-Control Fence. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Temporary Sediment-Control Fence." This price is full compensation for furnishing and placing the fence; trenching, fence posts, fabric and backfill; removal and disposal; and equipment, labor, tools, and incidentals. Removal of temporary sediment-control fence will not be paid for directly but is subsidiary to the installation Item. When the Engineer directs that the temporary sedimentation control fence installation or portions thereof be replaced, payment will be made at the unit price bid for "Temporary Sediment-Control Fence," which is full compensation for the removal and reinstallation of the temporary sediment-control fence.

APPENDIX C:
TEMPORARY EROSION, SEDIMENT, AND WATER POLLUTION CONTROL MEASURES
EC (1) - 93



SECTION A-A

SEDIMENT CONTROL FENCE USAGE GUIDELINES

A sediment control fence may be constructed near the downstream perimeter of a disturbed area along a contour to intercept sediment from overland runoff. A 2 year storm frequency may be used to calculate the flow rate to be filtered.

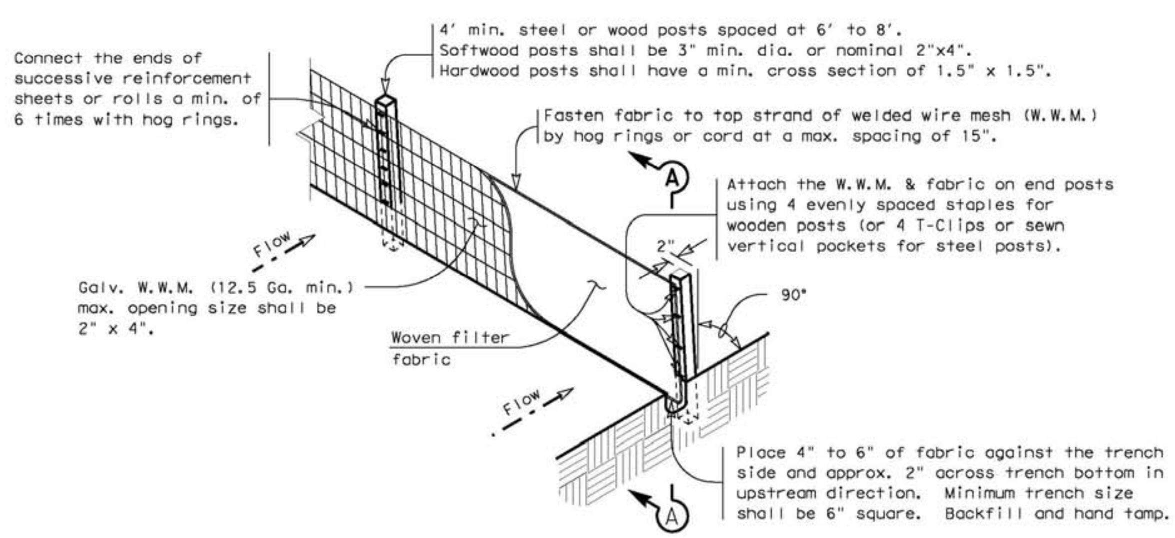
Sediment control fence should be sized to filter a max. flow through rate of 100 GPM/FT^2. Sediment control fence is not recommended to control erosion from a drainage area larger than 2 acres.

PLAN SHEET LEGEND

Sediment Control Fence —(SCF)—

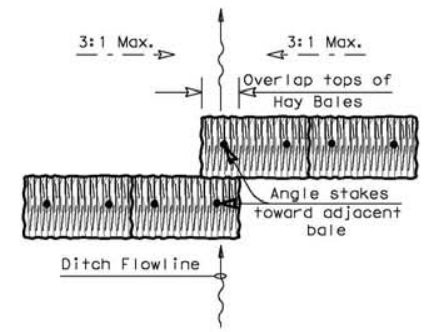
GENERAL NOTES

1. The guidelines shown hereon are suggestions only and may be modified by the Engineer.

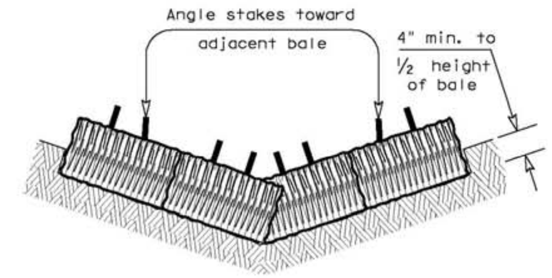


TEMPORARY SEDIMENT CONTROL FENCE

(SCF)



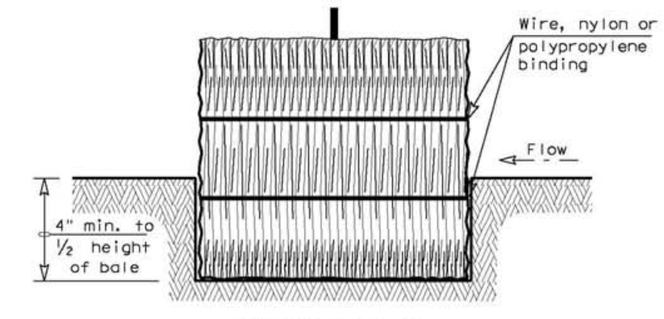
PLAN VIEW



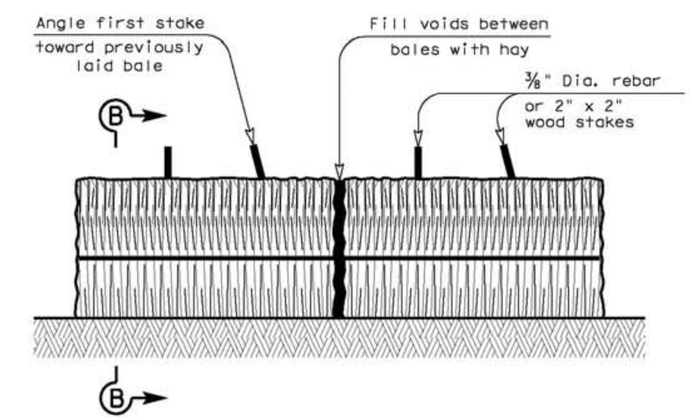
PROFILE VIEW

PLANS SHEET LEGEND

Baled Hay —(BH)—



SECTION B-B



BALED HAY FOR EROSION CONTROL

(BH)

BALED HAY USAGE GUIDELINES

A Baled Hay installation may be constructed near the downstream perimeter of a disturbed area along a contour to intercept sediment from overland runoff. A two year storm frequency may be used to calculate the flow rate to be filtered. The installation should be sized to filter a maximum flow thru rate of 5 GPM/FT^2 of cross sectional area. Baled hay may be used at the following locations:

1. Where the runoff approaching the baled hay flows over disturbed soil for less than 100'. If the slope of the disturbed soil exceeds 10%, the length of slope upstream the baled hay should be less than 50'.
2. Where the installation will be required for less than 3 months.
3. Where the contributing drainage area is less than ½ acre.

For Baled Hay installations in small ditches, the additional following considerations apply:

1. The ditch sideslopes should be graded as flat as possible to maximize the drainage flowrate thru the hay.
2. The ditch should be graded large enough to contain the overtopping drainage when sediment has filled to the top of the baled hay.

Bales should be replaced usually every 2 months or more often during wet weather when loss of structural integrity is accelerated.

GENERAL NOTES

1. Hay bales shall be a minimum of 30" in length and weigh a minimum of 50 Lbs.
2. Hay bales shall be bound by either wire or nylon or polypropylene string. The bales shall be composed entirely of vegetative matter.
3. Hay bales shall be embedded in the soil a minimum of 4" and where possible ½ the height of the bale.
4. Hay bales shall be placed in a row with ends tightly abutting the adjacent bales. The bales shall be placed with bindings parallel to the ground.
5. Hay bales shall be securely anchored in place with ⅜" Dia. rebar or 2" x 2" wood stakes, driven through the bales. The first stake shall be angled towards the previously laid bale to force the bales together.
6. The guidelines shown hereon are suggestions only and may be modified by the Engineer.

Texas Department of Transportation
Design Division (Roadway)

TEMPORARY EROSION, SEDIMENT AND WATER POLLUTION CONTROL MEASURES

FENCED & BALED HAY

EC(1)-93

FILE: EC193.DGN	DN: HEJ	CK: HEJ	DW: BGD	CK:
© TxDOT JUNE 1993	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY

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APPENDIX D:
FACT SHEET

FACT SHEET

Characteristics of Compost Filter Berms 0-4572-1

RESEARCH OBJECTIVES

- Determine the water quality impact of compost filter berms and compost filter socks using dairy manure compost (DMC), biosolids compost (CBS), and yard waste compost (YWC).
- Determine the water quality impact of wood mulch berms.
- Determine the water quality impact of vegetated compost filter berms using dairy manure compost, biosolids compost, and yard waste compost.
- Determine the structural stability of each type of compost filter berm, vegetated compost filter berm, compost filter sock, and wood mulch berm.
- Evaluate performance of silt fence and straw bales relative to compost filter berms.

RESEARCH METHODS

Unseeded Compost Filter Berms, Mulch Berms, and Compost/Mulch Filter Socks

- 3% slope on both clay and sand
- Potable water used at flow rate of 0.25 cfs for 15-minute flow
- Two rounds with three repetitions each round
- 30-minute continuous flow up to 0.35 cfs to test structural integrity
- Time-weighted samples collected at
  - 1 minute
  - 7 minutes
  - 15 minutes
  - 30 minutes
  - downstream after 45 minutes
- Sampling locations
  - in water reservoir
  - behind the berm (upstream of berm)
  - in front of the berm after infiltration

Straw Bales and Silt Fence

- Testing done in the same manner as the compost filter berms
- Water quality for total suspended solids only

Seeded Compost Filter Berms

- Six at-grade channels
  - Three at 3% , three at 7%
  - Berms were installed and seeded 45 days prior to testing
  - 30-minute flow at up to 0.35 cfs with potable water
  - Time-weighted samples collected at
    - 1 minute after infiltration
    - after overtopping ceased
    - behind the berm

Water Quality Laboratory Testing

Dissolved Oxygen	Temperature
Color	pH
Conductivity	Turbidity
Total/Fecal Coliform	BOD_5
Dissolved Solids	Alkalinity
Suspended Solids	Anions
Metals/Hardness	TOC

RESULTS AND CONCLUSIONS

Water Quality

- Sediment trapping capability of the unseeded berms could not be deduced from the results due to failure during sample collection.
- A drop in dissolved oxygen was observed for all the berms.
- The YWC berms introduced the least amount of dissolved solids including sulfates, nitrates, and phosphates.
- The CBS and the DMC berms performed unsatisfactorily as both compost types introduced substantial quantities of nutrients into the water.

Structural Stability

- ~100% structural failure of unseeded berms
- 100% success of seeded berms
- Compost filter socks - success
- Straw bales
  - clay – success
  - sand – failure
- Silt fence - success
- Wood mulch berm - success