Rainfall Simulation: Evaluating Hydroseeding & Plug Planting Techniques For Erosion Control & Improved Water Quality

Experiments:

RS2 & RS3

2001/2002

VEGETATION ESTABLISHMENT & MAINTENANCE STUDY

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SECTION I. EXECUTIVE SUMMARY

The general goal of this and included related experiments was to identify and select plant species that demonstrate initial fast growth and potential long-term erosion control under a variety of rainfall regimes and erosion control (EC) treatments to improve water quality. The plants examined in these studies included both native and non-native naturalized species. This year included two separate experiments, known as Rainfall Simulations 2 and 3 (RS2 & RS3). Additional information was gathered in small scale studies including rainfall simulator design, heavy metal transport and germination rates. (For more detail see Section II of the report). The specific objectives of the project in 2002 were:

- ❖ To compare the establishment of a native Central Coastal California seeding mix and a non-native seeding mix using hydroseeding versus the existing seed bank for rapid cover and their respective effectiveness at controlling sediment transport under intense simulated rainfall at 45 and 70 days. (RS2)
- ❖ To compare hydroseeded versus plug-planted California Brome (*Bromus carinatus* H.& A. *sensu stricto*) in respective effectiveness at controlling sediment transport under intense simulated rainfall at 70 days. (RS3)
- ❖ To develop a less expensive, portable, and more accurate rainfall simulator to be utilized for erosion control experiments.
- ❖ To compare the effects of six erosion control treatments on the germination rates of eight plant species Deer Lotus (*Lotus scoparius*), Lupine (*Lupinus succulentus*), California Sagebrush (*Artemesia californica*), California Buckwheat (*Eriogonum fasciculatum*), California Poppy (*Escholzia californica*), Brome (*Bromus carinatus*), Yarrow (*Achillea millefolium*), and Ryegrass (*Lolium multiflorum*) at ¼ and ½ inch depths.
- ❖ To determine the possible causes for heavy metal transport and ways to reduce this transport in runoff water.

For both RS2 and RS3, a total of 32 erosion test boxes were constructed and filled with Sandy Clay Loam (USDA) soil. Two Norton Ladder type variable sweep rainfall simulators were used to apply water to the test boxes. The quality of the runoff and the amount and types of vegetative cover were analyzed.

In RS2, percent vegetative cover was found to be positively effected by the EC treatments in general. The control (no EC treatment) had the least total percent cover of grasses and legumes. The highest amount of vegetative cover was consistently found with Jute netting. However, BFM, Straw, or Tackifier was not significantly different in percent cover. The least amount of vegetative cover was seen with Gypsum. Grass cover was increased the most by Straw or Tackifier. Percent legume cover was increased the most with Bonded Fiber Matrix or Jute. However the least percent grass cover was seen with Bonded Fiber Matrix. Significantly lower total percent cover was seen with Gypsum than other treatments. Commercial erosion control seed mix increased percent legume cover. In RS2, D-5 native seed mix resulted in statistically lower amounts of total runoff relative to commercial EC seed mix. The control (no EC treatment) had significantly higher total runoff.

The D-5 native seed mix produced the lowest average total sediment load. The control had the highest average total sediment load of the three seeding treatments. It was found that Jute, BFM or Straw produced the best overall water quality. BFM had the lowest sediment load. Among the treatments, Tackifier or Gypsum had the most amount of total sediment. Among the treatments, Tackifier or Gypsum had the highest concentration of sediment.

In RS3, at 70 days, hydroseeding California Brome had an overall increase in cover and a decrease in total sediment load over plug planting California Brome due to the presence of weedy annual plants. Plug planting produced a higher amount of cover of Brome and a low percentage of weedy annual plants as compared to the hydroseeded boxes. Plug treatments produced no statistically significant difference in total sediment load, suggesting that 22 plugs/m^2 may have a financial advantage over 44 plugs/m^2. Bonded Fiber Matrix, Fiber plus Tackifier, Imprinting, or Jute all produced greater vegetative cover than No EC Treatment and Control. The imprinting technique produced greater California Brome cover than all other treatments. Control or No EC Treatment had highest amount of No Vegetation as compared to the four EC treatments. Hydroseeding or plug planting significantly increased percent vegetative cover over the control (existing seed bank).

In RS3, the upper portion of the boxes had greater overall percent cover of three of the four types of vegetation recorded and less bare ground as compared to the lower portion of the boxes, due to the application of maintenance irrigation (used to keep plants alive) from the top of the boxes. In two boxes (unreplicated), one treated with seeds and one treated with plugs, nitrogen uptake increased, thus improving the quality of the runoff by removing nitrate from the soil. The lower portion of the control box had a high concentration of phosphorus in the soil of the, indicating that the phosphorus was transported with increased sediment load.

Preliminary results indicate benefits of using Jute netting for optimum vegetation cover. Results also indicate type of vegetation cover (grass, legume) is effected by erosion control treatment. Water quality improvements were seen the most with the use of BFM, Jute and Straw. Initial results indicated that sediment amounts were decreased with hydroseeding of native seeds as compared to plug planting. These findings are based upon lab findings and should be verified before site use. Site analysis is always recommended before erosion control measures are applied in the field.

SECTION II. PROJECT GOALS

GOALS

The general goal of this and included related experiments (Sections I to VII) is to identify and select plant species that demonstrate initial fast growth and potential long-term erosion control under a variety of rainfall regimes and erosion control treatments to improve water quality.

OBJECTIVES

The specific objectives of the project in 2002 were:

1. To compare the establishment of a native Central Coastal California seed mix and a non-native seed mix using hydroseeding versus the existing seed bank in the soil for rapid cover and their respective effectiveness at controlling sediment transport under intense simulated rainfall at 45 and 70 days.
2. To compare hydroseeded versus plug-planted California Brome (*Bromus carinatus* H. & A. *sensu stricto*) in respective effectiveness at controlling sediment transport under intense simulated rainfall at 70 days.
3. To develop a less expensive, portable, and more accurate rainfall simulator to be utilized for erosion control experiments.
4. To compare the effects of six erosion control treatments on the germination rates of eight plant species: Deer Lotus (*Lotus scoparius*), Lupine (*Lupinus succulentus*), California Sagebrush (*Artemesia californica*), California Buckwheat (*Eriogonum fasciculatum*), California Poppy (*Escholzia californica*), California Brome (*Bromus carinatus*), Yarrow (*Achillea millefolium*), and Ryegrass (*Lolium multiflorum*) at ¼ & ½ inch planting depths.
5. To determine the possible causes for heavy metal transport and ways to reduce this transport in stormwater runoff.

RS2 RAINFALL SIMULATION EXPERIMENT

Seed and erosion control treatments were randomly assigned to each of 30 soil boxes in a replicated, crossed design. Three seed treatments were paired with five erosion control treatments and subjected to two simulated rainfall treatments. Two additional boxes received no seed or erosion control treatment, but subjected to the two rainfall treatments as "controls".

RS2 Crossed Design and Number of Replicates

	V1	V2	V3	
EC1	*1*	*1*	*1*	R1
	1	*1*	*1*	R2
EC2	*1*	*1*	*1*	R1
	1	*1*	*1*	R2
EC3	*1*	*1*	*1*	R1
	1	*1*	*1*	R2
EC4	*1*	*1*	*1*	R1
	1	*1*	*1*	R2
EC5	*1*	*1*	*1*	R1
	1	*1*	*1*	R2
	10	*10*	*10*	

RS2 Vegetation Treatments

RS2 VEGETATION TREATMENTS

V1	Existing (*No Added Seed*)
V2	Existing+(600g EC Mix + wood Fiber @ 9 kg / 190 L)
V3	Existing+(1000g D5 Native Mix + Fiber @ 9 kg / 190 L)

RS2 EROSION CONTROL TREATMENTS

EC1	Crimped Straw @ 0.22 kg / m^2
EC2	Jute (25 mm mesh)
EC3	Gypsum (11 kg / 95 L)
EC4	BFM (22 kg / 190 L)
EC5	Tackifier (0.7 kg / 95 L)

RS2 SIMULATED RAINFALL TREATMENTS

R1	Storm Event @ 45 days only
R2	Storm Event @ 45 days & @ 70 days

RS3 RAINFALL SIMULATION EXPERIMENT

Seed or 75mm (3in) plugs of California Brome (*Bromus carinatus*) and erosion control treatments were randomly assigned to each of 30 soil boxes in a replicated, crossed design. Three seed treatments were paired with five erosion control treatments and were subjected to one simulated rainfall treatment at 70 days from installation. Two additional boxes, or controls, received no seed or erosion control treatment, but subjected to the same rainfall treatment.

RS3 Crossed Design and Number of Replicates

	V1	V2	V3	
EC1	2	2	2	R1
EC2	2	2	2	R1
EC3	2	2	2	R1
EC4	2	2	2	R1
EC5	2	2	2	R1
	10	*10*	*10*	

RS3 Treatments

RS3 SEED / PLUG TREATMENTS

V1	*Bromus carinatus* seed @ 580 PLS / m^2
V2	*Bromus carinatus* plugs @ 22 / m^2
V3	*Bromus carinatus* plugs @ 44 / m^2

RS3 EROSION CONTROL TREATMENTS

EC1	Jute (2.5cm mesh)
EC2	BFM (22kg / 190 L)
EC3	Fiber (22kg / 190 L + Tackifier (0.7 kg / 95 L)
EC4	Imprinting
EC5	None

RS3 SIMULATED RAINFALL TREATMENTS

R1	Storm Event @ 70 days from installation

SECTION IV. PROJECT FINDINGS

It is critical to consider the importance of vegetation establishment when selecting Erosion Control (EC) treatments to decrease erosion and improve water quality. There are notable interactions observed between vegetative establishment and erosion control materials. Therefore it is important to determine the final goal for each project site before determining which erosion control products and vegetation are appropriate for the site. The following research findings are preliminary and application to the field needs to have an onsite investigation. These trends and significant findings provide insight in establishing vegetative cover with various Erosion Control (EC) treatments for Caltrans District 5 and statewide. Support data, collected at 70 days post-installation, are provided for each finding.

RS2 RAINFALL SIMULATION EXPERIMENT

RS2 FINDING: *The EC treatments were found to have a positive effect on overall percent vegetative cover in general. (Figure 2.1)*

RS2 FINDING: *Jute consistently produced the highest amount of vegetative cover at 58 percent, However, BFM, Straw, or Tackifier were not significantly different. (Figure 2.1)*

RS2 FINDING: *Gypsum as an Erosion Control treatment produced the least amount of vegetative cover at 43 percent. (Figure 2.1)*

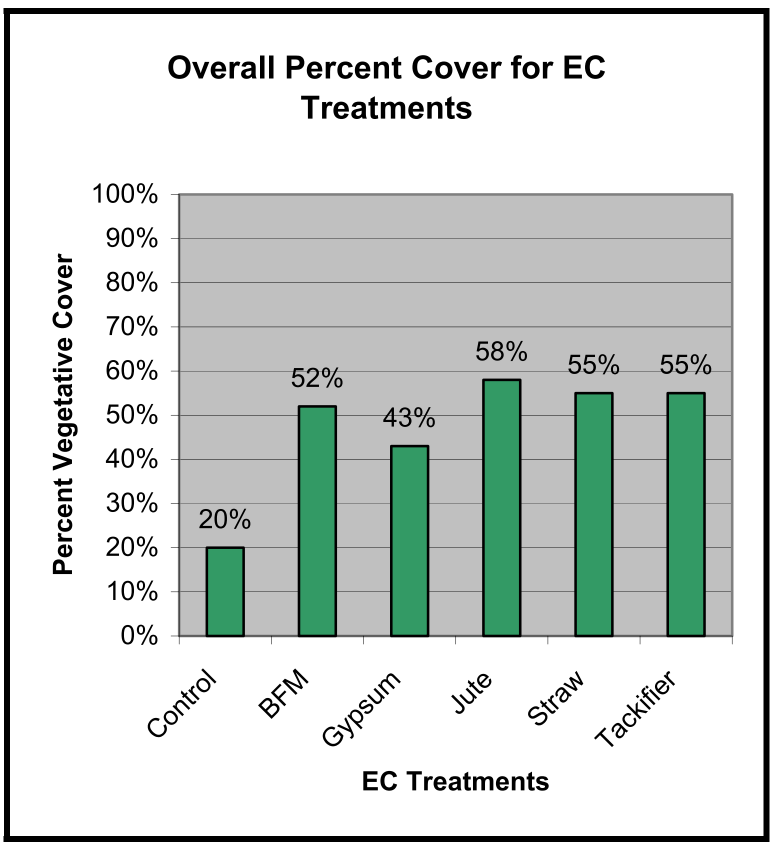


Figure 2.1

RS2 FINDING: *Straw or Tackifier increased percent grass cover the most. (Figure. 2.2)*

RS2 FINDING: *Bonded Fiber Matrix or Jute increased percent legume cover the most. (Figure 2.2)*

RS2 FINDING: *Bonded Fiber Matrix produced the least percent grass cover. (Figure 2.2)*

RS2 FINDING: *Gypsum had significantly lower total percent vegetative cover than other treatments. (Figure 2.2)*

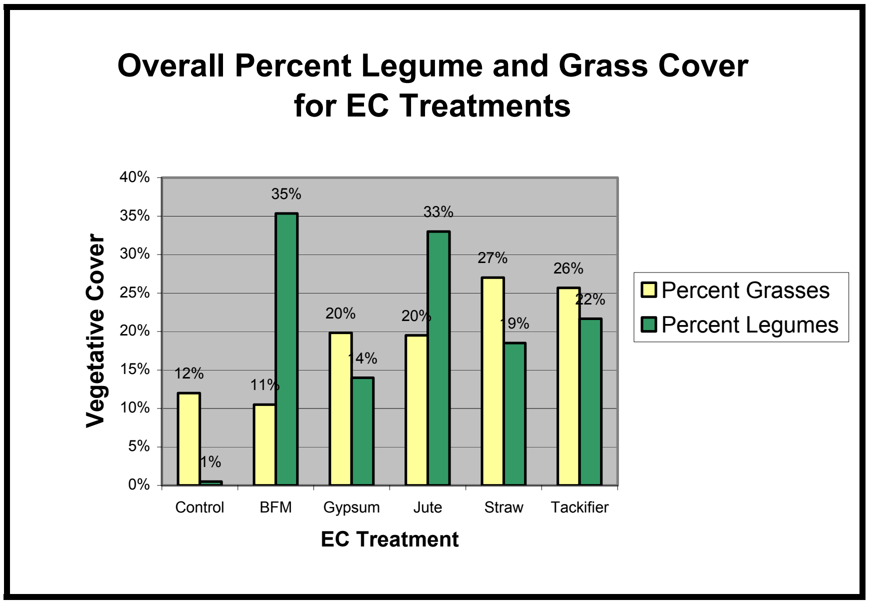


Figure 2.2

RS2 FINDING: *Commercial erosion control seed mix (EC) increased percent legume cover. (Figure 2.3)*

RS2 FINDING: *The control (no EC treatment) had the least total percent cover of grasses and legumes. (Figure 2.3)*

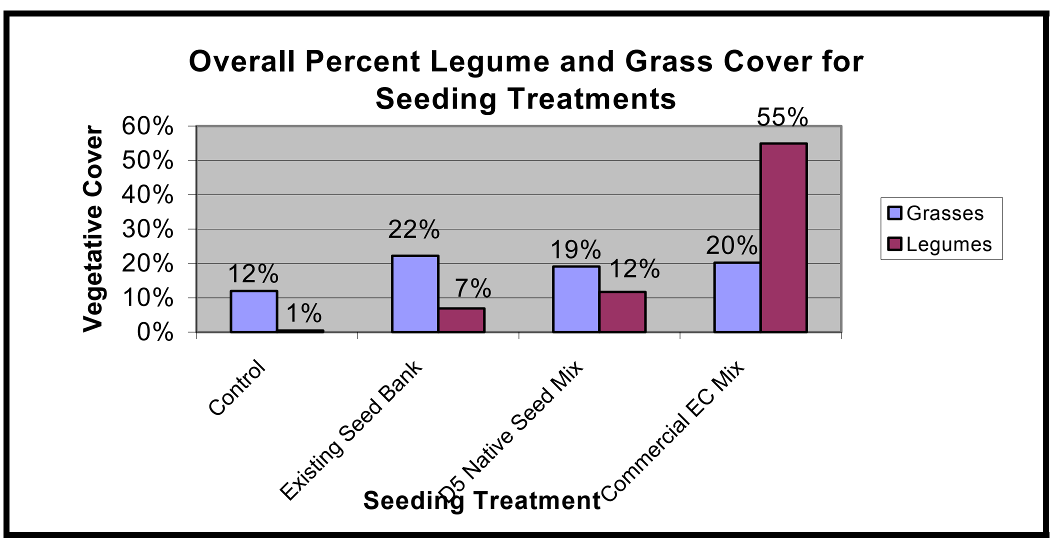


Figure 2.3

RS2 FINDING: *D-5 native seed mix resulted in statistically lower total runoff relative to commercial EC seed mix. (Figure 2.4)*

RS2 FINDING*:* *The control (no EC treatment) had significantly higher total runoff than the other treatments. (Figure 2.4)*

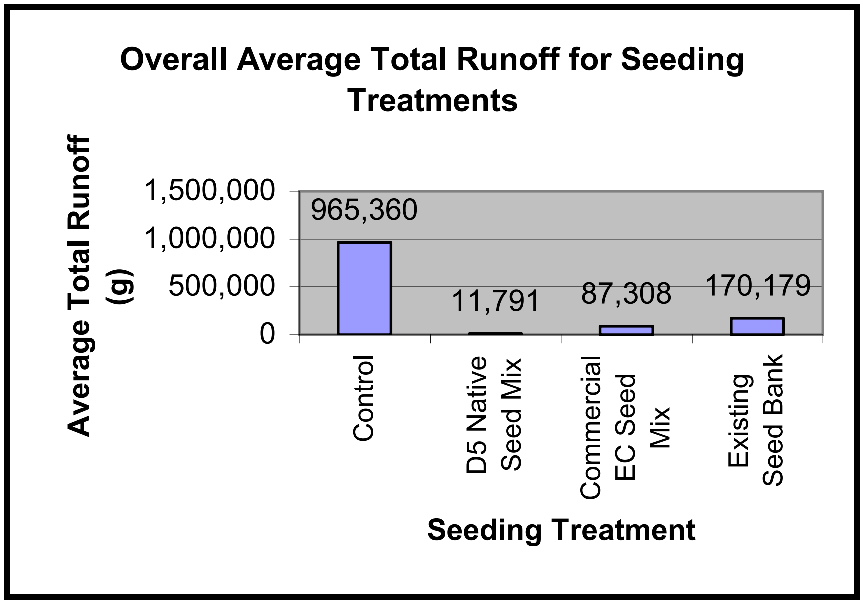


Figure 2.4

RS2 FINDING: *The D-5 native seed mix had the lowest average total sediment load. (Figure 2.5)*

RS2 FINDING: *The existing seed bank had the highest average total sediment load of the three seeding treatments. (Figure 2.5)*

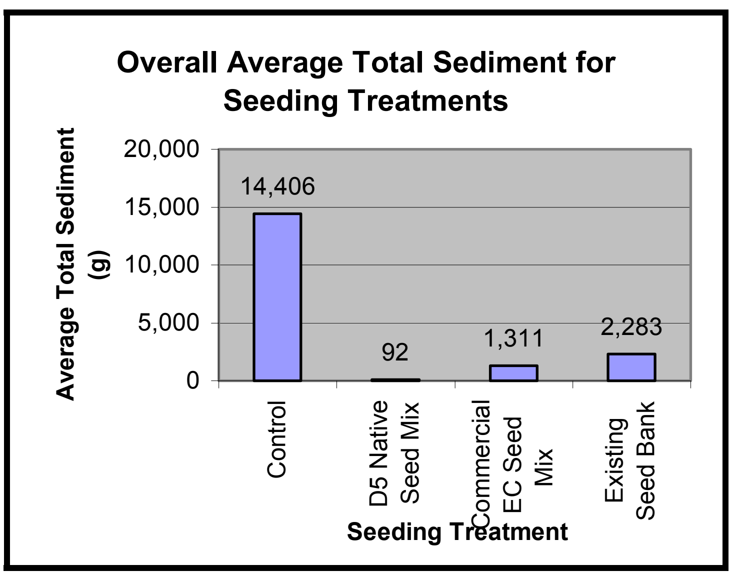


Figure 2.5

RS2 FINDING: *It was found that either Jute, BFM or Straw produced the best overall water quality.* (Table 2.1)*

RS2 FINDING: *BFM had the lowest sediment load. (Table 2.1)*

RS2 FINDING: *Tackifier or Gypsum had the highest total sediment. (Table 2.1)*

RS2 FINDING: *Tackifier or Gypsum had the highest concentration of sediment. (Table 2.1)*

Table 2.1 Overall Water Quality

	Control	BFM	Gypsum	Jute	Straw	Tackifier
Total Runoff (g)	965,359.7	438.5	179,733.0	2,103.2	3,012.3	249,458.9
Total Sediment (g)	14,406.4	0.4	2,622.3	3.6	11.6	3,667.0
Sediment Concentration (g/mL)	14,944.0	1,143.8	12,852.5	1,618.1	2,430.1	9,135.3

*Note: BFM had the best overall water quality with 438.5 g of total runoff, the lowest amount of sediment with 0.4 g and the lowest sediment concentration with 1,143.8 g/ml. Jute and Straw followed closely producing greater runoff, sediment, and sediment concentration. Gypsum and Tackifier produced greater than 60 times the total runoff, over 200 times the total sediment and over 4 times the sediment concentration of Jute and Straw. The control treatment (bare ground) produced the worst overall water quality including the most runoff at 965,359.7 g, the most sediment load at 14,406.4 g and the highest sediment concentration at 14,944.0 g/ml.

RS3 RAINFALL SIMULATION EXPERIMENT

RS3 FINDING: *Hydroseeding had an overall initial increase in cover and an initial decrease in sediment load over plug planting due to the presence of weedy annual plants. (Figure 2.6 and 2.7)*

RS3 FINDING: *Plug planting with California Brome produced 25% and 37% California Brome cover (22 plugs/m^2 and 44 plugs/m^2, respectively) and a low percentage of weedy annual plants as compared to the hydroseeded boxes. (Figure 2.6 and 2.7)*

RS3 FINDING: *Both plug treatments produced no statistically significant difference in sediment load, suggesting that Brome plugs @ 22/m^2 may have a financial advantage over Brome Plugs @ 44/m^2. (Figure 2.6 and Figure 2.7)*

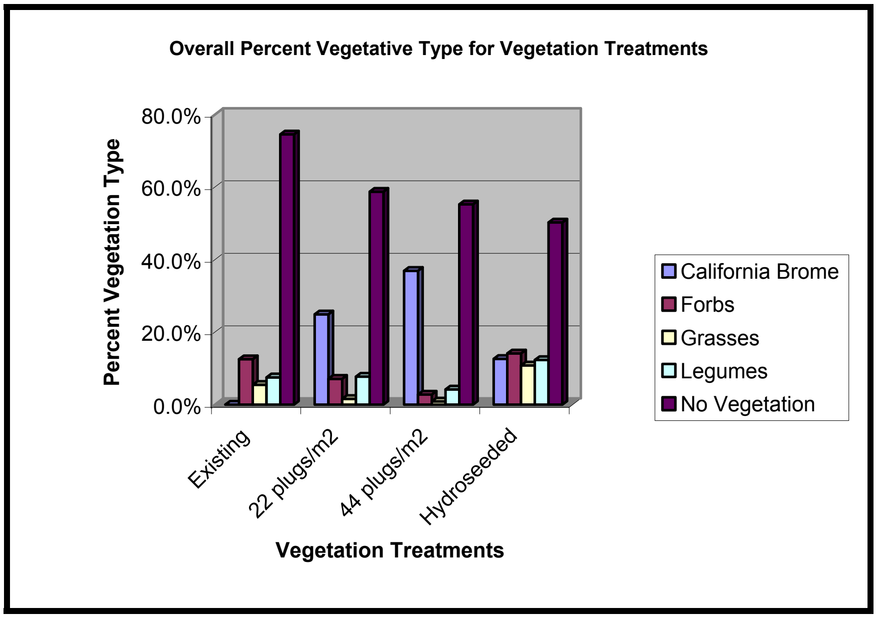


Figure 2.6

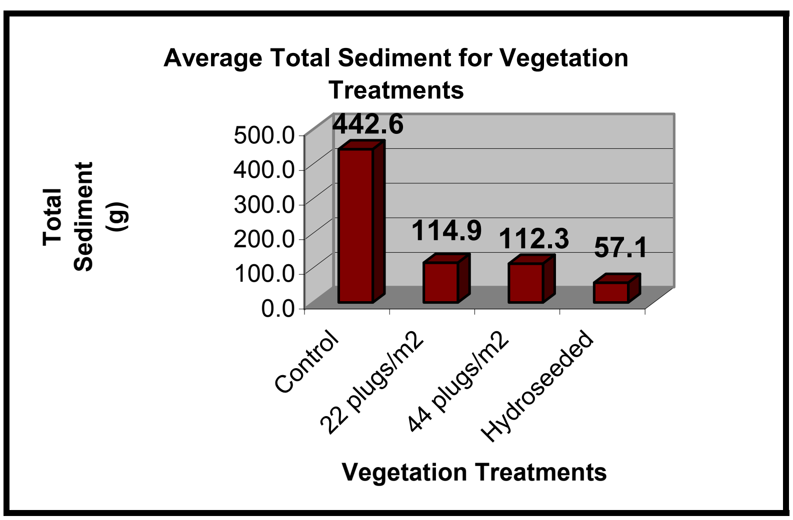


Figure 2.7

RS3 FINDING: *Bonded Fiber Matrix, Fiber + Tackifier, Imprinting, or Jute all produced greater vegetative cover than No EC Treatment and Control. (Figure 2.8)*

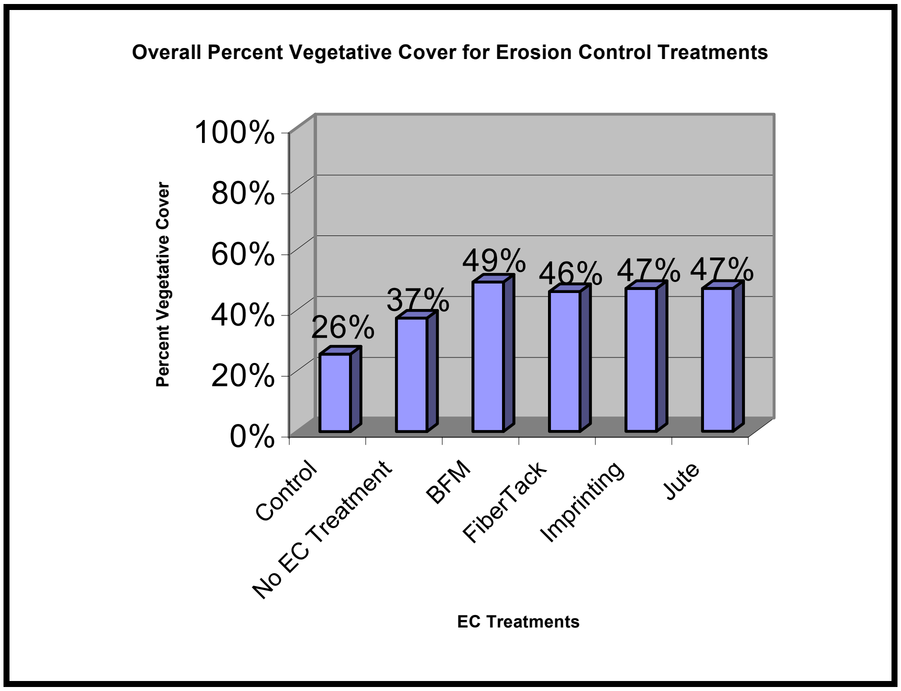


Figure 2.8

RS3 FINDING: *Imprinting produced greater California Brome cover than all other treatments.* (Figure 2.9)

RS3 FINDING: *Control or No EC Treatment had highest amount of No Vegetation as compared to the four EC treatments. (Figure 2.9)*

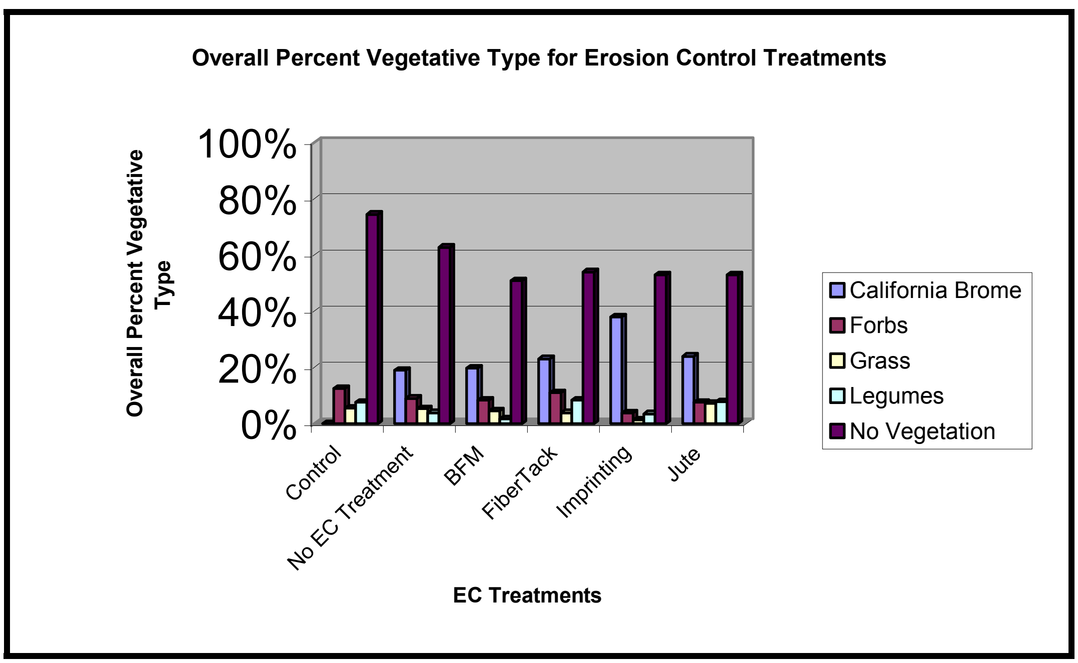


Figure 2.9

RS3 FINDING: *Hydroseeding or plug planting significantly increased percent vegetative cover over the control (existing seed bank). (Figure 2.10)*

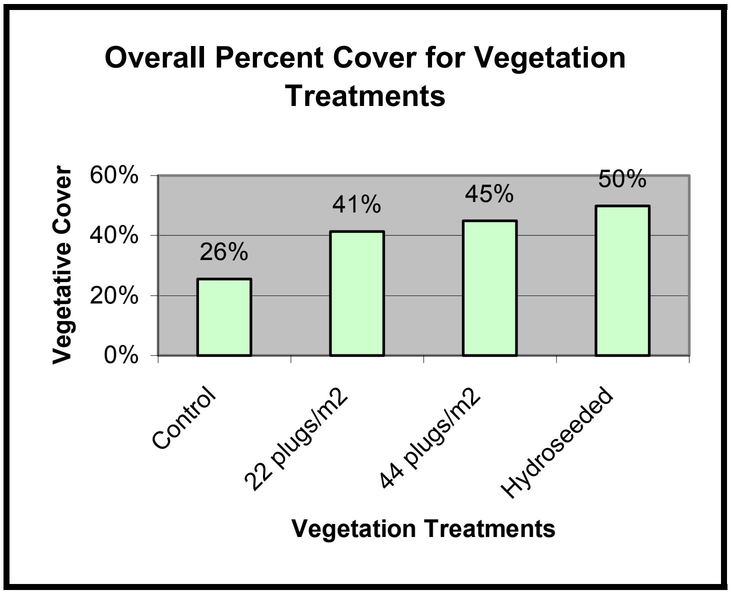


Figure 2.10

RS3 FINDING: *The upper portion of the boxes had greater overall percent cover of three of the four types of vegetation recorded and less bare ground as compared to the lower portion of the boxes, due to the application of maintenance irrigation from the top of the boxes. (Figure 2.11)*

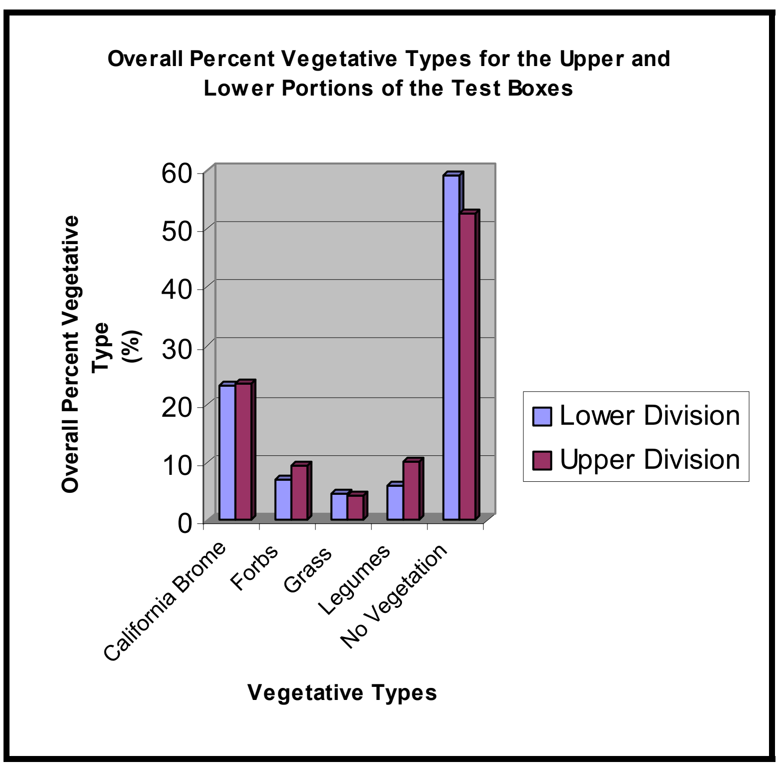


Figure 2.11

RS3 FINDING: *In two boxes (unreplicated), one treated with seeds and one treated with plugs, nitrogen uptake increased, thus improving the quality of the runoff by removing nitrate from the soil. (Figure 2.12)*

RS3 FINDING: *The control box had a high concentration of phosphorus in its lower portion, indicating that phosphorus was transported with increased sediment load. (Figure 2.12)*

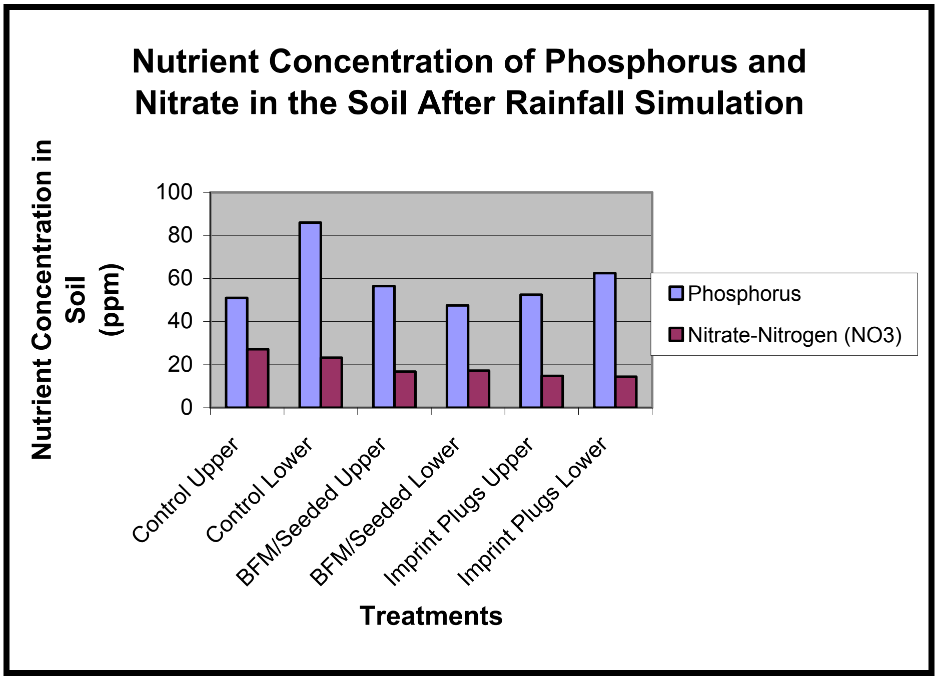


Figure 2.12

SEED GERMINATION EXPERIMENT

The purpose of this experiment was to compare different germination rates when establishing native vegetation through hydroseeding methods under varying erosion control mulches. The effects of six erosion control treatments on eight plant species at ¼ and ½ inch depths were tested.

FINDING: *Ryegrass (Lolium multiflorum) had the highest germination rate for all species, and had higher than 86% germination for all treatments. (Table 2.2)*

FINDING: *California Buckwheat (Eriogonum fasciculatum), California Sagebrush (Artemesia californica), or Deer Lotus (Lotus scoparius) experienced less than 18% germination for all treatments. (Table 2.2)*

FINDING: *Arroyo Lupine (Lupinus succulentus) experienced less than 13% germination for all treatments. (Table 2.2)*

FINDING: *BFM or Gypsum alone produced the lowest germination percentages. (Table 2.2)*

FINDING: *Tackifier, Fiber, or Fiber+Gypsum produced the highest germination percentage. (Table 2.2)*

Table 2.2 Seed Germination

	Gypsum	**Gypsum+ Fiber**	**Tackifier**	**Fiber**	**BFM**	**Bare**
Ryegrass	99%	100%	96%	91%	90%	86%
CA Poppy	28%	92%	71%	88%	79%	67%
CA Brome	74%	62%	65%	53%	56%	59%
Yarrow	41%	14%	42%	37%	6%	27%
CA Buckwheat	8%	13%	6%	18%	7%	8%
Arroyo Lupine	11%	11%	13%	9%	7%	10%
Deer Lotus	0%	8%	5%	2%	4%	1%
CA Sagebrush	2%	0%	0%	1%	1%	0%

RAINFALL SIMULATOR DESIGN

FINDING: *A portable rainfall simulator has been designed with the following criteria:*

- The chosen nozzle produces drop sizes and distribution near to natural rainfall for California storm conditions.
- The raindrops are at terminal velocity when they reach the soil surface.
- Uniformity of rainfall is greater than 90% over the entire test plot.
- The angle of impact of the drops from the nozzle is vertical.
- The computer-driven set up creates reproducible storm patterns that can be varied over a range of intensities.
- The simulator is affordable, priced at roughly $7,000.

HEAVY METAL TRANSPORT EXPERIMENT

The focus of this study was whether erosion control measures (such as increased vegetative cover and reduced slope) could prevent heavy metal transport. Various site factors were correlated to the transport of lead, copper, nickel, and cadmium along roadsides. These trends were used to determine the possible causes for heavy metal transport and ways to reduce this transport.

FINDING: *Increased sediment transport was a significant factor for increased cadmium and lead transport. (Table 2.3)*

FINDING: *Increased soil pH decreased the amount of lead & nickel transported. (Table 2.3)*

FINDING: *An increased slope was significant in increasing the transport of all metals analyzed. (Table 2.3)*

FINDING: *Increased slope led to increased removal of lead and cadmium from the site and increased the deposition of copper and nickel. (Table 2.3)*

FINDING: *Copper movement was not highly correlated with any of the factors analyzed and may depend primarily upon plant or microbial chelates. (Table 2.3)*

FINDING: *Nickel exhibited very little movement along roadsides and was not associated with sediment movement. (Table 2.3)*

Table 2.3 Factors affecting metal concentrations in roadside soils.

Factor	Metal			
	Pb	Cu	Ni	Cd
Distance from road edge (cm)	+			
Vegetative cover on sample §				
Clay content (%)	+			+
Presence of curb		+	+	
Slope of site (%)			+	-
Slope above sample (%)	-	+		
Slope of sample (%)				
Vegetative cover above sample §		+	-	+
Soil pH	-		-	
Depth (cm)				
Traffic braking §	-		-	
Traffic volume §				
Background metal concencetration (ppm)				

+ = increase in metal concentration with increase in magnitude of factor

- = decrease in metal concentration with increase in magnitude of factor

§ qualitative factor with 0 being none to a maxmimum of 1.0 (volume and cover) or 2.0 (braking)

SECTION V. VEGETATION ESTABLISHMENT & MAINTENANCE STUDY

PROJECT DESCRIPTION

Hydroseeding failures on disturbed sites are usually attributable to combinations of improper species selection, inappropriate seedbed, improper seed burial, or seeding at inappropriate times. To investigate these factors a study was conducted to assess their affect on vegetation establishment.

The purpose of this multi-year project is to develop guidance for effective establishment of erosion control vegetation for rapid short-term growth and for long-term establishment. The plants examined in this study included both native and non-native naturalized species. This year included two separate experiments, known as Rainfall Simulations 2 and 3 (RS2 & RS3). RS2 compared the establishment of a native Central Coastal California seeding mix, a non-native seeding mix, and the existing seed bank in the soil under different erosion control treatments. RS3 compared hydroseeded versus plug-planted California Brome (*Bromus carinatus*) in respective effectiveness at controlling sediment transport under different erosion control treatments.

Caltrans will use the results of this study in an effort to increase vegetation establishment, decrease erosion, and thereby improve water quality. There is a need to address proper seed selection, proper time of year for seeding, appropriate methods of hydroseeding, appropriate methods of plug planting, and plant establishment criteria as each factor relates to erosion control and soil stabilization.

EXPERIMENTAL DESIGN

RS2 Rainfall Simulation Experiment

Seed and erosion control treatments were randomly assigned to each of 30 soil boxes in a replicated, crossed design (Photo 3.1). Three different seed treatments were paired with five erosion control treatments and subjected to two simulated rainfall treatments (Table 3.1 and 3.2). Two additional boxes received no seed or erosion control treatment, but were subjected to the two rainfall treatments as "controls".

Table 3.1 RS2 Crossed Design & Number of Replicates

	V1	V2	V3	
EC1	*1*	*1*	*1*	**R1**
	1	*1*	*1*	**R2**
EC2	*1*	*1*	*1*	**R1**
	1	*1*	*1*	**R2**
EC3	*1*	*1*	*1*	**R1**
	1	*1*	*1*	**R2**
EC4	*1*	*1*	*1*	**R1**
	1	*1*	*1*	**R2**
EC5	*1*	*1*	*1*	**R1**
	1	*1*	*1*	**R2**
Total	*10*	*10*	*10*	

Table 3.2 RS2 Treatments

RS2 VEGETATION TREATMENTS

V1	Existing (*No Added Seed*)
V2	Existing+(600g EC Mix + wood Fiber @ 9 kg / 190 L)
V3	Existing+(1000g D5 Native Seed Mix + Fiber @ 9 kg / 190 L)

RS2 EROSION CONTROL TREATMENTS

EC1	Crimped Straw @ 0.22 kg / m^2
EC2	Jute (25 mm mesh)
EC3	Gypsum (11 kg / 95 L)
EC4	BFM (22 kg / 190 L)
EC5	Tackifier (0.7 kg / 95 L)

RS2 SIMULATED RAINFALL TREATMENTS

R1	Storm Event @ 45 days only
R2	Storm Event @ 45 days & @ 70 days

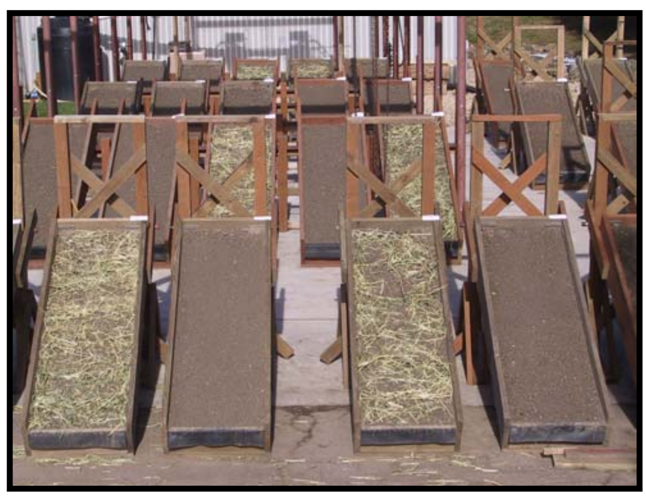


Photo 3.1

RS2 Hydroseeding

Boxes were placed in a random design before hydroseeding. Prior to hydroseeding, Straw was Crimped into the six EC1 treatment boxes. Hydroseeding proceeded according to the steps identified in Table 3.3. The tank on the hydroseeder was completely flushed with water between applications.

Table 3.3 Steps for Tank Loads

Tank Load	Water (L)	EC Material	Vegetation	Boxes Treated (#)
1	190	11 kg Fiber	V2	10
2	190	11 kg Fiber	V3	10
3	190	22 kg BFM		6
4	95	0.7 kg Tackifier		6
5	95	11 kg Gypsum		6

Table 3.4 RS2-V2: Erosion Control (EC) Alien Species Mix

Common Name	Scientific Name	Rate (seeds/m^2)	%PLS of mix
Annual Grasses			
Annual Ryegrass	*Lolium multiflorum*	580	70.0
Cereal Barley	*Hordeum vulgare*	580	10.0
Annual Forbs			
Rose clover	*Trifolium hirtum*	96	10.0
Crimson Clover	*Trifolium incarnatum*	96	10.0
			100.0

Table 3.5 RS2-V3: District 5 (D5) Native Species Mix

Common Name	Scientific Name	Rate (seeds/m^2)	%PLS of mix
Perennial Grasses			
California Brome	*Bromus carinatus*	580	*25.0*
Blue Wild Rye	*Elymus glaucus*	580	*12.5*
Foothill Needlegrass	*Nassella lepida*	580	*5.0*
Purple Needlegrass	*Nassella pulchra*	580	*5.0*
Annual Grasses			
Small Fescue	*Festuca microstachys*	580	*2.5*
Perennial Forbs			
Common Yarrow	*Achillea millefolium*	290	*2.5*
Annual Forbs			
California Poppy	*Eschscholzia californica*	96	*5.0*
Arroyo Lupine	*Lupinus succulentus*	96	*5.0*
Pinpoint Clover	*Trifolium gracilentum*	96	*12.5*
Shrubs			
California Sagebrush	*Artemisia californica*	96	*2.5*
Coyote Bush	*Baccharis pilularis*	96	*2.5*
California Buckwheat	*Eriogonum fasiculatum*	96	*12.5*
Deer Lotus	*Lotus scoparius*	96	*5.0*
Black Sage	*Salvia mellifera*	96	*2.5*
			100.0

RS3 Rainfall Simulation Experiment

Seed or 75mm (3in) plugs of California Brome (*Bromus carinatus*) and erosion control treatments were randomly assigned to each of 30 soil boxes in a replicated, crossed design. Three seed treatments were paired with five erosion control treatments and were subjected to one simulated rainfall treatment at 70 days from installation (see Table 3.6). Two additional boxes, or controls, received no seed or erosion control treatment, but were subjected to the same rainfall treatment.

Table 3.6 RS3 Crossed Design & Number of Replicates

	V1	V2	V3	
EC1	2	2	2	R1
EC2	2	2	2	R1
EC3	2	2	2	R1
EC4	2	2	2	R1
EC5	2	2	2	R1
Total	*10*	*10*	*10*	

RS3 Hydroseeding

Boxes were placed in a random design before hydroseeding (Photo 3.2). Prior to hydroseeding, the six EC4 treatment boxes were imprinted using spades to simulate a track-walk pattern. California Brome was seeded at a rate of 580 PLS per m^2. (Table 3.7)

Table 3.7 RS3 Treatments

RS3 SEED / PLUG TREATMENTS

V1	*Bromus carinatus* seed @ 580 PLS / m^2
V2	*Bromus carinatus* plugs @ 22 / m^2
V3	*Bromus carinatus* plugs @ 44 / m^2

RS3 EROSION CONTROL TREATMENTS

EC1	Jute (2.5cm mesh)
EC2	BFM (22kg / 190 L)
EC3	Fiber (22kg / 190 L + Tackifier (0.7 kg / 95 L)
EC4	Imprinting
EC5	None

RS3 SIMULATED RAINFALL TREATMENTS

R1	Storm Event @ 70 days from installation

Photo 3.2

Box Design

Two criteria were used to determine the size of the erosion test boxes. First, box dimensions must relate to boxes used in experiments found in the soil erosion literature. Second, size, shape, and weight must be appropriate for easy handling by two people using a simple one-ton chain hoist located on the test site. Pearce et al. (1998) utilized field micro-plots of 0.6 meters (2 feet) by 2.0 meters (6.6 feet) alongside standard plots of 3.0 meters (9.9 feet) by 10 meters (32.9 feet). A box having the same dimensions as the micro-plots and with a soil depth of 20 cm (7.8 inches) weighs less than one ton when saturated and is easily moved by two people using a hoist. A total of 32 erosion test boxes, each measuring 2.0m L x 0.6m W x 0.3m D, were constructed and filled with Sandy Clay Loam soil, which is typical for D5 fill slopes. One end of each box was cut to a height of 20 cm (7.8 inches) to coincide with the height of the added soil (Photos 3.3 and 3.4)

Photo 3.3

In addition to the erosion test boxes, plans were created for a support stand. Nineteen of these supports were used in this study. The supports are constructed of pressure treated lumber, and 2.5 cm OD galvanized steel pipe to support the boxes at a 2:1 (H:V) slope. These supports were used during rainfall simulations, and for positioning boxes throughout the experiment. The erosion test boxes were situated next to each other, two to six boxes per row with a total of eight rows (Photo 3.5).

Photo 3.4

Photo 3.5

A length of vinyl gutter was used to collect runoff from the base of the erosion test box and channel it into a basin where it was collected. A rectangular piece of synthetic pond liner was cut and riveted to the vinyl gutter (Photo 3.6). This prevented simulated rainfall from entering the erosion collection system. The collection system was secured to the box with screws (Photo 3.7). The basin consisted of a 22.3 Liter plastic container (Photo 3.8).

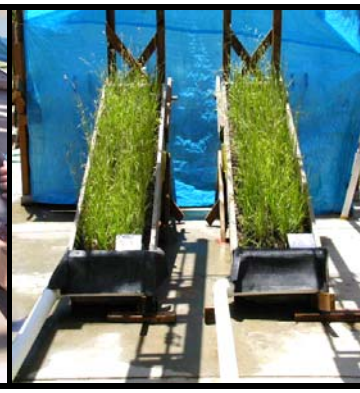




Photo 3.6 Photo 3.7 Photo 3.8

Soil Analysis

Soil core samples for laboratory analysis were taken from the upper and lower halves of boxes 14, 38, and a control box from RS3. Box 14 was treated with BFM and hydroseeded with California Brome (*Bromus carinatus*). Box 38 was imprinted and planted with California Brome plugs at $22/m^2$. The control box was untreated. Bulk density was calculated by the core method and soil texture was determined by the bouyoucos hydrometer method (Taskey, 1996). All soil chemical analyses were performed using the Lab Manual for the study of Fertilizers in Improving Soil Fertility (Dickson, 1990). The same soil was used for both experiments (RS2 and RS3).

The average bulk density in the upper and lower halves of the boxes was $1.40 g/cm^3$ and $1.54 g/cm^3$, respectively. The USDA texture is Sandy Clay Loam with an average grade of 57.6% sand, 20.8% silt, and 21.7% clay.

Table 3.8 Soil Physical Analysis

	Control Upper	**Control Lower**	**Box 14 Upper**	**Box 14 Lower**	**Box 38 Upper**	**Box 38 Lower**
% Clay	19.7	20.8	22.2	21.8	23.0	22.5
% Silt	22.8	21.7	21.5	20.5	20.6	17.5
% Sand	57.5	57.5	56.3	57.7	56.4	60.0
USDA Soil Texture	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Bulk Density*	1.46	1.58	1.32	1.52	1.42	1.53

*Bulk density calculations are in g/cm^3.

Rainfall Simulators

Photo 3.9

Two Norton Ladder type variable sweep rainfall simulators were used in this study developed by the USDA Erosion Research Center at Purdue University (Photo 3.9 and 3.10). The rainfall simulator is a pressurized nozzle type, currently utilized in erosion research. It consists of a boom oscillating side-to-side by way of a cam (see Photo 3.11). A small motor drives the cam at one end of each simulator. Intensity of rainfall is determined by how many times the nozzles of the boom sweep past the box opening in a given amount of time. The boxes are configured to regulate spray pattern and return non-effective rainfall to the water supply system. The rainfall simulators have industrial spray nozzles. They have an optimum pressure range of 35 to 2068 kPa (5 to 300 psi), and for rainfall simulation purposes, are set at 41 kPa (6 psi). At 41 kPa (6 psi), the drop size should be about 2.25 mm (.09 in) in diameter. This drop size corresponds to the average drop size of erosive storms in the Midwest. Drop size along the Pacific Coast is frequently smaller, but actual measurement data are lacking in the literature.

Photo 3.10

Photo 3.11

Maintenance Irrigation

The 50-year average annual rainfall for the San Luis Obispo area is 620 mm (24.4 in). The 2001-2002 rainfall season (1 July to 30 June) was the 9th driest on record with 405mm (15.94 in) or 65% of average (National Weather Service Oxnard, 2002). Please see Appendix B for weather station data from the experiment site. Due to insufficient and inconsistent natural precipitation during the duration of these experiments, all boxes were supplementally irrigated using micro sprayers so the soil was never allowed to dry completely. Thus, seedlings were grown under a "best-case" scenario in order to show the maximum potential of vegetation to control erosion.

Vegetation Measurements

The three primary measures of vegetation are density, biomass and cover. The density can be defined as the number of individuals of a species, lifeform, or structural class per unit of area. Biomass refers to the quantity of herbaceous or woody tissue produced by individuals of a species, lifeform, or structural class per unit of area. Cover is characterized as a two-dimensional perpendicular projection onto the ground surface of the three-dimensional aerial vegetation above (Bonham, 1989; Interagency Technical Team, 1996; Kent and Coker, 1992; Mueller-Dombois and Ellenberg, 1974).

For these experiments, aerial plant cover was reasoned to be the most logical and readily assessed vegetation variable. The interception of raindrops by aerial plant parts is fundamental in retarding water-driven soil erosion processes. Although plant density can provide important information about how many individuals of a given species in a seed mix germinated and established, obtaining plant counts is extremely labor intensive and time consuming, especially in a multi-species mix.

The oldest, most objective, and most repeatable measure of plant cover is by *point intercept* (Photo 3.12). This involves a theoretically infinite small point projected from above onto vegetation surfaces which contacts individual plant structures, soil surface litter, rock, or bare soil. Each contact is termed a "hit" for each category scored. Rules must be established beforehand regarding exactly what constitutes a "hit" for each purpose-dependent investigation.

For these experiments, a modified point-transect method was used (Photo 3.13). A 600mm (24 in) length of 20mm (0.8 in) square wood stock was notched along the length of each angled face at 25mm (0.98 in) intervals. Along each face 10 positions were selected using random numbers to render four different point position arrays. The ends of the stock were affixed and allowed to rotate on uprights so that the bar was held approximately 25mm (0.98 in) above, and parallel to, the soil surface.

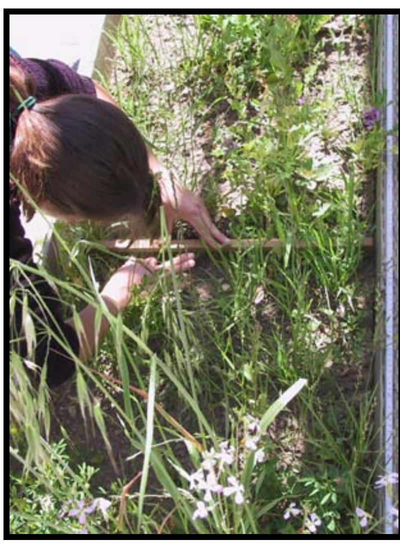


Photo 3.12

Photo 3.13

For sampling purposes, each soil test box was conceptually divided into an upper and a lower half. This was to assess whether differences in plant cover exist between the two halves owing to greater gravity water flow and retention in the lower end of each inclined box. Positions were marked every decimeter along the rails of each box. This rendered nine possible transect positions in each half of every box. A computer spreadsheet was used to assign randomly generated numbers to each of the nine possible positions, to sort the nine positions, and to select the first five unique positions for each box. Positions selected for the upper half were used for the lower half of the same box. Again, a computer spreadsheet was used to assign randomly generated numbers to each of the 21 possible sample point positions, to sort the 21 positions, and to select the first 10 unique positions for each transect. Positions selected for the five transects in the upper half were used for lower half transects of the same box. The design rendered 100 observations per box. Thus, a total of 3200 observations over 32 boxes were made.

Plant identifications were made based largely on observer knowledge of the flora. Verifications of some preliminary identifications were made using the most recent taxonomical manual (Hickman, 1993), and specimens in the Hoover Herbarium at Cal Poly. Data were then entered into a computer spreadsheet and verified for accuracy and completeness.

Water Quality Measurements

Total Solids (suspended plus settleable solids) were collected in 7.5 L plastic containers and analyzed for all runoff samples (Photo 3.14). The procedure combined two standards (ASTM D3977-97 and EPA Method 160.2) with common water treatment flocculant (1M $AlCl_3$) (Photo 3.15). After collection of each weighed runoff sample, highly turbid samples received 10-20 ml (.34-.68 fl.oz.) of the flocculant (Photo 3.16).

Photo 3.14

Photo 3.15

Photo 3.16

The supernatant, or clear water after flocculation, was then filtered through a Fisher Scientific fritted disc filter assembly using a pre-weighed Whatman 934 AH 90mm 1.5µm (micrometer) pore size, Cat. NO. 1827 090 filter paper to collect any suspended materials. The filter paper was then oven dried for 24 hours at 80^0C (176^0F) and weighed. The remaining sediment on the bottom of each storage container was rinsed into an evaporating dish to be oven dried. The storage container with sediment was oven dried at 115^0C (239^0F) for 24-48 hours until fully dried, and then weighed. The total water runoff weight was calculated from the original collection container minus the sediment and container weight. The total sediment weight was the filter sediment weight plus the evaporating dish sediment weight. Sediment concentration (mg/L) could then be calculated from the total runoff and total sediment values.

Weather Station

A weather station was set up in order to monitor the daily weather conditions at the simulation site. The weather station was mounted directly above the simulated rainfall boxes to effectively interpret the conditions surrounding the boxes. The weather monitoring station was linked (wirelessly) to a computer kept in the head house that logged weather data throughout the experiment. See Appendix B for weather data.

Statistical Methodology

Proportion cover was analyzed using logistic regression and vegetation specific analyses were analyzed with multinomial logistic regression.

Percent cover was measured in each box-half by determining cover or no cover for each of 50 points. If the presence or absence of plant matter is considered at each sampled location as the response variable of interest, then this is related to the experimental factors (Montogomery, 1991). Logistic regression is a method by which one can model the presence of plant matter at any point in the box as a function of erosion control treatment, vegetation treatment and other factors.

Water runoff, sediment in the runoff and sediment concentration in the runoff were analyzed (perhaps after an appropriate normalization transformation) via analysis of variance (ANOVA).

Data summaries and statistical analyses for RS2 and RS3 can be found in Appendix A.

RS2 Vegetation

At 45 days seedling cover was poor and rendered vegetation as an insignificant factor in runoff. Cover values are presented below (Table 3.9). No statistically significant difference was detected between grass cover (p=.253) and forb cover (p=.060) across the five EC treatments. However, there were differences in plant cover across the seeding treatments (p<.001). Seeding with the D5 native seed mix increased the forb cover while seeding with the commercial EC seed mix increased both forb and grass cover.

Table 3.9 RS2 Overall Percent Cover

Class	45_Day_Hits	ABSCover%	RELCover%	70_Day_Hits	ABSCover%	RELCover%
Grasses	189	6.3	53.8	615	20.5	38.8
Legume Forbs				735	24.5	46.3
Other Forbs				218	7.3	13.7
All Forbs	162	5.4	46.2	953	31.8	60.1
Shrubs	0			19	0.6	1.2
All Veg	351	11.7	100.0	1587	52.9	100.0
No Veg	2649	88.3		1413	47.1	
Total	3000	100.0		3000	100.0	

At 70 days, both the commercial EC seed mix and the D5 native seed mix produced significantly greater cover over the existing seed bank (p<.001). Thus, given the soil used for this experiment, added seed produced more plant cover. The EC treatments were found to have an effect on cover in general (disregarding the type of vegetation cover, p<.001) with Jute, Straw, BFM, or tack allowing the most plant cover and Gypsum allowing the least. The statistical analysis found differences among Jute, Straw, BFM, and tack to be statistically insignificant, but all were found to be statistically different from Gypsum with regards to cover. See Photo 3.17 for an example of a vegetated box.

Shrubs were so scarce that they were eliminated from the analysis (only 19 shrubs occurred in 3000 data points) because no relationships between treatments and shrub cover could be estimated with any reliability. With the adjusted analysis, we found that there was a statistically significant EC treatment effect on cover for legumes and grasses, but not for forbs. Jute or BFM seemed to increase legume cover the most and Gypsum the least. Jute, Tackifier or Straw increased grass cover the most and BFM the least. Jute seemed to be a middle ground in increasing cover for the two vegetation types, being among the best treatments for both plant types. Gypsum consistently rendered poor cover across vegetation types.

The seeding treatment also affected vegetation cover type. Seeding with D5 native seed mix increased legumes (p<.001) while seeding with the commercial EC seed mix increased both legumes and grasses (p<.001). There was no statistically significant effect of seeding method on forbs.

Photo 3.17

RS2 Water Quality

At 70 days, the D5 native seed mix resulted in statistically lower total runoff than the existing seed bank. Compared to the control, the D5 native seed mix reduced the average total sediment by over ten fold. The existing seed bank yielded the highest total sediment load. No seeding treatment had an effect on sediment concentration. Erosion control treatment analysis showed Jute or BFM to be the best for erosion control. Gypsum has a higher concentration in the runoff than Jute or BFM ($p=.05$). Jute or BFM is better than Tackifier as well ($p=.10$).

With respect to sediment load, D5 native seed mix is significantly better than commercial EC seed mix or existing seed bank. The best treatment is BFM followed by Jute, Straw, Gypsum and Tackifier. The D5 native seed mix yielded significantly lower sediment values than did commercial EC seed mix or existing seed bank. Sediment levels obtained from BFM, Jute, or Straw were not statistically different from each other. All three were significantly lower than Gypsum or Tackifier. With respect to sediment concentration, BFM, Straw, or Tackifier were not significantly different. Gypsum was significantly higher than the above three treatments.

RS2 Water Quality Natural Rainfall

The following boxes received natural rainfall. A total of three natural storms were collected and the runoff water was analyzed in the same method as the main experiment.

Storm Event 1/28/02

Please see Appendix A for data summaries.

For the EC treatments, BFM maintained the lowest total runoff, followed by Crimped Straw, Gypsum, bare, Tackifier, and Jute netting with the highest total runoff. For the seed mixtures, D5 native seed mix maintained the lowest total runoff, followed by existing seed bank, and commercial EC seed mix with the highest total runoff.

For the EC treatments, BFM maintained the lowest total sediment, followed by Crimped Straw, Jute, Gypsum, bare, and Tackifier with the most total sediment. For the seed mixtures, D5 native seed mix was maintained the lowest total sediment, followed by commercial EC seed mix, and existing seed bank with the most total sediment.

For the EC treatments, BFM maintained the lowest sediment concentration, followed by Jute, Tackifier, Gypsum, bare, and Crimped Straw with the highest sediment concentration. For the seed mixtures, commercial EC seed mix maintained the lowest sediment concentration, followed by D5 native seed mix, and existing seed bank with the highest sediment concentration.

Storm Event 3/6/02

For the EC treatments, BFM maintained the lowest total runoff, followed by Crimped Straw, Jute, Tackifier, bare, and Gypsum with the highest total runoff. For the seed mixtures, D5 native seed mix maintained the lowest total runoff, followed by commercial EC seed mix, and existing seed bank with the most total runoff.

For the EC treatments, BFM maintained the lowest total sediment, followed by Jute, Crimped Straw, Tackifier, bare, and Gypsum with the most total sediment. For the seed mixtures, commercial EC seed mix maintained the lowest total sediment, followed by D5 native seed mix, and existing seed bank with the most total sediment.

For the EC treatments, Jute maintained the lowest sediment concentration, followed by BFM, Crimped Straw, Tackifier, bare, and Gypsum with the highest sediment concentration. For the seed mixtures, commercial EC seed mix maintained the lowest sediment concentration, followed by D5 native seed mix, and existing seed bank with the highest sediment concentration.

Storm Event 3/17/02

For the EC treatments, BFM maintained the lowest total runoff, followed by Crimped Straw, Jute, bare, Gypsum, and Tackifier with the most total runoff. For the seed mixtures, D5 native seed mix maintained the lowest total runoff, followed by commercial EC seed mix, and existing seed bank with the highest total runoff.

For the EC treatments, BFM maintained the lowest total sediment, followed by Jute, Crimped Straw, bare, Gypsum, and Tackifier with the most total sediment. For the seed mixtures, D5 native seed mix maintained the lowest total sediment, followed by commercial EC seed mix, and existing seed bank with the most total sediment.

For the EC treatments, BFM maintained the lowest sediment concentration, followed by Jute, Crimped Straw, Tackifier, bare, and Gypsum with the highest sediment concentration. For the seed mixtures, D5 native seed mix maintained the lowest sediment concentration, followed by commercial EC seed mix, and existing seed bank with the highest sediment concentration.

RS3 Vegetation

Data summaries and statistical analyses for RS3 can be found in Appendix A.

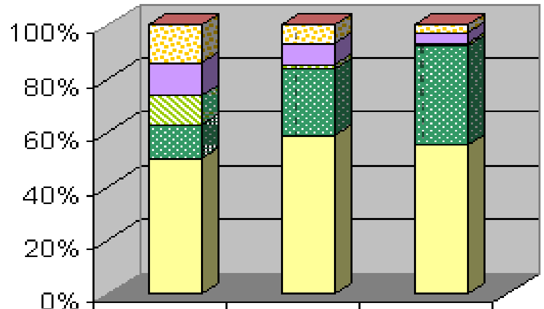
After 45 days, no significant differences existed in percent cover among vegetation treatments. However, EC treatment did have a statistically significant effect. Both Jute and Fiber + Tackifier allowed significantly more overall cover than BFM or Imprinting (at α=.05).

Different vegetation and EC treatments also had an effect on composition of plants in the boxes. For legumes, vegetation treatment had a significant effect ($p=.004$) with hydroseeded California Brome producing a higher legume cover than 22 plugs/m^2. Most of these legumes in the seeded boxes consisted of weedy annuals such as Bur Clover *(Medicago polymorpha)*, Yellow Sweet Clover *(Melilotus indica)*, and Spring Vetch *(Vicia sativa)*. This increase was perhaps due to the open disturbed soil without shade or competition from already established plugs. EC treatment also had a statistically significant legume cover rate ($p<.001$) with Jute netting resulting in a higher legume cover rate than no treatment.

After 70 days statistically significant differences in cover existed among vegetation treatments ($p<.001$) and EC treatments ($p=.001$). Among the vegetation treatments, hydroseeded Brome produced significantly more total cover than 22 plugs/m^2, but not significantly more than 44 plugs/m^2. See Photo 3.18 for an example of a box treated with 22 plugs/m^2. Among EC treatments, BFM, Jute, Imprinting, or Fiber + Tackifier were all found to produce greater cover than no treatment at all. There was no statistical difference in percent cover among these four preferred treatments.

There were statistically significant differences among vegetation and EC treatments and the composition of plants in the boxes (Figure 3.1). For legumes, vegetation treatment was significantly related to legume cover ($p<.001$) with hydroseeded Brome producing more legumes than 22 plugs/m^2. Again, these legumes predominantly consisted of those weedy species found at the 45 day analysis. EC treatment was also significantly related to the legume cover rate ($p<.001$) with Jute, BFM, or Fiber + Tackifier producing more legume cover than Imprinting which produced more legume cover than no treatment.

Figure 3.1 Percent Cover of Types of Vegetation at 70 days



	Seeded	22 Plugs/m2	44 Plugs/m2
Shrub	0.0	0.0	0.0
Other Forb	14.1	7.1	2.8
Legume Forb	12.2	7.7	4.2
Other Grass	10.8	1.6	0.9
Cal Brome	12.6	24.9	36.9
No Veg	50.2	58.7	55.2

Photo 3.18

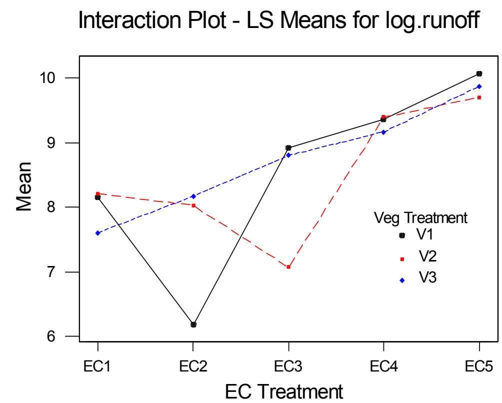
For other grasses, vegetation treatment was significantly related to cover ($p<.001$) with hydroseeded Brome producing more other grasses than 22 plugs/m^2. Like the legumes in the hydroseeded boxes, the majority of these species were common weedy ruderal grasses such as Ryegrass (*Lolium multiflorum*), Wild Oat (*Avena fatua)*, Soft Chess (*Bromus hordeaceus*), and Ripgut Brome (*Bromus diandrus*). The control and Imprinting had significantly lower other grass cover than Jute. BFM and Fiber + Tackifier had a lower other grass cover than did Jute. The control plot had lower other grass cover than all other treatments.

For other forbs, vegetation treatment was significantly related to cover ($p<.001$) with hydroseeded Brome resulting in a higher proportion forb cover than either plugging treatment. The majority of these species found in the 45 day analysis were weedy annuals. EC treatment was significantly related to forb cover ($p<.001$) with Fiber + Tackifier or Jute producing greater forb cover than no treatment and Imprinting. Like the previous hydroseeded boxes, most of these forbs were weedy annuals such as Knotweed (*Polygonum arenastrum*), Lamb's Quarters (*Chenopodium album*), Bristly Ox-tongue (*Picris echioides*), Blessed Milk Thistle (*Silybum marianum*), and Cheeseweed (*Malva parviflora*).

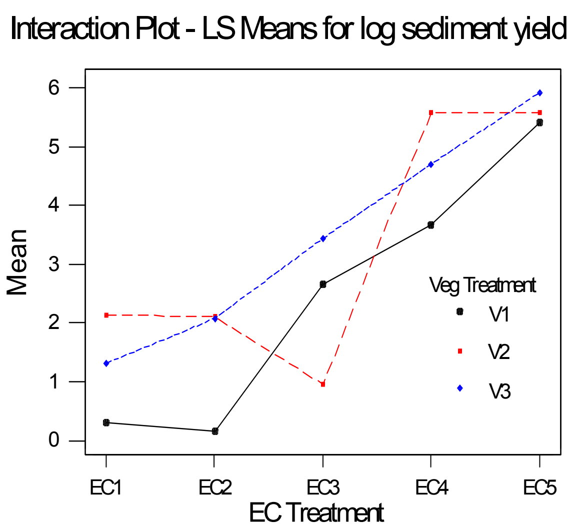
For California Brome, vegetation treatment was significantly related to cover ($p<.001$) with 44 plugs/m^2 yielding greater California Brome cover than 22 plugs/m^2 which yielded greater cover than seeding with California Brome.

RS3 Water Quality

When averaging the vegetation treatments, BFM and Fiber have significantly lower runoff than no treatment, but cannot be differentiated. There was no significant difference among Jute, imprinted soil, or no treatment. BFM and hydroseeded Brome had significantly lower runoff than either BFM and 22 plugs/m^2 or BFM and 44 plugs/m^2. Fiber + Tackifier with 22 plugs/m^2 had significantly lower runoff than Fiber and Tackifier with either existing seed bank or 22 plugs/m^2.



The erosion control treatment had a significant affect on sediment load in runoff. However, as with runoff, this effect differs with vegetation treatment. Jute, BFM or Fiber + Tackifier released lower total sediment than either Imprinted soil or no treatment. The total sediment load measured for the seeding treatment was significantly lower than brome plugs. While there is a statistically significant interaction between vegetation treatment and erosion control treatment (p=.036), post-hoc comparisons do not allow us to identify and vegetation treatments as specifically better or worse for any of the erosion control treatments.



Seeding with brome produces a lower sediment concentration than either plugging treatment. In terms of erosion control treatment, Jute, BFM or Fiber + Tackifier produced a lower sediment concentration in the runoff than control or Imprinting.

RS3 SEED / PLUG TREATMENTS

V1	*Bromus carinatus* seed @ 580 PLS / m^2
V2	*Bromus carinatus* plugs @ 22 / m^2
V3	*Bromus carinatus* plugs @ 44 / m^2

RS3 EROSION CONTROL TREATMENTS

EC1	Jute (2.5cm mesh)
EC2	BFM (22kg / 190 L)
EC3	Fiber (22kg / 190 L + Tackifier (0.7 kg / 95 L)
EC4	Imprinting
EC5	None

RS3 Vegetation & Water Quality Interactions

At 70 days, significant interactions existed among vegetation and EC treatments regarding runoff and sediment yield. The EC treatment effect ($p<.001$) differed by vegetation treatment ($p=.040$). While no significant difference existed across the three vegetation treatments for Jute netting, Imprinting, and control, hydroseeded Brome had significantly lower runoff than either plug treatments for BFM, and 22 plugs/m^2 had a significantly lower runoff than hydroseeded Brome and 44 plugs/m^2 for Fiber+Tackifier.

EC treatment was found to have a statistically significant effect on sediment yield that varied with vegetation treatment. At $\alpha = 0.10$, hydroseeded Brome had a lower sediment yield than 22 plugs/m^2 for Jute netting, a lower sediment yield than both plug treatments for BFM, and a lower sediment yield than 22 plugs/m^2 with Imprinting. Hydroseeded Brome did not consistently have lower sediment levels than the plugged treatments. For tack + Fiber mix, 22 plugs/m^2 had a lower sediment yield than hydroseeded Brome as well as 44 plugs/m^2.

The vegetation treatment had a significant effect on sediment concentration ($p=.002$). There was no significant interaction between the EC treatment and the vegetation treatment. Hydroseeded Brome had a significantly lower sediment concentration than either plug treatment.

Soil Chemical Analysis Results

These results were collected only from boxes 14, 38 and control. Because these are unreplicated results with very few samples, we cannot state any conclusions supported by statistical significance. Therefore, we cannot conclude that these numbers would occur in all of the boxes. We have included the following findings based on trends in these data.

The lower halves of the boxes (when divided horizontally across, halfway down the surface of the soil) had greater concentrations of phosphorus, chloride, sulfate and sodium, as well as higher electrical conductivity (EC). The high concentration of chloride (above 50 ppm) in the lower half of Box 38 could damage chloride sensitive plants. Additionally, the EC of the lower half of Box 38 was above 2.0 ms/cm and could cause problems with sensitive plants (Dickson, 1990). The high concentration of calcium and the moderately alkaline pH indicate a high amount of lime present in the soil.

Table 3.10 Soil Chemical Analysis

	Control Upper	**Control Lower**	**Box 14 Upper**	**Box 14 Lower**	**Box 38 Upper**	**Box 38 Lower**
PH	8.01	7.97	8.37	8.33	8.38	8.33
EC (ms/cm)	0.715	1.286	0.723	1.144	0.772	2.645
NO3 (ppm)	27.2	23.2	16.8	17.2	14.8	14.4
P (ppm)	51	86	56.5	47.5	52.5	62.5
Na (ppm)	110	165	115	170	125	230
Cl (ppm)	ND*	35	ND*	30	ND*	87.5
SO4 (ppm)	19.5	30.5	16.5	27	19	23.6
Ca (ppm)	3210	3265	3165	3095	3290	3170
Mg (ppm)	900	900	900	900	950	900
K (ppm)	275	340	245	225	270	240

*ND - Results below detection limit

SECTION VI. SEED GERMINATION

PROJECT NEED & DESCRIPTION

An ecosystem's native plant diversity can never be returned to its original state once anthropogenic disturbances take place, though properly researched rehabilitation may increase success rates. Ecosystems have characteristic disturbance thresholds and once crossed will greatly decrease the resiliency and recovery ability of sites. Engendering scientific research and management is a key component for successful plant reestablishment projects (Friedel, 1991).

Road engineering and development are major contributors to ecosystem alterations and leave harsh conditions for successful site rehabilitation. Disturbed sites are often marked by an increase in exotic weeds and a decrease in native species. Competition for water, light, and nutrients are the likeliest causes for this alteration. The addition of fertilizers has also been shown to increase the population of exotic species over native species (Hamilton et. al, 1999). A native southern California shrub recovery study on one to seventy year old human impacted sites found disturbed sites had 60 % more exotic annual species and undisturbed sites had 68 % of native shrub species. Older sites did not show resiliency in native habitation even after twenty-five years, supporting the theory once disturbance thresholds are crossed they can never be returned to original stable states. Lower amounts of nitrogen and organic matter were found on the majority of disturbed sites analyzed in a study (Stylinski and Allen, 1999). In California, for instance, coastal sagebrush has markedly been reduced since 1945 because of urbanization, recreation, and agriculture expansion (Kirkpatrick and Hutchinson, 1980). Some compaction is necessary for plant establishment, but heavy machinery and constant foot and vehicle traffic can destroy soil structure creating lower water holding capacities, alter soil biota populations, and make root penetration difficult (Bouwman and Arts, 2000).

Hydroseeding has become a standard technique for establishing vegetation on large-scale road construction sites and denuded hillsides (Caltrans, 1999). Hydroseeding has the advantage of being less labor intensive and allowing for vegetation reestablishment of steep slopes, but is subject to high failure rates due to erosion, drought, temperature extremes, seed predation, and weed competition. All seeds have very different germination and growth requirements controlled by respective microclimates; thus the choice of seed mixes is a primary consideration before beginning a project. Soil stabilizers are applied in hopes of creating suitable beds for seeds to germinate and establish, as well as to prevent erosion (Brofas and Varelides, 2000; Bradshaw and Roberts, 1985).

Burial depth influences germination rates of seeds. Seeds can easily be buried too deeply or too shallowly in the soil. Small seeds are more susceptible to decreased germination the deeper they are in the profile. On the other hand, the more exposed large seeds are to the surface, the more susceptible they are to dehydration than smaller seeds (Forcella et. al, 2000). Over application of erosion control materials may bury seeds at improper burial depths and decrease germination. This project is designed to investigate soil stabilization treatment and burial depth influences on the germination capabilities of several native California plant species and Annual Ryegrass.

MATERIALS & METHODS

Forty-eight pressure treated 1M x 1M x 0.3M wooden soil boxes were constructed and lined with silt fencing material (apparent opening size of 100-70, US sieve number equivalent), for soil moisture retention, covering a steel grating. Unsterilized landscaping soil with a medium sandy loam texture was used to fill the boxes 0.16 meters (6 inches) deep. 0.1 meters (4 inches) of steam-sterilized soil was placed on the unsterilized soil. Six EC treatments and eight seed species were used in the germination study. The soil, seed, mulching, and application rates met standards (Caltrans, 1999). Gypsum (G) applied at 907 kg/Ha (2000 lbs/ac), Gypsum and wood Fiber (GF) applied at 723 kg/Ha (1600 lbs/acre), guar Tackifier (T) applied at 136 kg/Ha (300 lbs/acre), wood Fiber (F) applied at 726 kg/Ha (1600 lbs/acre), and Bonded Fiber Matrix (BFM) applied at 726 kg/HA (1600 lbs/acre), were the hydraulically applied treatments with a bare as the sixth treatment. One hundred seeds of eight species Deerweed (*Lotus scoparius*, LSB), Lupine (*Lupinus succulentus*, LS), California Sagebrush (*Artemesia californica*, AC), California Buckwheat (*Eriogonum fasciculatum*, EF), California Poppy (*Eschscholzia californica,* EC), California Brome (*Bromus carinatus*, BC), Yarrow (*Achillea millefolium*, AM), and Ryegrass (*Lolium multiflorum*, LM) were hand planted in each treatment box (Photo 4.1). Each box was hand irrigated with ½ liters of water/day except during rainy weather where natural rain was accepted. Observations were taken 100 days after seed planting.

Photo 4.1

Observations included germinated plant count for each species and the corresponding treatment. Germinated plant count was performed by placing a planting grid over the plants and recording the number of plants in each grid resulting in a germination percentage. The observations were then used in an ANOVA for statistical analyses of treatments and species.

Table 4.1 Materials List

2.27M³ (600 gallon) Hydromulcher	600 seeds of:	Acronym
4,536 kg (10,000 lbs) landscaping soil	Deerweed (*Lotus scoparius*)	LSB
48 1M x 1M x 0.3M boxes made of pressure treated wood	Lupine (*Lupinus succulentus*)	LS
9.1 kg (20 lbs) Gypsum	California Sagebrush (*Artemesia californica*)	AC
2.3 kg (5 lbs) guar Tackifier	California Buckwheat (*Eriogonum fasciculatum*)	EF
11.3 kg (25 lbs) Bonded Fiber Matrix (BFM)	California Poppy (*Eschscholzia californica*)	EC
11.3 kg (25 lbs) wood Fiber	CaliforniaBrome (*Bromus carinatus*)	BC
0.51M x 0.51M panel with 0.05 M x 0.05M grid for seeding	Yarrow (*Achillea millefolium*)	AM
2 wood dowels with 0.0064 and 0.013 m (¼ and ½ in.) markings	Ryegrass (*Lolium multiflorum*)	LM
Steam soil sterilizer		
Municipal water supply		

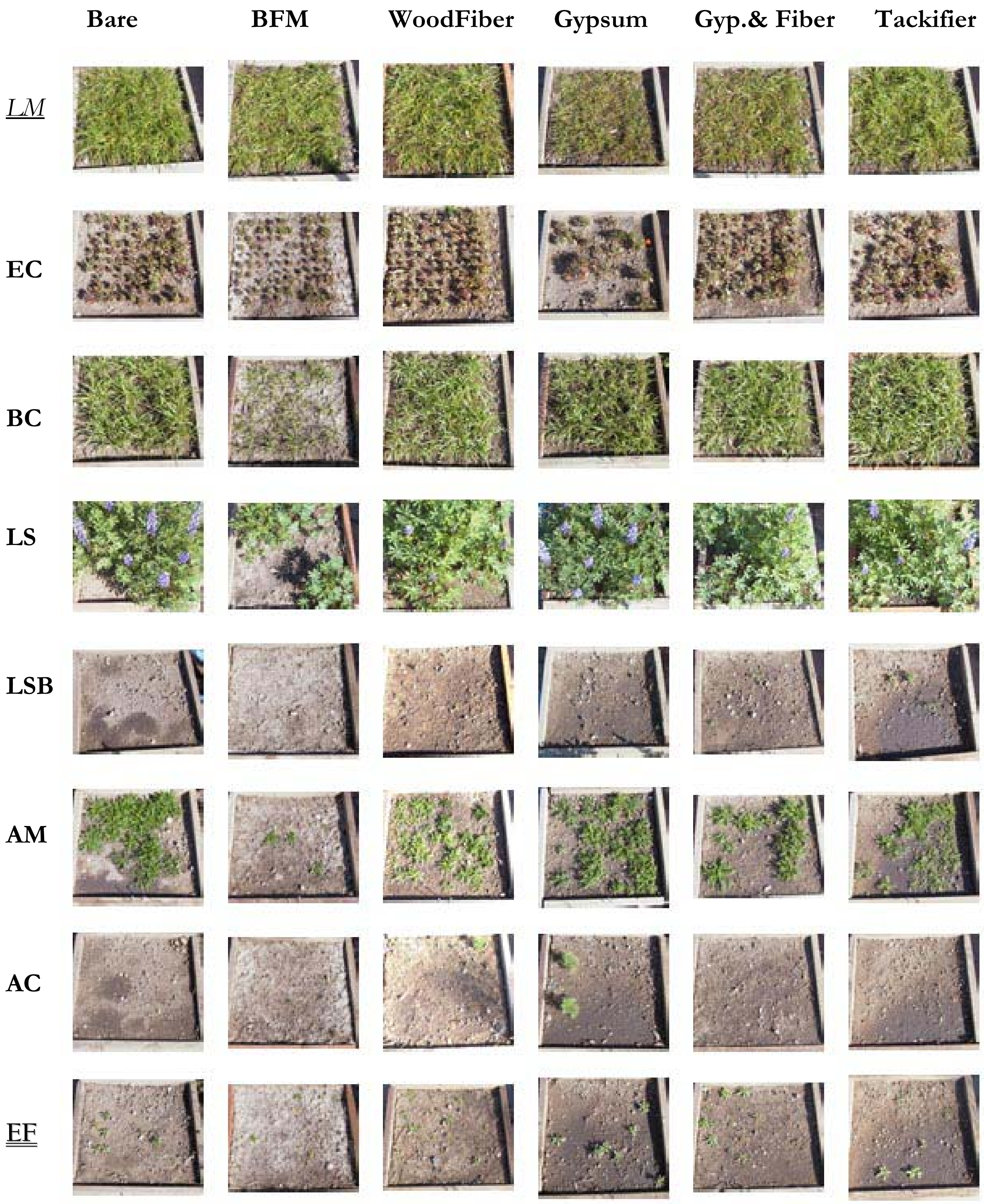


Figure 4.1 Treatment Box Layout

LM: Ryegrass (*Lolium multiflorum*)
BC: California Brome (*Bromus carinatus*)
LSB: Deerweed (*Lotus scoparius*)
AC: California Sage (*Artemesia californica*)
EC: California Poppy (*Eschscholzia californica*)
LS: Lupine (*Lupinus succulentus*)
AM: Yarrow (*Achillea millefolium*)
EF: California Buckwheat (*Eriogonum fasciculatum*)

Figure 4.2 Species Germination for Each Treatment

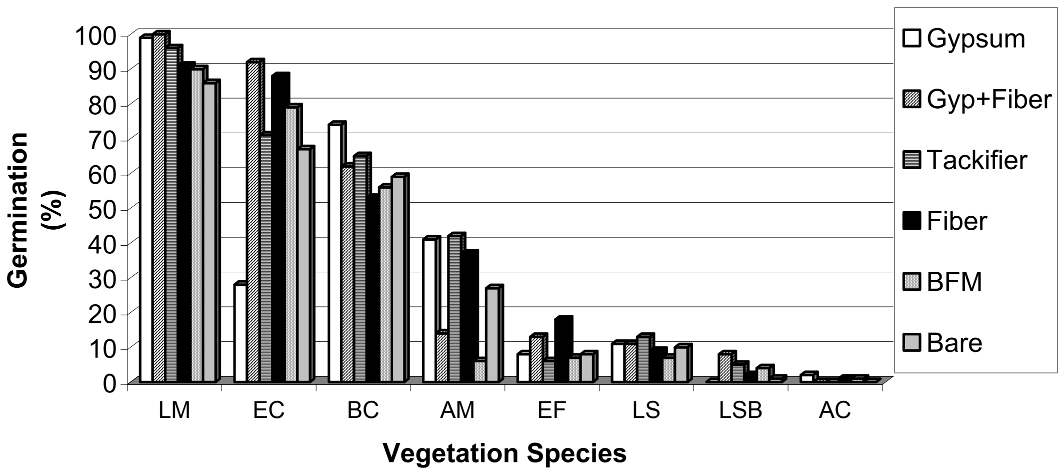


Figure 4.3 Species and Depth Results on Germination

Species Key

LSB -*Lotus scoparius*

LS -*Lupinus succulentus*

AC -*Artemesia californica*

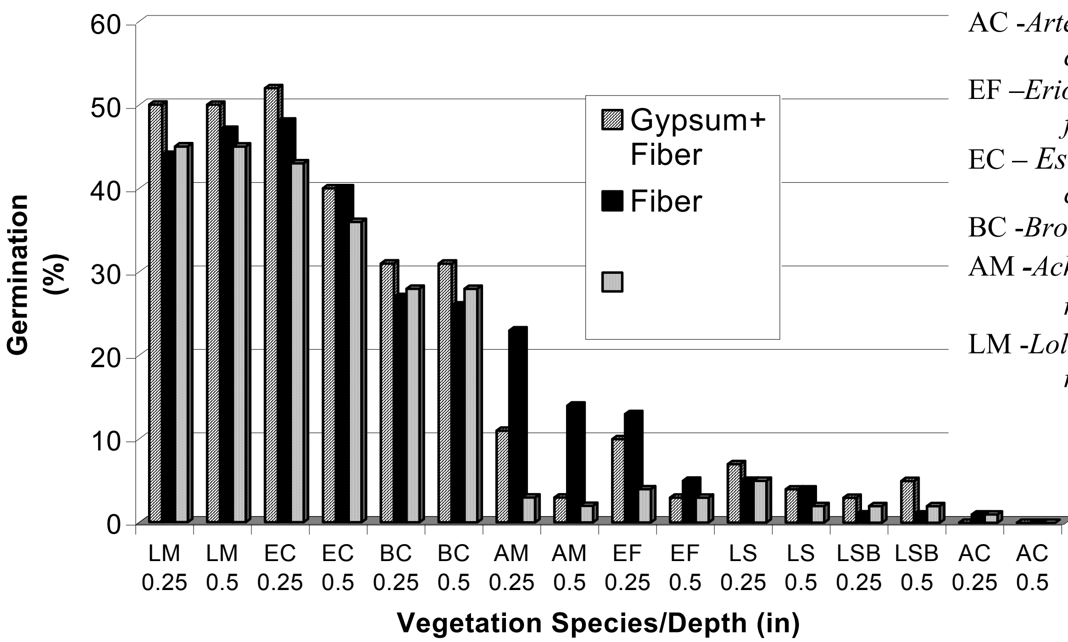
EF –*Eriogonum fasciculatum*

EC – *Eschscholzia californica*

BC -*Bromus carinatus*

AM -*Achillea millefolium*

LM -*Lolium multiflorum*



DISCUSSION

Soil stabilization treatment and burial depth influences on the germination capabilities of several native California plant species and annual ryegrass were statistically non-significant after ANOVA was performed. On the other hand, further statistical analysis of the species and their treatment and or depth interactions revealed a highly significant result. Graphing the results from the germination percentage count show a significant difference between species germination percentage for the treatments (Figure 4.1). The species, Ryegrass (*Lolium multiflorum*), California Poppy (*Escholzia californica*), or California Brome (*Bromus carinatus*), maintained a commanding high germination percentage over the shrubs and forbs of Deer Lotus (*Lotus scoparius*), Lupine (*Lupinus succulentus*), California Sagebrush (*Artemesia californica*), California Buckwheat (*Eriogonum fasciculatum*), or Common Yarrow (*Achillea millefolium*). Similar results were further shown regardless of the two different depths and treatment type (see Figure 4.2).

The best overall treatment (based upon all species and treatments shown in Figure 4.1 and Figure 4.2) was Fiber+Gypsum (GF), which resulted in the highest germination percentage. Gypsum alone or BFM had the lowest overall germination percentage. The greatest germination percentage occurred in the 0.25-inch burial depth. Ryegrass (*Lolium multiflorum*) maintained between 86 and 100 percent germination for all treatments (Figure 4.1). California sagebrush (*Artemesia californica*) maintained a germination percentage range of 0 to 2 percent germination for all treatments (Figure 4.1). Such varying results between species showing grasses and forbs with the highest germination and shrubs and other forbs with the lowest germination.

If these seeds used were to be hydraulically applied together then many interactions would undoubtedly occur. For example, Ryegrass has been found to compete with brush seedlings by using large amounts of water. Ryegrass will provide a large density of coverage the first year but in subsequent years density will be greatly reduced and perennials will increase in yield if managed correctly. The perennials are slower in establishment and will not compete with brush seedlings as much as Ryegrass. Brush seedlings planted in dense stands of Ryegrass have not been found with sufficient root depth to reach late summer water depths (Shultz and Biswell, 1952). Deep-rooted shrubs are more likely to prevent erosion and slope failure more than shallow rooted grasses (Shultz and Launchbaugh, 1955). Succession from annual exotics to perennial natives was observed over a studied time period on a disturbed field site (Brofas and Varelides, 2000).

In one study, under hydraulic methods, the most successful establishments were on plots only receiving seed and seed plus mulch. Seedling establishment requires the proper mix of moisture and surface sites. The results of this project show Gypsum and Fiber (Gypsum and mulch) to be the most successful treatment in establishing seedlings.

From the results of this research, one can expect Ryegrass, California Poppy, and California Brome to establish quite well under optimum growing conditions using most hydraulic applications within California's Central Coast. The shrubs and other forbs will be more intolerant of being applied by hydraulic applications of their seeds. Therefore, it is intrinsically better to establish early erosion control with grasses and forbs, and then later introduce shrubs and other forbs as young plants in plugs into the soil months after establishment. The plugs will be able to bypass early shrub/grass competition for water and, thus, increase establishment of the shrubs. Further, diversity of the plant ecosystem will be increased due to increased inhibitive competition of other plant species against invasive species such as Ryegrass (*Lolium multiflorum*).

SECTION VII. RAINFALL SIMULATOR DESIGN

PROJECT NEED AND DESCRIPTION

The primary purpose of a rainfall simulator is to simulate natural rainfall accurately and precisely. Rainfall is complex, with interactions among properties (drop size, drop velocity, etc.) and large climatic variation based on topography and marine influences.

Properly simulating rainfall requires several criteria: 1. Drop size distribution near to natural rainfall (Bubenzer, 1979a). 2. Drop impact velocity near natural rainfall of terminal velocity (Laws, 1941) (Gunn and Kinzer, 1949). 3. Uniform rainfall intensity and random drop size distribution (Laws and Parsons, 1943). 4. Uniform rainfall application over the entire test plot. 5. Vertical angle of impact. 6. Reproducible storm patterns of significant duration and intensity (Moore e. al., 1983) (Meyer and Harmon, 1979).

Drop size distribution, impact velocity and reproducible storm patterns must be met to simulate the kinetic energy of rainfall. Kinetic energy ($KE = mV^2/2$) is a single measure of the rainfall used to correlate natural storms and simulator settings.

Drop size distribution depends on many storm characteristics, especially rainfall intensity. Drop size distribution varies with intensity (from less than 1 mm to about 7 mm), increasing with the intensity to 2.25 mm median drop size for high intensity storms (Laws and Parsons, 1943). Most design standards were based on Laws and Parson's (1943) studies.

Unfortunately, most of the rainfall studies were in Illinois, Washington, Washington DC or locations in the south, outside California. The mountains and oceans add to the variation in the rainfall characteristics (McCool, 1979). California has both topographic and marine influences. No studies of rainfall characteristics, (drop size, storm intensity in microclimates, etc.) have ever been conducted in the state of California. Parameters can be approximated using the studies from other regions, but an accurate simulation of California rainfall is difficult without adequate research studies of California conditions.

Drop velocity is important in designing a rainfall simulator. Drops from natural rainfall are at terminal velocity when they hit the soil surface (Meyer and McCune, 1958). Therefore, a rainfall simulator must create drops of adequate size and velocity to simulate the same condition, indicating the importance between an adequate and related fall distance and drop size distribution. A direct relationship exists between drop diameter and fall distance (Laws, 1941).

A reproducible storm pattern is easy to simulate when a simulator can be adjusted to the desired intensities and duration. Since computers are relatively inexpensive, a simulator can be driven by specialized software controlling the intensity and duration of the storm. The VEMS team controls their simulators to create bell shaped storm patterns, based upon current research to simulate the intensity variation inherent in nature.

Previously Developed Rainfall Simulators

Simulators can be separated into two large groups (drop-forming simulators and pressurized nozzle simulators) (Thomas and El Swaify, 1989). Drop-forming simulators are impractical for field use since they require such a huge distance (10 meters) to reach terminal velocity (Grierson and Oades, 1977). The drop-forming simulators do not produce a distribution of drops unless a variety of drop-forming sized tubes are used. Another negative of the drop forming simulator is their limited application to small plots (Bubenzer, 1979b). Several points of raindrop production must be closely packed to create an intense enough downpour of rain. Drop forming simulators use small pieces of yarn, glass capillary tubes, hypodermic needles, polyethylene tubing, or metal tubing to form drops (Bubenzer, 1979b).

Pressurized nozzle simulators are suited for a variety of uses. They can be used in the field and their intensities can be varied more than the drop forming type (Grierson and Oades, 1977). Since drops exiting the nozzles have an initial velocity greater than zero due to the pressure driving them out, a shorter fall distance is required to reach terminal velocity. Nozzle intensities vary with orifice diameter, the hydraulic pressure on the nozzle, the spacing of the nozzle and nozzle movement (Meyer, 1979).

Pressurized nozzle simulators can produce variable storm intensities. A continuous spray from a nozzle creates an unnaturally intense storm. Some method of starting or stopping the spray is needed. The solutions have been a rotating disc, a rotating boom, a solenoid-controlled simulator (Miller, 1987) and an elaborate sprinkler system (Sumner et al., 1996). The simplest to use is a rotating or oscillating boom (Bubenzer, 1979b).

The most popular nozzle is the Veejet 80100 nozzle run at 41 kPa (6psi). It was chosen because it most closely resembles the drop size distribution of erosive storm patterns in the Midwest (Bubenzer, 1979a). Accurate testing of nozzles must be done to ensure adequate spray coverage and uniformity in the plot.

The Norton Simulator

The Norton Ladder Type Rainfall Simulator is a spray boom that oscillates across a test plot at varying speeds to produce variable-intensity storms (Photos 5.1 and 5.2). The rainfall simulator was designed for use at the USDA National Soil Erosion Research Lab at Purdue University. Boxes around each nozzle regulate the spray for proper nozzle overlap and swath width. A clutch brake starts and stops the boom as regulated by a signal from the control box. A small gear motor drives the clutch brake and the boom. The four nozzles are supplied with water in sets of two; each set of nozzles has its own hose and pressure gauge to adjust for differences in elevation, hose orientation, etc.

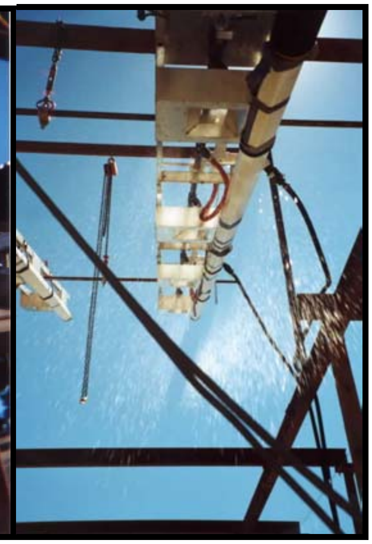


Photo 5.1 Photo 5.2

The rainfall simulator uses a Veejet 80100 nozzle. Typical, manufacturer specified uses for this nozzle include, dust control, industrial washing applications and fire control. Its uses are high-pressure, high-velocity- high-volume water applications; all things rainfall is not. The pressure range of the nozzle is quite large, from 34 to 3400 kPa (5 to 500 psi) yielding flow rates of 13.2 to 132 Liters per minute (3.5 to35 gpm). A pressure of 41 kPa (6 psi) produces drop size and intensity similar to natural rainfall (Bubenzer, 1979a). Most nozzles tend to produce irregular spray when used at its capacity limits due to machining differences. Thus, any differences between nozzles are amplified by the small psi used leading to a reduced uniformity. A new nozzle was needed, one with a narrower operation range, but similar drop size and intensity.

IMPORTANT SIMULATOR CHARACTERISTICS

Based upon the use and study of the ladder type rainfall simulators used by the VEMS team, a few design goals and parameters were considered. Above all, a rainfall simulator must be accurate and must meet all six criteria for properly simulating rainfall. Any other criteria are a matter of convenience for the user. These include weight, ease of use, reliability, accuracy and economy.

The simulator and support structure should be as light as possible. Since most of the use of the simulators is in the field and on slopes, researchers should easily place them in position. Conditions in the field lead to the necessity of strong and lightweight equipment.

In addition to being lightweight, the simulator should also be easy to use and set-up. The support system should be adequately strong to withstand any wind and all movements of the simulator. Ease of use also includes easily readable instrumentation and control systems. Proper instrumentation must be used to monitor the flow of water to the nozzles. These should be placed in such a position as to accurately measure and help regulate the inflow of water to the nozzles. Flow gauges are preferred for the rainfall simulator because of the elevation differences between the points and the difficult correlation of flow rate and pressure. The control box should be built to withstand the electronic loads placed on it with a safety factor to prevent burnout. A computer-driven labview set up is highly desirable.

Reliability ties in with strength and proper instrumentation of the rainfall simulator. Reliability relates to the repeatability of storm events. A computer-derived storm is the most reliable because it eliminates the human error involved in altering intensities. Also, when properly monitored by the correct instrumentation, the reliability will increase or at least be as high as possible.

Accuracy is achieved by creating uniform rainfall across the test plot. When a nozzle with good drop size distribution for simulating rainfall is chosen and is placed in series with adequate spacing to allow adequate overlap lateral uniformity is achieved. When this laterally-uniform boom is swept back and forth across an area, the spray will be uniform. Properly designing and testing the boxes used for cutting off the spray is critical for creating uniform rainfall.

Without question the most desirable characteristic of a rainfall simulator is its cost; it should be as low as possible. Designing a simulator must be done with cost in mind. The goal is to design and build a rainfall simulator for less than ten thousand dollars, which is the industry's standard cost.

Different nozzles require different lateral spacing, to create uniformity spray overlap. The overlap is necessary to achieve lateral uniformity thus uniformity of spray up and down the test plot. Since the variation between points is more important than amount of spray, standard deviation of points (6-inch cans capturing the spray) was found. Several different lateral spacings were tested.

Nozzle Choice

The nozzle tested was the Floodjet SS3/8k-45 with an orifice diameter of 5.51 mm (0.221 in). These were agricultural nozzles that closely resemble the Veejet 80100 flow rates (12.1 L/min at 34 kPa for the floodjet as compared to the 13.2 L/min at 34 kPa for the Veejet) as specified. The optimum range of the Floodjet is much narrower than the Veejet nozzle; its range is from 20.5 to 410 kPa (3 to 60 psi). The drop size distribution of the Floodjet nozzles were specified to be similar to natural rainfall in the catalogue (Photo 5.3).

Photo 5.3

The basis for boom length tests and drop-size tests is the nozzle. The Floodjet SS3/8k-45 nozzles are far superior for rainfall simulation than the Veejet nozzles. Veejet nozzles are industrial spray nozzles, used for cleaning tanks and other high-pressure applications whereas Floodjet nozzles are used for agricultural spraying practices. The Veejet that is presently used on the rainfall simulator has a much wider pressure range than the Floodjet nozzle. Thus, if there were a small pressure imbalance or fluctuation in the boom, the amount of rainfall applied to the test would vary significantly less with the Floodjet than with the Veejet.

Lateral Uniformity Testing

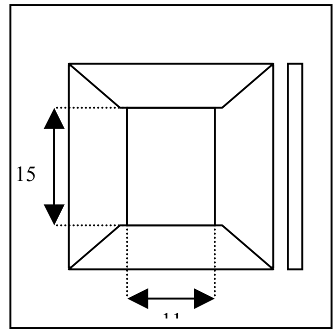
Several boom sizes were tested. The tests were conducted on calm, sunny days. The lateral uniformity was tested under a nozzle pressure of 48 kPa (7 psi). A spray angle of 53° was determined by geometry and the outside of the spray was cut off by boxes around the nozzle. The spray was captured by a grid-work of 6 inch stainless steel cans on the ground, 8-feet below the nozzles. The volume in each can was measured with a 1000 ml graduated cylinder and recorded. This process was repeated three times for each boom. The standard deviation of the spray was determined and a regression analysis was performed (Table 1).

The results indicate there are a number of boom lengths that can be used with the Flood Jet nozzle. The 48-inch boom had the lowest standard deviation; thus choosing this nozzle spacing will give the best uniformity for simulating rainfall. However, the 36, 39, 48 and 60-inch booms were not statistically different. So a design choice was made. The smaller lateral spacing gives a much more intense storm, which may or may not be appropriate for the test site climate.

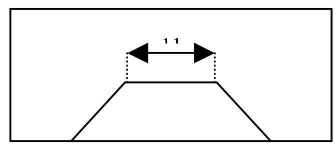
Table 5.1 Standard Deviations for the Tested Booms.

Nozzle Spacing in	Average Standard Deviation ml
60	62.34
54	77.66
51	98.92
48	62.54
42	82.62
39	55.16
36	56.63
Norton	139.19

Figure 5.1 Spray Box Views



Spray Box, Overhead View



Spray Box, Side View

Drop Size Test

Proper drop size is critical for simulation of rainfall. The drop size distribution was tested using Eigel and Moore's (1983) oil method. This entails mixing 1 part STP oil treatment and 1 part Swan brand mineral oil. Drops with ranges from 0.5- 7 mm (0.02 to 0.28 in) are caught in a petri dish of oil and held there for enough time to count and measure them. This approach was much simpler and easier to perform than the other methods, which include using flour and time-lapse photography.

The found drop size distribution is that of natural rainfall. Drop size ranges from less than 1 mm to about 7 mm (0.04 to 0.28 in) in diameter. The average drop size is 1.71 mm (0.067 in). The average drop size is smaller than the standard of 2.25 mm (0.089 in) used on previous simulators but, agrees with the literature for drop size for lower intensity storms [less than 50 mm, (2 in) per hour].

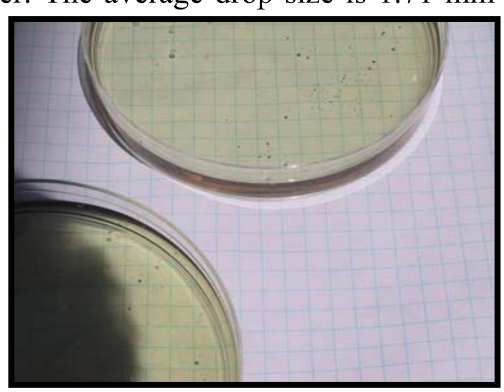


Photo 5.4

The drops were assumed to be at terminal velocity due to their size and the height of the boom. No tests were performed to find drop velocity or energy due to several previously conducted studies in the literature.

Final Dimensions

The tests performed led to the final, critical dimensions for the rainfall simulator. The nozzles are spaced 99 cm (39 in) apart. The simulator is approximately 3.56 m (140 in) long and 41 cm (16 in) wide. The box opening was determined by geometry and the opening as seen by the nozzle is 15 cm (6 in) wide, to cut off the spray for the desired spray angle, by 11 cm (4.5 in) long, to allow a large swath width (Figure 5.1).

CONCLUSIONS AND FINAL DESIGN

The final design of the rainfall simulator is similar to the original rainfall simulator with a few critical changes. The framework supporting the boom and machined components of the control box are made from aluminum. Since the nozzle was changed to the Floodjet SS3/8k-45 nozzles, the lateral spacing of the nozzles was changed to 99 cm (39 in). The box dimensions also changed to a wider, shorter opening to regulate the spray. The gear motor drives the same clutch-brake assembly, which regulates the oscillations of the spray boom. The water source is mounted on a trailer with a pump to feed the simulator. A network of hoses bring the water to the simulator and a gutter along the side of the simulator leading to hoses return unused water to the tank to be used again, thus using the water efficiently.

Flow gauges at the inlet to the water manifold are used in addition of pressure gauges on top of the water inlet manifold to regulate and monitor the flow of water to the nozzles. A laptop drives the system, bypassing many issues created by the control box and human-designed storms. The support system is made of aluminum rods and therefore is lightweight, strong and easily broken down. The design is based on a tent design utilizing a network of poles and connectors to support the simulator in six positions along the length.

Goals Achieved

The final simulator designed by the VEMS research team achieved the goals set forth. The chosen nozzle produces drop sizes and distribution near to natural rainfall for California storm conditions. Due to the height of the simulator and initial velocity of drops from the nozzle, the drops are at terminal velocity. Uniformity of rainfall is greater than 90% over the entire test plot (for one simulator the test plot is 3.56 m long and 1 m wide). The angle of impact of the drops from the nozzle is vertical. The computer-driven set up creates reproducible storm patterns that can be varied over a range of intensities.

The goals for the other more convenient considerations were also met. The designed simulator will cost approximately seven thousand dollars. The flow gauges at the source of water into the simulator help keep the nozzles flowing at the same rate, thus increasing both reliability and accuracy of the design storms. The software drives the system, thus eliminating human error and increasing the usability of the entire system. The freedom the computer provides allows for fewer people to run experiments and more time to observe the effects of the rainfall on the test plot. Few people are required to run the testing because the simulators are light and easy to set up and run.

PROJECT NEED & DESCRIPTION

The focus of the current study was whether erosion control measures (such as increased vegetative cover and reduced slope) could prevent heavy metal transport into storm-water runoff.

Extensive research has been conducted regarding ways to reduce sediment detachment and transport for erosion control. Slowing the water velocity and covering soil with natural or artificial canopies will help to keep sediment from entering waterways.

Historically, roadside contamination occurred primarily from direct deposition due to vehicles and from re-deposition of metals deposited onto the street (Harrison et al., 1981). Lead, cadmium, nickel, and copper are deposited at harmful levels along some roadsides (Sutherland, 2000; Lagerwerff and Specht 1970; Garg et al., 2000). Lead is deposited from leaded gasoline (Lagerwerff and Specht 1970). Cadmium deposition comes from contaminated motor oil and vehicle tires (Lagerwerff and Specht 1970). Nickel deposition is a result of some formulations of gasoline, but is mainly deposited from abrasion of nickel containing parts (Lagerwerff and Specht 1970). Copper is deposited from the dust of newer, non-asbestos brakes (Garg et al., 2000).

Chemical Immobilization

Chemical immobilization is a common way to prevent heavy metal transport in soils. The use of chemicals to make heavy metals less soluble can have unintended consequences.

Soil pH strongly influences metal migration through soils. Metals tend to become more soluble as pH decreases (California Fertilizer Association, 1995). Soil pH is increased by the addition of liming agents. Liming agents commonly contain calcium or magnesium. Copper adsorption in sandy soils decreased with an increase in magnesium and calcium ionic strength (Zhu and Alva, 1993). A high concentration of magnesium and any increase in calcium concentration significantly increased copper solubility. The addition of liming agents containing magnesium and calcium could increase heavy metal solubility in the soil.

Liming agents containing potassium or sodium could avoid this increase in heavy metal solubility. The addition of potassium, or increasing potassium's ionic strength, did not change the extent of copper adsorption (Zhu and Alva, 1993). The addition of monovalent cations (such as potassium and sodium) can cause dispersion in soil. This dispersion can cause less vegetative growth and can leave soil more susceptible to erosion.

Soil lead can be immobilized by phosphate addition. Lead particulate matter becomes dissolved and re-precipitated as pyromorphite (Yang et al., 2001). Pyromorphite is a stable and insoluble compound in the soil environment. When calcium is present in a soil, lead may form chloropyronophite (Yang et al., 2001). Chloropyronophite is slightly soluble and allows lead migration in contaminated soils. Runoff of phosphorus can cause eutrophication of waterways, causing stress on the ecology of these riparian zones (Calif. Fert. Assoc., 1995).

Sediment Association and Transport

Heavy metals move readily by preferential flow through aggregated soil. This is due to macropores or fractures in soil allowing contaminated colloids to move downward through a profile (Grolimund et al., 1996). Some heavy metals (i.e., lead) attach strongly to colloids in the soil. For these metals, colloid movement through macropores is considered the primary method of metal movement in the soil profile since the metals are sorbed tightly to the clay particles of aggregates. Heavy metals associated with soil colloids will primarily be transported from the site by overland runoff (Grolimund et al., 1996). Reduction of the transport of soil colloids from a contaminated soil should significantly eliminate the risk of waterway heavy metal contamination.

Heavy metals adsorb to clay colloids at different magnitudes depending on the type of clay present in a soil. Pardo, 2000, found that clays in soil preferentially sorbed Pb > Cu > Cd. Desorption of metals for all three of these soils was Cd > Cu > Pb. Soil properties allowing for selective sorption of some metals must inhibit metal desorption (Pardo, 2000). The order of the magnitude of desorption was Realojos > Mazowe > Talamana. This was attributed to the properties of the clay types in these soils (Pardo, 2000). Montmorillonite clays (2:1 silca:aluminum ratio) have a higher cation exchange capacity than kaolinite clays (1:1 silca:aluminum ratio). Therefore, montmorillonite clays more strongly attract heavy metals than kaolinte clays. Allophane activity may be a result of metals being held in suspension inside the fine tubes formed by the allophane. Heavy metals in soils with predominately kaolinite clays would be more likely to reach groundwater by traveling down the soil profile. Heavy metals in soils with predominately montmorillonite clays are more likely to reach waterways by traveling with sediments in overland runoff.

Metal Concentrations of Parent Material

Background lead, copper, cadmium, and nickel soil concentrations were determined for 3,045 minimally contaminated agricultural soils in the United States (Holmgren et al., 1993). Copper and nickel concentration were high in the 206 samples taken along the California coast. Elevated copper concentrations were due to mineralization and young geologic age, while elevated nickel concentrations were due to serpentine parent material (Holmgren et al., 1993).

Some areas in California have naturally elevated levels of cadmium (Lund et al., 1981). This elevated cadmium is associated with the Monterey Shale formation encompassing a large portion of San Luis Obispo County. This is associated with the presence of mercury mines in the County because cadmium and mercury behave similarly.

Heavy Metals Associations with Soil Fractions

Lead is associated most strongly with iron and manganese oxides in soils (44 %), with a significant portion of lead being associated with soil carbonates (26 %) (Harrison et al., 1981). About one percent of lead is held on cation exchange sites in a soil.

Copper in roadsides is strongly associated with the organic and residual fractions in soils. Forty-eight percent of copper was associated with the organic fraction in soils, and 37 % was associated with the residual fraction (Harrison et al., 1981).

Nickel does not move with the water in soils (Ma and Rao, 1997). Nickel associates to all soil fractions nearly equally (Ma and Rao, 1997).

Cadmium is associated with cation exchange sites in a soil (26 %), soil carbonates (24 %), and iron and manganese oxides (25 %) (Harrison et al., 1981). Cadmium is strongly associated with exchange sites in soils (Ma and Rao, 1997). These exchange sites are mostly derived from clay and organic matter. Calcium carbonate sorbs cadmium from the soil solution. Cadmium has similar sorption characteristics to both iron and aluminum hydroxides (Abu-Sharar et al., 1997).

Total Elements versus Extractable Elements

Roadside soils in Oahu, Hawaii, contained significant amounts of extractable lead, zinc, and copper compared to background levels for those same sites (Sutherland, 2000). No significant differences appeared between total copper concentrations in these background samples as compared to roadside soils. Soil metal extraction would be a better indicator of a soil's ability to contaminate a waterway with copper than would a total concentration analysis utilizing soil digestion. Most of the metals measured in a total acid digestion are in alumino-silicate minerals, and not readily subject to weathering. Significantly higher extractable lead, zinc, and copper concentrations occurred in the topsoil than the subsoil of these roadside sites. Subsoil and topsoil concentrations of lead, zinc, and copper were not significantly different for total metal concentrations (Sutherland, 2000). A soil's level of contamination and potential for waterway contamination would be more accurate using extraction methods for soil metal concentration analysis, than would total elemental analysis.

Project Objective

Site factors affecting metal contaminant transport and measures implementable to prevent metal transport were determined. Various site factors were correlated to the transport of lead, copper, nickel, and cadmium along roadsides. These trends were used to determine the possible causes for heavy metal transport and ways to reduce this transport.

MATERIALS & METHODS

Five roadside locations in San Luis Obispo, CA, were selected for study. All the locations were within a six square mile area from Los Osos Valley Road to Highland Avenue and had similar climatic regimes. Extractable metal concentrations and site factors were analyzed and recorded for each location. Quantitative site factors included the distance from the paved side of the road, the depth from the soil surface, the soil pH, the percentage of slope (both above the site and on the site), the percentage of clay, the percentage of sand, and the background metal concentrations. Qualitative site factors included the vegetative cover density estimates (both above the site and on the site), a traffic volume factor, and a traffic braking factor. These latter two site factors were created specifically for this project.

Soil samples were collected at each location during August and September in 2001. Samples were obtained in duplicate at distances of 30 cm and 2.5 m from the edge of the paved roadway at depths of 0 to 1 cm, and 1 to 4 cm. For some locations, the soil did not extend 2.5 m from the paved edge of the road. In those cases, no sample was taken at 2.5 m for those locations. A representative sample was taken at each location at a depth of 22 to 24 cm and a distance of 50 cm from the edge of the paved road. This sample was considered the background concentration for the site.

All soil samples were immediately sealed, stored at room temperature for two weeks, then analyzed for lead, copper, nickel, and copper using DTPA chelate extraction and analysis on the atomic adsorption spectrophotometer (Amacher, 1996). Soil pH was measured with a 10 g sample of soil amended with 20 ml of 0.01 *M* calcium chloride. Clay percentages and sand percentages were determined by the Bouyoucos hydrometer method. The percentage of vegetative cover was visually estimated at each site by the same researcher. The traffic volume was estimated for traffic using Foothill Blvd. traffic (in San Luis Obispo, CA) as a reference. A rating of zero for traffic volume was one car per day. A rating of one was one thousand cars per hour. Using this scale, the traffic volume for each site was evaluated between 0 and 1.

A scale was developed for estimating traffic braking. This scale ranged from a zero rating for a straight road with no stops, to a two rating being a four way signal controlled intersection with a parking lot next to the site. Using this scale, the traffic braking was evaluated between 0 and 2.

The statistical package contained in Minitab 10.5xtra Power was used to assess all data. Models for factors affecting metal concentrations were chosen using multiple linear regression included in the Minitab program.

RESULTS

Site factors at the five locations in San Luis Obispo, CA, were taken and recorded in the field and through samples analyzed in the laboratory. Samples 1 through 10 were relatively high in lead and cadmium, and samples 19 through 28 were relatively low in lead and cadmium (see Appendix A for complete sample data). Nickel was relatively high in samples 11 through 16, and low in samples 17 through 28. All samples, except 25 through 28, had a curb present along the road. Slopes at samples 9 through 16 were relatively high, while slopes at samples 5 through 8 were relatively low. Samples 1 through 4 had no overland water flow through the sample, because the sites were recessed into cement. Vegetative cover was high at samples 1 through 4 and samples 17 through 24. Samples 9 through 16 had low vegetative cover. Traffic braking was high in samples 9 through 24 and low at sites 1 through 4. Samples 9 through 28 had relatively high traffic volumes and samples 1 through 4 had low traffic volume. The soil pH was moderately acidic to moderately neutral (Table 6.1). Soil pH ranged from 6.04 to 7.52. Samples 1 through 8 were sandy soils with a moderate amount of clay. Samples 9 through sixteen are relatively clayey soils. Samples 17 through 28 are very sandy soils with a low clay percentage.

The twenty-eight soil samples collected from the five locations in San Luis Obispo, CA, were extracted with DTPA and analyzed via atomic adsorption spectroscopy for lead, copper, nickel and cadmium. Soil metal concentrations were calculated from the readings of the extracts (Table 6.2). Lead had the highest concentration in the soil and the widest range of concentrations. The soil lead concentrations ranged from 0.68 ppm to 98.80 ppm. Cadmium had the lowest concentration in the soil. Soil cadmium concentrations ranged from 0.14 to 0.44 ppm.

Table 6.1 Data for 28 Collected Soil Samples

Sample	Depth from surface	Distance from paved edge	Pb	Cu	Ni	Cd	pH	clay	sand
	- - - - - - - - cm	- - - - - - - - -	- - - - - - - - -	ppm	- - - - - - - - - -			- - - - - - - - %	- - - - - - - -
1	0.5	30	73.80	3.40	0.76	0.22	7.52	12.5	66.0
2	2.5	30	46.80	1.86	0.56	0.24	7.52	12.5	66.0
3	0.5	30	57.20	1.30	0.58	0.26	7.28	15.0	57.5
4	2.5	30	80.80	2.04	0.54	0.30	7.28	15.0	57.5
5	0.5	30	62.50	1.26	1.74	0.44	6.57	17.5	60.0
6	2.5	30	59.20	0.74	1.42	0.34	6.57	17.5	60.0
7	0.5	30	93.80	2.23	2.88	0.38	6.04	17.5	60.0
8	2.5	30	98.80	1.73	1.90	0.34	6.04	17.5	60.0
9	0.5	30	36.50	0.88	2.80	0.10	7.28	32.5	45.0
10	2.5	30	28.00	1.14	2.10	0.10	7.28	32.5	45.0
11	0.5	250	4.04	0.89	3.82	0.08	7.46	32.5	45.0
12	2.5	250	3.08	1.57	4.10	0.10	7.46	32.5	45.0
13	0.5	30	8.40	2.93	7.86	0.18	7.15	32.5	45.0
14	2.5	30	38.00	2.39	4.34	0.12	7.15	32.5	45.0
15	0.5	250	11.58	1.22	7.00	0.16	6.94	32.5	45.0
16	2.5	250	10.80	1.70	6.80	0.08	6.94	32.5	45.0
17	0.5	30	1.38	1.72	0.22	0.02	6.98	5.0	83.7
18	0.5	250	1.50	1.62	0.42	0.02	6.96	5.0	83.7
19	2.5	30	0.82	2.16	0.36	0.04	6.98	5.0	83.7
20	2.5	250	2.72	2.00	0.50	0.04	6.96	5.0	83.7
21	0.5	30	0.68	0.72	0.34	0.02	6.96	5.0	83.7
22	0.5	250	1.86	4.04	0.36	0.04	7.12	5.0	83.7
23	2.5	30	0.68	1.64	0.20	0.04	6.96	5.0	83.7
24	2.5	250	1.56	2.54	0.20	0.04	7.12	5.0	83.7
25	0.5	30	0.86	0.86	0.26	0.02	6.65	3.8	82.4
26	2.5	30	0.72	1.42	0.26	0.04	6.65	3.8	82.4
27	0.5	30	0.92	1.58	0.12	0.04	6.31	3.8	82.4
28	2.5	30	0.88	1.40	0.24	0.04	6.31	3.8	82.4

Table 6.2 Distribution of Values for Metal Concentration of All Soil Samples.

Metal	**Concentration of metals**			**Standard deviation**
	Low	**Average**	**High**	
	- - - - - - - - - - - - - - - - - - - ppm - - - - - - - - - - - - - - - - - - -			
Pb	0.68	26.00	98.80	32.44
Cu	0.72	1.75	4.04	0.79
Ni	0.12	1.88	7.86	2.28
Cd	0.02	0.14	0.44	0.13

Soil metal concentrations were correlated with physical and chemical site factors via multiple linear regression. Site factors analyzed explained a majority of the sample variation in Pb, Ni, and Cd concentrations, but did not explain the variation in copper concentrations (Table 6.3). Lead concentrations in the samples were strongly correlated with the distance from the paved road edge, the steepness of slope immediately above the sample, the amount of traffic braking, the soil pH, and the soil clay percentage. Copper concentrations in the samples were somewhat linked with the presence of a curb, the amount of vegetative cover on the slope above the sample, and the steepness of slope above the sample

Table 6.3. Factors affecting metal concentrations in sampled soils

Metal	Multiple linear regression equations	Standard error	R-squared
		ppm	%
Pb	Pb = 294 + 0.280 dist (cm) - 243 slope in (%) - 69.7 braking § - 28.7 pH + 3.41 clay (%)	9.34	93.2
Cu	Cu = 0.362 + 1.09 curb † + 3.53 cvr in ‡ x slp in (%)	0.73	20.5
Ni	Ni = 19.4 + 2.59 curb + 0.327 slope (%) - 2.96 cvr in - 1.18 braking - 2.94 pH	1.04	83.0
Cd	Cd = 0.0063 - 0.0296 slope (%) + 0.285 cvr in + 0.0212 clay (%)	0.03	95.5

† 0/1 denotes absence (0) /presence of curb (1); ‡ 0 to 1 denotes (0) no to full cover (1)

§ 0 to 1 denotes no braking (0) to heavy braking (2)

Nickel concentrations in the samples were strongly correlated with the presence of a curb, the steepness of the slope of the site, the amount of vegetative cover on the slope above the site, the amount of traffic braking, and the soil pH. Cadmium concentrations in the samples were strongly correlated with the slope of the site, the amount of vegetative cover on the slope above the site, and the soil clay percentage.

Background metal concentrations were not significantly related to the subsurface soil concentrations. Interactions between metals were evaluated statistically (Table 6.4). Cadmium and lead exhibited a strong statistical interaction. Lead concentration in the soil tended to increase as the cadmium concentration increased in the soil.

Table 6.4. Regression Equations and Correlation Coefficients for Metal Interactions.

Metal interactions	Linear relationship	Correlation coefficient	Significance
	- - - - - - - - - - ppm - - - - - - -		
Pb and Cd	Cd= 0.0035 x Pb + 0.0457	0.8985	***
Ni and Cd	Cd= 0.0093 x Ni + 0.01197	0.1661	NS
Pb and Cu	Cu= 0.0020 x Pb + 1.6976	0.0819	NS
Cu and Ni	Ni= 0.0579 x Cu + 1.7802	0.0200	NS
Pb and Ni	Ni = 0.0007 x Pb + 1.8636	0.0100	NS
Cu and Cd	Cd= 0.0008 x Cu + 0.1357	0.0055	NS

*** = significant at 0.1 % level

NS = not significant

DISCUSSION

Factors affecting metal concentrations were significant for all metals examined (Table 6.4). Copper, nickel, and cadmium were all affected by vegetative cover. Slope was a factor for all metal transport. Increased water movement was associated with both decreased lead and cadmium concentrations in soil. This would indicate water movement was transporting lead and cadmium off site. Lead and cadmium movement appeared to be transported along with clays, by water off site. Copper and nickel soil concentrations increased with increased water movement and with the presence of a curb. This indicates copper and nickel are concentrated in soils by water movement, but can be washed into waterways if the overland flow is too great due to a lack of a curb.

Table 6.5 Factors affecting metal concentrations in roadside soils.

Factor	**Metal**			
	Pb	**Cu**	**Ni**	**Cd**
Distance from road edge (cm)	+			
Vegetative cover on sample §				
Clay content (%)	+			+
Presence of curb		+	+	
Slope of site (%)			+	-
Slope above sample (%)	-	+		
Slope of sample (%)				
Vegetative cover above sample §		+	-	+
Soil pH	-		-	
Depth (cm)				
Traffic braking §	-		-	
Traffic volume §				
Background metal concencetration (ppm)				

+ increase in metal concentration with increase in magnitude of factor

- decrease in metal concentration with increase in magnitude of factor

§ qualitative factor with 0 being none to a maxmimum of 1.0 (volume and cover) or 2.0 (braking)

Lead and nickel concentrations decreased in the soil as pH increased. This indicates more acidic conditions favor lead and nickel migration. High lime or concrete would be expected to reduce lead and nickel concentrations.

Lead and cadmium soil concentrations increased with increased clay percentage. This indicates lead and cadmium have a high affinity to bind to soil colloids. Consequently, these metals may be transported with the clays.

The influence of traffic braking on lead and nickel might be due to a deposition from brake dust preferentially adsorbing to soil particles and causing subsequent desorption of lead and nickel. Another way traffic braking might affect metal deposition is by the reduction of wind. As a car goes by a road at a fast speed, a gust of wind is created in the wake of the vehicle. This wind can lift dust, soil, and other particulates from the street surface and transport them onto the side of the road. Vehicle braking may reduce the transport of certain metals onto roadside soils due the reduced wind associated with the slowed traffic speed.

Another reason for the affect of braking on lead and nickel might be chloride deposition. Chloride deposition increases as traffic braking increases (Garg et al., 2000). Metal chlorides are relatively soluble in soils. Consequently, nickel and lead may selectively leach as metal chlorides through the soil.

CONCLUSION

Reduction of the slope of the land and increasing vegetative cover along roadsides will potentially reduce transport of heavy metals. These measures are some of the same measures used for erosion control. Sediment transport and heavy metal transport can be addressed with many of the same control measures.

Adding phosphate or a liming agent could reduce metal solubility and transport. Water eutrophication by phosphates may occur if excess phosphate is applied to the soil. A liming agent could be applied to reduce nickel and lead movement. This liming agent should not be calcium containing, since calcium addition would cause an increase in copper transport. A liming agent high in magnesium might not be advisable in serpentine derived soils, such as occur frequently in some locations of San Luis Obispo County, CA. The addition of liming agents containing sodium and potassium may cause soil dispersion, an increase soil erosion, and possibly a reduction in vegetation establishment.

Physical measures (such as increasing vegetative cover and reducing slope) may be the most advisable and practical solution to reducing heavy metal transport along roadsides.

SECTION IX. RS1 SIMULATION EXPERIMENT FOLLOW UP

PROJECT NEED & DESCRIPTION

In order to follow up on the experiment conducted by VEMS in 2000-2001, 4 boxes were saved from the project to rain on at a later date. The vegetation on these boxes had browned and dried. The purpose of raining on these at a later date was to observe the long term effects of the vegetation and treatments on the surface of the soil. To learn more about the 2000-2001 experiment, otherwise known as RS1, please refer to the document titled "Vegetation Establishment for Erosion Control Under Simulated Rainfall, Volume 1, October 2001", document # CTSW-RT-01-078.

METHODS AND MATERIALS

To test these boxes, the same methods to simulate rainfall for the previous experiments were used. The boxes were moved beneath the rainfall simulator and received 3.5" of rainfall in 2.5 hours after 2 years of being planted.

RESULTS AND DISCUSSION

The following table (Table 7.1) shows the results of the water quality analysis conducted on the runoff that came from the boxes.

Table 7.1 Rainfall Simulation 1 (RS1) Results

Date	Box #	Treatment	Total Runoff Wt. (g)	Total Sediment Wt. (g)	Sediment Conc. (mg/L)
7/12/2002	M08	Sraw/Fertilizer	1053.23	0.57	541.19
7/12/2002	M16	Fert/Tackifier	681.77	0.43	630.71
7/13/2002	M06	Tackifier	745.43	1.47	1972.02
7/13/2002	M13	Straw	455.03	0.47	1032.90

Straw with fertilizer produced the greatest amount of runoff and Straw alone had the lowest total runoff. Tackifier alone produced more total sediment load. The remaining three treatments released less sediment. Tackifier alone produced the highest amount of sediment concentration while Straw and fertilizer had the lowest concentration. Overall, Straw alone (wheat Straw spread loose as a ground cover) appears to be performing the best for improving water quality and sediment load over the two year period.

SECTION X. QUALITY ASSURANCE

RAINFALL SIMULATOR UNIFORMITY

Every employee was instructed on the proper set-up and starting procedure for a rainfall simulation, sediment/runoff collection and analysis.

For the most recent simulations, uniformity tests on the Norton rainfall simulators were performed before each set of simulations at the 45 and 75 day rainfall periods. The addition of "C" clamps on the water line leading to the nozzles allowed for fine-tuning of the nozzle output pressures.

LAB ANALYSIS

Every employee was instructed on the proper methods of analyzing the runoff samples.
All glassware and storage containers were cleaned using deionized water prior to use. Containters requiring weight measurements were reweighed before use for initial weights. All runoff samples were weighed immediately, flocculated, and then covered to prevent dust contamination. Samples were analyzed within two days of a simulation to allow proper flocculation and a short storage time to reduce any possible chance of contamination.

SECTION XI. REFERENCES

VEGETATION ESTABLISHMENT AND MAINTENANCE STUDY

Agresti, A. 1996. An Introduction to Categorical Data Analysis. New York: Wiley & Sons.

American Society for Testing Materials. 2002. ASTM D3977-97. "Standard Test Methods for Determining Sediment Concentration in Water Samples."

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. New York: Wiley & Sons.

Dickson, Bruce. 1990. A Laboratory Manual for the study of Fertilizers In Improving Soil Fertility. Soil Science Department, California Polytechnic State University, San Luis Obispo.

Environmental Protection Agency. 2002. EPA Method 160.2. "Residue, Non-filterable, and Total Suspended Solids."

Fortin, M.-J., P. Drapeau, and P. Legendre. 1989. "Spatial autocorrelation and sampling design in plant ecology". Vegetatio 83: 209-222

Hickman, J.C. (ed.). 1993. The Jepson Manual: Higher Plants of California. Berkeley: University of California Press.

Interagency Technical Team. 1996. "Sampling Vegetation Attributes". Bureau of Land Management National Applied Resource Sciences Center. USDI-BLM/RS/ST-96/002+1730

Montgomery, D.C. 1991. Design And Analysis Of Experiments. ed. 3. New York: Wiley & Sons.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. New York: Wiley & Sons.

Pearce, R. A., G.W. Fraisier, M.J. Trlica, W.C. Leininger, J.S. Stednick, and J.L. Smith. 1998. "Sediment Filtration in a Montane Riparian Zone Under Simulated Rainfall". Journal of Range Management 51: 309-314.

Taskey, R.D.. 1996. Soil Physics Laboratory Manual. Soil Science Department, California Polytechnic State University, San Luis Obispo.

National Weather Service Oxnard. 2002. "A preliminary monthly precipitation summary and a seasonal precipitation summary for various stations in Southern California". http://www.wrh.noaa.gov/cgi-bin/Oxnard/afd?LAXPNSLOX

Bouwman, L.A., and W.B.M. Arts. 2000. Effects of soil compaction on the relationships between nematodes, grass production and soil physical properties. Applied soil ecology: a section of Agriculture, Ecosystems, and the Environment 14(3): 213-222.

Bradbury, David E., 1978. The evolution and persistence of a local sage/chamise community pattern in southern California. Yearbook Association of Pacific Coast Geographers 40:39-56.

Bradshaw, A.D., R.D. Roberts. 1985. The development of a hydraulic seeding technique for unstable sand slopes II. field evaluation. 1985. Journal of Applied Ecology 22:979-994.

Brofas, G., and C. Varelides. 2000. Hydroseeding and mulching for establishing vegetation on mining spoils in Greece. Land degradation and development

Caltrans. 1999. Standard Specifications July 1999. State of California Department of Transportation. Section 20.

Forcella, Frank, Roberto L. Benech Arnold, Rudolfo Sanchez and Claudio M. Ghersa. 2000. Modeling seedling emergence. Field Crops Research 67(2):123-139.

Friedal, M.H. Range condition assessment and the concept of thresholds: a viewpoint. 1991. Journal of Range Management 44:422-426.

Hamilton, Jason G., Claus Holzapfel, and Bruce Mahall. 1999. Coexistence and interference between a native perennial grass and nonnative annual grasses in California. Oecologia 121:518-526.

Kirkpatrick, J.B. and C.F. Hutchinson. 1980. The environmental relationships of California coastal sage scrub and some of its component communities and species. Journal of Biogeography 7:23-28.

Las Pilitas Nursery. 1995. A Native Plant Nursery: 3232 Las Pilitas Rd., Santa Margarita. Available: http://www.laspilitas.com

Montalvo, Arlee M, and Norman C. Ellstrand. 2001. Nonlocal transplantation and out breeding depression in the subshrub *Lotus scoparius* (Fabaceae). American Journal of Botany 88(2):258-269.

Nilsen, EricTallack, and Walter H. Muller. Phenology of the drought deciduous shrub Lotus scoparius: climactic control sand adaptive significance. Ecological Monographs 51(3):323-341.

Schultz, A.M. and H.H. Biswell. 1952. Competition between grasses reseeded on burned brushlands in California. Journal of Range Management 5:338-345. Schultz, A.M., and J.L.

Launchbaugh, and H.H. Biswell. 1955. Relationship between grass density and brush seedling survival. Ecology 36:226-238.

Stylinski, Cathlyn, and Edith B. Allen. 1999. Lack of native species recovery following severe exotic disturbances in southern Californian shrublands. Journal of Applied Ecology 36:544-554.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, June). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/

Bubenzer, G. D. 1979. Rainfall characteristics important for simulation. Pages 22-34 in Proceedings of the Rainfall Simulator Workshop, Tucson Arizona, March 7-9, 1979. U.S. Department of Agriculture Science and Education Administration Agricultural Reviews and Manuals. ARM-W-10/July 1979. (a)

Bubenzer, G. D.. 1979. Inventory of rainfall simulators. Pages 120-13. in Proceedings of the Rainfall Simulator Workshop, Tucson Arizona, March 7-9, 1979. U.S. Department of Agriculture Science and Education Administration Agricultural Reviews and Manuals. ARM-W-10/July 1979. (b)

Eigel, J. D., and I. D. Moore. 1983. A simplified technique for measuring raindrop size and distribution. Transactions of the ASAE:1079-1084

Grierson, I. T., J. M. Oades. 1977. A rainfall simulator for field studies of run-off and soil erosion. Agricultural Engineering Res. 22:37-44

Gunn, R., and G. D. Kinzer, 1949. The terminal velocity of fall for water droplets. Journal Of Meteorology 6:243-248.

Laws, J. O., 1941. Measurements of fall velocity of water drops and raindrops. Transactions of American Geophysics Union 22:709-721.

Laws, J. O., and D. A. Parsons, 1943. The relationship of raindrop-size to intensity. Transaction of American Geophysics Union 24:452-459

McCool, D. K. 1979. Regional differences if rainfall characteristics and their influence on rainfall simulator design. Pages 17- in Proceedings of the Rainfall Simulator Workshop, Tucson Arizona, March 7-9, 1979. U.S. Department of Agriculture Science and Education Administration Agricultural Reviews and Manuals. ARM-W-10/July 1979.

Meyer, L. D. and D. L. McCune. 1958. Rainfall simulator for runoff plots. Agricultural Engineering:10 644-648

Meyer, L D.. 1979. Methods for attaining desired rainfall characteristics in rainfall simulators. Pages 35-44 in Proceedings of the Rainfall Simulator Workshop, Tucson Arizona, March 7-9, 1979. U.S. Department of Agriculture Science and Education Administration Agricultural Reviews and Manuals. ARM-W-10/July 1979.

Meyer, L. D. and W. C. Harmon. 1979. Multiple-intensity rainfall simulator for erosion research on row sideslopes. Transactions of the American Society of Agricultural Engineers 22:100-103.

Miller, W. P. 1987. A solenoid-operated, variable intensity rainfall simulator. Soil Science Society of America Journal 51:832-834.

Moore, Ian D., Michael C. Hirschi, and Billy J Barfield. 1983. Kentucky rainfall simulator. Transactions of the American Society of Agricultural Engineers 23:1085-1089.

Sumner, H. R., R. D. Wauchope, C. C. Truman, C. C. Dowler, and J. E. Hook. 1996. Rainfall simulator and plot design for mesoplot runoff studies. Transactions of the American Society of Agricultural Engineers 39:125-130.

Thomas, N. P. and Samir A. El Swaify. 1989. Construction and calibration of a rainfall Simulator. Journal of Agricultural Engineering Research 43:1-9.

Abu-Sharar, T. M., K. H. Y. Mash'al, and M. K. Fayyad. 1997. Cadmium adsorption isotherms onto separates of a Yermic Cambisol soil from Central Jordan Valley. Arid Soil Research and Rehabilitation 11:23-34.

Amacher, Michael C. 1996. Nickel, cadmium, and lead. p. 739-768. *In* D. L. Sparks (ed.) Methods of soil analysis: Part 3- Chemical methods. Soil Science Society of America, Madison, WI.

California Fertilizer Association. 1995. Western fertilizer handbook. Interstate Publ., Inc., Danville, IL.

Garg, Bhagwan D., Steven H. Cadle, Patricia A. Mulawa, Peter J. Groblicki, Chris Laroo, and Graham A. Parr. 2000. Brake wear particulate matter emissions. Environmental Science and Technology 34: 4463-4469.

Grolimund, D., M. Borkovec, K. Barmettler, and H. Sticher. 1996. Colloid-facilitated transport of strongly sorbing contaminats in natural porous media: A laboratory column study. Environmental Science and Technology 30:3118-3123.

Harrison, Roy M., Duncan P. H. Laxen, and Simon J. Wilson. 1981. Chemical association of Pb, Cd, Cu, and Zn in street dusts and roadside soils. Environmental Science and Technology 15: 1378-1383.

Harrison, R. M., and D. P. H. Laxen. 1981. Lead pollution: Causes and control. Chapman and Hall, London, UK.

Holmgren, G. G. S., M. W. Meyer, R. L. Chaney, and R. B. Daniels. 1993. Cadmium, lead, zinc, copper, and nickel in agricultural soils of the United States of America. Journal of Environmental Quality 22: 335-348.

Lagerwerff, J. V. and A. W. Specht. 1970. Contamination of roadside and vegetation with cadmium, nickel, lead, and zinc. Evironmental Scientific and Technology 4: 583-585.

Lund, L. J., E. E. Betty, A. L. Page, and R. A. Elliott. 1981. Occurrence of naturally high cadmium levels in soils and its accumulation by vegetation. Journal of Environmental Quality 10:551-556.

Ma, Lena Q., and Gade N. Rao. 1997. Chemical fractionation of cadmium, copper, nickel, and zinc in contaminated soils. Journal of Environmental Quality 26: 259-264.

Pardo, M.T. 2000. Sorption of lead, copper, zinc, and cadmium by soils: Effect of nitriloacetic acid on metal retention. Commun. Soil Sci. Plant Anal. 31:31-40.

Sutherland, R. A. 2000. Depth variation in copper, lead, and zinc concentrations and mass enrichment ratios in soils of an urban watershed. Journal of Environmental Quality 29:1414-1422.

Yang, John, David E. Mosby, Stan W. Casteel, and Robert W. Blanchar. 2001. Lead immobilization using phosphoric acid in a smelter-contaminated urban soil. Environmental Science Technology 35:3553-3559.

Zhu, B., and A. K. Alva. 1993. Differential adsorption of trace metals by soils as influenced by exchangeable cations and ionic strength. Soil Science 155: 61-66.

RS2 Vegetation Statistical Analysis

A binary logistic regression is used to estimate the relationship between treatment factors and proportion cover. The logistic regression indicates that seeding treatment effects proportion cover with the EC mix outperforming the D5 mix, which outperformed the existing seed bank. There is a statistically significant difference in the proportion cover across the 5 EC treatments, but in the post-hoc analysis, no comparisons were significant (with the family-wide error rate of 0.05 … if we used a family-wide error rate of 0.10, BFM would appear to have a higher proportion cover (averaging 13.5% cover across the three veg treatments) than Straw (averaging 8.6% cover).

Estimated proportion cover according to each treatment at 45 days:

	BFM	Gypsum	Jute	Straw	Tackifier
Existing	0.0760	0.0523	0.06553	0.0466	0.0522
Existing+D5	0.1313	0.0922	0.1138	0.0824	0.0919
Existing+EC	0.1988	0.1428	0.1741	0.1284	0.1425

Note: these estimates are:
Estimates of the proportion cover we would observe at 45 days across all boxes that could receive any given treatment and not the actual proportion cover values we've measured.
Averaged over the two box-divisions
Dependent on the model (in this case, our model doesn't include interaction terms)
Based on data where the cover was observed at different times, mostly after 45 days, so some of these estimates are extrapolations.

The nominal logistic regression for 45 day veg cover indicates that there is not a statistically significant difference across the 5 EC treatments with regard to either Grass or Forbes (versus bare) at 45 days. (Note: when interactions between EC and seeding method are included there may be an EC treatment difference, but this analysis is not yet complete.) Seeding with the D5 mix increases the forb cover (but not grass cover) but seeding with the EC mix increases both forb and grass cover.

With a similar logistic regression we estimate the proportion cover according to each treatment at 70 days (similar points to note as above):

	BFM	Gypsum	Jute	Straw	Tackifier
Existing	0.1089	0.0678	0.1215	0.1189	0.1057
Existing+D5	0.1487	0.0942	0.1649	0.1617	0.1446
Existing+EC	0.4568	0.3352	0.4870	0.4812	0.4487

At 70 days the cover is greatly improved by use of the EC mix. The EC mix (with 44.2% cover, on average, over the EC treatments) outperforms the D5 mix (with 14.3% cover) which itself is better than the existing seed bank (with 10.5% cover). The EC treatments have an effect on cover (no matter the veg type of the cover) and the effect can be summarized:

Gypsum Tack BFM Straw Jute

Gypsum gives us 16.6% cover (on average over the veg treatments) while the other EC treatments give us an average of 24.6% cover.

For type-specific analyses at 70 days there were so few shrubs that they were eliminated from the analysis … no parameters associated with the relationship between treatment and could be estimated with any precision at all.

The nominal logistic regression for 70 day veg cover indicates that there is a statistically significant EC treatment effect for legumes and grasses, but not for forbs:

For Legumes:

Gypsum Straw Tack Jute BFM

For Grasses:

BFM Gypsum Jute Tack Straw

I.e. for Legumes, Jute and BFM seem to increase cover the most, Gypsum the least. For grasses, Jute, Tackifier and Straw increase the grass cover the most, BFM the least.

Seeding with D5 natives increases legumes. Seeding with EC mix increases legumes and grasses. There is not a statistically significant effect of seeding method on forbs.

45 Days

Binary Logistic Regression: covered versus SEED, EC, ...

Link Function: Logit

Response Information

Variable	Value	Count	
covered	1	351	(Event)
	0	2649	
	Total	3000	

Factor Information

Factor	Levels	Values				
SEED	3	Existing		Existing+D5Natives	Existing+EC Mix	
EC	5	BFM	Gypsum	Jute	Straw	Tackifier
Box Divi	2	L U				

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-817.1	163.6	-4.99	0.000			
SEED							
Existing+D5Natives	0.6093	0.1632	3.73	0.000	1.84	1.34	2.53
Existing+EC Mix	1.1052	0.1526	7.24	0.000	3.02	2.24	4.07
EC							
Gypsum	-0.3982	0.1881	-2.12	0.034	0.67	0.46	0.97
Jute	-0.1630	0.1790	-0.91	0.363	0.85	0.60	1.21
Straw	-0.5213	0.1919	-2.72	0.007	0.59	0.41	0.86
Tackifier	-0.4009	0.1863	-2.15	0.031	0.67	0.46	0.96
Sampling	0.021849	0.004388	4.98	0.000	1.02	1.01	1.03
Box Divi							
U	-0.1131	0.1154	-0.98	0.327	0.89	0.71	1.12

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
SEED	54.104	2	0.000
EC	9.735	4	0.045

Log-Likelihood = -1040.106
Test that all slopes are zero: G = 85.217, DF = 8, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	54.804	51	0.332
Deviance	57.123	51	0.258
Hosmer-Lemeshow	3.876	8	0.868
Brown:			
General Alternative	0.266	2	0.875
Symmetric Alternative	0.020	1	0.888

70 days

Binary Logistic Regression: covered versus SEED, EC, ...

Link Function: Logit

Response Information

Variable	Value	Count	
covered	1	1586	(Event)
	0	1413	
	Total	2999	

Factor Information

Factor	Levels	Values				
SEED	3	Existing		Existing+D5Natives	Existing+EC Mix	
EC	5	BFM	Gypsum	Jute	Straw	Tackifier
Box Divi	2	L U				

2999 cases were used
1 cases contained missing values

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-2429.7	490.2	-4.96	0.000			
SEED							
Existing+D5Natives	0.36062	0.09618	3.75	0.000	1.43	1.19	1.73
Existing+EC Mix	1.9611	0.1061	18.48	0.000	7.11	5.77	8.75
EC							
Gypsum	-0.5231	0.1318	-3.97	0.000	0.59	0.46	0.77
Jute	0.1243	0.1332	0.93	0.351	1.13	0.87	1.47
Straw	0.1003	0.1264	0.79	0.427	1.11	0.86	1.42
Tackifier	-0.0335	0.1313	-0.25	0.799	0.97	0.75	1.25
Sampling	0.06507	0.01313	4.96	0.000	1.07	1.04	1.10
Box Divi							
U	-0.61505	0.08056	-7.63	0.000	0.54	0.46	0.63

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
SEED	378.959	2	0.000
EC	33.416	4	0.000

Log-Likelihood = -1809.783
Test that all slopes are zero: G = 527.946, DF = 8, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	124.060	21	0.000
Deviance	131.776	21	0.000
Hosmer-Lemeshow	24.008	8	0.002
Brown:			
General Alternative	11.892	2	0.003
Symmetric Alternative	3.727	1	0.054

45 days

Nominal Logistic Regression: N,F,G,S versus EC, SEED, ...

Response Information

Variable	Value	Count	
N,F,G,S	N	2649	(Reference Event)
	G	189	
	F	162	
	Total	3000	

Factor Information

Factor	Levels	Values
EC	5	BFM Gypsum Jute Straw Tackifier
SEED	3	Existing Existing+D5Natives Existing+EC Mix
Box Divi	2	L U

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Logit 1: (G/N)							
Constant	-384.5	223.2	-1.72	0.085			
EC							
Gypsum	-0.1769	0.2387	-0.74	0.459	0.84	0.52	1.34
Jute	-0.1922	0.2376	-0.81	0.418	0.83	0.52	1.31
Straw	-0.5634	0.2576	-2.19	0.029	0.57	0.34	0.94
Tackifier	-0.3297	0.2407	-1.37	0.171	0.72	0.45	1.15
SEED							
Existing+D5Natives	0.2102	0.2343	0.90	0.370	1.23	0.78	1.95
Existing+EC Mix	1.2741	0.1980	6.43	0.000	3.58	2.43	5.27
Sampling	0.010232	0.005986	1.71	0.087	1.01	1.00	1.02
Box Divi							
U	-0.3069	0.1539	-1.99	0.046	0.74	0.54	0.99
Logit 2: (F/N)							
Constant	-1290.9	229.8	-5.62	0.000			
EC							
Gypsum	-0.6587	0.2832	-2.33	0.020	0.52	0.30	0.90
Jute	-0.1060	0.2525	-0.42	0.674	0.90	0.55	1.48
Straw	-0.5341	0.2738	-1.95	0.051	0.59	0.34	1.00
Tackifier	-0.5552	0.2772	-2.00	0.045	0.57	0.33	0.99
SEED							
Existing+D5Natives	0.9451	0.2236	4.23	0.000	2.57	1.66	3.99
Existing+EC Mix	0.8386	0.2278	3.68	0.000	2.31	1.48	3.62
Sampling	0.034532	0.006164	5.60	0.000	1.04	1.02	1.05
Box Divi							
U	0.1101	0.1638	0.67	0.501	1.12	0.81	1.54

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
Logit 1: (G/N)			
EC	5.348	4	0.253
SEED	57.603	2	0.000
Logit 2: (F/N)			
EC	9.033	4	0.060
SEED	19.290	2	0.000

Log-likelihood = -1264.407
Test that all slopes are zero: G = 121.124, DF = 16, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	149.678	102	0.001
Deviance	158.051	102	0.000

70 days

Nominal Logistic Regression: N,L,F,G versus EC, SEED, ...

Response Information

Variable	Value	Count	
N,L,F,G	N	1413	(Reference Event)
	L	735	
	G	615	
	F	218	
	Total	2981	

Factor Information

Factor	Levels	Values
EC	5	BFM Gypsum Jute Straw Tackifier
SEED	3	Existing Existing+D5Natives Existing+EC Mix
Box Divi	2	L U

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Logit 1: (L/N)							
Constant	-2458.4	801.7	-3.07	0.002			
EC							
Gypsum	-1.7234	0.1920	-8.97	0.000	0.18	0.12	0.26
Jute	-0.0928	0.1743	-0.53	0.594	0.91	0.65	1.28
Straw	-0.8393	0.1820	-4.61	0.000	0.43	0.30	0.62
Tackifier	-0.7758	0.1722	-4.50	0.000	0.46	0.33	0.65
SEED							
Existing+D5Natives	0.6448	0.1660	3.88	0.000	1.91	1.38	2.64
Existing+EC Mix	3.4339	0.1586	21.65	0.000	31.00	22.72	42.29
Sampling	0.06581	0.02147	3.06	0.002	1.07	1.02	1.11
Box Divi							
U	-0.8797	0.1128	-7.80	0.000	0.41	0.33	0.52
Logit 2: (G/N)							
Constant	-2231.4	629.8	-3.54	0.000			
EC							
Gypsum	0.1622	0.1860	0.87	0.383	1.18	0.82	1.69
Jute	0.5882	0.1876	3.14	0.002	1.80	1.25	2.60
Straw	0.8335	0.1758	4.74	0.000	2.30	1.63	3.25
Tackifier	0.6933	0.1823	3.80	0.000	2.00	1.40	2.86
SEED							
Existing+D5Natives	0.0729	0.1224	0.60	0.551	1.08	0.85	1.37
Existing+EC Mix	1.1594	0.1371	8.46	0.000	3.19	2.44	4.17
Sampling	0.05973	0.01687	3.54	0.000	1.06	1.03	1.10
Box Divi							
U	-0.6183	0.1005	-6.15	0.000	0.54	0.44	0.66
Logit 3: (F/N)							
Constant	-386.0	879.1	-0.44	0.661			
EC							
Gypsum	0.2556	0.2380	1.07	0.283	1.29	0.81	2.06
Jute	0.0115	0.2717	0.04	0.966	1.01	0.59	1.72
Straw	0.5308	0.2388	2.22	0.026	1.70	1.06	2.72
Tackifier	0.3122	0.2609	1.20	0.231	1.37	0.82	2.28
SEED							
Existing+D5Natives	0.3657	0.1692	2.16	0.031	1.44	1.03	2.01
Existing+EC Mix	0.0296	0.2389	0.12	0.901	1.03	0.64	1.65
Sampling	0.01028	0.02355	0.44	0.662	1.01	0.96	1.06
Box Divi							
U	-0.2354	0.1465	-1.61	0.108	0.79	0.59	1.05

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
Logit 1: (L/N)			
EC	106.420	4	0.000
SEED	619.922	2	0.000
Logit 2: (G/N)			
EC	36.377	4	0.000
SEED	87.348	2	0.000
Logit 3: (F/N)			
EC	7.066	4	0.132
SEED	5.535	2	0.063

Log-likelihood = -3065.888
Test that all slopes are zero: G = 1117.955, DF = 24, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	253.367	63	0.000
Deviance	258.411	63	0.000

RS2 Water Quality Data Summary

RS2 Forty-five Day Simulation Data Overview
2001-2002

TREATMENT KEY:

Seed mixture
S1= existing (no seed)
S2= existing + SLO EC seed mix
S3= existing + CT's D-5 seed mix

Erosion Control
EC1= Crimped Straw EC4= BFM
EC2= Jute netting EC5= tackifer
EC3= Gypsum

Values sorted by Total Runoff:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	SEDIMENT CONCENTRATION mg/L
2/8/02	9	S1EC4	152.00	0.31	2043.64
2/8/02	38	S2EC4	192.20	0.68	3550.54
2/11/02	41	S3EC1	398.20	0.43	1081.03
2/13/02	5	S2EC2	432.80	0.15	346.70
2/6/02	43	S2EC1	610.80	1.96	3219.24
2/21/02	22	S3EC2	953.80	0.39	409.06
2/11/02	27	S3EC4	959.10	0.12	125.13
2/21/02	28	S3EC5	3453.40	6.97	2022.38
2/7/02	12	S1EC2	7109.70	7.12	1002.45
2/12/02	40	S3EC3	8839.40	38.80	4408.79
2/15/02	24	S2EC3	17783.50	55.99	3158.37
2/7/02	23	S2EC5	18579.70	141.42	7669.91
2/13/02	17	S1EC1	23390.70	281.07	12162.46
2/12/02	10	S1EC3	27317.30	878.47	33226.51
2/15/02	19	S1EC5	31088.80	1392.58	46894.18
2/6/02	A	BARE	42966.10	1741.04	42232.56

Values sorted by Total Sediment:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	SEDIMENT CONCENTRATION mg/L
2/11/02	27	S3EC4	959.10	0.12	125.13
2/13/02	5	S2EC2	432.80	0.15	346.70
2/8/02	9	S1EC4	152.00	0.31	2043.64
2/21/02	22	S3EC2	953.80	0.39	409.06
2/11/02	41	S3EC1	398.20	0.43	1081.03
2/8/02	38	S2EC4	192.20	0.68	3550.54
2/6/02	43	S2EC1	610.80	1.96	3219.24
2/21/02	28	S3EC5	3453.40	6.97	2022.38
2/7/02	12	S1EC2	7109.70	7.12	1002.45
2/12/02	40	S3EC3	8839.40	38.80	4408.79
2/15/02	24	S2EC3	17783.50	55.99	3158.37
2/7/02	23	S2EC5	18579.70	141.42	7669.91
2/13/02	17	S1EC1	23390.70	281.07	12162.46
2/12/02	10	S1EC3	27317.30	878.47	33226.51
2/15/02	19	S1EC5	31088.80	1392.58	46894.18
2/6/02	A	BARE	42966.10	1741.04	42232.56

Values sorted by Suspended Sediment Concentration:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	SEDIMENT CONCENTRATION mg/L
2/11/02	27	S3EC4	959.10	0.12	125.13
2/13/02	5	S2EC2	432.80	0.15	346.70
2/21/02	22	S3EC2	953.80	0.39	409.06
2/7/02	12	S1EC2	7109.70	7.12	1002.45
2/11/02	41	S3EC1	398.20	0.43	1081.03
2/21/02	28	S3EC5	3453.40	6.97	2022.38
2/8/02	9	S1EC4	152.00	0.31	2043.64
2/15/02	24	S2EC3	17783.50	55.99	3158.37
2/6/02	43	S2EC1	610.80	1.96	3219.24
2/8/02	38	S2EC4	192.20	0.68	3550.54
2/12/02	40	S3EC3	8839.40	38.80	4408.79
2/7/02	23	S2EC5	18579.70	141.42	7669.91
2/13/02	17	S1EC1	23390.70	281.07	12162.46
2/12/02	10	S1EC3	27317.30	878.47	33226.51
2/6/02	A	BARE	42966.10	1741.04	42232.56
2/15/02	19	S1EC5	31088.80	1392.58	46894.18

- General Observations based on raw data (not statistical interpretation):
- BFM had the lowest total runoff and sediment for all three seed mixtures.
- Jute netting had the overall lowest suspended sediment concentrations and second to lowest total runoff and sediment (BFM was the lowest).
- Crimped Straw had the next lowest values.
- Gypsum and tackifer were very similar and the highest in all values.

RS2 Seventy Day Simulation Data Overview

2001-2002

TREATMENT KEY:

Seed mixture

S1= existing (no seed)

S2= existing + SLO EC seed mix

S3= existing + CT's D-5 seed mix

Erosion Control

EC1= Crimped Straw EC4= BFM

EC2= Jute netting EC5= tackifer

EC3= Gypsum

Values sorted by Total Runoff:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	Sediment Concentration (mg/l)
3/25/02	5	S2EC2	42.84	0.16	3734.83
3/22/02	22	S3EC2	92.96	0.24	2581.76
3/19/02	33	S1EC4	186.28	0.42	2254.67
3/22/02	30	S2EC4	252.67	0.33	1306.05
3/19/02	9	S1EC4	267.84	0.36	1344.09
3/20/02	34	S2EC1	356.14	0.76	2133.99
3/23/02	21	S3EC4	389.45	0.35	898.70
3/20/02	41	S3EC1	479.82	0.58	1208.77
3/22/02	14	S1EC2	521.31	0.19	364.47
3/22/02	38	S2EC4	532.86	0.24	450.40
3/20/02	25	S3EC1	598.63	2.07	3457.89
3/23/02	27	S3EC4	1001.99	0.61	608.79
3/22/02	32	S3EC2	1133.67	0.33	291.09
3/20/02	43	S2EC1	1439.83	0.67	465.33
3/26/02	20	S1EC1	2583.45	6.95	2690.20
3/25/02	39	S2EC2	3007.21	0.49	162.94
3/27/02	12	S1EC2	7821.47	20.13	2573.68
3/27/02	1	S2EC5	10308.93	18.17	1762.55
3/21/02	28	S3EC5	10316.43	22.57	2187.77
3/26/02	17	S1EC1	12615.96	58.34	4624.30
3/26/02	26	S3EC5	14669.53	32.47	2213.43
3/26/02	40	S3EC3	33139.22	69.68	2102.64
3/19/02	23	S2EC5	36587.81	689.49	18844.80
3/21/02	2	S3EC3	56086.72	791.78	14117.07
3/19/02	29	S2EC3	92674.53	1481.27	15983.57
3/25/02	10	S1EC3	115199.59	1756.01	15243.20
3/26/02	42	S1EC3	137724.65	2030.75	14745.00
3/26/02	B	Bare	252924.24	3786.76	14971.91
3/21/02	19	S1EC5	390648.89	5817.51	14891.91
3/24/02	24	S2EC3	643573.13	9604.27	14923.35
3/25/02	37	S1EC5	1034222.02	15421.78	14911.48
3/24/02	A	Bare	1677795.15	25026.05	14916.03

Values Sorted by Total Sediment:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	*TOTAL SEDIMENT* Wt. (g)	Sediment Concentration (mg/l)
3/25/02	5	S2EC2	42.84	0.16	3734.83
3/22/02	14	S1EC2	521.31	0.19	364.47
3/22/02	22	S3EC2	92.96	0.24	2581.76
3/22/02	38	S2EC4	532.86	0.24	450.40
3/22/02	32	S3EC2	1133.67	0.33	291.09
3/22/02	30	S2EC4	252.67	0.33	1306.05
3/23/02	21	S3EC4	389.45	0.35	898.70
3/19/02	9	S1EC4	267.84	0.36	1344.09
3/19/02	33	S1EC4	186.28	0.42	2254.67
3/25/02	39	S2EC2	3007.21	0.49	162.94
3/20/02	41	S3EC1	479.82	0.58	1208.79
3/23/02	27	S3EC4	1001.99	0.61	608.79
3/20/02	43	S2EC1	1439.83	0.67	465.33
3/20/02	34	S2EC1	356.14	0.76	2133.99
3/20/02	25	S3EC1	598.63	2.07	3457.89
3/26/02	20	S1EC1	2583.45	6.95	2690.20
3/27/02	1	S2EC5	10308.93	18.17	1762.55
3/27/02	12	S1EC2	7821.47	20.13	2573.68
3/21/02	28	S3EC5	10316.43	22.57	2187.77
3/26/02	26	S3EC5	14669.53	32.47	2213.43
3/26/02	17	S1EC1	12615.96	58.34	4624.30
3/26/02	40	S3EC3	33139.22	69.68	2102.64
3/19/02	23	S2EC5	36587.81	689.49	18844.80
3/21/02	2	S3EC3	56086.72	791.78	14117.07
3/19/02	29	S2EC3	92674.53	1481.27	15983.57
3/25/02	10	S1EC3	115199.59	1756.01	15243.20
3/26/02	42	S1EC3	137724.65	2030.75	14745.00
3/26/02	B	Bare	252924.24	3786.76	14971.91
3/21/02	19	S1EC5	390648.89	5817.51	14891.91
3/24/02	24	S2EC3	643573.13	9604.27	14923.35
3/25/02	37	S1EC5	1034222.02	15421.78	14911.48
3/24/02	A	Bare	1677795.15	25026.05	14916.03

Values Sorted by Suspended Sediment Concentration:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	Sediment Concentration (mg/l)
3/25/02	39	S2EC2	3007.21	0.49	162.94
3/22/02	32	S3EC2	1133.67	0.33	291.09
3/22/02	14	S1EC2	521.31	0.19	364.47
3/22/02	38	S2EC4	532.86	0.24	450.40
3/20/02	43	S2EC1	1439.83	0.67	465.33
3/23/02	27	S3EC4	1001.99	0.61	608.79
3/23/02	21	S3EC4	389.45	0.35	898.70
3/20/02	41	S3EC1	479.82	0.58	1208.79
3/22/02	30	S2EC4	252.67	0.33	1306.05
3/19/02	9	S1EC4	267.84	0.36	1344.09
3/27/02	1	S2EC5	10308.93	18.17	1762.55
3/26/02	40	S3EC3	33139.22	69.68	2102.64
3/20/02	34	S2EC1	356.14	0.76	2133.99
3/21/02	28	S3EC5	10316.43	22.57	2187.77
3/26/02	26	S3EC5	14669.53	32.47	2213.43
3/19/02	33	S1EC4	186.28	0.42	2254.67
3/27/02	12	S1EC2	7821.47	20.13	2573.68
3/22/02	22	S3EC2	92.96	0.24	2581.76
3/26/02	20	S1EC1	2583.45	6.95	2690.20
3/20/02	25	S3EC1	598.63	2.07	3457.89
3/25/02	5	S2EC2	42.84	0.16	3734.83
3/26/02	17	S1EC1	12615.96	58.34	4624.30
3/21/02	2	S3EC3	56086.72	791.78	14117.07
3/26/02	42	S1EC3	137724.65	2030.75	14745.00
3/21/02	19	S1EC5	390648.89	5817.51	14891.91
3/25/02	37	S1EC5	1034222.02	15421.78	14911.48
3/24/02	A	Bare	1677795.15	25026.05	14916.03
3/24/02	24	S2EC3	643573.13	9604.27	14923.35
3/26/02	B	Bare	252924.24	3786.76	14971.91
3/25/02	10	S1EC3	115199.59	1756.01	15243.20
3/19/02	29	S2EC3	92674.53	1481.27	15983.57
3/19/02	23	S2EC5	36587.81	689.49	18844.80

General Observations based on raw data (not statistical interpretation):

- Jute netting had the lowest total sediment for all three seed mixtures.
- BFM had the overall lowest total runoff for all three seed mixtures
- Jute netting had the overall lowest suspended sediment.
- Crimped Straw was third lowest for overall total sediment, total runoff, and sediment concentration for all three seed mixtures.
- Gypsum and tackifer were very similar and the highest in all values.

RS2 Water Quality Statistical Analysis

For TOTAL RUNOFF the ANOVA shows

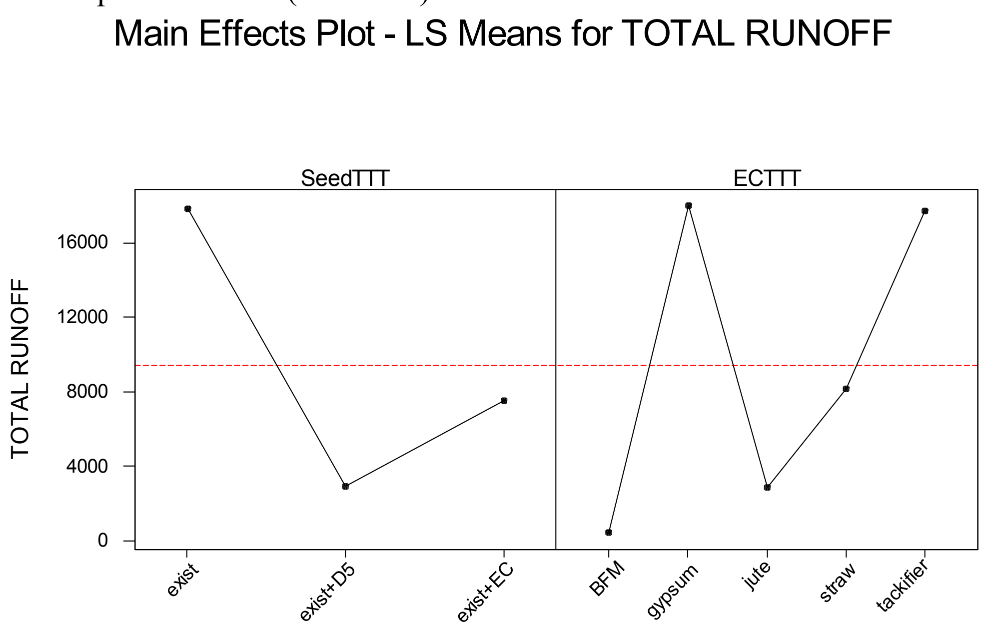
General Linear Model: TOTAL RUNOFF versus SeedTTT, ECTTT

Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier

Analysis of Variance for TOTAL RU, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	581356148	581356148	290678074	6.65	0.020
ECTTT	4	803251958	803251958	200812990	4.59	0.032
Error	8	349621760	349621760	43702720		
Total	14	1734229866				

Main effects plots for these (estimated) effects are:



Post-hoc analysis shows that the difference between exist and exist+D5 is statistically significant, but exist+EC is not statistically significantly different than either other group. (However, using the root of total runoff in an ANOVA with a .10 level post-hoc test, exist+EC also beats exist.)

Although there appears to be a statistically significant difference between EC treatments, the post-hoc comparisons do not allow us to say that BFM is clearly worse than Gypsum or Tackifier. (Note: if we had used the square root of total runoff as our response variable, we would conclude that BFM had a lower runoff than either Tackifier or Gypsum. Furthermore, at the .10 level, Jute has a lower runoff than Gypsum.)

For TOTAL SEDIMENT our ANOVA results are:

General Linear Model: TOTAL SEDIMENT versus SeedTTT, ECTTT

```
Factor     Type Levels Values
SeedTTT   fixed      3 exist    exist+D5 exist+EC
ECTTT     fixed      5 BFM       Gypsum    Jute      Straw     Tackifier

Analysis of Variance for TOTAL SE, using Adjusted SS for Tests

Source     DF     Seq SS     Adj SS     Adj MS       F      P
SeedTTT     2     793630     793630     396815    3.58  0.078
ECTTT       4     608997     608997     152249    1.37  0.325
Error       8     887025     887025     110878
Total      14    2289652
```

And do not indicate any significant difference in total sediment across the treatments.

If we were to analyze the square root of total runoff instead, the results are:

General Linear Model: root.sediment versus SeedTTT, ECTTT

```
Factor     Type Levels Values
SeedTTT   fixed      3 exist    exist+D5 exist+EC
ECTTT     fixed      5 BFM       Gypsum    Jute      Straw     Tackifier

Analysis of Variance for root.sed, using Adjusted SS for Tests

Source     DF     Seq SS     Adj SS     Adj MS       F      P
SeedTTT     2     679.77     679.77     339.89    5.66  0.029
ECTTT       4     695.25     695.25     173.81    2.89  0.094
Error       8     480.56     480.56      60.07
Total      14    1855.58
```

And the post-hoc analysis indicates that exist+D5 has lower runoff than exist. (At the .10 level, exist+EC has a lower runoff than exist.)

For SEDIMENT CONCENTRATION our ANOVA results indicate:

General Linear Model: SEDIMENT CONCENTRATION versus SeedTTT, ECTTT

Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier

Analysis of Variance for SEDIMENT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	913642092	913642092	456821046	3.91	0.065
ECTTT	4	743082661	743082661	185770665	1.59	0.267
Error	8	934976593	934976593	116872074		
Total	14	2591701345				

And do not indicate any difference across EC or Seed treatments.

However, if we were to analyze the natural log of concentration instead our results would be:

General Linear Model: log.conc versus SeedTTT, ECTTT

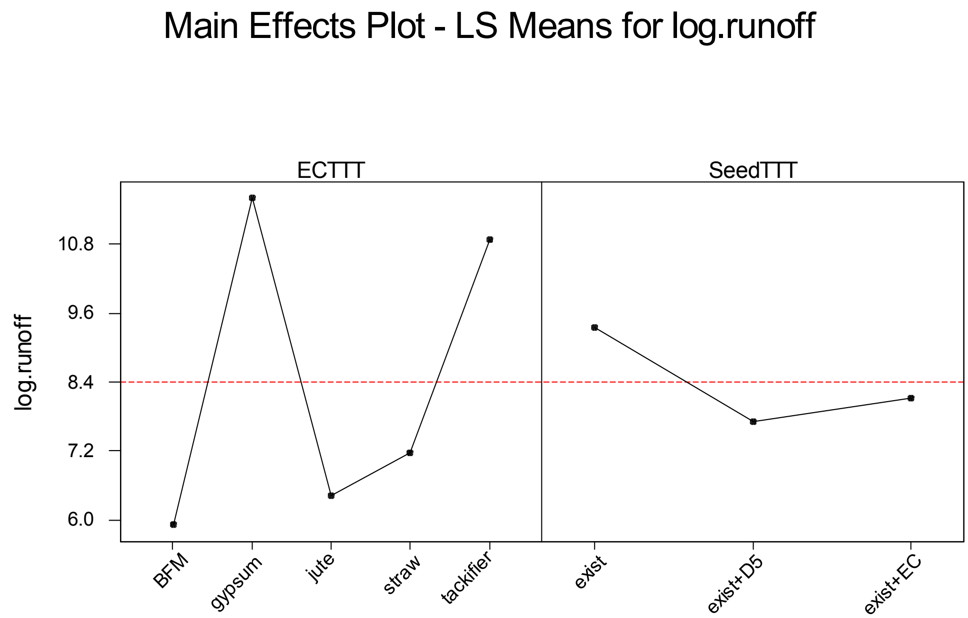
Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier

Analysis of Variance for log.conc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	12.7265	12.7265	6.3633	9.22	0.008
ECTTT	4	19.1044	19.1044	4.7761	6.92	0.010
Error	8	5.5199	5.5199	0.6900		
Total	14	37.3509				

And a post-hoc comparison indicates that exist+D5 is lower concentration than exist. (At the .10 level, exist+EC also has a lower concentration than exist.) In terms of the EC treatment, Jute has lower runoff than Tackifier or Gypsum. (At the .10 level, BFM also beats Tackifier and Gypsum.)

70 Day Runoff



General Linear Model: log.runoff versus SeedTTT, ECTTT, PrevBlowout

Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier
PrevBlow	fixed	2	0 1				

Analysis of Variance for log.runo, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	14.502	14.502	7.251	4.59	0.029
ECTTT	4	168.224	168.224	42.056	26.61	0.000
PrevBlow	1	0.126	0.126	0.126	0.08	0.782
SeedTTT*ECTTT	8	19.129	19.129	2.391	1.51	0.238
Error	14	22.124	22.124	1.580		
Total	29	224.105				

Seeding Treatment: exist+D5 beats exist. (At the .10 level, exist+EC also beats exist.)

EC Treatment: BFM, Jute and Straw beat Gypsum and Tackifier. However, BFM, Jute and Straw are cannot be differentiated.

75 day Sediment

General Linear Model: log.sediment versus SeedTTT, ECTTT, PrevBlowout

Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier
PrevBlow	fixed	2	0	1			

Analysis of Variance for log.sedi, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	34.319	34.319	17.160	9.36	0.003
ECTTT	4	334.819	334.819	83.705	45.68	0.000
PrevBlow	1	1.056	1.056	1.056	0.58	0.460
SeedTTT*ECTTT	8	29.871	29.871	3.734	2.04	0.117
Error	14	25.653	25.653	1.832		
Total	29	425.718				

Exist+D5 and exist+EC both have lower runoff than exist. BFM, Jute and Straw all have lower sediment levels in the runoff than do Gypsum and Tackifier.

75 day Concentration

General Linear Model: log.conc versus SeedTTT, ECTTT, PrevBlowout

Factor	Type	Levels	Values				
SeedTTT	fixed	3	exist	exist+D5	exist+EC		
ECTTT	fixed	5	BFM	Gypsum	Jute	Straw	Tackifier
PrevBlow	fixed	2	0	1			

Analysis of Variance for log.conc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SeedTTT	2	4.205	4.205	2.103	1.84	0.195
ECTTT	4	29.187	29.187	7.297	6.38	0.004
PrevBlow	1	0.452	0.452	0.452	0.40	0.540
SeedTTT*ECTTT	8	3.453	3.453	0.432	0.38	0.915
Error	14	16.003	16.003	1.143		
Total	29	53.300				

There is no significant difference in concentation due to Seed Treatment. However, due to EC treatment (at the .05 level):

```
 Jute   BFM  Straw  Tackifier  Gypsum
____________________________
           ___________________________
```

But at the .10 level:

```
 Jute   BFM  Straw  Tackifier  Gypsum
__________________
           __________________
                  ___________________
```

Vems RS-2: 1-26 Natural Rainfall Event Data
Values sorted by Total Runoff:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)	Wt. (g)	mg/L
1/29/02	26	S3EC5	*	1.73	*
1/29/02	33	S1EC4	0.00	0.00	0.00
1/29/02	2	S3EC3	0.00	0.00	0.00
1/29/02	34	S2EC1	0.00	0.00	0.00
1/29/02	25	S3EC1	0.00	0.00	0.00
1/29/02	23	S2EC5	0.00	0.00	0.00
1/29/02	21	S3EC4	0.00	0.00	0.00
1/29/02	30	S2EC4	0.00	0.00	0.00
1/29/02	38	S2EC4	0.00	0.00	0.00
1/29/02	9	S1EC4	0.00	0.00	0.00
1/29/02	27	S3EC4	0.00	0.00	0.00
1/29/02	41	S3EC1	0.00	0.00	0.00
1/29/02	28	S3EC5	0.00	0.00	0.00
1/29/02	20	S1EC1	110.89	0.51	4599.15
1/29/02	40	S3EC3	178.26	0.84	4695.31
1/29/02	43	S2EC1	273.61	0.49	1790.87
1/29/02	17	S1EC1	310.09	2.41	7771.94
1/29/02	22	S3EC3	524.95	0.05	92.31
1/29/02	32	S3EC2	648.00	0.00	0.00
1/29/02	1	S2EC5	942.10	2.90	3074.82
1/29/02	42	S1EC3	1448.66	8.34	5757.04
1/29/02	10	S1EC3	1471.27	6.23	4234.44
1/29/02	14	S1EC2	1600.84	0.16	99.95
1/29/02	12	S1EC2	1626.39	0.51	313.58
1/29/02	B	BARE	1693.03	9.77	5770.72
1/29/02	24	S2EC3	1975.89	2.51	1270.31
1/29/02	29	S2EC3	2055.60	2.60	1264.84
1/29/02	37	S1EC5	2360.31	10.19	4317.23
1/29/02	A	BARE	2364.78	16.92	7155.00
1/29/02	5	S1EC2	2370.19	0.11	44.51
1/29/02	19	S1EC5	2620.86	18.14	6921.39
1/29/02	39	S2EC2	5515.86	0.04	7.76

Values sorted by Total Sediment:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)	Wt. (g)	mg/L
1/29/02	33	S1EC4	0.00	0.00	0.00
1/29/02	2	S3EC3	0.00	0.00	0.00
1/29/02	34	S2EC1	0.00	0.00	0.00
1/29/02	25	S3EC1	0.00	0.00	0.00
1/29/02	23	S2EC5	0.00	0.00	0.00
1/29/02	21	S3EC4	0.00	0.00	0.00
1/29/02	30	S2EC4	0.00	0.00	0.00
1/29/02	38	S2EC4	0.00	0.00	0.00
1/29/02	9	S1EC4	0.00	0.00	0.00
1/29/02	27	S3EC4	0.00	0.00	0.00
1/29/02	41	S3EC1	0.00	0.00	0.00
1/29/02	28	S3EC5	0.00	0.00	0.00
1/29/02	32	S3EC2	648.00	0.00	0.00
1/29/02	39	S2EC2	5515.86	0.04	7.76
1/29/02	22	S3EC3	524.95	0.05	92.31
1/29/02	5	S2EC2	2370.19	0.11	44.51
1/29/02	14	S1EC2	1600.84	0.16	99.95
1/29/02	43	S2EC1	273.61	0.49	1790.87
1/29/02	20	S1EC1	110.89	0.51	4599.15
1/29/02	12	S1EC2	1626.39	0.51	313.58
1/29/02	40	S3EC3	178.26	0.84	4695.31
1/29/02	26	S3EC5	*	1.73	*
1/29/02	17	S1EC1	310.09	2.41	7771.94
1/29/02	24	S2EC3	1975.89	2.51	1270.31
1/29/02	29	S2EC3	2055.60	2.60	1264.84
1/29/02	1	S2EC5	942.10	2.90	3074.82
1/29/02	10	S1EC3	1471.27	6.23	4234.44
1/29/02	42	S1EC3	1448.66	8.34	5757.04
1/29/02	B	BARE	1693.03	9.77	5770.72
1/29/02	37	S1EC5	2360.31	10.19	4317.23
1/29/02	A	BARE	2364.78	16.92	7155.00
1/29/02	19	S1EC5	2620.86	18.14	6921.39

Values sorted by Sediment Concentration:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)		mg/L
1/29/02	26	S3EC5	*	1.73	*
1/29/02	33	S1EC4	0.00	0.00	0.00
	2	S3EC3	0.00	0.00	0.00
1/29/02	34	S2EC1	0.00	0.00	0.00
1/29/02	25	S3EC1	0.00	0.00	0.00
1/29/02	23	S2EC5	0.00	0.00	0.00
1/29/02	21	S3EC4	0.00	0.00	0.00
1/29/02	30	S2EC4	0.00	0.00	0.00
1/29/02	38	S2EC4	0.00	0.00	0.00
1/29/02	9	S1EC4	0.00	0.00	0.00
1/29/02	27	S3EC4	0.00	0.00	0.00
1/29/02	41	S3EC1	0.00	0.00	0.00
1/29/02	28	S3EC5	0.00	0.00	0.00
1/29/02	32		648.00	0.00	0.00
1/29/02	39	S2EC2	5515.86	0.04	7.76
1/29/02	5	S2EC2	2370.19	0.11	44.51
1/29/02	22	S3EC3	524.95	0.05	92.31
1/29/02	14	S1EC2	1600.84	0.16	99.95
1/29/02	12	S1EC2	1626.39	0.51	313.58
1/29/02	29	S2EC3	2055.60	2.60	1264.84
1/29/02	24	S2EC3	1975.89	2.51	1270.31
1/29/02	43	S2EC1	273.61	0.49	1790.87
1/29/02	1	S2EC5	942.10	2.90	3074.82
1/29/02	10	S1EC3	1471.27	6.23	4234.44
1/29/02	37	S1EC5	2360.31	10.19	4317.23
1/29/02	20	S1EC1	110.89	0.51	4599.15
1/29/02	40	S3EC3	178.26	0.84	4695.31
1/29/02	42	S1EC3	1448.66	8.34	5757.04
1/29/02	B	BARE	1693.03	9.77	5770.72
1/29/02	19	S1EC5	2620.86	18.14	6921.39
1/29/02	A	BARE	2364.78	16.92	7155.00
1/29/02	17	S1EC1	310.09	2.41	7771.94

Vems RS-2: 3-6-02 Natural Rainfall Event Data

Values sorted by Total Runoff:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)	Wt. (g)	mg/L
3/9/02	41	S3EC1	10.84	0.16	14760.15
3/9/02	22	S3EC2	12.03	0.07	5818.79
3/9/02	30	S2EC4	14.63	0.07	4784.69
3/9/02	27	S3EC4	27.48	0.22	8005.82
3/9/02	33	S1EC4	28.76	0.24	8344.92
3/9/02	21	S3EC4	37.21	0.19	5106.15
3/9/02	9	S1EC4	37.41	0.19	5078.86
3/9/02	34	S2EC1	42.57	0.13	3053.79
3/9/02	5	S2EC2	49.30	0.10	2028.40
3/9/02	25	S3EC1	52.05	0.35	6724.30
3/9/02	43	S2EC1	136.23	0.57	4184.10
3/9/02	28	S3EC5	192.85	0.65	3370.50
3/9/02	38	S2EC4	320.00	0.30	937.50
3/9/02	20	S1EC1	400.29	1.11	2772.99
3/9/02	14	S1EC2	731.71	0.09	123.00
3/9/02	32	S3EC2	766.68	0.12	156.52
3/9/02	1	S2EC5	1289.06	1.64	1272.24
3/9/02	26	S3EC5	1384.04	3.86	2788.94
3/9/02	23	S2EC5	2595.28	3.92	1510.43
3/9/02	17	S1EC1	2730.60	12.40	4541.13
3/9/02	42	S1EC3	3060.47	81.03	26476.33
3/9/02	2	S3EC3	3124.68	8.12	2598.67
3/9/02	40	S3EC3	3312.04	4.36	1316.41
3/9/02	12	S1EC2	3385.25	1.35	398.79
3/9/02	24	S2EC3	3826.92	6.28	1641.01
3/9/02	19	S1EC5	3933.00	47.40	12051.87
3/9/02	29	S2EC3	4039.97	7.63	1888.63
3/9/02	3	BARE B	4110.85	81.75	19886.40
3/9/02	10	S1EC3	4354.85	96.45	22147.72
3/9/02	7	BARE A	4762.27	77.63	16301.05
3/9/02	39	S2EC2	5612.13	0.17	30.29
3/9/02	37	S1EC5	8803.61	90.39	10267.38

Values sorted by Total Sediment:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)	Wt. (g)	mg/L
3/9/02	22	S3EC2	12.03	0.07	5818.79
3/9/02	30	S2EC4	14.63	0.07	4784.69
3/9/02	14	S1EC2	731.71	0.09	123.00
3/9/02	5	S2EC2	49.30	0.10	2028.40
3/9/02	32	S3EC2	766.68	0.12	156.52
3/9/02	34	S2EC1	42.57	0.13	3053.79
3/9/02	41	S3EC1	10.84	0.16	14760.15
3/9/02	39	S2EC2	5612.13	0.17	30.29
3/9/02	21	S3EC4	37.21	0.19	5106.15
3/9/02	9	S1EC4	37.41	0.19	5078.86
3/9/02	27	S3EC4	27.48	0.22	8005.82
3/9/02	33	S1EC4	28.76	0.24	8344.92
3/9/02	38	S2EC4	320.00	0.30	937.50
3/9/02	25	S3EC1	52.05	0.35	6724.30
3/9/02	43	S2EC1	136.23	0.57	4184.10
3/9/02	28	S3EC5	192.85	0.65	3370.50
3/9/02	20	S1EC1	400.29	1.11	2772.99
3/9/02	12	S1EC2	3385.25	1.35	398.79
3/9/02	1	S2EC5	1289.06	1.64	1272.24
3/9/02	26	S3EC5	1384.04	3.86	2788.94
3/9/02	23	S2EC5	2595.28	3.92	1510.43
3/9/02	40	S3EC3	3312.04	4.36	1316.41
3/9/02	24	S2EC3	3826.92	6.28	1641.01
3/9/02	29	S2EC3	4039.97	7.63	1888.63
3/9/02	2	S3EC3	3124.68	8.12	2598.67
3/9/02	17	S1EC1	2730.60	12.40	4541.13
3/9/02	19	S1EC5	3933.00	47.40	12051.87
3/9/02	7	BARE A	4762.27	77.63	16301.05
3/9/02	42	S1EC3	3060.47	81.03	26476.33
3/9/02	3	BARE B	4110.85	81.75	19886.40
3/9/02	37	S1EC5	8803.61	90.39	10267.38
3/9/02	10	S1EC3	4354.85	96.45	22147.72

Values sorted by Sediment Concentration:

Date	Box #	Treatment	TOTAL RUNOFF	TOTAL SEDIMENT	Sediment Concentration
			Wt. (g)	Wt. (g)	mg/L
3/9/02	39	S2EC2	5612.13	0.17	30.29
3/9/02	14	S1EC2	731.71	0.09	123.00
3/9/02	32	S3EC2	766.68	0.12	156.52
3/9/02	12	S1EC2	3385.25	1.35	398.79
3/9/02	38	S2EC4	320.00	0.30	937.50
3/9/02	1	S2EC5	1289.06	1.64	1272.24
3/9/02	40	S3EC3	3312.04	4.36	1316.41
3/9/02	23	S2EC5	2595.28	3.92	1510.43
3/9/02	24	S2EC3	3826.92	6.28	1641.01
3/9/02	29	S2EC3	4039.97	7.63	1888.63
3/9/02	5	S2EC2	49.30	0.10	2028.40
3/9/02	2	S3EC3	3124.68	8.12	2598.67
3/9/02	20		400.29	1.11	2772.99
3/9/02	26	S3EC5	1384.04		2788.94
3/9/02	34	S2EC1	42.57		3053.79
3/9/02	28	S3EC5	192.85	0.65	3370.50
	43	S2EC1	136.23	0.57	4184.10
3/9/02	17	S1EC1	2730.60	12.40	4541.13
3/9/02	30	S2EC4	14.63	0.07	4784.69
3/9/02	9	S1EC4	37.41	0.19	5078.86
3/9/02	21		37.21	0.19	5106.15
3/9/02	22	S3EC2	12.03		5818.79
3/9/02	25	S3EC1	52.05	0.35	6724.30
3/9/02	27	S3EC4	27.48	0.22	8005.82
3/9/02	33	S1EC4	28.76	0.24	8344.92
	37	S1EC5	8803.61	90.39	10267.38
3/9/02	19	S1EC5	3933.00	47.40	12051.87
3/9/02	41	S3EC1	10.84	0.16	14760.15
3/9/02	7	BARE A	4762.27	77.63	16301.05
3/9/02	3	BARE B	4110.85		19886.40
3/9/02	10	S1EC3	4354.85		22147.72
3/9/02	42	S1EC3	3060.47	81.03	26476.33

Vems RS-2: 3/17/02 Natural Rainfall Event Data

Values sorted by Total Runoff:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	Sediment Concentration mg/L
3/18/02	5	S2EC2	0.00	0.00	0.00
	41	S3EC1	0.00	0.00	0.00
3/18/02	27	S3EC4	0.00	0.00	0.00
3/18/02	9	S1EC4	0.00	0.00	0.00
3/18/02	38		0.00	0.00	0.00
3/18/02	22	S3EC2	0.00	0.00	0.00
3/18/02	21	S3EC4	0.00	0.00	0.00
3/18/02	25	S3EC1	0.00	0.00	0.00
3/18/02	34	S2EC1	0.00	0.00	0.00
3/18/02	33	S1EC4	0.00	0.00	0.00
3/18/02	43	S2EC1	89.25	0.35	3921.57
3/18/02	20		282.96	0.64	2261.80
3/18/02	32	S3EC2	317.78		62.94
3/18/02	14	S1EC2	457.58	0.02	43.71
3/18/02	28	S3EC5	615.71	0.79	1283.07
3/18/02	1	S2EC5	765.05	0.35	457.49
3/18/02	30	S2EC4	2010.87	0.13	64.65
3/18/02	23	S2EC5	2272.59	1.31	576.43
3/18/02	40	S3EC3	2396.36	1.84	767.83
3/18/02	26	S3EC4	2514.01	2.89	1149.56
3/18/02	12	S1EC2	2528.80	1.60	632.71
3/18/02	2	S3EC3	2647.67	3.83	1446.55
3/18/02	39	S2EC2	2853.59	0.01	3.50
3/18/02	42	S1EC3	2970.00	35.00	11784.51
3/18/02	17	S1EC1	3224.50	5.50	1705.69
3/18/02	29	S2EC3	3424.19	3.41	995.86
3/18/02	3	BARE B	3519.70	32.10	9120.10
3/18/02	10	S1EC3	3771.63	34.87	9245.34
3/18/02	24	S2EC3	3983.31	3.39	851.05
3/18/02	7	BARE A	4131.42	26.88	6506.24
3/18/02	19	S1EC5	4604.97	24.93	5413.72
3/18/02	37	S1EC5	6109.31	56.39	9230.17

Values sorted by Total Sediment:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	Sediment Concentration mg/L
3/18/02	5	S2EC2	0.00	0.00	0.00
3/18/02	41	S3EC1	0.00	0.00	0.00
3/18/02	27	S3EC4	0.00	0.00	0.00
3/18/02	9	S1EC4	0.00	0.00	0.00
3/18/02	38	S2EC4	0.00	0.00	0.00
3/18/02	22	S3EC2	0.00	0.00	0.00
3/18/02	21	S3EC4	0.00	0.00	0.00
3/18/02	25	S3EC1	0.00	0.00	0.00
3/18/02	34	S2EC1	0.00	0.00	0.00
3/18/02	33	S1EC4	0.00	0.00	0.00
3/18/02	39	S2EC2	2853.59	0.01	3.50
3/18/02	32	S3EC2	317.78	0.02	62.94
3/18/02	14	S1EC2	457.58	0.02	43.71
	30	S2EC4	2010.87	0.13	64.65
3/18/02	43	S2EC1	89.25	0.35	3921.57
3/18/02	1	S2EC5	765.05	0.35	457.49
3/18/02	20	S1EC1	282.96	0.64	2261.80
3/18/02	28	S3EC5	615.71	0.79	1283.07
3/18/02	23	S2EC5	2272.59	1.31	576.43
3/18/02	12	S1EC2	2528.80	1.60	632.71
3/18/02	40	S3EC3	2396.36	1.84	767.83
3/18/02	26	S3EC4	2514.01	2.89	1149.56
3/18/02	24	S2EC3	3983.31	3.39	851.05
3/18/02	29	S2EC3	3424.19	3.41	995.86
3/18/02	2	S3EC3	2647.67	3.83	1446.55
3/18/02	17	S1EC1	3224.50	5.50	1705.69
3/18/02	19	S1EC5	4604.97	24.93	5413.72
3/18/02	7	BARE A	4131.42	26.88	6506.24
3/18/02	3	BARE B	3519.70	32.10	9120.10
3/18/02	10	S1EC3	3771.63	34.87	9245.34
3/18/02	42	S1EC3	2970.00	35.00	11784.51
3/18/02	37	S1EC5	6109.31	56.39	9230.17

Values sorted by Sediment Concentration:

Date	Box #	Treatment	TOTAL RUNOFF Wt. (g)	TOTAL SEDIMENT Wt. (g)	Sediment Concentration mg/L
3/18/02	5	S2EC2	0.00	0.00	0.00
3/18/02	41	S3EC1	0.00	0.00	0.00
3/18/02	27	S3EC4	0.00	0.00	0.00
3/18/02	9	S1EC4	0.00	0.00	0.00
3/18/02	38	S2EC4	0.00	0.00	0.00
3/18/02	22	S3EC2	0.00	0.00	0.00
3/18/02	21	S3EC4	0.00	0.00	0.00
3/18/02	25	S3EC1	0.00	0.00	0.00
3/18/02	34	S2EC1	0.00	0.00	0.00
3/18/02	33	S1EC4	0.00	0.00	0.00
3/18/02	39	S2EC2	2853.59	0.01	3.50
3/18/02	14	S1EC2	457.58	0.02	43.71
3/18/02	32	S3EC2	317.78	0.02	62.94
3/18/02	30	S2EC4	2010.87	0.13	64.65
3/18/02	1	S2EC5	765.05	0.35	457.49
3/18/02	23	S2EC5	2272.59	1.31	576.43
3/18/02	12	S1EC2	2528.80	1.60	632.71
3/18/02	40	S3EC3	2396.36	1.84	767.83
3/18/02	24	S2EC3	3983.31	3.39	851.05
3/18/02	29	S2EC3	3424.19	3.41	995.86
3/18/02	26	S3EC4	2514.01	2.89	1149.56
3/18/02	28	S3EC5	615.71	0.79	1283.07
3/18/02	2	S3EC3	2647.67	3.83	1446.55
3/18/02	17	S1EC1	3224.50	5.50	1705.69
3/18/02	20	S1EC1	282.96	0.64	2261.80
3/18/02	43	S2EC1	89.25	0.35	3921.57
3/18/02	19	S1EC5	4604.97	24.93	5413.72
3/18/02	7	BARE A	4131.42	26.88	6506.24
3/18/02	3	BARE B	3519.70	32.10	9120.10
3/18/02	37	S1EC5	6109.31	56.39	9230.17
3/18/02	10	S1EC3	3771.63	34.87	9245.34
3/18/02	42	S1EC3	2970.00	35.00	11784.51

RS3 Vegetation Statistical Analysis

Veg Analysis at 45 days …

Proportion Cover

There is not a statistically significant effect of veg treatment on proportion cover ($p=.112$). There is a statistically significant effect of EC treatment ($p<.001$):

EC2 EC5 EC4 EC3 EC1

(for alpha=.05)

EC2 EC5 EC4 EC3 EC1

(for alpha=.10)

This would suggest EC1 (or perhaps EC3 or EC4) should be used over EC5 and EC2 if one wants high cover at 45 days.

Composition

For Legumes (L): Veg treatment has an effect on the legume cover rate ($p=.004$) with seeded brome producing a higher legume cover than 2 plants/ft^2 brome plugs. EC treatment also has a statistically significant effect on the legume cover rate ($p<.001$) with EC1 resulting in a higher legume cover rate than EC5.

For Grasses (G): Veg treatment has an effect on the grass (non-brome) cover rate ($p<.001$) with seeded brome producing a higher grass cover rate than 2 plants/ft^2 brome plugs. EC treatment is also statistically significantly related to grass cover ($p=.022$) but no post-hoc comparisons showed any significant differences at the .05 level (however, at the .10 level, EC1 produces more grass cover than EC4).

For Forbs (F): Veg treatment has an effect on the forb cover rate ($p<.001$) with 4 plants/ft^2 producing the lowest forb cover and seeded brome producing the highest forb cover. EC treatment is also significantly related to the forb cover rate ($p=.009$) but the post-hoc comparisons showed no significant differences at the .05 level (however at the .10 level, EC3 yields a higher forb cover than EC5).

For California Brome (C): Veg treatment has an effect on brome cover rate ($p<.001$) with 4 plants/ft^2 producing the highest brome cover rate and seeding producing the lowest brome cover. EC treatment is significantly related to brome cover ($p<.001$) with EC1 and EC4 resulting in more brome than EC2, EC3 and EC5.

Veg Analysis at 70 days …

Proportion Cover

There is a statistically significant effect of both veg treatment ($p<.001$) and EC treatment ($p=.001$) on proportion cover. For veg treatment:

2 plants/ft^2 4 plants/ft^2 Seeded brome

(for alpha=.05 and .10)

For EC treatment:

EC5 EC3 EC4 EC1 EC2

(for alpha=.05 and .10)

Composition

For Legumes (L): Veg treatment is significantly related to the legume cover ($p<.001$) with seeding brome producing more legumes than 2 plants/ft^2. EC treatment is significantly related to the legume cover rate ($p<.001$) with EC1, EC2 and EC3 producing more legume cover than EC4 which produces more legume cover than EC5.

For Grasses (G): Veg treatment is significantly related to the grass cover ($p<.001$) with seeding brome producing more grass than 2 plants/ft^2. EC treatment is significantly related to the grass cover rate ($p<.001$). EC5 and EC4 has significantly lower grass cover than EC1 (and at the .10 level, EC5 has lower grass cover than EC2 and EC3 has lower grass cover than EC1).

EC5 EC4 EC2 EC3 EC1

(for alpha=.05

EC5 EC4 EC2 EC3 EC1

(for alpha=.10)

For Forbs (F): Veg treatment is significantly related to the forb cover ($p<.001$) and seeding with brome results in a higher proportion cover than either plugging treatment. EC treatment is significantly related to forb cover ($p<.001$).

EC5 EC4 EC2 EC1 EC3

(for alpha=.05 and .10)

For California Brome (C): Veg treatment is significantly related to the brome cover ($p<.001$) with 2 plants/square foot yielding greater brome cover than 4 plants/square foot which yielded greater brome cover than seeding with brome. EC treatment is also significantly related to brome cover ($p<.001$).

EC1 EC3 EC5 EC2 EC4

Results for: 45 days

Binary Logistic Regression: covered versus VEG, EC, ...

Link Function: Logit

Response Information

Variable	Value	Count	
covered	1	1129	(Event)
	0	1869	
	Total	2998	

Factor Information

Factor	Levels	Values
VEG	3	2 PLANTS/SQ FT 4 PLANTS/SQ FT SEEDED BROME
EC	5	EC1 EC2 EC3 EC4 EC5
Box Divi	2	L U

2998 cases were used
2 cases contained missing values

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-0.9886	0.2936	-3.37	0.001			
VEG							
4 PLANTS/SQ FT	0.19166	0.09498	2.02	0.044	1.21	1.01	1.46
SEEDED BROME	0.13848	0.09373	1.48	0.140	1.15	0.96	1.38
EC							
EC2	-0.7097	0.1203	-5.90	0.000	0.49	0.39	0.62
EC3	-0.3067	0.1176	-2.61	0.009	0.74	0.58	0.93
EC4	-0.3338	0.1246	-2.68	0.007	0.72	0.56	0.91
EC5	-0.6973	0.1204	-5.79	0.000	0.50	0.39	0.63
DaysSinc	0.011747	0.003923	2.99	0.003	1.01	1.00	1.02
Box Divi							
U	-0.01393	0.07614	-0.18	0.855	0.99	0.85	1.14

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
VEG	4.381	2	0.112
EC	48.840	4	0.000

Log-Likelihood = -1956.450
Test that all slopes are zero: G = 58.654, DF = 8, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	85.020	39	0.000
Deviance	86.694	39	0.000
Hosmer-Lemeshow	6.898	8	0.548
Brown:			
General Alternative	1.481	2	0.477
Symmetric Alternative	1.107	1	0.293

Nominal Logistic Regression: N,C,G,L,F,S versus VEG, EC, ...

Response Information

Variable	Value	Count	
N,C,G,L,	N	1869	(Reference Event)
	L	79	
	G	191	
	F	208	
	C	651	
	Total	2998	

Factor Information

Factor	Levels	Values
VEG	3	2 PLANTS/SQ FT 4 PLANTS/SQ FT SEEDED BROME
EC	5	EC1 EC2 EC3 EC4 EC5
Box Divi	2	L U

Logistic Regression Table

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Logit 1: (L/N)							
Constant	-21.855	4.595	-4.76	0.000			
VEG							
4 PLANTS/SQ FT	0.8133	0.4098	1.98	0.047	2.26	1.01	5.04
SEEDED BROME	1.0546	0.3178	3.32	0.001	2.87	1.54	5.35
EC							
EC2	-0.1935	0.3550	-0.55	0.586	0.82	0.41	1.65
EC3	-0.7803	0.3376	-2.31	0.021	0.46	0.24	0.89
EC4	-0.4688	0.5340	-0.88	0.380	0.63	0.22	1.78
EC5	-1.8669	0.4245	-4.40	0.000	0.15	0.07	0.36
DaysSinc	0.25023	0.06087	4.11	0.000	1.28	1.14	1.45
Box Divi							
U	0.8007	0.2506	3.19	0.001	2.23	1.36	3.64
Logit 2: (G/N)							
Constant	-5.392	1.375	-3.92	0.000			
VEG							
4 PLANTS/SQ FT	-0.4932	0.3618	-1.36	0.173	0.61	0.30	1.24
SEEDED BROME	1.8160	0.2199	8.26	0.000	6.15	3.99	9.46
EC							
EC2	-0.3675	0.2357	-1.56	0.119	0.69	0.44	1.10
EC3	-0.2576	0.2282	-1.13	0.259	0.77	0.49	1.21
EC4	-1.7601	0.5913	-2.98	0.003	0.17	0.05	0.55
EC5	-0.5098	0.2314	-2.20	0.028	0.60	0.38	0.95
DaysSinc	0.03762	0.01847	2.04	0.042	1.04	1.00	1.08
Box Divi							
U	-0.0667	0.1601	-0.42	0.677	0.94	0.68	1.28
Logit 3: (F/N)							
Constant	-7.233	1.131	-6.39	0.000			
VEG							
4 PLANTS/SQ FT	-0.8250	0.2900	-2.84	0.004	0.44	0.25	0.77
SEEDED BROME	0.9211	0.1728	5.33	0.000	2.51	1.79	3.52
EC							
EC2	-0.4675	0.2357	-1.98	0.047	0.63	0.39	0.99
EC3	0.0501	0.2117	0.24	0.813	1.05	0.69	1.59
EC4	0.1110	0.3860	0.29	0.774	1.12	0.52	2.38
EC5	-0.6068	0.2396	-2.53	0.011	0.55	0.34	0.87
DaysSinc	0.07027	0.01520	4.62	0.000	1.07	1.04	1.11

Box Divi							
U	0.0986	0.1512	0.65	0.514	1.10	0.82	1.48

Logit 4: (C/N)

Constant	0.4023	0.3244	1.24	0.215			
VEG							
4 PLANTS/SQ FT	0.3081	0.1034	2.98	0.003	1.36	1.11	1.67
SEEDED BROME	-1.4233	0.1556	-9.15	0.000	0.24	0.18	0.33
EC							
EC2	-0.7698	0.1581	-4.87	0.000	0.46	0.34	0.63
EC3	-0.5653	0.1545	-3.66	0.000	0.57	0.42	0.77
EC4	0.0914	0.1416	0.65	0.519	1.10	0.83	1.45
EC5	-0.5245	0.1520	-3.45	0.001	0.59	0.44	0.80
DaysSinc	-0.014516	0.004433	-3.27	0.001	0.99	0.98	0.99
Box Divi							
U	-0.12146	0.09485	-1.28	0.200	0.89	0.74	1.07

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
Logit 1: (L/N)			
VEG	11.023	2	0.004
EC	21.713	4	0.000
Logit 2: (G/N)			
VEG	104.123	2	0.000
EC	11.417	4	0.022
Logit 3: (F/N)			
VEG	60.592	2	0.000
EC	13.621	4	0.009
Logit 4: (C/N)			
VEG	127.866	2	0.000
EC	49.747	4	0.000

Log-likelihood = -2839.835
Test that all slopes are zero: G = 811.387, DF = 32, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	399.983	156	0.000
Deviance	351.510	156	0.000

Results for: 70 days

Binary Logistic Regression: covered versus VEG, EC, ...

Link Function: Logit

Response Information

Variable	Value	Count	
covered	1	1359	(Event)
	0	1641	
	Total	3000	

Factor Information

Factor	Levels	Values
VEG	3	2 PLANTS/SQ FT 4 PLANTS/SQ FT SEEDED BROME
EC	5	EC1 EC2 EC3 EC4 EC5
Box Divi	2	L U

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-1.454	1.547	-0.94	0.347			
VEG							
4 PLANTS/SQ FT	0.1977	0.1209	1.63	0.102	1.22	0.96	1.54
SEEDED BROME	0.36497	0.09441	3.87	0.000	1.44	1.20	1.73
EC							
EC2	0.0458	0.1425	0.32	0.748	1.05	0.79	1.38
EC3	-0.0365	0.1189	-0.31	0.759	0.96	0.76	1.22
EC4	-0.0226	0.1186	-0.19	0.849	0.98	0.77	1.23
EC5	-0.4687	0.1619	-2.90	0.004	0.63	0.46	0.86
DaysSinc	0.01236	0.01846	0.67	0.503	1.01	0.98	1.05
Box Divi							
U	0.25906	0.07396	3.50	0.000	1.30	1.12	1.50

Tests for terms with more than 1 degree of freedom

Term	Chi-Square	DF	P
VEG	15.289	2	0.000
EC	18.946	4	0.001

Log-Likelihood = -2041.980
Test that all slopes are zero: G = 48.375, DF = 8, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	69.639	23	0.000
Deviance	70.921	23	0.000
Hosmer-Lemeshow	11.906	8	0.155
Brown:			
General Alternative	0.112	2	0.946
Symmetric Alternative	0.010	1	0.922

Nominal Logistic Regression: N,C,G,L,F,S versus VEG, EC, ...

Response Information

Variable	Value	Count	
N,C,G,L,	N	1641	(Reference Event)
	L	242	
	G	133	
	F	240	
	C	744	
	Total	3000	

Factor Information

Factor	Levels	Values
VEG	3	2 PLANTS/SQ FT 4 PLANTS/SQ FT SEEDED BROME
EC	5	EC1 EC2 EC3 EC4 EC5
Box Divi	2	L U

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Logit 1: (L/N)							
Constant	-22.306	3.656	-6.10	0.000			
VEG							
4 PLANTS/SQ FT	0.4024	0.2886	1.39	0.163	1.50	0.85	2.63
SEEDED BROME	0.9995	0.1876	5.33	0.000	2.72	1.88	3.92
EC							
EC2	0.0485	0.2381	0.20	0.839	1.05	0.66	1.67
EC3	-0.1458	0.2281	-0.64	0.523	0.86	0.55	1.35
EC4	-1.1485	0.3021	-3.80	0.000	0.32	0.18	0.57
EC5	-2.1354	0.3387	-6.31	0.000	0.12	0.06	0.23
DaysSinc	0.23533	0.04270	5.51	0.000	1.27	1.16	1.38
Box Divi							
U	0.6891	0.1465	4.70	0.000	1.99	1.49	2.65
Logit 2: (G/N)							
Constant	-27.494	6.068	-4.53	0.000			
VEG							
4 PLANTS/SQ FT	0.6638	0.5705	1.16	0.245	1.94	0.63	5.94
SEEDED BROME	2.3596	0.3344	7.06	0.000	10.59	5.50	20.39
EC							
EC2	-0.8930	0.2888	-3.09	0.002	0.41	0.23	0.72
EC3	-0.7582	0.2849	-2.66	0.008	0.47	0.27	0.82
EC4	-1.3564	0.4299	-3.16	0.002	0.26	0.11	0.60
EC5	-1.7975	0.3884	-4.63	0.000	0.17	0.08	0.35
DaysSinc	0.28620	0.06982	4.10	0.000	1.33	1.16	1.53
Box Divi							
U	0.0682	0.1888	0.36	0.718	1.07	0.74	1.55
Logit 3: (F/N)							
Constant	-19.248	3.524	-5.46	0.000			
VEG							
4 PLANTS/SQ FT	-0.0568	0.3021	-0.19	0.851	0.94	0.52	1.71
SEEDED BROME	1.0273	0.1726	5.95	0.000	2.79	1.99	3.92
EC							
EC2	-0.5139	0.2580	-1.99	0.046	0.60	0.36	0.99
EC3	0.1553	0.2188	0.71	0.478	1.17	0.76	1.79
EC4	-0.9687	0.2911	-3.33	0.001	0.38	0.21	0.67
EC5	-1.0813	0.2992	-3.61	0.000	0.34	0.19	0.61
DaysSinc	0.20089	0.04140	4.85	0.000	1.22	1.13	1.33

```
Box Divi
 U                 0.4414     0.1436     3.07 0.002     1.55     1.17     2.06

Logit 4: (C/N)
Constant           15.143      2.091     7.24 0.000
VEG
 4 PLANTS/SQ FT   -0.3679     0.1464    -2.51 0.012     0.69     0.52     0.92
 SEEDED BROME     -1.1209     0.1547    -7.25 0.000     0.33     0.24     0.44
EC
 EC2               1.0244     0.2183     4.69 0.000     2.79     1.82     4.27
 EC3               0.3283     0.1562     2.10 0.036     1.39     1.02     1.89
 EC4               1.0277     0.1557     6.60 0.000     2.79     2.06     3.79
 EC5               0.9379     0.2333     4.02 0.000     2.55     1.62     4.04
DaysSinc         -0.19437    0.02533    -7.67 0.000     0.82     0.78     0.87
Box Divi
 U                0.11154    0.09145     1.22 0.223     1.12     0.93     1.34

Tests for terms with more than 1 degree of freedom

Term       Chi-Square    DF      P
Logit 1: (L/N)
VEG            33.488     2  0.000
EC             84.433     4  0.000
Logit 2: (G/N)
VEG            75.139     2  0.000
EC             28.845     4  0.000
Logit 3: (F/N)
VEG            49.234     2  0.000
EC             28.968     4  0.000
Logit 4: (C/N)
VEG            58.503     2  0.000
EC             50.420     4  0.000

Log-likelihood = -3260.764
Test that all slopes are zero: G = 792.928, DF = 32, P-Value = 0.000

Goodness-of-Fit Tests

Method      Chi-Square    DF      P
Pearson        357.906    92  0.000
Deviance       319.935    92  0.000
```

RS3 Water Quality Statistical Analysis

Runoff:

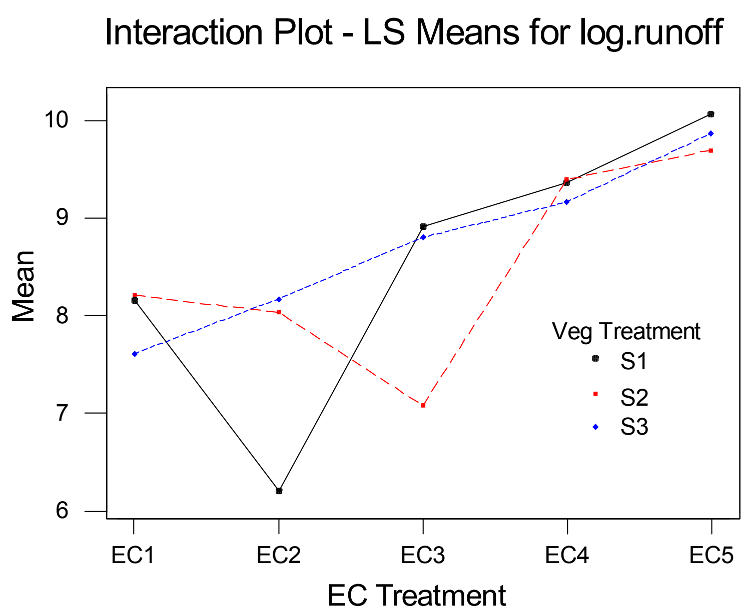
General Linear Model: log.runoff versus Seed Mix, EC. Treat.

Factor	Type	Levels	Values
Seed Mix	fixed	3	S1 S2 S3
EC. Trea	fixed	5	EC1 EC2 EC3 EC4 EC5

Analysis of Variance for log.runo, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Seed Mix	2	0.3230	0.3230	0.1615	0.38	0.688
EC. Trea	4	23.5073	23.5073	5.8768	13.96	0.000
Seed Mix*EC. Trea	8	9.4652	9.4652	1.1832	2.81	0.040
Error	15	6.3130	6.3130	0.4209		
Total	29	39.6085				

It looks like there is an EC treatment effect (p<.001) and that this effect differs by veg treatment (p=.040). An interaction plot (which shows the estimated log runoff for each different treatment combination) follows.



EC5 has a higher runoff than EC1, EC2 and EC3 (when averaging over the three veg treatments). For EC1, EC4 and EC5 there isn't any significant difference across the three veg treatments. For EC2, S1 has a significantly lower runoff than S2 and S3. For EC3, S2 has a significantly lower runoff than S1 and S3.

Sediment

General Linear Model: log. Sediment Quantity versus Seed Mix., EC. Treat.

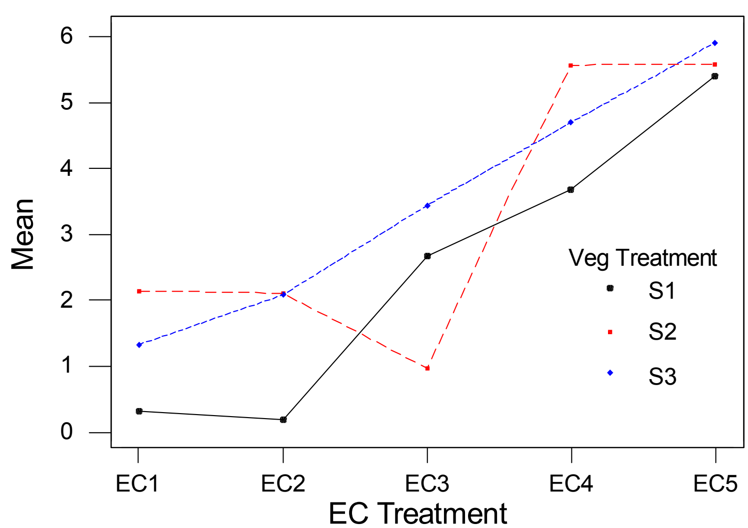
Factor	Type	Levels	Values
Seed Mix	fixed	3	S1 S2 S3
EC. Trea	fixed	5	EC1 EC2 EC3 EC4 EC5

Analysis of Variance for log.sed, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Seed Mix	2	6.1116	6.1116	3.0558	5.66	0.015
EC. Trea	4	93.0828	93.0828	23.2707	43.08	0.000
Seed Mix*EC. Trea	8	12.5325	12.5325	1.5666	2.90	0.036
Error	15	8.1028	8.1028	0.5402		
Total	29	119.8296				

EC treatment has a statistically significant effect on sediment in runoff. However, as with runoff, this effect differs by veg treatment.

Interaction Plot - LS Means for log sediment yield



EC treatments 1, 2 and 3 have runoff that, on average, is lower than the sediment from EC treatments 4 and 5. At the .05 level we cannot differentiate between sediment for any veg treatments for any EC treatment (but at the .10 level, S1 has a lower sediment than S2 for EC1, S1 has a lower sediment level than the other two veg treatments and for EC4 S1 has a lower sediment level than S1).

Concentration

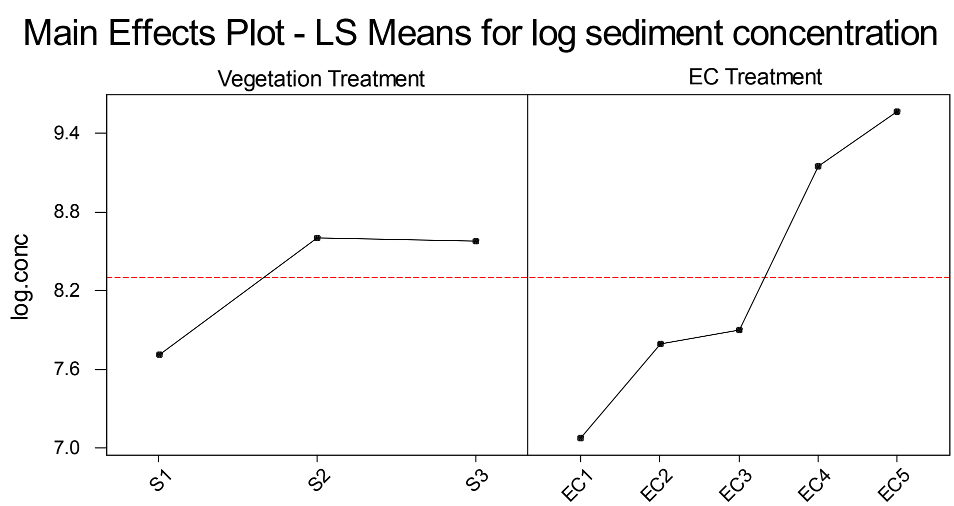
General Linear Model: log. Sediment Concentration versus Seed Mix., EC. Treat.

Factor	Type	Levels	Values
Seed Mix	fixed	3	S1 S2 S3
EC. Trea	fixed	5	EC1 EC2 EC3 EC4 EC5

Analysis of Variance for log.conc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Seed Mix	2	5.1095	5.1095	2.5548	10.01	0.002
EC. Trea	4	25.4368	25.4368	6.3592	24.91	0.000
Seed Mix*EC. Trea	8	3.7955	3.7955	0.4744	1.86	0.143
Error	15	3.8294	3.8294	0.2553		
Total	29	38.1712				

The EC treatment has an effect on sediment concentration in the runoff ($p<.001$) as does the veg treatment ($p=.002$). There is not a significant interaction.



Veg treatment S1 has a significantly lower concentration than S2 or S3. The EC treatment effects may be summarized:

EC1 EC2 EC3 EC4 EC5

Table 1. Metal concentrations, depth, distance from paved road edge, presence of curb, slope, vegetative cover, traffic braking, and traffic volume for twenty-eight collected soil samples

Sample	depth from Surface (cm)	distance from paved edge (cm)	Pb ppm	Cu ppm	Ni ppm	Cd ppm	curb †	slope of site (%)	slope above Sample(%)	slope of Sample (%)	cover above site (%)‡	cover above sample ‡ (%)	traffic braking § (%)	traffic volume ¶ (%)
1	0.5	30	73.80	3.40	0.76	0.22	1	11	24	0	1.0	1.0	0.2	0.07
2	2.5	30	46.80	1.86	0.56	0.24	1	11	24	0	1.0	1.0	0.2	0.07
3	0.5	30	57.20	1.30	0.58	0.26	1	11	24	0	1.0	1.0	0.2	0.07
4	2.5	30	80.80	2.04	0.54	0.30	1	11	24	0	1.0	1.0	0.2	0.07
5	0.5	30	62.50	1.26	1.74	0.44	1	5	5	11	0.5	0.5	1.3	0.56
6	2.5	30	59.20	0.74	1.42	0.34	1	5	5	11	0.5	0.5	1.3	0.56
7	0.5	30	93.80	2.23	2.88	0.38	1	5	5	11	0.5	0.5	1.3	0.56
8	2.5	30	98.80	1.73	1.90	0.34	1	5	5	11	0.5	0.5	1.3	0.56
9	0.5	30	36.50	0.88	2.80	0.10	1	22	16	50	0.3	0.2	2.0	1.00
10	2.5	30	28.00	1.14	2.10	0.10	1	22	16	50	0.3	0.2	2.0	1.00
11	0.5	250	4.04	0.89	3.82	0.08	1	22	50	50	0.2	0.2	2.0	1.00
12	2.5	250	3.08	1.57	4.10	0.10	1	22	50	50	0.2	0.2	2.0	1.00
13	0.5	30	8.40	2.93	7.86	0.18	1	22	16	50	0.3	0.2	2.0	1.00
14	2.5	30	38.00	2.39	4.34	0.12	1	22	16	50	0.3	0.2	2.0	1.00
15	0.5	250	11.58	1.22	7.00	0.16	1	22	50	50	0.2	0.2	2.0	1.00
16	2.5	250	10.80	1.70	6.80	0.08	1	22	50	50	0.2	0.2	2.0	1.00
17	0.5	30	1.38	1.72	0.22	0.02	1	11	0	24	0.9	0.9	1.7	0.90
18	0.5	250	1.50	1.62	0.42	0.02	1	11	24	24	0.9	0.9	1.7	0.90
19	2.5	30	0.82	2.16	0.36	0.04	1	11	0	24	0.9	0.9	1.7	0.90
20	2.5	250	2.72	2.00	0.50	0.04	1	11	24	24	0.9	0.9	1.7	0.90
21	0.5	30	0.68	0.72	0.34	0.02	1	11	0	24	0.9	0.9	1.7	0.90
22	0.5	250	1.86	4.04	0.36	0.04	1	11	24	24	0.9	0.9	1.7	0.90
23	2.5	30	0.68	1.64	0.20	0.04	1	11	0	24	0.9	0.9	1.7	0.90
24	2.5	250	1.56	2.54	0.20	0.04	1	11	24	24	0.9	0.9	1.7	0.90
25	0.5	30	0.86	0.86	0.26	0.02	0	12	27	8	1.0	0.4	0.9	0.90
26	2.5	30	0.72	1.42	0.26	0.04	0	12	27	8	1.0	0.4	0.9	0.90
27	0.5	30	0.92	1.58	0.12	0.04	0	12	27	8	1.0	0.4	0.9	0.90
28	2.5	30	0.88	1.40	0.24	0.04	0	12	27	8	1.0	0.4	0.9	0.90

† 0/1 denotes absence (0) /presence of curb (1); ‡ 0 to 1 denotes (0) no to full cover (1)

§ 0 to 1 denotes no braking (0) to heavy braking (2); ¶ 0 to 1 denotes light traffic (0) to heavy traffic (1)

APPENDIX B. WEATHER DATA

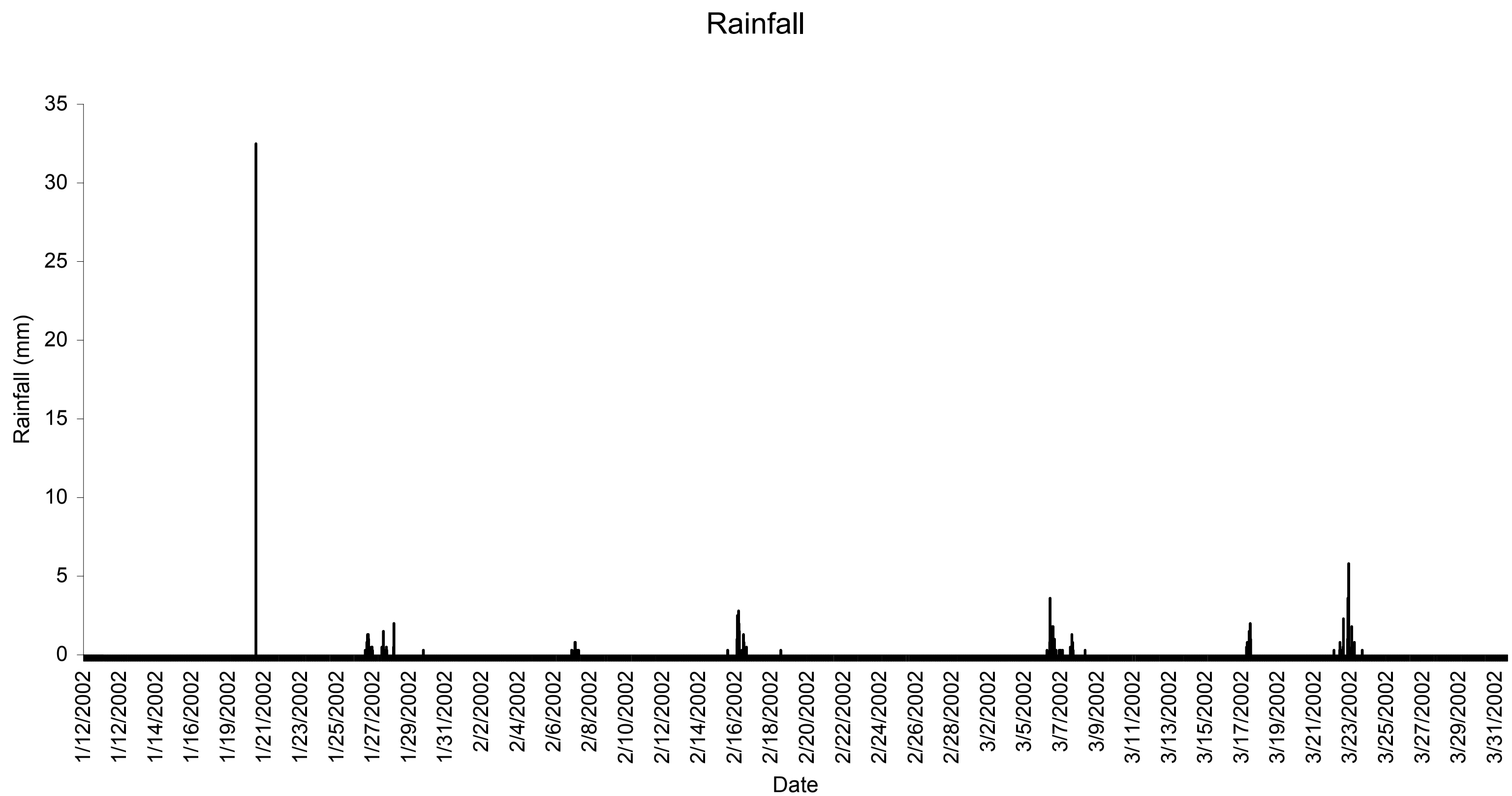
Weather Station

A weather station was set up in order to monitor the daily weather conditions at the simulation site. The weather station was mounted directly above the simulated rainfall boxes to effectively interpret the conditions surrounding the boxes. The weather monitoring station was linked (wirelessly) to a computer kept in the head house that logged weather data throughout the experiment.

Set-up for Simulated Box Monitoring:

- Davis Wireless Weather Monitor II Weather Station: This data collector was selected for its relatively low cost and rugged construction. The unit was self-contained, using a solar panel as an energy source. The sensors were contained in a rugged plastic housing. This unit sent data (via a radio frequency) to a receiver in the head house to collect data.
- Weather Link Data Logging Software (PC version) and Data Logger: This software was run on a custom built 486 computer, which downloaded data from the logger every five minutes. The computer and data logger were attached to an APC UPS 650va battery backup to allow two hours of uninterrupted data logging in the event of a power loss.
- Data Collection: Rain is measured via a tipping bucket rain gauge. This tipping bucket measured rainwater in 0.0254 cm (0.01in) intervals. Temperature, relative humidity, wind speed, wind direction, and dew point were all measured and recorded every five minutes along with the quantity of rain delivered.

The following pages include the data collected over the course of this experiment.



Rainfall
Rainfall (mm)
35
30
25
20
15
10
5
0
1/12/2002
1/12/2002
1/14/2002
1/16/2002
1/19/2002
1/21/2002
1/23/2002
1/25/2002
1/27/2002
1/29/2002
1/31/2002
2/2/2002
2/4/2002
2/6/2002
2/8/2002
2/10/2002
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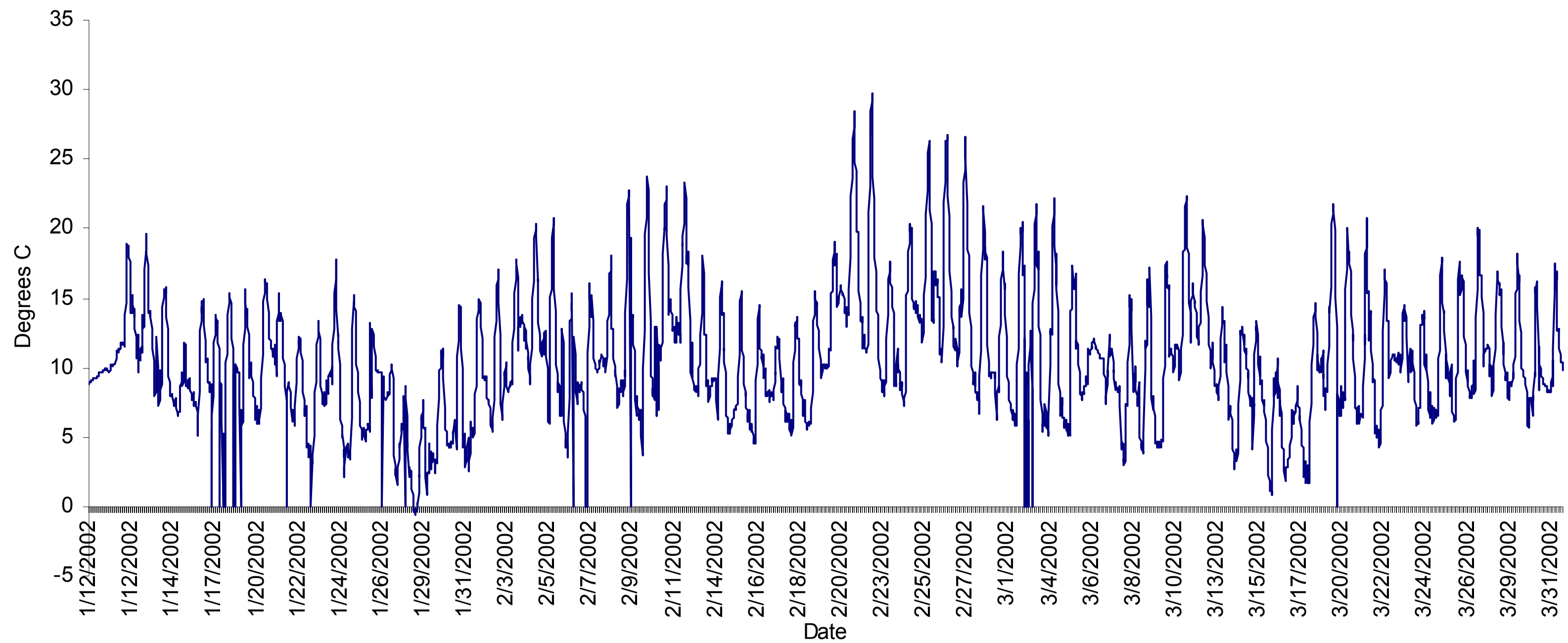
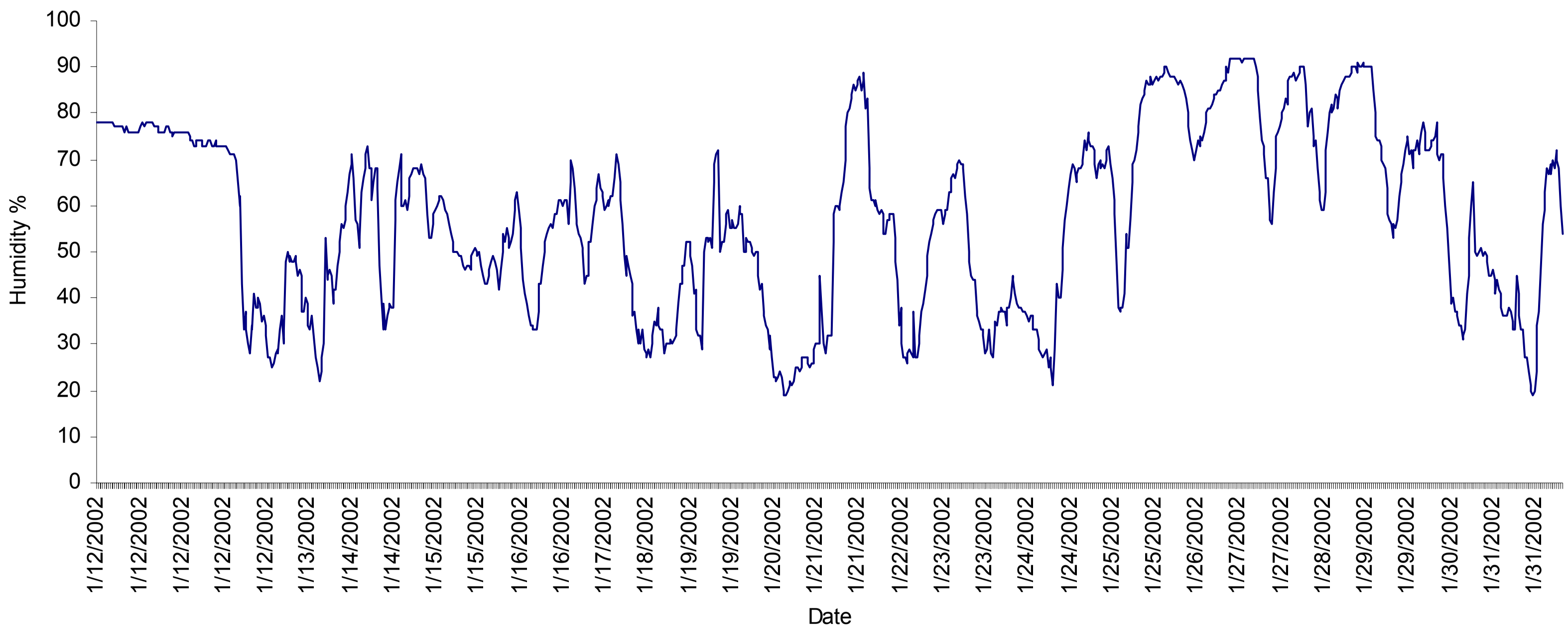
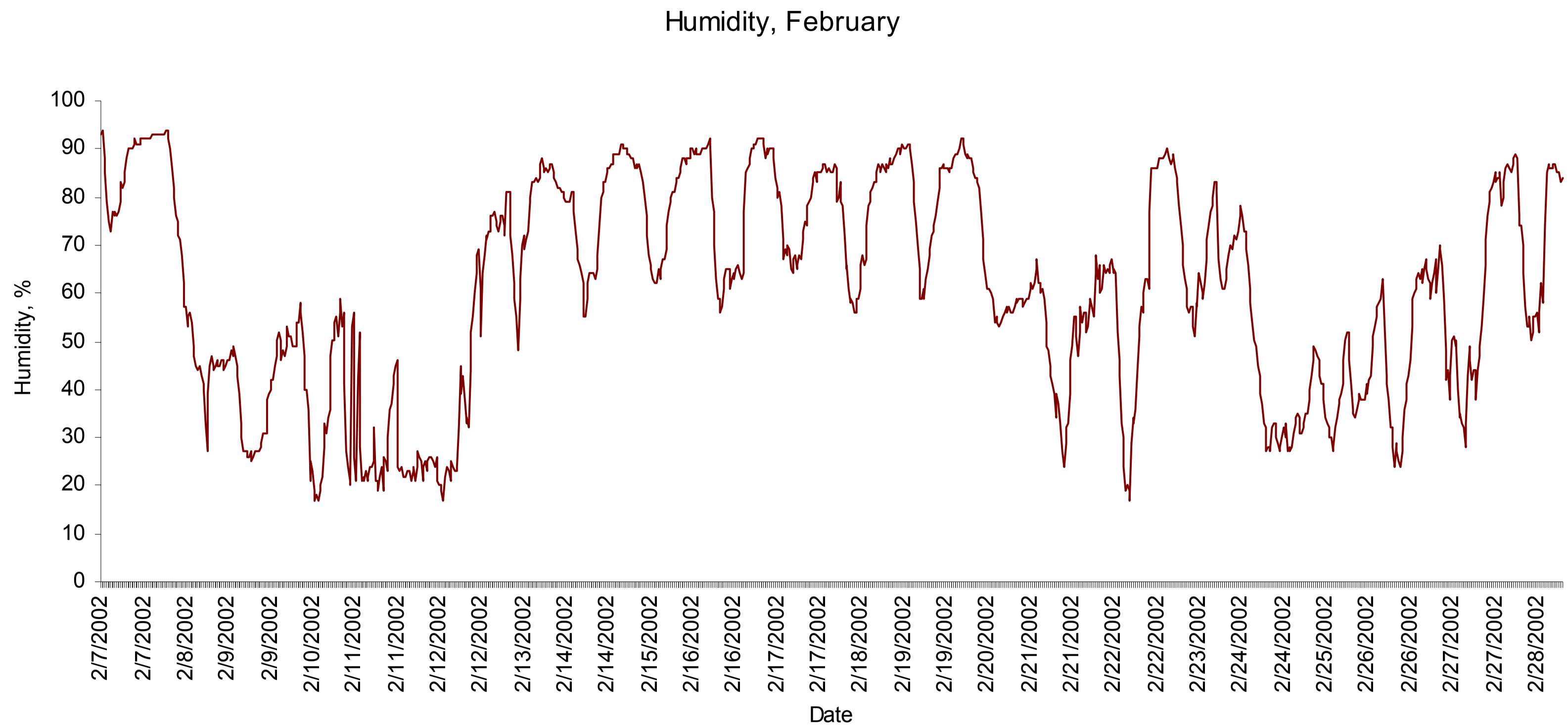
2/26/2002
2/28/2002
3/2/2002
3/5/2002
3/7/2002
3/9/2002
3/11/2002
3/13/2002
3/15/2002
3/17/2002
3/19/2002
3/21/2002
3/23/2002
3/25/2002
3/27/2002
3/29/2002
3/31/2002
Date

Average Temp outisde



Humidity, January




Humidity, February
Humidity, %
100
90
80
70
60
50
40
30
20
10
0
2/7/2002
2/7/2002
2/8/2002
2/9/2002
2/9/2002
2/10/2002
2/11/2002
2/11/2002
2/12/2002
2/12/2002
2/13/2002
2/14/2002
2/14/2002
2/15/2002
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2/17/2002
2/18/2002
2/19/2002
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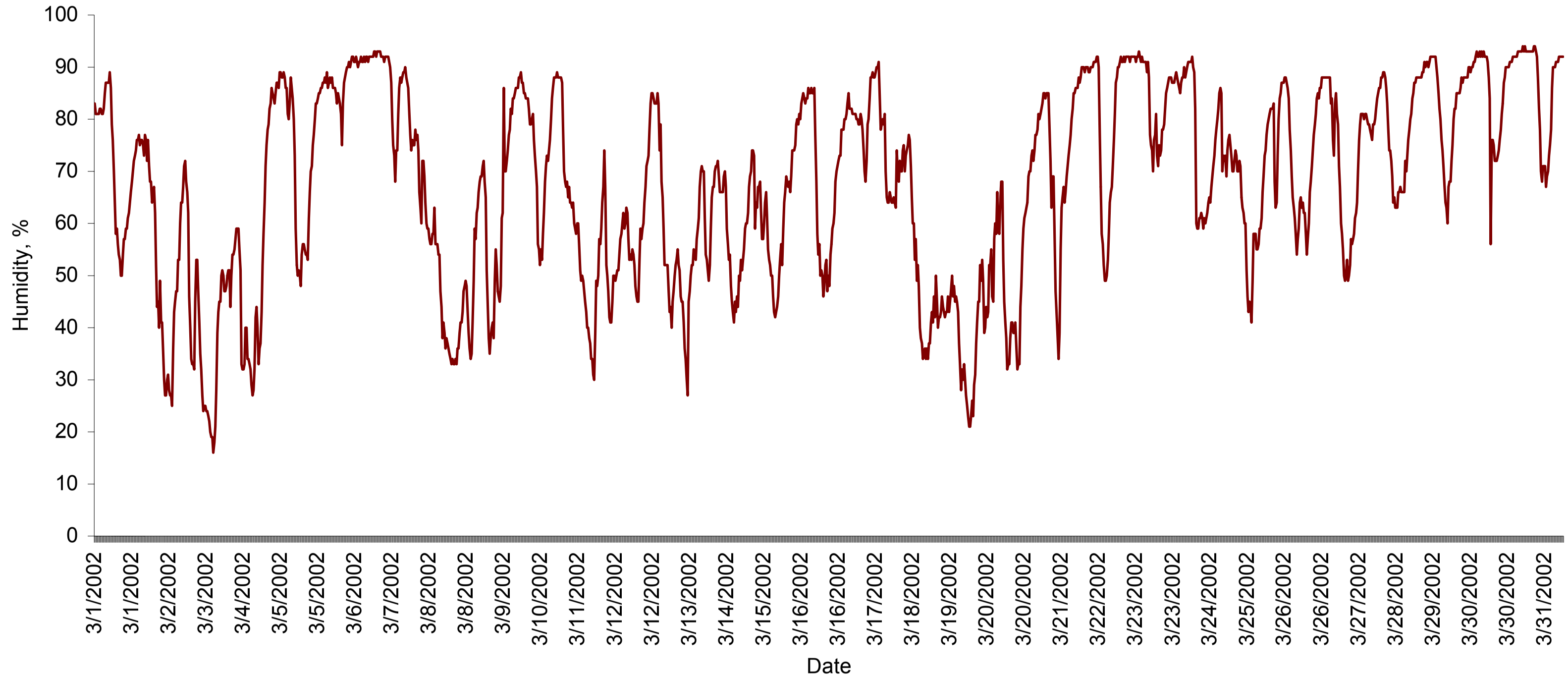
2/21/2002
2/22/2002
2/22/2002
2/23/2002
2/24/2002
2/24/2002
2/25/2002
2/26/2002
2/26/2002
2/27/2002
2/27/2002
2/28/2002
Date

Humidity, March



Title: Back to The Basics of Revegtation
Author: Mark Mustoe
Source: Land And Water Magazine
Publisher: Land And Water, Inc.
Date: March/April 1998
Key Words:

- Revegetation
- Soil Testing
- Seed

Abstract:

There are many ways invented and written about on how to apply and establish vegetation. However, there are a few basic principles that should always be applied to a project. 1) The soil must have the ability to sustain long-term plant growth. It must have a suitable pH, needed nutrients, and enough organics to retain moisture and maintain important soil organisms. 2) The selected species must be able to be successful for a long period of time on the specific site given the soil, rainfall, topography, and climate. Seed mixes are often useful to fit the microclimates found at certain sites. 3) Seed application must be appropriate for the species used. Seed placement, seed to soil contact, hyrdoseeding vs. drilling, and timing are very important. 4) Follow-up and patience are also important.

Title: Grassroots Revival: Innovation Through Collaboration
Author: Stephen Gruman
Source: Land And Water Magazine
Publisher: Land And Water, Inc.
Date: January/February 2001
Key Words:

- CalTrans
- Vegetation
- Washouts
- Restoration

Abstract:
The Central Coast Highway that runs along the Big Sur Coast is beautiful for tourists in the summer, but is a nightmare for CalTrans in the winter. CalTrans' efforts on the highway are continuously compromised by washouts. Successfully establishing deep-rooted vegetation that can stabilize the sandy slopes, yet survive California's seven month dry season, is challenging. The best engineering will fail without quality revegetation. A network of plants is needed to provide surface erosion control is California's variable conditions. Type and timing of Vegetation planted are very important. To combat the need for fast growing, deep rooted plants at a particular site, cold-stratifying native seed was used, fooling the seed to germinate in July rather than February.

Title: Combined Use of Ecoregions and Plant Hardiness Zones to Delineate Plant Material Adaption Zones of Native and Introduced Plant Germplasm.

Authors: *K. P. Vogel, J. J. Brejda,* and *R. A. Master*s, USDA-ARS, 344 Keim Hall, Univ. of Nebraska, Lincoln, NE 68583 0910.

Source: SRM "A Range Odyssey" Abstracts

Key Words:

- Re-vegetation
- Native Species
- Topography
- Ecoregions

Abstract:

Rangeland restoration and re-vegetation often involves planting native and introduced species in mixtures or as individual species. The best way to identify adapted plant material is to conduct field trials and monitor persistence and productivity. Because of the large numbers of species that are used in rangelands and seeded grasslands, the variability among sites due to differences in soil, topography, elevation, precipitation, and latitude, and the limited resources that are available for testing, field trial information is often not available or is limited. The use of local seed sources is often advocated but seed supplies are usually inadequate, not available, and seed quality is variable. Cultivars or strains of known origin or for which some field trial information is available are the most reliable seed sources for re-vegetation. Problems often arise in delineating adaptation areas for cultivars and strains of rangeland and grazing land species, both native and introduced. We propose a simple solution to this problem, which involves combining Ecoregions such as those described by Bailey (1997, Ecoregions of North America) with the USDA Plant Hardiness Zone Map using an Ecoregion-Hardiness Zone designation for adaption zones. As an example, the northern and southern northern sections of Eastern Nebraska would be designated 251-HZ 4 and 251-HZ 5, respectively. Adapted cultivars or strains for these plant material adaptation zones (PMAZ) could be determined for both native and introduced species by field testing, or with native species, using knowledge of germplasm origin.

Title: Effect of Vegetation Density and Microchannels on Resistance to Overland Flow.

Authors: *Gary W.Frasie*r, USDA-ARS, Rangelands Resources Res. Unit, Fort Collins, CO 80526; *Wayne C. Leininger,* Dept. Rangeland Ecosystem Sciences, Colorado State Univ., Fort Collins, CO 80523; and *Mark A. Weltz,* USDA-ARS, Great Plains Systems Res., 301 S. Howes, Fort Collins, CO 80522.

Source: SRM "A Range Odyssey" Abstracts

Key Words:

- Rainfall Simulator
- Microchannels
- Manning's Equation
- Velocities
- Sediment Transport

Abstract:

Rainfall simulator studies in both riparian and shortgrass ecosystems have shown that overland flow does not occur as sheet flow but rather as small rivulets in microchannels. Other studies have shown that standard methods of determining friction factors in overland flow such as the coefficient of roughness used in Manning's equation is not appropriate in estimating overland flow velocities in these microchannels when water depths are less than the height of the vegetation. A small laboratory flume was used to estimate friction factors of water flowing through stands of Poa spp. and Festuca spp. grasses both with and without microchannels. Results show that water velocities are increased by a factor of 3 to 10 times with a single microchannel compared to a solid grass stand. Some estimates of friction factors for use in flow equations are presented. The increased velocities of water in microchannels are important considerations when estimating residence time for contaminants or sediment transport.

Title: Geosynthetically Reinforced Vegetation vs. Riprap
Author: Timothy Lancaster
Source: Land And Water Magazine
Publisher: Land And Water, Inc.
Date: March/April 1997
Key Words:

- Erosion Control Materials
- Vegetative Channel Linings
- Reinforcement Mattings

Abstract:

"Hard Armor" Materials such as rock riprap were once thought to be the only suitable materials for lining channels designed to carry high velocity flow, high shear stress flows. Vegetative linings were simply out of the question for channels where expected velocities would exceed 2.1 meters per second (8 feet per second) or shear stresses topped the 178 pascals (3.7 pounds per square foot) mark. However, modern geosynthetic turf reinforcement mattings have proven the ability to substantially increase the erosion resistance of natural vegetation, enabling its use in channels where high velocities and sheer stresses are prevalent. This confirmation is to the delight of many designers who respect the low cost, low maintenance, low hazard, and environmental benefits of "soft armor" vegetative linings.

Title: Seeding, Spraying, and Spreading
Author: Joseph Lynn Tilton
Source: Erosion Control Magazine
Date: May/June 2000
Key Words:

- Fiber Matrix
- Seeding Methods
- Hydroseeders
- Native Vegetation

Abstract:

The erosion control industry has tried to introduce many different new types of ground material to apply to sites, however, Straw & hay, and wood or paper mulch still persist in the market. Seeders are also essentially designed the same as they were 50 years ago. When seeding, it is essential to have seed to soil contact. A logical carrier for seed application is soil, which eliminates the need for two processes. Before seeding with native grasses, the ground needs to be tested for residual chemicals from agronomic crops.

Title: A portable rainfall simulator for assessing infiltration
Author: Bruce W. Byars, Peter M. Allen, and Norman L. Bingham
Source: Journal of Soil and Water Conservation
Date: November-December, 1996
Key Words:

- Rainfall simulator
- Infiltration
- Runoff
- Runoff plot
- Soil
- Macropore

Abstract:

A rainfall simulator has been constructed that is capable of testing infiltration rates in a field setting. The simulator is constructed of standard PVC pipe and is readily transportable to remote field locations. A large runoff plot is used in order to give an accurate rate representation of runoff and infiltration over the area. The rainfall simulator has been applied successfully in field studies in central Texas, and can be used in a wide range of terrains and research applications.

Title: Revegetation and Stabilization of Deteriorated and Altered Lands. Author:

David G. Williams, The Univ. of Arizona, School of Renewable
Natural Resources, Tucson, AZ 85721, USA.

Source: SRM "A Range Odyssey" Abstracts

Key Words:

- Topsoil Loss
- Disturbances
- Re-vegetation
- Biodiversity

Abstract:

Natural and human-altered environments in the western United States are impacted by disturbances that result in the loss of topsoil, introduction of contaminants, reduction in productivity, and/or loss in structural and functional components of the affected and surrounding ecosystems. Severe disturbances have promoted the expansion of many invasive non-indigenous (weedy) species in many ecosystems. Some ecosystems are capable of recovering after disturbance through natural successional processes. Other disturbances require intervention to reestablish natural ecological processes. The Western Coordinating Committee 21 (WCC-21) membership is composed of representatives from Agricultural Experiment Stations and Federal and State Agencies involved in reclamation research activities. The objectives of WCC-21 are to promote communication and technology sharing among personnel involved in soil stabilization and revegetation research; promote technology transfer of research to user groups; identify research needs; coordinate research to avoid duplication; and to promote restoration ecology, biodiversity and ecosystem sustainability in revegetation programs. WCC-21 maintains a web page, which can be accessed at: http://ars-boi.ars.pn.usbr.gov/wcc21

Title: The Influence of Revegetation Techniques on Long-Term Plant Community Development.

Authors: *Edward F. Redente* and *Gregory J. Newma*n, Rangeland Ecosystem Science Dept., Colorado State Univ., Fort Collins, CO 80523.

Source: SRM "A Range Odyssey" Abstracts

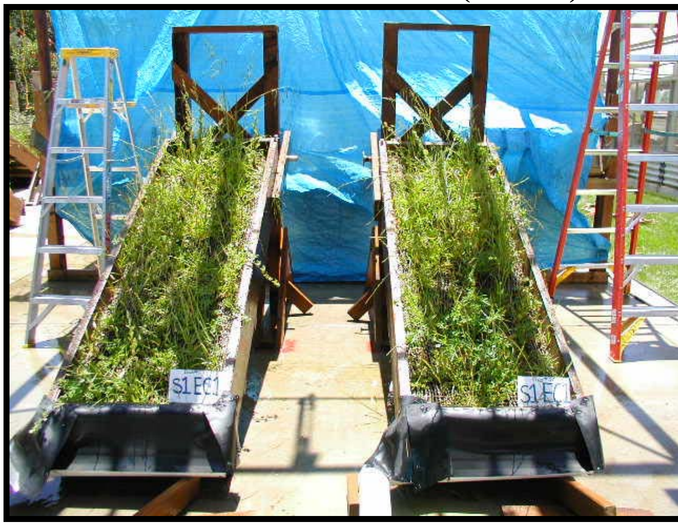
Key Words:

- Revegetation
- Native Seed Mixtures
- Biomass

Abstract:

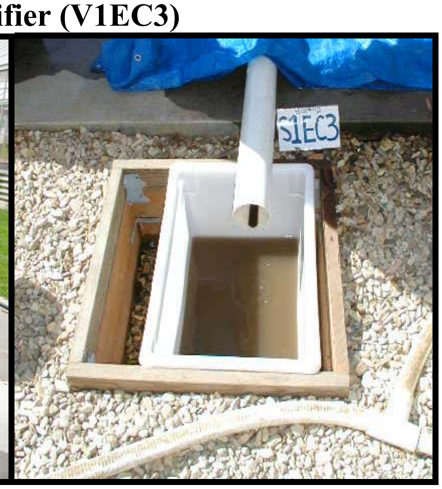
A revegetation techniques study was initiated during the fall of 1976 in northwestern Colorado in a disturbed sagebrush (Artemisia tridentata Nutt.) community. The study included two irrigation treatments, three seed mixtures, four seeding techniques, and two fertilization treatments. Short-term results were published and conclusions were made regarding the initial success of each treatment. The objective of the current study was to determine the effects of each treatment on plant community production, species composition, and species diversity after 20 years of plant community development. There was no significant difference in aboveground biomass between plots that received irrigation during the first two growing seasons and non-irrigated plots. However, among irrigated plots, the native seed mixture produced greater biomass compared to the introduced mixture and a mixture of both native and introduced species. The native mixture also resulted in greater species richness than the introduced mixture when averaging over all other treatments. Altered seeding rate ratios among life forms, altered seeding methods (drill versus broadcast seeding), and a single application of nitrogen and phosphorus showed few long-term effects. All revegetation plots have remained grass dominated over 20 years. However, shrub biomass was greater in the native and combination mixtures than in the introduced mixture on irrigated plots. The surrounding undisturbed plant community is shrub-dominated. Thus, the seed mixtures evaluated in this study have resulted in distinctly different plant communities and demonstrate that initial treatments can influence long-term plant community development on severely disturbed rangelands.

California Brome Seed with Jute (V1EC1)



California Brome Seed with BFM (V1EC2)

California Brome Seed with Fiber + Tackifier (V1EC3)



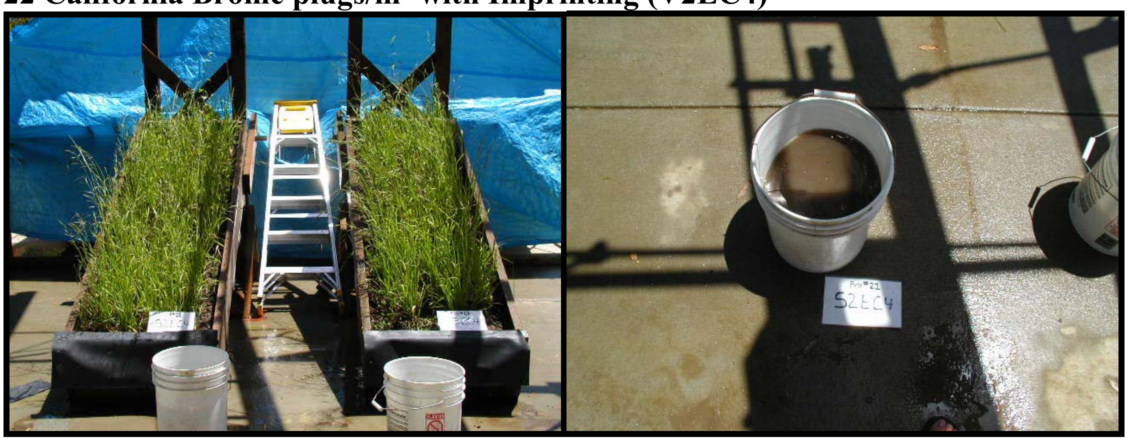
California Brome Seed with No EC Treatment (V1EC5)


22 California Brome plugs/m^2 with Jute (V2EC1)

22 California Brome plugs/m^2 with BFM (V2EC2)

22 California Brome plugs/m^2 with Fiber + Tackifier (V2EC3)

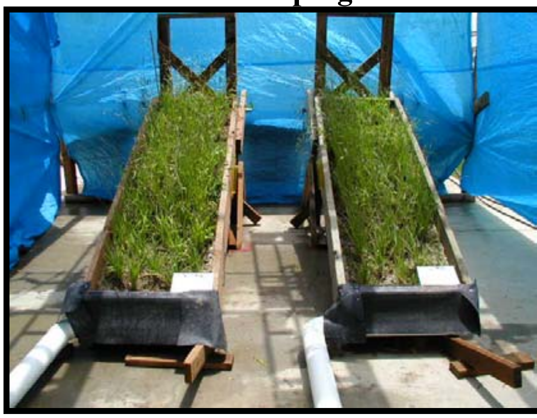
22 California Brome plugs/m^2 with Imprinting (V2EC4)



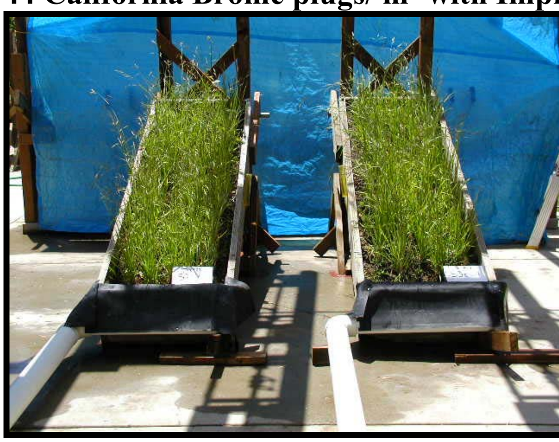
22 California Brome plugs/m^2 with No EC Treatment (V2EC5)

44 California Brome plugs/m^2 with Jute (V3EC1)

44 California Brome plugs/m^2 with BFM (V3EC2)



44 California Brome plugs/ m^2 with Imprinting (V3EC4)



44 California Brome plugs/m^2 with No EC Treatment (V3EC5)

Bare A and Bare B