

USE OF WOOD WASTE MATERIALS FOR EROSION CONTROL

By

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16. Abstract Three wood waste materials were evaluated for use as an erosion control mulch and one of the materials was used as an erosion control filter berm. Samples of the three materials were subjected to laboratory tests to determine their physical and chemical properties for comparison with the CONEG specifications for these erosion control applications. Each of the materials was subjected to large scale erosion control testing at a field site with a slope of 1 vertical to 2 horizontal. Fourteen test cells (5' W x 30' L each) were prepared with different wood waste treatments; nine contained erosion control mulch applications at thicknesses of ¾ to 3 inch. Two cells were left untreated as reference cells and three other cells were untreated but contained erosion control structures including wood waste filter berm, geosynthetic silt fence and hay bale silt barrier. The erosion control performance of each cell treatment was evaluated for eleven storm events of varying rainfall magnitude and intensity. Calibrated tipper buckets were used to measure the runoff from each cell and collection buckets were used to sample runoff and determine the mass of sediment eroded from each cell. Total rainfall and intensity of each storm was measured with an electronic rain gauge. The results show that wood waste material is very effective at reducing erosion when used as an erosion control mulch at a thickness of ¾ inch or greater. Additionally, the woos waste materials, used for an erosion control berm, were more effective at controlling erosion than a geosynthetic silt fence or hay bale berm.					
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Table of Contents

<u>Chapter</u>	<u>Page</u>
Technical Report Documentation.....	ii
Metric Conversion Chart.....	iii
Table of Contents.....	iv
1. Introduction.....	1
2. Literature Review.....	2
2.1 Composting of Natural Materials.....	2
2.2 Surface Erosion.....	3
2.3 Natural Materials for Controlling Erosion.....	4
3. Laboratory Testing of Properties.....	6
3.1 Physical Properties.....	6
3.2 Chemical Properties.....	8
4. Field Testing of Wood Waste Materials.....	11
4.1 Purpose of Field Test Site.....	11
4.2 Field Testing Program.....	12
4.2.1 Design of Test Facility.....	12
4.2.2 Construction of Test Installation.....	16
4.2.3 Behavior of Field Installation During Storms.....	16
4.3 Testing Program.....	17
5. Typical Field Test Data.....	19
5.1 Storm Event Sampling.....	19
5.2 Surface Runoff Volumes.....	21
5.3 Suspended Solids in Surface Runoff.....	21
6. Analysis and Discussion of Field Results.....	23
6.1 Runoff.....	23
6.2 Amount Eroded.....	25
6.2.1 Erosion Control Structures.....	27
6.2.2 “C” Factors.....	28
6.3 Variation of Soil Erodability with Time.....	29
7. Summary and Conclusions.....	31
8. Glossary of Terms.....	32
9. References.....	34

Appendices

Appendix A: Photographs of the Field Test Site.....	37
Appendix B: Rainfall- Time Plots at Maximum Storm Intensity	40
Appendix C: Total Runoff from Test Cells by Storm Events.....	47
Appendix D: Sediment Eroded from Test Cells by Storm Event.....	53

1.0 Introduction

Wood Waste Materials have been successfully used in the field by Maine Department of Transportation to control erosion on slopes and exposed soil surfaces (LaRoche, 1998). The material can consist of a mixture of bark, wood shavings, wood chips, wood scraps and mineral grit that is a by-product of the lumber, paper, construction or other industries. Use of this material requires that its physical and chemical characteristics be tested with accuracy and that its performance be documented quantitatively. Specifications for source separated composts have been developed by the Coalition of Northeastern Governors Source Reduction Task Force (CONEG), February 1996. This set of specifications contains such things as the desired particle size distribution or pH of the compost but does not contain testing protocols for the various properties. As a result, some wood waste materials that show the desired result of controlling erosion in the field do not have laboratory testing protocols that predict this behavior. Research relating laboratory test results to field behavior will allow Wood Waste Materials to be more widely used.

While CONEG has identified six applications for composts and mulches that are derived from source separated materials, only the applications as an erosion control mulch and an erosion control filter berm are being considered for wood waste materials. It is possible that wood waste materials may find use in the four other CONEG applications including 1) general use compost, 2) compost manufactured loam, 3) compost amended loam (topsoil), and 4) horticultural mulch. These applications would also depend on the physical and chemical characteristics of wood waste materials; properties which are known to vary from producer to producer depending upon the feedstock and processing. These applications are the topic of another study.

A previous project evaluated the effectiveness of source-separated compost for controlling erosion on slopes (Demars and Long, 1998). That study showed that source-separated compost controlled erosion at thinner applications than considered by the CONEG (1996) Specifications. This research looks at the effectiveness of using wood-waste material with various thicknesses to control erosion on soil slopes and as an erosion control filter berm.

The overall objective is to quantify the properties and behavior of wood waste materials for use as a medium to control erosion. Specific objectives of this study are to examine the effects of different wood waste materials as erosion control mulch when applied to slopes at a thickness of $\frac{3}{4}$ -inch up to 3 inches. Also, the limits of stability on a slope and shear strength of each material will be measured and compared to the soil it is used to protect. A comparison will be made of wood waste material used as filter berms as an alternative to conventional hay bales and geosynthetic silt fences as erosion control barriers. This investigation uses a combination of laboratory and field testing methods.

2.0 Literature Review

2.1: Composting of Natural Materials

During the past twelve years, reuse of material has become an important component in solid waste management in the United States. A popular method has been composting (Composting Council, 1994; Pettigrew, 1996; Hoitink and Keener, 1993; NRAES, 1992). This method has also been used in other parts of the world where resources are limited (van Veldhuisen, 1974; Oosthnoek and Smit, 1987; Baliff and Herre, 1988; Fricke and Vogtmann, 1993; Fullen et al, 1999). Similarly, the processes of turning timber into lumber or paper as well as the operations of processing tree stumps removed from construction sites, produce voluminous waste products that should be put to some worthwhile use.

Wood-waste materials and composted materials have similar functions in preventing soil erosion. The wood chipping, grinding and composting processes convert 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; Haynes, 1997 and Cal Trans, 1999). 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; Muller and Riccabona, 1984).

Besides wood-waste materials, there are several materials that can be successfully used once composted to prevent erosion: 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 literature on the use of natural materials to prevent erosion indicated that chemicals from the materials are a concern. The composting process shows that, depending on the

source of the compost, the toxicity of the leachate 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 wood waste materials to prevent erosion on construction sites.

2.2: 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 during 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). The similarities of wood waste material to compost are what prompted this study.

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:

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

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.

2.3: Natural Material to Control Erosion

The use of natural material to reduce erosion has been well established in certain applications. Much work has been done with composted material. The similarities of wood waste material suggest that the findings for one will apply to the other. 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 soil 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.

Muller 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 those 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 lightweight 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 an approved method of erosion control by many state Departments of Transportation.

The literature review indicated that our approach should be successful in comparing the erosion protection of wood waste material to other currently used methods.

3.0 Laboratory Testing of Properties

Several samples of materials were acquired from producers prior to and during field installation. All samples were subjected to laboratory testing for physical properties and some additional chemical tests for toxicity assessment were completed before these materials were placed at the field test site. The samples included three wood waste materials consisting of one paper mill wood waste and one pine bark mulch produced by Cousineau Forest Products of Strong, ME and one ground stump/wood waste mulch produced by ConnDOT in Enfield, CT. The test procedures that were used are American Society for Testing and Materials (ASTM, 1999) standard tests for soils, peat, and other natural aggregates. Because there are some limitations in applying soil test methods, a “Best-fit” of existing standards was tried with the available wood waste materials.

3.1: Physical Properties

Particle size distribution curves are shown in Figures 4.1 for the wood waste materials that were sampled. These results show that there is some variation in the gradation of wood waste materials 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 ($U=d_{60}/d_{10}$) greater than about four or five where d_{60} and d_{10} are particle diameters at 60 and 10 finer by weight, respectively. They are all comprised of coarse-sized particles with over 70 % by dry weight greater than 1 mm diameter plus 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 wood waste material. Yet, wood waste material particles have a lower density than mineral aggregates and many particles in wood waste have an elongated (needle) or chip (plate) shape that may require different test procedures. 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 #20 (0.840 mm) or greater. The paper mill wood waste was observed to have a larger quantity of inorganic gravel and sand particles than the other wood waste materials.

Some additional physical properties tests were performed on the available wood waste materials and the results are presented in Table 3.1. These included organic matter content (OMC), dry unit weight and friction angle. The OMC was measured by loss on ignition at 440 C after oven drying at 110 C (ASTM D-2974). Four specimens from each sample were tested because the muffle furnace could only handle a specimen with a mass of about 150 to 200 g and some of the samples (such as paper mill wood waste) had single particles with a weight of 50 g or more. A mechanical splitter was used to select the specimens and the larger oversize particles were divided with pruning pliers. The organic matter

contents are shown in Table 3.1. The smallest organic matter contents were for the paper mill wood waste and ground stump mulch which have the highest portion of inorganic gravel particles from processing.

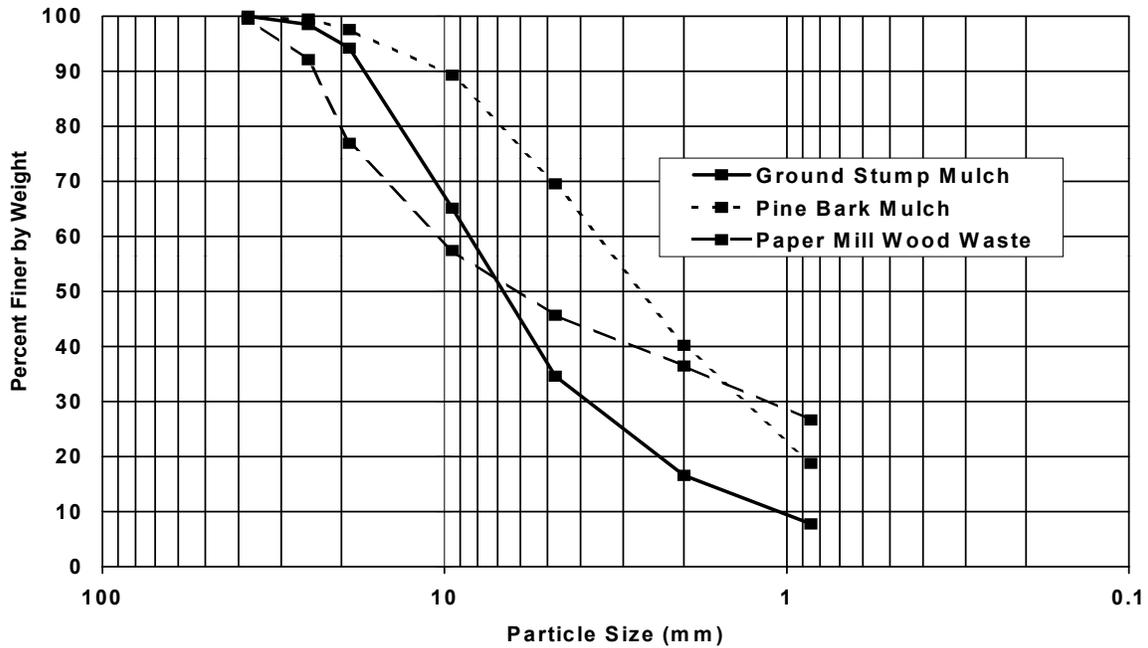


Figure 3.1: Gradation Curves for Wood Waste Samples

Table 3.1 Physical Properties of Wood Waste Samples

Material	Organic Matter * Content (% dry weight)	Dry Unit Weight** (lbs/cu. ft.)	Friction Angle (degrees)***
Ground Stump Mulch	63.6 (55.9 – 70.5)	11.2, 14.1, 15.0	47.5
Pine Bark Mulch	94.3 (91.4 – 95.6)	9.6, 11.3, 14.4	48.8
Paper Mill Wood Waste	35.6 (28.9 – 43.0)	36.1, 47.7, 48.6	43.1

* - Average of four samples, () - Range

** - Loose, After vibration, After 100 pound load

***- Average of 3 tests

Further, the paper mill wood waste and pine bark mulch have experienced some composting which should reduce OMC compared to the ground stump mulch which was not composted.

The dry unit weights were measured by placing the oven-dried materials into a 6-inch diameter steel Proctor mold and determining the volume under three different conditions. The material in the steel mold was initially compressed with a 3-pound plate to obtain a loose condition, followed by confined vibration on a shake table for 2 minutes to create a medium dense condition and, finally, compressed with a 100 pound weight to obtain a dense condition. The ground stump and pine bark mulches each have very low dry unit weights that are less than 15 lbs./cu. ft. In comparison, the paper mill wood waste has a much higher dry unit weight of up to 50 lbs./cu. ft. because of the significant quantity of inorganic material it contains.

The friction angle for each material was measured with a tilt table that was built from a pine board. The board surface was roughened by gluing mulch particles with a diameter up to ¼ inch size to the surface. A 2 to 3-inch thick layer of material was then placed loosely on the roughened surface and was contained on the sides by a cardboard box. The board and material was then tilted until mass movement (sliding) of the material occurred and the slope angle was measured. This process was repeated three times for each material to assure repeatability. The friction angles were all greater than 43 degrees and were about the same as the friction angle of 46 degrees measured for base soil (see Figure 4.1) that these materials were applied on at the field test site. These friction angles are significantly greater than the slope angle at the field site of 1 vertical to 2 horizontal, which is 26.6 degrees. Thus all of these materials are expected to be stable under the gravimetric forces that are imposed during the field tests.

3.2 Chemical Properties

Some of the chemical properties specified by CONEG for useable composts and mulches are presented in Table 3.2 for the three wood waste materials tested in this study and for the base soil at the test site. The stability is a measure of the degree of composting of the raw feedstock. This parameter was measured using the Solvita test with a numerical system from one (1) for raw non-composted feedstock to eight (8) for fully composted/ biodegraded and cured materials. This test verified that the Ground Stump Mulch was fresh raw material and the other two materials are further along in the composting process as evident from their color and appearance. CONEG recommends that erosion control materials should be very stable to stable which is not the case for the fresh ground stump material.

The pH and conductivity were measured on a supernatant produced from mixing 50 g of dry material with 500 g of de-ionized water for 16 hours. The liquid was separated from the material and the pH and conductivity were measured with a probe according to manufacturer specifications. The CONEG specifications require the pH to fall within the range of 5.5 – 8.0 and the conductivity should be less than 4.0 mmhos/cm (dS/m). All of the wood waste materials satisfy the conductivity requirement and most satisfy the pH requirement except for the Pine Bark Mulch which tends to be slightly more acidic than the specifications allow.

Table 3.2 Summary of Chemical Properties for Wood Waste Materials

Material	Stability *	pH **	Conductivity*** (mmhos/cm)
Ground Stump Mulch	Fresh Raw Compost (1)	6.99	3.88
Pine Bark Mulch	Finished Mature Compost (6-7)	4.86	3.14
Paper Mill Wood Waste	Past Active Compost Ready to Cure (5)	7.51	1.8
Base Soil	N.A.	6.60	0.55

*- based on Solvita Test Number () ranging from 1= raw to 8 = finished

** - based on compost/ de-ionized water ratio = 1/10 by weight

***- based on compost/ de-ionized water ratio = 1/10 by weight,
conductivity = 0.031 mmhos/cm for de-ionized water

Each of the wood waste materials and base soil from the field test site was subjected to chemical analysis for heavy metals. This step was taken to insure that no undesirable contaminants would be present in the wood waste material used at the field test site. Representative samples of each material (including the base soil) were submitted to the University of Connecticut’s Environmental Research Institute for analysis of 20 metals that are routinely evaluated for characterization of contaminated materials. The results of the tests are presented in Table 3.3 with units of parts per billion (ppb). The materials were prepared using the Synthetic Precipitation Leaching Procedure (SPLP) method and the leachate was analyzed using Environmental Protection Agency (EPA) approved testing protocols. None of the elements tested are close to the EPA limits specified for hazardous materials.

Table 3.3 Summary of Metals Analysis for Wood Waste Materials and Base Soil

PROJECT: Wood Waste Compost
 Date Samp. Received: 03/11/99 Matrix: SPLP
 Date Samples Prep.: 03/23/99 Prep. Method: 3010a
 Date Samples Analyzed: 03/31/99 Analysis Method: 6010a
 Sample Concentration : (ug/L)

Sample	Sample	ICP - AES																		GFAA	CVAA
Field ID#	Lab ID#	Al	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Se	Sn	V	Zn	As	Hg
Base Soil	MAR990564	370	15	2628	1	2	3	71	464	1123	458	396	9339	3	7	ND	ND	ND	14	ND	ND
Stump Grindings	MAR990565	477	23	11670	ND	2	6	56	643	18500	3951	220	23910	6	17	ND	ND	5	64	10	ND
Pine Bark Mulch	MAR990566	261	30	5388	ND	ND	4	45	355	27550	1937	289	20000	ND	7	ND	ND	ND	30	91	ND
Paper Mill Wood Waste	MAR990567	475	31	8631	ND	3	4	44	490	5481	1978	822	23810	5	ND	ND	ND	ND	55	ND	ND
Detection Limit		10	1	5	1	2	3	1	5	10	5	1	10	3	5	10	10	5	5	2	0.2

NOTE: All units are in ppb (ug/L)

NOTE: ND is not detected

SPLP is Synthetic Precipitation Leaching Procedure

ICP-AES Inductivity Coupled Plasma--- Atomic Emission Spectroscopy

GFAA Graphite Furnace Atomic Absorption

CVAA Cold Vapor Atomic Absorption

4.0 Field Testing of Wood Waste Materials

4.1 Purpose of Field Test Site

A field test site was selected at a ConnDOT maintenance facility at the junction of Routes 32 and 74 in Willington, CT. The site is the west slope of the facility near Route 32. It was selected because 1) it is long enough to accommodate a large number of test cells; 2) has a slope of two horizontal to one vertical (26.6 degrees), the steepest soil slope normally used by ConnDOT; and 3) the base soil is an easily eroded silty - sand with some gravel. The particle size distributions for two samples of this base soil (A and B) are shown in Figure 4.1 with silt-size particles comprising about 25 to 40% of the total soil mass. However, at a slope of 1 on 2, particles in the coarse sand to fine gravel size may also be eroded if no erosion protection is provided.

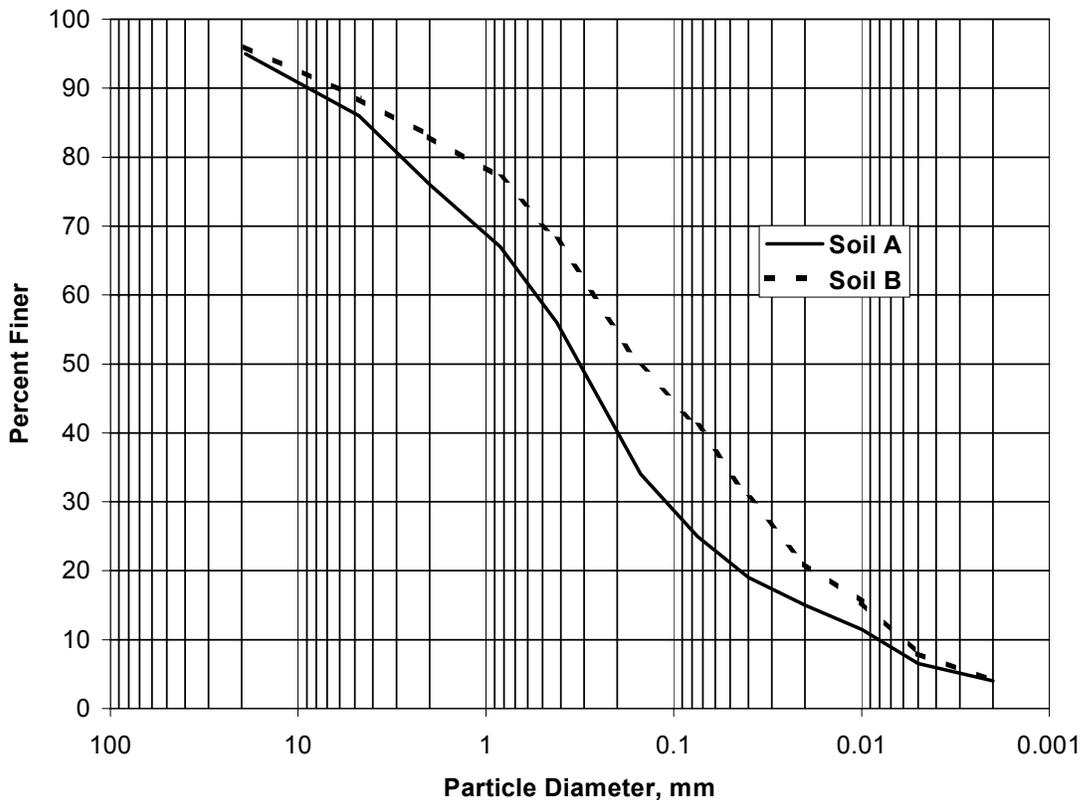


Figure 4.1: Gradation Curves for Two Base Soil Samples from Field Test Site

Based on the types of wood waste material available, the desired combinations of surface treatments and thickness to study for erosion prevention, it was decided to install fourteen test cells. The cells were arranged as shown in Figure 4.2 and were designed to contain the treatments summarized in Table 4.1.

Table 4.1: Surface Treatments Used in the Test Cells.

Cell No.	Surface Treatment
1	Paper Mill Wood Waste @ 3.0"
2	Paper Mill Wood Waste @ 1.5"
3	Paper Mill Wood Waste @ 0.75"
4	Control (Untreated)
5	Pine Bark Mulch @ 3.0"
6	Pine Bark Mulch @ 1.5"
7	Pine Bark Mulch @ 0.75"
8	Geotextile Silt Fence
9	Hay Bale Barrier
10	Filter Berm of Paper Mill Wood Waste
11	Control (Untreated)
12	Stump Grindings Mulch @ 3.0"
13	Stump Grindings Mulch @ 1.5"
14	Stump Grindings Mulch @ 0.75"

Note: All wood waste and chip materials were used in this project as a mulch that was placed over the soil and not blended.

4.2: Field Testing Program

4.2.1: Design of Test Facility

Fourteen test cells were prepared on a soil slope at an angle of two horizontal to one vertical. Each cell was 30 feet (9.1 m) long by 5 feet (1.5 m) wide with a 3 foot (0.9 m) long apron to collect runoff as shown in Figure 4.3. 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 tipper boxes where the flow rate could be measured. Each tipper box was calibrated in the laboratory to determine flow volume per tip and the number of tips per storm was recorded with a mechanical digital counter. The flow from the tipper box was released thru 5 discharge holes, each with a 2-inch diameter. The center hole of each tipper box was connected to a covered collection bucket at the bottom of the slope to obtain a representative sample of eroded sediment. Details of covered collection bucket arrangement are shown in Figure 4.4. A one-bucket arrangement for the collection of eroded solids was used and there was no 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.

The erosion control filter berm was made from Paper Mill Wood Waste in cell #10. A plywood riser was attached to 1 in. x 6 in. side boards of the cell to develop support for the plywood. A jute mesh was applied at the end to support the berm, which was placed between the plywood 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 measured with the tipper boxes, collected and analyzed for suspended solids.

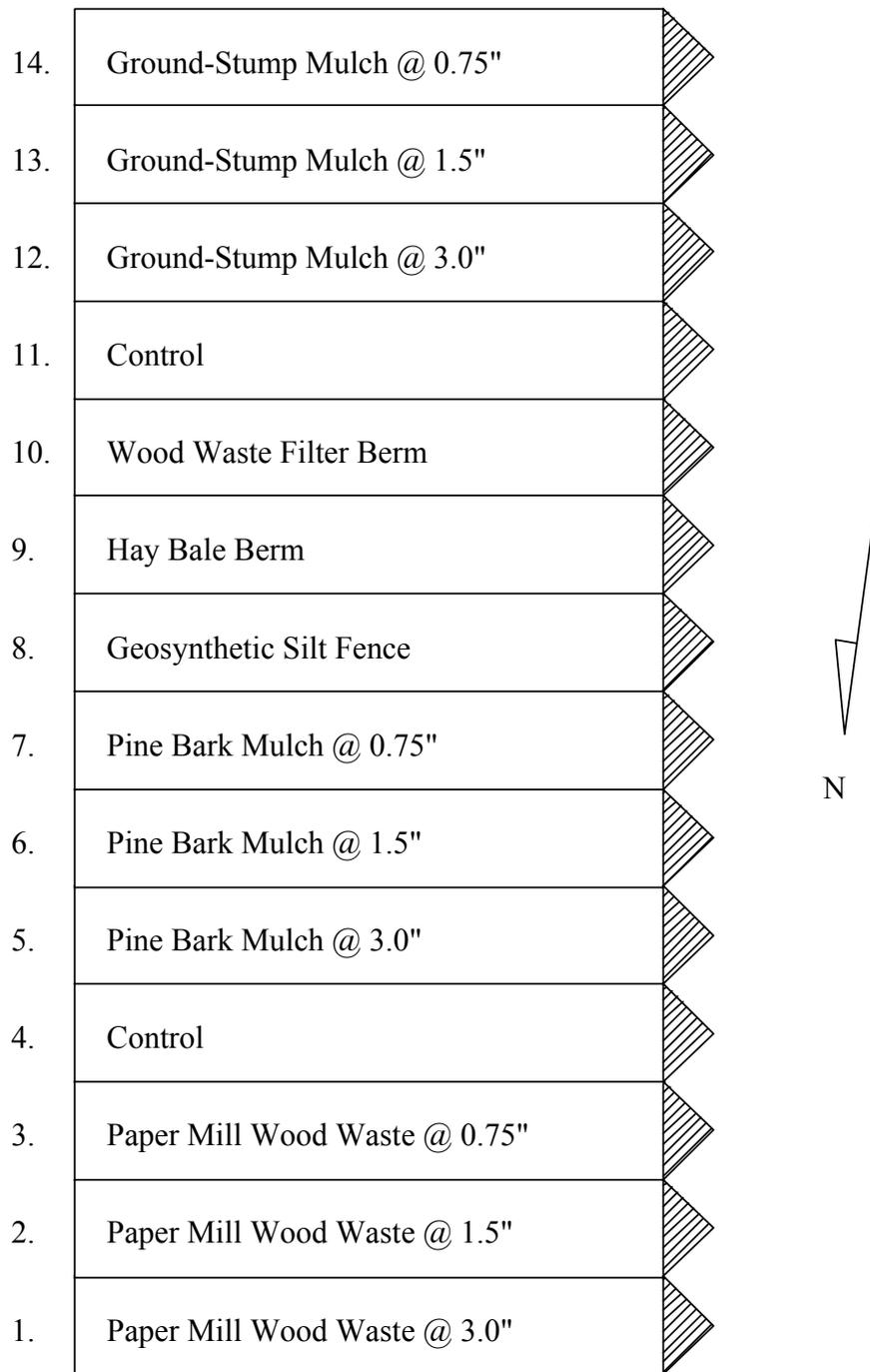


Figure 4.3. Layout of Cells

NOTE: Boards staked every 5'
to prevent flow between cells
and surrounding areas.

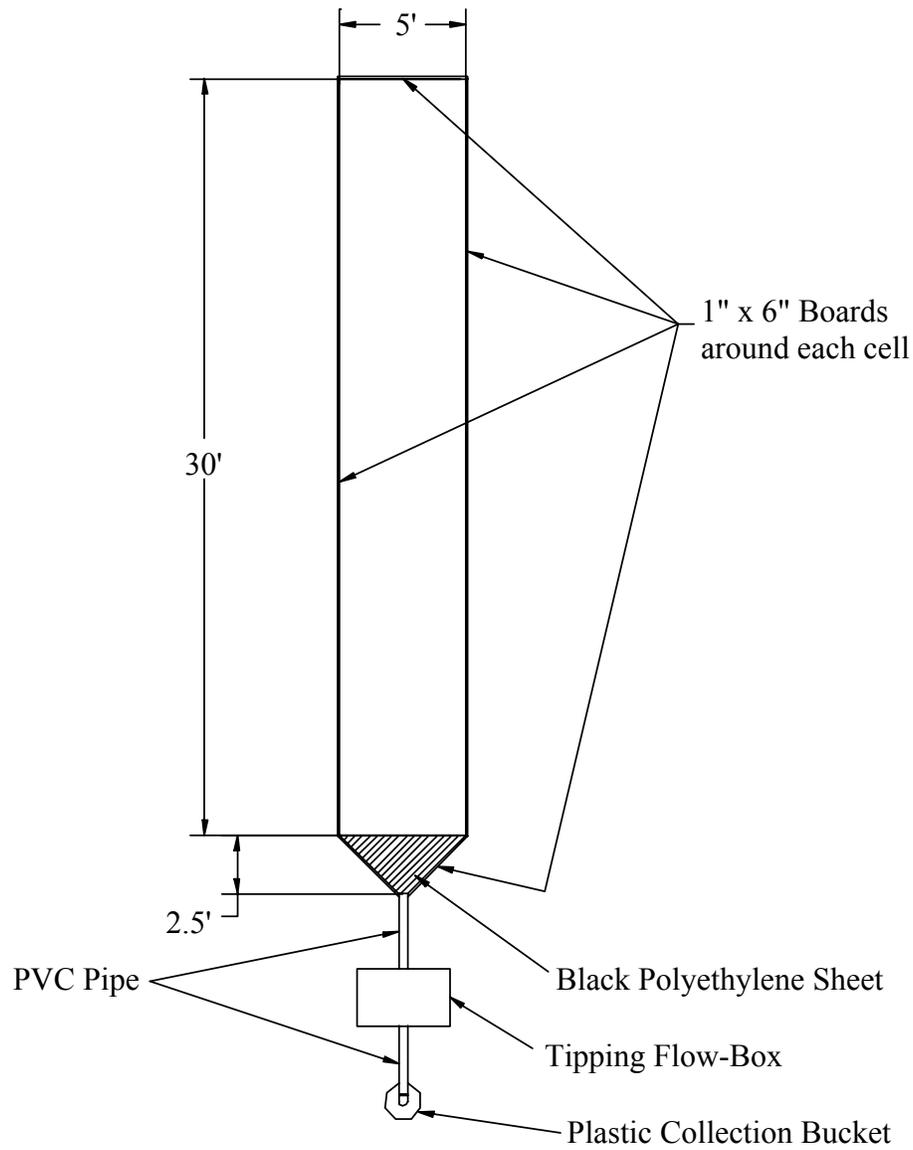


Figure 4.4. Typical Wood Waste Test Cell

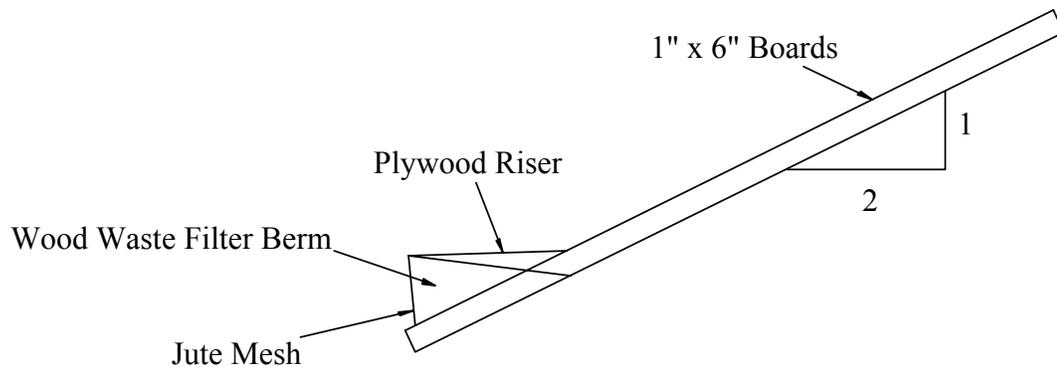


Figure 4.5. Test Cell with Erosion Control Filter Berm

4.2.2: Construction of Test Installation

The ConnDOT contractor built the test facility to specification in May 1999. The site was visited during construction to insure proper configurations of the cells. The initial installation was equipped with six tipper boxes to measure flow and eight of the cells contained no flow measuring capability other than the volume collected in the sample bucket. However, the first rainfall after completing the installation showed the importance of flow measurements and tipper boxes were added to all test cells. Also, a need for improved rainfall data resulted in the addition of an electronic rain gage with capability to measure magnitude and intensity. The installation was completed by mid June.

Several photographs from the field test site are presented in Appendix A. Figures A-1 and A-5 show overviews of the site after installation in mid May 1999 and at the end of August 1999, respectively. Some plant growth (volunteers) had established during the summer months. A close-up view of the paper mill wood waste filter berm, hay bale and geosynthetic silt fence treatments is presented in Figure A-2 after installation in May. Figure A-3 shows a view of typical tipper box with entrance pipe, tipper tray and mechanical counter. A view of the electronic rain gauge with cover removed and mounting stand is shown in Figure A-4. A view of the test cells #1 to 4 are shown in Figure A-6 as they appeared in late August 1999 with some plant growth.

4.2.3: Behavior of Field Installation during Storm Events

A number of small leaks in the flow and collection system were detected during the first few storms in May and June. These leaks were corrected and the system began to function as designed. However, during some very heavy or intense storms, the sediment load from the untreated control cells

(cells #4 and 11) was more than the tipper flow boxes could handle and the tipper trays remained full of sediment and permanently in the tipped position with flow continuing unmeasured. This condition never happened in any of the other test cells.

In late September 1999 at the end of the field test program, some construction grading and asphalt paving of the parking area above the test site lead to increased flow of water across test cell #4 during the last storm event on 9/30 – 10/4. Some rill erosion was observed in this test cell when the rainfall data and water samples for this storm event were collected.

4.3 Testing Program

An objective of the testing program was to evaluate the performance of the various surface treatments when subjected to the expected range of rainfall magnitude and intensity. This was difficult to achieve because of the random nature of storms but was accomplished by visiting the field site after each storm for the period of June through mid-October. As noted earlier, an immediate decision was made to either sample and record data from a storm or to clean up the site, and disregard the data, in anticipation of the next storm. This decision was made based on the rainfall accumulations measured in two simple rainfall site gauges and the flow volumes discharged from each cell that was measured by the tipper boxes. Fewer than 10 tips of the bucket in the control cells indicated that there had not been enough runoff from the treated cells to make any meaningful measurements.

In addition to the two simple rain gauges placed at the field site, one automated tipping-bucket rain gauge was used for more precise rainfall data. The two simple rain gages were only used with tipper box data for screening a storm event to decide if a thorough sampling and analysis of the test cell and storm data was warranted. They were used to measure the approximate amount of precipitation falling on the immediate area during each storm but provided no information about storm intensity. The automated tipping bucket rain gauge was used to determine rainfall magnitudes to an accuracy of 0.01 inches of rainfall / tip. An electronic data logger was used to record the time for each tip of the bucket; thus, the rainfall intensity could be determined. The electronic data logger uses a microprocessor chip to store the data and was purchased with software so that the data could be downloaded to a personal computer.

A typical rainfall-time plot for the July 19, 1999 storm is shown in Figure 4.7. as produced by the data logger computer software. Each dot on the graph represents 0.01 inch of rainfall at the time of day that the rainfall occurred. The slope of the curve represents the rainfall intensity. For purposes of analyzing the flow and solids eroded from each test cell, the total rainfall and maximum intensity of the most significant part of each storm were determined. In some analyses, an “average” intensity was used but in all instances, the method of determining intensity is approximate.

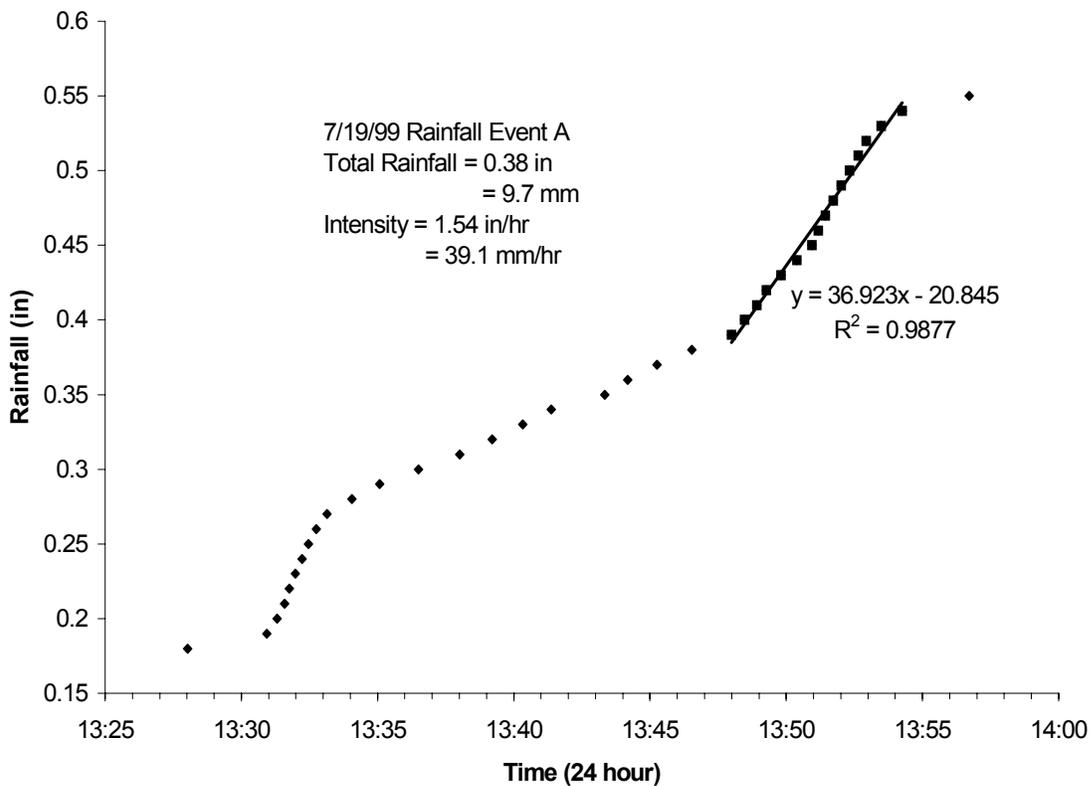


Figure 4.7 Typical Rainfall – Time Graph for 7/19/99 Storm

The summer, from June through July, was a very dry period with most rainfall occurring from thunderstorms of short duration and high intensity. It was common to have two or more storms (bursts of rainfall) in one day or over a weekend period. Multiple rainfall events during a day or over a weekend are treated as one storm event unless the site was sampled and data obtained between storm events as was achieved on 7/19/99 where the two storms are designated as “A” and “B”. Storms occurring from August onward tended to be of higher magnitude and lower intensity.

5.0 Typical Field Test Data

5.1 Storm Event Sampling

Preparation of the test site was completed in late April 1999 and all surface treatments were in place with appropriate thickness and cleaning completed by 6 May 1999. All test cells had tipper boxes installed by mid June at which time the electronic rain gage was placed at the site. None of the cells were seeded or stabilized other than by the wood waste surface treatments. Weed control was performed every month or so with a spray-on weed killer. Occasionally, some weeds were pulled or cut to keep roots from developing as an erosion retardant. As a result of weed control, the late fall storm events were expected to test the erosion resistance of these surface treatments before growth could be established.

The storm events sampled along with their total rainfall and intensities are summarized in Figure 5.1. Eleven storm events with rainfalls greater than 6 mm (1/4 inch) were sampled before subfreezing weather set-in during early November. The rainfalls varied from 6 mm to a maximum of 110 mm (4.35 inches) for Hurricane Floyd on 9/16/99. Some of the storms were very intense and, for brief periods, exceeded the capacity of the tipping bucket rain gauge. For each storm event, the maximum intensity level was estimated from the rainfall – time data such as that shown in Figure 4.7. The maximum rainfall intensities for each storm are also shown in Figure 5.1. Some storms were also accompanied by heavy winds. The combination of wind and runoff resulted in some disturbance (toppling) of the runoff collection system. Runoff samples were described by a number system that includes the test cell number, and storm date, such as, 3-7-6 for cell 3, and the storm on July 6, 1999. Only one test cell (Cell 4) experienced some rill erosion during the test period and that was a result of uncontrolled drainage from the parking area above during paving operations in late September.

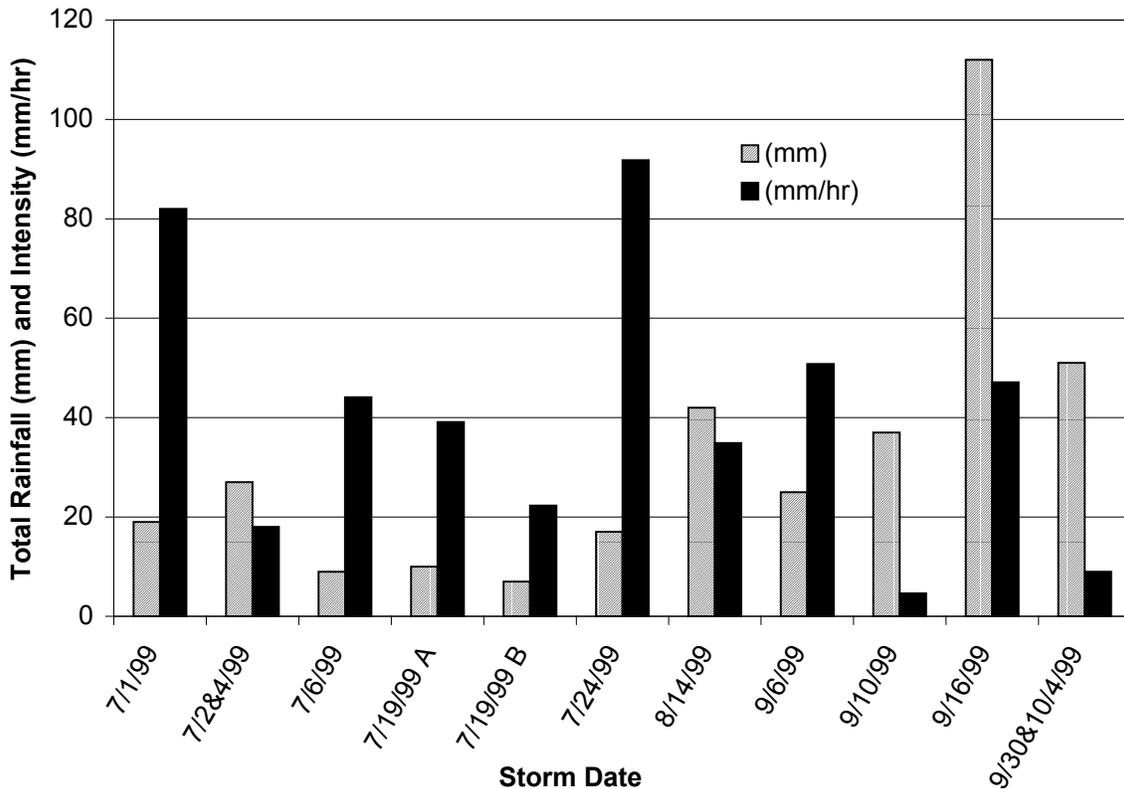


Figure 5.1 Summary of Storm Events Analyzed

A day or two after a storm event, each runoff collection bucket was sub-sampled with a 50 ml plastic vial for analysis of suspended solids in the runoff water. Sampling was achieved by stirring the contents of the bucket to create a homogeneous suspension and submerging the sampling vial to obtain a representative specimen. In the laboratory, the contents of each vial was oven-dried and weighed on an analytical balance to determine the suspended solids concentration for each collection bucket in g/l. These suspended solids measurements are an indicator of average erosion from each cell treatment and storm event, and are combined with the total runoff measured by the tipper boxes to determine the mass of sediment particles eroded from a slope. The mass of sediments eroded from each cell had to be corrected for the mass of coarse particles that tended to collect on the apron at the bottom of a slope and not enter the collection system. Thus, each apron was cleaned following a storm event and the mass retained on the apron was added to the mass of solids that flowed through the tipper boxes. All collection buckets and tipper boxes were washed and flushed with water before reconnecting to the system in anticipation of the next storm event.

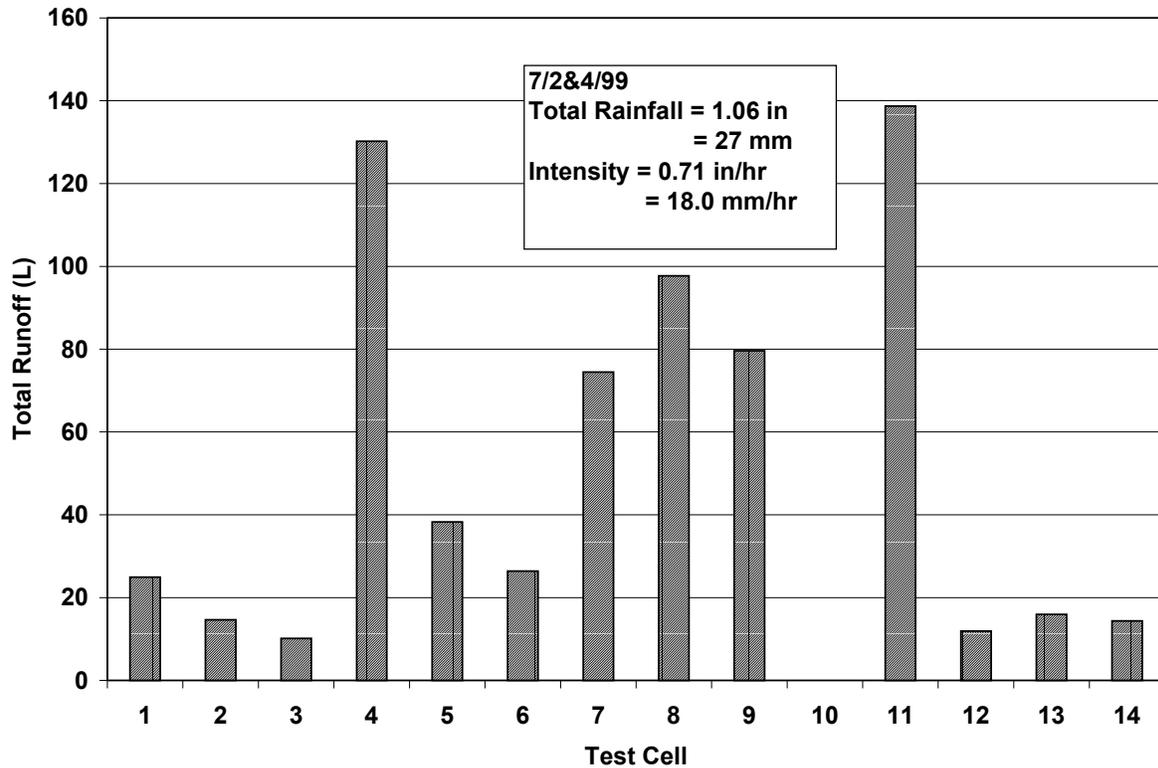


Figure 5.2. Typical Rainfall Runoff Data from Test Cells (Storm 7/2&4/99)

5.2 Surface Runoff Volumes

The amount of runoff was measured with the tipping buckets at the bottom of each cell. The volume of water to cause one tip was known from the calibration, and the number of tips was recorded with a digital counter attached to the tipper. The total runoff was adjusted for the amount that fell on the plastic sheet at the bottom of each cell, because this amount of rain could not erode any soil. Runoff from a typical storm event from the summer of 1999 is shown in Figure 5.2. This figure shows that the most runoff occurs in the control cell areas. These are the results for the storm event(s) of July 2&4, 1999, which resulted from a total rainfall of 27mm. The wood waste was probably dry at the beginning of this storm. Cell 10 measured only the amount of rain falling on the plastic apron, thus, there was no flow recorded. The other runoff water must have percolated into the soil at the berm or been absorbed by the wood waste. All runoff records of measured storms appear in Appendix C.

5.3 Suspended Solids in Surface Runoff

The performance of various cell surface treatments for a typical storm is displayed in Figure 5.3. Additional erosion charts are presented in Appendix D and are similar to these test results.

Figure 5.2 presents the runoff results from a storm event where a heavy rainfall of 27 mm (1.06 inch) occurred over a long weekend. 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). There were storm events, especially when the leaves began to fall, in which the entrance to the pipe became obstructed. In these cases the measured runoff was accurate and all of the eroded soil was accounted for by carefully cleaning the plastic apron and adding the resulting solids to that from the plastic bucket

There was a difficulty with the tipper buckets for the control cells during two of the longer, more intense storms. They received so much sediment that they were held in the down position. In these cases the amount of sediment was determined by carefully collecting all of the solids from the plastic apron, the tipper bucket and the plastic collection bucket. The amount of runoff was estimated from the data of the other cells.

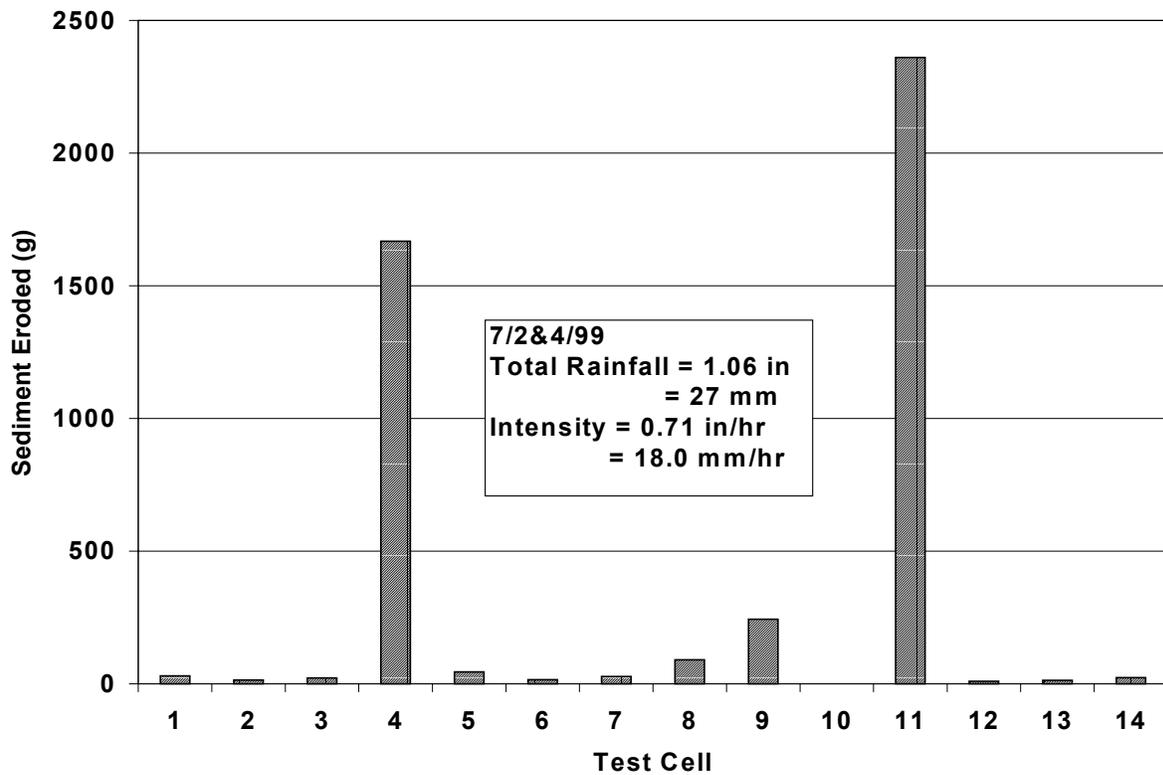


Figure 5.3: Sediment Eroded from the Storm on 7/2&4/99

6.0 Analysis and Discussion of Field Results

6.1 Runoff

The runoff volumes varied among the cells with the amount of total rainfall in the storm. Most of the storms measured were less than one inch in total rainfall, and the total runoff from a typical storm is shown in Figure 6.1. This data is taken from Storm 7/19/99A. In each plot of total runoff, the bars represent the measured amount less the amount that fell on the plastic apron at the bottom of each cell. Figure 6.1 shows that there is much less runoff from the treated cells than from the control cells. This is probably due to the wood waste coverings becoming dry between summer storms and allowing absorption and percolation of rainfall during a storm. It is important to note that cells 8,9, and 10 are used to compare the performance of the wood waste filter berm in cell 10 with the effectiveness of hay bales in cell 8 and a geosynthetic silt fence in cell 9. These cell surface areas are untreated like the control

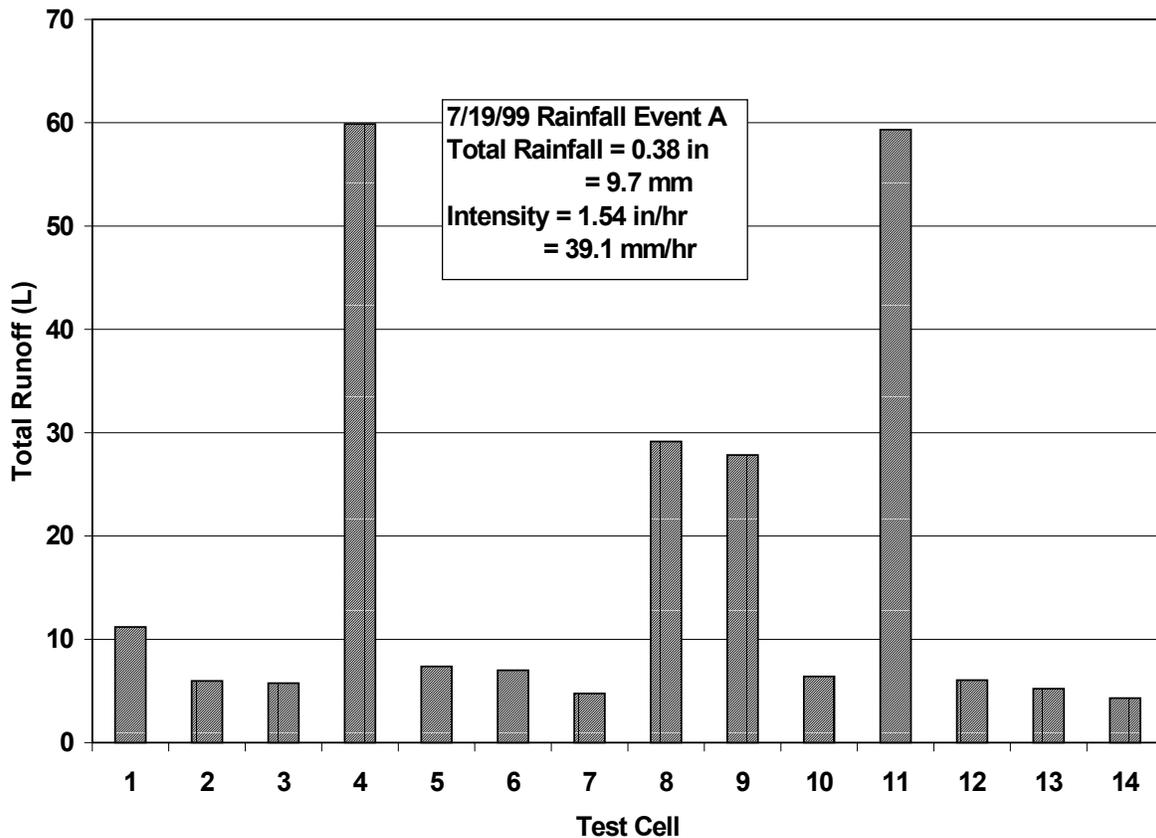


Figure 6.1 Total Runoff for all Cells for the Storm 7/19/99A

Cells. Their retention of the flow allows some of the runoff water to percolate into the soil.

The other extreme of runoff events occurred during Hurricane Floyd on 9/16/99. Figure 6.2 shows the runoff for each cell during this very heavy storm that dropped a total of 112 mm of rain. This storm lasted long enough to saturate the wood waste materials and, as a result, the runoff from the cells covered with wood waste is substantial, and approaching the amount from the control cells. Runoffs for all storms fell between these two patterns in Figures 6.1 and 6.2.

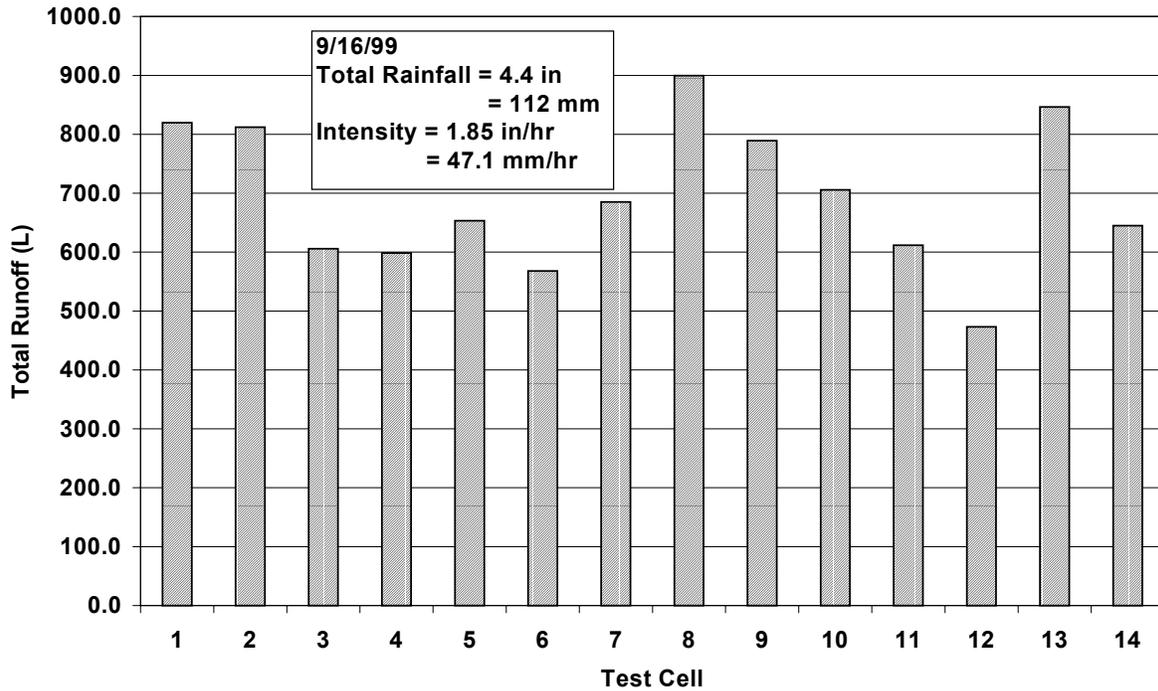


Figure 6.2 Runoff from the Biggest Storm (Hurricane Floyd)

The amount of runoff from the control cells 4 and 11 that resulted from all storms except the one of greatest intensity (7/24/99) are shown in Figure 6.3. As can be seen from this Figure the amount of runoff is directly related to the amount of rain in the storm. The data from storm 7/24/99 are omitted because the tippers in the control cells were overloaded with sediment and tipped in the down position resulting in poor data for these cells.

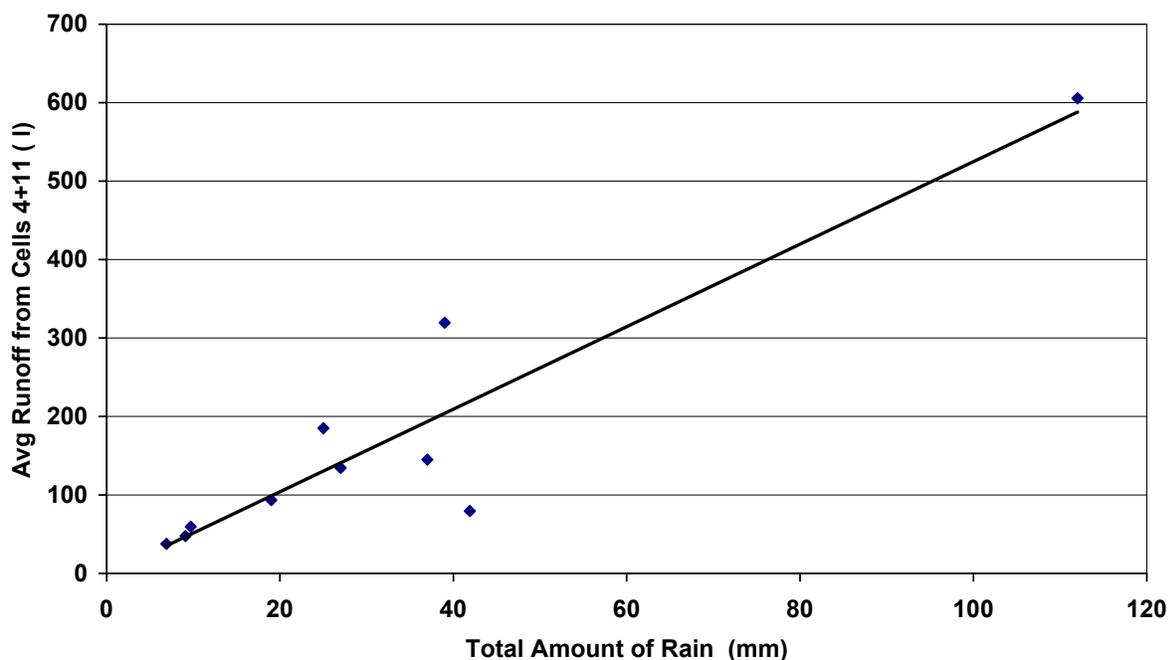


Figure 6.3 Surface Runoff from Control Cells 4 and 11 with Rainfall

6.2 Amount Eroded

The amount of soil eroded from each cell is shown in Figure 6.4 for a light rainfall, and in Figure 6.5 for the biggest storm event. As can be seen from both figures, the cells covered by the wood waste materials experienced little soil erosion compared to the control cells. These data show that the wood waste material is effective in preventing erosion. As expected, the larger storm increased the soil erosion from the control cells proportionately more than from the protected cells.

During all of the storm events, the wood waste filter berm was more effective in retaining erosion products than either the hay bales or the geosynthetic silt curtain.

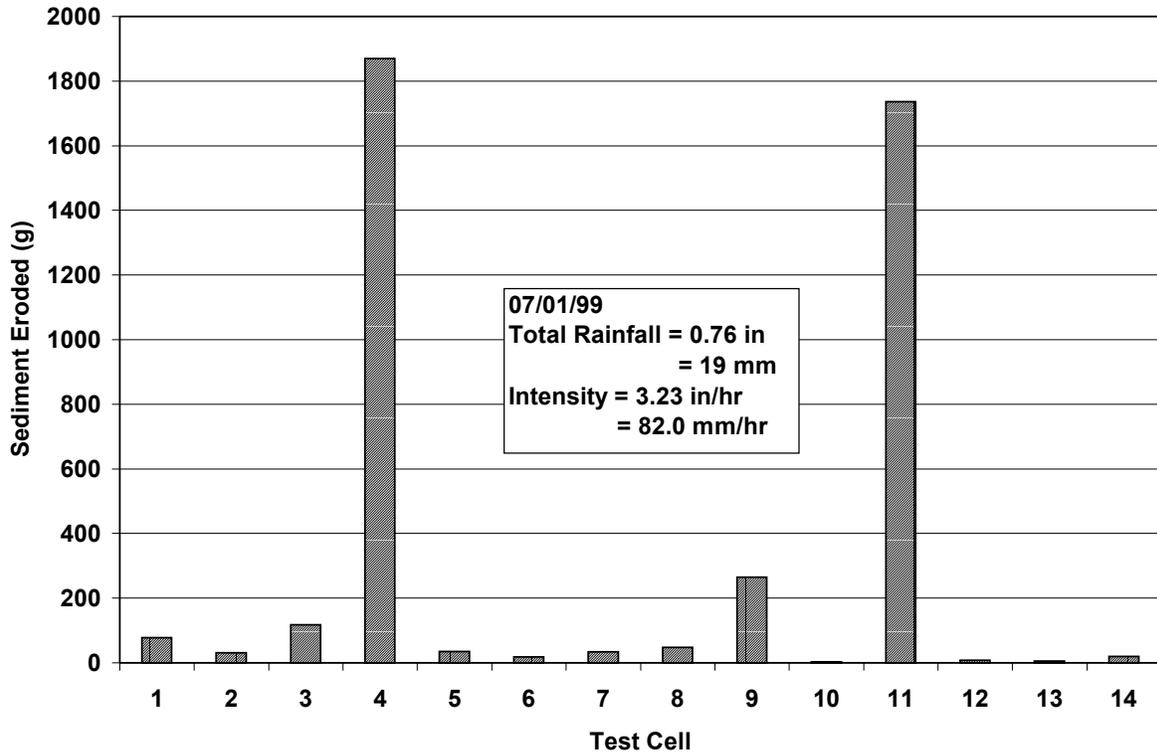


Figure 6.4 Amount of Soil Eroded from Various Cells (Storm 7/1/99)

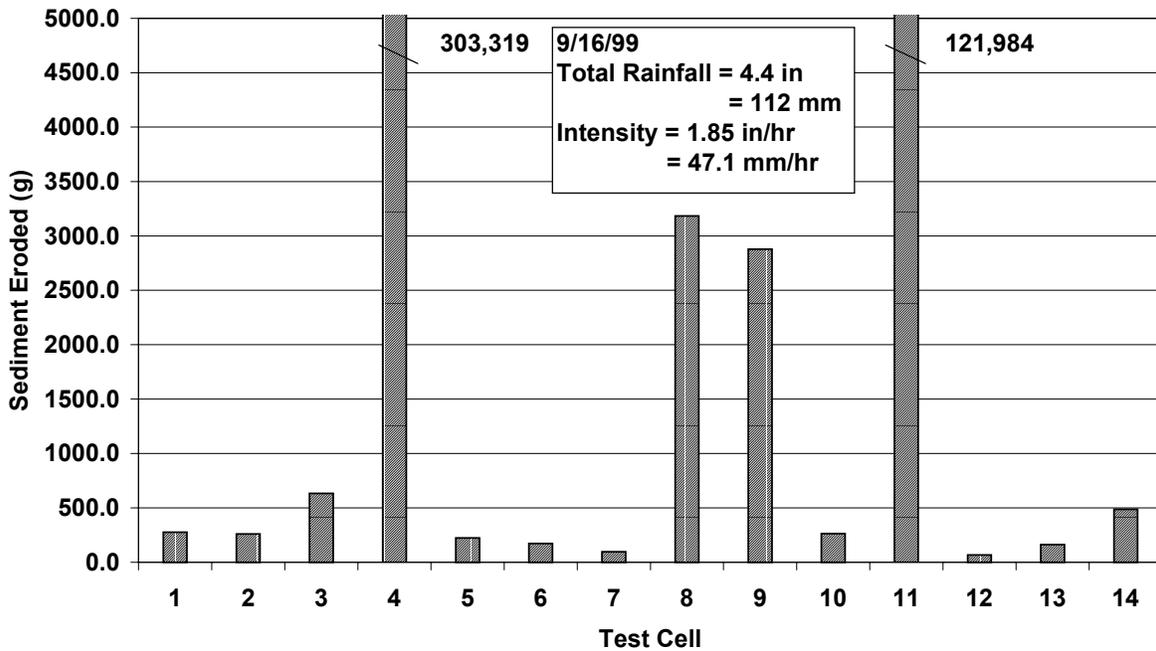


Figure 6.5: Soil Eroded from Cells during Hurricane Floyd (9/16/99)

6.2.1. Erosion Control Structures

The test cells for the erosion control structures including the geotextile silt fence (cell 8), hay bales (cell9) and wood waste filter berm (cell 10) have an erodable area (bare ground) from the top of the cell to the soil-retention structure near the bottom. Therefore it can be assumed that the amount eroded in cell 8,9, or 10 is similar to that eroded in the control cells. The difference in the amount of eroded soil reaching the measuring system is the effect of the erosion control structure. Figure 6.6 shows the ratio of the amount of soil reaching the measuring systems below the retention structures to that measured at the control cells. The results are presented as a percentage. As can be seen from Figure. 6.6 all erosion control structures are effective in significantly reducing the amount of eroded soil that gets past the structure. The geosynthetic silt fence is more effective than a hay bale berm, but the wood waste filter berm reduces the amount passed by nearly an order of magnitude.

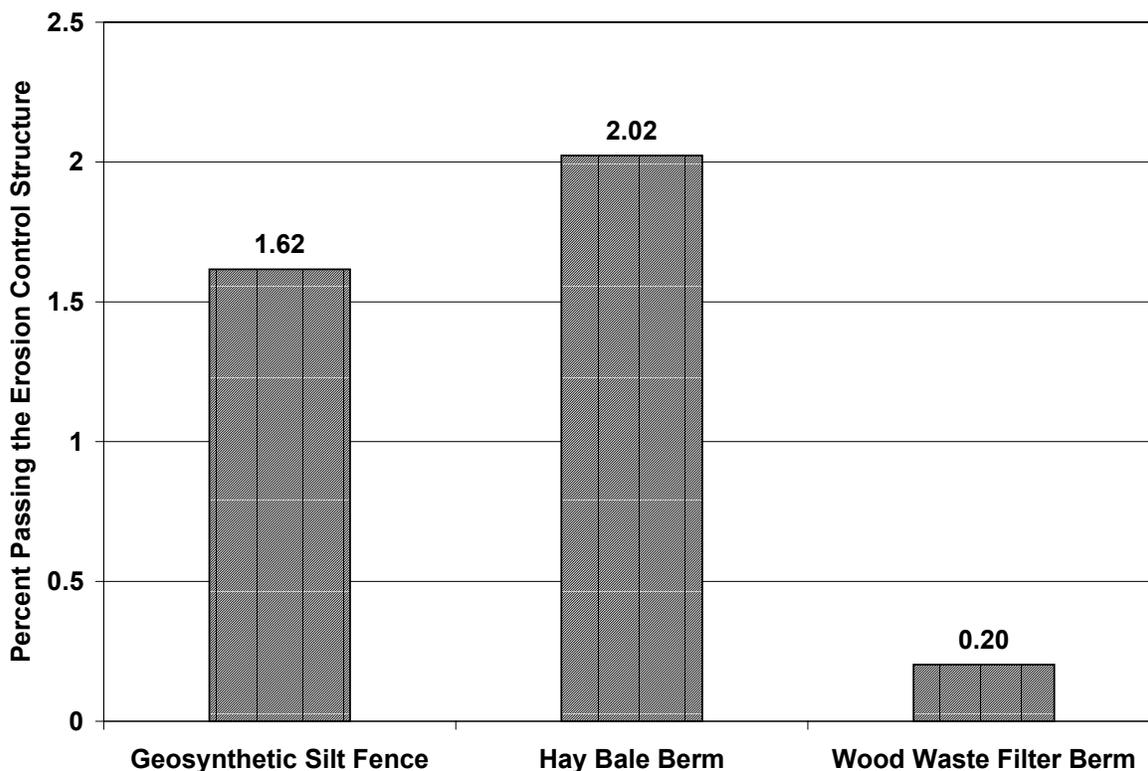


Figure 6.6 Comparison of the Effectiveness of the Erosion Control Structures

6.2.2 “C” Factors

The C factors should be calculated on the basis of erosion that occurs under a series of typical storms for a given region. This research period did not cover a period of typical storms, therefore these C

factors must be considered preliminary until more data can be gathered. Nevertheless the factors from the research reported here appear reasonable. These factors were calculated based on the ratio of the total soil eroded from the cell divided by the average total amount from the two control cells.

The amount of suspended solids and solids collected from the plastic apron were combined for each event for each cell, and summed over the storm events. Cells 4 and 11 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:

$$A = R K L S C P \quad (6.1)$$

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

The rainfall intensity factor, R, is the same for all cells, 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 erodibility 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:

$$\frac{A_{\text{treat}}}{A_{\text{control}}} = \frac{C_{\text{treat}}}{C_{\text{control}}} \quad (6.2)$$

Taking $C_{\text{control}} = 1.0$ (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 Figure 6.7 where the wood waste is effective in minimizing the erosion of soil from the slope. All of the factors shown in Figure 6.7 are lower than $C=0.01$ usually assigned to areas covered with mulch. Figure 6.7 shows that wood waste mulch at a thickness of 0.75 inches (19mm) protects the soil from being eroded as effectively as a thicker coverings. There is no discernable trend involving thickness of wood waste materials and erosion protection.

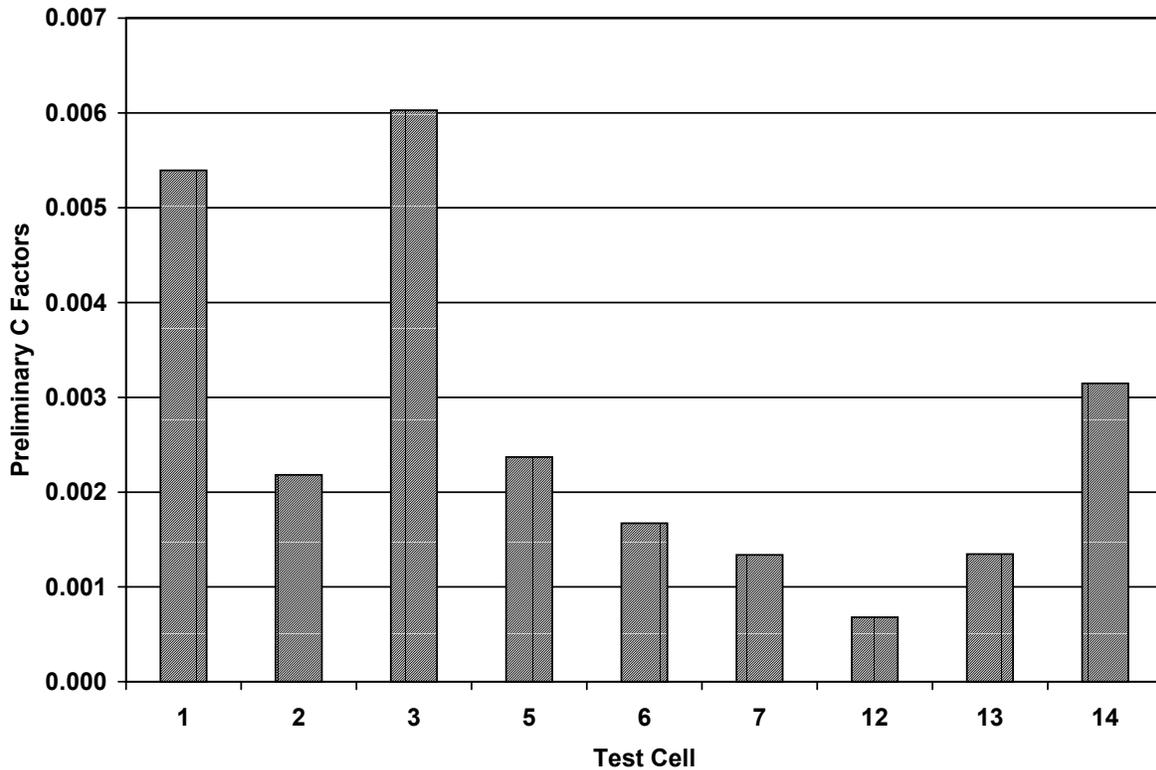


Figure 6.7 Preliminary C Factors for Wood Waste Coverings

6.3 Variation of Soil Erodability with Time

Soils in New England usually consist of a wide range of particle sizes. The smaller of these particles are more erodable than the larger sizes. To answer the question of erodability changes over the course of numerous storm events, the amount of soil eroded during each event was analyzed. The results are normalized by the amount of rain and the results are shown in Figure 6.8. All storm events except Hurricane Floyd are plotted in this Figure. As can be seen the erodability of the soil decreases with successive storms, probably due to the larger, more stable particles that remain behind.

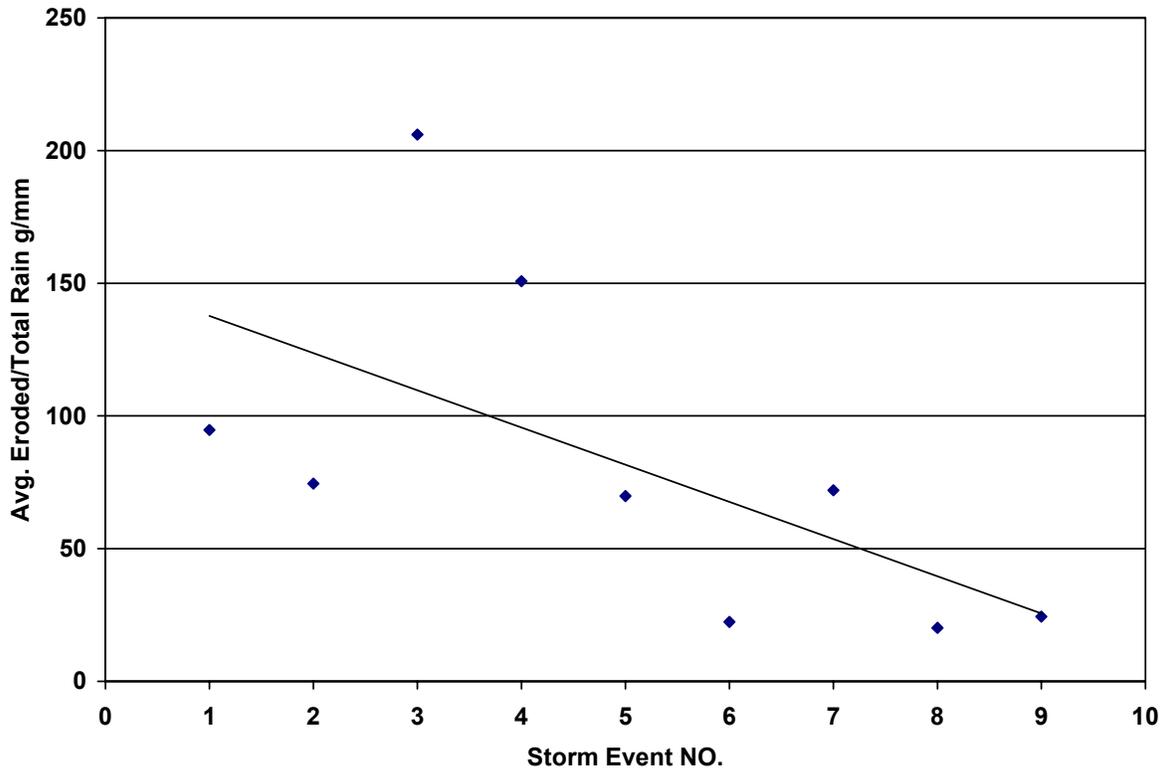


Figure 6.8: Change of Soil Erodability with Storm Event

7.0 Summary and Conclusions

Summary.

Three wood waste materials were evaluated for use as an erosion control mulch and one of the materials was used as an erosion control filter berm. Samples of the three materials were subjected to laboratory tests to determine their physical and chemical properties for comparison with the CONEG specifications for these erosion control applications. Each of the materials was subjected to large scale erosion control testing at a field site with a slope of 1 vertical to 2 horizontal. Fourteen test cells (5' W x 30' L each) were prepared with different wood waste treatments; nine contained erosion control mulch applications at thicknesses of $\frac{3}{4}$ to 3 inch. Two cells were left untreated as reference cells and three other cells were untreated but contained erosion control structures including wood waste filter berm, geosynthetic silt fence and hay bale silt barrier. The erosion control performance of each cell treatment was evaluated for eleven storm events of varying rainfall magnitude and intensity. Calibrated tipper buckets were used to measure the runoff from each cell and collection buckets were used to sample runoff and determine the mass of sediment eroded from each cell. Total rainfall and intensity of each storm was measured with an electronic rain gauge.

Conclusions.

1. Wood waste materials are effective in minimizing erosion when applied to the soil surface as an erosion control mulch with a thickness of 0.75 inches or more. An untreated soil surface produced over 50 times more sediment than a treated surface.
2. Wood waste materials are particularly effective in reducing runoff during storms under 0.5 inches by absorbing rainwater and by promoting percolation.
3. Layers of wood waste materials of 0.75 inches allow vegetation to root and grow through it.
4. The wood waste erosion control filter berm was more effective than either hay bales or geosynthetic silt fence at controlling erosion. While all erosion control structures were effective compared to no treatment, hay bales and geosynthetic silt fence released about an order magnitude more sediment than wood waste filter berm.

8. Glossary of Terms

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 bio-degradation and stabilization of organic matter under controlled conditions.

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

Compostable Material: a material that 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 in incinerators or landfills.

pH: a number between 0 and 14, and is a measure 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.

Refuse: 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 re-manufacturing 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 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 phyto-toxins.

Wood Waste Material: a material that can consist of a mixture of bark, wood shavings, wood chips, wood scraps and mineral grit that is a by-product of the lumber, paper, construction and other industries.

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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Appendix A Photographs of the Field Test Site

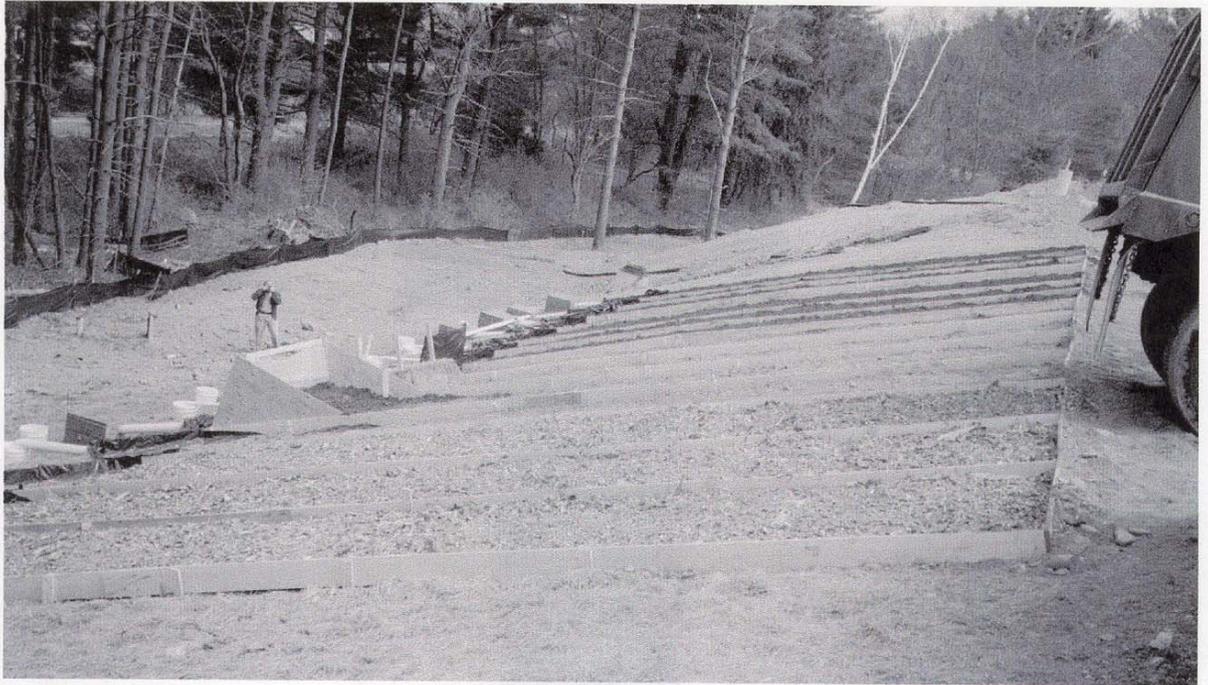


Figure A-1 Overview of Field Test Site in mid-May 1999



Figure A-2 View of Filter Berm, Hay Bale and Silt Fence

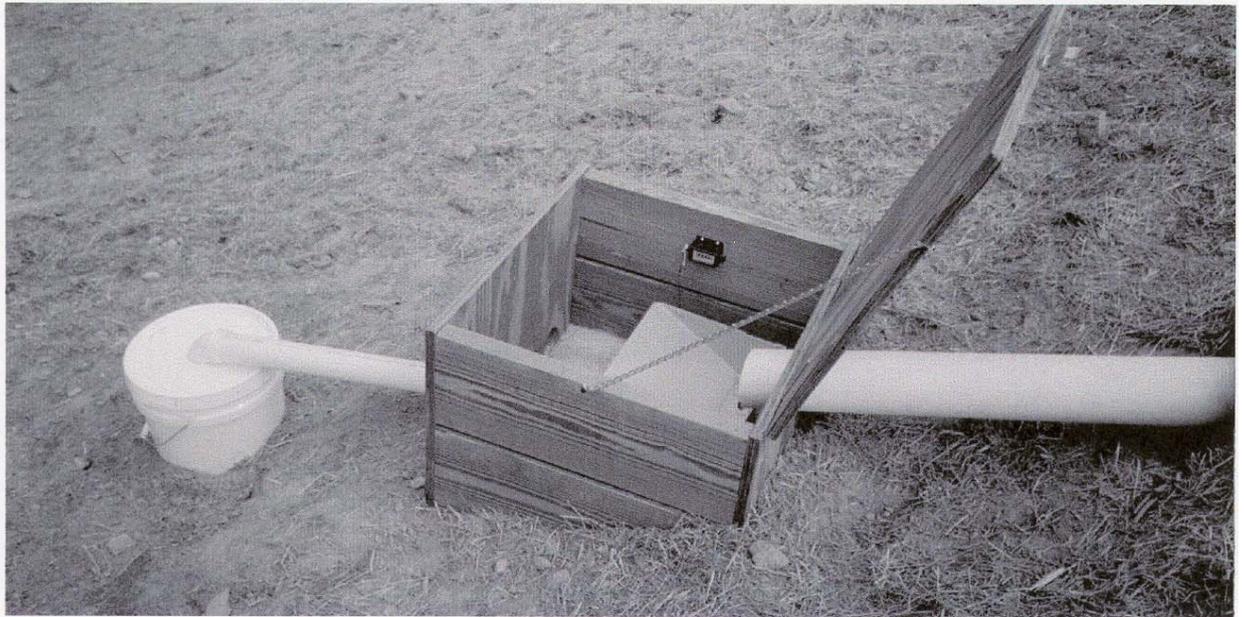


Figure A-3 View of Typical Tipper Box for Flow Measurement



Figure A-4 Close-up View of Electronic Rain Gauge without cover



Figure A-5 Overview of the Field Test Site at End of August 1999

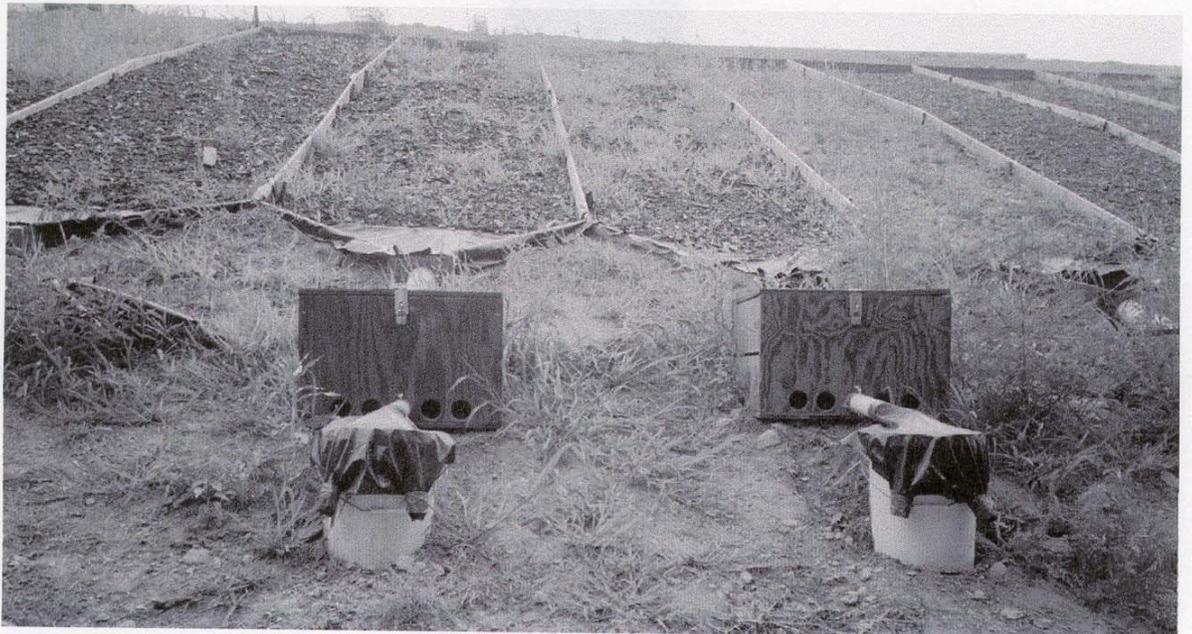
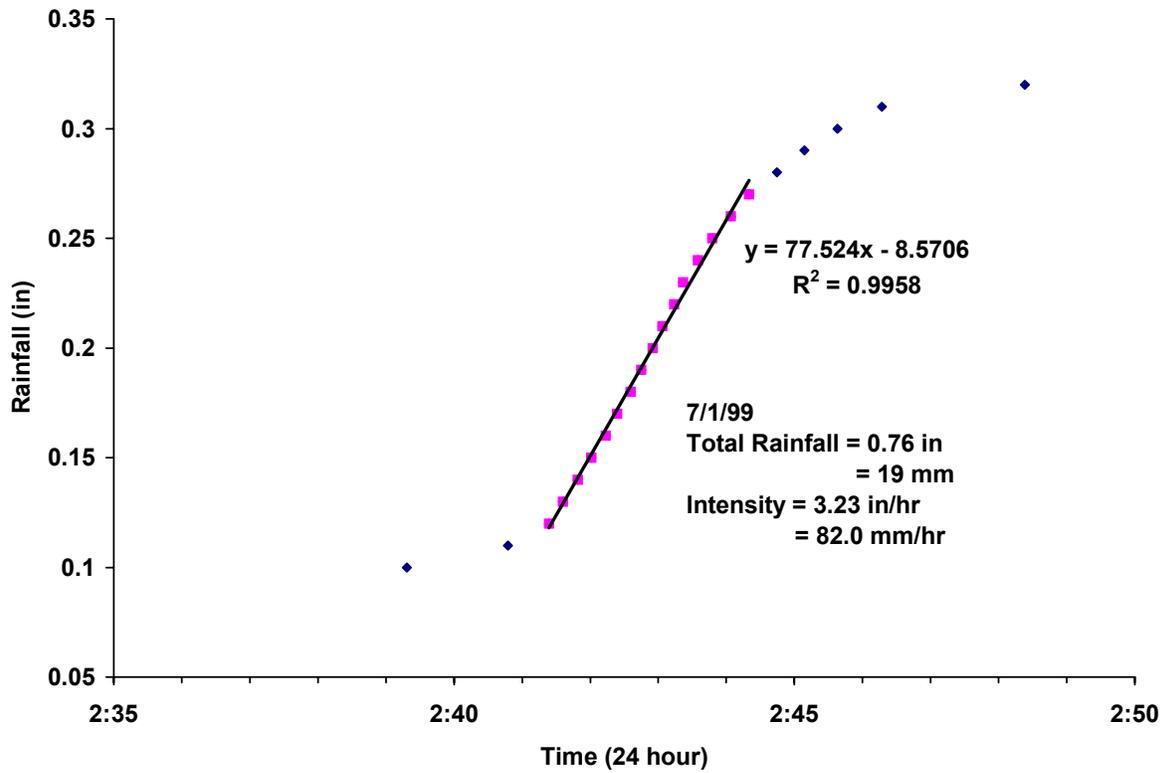
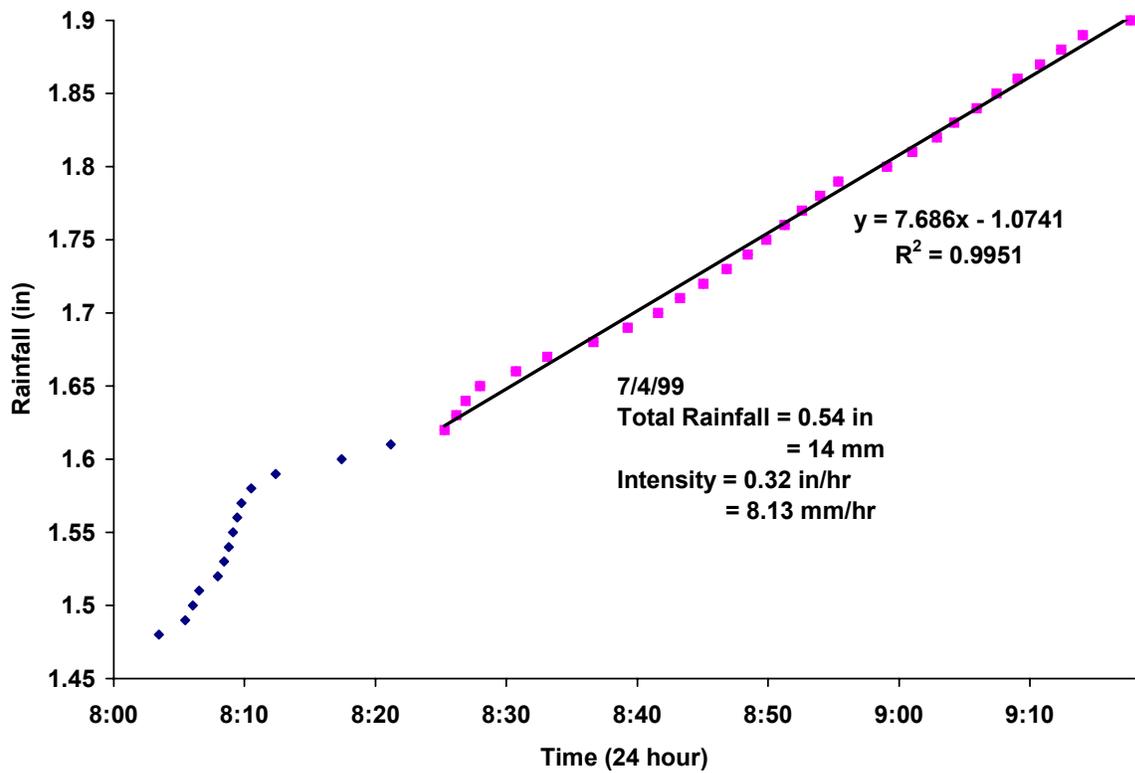
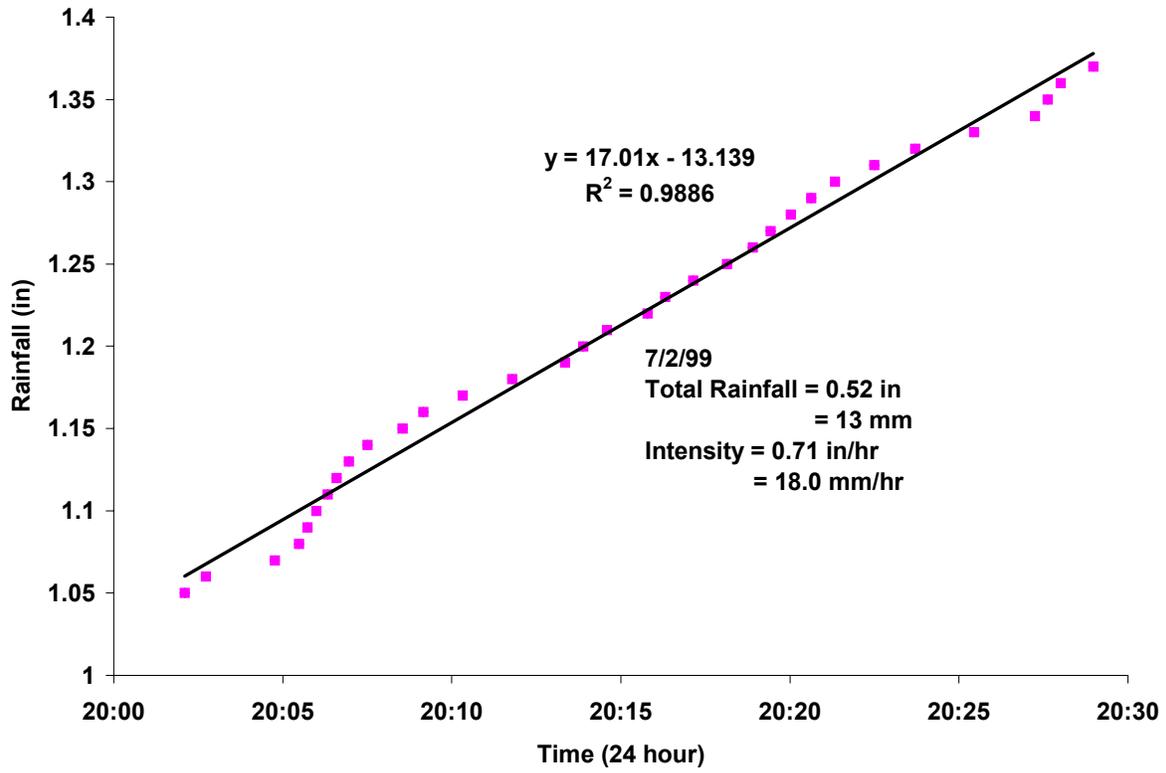


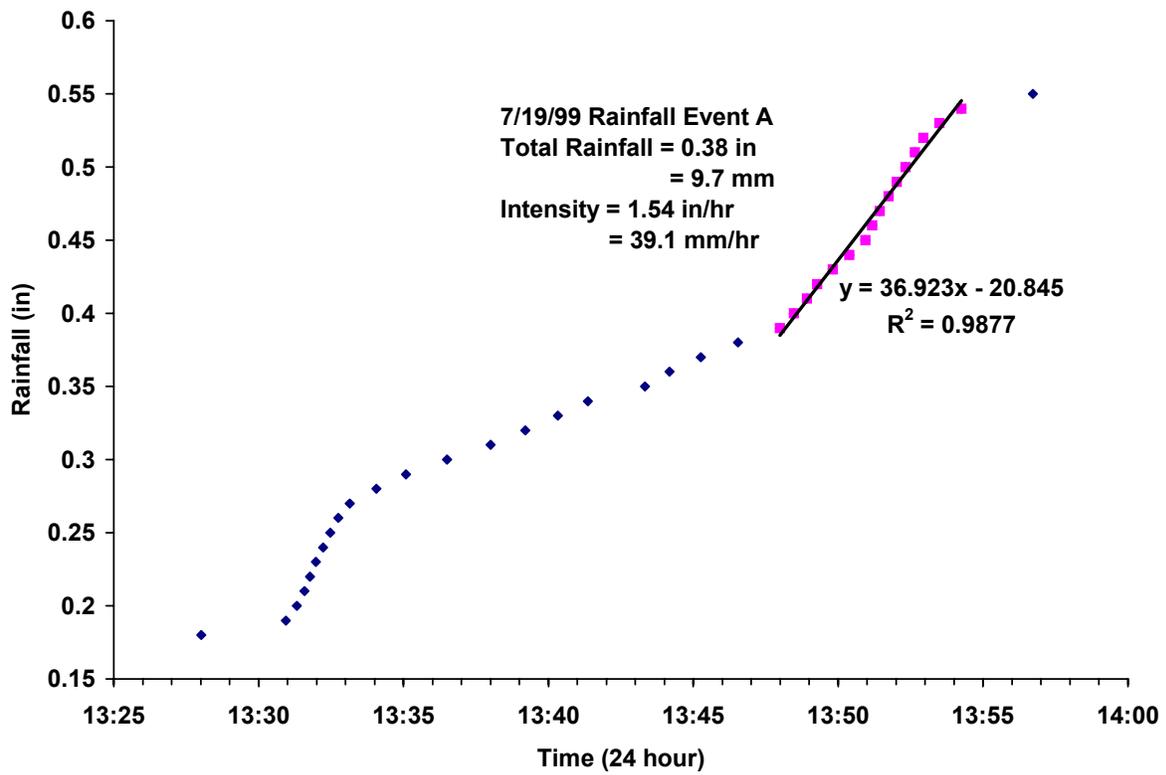
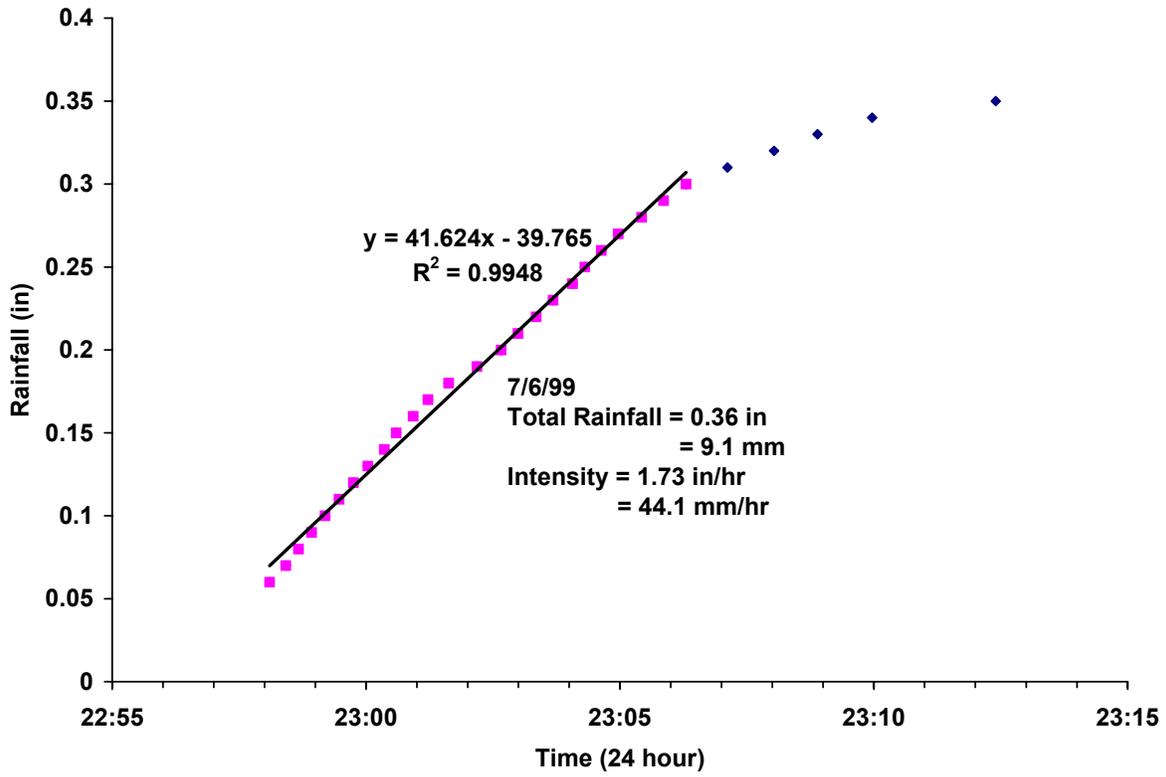
Figure A-6 View of Test Cells 1 (left) to 4 in Late August 1999

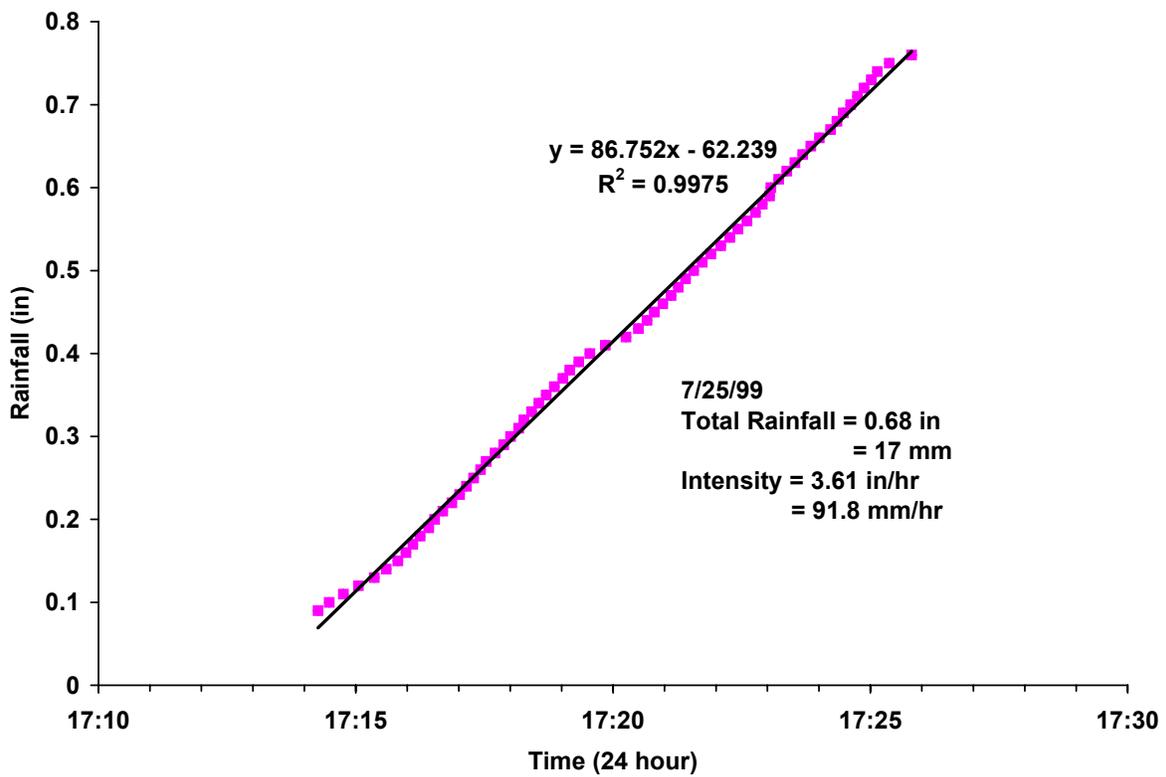
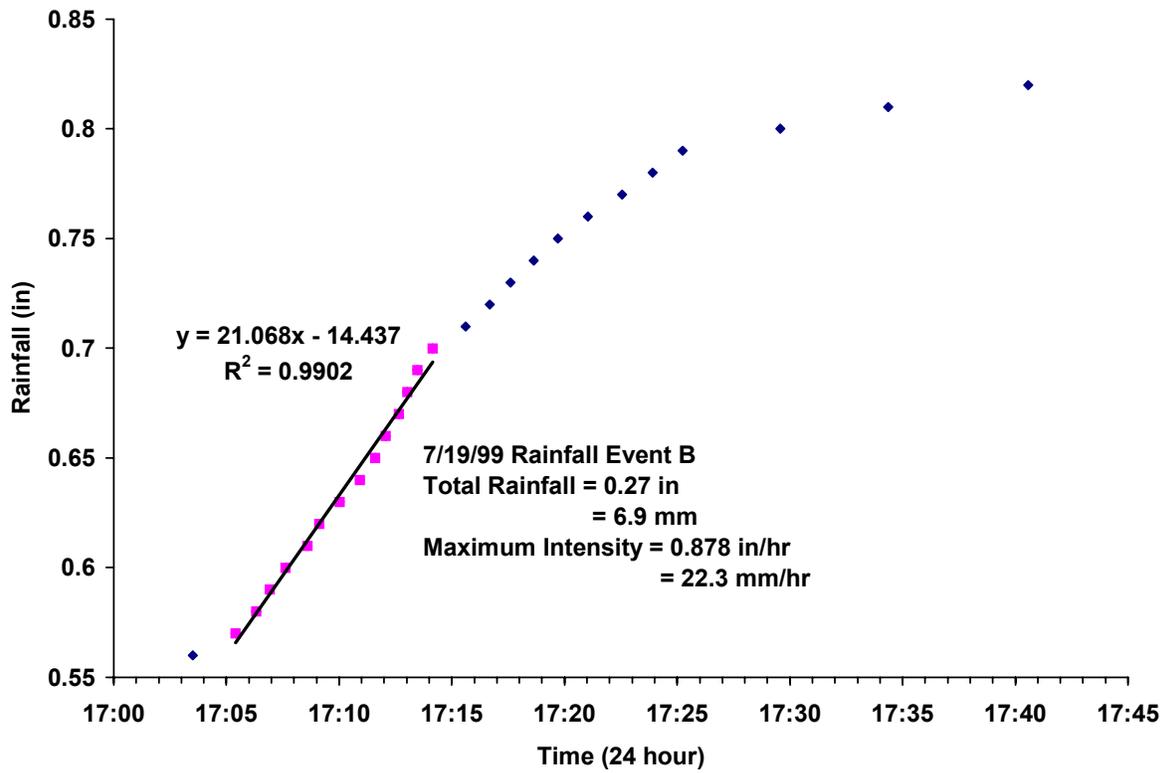
Figure A-6 View of Test Cells 1 (left) to 4 in Late August 1999

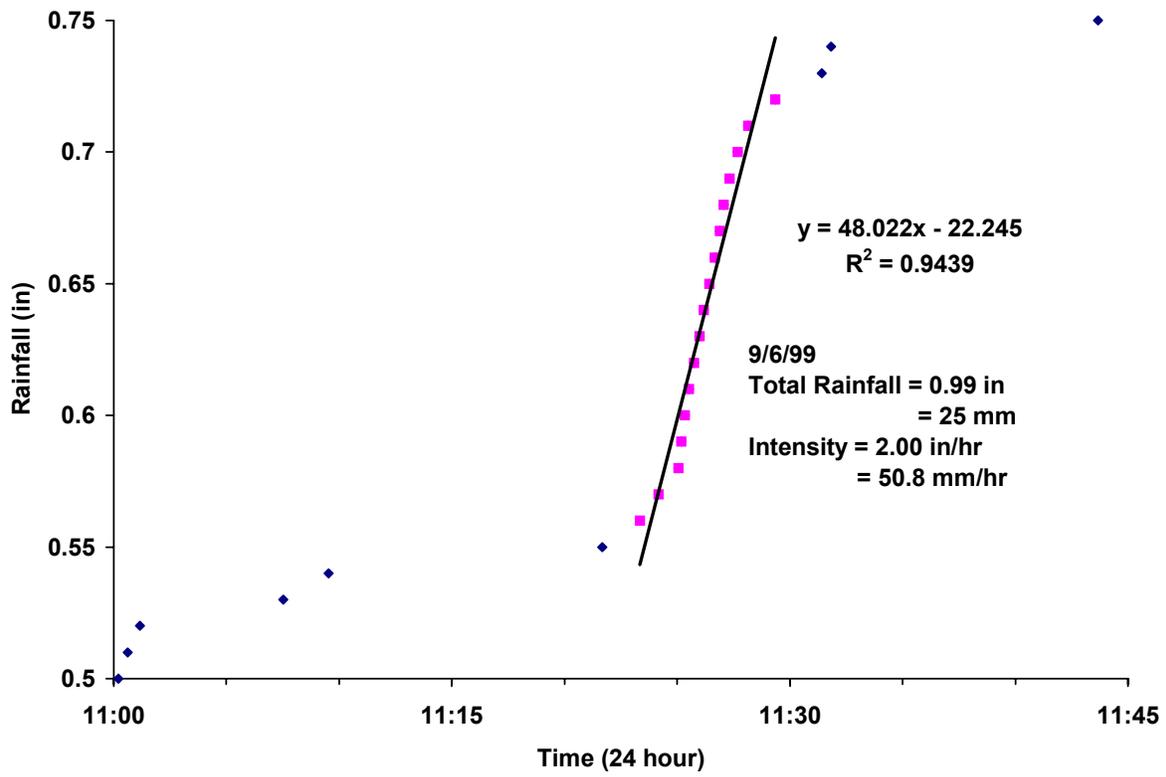
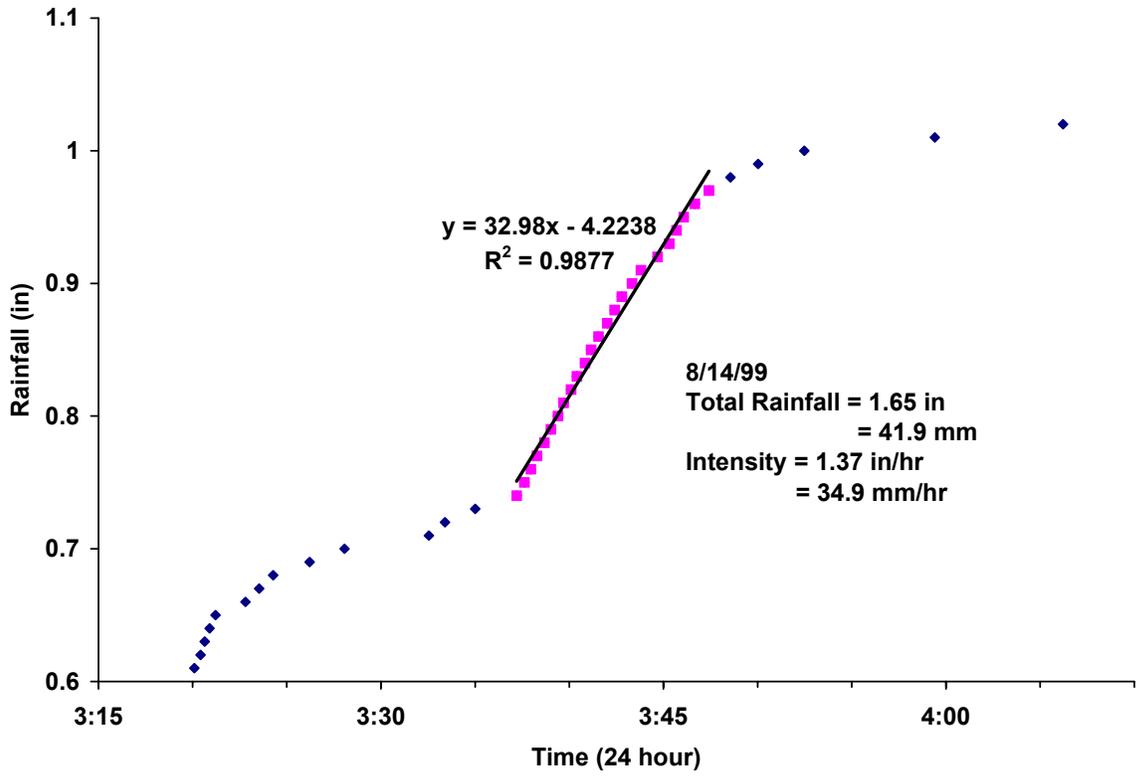
Appendix B Rainfall- Time Plots at Maximum Storm Intensity

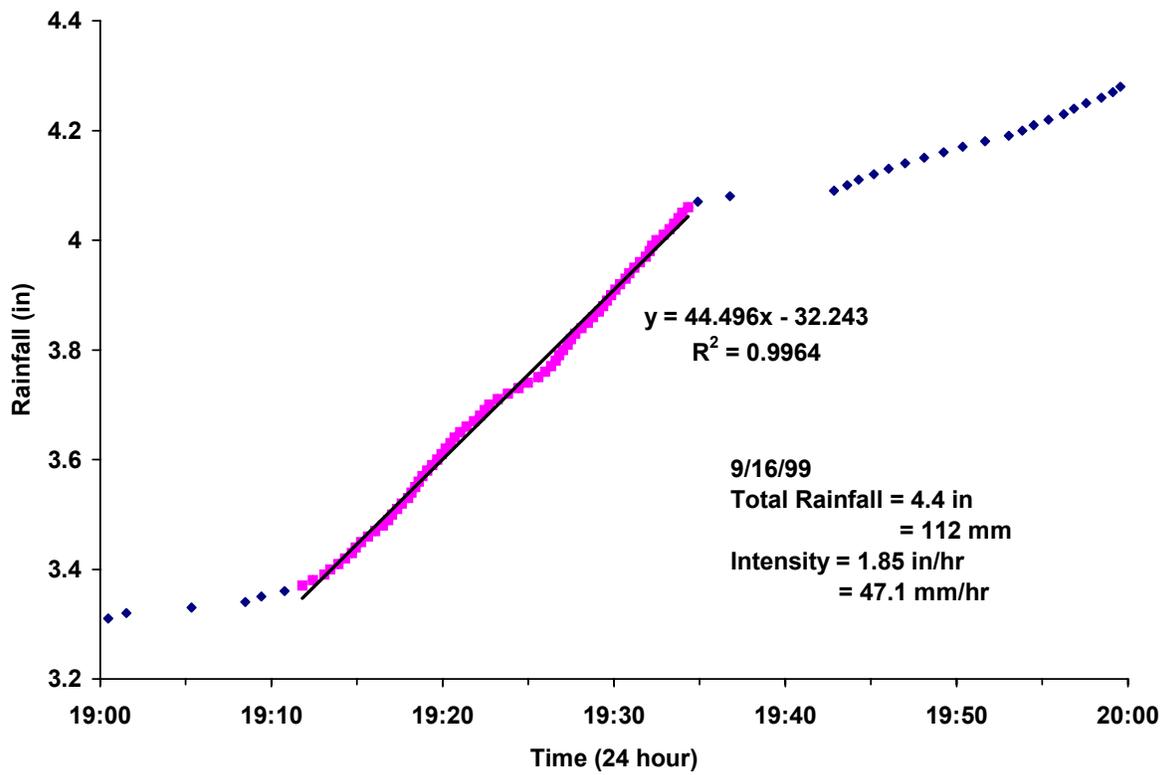
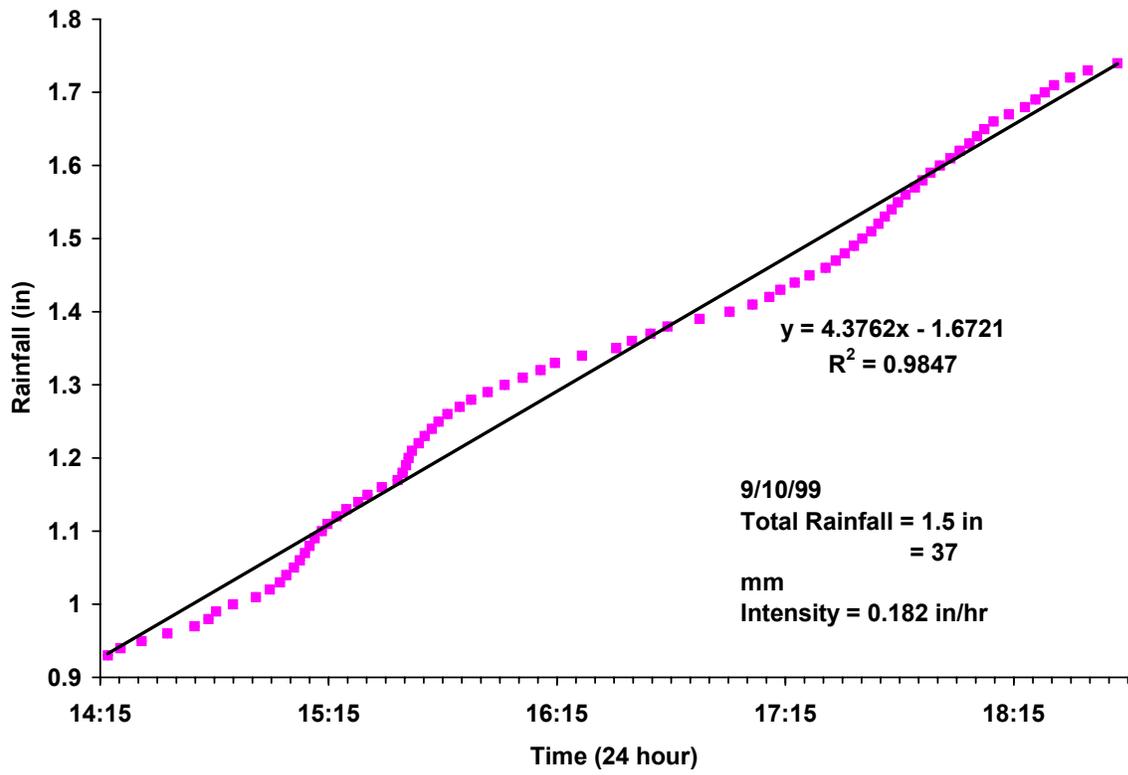


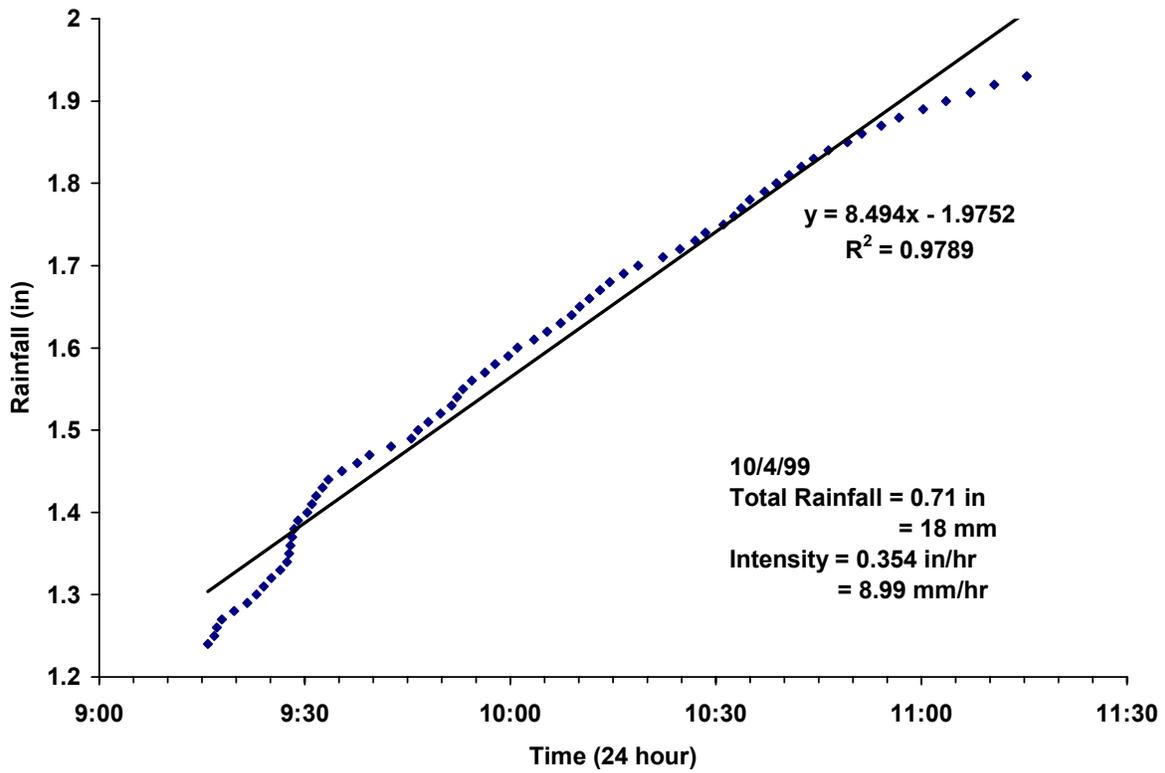
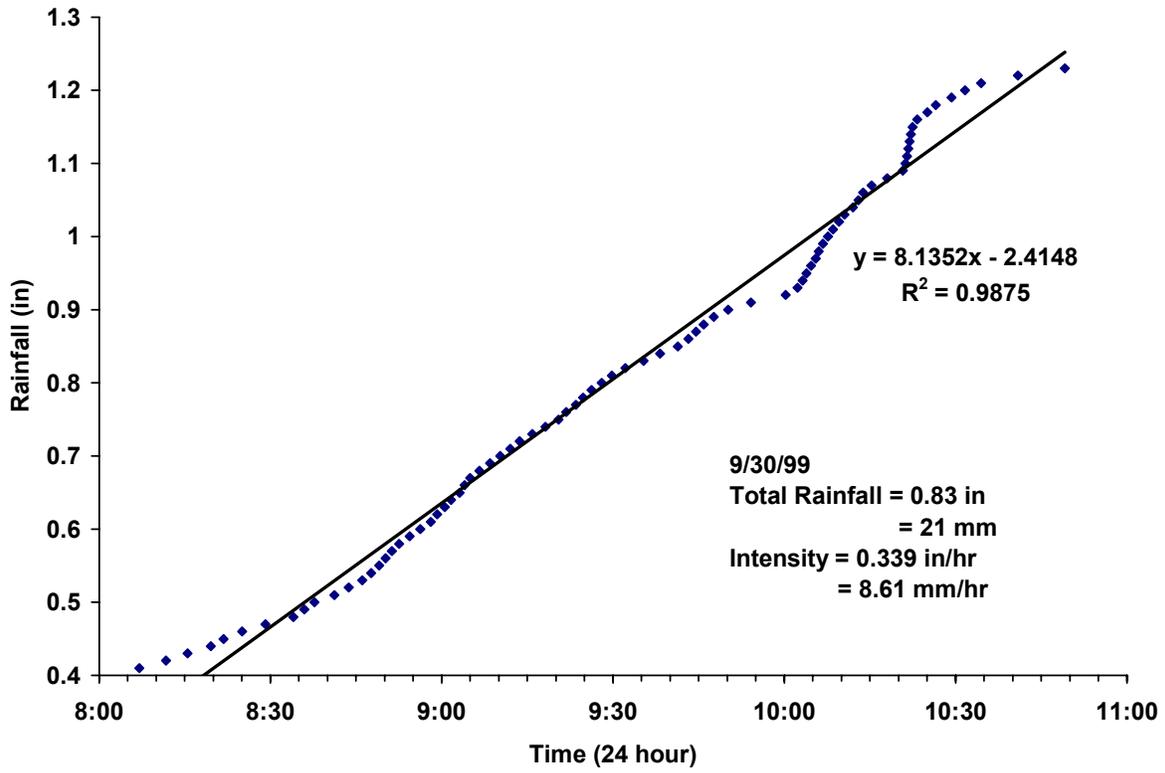




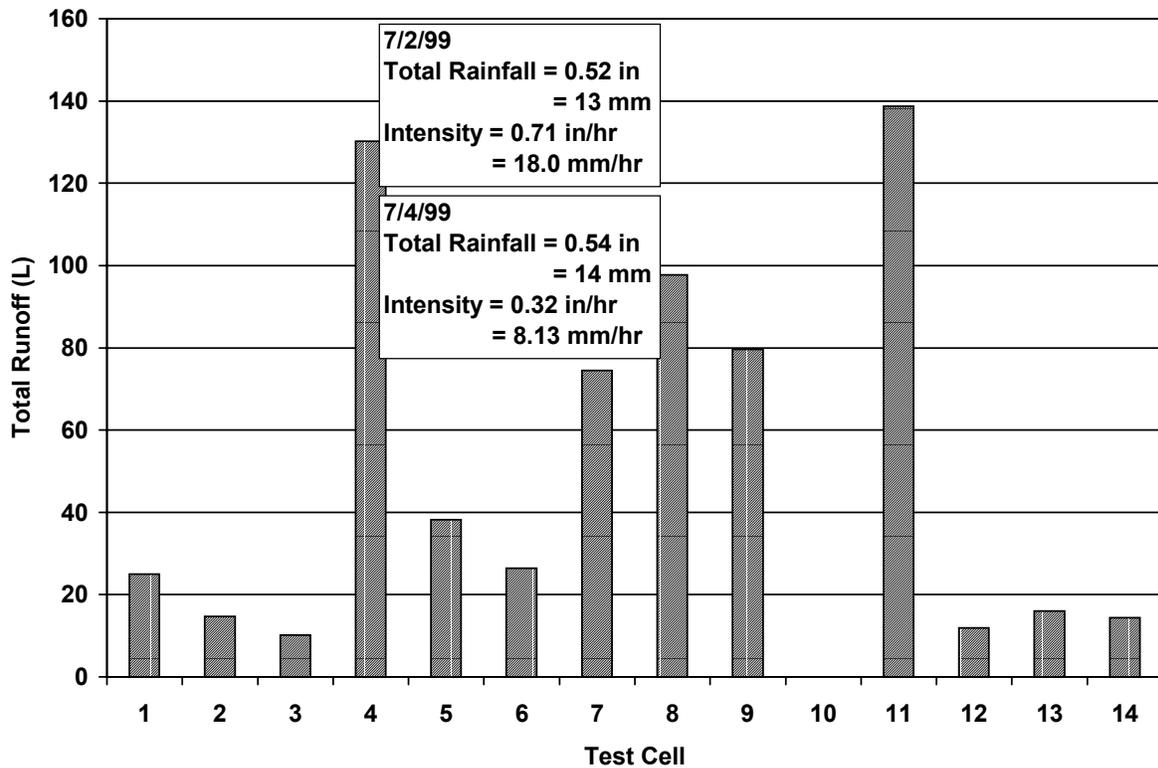
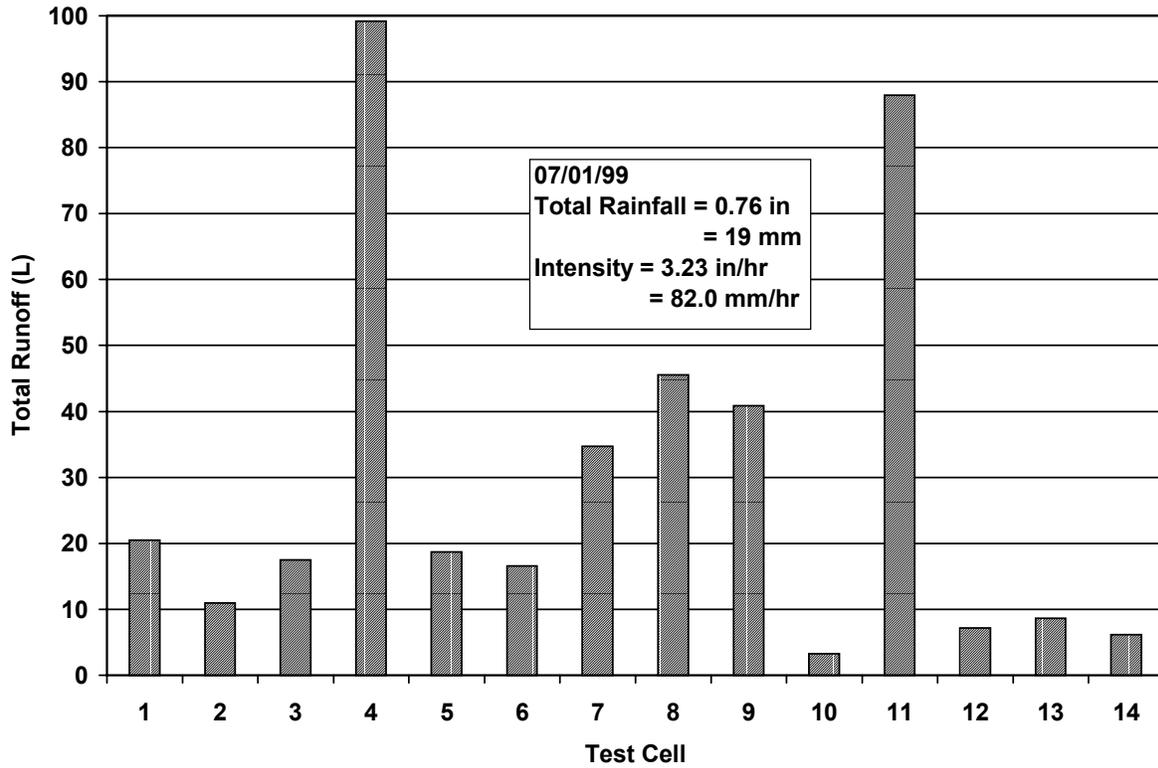


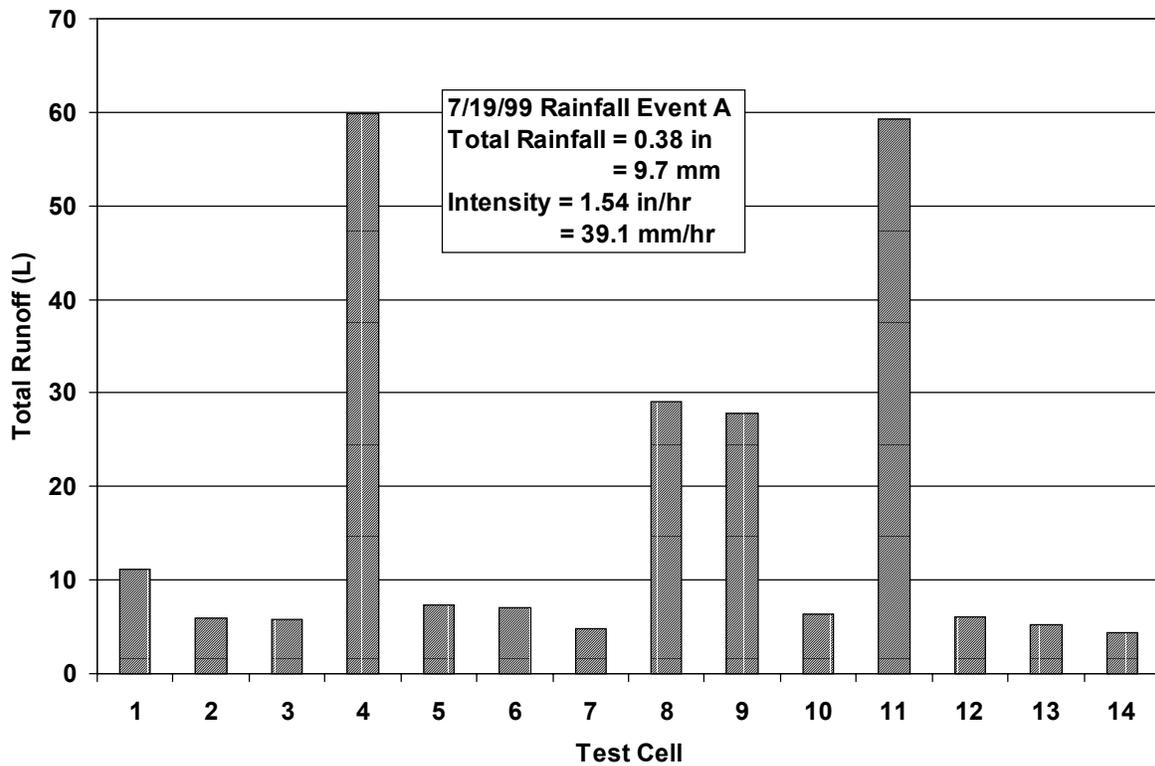
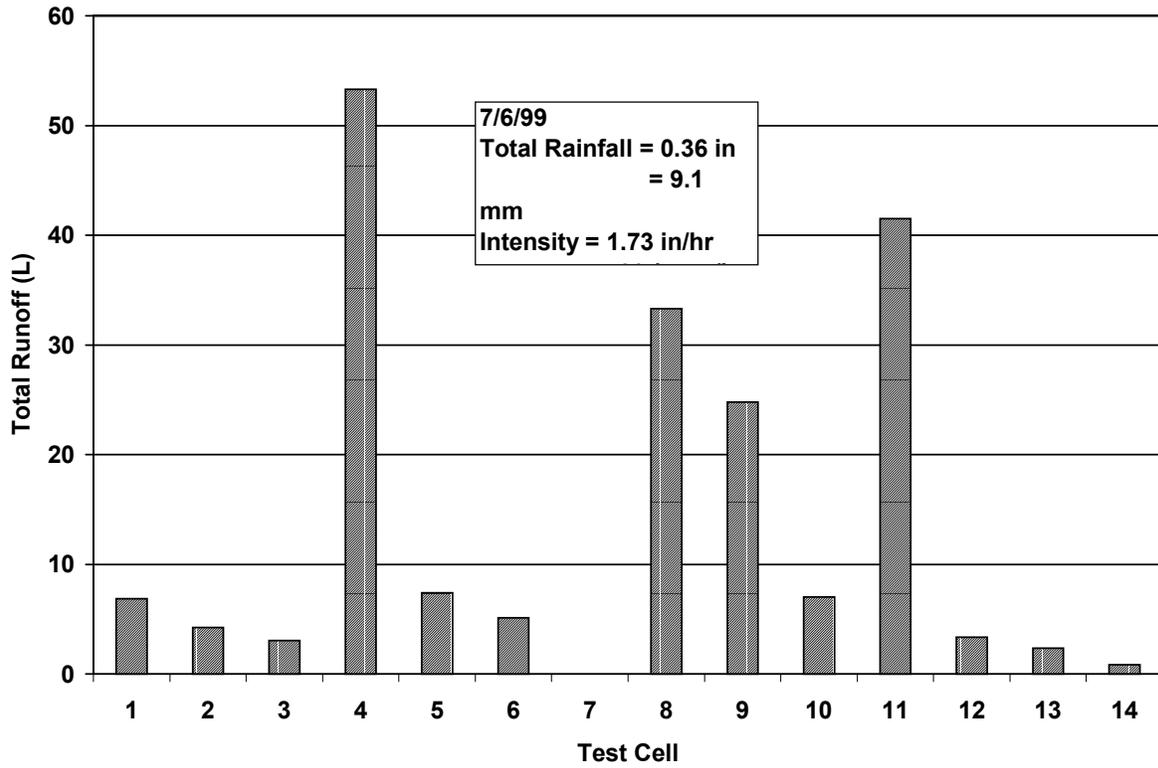


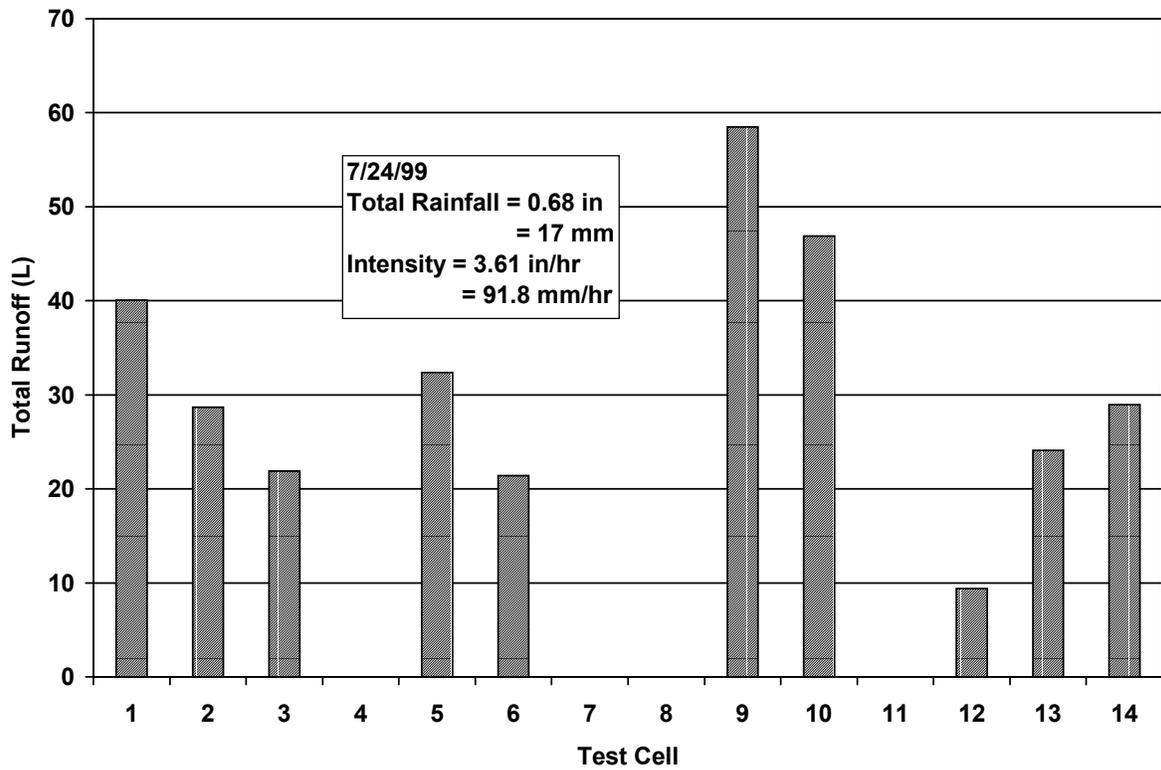
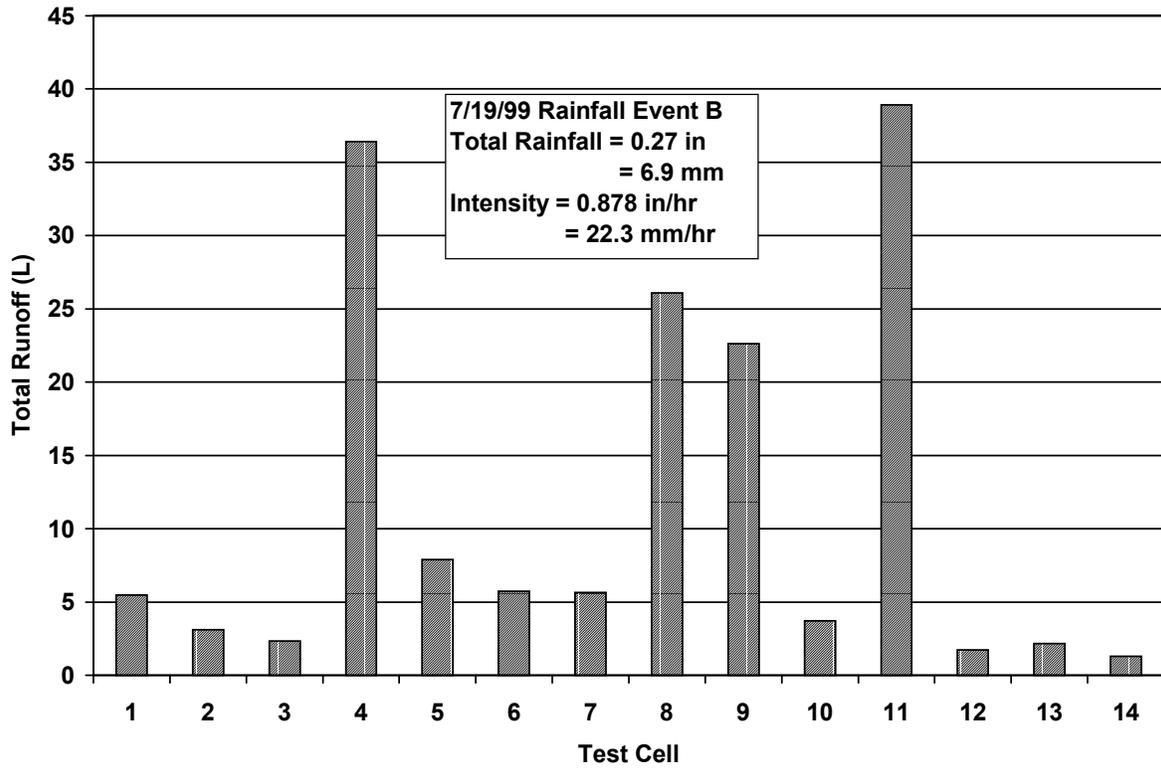


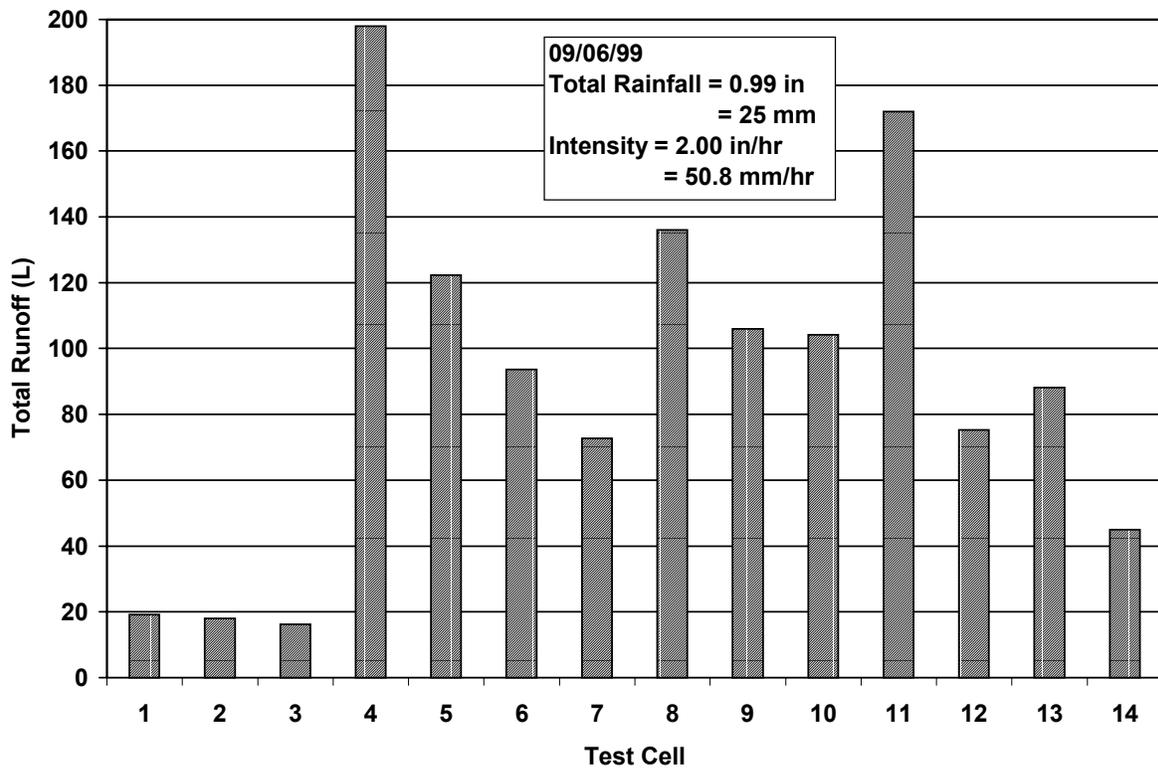
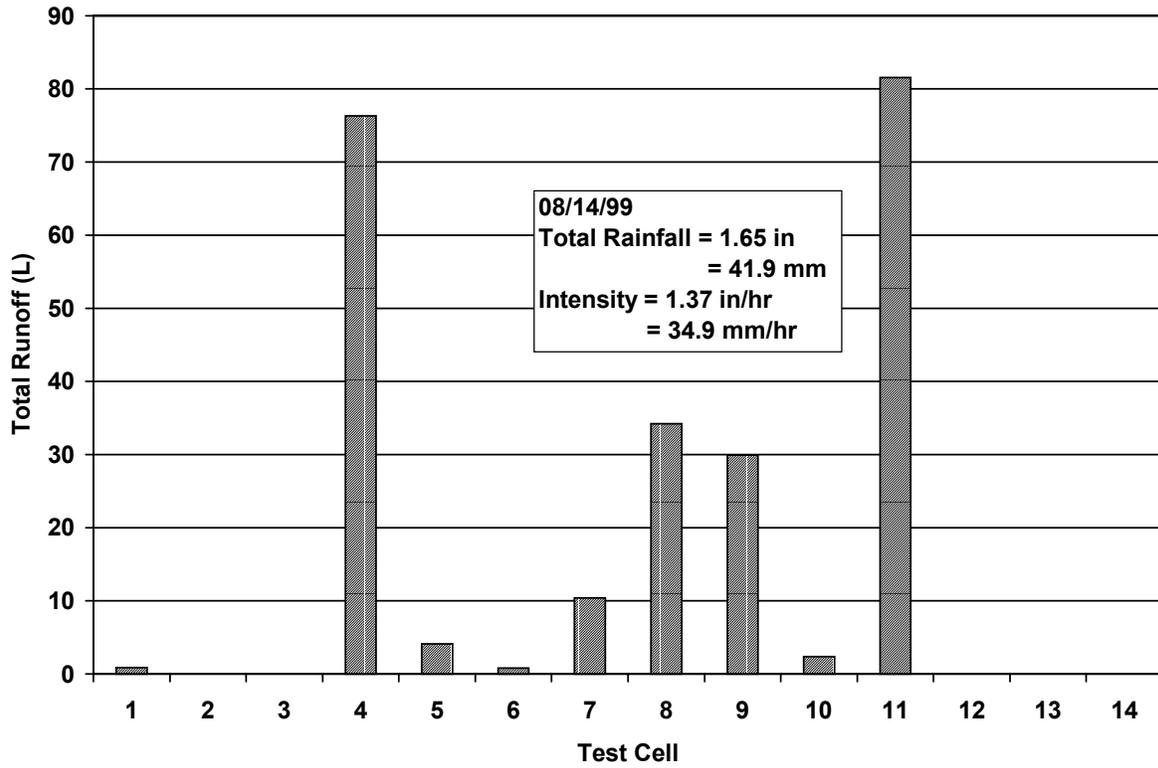


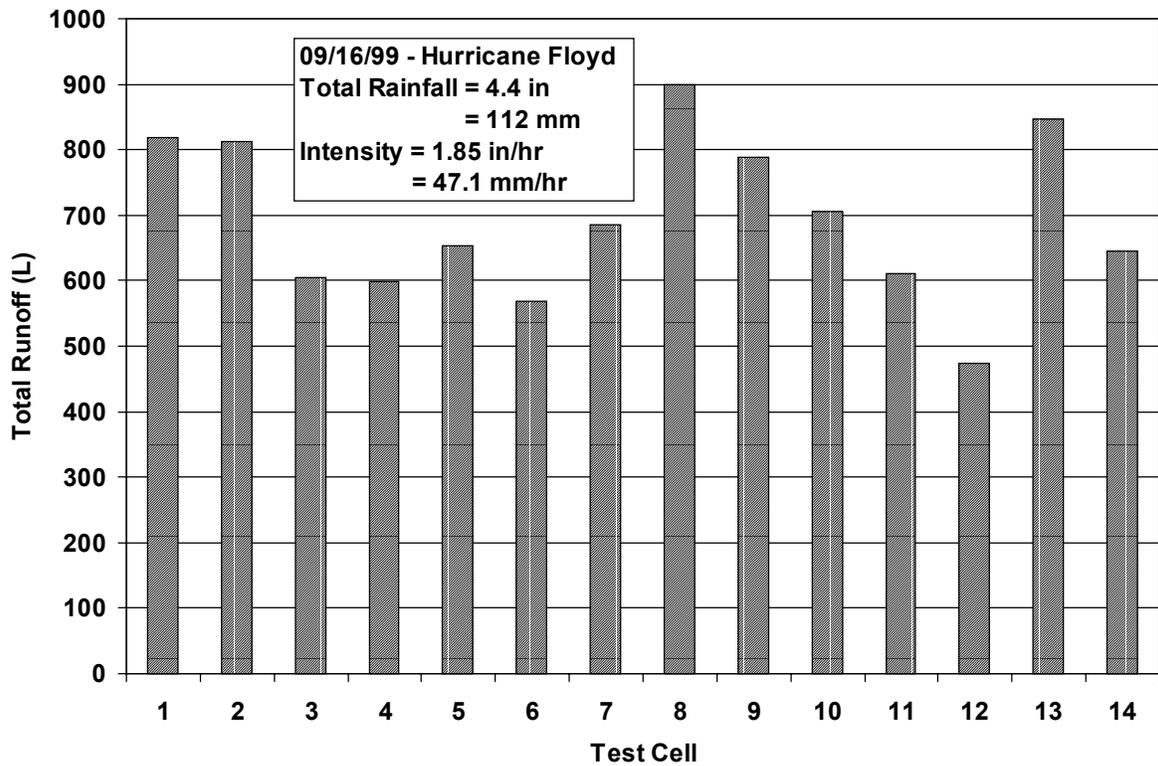
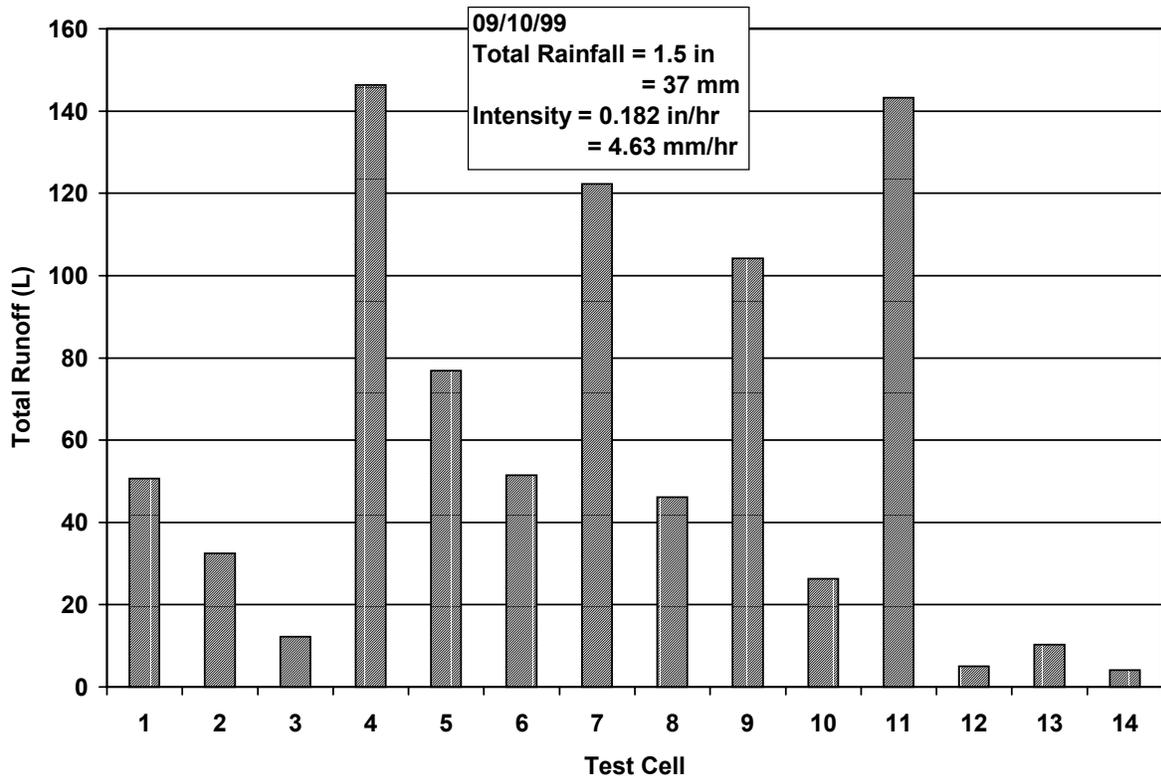
Appendix C Total Runoff from Test Cells by Storm Event



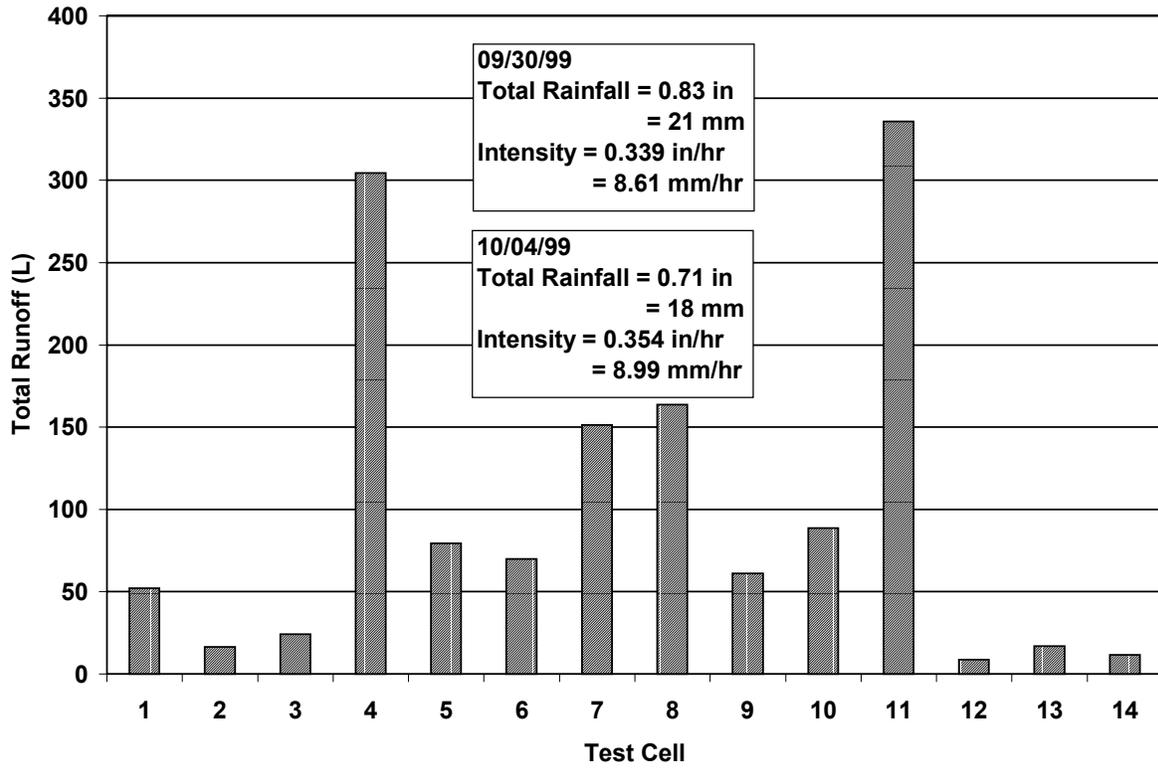




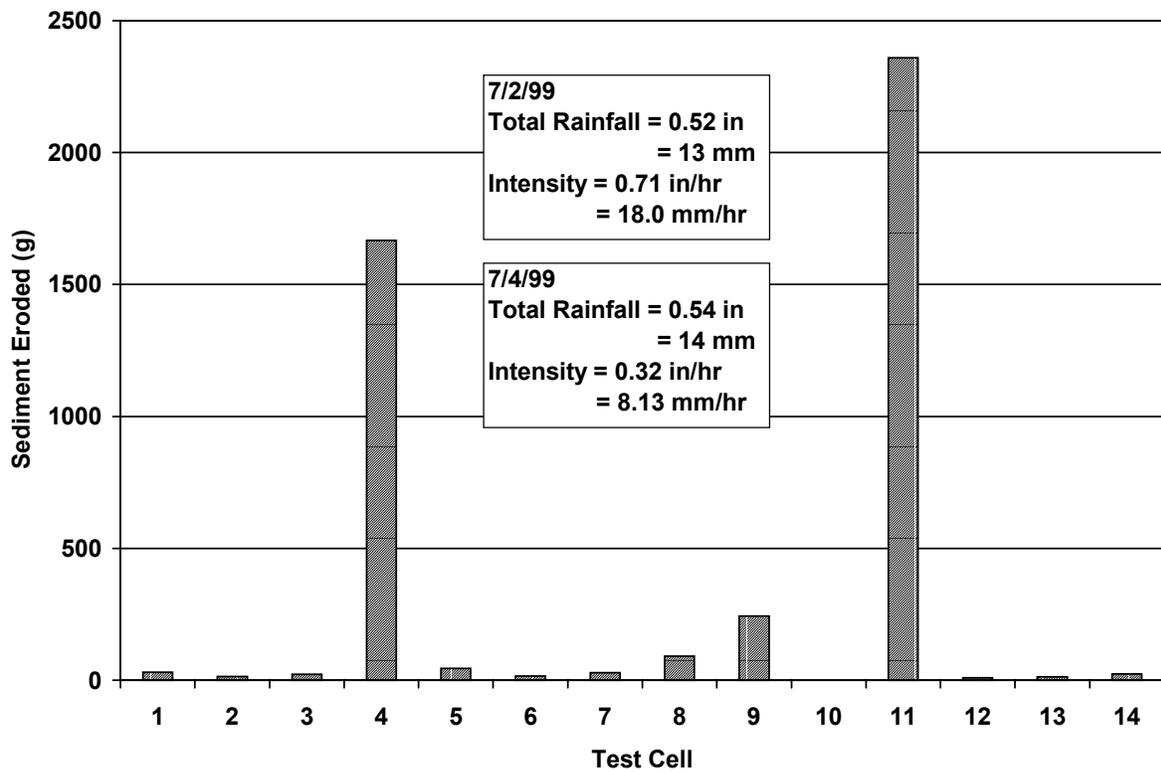
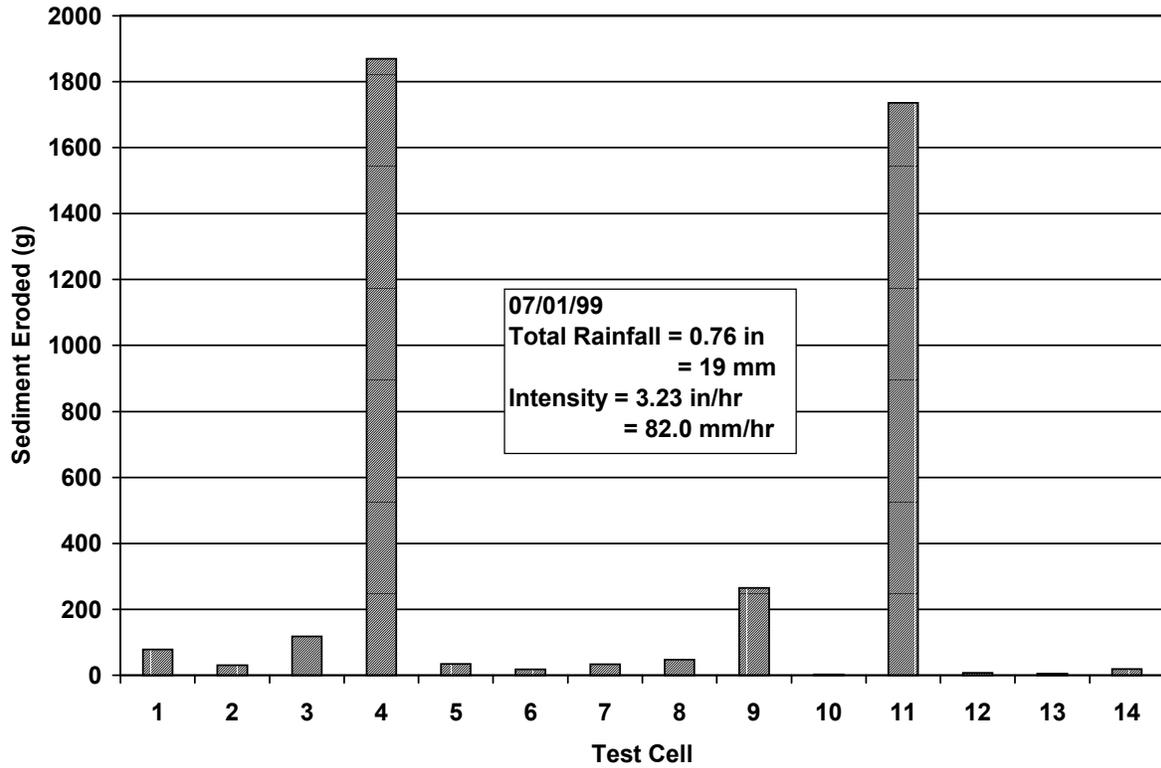


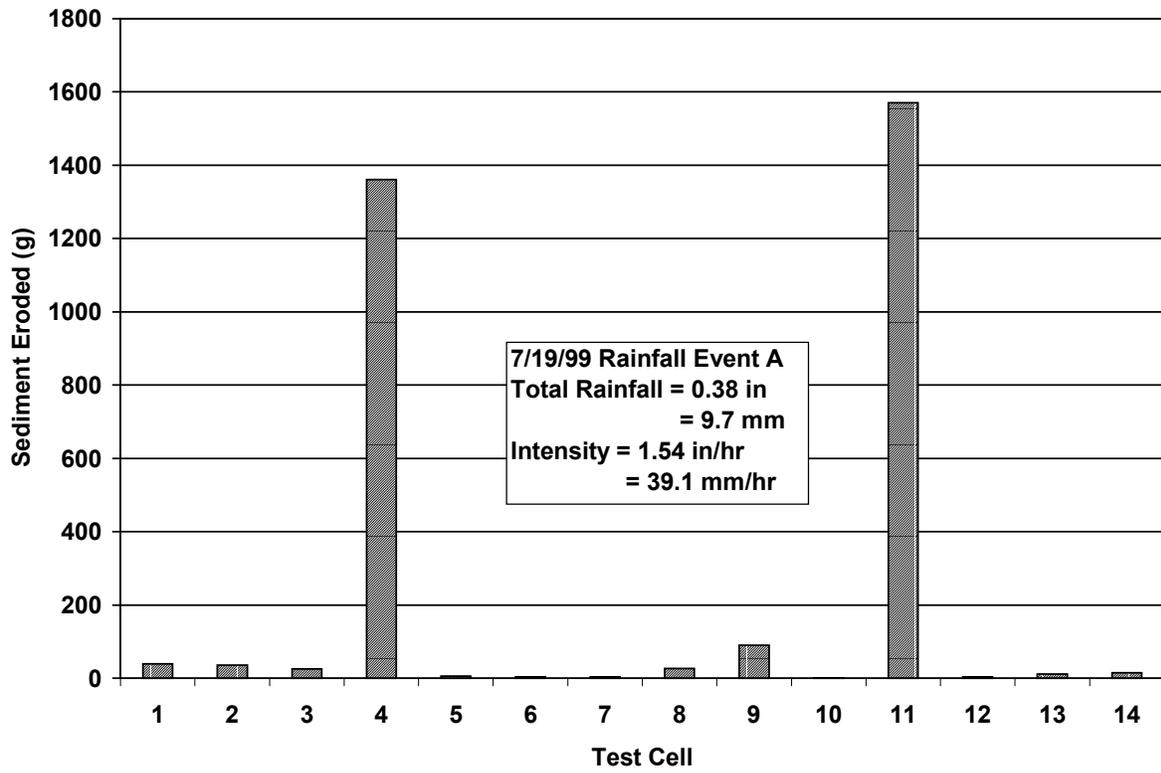
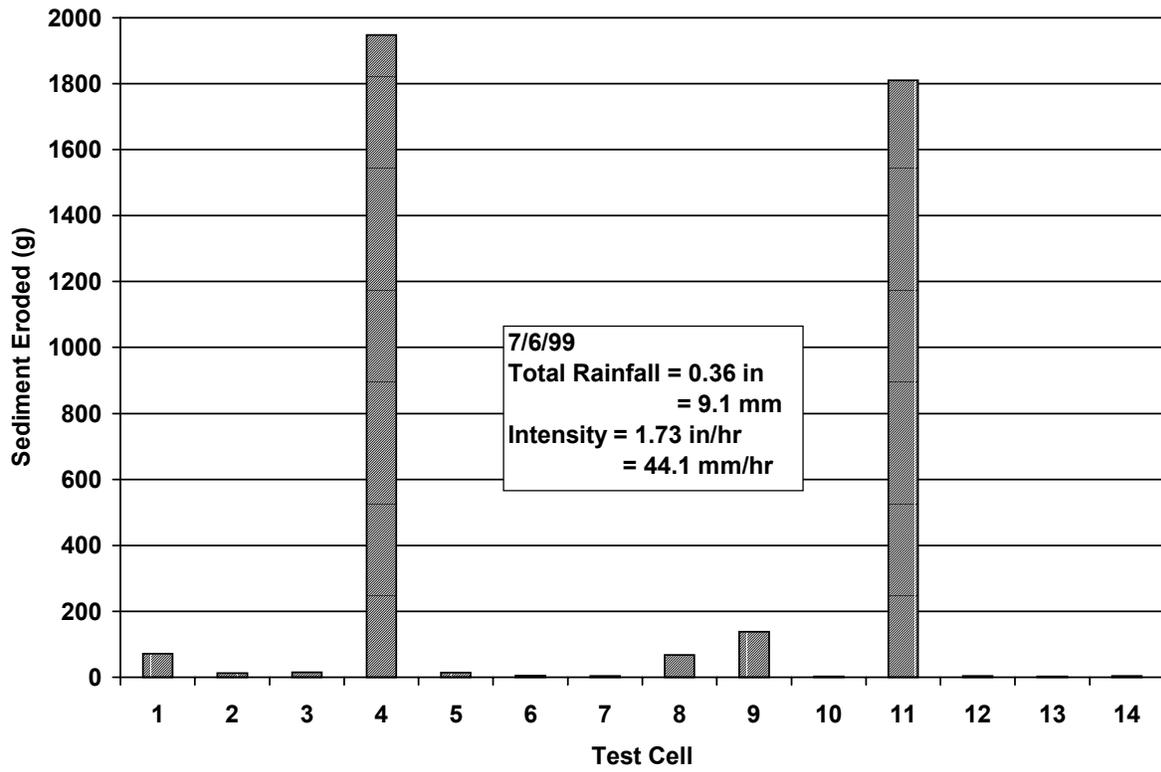


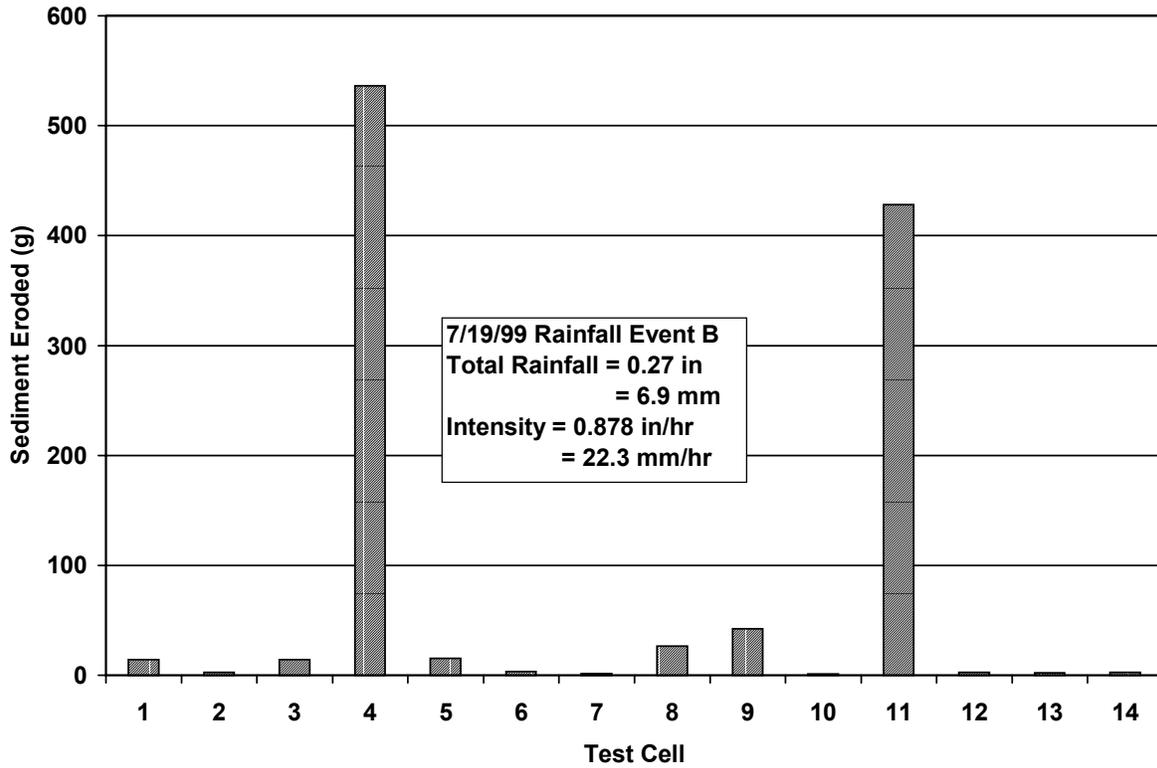
Total runoff data for two storms on 9/30/99 and 10/4/99.



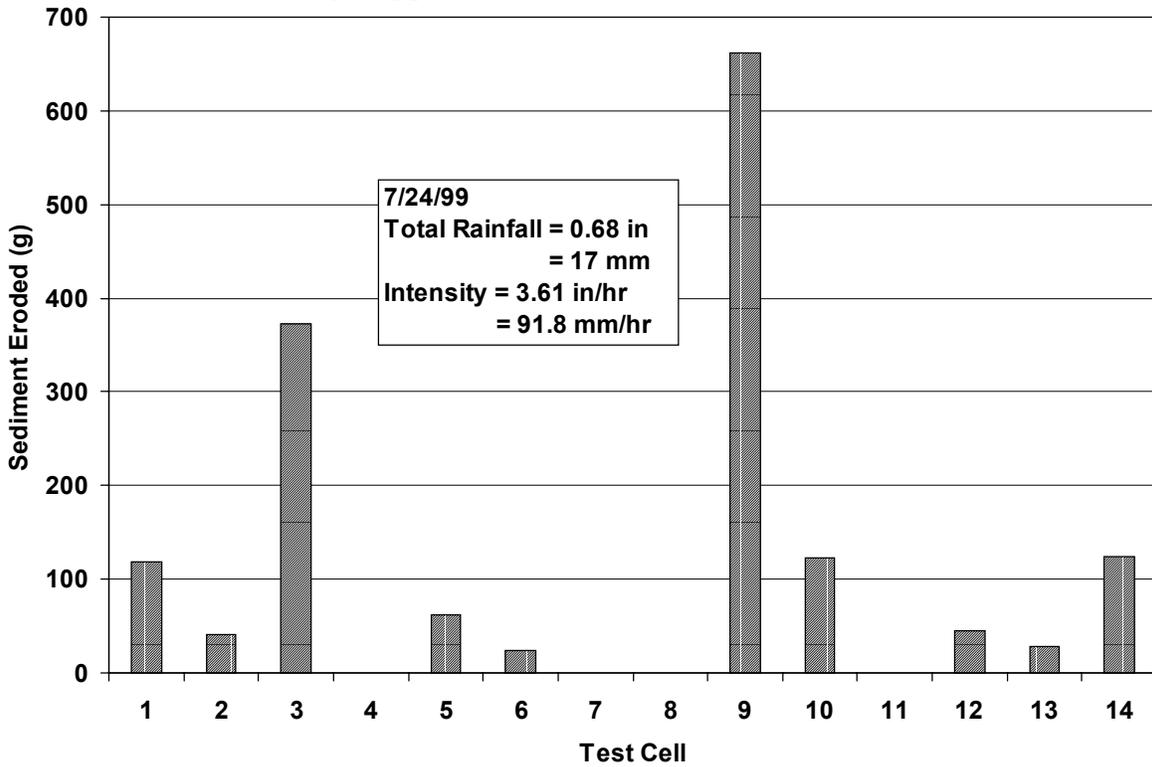
Appendix D Sediment Eroded from Test Cells by Storm Event

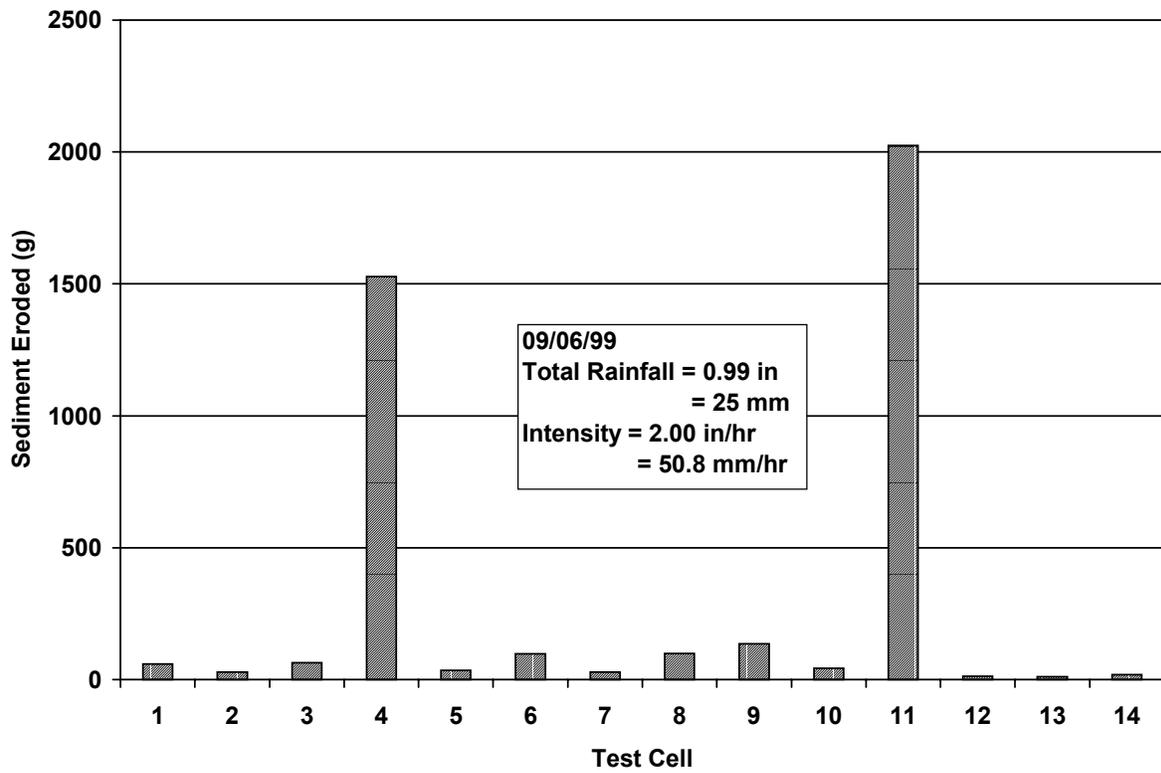
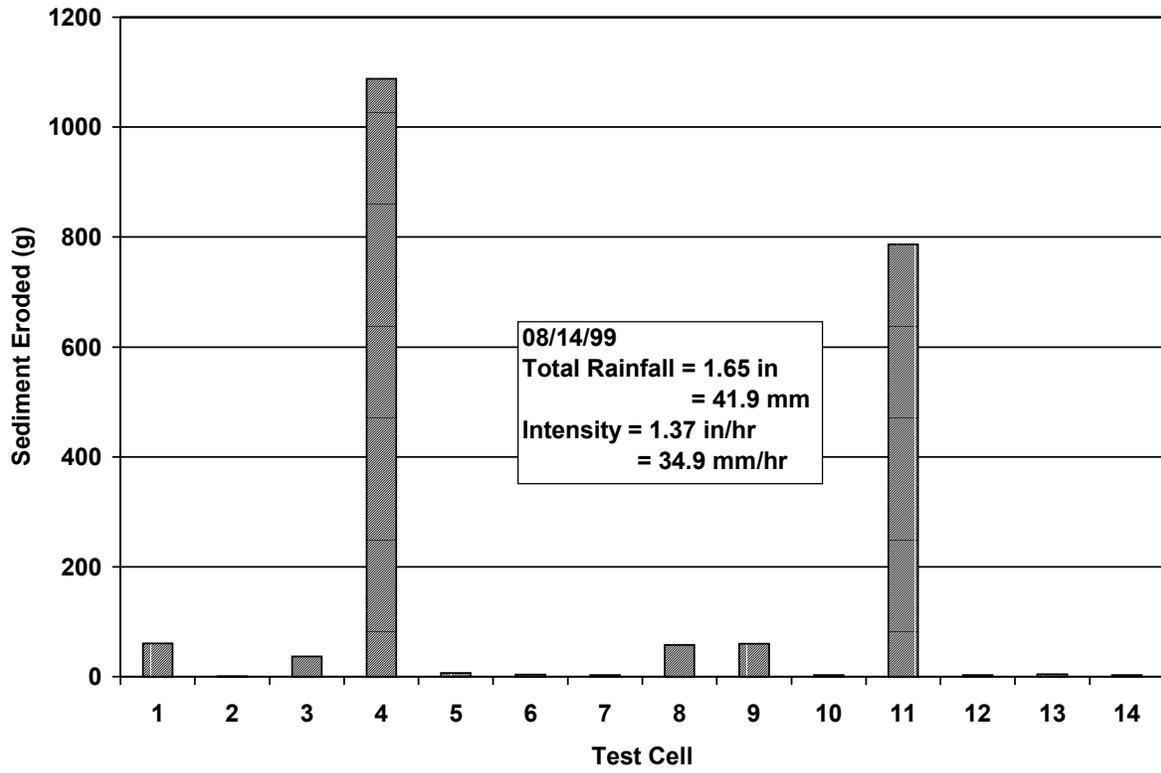


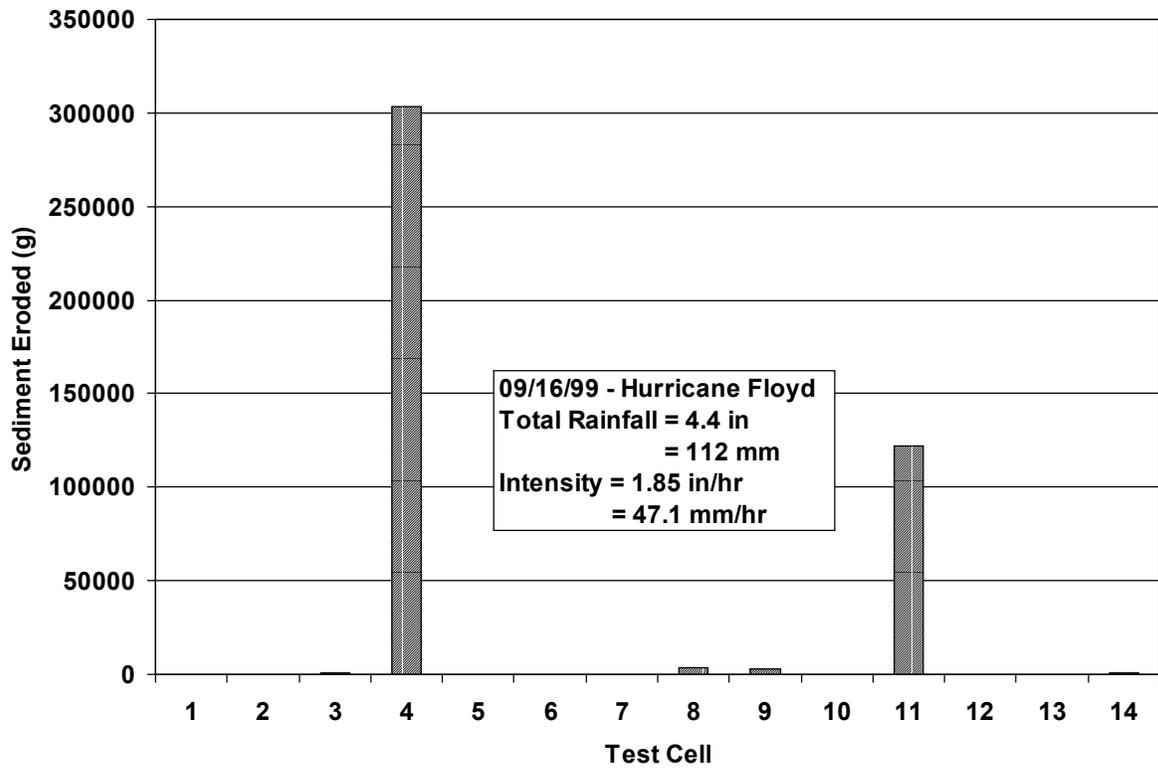
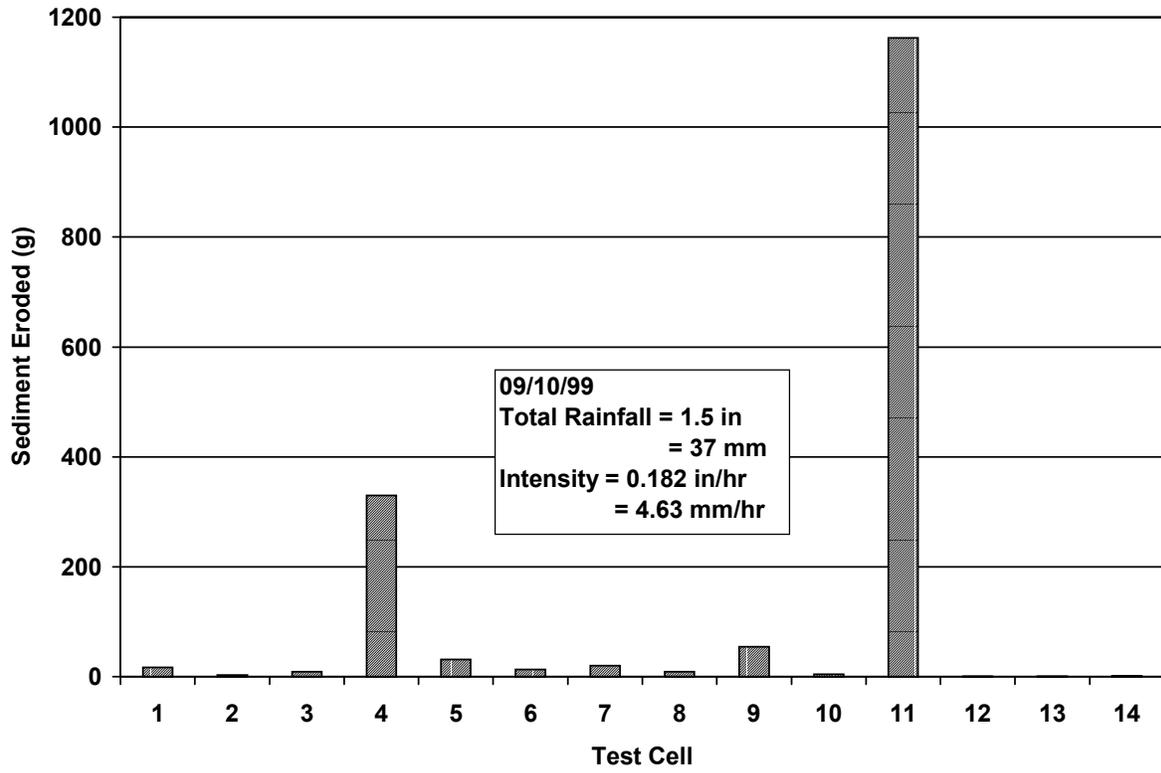




Storm of Greatest Intensity. Tipper Buckets Malfunctioned in Cells 4, 7, 8 and 11.







Total sediment eroded from two storms on 9/30/99 and 10/4/99.

