FIELD EVALUATION OF SOURCE-SEPARATED COMPOST AND CONEG MODEL PROCUREMENT SPECIFICATIONS FOR CONNECTICUT DOT PROJECTS

FINAL REPORT

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16. Abstract

Samples of compost and wood mulch were obtained from eight producers in Connecticut. The samples were subjected to laboratory tests to determine their physical and chemical properties for comparison with the CONEG specifications for source-separated compost. Three of the products were selected for large scale erosion control testing at a field site with a slope of 2 horizontal to 1 vertical. Eight test cells (10' W x 35' L each) were prepared with different surface treatments including an untreated reference cell and a standard ConnDOT hay and seed preparation. The compost and wood mulch products were used as erosion control filter berm material and erosion control mulch - with and without seeding. The surface runoff was collected in buckets at the base of the slope for several storm events over a one-year period. Following each storm, the runoff from each cell was analyzed for suspended solids concentration, conductivity, pH, nutrients and selected samples were subjected to metals analysis. Results indicate that compost and wood mulch are at least as effective as the standard ConnDOT hay treatment in preventing erosion from slopes. Additional wood mulch was shown to effectively filter sediment from storm water run-off when placed as a berm at the toe of slope.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	mililitres	mL
gal	gallons	3.785	Litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

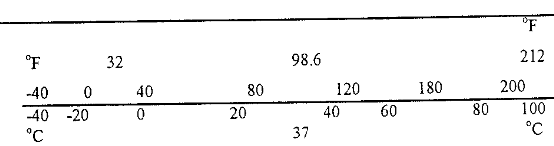
NOTE: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
^{0}F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	^{0}C

* SI is the symbol for the International System of Measurement

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
$^{\circ}C$	Celcius temperature	1.8C+32	Fahrenheit temperature	$^{\circ}F$



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EXECUTIVE SUMMARY

Field Evaluation of Source-Separated Compost and CONEG Model Procurement Specifications for Connecticut Department of Transportation Projects

This report documents a laboratory and field testing program using source-separated compost and wood mulch for erosion control applications.

Samples of compost and mulch were obtained from eight producers in Connecticut. The samples were subjected to laboratory tests to determine their physical and chemical properties for comparison with the CONEG model procurement specifications for source-separated compost. Three of the products were selected to test their effectiveness in erosion control at a field site.

A field site with erodible soil having a slope of 2 horizontal to 1 vertical was selected in Chaplin, CT. Eight parallel test cells (10' W x 35' L each) were prepared with different surface treatments including an untreated reference cell and a standard ConnDOT hay and seed preparation. The compost products were used as erosion control berm material and erosion control mulch - with and without seeding. The surface runoff was collected in buckets at the base of the slope for eight storm events over a one-year period from fall 1996 to summer 1997. Following each storm, the runoff from each cell was analyzed for total solids concentration, conductivity, pH, and nutrients; selected samples were analyzed for metals.

Based on the field and laboratory test results, the compost used as an erosion control mulch (with or without seeding), when applied at the 3-inch CONEG specification, reduces erosion by more than an order of magnitude compared to an untreated slope and performs at least as well as the standard hay and seed treatment. Also, there was no significant release of nutrients or soluble salts with runoff and the levels of heavy metals in both the compost and the test site runoff were within acceptable limits. Some qualitative test results were obtained for the performance of thinner (1.5" and 0.75") applications of compost as an erosion control mulch. These results show that thinner (than CONEG) applications may achieve a high level of erosion protection and may be as economical as other methods such as hay and seed.

The erosion control filter berm was very effective at retaining eroded solids from runoff while allowing the water to pass through. This application appears to be an alternative to using the geosynthetic silt fence for erosion control. Maintenance of the berm was minimal.

1. INTRODUCTION

The Coalition of Northeastern Governors (CONEG) has taken a leadership role in developing environmentally and economically sound regional approaches to solid waste management. This approach seeks to develop a public-private partnership with the goal of waste reduction and diversion for the region. Compost has been identified by CONEG as an important element in achieving waste reduction and diversion. Through its Regional Composting Initiatives Policy Statement, CONEG is encouraging the development of appropriate compost markets by proposing model product procurement specifications for composted source-separated material and by encouraging the Northeast states to enact model procurement preference legislation for compost.

Since compost can be made from most organic materials such as yard trimmings and leaves, food scraps, soiled paper, and organic biosolids; the potential quantity of feedstocks available for composting is substantial. Food scraps and yard trimmings alone have been estimated by the US Environmental Protection Agency (US EPA, 1997) to be about 25% of the municipal solid waste (MSW) potentially generated (before home composting and grasscycling). In FY 1997, the state of Connecticut generated about 3,000,000 tons of MSW (CT DEP 1998). Using the EPA estimate, CT has the potential to divert to composting more than 750,000 tons/year of source separated organics. Yet, only 230,000 tons of organics from Connecticut's waste stream were reported for FY 1997 as being composted, and 31,714 tons were estimated to have been source reduced through home composting and grasscycling. Together, this represents about 8.7% of the municipal solid waste stream, indicating that further potential for composting exists.

For the past decade the Connecticut Department of Transportation (ConnDOT) has been involved in research and demonstration projects on recycling and reuse of waste materials for highway applications. Waste materials have been proposed for use as fillers, extenders, substitutes, and modifiers with soil aggregates. The ConnDOT has a large demand for construction materials and aggregates and, therefore, provides an opportunity to use large volumes of materials assuming they are available when needed. However, ConnDOT will not use recycled materials if they are inferior, costly or environmentally unacceptable. ConnDOT requires detailed specifications for construction materials, recycled or not, so the supplier and customer know exactly what is acceptable to achieve its intended purpose. Research is needed to evaluate the physical and chemical properties, behavior, and variability of recycled materials including compost, so that proper specifications can be prepared.

Six applications for composts and mulches derived from source separated materials are addressed in the CONEG specifications (CONEG, 1996):

1) General use compost
2) Compost manufactured loam
3) Compost amended loam (topsoil) manufactured in-place
4) Horticultural mulch
5) Erosion control mulch
6) Erosion control filter berm

These applications should not be confused with the materials -- compost and mulch. In this study, compost material is the soil-like product of aerobically decomposed organic waste, whereas, mulch is a chunky, wood-like material made by shredding or chipping trees. (The complete CONEG specifications for these applications are in Appendix A.)

The CONEG specifications are generic and ConnDOT believes that laboratory testing and field trial installations are necessary prior to developing appropriate procurement specifications in a form useful to ConnDOT. The compost applications selected for this study are: [1]

1) Compost used as an erosion control mulch on highway slopes. The function of this application is to prevent erosion by dissipating the erosive energy of raindrops, help keep run-off water in sheet flow, protect the soil surface, and promote the establishment of vegetation. Two very different types of materials are specified for this application. One is a coarse ground woody material used when slopes are not intended to be seeded, and the other is a soil-like compost product used in conjunction with grass seed. CONEG specifications allow mulch on slopes with a 2H-1V grade or flatter with adequate compaction and contact with underlying soil.

2) Compost used as an erosion control filter berm during highway maintenance or construction. The berm would be constructed in the form of a water permeable windrow,

[1] Note: Compost amended soil (manufactured in-place) and compost manufactured loam, although not evaluated by the University, were utilized by ConnDOT on two construction projects in 1997 and 1998. These are being evaluated separately by ConnDOT.

and would act as a porous dam allowing runoff water to drain while filtering sediment. A coarse ground woody material, partially aged or composted to achieve an even distribution of coarse to fine particles, is used in this application.

Each of these applications require that specific compost properties be measured, such as particle size distribution, unit weight, and organic matter content, to verify that CONEG specifications are satisfied, and there are no undesirable environmental impacts on adjacent soil or groundwater with time and loading.

2. LITERATURE REVIEW

2.1: General

Three topics are important to this research: composted material, erosion of soil, and the application of composted material to control erosion. Of these three, the latter two are most important to this project, as the suppliers of composted material have all been reviewed by the Connecticut Department of Environmental Protection, and the objective of the project was not to produce better compost but to put the compost to use successfully.

2.2: Composted Material

During the past ten years, composting has grown to become an important component in solid waste management in the United States to meet State landfill diversion mandates (Composting Council, 1994; Pettigrew, 1996; Hoitink and Keener, 1993; NRAES, 1992). It has also been used in other parts of the world where resources are limited (van Veldhuijsen, 1974; Oosthnoek and Smit, 1987; Baliff and Herre, 1988; Fricke and Vogtmann, 1993)

The composting process converts large portions of the municipal solid waste stream into a versatile substrate that has potential applications in agriculture for soil amendment (Koch, 1965; Knoop et al, 1991: Shiralipour et al, 1992), in environmental industries for trace metal removal from water (Selby, 1986; W & H Pacific, 1992) and in the transportation and construction industries for erosion control (Anderson, 1996; Henry and Bush, 1996; Dunlap, 1997; and Haynes, 1997). The US Environmental Protection Agency has published a comprehensive manual on the processing and use of composted material from yard trimmings and municipal solid waste (US E.P.A., 1994). Applications of composted materials for erosion control and as soil amendments are used in many parts of the world (Oosthnoek and Smit, 1987; Ballif and Herre, 1988; Müller and Riccabona, 1984).

There are several materials that can be successfully composted: yard trimmings, food waste, biogenic residue, wood waste, and paper waste. The primary products of the composting process are substances that can be used as a soil amendment or a mulch, but there are other advantages of composting including volume reduction, increased recycling, and reduction of organic matter in the landfills and incinerators. These products are finding more and more uses (Shiralipour et al. 1992). Their primary benefits are to enhance the ability of soil to support plant growth by fostering the various activities that plants need from water retention to microbial life. Knoop et al. (1991) published a comprehensive literature review. They approached compost quality from various aspects: chemical, biological, and physical, and organized the information with respect to the source of the organic matter and contaminants. Their report also addressed operational concerns such as leachate, odor, and worker health.

The review of the available materials on the composting process showed that, depending on the source of the compost, the toxicity of chemicals should be checked as well as the pH (for environmental suitability and plant growth). The compost must be stable to insure no deleterious effects on the plantings. In addition, there is always concern about quality of the composted material as well as the health and safety aspects of compost processing and application (Boutin and Moline, 1987; Fricke and Vogtmann, 1993; Hutchins et al., 1985; Inbar et al., 1990). A complete review of the production and quality of composted material is beyond the scope of the present work, since the object of the present work is the use of properly prepared composted material to prevent erosion on construction sites.

2.3: Surface Erosion

Soil erosion has been a concern since farmers and others realized that erosion carries away the layer of soil most important to growing plants and grains (Maass et al. 1988; Schuch and Jordan, 1989). Becoming aware of the effects of environmental damage, measures to prevent erosion were used on highway construction. Use of composted material and mulch has been one of the recognized techniques for reducing or eliminating erosion on the construction site (Israelson et al., 1980 a&b; Sollenberger, 1987). The use of composted material to control erosion is, of course, not limited to construction sites (Henry and Bush, 1996; Haynes, 1997). Recently, the use of composted material by departments of transportation has increased in an attempt to use more environmentally friendly techniques (Mitchell, 1997).

Soil erosion is a complicated interaction between rainfall and runoff and is affected by type of soil, local rainfall pattern, slope length, slope steepness, land cover, and management practices (Wischmeier and Smith, 1978). There have been several attempts to combine these factors into an equation for predicting the loss of soil from a site. The Universal Soil Loss Equation (Ellison, 1944) had been the workhorse until 1985 when the US Department of Agriculture and other researchers decided to update the equation with the latest research results (Renard et al., 1994). The revised universal soil loss equation (RUSLE) can be written:

$$A = R\,K\,L\,S\,C\,P \qquad (2.1)$$

where: A = the computed soil loss, R = the rainfall intensity factor, K = soil erodibility factor, L = the slope length factor, S = slope steepness factor, C = the cover-management factor and P = the supporting practices factor.

The rainfall-runoff erosivity term, R, is the product of storm kinetic energy times the maximum 30-minute storm depth and summed for all the storms in a year. The "K" factor is a measure of the inherent erodibility of a given soil under the standard conditions and maintained in continuous fallow. Values of K range from about 0.10 to 0.45. The "C" factor can be the most important since it can be manipulated to decrease the erosion. It is not necessarily constant throughout the year. The "P" factor represents surface conditions and how they affect flow paths and flow hydraulics.

2.4: Composted Material to Control Erosion

The use of composted material to reduce erosion has been well established in certain applications. Soil erosion has been controlled with compost materials in the vineyards of Europe (Ballif and Herre, 1988; Banse, 1962; Klaghofer et al., 1990; Koch, 1965) and in general applications (Bloom, et al., 1984; Horner et al., 1989; van Veldhuijsen, 1974).

Ballif and Herre (1988) researched the effect of composted material on preventing the erosion of soil in a vineyard in the Champagne area of France. The experiment compared the erosion with and without compost and with and without vehicle traffic. The results showed that applying compost to the area caused a decrease of two orders of magnitude in the amount of eroded material on a weight basis.

Müller and Riccabona(1984) studied the effect of composted material on the erosion of slopes of 1 vertical to 5 horizontal. The slope was divided into cells and arranged so that erosion products could be collected and measured. They applied the compost in thickness of about 4.5 and 9 cm and tilled each cell to a depth of 10 cm. The original intent was to expose their system to natural rain but not enough occurred. They then decided to use an artificial rainmaker. The effect of the compost was masked by substantial growth of vegetation. The cell in which 4.5 cm of compost was tilled into the soil performed best.

Another experiment, similar to the one proposed for the research in the present study, was used by Klaghofer et al. (1990) to study erosion on slopes north of Eisenstadt, Burgenland, Germany. The slopes studied varied between 5° and 11° to the horizontal. The parcels with the most compost showed the most erosion loss, a fact attributed to the handling of weeds by plowing them in instead of treating them with chemicals.

Slick and Curtis (1985) indicated that composted MSW is susceptible to erosion under light rainfall because of its light weight and small particle size. In addition, there is some concern about health risks with the use of MSW and sewage sludge composts (Sollenberger, 1987)

In a recent demonstration project (W&H Pacific, 1993), test cells on a slope were used to evaluate several types of compost for erosion protection of the soil. They tested composted materials on slopes as steep as 1 vertical to about 2.5 horizontal. The composted materials showed results equivalent to the hydro-mulch application, which is considered to be the most effective method of erosion control.

The literature review indicated that our approach should be successful in comparing the erosion protection of source separated composted material to currently used methods.

3. RESEARCH APPROACH

3.1: Advisory Group

To guide this research, an advisory group was formed that consists of ConnDOT environmental planning, construction, maintenance, design, and research personnel, ConnDEP waste management planning and recycling personnel, a compost industry representative, and a representative from the CT Agricultural Experiment Station. A list of the members of the Advisory Group is shown in Appendix C. The group was established to provide guidance to the principal investigators and to define or refine compost performance criteria. The group met nine times between September, 1996 and May, 1998 to review research results and assist with material acquisition and the field construction phase of the demonstration projects.

After some initial discussions, it was decided to:

1) Survey and sample some of the available sources of Source-Separated Composted Materials (SSCM) in Connecticut and perform some preliminary classification and physical properties tests to identify variability and the need for further processing before use in the field testing program (August, 1996).

2) Select an appropriate site for a field installation to test compost as an erosion control mulch and as an erosion control filter berm. A field site was identified in September, 1996, plans were prepared in accordance with the intent of the CONEG Specifications and test cells were installed in early October, 1996.

3) Test the performance of the installations. Field tests continued for about one calendar year -- until September, 1997. Both the physical and chemical performance of the compost used at the demonstration site were monitored.

3.2: Compost Materials Available in Connecticut

To reach the objectives of the project, sources of composted material in Connecticut had to be identified, samples obtained and tested in the laboratories, and those meeting the CONEG Specifications tested in the field.

There are many producers of compost in Connecticut. Composted materials and mulches are produced by most cities and towns from recycled leaves and brush. In addition, there are a number of private enterprises that produce compost for profit. They range in size from one-man operations to large national producers such as Earthgro Inc. of Lebanon, CT. A number of these producers were visited at the start of this project and representative samples obtained. Additional samples were acquired throughout the study. Some of the materials were subjected to extensive laboratory testing because they are typical of the local yard trimmings composts (thus, abundant) and were selected for use in a field testing phase of this study. Other materials were subjected to minimum testing so that the properties of these samples could be compared to those in the CONEG specifications (CONEG, 1996). The producers that were visited and sampled in this study are presented in Table 3.1.

These producers of compost and their products are considered representative of the many composting operations in Connecticut. Therefore, the physical and chemical properties of these many materials provided a range of expected properties and also identified properties which do not meet the CONEG specifications. The CONEG specifications are illustrated in Table 3.2 with the Testing Protocols used in this research and they are discussed further in Appendix D along with the problems encountered during testing.

Table 3.1: Compost Producers Sampled in the Study

Source	Products Tested
1) Town of Manchester, CT	Yard trimming compost from leaves and grass - screened
2) Town of Glastonbury, CT	Mulch from chipped and shredded wood and brush, 2 - 3 in. screened
3) Earthgro Inc., Lebanon, CT	Yard trimmings compost from leaves, grass and shredded brush - screened
4) Grillo/ Greencycle, Milford, CT	Yard trimmings compost from leaves and grass - screened Yard trimmings compost blended with soil Mulch from pines, 2 in. screened
5) Town of Windsor, CT	Yard trimmings compost from leaves, grass and shredded brush-- screened Wood chip mulch
6) Jack Collins Farm, Ellington, CT	Composted cow manure
7) Agriblends, Voluntown, CT	Composted spent mushroom substrate
8) New Milford Farms, New Milford, CT	Ground brush and food processing residuals (coffee) compost

Table 3.2: Comparison of CONEG Specification Requirements for Composted Materials According to Use

Property	Slopes to be Mulched Only	Slopes to be mulched and Seeded	Erosion Control Filter Berm	Test Used[2]
Organic Matter Content	40% -- 60%	40% -- 60%	40% -- 60%	loss on ignition as dry weight (ASTM D2974)
Moisture Content	< 60% #	< 60% #	< 60% #	product loose and friable not dusty (ASTM D2216) test method "A"
Particle Size	100% < 3 inches Max 70% < 2.0 inches	100% , 0.75 inches 70% < 0.50 inches 0.25 mm <Max 50% < 2.0 mm Max 15% < 0.25 mm	100% < 3.0 inches Max 70% < 1.0 inches	(ASTM D422)
Soluble Salts	≤ 4.0 mmhos/cm (dS/m)	≤ 4.0 mmhos/cm (dS/m)	≤ 4.0 mmhos/cm (dS/m)	(Spurway Extraction Procedure) See App. D
Stability	Stable	Very Stable	Stable	Dewar Self-heating Test
pH	5.5 -- 8.0	5.5 -- 8.0	5.5 -- 8.0	Modified (ASTM D2976)

CONEG does not specify basis as either dry weight or wet weight.

[2] Test Method, Employed during the study by UConn. (not all are specified in the CONEG Specifications)

4. LABORATORY MEASUREMENTS

Each of the samples acquired from producers were subjected to laboratory testing for the CONEG properties. Some additional chemical tests for toxicity assessment were requested by ConnDOT before these materials were placed at the field test site. The type and quantity of tests vary greatly depending on the use and availability of samples. Some physical property tests originally intended to assess permeability, strength, and compression behavior were omitted because they were shown not to be relevant to the goals of this investigation.

The American Society for Testing and Materials (ASTM) has not adopted standard tests for composts and mulches; its standards are limited to soils, peats, and other natural aggregates. The test standards used can be found in ASTM, (1997). Agronomy tests such as those published in the text "Methods of Soil Analysis" by D.L. Sparks (1996) for the American Society of Agronomy may also have limitations when applied to composts and mulches. In the work described herein, a "Best-fit" of existing standards was tried with the available compost/mulch materials.

4.1: Physical Properties

4.1.1 Particle Size

Particle size distribution curves are shown in Figures 4.1 and 4.2 for many of the compost and mulch materials that were sampled. These results show that there is some variation in the gradation of composts and mulches among producers. In addition, it depends, as expected, on the blend of raw products and the degree of pre- and post-treatments including sorting, shredding, grinding, chipping, composting, and sifting, etc. All of these materials are well-graded with uniformity coefficients (U=d60/d10) greater than about four or five where d60 and d10 are particle diameters at 60 and 10 finer by weight, respectively. They are all comprised of coarse-sized particles with a small quantity of fine-sized particles. These gradation curves were obtained from conventional sifting tests (ASTM D-422) used for construction aggregates and at first glance appear appropriate for composts. Yet, compost and mulch particles have a lower density than mineral aggregates and many particles in wood mulch have an elongated (needle) shape that may require different test procedures. During sifting tests, the needle shaped particles can pass through the sieve on end so that the gradation curve is a measure of the particles diameter rather than length. Also, many of the finer particles would not pass through a fine sieve during vibration because of their light weight so many of the sieve tests were limited to coarser sieves of #40 or greater.

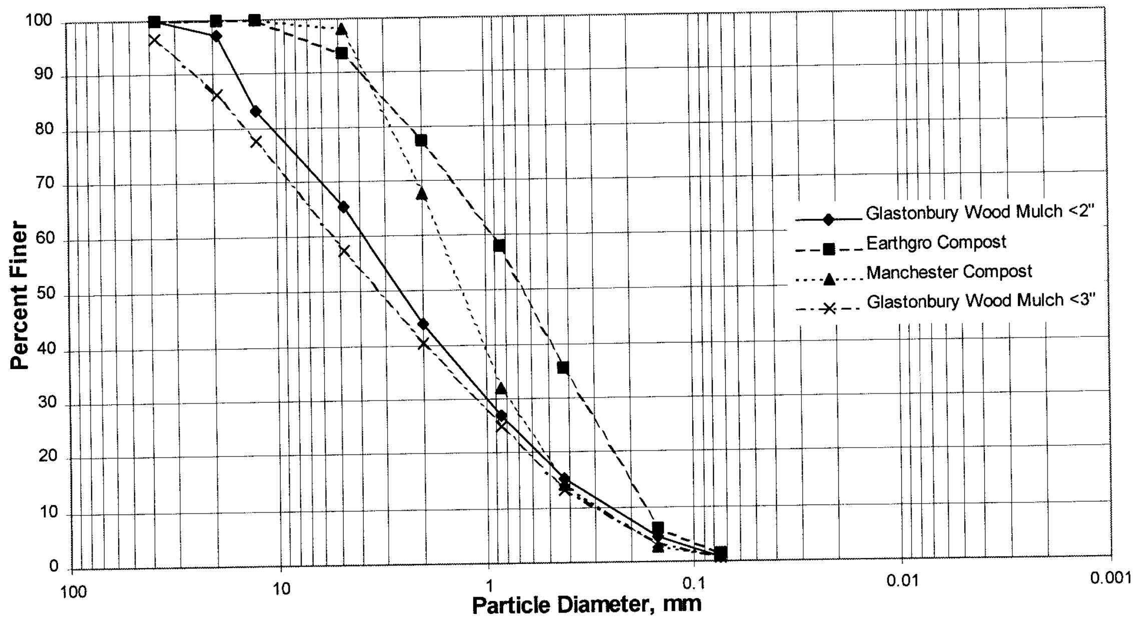

Figure 4.1: Gradation Curves for Compost and Mulch Samples

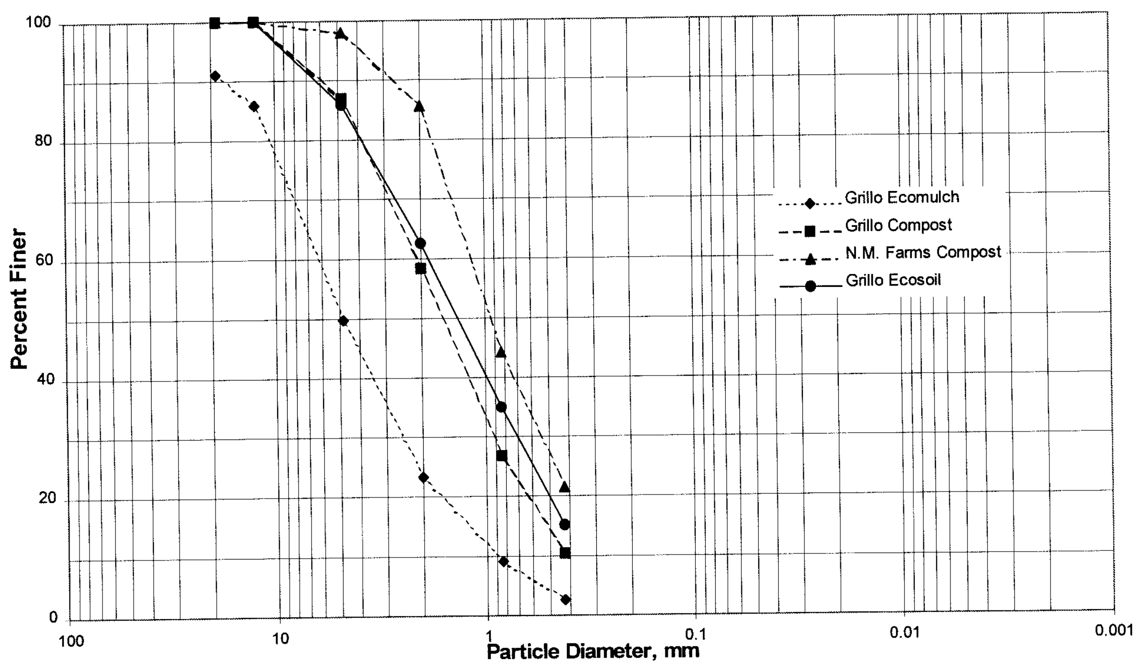

Figure 4.2: Gradation Curves for Compost and Mulch Samples

4.1.2 Moisture Content

The CONEG Specifications list limits of moisture content for each of the applications but make no statement as to whether the measure of moisture content should be based on dry weight of solids or total weight. The Composting Council (1994) defines both water holding capacity and moisture content as a percent of dry weight. Epstein (1997) does not define moisture content explicitly, but the astute can discern in some of the figures in his book, that he uses moisture content as a percent of total weight. Therefore, a case could be made for either method, and since the CONEG Specifications are silent on the definition, the moisture content can be argued indefinitely. The consequences are not trivial, however, since a content of 66% by the total weight is 200% by dry weight definition. Whether any of the materials used in this research meet the moisture content requirements depends on the definition one wants to use. Due to this confusion on the specifications, we measured the moisture content based on dry weight, but report it both ways in the tables. A graph to convert from dry weight to total weight is in Appendix D, Figure D-1.

The moisture contents of the composted materials used in this research are shown in Table 4.1. If the CONEG Specification for moisture content is based on a dry weight, most of these would not pass. Many would, however, pass if the moisture content were based on total weight. It is interesting to note that water contents vary from a low of 56% to a high of 205% by dry weight and are affected by the weather since most compost piles are stored outside, but upon air drying in a roofed structure, the water content can be reduced to 10 to 20%.

4.1.3 Organic Content and Unit Weight

Organic matter contents range from 17 to 91% and are affected by the degree of composting and blending with inorganic mineral solids. Dry unit weights are very low compared to mineral aggregates and range from a low of 8.1 pcf (220 pounds/cu. yd; 130kg/m^3) to 22.1 pcf (600 pounds/cu. yd; 356 kg/m^3). However, organic particles readily absorb water so that a compost containing water twice its dry weight will have a wet unit weight that is three times its dry unit weight.

TABLE 4.1: Physical Properties for Connecticut Material

Material	Moisture Content, % (a) by wet weight (dry weight)	Organic Matter Content, % (b)	Dry Unit Weight (pcf) (c)
Manchester Compost	66 (200.0 -- 204.8)	46.7 -- 48.3	20.3 -- 22.1
Glastonbury Wood Mulch	48 (93.7)	60.9 -- 70.4	15.5 -- 16.3
Earthgro Yard Trimmings Compost	40 - 41 (65.3 -- 70.3)	33.6	13.5 -- 16.1
Grillo Compost	53 - 55 (113.2 -- 122.6)	34.3 -- 42.0	14.4 -- 16.5
Grillo "Ecosoil"	48 (93.8)	70.5	29.7 -- 31.6
Grillo "Ecomulch"	60 (151.5)	91.3	8.1 -- 8.8
Windsor Compost	36 (55.9 -- 57.6)	17.0 -- 18.9	not measured
J. Collins Composted Manure	46 - 48 (85.7 -- 94.2)	17.9 -- 29.3	not measured
Agriblends Spent Mushroom Substock Compost	40 (66.3)	19.0	not measured
N.M. Farms Compost	53 (111.9)	44.0	22.8 -- 25.1

(a) by oven drying @ 105 ^{o}C
(b) loss on ignition @ 440 ^{o}C
(c) range for loose and compressed @ 0.5 psi

4.1.4 Product Variability

The variability of material produced by one supplier was examined by selecting five samples of one gallon size from a 4-foot high by 300-foot long windrow of yard trimmings compost at Grillo/ Greencycle in Milford, CT. The five samples were oven dried to determine moisture content, sieved to measure gradation, and burned at 440 ^{o}C for organic matter content. The gradation curves for the five samples are presented in Figure 4.3 and show there is very little variation between samples. The homogeneity of these samples is probably a result of frequent window aeration during composting. The water content and organic matter content data in

Table 4.2 are also typical of a homogeneous material. Yet, because the test specimen size is about 300 g for water content and 50 g for organic matter content, it is possible to have variation introduced by a single large particle. Material which is not frequently mixed or blended during composting would be expected to have more variability.

TABLE 4.2: Variability of Moisture Content and Organic Matter Content for Five Grillo Compost Samples

Sample	Moisture Content (%) Wet Weight (Dry Weight)	Organic Matter Content (%)
1	55 (122.6)	34.3
2	54 (118.8)	41.8
3	53 (113.2)	42.0
4	55 (120.5)	41.6
5	55 (120.3)	47.3
Average / Std. Dev.	54.5/.069 (119.1 / 3.55)	41.4 / 4.63

4.2: Chemical Properties

The CONEG Specifications contain limits for soluble salts by means of a conductivity measurement and for pH with appropriate apparatuses. There was some question about sample preparation for testing. To test the procedure, several samples were prepared with 25, 50, and 100 g of composted material suspended in 500 ml of deionized water. Conductivity measurements were made on liquid after various intervals of time up to one month. It was noted that the conductivity increased over several weeks and that the suspensions containing the 50 and 100 g of composted material appeared to be approaching the same conductivity albeit at different rates. The conclusion was that the equilibrium conditions could be achieved at a faster rate if the suspension were heated for a brief time (10 min.), thereby making the salts present in the compost more soluble. Several samples were tried and it was found that the conductivity remained fairly constant for several days after heating and returning the suspension to a temperature of about 20+/- degrees C. The heated samples were also used for pH measurements, since the suspension, after heating, is probably closer to equilibrium.

Conductivity and pH tests were performed on many samples acquired from producers to compare with the CONEG specifications. The tests were performed on a solution obtained by stirring 50 g of oven-dried compost with 500 ml of deionized water in a beaker. The mixture was heated with a Bunsen burner to a temperature of about 90 ^{o}C for ten minutes to accelerate the chemical equilibrium between compost and water. This process is similar to the Spurway Extraction procedure used for soil chemical analysis (Sparks, 1996). The conductivity probe and pH probe were inserted into the solution as specified by the manufacturer. Conductivity and pH data from these tests are presented on Table 4.3. All materials met CONEG specifications for soluble salts and pH.

At the request of ConnDOT, materials used at the field site were subjected to a thorough chemical analysis to show that no hazardous materials were present prior to use in the field test program. Thus, four subsamples were obtained from each source pile to represent each material: Manchester Compost; Earthgro Compost; Glastonbury Wood Mulch and the base (natural) soil at the site. These samples were oven dried at 105 ^{o}C and sieved through a #40 sieve. A 10 g specimen of the fraction passing #40 sieve was then subjected to a Toxicity Characteristic Leaching Procedure (TCLP) test with the measurement of 25 metals in the leachate. The test results are shown in Table 4.4 where the TCLP metal concentrations are presented in parts/billion and TCLP limits are presented in the bottom row in parts/million for the seven metals where limits exist. The results show that most metals are present in these materials at very low levels and that they are at concentrations significantly below the TCLP limits used to characterize hazardous materials. These results further show, as expected, that the metals concentration in the composts and mulch are about the same as the base soil at the field test site. By far the most abundant metals are sodium, calcium and other soluble elements which have no prescribed limits.

Table 4.3: Conductivity and pH Data for Compost and Mulch Samples.

Material	Conductivity (mmhos/cm)	pH
Manchester Compost	0.34	6.60
Glastonbury Wood Mulch	0.32	6.50
Earthgro Compost	0.38	7.25
Grillo Ecosoil	0.37	7.83
Grillo Ecomulch	0.44	6.23
Windsor Chip Mulch	1.02	7.20
N.M. Farms Compost	3.89	7.51

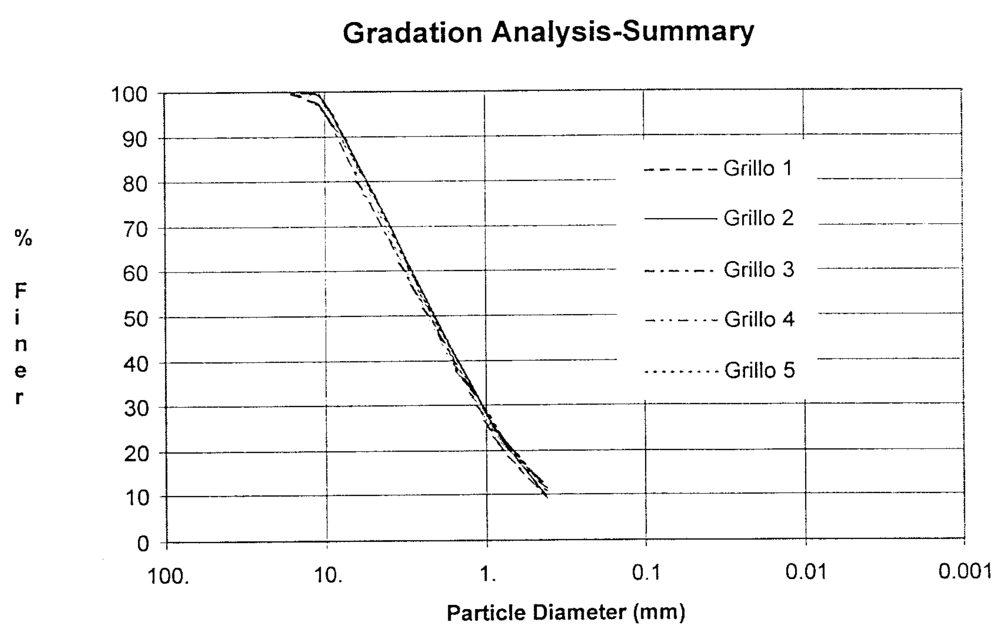

Figure 4.3: Gradation Analyses for Five Grillo Compost Samples

TABLE 4.4: TCLP Test Results For Materials Used At Field Test Site

PROJECT:	DOT COMPOST		
Samp. Received:	10/9/96	Matrix:	TCLP leachate
Samples Prep.:	10/11/96	Prep. Method:	3010
Samp. Analyzed:	10/21/96	Analysis Method:	6010 7000

Sample	Sample	ICP-AES																			GFAA					CVAA
Field ID#	Lab ID#	Ag	Al	Ba	Be	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Ti	V	Zn	As	Cd	Sb	Pb	Se	Hg
GLASTONBURY MULCH	OCT960059	ND	5212	1108	ND	88048	ND	11	125	2775	56032	25660	5263	16	1144700	39	12335	64	14	1042	18	5	ND	71	ND	ND
EARTHGRO COMPOST	OCT960059	ND	1041	632	ND	208050	ND	6	30	649	105816	40921	3976	24	1244400	28	16835	34	6	631	57	ND	ND	40	ND	ND
MANCHESTER COMPOST	OCT960059	ND	634	986	ND	183180	ND	ND	ND	666	82942	63502	9012	34	1122000	58	17138	ND	ND	666	5	ND	ND	29	ND	ND
BASE SOIL at field site	OCT960059	ND	8398	552	ND	19160	ND	ND	18	253	2906	1419	885	ND	1273400	ND	356	ND	ND	299	ND	ND	ND	39	ND	ND
DETECTION LIMIT		1	169	4	9	14	0	0	4	26	260	6	4	3	48	23	232	12	3	18	5	5	5	5	5	0.2
*TCLP LIMIT (X1000 = ppb)		5		100				5													5	1		5	1	

NOTE: All units are in ppb except *
NOTE: ND – Not Detected

*TCLP Limit For Hazardous Waste (ppm) (x1000 = ppb)
*ICP-AES Inductivety Coupled Plasma -- Atomic Emission Spectroscopy
GFAA Graphite Furness Atomic Absorption
CVAA Cold Vapor Atomic Absorption

5. SELECTING COMPOSTED MATERIALS FOR FIELD TESTING

Three different erosion related applications were to be field tested under this project:

1. Slopes to be Mulched Only
2. Slopes to be Mulched and Seeded
3. Organic Material to be used as a filter berm

The composted materials that came closest to meeting the CONEG Specification were:

1. Manchester Yard Trimmings Compost
2. Glastonbury Wood Mulch
3. Earthgro Yard Trimmings Compost

The suitability of these three materials as indicated by CONEG Specifications are shown in Tables 5.1, 5.2 and 5.3. As can be seen from these tables none of the selected materials meets all of the CONEG Specifications. It was decided to try these materials in the field, even though an exact match with the CONEG specifications could not be made, because these materials are typical of the composts and mulches made in Connecticut. Also, the sieve and testing protocols may not be appropriate for these organic materials and, therefore, may not give an accurate indication of field behavior. An example of this dilemma is shown in Figure 5.1. This is a photograph of Glastonbury Wood Mulch. The eye can see many rod-shaped particles having a length between two and three inches. The dimensions in the two perpendicular directions to the length are much smaller than the length. Sifting with screens having square openings, although common, is not appropriate for these materials in that the sifted results in Figure 4.2 indicate that 98% of the particles are less than one inch. The problems with sifting these materials and others of rod shaped particles are discussed in Appendix B.

Table 5.1: Comparison of CONEG Properties with Organic Materials Used as Erosion Control Mulch on Slopes, Mulched Only.

Property	**CONEG Specifications For Slopes to be Mulched Only**	**Manchester Yard Trimmings Compost**	**Glastonbury Wood Mulch**
Organic Matter Content by dry weight	40% -- 60%	46.7-48.3%	60.9-70.4%*
Moisture Content by wet weight (Dry Weight)	< 60% #	66.7-67.0%* (200-204%)	48.4% (93.7)
Particle Size	100%< 3 inches Max. 70%< 2.0 in.	100% < 3 inches 100%<2 inches *	100%<3 inches 100%<2 inches *
Soluble Salts	< 4.0 mmhos/cm(dS/m)	0.3 mmhos/cm(dS/m)	0.3 mmhos/cm(dS/m)
Stability	Stable	Stable	NM
pH	5.5 - 8.0	6.60	6.50

CONEG does not specify basis as either dry weight or wet weight.
Designation with an * indicates that the property did not meet CONEG Specifications.

Table 5.2: Comparison of CONEG Properties with Organic Materials Used as Erosion Control Mulch on Slopes to be Seeded

Property	CONEG Specifications For Slopes to be Seeded	Manchester Yard Trimmings Compost	Earthgro Yard Trimmings Compost
Organic Matter Content by dry weight	40% < Org. <60%	46.7-48.30%	33.60%*
Moisture Content by wet weight (Dry Weight)	< 60% #	66.7%-67.0%* (200-204%)	39.4% (65%)
Particle Size	100%<0.75 inches 70%< 0.50 inches 0.25mm<Max 50%<2.0mm Max 15% < 0.25mm	100% < 0.75 inches 98%<0.50 inches * 0.25mm<60%< 2.0mm * 7%< 0.25mm	100%< 0.75 inches 98% < 0.5 inches* 0.25mm<57%< 2.0mm * 15%<0.25mm
Soluble Salts	< µ 4.0 mmhos/cm(dS/m)	0.3 mmhos/cm(dS/m)	0.4 mmhos/cm(dS/m)
Stability	Very Stable	Stable	Stable
pH	5.5 - 8.0	6.60	7.25

CONEG does not specify basis as either dry weight or wet weight.
Designation with an * indicates that the property did not meet CONEG Specifications.

Table 5.3: Comparison of CONEG Properties with Organic Materials Used as Erosion Control Filter Berm

Property	CONEG Specifications Erosion Control Filter Berm	Glastonbury Wood Mulch
Organic Matter Content by dry weight	40% < Org. <60%	60.9-70.4%*
Moisture Content by wet weight (Dry Weight)	< 60% #	48.4% (93.7)
Particle Size	100%< 3.0 inches Max. 70%< 1.0 in.	100%<3.0 inches 98% < 1.0 inches*
Soluble Salts	≤ 4.0 mmhos/cm(dS/m)	0.3 mmhos/cm(dS/m)
Stability	Stable	NM
pH	5.5 - 8.0	6.50

CONEG does not specify basis as either dry weight or wet weight.
Designation with an * indicates that the property did not meet CONEG Specifications.

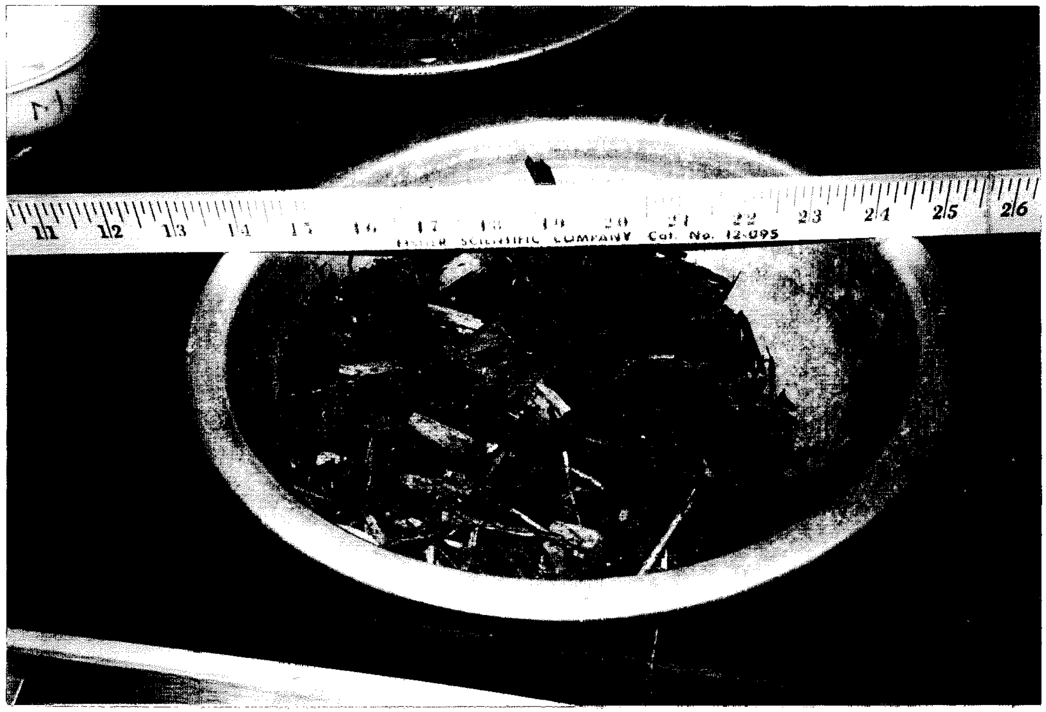

Figure 5.1: Glastonbury Wood Mulch

6. FIELD TESTING OF AVAILABLE COMPOSTED MATERIALS

6.1: General

A field test site was selected on a ConnDOT reconstruction project (#163 - 141) near the northern intersection of Rts. 198 and 6 in Chaplin, CT. Based on the desired combinations of surface treatments to study for erosion prevention, it was decided to install eight test cells. The site was selected because it has a steep slope of two horizontal to one vertical, the steepest soil slope normally used by ConnDOT, and the base soil is a silty - sand. The particle size distribution of this soil is shown in Figure 6.1, and has particle sizes that are easily eroded. The cells were arranged as shown in Fig. 6.2 and were designed to contain the treatments summarized in Table 6.1.

Table 6.1: Surface Treatments Used in the Test Cells.

Cell No.	Surface Treatment
1	Manchester Compost used as mulch
2	Hay and Seed (Std. DOT Treatment)
3	Manchester Compost used as mulch and seeded
4	Glastonbury mulch
5	Control -- no treatment
6	Berm made with Glastonbury mulch
7	*
8	Earthgro Compost used as mulch and seeded

Note: Compost was used in this project as a mulch in that it was placed over the soil and not blended.

* As originally designed, Cell #7 treatment of hydro mulch and seed was to be placed by spray-on machine. Unfortunately there were no locations close by on the construction project that required this treatment and it was too expensive to place the small amount needed for this study. As a result, Cell #7 remained untreated bare ground until the latter part of the study when a 1-1/2 inch (37 mm) layer of composted material, thinner than required by specifications, was applied to determine the effectiveness of thinner treatments of composted material in preventing erosion.

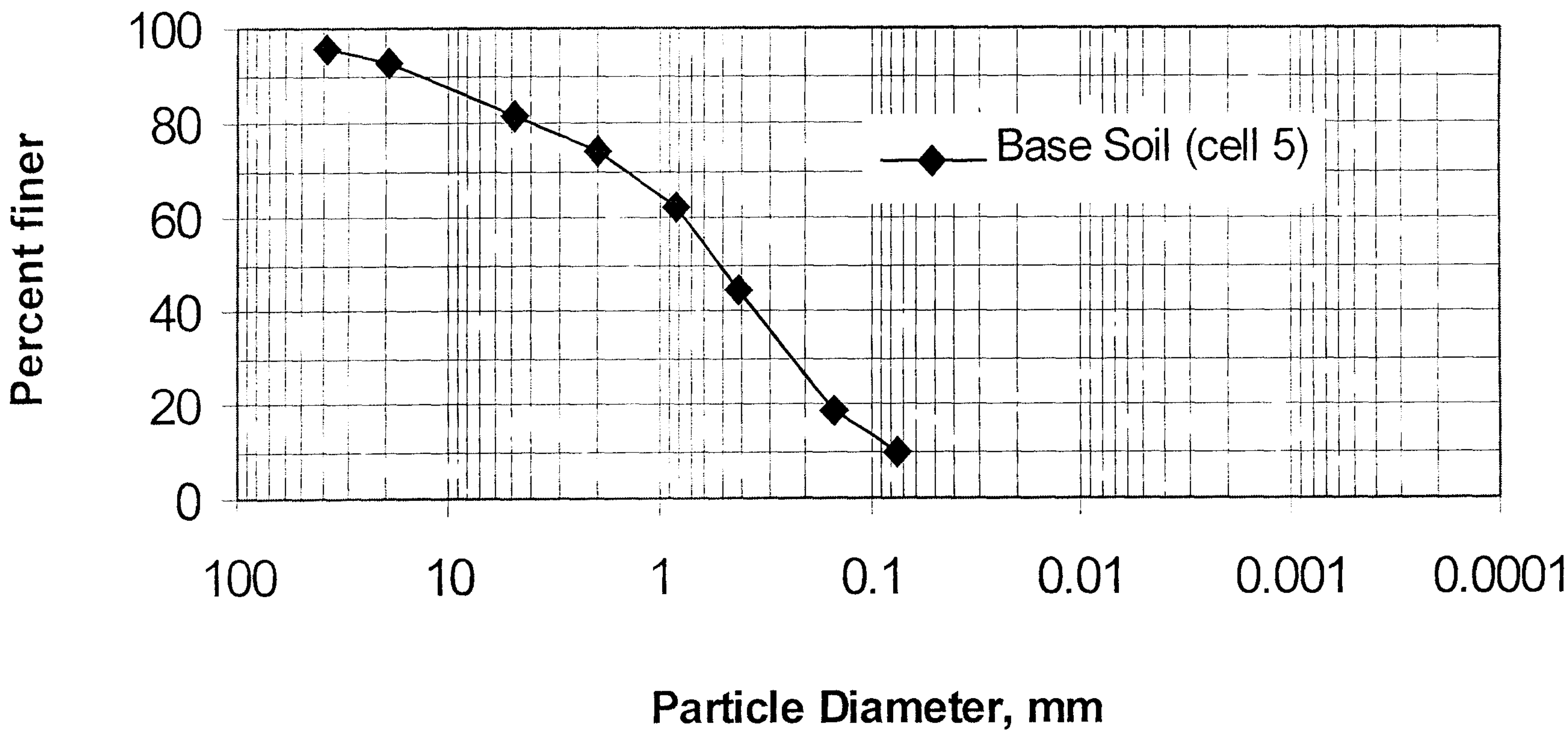

Figure 6.1: Gradation Curve for Base Soil at Field Test Site

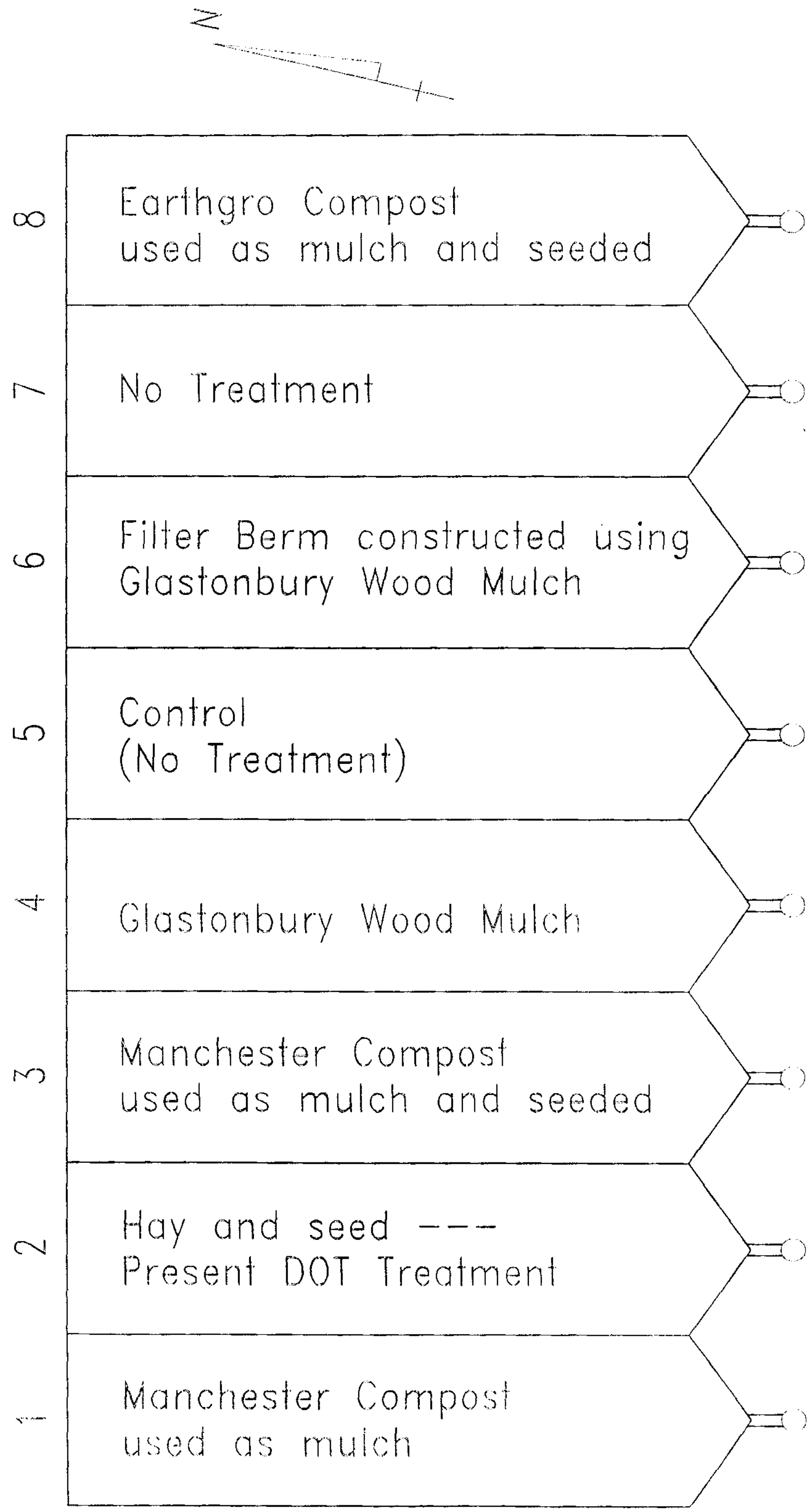

Figure 6.2: Layout of Erosion Test Cells As Built

6.2: Field Testing Program

6.2.1: Design of Test

The test installation consisted of eight test cells on a soil slope at an angle of two horizontal to one vertical and a free standing filter berm at the base of the slope next to the test cells. Each cell was 35 feet (10.7 m) long by 10 feet (3 m) wide with a 3 foot (0.9 m) long apron to collect runoff as shown in Figure 6.3 Cells were separated from each other and the surrounding area by 1 in. x 6 in. (25 mm x 150 mm) boards recessed into the soil about 1.5 inches (38 mm). In the lower 3 foot (0.9 m) apron of each cell, a polyethylene sheet covered the soil so that runoff and the eroded particles could be more readily conveyed to the covered collection buckets at the bottom of the slope. Details of covered collection bucket arrangement are shown in Figure 6.4. The three bucket arrangement for the collection of eroded solids was used in an attempt to determine if there was a difference in materials that eroded early in the storm as contrasted with those that were carried away later in the storm.

A filter berm made from Glastonbury Wood Mulch was field tested in two ways. A quantitative arrangement was set up in Cell #6 as shown in Figure 6.5. A plywood riser was attached to 1 in. x 6 in. boards to develop support for the sides and jute mesh was applied at the end to support the berm, which was placed between the risers to form a slope similar to that specified by CONEG. The end of the cell had the same polyethylene covering of the natural soil as the other cells so any of the eroded materials and runoff water passing through the berm could be collected and analyzed. Also, a qualitative installation was used at the base of the slope to the west of Cell #1. This installation was constructed to observe the behavior of the berm in an environment that approximates its normal use.

Two simple rain gages were used to measure the amount of precipitation falling on the immediate area during each storm.

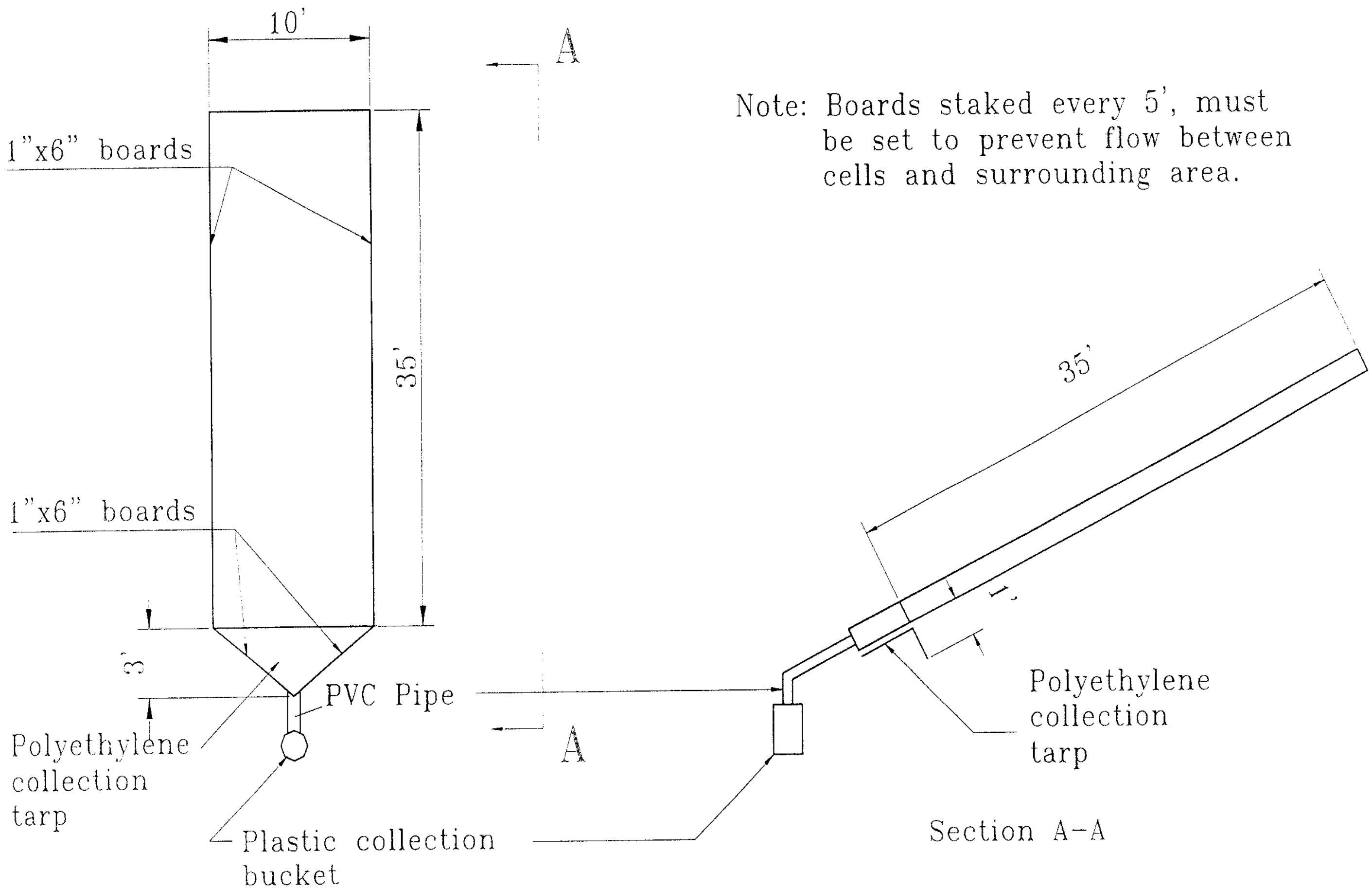

Figure 6.3: Typical Compost Test Cell

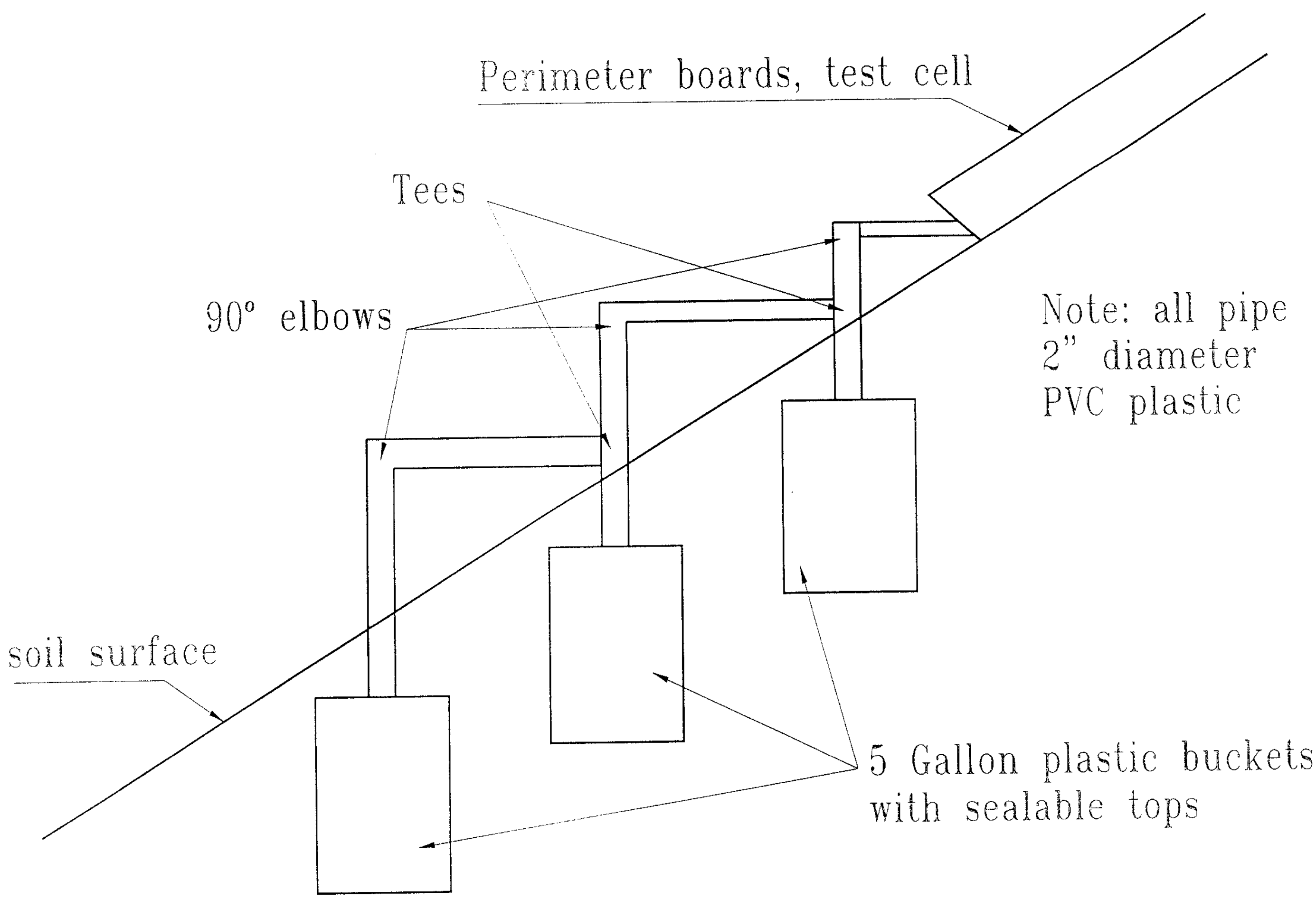

Figure 6.4: Diagram of Collection Bucket Arrangement

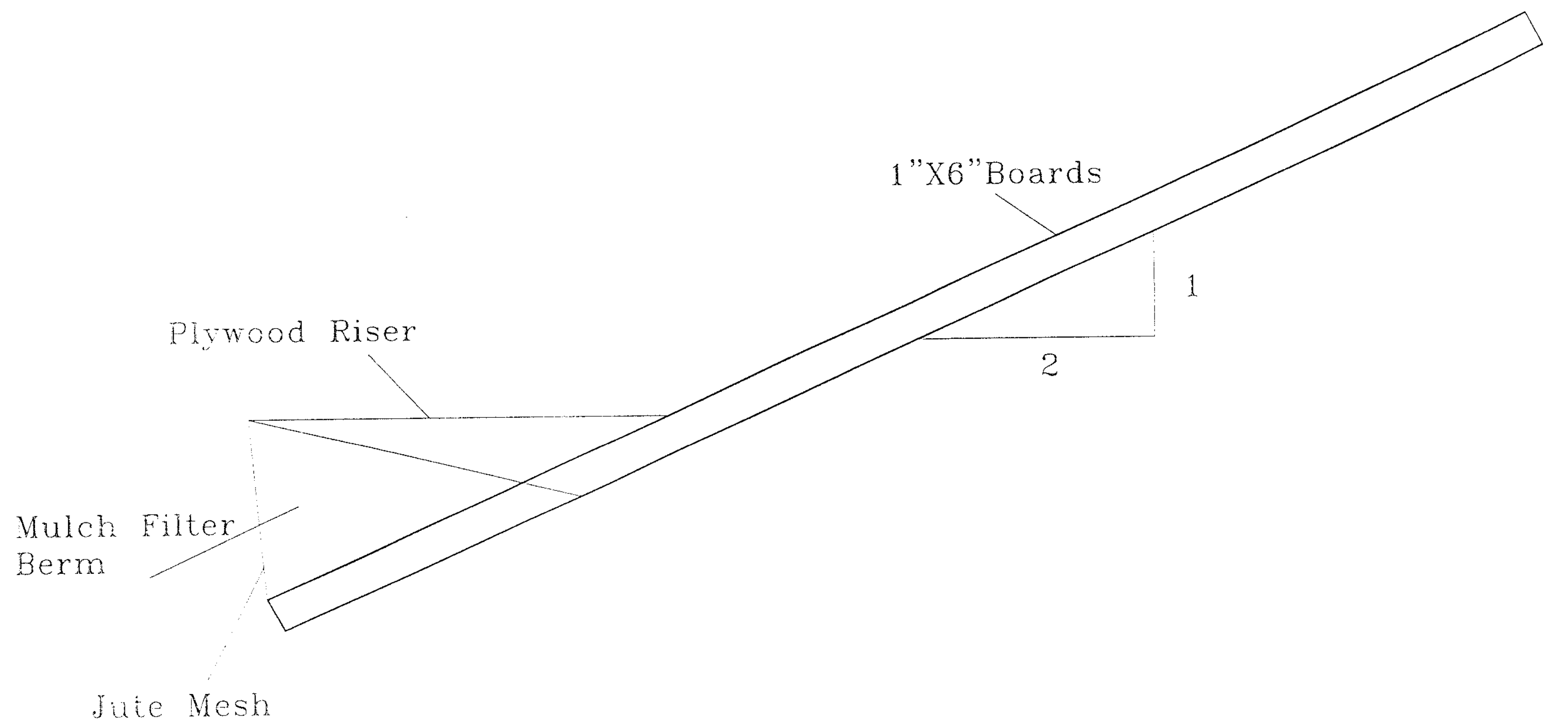

Figure 6.5: Schematic Diagram of Test Cell With Erosion Control Filter Berm

6.2.2: Construction of Test Installation

The test installation was built to specification by the ConnDOT contractor for Project 163-141. The site was visited during construction to insure proper configurations of the cells. Figure 6.6 shows the test cells near the completion of their layout. Figure 6.7 shows the composted materials being placed in their cells. Figure 6.8 shows Cell 6 from above. Note the plywood risers to contain the material on the sides and the Jute Mesh (geosynthetic net) to contain the front.

6.2.3: Behavior of Field Installation During Storm Events

The test installation succeeded in collecting runoff and eroded materials. There were some problems in some cells during certain storms. In these cells, water from the surface of the roadway above found its way underneath the 1 inch x 6 inch boards at the top of the slope and caused additional localized erosion in some of the cells that had no cover, i.e. cells 5, 6, and 7. These cells had untreated base ground. Cell #5 was the control. Cell #7 was left without cover as explained above. Cell #6 had a berm at the bottom of the cell but the slope above was bare. These problems were corrected by placing additional fill behind the boards at the top of the slope and redirecting road runoff. The data from these cells during the extra erosion were not used in the analysis.

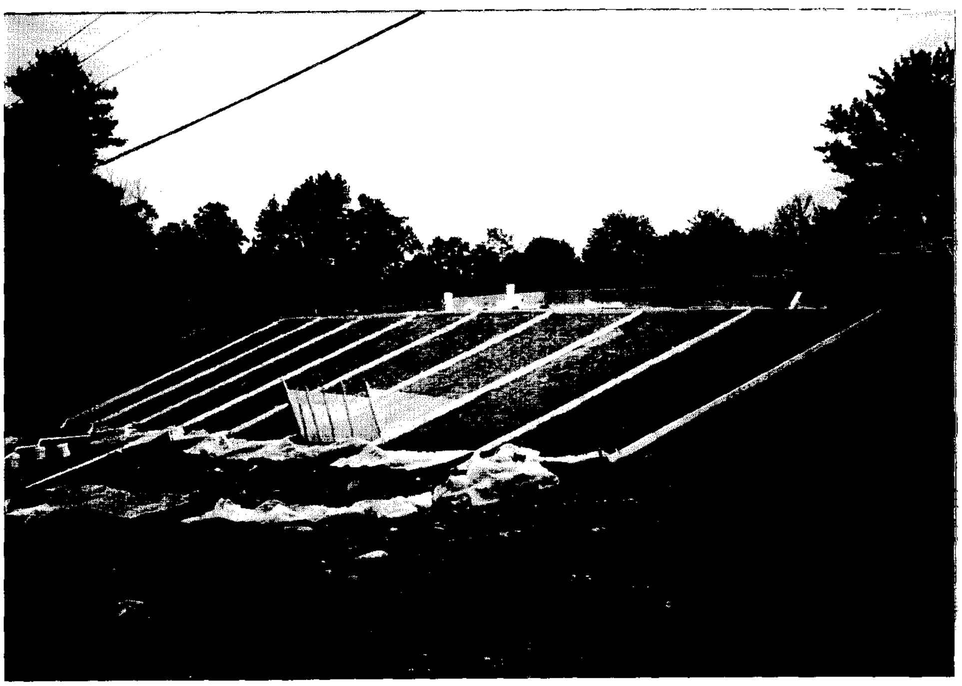

Figure 6.6: Construction of Test Installation Nearing Completion

Figure 6.7: Placement of Composted Material

Figure 6.8: View of Cell 6 from Above Berm

7. RESULTS OF FIELD TESTING

7.1: Storm Event Sampling

Preparation of the test site was completed in early October 1996 and most surface treatments were in place except for Cell 2, Cell 7, as previously discussed, and Cell 5 which was the untreated reference. Hay and seed was applied to Cell 2 on October 17 and seed was also applied to Cells 3 and 8. The seed was not expected to germinate and root at this late point in the growing season. As a result, the late fall storm events were expected to test the erosion resistance of these surface treatments before growth could be established the following spring.

The eight storm events with rainfall of 6 mm (1/4 inch) or more were sampled and the total rainfall for each event are summarized in Figure 7.1. The first six shown are storm events sampled before subfreezing weather arrived during late November 1996. The last two occurred in the Spring, 1997. The rainfall events sampled varied from 6 mm to 110 mm (4.35 inches). While many of the storms were intense, intensity levels could not be measured. Some of the storms were also accompanied by heavy winds. As a result of the combination of wind and runoff, some disturbance or toppling of the runoff collection system was observed and no samples were collected for some cells. In these instances, it was usually the second or third collection bucket that overturned or malfunctioned. Runoff samples collected were described by a letter - number system that includes the test cell, collection bucket and storm date, such as, 3A-11-9 for Cell 3, collection bucket A and the storm on November 9, 1996. The runoff collection buckets were removed for the winter on November 27, 1996 because of subfreezing weather.

The last two storm events were sampled after growth was established in Spring, 1997. Following the dormant winter period, some light maintenance was performed in April, prior to installing the sampling buckets, to cleanup winter erosion deposits, repair cell boards and regrade the untreated surfaces of deep erosion rills. Only one surface treatment (Cell 4) experienced rill erosion during the winter and that was a result of uncontrolled drainage from the road above. It was decided to continue sampling but at a reduced level until the project terminated in early Fall 1997. Only one storm event per 3 month period was to be sampled and only when the rainfall exceeded 13 mm (1/2 inch). Thus, two events were sampled, one in early May and one in mid-July after rainfalls of 14 and 18 mm, respectively.

A day or two after a storm event, the runoff collection buckets were processed. In general, the contents of each bucket was stirred and each subsampled with a one liter polyethylene jar for chemical analysis of water quality. The remainder of each was returned to the lab. In the lab, the contents of each bucket were stirred to create a homogeneous suspension and a pipette specimen withdrawn to determine the suspended solids concentration for each collection bucket. A conductivity probe was also used to determine soluble salt concentration. When two or more buckets contained runoff, the suspended solids concentrations or conductivities were averaged together for the cell. These suspended solids measurements are an indicator of erosion from each cell treatment and storm event. Total runoff was not measured. Following a storm event, each apron was cleaned and all collection buckets were washed and flushed with deionized water before reconnecting to the system in preparation for the next storm.

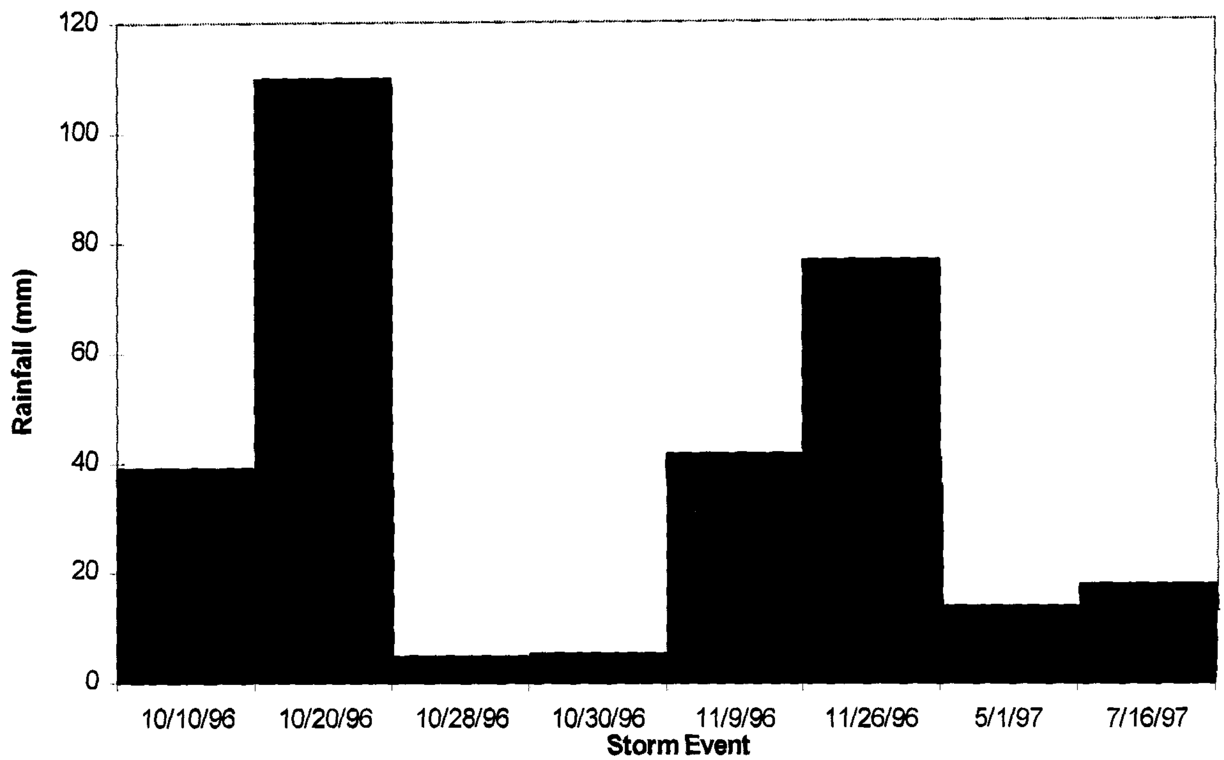

Figure 7.1: Summary of Storm Events Analyzed

7.2: Suspended Solids in Surface Runoff

The performance of various cell surface treatments are displayed by two typical erosion bar charts (Figures 7.2 and 7.3) for the storms on November 9, 1996 and July 16, 1997.

Additional erosion charts are presented in Appendix G and are similar to these test results. Figure 7.2 presents the results from a storm where a heavy rainfall of 41.5 mm (1.63 inch) occurred over a one-day period. The suspended solids concentration in the runoff was very high for the two untreated test cells where over 10 g/l of solids were measured. These erosion levels are more than an order of magnitude greater than the erosion for any of the treated test cells (< 1 g/l) including the present ConnDOT hay and seed treatment. It should be noted that the erosion results for the two untreated cells are usually quite erratic during many rainfalls because the pipes to the runoff collection buckets would choke off with sediment during the early part of the storm. Occasionally, mulch or leaves would obstruct the pipes of the treated test cells but this was generally less a problem than for the untreated cells.

The erosion results shown in Figure 7.3 are for a brief summer rainfall where 18 mm (0.70 inch) fell over a one to two hour period. At this event, grass was well established at the site on cells 2, 3 and 8 and weeds were observed throughout, even on untreated Cell 5. This could account for lower erosion levels discussed later. The previously untreated Cell 7 had been prepared with a 1-1/2 inch layer of Manchester compost about two months earlier which is one-half the treatment thickness of Cell 1. These test results again show high levels of erosion for the untreated Cell 5 of about 4.3 g/l of runoff which is about one order of magnitude greater than for the worst Cell (3) treatment of 0.6 g/l of runoff. While there is a small variation in erosion resistance among the treated cells, there appears to be little correlation to type of treatment, seeding or thickness of treatment. For example, Cell 7 had one-half the thickness of Manchester compost than cell 1, yet both cells had an equivalent loss of sediment. It also appears that rainfall magnitude and intensity affect results since the erosion measured for this storm is about half that shown in Figure 7.2 for a heavier rainfall. The lower erosion levels observed in Figure 7.3 than Figure 7.2 may also be explained by site maturity i.e. an older site is more resistent to erosion because the coarser particles are left behind.

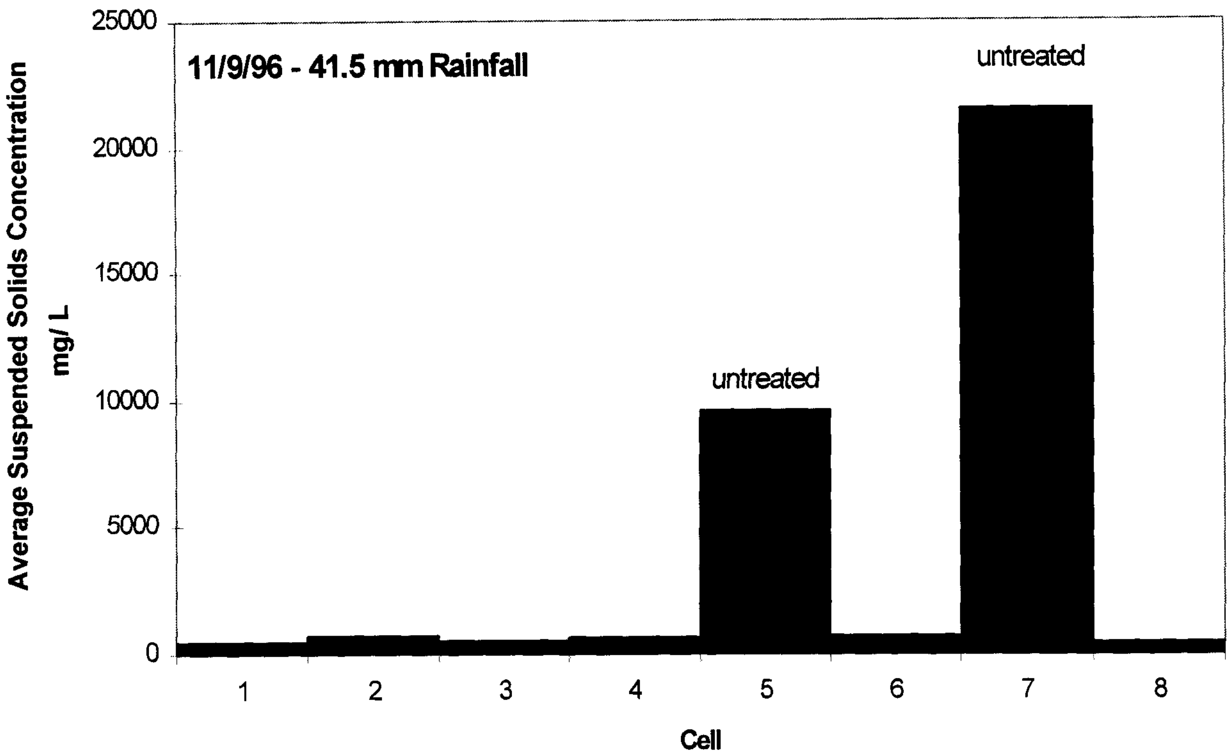

Figure 7.2: Erosion from Test Cells during 11/9/96 Storm

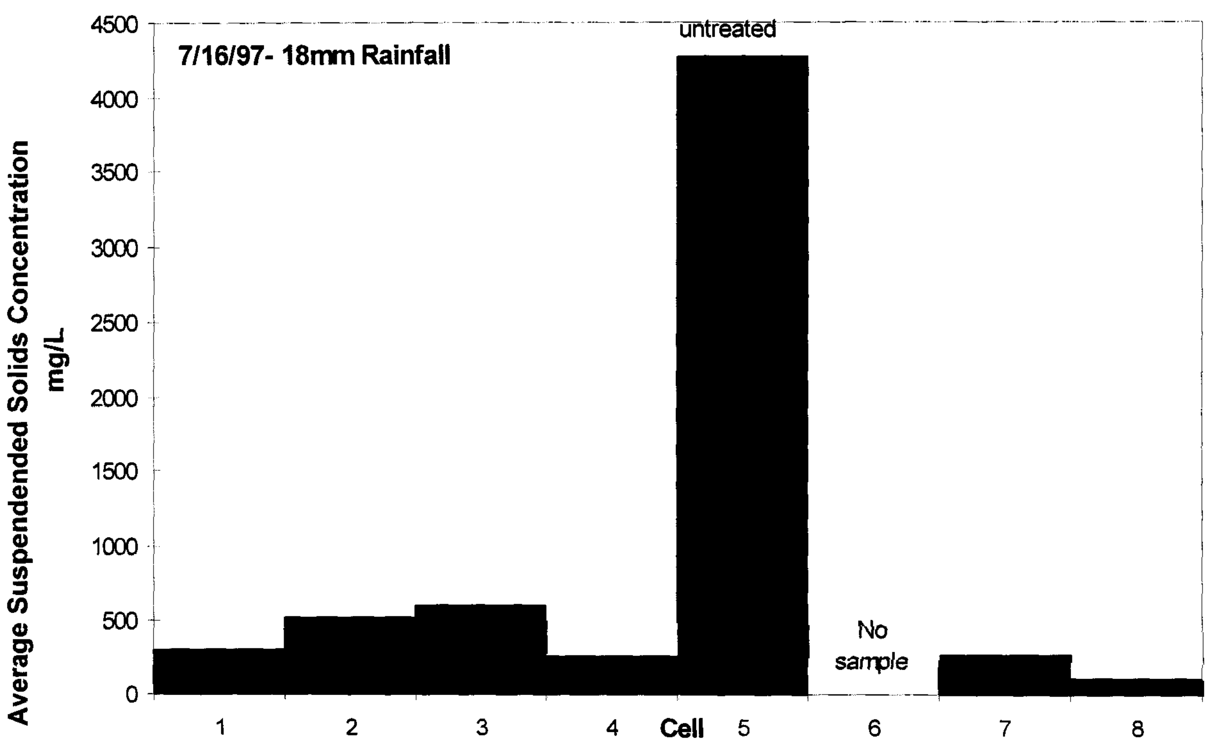

Figure 7.3: Erosion from Test Cells during 7/16/97 Storm.

7.3: Soluble Salts in Surface Runoff

The surface runoff collected from the test cells during each storm was tested for soluble salts using an electrical conductivity probe. Typical test results are presented in Figures 7.4 and 7.5 where the results from each cell can be compared to that of the untreated reference (cell 5) for the rainfall events of 41.5 mm and 18 mm, respectively. The results for additional storm events are presented in Appendix F but are similar to these results. In all instances, runoff from the reference cell had a very low conductivity/ soluble salt content (less than 0.05 mmhos) which was about the same or slightly less than that for any of the other surface treatments. The conductivities measured for these materials are summarized in Table 7.2. The drinking water at the University of Connecticut has a conductivity of about 0.150 mmhos/cm which is about the same as that for runoff from most test cells shown in Figures 7.4 and 7.5. Soluble salts do not appear to be a significant problem.

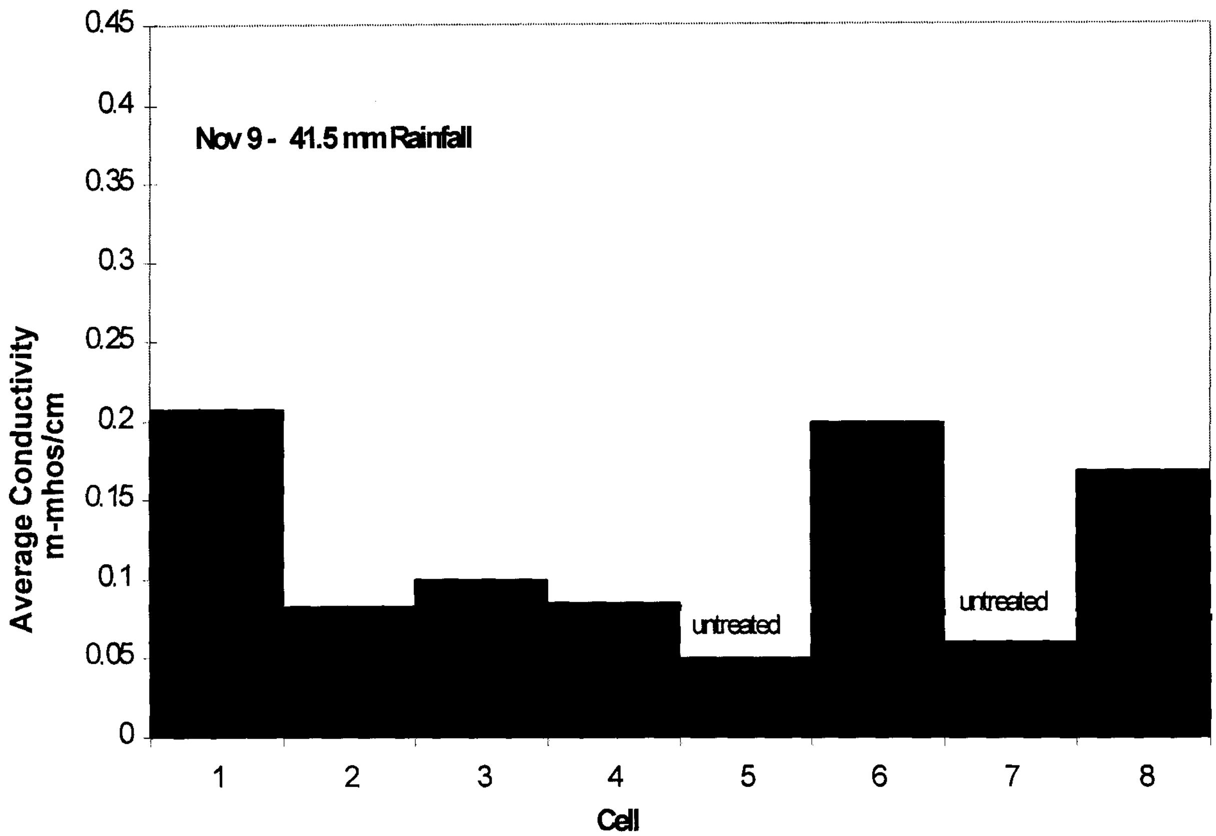

Figure 7.4: Soluble Salts in Runoff for Storm 11/9/96

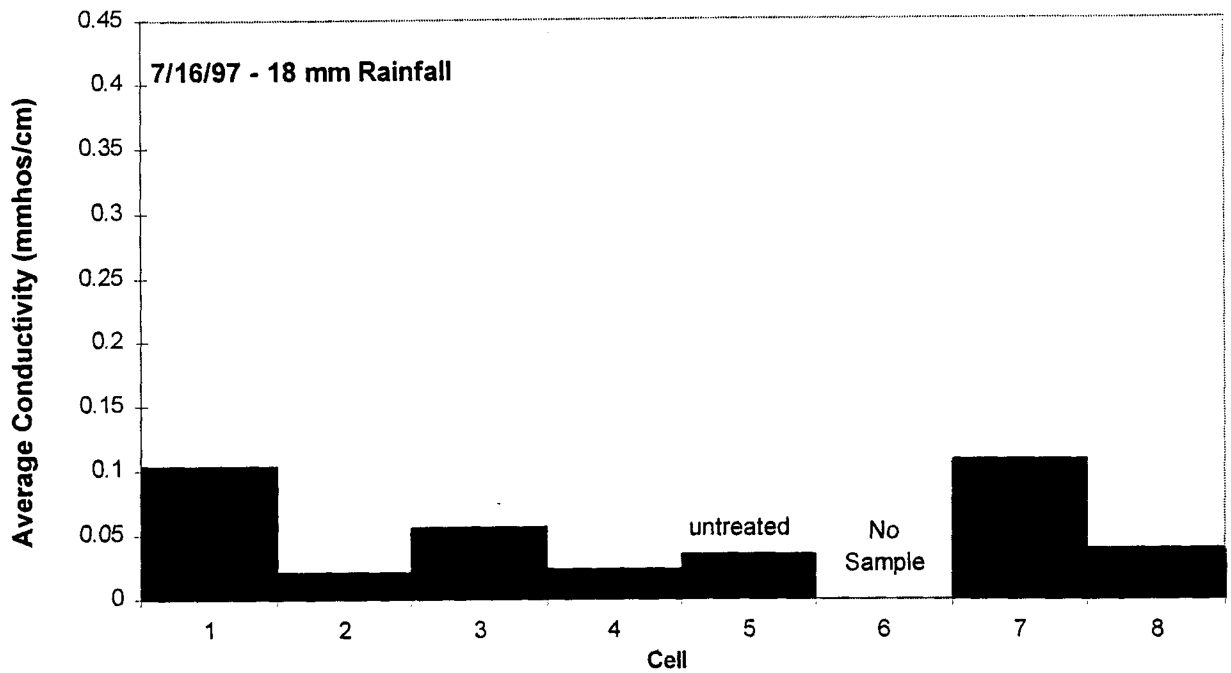

Figure 7.5: Soluble Salts in Runoff for Storm 7/16/97

7.4: Chemistry of Surface Runoff

Chemical analysis of surface water runoff for each of the different surface treatment materials was made to verify that no hazardous metals were present in the runoff and that nutrients were within acceptable limits. While the TCLP test results for metals presented in Table 4.4 shows that all metals are well within TCLP limits, ConnDOT has experienced problems with the metals zinc, lead and cadmium in natural soils at other locations in the state. Therefore, these metals were examined for the storm event on November 9, 1996. The results are presented in Table 7.1 for the different surface treatments where they are compared to the strict Connecticut drinking water standards (DWS). Although no DWS exists for zinc, the runoff concentrations for lead and cadmium are well within the DWS and the concentrations for zinc are low. The analyses show that the runoff from the composts and mulches at the field test site have metal concentrations well below the published limits for hazardous conditions.

Nutrient release from organic materials is a concern when applying composts and mulches to field sites and there are state discharge limits for storm water as well as drinking water limits for nutrients. Nutrient test results are presented in Table 7.2 for the surface runoff samples tested, along with the strict Connecticut drinking water standards, for chloride, nitrite and nitrate. DWS are not available for phosphate and sulfate. Most nutrient concentrations in the runoff are within the state DWS except for the two runoff samples for the Earthgro compost in cell 8 that was collected for the storms on October 10 and October 20, 1996. These were the first two storms to impact the test site after construction and at rainfall levels (39 and 110 mm, respectively) where surface runoff was collected. The chloride levels for these two water samples (cell 8) were also high but within state DWS limits. It is well known that chlorides and nitrates are very soluble and the data in Table 7.2 shows that they are washed from the compost material after two or three heavy rainfalls with only very low residual levels released during subsequent storms. In general, only the Earthgro compost experienced a short-term release of nutrients in runoff at elevated levels.

TABLE 7.1: Metals Analysis of Runoff From Storm (11/9/96)

Sample Field ID#	T/D	ICP-AES*	GFAA*	
		Zn	Pb	Cd
3A-11-8	T	75	8.9	ND
	D	22	2.1	ND
4A-11-8	T	71	3.0	ND
	D	32	2.0	ND
5A-11-8	T	ND	2.9	ND
	D	ND	1.5	ND
8A-11-8	T	45	2.8	ND
	D	ND	2.8	ND
DETECTION LIMIT		20	1.0	0.5
CONN. D.W.S.		---	15.0	5.0

NOTE1	T --- TOTAL (UNITS ARE ppb)
	D --- DISSOLVED (UNITS ARE ppb)
NOTE2	PREP. METHOD 3005 GFAA
NOTE3	ANALYSIS METHOD 6010,7000
* ICP -- AES	Inductivity Coupled Plasma -- Atomic Emission Spectroscopy
GFAA	Graphite Furness Atomic Absorption

TABLE 7.2: **Nutrient Analysis of Storm Water Runoff from Cells 3, 4, 5 and 8**

Method Ion Chromatograph Unit Detection Limit FIELD #	mg/L 0.1 Chloride	mg/L 0.1 Nitrite	mg/L 0.1 Nitrate	mg/L 0.1 Phosphate	mg/L 0.1 Sulfate	mmhos/cm Conductivity
3A-10-10	10.8	6.9	0.6	10.8	1.0	—
4A-10-10	8.4	ND	ND	0.8	0.5	—
5A-10-10	0.2	ND	0.2	ND	0.6	—
8A-10-10	87.9	ND	21.7	8.6	5.9	—
3A-10-20	24.4	1.0	0.8	23.1	4.1	—
4A-10-20	9.2	ND	ND	2.9	3.5	—
5A-10-20	0.3	ND	0.4	ND	0.4	—
8A-10-20	34.4	ND	49.5	6.8	4.7	—
3A-10-24	1.5	1.1	3.5	4.0	2.5	—
4A-10-24	1.4	ND	2.9	0.3	3.7	—
4A-10-24 dup.	1.4	ND	2.7	ND	3.7	—
5A-10-24	0.9	ND	1.3	ND	2.6	—
8A-10-24	1.3	1.1	1.9	2.9	3.2	—
3A-11-09	1.6	0.1	3.6	3.3	2.9	—
4A-11-09	2.2	ND	1.4	ND	3.8	—
5A-11-09	1.2	0.1	4.4	ND	4.4	—
8A-11-09	1.5	0.6	6.4	2.4	4.1	—
3A-5-1	1.77	ND	4.04	0.56	2.73	.052
4A-5-1	1.15	ND	1.97	ND	3.19	.026
5A-5-1	1.62	ND	1.83	ND	3.10	.097
8A-5-1	1.91	ND	4.30	0.68	2.74	.057
3A-7-16	2.20	ND	ND	ND	3.24	.068
4A-7-16	1.77	ND	ND	ND	3.05	.025
5A-7-16	0.85	ND	ND	ND	4.56	.033
8A-7-16	2.20	ND	ND	ND	2.94	.040
CONN. D.W.S.	250	1.0	10.0		**	
		10.0 COMBINED				

** NOT ESTABLISHED

8. ANALYSIS AND DISCUSSION OF FIELD TESTS

8.1: Quantitative Results

8.1.1 Universal Soil Loss Factors

Eroded solids were collected in plastic buckets at the bottom of each field cell. The original three bucket arrangement was found to be unnecessary in that no trends in erosion during the course of the storms were found. After two observations, the remaining storm events were sampled with a single cell-bucket.

After each storm event the bucket was removed, its lid secured and the bucket brought to the lab. Samples of water were removed for conductivity measurements and chemical analysis. The amount of suspended and settled solids were combined for each event for each cell. The amounts for each cell from each storm event were added together. Cells 5 and 7 were considered control cells since in each the surface of the ground was bare. The revised universal soil loss equation (RUSLE) as cited in the literature can be applied to the field data to determine an approximate cover-management factor, C. The RUSLE is:

$$A = R\,K\,L\,S\,C\,P \qquad (8.1)$$

For our application the following factors are the same for all cells:

The rainfall intensity factor, R, is the same for all soils, since the area occupied by the cells is small and it can be assumed that they all received about the same rainfall. The soil in each of the cells is the same so we can assume that, K, the soil erodibilty factor is the same for all the cells. All cells had the same length, L, and steepness, S, so this variable is eliminated for these tests, and the supporting practices factor is assumed equal. We can therefore compare the amounts eroded from each treated cell to the average amount eroded from the control cells based on the cover management factor C, thus:

$$\frac{A_{treat}}{A_{control}} = \frac{C_{treat}}{C_{control}} \qquad (8.2)$$

Taking $C_{control}$ = 1.0 (Israelson et. al, 1980) we can compute the C_{treat} for each treatment as the ratio of the amount eroded from the treated cell to the average amount eroded from the controls. The results are shown in Fig. 8.1. The ratios in Fig. 8.1 are illustrated as C factors for each treatment. As can be seen the composted materials are slightly more effective than the standard hay and seed method as used at present by ConnDOT.

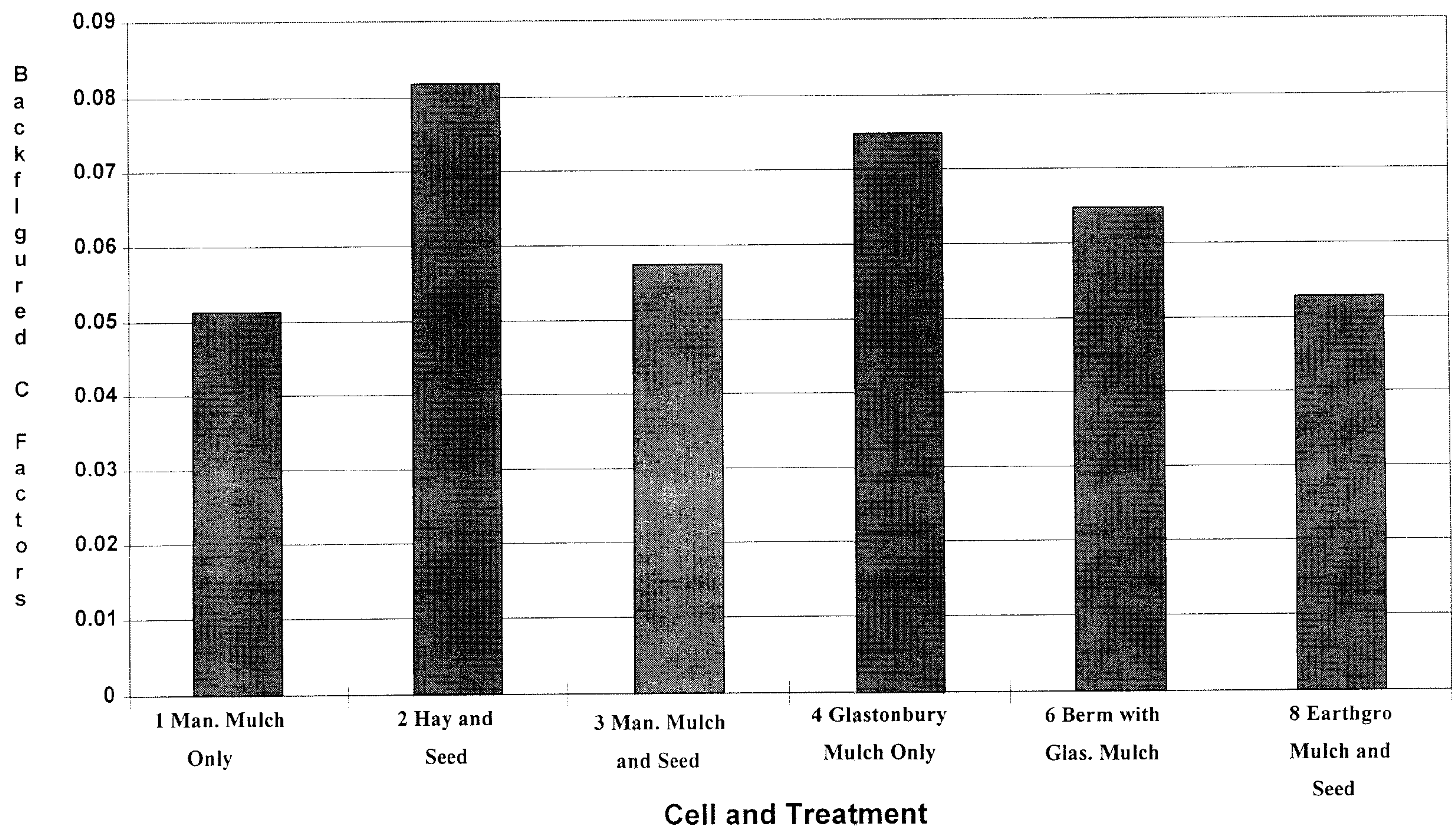

Figure 8.1: Comparison of Suspended Solids Test Cells to Control

8.1.2: Conductivity

The conductivity results from the field cells are shown in Figures 8.2 and 8.3. The data in both graphs show much scatter but general trends can be seen. The horizontal axes represent cumulative rainfall since the field testing began. As can be seen from Figure 8.2, the cells that contain bare ground (5 & 7) have conductivities that increase with cumulative rainfall. The cell containing the berm (6) is included, since most of the cell exposes the rainfall to bare ground and the time that the rainfall is in contact with the composted material in the berm is limited to the time required for water to pass through.

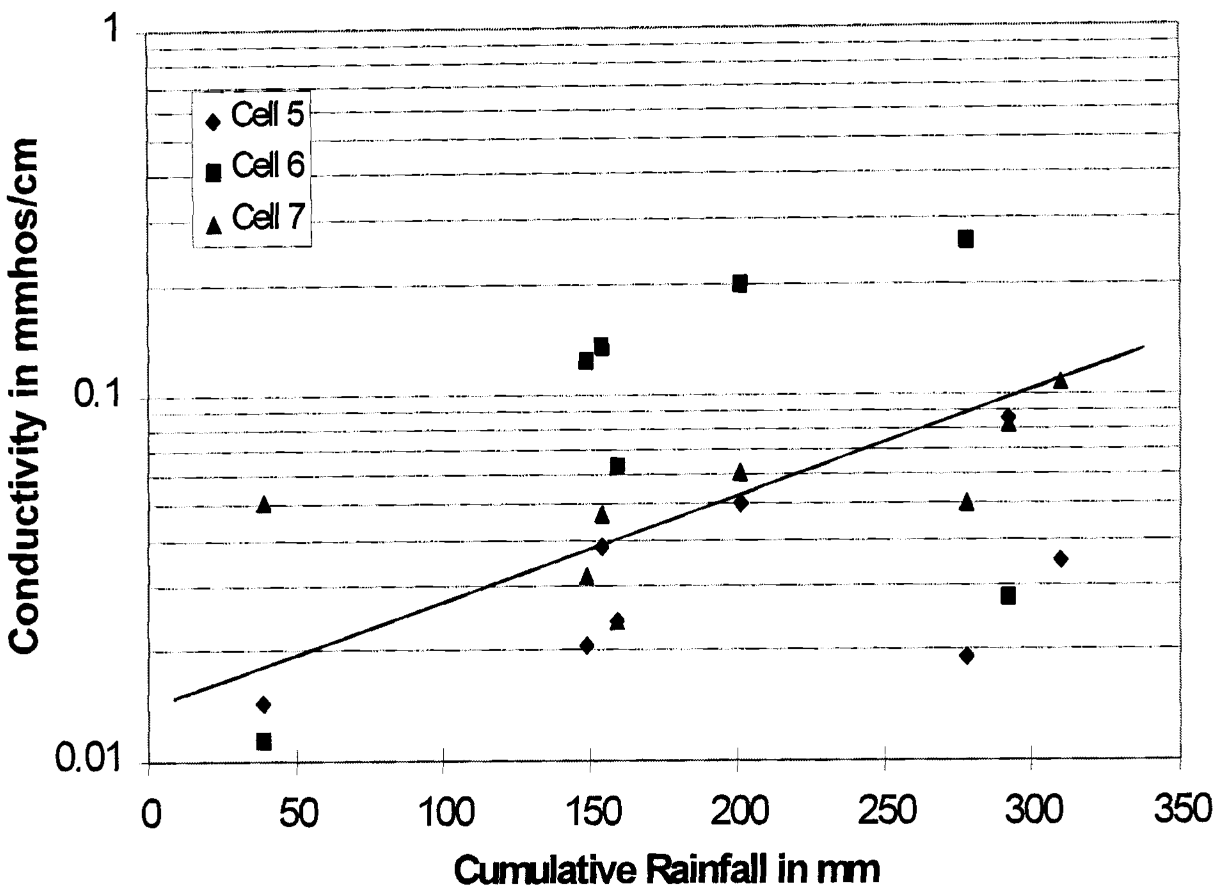

Figure 8.2: Conductivity of Runoff vs. Cumulative Rainfall for Untreated Areas

The conductivity from the cells with the surface treatments tended to decrease with cumulative rainfall as can be seen from Figure 8.3. The runoff from all cells show that the conductivities are tending toward the same order of magnitude.

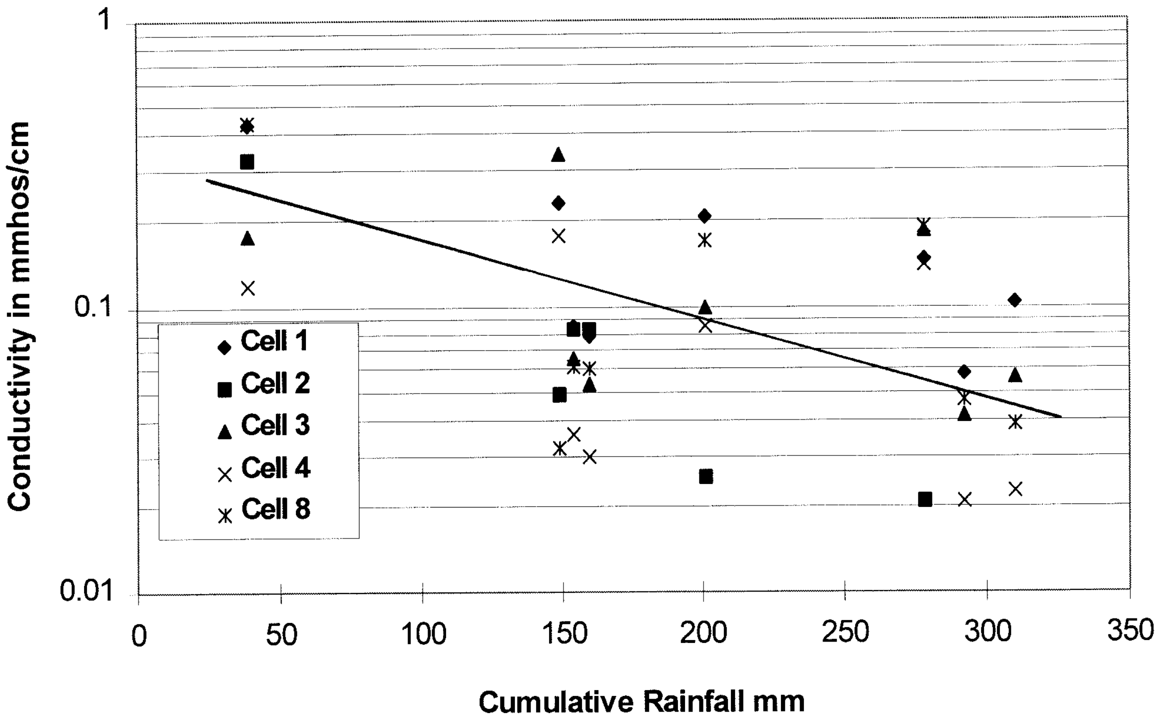

Figure 8.3: Conductivity of Runoff vs. Cumulative Rainfall for Treated Areas

8.1.3: Grass Establishment

Most soil surface treatments used on construction projects by ConnDOT have the long term objective of growing grass. Mulching without seed is used as temporary soil protection when the treatment is applied past the date in the fall of the year on which measurable growth can be expected before winter makes the growing process dormant.

The DOT requirement is that 100 plants per square foot be established in a treated area. Cells 2, 3, and 8 were seeded according to ConnDOT specifications. Grass germination in these cells was checked by counting from three areas of one square foot picked by random number coordinates in each cell during Fall, 1997. The results are shown in Table 8.1. All of the treatments supported sufficient grass growth to pass the DOT requirement.

Table 8.1: Grass Counts for Seeded Test Cells after 10 Months Growth (9/3/97)

Cell Number	Sample *	Plant Count/ Sq. Ft.
2 Hay and seed	1	365
	2	380
	3	340
3 Manchester Compost	1	290
	2	360
	3	306
8 Earthgro Compost	1	180
	2	490
	3	207

* All samples (1 foot square) taken from 3 random locations within each cell.

8.2: EVALUATION OF QUALITATIVE TRIALS

8.2.1: Areas with Thinner Composted Material Covers

Based on the results of the initial trials, it became clear that less than 3 inches of composted cover, as required by CONEG Specifications, would protect the slope. A cover of 1.5 inches of composted material, used as mulch, was tried in cell 7 and a small area adjacent to the cells was covered with 0.75 inches of the same material. No quantitative measurements could be made on the latter area but visual observation showed little, if any, loss due to erosion, indicating that thinner layers of mulch are adequate in some cases. This qualitative test area is shown in Figure 8.4.

8.2.2: Erosion Control Filter Berm

In addition to the filter berm contained in test cell 8, an additional filter berm was constructed just to the west of the test cells at the bottom of the slope using the Glastonbury Wood Mulch. Figure 8.5 shows the berm and the slope above it. Note the erosion rivulets in the slope. Figure 8.6 shows the berm beneath the erosion. Note how the eroded soil was contained by the filter berm. There was no visual evidence of eroded material coming through the berm and no measurements were made. After the field tests were complete, the berm was carefully dissected in the vicinity of the erosion containment. Little to no soil material was found to have penetrated the berm beyond the first 1 or 2 inches. The erosion control filter berm was completely successful.

The CONEG filter berm specifications state that a maximum of 70% of the particles can be less than 1.0 inches, but no minimum is stated. According to these specifications, all of the particles could be between 1.0 and 3.0 inches. For a filter berm to work properly, the eroded soil particles must be held back and the water allowed to pass through. The pores in the filter berm must be smaller than some of the soil particles to retain the eroded soil. This can not be the case unless there are small particles of material in the mulch. The Glastonbury Wood Mulch has sufficient small particles to filter this soil. Laboratory tests indicate that the pores are small enough to contain particles greater than 75μm, which set up an inverted filter in the retained soil.

8.2.3 Establishment of Indigenous Vegetation

Most of the test cells developed vegetation whether or not they were seeded. Figure 8.7 shows the test slope near the end of the project. The presence of vegetation of various types is evident.

Figure 8.4: Area to Which a Thickness of 0.75 inches of Compost was Applied

Figure 8.5: Slope above Wood Mulch Filter Berm

Figure 8.6: Close-up of Filter Berm

Figure 8.7: Test Installation Near the End of Field Observations

9. SUMMARY AND CONCLUSIONS

Summary.

Samples of compost and wood mulch were obtained from eight producers in Connecticut. The samples were subjected to laboratory tests to determine their physical and chemical properties for comparison with the CONEG specifications for compost as an erosion control mulch and for compost as an erosion control filter berm. Three of the products were selected for large scale erosion control testing at a field site with a slope of 2 horizontal to 1 vertical. Eight test cells (10' W x 35' L each) were prepared with different surface treatments including an untreated reference cell and a standard ConnDOT hay and seed preparation. The compost products were used as erosion control berm material and erosion control mulch - with and without seeding. The surface runoff was collected in buckets at the base of the slope for several storm events over a one-year period. Following each storm, the runoff from each cell was analyzed for solids concentration, conductivity, pH, nutrients, and selected samples were subjected to metals analysis.

Conclusions

Based on the laboratory and field test results obtained in this study, the following may be concluded:

1) The physical and chemical properties of compost and mulch vary considerably from producer to producer and depend upon the feedstock and processing. On the other hand, the compost product available from one producer tends to be very homogeneous based on evaluation of product from a one-year period.

2) None of the compost products tested from Connecticut fully satisfies all six of the CONEG specifications for the applications that were studied. Each material tended to be out of spec in one or more of the parameters. However, these materials appeared to function as intended.

3) All of the chemical tests on source-separated compost products show that they are not hazardous and are safe for environmental erosion control applications. While conductivity measurements vary considerably for the different products, most conductivities are at least one order of magnitude less than the CONEG limit of 4 mmhos/cm.

4) For compost used as an erosion control mulch (with or without seeding), a 3-inch CONEG application reduces erosion by more than an order of magnitude compared to an untreated slope with no significant release of nutrients or soluble salts with runoff. These results are about the same to slightly better than the standard ConnDOT method of hay and seed.

5) There are limited test results for the performance of thin applications of compost as an erosion control mulch. The available data show that thin applications may achieve a high level of erosion protection and be more economically competitive with the other available methods such as hay and seed.

6) The erosion control filter berm was very effective at retaining eroded solids from runoff while allowing the water to pass through to a water course. Maintenance of the berm was minimal and this application may be a cost effective alternative to the geosynthetic silt fence.

7) The cells with compost treatment that were seeded produced turf that exceed the DOT minimum specifications.

10. Glossary of Terms

(as used in this document, the source is CONEG, 1996)

Agricultural Residues: organic materials produced as by-products from the raising or growing of plants and animals on farms, feedlots, and forests which may include, but not be limited to manure, bedding, plant stalks, culls, hulls, leaves and vegetative matter.

Compost: stable, decomposed, humus-like organic material produced through composting. It is soil-like in appearance.

Composting: a process of accelerated aerobic biodegradation and stabilization of organic matter under controlled conditions.

Compostable: organic material that can be biologically decomposed under aerobic conditions.

Compostable Material: a material which can undergo physical, chemical, thermal and/or biological degradation under aerobic conditions and result in a humus-like organic material.

Heavy Metals: trace elements whose concentrations are regulated because of the potential for toxicity to humans, animals, or plants, and include arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium and zinc.

Municipal Solid Waste (MSW): wastes from residential, commercial, and institutional sources which are not source-separated and that are commonly disposed of in incinerators or landfills.

pH: a number between 0 and 14, and is a measure of the concentration of the concentration of hydrogen ions in solution; a pH of 7 is considered neutral; a substance that has a pH of 8 has 10 times fewer hydrogen ions than a substance with a pH of 7; the lower the pH, the more hydrogen ions present, and the more acidic the material is; the higher the pH, the fewer the hydrogen ions present, and the more basic (alkaline) it is.

Reuse: municipal solid wastes that may include, but not be limited to, plastics, metal, ceramics, glass, large stones, large pieces of wood, etc.

Recycling: transforming or remanufacturing waste materials into usable or marketable materials for use other than landfill disposal or incineration.

Soluble Salts Concentration: the concentration of soluble ions in a solution, which is measured by electrical conductivity, that is, the ability to carry an electrical current. Electrical conductivity varies both with the number and type of ions contained in the solution, which can indicate potential for phytotoxicity. Soluble salts in a compost will determine its ultimate end use. Each user group (e.g. vegetable growers, nursery industry, etc.) has its own set of salinity standards for growing specific plants or crops.

Source-Separated Compostable Materials (SSCM): organic material that has been separated from non-compostable material at the point of generation and may include, but not be limited to, food scraps, food processing residue, soiled or unrecycled paper, and leaves.

Stability: a state in the decomposition of organic matter during composting and is a function of biologic activity. Unstable compost, when applied to soil, could result in microbial activity which increases soil carbon dioxide and decreases oxygen. If stored, unstable, active compost can become anaerobic if not aerated and give rise to nuisance odors and can create organic phytotoxins.

Yard Trimmings: vegetative matter resulting from landscaping maintenance or land clearing operations and includes materials such as leaves, tree and shrub trimmings, grass clippings and weeds.

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APPENDICES

Appendix A: Excerpt from "CONEG Model Procurement Specifications for Source-Separated Compost" (sections on erosion control mulch and erosion control filter berm)

V. SPECIFICATIONS FOR COMPOST USED AS AN EROSION CONTROL MULCH (C.E.C.M.)

1. DESCRIPTION

This work shall consist of furnishing and placing approved composted erosion control mulch (C.E.C.M.) on designated slopes and other environmentally sensitive areas (i.e., next to streams, rivers, lakes and other bodies of water) in reasonably close conformity with the thickness called for on the plans, specifications or as directed by the project engineer. The function of this specification is to prevent erosion by dissipating the erosive energy of raindrops, help keep run-off water in sheet flow, protect the soil surface on a temporary basis and promote the establishment of vegetation. Exemptions to these specifications may be approved for specific applications based on review and possible on-site conditions.

2. MATERIALS

Compost shall be an organic substance produced by the biological and biochemical decomposition of source-separated compostable materials, separated at the point of waste generation, that may include, but are not limited to, leaves and yard trimmings, food scraps, food processing residues, manure and/or other agricultural residuals, forest residues and bark, and soiled or unrecyclable paper.

2.1 C.E.C.M. (for slopes to be mulched only) shall consist of coarse composted source-separated materials such as clean wood, bark and other materials that meet the testing parameters outlined below. C.E.C.M. shall be biodegradable within three (3) years, but without substantial degradation over a period of five (5) months. It shall be capable of being applied evenly to provide 100% initial soil coverage, adhering to the soil surface, not slipping on slopes during rain or when watered, not blowing off site, and dissipating raindrop splash. Compost used to manufacture erosion control mulch shall be reasonably free of refuse (subject to the approval of the project engineer), other physical contaminants, and any material toxic to plant growth. C.E.C.M. shall meet the following additional specifications:

A) Organic matter content shall be between 40 – 60% (dry weight basis) as determined by loss on ignition;

B) Moisture content shall be < 60% and the product shall be loose and friable, not dusty;

C) Particle size shall be:

1. 100% < 3.0 inches
2. Maximum 70% < 2.0 inches

D) Soluble salts content shall be < 4.0 mmhos/cm (dS/m);

E) Stability – mulch/compost shall be stable according to an acceptable testing method (see Appendix B); and

F) pH shall be between 5.5 – 8.0.

2.2 C.E.C.M. (for slopes to be seeded) shall consist of composted source-separated organic by-products comprised of any of the following; leaf and yard trimmings, clean wood, bark and other materials that meet the testing parameters below. C.E.C.M. shall be biodegradable within three (3) years, but without substantial degradation over a period of six (6) weeks. It shall be capable of being applied evenly, adhering to the soil surface, not slipping on slopes during rain or when watered, not blowing off site, dissipating raindrop splash, holding moisture, and moderating soil temperature. Compost used to manufacture C.E.C.M. shall be reasonably free of refuse (subject to the approval of the project engineer), other physical contaminants, and any material toxic to plant growth. Erosion control mulch shall meet the following specifications:

A) Organic matter content shall be between 40 – 60% (dry weight basis) as determined by loss on ignition;

B) Moisture content shall be < 60% and the product shall be loose and friable, not dusty;

C) Particle size shall be:

1. 100% < .75 inch;
2. 70% < .50 inch;

maximum 50% between .25 – 2.0mm

maximum 15% < .25mm:

D) Soluble salts content shall be < 4.0 mmhos/cm (dS/m);

E) Stability – mulch/compost shall be very stable according to an acceptable testing method (see Appendix B); and

F) pH shall be between 5.5 – 8.0

3. <u>CONSTRUCTION REQUIREMENTS</u>

Only slopes with a 2-1 grade or flatter and that are greater than 100 feet from a stream, river, lake, wetland, or other body of water or greater than 300 feet from a drinking water source (unless otherwise permitted) will be acceptable for spreading C.E.C.M. Spreading should be performed to ensure adequate compaction and contact with underlying soil; the project engineer may require additional compaction if needed.

On slopes to be seeded, C.E.C.M. shall be spread evenly and uniformly three (3) inches deep on prepared areas as designated by the plans or specifications. After the mulch is applied and at the time of seeding, the seed shall be mulched or raked as specified to ensure seed germination. All stones or other debris larger than two (2) inches in diameter shall be removed from the ground.

4. <u>METHOD OF MEASUREMENT</u>

Standard state language such as:

Composted erosion control mulch will be measured by the cubic yard complete in place after finishing to the required depths shown on the plans, specifications or directed by the project engineer. Cubic yards will be determined by actual surface measurements of the lengths, widths, and depths of the mulched areas.

5. BASIS OF PAYMENT

Standard state language such as:

The accepted quantities of C.E.C.M. will be paid for at the contract unit price per cubic yard.

Payment shall be full compensation for furnishing, placing and maintaining the C.E.C.M.

Pay Item	Pay Unit
(______) Composted Erosion Control Mulch	xxx cubic yards

VI. SPECIFICATIONS FOR COMPOST USED AS AN EROSION CONTROL FILTER BERM (E.C.F.B.)

1. DESCRIPTION

This work shall consist of furnishing, installing, maintaining and removing a water permeable windrow of a composted mulch to remove suspended soil particles from water moving off-site and into the adjacent waterways, as required by the plans, specifications, or as directed by the project engineer.

2. MATERIALS

Compost shall be an organic substance produced by the biological and biochemical decomposition of source-separated compostable materials, separated at the point of waste generation, that may include, but are not limited to, leaves and yard trimmings, food scraps, food processing residues, manure and/or other agricultural residuals, forest residues and bark, and soiled or unrecyclable paper.

Erosion control filter berm (E.C.F.B.) shall consist of coarse source-separated compost including clean wood, bark and other materials that meet the testing parameters outlined below. Compost used to manufacture E.C.F.B. shall be reasonably free of refuse (subject to the approval of the project engineer), other physical contaminants, and any material toxic to plant growth. Erosion control filter berm shall meet the following additional specifications:

A) Organic matter content shall be between 40 – 60% (dry weight basis) as determined by loss on ignition;

B) Moisture content shall be < 60% and the product shall be loose and friable, not dusty;

C) Particle size shall be:

1. 100% < 3.0 inch;
2. Maximum 70% < 1.0 inch;

D) Soluble salts content shall be ≤ 4.0 mmhos/cm (dS/m);

E) Stability – compost shall be stable according to any of the testing methods outlined in Appendix B;

F) pH shall be between 5.5 – 8.0.

3. CONSTRUCTION REQUIREMENTS

3.1 General. The size of the berm and its contributing drainage area shall be determined by an engineering analysis which includes structural stability of the berm based on the material used and the maximum hydraulic loading. Should a filter berm structurally fail, it could create a greater potential for pollution than the sediments which the berm is intended to control. The E.C.F.B. shall be placed uncompacted in a windrow at locations shown on the plans or as directed by the project engineer. The Berm shall be a minimum of 12 inches in height and a minimum of 48 inches in width. Apply the E.C.F.B. by bucket loader. Rounded shaping is to be done by hand.

3.2 Maintenance. The contractor shall maintain the erosion control filter berm in a functional condition at all times and it shall be inspected after each rainfall and at least daily during prolonged rainfall. All deficiencies shall be immediately corrected by the contractor. The contractor shall make a daily review of the location of the berm in areas where construction activity causes drainage runoff to ensure that the berm is properly located for effectiveness. Where deficiencies exist, additional berm material shall be installed as approved or directed by the project engineer. Setbacks shall be 100 feet from a stream, lake, or other body of water and 300 feet from a drinking water source (unless otherwise permitted).

Sediment deposits shall be removed when directed by the project engineer. Any sediment deposits remaining in place after the berm is no longer required shall be graded to conform with the existing ground, seeded and mulched immediately.

E.C.F.B. may stay in place indefinitely regardless of whether it is needed, at the discretion of the project engineer. The berm material shall be removed, however, when:

a. The material has decomposed, become clogged with sediment, eroded, or become ineffective; or

b. The E.C.F.B. is no longer needed and the project engineer has directed that it should be removed.

When the material is removed, it shall be distributed over an adjacent area not to exceed a depth of three (3) inches and immediately seeded and mulched.

4. METHOD OF MEASUREMENT

Standard state language such as:

Erosion control filter berm will be measured complete in-place after finishing to the required depths shown on the plans, specifications, or as directed by the project engineer. Cubic yards will be determined by actual surface measurements of the lengths, widths and depths of the mulched areas.

5. BASIS OF PAYMENT

Standard state language such as:

The accepted quantities of E.C.F.B. will be paid for at the contract unit price per cubic yard. Payment shall be full compensation for furnishing, placing, maintaining, and removing the E.C.F.B. material.

Pay item	Pay Unit
(______)Erosion Control Filter Berm	xxx cubic yards

Appendix B: Measuring Particle Sizes

INTRODUCTION

The Model Procurement Specifications for Source Separated Compost prepared for the Northeastern States by the Coalition of Northeastern Governors Source Reduction Task Force, February, 1996, do not contain testing protocols for measuring the particle sizes present in wood mulch. Typical wood mulch material tested in this project can be seen in Figure B.1. One can see particles with long dimensions that are greater than two or three inches, and that the particles are rod-like. The length is much greater than the dimensions perpendicular to it. A few of the larger particles have been removed and are shown in Figure B.2 so that the shape can be seen more clearly.

Although the CONEG Specs do not contain a particle size testing protocol, the stated size requirements are quite specific. For example, the size specification for Compost to be Used as an Erosion Control Mulch for slopes to be mulched only (not seeded) states:

100% < 3.0 inches;
maximum 70% < 2.0 inches

This specification indicates that there must be at least 30% of the particles between 2 and 3 inches in size. The mulch from which the particles in Figure B.2 were taken, prevents erosion in the field. It is the size of the particles in this mulch that makes it successful, sizes that are better defined by the length of the particles than the diameter.

Particle size is not the only way to specify mulch. It could also be done by pre-approving the source through a visual inspection by an agent of the purchasing organization, which is a method that is apparently used by the Maine DOT. Regardless of the method used it must be clear to both owner and contractor as to the method by which an acceptable product will be recognized. If it is to be through a specification, the first items to be determined are the characteristics that show a mulch will be successful in a specific application, after which a testing protocol must be developed that will select those mulches that will be successful and reject those that will not give a satisfactory performance. It is with the assumption that the method of using specifications is desired, that prompted an attempt to devise a method that would separate the sizes of a mulch according to the dimension of the individual particles that indicate success.

LIMITATIONS OF STANDARD SOIL SIEVES FOR MEASURING PARTICLES SIZES IN WOOD MULCH

The most efficient method of measuring particle size distributions in bulk materials when the particles are visible to the naked eye is sifting. Standard sieves have square holes formed by wire mesh. One of the more common applications of sifting engineering materials involves soils, especially sands. Sieves work well for sands, because sand particles have dimensions in three orthogonal directions that are approximately the same. The sorting during sifting relates the particle size to the length of one side of the square in the meshes of the smallest sieve through which the particle passes and the largest sieve on which it is retained.

Figure B.1: Glastonbury Wood Mulch

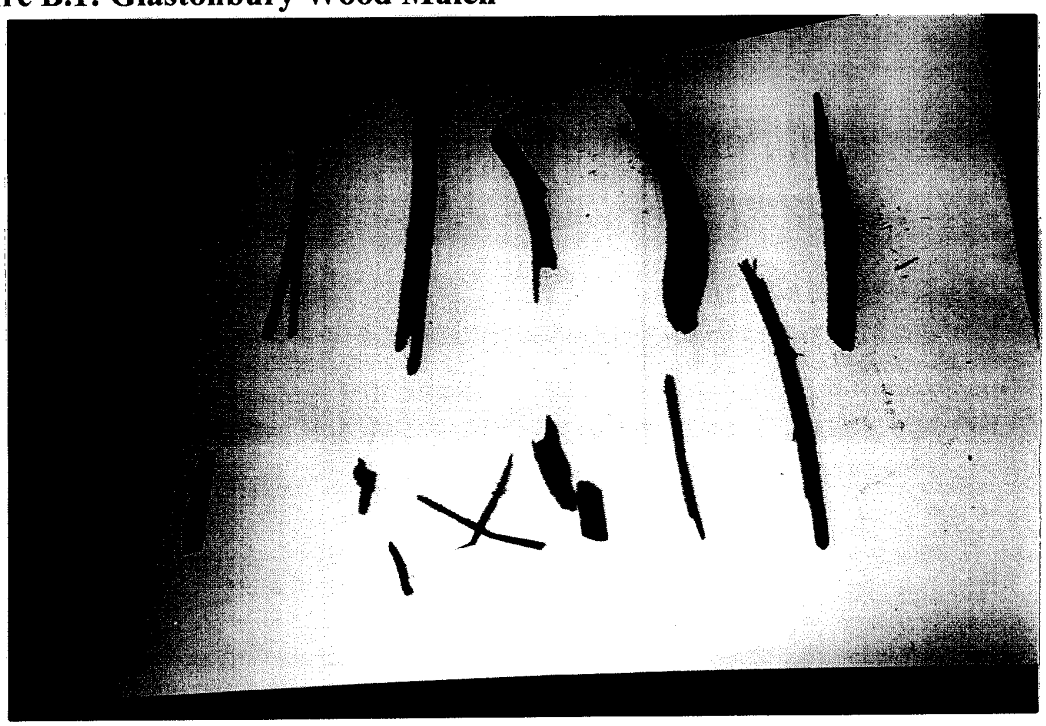
Figure B.2: Example of Rod-Shaped Particles

When the particles are not equidimensional the size by which the particles are sorted becomes less clear. The extremes in particle shapes can be envisioned as a particle with dimensions in two orthogonal directions about equal and the dimension in the third direction greatly different. If the third dimension is much smaller than the other two the particle can be described as plate shaped. If the third dimension is much larger than the other two, the particle has the shape of a rod.

Standard sieves are not as accurate in separating the rod-like particles found in wood mulch. The tapping during the sifting process gives the particles vertical motion allowing them opportunities to drop through the sieve mesh in various orientations. For rod-like particles in a standard sifting procedure the particles tend to separate according to the smallest dimension, the diameter. New sifting protocols may be needed if the wood mulch is to be separated into sizes that reflect its field behavior

DIFFICULTIES

The currently available wood mulch for erosion control in Connecticut do not meet the CONEG criteria by sifting with square opening sieves in the standard shaking device. Visually, the material has particles with the long dimension in the desired size range, but being rod-shaped they fall through sieves more closely sized to the much smaller diameter. Several controlled tests were conducted using wood dowels and a sieve containing round holes as shown in Figure B.3. In this demonstration, the particles were rolled across the round openings. This demonstration showed that particles in this arrangement were separated by their long dimension but they fell though an opening whose diameter was approximately one-half the length of the rod.

SOLUTION

As a result of these demonstrations a special sieve arrangement was constructed as shown in Figure B.4. This arrangement consists of a line of round-holed sieves of increasing opening

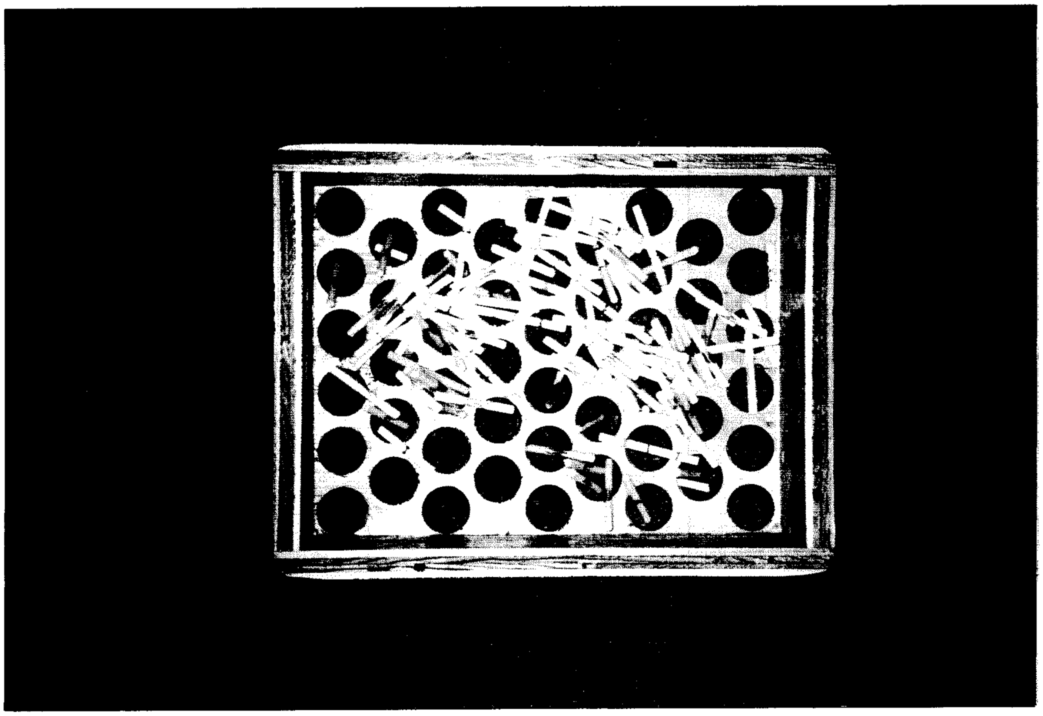

Figure B.3: Test Box for Measuring Largest Dimension of Particles

Figure B.4: View of Round-Holed Sieves from Smallest to Largest

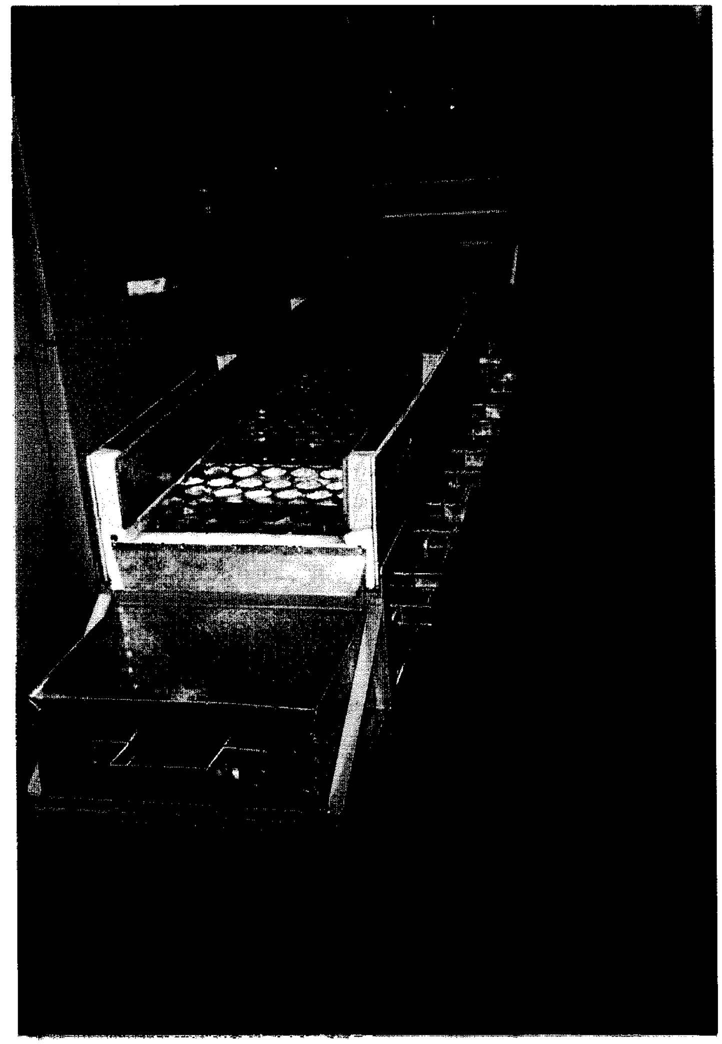

Figure B.5: View of Sifting Apparatus from Large Holed End size. The sample of wood mulch is deposited in a thin layer at the end with the sieve having the smallest opening size, them broomed across the line of sieves. The smallest particles fall out first and, as the wood mulch moves across the sieve line larger particles are removed until the particles over three inches long are caught at the end of the line. A view of the entire sieve arrangement is shown from the end with large holes in Figure B.5. Also seen in Figure B.5 are the drawers into which the particles fall after passing through the sieve. The drawers are removed for weighing the material. The container on the end catches the pieces that are greater than 3 inches.

The sizes of sieves in the line are as follows:

Opening Size	Largest Particle Falling Through	Designated Size Range
0.25"	0.5"	D<0.5"
0.38"	0.75"	0.5"<D<0.75
0.5 "	1.0"	0.75"<D<1.0
1.0"	2.0"	1.0"<D<2.0"
1.5"	3.0"	2.0"<D<3.0"
		3.0"<D

A comparison of the particle size distribution of a sample of the Glastonbury Wood Mulch sifted two ways is shown in Figure B.6. To pass CONEG specifications, the particle size distribution curve must lie outside of the cross-hatched area shown in B.6. This sample of wood mulch sifted using standard sieves is represented by the square data point and lies mostly in the shaded area. Analyzed by the round sieve procedure outlined here, the particle size distribution is shown with the diamond data points and grazes the corner of the shaded area. The Glastonbury Wood Mulch performed well in the field erosion prevention tests.

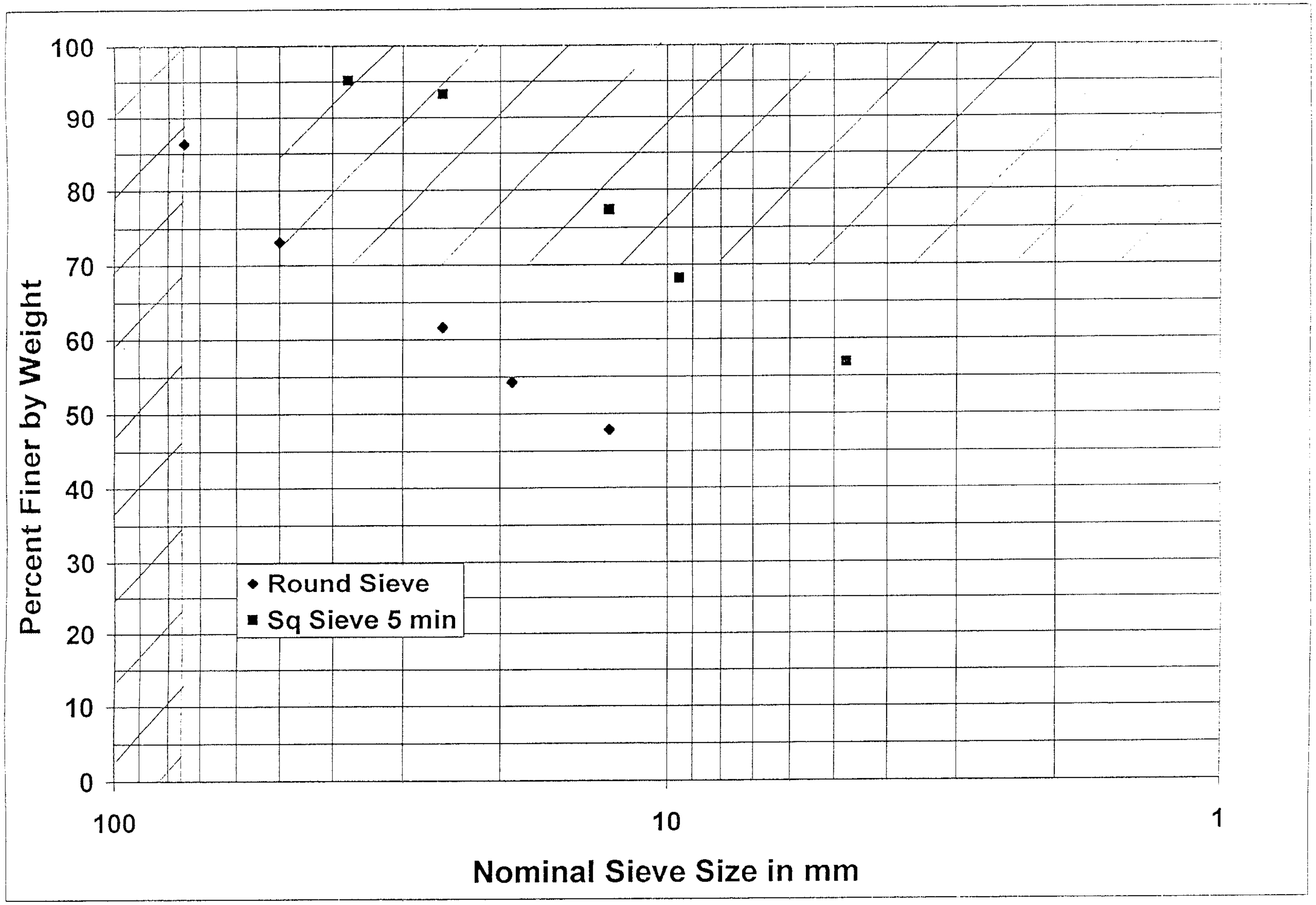

Figure B.6 Sifting Results Using Square and Round Holes

Appendix C

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Appendix D: CONEG Specification Problems and Suggested Solutions

This attempt to apply the CONEG Model Procurement Specifications for Source-Separated Compost raised many questions. This appendix focuses on the most important of these questions. The root of the problem is that the CONEG Specifications list limits but cite no testing protocols. Many of the composted products and mulches in Connecticut do not appear to meet the CONEG Specs. when existing standard tests methods are used. Yet, the "failed" materials that were used in the field tests on a construction site performed well in preventing erosion. Having specifications and testing protocols that allow potential users to develop confidence in selecting the correct compost or mulch to achieve the intended result will broaden and increase the use of these materials.

The CONEG specifications that require clarification are as follows.

ORGANIC MATTER CONENT

A) The specifications require the Organic Matter Content to be between 40 - 60% (dry weight basis) as determined by loss on ignition. The appropriate ASTM test D2974 method A Standard Test Methods for Moisture, Ash and Organic Matter of Peat and Other Organic Soils is not specified by CONEG but it seems appropriate for composts and mulches.

Commentary: The organic matter content in a material that has been taken to its composting endpoint is approximately 25%. Composting is a bacterial process where the original organic matter is digested. At the end of the process, the bacteria involved are the only organic matter present. Using partially composted material, that contains between 40 to 60% organic matter, makes it more difficult to meet the criteria for stability than an expanded range of 30 to 60%, for example.

MOISTURE CONTENT

B) Composted material is specified to have a Moisture Content < 60% and the product is loose and friable, not dusty. No test method is specified. The two ASTM standard procedures are ASTM D2216 Standard Test Method for Laboratory Determination of Water Content of Soil and Rock; and ASTM D2974 method A cited above. These are inadequate in that a standard procedure of testing is needed to select mulches that will be successful and reject others. Moisture Content can be reported two ways: on the basis of dry weight or on the basis of wet or as received weight. CONEG Specifications do not mention the manner by which the Moisture

Content should be reported, and many references on composted materials report it on the basis of dry weight but at least one uses wet weight, hence the confusion.

Commentary: The CONEG specifications should clearly state which method of reporting moisture content should be used. If the primary objective of this requirement is to insure that the compost is friable and not dusty, it can be at a much lower moisture content than allowed by present specifications. The lower moisture will insure that the product is lighter, easier to handle and more cost effective. Each composted material should be subjected to testing to find the optimum moisture content for placement. The relation between moisture content by dry weight and by total weight is shown in Figure D.1.

PARTCILE SIZE DISTRIBUTION

C) Depending on the application, particle size distributions of the compost or mulch are specified to fall within certain bounds. No test method is specified in CONEG but it is assumed that ASTM test methods (ASTM D422 Standard Test Method for Particle Size Analysis of Soils) are to be used.

Commentary: The wood mulch from Connecticut used in this field testing program had particles that are rod like, i.e. a diameter much smaller than its length. Sieves with square holes are used in ASTM D422. The sifting process involves rotation in a horizontal plane as well as tapping that causes the particles to move in vertical directions. The result is that this method of sifting yields partition of the particles based on the smaller dimension for rod-shaped particles. However, the erosion control benefits of the wood mulch depend on the length and size distribution of the particles. As a result, this method of sieving in conjunction with the CONEG specifications leads to rejection of materials that are effective in preventing erosion. A new sifting procedure may be needed that takes into account the actual shape of the larger particles.

The following CONEG specifications appear to apply to Connecticut materials but need some minor elaboration.

CONDUCTIVITY MEASUREMENTS

D) Soluble salt content is required to be < 4.0 mmhos/cm (dS/m). No method of sample preparation or testing procedure is specified. The Soil Testing Laboratories at UConn uses Spurway and Lawton (1949) extraction procedure or a variation thereof (UDAES, 1995). The standard ASTM D4542 measures salt content by Refractometer. A third method is in the book titled "Methods of Soil Analysis" by D.L. Sparks (1996). Laboratory testing on this project has shown that the soluble salts in a dry sample of compost that is immersed in water require a long time to come to equilibrium at room temperature and that the final conductivity is a complicated function of the amount of solids dispersed in the water.

Commentary: Any specifications that attempt to correlate conductivity with soluble salt concentration require a protocol defining a standard procedure for preparing the compost sample and for conducting the test.

STABILITY-

E) Compost and mulch should be very stable or stable according to the Compost Stability Index as measured by the Dewar Self-Heating Test or CO_2 generation rate which are summarized in Appendix B of the CONEG report (CONEG, 1996). It should be noted that the higher the level of Stability associated with biodegradation of organics, the lower will be the organic matter content. A fully biodegraded compost will have an organic matter content of about 25%.

Commentary: The organic content criteria, i.e. 40-60% and the stability criteria of stable or very stable may be in conflict in that a compost with a level of organics in the allowed range may continue to biodegrade and therefore be unstable.

ACIDITY DETERMINATION

F) pH is specified to fall between 5.5 - 8.0. No test method is specified by CONEG. The ASTM method (ASTM D2976 Standard Test Method for pH of Peat Materials) requires 3 g of air dried material and 50 ml of distilled water (or 50 ml of 0.01 M CaCl2 Solution) soaked in a beaker for 30 minutes followed by use of a pH meter as per manufacturers instructions. The ASTM solid liquid ratio is 1:16 T by weight. Epstein (1997) notes that the weight ratio for soil pH is 1:1 and that ratios of 1:50 (compost: water) have been recommended. In this study, a ratio of 1:10 was used as a compromise of the ratios recommended for soil and peat.

Commentary: The ASTM method for the pH of peat materials may be applied to compost.

APPLICATION THICKNESS

G) The thickness of application is one additional specification that is cited for Compost as an Erosion Control Mulch (C.E.C.M.) and that directly relates to the cost of a C.E.C.M. treatment. For use on slopes to be mulched only, CONEG specifies no application thickness but refers to conformity with construction plans, specifications or the project engineer. During this investigation, measurements of erosion resistance were primarily made on 3 inch applications on a 2 - 1 slope. However, one test area was treated with a 1-1/2 inch thick layer of compost for a brief period and performed about the same (one storm event) as the 3 inch layer. Also, two small test areas were treated with 3/4 inch thick applications of a compost and a mulch for qualitative erosion performance. These thin applications of mulch appeared to perform very well except during heavy/ torrential rain events. Therefore, there appears to be an erosion protection benefit to the use compost/ mulch when applied at any thickness as is also the case for straw or hay treatment.

For use on slopes to be seeded, CONEG requires the application of a uniform 3-inch thick layer to promote grass root development. The compost used for this application is of small particle size (100% < 0.75 inch diameter) and performed very well in this study as an erosion protection layer for a 2 - 1 grade compared to an untreated surface. It is probable that thinner application rates (i.e. 1 1/2 inches thick) would perform equally well but there is no data to support thinner application rates at this time.

Commentary: Thickness of application needs further study.

PARTICLE SIZE PROBLEMS FOR FILTER BERM

H.) The CONEG Specifications for the Erosion Control Filter Berm require the particle sizes in the Compost to be as follows:

1. 100% < 3.0 inch;
2. Maximum 70% < 1.0 inch

No minimum is stated for the amount finer than 1.0 inch. Therefore, all the particles in a berm could be between 1 and 3 inches and meet the stated specification. For a filter berm to work properly, the soil particles must be retained by the berm and the water allowed to pass through. The pores in the filter berm must be smaller than some of the soil particles to retain the eroded soil. The berm will not have pores this small unless there are small pieces in the mulch.

Commentary: The specifications must reflect the need for small particles in the mulch.

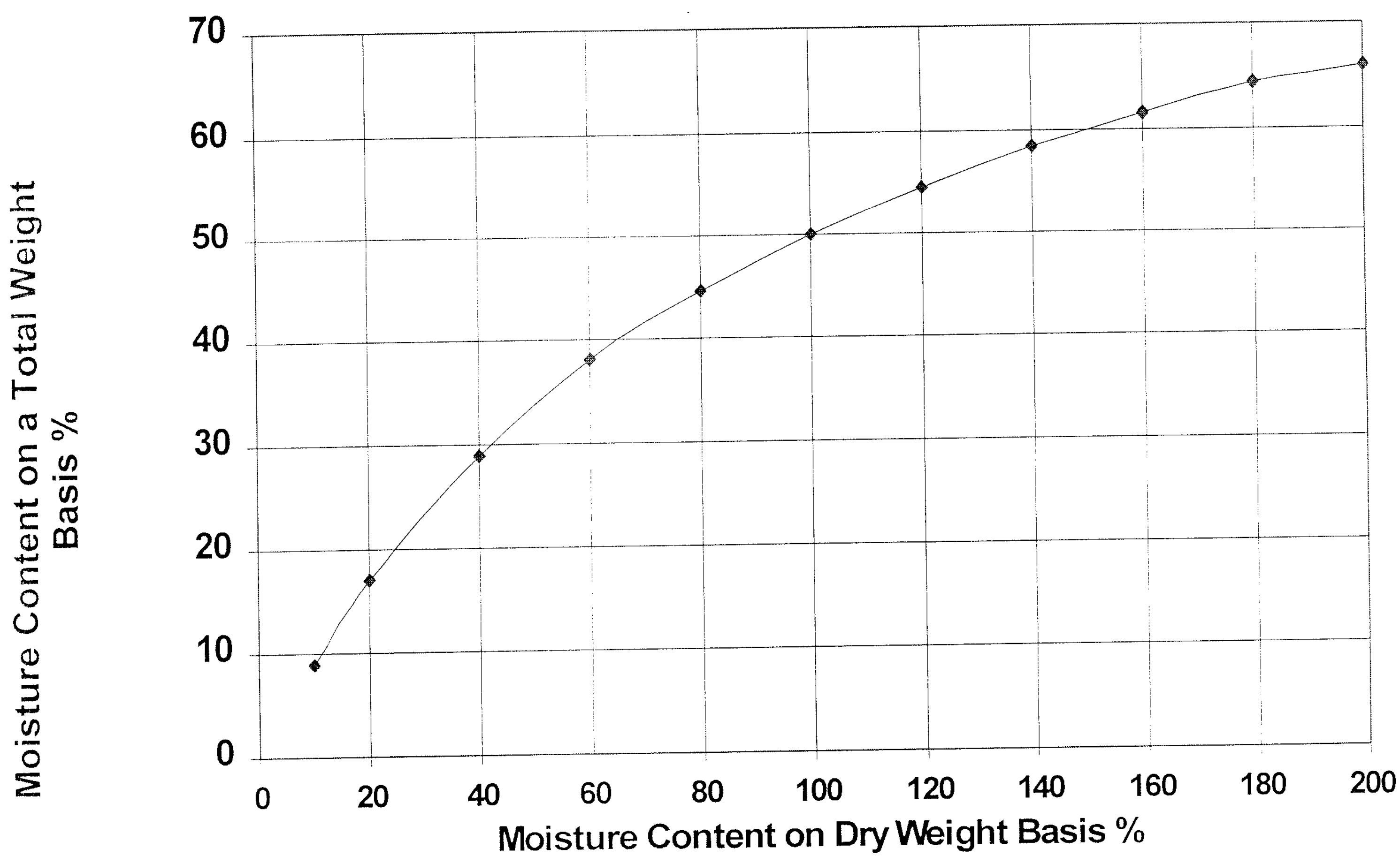


Figure D.1: Relation Between Moisture Content on Total Weight and Dry Weight Bases

Appendix E: NOTES ON FIELD INSTALLATION/ MONITORING

10/4 Test cells constructed by ConnDOT contractor at field site- junction of Rt. 6 and 198. Surface treatment applied to 5 of 8 cells. Cells 2, 5 and 7 remained untreated.

10/10 First rainfall = 39mm (1.5 in.) on test cells. Significant erosion observed on Cell 2, 5 and 7. Other cells performed well. Water samples taken.

10/17 Seed applied to cells 3 and 8 and straw and seed applied to cell two. Control cell five and cell seven (hydroseed) remains untreated.

10/19- 10-20 Heavy rain = 110 mm (4.35 in.) fall over weekend. Water samples taken on 10/22.

10/24 Rainfall = 9 mm (.35 in.) .

10/28 Water samples for previous storm taken during heavy brief rainfall = 5 mm. Water collection system was dismantled at time but heavy runoff was observed. Problems observed for mulch berm (cell 6) which was overflowed with water and sediment.

10/30 Rainfall = 5- 6 mm

11/4 Water samples collected for 10/30 rainfall

11/7 Berm in test cell 6 was reshaped to hold back water and sediment

11/9 Very heavy rainfall occurred - 40 - 43 mm

11/11 Water samples collected - tried to filter sediment in buckets through paper but took too long (hours/bucket). Better results using open geosynthetic cloth but would not retain silt.

11/26 Very heavy rainfall occurred with over 3 inches of rain recorded. Some rill erosion noted in cell #1 due to flow off of road.

11/27 Field test buckets removed for year cause of potential freeze damage. Water sampling terminated for year.

4/23 After winter, cleanup of test cells, plug gap under cell separator boards and construct swale at top of cells.

4/28 Extend mulch berm and reshape where needed. Add compost to cells with channel erosion. Raingage installed.

4/30 More compost added to erosion channels, as needed, and dressed off. Runoff collection buckets added.

5/1 Rainfall of 14mm (>1/2") and buckets disconnected.

5/3 Rainfall of 13mm was bypassed

5/5 Buckets collected for lab testing.

5/15 Attend field demonstration of compost blower/ Westport

5/20 Placed 1.5" Manchester compost in cell 7- Rain 26m

7/1 Install collection buckets and cleanup site.

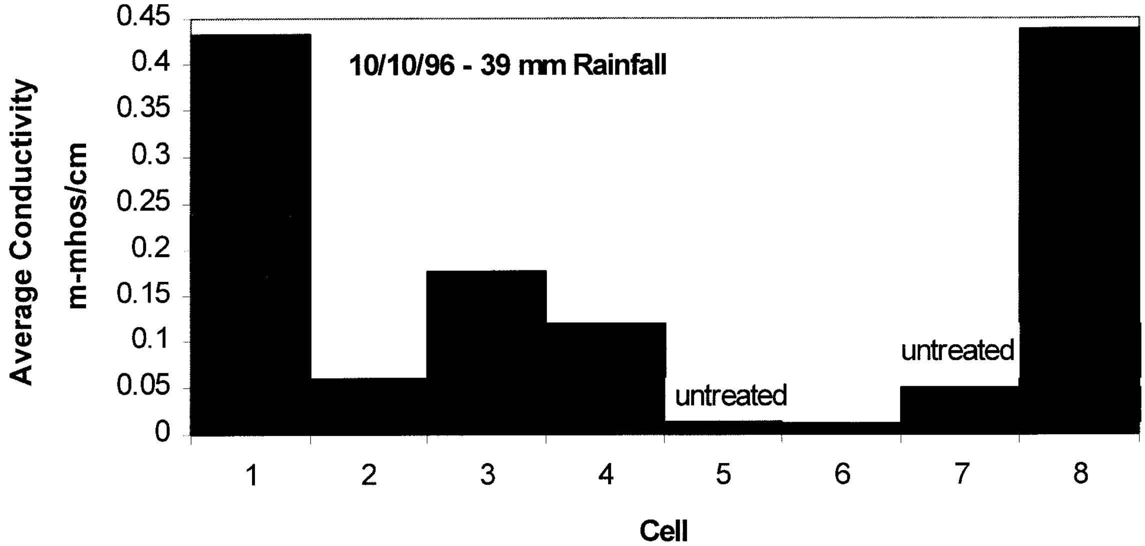
7/16 Rainfall was 0.7 inches (18 mm). Buckets disconnect and later picked up (7/29/97) for testing.

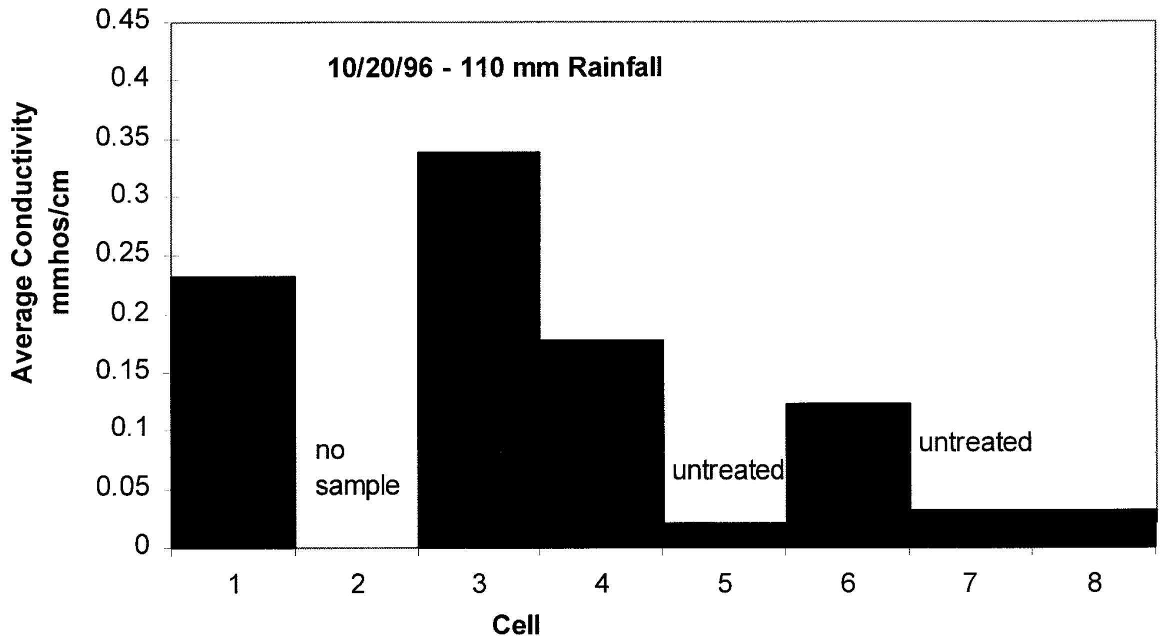
9/3 Plant growth samples taken from test cells 2,3 & 8. Berm was dissected and sampled. Samples of all test cells taken for lab testing.

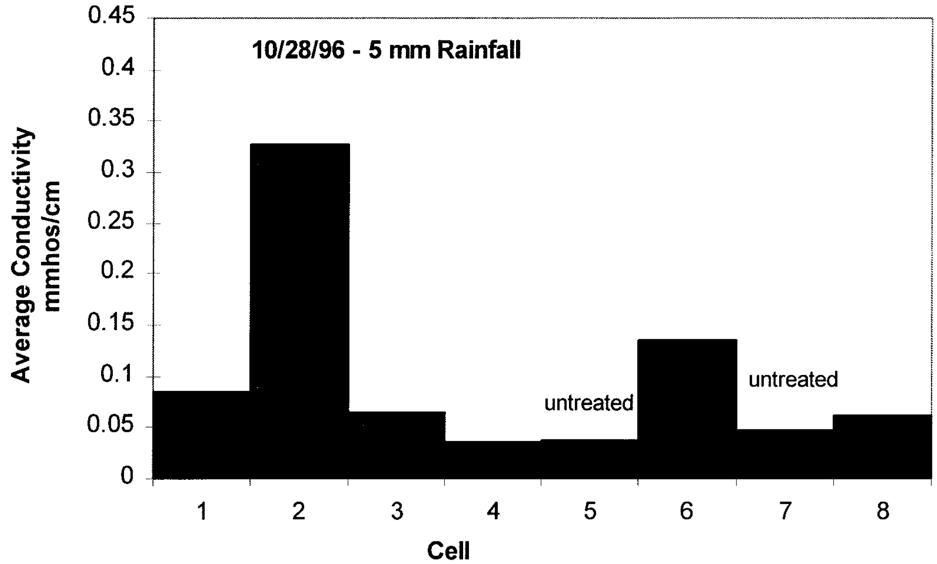
Appendix E 1 COMPOST FIELD INSTALLATION MATERIALS LIST

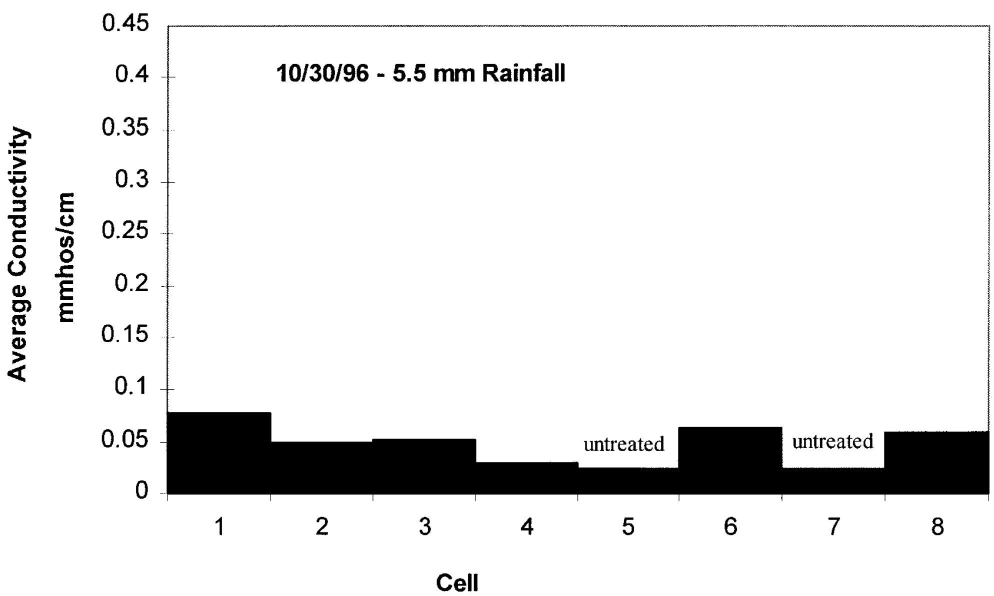
Quantity	Item
460 lineal feet	1" x 6" Untreated Lumber (may be rough cut)
10 x 80 feet	10 mil Polyethylene Sheet- Clear (4-10'x 20')
1- 4'x8' sheet	1/2" thick Plywood Untreated
120	1" x 3" x 12" Wooden Stakes with Point to anchor 1"x6" lumber
6	2" x 2" x 48" Wooden Stakes with Point
80 feet	2" diameter PVC Pipe (white or black
24	2" diameter PVC tees
24	2" diameter PVC Elbows
24	2" diameter PVC Couplings
24	5 gallon plastic buckets with covers
10 cu. yds.	Manchester, CT Compost
15 cu. yds.	Earthgro Mulch (meeting CONEG ECM Specs.)
300 sq. feet	ConnDOT Straw/ Seed Treatment
300 sq. feet	ConnDOT Wood Mulch/ Seed Treatment
1 sheet	3' x 12' Terra Jute Erosion Control Fabric (K. Demars called WebTec on 9/17/96)

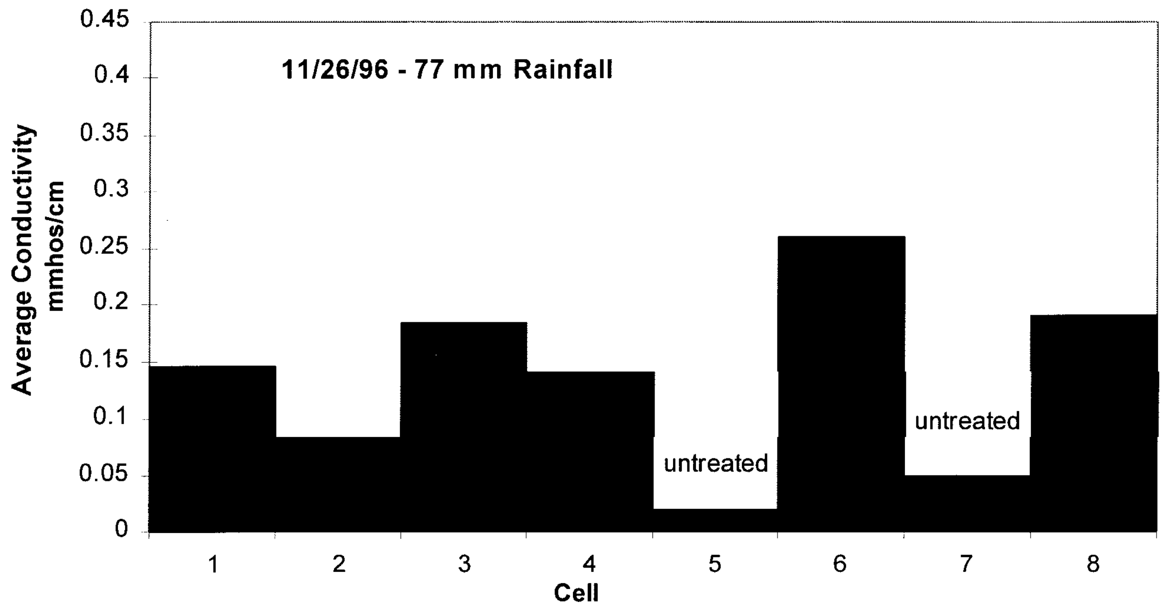
Appendix F: Conductivity Data

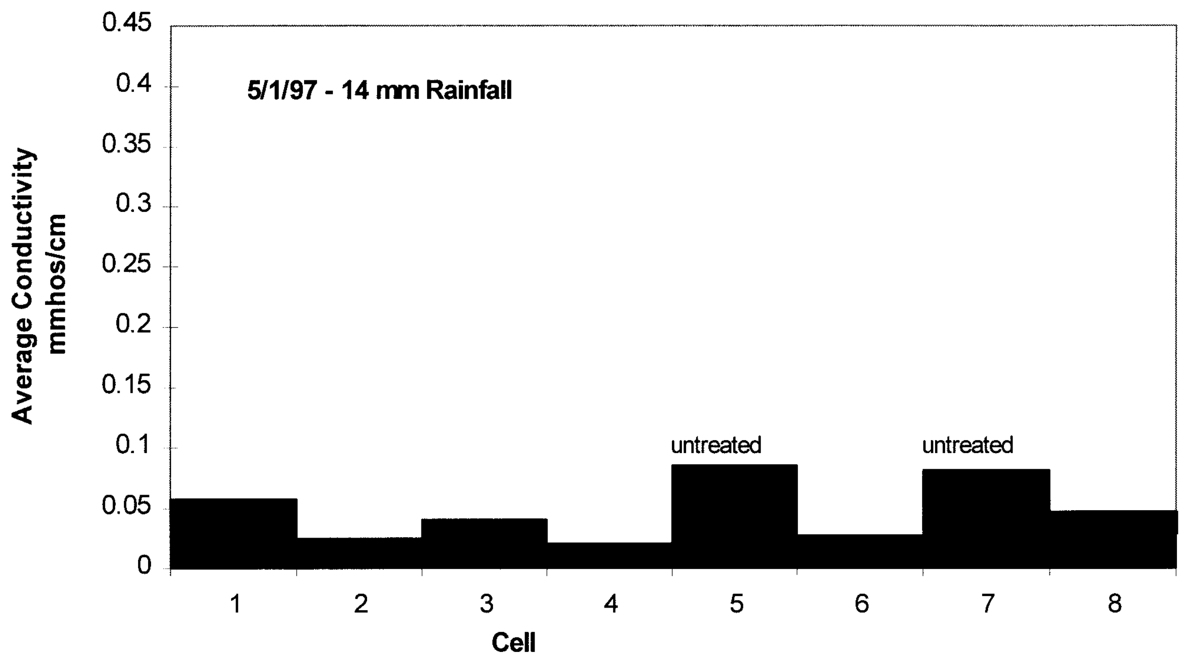




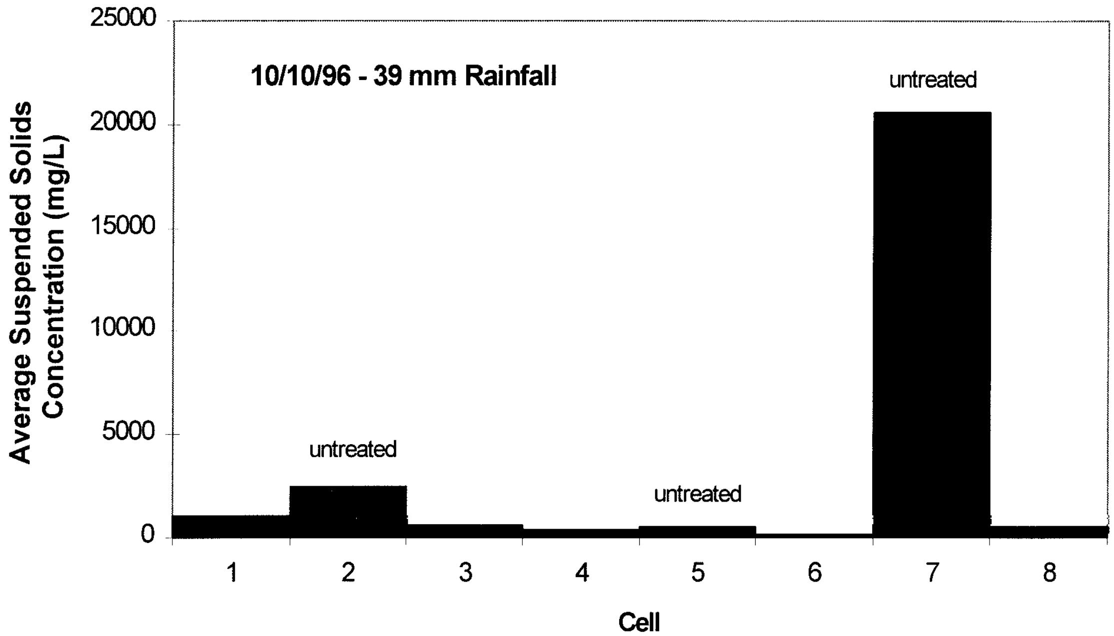

10/28/96 - 5 mm Rainfall
Average Conductivity
mmhos/cm
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell

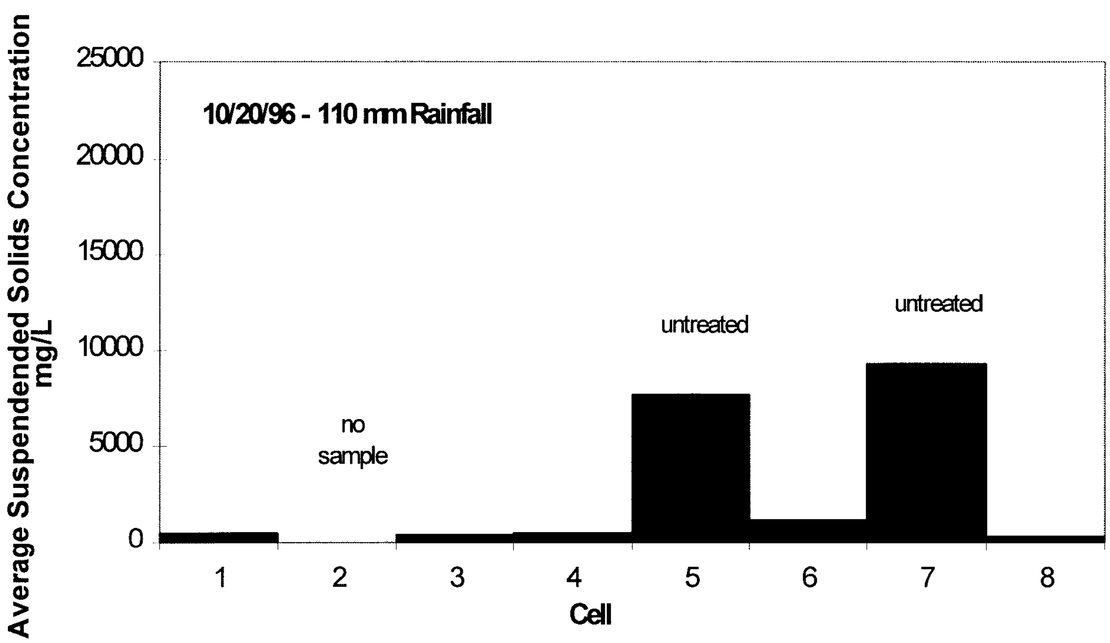

10/30/96 - 5.5 mm Rainfall
Average Conductivity
mmhos/cm
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell

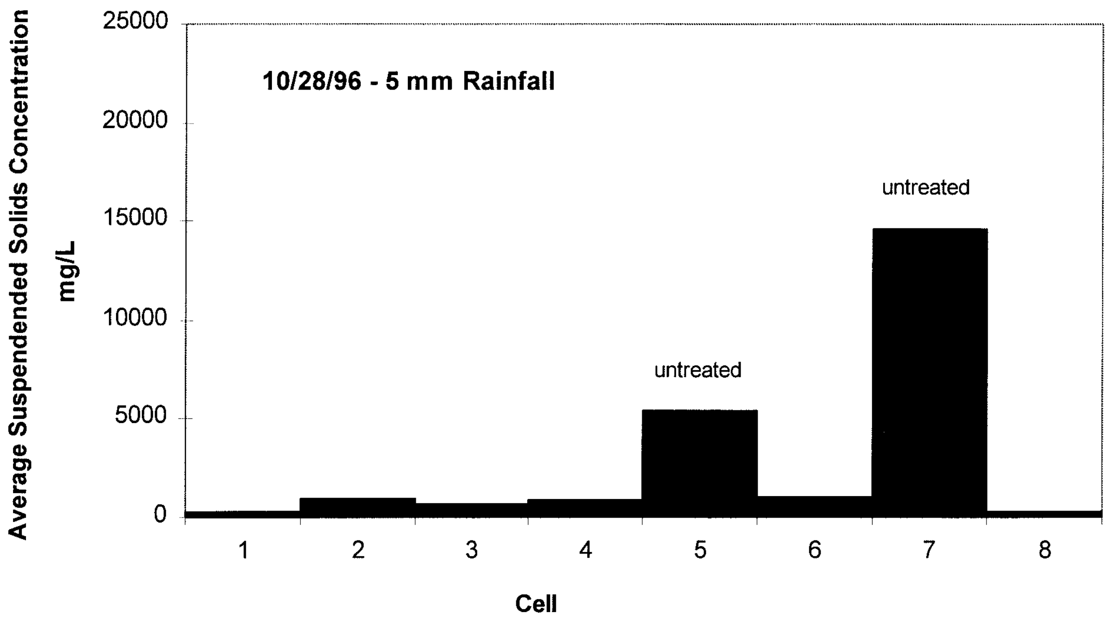

11/26/96 - 77 mm Rainfall
Average Conductivity
mmhos/cm
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell

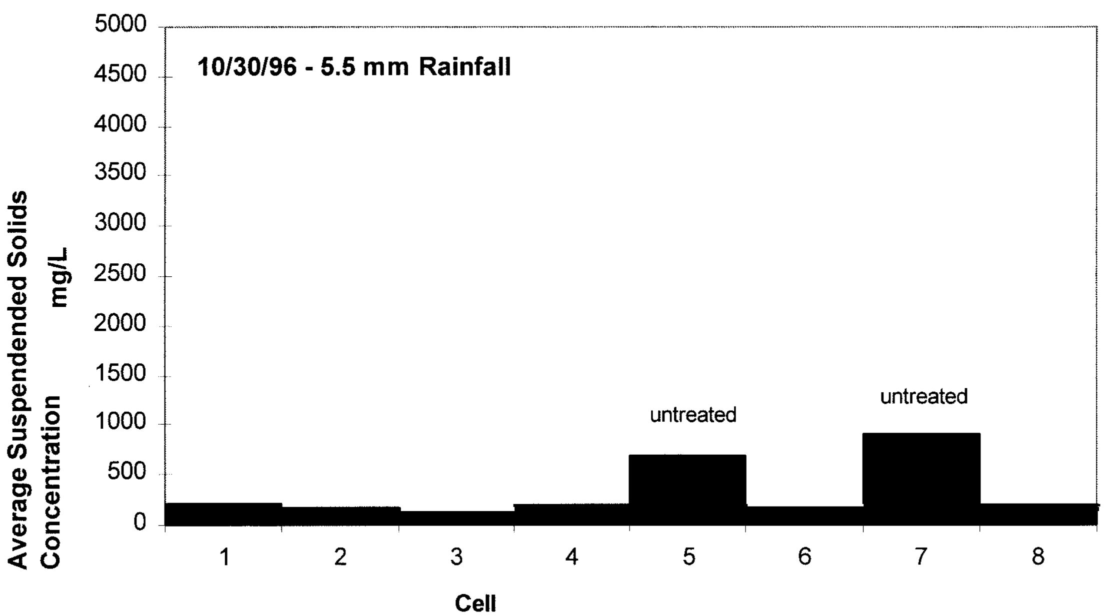

5/1/97 - 14 mm Rainfall
Average Conductivity
mmhos/cm
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell

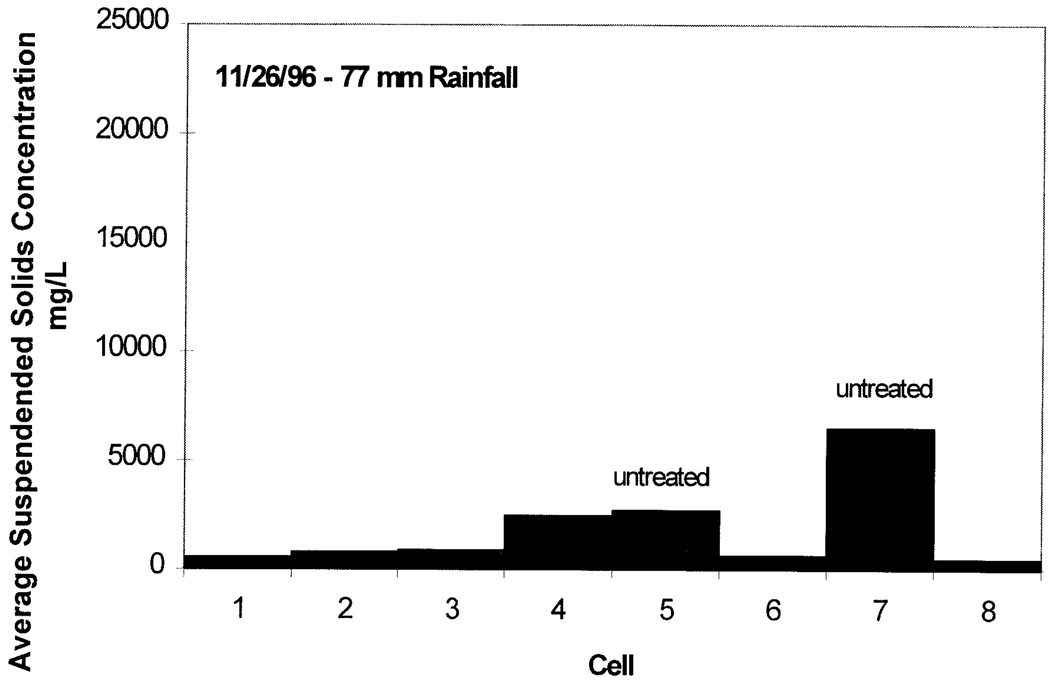
Appendix G: Suspended Solids in Storm Runoff



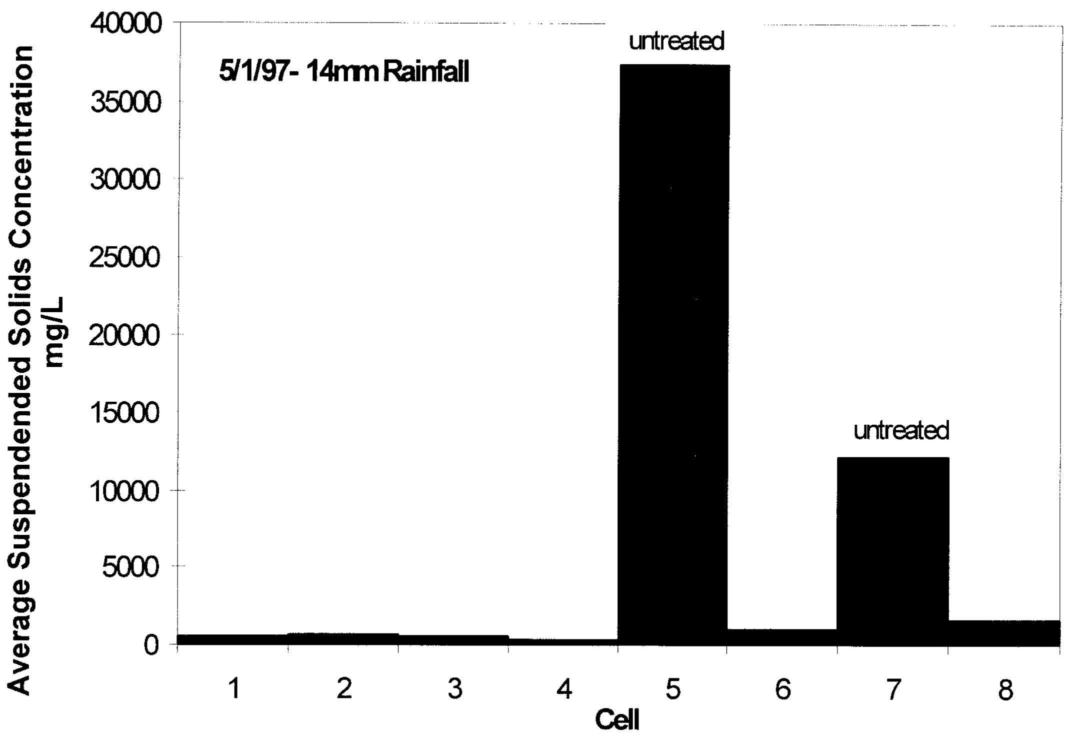



10/28/96 - 5 mm Rainfall
Average Suspended Solids Concentration mg/L
25000
20000
15000
10000
5000
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell


10/30/96 - 5.5 mm Rainfall
Average Suspended Solids Concentration mg/L
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
untreated
untreated
1
2
3
4
5
6
7
8
Cell



Average Suspendended Solids Concentration mg/L
25000
20000
15000
10000
5000
0
11/26/96 - 77 mm Rainfall
untreated
untreated
1
2
3
4
5
6
7
8
Cell



Average Suspendended Solids Concentration mg/L
40000
35000
30000
25000
20000
15000
10000
5000
0
5/1/97- 14mm Rainfall
untreated
untreated
1
2
3
4
5
6
7
8
Cell