DETERMINATION OF HYDROLOGIC PARAMETERS FOR SELECTED SOILS IN ARIZONA AND NEW MEXICO UTILIZING RAINFALL SIMULATION

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ABSTRACT

Estimation of runoff and sediment yield from small, ungaged watersheds is a difficult hydrologic task. Watershed models are useful in this regard, but require some information which is directly related to the hydrologic processes. Rainfall simulation is an important experimental technique for gathering such information, particularly in the pinyon-juniper forest lands of the Southwest.

This technical report contains the results from a study to determine hydrologic parameters for selected soils in Arizona and New Mexico. A small area (approximately 1 square meter or 10 square feet) spray-type simulator was used to collect water and sediment runoff from four pinyon-juniper forest sites. A total of 108 plot experiments were performed at the four sites. The sites were located near existing permanent runoff plots or at locations where the United States Department of Agriculture (USDA) Forest Service plans to conduct simulation experiments using 32.5 square meter (350 square foot) plots to enhance the data base being collected for the USDA - ARS Water Erosion Prediction Project.

Data analyses indicate that the infiltration characteristics among the sites are quite similar. Differences can be attributed to the amount of organic ground cover on a plot, the antecedent water content of the soil prior to the experiment, and the surface roughness as measured with a point frame. Clay content of the soil had an observable but minor effect on infiltration characteristics. Cover density had a noticeable effect on infiltration rates. Based on visual estimates in the field, plots were designated as having "high" or "low" cover, or were scraped bare of all cover. Some of the scraped plots were covered by window screen during the experiments. Relative to the unprotected scraped plots, the high, low, and protected scraped plots exhibited infiltration rates which were 3.3, 2.2, and 1.9 times higher, respectively. Sediment yields per unit area were 0.19, 0.36, and 0.56 as much for the high, low and screened plots, respectively, compared to the unprotected bare plot.

Numerous water chemistry samples were analyzed to determine potential nutrient loadings from forest lands to water bodies. Total phosphorus and organic solids are related to inorganic sediment yield. Total nitrogen also appears to be related to inorganic and organic sediment yields.

Keywords: pinyon-juniper, computer models, data collection, hydrologic models, hydrologic processes, infiltration, parametric hydrology, runoff plot, sediment yield, simulated rainfall, soil erosion, nutrients.

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INTRODUCTION

The pinyon-juniper (PJ) vegetation type covers much of the semiarid Southwest. It forms the transition zone between the typically overgrazed lower elevation grasslands and the higher elevation pine and fir forests. Pinyon-juniper areas are subjected to a variety of stresses including roads to higher elevations for timber or fuelwood harvest and livestock grazing. Because the PJ is subject to intense land use pressures, it is important that land managers have as much information as possible about how the PJ will respond to these pressures.

One important aspect of these stresses is how they affect the movement of water and soil over the land surface. Ideal surface conditions would exist if all of the precipitation would infiltrate and the soil would not erode. In reality, however, water does run off the soil surface transporting soil particles, litter and nutrients. This loss of material reduces potential site productivity and can damage downslope areas through gullying or excess loadings of materials to water bodies. To understand the hydrologic function of the PJ, controlled experiments must be conducted which measure key variables affecting that function. Specifically, parameters for infiltration and erosion which characterize the hydrologic function, and the site variables found in the PJ which influence the parameters, must be identified and quantified. With this information, scientists, managers, and engineers can make informed decisions as to the hydrologic effects of a given land use practice.

Rainfall simulators are important devices for gathering data that can be analyzed to define the hydrologic and hydraulic characteristics of natural and disturbed lands. Information obtained from rainfall simulator experiments includes infiltration characteristics of the soil/vegetation complex, sediment yield/erosion parameters, and nutrient export indices. During the summer of 1988, rainfall simulation experiments were conducted on selected soil-vegetation complexes in New Mexico and Arizona. Most sites were located in the PJ vegetation zone on soils derived from volcanic rocks. Some sites were located under the canopy and others in the open rangelands at the canopy edge.

This report presents a summary and analysis of the data collected during the experiments from the pinyon-juniper soil-vegetation complexes. Comparisons are made among the sites and at the sites among different vegetation covers for different hydraulic and hydrologic characteristics. The information provided in this report should aid resource managers in policy formation related to land use and expand the data base needed by scientists and engineers for modeling complex water-soil-vegetation systems.

Goals and Objectives

The study's primary goal was to determine infiltration and soil erosion parameters for a variety of soil-vegetation complexes in the PJ vegetation zone of western New Mexico and eastern Arizona. The parameters were determined so that they can be used in mathematical models of surface erosion being prepared for the interagency USDA - Water Erosion Prediction Project (WEPP). The parameters were derived from the results of field rainfall simulation experiments using a modified Bertrand and Parr small-area simulator (Seiger 1984). Primary parameters included the hydraulic conductivity of soil, average capillary head in the soil during the experiment, soil porosity, soil moisture content, and soil splash/flow transport erosion.

Determination of these parameters alone does not help a potential user of the WEPP model unless the parameters can be functionally and statistically related to other site or soil characteristics such as rock cover, vegetative cover, soil texture, slope, or surface roughness. Still photographs and color video recordings (VHS) were taken of the sites and the experiments to document field conditions and other observations. These photographs and video tapes should prove useful in describing the sites and conditions to potential model users.

Specific objectives related to the overall goal of this study were to:

1. Use artificial rainfall simulation with a spray-down type simulator to collect water and material runoff from selected sites in the PJ.

2. Use the water runoff data to determine the infiltration rate of the soil; this will be done by determination of parameters used in the Green-Ampt infiltration equation as implemented by the ARS in WEPP.

3. Use the sediment runoff data to develop a parameter, as described below, for splash/transport erosion, similar to a raindrop detachment coefficient.

4. Measure soil and surface conditions at the sites including soil gradation, soil moisture, soil porosity, cover, and slope.

5. Collect treated, preserved samples to determine the type and quantity of nutrient export from the sites, specifically, nitrogen, phosphorus, and organic solids.

6. Functionally and statistically relate soil and surface conditions to the parameters determined in objectives 3., 4., and 5. above.

7. Document the findings and observations with scientific reports, photographs and video tapes.

These objectives were met as detailed in this report.

Scope of Report

This report is a summary and analysis of rainfall-runoff and erosion data collected from four sites on range and forest lands using a small area simulator. Primary data collection methods and techniques were presented previously in Ward (1986) and Ward and Bolin (1988) and are modified or reiterated in this report only as needed (Appendix A). This final report includes analyses of the data as related to the goals and objectives of the study.

Previous Studies

In this study, rainfall simulation was used to gather runoff data from several small plots (1 meter by 1 meter) on soil-vegetation complexes at selected locations in New Mexico and Arizona. Rainfall simulation was used, as it provides better control of water input and location of plots. This is very important in the semiarid, PJ zone as timing of rainstorms producing significant runoff is completely stochastic. Through simulation, a controlled volume of water can be delivered exclusively to the plots of interest. The use of small plots increases the number that can be sampled and thus provides more information on the range of conditions that may be present in the PJ. Small plot simulators also have the advantage of requiring a smaller field crew and less water to operate than do large area simulators. Disadvantages of small plot simulators are that they do not cover a large integrated area, they tend to measure only the raindrop splash/transport of sediment, they are a bit more susceptible to edge effects, and, like big simulators, they do not precisely match variations in rainfall intensities and energies.

Two general problems occur when trying to compare data from different simulators. First is the effect of scale. Wicks et al. (1988) used the small plot data of Devaurs and Gifford (1984) to estimate hydraulic conductivity for ARS simulator experiments at Reynolds Creek, Idaho. Wicks et al. concluded that the average of the small plot data gave good results when used to model the behavior of the larger ARS plots. Previous work by Ward (1986) demonstrated how the results from a small plot simulator were related to a CSU type large-plot simulator. Results of that work indicated that infiltration parameters were comparable between plots, but sediment yields per unit area were higher for the small plots than for the large plots. It appears that the small plots are more controlled by splash/transport erosion (Serrag, 1987), whereas the larger plots are more a combination of interrill splash/transport and concentrated flow in shallow rill channels. Although the total sediment yield for the large plots was higher, as expected, the contributing area was also much larger, thus reducing the per unit area yield. The factors controlling sediment yield for the big plots were more complicated and integrated than on the small plots.

A study by Ward and Bolin (1988) related the results from the small simulator to results from the ARS rotating-boom simulator on selected ARS sites in New Mexico and Arizona. Findings from that study confirm those found in the Ward (1986) investigation, but indicate an even higher level of sediment yield per unit area for the small plots above that measured from the ARS plots. The difference in the 1986 study was about two to three times higher sediment yields per unit area for the small plots, whereas in the 1988 study the yields were about four times higher.

The second general problem when comparing data from different simulators is developing an accurate and reliable method of measuring rainfall intensity for simulators and natural storms. Tracy, Renard and Fogel (1984) show that kinetic energies for rainfall at the Walnut Gulch watershed are in excess of what would be computed from the Universal Soil Loss Equation (USLE) algorithm. Therefore, the approach used to scale the sediment yields based on the fraction of USLE energy is open to criticism. Until a better approach is suggested, that method will probably persist. Unfortunately, as Wicks et al. (1988)

found, this may lead to large errors when trying to use simulator results to predict yields from field sized plots (one hectare in this instance).

The density of the vegetative and rock cover usually affects plot response to rainfall, but not necessarily as one might expect. This is an important point because many beliefs based upon common wisdom can be hypothesized then scientifically confirmed through field tests. Studies of natural rainfall plots have found that differences may be difficult to detect between plots in arid regions. Cordery, Pilgrim and Doran (1983) report on runoff from small (25 square meter or about 270 square feet) natural rainfall plots in western New South Wales, Australia. Under a given set of climatic conditions, systematic differences in runoff between plots were not evident despite differences in physical properties of the plots. Runoff from all of the plots was lower during a wet period with lush vegetation than during a dry period with sparse vegetation. They attributed this difference to the increased interception losses caused by denser vegetation.

Many studies in arid regions that have used rainfall simulators have shown significant differences in plot responses based on vegetative and soil surface conditions. Lane et al. (1987) found rock and gravel cover and canopy cover to be negatively correlated with runoff depth. Kincaid, Gardner and Schreiber (1964) also found shrub cover, grass and litter cover, and gravel cover to be negatively related to runoff. In contrast, some studies (e.g. Blackburn 1975, Tromble, Renard and Thatcher 1974) found rock cover and erosion pavement to be positively related to runoff.

These studies and others that used rainfall simulators in arid and semiarid regions with low vegetative cover have found that cover (shrub canopy cover in particular) is an important factor in reducing runoff and erosion. However, other studies of runoff from natural rainfall plots indicate that differences due to vegetation cover and rock cover are difficult to detect. A simulator rainfall study (Bolin and Ward, 1987) at the Jornada Long Term Ecological Research (LTER) site north of Las Cruces supported analyses of the natural rainfall plot studies at the same site with regard to sediment yields. In that study, average water and sediment yields were not significantly different from plots with and without shrubs. The natural rainfall data set contained information from low energy storms only. This may help explain why statistical differences were not found between plots with different vegetation and soil features from the natural rainfall plots. At lower energies, in a sparsely vegetated area like the Jornada LTER site, the role of rainfall energy predominates in determining runoff and sediment yield. At higher energy levels, a threshold is reached in terms of additional sediment yield from energy increases alone. However, it was noted that at higher energy levels of the simulated rainfall, some differences appeared which could be attributed to plot cover characteristics. These results are supportive of Gifford's (1985) suggestion that vegetal cover may be of minimal importance in determining infiltration and erosion rates on some semiarid rangelands. He indicates erosion rates may be a complex function of plant-soil-storm characteristics that are not well understood. Gifford also suggests that cover density above about 50 to 60 percent has little effect on increasing infiltration or reducing erosion. It is in between the low cover situations like those found at the Jornada and the high cover situations as suggested by Gifford where cover improvements may improve infiltration and reduce soil erosion.

A related measure of surface conditions is "roughness" as measured with a point frame. This type of roughness is defined as the standard deviation of a set of elevation measurements for the plot surface. Sanchez and Wood (1987) review the use of point frame roughness and describe the results of plot experiments conducted for a variety of land-use conditions. Their results indicate that point frame roughness measured parallel to the direction of water flow, perpendicular to the direction of water flow or different combinations of the two directions of measurements could be correlated with infiltration and sediment yield. No single set of measurements was superior in terms of estimation of infiltration or sediment yield. The importance of surface roughness has been recognized by the WEPP study (Gilley et al. 1987), and numerous measurements have been gathered during that study. Physically, "roughness" should be related to surface storage and overland flow resistance. Hydraulic roughness which controls overland flow resistance can be measured through runoff hydrographs from simulator plots (Engman 1986). The connection that is needed is the relationship between measurable surface conditions, such as cover density or point frame roughness, and the overland flow resistance. Hartley (1984) demonstrated that overland flow resistance could be related to cover density for plots he studied. Hopefully, the WEPP study will answer some of these questions.

METHODOLOGY

Location of Sample Sites

The four sites sampled in this study were located in New Mexico (one) and Arizona (three) (see figure 1.). The sites were, in order of sampling, Beaverhead, New Mexico; Springerville, Arizona; Loco Knolls, Arizona; and Heber, Arizona. The small area simulator was used at all four sites, and the large area ARS type simulator will be used at or near two of the sites. The small simulator experiments were conducted between May 10 and June 8, 1988.

Beaverhead, New Mexico. The Beaverhead site was located north and east of the USDA Forest Service's Beaverhead Work Center in the Gila National Forest west of Truth or Consequences, New Mexico. Eighteen plots were located in Section 36, T.9S., R.12W. near the junction of forest roads 584 and 953. The site is in a pinyon-juniper area and is adjacent to natural rainfall-runoff plots maintained by M. Karl Wood of the College of Agriculture and Home Economics, New Mexico State University. The simulator plots were located on the flanks of the ridges above the natural rainfall plots. The soils at the site have been described as Lithic Haplustalfs by Charles Souders (pers. com. 1988), soil scientist, Gila National Forest, Silver City, New Mexico. Elevation at the site is about 2280 meters. Of the eighteen plots, six were placed in "high" vegetative cover (based on visual estimates), 6 in "low" cover, and 6 were "scraped" bare (top layer of vegetation and rock removed). Three of the bare

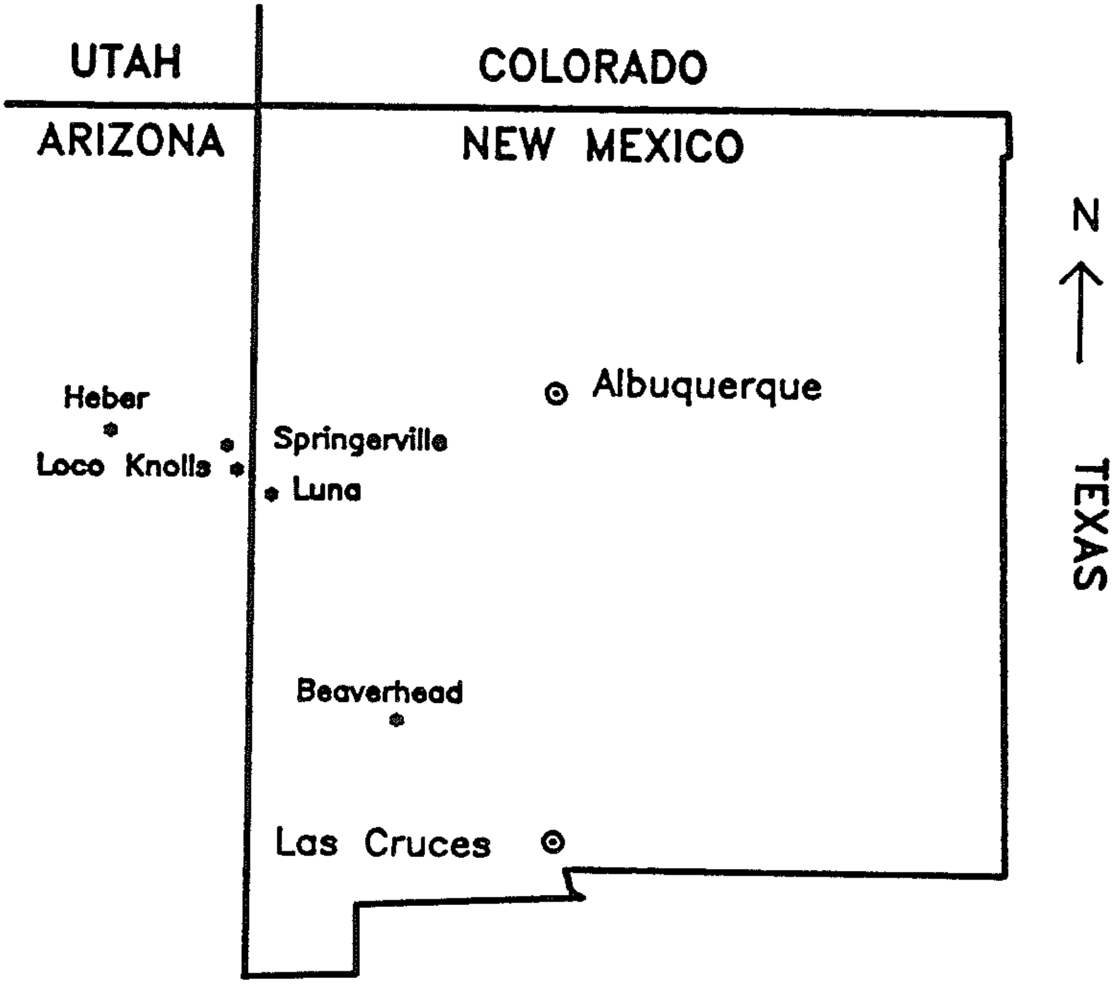

Fig. 1. Location of Sample Sites

plots were protected by a layer of window screen at a height of about four inches above the soil surface. The screen was used to create the effect of raindrop impact protection afforded by vegetation and rock cover. Data on thirty-six plot-runs were collected at this site.

Springerville, Arizona. The Springerville site was located south of Springerville, Arizona, in Section 14, T.8N., R.29W. on the Apache-Sitgreaves National Forest. Eighteen plots were installed at the site, six under the canopy and twelve in the rangeland on the edge of the canopy. The plots were divided into the three groups as used at Beaverhead: high cover, low cover, and bare with and without screen. Site elevation is about 2240 meters. Data on thirty-six plot-runs were collected during the experiments.

Loco Knolls, Arizona. This site was located east and south of Springerville, Arizona, in Section 6, T.8N., R.31E. Six plots were located in the rocky rangeland soils on the edge of the canopy. Four of the plots had vegetative cover (two high and two low) and the remaining two were scraped bare. The low cover plots were barely distinguishable from the high cover plots because of the dense vegetation and rock cover at this site. The site is at an elevation of about 2380 meters. Twelve plot-runs were made at this site.

Heber, Arizona. This site was located within a pinyon-juniper area north and west of Heber, Arizona, in Section 33, T.13N., R.17E. The site is in the Apache-Sitgreaves National Forest at an elevation of about 2000 meters. Twelve plots were sampled; four high cover, four low cover, and four bare (two with screening and two without). Data on 24 plot-runs were collected during the experiments.

Luna, New Mexico. After consultation with the USDA Forest Service Technical representative, additional plots planned for the Beaverhead area were "moved" to a site with highly eroded, piped alluvial soils north and east of Luna, New Mexico. Although sampled as part of the overall study, results from that site are significantly different from the other four sites described above, and will not be analyzed or discussed as part of this report. Results from the Luna sites will be presented in a later report. Thirty-two plot runs were collected at the Luna site which is at an elevation of about 2300 meters.

Procedures

Procedures generally conform to those followed and reported in Ward (1986) and Ward and Bolin (1988) (Appendix A). For this study, new experiments and measurements were added to supplement those used in the previous studies. As described above, the plots were selected to provide more of a range in the cover density on the soil surface. An extreme was created by scraping the soil surface to remove vegetation and rock cover (usually less than 5 centimeters). Window screening was used on one-half of the scraped plots to simulate the cover which had been removed, except that the screening was much more uniform and consistent in density. The purpose of these treatments was to determine the effect of natural and simulated cover on plot response to the simulated rainfall.

Cover was measured with a much more rigorous technique during this study. Cover and "roughness" measurements were collected using a point frame device. The point frame consisted of twenty-five small metal rods spaced approximately 3.8 cm apart. The rods were suspended from a 1 m long frame which rested on the plot borders. For cover measurements, two "hits" for each rod were recorded, a hit of vegetation above the ground surface (canopy) and a ground hit. Canopy hits were recorded as shrub, grass or forb. Ground hits were classified as basal vegetation, cryptogams, soil (less than 5mm particle size), gravel (less than 20mm), rock (greater than 20mm), persistent litter or non-persistent litter. Three measurements across the plot, spaced about 25 cm apart, were made for vegetation. Average cover for each category was computed as the number of hits out of seventy-five total possible hits.

To determine roughness, the same frame was used. Six measurements were made, three down the plot and three across the plot. A backboard to the point frame with horizontal lines across it was used to estimate the height of each rod after it was placed carefully on the ground surface. The standard deviation of the heights of the rods was used as the roughness measure. Mean standard deviations were computed for each line, for the three lines across the plot, for the three lines down the plot, and for all six lines. In the analyses, the mean standard deviations across the plot, down the plot and for all six lines were used.

Derivation of Parameters

Selected parameters were derived from the data using statistical and numerical techniques. For infiltration, the key model parameters are steady-state infiltration rate and a soil water parameter such as capillary suction. These values can be determined from rainfall rate and measured runoff. In the reports by Ward (1986) and Ward and Bolin (1988), the hydraulic conductivity (infiltration) was found from either a least squares fit of the incremental loss rate and the reciprocal of the infiltrated depth or, if this method yielded unreasonable results, by averaging the last few steady loss rates. The capillary suction parameter was derived from the least squares parameters, the appropriate loss rate (infiltration rate), and soil characteristics of porosity and saturation. Ward and Bolin (1988) also investigated two other techniques, one of which is reported here. In this approach, a hybrid was developed which uses the average steady state infiltration rate and the Green and Ampt steady rainfall infiltration formulation proposed by Mein and Larson (1971) and expanded upon by Li, Stevens, and Simons (1976). In this technique, the equation

$$F - a \ln(1 + Fa) = C \tag{1}$$

where:

F = total depth of infiltrated water at the end of the experiment (L),

a = Hc(1 - Si)n,

Hc = capillary head (L),

Si = initial soil saturation at the beginning of the experiment,

n = soil porosity,

Fa = Fp/a,

Fp = i tp = infiltrated depth of water at time of ponding (L),

i = steady rainfall rate (L/T)

tp = time to ponding since beginning of effective rainfall (T)

C = kw(T - tp) + Fp - a ln(1 + Fp/a),

kw = saturated hydraulic conductivity,

T = duration of rainfall (may be effective rainfall) (T),

is solved for "a" using a Newton-Raphson search. The value of kw is assumed to be known and is found by summing the volume of runoff for the last three sample periods and then dividing by the total duration of the three sample periods. The search is facilitated by a first guess of "a" as

$$a = F/2(F/(kw\ T) - 1.) \qquad (2).$$

The method gave reasonable results for Hc for most cases. However, there were certain instances when, given variations in the data or the small magnitude of "a", that the method will not converge. In those cases, a direct trial and error procedure using Eqn. 1 was employed. This was only necessary in about five plot-runs.

This procedure for estimating Hc when other techniques fail has some advantages and some disadvantages. First, the total depth of infiltration is used. This value is not affected by surface storage and routing effects as are the incremental depths. Second, the steady state loss rate is the integral of several measurements and does not rely on the last measurement. Third, once kw is determined, the method gives a value of Hc which will provide (in most cases) an exact estimate of the total infiltration depth. Fourth, the method can be modified to account for interception and surface retention effects on the total infiltration by reducing both the apparent infiltration depth and the apparent duration of the infiltration process. A major disadvantage is that the method does not use all of the collected information, such as the incremental loss rates.

Erosion on overland flow surfaces comes about when there is sufficient energy to dislodge and move the soil materials. The two sources of energy present in simulator studies are from raindrop impact and overland flow. Raindrop impact works by dislodging particles and transporting them relatively short distances in splash water. In the absence of overland flow, splash is an inefficient transport mechanism. Overland flow, specifically sheet and rill flow, typically has lower energy for detachment, but is more efficient at transporting sediment. In combination, the two energy inputs provide an effective method of soil erosion. It is difficult to separate precisely the two processes when analyzing soil erosion data. Instead, a balance between the two is found by analyzing data from different rainfall intensity and overland flow rate experiments. This is a primary reason for conducting a series of experiments on a site.

For the determination of surface erosion, the key parameters are raindrop splash detachment and overland flow detachment coefficients. Of primary importance for the small area simulator experiments is the raindrop splash erosion/transport parameter (Ward 1986; Ward and Bolin 1988). That parameter was determined following the procedures outlined by Ward (1986).

The remainder of this report is dedicated to data presentation and analyses. Of general interest are the comparisons of plot responses between sites and among the plots and types of experiments.

RESULTS AND ANALYSES

Data collected from the different sites were reduced, analyzed and summarized. The results, as presented in the following sections, are compared among the sites in order to identify differences and similarities in the hydrologic functions between areas. The results also provide a basis for relating the small plot data to requirements of the WEPP model. Note that in the discussions the following conversions apply: 25.4 mm = 1 inch, 1 kilogram (force) = 2.205 pounds, 1 kilogram (force)/hectare = 0.893 pounds/acre, 1 kilogram force/hectare-mm (unit area yield per unit of runoff depth) = 22.682 tons/acre-in. The units of kg (force)/hectare-mm are equivalent to the units of mg/L divided by 100.

Site Characteristics

Table 1 is a list of the summarized site measurements for the simulator plots at Beaverhead, Springerville, Loco Knolls and Heber. Means and standard deviations of each measured variable were determined from the data listed in Appendix B. Most information in these tables is self-explanatory. Gradation was determined from sieving the bulk soil samples and using a hydrometer analysis to determine the silt-clay division of the fine materials. Gravel percent is the average percent by total sample weight of particles larger than 4.75 mm in diameter. Sand represents the size fraction between 4.75 mm and 0.075 mm, and fines are less than 0.075 mm in size. The silt fraction is defined to be between 0.075 mm and 0.002 mm. The clay fraction

TABLE 1

Means and Standard Deviations (in parentheses) of Plot Characteristics for Each Site

Site	#	Cover	Poros %	Slope %	Canopy Cover %	Organic Cover %	Rock Cover %	Gravel %	Sand %	Silt %	Clay %	Rough-ness	Amc	
													Dry %	Wet %
BH	3	B	40.9	3.5	-	-	-	18.8	64.1	15.2	1.9	-	3.4	25.7
			(2.1)	(0.7)	-	-	-	(5.6)	(2.0)	(3.7)	(0.2)	-	(1.7)	(1.4)
BH	3	BS	43.1	3.3	-	-	-	28.8	60.0	9.8	1.4	-	2.1	20.3
			(3.8)	(1.3)	-	-	-	(3.6)	(1.8)	(1.5)	(0.3)	-	(0.3)	(3.5)
BH	6	L	42.0	2.5	9.3	41.1	37.8	22.9	63.8	11.6	1.6	0.33	2.5	21.4
			(4.1)	(1.0)	(7.9)	(15.9)	(23.5)	(5.6)	(3.2)	(3.9)	(0.3)	(0.07)	(0.5)	(3.8)
BH	6	H	39.3	3.4	19.6	57.6	20.9	25.9	61.9	10.7	1.5	0.41	3.2	20.2
			(4.0)	(0.5)	(11.1)	(12.9)	(11.5)	(6.1)	(5.1)	(2.5)	(0.4)	(0.07)	(1.0)	(4.1)
HB	2	B	24.0	3.3	-	-	-	40.5	47.4	10.7	1.4	-	0.7	15.0
			(16.8)	(0.4)	-	-	-	(2.2)	(1.2)	(0.6)	(0.4)	-	(0.1)	(1.6)
HB	2	BS	47.1	2.3	-	-	-	42.8	45.2	10.9	1.1	-	1.8	13.2
			(30.1)	(0.4)	-	-	-	(10.7)	(8.7)	(2.0)	-	-	(1.0)	(2.6)
HB	4	L	20.6	2.8	18.0	27.7	32.0	47.4	42.0	9.4	1.2	0.42	1.0	10.7
			(6.1)	(1.0)	(12.6)	(22.0)	(14.1)	(8.1)	(6.5)	(1.7)	(0.2)	(0.06)	(0.3)	(2.6)
HB	4	H	37.2	2.3	12.3	41.3	27.7	42.9	45.5	10.3	1.3	0.47	1.4	12.1
			(21.8)	(1.0)	(4.7)	(28.5)	(14.5)	(10.0)	(7.6)	(2.3)	(0.3)	(0.13)	(0.8)	(4.1)
LK	1	B	67.3	3.0	-	-	-	18.3	71.9	8.3	1.5	-	4.7	30.6
			-	-	-	-	-	-	-	-	-	-	-	-
LK	1	BS	67.3	3.0	-	-	-	18.3	71.9	8.3	1.5	-	4.7	30.6
			-	-	-	-	-	-	-	-	-	-	-	-
LK	2	L	52.2	3.5	36.7	52.7	14.7	28.3	62.9	7.4	1.4	0.51	4.1	31.2
			(0.8)	(0.7)	(14.7)	(0.9)	(10.0)	(4.0)	(3.6)	(0.4)	(0.1)	(0.01)	(0.1)	(6.6)
LK	2	H	52.2	3.0	39.3	55.3	21.3	28.3	62.9	7.4	1.4	0.57	4.1	31.2
			(0.8)	(0.0)	(2.8)	(4.7)	(1.9)	(4.0)	(3.6)	(0.4)	(0.1)	(0.05)	(0.1)	(6.6)
SP	3	B	58.8	4.8	-	-	-	25.1	67.0	6.7	1.3	-	3.6	23.4
			(7.1)	(1.8)	-	-	-	(14.5)	(13.7)	(0.9)	(0.1)	-	(0.5)	(3.8)
SP	3	BS	58.8	4.7	-	-	-	25.1	67.0	6.7	1.3	-	3.6	23.4
			(7.1)	(0.6)	-	-	-	(14.5)	(13.7)	(0.9)	(0.1)	-	(0.5)	(3.8)
SP	6	L	52.1	5.6	32.2	19.6	25.8	29.1	62.9	6.9	1.2	0.35	3.8	20.2
			(10.4)	(2.3)	(11.8)	(6.5)	(17.6)	(10.0)	(10.0)	(1.0)	(0.2)	(0.07)	(1.3)	(0.5)
SP	6	H	48.1	4.8	29.6	64.4	6.0	27.3	64.6	7.1	1.1	0.36	3.8	19.8
			(10.2)	(1.8)	(24.0)	(24.0)	(6.5)	(9.4)	(9.5)	(1.0)	(0.2)	(0.08)	(1.3)	(1.0)

BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville
\# - number of plots at each location

Note: Organic cover is basal vegetation, cryptogams and litter.
Rock cover is rock and gravel cover.
Cover is the four assigned cover categories, B=bare, BS=bare-screened, L=low cover, H=high cover.
Roughness is the mean standard deviation in pin heights across and down the plot.

is below 0.002 mm in size. Dry and wet AMCs are the antecedent moisture contents on a dry weight basis sampled just prior to the rainfall application.

A least-squares means test was done to compare soil characteristics among sites. Heber samples had significantly more gravel and significantly less sand in the soil than the other sites. Beaverhead and Heber had the same amount of silt. Loco Knolls had the same amount of silt as Heber and Springerville. Beaverhead had more clay than Heber and Springerville. Except for Loco Knolls and Springerville, all of the sites had different ratios of fines to sand.

Results from Rainfall Experiments

Table 2 lists the summarized results of the rainfall experiments at the PJ forest sites. Means are presented for the four perceived cover categories of high, low, bare, and bare with screening. At each site, plots were designated as having high or low cover relative to other plots at that site. In addition, a third of the plots at each site were scraped clear of vegetation and half of these plots were screened during simulation. Individual small plot measurements are listed in Appendix C for the four sites.

Rainfall and Runoff - Within Sites. Comparisons were made at each site between the different cover types: bare, bare-screen, low cover and high cover. Results of the analysis of runoff to rainfall ratios were as expected. The bare and the

TABLE 2

Means and Standard Deviations (in parenthesis) of Rainfall and Runoff Characteristics for Each Site

Site	#	Cover	Intensity (mm/hr)		Duration of Rain (min.)		Duration of Runoff (min.)		Runoff (mm)		Runoff/Rainfall (percent)	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	3	B	88.0	87.4	34.7	23.6	32.0	22.4	26.1	25.0	51.1	72.0
			(5.4)	(4.2)	(11.5)	(7.2)	(9.9)	(7.4)	(9.7)	(8.5)	(4.4)	(1.3)
BH	3	BS	87.4	82.7	34.3	33.0	31.0	31.1	20.5	30.0	41.8	68.2
			(1.7)	(1.5)	(2.4)	(11.5)	(3.3)	(11.5)	(6.7)	(6.8)	(15.4)	(11.6)
BH	6	L	84.8	84.0	47.9	26.7	43.2	24.3	19.4	21.0	27.9	56.5
			(9.1)	(5.0)	(10.7)	(8.0)	(11.0)	(7.5)	(12.4)	(9.1)	(14.9)	(15.4)
BH	6	H	84.5	82.0	49.3	40.7	45.1	28.1	9.6	18.0	13.1	36.2
			(3.7)	(1.2)	(12.9)	(23.7)	(12.4)	(9.1)	(5.8)	(13.5)	(6.2)	(23.1)
HB	2	B	91.6	92.1	32.1	19.4	29.6	18.1	31.4	24.8	64.3	83.4
			(2.4)	(2.1)	(9.1)	(1.3)	(10.2)	(0.4)	(8.0)	(0.1)	(0.3)	(2.9)
HB	2	BS	98.5	84.9	31.0	19.5	27.6	18.4	31.6	19.3	62.2	74.8
			(10.9)	(2.0)	(2.1)	(4.2)	(4.6)	(4.2)	(3.8)	(6.1)	(3.7)	(39.9)
HB	4	L	83.9	86.0	39.1	30.7	34.0	27.9	13.3	24.6	24.4	57.7
			(4.8)	(4.3)	(15.4)	(13.5)	(13.3)	(12.5)	(6.3)	(7.9)	(3.6)	(10.3)
HB	4	H	83.5	83.7	34.8	22.4	29.0	20.1	13.5	10.9	22.3	42.3
			(2.0)	(1.5)	(4.8)	(2.9)	(5.4)	(3.3)	(4.9)	(3.8)	(6.8)	(10.3)
LK	1	B	86.1	91.9	51.7	16.6	46.0	15.9	35.6	20.0	48.0	78.7
			.	.	.	.	.	.	.	.	.	.
LK	1	BS	79.7	82.4	42.4	21.5	32.9	19.3	11.5	15.9	20.4	53.9
			.	.	.	.	.	.	.	.	.	.
LK	2	L	89.0	93.7	35.1	45.5	30.4	42.4	1.0	29.8	1.9	44.9
			(4.4)	(4.2)	(3.6)	(10.6)	(6.7)	(9.8)	(0.1)	(7.7)	(0.2)	(23.2)
LK	2	H	86.0	88.8	40.1	32.1	23.0	26.8	0.8	19.8	1.4	40.1
			(6.9)	(8.0)	(5.4)	(1.2)	(5.9)	(0.1)	(0.6)	(13.4)	(1.2)	(23.0)
SP	3	B	81.5	88.7	35.3	22.7	29.3	21.7	25.7	25.6	53.4	76.2
			(3.3)	(3.8)	(0.5)	(2.6)	(2.2)	(2.4)	(3.7)	(3.9)	(5.3)	(1.6)
SP	3	BS	84.8	86.2	41.2	23.6	35.4	21.5	21.9	20.2	38.5	60.7
			(5.6)	(7.4)	(5.2)	(3.9)	(3.6)	(3.3)	(3.6)	(1.7)	(11.3)	(9.6)
SP	6	L	88.2	85.4	33.5	26.1	27.8	23.8	19.1	24.0	39.2	64.4
			(7.6)	(4.5)	(8.1)	(4.3)	(8.2)	(3.8)	(6.4)	(5.3)	(11.0)	(7.5)
SP	6	H	83.1	85.3	37.4	24.0	31.5	20.5	14.4	13.7	29.1	39.5
			(6.1)	(4.4)	(10.3)	(5.5)	(9.5)	(5.1)	(8.9)	(6.1)	(16.5)	(15.4)

BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville
\# - number of plots at each location

Cover is the four assigned cover categories: B=bare, BS=bare-screened, L=low cover, H=high cover.

bare-screened plots at Beaverhead were different from the cover plots, but not from each other. The high cover plots were different from the low cover plots for the dry runs. At Springerville, for the dry runs, the only difference was between the bare plots and the cover plots. The ground cover at Springerville was fairly uniform and the differences between the high and low cover percentages were not great. At Loco Knolls, for the dry runs, bare and bare-screened plots were different from the cover plots, but there were no differences between high and low cover. At Loco Knolls, as at Springerville, the cover was so uniform that there were only small differences between the high and low cover percentages. At Heber, the bare plots were different from the bare-screened plots and the cover plots. There were no differences between the high and low cover plots. For the wet runs, there were no significant differences in runoff to rainfall ratios at any of the sites between the cover types.

Rainfall and Runoff - Among Sites. Plots that were scraped clear of vegetation (includes bare and bare-screened) were analyzed separately from those with natural vegetation. A paired difference t-test indicated a significantly higher ratio of runoff to rainfall from the wet runs than from the dry runs. Further analysis of runoff to rainfall ratios were done on dry runs and wet runs separately. A least-squares means test was conducted to examine the differences in the runoff to rainfall ratio among the four small simulator sites. Results for the dry runs indicate that, on the scraped plots, Heber had a significantly higher percent runoff than the other sites. This may be due to the slightly higher applied rainfall intensity at Heber. For the natural plots, the runoff ratio at Heber was the same as Beaverhead and Springerville. Loco Knolls had significantly less runoff to rainfall than the other sites because of the high cover on the natural plots. For the wet runs, there were no differences between the sites for the scraped plots or the natural plots. Box plots in figure 2 illustrate the runoff to rainfall relationships between sites for the natural cover plots. The center line in each box is the median value. The top and bottom line of each box signifies the 75th percentile and the 25th percentile value, respectively, for each site. The top and bottom bars at the end of the vertical line are the 90th and 10th percentile, respectively. If the median line of one box lies within the slanted portion of another box then the medians for the sites characterized by the two boxes are not significantly different.

Sediment Yields - Within Sites. Table 3 is a summary of the sediment yields collected with the small simulator. The yields are reported in weight per area and weight per area per unit depth of runoff. The latter values are equivalent to concentrations in mg per liter divided by 100 and are calculated to remove the effects of runoff energy from the yields. Suspended yields are sampled from the pumped runoff water while deposited yields are comprised of those sediments which were

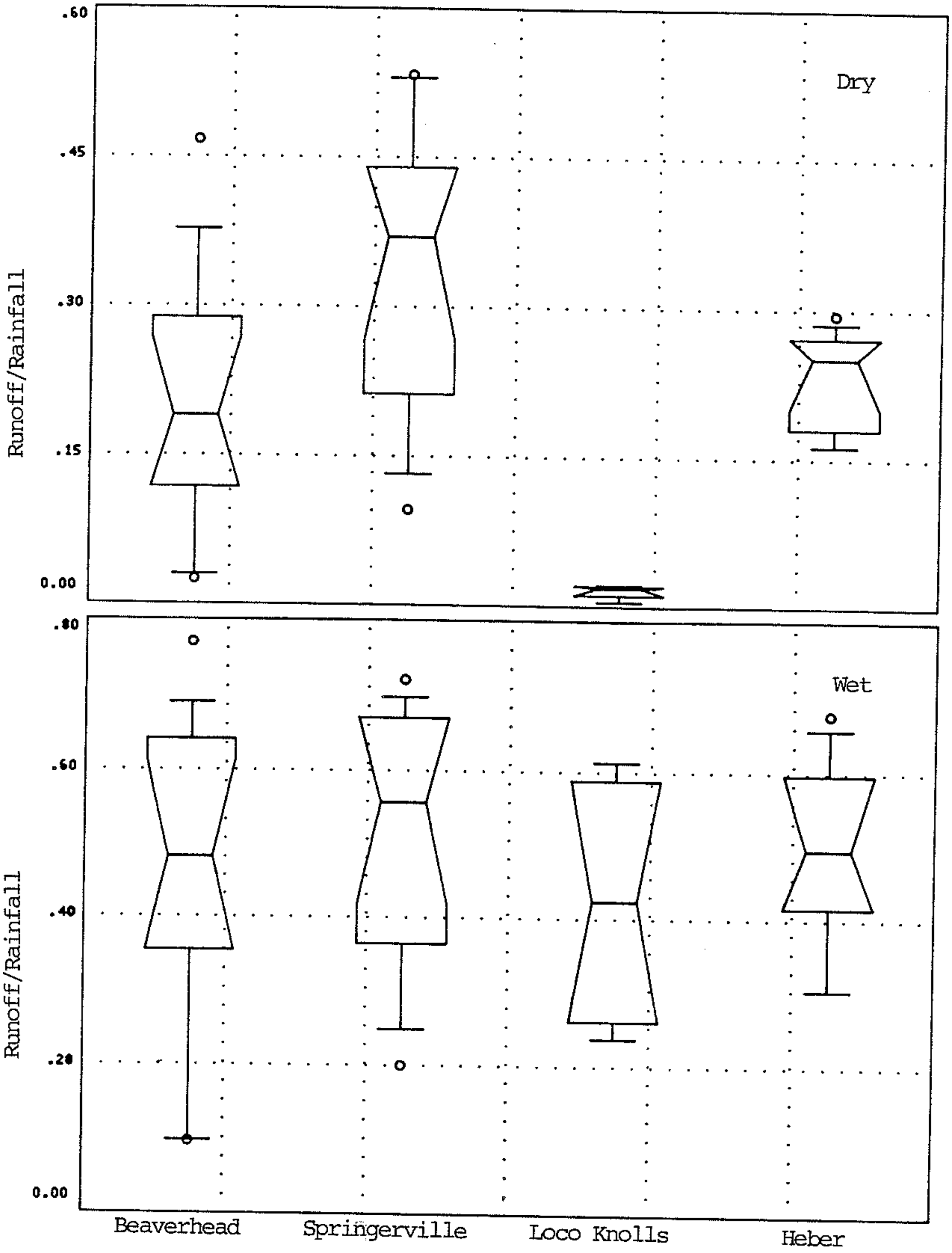

Fig. 2. Box plots of runoff to rainfall ratio at each site for natural plots.

TABLE 3

Means and Standard Deviations (in parentheses) of the Components of Sediment Yield for Each Site

Site	#	Cover	Runoff (mm)		Suspended Yield (kg/ha)		Suspended Yield (kg/ha/mm)		Deposit (kg/ha)		Deposit (kg/ha/mm)	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	3	B	26.1 (9.7)	25.0 (8.5)	440.2 (53.3)	338.6 (241.0)	17.9 (4.3)	14.3 (8.5)	579.0 (320.1)	616.5 (126.7)	23.8 (15.7)	26.4 (8.3)
BH	3	BS	20.5 (6.7)	30.0 (6.8)	322.2 (174.2)	343.2 (305.3)	16.1 (7.8)	10.4 (6.9)	219.9 (120.9)	512.9 (328.7)	10.5 (4.8)	17.3 (12.4)
BH	6	L	19.4 (12.4)	21.0 (9.1)	102.3 (95.6)	80.5 (28.1)	6.0 (3.3)	4.5 (2.6)	339.6 (324.5)	461.9 (205.7)	24.4 (21.5)	23.6 (12.0)
BH	6	H	9.6 (5.8)	18.0 (13.5)	51.5 (40.0)	61.6 (30.6)	6.0 (3.6)	4.0 (1.5)	207.7 (103.2)	297.7 (150.4)	28.4 (17.4)	20.7 (10.5)
HB	2	B	31.4 (8.0)	24.8 (0.1)	896.2 (551.0)	465.0 (307.6)	27.2 (10.6)	18.7 (12.3)	1621.4 (606.6)	1951.8 (514.6)	50.9 (6.4)	78.8 (21.2)
HB	2	BS	31.6 (3.8)	19.3 (6.1)	1415.6 (1265.9)	269.6 (4.3)	42.7 (34.9)	14.7 (4.4)	411.1 (206.9)	469.1 (106.8)	13.5 (8.2)	24.7 (2.2)
HB	4	L	13.3 (6.3)	24.6 (7.9)	104.3 (65.7)	153.5 (134.4)	7.7 (3.8)	6.5 (5.5)	663.1 (112.0)	1250.8 (854.5)	57.2 (21.4)	54.3 (36.4)
HB	4	H	10.9 (3.8)	13.5 (4.9)	88.9 (72.4)	96.8 (44.3)	7.6 (4.6)	7.5 (3.2)	510.6 (234.2)	769.7 (625.8)	50.6 (30.8)	53.5 (30.3)
LK	1	B	35.6 .	20.0 .	808.5 .	746.8 .	22.7 .	37.3 .	3709.3 .	2950.0 .	104.2 .	147.5 .
LK	1	BS	11.5 .	15.9 .	45.1 .	132.5 .	3.9 .	8.3 .	265.4 .	369.2 .	23.1 .	23.2 .
LK	2	L	1.0 (0.1)	29.8 (7.7)	7.6 (4.2)	412.7 (236.2)	7.4 (3.2)	13.3 (4.5)	174.4 (15.3)	786.9 (158.8)	175.1 (9.4)	28.1 (12.6)
LK	2	H	0.8 (0.6)	19.8 (13.3)	3.1 (3.7)	68.3 (29.8)	3.1 (2.3)	3.8 (1.1)	80.3 (46.6)	367.3 (140.8)	126.0 (44.7)	27.2 (25.6)
SP	3	B	25.7 (3.7)	25.6 (3.9)	970.2 (735.6)	443.5 (260.4)	35.8 (22.5)	16.9 (8.8)	1459.7 (835.7)	2477.9 (1216.4)	60.4 (38.9)	101.5 (57.2)
SP	3	BS	21.9 (3.6)	20.2 (1.7)	235.6 (44.4)	223.5 (99.8)	10.9 (2.8)	11.4 (5.7)	2123.3 (867.7)	1556.6 (468.7)	94.7 (23.3)	76.2 (19.4)
SP	6	L	19.1 (6.4)	24.0 (5.3)	210.4 (163.9)	181.1 (109.9)	10.7 (7.2)	8.1 (6.1)	806.9 (421.2)	689.2 (407.9)	44.5 (19.2)	29.7 (16.0)
SP	6	H	14.4 (8.9)	13.7 (6.1)	107.7 (98.4)	37.9 (20.5)	9.2 (9.4)	3.8 (3.2)	380.9 (188.7)	274.9 (72.8)	30.3 (17.5)	25.7 (16.7)

Total yields are found by adding suspended and deposit values.

BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville
\# - number of plots at each location

Cover is the four assigned cover categories: B=bare, BS=bare-screened, L=low cover, H=high cover.

deposited on the runoff tray or in the runoff trough. The filtered sample technique was used to determine sediment concentrations for these sediment measures. Values were log-transformed for analysis.

A paired difference t-test was used to compare the dry run and wet run sediment yields. At Beaverhead, differences exist for total (suspended plus deposit) yield and deposit yield, and for suspended yield per mm of runoff. For Heber, differences were found for suspended yield per mm of runoff and for deposit yield. At Loco Knolls, differences were found for suspended, deposit, and total yields, and for suspended yield per mm of runoff. For Springerville, differences existed for suspended yield, suspended yield per mm of runoff, and total yield per mm of runoff. In general, the wet runs produce less sediment yield than do the dry runs. This is to be expected because the readily available material is usually washed off the plot during the dry run thus decreasing the supply for the wet run.

At each site, the four cover conditions were compared with a least-squares means test for differences in total yield from the cover types. For the dry runs at Beaverhead, there were no significant differences in the total sediment concentrations (kg/ha/mm of runoff) from the four cover conditions. For total sediment yield (kg/ha), the bare plots had significantly more sediment yield than the natural cover plots but there were no differences between the high and low cover plots. There were no differences in yields from the cover types for the wet runs.

At Springerville, the total sediment concentrations and total sediment yields from the bare and bare-screened plots were significantly higher than those from the natural plots for the dry and wet runs. There were no differences between the high and low cover plots for the dry runs, but the total sediment yield from the high cover plots was less than that from the low cover plots for the wet run.

At Loco Knolls, the bare-screened plots had significantly lower concentrations of total sediment than the other cover types for the dry runs. The bare plots had significantly higher yields of total sediment than the other plots. There were no differences between cover types for the wet runs.

At Heber, the total sediment concentrations for the dry runs were not different among cover types. Total sediment yield from the natural plots was less than that from the bare or bare-screened plots. There were no differences among the cover types for either total sediment measurement for the wet runs.

Sediment Yields - Among Sites. A least-squares means test was conducted on log-transformed values of the sediment yields to test for differences among sites. For the dry runs on scraped plots, the suspended sediment yields were significantly higher at Heber than at Loco Knolls; there were no significant differences at the other sites. For deposited yields from scraped plots, Beaverhead had significantly less yield than Springerville. The scraped plots at Beaverhead had significantly less total sediment yield than the scraped plots at Heber or Springerville. The suspended sediment concentrations (kg/ha/mm) for the dry runs were not significantly different at any site. Beaverhead had significantly lower concentrations of deposits than Springerville and significantly lower concentrations of total yield than Springerville or Heber.

For the wet runs on scraped plots, there were no significant differences among sites for suspended yield or suspended concentration. For all other measures of sediment yield, Beaverhead had significantly less yield than Springerville for the wet runs. All other sites were not significantly different.

The differences among plots were slightly more intricate for the natural cover plots. For the dry runs, Heber had significantly lower suspended sediment yields than the other sites, but there were no differences in concentrations among the sites. For deposit yields, Beaverhead was the same as Loco Knolls and Heber was the same as Springerville. All other site comparisons were significantly different. Springerville deposit concentrations were the same as at Beaverhead and Heber, all other sites were significantly different. For total sediment yields, Heber was not significantly different from Springerville, but all other sites were significantly different. Loco Knolls had the least total sediment yield and Heber had the most. For total sediment concentration on the dry runs, Beaverhead and Heber were not significantly different from Springerville, while all other sites were different.

For the wet runs on the natural plots, there were no differences in suspended sediment yield or concentration among the sites. Heber had significantly more deposit yield and concentration than Beaverhead and Springerville. Beaverhead had significantly less total sediment yield (both measures) than Heber and Heber had significantly more total sediment yield (both measures) than Springerville. There were no significant differences among other sites. There were no significant differences for dry or wet runs between the field-assigned low and high cover plots for any measure of sediment yield.

Figures 3 through 8 illustrate the differences between sites for the different sediment yields from natural plots. Box plots can be used to indicate significant differences between medians. If the median, the central line in a box, overlaps with the slanted portion of any other box, the medians are not significantly different at the p=0.05 level. Findings from Ward and Bolin, (1988) indicate that yields determined from the small simulator should be scaled down by a factor of 3.5 to 5 (depending on the energy adjustment) to be more comparable with the WEPP simulator.

Infiltration and Erosion Characteristics . For the small plots, hydraulic conductivity (infiltration) and capillary head were derived from the runoff data as detailed in the methodology section. The raindrop splash erosion/transport coefficient was derived from the total sediment yield, cover, and rainfall data

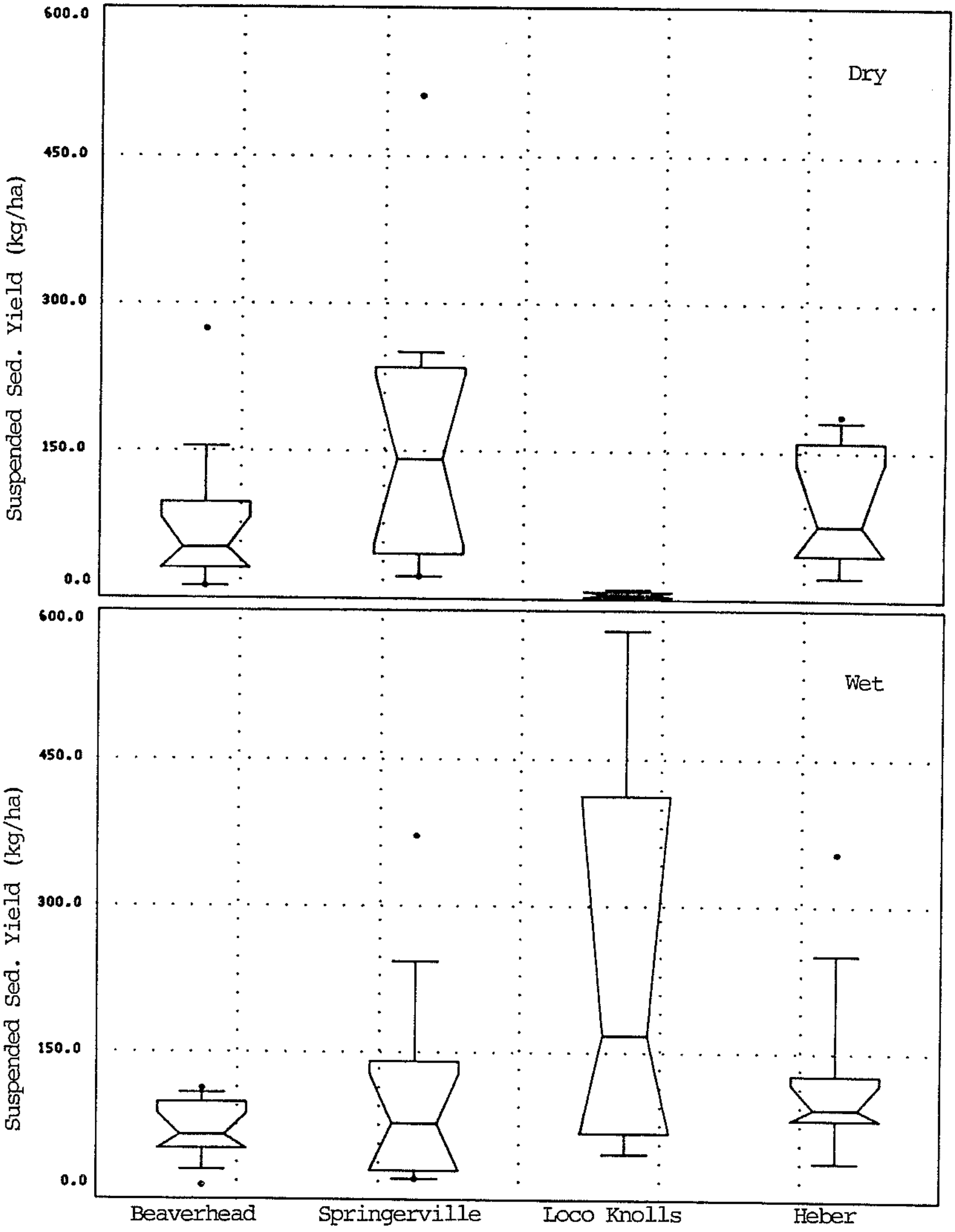

Fig. 3. Box plots of suspended sediment yield (kg/ha) at each site for natural plots.

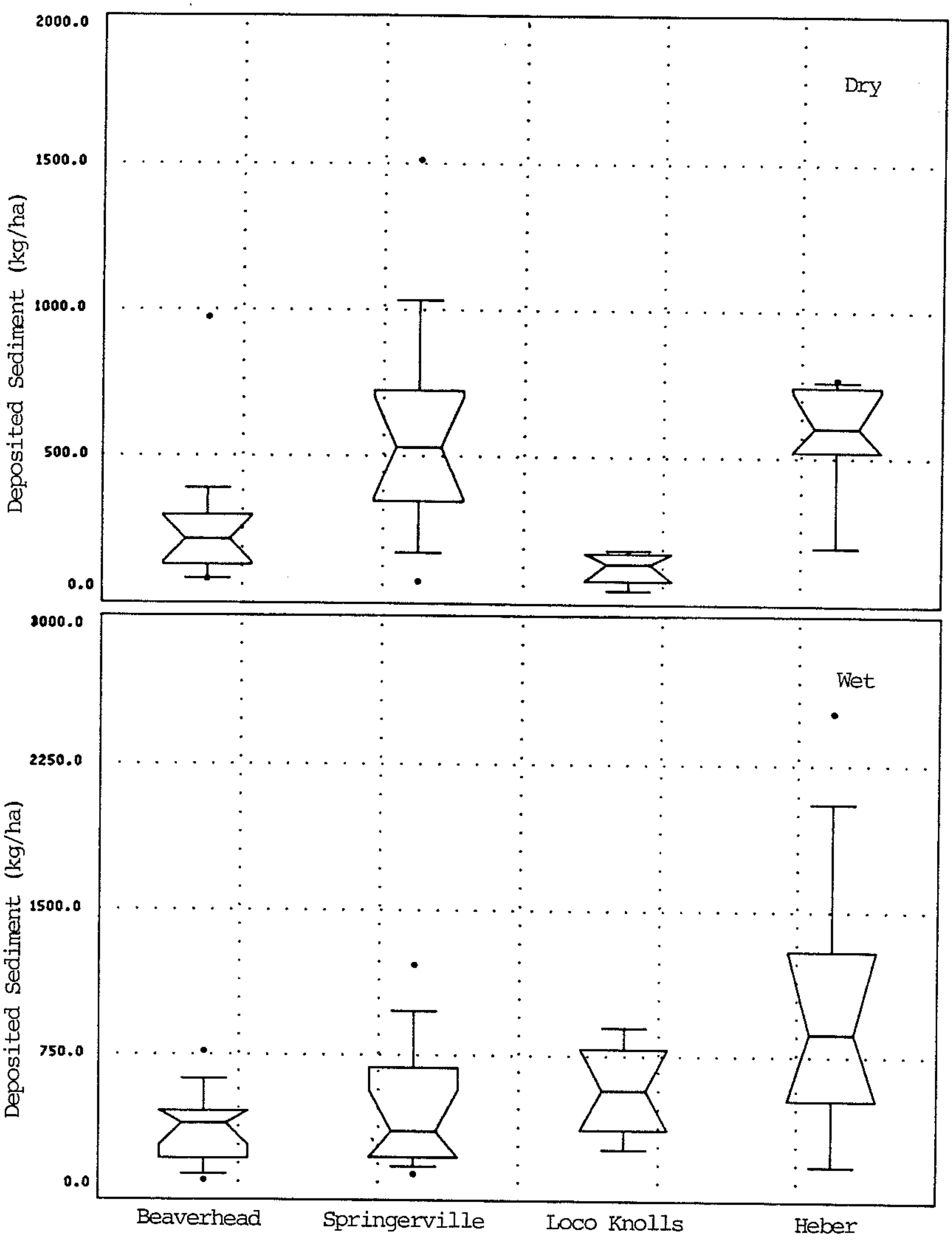

Fig. 4. Box plots of deposited sediment yield (kg/ha) at each site for natual plots.

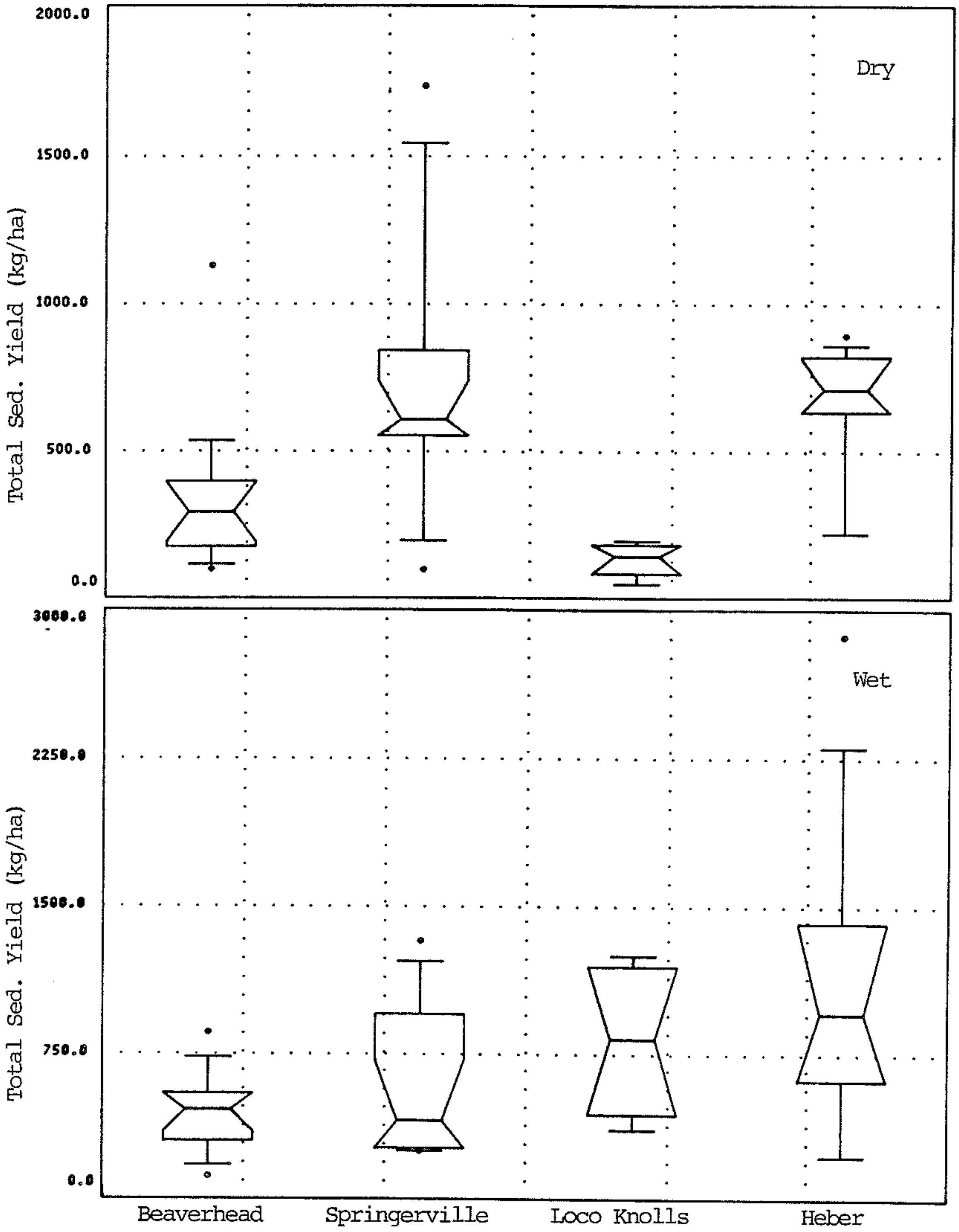

Fig. 5. Box plots of total sediment yield (kg/ha) at each site for natural plots.

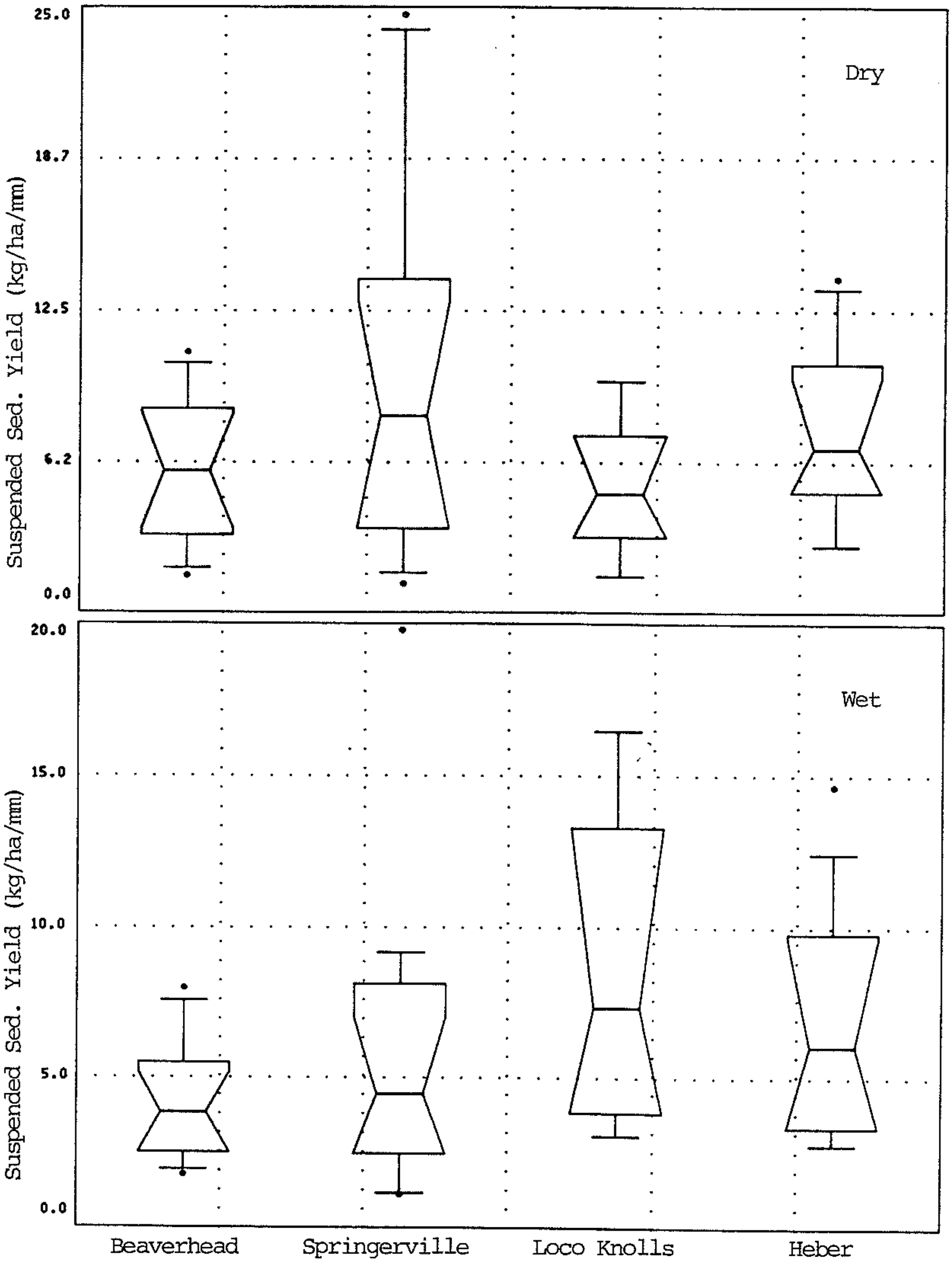

Fig. 6. Box plots of suspended sediment yield (kg/ha/mm) at each site for natural plots.

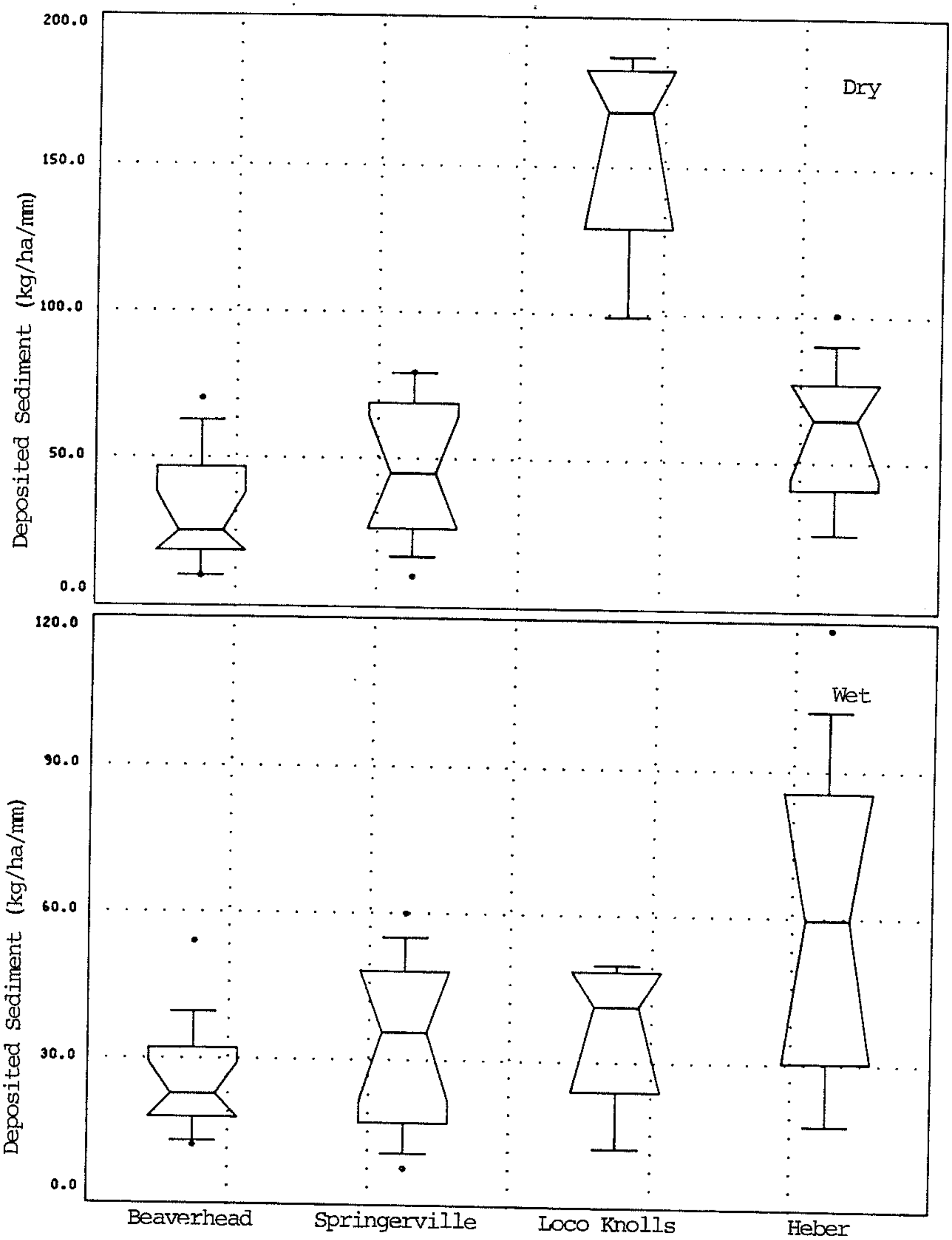

Fig. 7. Box plots of deposited sediment yield (kg/ha/mm) at each site for natural plots.

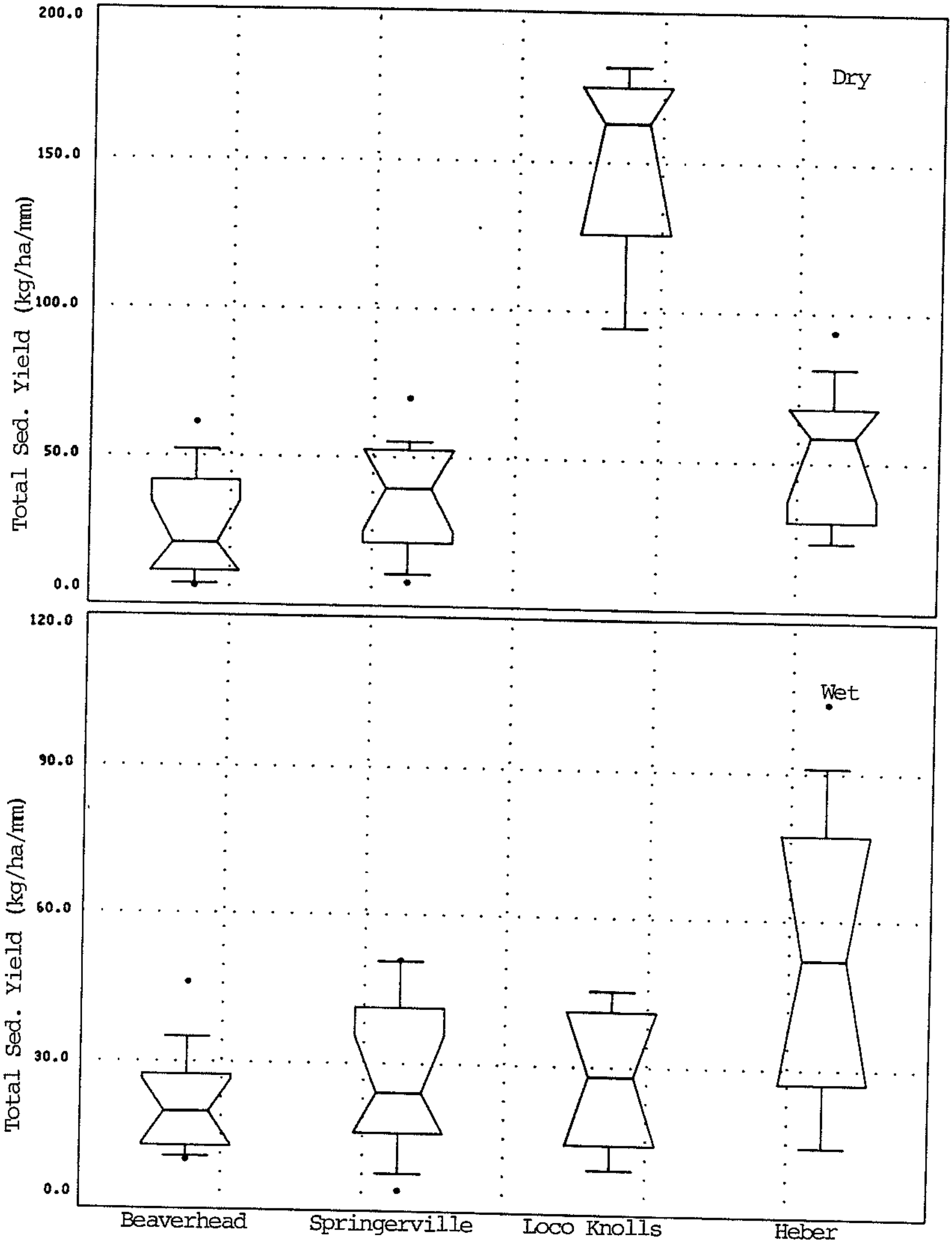

Fig. 8. Box plots of total sediment yield (kg/ha/mm) at each site for natural plots.

as suggested by Ward (1986). The individual plot values are listed in Appendix E and summarized in table 4. Note that splash coefficients for the suspended and deposited yields can be calculated from the values listed in Appendix E and table 4 by dividing by the total sediment yield per unit area and then multiplying by the appropriate yield, suspended or deposited, calculated for the wet and the dry experiments. These values were derived using the method applied to the small simulator data. This may not be the most appropriate methodology, but it is consistent and as the table shows, it produces comparable results among the sites.

Examination of the small plot data indicates that the estimated average value of saturated hydraulic conductivity (infiltration) decreases between dry and wet runs. The capillary head is much more variable and may increase or decrease with the antecedent moisture condition. Paired difference t-tests were performed on the infiltration and capillary head values between the soil moisture conditions. There were significant differences for both parameters between the dry and wet runs. The dry run infiltrations are higher while the capillary heads are lower. It should be noted, however, that the confidence in the derived capillary head values is very low compared to the other values determined in this study. Differences in the capillary heads may be artifacts arising from the particular method of data analysis.

TABLE 4

Means and Standard Deviations (in parenthesis) of Derived Infiltration and Erosion Parameters for Each Site .

			Est. Hydraulic Conductivity (mm/hr)		Derived Capillary Head (mm)		Splash Coefficient (kg-hr/ha-sq.mm)	
Site	#	Cov	Dry	Wet	Dry	Wet	Dry	Wet
BH	3	B	18.6	16.3	63.7	103.3	0.24	0.35
			(12.2)	(2.1)	(59.0)	(101.2)	(0.08)	(0.15)
BH	3	BS	33.1	15.6	548.7	46.6	0.13	0.25
			(29.3)	(15.9)	(944.2)	(32.2)	(0.08)	(0.15)
BH	6	L	36.0	18.3	72.6	448.0	0.45	1.13
			(24.3)	(12.4)	(70.4)	(835.3)	(0.33)	(0.54)
BH	6	H	61.3	33.3	27.0	327.0	0.46	0.89
			(16.5)	(21.1)	(37.3)	(413.3)	(0.46)	(0.94)
HB	2	B	10.2	6.4	382.2	1003.5	0.58	0.93
			(9.6)	(2.7)	(528.7)	(1374.2)	(0.14)	(0.10)
HB	2	BS	23.2	19.6	18.3	281.8	0.36	0.35
			(14.3)	(26.5)	(22.4)	(396.6)	(0.12)	(0.14)
HB	4	L	45.4	23.2	36.0	925.2	0.69	1.39
			(5.3)	(13.4)	(20.8)	(1329.7)	(0.45)	(1.20)
HB	4	H	46.0	25.3	31.9	1939.8	0.74	1.47
			(5.4)	(20.8)	(28.3)	(3385.4)	(0.52)	(1.15)
LK	1	B	5.9	1.7	203.9	75.0	0.74	1.66
			.	.	.	.	.	.
LK	1	BS	38.7	16.6	21.6	18.4	0.07	0.22
			.	.	.	.	.	.
LK	2	L	86.7	31.2	0.43	100.0	0.19	0.90
			(4.2)	(18.9)	(0.25)	(28.3)	(0.02)	(0.18)
LK	2	H	83.9	27.9	0.02	230.3	0.12	0.78
			(5.6)	(13.8)	(0.03)	(243.2)	(0.08)	(0.41)
SP	3	B	20.5	13.8	12.6	8.1	0.66	1.08
			(2.1)	(9.3)	(3.1)	(9.2)	(0.08)	(0.56)
SP	3	BS	42.9	18.4	6.3	151.9	0.52	0.65
			(17.8)	(18.0)	(9.4)	(258.0)	(0.25)	(0.16)
SP	6	L	28.4	15.7	25.6	114.3	0.73	0.84
			(13.2)	(3.4)	(15.7)	(242.9)	(0.38)	(0.39)
SP	6	H	48.6	43.9	9.9	68.8	1.08	0.94
			(17.4)	(14.4)	(14.0)	(158.0)	(1.43)	(0.78)

BH - Beaverhead
HB - Heber
LK - Loco Knolls
SP - Springerville
\# - number of plots at each location

Computed infiltrations were not significantly different among sites for the dry or wet, scraped plots. The mean infiltration rate at Loco Knolls on the natural plots was significantly higher than the other sites for the dry runs. There were no differences among sites for the wet runs on the natural plots. Box plots in figure 9 illustrate the relationships among sites for infiltration.

The splash detachment coefficients are an index of rainfall erosion at a site per unit area of bare ground. Sites with higher values indicate higher erodability of the exposed soil. These values tend to complement the yield values but also incorporate rainfall and cover effects. Although differences exist among sites as shown by the data tables, there is no significant difference between dry and wet runs because the variability of this coefficient is so high. The splash coefficient derived from small simulator data should be useful in the WEPP effort to provide an estimate for modeling.

Correlation of Parameters. The hydraulic and sediment yield values presented above were correlated to site and rainfall characteristics in an attempt to understand better the factors controlling the runoff and erosion processes. Runoff was positively correlated with rainfall intensity and antecedent soil moisture and negatively related to horizontal roughness (roughness measured across the plot) and total roughness (roughness measured across and down the plot). Sediment yields (suspended, deposited and total) were positively correlated with

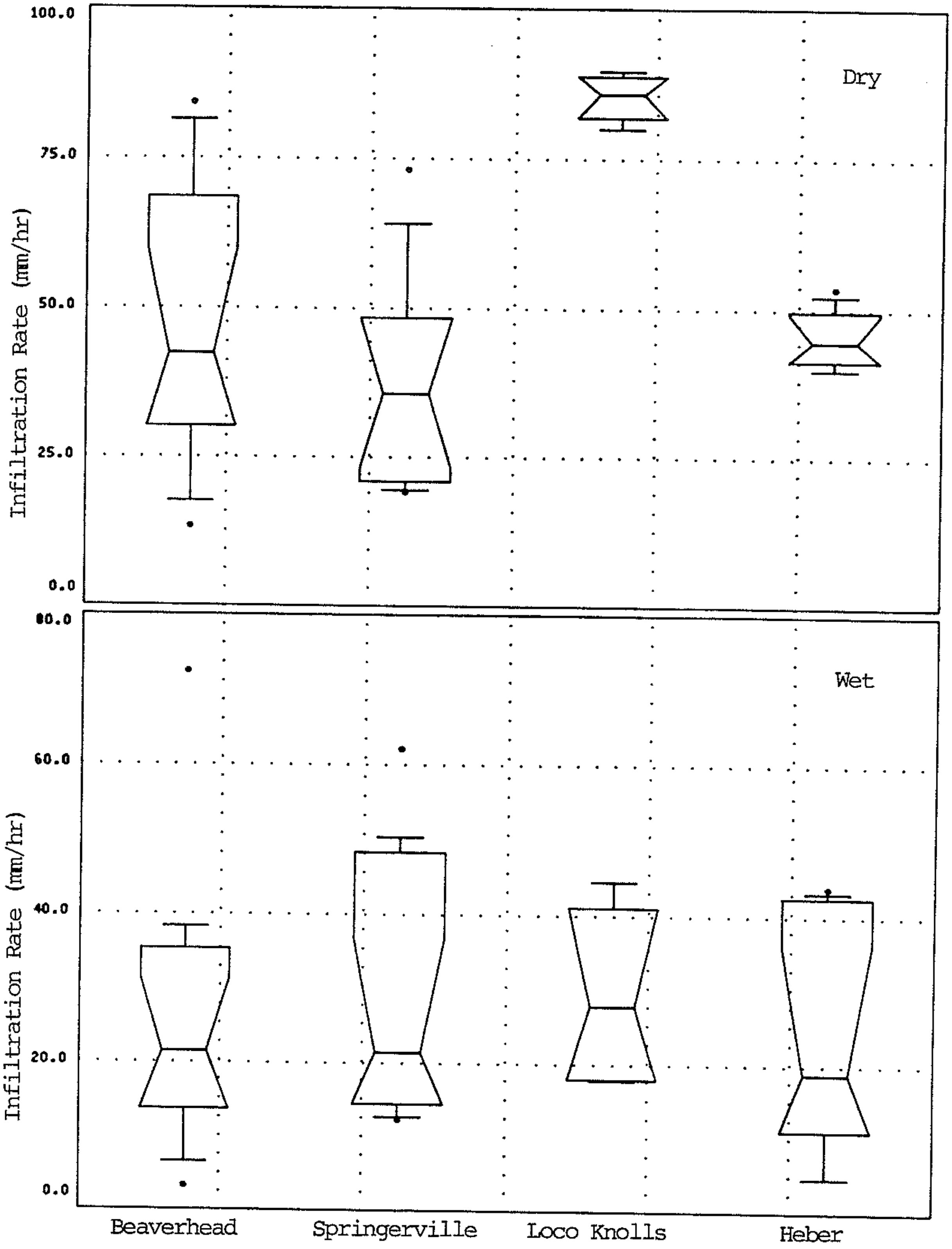

Fig. 9. Box plots of infiltration rates at each site for natural plots.

rainfall intensity, runoff, and bare soil and negatively correlated with total cover (basal vegetation, litter, rock, gravel, and cryptogams) and organic cover (same as total, but without rock and gravel). Unit area yields per mm of runoff appear to be inversely correlated to the same variables that runoff is positively correlated to, except rainfall intensity, which was expected. Hydraulic conductivity, capillary head, and the detachment coefficient are derived parameters, therefore some correlations are spurious. Conductivity is negatively correlated to bare soil and initial saturation, and positively correlated to total and organic cover, as well as horizontal and total plot roughness. At the one-percent level, capillary head is not significantly correlated with any plot variables. The detachment coefficient is negatively correlated with the percent of total fines in the soil.

Chemical Concentrations and Yields - Within Sites. Water chemistry data collected with the small simulator is summarized in table 5, and the individual values are listed in Appendix F. Before analysis, chemical concentrations in the simulator rainwater (background concentrations) were subtracted from the runoff concentrations (see Appendix G). High background measurements of nitrogen occurred at Heber (contaminated nonpotable water supply), which resulted in negative concentrations when the backgrounds were subtracted. Heber was not used in the analysis of nitrogen yields. Chemical values were log-transformed before analysis to satisfy the assumption of a normal

TABLE 5

Means and Standard Deviations (in parentheses) of Chemical Yields for Each Site

Site	Cov	Total Phos. (kg/ha)		Total Phos. (kg/ha/mm)		Total Nitrogen (kg/ha)		Total Nitrogen (kg/ha/mm)		Total Volatile Suspended (kg/ha)		Total VSS (kg/ha/mm)	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	B	0.219	0.140	0.009	0.006	1.91	1.52	0.079	0.077	129.74	74.81	5.617	3.433
		(0.024)	(0.068)	(0.004)	(0.004)	(0.72)	(1.10)	(0.044)	(0.076)	20.12	41.93	2.837	2.349
BH	BS	0.157	0.068	0.008	0.002	1.25	3.66	0.057	0.101	107.76	135.28	5.423	3.797
		(0.106)	(0.063)	(0.005)	(0.003)	(1.13)	(5.42)	(0.053)	(0.140)	112.67	185.52	5.192	4.701
BH	L	0.069	0.042	0.004	0.002	0.80	0.31	0.043	0.017	22.44	16.39	1.065	0.958
		(0.093)	(0.023)	(0.003)	(0.002)	(0.87)	(0.23)	(0.038)	(0.013)	29.47	12.98	0.790	0.967
BH	H	0.037	0.042	0.005	0.003	0.25	0.36	0.027	0.020	8.87	8.74	1.138	0.553
		(0.026)	(0.026)	(0.004)	(0.002)	(0.19)	(0.36)	(0.015)	(0.009)	6.27	5.90	0.753	0.264
HB	B	0.285	0.117	0.009	0.005	374.30	-252.73	14.648	-10.231	148.44	61.58	4.525	2.480
		(0.126)	(0.056)	(0.002)	(0.002)	(549.39)	(346.81)	(21.258)	(14.043)	87.81	28.41	1.648	1.131
HB	BS	0.282	0.133	0.009	0.008	-498.90	-136.95	-17.287	-5.776	506.85	66.59	14.955	4.035
		(0.144)	(0.026)	(0.004)	(0.004)	(718.16)	(196.80)	(24.816)	(8.377)	624.43	47.11	17.953	3.712
HB	L	0.041	0.059	0.003	0.003	-98.49	-4.46	-8.738	2.122	18.14	28.39	1.3750	1.1925
		(0.027)	(0.053)	(0.002)	(0.002)	(193.32)	(258.74)	(17.296)	(14.638)	8.65	17.32	0.3948	0.6984
HB	H	0.034	0.031	0.003	0.002	-93.37	-175.51	-5.140	-13.549	15.10	16.50	1.2950	1.2425
		(0.015)	(0.018)	(0.002)	(0.002)	(191.71)	(201.85)	(16.130)	(16.972)	12.69	8.57	0.8304	0.5025
LK	B	0.771	0.309	0.022	0.016	1.44	1.39	0.041	0.070	136.35	107.60	3.8300	5.3800
		.	.	.	.	.	.	.	.	.	.	.	.
LK	BS	0.056	0.064	0.005	0.004	0.11	0.06	0.010	0.003	10.81	26.39	0.9400	1.6600
		.	.	.	.	.	.	.	.	.	.	.	.
LK	L	0.008	0.187	0.008	0.006	0.02	0.37	0.014	0.011	1.41	54.33	1.3650	1.7650
		(0.006)	(0.046)	(0.004)	(0.000)	(0.01)	(0.36)	(0.008)	(0.009)	0.82	27.70	0.6293	0.4738
LK	H	0.004	0.057	0.006	0.003	0.01	0.11	0.017	0.005	0.54	11.40	0.6000	0.6300
		(0.003)	(0.050)	(0.001)	(0.001)	(0.002)	(0.08)	(0.012)	(0.001)	0.59	5.35	0.2828	0.1556
SP	B	0.741	0.341	0.027	0.013	0.17	0.03	0.006	0.001	191.48	69.07	7.0533	2.6300
		(0.676)	(0.303)	(0.022)	(0.011)	(0.15)	(0.01)	(0.005)	(0.001)	157.32	35.12	4.8846	1.1458
SP	BS	0.211	0.169	0.010	0.008	0.13	0.05	0.006	0.002	59.47	46.34	2.8000	2.3500
		(0.065)	(0.055)	(0.002)	(0.003)	(0.04)	(0.01)	(0.001)	(0.0004)	10.98	21.78	0.8445	1.1953
SP	L	0.188	0.153	0.009	0.007	0.11	0.06	0.006	0.002	30.90	29.25	1.6367	1.2433
		(0.136)	(0.098)	(0.005)	(0.006)	(0.06)	(0.03)	(0.003)	(0.001)	15.46	12.80	0.6213	0.5332
SP	H	0.072	0.042	0.006	0.004	0.12	0.07	0.009	0.005	17.12	8.24	1.4300	0.8000
		(0.028)	(0.011)	(0.004)	(0.002)	(0.09)	(0.08)	(0.004)	(0.003)	12.75	3.73	1.1372	0.6349

BH - Beaverhead
HB - Heber
LK - Loco Knolls
SP - Springerville

distribution. As with the sediment yields, chemical yields are computed as yields (kg/ha) and as concentrations (kg/ha/mm).

A paired difference t-test was performed for each site to define differences between dry runs and wet runs. At Beaverhead and Heber, there were no differences in the chemical yields (total phosphorus, total nitrogen, or total volatile suspended solids) between dry runs and wet runs. At Springerville, the volatile solids yields were different, but not the total phosphorus or nitrogen yields. Total phosphorus concentrations were different at Beaverhead and Springerville. Total nitrogen concentrations were different only at Springerville. Total volatile suspended solids concentrations were different for dry and wet runs at all sites.

At Beaverhead, there were no significant differences in nitrogen or phosphorus concentrations from the different plot cover types for the dry or wet runs. The concentration of volatile suspended solids from dry and wet runs was significantly greater from the bare and bare-screened plots than from the natural cover plots. For the dry runs, there was significantly more total phosphorus yield from the bare and bare-screened plots than from the natural plots. On the wet runs, there was significantly more total phosphorus yield from the bare plots than from the natural plots. The bare plots had more total nitrogen yield than the natural plots for the dry runs and the bare and bare-screened plots had more total nitrogen yield than the natural plots on the wet run. The bare and bare-screened plots had significantly more volatile solids yield than the natural plots on wet and dry runs.

At Heber, for the dry runs, the total phosphorus concentrations and yields were significantly higher from the bare and bare-screened plots than from the natural plots. The volatile suspended solids concentration was greater from the bare-screened plots than from the natural plots and the total volatile suspended solids yield was significantly less from the natural plots compared to the bare and bare-screened plots at the $p = 0.05$ level. There were no statistical differences in chemical concentrations or yields from the different plot types for the wet runs at Heber.

There were no significant differences in chemical concentrations from the plot cover types at Loco Knolls for the dry runs. The total nitrogen concentration from the bare plots on the wet runs was significantly greater than from the bare-screened or natural plots. For the dry runs, total phosphorus yield and total volatile suspended solids yield were significantly greater from the bare plots than from the natural plots. The total nitrogen yields were different from all plot types for the dry runs. There were no significant differences in chemical yields from the plot cover types for the wet runs at Loco Knolls.

At Springerville, for the dry and wet runs, the concentration of total phosphorus was significantly greater from the bare plots than from the natural plots; there were not any statistical differences in total nitrogen concentration from the different plot cover types. For the dry runs, the bare plots had higher volatile suspended solids concentrations than the natural plots. For the wet runs, the bare plots and the bare-screened plots had greater volatile suspended solids concentrations than the natural plots. For wet and dry runs, the total phosphorus yields were significantly higher from the bare plots than the natural plots. There were no differences in total nitrogen yield for wet or dry runs among the plot cover types. For the dry runs, the bare plots had significantly greater yields of volatile suspended solids than the natural plots. For the wet runs, the bare and bare-screened plots had greater volatile suspended solids yields than the natural plots.

Chemical Concentrations and Yields - Among Sites. A least-squares means test was used to examine differences among sites. Analyses were conducted on wet runs and dry runs separately and compared scraped plots and natural vegetation plots separately. For dry, scraped plots, there were no differences among sites in either measurement of total phosphorus, yield or concentration. On the wet runs, the two total phosphorus measurements were different at Beaverhead and Springerville for the scraped plots. For the dry, natural plots, total phosphorus yield (kg/ha) was different at all sites except Beaverhead and Heber. Total phosphorus yield at Beaverhead from wet, natural plots was the same as Heber and Loco Knolls, and Loco Knolls was the same as Springerville. For total phosphorus concentration, dry runs and wet runs, Springerville was different from Beaverhead and Heber.

Total nitrogen yield (kg/ha) and concentration (kg/ha/mm) were significantly higher at Beaverhead than at Springerville for the dry and wet, scraped plots. Total nitrogen concentrations from dry, natural plots were statistically higher at Beaverhead than at Springerville. For the wet runs, total nitrogen concentrations were significantly higher at Beaverhead compared to Loco Knolls and Springerville. Total nitrogen yields from the dry, natural plots are significantly lower at Loco Knolls than from Beaverhead or Springerville. Beaverhead had significantly more total nitrogen yield than Springerville from the wet, natural plots.

The total volatile suspended solids yield was the same for both measures at all sites for the wet and dry, scraped runs. Heber was the same as Springerville and Beaverhead for volatile solids yield from dry, natural plots. Volatile solids concentrations from dry, natural plots were statistically the same for all sites. For wet, natural plots, volatile solids concentrations were different at Beaverhead and Heber. Total volatile suspended solids yield (kg/ha) from wet, natural plots was the same for all sites.

Spearman correlation analysis was done on the chemical yields to investigate relationships between the chemicals and site characteristics. A significance level of 0.01 was used in the analysis. Chemical yields were not significantly correlated with initial soil saturation. Therefore, subsequent analyses focused on dry and wet runs combined.

Total phosphorus yield was most strongly correlated with total sediment yield, the two components of total sediment yield (suspended and deposited yield) and total organic suspended sediment yield. It was inversely related to cryptogamic cover. Total phosphorus yield was also related to the same plot characteristics as was sediment yield.

Total nitrogen yield was correlated with total suspended sediment yield, total organic suspended sediment yield and total phosphorus yield. Total phosphorus yield and total nitrogen are tied closely to the amount of soil that washes off the plots. The higher the organic fraction of suspended sediment yield, the more phosphorus and nitrogen that are present. In addition, the organic fraction of the sediment yield was strongly correlated with total phosphorus, total nitrogen and total sediment yields.

Estimation of Parameters

The primary model parameters of steady-state infiltration rate (hydraulic conductivity), soil capillary suction, and raindrop splash/detachment coefficient were regressed against site and soil characteristics to determine if they could be estimated from the other measured variables. An appropriate model for the conductivity is:

$$\mathrm{Log}_{10} = 1.16 + 0.77\ \mathrm{Rga} - 0.01\ \mathrm{AMC} + 0.004\ \mathrm{Corg} \quad (r = 0.71) \qquad (3)$$

where Kw is the hydraulic conductivity in mm/hr, Rga is the plot roughness determined from all 150 point frame measurements, AMC is the antecedent soil moisture content in percent of dry soil weight, and Corg is the percent of organic ground cover (litter + cryptogams + basal) as measured with the point frame. The root mean squared error is 0.25 (log units) compared with the mean Kw value of 1.40 (log units) (= 25 mm/hr). Roughness and organic cover increase infiltration in that they act to retain or retard water on the plot and increase infiltration "opportunity". Basal cover, which is part of the total organic cover, is also positively correlated with porosity. Increases in porosity also lead to higher infiltration rates. The decrease in infiltration rate caused by an increase in soil moisture was observed at almost every plot, as discussed previously. Equation 3 supports that observation. The increase in soil moisture may cause changes in the clay fraction of the soil which result in a lowered infiltration rate. A wet soil also may have a lower conductivity to air, or capacity for air movement, which may reduce the infiltration rate. The hydraulic conductivity was negatively correlated with the clay fraction, but the correlation was not statistically significant. Effects of trapped air may be important, particularly in clay-rich soils, but no field measurements were taken to confirm this hypothesis. It would seem, however, that there would be sufficient escape routes for air through the plot boundaries so that the trapped air effect would be insignificant.

The capillary head is a much more difficult parameter to quantify as it is derived from the runoff data and other plot characteristics (soil moisture and porosity). An appropriate, but very poor, equation for capillary head is:

$$\mathrm{Log}(Yc) = -0.63 + 0.02\ Pg + 0.11\ Pm + 0.03\ AMC \quad (r = 0.37) \qquad (4)$$

where Yc is the capillary head in mm of water, Pg is the percent of gravel in the soil sample, Pm is the percent of silt in the soil sample, and AMC is the antecedent moisture content as defined previously. The presence of gravel in the equation is due to the relationship between gravel and some of the other soil characteristics. Percent silt and AMC more properly represent the soil conditions. The AMC is a spurious variable because it is used in computing the value of Yc from the original data. It is recommended that equation 4 not be used to estimate the capillary head in the soil, but as a guide to variable relationships.

A more useful relationship for estimating purposes is between hydraulic conductivity and the capillary head. Once the hydraulic conductivity is estimated from equations such as equation 3 or those presented by Rawls and Brakensiek (1985), then the capillary head can be estimated from a power equation between head and conductivity. Three equations were developed from different sources. For the data set obtained in this study, the power equation (log-log equation) is:

$$\mathrm{Log}(Yc) = 3.69 - 1.67\ \mathrm{Log}(Kw) \qquad (r = 0.53) \qquad (5)$$

where all terms were defined previously. Rawls, Brakensiek and Miller (1983) presented a table of Yc and Kw values for eleven soil types. Those values yielded a relationship of:

$$\mathrm{Log}(Yc) = 2.34 - 0.33\ \mathrm{Log}(Kw) \qquad (r = 0.94) \qquad (6)$$

Rawls and Brakensiek (1985) presented two complex equations relating Yc and Kw to different soil measures. For this study, a Monte Carlo generator was used to provide input to those equations. The resultant values were regressed to yield an equation for Yc as a function of Kw:

$$\mathrm{Log}(Yc) = 2.64 - 0.41\ \mathrm{Log}(Kw) \qquad (r = 0.93) \qquad (7)$$

All three equations are different from one another, but it should be noted that they all have the same form which confirms the belief that the capillary head should be inversely related to the hydraulic conductivity.

The final parameter estimated was the splash detachment/transport coefficient. The resultant equation for that coefficient was:

$$\mathrm{Log}(Dr) = -0.48 + 0.02\ Pg - 0.05\ Pf + 0.03\ AMC \qquad (8)$$
$$(r = 0.45)$$

where Dr is the detachment coefficient in $kg\text{-}hr/ha\text{-}mm^2$, Pg is the percent of gravel in the soil sample, Pf is the percent of fines in the soil sample, and AMC is the antecedent moisture content as defined previously. The presence of gravel in the equation is due to the relationship between gravel and cover on the plot. Soil porosity was also related to Dr but was excluded from the model because it was significantly correlated with most of the other cover measurements. Percent fines and AMC more properly represent the soil conditions. The AMC reflects the difference in sediment yields between dry and wet runs, while the fines represent the "cohesive" nature of the soil or its ability to resist erosion.

Point Frame Sampling

Cover percentages and "roughness" were measured using a twenty-five pin point frame as described in the methods section. This type of sampling is in contrast to that used in previous studies when the field crew made visual estimates of cover. Both techniques were used during this study so that the results could be compared.

Probably the most important cover estimate is the amount or fraction of bare ground exposed on the surface to potential erosion. During the sampling, only "hits" with the pin associated with the bare ground (soil) could be measured. Out of a total number of possible points, N, in the plot, there are only nb points of bare ground. The sample with the point frame takes n (=75) points, with x of these being bare ground. This sampling scheme leads to a hypergeometric distribution (Haan 1977) or:

$$fx = \frac{\binom{nb}{x}\binom{N - nb}{n - x}}{\binom{N}{n}} \qquad (9)$$

where fx is the probability of sampling x successes from n points given N possible points to sample with nb of those being successful (i.e. bare). The parentheses denote the binomial coefficient of the enclosed terms. The mean and variance of this distribution are:

$$E(x) = (n/N)\ nb \tag{10}$$

and

$$Var(x) = (n\ nb\ (N-nb)(N-n))/(N^2\ (N-1)) \tag{11}$$

where E(x) is the expected value (mean) of x and Var(x) is the variance (standard deviation squared) of x. If N is a large number, such as 1000 x 1000 points in a 1 square meter plot, and n and nb relatively small in comparison, then equations 10 and 11 are approximately:

$$E(x) = n\ p \tag{12}$$

and

$$Var(x) = n\ p\ q \tag{13}$$

where p is the probability of any one point being bare (fraction of the bare ground) and q (= 1-p) is the probability that the point is not bare. These are the mean and variance of a binomial distribution. This observation can be used to calculate the sampling error associated with computed cover percentages.

Equations 12 and 13 are entered into a Z transform and a Normal approximation to the binomial is employed. Because n = 75 from the point frame sample, it is possible to set confidence intervals and determine the possible range in values associated with those observations. If a 95% confidence interval is used and the actual fraction of bare ground is 0.5, then the number of points which could be counted while still remaining within the confidence interval ranges from 29 (39% cover based on a sample of 75 points) to 46 (61% cover). At the extremes, 95% cover or

95% bare, the range of counts is about 8 or 11% cover. Therefore, it can be concluded that the probable error in the point frame measurements will be about plus or minus 5 percent to 10 percent based on a confidence interval of 95%. This magnitude of error should be remembered in all of the analyses using point frame cover estimates.

In the field, one individual was responsible for visually estimating and recording cover from which the fraction of bare ground could be calculated. For selected plots, percent of cover and bare ground also was estimated from color photographs. Linear correlation was significant ($p < 0.05$ and $n = 14$) between point-frame and photograph estimates of vegetative cover, between field and photograph vegetative cover, and between point frame and field estimates of bare ground. The point frame measurements were on average lower for vegetative cover and, conversely, higher for bare ground compared to the field and photograph estimates. It appears that the point frame is a more precise measure of the percent of bare ground, but that the visual estimates may be as good an indicator of soil protection.

The measured and log-transformed values of point-frame and field estimated vegetative cover and bare soil ($n = 35$ and $n = 36$, respectively) were correlated and regressed. Correlations between the matched pairs were all significant ($p < 0.05$), with the log-transformed values yielding the higher correlations. Appropriate equations to relate the point frame and field estimated values were determined to be:

$$\mathrm{Log}(Pv+1.) = 1 + 0.47\ \mathrm{Log}(Vv+1.) \qquad (r = 0.65) \qquad (14)$$

and

$$\mathrm{Log}(Pb+1.) = 0.31 + 0.55\ \mathrm{Log}(Vb+1.) \qquad (r = 0.63) \qquad (15)$$

where Log( ) is base 10 logarithm of the enclosed value, Pv is the point frame measured vegetative cover (excluding litter and canopy), Vv is the visual estimate of vegetative cover (excluding litter), Pb is the point frame measured bare soil, and Vb is the calculated bare soil from visual estimates. The calculated bare soil is equal to 100 percent minus all visual estimates of vegetation, rock, gravel and litter cover. All cover values are in percent of plot coverage and should sum to 100 percent. A value of 1.0 has been added to each cover percentage to avoid taking the logarithm of zero. Note that the intercept value of 0.31 in equation 10 is not statistically different than 0.0 ($p = 0.10$), but is the best estimate of the intercept. Also note that the point frame values are related to about the square root of the visual estimates. Equations 14 and 15 should provide guidance when comparing point frame measurements with visual observations.

Comparison of Techniques for Estimating Total Suspended Solids

Ward and Bolin (1988) noted a difference between the suspended sediment concentrations measured using three different methods. The method used by them, and in this study, involves centrifuging a sample, drying the concentrated residue, and weighing it. A second method involves filtration of a sample through a micropore filter under a negative pressure gradient.

The third method, used by the ARS WEPP study team in Tucson, Arizona, is to dry the entire sample in the sample container to determine the weight of dry material to the total weight. A concern was raised by Ward and Bolin that the third method may be measuring dissolved solids which also precipitate out when the liquid is evaporated during drying.

During this study, a random sample of twenty-six bottles were collected from different plot runs. The sample bottles were weighed before being sent to the field. A laboratory electrical conductivity meter was used to estimate dissolved solid content in the full bottle. Then, the bottles were weighed with water and sediments/dissolved materials, dried, weighed with residue, cleaned and weighed without residue. The appropriate weights were used to determine the weight of water plus residue and just residue. The twenty-six random measurements were compared to the corresponding centrifuge and filtration samples. In addition, the filtration and centrifuge samples were compared.

In general, the bottle-dried samples produced higher calculated suspended sediment concentrations than did the other two methods. The centrifuge samples provided lower values than the filtered samples. The average ratio of filtered sample suspended sediment concentration to centrifuge concentration was 1.25 (n = 107). The average ratio of bottle-dried to centrifuge sample concentrations was 1.93 (n = 26), if the dissolved solid content is ignored, and 1.46 if the dissolved concentration is considered. The average ratio of bottle-dried to filtered sample concentrations was 1.17, which is not significantly different from the expected value of 1.0. It appears that the centrifuge samples yield lower values than the other measurement methods. This may be a result of technique, whereby some of the heavier sediments settle out of suspension before the centrifuge bottle can be filled; therefore, the centrifuge sample is a bit lower in sediment. Appropriate linear models were investigated to find conversion formulas between centrifuge concentrations and the other two techniques. These equations are:

$$\text{Log}(Fs) = 0.05 + 1.01\,\text{Log}(Cs) \qquad (r = 0.94), \qquad (16)$$

$$Bs = -115 + 1.58\,Cs \qquad (r = 0.92), \qquad (17)$$

and

$$\text{Log}(Bs) = -0.14 + 1.06\,\text{Log}(Fs) \qquad (r = 0.91) \qquad (18)$$

where Fs is the sediment concentration from the filtration technique (all concentrations in mg/L), Cs is the concentration from the centrifuge technique, and Bs is the concentration from the dried bottle technique (after correction for dissolved solids calculated from conductivity). The intercept values of 0.05, -115, and -0.14 in equations 16 through 18, respectively, are not significantly different than 0.0, but are the best estimates of the intercepts. **For this report, filtered sediment concentrations were used in the analyses.**

Summary

One hundred and eight plot runs using a small simulator were conducted at four pinyon-juniper sites in New Mexico and Arizona.

A tremendous amount of data was gathered and analyzed. Information was developed for rainfall rate, runoff rate, types and percent of ground cover, surface roughness and slope of the sampled plots, soil particle size gradation, soil water content, soil porosity, sediment yield, infiltration parameters, erosion parameters, and water chemistry. The analyses presented here compared site characteristics, how the sites responded to simulated rainfall, how different plots at a site responded to the rainfall simulation, and how derived parameters related to site characteristics. The data base developed during this study will provide information for better land management practices in the pinyon-juniper zones of the Southwest.

CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this study was to determine infiltration and soil erosion parameters for a variety of soil-vegetation complexes in the PJ vegetation zone of western New Mexico and eastern Arizona. Rainfall simulation on small area (1 meter by 1 meter) plots was used to collect the necessary runoff data from which the parameters of interest could be derived. A total of 108 plot runs were conducted at four sites on plots which had natural cover, were scraped bare, or were scraped bare then covered with window screening before the experiment began. Infiltration and erosion responses of the plots are different depending on whether the plot had been rained upon previously in a prior experiment. On average, the "wet" plot runs had significantly lower infiltration rates (hydraulic conductivities) and significantly lower sediment concentrations than the "dry" plot runs. Total sediment yields per unit area were not significantly different between the dry and wet runs. Infiltration rates increased and sediment yields decreased as the amount of surface or ground cover on the plot increased. The average dry run infiltration rates for the plots with natural cover was 50 mm/hr. The average for the dry run scraped bare plots was 16 mm/hr, and for the scraped bare with screen plots, it was 35 mm/hr. For the same plots with the wet runs, the averages were 28, 12, and 18, respectively. Sediment yields reported as kg/hectare-mm of runoff (concentration-like units) were, for the dry runs on the plots, 58.7, 77.4, and 59.5, for the natural cover, scraped, and screen covered plots respectively; and for the wet runs, 36.9, 95.2, and 50.7, respectively.

The steady-state infiltration rate can be modeled as a function of ground cover, surface roughness, and soil moisture at the beginning of rainfall. Models for capillary head in the soil and for the rainfall splash detachment (erosion/transport) coefficient were not as good as for infiltration rate. These two parameters were related, however, to similar variables of percent gravel in the soil, percent of fines or silt in the soil, and antecedent soil moisture condition.

Three techniques for measurement of suspended sediment concentration were used then compared in this study. Results show that although the methods provide highly correlated results, the answers are different. A review of current measurement techniques is planned in light of these analyses.

A different technique for estimating the density of ground cover was used in this study as compared to previous studies with the small simulator. A point frame was utilized to measure cover and surface roughness at 75 and 150 points, respectively, on the plots. The cover estimates were compared with visual observations and estimates from photographs of the plots. The point frame and visual estimates were strongly correlated, but were different, for the key estimates of percent vegetative cover and percent of bare soil. In general, the point frame estimates are lower than visual observations for the cover, but higher for the amount of bare soil. Because the point frame requires a significant measurement and analysis time, further use of the technique should be carefully considered.

Numerous water quality samples were collected during the simulations to determine the magnitude of phosphorus, nitrogen, and volatile suspended solids, which might run off during rainfall. Results indicate, as in previous studies, that phosphorus and organic suspended solids are strongly related to the inorganic sediment yields. Nitrogen was significantly correlated with phosphorus, and organic and inorganic suspended solids.

Considering the results of this study, the following topics for further investigations are suggested:

1) Evaluate the continued use of the point frame as a practical technique for estimating cover and roughness when compared to visual cover estimates.
2) Investigate why the different suspended sediment measurement techniques provide such different answers.
3) Investigate the development of a more portable nozzle stand so the simulator can be more remote from the water supply trailer.
4) Conduct additional experiments on the same plots/sites during the coming field season to determine if there is a yearly variation or if there is an impact effect from rainfall applied in this study.

In conclusion, this study provided a tremendous amount of information that illustrated the similarities and differences between various sites in the pinyon-juniper vegetation zone of western New Mexico and eastern Arizona.

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APPENDICES

Appendix A. Field and Laboratory Procedures for Small Simulator Experiments

The following standardized procedures have been developed for collecting and processing data from the small plot rainfall simulator. These procedures are followed except as modified for specific needs.

Data are collected using a modified Purdue simulator (Seiger 1984) mounted on a 4.9 meter (16 feet) long trailer. A pair of nozzles is mounted on two separate booms, one boom on either side of the trailer. At each parking spot, it is possible to collect simultaneously two samples from the one square meter (10 square feet) target shape with one side driven flush with the soil surface. That side is where runoff exits the plot, enters a collection trough and is sampled with a small aquarium pump. Water is delivered simultaneously to both booms by a pump and water tank mounted on the trailer. First a dry run, then a wet run, is conducted as described by the following sequence.

DRY RUN

1. Select site and fill in general information on sample (data) sheet.
2. Initially position one square meter plot frames.
3. Position trailer carrying rainfall simulator so that it covers the plots as desired.
4. Install plot frames with trench for collection trough.
5. Repair disturbed edges of soil with gravel and water as needed.
6. Take pictures of the plots and estimate cover.

7. Connect suction pumps to troughs.
8. Collect soil moisture and density samples from top five cm of surface in a 2 inch internal diameter sampling tube. Collect on outside edge of plot frame. Put in soil cans, label and seal.
9. Place impervious rainfall collection cover on plot.
10. Install rain gages.
11. Install wind screens as needed.
12. Begin rainfall.
13. Measure rainfall rate using runoff from impervious cover.
14. Remove cover.
15. Note times of ponding and runoff into the trough.
16. Pump troughs as necessary (every one to five minutes).
17. Record pumped volume and save sample in barrel.
18. Rain for 25 to 45 minutes until a steady-state runoff is achieved.
19. Replace cover and again measure rainfall rate.
20. Stop rain and pump trough a final time, then drain pump and hoses into collection barrel.
21. Measure depths in barrels.
22. Agitate barrels and collect a quart jar of water and sediment. Label the jars as to site and run. These samples are for the analysis of total suspended solids.
23. At selected representative sites, agitate barrels and collect two, 250 ml samples of water and sediment. Preserve one of the 250 ml samples with sulfuric or hydrochloric acid and place both 250 ml samples in an ice chest. (These samples are for the analysis of phosphorus, nitrogen, and organic solids).

24. At selected sites, fill a 500 ml plastic bottle after agitating the barrel. These samples are for the oven-dry technique of measuring suspended solids.

25. Remove deposited material from runoff trough and runoff tray (metal flume between plot and trough). Bag material in plastic sealable bags and label.

26. Record rain gage depths.

27. Measure depth to wetted front on outside edge of plot.

28. Measure surface roughness and cover with point frame.

29. Cover plot with plastic sheet, plywood, and dirt until wet run.

30. Collect two 250 ml samples of the rainwater from the trailer after the water has passed through the filters, usually from impervious runoff tray. Treat as in Step 23.

<u>WET RUN</u> (12 to 24 hours later)

31. Repeat steps 8 to 30 above as necessary except rain for a minimum of 20 minutes or until steady runoff is observed.

32. Measure slope in plot with a Brunton compass.

33. Remove about 1 kilogram of soil for sieve analysis from the center of the plot (destructive sampling) or from an undisturbed area near the plot (nondestructive sampling).

Samples of water, sediment, and soil are transferred along with sample sheets.

Once the data sheets and field samples are returned to New Mexico State University, they are measured and analyzed for several basic items including:

1. Rainfall depth and duration.

2. Total runoff.
3. Suspended sediment concentration and yield.
4. Deposited sediment yield.
5. Final infiltration rate.
6. Infiltration parameters.
7. Soil moisture and porosity.
8. Depth to wetted front.
9. Soil particle size distribution.
10. Percent and type of cover.
11. Erosion parameters.

Suspended solid samples are centrifuged in a Beckman J2-21 centrifuge. After centrifuging, the water is poured out of the bottles into preweighed dishes. Distilled water is used to wash all of the soil particles out of the bottle into the sample dish. The dish and soil is dried in a 105 degree C oven for 24 hours then weighed again. Since a known volume of sample was centrifuged, and the weight of soil in the sample is known, the concentration of total suspended solids can be computed. When water chemistry samples are collected, those samples are filtered and sediment concentrations are computed. The oven dry bottles are weighed and then dried in a 100 degree C oven until the water has evaporated and then reweighed. When this is done, the three types of measurements are compared. The techniques provide slightly different, but comparable results.

The samples in the 250 ml bottles are taken to the Soil and Water Testing Laboratory at NMSU. The samples are analyzed on auto-analyzing equipment for total phosphorus, total Kjeldahl nitrogen, nitrate-nitrite, and organic suspended solids. Cover estimates from the field are checked with photographs of the plots. Soil moisture is measured following procedures found in USGS (1977). Soil gradation is determined on a split sample following ASTM specifications D421-58 and D422-63. Bulk density is measured from oven dried weights of measured cores.

Cover and "roughness" measurements were collected using a point frame device. The point frame consisted of twenty-five small metal rods spaced approximately 3.8 cm apart. The rods were suspended from a 1 m long frame which rested on the plot borders. For cover measurements, two "hits" for each rod were recorded, a hit of vegetation above the ground surface (canopy) and a ground hit. Canopy hits were recorded as shrub, grass or forb. Ground hits were classified as basal vegetation, cryptograms, soil (less than 5mm particle size), gravel (less than 20mm), rock (greater than 20mm), persistent litter or non-persistent litter. Three measurements across the plot, spaced about 25 cm apart, were made for vegetation. Average cover for each category was computed as the number of hits out of seventy-five possible hits.

For roughness, the same frame was used. Six measurements were made, three down the plot and three across the plot. A backboard to the point frame with horizontal lines across it was used to estimate the height of each rod after it was carefully placed on the ground. The standard deviation of the heights of the rods was used as the roughness measure. Mean standard deviations were computed for each line, for the three lines across the plot, for the three lines down the plot, and for all six lines. In the analyses, the mean standard deviations across the plot, down the plot and for all six lines were used.

A battery-powered video camcorder was used to make a visual record of how plots behave under rainfall simulation. Video tapes were made of the general experimental sites to get a broad view of the area. Rainfall simulations showing how plots respond to applied rainfall were also taped.

The primary hydrologic parameters that can be derived from the field and the analyzed data include final infiltration rate, the Green-Ampt parameters of hydraulic conductivity and capillary suction head, and a rainfall splash/transport coefficient. Approaches for determining the desired parameters have previously been used by Ward (1986a and 1986b) and will be employed in this study. The techniques for determining the hydrologic parameters are detailed in the following paragraphs.

The Green-Ampt infiltration model can be rewritten as:

$$f = Kw \frac{(F + Hc)}{F} \qquad (A1)$$

where f is infiltration rate. Hc is a grouping of soil parameters which is computed as the difference between final and initial soil saturation times the porosity times the capillary suction head. F is the infiltrated volume, and Kw is hydraulic conductivity. Using rainfall simulator data, the following method can be used to obtain estimates of hydraulic conductivity, Kw, and capillary suction head, Yc.

1. Plot the infiltration rate and infiltrated volume as a function of time. The infiltration rate is the measured rainfall rate minus the measured runoff rate, in inches per hour.

2. Plot the infiltration rate versus the reciprocal of the infiltrated volume using the curves plotted in step 1 of the procedure.

3. The curve of infiltration rate as a function of the reciprocal of infiltrated volume is nearly a straight line, to the extent that the Green-Ampt equation represents the actual soil process. If a straight line is fitted to these data (excluding the first point and the last point as they include rainfall simulator operation and non-infiltration effects), then the y-intercept is Kw and the slope is (Kw)(Hc). Thus estimates of Kw and Yc can be obtained by measuring the slope and intercept of the line fit to the data.

This approach does not always work as negative intercepts can be obtained which do not have a physical interpretation. Therefore, this alternative approach is suggested :

1. Plot and examine the data as suggested in the first approach.
2. Use an average infiltration rate calculated from the last three steady rate values. This average value is assumed to be Kw.
3. Calculate a revised set of data pairs as $y = (f - Kw)/Kw$ and $x = 1/F$. Note that the first data point is not used since it represents an amount of water that has been infiltrated and intercepted. The last data point is excluded also from the analysis because it represents water that was on the soil surface and ran off after the rainfall stopped.
4. Fit a no-intercept straight line to the revised data (a no-intercept line passes through the data point (0,0)). The slope of this line is (Kw)(Hc).

Both approaches are suggested as a method of obtaining the necessary soil hydrologic characteristics. The standard approach should be used first, then if the intercept Kw is negative, the time approach should be used.

A rainfall erosion/transport (detachment) coefficient can be derived from rainfall simulation data. This coefficient is used as a measure of sediment supply. The coefficient is determined from the following equation:

$$Dr = Y/(I^2 \, t \, Ab) \tag{A2}$$

where Dr is the detachment coefficient, Y is the sediment yield, I is the rainfall intensity, t is the duration of rainfall on the plot, and Ab is the fraction of the plot soil which is exposed to the rainfall, i.e. has no cover. The detachment coefficient is dimensional depending on the units used to derive it. The rainfall splash detachment coefficient is a function of soil type, soil structure, moisture conditions, and cohesion.

The measured and derived data and parameters are subjected to a wide variety of statistical tests. As a first step, the data are subjected to a frequency distribution analysis to determine the form of their distribution curves (normal, log-normal, etc.). This enables a more appropriate selection of parametric or non-parametric tests for later analyses. Correlation analyses is performed on the original and transformed data to check for anticipated and spurious correlations. Paired difference t-tests are run on the variables using the dry and wet data sets as the different experiments on the same subject (plot). An appropriate ANOVA is run among the sites on selected variables to determine site/soil differences. Multiple regression analyses are performed on the hydrologic parameters in order to relate them to soil and site characteristics. Statistical analyses and practical considerations will help in determination of which type of equation should be used for predictive purposes.

Appendix B. Physical Characteristics of Each Plot.

SITE	COVER	INITIAL WATER CONTENT % DRY	INITIAL WATER CONTENT % WET	SLOPE %	POROSITY %	ORGANIC COVER %	TOTAL COVER %	Grain Size Analysis GRAVEL %	Grain Size Analysis SAND %	Grain Size Analysis SILT %	Grain Size Analysis CLAY %
BH 1-E	L	3.2	27.2	2.0	38.5	42.7	56.0	14.0	64.9	19.0	2.1
BH 1-O	B	3.2	27.2	3.0	38.5	.	.	14.0	64.9	19.0	2.1
BH 2-E	H	2.8	25.0	.	36.4	54.7	65.3	19.1	69.3	10.2	1.4
BH 2-O	L	2.8	25.0	4.0	36.4	72.0	76.0	19.1	69.3	10.2	1.4
BH 3-E	B	5.2	25.7	.	42.3	.	.	17.4	65.6	15.2	1.8
BH 3-O	H	5.2	25.7	.	42.3	52.0	73.3	17.4	65.6	15.2	1.8
BH 4-E	B	1.8	24.4	4.0	41.9	.	.	25.0	61.8	11.6	1.7
BH 4-O	BS	1.8	24.4	4.5	41.9	.	.	25.0	61.8	11.6	1.7
BH 5-E	H	2.9	16.8	.	35.8	69.3	92.0	29.9	57.2	11.1	1.8
BH 5-O	H	2.9	16.8	3.3	35.8	56.0	65.3	29.9	57.2	11.1	1.8
BH 6-E	L	1.9	20.3	2.0	42.3	32.0	85.4	24.1	62.3	11.9	1.8
BH 6-O	L	1.9	20.3	2.0	42.3	38.7	80.0	24.1	62.3	11.9	1.8
BH 7-E	L	2.9	18.1	3.5	45.3	30.7	90.7	26.9	64.0	8.0	1.2
BH 7-O	H	2.9	18.1	3.0	45.3	74.7	94.7	26.9	64.0	8.0	1.2
BH 8-E	H	2.3	18.8	4.0	40.0	38.7	80.0	32.0	58.2	8.8	1.0
BH 8-O	BS	2.3	18.8	2.0	40.0	.	.	32.0	58.2	8.8	1.0
BH 9-E	BS	2.3	17.8	3.5	47.4	.	.	29.5	60.1	9.0	1.4
BH 9-O	L	2.3	17.8	1.5	47.4	30.7	85.3	29.5	60.1	9.0	1.4
HB 1-E	L	1.1	7.8	2.5	23.9	12.0	36.0	57.5	34.3	7.0	1.2
HB 1-O	H	1.1	7.8	3.0	23.9	45.3	77.3	57.5	34.3	7.0	1.2
HB 2-E	B	0.8	16.1	3.0	35.9	.	.	38.9	48.2	11.2	1.7
HB 2-O	H	0.8	16.1	3.0	35.9	80.0	86.7	38.9	48.2	11.2	1.7
HB 3-E	BS	1.1	11.4	2.0	25.8	.	.	50.3	39.1	9.5	1.1
HB 3-O	L	1.1	11.4	3.5	25.8	16.0	66.7	50.3	39.1	9.5	1.1
HB 4-E	H	2.6	15.1	2.0	68.3	17.3	57.3	35.3	51.4	12.3	1.1
HB 4-O	BS	2.6	15.1	2.5	68.3	.	.	35.3	51.4	12.3	1.1
HB 5-E	L	0.6	13.9	3.5	12.1	22.7	57.3	42.0	46.6	10.3	1.1
HB 5-O	B	0.6	13.9	3.5	12.1	.	.	42.0	46.6	10.3	1.1
HB 6-E	H	1.3	9.6	1.0	20.5	22.7	54.7	39.8	48.1	10.7	1.4
HB 6-O	L	1.3	9.6	1.5	20.5	60.0	78.7	39.8	48.1	10.7	1.4
LK 1-E	BS	4.7	30.6	3.0	67.3	.	.	18.3	71.9	8.3	1.5
LK 1-O	B	4.7	30.6	3.0	67.3	.	.	18.3	71.9	8.3	1.5
LK 2-E	H	4.2	35.9	3.0	51.6	52.0	74.7	31.1	60.3	7.1	1.5
LK 2-O	L	4.2	35.9	4.0	51.6	52.0	66.7	31.1	60.3	7.1	1.5
LK 3-E	H	4.0	26.5	3.0	52.8	58.7	78.7	25.4	65.5	7.8	1.3
LK 3-O	L	4.0	26.5	3.0	52.8	53.3	68.0	25.4	65.5	7.8	1.3
SP 1-E	L	4.0	20.0	7.0	56.6	34.7	57.3	33.5	58.4	6.8	1.3
SP 1-O	L	4.0	20.0	7.0	56.6	28.0	57.3	33.5	58.4	6.8	1.3
SP 2-E	B	4.0	20.0	6.5	56.6	.	.	29.6	62.6	6.5	1.2
SP 2-O	BS	4.0	20.0	5.0	56.6	.	.	29.6	62.6	6.5	1.2
SP 3-E	H	4.0	18.6	3.5	44.6	50.7	60.0	28.3	63.4	7.4	0.9
SP 3-O	H	4.0	18.6	6.0	44.6	42.7	60.0	28.3	63.4	7.4	0.9
SP 4-E	H	5.9	19.7	7.0	47.1	94.7	94.7	35.4	57.8	5.6	1.2
SP 4-O	L	5.9	19.7	7.0	47.1	10.7	69.3	35.4	57.8	5.6	1.2
SP 5-E	BS	3.0	22.7	4.0	53.1	.	.	36.9	55.9	5.8	1.4
SP 5-O	B	3.0	22.7	5.0	53.1	.	.	36.9	55.9	5.8	1.4
SP 6-E	L	1.8	21.0	4.0	33.5	36.0	46.7	33.8	56.4	8.6	1.2
SP 6-O	H	1.8	21.0	5.0	33.5	90.7	92.0	33.8	56.4	8.6	1.2
SP 7-E	H	4.0	20.0	2.0	56.6	40.0	42.7	9.1	82.8	6.8	1.3
SP 7-O	L	4.0	20.0	1.5	56.6	40.0	52.0	9.1	82.8	6.8	1.3
SP 8-E	B	3.8	27.4	3.0	66.7	.	.	8.9	82.3	7.6	1.2
SP 8-O	BS	3.8	27.4	5.0	66.7	.	.	8.9	82.3	7.6	1.2
SP 9-E	H	3.4	20.8	5.0	62.4	68.0	73.3	29.1	63.5	6.6	0.8
SP 9-O	L	3.4	20.8	7.0	62.4	44.0	65.3	29.1	63.5	6.6	0.8

L = low cover; B = bare; BS = bare with screen; H = high cover
BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville.

Appendix C. Plot Rainfall-Runoff Characteristics

SITE	AMC	INTENSITY	DURATION	RAINMM	RUNMM	RORAIN
BH 1 E	DRY	102.1	42.25	71.9	33.6	0.467
BH 1 O	DRY	94.3	23.38	36.8	17.5	0.476
BH 2 E	DRY	87.9	48.25	70.7	10.3	0.146
BH 2 O	DRY	83.5	43.28	60.2	19.3	0.320
BH 3 E	DRY	84.6	46.42	65.4	36.7	0.561
BH 3 O	DRY	84.1	59.17	82.9	10.4	0.125
BH 4 E	DRY	85.2	34.25	48.6	24.2	0.498
BH 4 O	DRY	86.2	32.17	46.2	21.1	0.457
BH 5 E	DRY	87.0	38.83	56.3	10.6	0.188
BH 5 O	DRY	86.4	38.38	55.3	1.4	0.025
BH 6 E	DRY	78.2	50.25	65.5	14.2	0.217
BH 6 O	DRY	86.9	45.12	65.3	2.3	0.035
BH 7 E	DRY	78.9	68.17	89.6	33.9	0.378
BH 7 O	DRY	83.1	70.25	97.3	18.8	0.193
BH 8 E	DRY	78.2	41.08	53.5	5.9	0.110
BH 8 O	DRY	86.7	34.00	49.1	26.9	0.548
BH 9 E	DRY	89.3	36.85	54.8	13.6	0.248
BH 9 O	DRY	79.2	38.42	50.7	13.0	0.256
BH 1 E	WET	79.7	16.28	21.6	14.9	0.690
BH 1 O	WET	82.8	15.30	21.1	15.2	0.720
BH 2 E	WET	80.5	20.33	27.3	12.7	0.465
BH 2 O	WET	87.4	18.70	27.2	13.6	0.500
BH 3 E	WET	90.6	28.22	42.6	30.1	0.707
BH 3 O	WET	84.1	31.97	44.8	23.9	0.533
BH 4 E	WET	88.7	27.33	40.4	29.6	0.733
BH 4 O	WET	83.1	46.00	63.7	37.9	0.595
BH 5 E	WET	83.1	31.03	43.0	13.9	0.323
BH 5 O	WET	82.3	28.42	39.0	3.8	0.097
BH 6 E	WET	83.5	34.67	48.2	37.1	0.770
BH 6 O	WET	81.1	34.45	46.6	18.0	0.386
BH 7 E	WET	79.7	31.50	41.8	26.2	0.627
BH 7 O	WET	82.5	46.85	64.4	42.2	0.655
BH 8 E	WET	82.5	85.83	118.0	11.7	0.099
BH 8 O	WET	81.0	24.33	32.8	26.7	0.814
BH 9 E	WET	83.9	28.58	40.0	25.5	0.638
BH 9 O	WET	92.3	24.78	38.1	16.0	0.420
HB 1 E	DRY	82.0	41.92	57.3	11.1	0.194
HB 1 O	DRY	82.9	39.68	54.8	14.6	0.266
HB 2 E	DRY	93.3	25.60	39.8	25.7	0.646
HB 2 O	DRY	86.4	31.72	45.7	13.5	0.295
HB 3 E	DRY	90.8	29.50	44.6	28.9	0.648
HB 3 O	DRY	79.6	34.10	45.2	11.2	0.248
HB 4 E	DRY	82.2	29.75	40.8	6.8	0.167
HB 4 O	DRY	106.2	32.53	57.6	34.3	0.595
HB 5 E	DRY	83.4	58.55	81.4	22.6	0.278
HB 5 O	DRY	89.9	38.52	57.7	37.0	0.641
HB 6 E	DRY	82.3	38.00	52.1	8.5	0.163
HB 6 O	DRY	90.7	21.73	32.9	8.4	0.255
HB 1 E	WET	80.5	19.67	26.4	14.5	0.549
HB 1 O	WET	82.7	26.63	36.7	20.4	0.556
HB 2 E	WET	93.6	18.50	28.9	24.7	0.855
HB 2 O	WET	84.0	21.32	29.8	9.1	0.305
HB 3 E	WET	83.4	16.50	22.9	23.6	1.031
HB 3 O	WET	87.3	26.10	38.0	24.2	0.637
HB 4 E	WET	85.7	20.00	28.6	11.6	0.406
HB 4 O	WET	86.3	22.42	32.2	15.0	0.466

INTENSITY=rainfall intensity in mm/hr; DURATION= duration of rainfall in minutes; RAINMM=rainfall in mm; RUNMM=runoff in mm; RORAIN=runoff/rainfall; AMC=antecedent soil moisture condition.

Appendix C. (cont.)

SITE	AMC	INTENSITY	DURATION	RAINMM	RUNMM	RORAIN
HB 5 E	WET	85.5	26.75	38.1	25.8	0.677
HB 5 O	WET	90.6	20.28	30.6	24.9	0.814
HB 6 E	WET	82.5	21.83	30.0	12.8	0.427
HB 6 O	WET	90.7	50.35	76.1	33.8	0.444
LK 1 E	DRY	79.7	42.38	56.3	11.5	0.204
LK 1 O	DRY	86.1	51.70	74.2	35.6	0.480
LK 2 E	DRY	80.7	43.93	59.1	0.3	0.005
LK 2 O	DRY	85.9	37.63	53.9	1.1	0.020
LK 3 E	DRY	90.4	36.25	54.6	1.2	0.022
LK 3 O	DRY	92.1	32.47	49.8	0.9	0.018
LK 1 E	WET	82.4	21.50	29.5	15.9	0.539
LK 1 O	WET	91.9	16.57	25.4	20.0	0.787
LK 2 E	WET	94.4	32.92	51.8	29.2	0.564
LK 2 O	WET	90.7	37.97	57.4	35.2	0.613
LK 3 E	WET	83.1	31.25	43.3	10.3	0.238
LK 3 O	WET	96.6	53.02	85.4	24.3	0.284
SP 1 E	DRY	93.8	28.75	44.9	23.8	0.530
SP 1 O	DRY	92.5	31.05	47.9	17.8	0.372
SP 2 E	DRY	80.8	34.78	46.8	25.7	0.549
SP 2 O	DRY	78.5	43.85	57.4	19.7	0.343
SP 3 E	DRY	86.6	39.17	56.5	9.5	0.168
SP 3 O	DRY	79.6	53.33	70.8	6.8	0.096
SP 4 E	DRY	80.1	27.42	36.6	19.5	0.533
SP 4 O	DRY	89.9	31.02	46.5	20.7	0.445
SP 5 E	DRY	86.6	35.25	50.9	26.1	0.513
SP 5 O	DRY	78.6	35.32	46.3	22.0	0.475
SP 6 E	DRY	73.1	29.00	35.3	15.2	0.431
SP 6 O	DRY	76.6	32.65	41.7	9.3	0.223
SP 7 E	DRY	93.6	44.67	69.7	30.3	0.435
SP 7 O	DRY	90.4	31.08	46.8	9.5	0.203
SP 8 E	DRY	85.1	35.83	50.8	29.4	0.579
SP 8 O	DRY	89.3	44.58	66.4	19.9	0.300
SP 9 E	DRY	82.1	27.33	37.4	10.9	0.291
SP 9 O	DRY	89.2	49.88	74.2	27.4	0.369
SP 1 E	WET	81.0	34.08	46.0	32.1	0.698
SP 1 O	WET	88.5	26.23	38.7	27.9	0.721
SP 2 E	WET	89.1	24.42	36.3	27.1	0.747
SP 2 O	WET	79.4	27.90	36.9	18.7	0.507
SP 3 E	WET	87.6	17.50	25.5	5.1	0.200
SP 3 O	WET	82.2	18.27	25.0	7.9	0.316
SP 4 E	WET	80.1	23.92	31.9	19.1	0.599
SP 4 O	WET	78.6	21.73	28.5	18.8	0.660
SP 5 E	WET	94.1	20.12	31.5	22.0	0.698
SP 5 O	WET	84.7	19.73	27.9	21.2	0.760
SP 6 E	WET	86.6	24.50	35.4	24.1	0.681
SP 6 O	WET	82.1	31.65	43.3	12.9	0.298
SP 7 E	WET	89.0	24.00	35.6	19.4	0.545
SP 7 O	WET	89.5	26.45	39.5	22.5	0.570
SP 8 E	WET	92.2	23.87	36.7	28.6	0.779
SP 8 O	WET	85.2	22.88	32.5	20.0	0.615
SP 9 E	WET	90.9	28.42	43.1	17.8	0.413
SP 9 O	WET	88.1	23.78	34.9	18.6	0.533

INTENSITY=rainfall intensity in mm/hr; DURATION= duration of rainfall in minutes; RAINMM=rainfall in mm; RUNMM=runoff in mm; RORAIN=runoff/rainfall; AMC=antecedent soil moisture condition.

Appendix D. Sediment Yields from the Plots

SITE	AMC	INTENSITY (mm/hr)	RUNOFF (mm)	SUSPENDED SEDIMENT (kg/ha)	SUSPENDED SEDIMENT (kg/ha/mm)	DEPOSITS (kg/ha)	DEPOSITS (kg/ha/mm)	TOTAL SEDIMENT (kg/ha/mm)
BH 1 E	DRY	102.1	33.6	274.5	8.2	262.5	7.8	16.0
BH 1 O	DRY	94.3	17.5	385.7	22.0	702.7	40.2	62.2
BH 2 E	DRY	87.9	10.3	79.5	7.7	140.9	13.7	21.4
BH 2 O	DRY	83.5	19.3	154.8	8.0	974.3	50.5	58.5
BH 3 E	DRY	84.6	36.7	492.2	13.4	818.8	22.3	35.7
BH 3 O	DRY	84.1	10.4	37.8	3.6	230.7	22.2	25.8
BH 4 E	DRY	85.2	24.2	442.9	18.3	215.5	8.9	27.2
BH 4 O	DRY	86.2	21.1	520.1	24.6	336.6	16.0	40.6
BH 5 E	DRY	87.0	10.6	114.8	10.8	203.6	19.2	30.0
BH 5 O	DRY	86.4	1.4	12.4	8.8	86.0	61.4	70.3
BH 6 E	DRY	78.2	14.2	57.6	4.0	296.3	20.9	24.9
BH 6 O	DRY	86.9	2.3	23.9	10.4	120.3	52.3	62.7
BH 7 E	DRY	78.9	33.9	51.5	1.5	302.3	8.9	10.4
BH 7 O	DRY	83.1	18.8	51.7	2.8	390.0	20.7	23.5
BH 8 E	DRY	78.2	5.9	12.9	2.2	194.9	33.0	35.2
BH 8 O	DRY	86.7	26.9	254.5	9.5	228.1	8.5	17.9
BH 9 E	DRY	89.3	13.6	192.0	14.1	95.1	7.0	21.1
BH 9 O	DRY	79.2	13.0	51.4	4.0	81.9	6.3	10.2
BH 1 E	WET	79.7	14.9	113.1	7.6	190.2	12.8	20.4
BH 1 O	WET	82.8	15.2	270.9	17.8	531.2	35.0	52.8
BH 2 E	WET	80.5	12.7	68.4	5.4	165.3	13.0	18.4
BH 2 O	WET	87.4	13.6	108.8	8.0	625.6	46.0	54.0
BH 3 E	WET	90.6	30.1	138.8	4.6	556.2	18.5	23.1
BH 3 O	WET	84.1	23.9	50.4	2.1	241.3	10.1	12.2
BH 4 E	WET	88.7	29.6	606.2	20.5	762.1	25.7	46.2
BH 4 O	WET	83.1	37.9	695.1	18.3	542.3	14.3	32.6
BH 5 E	WET	83.1	13.9	78.0	5.6	382.8	27.5	33.1
BH 5 O	WET	82.3	3.8	14.2	3.7	102.8	27.1	30.8
BH 6 E	WET	83.5	37.1	92.8	2.5	767.1	20.7	23.2
BH 6 O	WET	81.1	18.0	59.4	3.3	341.5	19.0	22.3
BH 7 E	WET	79.7	26.2	46.4	1.8	410.6	15.7	17.4
BH 7 O	WET	82.5	42.2	105.5	2.5	483.7	11.5	14.0
BH 8 E	WET	82.5	11.7	53.2	4.6	410.1	35.0	39.6
BH 8 O	WET	81.0	26.7	185.6	7.0	825.9	30.9	37.9
BH 9 E	WET	83.9	25.5	148.9	5.8	170.5	6.7	12.5
BH 9 O	WET	92.3	16.0	62.7	3.9	436.2	27.3	31.2
HB 1 E	DRY	82.0	11.1	52.8	4.8	768.2	69.2	74.0
HB 1 O	DRY	82.9	14.6	98.0	6.7	732.1	50.1	56.9
HB 2 E	DRY	93.3	25.7	506.6	19.7	1192.4	46.4	66.1
HB 2 O	DRY	86.4	13.5	186.8	13.8	476.0	35.3	49.1
HB 3 E	DRY	90.8	28.9	520.5	18.0	557.4	19.3	37.3
HB 3 O	DRY	79.6	11.2	145.2	13.0	751.6	67.1	80.1
HB 4 E	DRY	82.2	6.8	47.3	7.0	637.2	93.7	100.7
HB 4 O	DRY	106.2	34.3	2310.8	67.4	264.8	7.7	75.1
HB 5 E	DRY	83.4	22.6	175.2	7.8	567.0	25.1	32.8
HB 5 O	DRY	89.9	37.0	1285.8	34.8	2050.3	55.4	90.2
HB 6 E	DRY	82.3	8.5	23.3	2.7	197.1	23.2	25.9
HB 6 O	DRY	90.7	8.4	44.1	5.2	565.5	67.3	72.6
HB 1 E	WET	80.5	14.5	72.1	5.0	855.6	59.0	64.0
HB 1 O	WET	82.7	20.4	145.9	7.2	1599.3	78.4	85.5
HB 2 E	WET	93.6	24.7	247.5	10.0	2315.7	93.8	103.8
HB 2 O	WET	84.0	9.1	93.0	10.2	410.5	45.1	55.3
HB 3 E	WET	83.4	23.6	272.6	11.6	544.6	23.1	34.6
HB 3 O	WET	87.3	24.2	354.5	14.6	2512.5	103.8	118.5

BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville.

Appendix D. (cont.)

SITE	AMC	INTENSITY (mm/hr)	RUNOFF (mm)	SUSPENDED SEDIMENT (kg/ha)	SUSPENDED SEDIMENT (kg/ha/mm)	DEPOSITS (kg/ha)	DEPOSITS (kg/ha/mm)	TOTAL SEDIMENT (kg/ha/mm)
HB 4 E	WET	85.7	11.6	109.2	9.4	885.6	76.3	85.8
HB 4 O	WET	86.3	15.0	266.6	17.8	393.6	26.2	44.0
HB 5 E	WET	85.5	25.8	93.6	3.6	634.4	24.6	28.2
HB 5 O	WET	90.6	24.9	682.5	27.4	1588.0	63.8	91.2
HB 6 E	WET	82.5	12.8	39.2	3.1	183.2	14.3	17.4
HB 6 O	WET	90.7	33.8	93.6	2.8	1000.8	29.6	32.4
LK 1 E	DRY	79.7	11.5	45.1	3.9	265.4	23.1	27.0
LK 1 O	DRY	86.1	35.6	808.5	22.7	3709.3	104.2	126.9
LK 2 E	DRY	80.7	0.3	0.4	1.5	47.3	157.6	159.1
LK 2 O	DRY	85.9	1.1	10.6	9.6	185.2	168.4	178.0
LK 3 E	DRY	90.4	1.2	5.7	4.7	113.2	94.4	99.1
LK 3 O	DRY	92.1	0.9	4.6	5.1	163.6	181.7	186.9
LK 1 E	WET	82.4	15.9	132.4	8.3	369.2	23.2	31.6
LK 1 O	WET	91.9	20.0	746.8	37.3	2950.0	147.5	184.8
LK 2 E	WET	94.4	29.2	89.4	3.1	267.7	9.2	12.2
LK 2 O	WET	90.7	35.2	579.7	16.5	674.6	19.2	35.6
LK 3 E	WET	83.1	10.3	47.3	4.6	466.8	45.3	49.9
LK 3 O	WET	96.6	24.3	245.7	10.1	899.2	37.0	47.1
SP 1 E	DRY	93.8	23.8	249.4	10.5	317.4	13.3	23.8
SP 1 O	DRY	92.5	17.8	120.0	6.7	787.0	44.2	51.0
SP 2 E	DRY	80.8	25.7	646.1	25.1	1853.4	72.1	97.2
SP 2 O	DRY	78.5	19.7	192.1	9.8	1831.0	92.9	102.7
SP 3 E	DRY	86.6	9.5	162.9	17.2	431.2	45.4	62.5
SP 3 O	DRY	79.6	6.8	163.6	24.1	376.1	55.3	79.4
SP 4 E	DRY	80.1	19.5	23.0	1.2	598.4	30.7	31.9
SP 4 O	DRY	89.9	20.7	510.9	24.7	1033.8	49.9	74.6
SP 5 E	DRY	86.6	26.1	233.9	9.0	3099.3	118.7	127.7
SP 5 O	DRY	78.6	22.0	452.3	20.6	2025.9	92.1	112.6
SP 6 E	DRY	73.1	15.2	68.1	4.5	528.0	34.7	39.2
SP 6 O	DRY	76.6	9.3	22.6	2.4	74.7	8.0	10.5
SP 7 E	DRY	93.6	30.3	251.2	8.3	532.0	17.6	25.8
SP 7 O	DRY	90.4	9.5	92.3	9.7	663.4	69.8	79.6
SP 8 E	DRY	85.1	29.4	1812.2	61.6	499.9	17.0	78.6
SP 8 O	DRY	89.3	19.9	280.8	14.1	1439.4	72.3	86.4
SP 9 E	DRY	82.1	10.9	22.7	2.1	272.8	25.0	27.1
SP 9 O	DRY	89.2	27.4	221.7	8.1	1512.0	55.2	63.3
SP 1 E	WET	81.0	32.1	111.1	3.5	136.2	4.2	7.7
SP 1 O	WET	88.5	27.9	243.0	8.7	981.1	35.2	43.9
SP 2 E	WET	89.1	27.1	732.0	27.0	3224.2	119.0	146.0
SP 2 O	WET	79.4	18.7	301.6	16.1	1015.4	54.3	70.4
SP 3 E	WET	87.6	5.1	31.0	6.1	217.8	42.7	48.8
SP 3 O	WET	82.2	7.9	72.6	9.2	401.4	50.8	60.0
SP 4 E	WET	80.1	19.1	21.2	1.1	314.0	16.4	17.5
SP 4 O	WET	78.6	18.8	372.0	19.8	472.6	25.1	44.9
SP 5 E	WET	94.1	22.0	111.1	5.0	1832.0	83.3	88.3
SP 5 O	WET	84.7	21.2	225.8	10.6	3135.1	147.9	158.5
SP 6 E	WET	86.6	24.1	107.2	4.4	1219.8	50.6	55.1
SP 6 O	WET	82.1	12.9	28.6	2.2	228.5	17.7	19.9
SP 7 E	WET	89.0	19.4	52.6	2.7	215.2	11.1	13.8
SP 7 O	WET	89.5	22.5	170.6	7.6	898.2	39.9	47.5
SP 8 E	WET	92.2	28.6	372.7	13.0	1074.3	37.6	50.6
SP 8 O	WET	85.2	20.0	257.8	12.9	1822.3	91.1	104.0
SP 9 E	WET	90.9	17.8	21.5	1.2	272.2	15.3	16.5
SP 9 O	WET	88.1	18.6	82.8	4.4	427.1	23.0	27.4

BH = Beaverhead; HB = Heber; LK = Loco Knolls; SP = Springerville.

Appendix E. Estimated Plot Hydraulic Parameters

SITE			AMC	KW	PSI	ACOEFF
BH	1	E	DRY	22.93	71.98	0.21
BH	1	O	DRY	32.22	10.30	0.33
BH	2	E	DRY	65.50	10.71	0.15
BH	2	O	DRY	21.78	109.33	0.99
BH	3	E	DRY	8.91	127.02	0.25
BH	3	O	DRY	41.83	91.86	0.18
BH	4	E	DRY	14.61	53.84	0.17
BH	4	O	DRY	40.86	1.61	0.23
BH	5	E	DRY	71.63	0.03	0.81
BH	5	O	DRY	84.23	0.16	0.08
BH	6	E	DRY	39.25	36.40	0.50
BH	6	O	DRY	81.39	2.41	0.13
BH	7	E	DRY	13.35	193.51	0.66
BH	7	O	DRY	43.05	52.38	1.22
BH	8	E	DRY	61.62	7.17	0.35
BH	8	O	DRY	0.71	1638.93	0.12
BH	9	E	DRY	57.69	5.56	0.06
BH	9	O	DRY	37.48	21.70	0.24
BH	1	E	WET	13.54	267.53	0.50
BH	1	O	WET	14.47	207.79	0.48
BH	2	E	WET	23.53	1131.87	0.44
BH	2	O	WET	19.44	2142.86	1.36
BH	3	E	WET	15.88	96.42	0.19
BH	3	O	WET	19.02	253.83	0.36
BH	4	E	WET	18.69	5.71	0.40
BH	4	O	WET	33.75	7.76	0.25
BH	5	E	WET	32.74	140.13	1.61
BH	5	O	WET	72.37	1.51	0.13
BH	6	E	WET	3.24	152.84	1.54
BH	6	O	WET	25.79	64.30	0.54
BH	7	E	WET	9.85	47.84	1.81
BH	7	O	WET	13.90	82.99	2.48
BH	8	E	WET	38.36	351.72	0.34
BH	8	O	WET	4.54	55.68	0.40
BH	9	E	WET	8.46	76.45	0.10
BH	9	O	WET	38.10	12.83	1.02
HB	1	E	DRY	39.97	66.60	0.33
HB	1	O	DRY	45.07	26.83	0.94
HB	2	E	DRY	17.05	8.32	0.48
HB	2	O	DRY	41.11	22.77	1.35
HB	3	E	DRY	13.03	34.10	0.28
HB	3	O	DRY	41.80	26.51	0.92
HB	4	E	DRY	53.63	5.96	0.54
HB	4	O	DRY	33.29	2.48	0.44
HB	5	E	DRY	51.15	30.02	0.30
HB	5	O	DRY	3.45	756.04	0.68
HB	6	E	DRY	44.27	72.06	0.14
HB	6	O	DRY	48.54	20.85	1.22
HB	1	E	WET	20.07	41.33	0.81
HB	1	O	WET	4.72	730.89	2.97
HB	2	E	WET	4.45	31.74	1.00
HB	2	O	WET	43.89	34.08	1.61
HB	3	E	WET	0.97	562.29	0.45
HB	3	O	WET	12.31	269.90	3.19
HB	4	E	WET	42.52	1.62	1.07
HB	4	O	WET	38.39	1.40	0.25

KW=estimated hydraulic conductivity in mm/hr; PSI=derived capillary suction in mm; ACOEFF=splash coefficient in kg-hr/ha-sq.mm.

Appendix E. (cont.)

SITE			AMC	KW	PSI	ACOEFF
HB	5	E	WET	17.64	2900.83	0.62
HB	5	O	WET	8.30	1975.21	0.86
HB	6	E	WET	10.00	6992.74	0.24
HB	6	O	WET	42.68	488.78	0.94
LK	1	E	DRY	38.66	21.65	0.07
LK	1	O	DRY	5.92	203.86	0.74
LK	2	E	DRY	79.95	0.00	0.07
LK	2	O	DRY	83.69	0.26	0.18
LK	3	E	DRY	87.85	0.04	0.18
LK	3	O	DRY	89.62	0.61	0.20
LK	1	E	WET	16.57	18.42	0.22
LK	1	O	WET	1.71	74.99	1.67
LK	2	E	WET	18.10	402.22	0.49
LK	2	O	WET	17.81	119.95	1.02
LK	3	E	WET	37.66	58.35	1.07
LK	3	O	WET	44.57	79.98	0.78
SP	1	E	DRY	19.76	14.59	0.39
SP	1	O	DRY	21.11	46.18	0.57
SP	2	E	DRY	18.44	16.00	0.70
SP	2	O	DRY	47.58	1.33	0.47
SP	3	E	DRY	46.06	32.83	0.62
SP	3	O	DRY	73.16	0.26	0.35
SP	4	E	DRY	31.04	0.82	3.98
SP	4	O	DRY	20.67	33.21	1.35
SP	5	E	DRY	23.26	17.09	0.80
SP	5	O	DRY	22.56	9.89	0.72
SP	6	E	DRY	19.12	30.91	0.52
SP	6	O	DRY	64.24	1.32	0.39
SP	7	E	DRY	29.87	22.36	0.33
SP	7	O	DRY	40.46	27.34	0.49
SP	8	E	DRY	20.46	12.01	0.56
SP	8	O	DRY	57.85	0.46	0.30
SP	9	E	DRY	47.38	2.34	0.82
SP	9	O	DRY	49.53	1.22	1.07
SP	1	E	WET	13.54	6.43	0.19
SP	1	O	WET	13.12	6.91	1.00
SP	2	E	WET	24.13	0.06	1.29
SP	2	O	WET	37.10	0.24	0.47
SP	3	E	WET	62.11	2.08	0.56
SP	3	O	WET	50.39	1.50	0.86
SP	4	E	WET	32.27	0.15	2.46
SP	4	O	WET	21.12	0.26	1.38
SP	5	E	WET	17.09	5.75	0.69
SP	5	O	WET	10.95	6.07	1.50
SP	6	E	WET	15.45	608.96	0.98
SP	6	O	WET	49.29	391.04	0.92
SP	7	E	WET	21.75	17.08	0.23
SP	7	O	WET	12.36	45.98	0.83
SP	8	E	WET	6.19	18.21	0.45
SP	8	O	WET	1.10	449.78	0.79
SP	9	E	WET	47.41	0.70	0.64
SP	9	O	WET	18.39	17.43	0.68

KW=estimated hydraulic conductivity in mm/hr; PSI=derived capillary suction in mm; ACOEFF=splash coefficient in kg-hr/ha-sq. mm.

Appendix F. Sediment and Chemical Concentrations in Milligrams/Liter

SITE	AMC	TP	TKN	NO2-3	TVSS	CTSS	BTSS	NBTSS	FTSS	WATER
BH 1 O	DRY	1.38	12.30	0.52	874	1362	2620	2442	2204	AG
BH 1 E	DRY	0.72	4.60	0.37	237	560	1020	835	817	AG
BH 2 O	DRY	0.54	10.60	0.32	149	735	.	.	802	AG
BH 2 E	DRY	0.58	3.70	0.63	102	668	.	.	772	AG
BH 3 O	DRY	0.34	2.90	0.10	81	320	.	.	363	AH
BH 3 E	DRY	0.61	6.50	0.02	320	1048	.	.	1341	AH
BH 4 O	DRY	1.31	11.60	-0.02	1126	1602	3510	3361	2465	AI
BH 4 E	DRY	0.80	4.50	-0.02	491	1258	.	.	1830	AI
BH 5 O	DRY	1.28	1.50	0.14	224	962	1100	904	884	AJ
BH 5 E	DRY	0.72	4.80	-0.33	187	770	.	.	1083	AJ
BH 6 O	DRY	0.56	5.70	-0.04	121	915	.	.	1039	AJ
BH 6 E	DRY	0.11	1.60	-0.06	53	322	.	.	406	AJ
BH 7 O	DRY	0.12	1.00	-0.29	47	188	550	379	275	AM
BH 7 E	DRY	0.06	1.60	-0.05	27	110	.	.	152	AM
BH 8 O	DRY	0.28	4.10	0.01	132	875	1370	1197	946	AM
BH 8 E	DRY	0.14	1.80	0.15	42	258	.	.	218	AM
BH 9 O	DRY	0.11	0.65	0.34	52	380	.	.	395	AN
BH 9 E	DRY	0.88	0.95	0.50	369	1112	.	.	1412	AN
BH 1 O	WET	0.96	15.90	0.10	562	1192	.	.	1782	AH
BH 1 E	WET	0.51	2.60	0.03	276	598	.	.	759	AH
BH 2 O	WET	0.42	3.50	0.02	137	642	.	.	800	AI
BH 2 E	WET	0.34	2.20	0.01	78	492	.	.	539	AI
BH 3 O	WET	0.15	.80	0.01	43	168	.	.	211	AI
BH 3 E	WET	0.23	1.00	-0.02	95	360	.	.	461	AI
BH 4 O	WET	0.09	27.10	-0.95	922	860	.	.	1834	AJ
BH 4 E	WET	0.69	6.20	-0.04	373	1100	.	.	2048	AJ
BH 5 O	WET	0.26	2.80	0.02	74	352	.	.	373	AK
BH 5 E	WET	0.64	3.00	-0.31	14	522	.	.	561	AK
BH 6 O	WET	0.18	1.80	-1.08	57	260	.	.	330	AL
BH 6 E	WET	0.13	1.00	-0.88	39	118	.	.	250	AL
BH 7 O	WET	0.09	2.55	-0.01	43	218	.	.	250	AN
BH 7 E	WET	0.09	1.95	0.46	32	108	.	.	177	AN
BH 8 O	WET	0.11	2.25	0.60	89	625	.	.	695	AN
BH 8 E	WET	0.30	0.55	0.47	80	458	.	.	455	AN
BH 9 O	WET	0.08	0.65	0.37	34	345	.	.	392	AN
BH 9 E	WET	0.55	0.65	0.51	128	355	.	.	584	AN
HB 1 O	DRY	0.27	1841.50	-0.02	104	695	.	.	671	M
HB 1 E	DRY	0.30	79.00	-0.06	111	480	1349	1044	476	M
HB 2 O	DRY	0.33	1740.30	-0.12	243	1295	.	.	1384	M
HB 2 E	DRY	0.76	2968.00	< 0.01	336	2030	2266	1963	1971	M
HB 3 O	DRY	0.66	3466.50	- 0.05	196	1325	.	.	1296	N
HB 3 E	DRY	0.62	3483.50	- 0.05	226	1098	.	.	1801	N
HB 4 O	DRY	1.12	32.90	0.10	2765	2730	5281	5007	6737	P
HB 4 E	DRY	0.59	-29.40	< 0.01	126	685	.	.	696	P
HB 5 O	DRY	1.01	-31.40	0.08	569	3355	.	.	3475	P
HB 5 E	DRY	0.21	-31.20	-0.07	126	468	.	.	775	P
HB 6 O	DRY	0.10	-69.30	-0.11	117	438	903	611	525	O
HB 6 E	DRY	0.14	1562.20	0.03	45	382	.	.	274	O
HB 1 O	WET	0.23	1841.70	< 0.01	134	740	.	.	715	M
HB 1 E	WET	0.37	2228.00	0.04	100	438	725	409	497	M
HB 2 O	WET	0.50	3548.40	-0.12	163	1198	.	.	1022	N
HB 2 E	WET	0.32	2016.00	-0.05	168	765	1265	957	1002	N
HB 3 O	WET	0.54	1280.00	-0.02	222	1088	.	.	1465	N
HB 3 E	WET	0.48	1170.00	-0.03	141	1088	.	.	1155	N

TP=total phosphorus; TKN=Kjeldahl nitrogen; NO2-3=nitrate-nitrite; TVSS=total volatile suspended solids; BTSS=oven dried suspended solids; NBTSS=oven dried suspended solids with conductivity subtracted out;FTSS=filtered suspended solids. CTSS=centrifuged suspended solids; WATER=id in next appendix for simulator water.

Appendix F. (cont.)

SITE	AMC	TP	TKN	NO2-3	TVSS	CTSS	BTSS	NBTSS	FTSS	WATER
HB 4 O	WET	1.01	14.60	0.11	666	1208	2428	2131	1777	Q
HB 4 E	WET	0.12	-29.50	0.05	149	802	.	.	941	Q
HB 5 O	WET	0.63	-30.20	0.10	328	2518	.	.	2741	Q
HB 5 E	WET	0.02	-30.80	-0.07	88	290	.	.	363	Q
HB 6 O	WET	0.14	-68.60	0.02	67	298	645	346	277	O
HB 6 E	WET	0.14	-.10	0.03	51	325	.	.	306	O
LK 1 O	DRY	2.16	4.05	< 0.01	383	3202	1139	4818	2271	K
LK 1 E	DRY	0.48	.95	< 0.01	94	425	.	.	392	K
LK 2 O	DRY	1.12	1.95	0.08	181	1100	974	630	964	K
LK 2 E	DRY	0.62	2.55	0.06	40	557	.	.	149	K
LK 3 O	DRY	0.48	.85	0.02	92	825	.	.	514	K
LK 3 E	DRY	0.48	.85	0.00	80	590	.	.	473	K
LK 1 O	WET	1.54	.65	0.02	538	3272	5615	5290	3734	L
LK 1 E	WET	0.40	.35	< 0.01	166	658	.	.	833	L
LK 2 O	WET	0.62	1.75	0.02	210	1012	1398	1085	1647	L
LK 2 E	WET	0.32	.55	0.02	52	189	.	.	306	L
LK 3 O	WET	0.64	.45	< 0.01	143	920	.	.	1011	L
LK 3 E	WET	0.20	.45	< 0.01	74	460	.	.	459	L
SP 1 O	DRY	0.54	0.80	0.01	110	550	.	.	674	C
SP 1 E	DRY	0.94	0.80	0.02	153	790	.	.	1048	C
SP 2 O	DRY	0.76	0.50	< 0.01	290	710	.	.	975	C
SP 2 E	DRY	2.54	0.50	0.05	406	1285	.	.	2514	C
SP 3 O	DRY	1.32	1.00	0.06	297	1468	.	.	2406	D
SP 3 E	DRY	0.76	0.60	0.02	272	2338	.	.	1715	D
SP 4 O	DRY	1.72	0.35	0.02	280	2250	3950	3625	2468	F
SP 4 E	DRY	0.40	1.55	0.02	32	142	. .	.	118	F
SP 5 O	DRY	0.52	0.15	0.04	441	1312	1745	1418	2056	F
SP 5 E	DRY	1.08	0.65	0.00	191	570	.	.	896	F
SP 6 O	DRY	0.42	0.85	< 0.01	76	192	.	.	243	F
SP 6 E	DRY	0.54	0.85	0.01	135	330	.	.	448	F
SP 7 O	DRY	0.40	0.35	< 0.01	181	930	.	.	972	H
SP 7 E	DRY	0.36	0.35	0.02	122	718	.	.	829	H
SP 8 O	DRY	1.02	0.65	0.02	359	970	2623	2292	1411	H
SP 8 E	DRY	5.00	1.05	0.08	1269	2875	.	.	6164	H
SP 9 O	DRY	1.20	0.35	0.02	123	610	1775	1460	809	H
SP 9 E	DRY	0.38	0.85	0.02	59	178	.	.	208	H
SP 1 O	WET	0.47	0.30	< 0.01	177	918	.	.	871	E
SP 1 E	WET	0.47	0.20	< 0.01	60	200	.	.	346	E
SP 2 O	WET	1.12	0.20	0.01	302	1236	.	.	1613	E
SP 2 E	WET	2.55	0.00	0.08	391	1316	.	.	2701	E
SP 3 O	WET	0.58	0.40	0.04	189	842	.	.	919	E
SP 3 E	WET	0.69	0.40	0.02	122	5426	.	.	607	E
SP 4 O	WET	1.78	0.25	0.02	190	1120	.	.	1979	G
SP 4 E	WET	0.22	0.55	< 0.01	28	100	334	44	111	G
SP 5 O	WET	0.74	0.15	.02	170	1286	702	376	1065	G
SP 5 E	WET	0.48	0.25	< .01	97	422	.	.	505	G
SP 6 O	WET	0.22	0.15	< .01	61	198	.	.	222	G
SP 6 E	WET	0.44	0.35	< .01	129	216	.	.	445	G
SP 7 O	WET	0.70	0.35	.02	120	732	.	.	758	J
SP 7 E	WET	0.32	1.15	< .01	51	260	.	.	271	J
SP 8 O	WET	1.00	0.25	.04	306	718	1820	1487	1289	J
SP 8 E	WET	0.62	0.05	.02	228	968	.	.	1303	J
SP 9 O	WET	0.22	< 0.10	.02	70	432	1022	698	445	I
SP 9 E	WET	0.20	0.35	< .01	29	153	.	.	121	I

TP=total phosphorus; TKN=Kjeldahl nitrogen; NO2-3=nitrate-nitrite; TVSS=total volatile suspended solids; BTSS=oven dried suspended solids; NBTSS=oven dried suspended solids with conductivity subtracted out;FTSS=filtered suspended solids. CTSS=centrifuged suspended solids; WATER=id in next appendix for simulator water.

Appendix G. Sediment and Chemical Concentrations in Simulator Rainwater

I.D. Letter	Total Phosphorus	Kjeldahl Nitrogen	Nitrate-Nitrite	Total Volatile Suspended Solids	Total Suspended Solids
C	< 0.01	0.2	0.02	3	8
D	0.03	0.3	< 0.01	5	16
E	0.04	0.5	< 0.01	< 1	11
F	< 0.01	< 0.1	< 0.01	8	26
G	< 0.01	< 0.1	< 0.01	1	1
H	< 0.01	< 0.1	< 0.01	< 1	< 1
I	< 0.01	< 0.1	< 0.01	12	13
J	< 0.01	< 0.1	< 0.01	< 1	< 1
K	< 0.01	< 0.1	< 0.01	4	6
L	< 0.01	< 0.1	< 0.01	< 1	< 1
M	0.01	1842.0	0.13	< 1	3
N	< 0.01	3550.0	0.13	< 1	4
O	< 0.01	69.8	0.13	2	5
P	0.06	31.8	0.13	23	33
Q	0.02	31.1	0.11	3	4
AG	< 0.01	0.6	0.85	3	13
AH	0.02	0.3	1.32	16	30
AI	0.06	0.8	1.39	8	50
AJ	0.01	0.2	1.44	2	13
AK	0.01	0.2	1.43	2	6
AL	0.02	0.2	2.20	1	19
AM	< 0.01	0.4	1.84	3	9
AN	0.03	< 0.1	1.36	8	18

*See previous appendix for the plots to which the id letters correspond.