A COMPARISON OF SEDIMENT PRODUCTION ON CHEMICALLY TREATED AND UNTREATED SAGEBRUSH RANGELAND IN THE RIO PUERCO HEADWATERS NEAR CUBA, NEW MEXICO

By

Regina G. Rone

Submitted in Partial Fulfillment of the Requirements
For the Degree of
Master of Science in Geology

New Mexico Institute of Mining and Technology
Socorro, New Mexico

April 2001

ABSTRACT

Chemical treatment of sagebrush rangeland with herbicides has been utilized in the southwest United States for two decades and has improved overall rangeland conditions. Though sagebrush eradication allows for increased vegetative cover, reduced runoff, erosion, and sediment transport, the lack of monitoring and evaluation of grazing land after treatment has resulted in the need to gather baseline data on vegetation changes and sediment production.

A small first-order drainage basin in Arroyo Chijuilla, an ephemeral stream near Cuba, NM, was chosen to study the effects of sagebrush treatment on sediment movement. Rainfall simulations on 1 m^2 plots were used to collect runoff data from a total of 36 plot-runs. Half of the simulations were performed over initially dry soil (dry run) whereas the other half were carried out over the partially saturated soil the following day (wet run). Additional vegetation assessments, erosion pins, infiltration measurements, and soil analyses were used to evaluate vegetation changes and soil properties on treated and untreated sagebrush rangeland.

Chemical treatment resulted in significant decreases in sediment concentrations (kg/ha-mm) for both grass and three shrub plots. Dry runs between grass plots produced similar sediment yields, whereas wet runs showed a nine-fold increase in sediment yield from treated plots compared to untreated. Sediment production on untreated shrub plots was about 5 times higher for the dry and 8 times higher for the wet run than from treated plots. Treated shrub plots produced less than half of the sediment yield of the grass plots. Bare plots acted as controls and show no significant differences between treated and untreated areas.

Chemical treatment resulted in increases in vegetative cover on all grass and shrub plots. Treated areas not only have greater quantities of ground cover than untreated areas, but also contain slightly more diverse species, especially grasses. Although the percentage of area covered by bare ground was less in the treated plots, the average size of the bare patches was only slightly smaller. The decrease in bare area is therefore controlled by frequency of bare patches rather than their size.

Estimates of Green-and-Ampt conductivities were used to evaluate variations in saturated conductivity between treated and untreated rainfall simulation plots. Conductivity values are significantly higher during wet runs on grass plots and both dry and wet runs on shrub plots between treated and untreated areas. The differences are due to percent vegetative cover and related root growth rather than to changes in soil properties.

Density and spatial arrangement of vegetation appear to exercise the strongest controls on the amount of runoff and erosion. Increased growth of herbaceous ground cover affects sediment movement through: (1) formation of continuous barriers that slow runoff velocity; (2) enhanced surface microtopography; (3) increased infiltration due to ponding; and (4) detainment of sediments. Sagebrush treatment therefore encourages the re-establishment of herbaceous ground cover, thus effectively reducing sediment movement.

.

ACKNOWLEDGMENTS

This work was made possible by financial support from a NM Tech research grant, NM Geological Society, NM Garden Club, NM Tech Graduate Student Association, and Dr. Tim J. Ward, who loaned me the rainfall simulation equipment. I especially thank the NM Bureau of Mines & Mineral Resources for providing transportation to the field site on numerous occasions.

My advisors Dave Love, Bruce Harrison, Tim J. Ward, and Peter Mozley provided valuable insights during the past year. A special thanks to Dennis Lee, Joey Fields, and Merlin who where indispensable during data collection, and Kenny Stevens who brought the whole rainfall system back to life.

Flaviano Aragon from the BLM Cuba Field Office and Jerry Wall, Brian Lloyd, Dave Sitzler, John Gilmore, Gene Tatum, and Steve Fischer from the BLM Albuquerque Office have also contributed extensively to the research. I would also like to thank Ruben Crespin, George Austin, Allen Gellis, Lynn Brandvold, Bill McIntosh, Steven Yanoff, Jan Hendrickx, David Welch, Becky Davis, and Eric Small for their help. A final thanks to the great people of Cuba, NM: Richard and Raoul of Richard’s True Value Hardware, Timothy Johnson, Worthington Smelser, Alvin & Mike, and Eli who fixed the generator.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Overview

The Rio Puerco watershed in New Mexico is known for its high sediment yields and has been the focus of many studies since the 1920's (Bryan, 1928; Nordin, 1964; Wells et al. 1982; Aguilar and Aldon, 1991; Elliott et al., 1997; Gellis and Pavich, 1999). Despite the relatively small size and small annual water yield of the Rio Puerco, suspended-sediment concentrations in excess of 400,000 ppm were observed by Nordin (1963) near Bernardo and averages of 79,000 mg/L were reported by the Bureau of Reclamation (1994).

Simons and others (1991) estimated that 90 percent of the suspended-sediment load in the Rio Puerco is silt and clay (<0.062mm). The generation of large amounts of bedload by the Rio Puerco has a significant impact on the Rio Grande's water quality and leads to increased sedimentation and reduced storage capacity of Elephant Butte reservoir downstream from the confluence.

During the development of the Rio Puerco watershed, sediments eroded from the headwaters were delivered downstream at variable rates (Love, 1986). Based on the extent of basin-fill deposits, at least 250 km^3 were removed from the headwaters between 3 Ma and 1 Ma ago and deposited in the Albuquerque basin (Love, 1986). Approximately 200 km^3 have been removed from the present middle and lower Rio Puerco in a series of alternating erosional and aggradational events (Love, 1986). Over the past six decades, a decrease in suspended sediment load has been measured and attributed to channel changes (Elliott, 1979; Gellis, 1992; Elliott et al, 1998;), to a decrease in annual peak flow since the 1930's coupled with the planting of tamarisk (Love, 1997), and to the success of erosion control strategies by various land-management agencies (Soil Conservation Service, 1977).

Though the Rio Puerco drainage system is extremely inefficient in sediment delivery to the Rio Grande at present (Love, 1986), it has the highest sediment load of any stream in the Upper Rio Grande Basin and ranks among the highest in the nation (Dortignac, 1956). Annual suspended sediment discharge is estimated to average 2.7 million metric tons (Amin, 1983). Sediment is stored locally throughout the system in alluvial fans and plains, valley fills, terraces, and even in the active channel and floodplain (Love, 1986). But within the mainstem Rio Puerco, much of the current sediment load is from erosion of the adjacent channel margin (Love, 1986), mainly by flash floods which occur during the summer monsoon season.

High rates of gully erosion have also been associated with major changes in natural vegetation attributed to overgrazing or a climatic shift (Bryan, 1928; Bailey, 1935; Scholl and Aldon, 1988). Increased erosion rates began almost simultaneously with Spanish settlement and the grazing of sheep and cattle. However, climate change may have also initiated erosion.

Sagebrush-grassland communities along with pinyon-juniper ecosystems comprise much of the Rio Puerco headwaters and are primarily used as rangeland. Various land-management agencies, such as the Bureau of Land Management and Bureau of Indian Affairs, have implemented programs on rangeland to reduce erosion and to improve vegetation cover. One of these programs involves the application of chemicals to reduce sagebrush on rangeland.

Sagebrush in the Rio Puerco headwaters has been sprayed for several decades and anecdotal evidence suggests that overall land conditions have improved (S. Fischer and W. Smelser, personal communication 1999). Removal of sagebrush allows grasses and other plant material to cover bare soil between shrubs, therefore reducing erosion and movement of sediments (Bastian et al., 1995; Henry, 1998). Though it appears that sagebrush treatment allows for increased grass cover, the lack of monitoring and evaluation of grazing land after treatment has resulted in the need to gather baseline data on vegetation changes and sediment production.

Purpose and Objectives

The purpose of this study involves the comparison of chemically treated and untreated rangeland to quantify the effect of sagebrush eradication on sediment production. The objectives are to (1) determine whether chemical treatment of sagebrush encourages the reestablishment of grasses and (2) evaluate if a resulting increase in vegetation cover decreases sediment yield. To attain these objectives, chemically treated and untreated areas of a small drainage were studied. Results provide baseline data on sediment production and vegetation changes that the Bureau of Land Management and private ranchers can use to assess and manage erosion problems in the headwaters of the Rio Puerco watershed.

To measure sediment production and runoff characteristics, rainfall simulations on 1 m^2 plots were used to collect data from a total of 36 plot-runs. Additional field measurements were employed to gain further insights on differences between treated and untreated areas. These included (1) monitoring of sediment production throughout the year with four natural runoff plots and an erosion pin transect; (2) description of soil horizons in small pits associated with the runoff plots; (3) analyses of particle size distribution on sediments collected from rainfall simulations and soil pits; and (4) evaluation of vegetation distribution through line transects, plant identification, and point frame counts on rainfall simulation plots.

Study Site

The study was conducted in a small first-order drainage basin (named Bastard Draw by the author), a tributary of Arroyo Chijuilla, near Cuba, NM (Fig. 1). Bastard Draw is carved into the Cuba Mesa Member of the San Jose Formation, a thick sheet sandstone and conglomerate with minor mudstone. These unconformably overlie the Escavada Member of the Paleocene Nacimiento Formation (Williamson and Lucas, 1992).

The climate of the area is semiarid with an average annual precipitation of 336 mm (Western Regional Climate Center, NV, 1941-1999). The nearest long-term weather station is at the Johnson Ranch, about 16 miles south of the study site. Rainstorms in the summer are characterized by high intensity rain of short duration, especially during the months of July and August, and average between 30 to 50 mm/hr (U.S. Department of Commerce, 1975; A. Gellis,

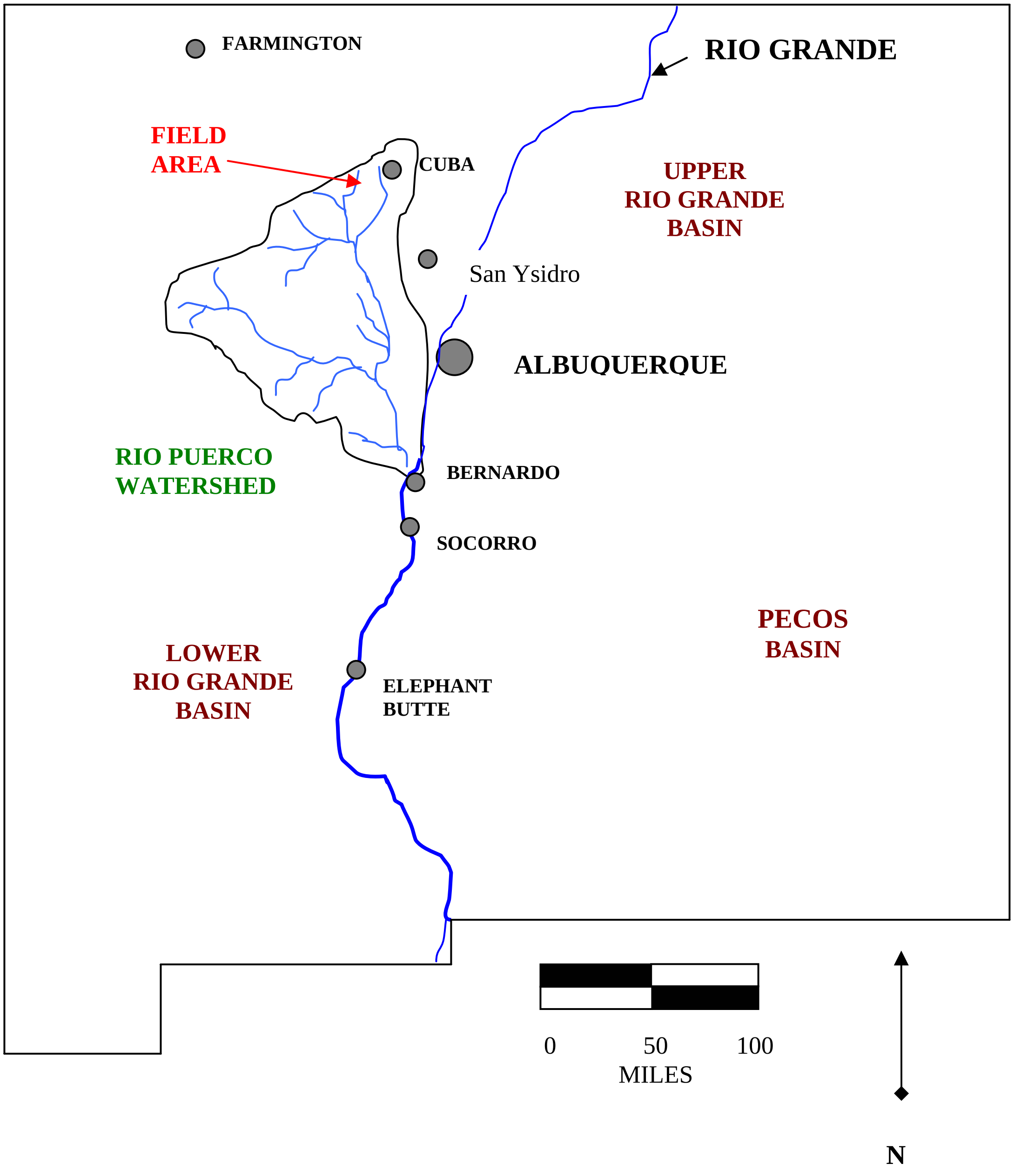


Figure 1: Outline of the Rio Puerco watershed and field area location near Cuba, New Mexico.

written communication, 2001; Western Regional Climate Center, 2001). Snowfall during the winter and spring accumulates and often provides snow cover from November through March.

The drainage basin was selected on the basis of accessibility and the presence of both chemically treated and untreated sections that were sprayed with tebuthiuron by the Bureau of Land Management (BLM) in the fall of 1997 (Fig. 2). Exclusion from cattle grazing lasted approximately 2 years after chemical treatment. In general, the vegetation within the basin is representative of a sagebrush-grass ecosystem or sagebrush steppe, which comprises roughly 1/5 or 164 square miles of the upper Rio Puerco. Closely associated are pinyon-juniper woodlands that can be found on the ridges, mesas, and mesa side slopes.

Both treated and untreated study sites occur at an elevation between 7060 and 7120 m and lie within ~350 m of each other on small alluvial fans on south-facing slopes (Fig. 3). Mesas and slopes are situated within the sandy loam and clay loam rich Vessilla-Menefee-Rock outcrop complex that supplies the valley bottom with weathered sand originating from surrounding cliffs. Valley floors contain fine sandy loam and clays that belong to the Orlie-Sparham association (Soil Survey of Sandoval County, 1987).

BACKGROUND

Sagebrush Rangeland

The competitive characteristics of sagebrush (*Artemisia tridentata*) versus herbaceous plants and grasses on western rangeland are well recognized (Miller et al.,1980; Clary, et al., 1985; McDaniel, et al., 1992). Based on evidence from historical accounts and vegetation surveys over the past 100 years, open shrub communities have replaced grassland over many parts of the western United States. This phenomena has been attributed to cattle grazing, climate change, increased numbers of rodents, and fire suppression (Humphrey, 1958; Hastings and Turner, 1965; Abrahams et al., 1995). Schlesinger et al. (1990) suggested that while such factors may initiate

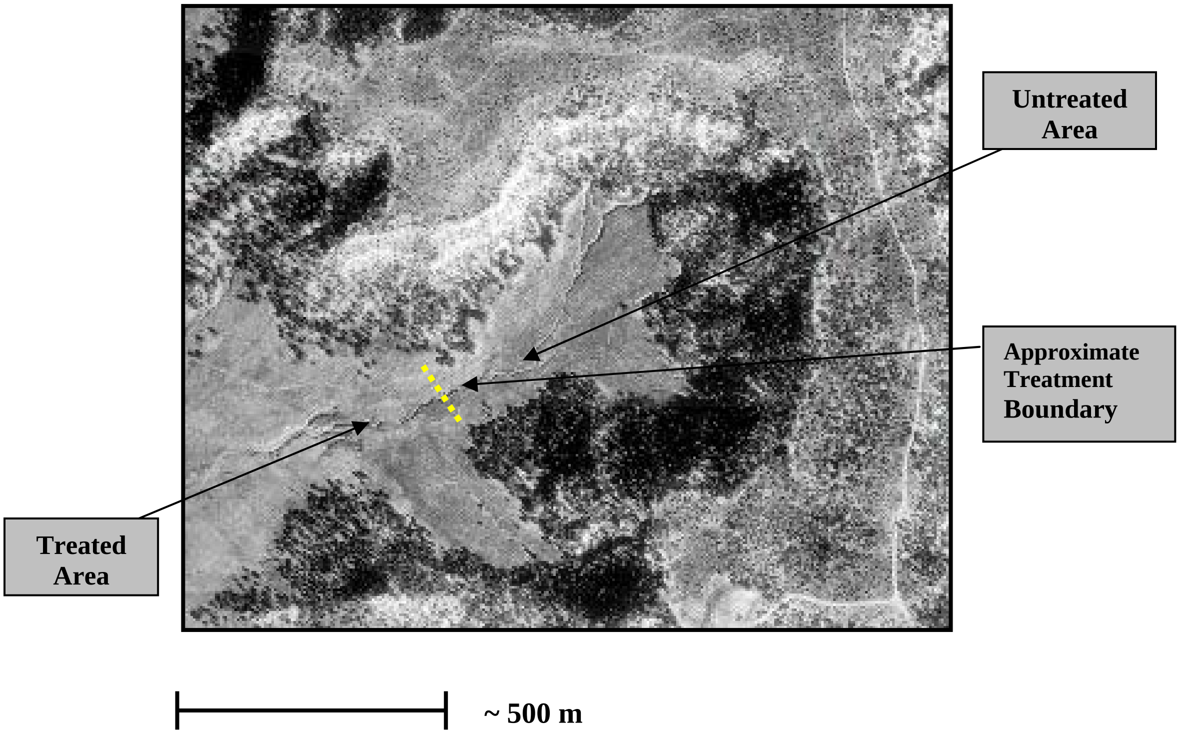


Figure 2: Aerial photo of Bastard Draw.

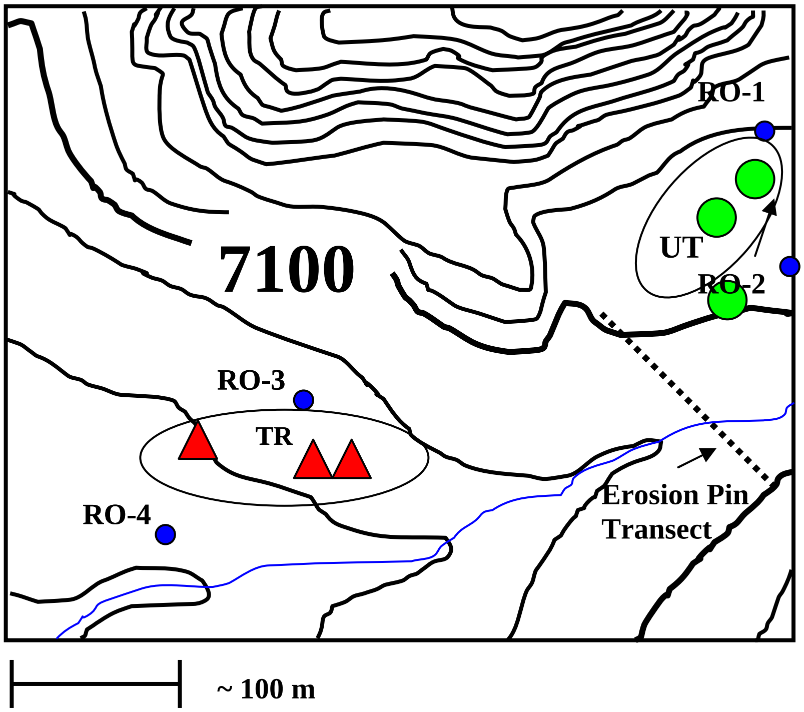


Figure 3: Location of treated (red) and untreated (green) rainfall simulation sites in Bastard Draw, T21N R2W, Arroyo Chijuillita, NM, 7.5 Quad, USGS. Circles display general sampling sites for treated and untreated areas.

the vegetation change, the proliferation and persistence of shrubs is due to a number of feedback mechanisms that enable the shrub community to become self-perpetuating.

Biologists use the term allelopathy to refer to biochemical interactions between different plants. Allelopathy refers to plants that produce one or more chemicals that have an inhibitory effect on nearby plants. Shrubs tend to be spaced very uniformly with respect to each other, and often the ground between the shrubs is devoid of grasses and other herbaceous plants. Sagebrush, especially its litter and fresh leaves, produces both water soluble and volatile chemicals (terpenes) that inhibit the germination and growth of other plant species (Hoffman and Hazlett, 1977; Benedict, 1991; Henry, 1998). This prevents nearby species from competing with the resident plants for water and nutrients, which in a desert are in short supply.

When combined with a mixture of grasses and forbs, big sagebrush is an integral part of the plant community. The root systems of all subspecies of big sagebrush are well adapted to extract moisture from both shallow and deep portions of the soil profile. This makes them highly competitive with associated grasses and forbs. As sagebrush density increases, reduced soil moisture and lowered water tables are observed (Henry, 1998).

Sagebrush Control

The sagebrush-grass ecosystem occupies a substantial portion of native rangelands in the western United States (Bastian, 1995). Estimates of coverage vary from 30 to 109 million ha (Blaisdell et al., 1982) with big sagebrush (*Artemisia tridentata*) being the dominant range cover on approximately 39 million ha in the West (Alley, 1965; Tisdale et al., 1969). Because sagebrush-grass communities are used to produce forage for livestock and wildlife, management of these rangelands has become an important subject for private ranchers and government agencies.

Techniques used to reduce sagebrush density in rangelands include burning, mechanical controls, plowing, and chemical spraying. Of these, plowing is the least effective (Bastian et al., 1995). Applications of chemical agents, such as 2,4-D (2,4-dichlorophenoxyacetic acid) and tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N-dimethylurea), commonly known as Spike, are very effective in controlling woody plants (Hull and Vaughn, 1951; Hull et al., 1952; Hyder and Sneva, 1962; Clary et al., 1985; McDaniel and Balliette, 1986; Olson et al., 1994). The effectiveness of tebuthiuron is dependent on its availability for plant uptake, which is dependent on soil characteristics (Henry, 1998).

Tebuthiuron is a broad-spectrum herbicide used to control weeds in non-cropland areas and rangelands. It is absorbed through roots, moves to the plant stems and leaves, and acts by inhibiting photosynthesis. Tebuthiuron is practically non-toxic to fish, birds, and mammals and is rapidly metabolized and excreted (Weed Science Society, 1994; U.S. National Library of Medicine, 1995).

Products formed by the breakdown of tebuthiuron by soil microorganisms are low in toxicity and therefore are no hazard to the environment. The chemical is absorbed easily by soils with high organic matter and clay content and has an average half-life of 12 to 15 months. Though tebuthiuron dissolves in water and is moderately mobile in soils, leaching usually does not carry the solute below 24 inches (Weed Science Society, 1994).

Forage response after control varies greatly, from 0 to 400% of production on comparable uncontrolled sites (Bastian, 1995). An increase in ground cover is usually observed within the next growing season but success of treatment depends on several conditions. Precipitation, composition of understory vegetation, sagebrush mortality, grazing management after control, and density of sagebrush before control all come into play (Pechanec et al., 1954; Mueggler and Blaisdell, 1958; Tabler, 1959; Kearl, 1965; Kearl and Brannan, 1967; Environmental Protection Agency, 1972; Bartolome and Heady, 1978; Smith and Busby, 1981; Blackburn, 1983; Alley and Bohmont, 1985; Sturges, 1986; Wambolt and Payne, 1986; Tanaka and Workman, 1988). Forage response also depends on rates of application, dates of spraying, and types of spraying carriers used (Hull et al., 1952; Cornelius and Graham, 1958; Hyder and Sneva, 1962; McDaniel et al., 1992).

The effect of big sagebrush control is highly variable and is influenced greatly by the degree of application. In Wyoming, Thilenius et al. (1974) observed some big sagebrush reinvasion within 10 years after herbicide application with the primary cause of re-invasion often being unkilled sagebrush (Johnson and Payne, 1968). In general, sagebrush control is expected to last between 15 to 25 years with maximum forage utilization increase assumed to occur in year 4 (Bastian, 1995).

Benefits of sagebrush removal are not just confined to an increase in understory vegetation. Sagebrush skeletons remain for many years after treatment and are important perch sites for a variety of birds and small mammals. Blowing snow is trapped during the cold season and further improves soil moisture availability (Henry, 1998). In addition, more palatable forage in treated sites attracts livestock and cattle, keeping them away from sensitive riparian areas. Blackburn and Pierson (1994) found that shrub cover or standing biomass indirectly control the runoff and erosion from sagebrush-dominated rangelands. Shrubs and grasses influence the site by modifying the microenvironment through addition of litter and organic matter to the soil surface, capturing wind and water born soil particles, and enhancing the micro-flora and micro-fauna.

Hydrologic Processes and Soil Erosion

Vegetation cover not only affects the timing of runoff and the percentage of precipitation that becomes runoff, but it also drastically affects erosion (Lusby, 1979; Blackburn, 1983). The loss of sediment and nutrients through rainfall runoff and erosion processes may reduce watershed productivity and lead to further loss of vegetation and increased erosion (Gifford and Busby, 1973).

Several models are available to describe mechanisms that produce runoff. These include: (1) Hortonian overland flow, which occurs when rainfall rate exceeds the infiltration rate of the soil and the excess precipitation flows over the ground surface; (2) saturated overland flow in which a high water table causes saturation and generates overland flow; (3) subsurface flow of infiltrated water moving laterally through the soil mantle; and (4) expansion of the channel system during storms to tap surface flow systems and permit overland flow from variable source areas (Ward, 1986).

In arid to semiarid regions, infiltration rates are generally lower than the rainfall intensities of most storms (Yair and Lavee, 1985), especially during the monsoon season. Occurrence of Hortonian overland flow is therefore considered to be high in frequency and magnitude (Yair and Lavee, 1985). Directly related to sheet flows are processes of sealing and crust formation that control infiltration of rainwater into bare soils (Morin and Van Winkel, 1996). Raindrop impact energy and intensity appear to be important parameters in crust formation or destruction by disintegrating soil particles. Water drops beat the soil surface and disrupt the aggregates, compact the upper soil layer, and seal the pore space with fine particles forming a crust upon drying (Ben-Hur et al., 1987). Formation of soil crusts may promote erosion, whereas increased soil strength may reduce detachment, erosion (Moore and Singer, 1990), and infiltration rates (Morin and Van Winkel, 1996**)**.

Other surface characteristics directly related to infiltration and erosion are soil surface roughness and macroporosity (Simanton and Renard, 1982). These parameters are not easily measured and are often replaced by more readily available measurements like bulk density (Dixon, 1975). Loss of bulk density, macropore space, and increase in soil surface compaction on rangeland can most commonly be related to cattle grazing but also depend on compaction force, soil water content, soil texture, and initial porosity (Gifford and Hawkins, 1976; Stephenson and Veigel, 1987; Scholl, 1989).

The fact that soil and vegetation influence the hydrologic response of sagebrush rangelands is well established. Blackburn (1975) and Johnson and Gordon (1988) found the existence of significant, small-scale spatial variability in hydrologic and erosion processes between sagebrush shrub and shrub-interspace areas (Pierson et al., 1994b). Moreover, overland flow through some sagebrush communities concentrates in the lower microtopographic positions between shrubs (Pierson et al., 1994a) and on bare areas devoid of vegetation. Consequently, increased sediment yields are produced due to a combination of greater discharge and lower resistance to flow.

Rainfall Simulations

Rainfall simulation is a valuable tool for assessing runoff and infiltration under a variety of field conditions. It allows the investigator to control where, when, and how data are collected. Through simulation, a controlled volume of water can be delivered over differing time intervals, providing data used for modeling hydrologic processes that are otherwise difficult to measure.

Many studies, in the field or in the lab, have successfully used rainfall simulations to investigate effects of runoff, infiltration, and soil loss (Chow and Harbaugh, 1965; Johnson and Gordon, 1988; Ward and Bolin, 1989). Results from rainfall simulation research have been used to determine temporal variability of soil erosion processes (Simanton et al., 1991), vegetation induced changes in interrill erosion (Blackburn and Pierson, 1994), and small scale spatial fluctuations of soil, plant, and hydrologic characteristics on soil erosion (Pierson et al., 1994a). Rainfall simulation experiments are also used to develop improved erosion-prediction technology for the National Water Erosion Prediction Project (WEPP) (Laflen et al., 1991).

On plots with different vegetative and soil surface conditions, numerous rainfall simulator studies have shown significant differences in plot responses (Blackburn, 1975; Bolton and Ward, 1991). Controversy remains as to whether shrub, grass, litter, or gravel covers are positively or negatively related to runoff (Kincaid et al., 1964; Tromble et al., 1974; Blackburn, 1975; Lane et al., 1987). Gifford (1985) suggests that vegetative cover between 50% to 60% tends to minimize erosion and maximize infiltration; any further increase in cover produces little improvement in either (Bolton and Ward, 1991).

Several general problems occur when analyzing data from rainfall simulations. First is the effect of scale. Ward (1986) and Ward and Bolin (1989) demonstrated that infiltration parameters are comparable between plots of different sizes though sediment yields per unit area (kg/ha) are about two to three times higher on small plots (1m^2) compared to large plots (186 m^2). Higher yields on small plots are related to the shorter travel distance of sediments to the collection point (Ward and Bolin, 1989) and the greater homogeneity of infiltration parameters over a small area.

Other studies have shown large sediment loads from parts of the slopes but at the same time, total sediment yields at the basin scale are minute in comparison (Rieger et al., 1988; Pierson et al., 1994b). On a small scale, erosion and deposition takes place across a landscape and does not result in large sediment loads being delivered to stream channels (Pierson et al., 1994b). Soil particles are eroded then deposited only a short distance away indicating that the erosion process is transport - and not detachment - limited (Pierson et al., 1994b). This suggests that predictions for small-plot erosion response may not be adequate to describe all the processes that take place across a landscape and that yields can be taken as a maximum.

The second general problem when comparing data from different simulators is developing an accurate and reliable method of measuring rainfall energy for simulators and natural storms (Ward and Bolton, 1991). Kinetic energy for rainfall is often in excess of what would be computed from the Universal Soil Loss Equation (USLE) algorithm (Tracy, 1984). This may lead to large errors when simulator results are used to predict yields from field-sized plots (Wicks et al., 1988).

Finally, infiltration rates vary with different devices and conditions. Field measurements of infiltration rates are frequently used to provide an on-site index of how soils respond during rainstorms. Aboulabbes et al. (1985) showed that infiltration ponding-ring rates determined from a infiltrometer are seldom the same as rainfall-defined rates, and thus should not be blindly used in rainfall-runoff generating schemes. Usually the ring measurements produce infiltration rates that are much higher than rainfall simulation rates. However, at low rates (less than 1 cm/hr, ring) rainfall appears to be higher (Aboulabbes et al., 1985).

METHODS

The study site was selected based on accessibility and the presence of both chemically treated and untreated sagebrush areas within the drainage. Several different methods were used to determine differences in sediment production and to assess vegetation between treated and untreated areas. These included (1) rainfall simulations on 1 m^2 plots to determine runoff characteristics and sediment yield; (2) natural runoff plots (3.5 m^2) to estimate sediment yield throughout the year; (3) an erosion pin transect to evaluate sediment dynamics across the landscape; and (4) vegetation assessments to measure changes in coverage and species diversity.

Rainfall simulations on 1 m^2 plots were conducted to collect sediment yield and runoff data from a total of thirty-six plot-runs (18 plots – dry and wet runs). A erosion pin transect and several natural runoff plots were used to monitor sediment movement in Bastard Draw throughout the year.

All soil samples from natural runoff plots, rainfall simulation plots, and ring infiltration sites were analyzed for particle size distribution, whereas soil horizons and alluvial stratigraphy in several pits were described and further examined for clay mineralogy using x-ray diffraction (XRD). Soil moisture, bulk density, and loss on ignition on soils were measured on the rainfall simulation plots. Vegetation assessments were used to determine biodiversity and differences in ground cover between treated and untreated areas. These included point frame vegetation cover estimates, line intercept vegetation transects, and plant identification.

Infiltration rates were measured with soil rings whereas parameters established from rainfall simulations were modeled to estimate Green-and-Ampt conductivities. Results from both approaches were used to interpret infiltration characteristics for treated and untreated sites.

Untreated and Treated Areas

Experimental areas in Bastard Draw were chosen based on similar south-facing aspect, slope (between 2 to 3 degrees), and presence of treated and untreated sagebrush (Fig. 4). However, both areas are located on different portions of different fans and therefore display variations in soil properties and particle size distribution (Fig. 5). The treated area is positioned on the more distal mid-section of a fan and contains greater amounts of fine material. The untreated area, near the apex of a fan, is closer to the sandy source of the surrounding outcrops and contains greater amounts of coarse material. With distance away from the source area, coarser material and sand is left behind and give way to silts and clays. Preliminary observations showed that gravel content is low for both areas though lateral fining of sediments is seen with distance from the surrounding cliffs and towards the center and mouth of the tributary.

Rainfall Simulations

Eighteen 1 m^2 rainfall simulation plots were randomly selected by throwing an object onto the selected area (either treated or untreated) and placing the plot on or near the object's point of landing. By using this method, three grass (Fig. 6), three shrub (Fig. 7), and three bare plots (Fig. 8) were chosen in the treated and untreated area for a total of eighteen plots (Fig. 9). All were covered with plastic sheets to reduce disturbance and to ensure consistent initial soil moisture since the experiments took place over several days and afternoon thunderstorms were possible.

Figure 4: Comparison of chemically treated (above) vs. untreated (below) areas.

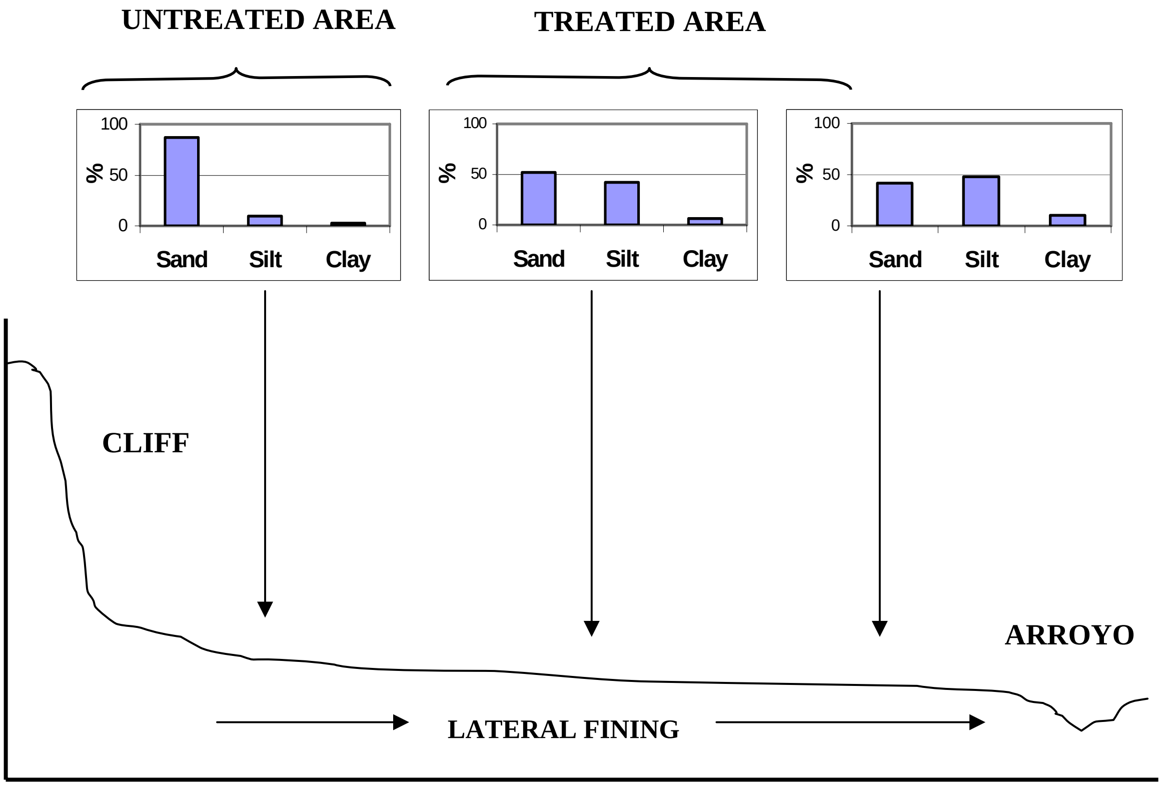


Figure 5: Generalized sketch of lateral fining within drainage relative to location of untreated and treated areas. Estimated sand, silt, and clay content was calculated from particle size data from natural runoff plots. For detailed location of sampling sites, refer to Figure 3.

Preparation of each plot began by placing a 1 m^2 metal frame and runoff tray into the ground and securing the corners and sides so that no moisture could flow underneath (Fig 10). A PVC pipe trough was placed in front of the runoff tray to collect the deposited sediments and runoff during rainfall simulation. The pipe was connected to a small pump that allowed periodic pumping of runoff as it collected in the trough. The volume of pumped runoff was measured and transferred into a collection barrel from which suspended sediments were sampled after completion of each run. Similarly, deposited sediments that collected in the trough were retrieved for further analyses in the laboratory (see laboratory techniques in this section).

Grass Treated

Grass Untreated

Figure 6: Typical surface characteristics for treated (above) and untreated (below) grass plots. Rainfall simulation plots measure 1 m^2.

Shrub Treated

Shrub Untreated

Figure 7: Typical surface characteristics for treated (above) and untreated (below) shrub plots. Rainfall simulation plots measure 1 m^2.

Bare Treated

Bare Untreated

Figure 8: Typical surface characteristics of treated (above) and untreated (below) bare plots. Rainfall simulation plots measure 1 m^2.

Flowchart

(see file flowchart.doc)

Figure 10: Sprinkler system over rainfall simulation plots. Tower height is 2.06 m.

Two rainfall simulations were performed on each plot; first, the dry run on the initially dry soil. After each dry run, the plot was covered with plastic until the following morning when the wet run was carried out. Dry and wet runs are commonly used to evaluate runoff behavior and sediment production during preceding moisture conditions and at field capacity (Pierson et al., 1994a; Simanton and Emmerich, 1994). The first two runs (dry and wet) on the untreated grass plots lasted 30 minutes, but rainfall duration was later reduced to 20 minutes to preserve water. However, the first two runs on treated grass plots also lasted 30 minutes to ensure that all grass plot results were compatible. Upon completion of the wet run, the metal frame was removed and southwest and northeast corners of the plot were marked with 15-inch long rebar. A detailed description of the experiment is outlined in Appendix H.

Figure 11: Original (above) and final set-up (below). The large pump was replaced by a small aquarium pump that delivered water to the sprinkler system.

Creation of constant rainfall intensities proved to be a problem. Changing water pressure and fluctuating electrical supply from the generator made it difficult to regulate the rate of rainfall. When the water flow was restricted, it resulted in irregular rainfall patterns that did not cover the entire plot so rainfall had to be increased to an average 270 mm/hr. Although this is a very high rate, it is not unheard of for natural rainstorms in New Mexico but it does exceed the level needed for full-area runoff contribution (T.J. Ward, personal communication 2001).

Runoff Plots

To measure the effect of natural rainfall events throughout the year, four natural runoff plots were installed in Bastard Draw. Plots were specifically located in areas that represented high grass cover in the treated and low grass cover in the untreated area. A soil pit between 0.5 and 0.6 m deep was excavated, soil profiles were described, and samples were taken that were later analyzed for particle size. Descriptions for soil profiles used terminology developed by the Soil Survey Division Staff (1993) outlined in Birkeland (1999).

A 26-gallon plastic garbage can was placed into the pit and covered with corrugated sheet metal and rocks to protect it from rainfall or runoff other than from the plot itself (Fig. 12). Plots were enclosed by installing three-inch galvanized sheet metal flashing and defined a circumference that generally measured between 7.1 and 7.2 meters. Each plot was surrounded by mesh wire to discourage cattle from disturbing the soil. To collect rainfall runoff and sediment, a galvanized rain gutter pipe connected the sheet metal with a garbage can that was inspected when the field site was visited. Water volume in the garbage can was recorded and bottom sediments were collected and analyzed for weight in the lab. Consistent sampling of suspended sediments was not possible and was therefore disregarded.

Figure 12: Typical layout of runoff plots (RO-4 in treated area shown).

Erosion Pins

An erosion pin transect was established in the untreated portion of Bastard Draw to measure the dynamics of sediment movement throughout the year. Ten 15-inch-rebar stakes were placed along a north-south bearing across the tributary at intervals between 10 to 25 m. The visible part of the rebar was measured and its length recorded. Initial numbers were then normalized to zero so that later measurements throughout the year could be used to determine if erosion or aggradation took place around the pin.

Survey

Rainfall simulation plots were surveyed with a Trimble Pro XRS TSC 1 Asset Surveyor. The Global Positioning System (GPS) unit was placed on each of the four corners of the 18 rainfall plots. Natural runoff plots and the erosion pin transect were surveyed with a Trimble Pathfinder Geoexplorer II. Data were analyzed using Pathfinder Office 2.5 software and transferred into ArcView® to allow for more detailed location plotting.

Vegetation Cover Estimates and Transects

A point frame was used to obtain vegetation cover estimates for each of the 18 plots following methods described by Bonham (1989). Ten pinholes made up the 1 m long point frame so that 100 measurements were taken over each 1 m^2 plot (Fig. 13). When the pin was lowered, the first type of vegetation (first hit) was recorded so that the total vegetation coverage was estimated and could later be transformed into percentage grass, shrub, and bare.

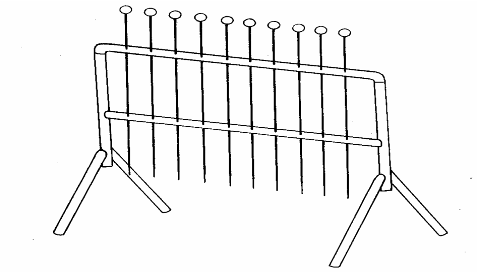


Figure 13: Point frame with 10 pins (from Bonham, 1989).

Twenty vegetation cover estimates were also obtained using the line intercept method (Bonham, 1989). A tape was stretched for 25 m at ground level from a random point at an azimuth of 300 degrees in both treated and untreated areas. The azimuth of 300 degrees was randomly determined before taking any of the transects to reduce bias. The total linear length (or sum) of grass, shrub, or bare patches was measured, recorded, and divided by the length of the tape to obtain percentage of cover. Averages of the linear patch sizes were also used and calculated by taking the length of all individual patches, i.e. shrub (Fig. 14), and averaging it.

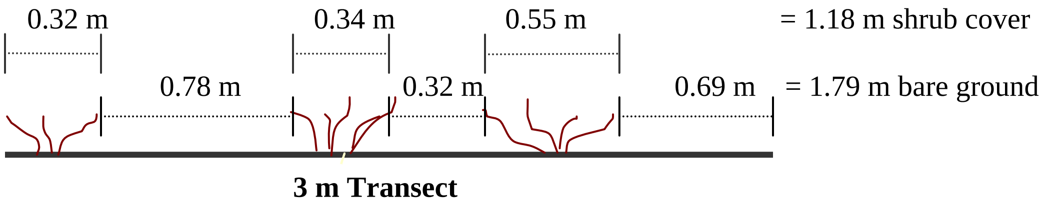


Figure 14: Measurement, for example sum of shrub cover and bare ground (above), of vegetation transects. Linear length recorded was either averaged or added together and displayed as a mean or sum of all transects.

Rainfall Intensities and Runoff -to-Rainfall Ratios

Differences in intensity values were caused by failure of the original pump system. The replacement pump was unable to provide uniform pressure, which made it difficult to control rainfall intensities for all 36 plot runs. Runoff-to-rainfall ratios were therefore compared for equal time and equal rainfall depth components of the rainfall simulations to ensure that the application of different rainfall intensities had no effect on the ratio.

Equal rainfall depths for all plots were calculated based on the lowest intensity value (70 mm or 210 mm/hr) found on the treated Bare 1 Dry plot after a twenty minute rainfall (Appendix B). Calculations included: (1) the time when 70 mm of water rained on each plot; and (2) the new runoff to rainfall ratios when 70 mm of water were applied on the plot (equal depth). Original runoff-to-rainfall ratios (equal time at 20 min.) were compared to new ratios established from the equal depth application. T-tests showed no significant differences between the original and newly calculated ratios.

Laboratory Techniques

Deposited Sediment Samples

Deposited sediment samples from rainfall simulation experiments were placed into pre-weighed containers and dried at 105°C overnight. After cooling, samples were weighed again to record the amount of sediments gathered from each plot. The deposited sediments were then presented as concentrations of sediment per volume of water or mg/l of runoff using the following conversions:

$$\frac{g\ deposits}{mm\ runoff} * \frac{1}{m^2} * 10 = \frac{kg}{ha - mm} \tag{1}$$

Note that the units of kg/ha-mm are equivalent to concentration through the following:

$$mg / l / 100 = kg / ha - mm \tag{2}$$

Throughout the remainder of the paper, the concentration of kg/ha-mm will be addressed as sediment yield. Particle size analysis was utilized to determine percent sand, silt, and clay fractions. Procedures are outlined under Particle Size Distribution and X-Ray Diffraction in this section.

Suspended Sediment Samples

Suspended sediment samples were analyzed for electrical conductivity, dried on a hot plate, and put into the oven overnight at 105°C to ensure that samples were completely dry. Measurement of conductivity was necessary because water used for the rainfall simulations contained soluble salts. The weight of dissolved solids (DS in g) was calculated using the following equation:

$$DS = 0.7\left[Cond * \left(\frac{Water}{1000}\right)\right] \tag{3}$$

where Cond is conductivity in milliSiemens, 0.7 is a conversion factor (American Public Health Assoc., 1992), and Water is the weight of water in the jar in grams. Subtraction of the DS from the total amount of residue (eq. 4) in the jars yielded the weight of suspended solids derived from the rainfall plot during the simulations.

$$Suspended\ solids\ weight(g) = Sample\ weight(g) - Weight\ of\ dissolved\ solids(g) \tag{4}$$

The suspended solids were then converted into yields per unit runoff, or kg/ha-mm, using equations 1 and 2.

Soil Moisture and Bulk Density

For each dry and wet run, soil ring samples (100 ml) were taken from the upper 5 cm of soil adjacent to the plot. These were placed in pre-weighed metal soil cans, sealed, and labeled. In the lab, the lids were removed, the filled cans were weighed and placed in an oven at 105°C overnight. After drying, the cans were re-weighed and the soil moisture percentage calculated by dividing the weight of water by the weight of oven-dried soil. Dividing the soil weight by 100 cm^3 (volume) yielded bulk density in g/cm^3.

Loss on Ignition

Loss on ignition (LOI) was determined by placing oven-dried soil samples into cans, which were weighed and put into a muffle furnace at 550°C for 3 hours. Samples were taken out of the furnace every 20 to 30 minutes and quickly stirred to ensure that all organic material volatized. After cooling, the cans were re-weighed and the LOI loss calculated by subtracting the weight after from the weight before the furnace treatment. The LOI expressed as a percentage is calculated by:

$$\%\,LOI = \frac{sample\,before(g) - sample\,after(g)}{(Sample\,weight\,before\,(g) - Tin\,weight\,(g))} * 100 \tag{5}$$

The LOI data presented in the Results section assumes that the weight loss of samples is attributable to the total amount of organic carbon.

Particle Size and X-Ray Diffraction

Particle size analysis and X-Ray Diffraction (XRD) followed procedures used by the New Mexico Bureau of Mines and Mineral Resources Clay Lab (modified from Folk 1974) (Austin, written communication, 2000) as follows. (1) Two sediment samples are split to retain a duplicate by placing 15 to 20 g into pre-weighed beakers in an oven at 105°C overnight. The beaker is than removed from the oven, placed in a dessicator, and allowed to cool for about 20 to

30 minutes. After removal from dessicator, the beaker (with sample) is weighed to 4 decimal places. The sample is wet sieved in a shaker, the water and clay/silt fraction is collected in a flask, and the sand fraction is left in 2 stacked sieves (>230µ). The clay/silt water is put into a 1000 ml container and allowed to stand undisturbed for 30 minutes. On a sample sheet, the amount of water in the flask is recorded using multiplication factors for calculations outlined in Table 1.

Table 1: Multiplication factors for particle size calculations.

Amount of water used	Multiplication factor
1000 ml	x 25
1200 ml	x 30
1400 ml	x 35
1600 ml	x 40

Next, the sand fraction is removed from sieves into a beaker and placed into an oven at 105°C overnight. Using a pipette, 40 ml of the clay suspension is extracted from the upper 1 cm of the container, put into a small beaker, placed in the oven, and dried overnight. After cooling, the dried samples are weighed, values are recorded, and sand, silt, and clay fractions are calculated. Duplicates need to be within ±2%.

XRD analysis included air-dried clay mineralogy, bulk mineralogy, ethylene glycol treatment, and heat treatment (Appendix E). Particle size analysis and XRD were performed on soil samples collected from the four natural runoff plots. Deposit samples from the rainfall simulations were analyzed for particle size distribution only. None of the suspended samples were analyzed for particle size distribution due to small sample size after drying and residue from water.

Infiltration Rates

Several approaches were used to determine infiltration rates in the treated and untreated areas including ring infiltrometry. A small metal soil ring (100 ml) was filled with water and the time to infiltrate 1 cm (marked below the rim) was measured at 14 bare spots and 10 coppice dune sites underneath shrubs in the treated and untreated area. Infiltration rates were also determined from the rainfall simulations using the Green & Ampt (1911) model. This is a physical process model that relates the rate of infiltration to measurable soil properties such as the porosity, hydraulic conductivity, and the moisture content of a particular soil. The cumulative infiltration as a function of time can be written in the form (Green and Ampt, 1911; Mein and Larson, 1973)

$$K_S(t - t_p + t'_p) = F - (\phi - \theta_i)\Phi_f \ln\left[1 + \frac{F}{(\phi - \theta_i)\Phi_f)}\right] \tag{6}$$

where K_s is the hydraulic conductivity over time in the wetted zone (mm/hr), F is the total water infiltrated (mm), ϕ is the soil porosity (%), θ_i is the initial volumetric water content of the soil, Φ_f is the wetting front suction or head at wetting front (mm), and the times t (min) are, respectively, total time (t), time to ponding (t_p), and time to infiltrate F under the condition of surface ponding from t = 0 (t'_p).

Soil water content was measured from field samples, and porosity was calculated from bulk density data. Soil suction head was estimated by using a geometric mean of the results of two equations (7 and 8) from Ward and Bolton (1989, 1991).

$$\log(Y_c) = 3.69 - 1.67\log(K_s) \tag{7}$$

$$\log(Y_c) = 2.53 - 1.18\log(K_s) \tag{8}$$

where Y_c is the capillary head in mm of water and K_s saturated hydraulic conductivity in mm/hr. Ward and Bolton (1989, 1991) related K_s to Φ_f using numerous rainfall simulation results in New Mexico and Arizona. The two parameters are physically and computationally inversely related, as the equations demonstrated.

Statistical Techniques

Histograms were made for each of the data sets to determine the type of underlying distribution. Two-way analysis of variance (ANOVA) and interaction and paired t-tests were calculated in Microsoft Excel (Appendix I). For all approaches, confidence levels of 95% ($p < .05$) were used. Data were generally compared by using sums and averages of the triplicate runs for grass, shrub, and bare plot types in untreated vs. treated areas and dry and wet runs.

RESULTS

Vegetation Assessments

Point-frame Counts

Point-frame counts were used on all rainfall simulation plots to determine percent coverage of grass, shrub, and bare area (Fig. 15; Appendix E). Grasses increased from 48% to 74% on treated areas and there was a two-fold decrease to 26% bare space on treated grass plots. Treated shrub plots reveal a three-fold increase in grass coverage and an almost three-fold reduction in bare space as a direct result of the eradication of sagebrush.

Shrub percentages for treated and untreated plots were kept similar and measured as canopy, either dead or alive, for the purpose of providing a comparable area of interception during the rainfall simulations. However, grasses on treated shrub plots increased almost three-fold whereas bare area was reduced from 48% to 18%. The bare plots acted as controls based on the lack of vegetation and show similar bare ground percentages above 90%.

Vegetation Transects

Although point frame counts show that vegetation differed on the thirty-six 1 m^2 simulation plots, it is important to measure larger vegetated areas representative of the treated and untreated portions of the tributary. Twenty such transects show that grass coverage increased more than three times in the treated compared to untreated area (Table 2; Figs. 16 and 17).

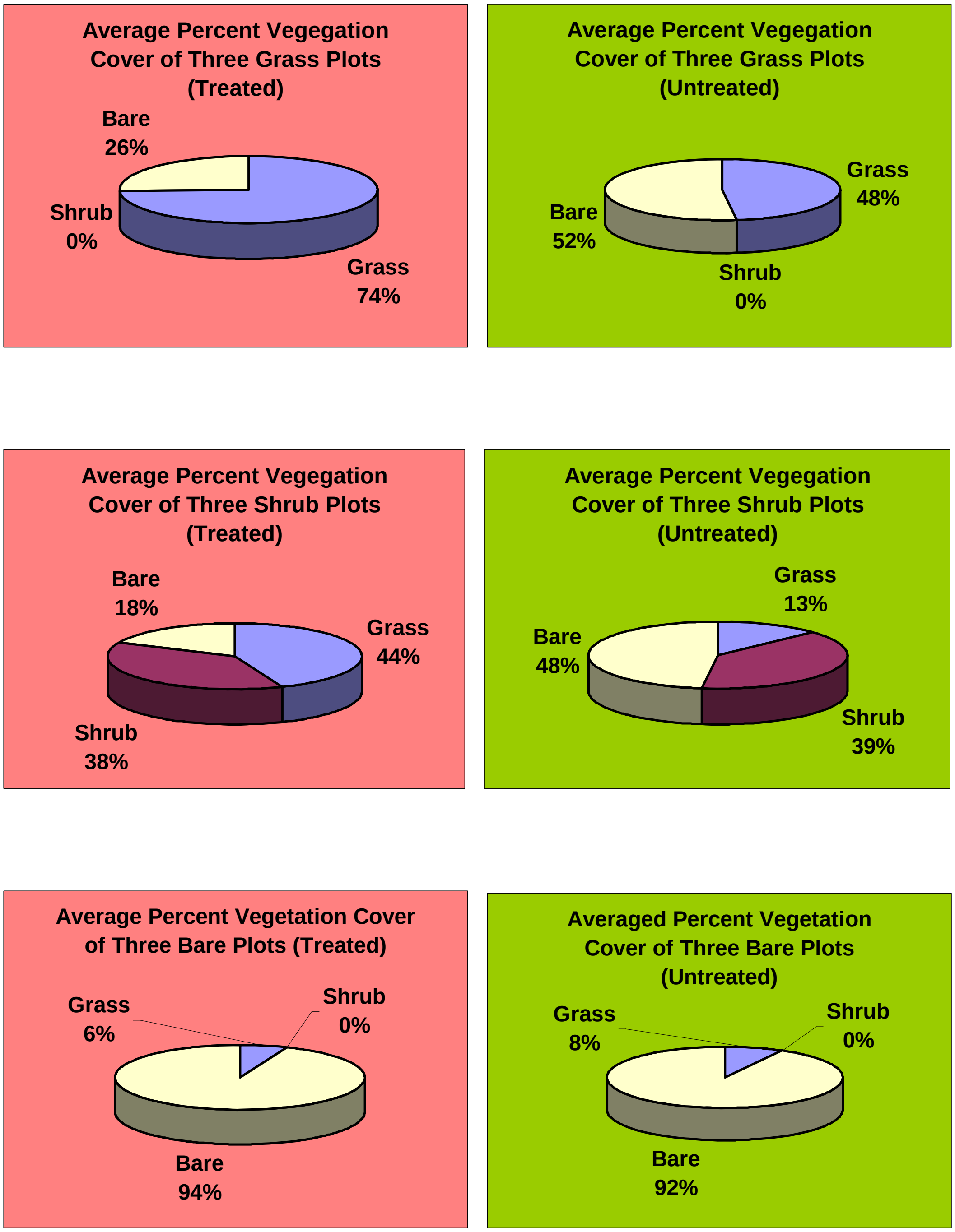
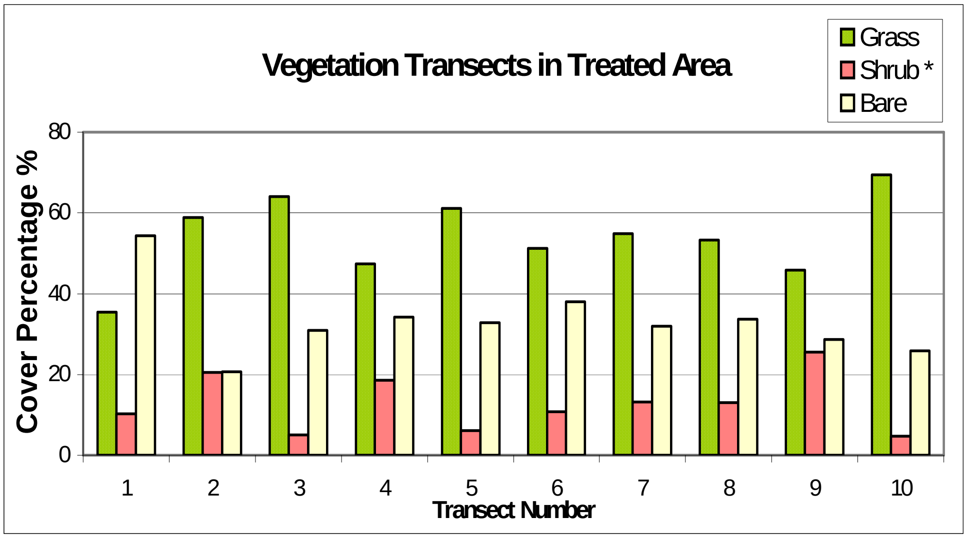


Figure 15: Average percent grass, shrub, and bare coverages on rainfall simulation plots from point frame counts.

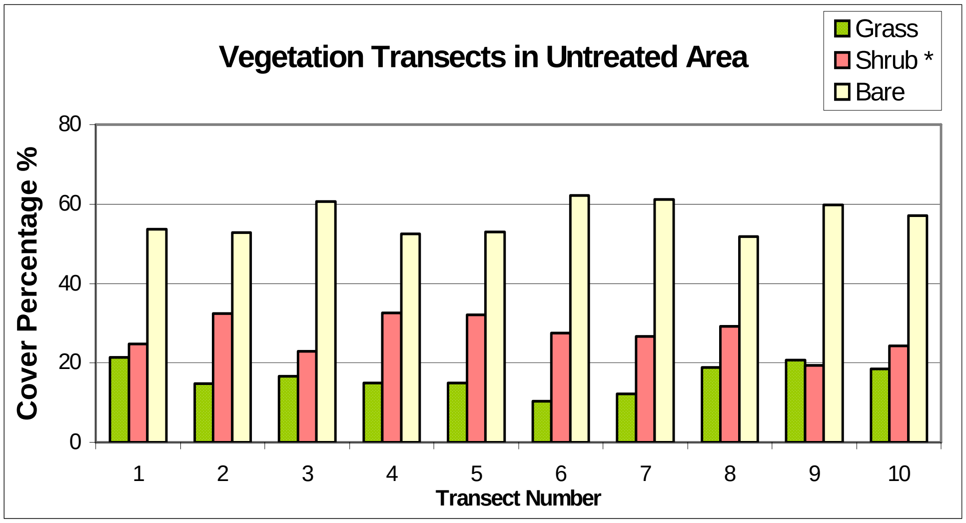
Table 2: Cover percentages for ten vegetation transects in treated and untreated areas.

	Grass TR	Grass UT	Shrub TR	Shrub UT	Bare TR	Bare UT
Median	54.10	15.84	11.88	27.06	32.34	55.42
Average	**54.15**	**16.35**	**12.78**	**27.21**	**33.08**	**56.47**
Std. Dev.	9.89	3.60	6.96	4.46	8.88	4.14



* Shrub measured as canopy. Includes dead sagebrush in treated area.

Figure 16: Vegetation transect in treated area.



* Shrub measured as canopy. Includes dead sagebrush in treated area.

Figure 17: Vegetation transects in untreated area.

Bare soil patches decreased from 56 to 33 percent in the treated area whereas shrubs show a reduction from 27 to 13 percent with treatment (Table 2). These data, however, are not as representative as the grass and bare results because dead sagebrush was measured the same as live shrubs to account for similar interception during rainfall simulations.

Average linear patch sizes were calculated from all transects in both treated and untreated areas (Table 3 and Appendix D). These data show that average grass patch size increased four-fold after treatment to 0.43 m. Shrub canopy decreased from 0.63 m to 0.42 m, with the latter being represented by dead sagebrush that will decrease further in size over time as the brush slowly breaks down. The averaged bare soil area data on transects is surprising because although the overall percentage decreases, bare patches are only slightly smaller and remain at about 0.28 m even after the area was treated.

Table 3: Average size of grass, shrub, and bare patches (in meters) for ten vegetation transects in both treated and untreated areas.

	Grass TR	**Grass UT**	**Shrub TR**	**Shrub UT**	**Bare TR**	**Bare UT**
Median	0.44	0.10	0.41	0.61	0.28	0.32
Average	**0.43**	**0.11**	**0.42**	**0.63**	**0.28**	**0.33**
Std. Dev.	0.12	0.02	0.14	0.09	0.07	0.07

Plant Identification

The abundance and diversity of plant species in treated and untreated areas were measured. A total of 24 herbaceous and woody species were identified in the two areas of which 19 were found in the untreated and 23 were found in the treated area (Table 4). Grasses were also identified (Table 5). Out of seven grass species encountered in the treated area, only three are found in the untreated portion of the tributary. By far the most common, blue grama (*Bouteloua gracilis*), can be found everywhere though stands are thicker and even taller in the treated area. Unfortunately, cold-winter species are not represented in the count; however, the diversity and abundance of grasses in the treated area shows an improvement of ground coverage.

Table 4: List of plants found throughout treated and treated areas within Bastard Draw.

Plant Name		**TR**	**UT**	**Origin***	**Palatability (cattle)****
Big Sagebrush	*Artemisia tridentata*	**X**	**X**	**N**	**Poor**
Four wing saltbrush	*Atriplex canescens*	**X**	**X**	**N**	**Good**
Desert paintbrush	*Castilleja chromosa*	**X**	**X**	**N**	
Rabbit brush	*Chrysothamnus nauseosus*	**X**	**X**	**N**	**Poor**
Spectacle Pod	*Dithyrea wislizenii*	**X**	**X**	**N**	
Fleabane	*Erigeron spp.*	**X**	**X**	**N**	
Bush buckwheat	*Eriogonum leptophyllum*		**X**	**N**	
Yellow Gaillardia	*Gaillardia pinnatifida*	**X**	**X**	**N**	**Poor**
Gumweed	*Grindelia squarrosa*	**X**	**X**	**N**	**Not**
Broom snakeweed	*Gutierrezia sarothrae*	**X**	**X**	**N**	**Not**
Sunflower	*Helianthus spp.*	**X**		**N**	
Pale trumpets	*Ipomopsis longiflora*	**X**	**X**	**N**	
Skyrocket	*Ipomopsis aggregata*	**X**		**N**	
Juniper	*Juniperus* spp.	**X**	**X**	**N**	**Not**
Primrose	*Oenothera* spp.	**X**		**N**	
Prickly pear	*Opuntia* spp.	**X**	**X**	**N**	**Poor**
Pinon	*Pinus edulis*	**X**	**X**	**N**	**Poor**
Paperflower	*Psilostrophe cooperi*	**X**	**X**	**N**	
Skunkbrush	*Rhus trilobata*	**X**		**N**	**Fair**
Russian thistle	*Salsola australis*	**X**	**X**	**I**	**Fair**
Threadleaf groundsel	*Senecio douglasii*	**X**	**X**	**N**	
Western salsify	*Tragopogon dubius*	**X**		**I**	**Poor**
Cocklebur	*Xanthium strumarium*	**X**	**X**	**I**	**Not**
Cota (Navajo tea)	*Thelesperma megapotamicum*	**X**	**X**	**N**	

* N = Native
I = Introduced
** U.S. Department of Agriculture, 2001

Table 5: List of grasses found throughout treated and treated areas within Bastard Draw.

Grasses		**TR**	**UT**	**Origin***	**Palatability (cattle)****
Wheatgrass	*Agropyron desertorum*	**X**	**X**	**I**	**Fair**
Three-awn, red	*Aristida purpurea*	**X**		**N**	**Poor to Fair**
Blue grama	*Bouteloua gracilis*	**X**	**X**	**N**	**Good**
Bottlebrush squirreltail	*Elymus elymoides*	**X**		**N**	**Fair**
Alkali sacaton	*Sporobulus airoides*	**X**		**N**	**Fair to Good**
Mesa dropseed	*Sporobulus flexuosus*	**X**		**N**	**Fair**
Indian ricegrass	*Stipa hymenoides*	**X**	**X**	**N**	**Good**

* N = Native
I = Introduced
** U.S. Department of Agriculture, 2001

Although an increase in grass and plant diversity reflects promising changes, it is important to ask whether these species reflect a degradation of rangeland. Fortunately, all collected plant and grass species are native to the area, with the exception of Russian thistle (*Salsola australis),* western salsify (T*ragopogon dubius),* cocklebur (*Xanthium strumarium),* and desert wheatgrass (*Agropyron desertorum).* The palatability of grasses for cattle grazing ranges from fair to good except three-awn (*Aristida purpurea),* which is poor to fair. The limited presence of introduced species is most likely due to minimal disturbance of the soil because the chemical treatment was applied by plane. Any mechanical tilling, chaining, or burning would have made the area more susceptible to weeds and other less desirable plants.

Particle Size Distribution and Soil Morphology

Particle Size Analysis Results from Rainfall Simulations

Significant differences in particle sizes of deposited sediments between treated and untreated areas are found for the sand, silt, and clay percentages on dry runs (Table 6; statistical results are summarized in Appendix I). Clay percentages of wet runs on bare plots and sand and silt percentages on wet shrub-plot runs also differ significantly between treated and untreated areas. In most cases, the sand fraction increases slightly with the wet runs, whereas most plots show a decrease in silt fraction. Grass plots in the treated area contain higher sand fractions compared to surrounding shrub and bare plots. All three plot types had a reduction in the clay size fraction with the wet run except with the treated shrub plots where an increase is observed. Size fractions of sediments of all bare plots and the sand fraction of the shrub plots were significantly different between both treated and untreated areas.

Table 6: Averages and standard deviations (in parenthesis) of particle size distribution of deposited sediments for untreated and treated simulation plots. Values were calculated from triplicate runs.

	Untreated			**Treated**		
Plot	**Sand**	**Silt**	**Clay**	**Sand**	**Silt**	**Clay**
Grass Dry	81.05 (5.39)	17.15 (5.54)	1.81 (0.34)	73.57 (12.48)	22.20 (9.42)	4.20 (3.18)
Grass Wet	83.79 (4.11)	14.51 (4.07)	1.71 (0.16)	79.97 (6.67)	16.63 (5.49)	3.41 (1.37)
Shrub Dry	86.11 (11.07)	11.50 (9.71)	2.39 (1.36)	69.70 (7.77)	25.38 (8.94)	4.91 (2.57)
Shrub Wet	91.07 (3.48)	7.36 (3.41)	1.56 (0.17)	67.26 (4.50)	26.33 (0.87)	6.41 (4.37)
Bare Dry	92.14 (3.25)	6.29 (3.05)	1.57 (0.32)	61.55 (10.38)	35.38 (10.59)	3.08 (0.36)
Bare Wet	86.92 (12.58)	11.70 (12.34)	1.37 (0.32)	66.40 (11.16)	30.77 (11.42)	2.84 (0.48)

Particle-Size Analysis and Stratigraphic Profile Descriptions from Natural Runoff Plots

Particle-size-distribution data from the stratigraphic profiles observed in pits of the natural runoff plots are similar to those from rainfall simulation plots (Table 7). In general, three stratigraphic units were identified for each 0.5-meter-deep pit except for RO-2, which contained four (Appendix C). Untreated runoff plots are on weakly developed yellowish brown soils of loamy sand or sandy loam. At about 0.25 m depth, an increase in clays is observed which occurs as clay films on ped faces or in interstitial pores. Soils present in the treated area are yellowish brown fine silty clay loams and silty clays that overlie brown sandy loams. Clays are distinct at much shallower depths, generally as films, in pores, and as coats and bridges holding grains together. No carbonates were detected in the soils.

Lateral fining of particle sizes is observed with distance from the surrounding outcrops towards the center of the tributary. This is reflected by a steadily decreasing amount of coarse material from RO-1 to RO-3. Plot RO-4, located near the center of the tributary, differs most by having the lowest sand and highest silt and clay fractions of all soil pits in its upper stratum.

Table 7: Particle size distribution in depositional units of four natural runoff plots.

	Depth	Untreated				Depth	Treated		
Plot	**(cm)**	**Sand**	**Silt**	**Clay**	**Plot**	**(cm)**	**Sand**	**Silt**	**Clay**
RO1-1	0 – 3	85.52	11.30	3.18	**RO3-1**	0 – 3	70.51	26.92	2.58
RO1-2	3 – 27	89.29	8.71	2.00	**RO3-2**	3 – 27	42.41	49.81	7.78
RO1-3	27 – 50	57.40	34.84	7.76	**RO3-3**	27 – 50	61.40	33.46	5.15
RO2-1	0 – 5	86.37	11.09	2.55	**RO4-1**	0 – 2	30.89	54.75	14.37
RO2-2	5 – 25	89.07	8.58	2.36	**RO4-2**	2 – 25	52.65	41.15	6.21
RO2-3	25 – 32	68.36	26.88	4.77	**RO4-3**	25 - 50	84.29	12.64	3.08
RO2-4	32 - 50	78.01	18.01	3.99					

Additional bulk mineralogy analyses and X-Ray diffraction (XRD) undertaken for all soil horizons show that the majority of minerals present in the soils are quartz and feldspars (Appendix G). XRD analysis showed equal distributions of illite, smectite, and mixed layer clays. However, kaolinite is found to be significantly higher in the treated area (Appendix D).

Bulk Density, Soil Moisture, and Loss on Ignition

Bulk Density

Average bulk density values of surface soil horizons from rainfall simulation plots range from 1.26 to 1.50 g/cm^3 for both treated and untreated areas (Table 8). During the wet run, average bulk density increased slightly by one to two tenths for most plots. Averages for each application (dry or wet) and treatment type, however, show that bulk density is slightly lower for all treated plots except bare.

Soil Moisture

Soil moisture measurements taken before dry and after wet runs were not significantly different between treated and untreated areas (Table 8). Dry and wet runs for each plot type, however, were all significantly different. Average moisture content, by weight, ranges between 1.96 to 6.69 percent for dry plots and 14.95 to 21.58 percent for wet plots. When the three wet runs for each treatment type are averaged and compared, moisture contents for treated plots are about two to three percent higher for the bare and shrub plots, respectively and five percent higher for grass plots.

Table 8: Averages and standard deviations (in parenthesis) for bulk density, soil moisture, and total organic carbon values from triplicate rainfall simulations between treated and untreated areas.

	TR Bulk Density g/cm^3	UT Bulk Density g/cm^3	TR Soil Moisture %	UT Soil Moisture %	TR Loss on Ignition %	UT Loss on Ignition %
Grass Dry	1.26 (0.19)	1.42 (0.05)	3.47 (0.83)	1.96 (0.07)	4.37 (1.17)	1.87 (0.09)
Grass Wet	1.48 (0.05)	1.50 (0.03)	21.50 (3.31)	16.72 (1.96)	2.81 (0.49)	2.25 (0.64)
Shrub Dry	1.29 (0.09)	1.34 (0.05)	6.26 (3.32)	6.69 (4.19)	3.31 (1.24)	2.71 (0.36)
Shrub Wet	1.34 (0.10)	1.43 (0.09)	21.58 (4.36)	18.27 (3.56)	3.25 (1.61)	2.20 (0.74)
Bare Dry	1.42 (0.12)	1.39 (0.03)	4.74 (1.46)	6.66 (2.18)	2.36 (0.85)	1.71 (0.91)
Bare Wet	1.43 (0.03)	1.43 (0.05)	16.53 (1.33)	14.95 (1.85)	2.12 (0.38)	1.14 (0.33)

Loss on Ignition

The majority of samples show a decrease in soil organic carbon (as measured by loss on ignition) after wet runs though two out of three samples on wet untreated grass and treated shrub plots contain higher LOI percentages than before (Table 8 and Appendix C). Results were only significantly different on wet runs between treated and untreated bare plots.

Rainfall Intensity

Rainfall intensities during 36 rainfall simulation plot-runs varied between 210 and 320 mm/hr (Figs. 18 to 20). T-tests show that rainfall intensity of dry runs on shrub and bare plots between treated and untreated areas were significantly different. Average intensity values of all plot types and dry and wet runs (Table 9) range between 236 mm/hr for grass dry runs and 301 mm/hr for bare wet runs.

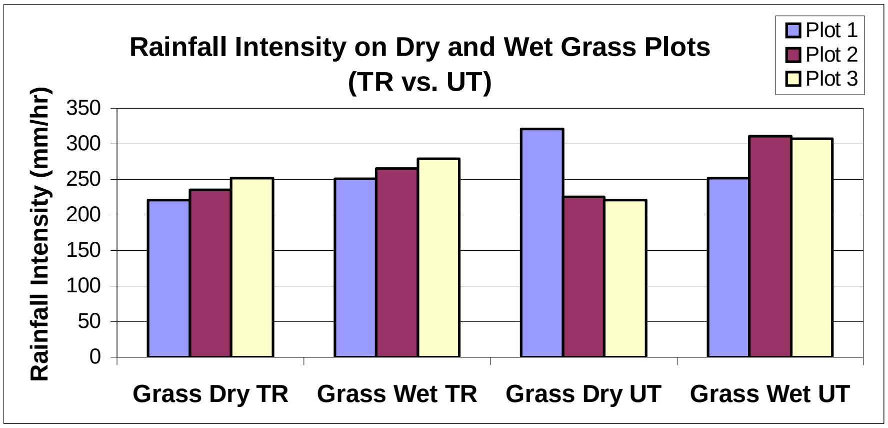


Figure 18: Rainfall intensity of dry and wet runs on grass plots.

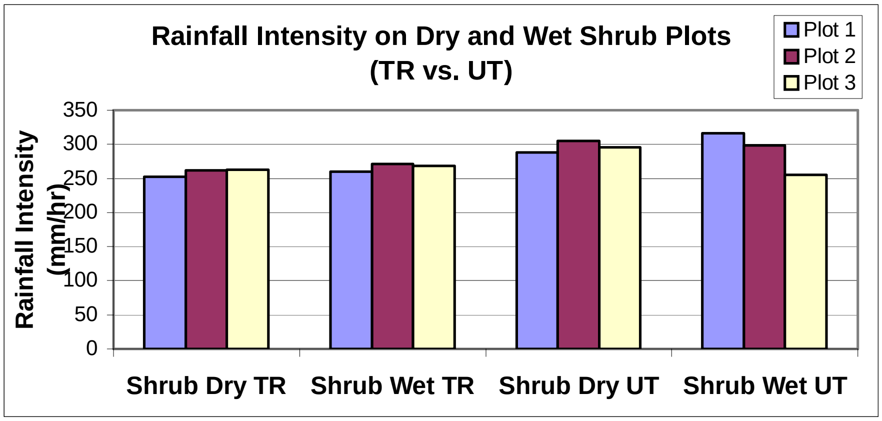


Figure 19: Rainfall intensity on dry and wet shrub plots.

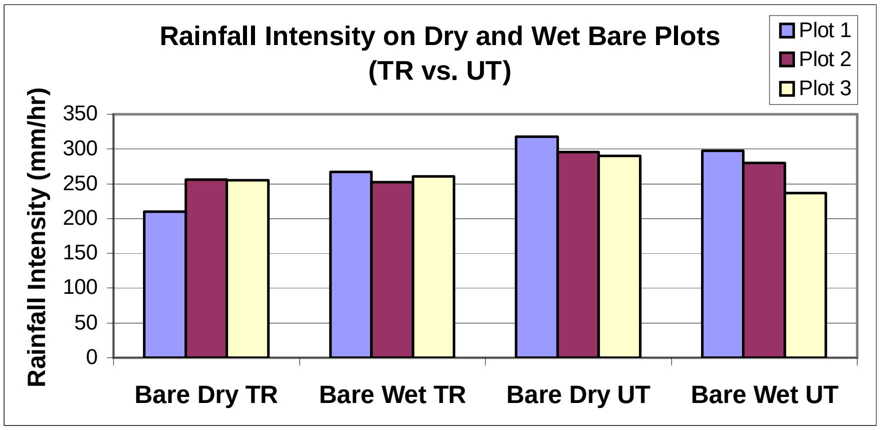


Figure 20: Rainfall intensity on dry and wet bare plots.

Table 9: Averages and standard deviations (in parenthesis) for rainfall intensities on grass, shrub, and bare plots. Values were calculated from triplicate runs.

	Intensity (mm/hr)	
Plot	**Treated**	**Untreated**
Grass Dry	235.6 (15.76)	255.48 (56.73)
Grass Wet	265.02 (14.23)	289.8 (32.79)
Shrub Dry	258.9 (5.99)	296.16 (8.48)
Shrub Wet	266.52 (5.85)	289.86 (31.40)
Bare Dry	240.54 (26.41)	301.26 (14.22)
Bare Wet	259.98 (7.52)	271.74 (31.25)

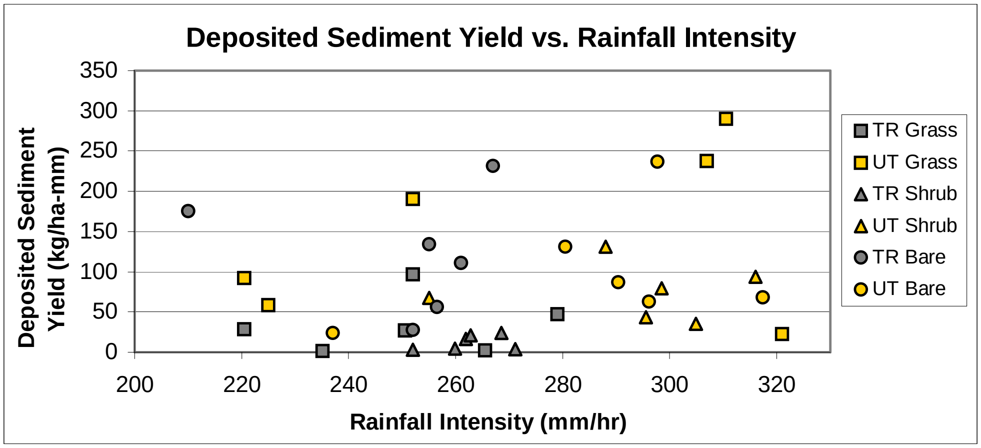


Figure 21: Deposited sediment yield vs. rainfall intensity.

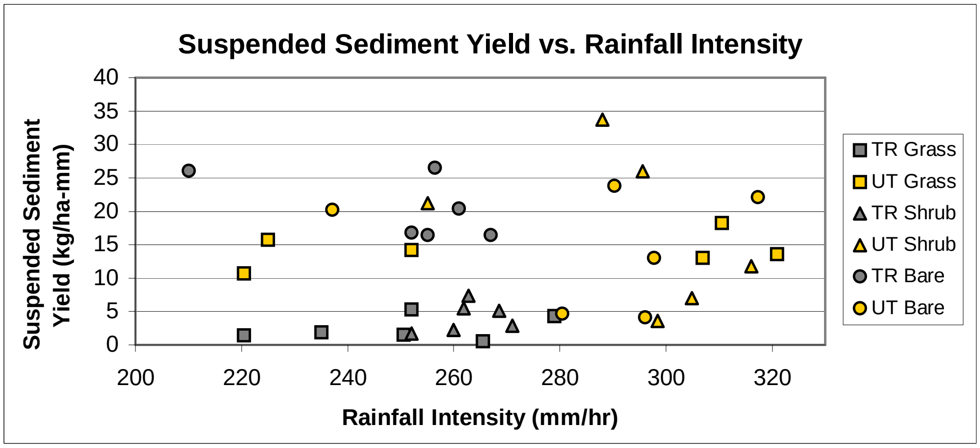


Figure 22: Suspended sediment yield vs. rainfall intensity.

Figures 21 and 22 show the variability of yields for deposited and suspended sediment with changes in rainfall intensity. The untreated area generally received greater rainfall intensities that, nevertheless, not always translated to greater sediment yields. Similarly, treated plots, especially bare, showed an increase in sediment yield despite lower intensities.

Runoff-to-Rainfall Ratios

Average runoff-to-rainfall ratios range from 31.5% for dry bare treated to 57.8% for wet grass untreated. Runoff-to-rainfall ratios for treated and untreated areas are about two to three times lower on the grass and shrub plots of the treated area. There are also significant differences between wet runs of shrub and grass plots between the two areas (Fig. 23 and 24). Bare plots show no significant differences between treated and untreated areas (Fig 25). T-tests between dry and wet runs on each plot for the three treatment types were also non-significant.

A plot of runoff-to-rainfall ratios vs. bare ground coverage (Fig. 26) shows that the majority of treated grass and shrub plots have consistently lower runoff-to-rainfall ratios when bare ground is at or below 30 percent. Although some of results overlap, the remaining untreated grass and shrub plots and all bare plots have higher runoff-to-rainfall ratios with increased amounts of bare ground. Similarly, comparison of runoff-to-rainfall ratios to suspended (Fig. 27) and deposited sediment yield (Fig. 28) show that most treated grass and shrub plots that have the lowest sediment yield also have the lowest runoff-to-rainfall ratios.

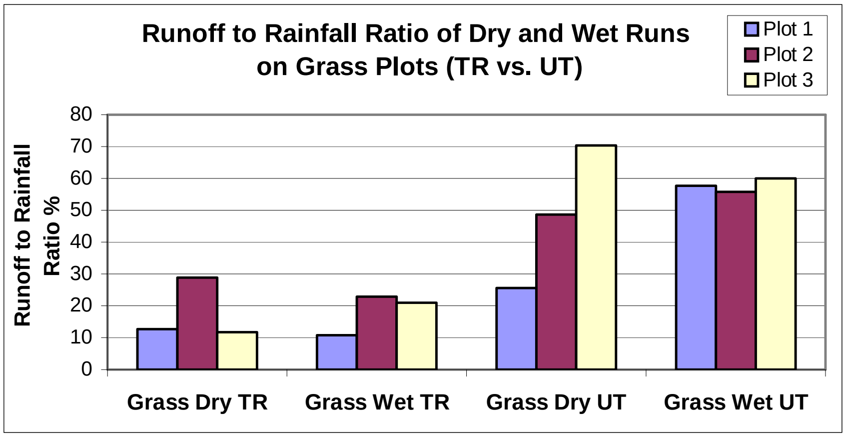


Figure 23: Runoff-to-rainfall ratio on grass plots.

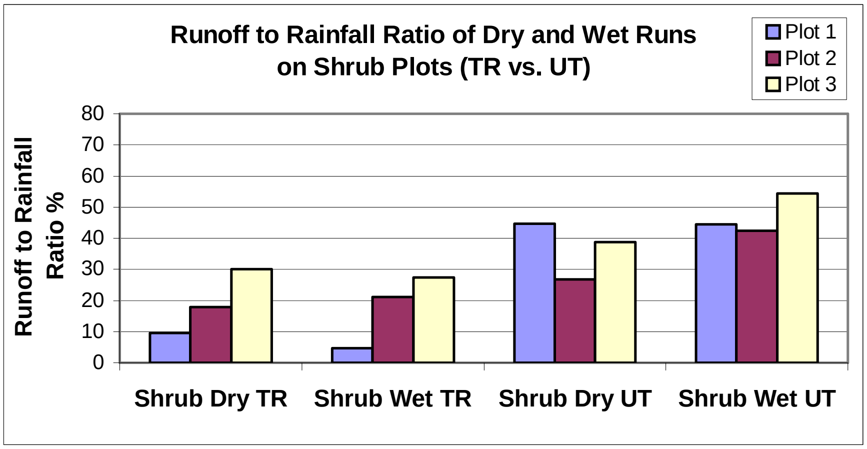


Figure 24: Runoff-to-rainfall ratio on shrub plots.

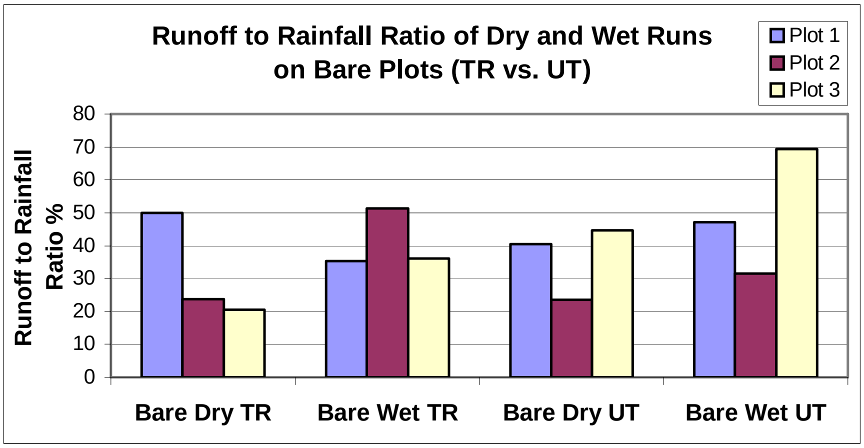


Figure 25: Runoff-to-rainfall ratio on bare plots

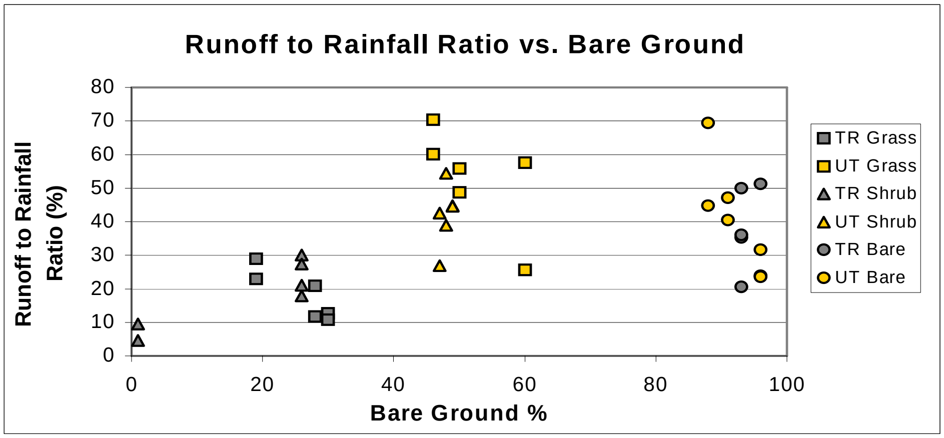


Figure 26: Runoff-to-rainfall ratio vs. bare ground percentage.

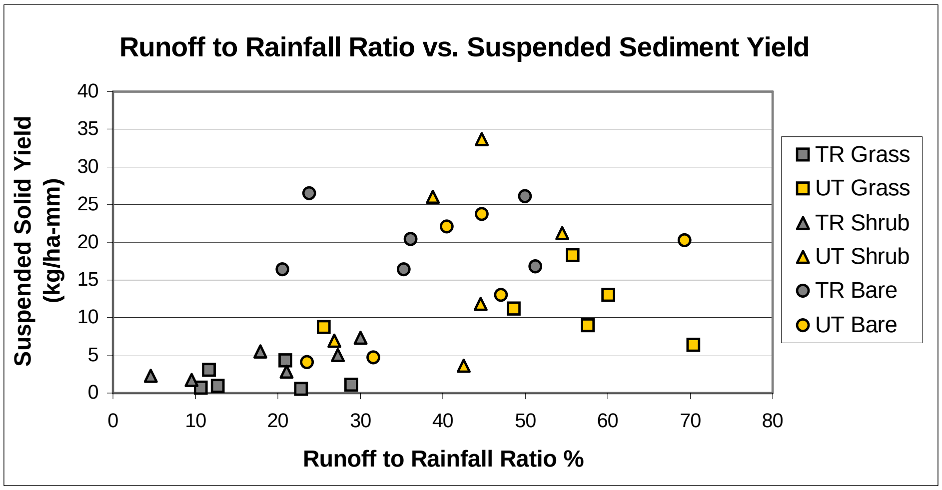


Figure 27: Runoff-to-rainfall ratio vs. suspended sediment yield.

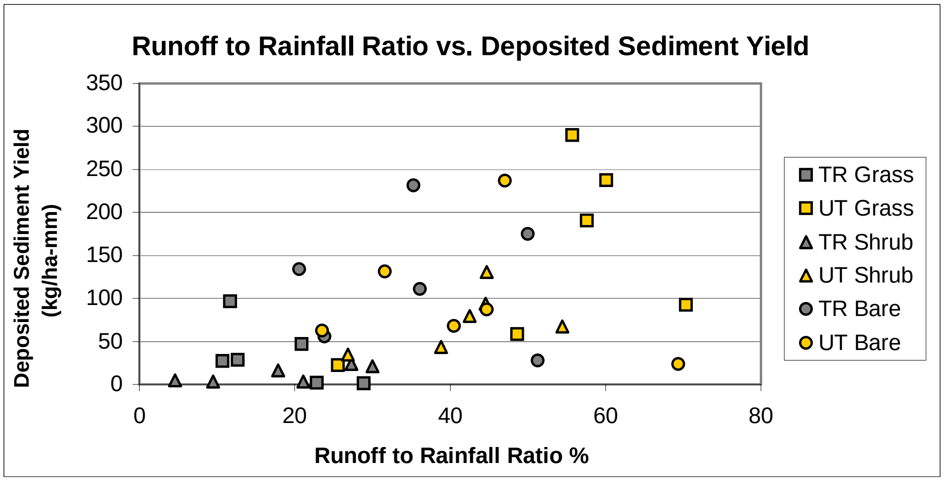


Figure 28: Runoff-to-rainfall ratio vs. deposited sediment yield.

Ring Infiltration Rates

Single ring infiltration experiments were conducted to measure the amount of time it would take for a fixed amount of water to infiltrate into selected bare soil patches and under shrubs (coppice) in the untreated and treated areas. Rates for bare soil infiltrations range between 24 and 184 mm/hr for the untreated and 18 and 143 mm/hr for the treated area and are not significantly different between treatments (Table 10).

Bulk density and initial soil moisture measurements were also taken adjacent to each ring-infiltration sampling site. Bulk densities are similar whereas soil moistures are significantly different between treated and untreated areas. Soil moisture measured ~14% in the treated area and is twice as high compared to the untreated area.

Table 10: Results of ring infiltrations on bare soil patches in treated and untreated areas (7 samples each) showing time to infiltrate 1 cm of standing water, soil moisture, and bulk density.

Treated	**Time min**	**Time mm/hr**	**Bulk Density g/cm^3**	**Soil Moisture %**
TR-1	9.19	65.3	1.24	14.21
TR-2	4.19	143.2	1.35	13.67
TR-3	10.07	59.6	1.22	13.47
TR-4	32.24	18.6	1.38	12.32
TR-5	9.35	64.2	1.50	14.12
TR-6	15.53	38.6	1.26	12.54
TR-7	17.09	35.1	1.29	14.22
Average	**13.01**	**70.17**	**1.34**	**13.56**
Std. Dev.	**9.14**	**40.32**	**0.10**	**0.79**
Untreated	**Time min**	**Time mm/hr**	**Bulk Density g/cm^3**	**Soil Moisture %**
UT-1	24.51	24.5	1.43	8.09
UT-2	20.43	29.4	1.43	6.18
UT-3	5.17	116.1	1.38	9.37
UT-4	5.03	119.3	1.45	8.56
UT-5	3.26	184.0	1.40	9.11
UT-6	5.18	115.8	1.07	7.31
UT-7	6.57	91.3	1.46	5.98
Average	**11.68**	**94.65**	**1.38**	**7.80**
Std. Dev.	8.64	55.76	0.14	1.36

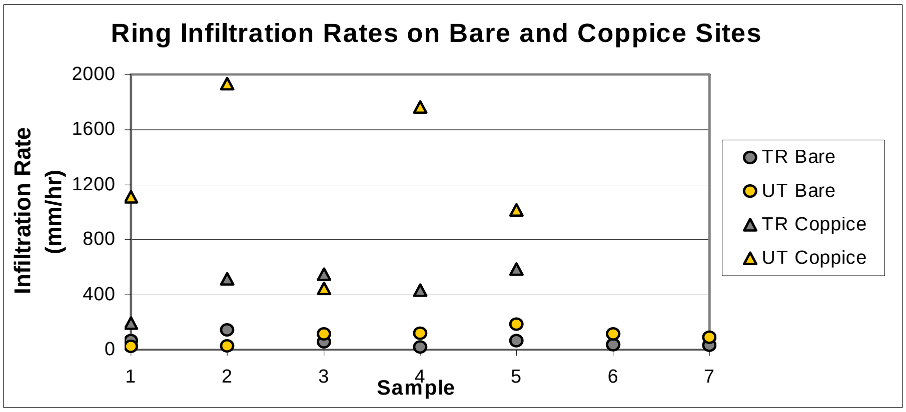


Figure 29: Ring infiltration rate differences between bare and coppice dune measurements in treated and untreated areas.

Infiltration rates measured on small coppice dunes under shrubs (Table 11) are higher than on bare soils (Fig. 29). Rates range between 444 to 1935 mm/hr for the untreated and 192 to 588 mm/hr for the treated area and differences between treatments are significant. Differences in soil moisture and bulk density are not significant.

Table 11: Results of ring infiltrations under shrubs (coppice) in treated and untreated areas (5 samples each) showing time to infiltrate 1 cm of standing water, soil moisture, and bulk density.

Treated	**Time min**	**Time mm/hr**	**Bulk Density g/cm^3**	**Soil Moisture %**
TRC-1	3.12	192.31	1.14	3.27
TRC-2	1.16	517.24	1.18	4.40
TRC-3	1.09	550.46	1.18	11.08
TRC-4	1.38	434.78	1.07	3.70
TRC-5	1.02	588.24	0.84	6.23
Average	**1.55**	**456.61**	**1.08**	**5.74**
Std. Dev.	0.89	158.23	0.14	3.19
Untreated	**Time min**	**Time mm/hr**	**Bulk Density g/cm^3**	**Soil Moisture %**
UTC-1	0.54	1111.11	1.07	2.76
UTC-2	0.31	1935.48	0.93	2.48
UTC-3	1.35	444.44	0.91	3.77
UTC-4	0.34	1764.71	1.36	2.34
UTC-5	0.59	1016.95	1.07	6.21
Average	**0.63**	**1254.54**	**1.07**	**3.51**
Std. Dev.	0.42	603.58	0.18	1.61

Estimates of Green-and-Ampt Conductivity

T-tests were used to analyze estimates of Green-and-Ampt conductivities and indicate significant differences for wet runs on grass plots between treated and untreated areas (Table 12). Saturated hydraulic conductivities were also compared for interaction against the amount of bare ground percentage on each plot (Fig. 30) by using two-way Analysis of Variance (ANOVA). Results indicate significant differences in interaction among wet runs on grass and both dry and wet runs on shrub plots between both treatment types.

Table 12: Averages of estimated Green and Ampt conductivities for dry and wet runs of rainfall simulations. Values were calculated from triplicate runs.

	Estimated Green-and-Ampt Conductivity (mm/hr)	
	Dry	**Wet**
Grass TR	75.3 (17.4)	74.9 (26.7)
Grass UT	43.3 (50.8)	23.0 (19.1)
Shrub TR	41.9 (11.0)	58.8 (6.4)
Shrub UT	36.8 (16.9)	39.2 (13.0)
Bare TR	32.6 (18.1)	39.0 (10.3)
Bare UT	40.5 (15.1)	33.2 (22.0)

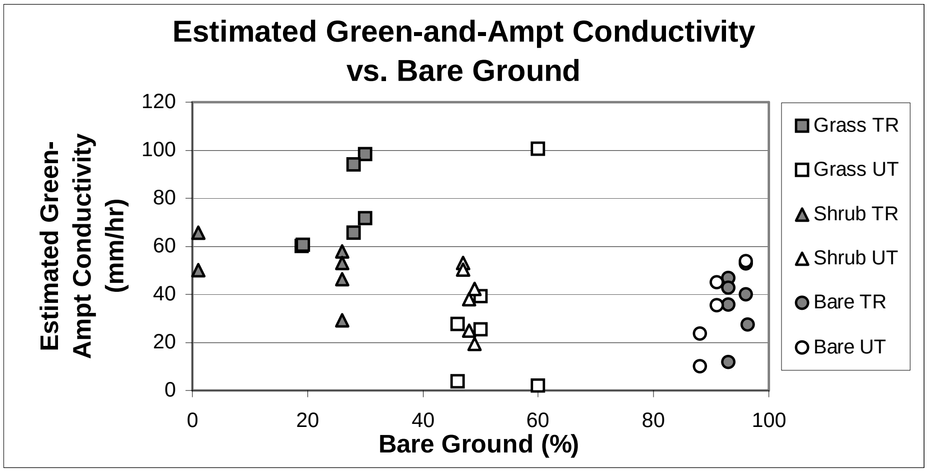


Figure 30: Estimated Green-Ampt conductivity vs. bare ground percentages.

Natural Runoff Plots

Four natural runoff (RO) plots were installed in both treated and untreated parts of Bastard Draw and sampled each time the tributary was visited. Results in Table 13 show that RO 1 and 2, located in the untreated area, produced a greater amount of both sediment and runoff than RO 3 and 4 in the treated area. When runoff results for RO-2 (UT) are compared to RO-3 (TR), RO-2 in the untreated area shows a sixteen-fold increase in runoff compared to the treated plots. Comparison of sediment production between RO-1 (UT) and RO-3 (TR) show that untreated plots produced 23 times the amount of sediments recorded for the treated area.

Table 13: Amount of sediments and water collected from four runoff plots in treated and untreated areas.

RO Plot #	July 16		August 27		October 30		Total	
	Water (l)	Sed. (g)	Water (l)	Sed. (g)	Water (l)	Sed. (g)	Water (l)	Sed. (g)
1-UT	16.00*	23.58	11.00	14.21	28.00	30.8	**>69.21**	**68.59**
2-UT	48.00	27.89	4.00	17.75	30.00	**	**127.64**	**>45.64**
3-TR	6	0	0	0	2	2.93	**8.00**	**2.93**
4-TR	0	0	0	0	0	0	**0**	**0**

* Bucket was lifted out of hole during storm and resulted in loss of water
** Sediment sample was discarded for health reasons

During a storm in July 2000, the sediment and rainfall from RO-1 was lost. Also, the sediment sample for RO-2 in October included decomposed rodent parts so that the sample had to be discarded. RO-3 produced a small runoff sample in July though the amount of sediment in the bucket was practically non-retrievable. On the other hand, a sediment sample was collected in October but the runoff was barely enough to be measured. RO-4, located near the center of the tributary in the treated area, produced no runoff or sediment during the entire sampling time.

Erosion Pins

An erosion pin transect was placed in the untreated portion of Bastard Draw in October 1999, crossing the center of the tributary in a north-south direction (Fig. 3). Original pin heights were normalized to zero and all following measurements were compared against them (Fig. 31). The most active sediment increase was apparent on the south-facing slopes where pins were placed in a very shallow drainage that encountered extensive amounts of sheet flow. Sediments around these pins aggraded all through the year to a total of 4.7 cm (# 1). Most mid-sections of the tributary eroded slightly during the summer months but aggraded again by fall and spring, generally by about 1 cm, although one pin (# 6) appeared to be fairly stable. On the opposite north-facing slope, sediment loss around the southernmost pin (# 10) was 0.4 cm and no aggradation was measured during all counts except in the spring of 2001.

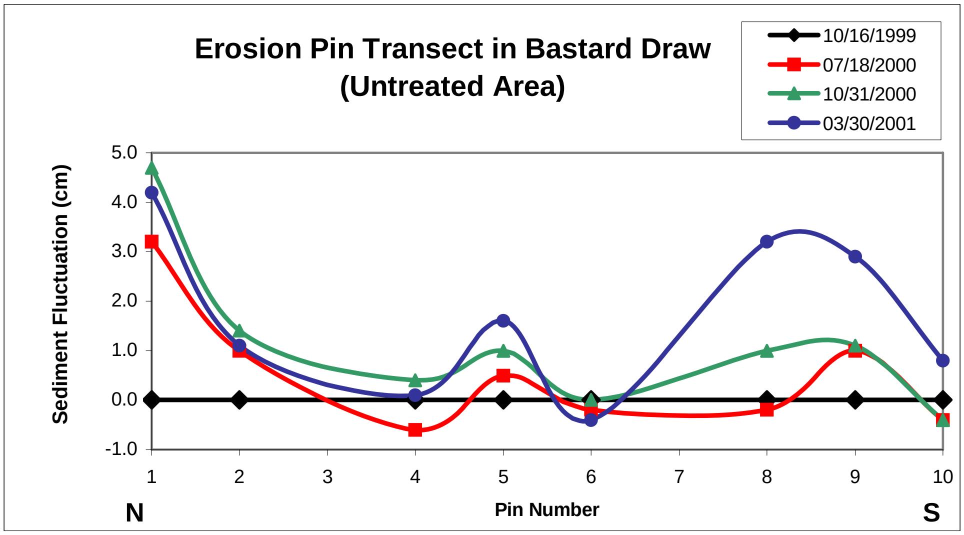


Figure 31: Erosion pin transect through untreated area.

Sediment Yield

Deposited Sediment Yield Results

Comparison of 36 rainfall simulations on grass, shrub, and bare plots in chemically treated and untreated areas of Bastard Draw revealed significant differences in deposited sediment. Sediment concentration (kg/ha-mm), thereafter addressed as sediment yield, of wet runs on three grass and three shrub plots are significantly higher in untreated areas compared to treated plots (Table 14). In general, more sediment was produced during the wet runs in the untreated area whereas more sediment was produced during dry runs in the treated area. Three treated grass plots produced an average 42 kg/ha-mm during the dry and ~25 kg/ha-mm for the wet run. Untreated grass plots had the highest sediment yield of all plots producing an average of 57.91 kg/ha-mm during the dry and 239.24 kg/ha-mm during the wet run. This is a nine-fold increase in sediment production between treated and untreated grass plot wet runs (Fig. 32).

Table 14: Averaged and standard deviations (in parenthesis) of total sediment yield, suspended solid and sediment yield for dry and wet runs on grass, shrub, and bare rainfall simulation plots for both treatment types.

	Total Sediment Yield kg/ha-mm		**Suspended Sed. Yield kg/ha-mm**		**Sediment Yield kg/ha-mm**	
Site	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**
Grass Dry	45.72 (51.12)	71.24 (33.64)	2.90 (2.08)	13.33 (2.52)	42.32 (49.18)	57.91 (34.96)
Grass Wet	27.55 (24.31)	254.42 (51.95)	2.12 (1.98)	15.18 (2.75)	25.42 (22.42)	239.24 (49.82)
Shrub Dry	18.37 (12.22)	92.14 (64.42)	4.86 (2.89)	22.23 (13.76)	13.51 (9.34)	69.91 (53.14)
Shrub Wet	12.21 (8.78)	92.51 (11.60)	3.39 (1.49)	12.21 (8.78)	10.73 (11.63)	80.30 (13.14)
Bare Dry	144.90 (59.62)	89.16 (22.03)	22.99 (5.70)	16.66 (10.90)	121.91 (60.56)	72.51 (12.82)
Bare Wet	141.40 (102.07)	143.40 (102.92)	17.88 (2.22)	12.66 (7.78)	123.52 (102.44)	130.74 (106.36)

For shrub plots, sediment production was about 5 times higher for the dry and 8 times higher for the wet runs on untreated plots than treated plots (Fig. 33). Treated shrub plots produced less than half of the sediment yield than treated grass plots.

High sediment production in Bastard Draw was observed on bare plots located in interspace areas between shrubs (Fig. 34). T-tests show no significant differences in sediment yield between treated and untreated bare plots and between dry and wet runs. Treated bare plots produced a total average of 245 kg/ha-mm and untreated plots yielded 203 kg/ha-mm (dry and wet runs combined).

Figure 35 shows that when bare ground is less than 30 percent, the sediment yield on the treated grass and shrub plots is consistently lower than untreated grass and shrub plots and all bare plots. The majority of untreated grass and shrub plots and all bare plots display a greater distribution of sediment yield than treated grass and shrub plots. Highest sediment yield was produced on untreated grass plots, especially during the wet run.

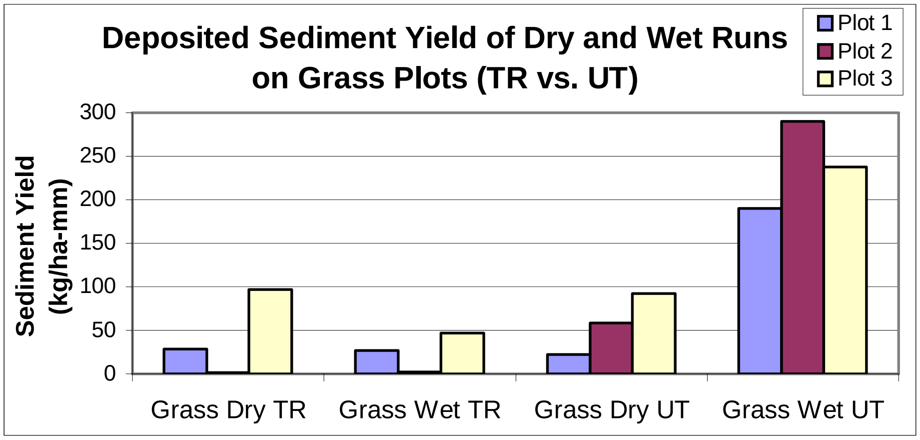


Figure 32: Deposited sediment yield of dry and wet runs on grass plots.

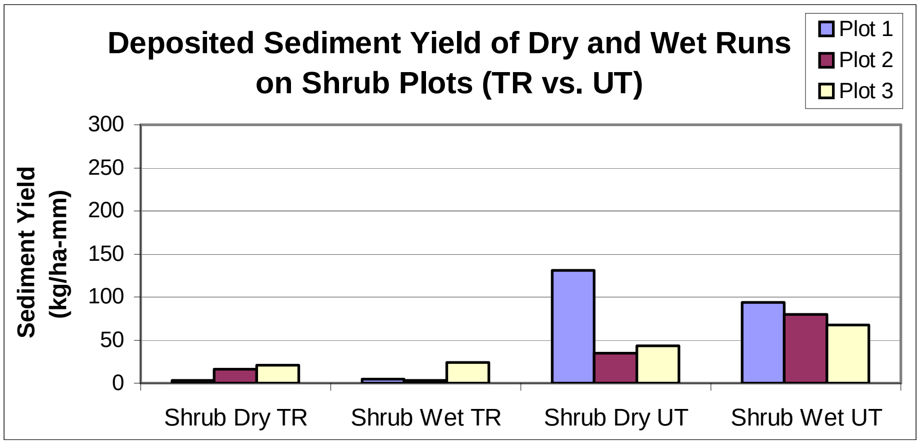


Figure 33: Deposited sediment yield of dry and wet runs on shrub plots.

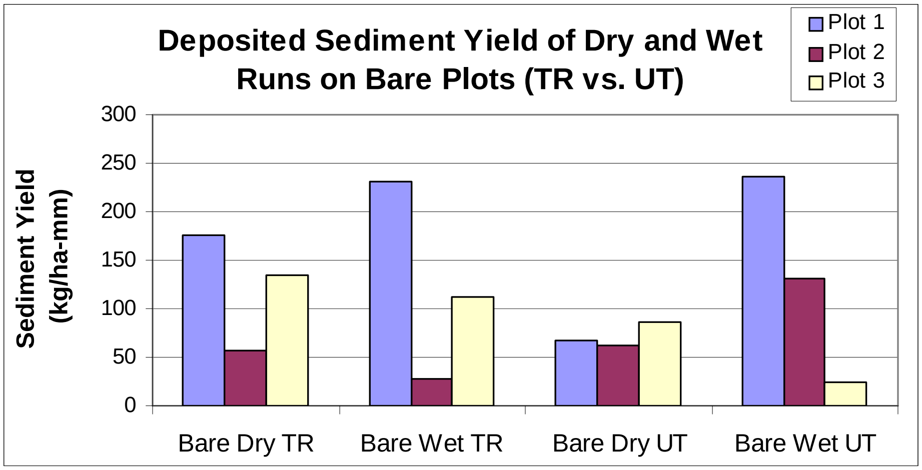


Figure 34: Deposited sediment yield of dry and wet runs on bare plots.

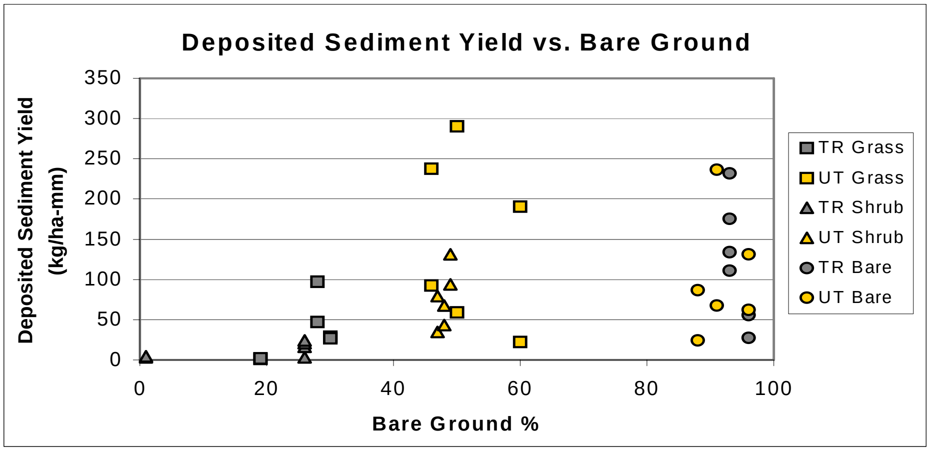


Figure 35: Deposited sediment yield vs. bare ground percentage.

To determine if an increase in resistance through vegetation influences runoff patterns, times to first runoff from the rainfall simulation plots were compared (Table 15). Data for treated and untreated grass plots are significantly different showing that it takes almost 4 times longer for first runoff to occur in the treated vs. the untreated area. Runoff time is also slower on shrub plots but is similar for bare control plots.

Table 15: Time to first runoff (minutes) from the rainfall simulation plots.

	Grass		Shrub		Bare	
	Time to Runoff (min)		Time to Runoff (min)		Time to Runoff (min)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
1 DRY	3:22	2:07	3:37	0:50	2:34	1:09
1 WET	1:56	0:28	7:52	0:31	0:51	0:39
2 DRY	2:51	0:54	2:22	1:06	2:23	2:38
2 WET	3:42	0:24	1:57	0:35	1:01	0:50
3 DRY	2:23	0:46	1:50	1:55	2:30	1:16
3 WET	1:15	0:14	1:33	1:12	1:07	0:30
Average	**2:35**	**0:48**	**3:11**	**1:01**	**1:44**	**1:10**

Suspended Sediment Yield Results

Suspended sediment yield, determined from collected runoff samples after each rainfall simulation, were similar to those found for deposited sediment yields. Lowest suspended sediment yield (Table 14) occurs on treated grass plots which were 5 and 7 times lower for the dry and wet runs respectively, compared to untreated grass plots (Fig. 36). Treated shrub plots

(Fig. 37) produced about 4 times less suspended sediments than untreated shrub plots for both dry and wet runs. No significant differences in suspended sediment yield were found between bare plots in the treated and untreated area.(Fig. 38). Suspended sediment yields are reduced during the wet run, particularly for untreated shrub plots. Comparison of suspended yield vs. amount of bare ground (Fig. 39) shows that the majority of treated grass and shrub plots produced the lowest amounts of sediment at or below 30% bare ground.

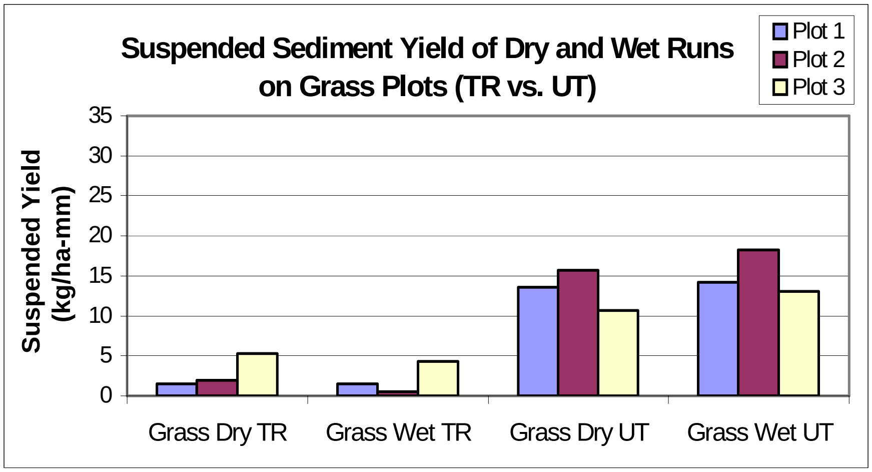


Figure 36: Suspended sediment yield for dry and wet runs on grass plots.

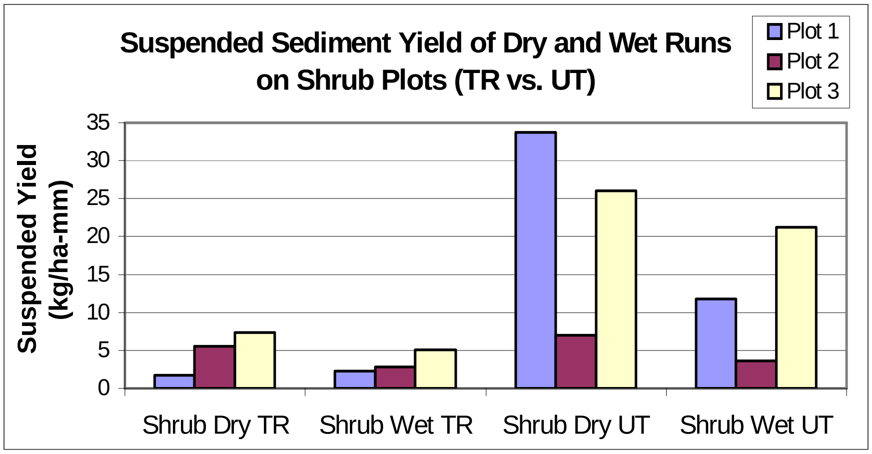


Figure 37: Suspended sediment yield of dry and wet runs on shrub plots.

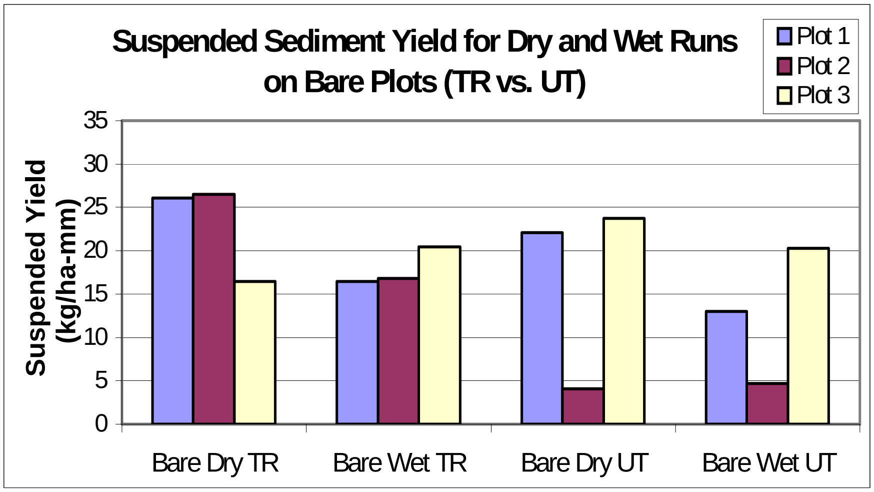


Figure 38: Suspended sediment yield of dry an wet runs on bare plots.

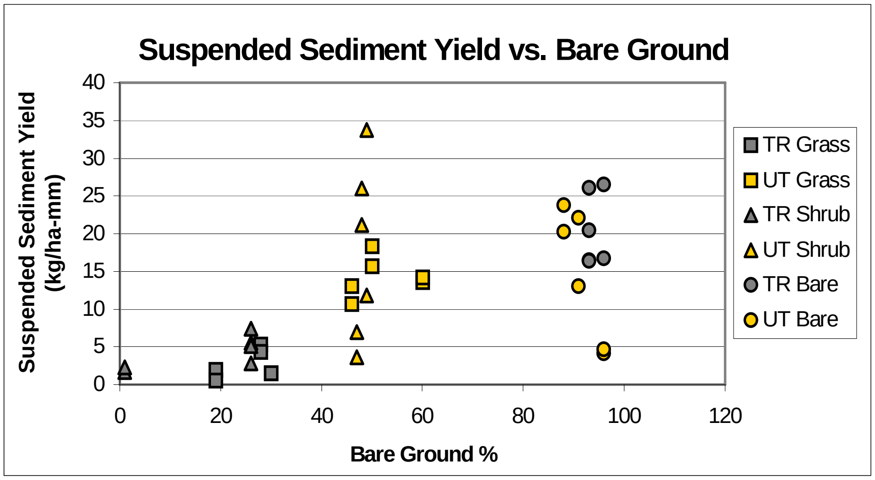


Figure 39: Suspended sediment yield vs. bare ground.

Total Sediment Yield Results

Deposited sediment and suspended sediment values were added to determine total sediment yield for grass, shrub, and bare plots (Figs. 40 to 42). T-tests performed on sample values of grass and shrub plots show significant differences between wet runs in treated and untreated areas and between the dry and wet runs on untreated grass plots. Results for grass plots also show a significant difference of total sediment production between dry and wet runs.

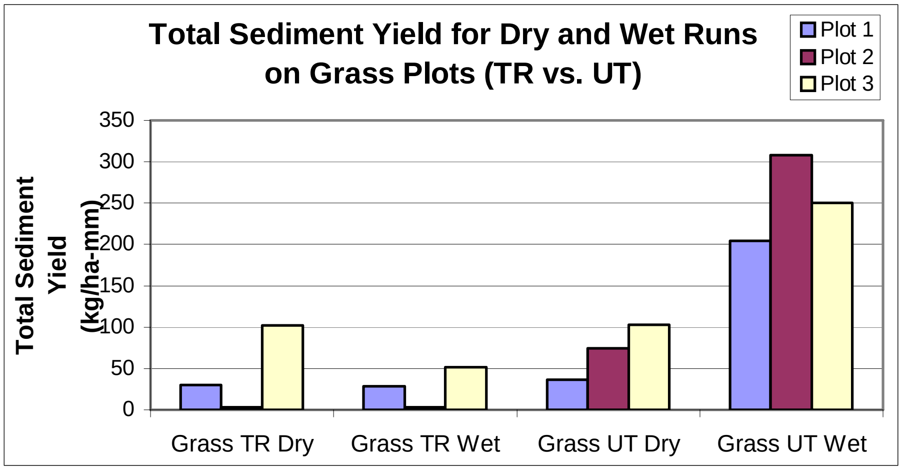


Figure 40: Total sediment yield for dry and wet runs on grass plots.

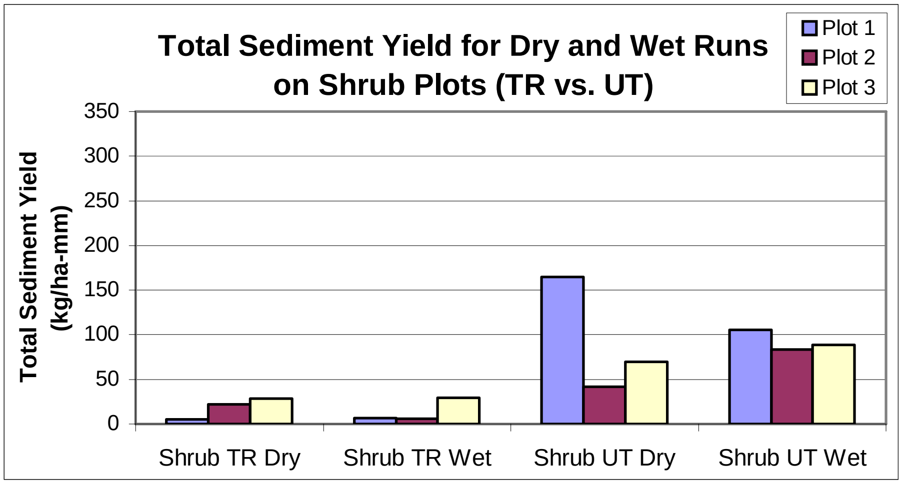


Figure 41: Total sediment yield of dry and wet runs on shrub plots.

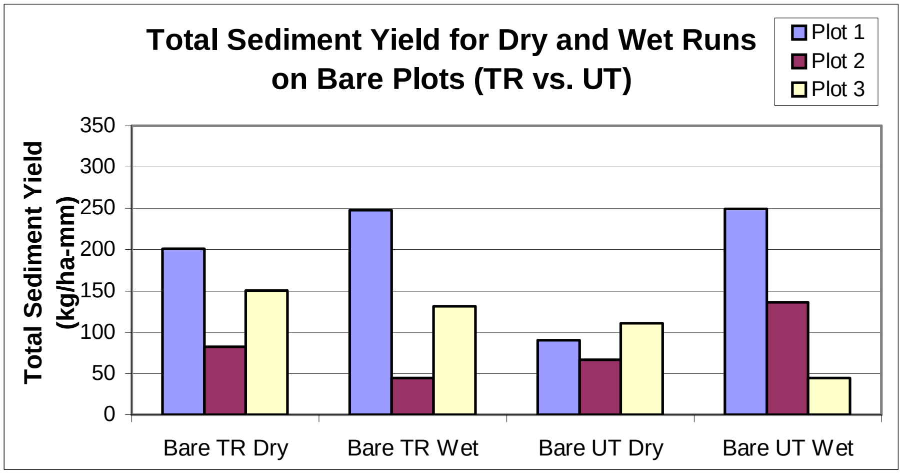


Figure 42: Total sediment yield of dry and wet runs on bare plots.

Total Sediment Yield in Kg/Ha

Throughout the previous sections, sediment yields are addressed as concentrations were sediment production is related to the amount of runoff from each of the rainfall simulation plots. Table 16 shows averages of total sediment yield in kg/ha. Values for grass plots cannot be directly related to the remaining plots because some of the runs were carried out over 30 minutes instead of 20 minutes (see Appendix D for identification of these plots). Treated areas, however, indicate that sediment production is lower compared to the untreated with the exception of treated bare plots.

Table 16: Averages and standard deviations (in parenthesis) of total sediment yield in kg/ha for treated and untreated grass, shrub, and bare plots.

	Total Sediment Yield kg/ha	
Site	**Treated**	**Untreated**
Grass Dry	770.17 (843.88)	4770.14 (3806.38)
Grass Wet	526.08 (471.36)	16275.02 (1314.96)
Shrub Dry	376.52 (358.11)	3629.44 (3081.26)
Shrub Wet	286.78 (373.10)	4195.09 (719.52)
Bare Dry	3789.09 (2863.64)	3401.25 (1669.50)
Bare Wet	8147.31 (6417.63)	6035.09 (4937.67)

DISCUSSION

Slope erosion processes operate at different levels and scales and are greatly influenced by soil properties and vegetation differences (Pierson et al., 1994b). Sediment yields of erosion studies are scale-dependent and are generally higher for smaller plot sizes (Ward, 1986; Ward and Bolin, 1989). Rainfall simulation results from 1 m^2 plots, as used in this study, are not representative of slope processes at a larger catchment scale and need to be interpreted with caution. But on the basis of other peoples work, these data represent the high end of sediment yields.

Vegetation density and its spatial arrangement were also measured to allow for a direct comparison of sediment movement to ground cover changes between chemically treated and untreated areas. The results are used to determine whether sagebrush enhances the forage capacities of associated rangeland and at the same time reduces soil erosion.

Effects of Chemical Sagebrush Treatment on Vegetation Patterns, Composition, and Density

Chemical treatment of sagebrush results in an increase in vegetation and decrease in bare ground. Point-frame counts, line-point transects, and plant collections were combined to estimate frequency and cover percentage of vegetation in Bastard Draw. Findings from point-frame counts confirm increased vegetation in the chemically treated area compared to untreated portions of the drainage (Fig. 15). Growth of herbaceous vegetation is usually retarded under a dense stand of sagebrush because shrubs contain soil-based and volatile terpenes. However, chemical treatment appears to reverse the negative influence that sagebrush has on its immediate surroundings (Fig. 7). This is in agreement with findings by McDaniel et al. (1992) who conclude that, with minor exception, all perennial grass species benefit from sagebrush control and increase their yield relative to untreated areas.

Transect results appear to be the strongest indicator of how vegetation has changed within the tributary after chemical treatment (Figs. 16 and 17). Data from twenty transects indicate density differences between treated and untreated areas and permit measurement of average sizes of grass, shrub, and bare patches. The enlarged grass patch areas suggest that grasses connect and propagate to previously bare areas that surround them, increasing their patch sizes rather than establishing new bunches (Table 2). Consequently, the decrease in bare area shown in Table 2 appears to be determined by the reduced frequency of bare patches rather than their size (Table 3).

The increase in species diversity and density indicates that the vegetation in the treated area has changed over the three years after treatment by shifting from a sagebrush-dominated ecosystem to a grassland (Tables 4 and 5). However, grazing and other land-use practices have had a significant impact throughout the Rio Puerco watershed. With intense grazing pressure and drought years, selective feeding by livestock has encouraged the spread of less palatable species, both native and introduced, and has greatly altered the species composition of these ecosystems. Highly competitive species, such as Russian thistle, cheatgrass, and other drought-adapted shrubs and plants, are increasing in abundance at the expense of native grasses and forbs in the Southwest (Benedict, 1991). Though no cheatgrass was found in Bastard Draw, Russian thistle and rabbitbrush are present, especially in the treated area and towards the mouth of the tributary where higher cattle traffic may enhance the spreading and establishment of such species.

Differences in Soil Properties between Treated and Untreated Areas

Particle Size Distribution and Soil Morphology

Texture is one of the most important characteristics of a soil profile (Birkeland, 1999). The proportion of clay, silt, and sand content provides qualitative information on soils and aids in the interpretation of soil moisture movement within a profile. An increase in finer particles, especially silt, is detected throughout the sampling area in the treated portion of the drainage

(Table 6). Elevated silt content in the treated area can be related to sample locale within the tributary (Figs. 3 and 5) because they are situated in the mid-section of a fan further away from the cliffs. With distance from outcrops, coarse material is left behind and silts and clays become dominant as indicated by particle size analyses for soil pits from the natural runoff plots (Table 7). Higher sand fractions are detected in the untreated area and can be related to the proximity of the sampling area near the apex of a fan. Coarse material from surrounding cliffs is eroded into the drainage, as can be seen especially for bare plots (Tables 6).

The profile descriptions and particle analyses of the natural runoff plots give insights on the variability of material in stratigraphic horizons at depth (Table 7; Appendix C). In general, soils in Bastard Draw are weakly developed, especially around the perimeter of the drainage where material from surrounding sandstone cliffs is deposited. The constant replenishment of sediments across the landscape is reflected by the stratigraphic profiles that contain predominately sand and no buried soils (Table 7). Clay content and its development is minor, especially in the untreated area, and suggests that the drainage is very active and lacks long-term stability.

X-ray diffraction of soil profiles indicates that greater amounts of clay (kaolinite) are present in the treated area, especially towards the center of the drainage (Appendix G). Whether kaolinite was transported from a different source onto the fan, altered in place from parent material, or formed under different environmental conditions in the past is difficult to determine. The diversity of clay development within soil horizons can be related to changes in pH, variations in charge of particles and ionic concentration, or chemical conditions at the site. Because soil differences in Bastard Draw are not directly related to the chemical treatment of the area, it is beyond the scope of this study to determine the origin of the clays present in each soil horizon.

Grass plots in the treated area contain a higher sand fraction than nearby shrub and bare plots (Table 6). This suggests that grass patches retain and concentrate increased amounts of coarse particles due to two possible processes. First, the increased sand fraction may be the result of selective removal of the finer fraction (i.e. winnowing). More likely, damming by vegetation reduces the runoff velocity to a level where flow can no longer transport the load so that ponding may encourage the settling of particles (Table 15).

Bulk Density, Soil Moisture, and Loss on Ignition (LOI)

Bulk density increases with the degree of compaction. Its variation can also be attributed to relative proportion and specific gravity of soil organic and inorganic particles and to the porosity of soil (Birkeland, 1999). Though bulk densities from treated and untreated rainfall simulation plots are not significantly different, slight increases in bulk densities are detected during the wet run (Table 8). This is likely caused by a reduction in pore space due to compaction from continuous rainfall impact. Bulk density can also be affected by size distribution and clay type (Tindall et al., 1999). Fine textured soils, such as in the treated area, tend to be less dense than sands (Marshall et al., 1996). However, an increase in root biomass is likely responsible for reduced bulk densities seen on treated grass and shrub plots.

The amount of water held by a soil is influenced by a number of soil properties including its texture, structure, clay minerals, and organic content (Marshall et al., 1996). Variations in soil moisture are likely caused by greater amounts of fine grain sizes (Table 6) and organic material (Table 8) in the treated soils. Silts and clays provide a larger surface area and, just like organic material, can considerably increase the water-holding capacity of soils (Ben-Hur et al., 1987; Birkeland, 1999).

An increase in carbon content after the wet run is difficult to explain (Table 8). However, it is possible to mobilize organic material buried near the surface after an ample amount of rain removes the sediment cover. Differences in carbon content between treated and untreated bare plots suggest that organic material from vegetated areas adjacent to treated bare space may have been moved onto the bare ground. The lower amount of vegetation in the untreated area provides less organic material, therefore resulting in decreased LOI values for untreated bare plots.

Effects of Rainfall on Sediment Production

Rainfall Intensity

When rain falls on a soil surface, the amount of runoff produced by an event is directly related to the amount of rain (Kinnell, 1997). As a general rule, the energy per unit quantity of rain increases exponentially with rainfall intensity (Renard et al., 1993). An increase in erosion can therefore be expected with an increase in intensity. The amount of rainfall applied to the simulation plots was unusually high (~104 mm/20 min.) and was a result of equipment problems. Nevertheless, convectional thunderstorms during the summer monsoon season are able to deliver high intensity rainstorms over short durations. Gellis (written communication, 2001) measured 67 mm of rain over 15 minutes in June of 1997 in Arroyo Chavez, a major tributary of the Rio Puerco south of Bastard Draw. Sediment yield from this study, however, are probably higher than would be produced under average summer rainfall intensities.

Variable rainfall intensities during rainfall simulations were a problem (Figs. 18 to 20; Table 9). T-test results of the intensity data vary depending on how the data are evaluated. Comparison of treated and untreated intensity values show that dry runs on shrub and bare plots were significantly different. When the suspended sediment yield (in kg/ha) was divided by intensity squared, wet runs on grass plots were significantly different between treated and untreated areas. Conduction of a non-parametric Kruskal-Wallace test on the suspended sediment in units of kg/ha/intensity^2 also yielded ranking sequences of intensities that were difficult to interpret (Ward, T.J., written communication, 2001). Determination of significant differences between rainfall simulations is therefore inconclusive.

Nevertheless, Figures 21 and 22 show that higher intensities did not necessarily result in higher sediment yields. Sediment yields on untreated grass plots were widely scattered from low to high intensities, which likely resulted in the production of an unusually high average in deposited sediment yield (Table 14). Likewise, treated bare plots received similar rainfall intensities as treated shrub and grass plots but show increased sediment production that can be related to a decrease in vegetation (Fig. 39).

It is unclear why untreated bare plots produced less sediment yield than treated bare plots although higher rainfall intensities were applied on untreated plots. Estimated Green-and-Ampt conductivites for all bare plots are similar (Fig. 30) so higher infiltration rates may not be the cause. Differences in particle-size-fraction, however, could produce different sediment yields, which are especially apparent during the dry run (Table 14). Silts in the treated area likely did not need higher intensities to be mobilized compared to higher sand fractions present in the untreated area.

Runoff-to-Rainfall Ratios

Runoff-to-rainfall ratios are influenced by intensity but are mainly estimates that relate infiltration and rainfall runoff. Although grass and shrub vegetation is present on untreated plots, it appears that it is not enough to drastically reduce runoff (Figs. 25 to 27). Channelization of water on partially vegetated plots, such as untreated grass plots, promotes concentrated runoff that may increase velocity and carrying capacity of sediments. Conversely, areas with large bare patches and reduced vegetation likely do not concentrate flow as much, thus reducing the initial potential for erosion and transport, such as indicated in time-to-first-runoff results (Table 15). Elevated runoff may therefore affect infiltration, contributing to greater runoff-to-rainfall ratios on untreated plots.

Runoff patterns observed on the treated grass and shrub plots are dominated by vegetative barriers that obstruct the flow of runoff and reduce the amount of erosion (Tables 15, 2, and 3). The increase in vegetation may also increase infiltration rates due to ponding that occurs behind connected grass patches. Increased estimates of Green-and-Ampt conductivities (Fig. 30) seen for treated grass and shrub plots therefore likely contribute to reduced runoff-to-rainfall ratios.

Differences in Infiltration Rates between Treated and Untreated Areas

Ring Infiltration

Differences in soil properties can lead to variations in infiltration rates. Horton (1939) suggested that the reduction in infiltration rate with time is controlled by factors operating at the soil surface. Ring infiltration data on bare ground (Table 11) indicate significantly higher infiltration rates in the untreated compared to the treated area. Despite the increased infiltration rates, abundant bare interspace soil around a sagebrush and the lack of understory grasses and vegetative barriers in the untreated area (Fig. 15) increase runoff (Fig. 26) and erosion (Figs. 35 and 39) that consequently reduce time for infiltration to occur.

Infiltration rates measured on small coppice dunes under shrubs (Table 11) are higher than on bare soils for both treated and untreated areas (Fig. 29). Compared to untreated coppice sites, coppice dunes in the treated area show reduced infiltration rates (Table 11) that can be related to an increased fine fraction in the area (Fig. 5; Table 6). In contrast, higher infiltration rates on untreated coppice dunes are likely caused by a larger amount of leaf litter under the live shrub.

Bulk density and soil moisture were also measured adjacent to each ring infiltration site (Table 10 and 11). The increase in soil moisture content for bare ground samples in the treated area (Table 10) may be caused by higher amounts of fines present in the treated area (Table 6). An increase in organic content, as shown in LOI results for treated bare plots (Table 8), could also contribute to increased moisture content. Daily soil temperature fluctuations also affect the soil moisture content and flux, which in turn influences soil infiltration capacity, biotic activity, and soil structural properties (Jaynes, 1990). Decreased bulk density of coppice dunes likely contributed to higher infiltration rates on coppice compared to bare surface infiltration samples.

Estimated Green-and-Ampt Conductivity

Results of estimated Green-and-Ampt conductivities (Table 12; Fig. 30) suggest that there is a relation between amounts of bare ground and hydraulic conductivity on grass and shrub plots between treatment areas. This can be seen in Fig. 30 where highest hydraulic conductivities are associated with a reduction in bare ground.

An increase in vegetation in the treated area is believed to have a net effect of retarding surface flow and allow more time for water to permeate into the subsurface (Table 15). Plant roots may also increase hydraulic conductivity by adding pore space near the soil surface and increasing infiltration rates. Therefore, infiltration rates may vary a great deal because of variations in types and density of vegetation.

While ring infiltration data indicates that infiltration rates on the treated area are generally slower than the untreated (Tables 10 and 15; Fig. 29), estimated Green-and-Ampt conductivities from rainfall simulations show opposite results (Table 12; Fig. 30). The method used for ring infiltration cannot be compared to the Green-and-Ampt data because of differences in application time, sample area size, and amount of water used.

Properties Influencing Infiltration

An infiltration rate depends on hydraulic conductivity, initial water content, and water potential gradient in the soil profile (Morin et al., 1988). Soil surface conditions are equally important and can be influenced through formation of depositional crusts, clogging of pores by silts and clays, or biological crusts.

Depositional crusts are formed when water flows over a soil surface causing entrainment and subsequent deposition of suspended particles (Shainberg and Singer, 1985). Crust formation also occurs due to the combined effect of raindrop impact energy and the dispersion of clay particles at the soil surface (Agassi et al., 1985). The development of a thin dispersed layer of clay at or near the soil surface has a strong effect on water movement into the soil (Helalia et al., 1988).

Evidence that clay dispersion and clogging of pores within a soil column reduces hydraulic conductivity has been well documented (Felhendler et al., 1974; Ben-Hur et al., 1987; Helalia et al., 1988). Although clay content of soils in the tributary is not very high (1 to 5 percent), the average silt content measured on sediments removed from treated rainfall simulation plots is about two to three times higher than in the untreated area and may promote clogging of pores at or near the surface (Table 6). Silts may also increase soil moisture holding capacity (Table 8) and reduce hydraulic conductivity in the treated area. However, Fig. 30 shows that hydraulic conductivities are higher in the treated than untreated area, suggesting that increased vegetation has a positive affect on infiltration properties despite underlying soil textural differences.

Increased runoff due to decreased permeability promotes erosion, whereas increased soil strength reduces detachment of particles (Moore and Singer, 1990). Sand fractions in the untreated area are higher than in the treated area (Table 6), providing increased permeability to greater depths. Enhanced infiltration capabilities (Tables 10 and 11), however, are offset by elevated runoff velocities (Table 15), lower microtopography, and most importantly less vegetation (Figs. 15 to 17). Sediment production is therefore significantly higher on the untreated plots.

In comparison, the treated area produces less sediment because of increased moisture holding capacity (Tables 8, 10 and 11) and increased hydraulic conductivity (Fig. 30). Nevertheless, these factors are influenced by the spatial arrangement and density of vegetation, especially grasses (Tables 2 and 3). They act to slow runoff and increase ponding, which in turn allows more water to infiltrate. Thus less sediment is produced from the treated area (Figs. 40 to 42).

Microphytes – mosses, lichens, and algae – also contribute to the development of crusts on rangeland soils (Williams et al., 1995). Removal of the plastic cover over soils from the rainfall plots in both treated and untreated areas before the wet run often revealed surficial algal growth that established overnight. Their abundance and location were not documented so it is difficult to determine if they had any affect on infiltration or sediment movement during the simulations. Algal mats were most likely destroyed during the initial raindrop impacts and should not have influenced any results. However, the presence of mycrophytic crusts and particles may potentially alter infiltration and soil structure on the soil surface that influence runoff during natural rainfall.

Causes for Sediment Yield Differences Between Dry and Wet Runs

Following completion of a dry run, each plot was covered with a plastic sheet until the wet run was carried out the following day. The deposited sediment and suspended yield during the wet run were expected to be higher because the soil was saturated and infiltration capacities would be exceeded more easily. However, that was not always the case. Several physical differences relating to sediment and plot characteristics could have been the cause and are discussed in the following section.

Vegetation Patterns and Slope

Vegetation patterns appear to be the strongest, most important factors that influence plot runoff during dry and wet runs. As discussed previously, spatial arrangement plays an important role and contributes to the runoff patterns on each individual plot. Data in Table 6 of the particle-size section shows that sand fraction production was increased during the majority of wet runs. Vegetation is capable of trapping larger particles that are mobilized at a later time when soils are saturated and runoff is increasing. Finally, slope is also a defining factor though all plots were within 1 degree of each other but may differ in terms of microtopography.

Availability of Detachable Particles

During the first minutes of rainfall, particles are mobilized and moved off the plot due to increased availability of detachable particles on a dry surface. This is reflected in the suspended solids data where most dry runs have higher yields than wet runs because finer particles were removed immediately (Table 6). The deposited sediment yield data is not as predictable, especially in the untreated area where soils have an increased sand distribution and dry runs generally produced less sediment than wet runs (Table 6). This suggests that the larger particle size required elevated flow, which can be expected with increased soil saturation. In contrast, the treated area holds greater amounts of fines so that the formation of thin crusts or seals on the surface may have reduced sediment yields during most of the wet runs.

Spatial Variability of Soils

Spatial variability of soils is apparent over very short distances because plots were located on small alluvial fans (Figs. 3 and 5; Tables 6 and 7; Appendix D for soil descriptions). Although one plot, i.e. Bare 2 untreated, produced less sediments during the wet run, Bare 3 untreated, only a few meters away, had opposite results (Fig. 31). Soil variations on the surface, such as crusts, and at depth (Appendix C) may contribute to infiltration differences that determine final sediment yield and amount and velocity of runoff.

Variation in Rainfall Intensity

Variations in rainfall intensity may have also played an important role that influenced differences between dry and wet runs on each plot. Rainfall intensities were generally lower during the dry run on treated plots (Appendix B). In contrast, most of the dry runs on the untreated plots received higher intensities. Thus, it can not be excluded that variable rainfall intensities played a role in dry and wet run results for sediment yield, runoff-to-rainfall ratios, and estimated Green-and-Ampt conductivities.

Dynamics of Sediment Movement in Bastard Draw

Erosion Pins

Erosion pin measurements taken throughout the year reveal the dynamics of sediment movement across the landscape throughout that period, especially highlighting differences on opposing slopes (Fig. 31). The increased aggradation detected in the spring is due to expansion of soils around most pins whereas sandier surfaces, such as around pins one through four in the shallow drainage and pin six in the arroyo, indicate slight erosion. Though two pins were lost during a large storm, results show that some sediment fluctuation occurred between summer and fall.

Greatest amounts of aggradation are observed on south-facing slopes whereas north-facing slopes, especially around pin ten, show erosional trends. Two possible explanations can be applied. First, the pin is located in an area that accounts for a consistent rate of erosion so that aggradation is minimal. Second, slope processes in Bastard Draw are different for parts of the tributary due to aspect, microtopography, soils, and vegetation. North-facing slopes differ distinctly from south-facing slopes by higher amounts of vegetation, mainly juniper, ponderosa pine, brush, and associated litter.

Because increased vegetation provides a more stable, protective, and flow-reducing environment on north-facing slopes, weathering processes on the sandstone cliffs may be slightly different than on the more exposed opposing side. A study by McMahon (1998) found that initial driving forces, such as variable solar radiation input, induces changes in vegetation, microtopography, and soils that enhance the vegetation contrasts through time. Consequently, sediments may be held back on the slopes, which leads to supply and transport limitations that result in reduced amounts of sediments from the slopes, thus showing erosional trends around pin ten.

Natural Runoff Plots

Four natural runoff plots were installed to determine sediment yield and runoff from natural rainstorm events (Table 13). Unfortunately, lack of rainfall intensity and duration data and incomplete measurements make it difficult to develop ratios or calculate sediment yield that could be compared to the rainfall simulation results. However, increased vegetation abundance and density on the treated runoff plots compared to the untreated plots are the likely factor that causes differences in runoff and sediment yield. Infiltration differences may have also affected the results, especially since particle size analyses (Table 6) show that the treated area contains a greater amount of fines than the untreated.

Effects of Chemical Sagebrush Treatment on Sediment Production

Rainfall simulation experiments show that the greatest sediment yield was produced in the order bare ground > grass > shrub on treated and grass > bare ground > shrub on untreated portions of the drainage (Figs. 32 to 34; Table 14). Shrub plots had the lowest overall sediment yield for both treated and untreated areas. However, untreated shrub plots produced more sediment than treated ones because of the ability of live canopy to intercept rain more effectively than dead shrubs. The most likely explanation lies in increased amounts of bare ground around the brush in the untreated area that, unlike the treated brush, are not surrounded by denser vegetation that provide effective barriers to runoff (Fig. 35).

Highest suspended sediment yield was produced in the order bare ground > shrub > grass in the treated and shrub > bare ground > grass in the untreated area (Figs. 36 to 38; Table 14). Increased supply of suspended sediments in the untreated area appear to originate from coppice dunes under shrubs while coppice dunes under treated shrubs were stabilized by increased grass cover (Fig. 7).

A decrease in suspended sediment yield during the wet run is due to limited loose sediment on the surface that would be removed on the dry run first, making sediments less available for the following wet run. In addition, an increase in bare ground percentage results in greater sediment production (Fig. 39). Treated grass and shrub plots contain higher amounts of vegetation and decreased bare area, thus resulting in lower sediment yields. In contrast, untreated grass and shrub plots and all bare plots showed that an increase in sediment production can be related to greater amounts of bare ground and concentration of flow. Fig. 39 suggests that the threshold boundary for elevated sediment production due to bare ground lies at approximately 30 to 40 percent.

Total sediment production is highest in the order bare ground > grass > shrub on the treated and grass > bare ground > shrub in the untreated area (Figs. 40 to 42; Table 14). Treated shrub plots have the lowest yield, showing that a combination of dead canopy and underlying grasses may further reduce rainfall impact and splash detachment. Untreated grass plots are believed to produce higher amounts of sediments than bare plots because of channeling around isolated grass patches. As discussed previously, bare plots likely provide a greater area of uniform runoff that enhances infiltration rates and reduces localized erosive channeling. Unusually high yields during the wet run may also have been caused by increased intensities.

Because plants and grasses protrude higher and are denser in the treated area, overland flow is more dispersed and encounters higher microtopographic elements than the untreated area (Table 2 and 3). Thus, slower runoff patterns between both areas are mainly a consequence of increased surface obstruction in the treated area because grasses provide a higher resistance to flow (Table 15). This difference in hydraulic resistance decreases overland flow velocities which, in turn, reduces soil detachment and transport and leads to differences in erosion rates (Johnson and Blackburn, 1989; Abrahams et al., 1995).

Time-to-first-runoff results show that highly vegetated areas, such as treated grass plots, reduce water flow more effectively (Table 15). This increase in time-to-first-runoff is believed to enhance ponding that likely increases infiltration rates due to greater hydraulic conductivity (Fig. 30). Bare plots actually had a longer time-to-first-runoff than untreated grass and shrub plots.

This may be the result of concentrated channeling around isolated vegetated patches that enable the water to be transported more efficiently off the plots. Runoff on bare plots may occur over a broader area in a sheet-like fashion, therefore enhancing the area present for infiltration and slowing down runoff during initial rainfall.

Similar results were seen with sediment production where untreated grass plots produced the highest amount of sediment yield, followed by bare and shrub plots (Table 14). Again, runoff velocities and erosion likely increase as water is channeled around grass patches, as opposed to sheet-flow and a lower sediment yield for bare plots. The combination of dense canopy cover (Table 2) and the ability of higher infiltration rates on coppice dunes underlying sagebrush (Table 11) may have produced the lowest amount of sediment yield on shrub plots in the untreated area.

Throughout the discussion, sediment yields are addressed as concentrations rather than yields in kg/ha as is commonly done in other sediment studies. Concentrations are used to relate the yield to the amount of runoff, which is particularly important because some of the initial rainfall simulations on the grass plots lasted 30 instead of 20 minutes. By using concentrations, the time differences become negligent. Conversion of total sediment yield to kg/ha, however, reflects the differences in sediment production between treated and untreated areas without the runoff factor (Table 16). Shrub plots continue to produce the lowest amount of erosion in both the treated and untreated area, suggesting that interception and vegetative cover, especially in the treated area, have a positive effect in sediment reduction.

Therefore, physical contrasts between density and spatial arrangement of vegetation appear to exercise the strongest control over the amount of runoff and soil erosion between both treatment types. Vegetative barriers are expected to reduce runoff velocity by damming the flow, thus holding back sediments more efficiently and providing more time for infiltration to take place. Figure 43 summarizes expected changes in runoff behavior on sagebrush rangeland due to differences in ground cover.

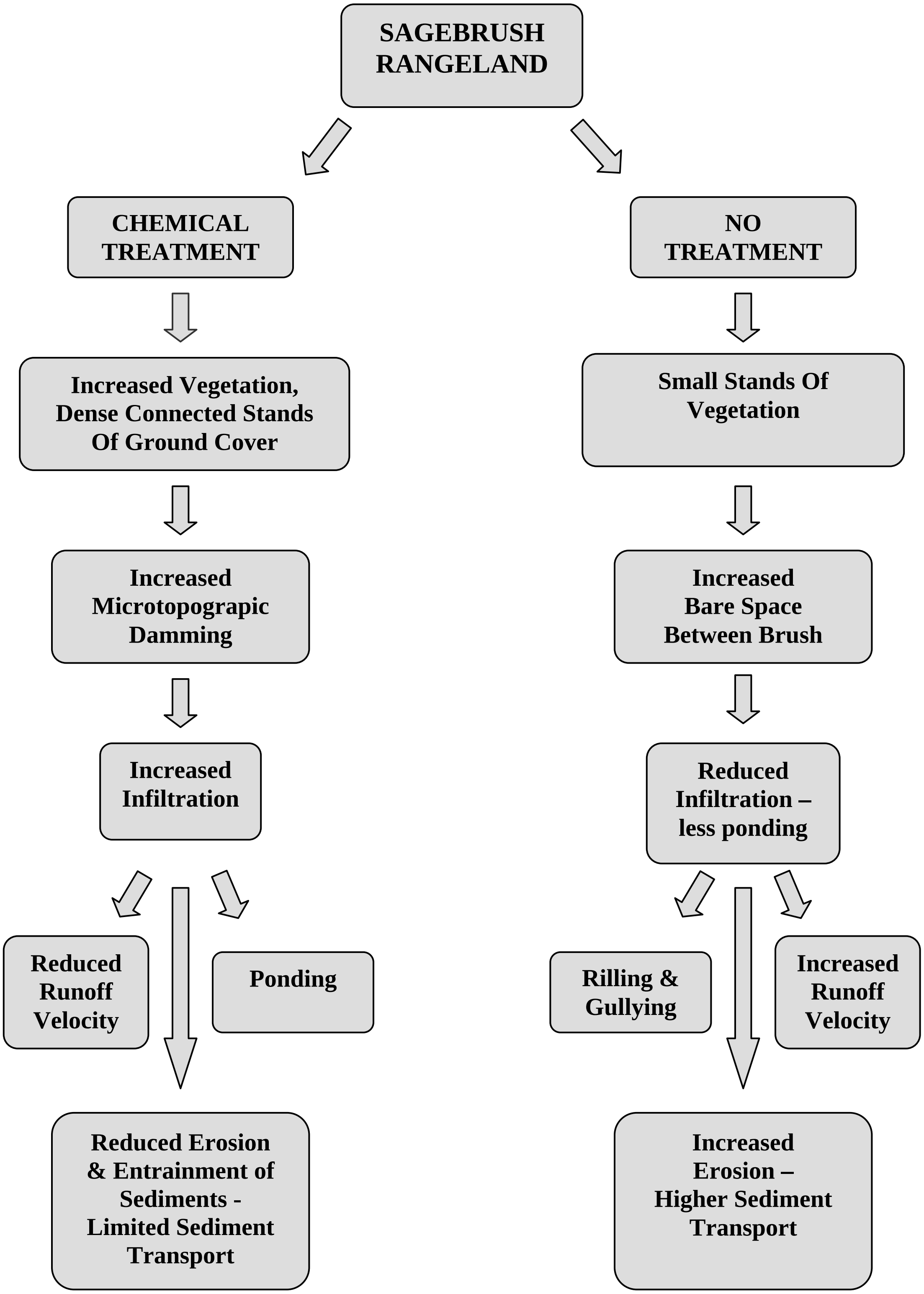


Figure 43: Flowchart of possible runoff behavior for treated and untreated sagebrush rangeland.

SUMMARY AND CONCLUSIONS

Comparison of chemically treated and untreated sagebrush rangeland in the small first-order drainage of Bastard Draw resulted in significant differences in sediment production. Rainfall simulations over 1 m^2 plots were used to collect runoff data from a total of 36 runs. Greatest sediment yield was produced in the order bare ground > grass > shrub on treated and grass > bare ground > shrub on untreated portions of the tributary.

Significant differences in the vegetation coverage were present between both treatment types. Treated areas not only had greater quantities of ground cover than untreated areas but also reflected slight variations in species diversity, especially grasses. However, averaged bare soil patches, although decreasing in overall percentage, were only slightly smaller in the treated area. The bare area is therefore not controlled by the size of patches but rather its decline in frequency and abundance.

Density and spatial arrangement of vegetation appear to exercise the strongest control over the amount of runoff and soil erosion. Increased growth of herbaceous ground cover affects sediment movement through (1) formation of continuous barriers that slow runoff velocity, (2) enhanced surface microtopography, (3) increased infiltration due to ponding, and (4) detainment of sediments.

The increase of vegetation and the reduction of bare space after chemical treatment also influenced conductivity. Estimates of Green-Ampt conductivities increased on plots with elevated amount of ground cover, suggesting that vegetation density, especially the connectivity of grasses, encourage ponding that allows for a greater time to infiltrate runoff.

Although results from this study support the chemical treatment of sagebrush rangeland, it needs to be remembered that erosion processes are complex and are characterized by significant spatial and temporal variation. Continuous monitoring should therefore be an ongoing effort to ensure that each chemical application on sagebrush rangeland results in the desired increase of ground cover and reduction of erosion.

FUTURE WORK

Future efforts should address a more detailed evaluation of the role that vegetation density and its spatial distribution play in sediment movement. This should be accomplished with rainfall simulations during different seasons and on varying plot sizes. Experiments at different locations would expand variations in soil moisture, bulk density, soil type, and slope to determine a broader understanding of how vegetation, surface, and landscape interactions influence sediment production.

Of additional value would be long-term studies that use inexpensive, simple techniques to monitor changes in chemically treated and untreated rangeland. Installation of additional erosion pin transects may aid in recording the dynamics of sediment movement in target tributaries or small watersheds. Evaluation of these dynamics before and after treatment over several years could show if and where the greatest changes in sediment production occur.

To further measure the transformation before and after chemical treatment, vegetation transects should be compiled over the years to monitor if, how, and when treatment shows results. Vegetation and erosion transects could be joined to allow for additional low-cost observations that provide data for watershed modeling.

REFERENCES

Aboulabbes, O., D.J. Kotansky, and R.H. Hawkins, 1985. Interrelating infiltration measurements. In Watershed Management in the Eighties, Proceedings of the Symposium Sponsored by the Committee on Watershed Management of the Irrigation and Drainage Division of the ASCE in conjunction with the ASCE Convention in Denver, CO., pp. 273-284.

Abrahams, A.D., A.J. Parsons, and J. Wainwright, 1995. Effects of vegetation change on interrill runoff and erosion, Walnut Gulch, southern Arizona. Geomorphology, 13:37-48.

Agassi, M., J. Morin, and I. Shainberg, 1985. Effect of drop impact energy and water salinity on filtration rates of sodic soils. Soil Sci. Soc. Am. J. 49:186-190.

Aguilar, R., and E.F. Aldon, 1991. Runoff and sediment rates on San Mateo and Querencia soils, Rio Puerco Watershed Management Area, NM. USDA Forest Serv. Res. Note RM-506, 7pp.

Alley, H.P., 1965. Big sagebrush control. Wyoming Agr. Exp. Sta., Bull. 345R, Laramie, WY.

Alley, H.P., and D.W. Bohmont, 1958. Big sagebrush control. Wyoming Agr. Exp. Sta., Bull. 345, Laramie, WY.

American Public Health Assoc., American Water Works Assoc., and Water Env. Fed., 1992. Standard methods for the examination of water and wastewater. 18th ed., Washington, D.C., p. 2-44.

Amin, I.E., 1983. Modeling of sediment transport in the Rio Puerco, New Mexico. Masters Thesis, NM Inst. of Mining and Tech., Socorro, NM.

Austin, G., NM Bureau of Mines and Mineral Resources, written communication 2000.

Bailey, R.W., 1935. Epicycles of erosion in the valleys of the Colorado Plateau Province. J. of Geol., 63:337-355.

Balliette, J.F., K.C. McDaniel, and M.K. Wood, 1986. Infiltration and sediment production following chemical control of sagebrush in New Mexico. J. Range Management, 39(2):160-165.

Bastian, C.T., J.J. Jacobs, and M.A. Smith, 1995. How much sagebrush is too much: an economic threshold analysis. J. Range Management, 48:73-80.

Bartolome, J.W., and H.F. Heady, 1978. Ages of big sagebrush following brush control. J. Range Management, 31:403-411.

Benedict, A.D., 1991. A Sierra Club naturalist's guide: the Southern Rockies: the Rocky Mountain regions of southern Wyoming, Colorado, and northern New Mexico. Sierra Club Books, San Francisco.

Ben-Hur, M., I Shainberg, and J. Morin, 1987. Variability of infiltration in a field with surface-sealed soil. Soil Sci. Soc. Am. J., 51:1299-1302.

Birkeland, P.W., 1999. Soils and geomorphology, 3rd ed., Oxford Univ. Press, Inc.

Blackburn, W.H., R.O. Meeuwig, and C.M. Skau, 1974. A mobile infiltrometer for use on rangeland. J. Range Management, 27:322-323.

Blackburn, W.H., 1975. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resour. Res., 11:929-937.

Blackburn, W.H., 1983. Influence of brush control on hydrologic characteristics of range watersheds. Proc. Brush Management Symp., Soc. for Range Management, Albuquerque, NM, Feb. 16, 1983. Texas Tech Univ. Press, pp. 73-88.

Blackburn, W.H., and Pierson, F.B., 1994. Sources of variation in interrill erosion on rangelands. Variability of Rangeland Water Erosion Processes, Soil Sci. Soc. of Amer. Special Publication 38, pp. 1-9.

Blaisdell, J.P., R.B. Murray, and E.D. McArthur, 1982. Managing inter-mountain rangelands; sagebrush-grass ranges. Gen. Tech. Rep. INT-134, USDA Intermountain Forest and Range Exp. Sta., Ogden, UT.

Bolton, S.M., and T.J. Ward, 1991. Hydrologic processes in the pinyon-juniper vegetation zone of Arizona and New Mexico. Proc. of 36th Annual NM Water Conf., NM Water Resour. Res. Inst. Rep. 265, pp. 31-44.

Bonham, C.D., 1989. Measurements for terrestrial vegetation. J. Wiley & Sons, New York, p. 22.

Bryan, K., 1928. Historic evidence on changes in the channel of Rio Puerco, a tributary of the Rio Grande in New Mexico. J. of Geol., 36:265-282.

Cary, J.W., and D.D. Evans, 1974. Soil crusts. Tech. Bull. No. 214, Univ. of Arizona, Tucson.

Chow, V.T. and T.E. Harbaugh, 1965. Raindrop production for laboratory watershed experimentation. J. Geophys. Res., 70(24):6111-6119.

Clary, W.P., S. Goodrich, and B.M. Smith, 1985. Response to tebuthiuron by Utah juniper and mountain big sagebrush communities. J. Range Management, 38(1):56-60.

Cornelius, D.R., and C.A. Graham, 1958. Sagebrush control with 2,4-D. J. Range Management, 11:122-125.

Dixon, R.M., 1975. Infiltration control through soil surface management. Proc. Symp. On Watershed Management, ASCE, Logan, UT, pp. 543-567.

Dortignac, E.J., 1956. Watershed resources and problems of the Upper Rio Grande Basin. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

Elliott, J.G., 1979. Evolution of large arroyos – the Rio Puerco of New Mexico. Unp. Masters’s Thesis, Col. State Univ., Ft. Collins.

Elliott, J.G., A.C. Gellis, S.B. Aby, and M.J. Pavich, 1997. 20th century evolution of the Rio Puerco arroyo, New Mexico; channel-geometry changes and inner floodplain aggradation. Geol. Soc. of Amer. Abstr. 29(6):372.

Elliott, J.G., A.C. Gellis, and S.B. Aby, 1998. Evolution of arroyos – incised channels of the southwestern United States. In Thorne, C., ed. Incised Channels, in press.

Environmental Protection Agency, 1972. Pesticide Study Series – The use and effects of pesticides for rangeland sagebrush control. Office of Water Programs, Washington, D.C.

Felhendler, R.I., I. Shainberg, and H. Frenkel, 1974. Dispersion and hydraulic conductivity of soils mixed in solution. Trans. Int. Cong. Soil Sci., 10th, 1:103-112.

Fischer, S., BLM Albuquerque, personal communication, spring 2000.

Folk, R.L., 1974. Petrology of sedimentary rocks. Hemphill, Austin, TX, 182 p.

Gellis, A.C., 1992. Decreasing trends of suspended sediment loads in selected streamflow stations in New Mexico. NM Water Resour. Res. Inst. Rep. no. 265, Proc. of the 36th ann. NM Water Conf., Las Cruces, NM, p. 77-93.

Gellis, A.C., and M.J. Pavich, 1999. The U.S. Geological Survey global climate change program in the Rio Puerco basin, New Mexico. USGS middle Rio Grande basin study, USGS Open-File Report.

Gellis, A.C., U.S. Geological Survey, Reston, VA, written communication, 2001.

Gifford, G.F., and F.E. Busby, 1973. Loss of particulate organic materials from semiarid watersheds as a result of extreme hydrologic events. Water Resour. Res., 9(5):1443-1449.

Gifford, G.F., and R.H. Hawkins, 1976. Grazing systems and watershed management: a look at the record. J. Soil Water Cons., 31(6):281-283.

Gifford, G.F., 1985. Cover allocation in rangeland watershed management (A review). Watershed Management in the Eighties. Edited by E.B. Jones and T.J. Ward. New York, NY: ASCE.

Green, W.H., and G. Ampt, 1911. Studies of soil physics, Part I: The flow of air and water through soils. J.Agric. Sci., 4(1)1-24.

Hastings, J.R., and R.M. Turner, 1965. The changing mile. University of Arizona Press, Tucson, 317 pp.

Helalia, A.M., J. Letey, and R.C. Graham, 1988. Crust formation and clay migration effects on infiltration rate. Soil Sci. Soc. Am. J. 52:251-255.

Henry, C., 1998. Benefits of sagebrush thinning. Vegetation Managers J., 1(2):4-7.

Hoffman, G.R., and D.L. Hazlett, 1977. Effects of aqueous Artemisia extracts and volatile substances on germination of selected species. J. Range Management, 30(2):134-137.

Horton, R. E., 1939. Analysis of runoff plot experiments with varying infiltration capacity. Trans. Am. Geophys. Un., pt. 5, pp 693-694.

Hull, A. C., Jr., and W.T. Vaughn, 1951. Controlling big sagebrush with 2,4-D and other chemicals. J. Range Management, 4:158-164.

Hull, A. C., Jr., N.A. Kissinger, Jr., and W.T. Vaughn, 1952. Chemical control of big sagebrush in Wyoming. J. Range Management, 5:398-402.

Humphrey, R.R., 1958. The desert grassland: a history of vegetation change and analysis of causes. Bot. Rev., 24:193-252.

Hyder, D.N., and F.A. Sneva, 1962. Selective control of big sagebrush associated with bitterbrush. J. Range Management, 15:211-219.

Jaynes, D.B., 1990. Temperature variations effect on field measured infiltration. Soil Sci. Soc. Am. J. 54:305-312.

Johnson, J.R., and G.F. Payne, 1968. Sagebrush reinvasion as affected by some environmental influences. J. Range Management, 21:209-213.

Johnson, J.R., and N.D. Gordon, 1988. Runoff and erosion from rainfall simulator plots on sagebrush rangeland. Transactions of the ASAE, 31:421-427.

Johnson, C.W., and W.H. Blackburn, 1989. Factors contributing to sagebrush rangeland soil loss. Transactions of the ASAE, 32(1):155-160.

Kearl, W.G., 1965. A survey of big sagebrush control in Wyoming, 1952-64. Wyoming Agr. Exp. Sta. Bull. M.C. 217, Laramie, WY.

Kearl, W.G., and M. Brannan, 1967. Economics of mechanical control of sagebrush in Wyoming. Wyoming Agr. Exp. Sta. Science Mono. 5, Laramie, WY.

Kincaid, D.R., J.L. Gardner, and H.A. Schreiber, 1964. Soil and vegetation parameters affecting infiltration under semiarid conditions. Bull. IAHS, 64:440-453.

Kinnell, P.I.A., 1997. Runoff ratio as a factor in the empirical modeling of soil erosion by individual rainstorms. Aust. J. Soil Res., 35:1-13.

Laflen, J.M., L.J. Lane, and G.R. Foster, 1991. WEPP, a new generation of erosion prediction technology. J. Soil Water Conserv., 46:34-48.

Lane, L.J., J.R. Simanton, T.E. Hakonson, and E.M. Romney, 1987. Large-plot infiltration studies in desert and semiarid rangeland areas of the Southwestern USA. Proc. of the Intl. Conf. on Infiltration Dev. and Appl., Honolulu, HI, Jan. 6-8.

Love, D.W., 1986. A geological perspective of sediment storage and delivery along the Rio Puerco, central New Mexico. In Drainage Basin Sediment Delivery, in Hadley, R.F. ed. Intl. Assoc. of Hydrological Sciences Publication 159, p. 305-322.

Love, D.W., 1997. Implications for models of arroyo entrenchment and distribution of archaelogical sites in the middle Rio Puerco. In Duran, M.S. and Kirkpatrick, D.T., eds., Layers of Time, the Arch. Soc. of NM, 23:69-84.

Lusby, G.C., 1979. Effects of converting sagebrush cover to grass on the hydrology of small watersheds at Boco mountain, Colorado. U.S. Geol. Surv. Water Supply Paper 1532-J, 36 pp.

Marshall, T.J., J.W. Holmes, and C.W. Rose, 1996. Soil Physics. Cambridge Univ. Press, 3rd ed., 453 pp.

McDaniel, K.C., and F.F. Balliette, 1986. Control of big sagebrush (Artemisia tridentata) with pelleted tebuthiuron. Weed Science, 34:276-280.

McDaniel, K.C., D.L. Anderson, and L.A. Torrel, 1992. Vegetation change following big sagebrush control with tebuthiuron. Agric. Exp. Station, NM State Univ., Bulletin 764, 41 pp.

McMahon, Dennis, 1998. Soil, landscape and vegetation interactions in a small semi-arid drainage basin: Sevilleta National Wildlife Refuge, New Mexico. M.S. thesis, NM Inst. of Mining and Technology.

Mein, R.G., and C.L. Larson, 1973. Modeling infiltration during a steady rain. Water Res. Research, 9(2):384-394.

Miller, R.F., R.R. Findley, and J. Alderfer-Findley, 1980. Changes in mountain big sagebrush habitat types following spray release. J. Range Management, 33(4):278-281.

Morin, J., R. Keren, Y. Benjamini, M. Ben-Hur, and I. Shainberg, 1988. Water infiltration as affected by soil crust and moisture profile. Soil Science 148(1):53-59.

Morin, J., and J. Van Winkel, 1996. The effect of raindrop impact and sheet erosion on infiltration rate and crust formation. Soil Sci. Soc. Am. J., 60:1223-1227.

Moore, D., and M.J. Singer, 1990. Crust formation and soil erosion processes. Soil Sci. Soc. Am. J., 54:1117-1123.

Mueggler, W.F., and J.P Blaisdell, 1958. Effects of associated species of burning, roto-beating, spraying, and railing sagebrush. J. Range Management, 11:61-66.

Nordin, C.F., 1963. A preliminary study of sediment transport parameters, Rio Puerco near Bernardo, New Mexico. USGS Prof. Pap. 462-C.

Nordin, C.F., 1964. Study of channel erosion and sediment transport. Proc. of the Amer. Soc. of Civ. Eng. 90(4):173-192.

Olson, R., J. Hansen, T. Whitson, and K. Johnson, 1994. Tebuthiuron to enhance rangeland diversity. Rangelands, 16(5):197-201.

Parsons, A.J., A.D. Abrahams, and J.R. Simanton, 1992. Microtopography and soil-surface materials on semi-arid piedmont hillslopes, southern Arizona. J. Arid Environ., 22:107-115.

Pechanec, J.F., G. Stewart, A.P. Plummer, J.H. Robertson, and A.C. Hull, Jr., 1954. Controlling sagebrush on rangelands. USDA Farmer’s Bull. No. 2072, Washington, D.C., U.S. Govt. Printing Office.

Pierson, F.B., S.S. Van Vactor, W.H. Blackburn, and J.C. Wood. 1994a. Incorporating small scale spatial variability into predictions of hydrologic response on sagebrush rangelands. In Variability of Rangeland Water Erosion Processes, Proc. of a Symp. of the Soil Sci. Soc. of Am. in Minneapolis, MN, 1-6 Nov., Special Pub. 38.

Pierson, F.B., W.H. Blackburn, S.S. Van Vactor, and J.C. Wood. 1994b. Partitioning small scale spatial variability of runoff and erosion on sagebrush rangeland. Water Res. Bull., 30(6):1081-1089.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, 1993. Prediciting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook 703, U.S. Dept. Agric., Washington. D.C.

Rieger, W.A., L.J. Olive, and C.J. Gippel, 1988. Channel sediment behavior as a basis for modeling delivery processes. Sediment Budgets, Proceedings of the Porto Alegre Symposium, IAHS Publ. No. 174.

Schlesinger, W.H., J.F. Reynolds, G.L Cunningham, L.F. Huennecke, W.M. Jarrell, R.A. Virginia, and W.G. Whitford, 1990. Biological feedbacks in global desertification. Science, 247:1043-1048.

Scholl, D.G., and Aldon, E.F., 1988. Runoff and sediment yield from two semiarid sites in New Mexico’s Rio Puerco watershed. Fort Collins, CO. Rocky Mountain Forest and Range Experiment Station, Research Note RM-488, 4 pp.

Scholl, D.G., 1989. Soil compaction from cattle trampling on a semiarid watershed in northwest New Mexico. NM J. Science, 29(2):105-112.

Shainberg, I., and M.J. Singer, 1985. Effect of electrolytic concentration on the hydraulic properties of depositional crusts. Soil Sci. Soc. Am. J. 49:1260-1263.

Simanton, J.R., and K.G. Renard, 1982. Seasonal change in infiltration and erosion from USLE plots in southeastern Arizona. Hydrol. and Water Res. in Ariz. and the Southwest Proc., Am. Wat. Res. Assn., vol. 12, April 24, 1982, Tempe, AZ., pp. 37-46.

Simanton, J.R., M.A. Weltz, and H.D. Larsen, 1991. Rangeland experiments to parameterize the Water Erosion Prediction Project Model: vegetation canopy cover effects. J. Range Sci. 44(3):276-282.

Simanton, J.R., and E. Emmerich, 1994. Temporal variability in rangeland erosion processes. Variability of Rangeland Water Erosion Processes, Soil Sci. Soc. Of Amer. Special Publication 38, pp. 51-65.

Simons, D.B., R. Li, L. Li, and M.J. Ballantine, 1981. Erosion and sedimentation analysis of the Rio Puerco and Rio Salado Watersheds. Simons Li and Associates, Report submitted to the U.S. Army Corps of Engineers, Albuquerque District, 66 p.

Smelser, W., personal communication 1999.

Smith, M.A., and F. Busby, 1981. Prescribed burning: effective control of sagebrush in Wyoming. Wyoming Agr. Exp. Sta. Bull. RJ-165, Laramie, WY.

Soil Survey Division Staff, 1993. Soil survey manual. U.S. Dept. Agri. Handbook No. 436, 754 pp.

Soil Survey of Sandoval County, U.S. Dept. of Agr. Soil Conservation Service, 1987.

Soil Conservation Service, 1977. The small watershed program in New Mexico, 18 pp.

Stephenson, G.R., and A. Veigel, 1987. Recovery of compacted soil on pastures used for winter cattle feeding. J. Range Management, 40:46-48.

Sturges, D.L., 1986. Responses of vegetation and ground cover to spraying a high elevation, big sagebrush watershed with 2,4-D. J. Range Management, 39:141-146.

Tabler, R.D., 1959. The root system of Artemisia tridentata. Ecology, 45:633-636.

Tanaka, J.A., and J.P. Workman, 1988. Economic optimum big sagebrush control for increasing crested wheatgrass production. J. Range Management, 41:172-177.

Thilenius, J.F., G.R. Brown, and R. Gary, 1974. Long-term effects of chemical control of big sagebrush. J. Range Management, 27(3):223-224.

Tindall, J.A., J.R. Kunkel, and D.E. Anderson, 1999. Unsaturated Zone Hydrology. Prentice Hall, NJ, 624 pp.

Tisdale, E.W., M. Hironaka, and M.A. Fosberg, 1969. The sagebrush region in Idaho – a problem in range resource management. Idaho Agr. Exp. Sta. Tech. Bull. 512, Univ. of Idaho, Moscow.

Tracy, F.C., K.G. Renard, and M.M. Fogel, 1984. Rainfall energy characteristics for southeastern Arizona. In J.A. Repogle and K.G. Renard (eds.) Water Today and Tomorrow, ASCE, New York, New York, pp. 559-566.

Tromble, J.M., K.G. Renard, and A.P. Thatcher, 1974. Infiltration for three rangeland soil-vegetaion complexes. J. Range Management, 27(4):3318-321.

U.S. Bureau of Reclamation, 1994. Rio Puerco sedimentation and water quality study. U.S. Bureau of Reclamation Preliminary Findings Report, 47 p.

U.S. Department of Agriculture, 2001. Fire effects information. Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Fire Effects Information System: http://www.fs.fed.us/database/feis/

U.S. Department of Commerce, 1973. Precipitation frequency atlas of the western United States. v. IV, NM. Natl. Oceanic and Atm. Admin., Natl. Weather Serv., Atlas 2.

U.S. National Library of Medicine, 1995. Hazardous Substances Databank. Bethesda, MD.

Wambolt, C.L., and G.F. Payne, 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. J. Range Management, 39:314-319.

Ward, T.J., personal communication, spring 2001.

Ward, T.J., 1986. A study of runoff and erosion processes using large and small area rainfall simulators. NM Water Resour. Res. Inst., Tech. Compl. Rep. no. 215, NM State Univ., 71 pp.

Ward, T.J., and S.B. Bolin, 1989. Determination of hydrologic parameters for selected soils in Arizona and New Mexico utilizing rainfall simulation. NM Water Resour. Res. Inst., Tech. Compl. Rep. no. 243, NM State Univ., 84 pp.

Ward, T.J., and S.M. Bolton, 1991. Hydrologic parameters for selected soils in Arizona and New Mexico as determined by rainfall simulation. NM Water Resour. Res. Inst., Tech. Compl. Rep. no. 259, NM State Univ., 79 pp.

Weed Science Society of America, 1994. Herbicide Handbook, 7th Edition. Champaign, IL.

Wells, S. G., T.F. Bullard, C.D. Condit, M. Jercinovic, R.P. Lozinsky, and D.E. Rose, 1982. Geomorphic processes on the alluvial valley floor of the Rio Puerco. NM Geol. Soc. Guidebook, Albuquerque Country II, 33:45-47.

Western Regional Climate Center, Desert Research Institute, Reno, NV. http://www.wrcc.dri.edu/cgi-bin/cliMONtpre.pl?nmcuba

Wicks, J.M., J.C. Bathurst, C.W. Johnson, and T.J. Ward, 1988. Application of two physically-based sediment yield models at plot and field scales. Proceedings of the IAHS Intl. Symposium on Sediment Budgets, Porto Alegre, Brazil, Dec. 11-15, 1988.

Williams, J.D., J.P. Dobrolowski, and N.E. West, 1995. Microphytic crust influence on interrill erosion and infiltration capacity. Trans. of the ASAE 38(1):139-146.

Williamson, T.E., and S.G. Lucas, 1992. Stratigraphy and mammalian biostratigraphy of the Paleocene Nacimiento Formation, southern San Juan Basin, New Mexico. New Mexico Geological Society Guidebook, 43rd Field Conference, San Juan Basin IV.

Yair, A., and H. Lavee, 1985. Runoff generation in arid and semi-arid zones. Hydrol. Forecasting, Ch. 8:183-205, J. Wiley & Sons Ltd.

APPENDIX A

Data Collection Sheets for Untreated and Treated Plots

TREATED Grass 1 Dry

PLOT ID#: Grass 1 (long grass) **DATE:** 7/2/2000 **DRY** **WIND:** ~5 **SKY:** clouding up

VEGETATION: 75
BRUSH: 0
BARE SOIL: 25 (see remarks)
TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 3:14:45
TIME TO PONDING: 3:18:59
TIME TO RUNOFF ONTO TRAY: 3:18:07
TIME AT RAINFALL OFF: 3:44:45
TIME AT END OF RUNOFF: 3:44:47

PAN RUNOFF / 20 SEC: 1200 1250 1175 1225 **1213**

RUNOFF VOLUME TOTAL (ml): 15000

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 10.5

Runoff (ml)	**Time**
3450	3:24:30
3600	3:30:30
3500	3:37:00
4000	
450	
15000	

Remarks: ~500 ml at 2 min. from rain hitting flume grass catches everything, hardly any runoff (3:21:00) most runoff from flume, tiny bit of seds from small area in front of flume

Bare % actually higher but coverd by long grass

TREATED Grass 1 Wet

PLOT ID#: Grass 1 **DATE:** 7/3/2000 **WET** **WIND:** ~2-3 **SKY:** CLEAR

VEGETATION: 75
BRUSH: 0
BARE SOIL: 25
TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 10:16:00
TIME TO PONDING: 10:17:30
TIME TO RUNOFF ONTO TRAY: 10:17:56
TIME AT RAINFALL OFF: 10:46:00
TIME AT END OF RUNOFF: 10:46:40

PAN RUNOFF / 20 SEC: 1250 1350 1400 1400 1375 1355

RUNOFF VOLUME TOTAL (ml): 18350

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 13.0

Runoff (ml)	**Time**
3750	10:27:00
3750	10:33:00
3950	10:38:30
3800	
3100	
18350	

TREATED Grass 2 Dry

PLOT ID#: Grass 2 (short grass) **DATE:** 7/3/2000 **DRY** **WIND:** 0-2 **SKY:** clear

VEGETATION: 80
BRUSH: 0
BARE SOIL: 20

TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 12:14:30
TIME TO PONDING: 12:15:52
TIME TO RUNOFF ONTO TRAY: 12:17:21
TIME AT RAINFALL OFF: 12:44:30
TIME AT END OF RUNOFF: 12:45:22

PAN RUNOFF / 20 SEC: 1300 1425 1275 1225 1300 1350 **1313**

RUNOFF VOLUME TOTAL (ml): 39300

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 26.5

Runoff (ml)	Time
2750	12:21:00
3750	12:24:40
3900	12:27:00
3950	12:29:30
4000	12:32:00
3500	12:34:00
3900	12:36:30
3850	12:39:00
3750	12:41:00
3550	12:43:00
2400	
39300	

Remarks: water ponds but is trapped by grass patches
so hardly any runoff occurs (12:17:00);
mostly clear water, no seds, get trapped by grass (12:31:00)

TREATED Grass 2 Wet

PLOT ID#: Grass 2 **DATE:** 7/4/2000 **WET** **WIND:** **SKY:** partly cloudy

VEGETATION: 80
BRUSH: 0
BARE SOIL: 20

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 8:45:00
TIME TO PONDING: 8:45:52
TIME TO RUNOFF ONTO TRAY: 8:48:42
TIME AT RAINFALL OFF: 9:05:00
TIME AT END OF RUNOFF: 9:06:23

Runoff (ml)	Time
3575	8:52:30
3500	8:55:15
3800	8:57:15
3250	9:01:00
3250	9:03:30
2850	
20225	

PAN RUNOFF / 20 SEC: 1425 1475 1475 1475 **1463**

RUNOFF VOLUME TOTAL (ml): 20225

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 14.5

TREATED Grass 3 Dry

PLOT ID#: Grass 3 **DATE:** 7/4/2000 **DRY** **WIND:** **SKY:** partly cloudy

VEGETATION: 75
BRUSH: 0
BARE SOIL: 25 (see remarks)

TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 2:17:00
TIME TO PONDING: 2:18:51
TIME TO RUNOFF ONTO TRAY: 2:19:23
TIME AT RAINFALL OFF: 2:47:00
TIME AT END OF RUNOFF: 2:47:56

Runoff (ml)	Time
3800	2:27:00
3800	2:33:00
3850	2:40:00
3900	2:45:00
1550	
16900	

PAN RUNOFF / 20 SEC: 1400 1400 1425 1400 **1406**

RUNOFF VOLUME TOTAL (ml): 16900

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 12.2

Remarks: sed runoff froma a bare spot not surrounded by grasses, otherwise nothing but clear water

Bare soil overlapped by long grasses

TREATED Grass 3 Wet

PLOT ID#: Grass 3 **DATE:** 7/4/2000 **WET** **WIND:** 0 **SKY:** clear

VEGETATION: 75
BRUSH: 0
BARE SOIL: 25

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 8:43:00
TIME TO PONDING: 8:44:01 (in some spots)
TIME TO RUNOFF ONTO TRAY: 8:44:15 (out of front of flume)
TIME AT RAINFALL OFF: 9:03:00
TIME AT END OF RUNOFF: 9:04:01

Runoff (ml)	Time
3800	8:49:00
3900	8:54:00
3650	8:57:00
3850	9:00:30
3950	
300	
19450	

PAN RUNOFF / 20 SEC: 1450 1500 1550 1550 1550 1520

RUNOFF VOLUME TOTAL (ml): 19450

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 14.0

Remarks: mostly clear water running off, lots from water hitting flume

TREATED Shrub 1 Dry

										Runoff (ml)	**Time**
PLOT ID#:	Shrub 1	**DATE:**	7/2/2000	**DRY**		**WIND:**	5	**SKY:**	partly cloudy	3600	4:34:00
										3550	
VEGETATION:	20			**TIME OF PAN REMOVAL:**				4:21:15		850	
BRUSH:	75			**TIME TO PONDING:**				4:23:20	(in sm. Pocket of bare soil)	8000	
BARE SOIL:	5			**TIME TO RUNOFF ONTO TRAY:**				4:24:52			
				TIME AT RAINFALL OFF:				4:41:15			
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**				4:42:10			
PAN RUNOFF / 20 SEC:	1550	1425	1400	1375		**1438**					
RUNOFF VOLUME TOTAL (ml):	8000										
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	6.0										

TREATED Shrub 1 Wet

										Runoff (ml)	**Time**
PLOT ID#:	Shrub 1	**DATE:**	7/3/2000	**WET**		**WIND:**	0-4	**SKY:**	clear	2950	9:52:30
										1025	
VEGETATION:	20			**TIME OF PAN REMOVAL:**				9:35:15		3975	
BRUSH:	75			**TIME TO PONDING:**				9:36:11	(in sm. Pocket of bare soil)		
BARE SOIL:	5			**TIME TO RUNOFF ONTO TRAY:**				9:43:07	(first runoff from sm. Bare pockets)		
				TIME AT RAINFALL OFF:				9:55:15			
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**				9:56:11			
PAN RUNOFF / 20 SEC:	1325	1400	1275	1500	1450	1425		**1396**			
RUNOFF VOLUME TOTAL (ml):	3975										
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	3.0										

TREATED Shrub 2 Dry

										Runoff (ml)	**Time**
PLOT ID#:	Shrub 2	**DATE:**	7/3/2000	**DRY**		**WIND:**		**SKY:**	clear	3675	11:31:45
										3600	11:35:00
VEGETATION:	30			**TIME OF PAN REMOVAL:**			11:23:00			3300	11:39:00
BRUSH:	45			**TIME TO PONDING:**			11:24:16			3250	11:42:00
BARE SOIL:	25			**TIME TO RUNOFF ONTO TRAY:**			11:25:22			1800	
				TIME AT RAINFALL OFF:			11:43:00			15625	
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**			11:43:57				
PAN RUNOFF / 20 SEC:	1425	1450	1450	1500	1450		**1455**				
RUNOFF VOLUME TOTAL (ml):	15625										
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	11.5										

TREATED Shrub 2 Wet

										Runoff (ml)	**Time**
PLOT ID#:	Shrub 2	**DATE:**	7/4/2000	**WET**		**WIND:**	~2-5	**SKY:**	partly cloudy	3900	9:39:00
										3500	9:42:00
VEGETATION:	30			**TIME OF PAN REMOVAL:**			9:30:30			3400	9:45:00
BRUSH:	45			**TIME TO PONDING:**			9:31:40			3400	9:47:30
BARE SOIL:	25			**TIME TO RUNOFF ONTO TRAY:**			9:32:27			2600	
				TIME AT RAINFALL OFF:			9:50:00			2250	
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**			9:51:32			19050	
PAN RUNOFF / 20 SEC:	1525	1500	1500	1500		**1506**					
RUNOFF VOLUME TOTAL (ml):	19050										
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	13.8										

TREATED Shrub 3 Dry

PLOT ID#: Shrub 3 **DATE:** 7/4/2000 **DRY** **WIND:** ~2-5 **SKY:** clear

VEGETATION: 40
BRUSH: 40
BARE SOIL: 20

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 10:33:00
TIME TO PONDING: 10:34:31
TIME TO RUNOFF ONTO TRAY: 10:34:50
TIME AT RAINFALL OFF: 10:53:00
TIME AT END OF RUNOFF: 10:54:07

PAN RUNOFF / 20 SEC: 1450 1400 1500 1475 1475 **1460**

RUNOFF VOLUME TOTAL (ml): 26300

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 18.5

Runoff (ml)	**Time**
3850	10:39:00
3900	10:42:00
3900	10:44:00
3800	10:46:00
3450	10:48:00
2450	10:51:00
3050	
1900	
26300	

TREATED Shrub 3 Wet

PLOT ID#: Shrub 3 **DATE:** 7/5/2000 **WET** **WIND:** ~0-1 **SKY:** clear

VEGETATION: 40
BRUSH: 40
BARE SOIL: 20

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 9:25:30
TIME TO PONDING: 9:26:13
TIME TO RUNOFF ONTO TRAY: 9:27:03
TIME AT RAINFALL OFF: 9:45:33
TIME AT END OF RUNOFF: 9;47:05

PAN RUNOFF / 20 SEC: 1450 1650 1475 1500 1500 **1515**

RUNOFF VOLUME TOTAL (ml): 24450

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 17.5

Runoff (ml)	**Time**
3900	9:31:15
3900	9:34:30
3950	9:38:00
3900	9:39:30
3900	9:42:00
3050	9:44:00
1850	
24450	

TREATED Bare 1 Dry

PLOT ID#: Bare 1 **DATE:** 7/2/2000 **DRY** **WIND:** ~5 **SKY:** partly cloudy

VEGETATION: 2
BRUSH: 2
BARE SOIL: 96

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 5:07:45
TIME TO PONDING: 5:09:43
TIME TO RUNOFF ONTO TRAY: 5:10:19
TIME AT RAINFALL OFF: 5:27:52
TIME AT END OF RUNOFF: 5:29:05

PAN RUNOFF / 20 SEC: 1200 1150 1150 **1167** **1200**

RUNOFF VOLUME TOTAL (ml): 35000

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 24.0

Runoff (ml)	**Time**
3950	5:14:00
3900	5:16:00
3900	5:18:00
3950	5:20:00
3900	5:22:00
3950	5:24:00
3900	5:25:00
3900	5:27:00
3150	
500	
35000	

Remarks: at 5:11:30 switched to lower pressure (~2psi); water flow was too much of a spray w. 4-5 psi but had it that high to get higher ml for calibration

Pan runoff after: ~1200 ml

TREATED Bare 1 Wet

PLOT ID#: Bare 1 **DATE:** 7/3/2000 **WET** **WIND:** ~0-3 **SKY:** clearing

VEGETATION: 2
BRUSH: 2
BARE SOIL: 96

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 8:42:30
TIME TO PONDING: 8:43:15
TIME TO RUNOFF ONTO TRAY: 8:43:21
TIME AT RAINFALL OFF: 9:02:30
TIME AT END OF RUNOFF: 9:03:32

PAN RUNOFF / 20 SEC: 1350 1500 1400 1500 1450 **1440**

RUNOFF VOLUME TOTAL (ml): 31400

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 20.7

Runoff (ml)	**Time**
3850	8:47:05
3700	8:49:00
3300	8:51:00
3900	8:53:40
3950	8:56:00
3600	8:57:45
3500	9:00:00
3900	
1700	
31400	

Remarks: sputtering rainfall due to moody generator!!!

TREATED Bare 2 Dry

									Runoff (ml)	**Time**
PLOT ID#:	Bare 2	**DATE:**	7/3/2000	**DRY**	**WIND:**	~1-2	**SKY:**	clear	3750	1:27:00
									3800	1:25:00
VEGETATION:	2			**TIME OF PAN REMOVAL:**			1:13:30		3750	1:28:00
BRUSH:	0			**TIME TO PONDING:**			1:14:42		3775	1:30:00
BARE SOIL:	98			**TIME TO RUNOFF ONTO TRAY:**			1:15:53		3475	1:32:00
				TIME AT RAINFALL OFF:			1:33:30		1800	
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**			1:34:21		20350	
PAN RUNOFF / 20 SEC:	1350	1400	1450	1400	1450	**1410**				
RUNOFF VOLUME TOTAL (ml):	20350									
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	15.0									

TREATED Bare 2 Wet

									Runoff (ml)	**Time**
PLOT ID#:	Bare 2	**DATE:**	7/4/2000	**WET**	**WIND:**	~0-2	**SKY:**	clear	3900	7:58:00
									3925	8:00:00
VEGETATION:	2			**TIME OF PAN REMOVAL:**			7:54:15		3900	8:02:00
BRUSH:	0			**TIME TO PONDING:**			7:54:44		3750	8:03:30
BARE SOIL:	98			**TIME TO RUNOFF ONTO TRAY:**			7:55:16		3850	8:05:00
				TIME AT RAINFALL OFF:			8:14:15		3875	8:06:30
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**			8:15:49		3875	8:08:00
									3850	8:09:30
									3850	8:10:30
PAN RUNOFF / 20 SEC:	1300	1400	1400	1400	**1375**				3950	8:12:00
									3900	8:13:30
RUNOFF VOLUME TOTAL (ml):	43050								3875	
									450	
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	30.7								43050	

TREATED Bare 3 Dry

PLOT ID#: Bare 3 **DATE:** 7/4/2000 **DRY** **WIND:** ~5-10 **SKY:** clear

VEGETATION: 5
BRUSH: 0
BARE SOIL: 95 (some sticks)

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 3:09:15
TIME TO PONDING: 3:11:05
TIME TO RUNOFF ONTO TRAY: 3:11:45
TIME AT RAINFALL OFF: 3:29:15
TIME AT END OF RUNOFF: 3:29:55

PAN RUNOFF / 20 SEC: 1275 1400 1425 1425 **1381**

RUNOFF VOLUME TOTAL (ml): 17500

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 12.0

Runoff (ml)	**Time**
3600	3:17:15
3750	3:21:00
3850	3:24:00
3800	3:27:00
2500	
17500	

TREATED Bare 3 Wet

PLOT ID#: Bare 3 **DATE:** 7/5/2000 **WET** **WIND:** ~0-2 **SKY:** clear

VEGETATION: 5
BRUSH: 0
BARE SOIL: 95 (some sticks)

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 7:55:00
TIME TO PONDING: 7:55:41
TIME TO RUNOFF ONTO TRAY: 7:56:07
TIME AT RAINFALL OFF: 8:15:00
TIME AT END OF RUNOFF: 8:16:15

PAN RUNOFF / 20 SEC: 1450 1450 1450 **1450**

RUNOFF VOLUME TOTAL (ml): 31400 (messes up pump, measured later after run was over)

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 15.2

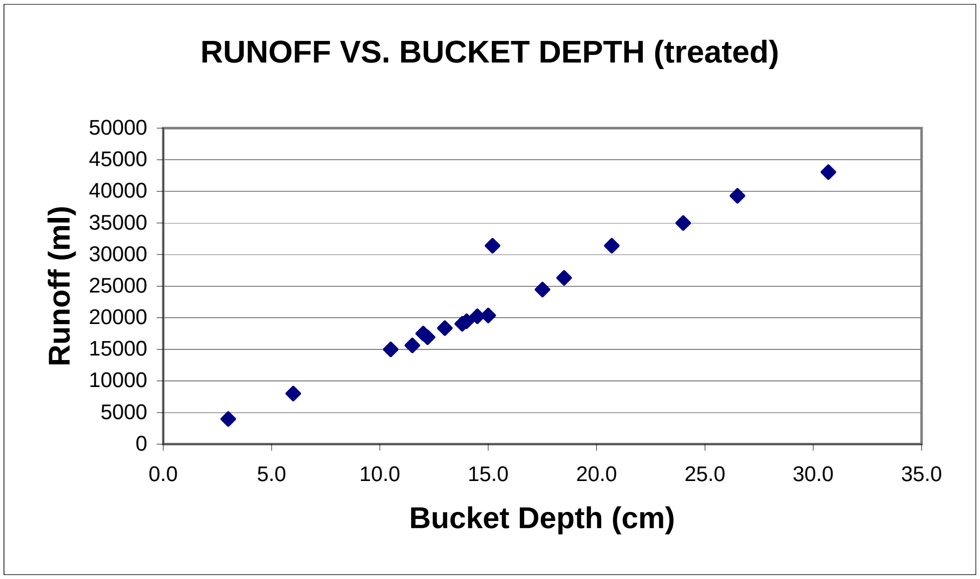
Runoff (ml)	**Time**
1150	no time data
3900	trough overflowed due to
3950	pump failure
3950	
3400	
3950	
1300	
3000	
3300	
3500	
31400	

Remarks: small trough pump went out, lost small fraction of water
no suspended sample, took it from bedload leftover

RUNOFF

PLOT ID	PAN RUNOFF/ 20 MIN	BUCKET DEPTH	RUNOFF TOTAL
GRASS 1 DRY	1213	10.5	15000
GRASS 1 WET	1355	13.0	18350
GRASS 2 DRY	1313	26.5	39300
GRASS 2 WET	1463	14.5	20225
GRASS 3 DRY	14.6	12.2	16900
GRASS 3 WET	1520	14.0	19450
SHRUB 1 DRY	1438	6.0	8000
SHRUB 1 WET	1396	3.0	3975
SHRUB 2 DRY	1455	11.5	15625
SHRUB 2 WET	1506	13.8	19050
SHRUB 3 DRY	1460	18.5	26300
SHRUB 3 WET	1515	17.5	24450
BARE 1 DRY	1200	24.0	35000
BARE 1 WET	1440	20.7	31400
BARE 2 DRY	1410	15.0	20350
BARE 2 WET	1375	30.7	43050
BARE 3 DRY	1381	12.0	17500
BARE 3 WET	1450	15.2	31400

PLOT ID	PAN RUNOFF/ 20 MIN	BUCKET DEPTH	RUNOFF TOTAL
GRASS 1 DRY	1213	10.5	15000
GRASS 2 DRY	1313	26.5	39300
GRASS 3 DRY	14.6	12.2	16900
GRASS 1 WET	1355	13.0	18350
GRASS 2 WET	1463	14.5	20225
GRASS 3 WET	1520	14.0	19450



UNTREATED Grass 1 Dry

PLOT ID#: Grass 1 **DATE:** 6/27/2000 **DRY** **WIND:** ~10 **SKY:** cloudy

VEGETATION: 40
BRUSH: 0
BARE SOIL: 60

TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 11:51:00
TIME TO PONDING: 11:53:00
TIME TO RUNOFF ONTO TRAY: 11:53:07
TIME AT RAINFALL OFF: 12:21:30
TIME AT END OF RUNOFF: 12:23:25

PAN RUNOFF / 20 SEC: 1700 1800 1750 1800 **1763**

RUNOFF VOLUME TOTAL (ml) 42300

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm) 28.02

Runoff (ml)	Time
3700	11:55:03
2800	11:57:10
2600	11:59:00
2900	12:01:00
2650	12:03:00
3250	12:05:00
3150	12:07:00
3150	12:09:00
3150	12:11:00
3100	12:13:00
3100	12:15:00
3050	12:17:00
3050	12:19:00
2650	12:21:00
42300	

UNTREATED Grass 1 Wet

PLOT ID#: Grass 1 **DATE:** 6/28/2000 **WET** **WIND:** 5-Feb **SKY:** cloudy

VEGETATION: 40
BRUSH: 0
BARE SOIL: 60

TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 10:27:00
TIME TO PONDING: 10:27:12
TIME TO RUNOFF ONTO TRAY: 10:27:20
TIME AT RAINFALL OFF: 11:03:51
TIME AT END OF RUNOFF: 11:05:06

PAN RUNOFF / 20 SEC: 1300 1400 1400 1400 1400 **1380**

RUNOFF VOLUME TOTAL (ml) 76500

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm) 51.5

Runoff (ml)	Time	Runoff (ml)	Time
2850	10:29:00	1950	10:43:00
2600	10:30:00	2000	10:44:00
2500	10:31:00	2850	10:44:30
2500	10:32:00	2800	10:45:30
1750	10:33:00	2850	10:46:30
1950	10:34:00	2800	10:47:30
2950	10:35:00	2850	10:48:30
2900	10:36:00	2750	10:49:30
2750	10:37:00	2500	10:50:30
2500	10:38:00	2350	10:51:30
2600	10:39:00	2800	10:52:45
2900	10:40:04	2850	10:53:30
1850	10:41:00	2750	10:54:30
1950	10:42:00	1900	10:55
34550		3000	10:56:30
		2950	
		76500	

UNTREATED Grass 2 Dry

PLOT ID#:	Grass 2	**DATE:**	6/29/2000	**DRY**		**WIND:**	~0-5	**SKY:**	clear/partly cloudy
VEGETATION:	45			**TIME OF PAN REMOVAL:**				12:15:18	
BRUSH:	0			**TIME TO PONDING:**				12:15:50	
BARE SOIL:	55			**TIME TO RUNOFF ONTO TRAY:**				12:16:12	
				TIME AT RAINFALL OFF:				12:41:30	
TOTAL RAINFALL TIME:	26 min (ran out of water)			**TIME AT END OF RUNOFF:**				12:43:56	
PAN RUNOFF / 20 SEC:	1250	1250	1250		**1250**				
RUNOFF VOLUME TOTAL (ml):	51300								
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	34.5								

Runoff (ml)	**Time**	**Runoff (ml)**	**Time**
2500	12:18:45	2800	12:31:15
3000	12:20:00	2700	12:32:15
2750	12:21:30	2850	12:34:15
2750	12:22:45	2700	12:36:00
2800	12:23:45	2750	12:37:15
2750	12:24:45	3850	12:39:00
2800	12:25:45	2600	12:40:00
2450	12:26:45	3800	12:41:58
2750	12:28:45	51300	
2700	12:29:45		

UNTREATED Grass 2 Wet

PLOT ID#:	Grass 2	**DATE:**	6/30/2000	**WET**		**WIND:**	~1	**SKY:**	clear
VEGETATION:	45			**TIME OF PAN REMOVAL:**				11:16:00	
BRUSH:	0			**TIME TO PONDING:**				11:16:10	
BARE SOIL:	55			**TIME TO RUNOFF ONTO TRAY:**				11:16:24	
				TIME AT RAINFALL OFF:				11:36:00	
TOTAL RAINFALL TIME:	20 min			**TIME AT END OF RUNOFF:**				11:37:28	
PAN RUNOFF / 20 SEC:	1650	1750	1700	1725		**1706**			
RUNOFF VOLUME TOTAL (ml):	57700								
DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm):	37.5								

Runoff (ml)	**Time**
3850	11:18:25
3850	11:20:00
3850	11:21:30
3900	11:22:45
3950	11:24:00
3900	11:25:15
3900	11:26:30
3950	11:28:00
4000	11:29:00
3700	11:30:30
3800	11:31:45
3950	11:33:00
3850	11:34:00
3900	11:35:00
3350	
57700	

UNTREATED Grass 3 Dry

PLOT ID#: Grass 3 **DATE:** 6/29/2000 **DRY** **WIND:** ~5 **SKY:** cloudy

VEGETATION: 45
BRUSH: 0
BARE SOIL: 55

TOTAL RAINFALL TIME: 30 min

TIME OF PAN REMOVAL: 3:19:52
TIME TO PONDING: 3:20:15
TIME TO RUNOFF ONTO TRAY: 3:20:38
TIME AT RAINFALL OFF: 3:49:51
TIME AT END OF RUNOFF: 3:51:14

PAN RUNOFF / 20 SEC: 1250 1200 1225 1200 1250 1225 **1225**

RUNOFF VOLUME TOTAL (ml): 86900

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 54.5

Runoff (ml)	Time	Runoff (ml)	Time
3800	3:23:45	3850	3:40:35
3800	3:24:33	3900	3:41:35
3850	3:26:10	3900	3:42:30
3850	3:27:10	3950	3:43:20
3850	3:28:45	3950	3:44:40
3850	3:30:00	3900	3:46:15
3900	3:31:30	3850	3:47:15
3900	3:32:45	3900	3:48:15
3850	3:34:00	3900	3:49:30
3900	3:35:00	1900	
3850	3:36:15	86900	
3800	3:37:50		
3700	3:39:10		

UNTREATED Grass 3 Wet

PLOT ID#: Grass 3 **DATE:** 6/30/2000 **WET** **WIND:** 0-2 **SKY:** clear

VEGETATION: 45
BRUSH: 0
BARE SOIL: 55

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 12:24:00
TIME TO PONDING: 12:24:37
TIME TO RUNOFF ONTO TRAY: 12:24:14
TIME AT RAINFALL OFF: 12:44:00
TIME AT END OF RUNOFF: 12:44:33

PAN RUNOFF / 20 SEC: 1700 1775 1800 1800 1750 1800 1650 1650 **1741**

RUNOFF VOLUME TOTAL (ml): 61450

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 42.0

Runoff (ml)	Time
3900	12:26:45
3950	12:28:00
3950	12:29:15
3950	12:30:15
4000	12:31:25
3950	12:32:20
3950	12:33:15
3400	12:34:15
3850	12:35:50
3900	12:36:50
4000	12:37:45
3950	12:38:55
3950	12:39:50
4000	12:40:50
3950	12:42:00
2800	12:43:15
61450	

UNTREATED Shrub 1 Dry

PLOT ID#: Shrub 1 **DATE:** 6/30/2000 **DRY** **WIND:** ~0-2 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 10:09:00
TIME TO PONDING: 10:09:43
TIME TO RUNOFF ONTO TRAY: 10:09:50
TIME AT RAINFALL OFF: 10:29:02
TIME AT END OF RUNOFF: 10:30:32

PAN RUNOFF / 20 SEC: 1600 1600 1700 1600 1600 **1620**

RUNOFF VOLUME TOTAL (ml): 42950

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 29.7

Runoff (ml)	Time
3750	10:12:40
3800	10:14:00
3850	10:15:40
3800	10:17:30
3800	10:19:15
3800	10:20:45
3850	10:22:15
3500	10:23:45
3850	10:25:30
3800	10:27:00
3850	10:28:35
1300	
42950	

UNTREATED Shrub 1 Wet

PLOT ID#: Shrub 1 **DATE:** 7/1/2000 **WET** **WIND:** ~0-2 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 19:17:30 (actually 7:30 am,)
TIME TO PONDING: 19:17:54
TIME TO RUNOFF ONTO TRAY: 19:18:01
TIME AT RAINFALL OFF: 19:37:30
TIME AT END OF RUNOFF: 19:38:58

PAN RUNOFF / 20 SEC: 1500 1725 1775 1775 1750 **1705**

RUNOFF VOLUME TOTAL (ml): 46950

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 30.5

Runoff (ml)	Time
3950	7:21:00
3950	7:23:05
3900	7:24:35
3950	7:26:05
3950	7:27:45
3950	7:29:21
4000	7:30:30
3950	7:32:00
3900	7:33:35
3950	7:35:00
3900	7:36:20
3600	7:37:45
46950	

UNTREATED Shrub 2 Dry

PLOT ID#: Shrub 2 **DATE:** 7/1/2000 **DRY** **WIND:** ~1-2 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 9:17:45
TIME TO PONDING: 9:18:35
TIME TO RUNOFF ONTO TRAY: 9:18:51
TIME AT RAINFALL OFF: 9:37:45
TIME AT END OF RUNOFF: 9:38:38

PAN RUNOFF / 20 SEC: 1450 1600 1700 1675 1700 1700 **1638**

RUNOFF VOLUME TOTAL (ml): 27300

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 18.5

Runoff (ml)	Time
3850	9:23:00
3900	9:26:00
3900	9:29:00
3900	9:31:30
3950	9:33:30
3900	9:35:45
2900	9:37:15
1000	
27300	

UNTREATED Shrub 2 Wet

PLOT ID#: Shrub 2 **DATE:** 7/2/2000 **WET** **WIND:** ~0-2 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 9:53:15
TIME TO PONDING: 9:53:43
TIME TO RUNOFF ONTO TRAY: 9:53:50
TIME AT RAINFALL OFF: 10:13:15
TIME AT END OF RUNOFF: 10:13:59

PAN RUNOFF / 20 SEC: 1650 1650 1675 **1658**

RUNOFF VOLUME TOTAL (ml): 42300

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 27.7

Runoff (ml)	Time
3800	9:56:30
3800	9:58:30
4150	10:00:00
3950	10:02:00
3800	10:03:30
3900	10:05:15
3950	10:07:15
3900	10:09:15
3850	10:10:30
3850	10:12:00
3350	
42300	

UNTREATED Shrub 3 Dry

PLOT ID#: Shrub 3 **DATE:** 7/1/2000 **DRY** **WIND:** ~5 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 1:59:30
TIME TO PONDING: 2:00:48
TIME TO RUNOFF ONTO TRAY: 2:01:25
TIME AT RAINFALL OFF: 2:19:30
TIME AT END OF RUNOFF: 2:20:22

PAN RUNOFF / 20 SEC: 1500 1625 1650 1650 **1606**

RUNOFF VOLUME TOTAL (ml): 38250

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 31.7

Runoff (ml)	Time
3650	2:04:00
3600	2:05:45
3650	2:07:15
3700	2:09:00
3600	2:10:45
3650	2:12:30
3550	2:14:00
3450	2:15:30
3500	2:17:00
3400	2:18:30
2500	
38250	

UNTREATED Shrub 3 Wet

PLOT ID#: Shrub 3 **DATE:** 7/2/2000 **WET** **WIND:** ~0-1 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 8:00:30
TIME TO PONDING: 8:01:35
TIME TO RUNOFF ONTO TRAY: 8:01:42
TIME AT RAINFALL OFF: 8:20:30
TIME AT END OF RUNOFF: 8:21:44

PAN RUNOFF / 20 SEC: 1200 1400 1400 1100 1450 **1310**

RUNOFF VOLUME TOTAL (ml): 46350

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 30.2

Runoff (ml)	Time
3500	8:04:00
3650	8:05:35
3950	8:07:30
3850	8:09:00
3850	8:10:30
3750	8:12:00
3950	8:13:30
3900	8:15:00
3900	8:16:15
4000	8:17:45
3950	8:19:15
3700	
400	
46350	

UNTREATED Bare 1 Dry

PLOT ID#: Bare 1 **DATE:** 6/30/2000 **DRY** **WIND:** ~4-5 **SKY:** partly cloudy

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 1:42:30
TIME TO PONDING: 1:42:51
TIME TO RUNOFF ONTO TRAY: 1:43:39
TIME AT RAINFALL OFF: 2:02:11
TIME AT END OF RUNOFF: 2:02:46

PAN RUNOFF / 20 SEC: 1750 1775 1775 1750 **1763**

RUNOFF VOLUME TOTAL (ml): 42850

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 31.0

Runoff (ml)	Time
3500	1:45:45
3850	1:47:30
3700	1:49:00
3500	1:50:30
3950	1:51:15
3550	1:53:30
3150	1:54:45
3500	1:56:00
4000	1:57:55
3850	1:59:00
3950	2:00:10
2350	2:01:15
42850	

UNTREATED Bare 1 Wet

PLOT ID#: Bare 1 **DATE:** 7/1/2000 **WET** **WIND:** ~0-2 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 10:15:30
TIME TO PONDING: 10:16:02
TIME TO RUNOFF ONTO TRAY: 10:16:09
TIME AT RAINFALL OFF: 10:35:30
TIME AT END OF RUNOFF: 10:36:15

PAN RUNOFF / 20 SEC: 1550 1600 1650 1700 1675 1650 1650 **1639**

RUNOFF VOLUME TOTAL (ml): 46700

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 30.8

Runoff (ml)	Time
3750	10:18:30
3900	10:20:30
3900	10:22:30
3950	10:24:15
3950	10:25:15
3900	10:26:45
3900	10:28:30
3900	10:30:05
3900	10:31:25
3900	10:32:50
3900	10:34:00
3850	10:35:10
46700	

UNTREATED Bare 2 Dry

PLOT ID#: Bare 2 **DATE:** 7/1/2000 **DRY** **WIND:** ~0-5 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 11:28:00
TIME TO PONDING: 11:29:29
TIME TO RUNOFF ONTO TRAY: 11:30:38
TIME AT RAINFALL OFF: 11:48:00
TIME AT END OF RUNOFF: 11:48:34

PAN RUNOFF / 20 SEC: 1500 1600 1675 1650 1675 1625.0 **1621**

RUNOFF VOLUME TOTAL (ml): 23250

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 18.7

Runoff (ml)	Time
1400	11:32:15
3900	11:36:30
3550	11:38:00
3400	11:40:45
3900	11:44:30
3850	11:46:45
2950	11:48:00
300	
23250	

UNTREATED Bare 2 Wet

PLOT ID#: Bare 2 **DATE:** 7/2/2000 **WET** **WIND:** ~0-5 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 1:28:45
TIME TO PONDING: 1:29:15
TIME TO RUNOFF ONTO TRAY: 1:29:35
TIME AT RAINFALL OFF: 1:48:49
TIME AT END OF RUNOFF: 1:49:07

PAN RUNOFF / 20 SEC: 1250 1575 1525 1575 **1481**

RUNOFF VOLUME TOTAL (ml): 29500

DEPTH TO RUNOFF WATER
IN COLLECTION BUCKET (cm): 19.0

Runoff (ml)	Time
3500	1:32:30
3100	1:34:30
2900	1:36:30
3850	1:39:00
3800	1:41:00
3850	1:43:00
3450	1:45:00
2900	1:47:15
2150	
29500	

UNTREATED Bare 3 Dry

PLOT ID#: Bare 3 **DATE:** 7/1/2000 **DRY** **WIND:** ~0-5 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 1:08:30
TIME TO PONDING: 1:09:23
TIME TO RUNOFF ONTO TRAY: 1:09:46
TIME AT RAINFALL OFF: 1:28:30
TIME AT END OF RUNOFF: 1:29:12

PAN RUNOFF / 20 SEC: 1500 1525 1600 1600 1625 1625.0 **1579**

RUNOFF VOLUME TOTAL (ml): 43300

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 29.2

Runoff (ml)	Time
3900	1:12:30
3900	1:14:00
3950	1:16:15
3900	1:18:00
3950	1:19:30
3900	1:21:00
3950	1:22:30
4000	1:24:00
3950	1:25:30
3550	1:26:45
3650	1:28:15
700	
43300	

UNTREATED Bare 3 Wet

PLOT ID#: Bare 3 **DATE:** 7/2/2000 **WET** **WIND:** ~0 **SKY:** clear

VEGETATION:
BRUSH:
BARE SOIL:

TOTAL RAINFALL TIME: 20 min

TIME OF PAN REMOVAL: 8:50:30
TIME TO PONDING: 8:51:00
TIME TO RUNOFF ONTO TRAY: 8:51:00
TIME AT RAINFALL OFF: 9:10:33
TIME AT END OF RUNOFF: 9:11:31

PAN RUNOFF / 20 SEC: 1050 1000 1100 1650 1375 1300.0 1275 **1250**

RUNOFF VOLUME TOTAL (ml): 54800

DEPTH TO RUNOFF WATER IN COLLECTION BUCKET (cm): 36.0

Runoff (ml)	Time
3900	8:52:52
4000	8:53:50
3900	8:55:15
3900	8:56:30
3900	8:58:10
3900	8:59:15
3850	9:00:30
3900	9:02:00
4000	9:03:30
3950	9:05:00
3900	9:06:15
3950	9:07:45
3900	9:09:15
3850	
54800	

PLOT ID	PAN RUNOFF/ 20 MIN	RUNOFF TOTAL	
GRASS 1 DRY	1763	42300	28.2
GRASS 1 WET	1380	76500	51.5
GRASS 2 DRY	1250	51300	34.5
GRASS 2 WET	1706	57700	37.5
GRASS 3 DRY	1225	86900	54.5
GRASS 3 WET	1741	61450	42.0
SHRUB 1 DRY	1620	42950	29.7
SHRUB 1 WET	1705	46950	30.5
SHRUB 2 DRY	1638	27300	18.5
SHRUB 2 WET	1658	42300	37.7
SHRUB 3 DRY	1606	38250	31.7
SHRUB 3 WET	1310	46300	30.2
BARE 1 DRY	1763	42850	31.0
BARE 1 WET	1639	46700	30.8
BARE 2 DRY	1621	23250	18.7
BARE 2 WET	1481	29500	19.0
BARE 3 DRY	1579	43300	29.2
BARE 3 WET	1250	54800	36.0

APPENDIX B

Rainfall and Intensity Data

Equal Depth Calculations

Runoff-to-Rainfall Ratios

Rainfall Intensity Data Charts

(see rainfall_int_&_equal_depth_charts.doc)

Runoff to Rainfall Ratios for 20 Minutes

TREATED PLOT ID	Rainfall /20 sec	Runoff Total (ml) 20 min	Intensity Rainfall mm/hr	Rainfall per 20 min (mm)	Runoff to Rainfall ratio %
Grass 1 DRY	1225	9338	220.50	73.50	12.70
Grass 1 WET	1392	8936	250.56	83.52	10.70
Grass 2 DRY	1306	22630	235.08	78.36	28.88
Grass 2 WET	1475	20225	265.50	88.50	22.85
Grass 3 DRY	1400	9800	252.00	84.00	11.67
Grass 3 WET	1550	19450	279.00	93.00	20.91
Shrub 1 DRY	1400	8000	252.00	84.00	9.52
Shrub 2 WET	1444	3975	259.92	86.64	4.59
Shrub 2 DRY	1455	15625	261.90	87.30	17.90
Shrub 2 WET	1506	19050	271.08	90.36	21.08
Shrub 3 DRY	1460	26300	262.80	87.60	30.02
Shrub 3 WET	1492	24450	268.56	89.52	27.31
Bare 1 DRY	1167	35000	210.06	70.02	49.99
Bare 1 WET	1483	31400	266.94	88.98	35.29
Bare 2 DRY	1425	20350	256.50	85.50	23.80
Bare 2 WET	1400	43050	252.00	84.00	51.25
Bare 3 DRY	1417	17500	255.06	85.02	20.58
Bare 3 WET	1450	31400	261.00	87.00	36.09

UNTREATED PLOT ID	Rainfall / 20 sec	Runoff Total (ml) 20 min	Intensity Rainfall mm/hr	Rainfall per 20 min (mm)	Runoff to Rainfall ratio %
GRASS 1 DRY	1783	27350	320.94	106.98	25.57
GRASS 1 WET	1400	48400	252.00	84.00	57.62
GRASS 2 DRY	1250	36482	225.00	75.00	48.64
GRASS 2 WET	1725	57700	310.50	103.50	55.75
GRASS 3 DRY	1225	51712	220.50	73.50	70.36
GRASS 3 WET	1705	61450	306.90	102.30	60.07
SHRUB 1 DRY	1600	42950	288.00	96.00	44.74
SHRUB 1 WET	1756	46950	316.08	105.36	44.56
SHRUB 2 DRY	1694	27300	304.92	101.64	26.86
SHRUB 2 WET	1658	42300	298.44	99.48	42.52
SHRUB 3 DRY	1642	38250	295.56	98.52	38.82
SHRUB 3 WET	1417	46300	255.06	85.02	54.46
BARE 1 DRY	1763	42850	317.34	105.78	40.51
BARE 1 WET	1654	46700	297.72	99.24	47.06
BARE 2 DRY	1645	23250	296.10	98.70	23.56
BARE 2 WET	1558	29500	280.44	93.48	31.56
BARE 3 DRY	1613	43300	290.34	96.78	44.74
BARE 3 WET	1317	54800	237.06	79.02	69.35

Rainfall and Intensity Data

Treated

TREATED PLOT ID	"Calibrated" Rainfall (ml) /20 Sec	"Calibrated" Rainfall (ml) 20 min	Runoff Total (ml)	20 min Runoff Volume (L)	20 min Runoff Depth (mm)	Event Total Runoff (mm)*	Intensity mm/hr
Grass 1 DRY	1225	73500	9338	9.34	9.34	15.00	220.50
Grass 1 WET	1392	83520	8936	8.94	8.94	18.35	250.56
Grass 2 DRY	1306	78360	22630	22.63	22.63	39.30	235.08
Grass 2 WET	1475	88500	20225	20.23	20.23	20.23	265.50
Grass 3 DRY	1400	84000	9800	9.80	9.80	16.90	252.00
Grass 3 WET	1550	93000	19450	19.45	19.45	19.45	279.00
Shrub 1 DRY	1400	84000	8000	8.00	8.00	8.00	252.00
Shrub 2 WET	1444	86640	3975	3.98	3.98	3.98	259.92
Shrub 2 DRY	1455	87300	15625	15.63	15.63	15.63	261.90
Shrub 2 WET	1506	90360	19050	19.05	19.05	19.05	271.08
Shrub 3 DRY	1460	87600	26300	26.30	26.30	26.30	262.80
Shrub 3 WET	1492	89520	24450	24.45	24.45	24.45	268.56
Bare 1 DRY	1167	70020	35000	35.00	35.00	35.00	210.06
Bare 1 WET	1483	88980	31400	31.40	31.40	31.40	266.94
Bare 2 DRY	1425	85500	20350	20.35	20.35	20.35	256.50
Bare 2 WET	1400	84000	43050	43.05	43.05	43.05	252.00
Bare 3 DRY	1417	85020	17500	17.50	17.50	17.50	255.06
Bare 3 WET	1450	87000	31400	31.40	31.40	31.4	261.00

Rainfall and Intensity Data Cont.

Untreated

PLOT ID	"Calibrated" Rainfall (ml) /20 Sec	"Calibrated" Rainfall (ml) /20 Min	Runoff Total (ml)	20 min Runoff Volume (L)	20 min Runoff Depth (mm)	Event Total Runoff (mm)	Intensity mm/hr
Grass 1 DRY	1783	106980	27350	27.35	27.35	42.30	320.94
Grass 1 WET	1400	84000	48400	48.40	48.40	76.50	252.00
Grass 2 DRY	1250	75000	36482	36.48	36.48	51.30	225.00
Grass 2 WET	1725	103500	57700	57.70	57.70	57.70	310.50
Grass 3 DRY	1225	73500	51712	51.71	51.71	86.90	220.50
Grass 3 WET	1705	102300	61450	61.45	61.45	61.45	306.90
Shrub 1 DRY	1600	96000	42950	42.95	42.95	42.95	288.00
Shrub 2 WET	1756	105360	46950	46.95	46.95	46.95	316.08
Shrub 2 DRY	1694	101640	27300	27.30	27.30	27.30	304.92
Shrub 2 WET	1658	99480	42300	42.30	42.30	42.30	298.44
Shrub 3 DRY	1642	98520	38250	38.25	38.25	38.25	295.56
Shrub 3 WET	1417	85020	46300	46.30	46.30	46.30	255.06
Bare 1 DRY	1763	105780	42850	42.85	42.85	42.85	317.34
Bare 1 WET	1654	99240	46700	46.70	46.70	46.70	297.72
Bare 2 DRY	1645	98700	23250	23.25	23.25	23.25	296.10
Bare 2 WET	1558	93480	29500	29.50	29.50	29.50	280.44
Bare 3 DRY	1613	96780	43300	43.30	43.30	43.30	290.34
Bare 3 WET	1317	79020	54800	54.80	54.80	54.80	237.06

Equal Depth Calculations

This table gives the ratio of runoff to rainfall at the same depth of rainfall = 70 mm (minimum amount applied)
Treated

GRASS	**Intensity mm/hr**	**Time when 70.02 mm rained (min)**	**Interpolated Runoff at 70 mm rainfall Time (ml)**	**Runoff after Rainfall Stopped (ml)**	**Estimated total Runoff at 70 mm time (ml)**	**Runoff to Rainfall Ratio at 70 mm time**	**Total**	**Event Rainfall**	**Event Runoff**	**“Old” Runoff to Rainfall Ratio Entire Event**
1 DRY	221	19.0	8800	450	9250	0.13	0.13	110.5	15.00	0.14
1 WET	251	16.8	7500	3100	10600	0.11	0.15	125.50	18.35	0.15
2 DRY	235	17.9	19663	720	20383	0.28	0.29	117.50	39.30	0.33
2 WET	266	15.8	14125	1295	15420	0.20	0.22	88.67	20.23	0.23
3 DRY	252	16.7	8013	517	8530	0.11	0.12	126.00	16.90	0.13
3 WET	279	15.1	12634	300	12934	0.18	0.18	93.00	19.45	0.21
SHRUB										
1 DRY	252	16.7	5375	0	5375	0.08	0.08	84.00	8.00	0.10
1 WET	260	16.2	2776	257	3033	0.04	0.04	86.67	3.98	0.05
2 DRY	262	16.0	10575	900	11475	0.15	0.16	87.33	15.63	0.18
2 WET	271	15.5	12160	2250	14410	0.17	0.21	90.33	19.05	0.21
3 DRY	263	16.0	20125	1900	22025	0.29	0.31	87.67	26.30	0.30
3 WET	269	15.6	17990	925	18915	0.26	0.27	89.67	24.45	0.27
BARE										
1 DRY	210	20.0	35000	0	35000	0.50	0.50	70.00	35.00	0.50
1 WET	267	15.7	23077	1700	24777	0.33	0.35	89.00	31.40	0.35
2 DRY	257	16.4	15075	720	15795	0.22	0.23	85.67	20.35	0.24
2 WET	252	16.7	32217	2754	34971	0.46	0.50	84.00	43.05	0.51
3 DRY	255	16.5	13417	455	13872	0.19	0.20	85.00	17.50	0.21
3 WET	261	16.1	21600	3000	24600	0.31	0.35	87.00	31.40	0.36

Equal Depth Calculations Cont.

Untreated

GRASS	Intensity mm/hr	Time when 70.02 mm rained (min)	Interpolated Runoff at 70 mm rainfall Time (ml)	Runoff after Rainfall Stopped (ml)	Estimated total Runoff at 70 mm time (ml)	Runoff to Rainfall Ratio at 70 mm time	Total	Event Rainfall	Event Runoff	“Old” Runoff to Rainfall Ratio Entire Event
1 DRY	320.94	13.1	16275	500	16775	0.23	0.24	160.47	42.30	0.26
1 WET	252.00	16.7	37500	1967	39467	0.54	0.56	126.00	76.50	0.61
2 DRY	225.00	18.7	35600	500	36100	0.51	0.52	112.50	51.30	0.46
2 WET	310.50	13.5	36383	2010	38393	0.52	0.55	103.50	57.70	0.56
3 DRY	220.50	19.1	49900	1357	51257	0.71	0.73	110.25	86.90	0.79
3 WET	306.90	13.7	42800	500	43300	0.61	0.62	102.30	61.45	0.60
SHRUB										
1 DRY	288.00	14.6	30150	975	31125	0.43	0.44	96.00	42.95	0.45
1 WET	316.08	13.3	31600	500	32100	0.45	0.46	105.36	46.95	0.45
2 DRY	304.92	13.8	15550	666	16216	0.22	0.23	101.64	27.30	0.27
2 WET	298.44	14.1	27350	1256	28606	0.39	0.41	99.48	42.30	0.43
3 DRY	295.56	14.2	24808	1071	25879	0.35	0.37	98.52	38.25	0.39
3 WET	255.06	16.5	36300	2050	38350	0.52	0.55	85.02	46.30	0.54
BARE										
1 DRY	317.34	13.2	28000	500	28500	0.40	0.41	105.78	42.85	0.41
1 WET	297.72	14.1	29850	500	30350	0.43	0.43	99.24	46.70	0.47
2 DRY	296.10	14.2	13810	500	14310	0.20	0.20	98.70	23.25	0.24
2 WET	280.44	15.0	22294	538	22832	0.32	0.33	93.48	29.50	0.32
3 DRY	290.34	14.5	28783	525	29308	0.41	0.42	96.78	43.30	0.45
3 WET	237.06	17.7	48350	1711	50061	0.69	0.72	79.02	54.80	0.69

APPENDIX C

Particle Size Analysis for Rainfall Simulation Plot Runs

Treated

				AVERAGE		
GRASS	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	84.87	13.10	2.03			
1 DRY B	85.60	12.55	1.85	85.24	12.83	1.94
1 WET A	87.86	9.82	2.32			
1 WET B	87.49	10.87	1.64	87.68	10.35	1.98
2 DRY A	59.40	31.66	8.93			
2 DRY B	61.41	31.68	6.75	60.41	31.67	7.84
2 WET A	79.02	16.42	4.57			
2 WET B	73.48	21.66	4.87	76.25	19.04	4.72
3 DRY A	75.35	22.02	2.63			
3 DRY B	74.81	22.16	3.03	75.08	22.09	2.83
3 WET A	76.45	19.98	3.56			
3 WET B	75.52	21.01	3.50	75.99	20.50	3.53

				AVERAGE		
SHRUB	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	71.69	19.88	8.42			
1 DRY B	73.95	18.71	7.34	72.82	19.30	7.88
1 WET A	62.18	27.09	10.73			
1 WET B	62.12	25.69	12.18	62.15	26.39	11.46
2 DRY A	74.44	22.08	3.49			
2 DRY B	76.42	20.33	3.24	75.43	21.21	3.37
2 WET A	69.96	26.35	3.70			
2 WET B	68.02	28.00	3.98	68.99	27.18	3.84
3 DRY A	60.58	35.89	3.53			
3 DRY B	61.13	35.4	3.46	60.86	35.65	3.50
3 WET A	70.40	25.53	4.07			
3 WET B	70.89	25.34	3.77	70.65	25.44	3.92

				AVERAGE		
BARE	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	72.78	23.2	4.02			
1 DRY B	73.86	23.68	2.46	73.32	23.44	3.24
1 WET A	78.98	17.91	3.1			
1 WET B	80.28	17.17	2.55	79.63	17.54	2.83
2 DRY A	54.39	43.17	2.49			
2 DRY B	53.05	44.11	2.85	53.72	43.64	2.67
2 WET A	59.41	38.12	2.47			
2 WET B	59.87	37.87	2.26	59.64	38.00	2.37
3 DRY A	58.27	38.73	3.01			
3 DRY B	56.96	39.38	3.66	57.62	39.06	3.34
3 WET A	60.25	36.29	3.46			
3 WET B	59.59	37.23	3.18	59.92	36.76	3.32

Particle Size Analysis for Rainfall Simulation Plot Runs Cont.

Untreated

				AVERAGE		
GRASS	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	77.98	19.96	2.07			
1 DRY B	76.3	21.79	1.9	77.14	20.88	1.99
1 WET A	79.36	18.79	1.85			
1 WET B	78.89	19.37	1.74	79.13	19.08	1.80
2 DRY A	78.96	19.7	1.34			
2 DRY B	78.63	19.88	1.49	78.80	19.79	1.42
2 WET A	86.59	11.55	1.86			
2 WET B	87.19	11.06	1.76	86.89	11.31	1.81
3 DRY A	86.69	11.16	2.15			
3 DRY B	87.71	10.4	1.89	87.20	10.78	2.02
3 WET A	85.34	13.06	1.6			
3 WET B	85.36	13.2	1.44	85.35	13.13	1.52

				AVERAGE		
SHRUB	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	73.95	21.73	4.32			
1 DRY B	73.08	23.33	3.59	73.52	22.53	3.96
1 WET A	87.45	11.05	1.5			
1 WET B	87.15	11.2	1.65	87.30	11.13	1.58
2 DRY A	89.71	8.54	1.75			
2 DRY B	91.25	6.99	1.77	90.48	7.77	1.76
2 WET A	91.87	6.23	1.9			
2 WET B	91.67	6.76	1.56	91.77	6.50	1.73
3 DRY A	94.88	4.02	1.10			
3 DRY B	93.77	4.40	1.83	94.33	4.21	1.47
3 WET A	94.43	4.25	1.32			
3 WET B	93.87	4.68	1.45	94.15	4.47	1.39

				AVERAGE		
BARE	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
1 DRY A	92.69	5.61	1.70			
1 DRY B	92.87	5.54	1.59	92.78	5.58	1.65
1 WET A	93.07	5.3	1.63			
1 WET B	92.36	6.22	1.41	92.72	5.76	1.52
2 DRY A	94.4	4.19	1.41			
2 DRY B	95.66	3.13	1.2	95.03	3.66	1.31
2 WET A	95.49	3.34	1.18			
2 WET B	95.62	3.55	0.83	95.56	3.45	1.01
3 DRY A	88.79	9.19	2.01			
3 DRY B	88.45	10.07	1.48	88.62	9.63	1.75
3 WET A	72.70	25.63	1.66			
3 WET B	72.27	26.13	1.52	72.49	25.88	1.59

Particle Size Analysis for Stratigraphic Units in Pits of Natural Runoff Plots

RO-1 and RO-2 in Untreated Area
RO-3 and RO-4 in Treated Area

				AVERAGE		
PLOT	**SAND**	**SILT**	**CLAY**	**SAND**	**SILT**	**CLAY**
RO1-1A	85.37	11.40	3.23	85.52	11.30	3.18
RO1-1B	85.67	11.19	3.13			
RO1-2A	89.29	8.54	2.17	89.29	8.71	2.00
RO1-2B	89.29	8.88	1.83			
RO1-3A	57.32	35.17	7.50	57.40	34.84	7.76
RO1-3B	57.48	34.51	8.01			
RO2-1A	86.13	10.84	3.02	86.37	11.09	2.55
RO2-1B	86.60	11.34	2.07			
RO2-2A	88.87	8.26	2.87	89.07	8.58	2.36
RO2-2B	89.27	8.89	1.84			
RO2-3A	68.64	26.57	4.79	68.36	26.88	4.77
RO2-3B	68.07	27.18	4.74			
RO2-4A	77.47	19.00	3.52	78.01	18.01	3.99
RO2-4B	78.54	17.01	4.45			
RO3-1A	70.45	26.92	2.63	70.51	26.92	2.58
RO3-1B	70.56	26.91	2.53			
RO3-2A	42.62	50.15	7.23	42.41	49.81	7.78
RO3-2B	42.20	49.47	8.33			
RO3-3A	61.50	33.22	5.28	61.40	33.46	5.15
RO3-3B	61.29	33.69	5.02			
RO4-1A	30.54	55.47	13.99	30.89	54.75	14.37
RO4-1B	31.23	54.02	14.75			
RO4-2A	53.26	40.21	6.53	52.65	41.15	6.21
RO4-2B	52.03	42.08	5.89			
RO4-3A	84.14	12.44	3.42	84.29	12.64	3.08
RO4-3B	84.43	12.83	2.74			

Loss on Ignition (LOI)

	Treated			Untreated		
GRASS	**Soil Weight (g)**	**LOI g**	**LOI %**	**Soil Weight (g)**	**LOI g**	**LOI %**
1 DRY	136.55	5.18	3.79	133.45	2.39	1.79
1 WET	145.62	4.87	3.34	143.69	2.86	1.99
2 DRY	98.76	5.65	5.72	140.96	2.77	1.97
2 WET	142.12	3.37	2.37	145.38	4.33	2.98
3 DRY	125.49	4.52	3.60	140.74	2.62	1.86
3 WET	138.40	3.76	2.72	143.16	2.55	1.78
SHRUB						
1 DRY	116.92	4.62	3.95	133.13	4.07	3.06
1 WET	115.01	5.83	5.07	140.35	1.9	1.35
2 DRY	120.27	4.94	4.11	124.10	2.91	2.34
2 WET	137.13	2.77	2.02	144.35	3.92	2.72
3 DRY	136.45	2.57	1.88	130.57	3.58	2.74
3 WET	133.03	3.52	2.65	139.16	3.5	2.52
BARE						
1 DRY	134.59	2.81	2.09	136.35	3.69	2.71
1 WET	139.05	2.76	1.98	134.07	1.89	1.41
2 DRY	126.33	4.18	3.31	138.76	1.3	0.94
2 WET	138.04	2.51	1.82	141.86	1.09	0.77
3 DRY	151.49	2.53	1.67	132.19	1.95	1.48
3 WET	141.85	3.62	2.55	143.73	1.8	1.25

Bulk Density & Soil Moisture on Rainfall Simulation Plots

Treated	Soil Moisture (g)	Soil Weight (g)	Soil Moisture (%)	Bulk Density (g/cm3)
Grass 1 DRY	4.56	142.35	3.20	1.42
Grass 1 WET	27.61	152.75	18.07	1.53
Grass 2 DRY	2.94	104.59	2.81	1.05
Grass 2 WET	32.12	147.68	21.75	1.48
Grass 3 DRY	5.74	130.16	4.41	1.30
Grass 3 WET	35.63	144.38	24.68	1.44
Shrub 1 DRY	12.08	121.65	9.93	1.22
Shrub 2 WET	27.21	121.77	22.34	1.22
Shrub 2 DRY	6.75	125.71	5.37	1.26
Shrub 2 WET	23.74	140.53	16.89	1.41
Shrub 3 DRY	4.83	139.11	3.47	1.39
Shrub 3 WET	35.28	138.31	25.51	1.38
Bare 1 DRY	6.94	137.93	5.03	1.38
Bare 1 WET	24.14	141.36	17.08	1.41
Bare 2 DRY	7.95	131.61	6.04	1.32
Bare 2 WET	21.26	141.60	15.01	1.42
Bare 3 DRY	4.88	154.62	3.16	1.55
Bare 3 WET	25.56	146.10	17.49	1.46

Untreated	Soil Moisture (g)	Soil Weight (g)	Soil Moisture (%)	Bulk Density (g/cm3)
Grass 1 DRY	2.64	136.06	1.94	1.36
Grass 1 WET	22.21	148.00	15.01	1.48
Grass 2 DRY	2.95	145.46	2.03	1.45
Grass 2 WET	28.83	152.84	18.86	1.53
Grass 3 DRY	2.73	144.03	1.90	1.44
Grass 3 WET	24.09	147.81	16.30	1.48
Shrub 1 DRY	3.91	137.68	2.84	1.38
Shrub 2 WET	20.27	143.03	14.17	1.43
Shrub 2 DRY	7.75	127.65	6.07	1.28
Shrub 2 WET	30.42	151.61	20.06	1.52
Shrub 3 DRY	15.02	134.56	11.16	1.35
Shrub 3 WET	29.48	143.16	20.59	1.43
Bare 1 DRY	12.62	140.73	8.97	1.41
Bare 1 WET	17.63	137.11	12.86	1.37
Bare 2 DRY	6.51	140.76	4.63	1.41
Bare 2 WET	23.59	144.13	16.37	1.44
Bare 3 DRY	8.68	135.93	6.39	1.36
Bare 3 WET	22.92	146.67	15.63	1.47

RUNOFF PLOT 1 (RO-1) “BIG CITY” (UNTREATED)

Location:	Bastard Draw, Arroyo Chijuillita Quadrangle
Aspect:	S/SW
Slope:	4 - 5°
Vegetation:	Pinon/juniper, sagebrush
Date described:	3/15/2000

		Color				**Consistance**						
Horizon	**Depth (cm)**	**Moist**	**Dry**	**Gravel vol. %**	**Structure**	**Wet**	**Dry**	**Texture**	**Clay Films**	**Roots**	**Pores**	**Carbonate**
A	0 - 3	2.5 Y 5/3	2.4 Y 4/3	10	2c, 2m gr	so, ps	lo	SL	1f,pf	1	0.5 - 2	None
C_1	3 - 27	2.5 Y 4/4	2.5 Y 4/2	20	2m, gr	ss, ps	so	SL	1f, pf	2	0.5 -2	None
C_2	27 - 50	10 YR 4/3	10 YR 5/3	10	3f, sbk	s, p	h	SC	3d, po	1	<0.5	None

RUNOFF PLOT 2 (RO-2) “RUBBERMAID QUEEN” (UNTREATED)

Location:	Bastard Draw, Arroyo Chijuillita Quadrangle
Aspect:	S/SW
Slope:	3-4°
Vegetation:	Pinon/juniper, sagebrush
Date described:	3/14/2000

		Color				**Consistance**						
Horizon	**Depth (cm)**	**Moist**	**Dry**	**Gravel vol. %**	**Structure**	**Wet**	**Dry**	**Texture**	**Clay Films**	**Roots**	**Pores**	**Carbonate**
A	0 - 5	10 YR 3/3	2.5 Y 6/3	10	1f, gr	so, po	lo	LS	v1, f	3	0.5 - 2	None
C	5 - 25	10 YR 3/4	2.5 Y 5/4	10	2c, gr	so, po	lo	LS	v1, f	2	0.5 -2	None
Bt_1	25 - 32	10 YR 4/3	10 YR 4/3	10	3m, gr	s, p	sh	SCL	2d, pf	2	<0.5	None
Bt_2	32 - 50	10 YR 4/3	10 YR 4/3	10	2c, gr	ss, po	so	LS	2d, pf	3	<0.5	None

RUNOFF PLOT 3 (RO-3) “OUTBACK” (TREATED)

Location: Bastard Draw, Arroyo Chijuillita Quadrangle
Aspect: S/SW
Slope: 3-4°
Vegetation: Pinon/juniper, grassland, dead sagebrush
Date described: 3/15/2000

		Color				Consistance						
Horizon	**Depth (cm)**	**Moist**	**Dry**	**Gravel vol. %**	**Structure**	**Wet**	**Dry**	**Texture**	**Clay Films**	**Roots**	**Pores**	**Carbonate**
A	0 - 3	2.5 Y 4/3	2.5 Y 5/3	10	2f, gr	ss, p	so	SCL	1f, pf	1	<0.5	None
C_1	3 - 27	10 YR 3/3	10 YR 4/4	10	3m, gr	ss, p	so	SL	3d, pf	3	0.5 – 2	None
C_2	27 - 50	10 YR 4/3	2.5 Y 5/3	20	2m, gr	ss, ps	so	SL	2d, po	2	<0.5	None

RUNOFF PLOT 4 (RO-4) “PROBLEM CHILD” (TREATED)

Location: Bastard Draw, Arroyo Chijuillita Quadrangle
Aspect: S/SW
Slope: 3-4°
Vegetation: grassland, dead sagebrush
Date described: 3/15/2000

		Color				Consistance						
Horizon	**Depth (cm)**	**Moist**	**Dry**	**Gravel vol. %**	**Structure**	**Wet**	**Dry**	**Texture**	**Clay Films**	**Roots**	**Pores**	**Carbonate**
A	0 – 2	2.5 Y 3.2	2.5 Y 5/3	20	2m, gr	s, p	so	SIC	p, po	1	<0.5	None
C_1	2 – 25	2.5 Y 3/3	2.5 Y 5/2	0	3vf, gr	ss, vp	lo	SIC	3d, cobr	2	<0.5	None
C_2	25 – 50	10 YR 4/2	10 YR 5/4	10	2m, gr	ss, ps	so	SL	2d, cobr	1	<0.5	None

APPENDIX D

Suspended Sediment Yield

Deposited Sediment Yield

Sediment Yield in Kg/Ha

Suspended Sediments

Treated

GRASS	Conductivity (milli Siemens)	Sample Weight (g)	Weight of diss. Solids	Weight Water	Susp. Solids weight (mg/l)	Conc mg/L	Runoff Vol, (l)	Susp. Yield (g)	Susp Yield kg/ha/mm
1 DRY	1.52	1.01	0.89	833.79	0.12	147.34	15.00	2.21	1.47
1 WET	1.54	0.91	0.80	739.97	0.11	151.78	18.35	2.79	1.52
2 DRY	1.49	1.05	0.89	849.45	0.16	193.09	39.30	7.59	1.93
2 WET	1.48	0.94	0.90	864.12	0.04	51.81	20.23	1.05	0.52
3 DRY	1.49	1.34	0.89	852.34	0.45	529.14	16.90	8.94	5.29
3 WET	1.48	1.22	0.86	830.30	0.36	433.35	19.45	8.43	4.33
SHRUB									
1 DRY	1.51	1.04	0.90	847.75	0.14	169.78	8.00	1.36	1.70
1 WET	1.51	1.07	0.88	834.54	0.19	225.14	3.98	0.89	2.25
2 DRY	1.51	1.31	0.86	814.76	0.45	550.84	15.63	8.61	5.51
2 WET	1.53	1.18	0.93	871.22	0.25	283.42	19.05	5.40	2.83
3 DRY	1.48	1.52	0.89	857.44	0.63	736.72	26.30	19.38	7.37
3 WET	1.51	1.36	0.919	869.03	0.44	507.96	24.45	12.42	5.08
BARE									
1 DRY	1.53	3.05	0.89	828.97	2.16	2608.26	35.00	91.29	26.08
1 WET	1.51	2.31	0.90	855.34	1.41	1643.68	31.40	51.61	16.44
2 DRY	1.50	3.29	0.93	889.69	2.36	2647.92	20.35	53.89	26.48
2 WET	1.48	2.30	0.88	847.89	1.42	1676.62	43.05	72.18	16.77
3 DRY	1.49	2.35	0.91	875.25	1.44	1641.95	17.50	28.73	16.42
3 WET	1.51	10.82	0.31	293.48	10.51	35810.93	31.40	1124.46	20.44

- Bare 3 Wet had to be estimated from water in PVC trough since regular sample was discarded by mistake

Suspended Sediments Cont.

Untreated

GRASS	Conductivity (milli Siemens)	Sample Weight (g)	Weight of diss. Solids	Weight Water	Susp. Solids weight (mg/l)	Conc mg/L	Runoff Vol, (l)	Susp. Yield (g)	Susp Yield kg/ha/mm
1 DRY	1.50	2.02	0.88	838.98	1.14	1357.69	42.30	57.43	13.58
1 WET	1.49	2.10	0.89	852.50	1.21	1420.34	76.50	108.66	14.20
2 DRY	1.50	2.29	0.92	873.50	1.37	1571.64	51.30	80.62	15.72
2 WET	1.54	2.48	0.92	853.17	1.56	1828.81	57.70	105.52	18.29
3 DRY	1.54	1.83	0.92	851.96	0.91	1069.99	86.90	92.98	10.70
3 WET	1.51	2.05	0.92	867.87	1.13	1305.10	61.45	80.20	13.05
SHRUB									
1 DRY	1.54	3.76	0.91	844.97	2.85	3371.86	42.95	144.82	33.72
1 WET	1.54	1.98	0.94	876.14	1.04	1181.91	46.95	55.49	11.82
2 DRY	1.54	1.54	0.93	867.27	0.61	697.69	27.30	19.05	6.98
2 WET	1.54	1.23	0.92	853.27	0.31	363.51	42.30	15.38	3.64
3 DRY	1.54	3.11	0.91	845.58	2.20	2599.95	38.25	99.45	26.00
3 WET	1.54	2.69	0.91	841.43	1.78	2118.94	46.30	98.11	21.19
BARE									
1 DRY	1.51	2.85	0.92	873.05	1.93	2207.42	42.85	94.59	22.07
1 WET	1.51	2.08	0.93	882.06	1.15	1301.12	46.70	60.76	13.01
2 DRY	1.51	1.29	0.93	878.58	0.36	411.28	23.25	9.56	4.11
2 WET	1.51	1.25	0.87	818.48	0.38	470.22	29.50	13.87	4.70
3 DRY	1.52	3.03	0.94	880.20	2.09	2378.40	43.30	102.98	23.78
3 WET	1.54	2.66	0.92	856.83	1.74	2026.47	54.80	111.05	20.26

Deposited Sediment Yield

TREATED PLOT ID	RUNOFF TOTAL (ml)	RUNOFF TOTAL (L) & DEPTH OF RUNOFF (mm)	BEDLOAD (g)	BEDLOAD (kg/ha-mm)
GRASS 1 DRY	9338	15.00	42.94	28.63
GRASS 1 WET	8936	18.35	49.40	26.92
GRASS 2 DRY	22630	39.30	5.62	1.43
GRASS 2 WET	20225	20.23	4.63	2.29
GRASS 3 DRY	9800	16.90	163.76	96.90
GRASS 3 WET	19450	19.45	91.52	47.06
SHRUB 1 DRY	8000	8.00	2.51	3.13
SHRUB 1 WET	3975	3.98	1.85	4.65
SHRUB 2 DRY	15625	15.63	25.29	16.19
SHRUB 2 WET	19050	19.05	6.45	3.39
SHRUB 3 DRY	26300	26.30	55.82	21.22
SHRUB 3 WET	24450	24.45	59.02	24.14
BARE 1 DRY	35000	35.00	613.64	175.33
BARE 1 WET	31400	31.40	727.06	231.55
BARE 2 DRY	20350	20.35	114.18	56.11
BARE 2 WET	43050	43.05	119.58	27.78
BARE 3 DRY	17500	17.50	234.99	134.28
BARE 3 WET	31400	31.40	349.30	111.24

UNTREATED PLOT ID	RUNOFF TOTAL (ml)	RUNOFF TOTAL (L) & DEPTH OF RUNOFF (mm)	BEDLOAD (g)	BEDLOAD (kg/ha-mm)
Grass 1 DRY	27350	42.30	95.19	22.50
Grass 1 WET	48400	76.50	1456.34	190.37
Grass 2 DRY	36482	51.30	301.76	58.82
Grass 2 WET	57700	57.70	1673.07	289.96
Grass 3 DRY	51712	86.90	803.06	92.41
Grass 3 WET	61450	61.45	1458.72	237.38
Shrub 1 DRY	42950	42.95	562.95	131.07
Shrub 2 WET	46950	46.95	440.06	93.73
Shrub 2 DRY	27300	27.30	95.57	35.01
Shrub 2 WET	42300	42.30	337.12	79.70
Shrub 3 DRY	38250	38.25	167.00	43.66
Shrub 3 WET	46300	46.30	312.37	67.47
Bare 1 DRY	42850	42.85	291.00	67.91
Bare 1 WET	46700	46.70	1105.43	236.71
Bare 2 DRY	23250	23.25	145.59	62.62
Bare 2 WET	29500	29.50	387.97	131.51
Bare 3 DRY	43300	43.30	376.65	86.99
Bare 3 WET	54800	54.80	131.45	23.99

Total Sediment Yield in Kg/Ha

	Total Sediment Yield kg/ha	
GRASS	**Treated**	**Untreated**
1 DRY	451.49	1526.20
1 WET	521.90	15649.96
2 DRY	132.04	3823.81
2 WET	56.83	17785.92
3 DRY	1726.98	8960.42
3 WET	999.53	15389.19
SHRUB		
1 DRY	38.65	7077.69
1 WET	27.45	4955.51
2 DRY	339.01	1146.15
2 WET	118.51	3525.00
3 DRY	751.91	2664.48
3 WET	714.38	4104.77
BARE		
1 DRY	7049.29	3855.88
1 WET	7786.72	11661.92
2 DRY	1680.69	1551.52
2 WET	1917.57	4018.38
3 DRY	2637.29	4796.35
3 WET	14737.63	2424.98

APPENDIX E

Vegetation Cover Estimates

Vegetation Transects

Vegetation Cover Estimates of Rainfall Simulation Plots

(August 29, 2000)

Grass = 1
Shrub = 2
Bare = 3

Grass 1

	5	15	25	35	45	55	65	75	85	95
5	1	1	1	3	1	1	1	1	1	1
15	1	1	1	1	1	1	1	3	3	1
25	1	1	1	1	1	1	1	1	3	3
35	3	3	1	1	1	1	1	1	3	3
45	1	1	3	3	1	1	1	1	1	1
55	1	1	3	1	3	1	1	1	1	1
65	1	1	1	1	3	3	1	1	1	3
75	3	3	1	1	3	3	1	1	1	1
85	3	3	1	1	1	3	3	1	3	3
95	1	1	3	1	1	1	1	3	3	3

Grass 2

	5	15	25	35	45	55	65	75	85	95
5	1	1	3	1	3	3	1	1	1	1
15	1	1	1	1	1	1	3	1	3	1
25	1	1	1	1	1	3	1	3	1	1
35	1	1	1	1	1	1	1	1	1	3
45	1	1	1	1	1	3	1	1	3	3
55	1	3	1	1	1	1	1	1	1	1
65	1	1	1	1	1	1	1	1	1	3
75	1	3	1	1	1	1	1	3	1	1
85	1	1	1	1	1	1	1	1	1	1
95	3	3	1	1	1	1	1	1	3	3

Grass 3

	5	15	25	35	45	55	65	75	85	95
5	3	1	1	3	1	1	3	3	1	1
15	1	1	1	1	1	3	1	3	1	1
25	3	3	1	1	1	1	3	1	3	1
35	1	1	1	1	1	1	1	3	1	3
45	1	1	1	1	1	1	1	1	1	3
55	3	1	3	1	3	1	1	1	1	1
65	1	3	1	1	1	3	1	1	1	1
75	3	1	1	1	1	3	3	1	1	1
85	1	1	1	3	1	1	1	1	3	3
95	1	1	1	3	1	1	3	1	3	3

Shrub 1 Treated

	5	15	25	35	45	55	65	75	85	95
5	1	1	2	2	2	2	2	1	1	1
15	1	1	2	2	2	2	2	1	1	1
25	1	1	2	2	2	2	2	2	1	1
35	1	2	2	2	2	2	2	2	2	2
45	1	1	1	2	2	2	2	2	2	2
55	1	2	2	2	2	2	2	2	2	1
65	1	1	1	2	2	2	2	2	1	1
75	1	1	1	2	2	2	2	2	1	1
85	1	1	1	1	1	1	2	2	1	1
95	1	1	1	1	1	1	1	1	1	1

Shrub 2 Treated

	5	15	25	35	45	55	65	75	85	95
5	1	1	1	2	2	2	2	1	3	3
15	1	3	3	2	2	2	2	3	3	3
25	1	3	3	2	2	2	2	3	3	3
35	1	1	1	2	2	2	1	1	3	3
45	1	1	1	1	2	2	2	1	3	3
55	1	1	1	1	2	2	2	1	3	3
65	1	1	1	1	2	2	2	1	3	3
75	1	1	1	1	1	2	1	1	3	3
85	1	1	1	1	1	1	1	1	3	3
95	1	1	1	1	1	1	1	1	3	3

Shrub 3 Treated

	5	15	25	35	45	55	65	75	85	95
5	3	3	1	1	3	1	1	1	1	3
15	1	3	1	2	2	2	1	1	1	3
25	1	3	1	2	2	2	2	1	1	1
35	1	1	1	2	2	2	2	2	2	3
45	3	1	1	2	2	2	2	2	3	3
55	1	3	1	2	2	2	2	2	2	3
65	1	1	3	2	2	2	2	2	2	3
75	1	1	3	1	2	2	2	2	3	1
85	3	1	3	1	2	2	2	1	3	3
95	1	1	1	3	3	1	2	3	3	3

Bare 1 Treated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	3	3	3	3	3	2	3
15	3	3	3	3	3	3	3	3	3	3
25	3	3	3	3	3	3	3	3	3	3
35	3	3	3	3	3	3	3	3	3	3
45	3	3	3	3	3	3	3	3	3	3
55	3	3	3	3	1	3	3	3	3	3
65	3	3	3	3	3	3	3	1	3	3
75	3	3	3	3	3	3	3	3	3	3
85	3	3	3	1	3	3	3	1	3	3
95	3	3	1	3	3	1	3	3	3	3

Bare 2 Treated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	1	3	3	3
25	3	3	3	1	3	3	3	3	3	3
35	3	3	3	3	3	3	3	3	1	3
45	3	3	3	3	3	3	3	3	3	3
55	3	3	3	3	3	3	3	3	3	3
65	3	3	3	3	3	1	3	3	3	3
75	3	3	3	3	3	3	3	3	3	3
85	3	3	3	3	3	3	3	3	3	3
95	3	3	3	3	3	3	3	3	3	3

Bare 3 Treated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	3	3	3	3
25	3	3	3	3	3	3	3	3	3	1
35	3	3	3	3	3	3	3	3	3	1
45	3	3	3	3	3	3	3	3	1	3
55	3	3	3	3	3	3	3	3	1	3
65	3	3	3	3	3	3	1	3	3	3
75	3	3	3	3	3	3	3	3	3	3
85	3	3	3	3	3	3	3	3	3	3
95	1	3	3	3	1	3	3	3	3	3

Grass 1 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	1	1	3	3	1	1	3	1	3
15	3	3	3	1	3	1	3	1	3	3
25	3	1	3	3	3	3	3	3	1	3
35	3	1	3	1	3	3	1	1	3	1
45	3	1	1	1	1	3	1	3	1	3
55	3	1	3	1	3	1	3	3	3	3
65	1	1	1	3	3	3	1	1	1	3
75	1	3	1	1	3	3	3	3	3	1
85	1	1	1	3	1	3	3	3	3	3
95	3	1	3	3	3	1	3	3	3	3

Grass 2 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	1	1	1	3	1	1	3	3	3
15	3	3	3	3	3	3	3	3	3	1
25	3	3	3	1	1	3	3	1	3	1
35	3	1	3	1	1	1	1	1	3	3
45	3	1	1	3	1	1	1	3	3	3
55	3	3	1	1	3	1	3	3	3	1
65	1	1	3	3	1	1	3	3	1	1
75	3	3	1	1	1	1	1	3	1	1
85	1	1	3	1	1	1	1	3	3	1
95	1	1	3	3	1	1	3	3	1	3

Grass 3 Untreated

	5	15	25	35	45	55	65	75	85	95
5	1	1	1	3	3	1	1	3	1	1
15	1	1	3	1	1	1	1	3	3	3
25	3	3	3	3	3	3	1	3	1	3
35	1	1	1	1	1	3	3	1	1	1
45	3	1	1	1	1	1	3	3	3	1
55	1	1	3	3	1	3	1	3	3	1
65	1	1	1	1	3	3	1	1	1	1
75	3	3	3	1	1	3	1	1	1	1
85	3	1	1	3	3	1	3	1	3	3
95	1	3	3	3	3	3	3	1	3	3

Shrub 1 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	1	3	1	3	3	3	3
15	3	2	3	2	2	2	2	2	2	3
25	3	3	2	2	2	2	2	2	2	3
35	3	2	2	2	2	2	2	2	2	3
45	3	2	2	2	2	2	2	2	2	3
55	3	2	2	2	2	2	2	2	3	3
65	3	3	2	2	2	2	2	2	3	3
75	3	3	3	2	2	2	3	2	3	3
85	3	3	3	3	3	3	3	3	3	3
95	1	3	1	3	3	3	3	3	3	3

Shrub 2 Untreated

	5	15	25	35	45	55	65	75	85	95
5	1	1	3	3	1	3	3	3	3	3
15	3	3	2	2	2	2	3	3	3	2
25	3	3	2	2	2	3	3	3	2	1
35	3	3	2	2	2	2	3	3	3	3
45	3	2	2	2	2	2	2	3	3	3
55	3	3	3	2	2	2	2	2	3	1
65	3	1	1	2	2	2	3	3	3	3
75	1	2	2	2	2	2	2	1	1	3
85	3	2	2	2	2	2	1	3	3	3
95	3	3	2	2	2	3	3	1	3	3

Shrub 3 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	1	1	3	3	1	3	3	1	3
15	3	1	3	3	3	3	3	3	3	1
25	1	1	2	2	2	2	3	3	3	1
35	1	1	2	2	2	2	3	3	3	1
45	3	1	1	2	2	2	2	3	3	3
55	3	3	2	2	2	2	2	2	3	3
65	1	3	3	2	2	2	2	2	3	3
75	1	3	3	2	2	2	2	2	3	1
85	1	3	1	1	1	3	3	3	3	1
95	3	3	3	1	3	3	3	3	3	1

Bare 1 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	1	3	3	3	3	3	3	3	3
15	1	1	3	3	3	3	3	3	3	3
25	3	3	3	3	3	3	3	3	3	3
35	3	3	3	3	3	3	3	3	3	3
45	3	3	3	3	3	3	3	3	3	3
55	3	3	3	3	3	3	3	3	3	1
65	3	3	3	3	3	3	3	3	3	1
75	3	3	3	3	3	3	3	3	3	1
85	3	3	3	3	3	3	3	1	3	3
95	3	3	1	3	3	3	3	3	1	3

Bare 2 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	3	3	3	3
25	3	3	3	3	3	3	3	3	3	3
35	3	3	3	3	3	3	3	3	3	3
45	3	3	3	3	3	3	3	3	3	3
55	3	3	3	3	3	3	3	3	3	3
65	3	3	3	3	3	3	3	3	3	3
75	3	3	3	3	3	3	3	3	3	3
85	3	3	3	3	3	3	3	3	3	1
95	3	3	3	1	3	3	3	3	1	1

Bare 3 Untreated

	5	15	25	35	45	55	65	75	85	95
5	3	3	3	3	1	3	3	3	3	3
15	3	3	3	1	3	3	3	3	3	3
25	3	3	1	3	1	1	3	3	3	3
35	1	3	3	3	3	3	1	3	3	3
45	1	3	3	3	3	3	3	3	3	3
55	3	3	3	3	3	3	3	3	3	3
65	3	3	3	3	3	3	3	3	3	3
75	3	1	3	3	3	3	3	3	3	3
85	3	3	3	3	3	3	3	3	1	1
95	3	3	3	3	3	3	3	3	1	3

Summary of Vegetation Cover Estimates

Treated

	Grass	Shrub	Bare
Grass 1	70	0	30
Grass 2	81	0	19
Grass 3	72	0	28
Shrub 1	48	51	1
Shrub 2	49	25	26
Shrub 3	36	38	26
Bare 1	6	1	93
Bare 2	4	0	96
Bare 3	7	0	93

Untreated

	Grass	Shrub	Bare
Grass 1	40	0	60
Grass 2	50	0	50
Grass 3	54	0	46
Shrub 1	4	47	49
Shrub 2	12	41	47
Shrub 3	24	28	48
Bare 1	9	0	91
Bare 2	4	0	96
Bare 3	12	0	88

Vegetation Transects **(8/30/2000)**

Vegetation Cover Category = increments on measuring tape for 25 m long transect.

Cover Type
Grass = 1
Shrub = 2
Bare = 3

Calculated length = length of grass, shrub, or bare patch measured according to increment size.

Untreated UT-1

Vegetation Cover Category	Cover Type	Calculated length (cm)
0.30		
0.67	2	0.37
1.00	3	0.33
1.06	1	0.06
1.75	3	0.69
1.83	1	0.08
2.05	3	0.22
2.18	1	0.13
2.40	3	0.22
2.46	1	0.06
3.40	3	0.94
3.48	1	0.08
3.96	3	0.48
4.04	1	0.08
4.24	3	0.20
5.03	2	0.79
5.53	3	0.50
5.68	2	0.15
7.28	3	1.60
7.83	2	0.55
7.86	1	0.03
8.39	3	0.53
8.72	1	0.33
9.98	3	1.26
10.05	1	0.07
10.11	3	0.06
10.22	1	0.11
10.28	3	0.06
10.72	1	0.44
11.07	3	0.35
11.12	1	0.05
11.83	3	0.71
13.67	2	1.84
13.98	3	0.31

Vegetation Cover Category	Cover Type	Calculated length (m)
14.04	1	0.06
14.50	3	0.46
14.89	2	0.39
14.94	3	0.05
15.00	1	0.06
15.69	3	0.69
15.83	1	0.14
16.01	2	0.18
16.38	3	0.37
16.43	1	0.05
16.60	3	0.17
16.83	2	0.23
17.20	3	0.37
17.92	2	0.72
18.71	3	0.79
19.50	2	0.79
20.01	3	0.51
20.22	2	0.21
20.82	3	0.60
20.93	2	0.11
21.70	3	0.77
21.96	2	0.26
22.11	3	0.15
22.18	1	0.07
22.30	3	0.12
22.34	1	0.04
22.51	3	0.17
22.57	1	0.06
22.60	3	0.03
22.65	1	0.05
22.75	3	0.10
22.79	1	0.04
22.96	3	0.17
23.12	1	0.16

Categorized Values of UT-1

Cont.

Vegetation Cover Category	Cover Type	Calculated length (m)
23.41	3	0.29
23.90	2	0.49
24.36	3	0.46
24.53	1	0.17
24.62	3	0.09
24.75	2	0.13
24.84	1	0.09
25.30	3	0.46

	1	2	3
	Grass	**Shrub**	**Bare**
	0.06	0.37	0.33
	0.08	0.79	0.69
	0.13	0.15	0.22
	0.06	0.55	0.22
	0.08	1.84	0.94
	0.08	0.39	0.48
	0.03	0.18	0.20
	0.33	0.23	0.50
	0.07	0.72	1.60
	0.11	0.79	0.53
	0.44	0.21	1.26
	0.05	0.11	0.06
	0.06	0.26	0.06
	0.06	0.49	0.35
	0.14	0.13	0.71
	0.05		0.31
	0.07		0.46
	0.04		0.05
	0.06		0.69
	0.05		0.37
	0.04		0.17
	0.16		0.37
	0.17		0.79
	0.09		0.51
			0.60
			0.77
			0.15
			0.12
			0.17
			0.03
			0.10
			0.17
			0.29
			0.46
			0.09
			0.46
Total (m)	2.51	7.21	15.28
Average	0.12	0.62	0.25
Percentage	10.04	28.84	61.12

UT-2

Vegetation Cover Category	Cover Type	Calculated length (m)
0.00		
0.09	3	0.09
0.12	1	0.03
0.19	3	0.07
0.21	1	0.02
0.25	3	0.04
0.29	1	0.04
0.31	3	0.02
0.35	1	0.04
0.39	3	0.04
0.41	1	0.02
0.48	3	0.07
0.51	1	0.03
0.59	3	0.08
0.63	1	0.04
0.65	3	0.02
0.67	1	0.02
0.84	3	0.17
1.11	1	0.27
1.25	3	0.14
1.35	1	0.10
1.62	3	0.27
1.74	1	0.12
1.91	3	0.17
2.06	1	0.15
3.16	2	1.10
3.59	3	0.43
4.00	2	0.41
4.05	1	0.05
4.23	3	0.18
4.39	2	0.16
4.49	3	0.10
4.54	1	0.05
4.66	3	0.12
4.72	1	0.06
4.97	3	0.25
5.01	1	0.04
5.65	3	0.64
5.73	1	0.08
5.98	3	0.25
6.03	1	0.05
6.15	3	0.12
6.19	1	0.04
6.26	3	0.07
6.30	1	0.04
6.49	3	0.19
6.53	1	0.04
6.76	3	0.23
6.92	1	0.16
7.08	3	0.16
7.32	1	0.24
7.47	3	0.15
7.51	1	0.04
7.59	3	0.08
7.67	1	0.08
7.73	3	0.06
7.83	1	0.10
7.97	3	0.14
8.02	1	0.05
8.23	3	0.21
9.90	2	1.67
10.02	3	0.12
10.20	1	0.18
10.51	3	0.31
10.53	1	0.02
10.63	3	0.10
10.75	1	0.12
11.04	3	0.29
11.12	1	0.08
11.16	3	0.04
12.26	2	1.10
13.36	3	1.10
13.40	1	0.04
13.52	3	0.12
13.55	1	0.03
14.42	3	0.87
14.45	1	0.03
14.53	3	0.08
14.62	1	0.09
14.88	3	0.26
14.91	1	0.03
14.97	3	0.06
15.16	1	0.19
15.33	3	0.17
15.38	1	0.05
15.67	3	0.29
16.40	2	0.73
16.56	3	0.16
16.66	1	0.10
17.63	3	0.97

Vegetation Cover Category	Cover Type	Calculated length (m)
17.71	1	0.08
17.79	3	0.08
17.83	1	0.04
17.91	3	0.08
17.99	1	0.08
18.03	3	0.04
18.13	1	0.10
18.32	3	0.19
18.40	1	0.08
18.53	3	0.13
18.61	1	0.08
19.59	3	0.98
20.34	2	0.75
20.56	3	0.22
20.78	2	0.22
21.04	3	0.26
21.13	2	0.09
21.43	3	0.30
23.10	2	1.67
23.18	3	0.08
23.40	2	0.22
24.27	3	0.87
24.35	1	0.08
24.59	3	0.24
24.70	1	0.11
24.78	3	0.08
24.83	1	0.05
24.97	3	0.14
24.99	1	0.02
25.00	3	0.01

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	0.03	1.10	0.09
	0.02	0.41	0.07
	0.04	0.16	0.04
	0.04	1.67	0.02
	0.02	1.10	0.04
	0.03	0.73	0.07
	0.04	0.75	0.08
	0.02	0.22	0.02
	0.27	0.09	0.17
	0.10	1.67	0.14
	0.12	0.22	0.27
	0.15		0.17
	0.05		0.43
	0.05		0.18
	0.06		0.10
	0.04		0.12
	0.08		0.25
	0.05		0.64
	0.04		0.25
	0.04		0.12
	0.04		0.07
	0.16		0.19
	0.24		0.23
	0.04		0.16
	0.08		0.15
	0.10		0.08
	0.05		0.06
	0.18		0.14
	0.02		0.21
	0.12		0.12
	0.08		0.31
	0.04		0.10
	0.03		0.29
	0.03		0.04
	0.09		1.10
	0.03		0.12
	0.19		0.87
	0.05		0.08
	0.10		0.26
	0.08		0.06
	0.04		0.17
	0.08		0.29
	0.10		0.16
	0.08		0.97
	0.08		0.08
	0.08		0.08
	0.11		0.04
	0.05		0.19
	0.02		0.13
			0.98
			0.22
			0.26
			0.30
			0.08
			0.87
			0.24
			0.08
			0.14
			0.01
Total (m)	**3.68**	**8.12**	**11.41**
Average	**0.08**	**0.74**	**0.22**
Percentage	**14.72**	**32.48**	**52.80**

UT-3

Vegetation Cover Category	Cover Type	Calculated length (m)
0.20		0.20
0.62	3	0.42
0.70	1	0.08
0.74	3	0.04
0.79	1	0.05
0.89	3	0.10
1.02	1	0.13
1.19	3	0.17
1.21	1	0.02
1.81	3	0.60
1.85	1	0.04
1.95	3	0.10
2.89	2	0.94
3.05	1	0.16
3.35	3	0.30
3.79	2	0.44
4.22	3	0.43
4.33	2	0.11
4.68	3	0.35
5.23	2	0.55
5.59	3	0.36
5.72	1	0.13
6.63	3	0.91
6.68	1	0.05
6.73	3	0.05
6.99	1	0.26
7.17	3	0.18
7.35	2	0.18
7.40	3	0.05
7.81	1	0.41
7.91	3	0.10
7.96	1	0.05
8.08	3	0.12
8.14	1	0.06
8.43	3	0.29
8.48	1	0.05
8.97	3	0.49
9.02	1	0.05
9.13	3	0.11
9.17	1	0.04
9.62	3	0.45
9.68	1	0.06
9.75	3	0.07
9.79	1	0.04
10.29	3	0.50
10.34	1	0.05
10.49	3	0.15
10.55	1	0.06
10.75	3	0.20
10.79	1	0.04
10.90	3	0.11
10.95	1	0.05
11.06	3	0.11
11.15	1	0.09
11.24	3	0.09
11.25	1	0.01
11.55	3	0.30
11.62	1	0.07
11.77	2	0.15
11.94	1	0.17
12.01	3	0.07
12.04	1	0.03
12.11	3	0.07
12.15	1	0.04
12.52	3	0.37
12.61	1	0.09
12.79	3	0.18
13.04	1	0.25
13.30	2	0.26
13.95	3	0.65
14.03	1	0.08
14.05	3	0.02
14.09	1	0.04
14.18	3	0.09
14.51	1	0.33
14.98	3	0.47
15.15	1	0.17
15.52	3	0.37
17.51	2	1.99
18.33	3	0.82
18.61	1	0.28
18.88	3	0.27
18.94	1	0.06
20.53	3	1.59
20.96	2	0.43
21.12	3	0.16
21.29	1	0.17
22.68	3	1.39

Vegetation Cover Category	Cover Type	Calculated length (m)
23.18	2	0.50
23.29	3	0.11
23.54	1	0.25
23.61	3	0.07
23.67	1	0.06
23.79	3	0.12
23.83	1	0.04
24.49	3	0.66
24.56	1	0.07
24.82	3	0.26
24.99	2	0.17
25.20	3	0.21

	1	2	3
	Grass	**Shrub**	**Bare**
	0.08	0.94	0.42
	0.05	0.44	0.04
	0.13	0.11	0.10
	0.02	0.55	0.17
	0.04	0.18	0.60
	0.16	0.15	0.10
	0.13	0.26	0.30
	0.05	1.99	0.43
	0.26	0.43	0.35
	0.41	0.50	0.36
	0.05	0.17	0.91
	0.06		0.05
	0.05		0.18
	0.05		0.05
	0.04		0.10
	0.06		0.12
	0.04		0.29
	0.05		0.49
	0.06		0.11
	0.04		0.45
	0.05		0.07
	0.09		0.50
	0.01		0.15
	0.07		0.06
	0.17		0.20
	0.03		0.11
	0.04		0.11
	0.09		0.09
	0.25		0.30
	0.08		0.07
	0.04		0.07
	0.33		0.37
	0.17		0.18
	0.28		0.65
	0.06		0.02
	0.17		0.09
	0.25		0.47
	0.06		0.37
	0.04		0.82
	0.07		0.27
			1.59
			0.16
			1.39
			0.11
			0.07
			0.12
			0.66
			0.26
			0.21
Total (m)	**4.18**	**5.72**	**15.16**
Average	**0.10**	**0.52**	**0.31**
Percentage	**16.72**	**22.88**	**60.64**

UT-4

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		0.30
0.35	3	0.05
0.43	1	0.08
0.56	3	0.13
0.64	1	0.08
0.74	3	0.10
0.79	1	0.05
0.99	3	0.20
1.11	1	0.12
1.30	3	0.19
1.34	1	0.04
1.51	3	0.17
1.60	1	0.09
2.37	3	0.77
2.62	1	0.25
2.77	3	0.15
2.84	1	0.07
2.96	3	0.12
3.04	1	0.08
3.71	2	0.67
4.87	3	1.16
4.94	1	0.07
5.31	3	0.37
5.45	1	0.14
5.82	3	0.37
5.99	1	0.17
6.12	3	0.13
6.38	1	0.26
7.33	3	0.95
7.84	2	0.51
8.42	1	0.58
9.26	2	0.84
9.49	3	0.23
9.61	1	0.12
11.38	3	1.77
11.46	1	0.08
12.27	2	0.81
12.32	1	0.05
12.46	3	0.14
12.51	1	0.05
12.57	3	0.06
12.61	1	0.04
12.82	3	0.21

Vegetation Cover Category	Cover Type	Calculated length (m)
12.98	1	0.16
13.48	3	0.50
15.48	2	2.00
15.82	3	0.34
16.98	2	1.16
17.35	3	0.37
18.11	2	0.76
18.25	1	0.14
18.83	3	0.58
18.91	1	0.08
19.34	3	0.43
19.52	1	0.18
19.61	3	0.09
19.63	1	0.02
20.11	3	0.48
20.18	1	0.07
20.92	3	0.74
21.57	1	0.65
22.86	3	1.29
23.37	2	0.51
23.78	3	0.41
23.84	2	0.06
24.01	3	0.17
24.17	2	0.16
24.44	3	0.27
25.13	2	0.69
25.30	3	0.17

Categorized Values of UT-2

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	0.08	0.67	0.05
	0.08	0.51	0.13
	0.05	0.84	0.10
	0.12	0.81	0.20
	0.04	2.00	0.19
	0.09	1.16	0.17
	0.25	0.76	0.77
	0.07	0.51	0.15
	0.08	0.06	0.12
	0.07	0.16	1.16
	0.14	0.69	0.37
	0.17		0.37
	0.26		0.13
	0.58		0.95
	0.12		0.23
	0.08		1.77
	0.05		0.14
	0.05		0.06
	0.04		0.21
	0.16		0.50
	0.14		0.34
	0.08		0.37
	0.18		0.58
	0.02		0.43
	0.07		0.09
	0.65		0.48
			0.74
			1.29
			0.41
			0.17
			0.27
			0.17
Total (m)	**3.72**	**8.17**	**13.11**
Average	**0.14**	**0.74**	**0.41**
Percentage	**14.88**	**32.68**	**52.44**

UT-5

Vegetation Cover Category	Cover Type	Calculated length (m)
0.40		
0.60	2	0.20
1.22	3	0.62
1.61	2	0.39
1.71	1	0.10
1.76	3	0.05
1.93	1	0.17
2.12	2	0.19
2.55	3	0.43
2.67	1	0.12
2.75	3	0.08
2.90	1	0.15
3.15	3	0.25
5.19	2	2.04
5.36	3	0.17
5.41	1	0.05
5.69	3	0.28
5.93	2	0.24
6.14	1	0.21
6.20	3	0.06
6.76	2	0.56
7.24	3	0.48
7.32	1	0.08
7.69	3	0.37
7.74	1	0.05
7.88	3	0.14
8.01	1	0.13
12.84	3	4.83
13.26	2	0.42
13.48	3	0.22
13.65	2	0.17
14.58	3	0.93
14.68	1	0.10
14.88	2	0.20
15.95	3	1.07
16.01	1	0.06
16.18	3	0.17
16.22	1	0.04
16.28	3	0.06
16.37	1	0.09
16.51	3	0.14
17.28	2	0.77
17.41	3	0.13
17.63	1	0.22
17.87	3	0.24
18.13	1	0.26
18.26	3	0.13
18.29	1	0.03
18.51	3	0.22
18.64	1	0.13
18.86	3	0.22
18.89	1	0.03
18.98	3	0.09
19.04	1	0.06
19.12	3	0.08
19.17	1	0.05
19.61	2	0.44
20.11	1	0.50
20.38	3	0.27
21.77	2	1.39
22.21	3	0.44
22.54	1	0.33
22.61	3	0.07
22.73	1	0.12
22.78	3	0.05
22.98	1	0.20
23.01	3	0.03
23.13	1	0.12
23.29	3	0.16
23.45	2	0.16
23.73	3	0.28
23.78	1	0.05
24.63	2	0.85
24.86	3	0.23
24.95	1	0.09
25.10	3	0.15
25.21	1	0.11
25.31	3	0.10
25.40	1	0.09

Categorized Values of UT-5

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	0.10	0.20	0.62
	0.17	0.39	0.05
	0.12	0.19	0.43
	0.15	2.04	0.08
	0.05	0.24	0.25
	0.21	0.56	0.17
	0.08	0.42	0.28
	0.05	0.17	0.06
	0.13	0.20	0.48
	0.10	0.77	0.37
	0.06	0.44	0.14
	0.04	1.39	4.83
	0.09	0.16	0.22
	0.22	0.85	0.93
	0.26		1.07
	0.03		0.17
	0.13		0.06
	0.03		0.14
	0.06		0.13
	0.05		0.24
	0.50		0.13
	0.33		0.22
	0.12		0.22
	0.20		0.09
	0.12		0.08
	0.05		0.27
	0.09		0.44
	0.11		0.07
	0.09		0.05
			0.03
			0.16
			0.28
			0.23
			0.15
			0.10
Total (m)	**3.74**	**8.02**	**13.24**
Average	**0.13**	**0.57**	**0.38**
Percentage	**14.96**	**32.08**	**52.96**

UT-6

Vegetation Cover Category	Cover Type	Calculated length (m)
0.50		
0.71	2	0.21
0.77	1	0.06
0.91	3	0.14
0.98	1	0.07
1.03	3	0.05
1.07	1	0.04
1.56	3	0.49
2.68	2	1.12
3.03	3	0.35
3.07	1	0.04
3.79	3	0.72
3.83	1	0.04
4.48	3	0.65
4.57	1	0.09
5.68	2	1.11
5.78	3	0.10
5.84	1	0.06
6.39	3	0.55
6.45	1	0.06
6.96	3	0.51
7.13	1	0.17
8.34	3	1.21
8.47	1	0.13
8.57	3	0.10
8.66	1	0.09
9.09	3	0.43
9.18	1	0.09
9.79	3	0.61
9.88	1	0.09
10.30	3	0.42
10.40	1	0.10
10.45	3	0.05
10.78	2	0.33
11.02	1	0.24
11.08	3	0.06
11.13	1	0.05
11.34	3	0.21
11.38	1	0.04
11.44	3	0.06
11.51	1	0.07
11.68	3	0.17
11.73	1	0.05
11.82	3	0.09

Vegetation Cover Category	Cover Type	Calculated length (m)
11.86	1	0.04
12.07	3	0.21
12.12	1	0.05
12.41	3	0.29
13.84	2	1.43
14.07	3	0.23
14.12	1	0.05
15.35	3	1.23
15.38	1	0.03
16.16	3	0.78
16.23	1	0.07
16.66	3	0.43
16.71	1	0.05
16.79	3	0.08
16.83	1	0.04
16.89	3	0.06
17.02	1	0.13
17.68	3	0.66
17.80	1	0.12
17.91	3	0.11
18.02	2	0.11
18.13	1	0.11
18.69	3	0.56
18.72	1	0.03
19.07	3	0.35
20.62	2	1.55
20.99	3	0.37
21.28	2	0.29
21.97	3	0.69
22.31	2	0.34
22.83	3	0.52
23.22	2	0.39
24.43	3	1.21
24.61	1	0.18
25.07	3	0.46
25.12	1	0.05
25.37	3	0.25
25.42	1	0.05
25.50	3	0.08

Categorized Values of UT-6

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	0.06	0.21	0.14
	0.07	1.12	0.05
	0.04	1.11	0.49
	0.04	0.33	0.35
	0.04	1.43	0.72
	0.09	0.11	0.65
	0.06	1.55	0.10
	0.06	0.29	0.55
	0.17	0.34	0.51
	0.13	0.39	1.21
	0.09		0.10
	0.09		0.43
	0.09		0.61
	0.10		0.42
	0.24		0.05
	0.05		0.06
	0.04		0.21
	0.07		0.06
	0.05		0.17
	0.04		0.09
	0.05		0.21
	0.05		0.29
	0.03		0.23
	0.07		1.23
	0.05		0.78
	0.04		0.43
	0.13		0.08
	0.12		0.06
	0.11		0.66
	0.03		0.11
	0.18		0.56
	0.05		0.35
	0.05		0.37
			0.69
			0.52
			1.21
			0.46
			0.25
			0.08
Total (m)	**2.58**	**6.88**	**15.54**
Average	**0.08**	**0.69**	**0.40**
Percentage	**10.32**	**27.52**	**62.16**

UT-7

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
0.76	3	0.46
0.96	1	0.20
1.05	3	0.09
1.15	1	0.10
1.24	3	0.09
2.28	2	1.04
2.49	3	0.21
2.54	1	0.05
2.67	3	0.13
2.71	1	0.04
2.85	3	0.14
3.04	1	0.19
3.69	3	0.65
3.73	1	0.04
4.03	3	0.30
4.07	1	0.04
4.88	3	0.81
4.94	1	0.06
5.71	3	0.77
5.86	2	0.15
5.98	3	0.12
6.02	1	0.04
6.20	3	0.18
6.28	1	0.08
6.47	2	0.19
6.81	3	0.34
6.88	1	0.07
6.96	3	0.08
7.07	1	0.11
7.28	3	0.21
7.89	2	0.61
8.80	3	0.91
9.01	1	0.21
9.43	3	0.42
9.56	1	0.13
9.75	3	0.19
9.90	1	0.15
10.28	3	0.38
10.39	1	0.11
10.62	3	0.23
10.81	1	0.19
13.09	3	2.28
13.54	2	0.45

Vegetation Cover Category	Cover Type	Calculated length (m)
14.10	3	0.56
14.19	1	0.09
15.52	2	1.33
15.86	3	0.34
15.97	1	0.11
16.44	3	0.47
17.14	2	0.70
17.90	3	0.76
17.94	1	0.04
18.23	3	0.29
18.27	1	0.04
19.02	3	0.75
19.16	1	0.14
20.01	3	0.85
20.23	2	0.22
20.44	3	0.21
20.52	1	0.08
21.81	3	1.29
22.00	2	0.19
22.27	3	0.27
23.08	2	0.81
23.25	1	0.17
24.21	2	0.96
24.28	3	0.07
24.39	1	0.11
24.48	3	0.09
24.58	1	0.10
24.63	3	0.05
24.73	1	0.10
24.79	3	0.06
24.89	1	0.10
25.00	3	0.11
25.09	1	0.09
25.19	3	0.10
25.27	1	0.08
25.30	3	0.03

Categorized Values for UT-7

	1	2	3
	Grass	**Shrub**	**Bare**
	0.20	1.04	0.46
	0.10	0.15	0.09
	0.05	0.19	0.09
	0.04	0.61	0.21
	0.19	0.45	0.13
	0.04	1.33	0.14
	0.04	0.70	0.65
	0.06	0.22	0.30
	0.04	0.19	0.81
	0.08	0.81	0.77
	0.07	0.96	0.12
	0.11		0.18
	0.21		0.34
	0.13		0.08
	0.15		0.21
	0.11		0.91
	0.19		0.42
	0.09		0.19
	0.11		0.38
	0.04		0.23
	0.04		2.28
	0.14		0.56
	0.08		0.34
	0.17		0.47
	0.11		0.76
	0.10		0.29
	0.10		0.75
	0.10		0.85
	0.09		0.21
	0.08		1.29
			0.27
			0.07
			0.09
			0.05
			0.06
			0.11
			0.10
			0.03
Total (m)	**3.06**	**6.65**	**15.29**
Average	**0.10**	**0.60**	**0.40**
Percentage	**12.24**	**26.60**	**61.16**

UT-8

Vegetation Cover Category	Cover Type	Calculated length (m)
0.40		
0.54	1	0.14
0.75	2	0.21
1.09	3	0.34
1.15	1	0.06
1.22	3	0.07
1.25	1	0.03
1.50	3	0.25
1.54	1	0.04
1.61	3	0.07
1.99	1	0.38
2.05	3	0.06
2.09	1	0.04
2.29	3	0.20
2.34	1	0.05
2.43	3	0.09
2.52	1	0.09
2.92	3	0.40
2.98	1	0.06
3.04	3	0.06
3.09	1	0.05
3.39	3	0.30
3.43	1	0.04
3.69	3	0.26
3.75	1	0.06
3.86	3	0.11
3.91	1	0.05
4.02	3	0.11
4.47	1	0.45
4.75	2	0.28
4.85	1	0.10
4.90	3	0.05
4.93	1	0.03
5.09	3	0.16
5.14	1	0.05
5.24	3	0.10
5.32	1	0.08
5.38	3	0.06
5.43	1	0.05
6.00	2	0.57
6.14	1	0.14
6.40	3	0.26
6.46	1	0.06
6.51	3	0.05

Vegetation Cover Category	Cover Type	Calculated length (m)
6.54	1	0.03
6.85	3	0.31
6.89	1	0.04
8.45	3	1.56
8.51	1	0.06
8.77	3	0.26
8.84	1	0.07
9.11	3	0.27
9.24	1	0.13
10.90	2	1.66
11.02	3	0.12
11.13	1	0.11
11.24	3	0.11
11.39	1	0.15
11.53	3	0.14
11.64	1	0.11
11.79	3	0.15
11.82	1	0.03
12.01	3	0.19
12.06	1	0.05
12.18	3	0.12
12.27	1	0.09
13.29	3	1.02
13.36	1	0.07
13.48	3	0.12
13.55	1	0.07
13.61	3	0.06
13.74	1	0.13
14.22	3	0.48
14.26	1	0.04
14.48	3	0.22
14.51	1	0.03
14.55	3	0.04
14.82	2	0.27
15.03	1	0.21
16.73	3	1.70
17.19	2	0.46
17.25	3	0.06
17.33	1	0.08
18.36	2	1.03
18.43	1	0.07
19.07	3	0.64
20.56	2	1.49
20.60	1	0.04

Vegetation Cover Category	Cover Type	Calculated length (m)
20.92	3	0.32
21.12	1	0.20
22.32	2	1.20
22.41	3	0.09
22.50	1	0.09
22.99	3	0.49
23.11	1	0.12
23.52	3	0.41
23.73	1	0.21
24.25	3	0.52
24.41	1	0.16
24.46	3	0.05
24.50	1	0.04
25.02	3	0.52
25.26	1	0.24
25.40	2	0.14

	1	2	3
	Grass	**Shrub**	**Bare**
	0.14	0.21	0.34
	0.06	0.28	0.07
	0.03	0.57	0.25
	0.04	1.66	0.07
	0.38	0.27	0.06
	0.04	0.46	0.20
	0.05	1.03	0.09
	0.09	1.49	0.40
	0.06	1.20	0.06
	0.05	0.14	0.30
	0.04		0.26
	0.06		0.11
	0.05		0.11
	0.45		0.05
	0.10		0.16
	0.03		0.10
	0.05		0.06
	0.08		0.26
	0.05		0.05
	0.14		0.31
	0.06		1.56
	0.03		0.26
	0.04		0.27
	0.06		0.12
	0.07		0.11
	0.13		0.14
	0.11		0.15
	0.15		0.19
	0.11		0.12
	0.03		1.02
	0.05		0.12
	0.09		0.06
	0.07		0.48
	0.07		0.22
	0.13		0.04
	0.04		1.70
	0.03		0.06
	0.21		0.64
	0.08		0.32
	0.07		0.09
	0.04		0.49
	0.20		0.41
	0.09		0.52
	0.12		0.05
	0.21		0.52
	0.16		
	0.04		
	0.24		
Total (m)	**4.72**	**7.31**	**12.97**
Average	**0.10**	**0.73**	**0.29**
Percentage	**18.88**	**29.24**	**51.88**

UT-9

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
2.29	3	1.99
2.33	1	0.04
4.34	3	2.01
4.68	2	0.34
5.33	3	0.65
6.26	1	0.93
6.69	3	0.43
6.88	1	0.19
6.99	3	0.11
7.33	1	0.34
7.39	3	0.06
7.75	2	0.36
7.98	3	0.23
8.08	1	0.10
8.14	3	0.06
8.25	1	0.11
8.39	3	0.14
8.48	1	0.09
8.56	3	0.08
8.64	1	0.08
9.01	3	0.37
10.15	2	1.14
10.23	1	0.08
10.30	3	0.07
10.36	1	0.06
10.98	3	0.62
11.16	1	0.18
11.67	3	0.51
11.88	2	0.21
11.94	1	0.06
12.10	3	0.16
12.18	1	0.08
12.36	3	0.18
12.67	2	0.31
12.85	1	0.18
13.25	3	0.40
14.16	2	0.91
14.32	3	0.16
14.41	1	0.09
14.61	3	0.20
15.02	1	0.41
15.80	3	0.78
15.92	1	0.12
16.03	3	0.11
16.09	1	0.06
16.52	3	0.43
17.19	2	0.67
17.41	3	0.22
17.54	1	0.13
17.69	3	0.15
17.76	1	0.07
17.92	3	0.16
18.02	1	0.10
18.21	3	0.19
18.38	1	0.17
18.98	2	0.60
19.31	3	0.33
19.34	1	0.03
19.52	3	0.18
19.56	1	0.04
19.95	3	0.39
20.23	1	0.28
21.26	3	1.03
21.42	1	0.16
21.50	3	0.08
21.64	1	0.14
22.02	3	0.38
22.07	1	0.05
22.12	3	0.05
22.17	1	0.05
22.33	3	0.16
22.39	1	0.06
22.45	3	0.06
22.58	1	0.13
22.68	3	0.10
22.74	1	0.06
22.89	3	0.15
22.99	1	0.10
23.31	3	0.32
23.63	2	0.32
24.01	3	0.38
24.10	1	0.09
24.26	3	0.16
24.30	1	0.04
24.34	3	0.04
24.38	1	0.04
24.45	3	0.07

Vegetation Cover Category	Cover Type	Calculated length (m)
24.55	1	0.10
24.61	3	0.06
24.70	1	0.09
24.77	3	0.07
24.83	1	0.06
25.30	3	0.47

1	2	3
Grass	**Shrub**	**Bare**
0.04	0.34	1.99
0.93	0.36	2.01
0.19	1.14	0.65
0.34	0.21	0.43
0.10	0.31	0.11
0.11	0.91	0.06
0.09	0.67	0.23
0.08	0.60	0.06
0.08	0.32	0.14
0.06		0.08
0.18		0.37
0.06		0.07
0.08		0.62
0.18		0.51
0.09		0.16
0.41		0.18
0.12		0.40
0.06		0.16
0.13		0.20
0.07		0.78
0.10		0.11
0.17		0.43
0.03		0.22
0.04		0.15
0.28		0.16
0.16		0.19
0.14		0.33
0.05		0.18
0.05		0.39
0.06		1.03
0.13		0.08
0.06		0.38
0.10		0.05
0.09		0.16
0.04		0.06
0.04		0.10

cont.	Grass	Shrub	Bare
	0.10		0.15
	0.09		0.32
	0.06		0.38
			0.16
			0.04
			0.07
			0.06
			0.07
			0.47
Total (m)	**5.19**	**4.86**	**14.95**
Average	**0.13**	**0.54**	**0.33**
Percentage	**20.76**	**19.44**	**59.80**

UT-10

Vegetation Cover Category	Cover Type	Calculated length (m)
0.40		
0.73	2	0.33
1.57	3	0.84
1.66	1	0.09
2.26	3	0.60
2.33	1	0.07
2.48	3	0.15
2.50	1	0.02
2.54	3	0.04
2.69	1	0.15
2.94	3	0.25
2.99	1	0.05
3.51	3	0.52
4.30	1	0.79
4.50	3	0.20
4.54	1	0.04
4.99	3	0.45
5.58	2	0.59
5.81	3	0.23
5.84	1	0.03
6.12	3	0.28
6.19	1	0.07
6.26	3	0.07
6.49	1	0.23
6.56	3	0.07
6.82	1	0.26
6.96	3	0.14
8.14	2	1.18
8.53	3	0.39
8.99	2	0.46
9.60	3	0.61
9.92	2	0.32
10.21	3	0.29
10.65	2	0.44
11.06	3	0.41
11.18	1	0.12
11.44	3	0.26
11.51	1	0.07
11.64	3	0.13
11.86	1	0.22
12.08	3	0.22
12.12	1	0.04
12.15	3	0.03
12.18	1	0.03
12.21	3	0.03
12.24	1	0.03
12.30	3	0.06
12.32	1	0.02
12.44	3	0.12
12.46	1	0.02
12.57	3	0.11
12.73	1	0.16
13.43	3	0.70
13.49	1	0.06
14.60	3	1.11
14.70	1	0.10
15.01	3	0.31
15.59	2	0.58
15.85	3	0.26
15.91	1	0.06
16.00	3	0.09
16.03	1	0.03
16.13	3	0.10
16.24	1	0.11
16.34	3	0.10
16.38	1	0.04
16.51	3	0.13
16.66	1	0.15
16.97	3	0.31
17.09	2	0.12
17.29	3	0.20
17.78	2	0.49
17.91	1	0.13
18.08	3	0.17
19.04	2	0.96
19.26	1	0.22
19.75	3	0.49
19.81	1	0.06
19.90	3	0.09
19.96	1	0.06
20.08	3	0.12
20.12	1	0.04
20.16	3	0.04
20.25	1	0.09
20.44	3	0.19
20.68	1	0.24
21.21	3	0.53
21.42	2	0.21

Vegetation Cover Category	Cover Type	Calculated length (m)
21.66	3	0.24
22.06	2	0.40
22.85	3	0.79
23.00	1	0.15
23.10	3	0.10
23.25	1	0.15
23.37	3	0.12
23.42	1	0.05
23.52	3	0.10
23.56	1	0.04
23.76	3	0.20
23.80	1	0.04
23.92	3	0.12
23.95	1	0.03
24.02	3	0.07
24.06	1	0.04
24.24	3	0.18
24.29	1	0.05
24.46	3	0.17
24.52	1	0.06
24.73	3	0.21
24.81	1	0.08
24.86	3	0.05
24.91	1	0.05
25.40	3	0.49

	1	2	3
	Grass	**Shrub**	**Bare**
	0.09	0.33	0.84
	0.07	0.59	0.60
	0.02	1.18	0.15
	0.15	0.46	0.04
	0.05	0.32	0.25
	0.79	0.44	0.52
	0.04	0.58	0.20
	0.03	0.12	0.45
	0.07	0.49	0.23
	0.23	0.96	0.28
	0.26	0.21	0.07
	0.12	0.40	0.07
	0.07		0.14
	0.22		0.39
	0.04		0.61
	0.03		0.29
	0.03		0.41
cont.	**Grass**	**Shrub**	**Bare**
	0.02		0.26
	0.02		0.13
	0.16		0.22
	0.06		0.03
	0.10		0.03
	0.06		0.06
	0.03		0.12
	0.11		0.11
	0.04		0.70
	0.15		1.11
	0.13		0.31
	0.22		0.26
	0.06		0.09
	0.06		0.10
	0.04		0.10
	0.09		0.13
	0.24		0.31
	0.15		0.20
	0.15		0.17
	0.05		0.49
	0.04		0.09
	0.04		0.12
	0.03		0.04
	0.04		0.19
	0.05		0.53
	0.06		0.24
	0.08		0.79
	0.05		0.10
			0.12
			0.10
			0.20
			0.12
			0.07
			0.18
			0.17
			0.21
			0.05
			0.49
Total (m)	**4.64**	**6.08**	**14.28**
Average	**0.10**	**0.51**	**0.26**
Percentage	**18.56**	**24.32**	**57.12**

Treated Plots

TR-1

Vegetation Cover Category	Cover Type	Calculated length (m)
0.00		
0.11	1	0.11
0.19	3	0.08
0.28	1	0.09
0.60	3	0.32
1.30	1	0.70
1.83	3	0.53
2.49	1	0.66
3.30	3	0.81
3.51	1	0.21
4.21	3	0.70
4.44	1	0.23
4.91	3	0.47
5.00	1	0.09
5.22	3	0.22
5.24	1	0.02
5.29	3	0.05
5.37	1	0.08
5.45	3	0.08
5.57	1	0.12
5.72	3	0.15
5.78	1	0.06
5.84	3	0.06
5.91	1	0.07
6.21	3	0.30
6.23	1	0.02
6.29	3	0.06
6.42	1	0.13
6.54	3	0.12
7.12	1	0.58
7.17	3	0.05
7.33	1	0.16
8.05	3	0.72
9.20	2	1.15
9.41	3	0.21
9.85	1	0.44
10.00	3	0.15
10.21	2	0.21
10.71	3	0.50
11.12	1	0.41
11.32	3	0.20
11.66	2	0.34
11.79	3	0.13
12.32	1	0.53
13.52	3	1.20
14.00	1	0.48
14.31	3	0.31
14.33	1	0.02
14.51	3	0.18
14.92	1	0.41
16.00	3	1.08
16.37	2	0.37
16.52	1	0.15
17.11	3	0.59
17.45	1	0.34
17.61	3	0.16
17.78	1	0.17
18.26	3	0.48
18.58	1	0.32
18.65	3	0.07
18.78	1	0.13
18.87	3	0.09
18.99	1	0.12
20.12	3	1.13
20.26	2	0.14
21.10	3	0.84
21.31	1	0.21
21.38	3	0.07
21.45	1	0.07
21.50	3	0.05
21.62	1	0.12
21.75	3	0.13
21.86	1	0.11
21.93	3	0.07
22.06	1	0.13
22.17	3	0.11
22.32	1	0.15
22.38	3	0.06
22.75	2	0.37
22.78	3	0.03
22.88	1	0.10
23.29	3	0.41
23.51	1	0.22
23.76	3	0.25
23.92	1	0.16
23.97	3	0.05

Vegetation Cover Category	Cover Type	Calculated length (m)
24.18	1	0.21
24.24	3	0.06
24.33	1	0.09
24.47	3	0.14
24.86	1	0.39
24.96	3	0.10
25.00	1	0.04

	1	2	3
	Grass	Shrub	Bare
	0.11	1.15	0.08
	0.09	0.21	0.32
	0.70	0.34	0.53
	0.66	0.37	0.81
	0.21	0.14	0.70
	0.23	0.37	0.47
	0.09		0.22
	0.02		0.05
	0.08		0.08
	0.12		0.15
	0.06		0.06
	0.07		0.30
	0.02		0.06
	0.13		0.12
	0.58		0.05
	0.16		0.72
	0.44		0.21
	0.41		0.15
	0.53		0.50
	0.48		0.20
	0.02		0.13
	0.41		1.20
	0.15		0.31
	0.34		0.18
	0.17		1.08
	0.32		0.59
	0.13		0.16
	0.12		0.48
	0.21		0.07
	0.07		0.09
	0.12		1.13
	0.11		0.84
	0.13		0.07
	0.15		0.05
	0.10		0.13
cont.	Grass	Shrub	Bare
	0.22		0.07
	0.16		0.11
	0.21		0.06
	0.09		0.03
	0.39		0.41
	0.04		0.25
			0.05
			0.06
			0.14
			0.10
Total (m)	**8.85**	**2.58**	**13.57**
Average	**0.22**	**0.43**	**0.30**
Percentage	**35.40**	**10.32**	**54.25**

TR-2

Vegetation Cover Category	Cover Type	Calculated length (m)
0.00		
0.12	1	0.12
0.29	3	0.17
0.34	1	0.05
0.44	3	0.10
0.56	1	0.12
0.64	3	0.08
0.72	1	0.08
0.78	3	0.06
0.90	1	0.12
0.98	3	0.08
1.05	1	0.07
1.11	3	0.06
1.17	1	0.06
1.37	3	0.20
1.86	1	0.49
3.20	2	1.34
5.55	1	2.35
6.18	2	0.63
7.21	1	1.03
7.55	2	0.34
7.62	3	0.07
7.98	1	0.36
8.14	3	0.16
9.61	1	1.47
9.73	2	0.12
10.11	1	0.38
10.37	3	0.26
11.49	1	1.12
11.61	3	0.12
11.67	1	0.06
11.72	3	0.05
11.87	1	0.15
11.98	3	0.11
12.13	1	0.15
12.28	3	0.15
12.36	1	0.08
12.41	3	0.05
12.46	1	0.05
12.75	3	0.29
13.10	1	0.35
13.88	2	0.78
14.59	3	0.71
14.83	1	0.24

Vegetation Cover Category	Cover Type	Calculated length (m)
14.93	3	0.10
15.03	1	0.10
15.17	3	0.14
15.26	1	0.09
15.37	3	0.11
15.45	1	0.08
16.00	2	0.55
16.22	3	0.22
16.41	1	0.19
16.60	3	0.19
16.72	1	0.12
17.02	3	0.30
17.53	1	0.51
17.61	3	0.08
18.75	1	1.14
19.00	3	0.25
19.89	1	0.89
19.95	3	0.06
20.11	1	0.16
20.61	3	0.50
22.21	1	1.60
22.70	2	0.49
22.73	3	0.03
22.95	1	0.22
23.17	3	0.22
23.42	1	0.25
23.59	3	0.17
23.62	1	0.03
24.51	2	0.89
24.93	1	0.42
25.00	3	0.07

Categorized Values of TR-2

	1 Grass	2 Shrub	3 Bare
	0.12	1.34	0.17
	0.05	0.63	0.10
	0.12	0.34	0.08
	0.08	0.12	0.06
	0.12	0.78	0.08
	0.07	0.55	0.06
	0.06	0.49	0.20
	0.49	0.89	0.07
	2.35		0.16
	1.03		0.26
	0.36		0.12
	1.47		0.05
	0.38		0.11
	1.12		0.15
	0.06		0.05
	0.15		0.29
	0.15		0.71
	0.08		0.10
	0.05		0.14
	0.35		0.11
	0.24		0.22
	0.10		0.19
	0.09		0.30
	0.08		0.08
	0.19		0.25
	0.12		0.06
	0.51		0.50
	1.14		0.03
	0.89		0.22
	0.16		0.17
	1.60		0.07
	0.22		
	0.25		
	0.03		
	0.42		
Total (m)	**14.70**	**5.14**	**5.16**
Average	**0.42**	**0.64**	**0.17**
Percentage	**58.80**	**20.56**	**20.64**

TR-3

Vegetation Cover Category	Cover Type	Calculated length (m)
0.40		
1.26	1	0.86
1.51	3	0.25
2.25	1	0.74
2.41	3	0.16
3.42	1	1.01
3.95	3	0.53
4.26	1	0.31
4.86	3	0.60
5.86	1	1.00
6.23	3	0.37
6.38	1	0.15
6.68	3	0.30
8.51	1	1.83
8.79	3	0.28
8.92	1	0.13
9.14	3	0.22
10.01	1	0.87
10.45	3	0.44
10.52	2	0.07
10.68	3	0.16
10.79	1	0.11
11.00	3	0.21
11.32	1	0.32
11.52	3	0.20
11.70	1	0.18
11.86	3	0.16
12.14	2	0.28
12.85	3	0.71
13.22	1	0.37
13.73	3	0.51
14.11	1	0.38
14.36	3	0.25
14.48	1	0.12
14.81	3	0.33
15.00	1	0.19
15.13	3	0.13
15.25	1	0.12
15.39	3	0.14
15.51	1	0.12
15.76	3	0.25
15.82	1	0.06
15.88	3	0.06
19.02	1	3.14
19.23	3	0.21
19.29	1	0.06
19.34	3	0.05
19.66	1	0.32
19.88	3	0.22
19.98	1	0.10
20.03	3	0.05
20.61	1	0.58
21.11	2	0.50
21.91	3	0.80
23.73	1	1.82
23.86	3	0.13
24.95	1	1.09
25.36	2	0.41
25.40	1	0.04

Categorized Values of TR-3

	1 Grass	2 Shrub	3 Bare
	0.86	0.07	0.25
	0.74	0.28	0.16
	1.01	0.50	0.53
	0.31	0.41	0.60
	1.00		0.37
	0.15		0.30
	1.83		0.28
	0.13		0.22
	0.87		0.44
	0.11		0.16
	0.32		0.21
	0.18		0.20
	0.37		0.16
	0.38		0.71
	0.12		0.51
	0.19		0.25
	0.12		0.33
	0.12		0.13
	0.06		0.14
	3.14		0.25
	0.06		0.06
	0.32		0.21
	0.10		0.05
	0.58		0.22
	1.82		0.05
	1.09		0.80
	0.04		0.13
Total (m)	**16.02**	**1.26**	**7.72**
Average	**0.59**	**0.32**	**0.29**
Percentage	**64.08**	**5.04**	**30.88**

TR-4

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
1.16	1	0.86
2.32	2	1.16
2.74	1	0.42
2.83	3	0.09
2.87	1	0.04
3.00	3	0.13
3.38	1	0.38
3.52	2	0.14
3.82	1	0.30
4.45	3	0.63
4.95	1	0.50
5.03	3	0.08
5.52	1	0.49
6.04	2	0.52
6.43	3	0.39
7.08	1	0.65
7.47	3	0.39
7.93	1	0.46
8.15	3	0.22
8.23	1	0.08
8.28	3	0.05
8.33	1	0.05
8.38	3	0.05
8.42	1	0.04
8.47	3	0.05
8.60	1	0.13
8.72	3	0.12
8.80	1	0.08
9.01	3	0.21
9.06	1	0.05
9.30	3	0.24
9.41	1	0.11
9.46	3	0.05
9.56	1	0.10
9.66	3	0.10
9.78	1	0.12
9.87	3	0.09
9.90	1	0.03
10.06	3	0.16
10.15	1	0.09
10.41	3	0.26
10.79	1	0.38
11.41	2	0.62

Vegetation Cover Category	Cover Type	Calculated length (m)
11.96	1	0.55
12.38	3	0.42
12.44	1	0.06
12.88	3	0.44
12.94	1	0.06
13.40	3	0.46
13.58	1	0.18
14.58	2	1.00
14.66	3	0.08
14.85	1	0.19
14.91	3	0.06
14.94	1	0.03
15.16	3	0.22
15.39	1	0.23
15.55	2	0.16
15.92	1	0.37
15.99	3	0.07
16.02	1	0.03
16.15	3	0.13
16.22	1	0.07
16.28	3	0.06
16.33	1	0.05
16.52	3	0.19
16.73	1	0.21
16.83	3	0.10
17.40	1	0.57
17.49	3	0.09
17.70	1	0.21
17.98	3	0.28
18.54	1	0.56
18.91	3	0.37
19.83	1	0.92
20.70	3	0.87
21.22	1	0.52
21.48	3	0.26
21.77	1	0.29
22.80	2	1.03
23.78	3	0.98
24.62	1	0.84
24.77	3	0.15
25.30	1	0.53

Categorized Values of TR-4

	1	2	3
	Grass	**Shrub**	**Bare**
	0.86	1.16	0.09
	0.42	0.14	0.13
	0.04	0.52	0.63
	0.38	0.62	0.08
	0.30	1.00	0.39
	0.50	0.16	0.39
	0.49	1.03	0.22
	0.65		0.05
	0.46		0.05
	0.08		0.05
	0.05		0.12
	0.04		0.21
	0.13		0.24
	0.08		0.05
	0.05		0.10
	0.11		0.09
	0.10		0.16
	0.12		0.26
	0.03		0.42
	0.09		0.44
	0.38		0.46
	0.55		0.08
	0.06		0.06
	0.06		0.22
	0.18		0.07
	0.19		0.13
	0.03		0.06
	0.23		0.19
	0.37		0.10
	0.03		0.09
	0.07		0.28
	0.05		0.37
	0.21		0.87
	0.57		0.26
	0.21		0.98
	0.56		0.15
	0.92		
	0.52		
	0.29		
	0.84		
	0.53		
Total (m)	**11.83**	**4.63**	**8.54**
Average	**0.29**	**0.66**	**0.24**
Percentage	**47.32**	**18.52**	**34.16**

TR-5

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
1.82	1	1.52
2.03	2	0.21
2.16	3	0.13
2.23	1	0.07
2.51	3	0.28
2.79	1	0.28
3.02	3	0.23
3.26	1	0.24
3.37	3	0.11
3.61	1	0.24
3.82	3	0.21
4.42	1	0.60
4.54	3	0.12
4.92	1	0.38
5.18	3	0.26
5.31	1	0.13
5.46	3	0.15
5.97	1	0.51
6.47	3	0.50
7.46	1	0.99
7.83	2	0.37
7.98	3	0.15
8.21	1	0.23
8.60	3	0.39
8.98	1	0.38
9.24	2	0.26
9.36	3	0.12
10.22	1	0.86
10.59	3	0.37
12.34	1	1.75
12.57	3	0.23
12.67	1	0.10
12.87	3	0.20
13.10	1	0.23
13.51	3	0.41
13.64	1	0.13
13.84	3	0.20
14.43	1	0.59
14.61	3	0.18
14.96	1	0.35
15.11	3	0.15
15.87	1	0.76
16.25	2	0.38

Vegetation Cover Category	Cover Type	Calculated length (m)
16.59	1	0.34
16.79	3	0.20
17.17	1	0.38
17.34	3	0.17
19.04	1	1.70
20.12	3	1.08
20.62	1	0.50
20.74	3	0.12
20.81	1	0.07
20.97	3	0.16
21.13	1	0.16
21.68	3	0.55
21.88	1	0.20
22.10	3	0.22
22.22	1	0.12
22.52	2	0.30
22.68	1	0.16
22.90	3	0.22
23.46	1	0.56
24.04	3	0.58
24.48	1	0.44
24.83	3	0.35
24.88	1	0.05
25.03	3	0.15
25.30	1	0.27

Categorized Values for TR-5

	1	2	3
	Grass	**Shrub**	**Bare**
	1.52	0.21	0.13
	0.07	0.37	0.28
	0.28	0.26	0.23
	0.24	0.38	0.11
	0.24	0.30	0.21
	0.60		0.12
	0.38		0.26
	0.13		0.15
	0.51		0.50
	0.99		0.15
	0.23		0.39
	0.38		0.12
	0.86		0.37
	1.75		0.23
	0.10		0.20
	0.23		0.41
	0.13		0.20
	0.59		0.18
	0.35		0.15
	0.76		0.20
	0.34		0.17
	0.38		1.08
	1.70		0.12
	0.50		0.16
	0.07		0.55
	0.16		0.22
	0.20		0.22
	0.12		0.58
	0.16		0.35
	0.56		0.15
	0.44		
	0.05		
	0.27		
Total (m)	**15.29**	**1.52**	**8.19**
Average	**0.46**	**0.30**	**0.27**
Percentage	**61.16**	**6.08**	**32.76**

TR-6

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
0.45	2	0.15
0.66	1	0.21
1.80	3	1.14
3.82	1	2.02
4.23	3	0.41
5.19	1	0.96
5.28	3	0.09
5.42	1	0.14
5.58	3	0.16
5.76	1	0.18
6.05	3	0.29
7.38	1	1.33
7.73	2	0.35
7.81	1	0.08
7.98	3	0.17
8.78	1	0.80
9.02	3	0.24
10.81	1	1.79
10.99	3	0.18
11.24	1	0.25
11.50	3	0.26
11.69	2	0.19
13.04	1	1.35
13.45	3	0.41
13.63	1	0.18
14.72	3	1.09
16.13	2	1.41
16.70	3	0.57
17.93	1	1.23
18.12	3	0.19
19.03	1	0.91
20.61	3	1.58
20.69	1	0.08
20.94	3	0.25
21.13	1	0.19
21.87	3	0.74
22.23	1	0.36
22.69	3	0.46
22.73	2	0.04
22.98	3	0.25
23.12	1	0.14
23.34	3	0.22
23.56	1	0.22
23.66	3	0.10
23.72	1	0.06
24.16	3	0.44
24.27	1	0.11
24.42	3	0.15
24.64	1	0.22
24.77	3	0.13
25.30	2	0.53

Categorized Values of TR-6

	1 Grass	2 Shrub	3 Bare
	0.21	0.15	1.14
	2.02	0.35	0.41
	0.96	0.19	0.09
	0.14	1.41	0.16
	0.18	0.04	0.29
	1.33	0.53	0.17
	0.08		0.24
	0.80		0.18
	1.79		0.26
	0.25		0.41
	1.35		1.09
	0.18		0.57
	1.23		0.19
	0.91		1.58
	0.08		0.25
	0.19		0.74
	0.36		0.46
	0.14		0.25
	0.22		0.22
	0.06		0.10
	0.11		0.44
	0.22		0.15
			0.13
Total (m)	**12.81**	**2.67**	**9.52**
Average	**0.58**	**0.45**	**0.41**
Percentage	**51.24**	**10.68**	**38.08**

TR-7

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
1.85	1	1.55
2.02	3	0.17
2.62	1	0.60
2.74	3	0.12
2.99	1	0.25
3.24	3	0.25
6.05	1	2.81
6.70	2	0.65
7.33	3	0.63
7.37	1	0.04
7.74	3	0.37
8.17	1	0.43
8.46	3	0.29
8.74	1	0.28
8.91	3	0.17
9.33	2	0.42
9.52	1	0.19
10.08	3	0.56
10.46	2	0.38
10.67	3	0.21
10.81	1	0.14
11.20	3	0.39
11.57	2	0.37
11.75	1	0.18
12.03	3	0.28
12.88	1	0.85
13.86	3	0.98
15.41	1	1.55
15.95	2	0.54
16.50	1	0.55
16.74	3	0.24
16.77	1	0.03
17.03	3	0.26
17.56	1	0.53
18.10	3	0.54
18.39	1	0.29
18.71	3	0.32
19.04	1	0.33
19.26	2	0.22
19.43	1	0.17
19.65	2	0.22
19.84	1	0.19
19.95	3	0.11

Vegetation Cover Category	Cover Type	Calculated length (m)
20.16	1	0.21
20.51	3	0.35
20.66	1	0.15
20.89	3	0.23
21.03	1	0.14
21.28	3	0.25
21.30	1	0.02
21.77	3	0.47
22.98	1	1.21
23.26	3	0.28
23.46	1	0.20
23.96	3	0.50
24.10	1	0.14
24.60	2	0.50
25.30	1	0.70

Categorized Values of TR-7

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	1.55	0.65	0.17
	0.60	0.42	0.12
	0.25	0.38	0.25
	2.81	0.37	0.63
	0.04	0.54	0.37
	0.43	0.22	0.29
	0.28	0.22	0.17
	0.19	0.50	0.56
	0.14		0.21
	0.18		0.39
	0.85		0.28
	1.55		0.98
	0.55		0.24
	0.03		0.26
	0.53		0.54
	0.29		0.32
	0.33		0.11
	0.17		0.35
	0.19		0.23
	0.21		0.25
	0.15		0.47
	0.14		0.28
	0.02		0.50
	1.21		
	0.20		
	0.14		
	0.70		
Total (m)	**13.73**	**3.30**	**7.97**
Average	**0.51**	**0.41**	**0.35**
Percentage	**54.92**	**13.20**	**31.88**

TR-8

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
0.85	1	0.55
1.01	3	0.16
1.25	1	0.24
1.52	3	0.27
1.63	2	0.11
1.68	1	0.05
2.03	3	0.35
2.76	1	0.73
2.95	3	0.19
3.32	2	0.37
3.75	3	0.43
7.24	1	3.49
7.47	2	0.23
7.61	1	0.14
7.73	3	0.12
8.32	1	0.59
8.47	3	0.15
8.62	1	0.15
8.70	3	0.08
8.78	1	0.08
9.29	3	0.51
9.60	2	0.31
10.08	1	0.48
10.18	3	0.10
10.26	1	0.08
10.47	3	0.21
10.77	1	0.30
10.91	3	0.14
11.34	1	0.43
11.50	3	0.16
11.82	1	0.32
11.92	3	0.10
11.95	1	0.03
12.14	3	0.19
12.72	1	0.58
13.43	2	0.71
13.95	1	0.52
14.13	3	0.18
14.87	1	0.74
14.96	3	0.09
15.40	1	0.44
15.63	2	0.23
16.07	1	0.44
16.16	3	0.09
16.62	1	0.46
16.84	2	0.22
17.26	1	0.42
17.53	3	0.27
17.65	1	0.12
17.73	3	0.08
18.32	1	0.59
19.02	2	0.70
19.12	1	0.10
20.25	3	1.13
20.55	1	0.30
20.79	3	0.24
20.89	1	0.10
22.00	3	1.11
22.18	1	0.18
22.35	3	0.17
22.53	1	0.18
22.89	3	0.36
23.06	1	0.17
23.45	2	0.39
23.85	3	0.40
23.98	1	0.13
25.05	3	1.07
25.24	1	0.19
25.30	3	0.06

Categorized Values for TR-8

	1 Grass	2 Shrub	3 Bare
	0.55	0.11	0.16
	0.24	0.37	0.27
	0.05	0.23	0.35
	0.73	0.31	0.19
	3.49	0.71	0.43
	0.14	0.23	0.12
	0.59	0.22	0.15
	0.15	0.70	0.08
	0.08	0.39	0.51
	0.48		0.10
	0.08		0.21
	0.30		0.14
	0.43		0.16
	0.32		0.10
	0.03		0.19
	0.58		0.18
	0.52		0.09
	0.74		0.09
	0.44		0.27
	0.44		0.08
	0.46		1.13
	0.42		0.24
	0.12		1.11
	0.59		0.17
	0.10		0.36
	0.30		0.40
	0.10		1.07
	0.18		0.06
	0.18		
	0.17		
	0.13		
	0.19		
Total (m)	**13.32**	**3.27**	**8.41**
Average	**0.42**	**0.36**	**0.30**
Percentage	**53.28**	**13.08**	**33.64**

TR-9

Vegetation Cover Category	Cover Type	Calculated length (m)
0.30		
2.02	1	1.72
2.22	3	0.20
2.53	1	0.31
2.71	3	0.18
2.82	1	0.11
3.32	3	0.50
4.04	1	0.72
4.20	3	0.16
4.66	1	0.46
5.30	2	0.64
5.68	1	0.38
5.82	3	0.14
5.91	1	0.09
6.13	3	0.22
6.67	2	0.54
6.82	3	0.15
7.04	1	0.22
7.35	2	0.31
7.82	3	0.47
8.21	1	0.39
8.37	3	0.16
8.54	2	0.17
8.83	1	0.29
9.02	2	0.19
9.55	1	0.53
9.74	3	0.19
9.83	1	0.09
9.94	3	0.11
10.10	1	0.16
10.48	2	0.38
10.87	3	0.39
11.91	2	1.04
12.39	1	0.48
12.46	3	0.07
12.93	1	0.47
13.40	2	0.47
13.74	1	0.34
13.93	3	0.19
14.22	1	0.29
14.50	2	0.28
15.34	1	0.84
15.85	2	0.51
16.09	3	0.24

Vegetation Cover Category	Cover Type	Calculated length (m)
16.54	1	0.45
16.64	3	0.10
16.80	1	0.16
16.93	3	0.13
17.07	1	0.14
17.13	3	0.06
17.43	1	0.30
17.97	3	0.54
18.05	2	0.08
18.70	3	0.65
18.96	1	0.26
19.82	2	0.86
20.05	3	0.23
20.25	2	0.20
20.32	3	0.07
20.42	1	0.10
21.23	3	0.81
21.35	1	0.12
21.43	3	0.08
21.64	1	0.21
21.72	3	0.08
21.95	1	0.23
22.10	3	0.15
22.33	2	0.23
22.54	1	0.21
22.93	3	0.39
23.22	1	0.29
23.30	3	0.08
23.62	1	0.32
23.96	3	0.34
24.20	1	0.24
24.50	2	0.30
24.96	1	0.46
25.14	2	0.18
25.22	3	0.08
25.30	1	0.08

Categorized Values of TR-9

	1	**2**	**3**
	Grass	**Shrub**	**Bare**
	1.72	0.64	0.20
	0.31	0.54	0.18
	0.11	0.31	0.50
	0.72	0.17	0.16
	0.46	0.19	0.14
	0.38	0.38	0.22
	0.09	1.04	0.15
	0.22	0.47	0.47
	0.39	0.28	0.16
	0.29	0.51	0.19
	0.53	0.08	0.11
	0.09	0.86	0.39
	0.16	0.20	0.07
	0.48	0.23	0.19
	0.47	0.30	0.24
	0.34	0.18	0.10
	0.29		0.13
	0.84		0.06
	0.45		0.54
	0.16		0.65
	0.14		0.23
	0.30		0.07
	0.26		0.81
	0.10		0.08
	0.12		0.08
	0.21		0.15
	0.23		0.39
	0.21		0.08
	0.29		0.34
	0.32		0.08
	0.24		
	0.46		
	0.08		
Total (m)	**11.46**	**6.38**	**7.16**
Average	**0.35**	**0.40**	**0.24**
Percentage	**45.84**	**25.52**	**28.64**

TR-10

Vegetation Cover Category	Cover Type	Calculated length (m)
0		
0.75	1	0.75
0.98	3	0.23
1.21	1	0.23
1.40	3	0.19
1.46	1	0.06
1.90	3	0.44
2.62	1	0.72
3.05	2	0.43
3.22	1	0.17
3.45	3	0.23
3.95	1	0.50
4.11	3	0.16
4.55	1	0.44
5.03	3	0.48
5.22	1	0.19
5.31	3	0.09
5.98	1	0.67
6.18	3	0.20
6.53	1	0.35
6.80	3	0.27
7.54	1	0.74
7.66	3	0.12
8.92	1	1.26
9.21	2	0.29
10.18	1	0.97
10.32	3	0.14
10.42	1	0.10
10.57	3	0.15
11.78	1	1.21
11.92	2	0.14
12.76	1	0.84
13.07	3	0.31
13.30	1	0.23
13.49	2	0.19
14.04	1	0.55
14.49	3	0.45
14.55	1	0.06
14.64	3	0.09
14.83	1	0.19
15.40	3	0.57
15.92	1	0.52
16.02	3	0.10
16.29	1	0.27

Vegetation Cover Category	Cover Type	Calculated length (m)
16.50	3	0.21
16.82	1	0.32
16.96	2	0.14
17.08	3	0.12
17.15	1	0.07
17.20	3	0.05
17.75	1	0.55
17.92	3	0.17
18.01	1	0.09
18.17	3	0.16
18.26	1	0.09
18.32	3	0.06
18.64	1	0.32
18.73	3	0.09
18.90	1	0.17
19.17	3	0.27
19.43	1	0.26
19.61	3	0.18
19.81	1	0.20
19.87	3	0.06
20.82	1	0.95
21.15	3	0.33
22.26	1	1.11
22.61	3	0.35
23.04	1	0.43
23.22	3	0.18
25.00	1	1.78

Categorized Values for TR-10

	1	2	3
	Grass	**Shrub**	**Bare**
	0.75	0.43	0.23
	0.23	0.29	0.19
	0.06	0.14	0.44
	0.72	0.19	0.23
	0.17	0.14	0.16
	0.50		0.48
	0.44		0.09
	0.19		0.20
	0.67		0.27
	0.35		0.12
	0.74		0.14
	1.26		0.15
	0.97		0.31
	0.10		0.45
	1.21		0.09
	0.84		0.57
	0.23		0.10
	0.55		0.21
	0.06		0.12
	0.19		0.05
	0.52		0.17
	0.27		0.16
	0.32		0.06
	0.07		0.09
	0.55		0.27
	0.09		0.18
	0.09		0.06
	0.32		0.33
	0.17		0.35
	0.26		0.18
	0.20		
	0.95		
	1.11		
	0.43		
	1.78		
Total (m)	**17.36**	**1.19**	**6.45**
Average	**0.50**	**0.24**	**0.22**
Percentage	**69.44**	**4.76**	**25.80**

APPENDIX F

Green Ampt Calculations

Calculations of Estimates of Green-and-Ampt Conductivity on Rainfall Simulation Plots

Treated

GRASS	Rain rate mm/hr	Duration minutes	Event Intensity mm	Runoff ml	Runoff mm	Time to ponding min	Bulk Density g/cc	Porosity	Wt. Dry Soil grams	Wt. Water grams	Intial Soil Saturation
1 DRY	221	30	110.50	15000	15.00	4.23	1.42	0.46	142.35	4.88	0.11
1 WET	251	30	125.50	18350	18.35	1.50	1.53	0.42	152.75	25.56	0.60
2 DRY	235	30	117.50	39300	39.30	1.20	1.05	0.61	104.59	2.94	0.05
2 WET	266	20	88.67	20225	20.23	0.87	1.48	0.44	147.68	32.12	0.73
3 DRY	252	30	126.00	16900	16.90	1.85	1.30	0.51	130.16	5.74	0.11
3 WET	279	20	93.00	19450	19.45	1.02	1.44	0.46	144.38	35.63	0.78
SHRUB											
1 DRY	252	20	84.00	8000	8.00	2.08	1.22	0.54	121.65	12.08	0.22
1 WET	260	20	86.67	3975	3.98	1.93	1.22	0.54	121.77	27.21	0.50
2 DRY	262	20	87.33	15625	15.63	1.27	1.26	0.53	125.71	6.75	0.13
2 WET	271	20	90.33	19050	19.05	1.17	1.41	0.47	140.53	23.74	0.51
3 DRY	263	20	87.67	26300	26.30	1.52	1.39	0.48	139.11	4.83	0.10
3 WET	269	20	89.67	24450	24.45	1.72	1.38	0.48	138.31	35.28	0.74
BARE											
1 DRY	210	20	70.00	35000	35.00	1.97	1.38	0.48	137.93	4.56	0.10
1 WET	267	20	89.00	31400	31.40	0.75	1.41	0.47	141.36	27.61	0.59
2 DRY	257	20	85.67	20350	20.35	1.20	1.32	0.50	131.61	6.94	0.14
2 WET	252	20	84.00	43050	43.05	0.48	1.42	0.47	141.60	24.14	0.52
3 DRY	255	20	85.00	17500	17.50	1.83	1.55	0.42	154.62	7.95	0.19
3 WET	261	20	87.00	31400	31.40	0.68	1.46	0.45	146.10	21.26	0.47

Estimates of Green-and-Ampt Conductivity for Treated Area Cont.

Fraction Bare Area	Calculated Interception time minutes	K est. mm/hr	Calculated F prior to ponding mm	Calculated time to ponding min	F adjusted mm	t adjusted hours	Psi Est. 1989 Rep. 243 mm	Psi Est. 1991 Rep. 259 mm	Combined Psi est mm	Theta Term mm	K calculated mm/hr
0.30	0.483	72	0.581	0.158	80	0.489	3.875	2.174	2.90	1.202	72
0.30	0.425	98	0.201	0.048	101	0.492	2.316	1.511	1.87	0.314	98
0.19	0.525	60	0.743	0.190	74	0.488	5.254	2.696	3.76	2.168	60
0.19	0.464	61	0.133	0.030	65	0.325	5.111	2.644	3.68	0.447	61
0.28	0.435	94	0.533	0.127	101	0.491	2.483	1.587	1.99	0.896	94
0.28	0.393	66	0.101	0.022	69	0.326	4.481	2.409	3.29	0.325	66
0.00	0.605	50	0.508	0.121	67	0.321	7.124	3.343	4.88	2.050	50
0.00	0.586	66	0.300	0.069	74	0.322	4.481	2.409	3.29	0.882	66
0.22	0.454	46	0.536	0.123	66	0.324	8.189	3.689	5.50	2.518	46
0.22	0.439	58	0.250	0.055	66	0.325	5.560	2.806	3.95	0.918	58
0.25	0.435	29	0.561	0.128	55	0.324	17.694	6.358	10.61	4.526	29
0.25	0.425	53	0.138	0.031	58	0.326	6.464	3.121	4.49	0.563	53
0.93	0.051	25	0.768	0.220	34	0.329	22.670	7.574	13.10	5.686	12
0.93	0.040	47	0.217	0.049	54	0.332	7.900	3.596	5.33	1.015	47
0.96	0.024	40	0.537	0.125	60	0.331	10.341	4.350	6.71	2.911	40
0.96	0.024	27	0.316	0.075	39	0.332	19.936	6.917	11.74	2.633	27
0.93	0.042	46	0.408	0.096	60	0.331	8.189	3.689	5.50	1.852	46
0.93	0.041	43	0.282	0.065	53	0.332	9.165	3.994	6.05	1.428	43

Estimates of Green-and-Ampt Conductivity on Untreated Plots

GRASS	Rain rate mm/hr	Duration minutes	Event Intensity mm	Runoff ml	Runoff mm	Time to ponding min	Bulk Density g/cc	Porosity	Wt. Dry Soil grams	Wt. Water grams	Initial Soil Saturation
1 DRY	321	30	160.50	42300	42.30	2.00	1.36	0.49	136.06	2.64	0.05
1 WET	252	20	84.00	76500	76.50	0.33	1.48	0.44	148.00	22.21	0.50
2 DRY	225	26	97.50	51300	51.30	0.53	1.45	0.45	145.46	2.95	0.07
2 WET	311	20	103.67	57700	57.70	0.17	1.53	0.42	152.84	28.83	0.68
3 DRY	221	30	110.50	86900	86.90	0.38	1.44	0.46	144.03	2.73	0.06
3 WET	307	20	102.33	61450	61.45	0.62	1.48	0.44	147.81	24.09	0.54
SHRUB											
1 DRY	288	20	96.00	42950	42.95	0.72	1.38	0.48	137.68	3.91	0.08
1 WET	316	20	105.33	49950	49.95	0.40	1.43	0.46	143.03	20.27	0.44
2 DRY	305	20	101.67	27300	27.30	0.83	1.28	0.52	127.65	7.75	0.15
2 WET	299	20	99.67	42300	42.30	0.47	1.52	0.43	151.61	30.42	0.71
3 DRY	296	20	98.67	38250	38.25	1.30	1.35	0.49	134.56	15.02	0.31
3 WET	255	20	85.00	46350	46.35	1.25	1.43	0.46	143.16	29.48	0.64
BARE											
1 DRY	317	20	105.67	42850	42.85	0.68	1.41	0.47	140.73	12.62	0.27
1 WET	298	20	99.33	46700	46.70	0.53	1.37	0.48	137.11	17.63	0.37
2 DRY	296	20	98.67	23250	23.25	1.48	1.41	0.47	140.76	6.51	0.14
2 WET	281	20	93.67	29500	29.50	0.50	1.44	0.46	144.13	23.59	0.52
3 DRY	290	20	96.67	43300	43.30	0.88	1.36	0.49	135.93	8.68	0.18
3 WET	237	20	79.00	54800	54.80	0.50	1.47	0.45	146.67	22.92	0.51

Estimates of Green-and-Ampt Conductivity for Unreated Area Cont.

Fraction Bare Area	Calculated Interception time minutes	K (or f) est. mm/hr	Calculated F prior to ponding mm	Calculated time to ponding min	F adjusted mm	t adjusted hours	Psi Est. 1989 Rep. 243 mm	Psi Est. 1991 Rep. 259 mm	Combined Psi est mm	Theta Term mm	K (or f) calculated mm/hr
0.60	0.190	101	0.379	0.071	108	0.496	2.20	1.45	1.79	0.82	101
0.60	0.242	2	0.841	0.200	6	0.326	1539.21	149.17	479.18	105.13	2
0.50	0.339	26	0.683	0.182	44	0.425	21.23	7.23	12.39	5.22	26
0.50	0.245	39	0.135	0.026	45	0.329	10.78	4.48	6.95	0.93	39
0.40	0.414	4	1.412	0.383	22	0.487	483.70	65.83	178.46	76.59	4
0.40	0.298	28	0.225	0.044	38	0.328	18.76	6.62	11.15	2.24	28
0.51	0.259	22	0.574	0.120	50	0.327	28.066	8.80	15.72	6.93	19
0.51	0.236	42	0.247	0.047	53	0.329	9.532	4.10	6.26	1.61	42
0.47	0.265	53	0.416	0.082	70	0.328	6.464	3.12	4.49	1.98	53
0.47	0.270	50	0.121	0.024	55	0.328	7.124	3.34	4.88	0.60	50
0.48	0.268	38	0.364	0.074	54	0.328	11.266	4.62	7.22	2.46	38
0.48	0.311	25	0.235	0.055	33	0.327	22.670	7.57	13.10	2.16	25
0.91	0.043	45	0.322	0.061	59	0.332	8.495	3.78	5.67	1.94	45
0.91	0.046	36	0.328	0.066	50	0.331	12.331	4.92	7.79	2.38	36
0.96	0.021	53	0.396	0.080	68	0.332	6.464	3.12	4.49	1.81	53
0.96	0.022	54	0.229	0.049	62	0.332	6.265	3.05	4.37	0.96	54
0.88	0.063	24	0.502	0.104	49	0.331	24.270	7.94	13.89	5.55	24
0.88	0.077	10	0.463	0.117	22	0.330	104.717	22.33	48.36	10.51	10

APPENDIX G

Slopes

Erosion Pins

X-Ray Diffraction:

Clay Mineralogy
Bulk Mineralogy Sample Sheet

Slopes (measured with Brunton Compass)

PLOT ID	TR Slope %	UT Slope %
Grass 1 DRY	3.0	2.5
Grass 1 WET	3.0	2.5
Grass 2 DRY	2.5	2.0
Grass 2 WET	2.5	2.0
Grass 3 DRY	2.5	2.0
Grass 3 WET	2.5	2.0
Shrub 1 DRY	2.5	3.0
Shrub 2 WET	2.5	3.0
Shrub 2 DRY	2.5	3.0
Shrub 2 WET	2.5	3.0
Shrub 3 DRY	2.5	2.5
Shrub 3 WET	2.5	2.5
Bare 1 DRY	2.0	1.5
Bare 1 WET	2.0	1.5
Bare 2 DRY	2.5	2.5
Bare 2 WET	2.5	2.5
Bare 3 DRY	2.0	2.5
Bare 3 WET	2.0	2.5

Erosion Pins Transect in Untreated Area

Measured length (in cm) of rebar above surface soil.

Pin #	10/16/1999	07/18/2000	10/31/2000	03/30/2001
1	16.2	13.0	11.5	12.0
2	17.0	16.0	15.6	15.9
4	16.6	17.2	16.2	16.5
5	18.0	17.5	17.0	16.4
6	19.2	19.4	19.2	19.6
8	16.8	17.0	15.8	13.6
9	17.2	16.2	16.1	14.3
10	18.6	19.0	19.0	17.8

X-Ray Diffraction

Clay mineralogy from stratigraphic horizons in pits from natural runoff plots.

Sample #	ILLITE	SMECTITE	MIXED LAYERS I/S	KAOLINITE
RO1-1	3/10 (2.91)	1/10 (0.96)	2/10 (1.84)	4/10 (4.28)
RO1-2	1/10 (1.55)	2/10 (1.77)	3/10 (2.85)	4/10 (3.83)
RO1-3	3/10 (2.68)	3/10 (2.81)	0/10 (0.25)	4/10 (4.27)
RO2-1	2/10 (1.96)	2/10 (1.49)	3/10 (3.07)	3/10 (3.48)
RO2-2	1/10 (1.47)	2/10 (2.12)	4/10 (3.75)	3/10 (2.66)
RO2-3	1/10 (1.20)	2/10 (1.91)	4/10 (4.20)	3/10 (2.69)
RO2-4	1/10 (1.55)	2/10 (2.04)	4/10 (3.85)	3/10 (2.56)
RO3-1	2/10 (2.35)	2/10 (2.19)	4/10 (3.84)	2/10 (2.61)
RO3-2	2/10 (2.10)	3/10 (3.27)	2/10 (1.49)	3/10 (3.15)
RO3-3	2/10 (1.68)	2/10 (2.18)	4/10 (3.72)	2/10 (2.41)
RO4-1	2/10 (2.26)	1/10 (1.40)	4/10 (3.63)	3/10 (2.72)
RO4-2	1/10 (1.24)	2/10 (1.72)	5/10 (5.24)	2/10 (1.79)
RO4-3	2/10 (1.66)	2/10 (2.42)	4/10 (3.59)	2/10 (2.34)

XRD Bulk Mineralogy Sample Sheet

APPENDIX H

Methods for:

X-Ray Diffraction of Clays

Rainfall Simulations

Rainfall Simulation Sample Sheet

X-Ray Diffraction of Clays

Procedure for preparation of oriented clay mineral aggregates

1. Place a small sample (20 to 25 g) in a 100 ml beaker with distilled water. Mix and wait 5 minutes.

2. If the clay flocculates or settles out, pour off clear water, add more water, and remix. If the clay does not disperse, repeat this step several more times.

3. If the clay still flocculates, add a few drops of dilute solution (50 g/l) of sodium hexametaphosphate (Calgon) and remix. If the clay flocculates, repeat step 2.

4. Centrifuge for 4 minutes, wash with distilled water, and centrifuge again as often as needed.

5. Once the clay is in a dispersed state, allow the beaker and its contents to remain undisturbed for 10 minutes. At the end of the period, use small pipette (1 to 2 ml) to draw off enough suspension from the surface to cover a glass slide completely. This decanted fraction is < 2μm. Prepare at least two slides and allow to air dry.

6. Use petrographic glass slides that have a high melting point.

7. If clay slurry flocculates on the slide surface, remake slide.

8. Run the slide of oriented clay on diffractometer at 2° 2θ/minute from 2° to 35° 2θ with monochromatic or Ni-filtered Cu radiation. Subsequent runs (glycolated and heat treatment) will vary depending on the mineralogy and nature of the information needed.

Bulk Mineralogy

1. Crush sample.

2. Sieve sample (>270μ).

3. Apply thin layer of petroleum jelly on one half of a glass slide and sprinkle sample onto it.

4. Run the slide as above.

Rainfall Simulation Procedures

Dry Run:

1. Select site at random.
2. Initially position one square meter plot frames.
3. Position rainfall simulator so that it covers plot as desired.
4. Install plot frames with trench for collection trough.
5. Seal disturbed edges of soil by pressing it against metal frame on both sides.
6. Take pictures of the plots and estimate cover.
7. Connect suction pumps to troughs.
8. Collect soil moisture and density samples from top 5 cm of surface in a sampling ring on outside edge of plot frame. Put in ziploc bags, label, and seal.
9. Place impervious rainfall collection cover on plot.
10. Install windscreens as needed.
11. Begin rainfall.
12. Sample rainfall rate every 20 seconds using runoff from impervious cover into a graduated cylinder.
13. Remove cover.
14. Note time of ponding and runoff into the trough.
15. Pump troughs as necessary.
16. Record pumped volume and save sample in barrel.
17. Rain for 20 minutes to assure steady-state runoff.
18. Replace cover and again sample rainfall rate.
19. Stop rain and pump trough a final time.
20. Measure depths in barrels.
21. Agitate barrels and collect sample of about 500 ml of water and sediment, label.

22. Remove deposited material (bed load) from runoff collection trough and from runoff tray (metal flume between plot and trough). Bag material in plastic bags or mason jars and label.

23. Cover plot with plastic sheet and dirt until wet run.

Wet Run:

24. Repeat steps 6 to 23.

25. Measure slope in plot with Brunton compass.

26. Restore plot to original state.

Rainfall Simulation Sample Sheet

Site (U or T):____________________

Plot ID Number: _________________ Date: _____________ Observer: __________

Wet run: _____ Dry run:_____ Wind: ____________ Sky: ______________

Vegetation cover %: _______________ Bare soil %: _______________

Brush %: _______________ Roughness: _______________

BEFORE RUN

Moisture Content Samples

0 – 5 cm ____________

5 – 10 cm ____________

Boom orientation ____________

(indicate on map below)

Pan Runoff Volume every 20 seconds:

________, ________ , ________ , ________

________, ________ , ________ , ________

AFTER RUN

Bed Load Sample ______________

Suspended Sediment Sample ______________

Depth to Wetted Front ______________

Pan Runoff Volume every 20 seconds:

________, ________ , ________ , ________

________, ________ , ________ , ________

Cover plot after dry run ______________

AFTER WET RUN

Soil Sample ____________

Slope ____________

Clock time at start of rainfall ______________

All other times measured from start of rainfall (min:sec)

Time of pan removal ________________

Time to ponding ________________

Time to runoff onto tray________________

Time of pan replacement ______________

Time at rainfall off ______________

Time at end of runoff ______________

TIME (min:sec)	**RUNOFF VOL.** (ml)	**TIME** (min:sec)	**RUNOFF VOL.** (ml)	**TIME** (min:sec)	**RUNOFF VOL.** (ml)

Depth of runoff water in collection bucket: _______________ inches

APPENDIX I

Statistics

Two-way t-test Results (unless otherwise noted)

n = 3
p-value < 0.05

Deposited Sediment Yield

	Grass	Shrub	Bare
TR Dry vs. Wet	0.6284	0.7632	0.9826
UT Dry vs. Wet	0.0089	0.7706	0.4434
TR vs. UT Dry	0.6800	0.2045	0.2916
TR vs. UT Wet	0.0083	0.0025	0.9366

Suspended Sediment Yield

	Grass	Shrub	Bare
TR Dry vs. Wet	0.6653	0.4902	0.2569
UT Dry vs. Wet	0.4401	0.3575	0.6352
TR vs. UT Dry	0.0058	0.15534	0.4373
TR vs. UT Wet	0.0037	0.2213	0.3657

Total Sediment Yield

	Grass	Shrub	Bare
TR Dry vs. Wet	0.6281	0.7017	0.9621
UT Dry vs. Wet	0.0103	0.9930	0.4594
TR vs. UT Dry	0.5081	0.1821	0.2420
TR vs. UT Wet	0.0076	0.0016	0.9821

Runoff to Rainfall Ratios

	Grass	Shrub	Bare
TR Dry vs. Wet	0.9554	0.8772	0.4395
UT Dry vs. Wet	0.5348	0.1898	0.3756
TR vs. UT Dry	0.1287	0.0912	0.6956
TR vs. UT Wet	0.0049	0.0299	0.5388

Loss on Ignition

	Grass	Shrub	Bare
TR Dry vs. Wet	0.1385	0.9483	0.6807
UT Dry vs. Wet	0.2466	0.2196	0.3935
TR vs. UT Dry	0.0655	0.4959	0.4192
TR vs. UT Wet	0.3000	0.3849	0.0303

Bulk Density

	Grass	Shrub	Bare
TR Dry vs. Wet	0.1698	0.5169	0.8653
UT Dry vs. Wet	0.0902	0.0878	0.2683
TR vs. UT Dry	0.2772	0.4851	0.7703
TR vs. UT Wet	0.6921	0.2783	0.9267

Soil Moisture

	Grass	Shrub	Bare
TR Dry vs. Wet	0.0080	0.0099	0.0005
UT Dry vs. Wet	0.0058	0.0229	0.0079
TR vs. UT Dry	0.0869	0.8955	0.2834
TR vs. UT Wet	0.1138	0.3687	0.3039

Particle Size Distribution for Rainfall Simulation Plot Runs

GRASS	Sand	Silt	Clay
TR Dry vs. Wet	0.4899	0.4376	0.7207
UT Dry vs. Wet	0.5247	0.5449	0.6832
TR vs. UT Dry	0.4179	0.4785	0.3214
TR vs. UT Wet	0.4552	0.6214	0.1634
SHRUBS	**Sand**	**Silt**	**Clay**
TR Dry vs. Wet	0.6682	0.8710	0.6433
UT Dry vs. Wet	0.5246	0.5456	0.4016
TR vs. UT Dry	0.1116	0.1432	0.2292
TR vs. UT Wet	0.0024	0.0075	0.1950
BARE	**Sand**	**Silt**	**Clay**
TR Dry vs. Wet	0.6164	0.6359	0.5198
UT Dry vs. Wet	0.5507	0.5306	0.4477
TR vs. UT Dry	0.0275	0.0333	0.0059
TR vs. UT Wet	0.1056	0.1218	0.0156

Estimated Green-and-Ampt Conductivities (Log-Transformed Data)

	Grass	Shrub	Bare
TR Dry vs. Wet	0.9562	0.1501	0.5584
UT Dry vs. Wet	0.7329	0.7925	0.5734
TR vs. UT Dry	0.3205	0.6256	0.5653
TR vs. UT Wet	0.2046	0.1628	0.5716

Estimated Green-and-Ampt Conductivities (Not Log-Transformed)

	Grass	Shrub	Bare
TR Dry vs. Wet	0.9797	0.0987	0.5826
UT Dry vs. Wet	0.5703	0.8557	0.8339
TR vs. UT Dry	0.3930	0.6910	0.5930
TR vs. UT Wet	0.0328	0.1028	0.8440

XRD – Clay Mineralogy on Soil Profiles of natural Runoff Plots

	ILLITE	SMECTITE	MIXED LAYERS I/S	KAOLINITE
RO-1 and 2 vs. RO-3 and 4	0.9433	0.3606	0.3146	0.0262

Two-Way ANOVA with Replication

Results for Interaction between Estimated Green-and-Ampt Conductivity and Bare Area. Treated and untreated results for hydraulic conductivities were grouped and compared to the amount of bare area present on each plot category.

n = 6
p-value < 0.05

	Grass	Shrub	Bare
TR vs. UT Dry	0.1138	0.0269	0.4804
TR vs. UT Wet	0.0024	0.0017	0.8147