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SUBJECT: BCS - Small Plot Rainfall Simulation:
Background and Procedures for Rangeland Hydrology

TO: Regional Conservationists
State Conservationists
National Technical Center Directors
Director, Pacific Basin and Caribbean
Division Directors and Above

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In preparation for writing The Third RCA Appraisal, state-of-the-science methods and procedures for a variety of natural resource conservation topics have been gathered. The attached Technical Note, "Small Plot Rainfall Simulation: Background and Procedures for Rangeland Hydrology," thoroughly explores the background and importance of rangeland watersheds throughout the Western United States, and the response to improved management in the Western United States. Described within this Technical Note are common problems and issues associated with rangeland watershed dysfunctionality, and the use of small plot rainfall simulators to provide cost effective and meaningful ecological information concerning the many associated variables which affect the hydrologic process.

The Technical Note contains guidance on plot size, installation procedures, data collection procedures, equations, and techniques for calculating infiltration and soil erosion on rangeland sites. This release represents input from leading Agriculture Research Service (ARS) researchers on rangeland hydrology as well as leading NRCS personnel working in the field of range management and application. For additional copies contact Ken Spaeth, NRCS/ARS, Northwest Watershed Research Center, 800 Park Boulevard, Plaza 4, Suite 105, Boise, Idaho 83712-1716.

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USDA-Natural Resources Conservation Service Technical Note
Rangeland Hydrology

Small Plot Rainfall Simulation: Background and Procedures

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Introduction:

The increasing importance of water to society has added a new dimension to the value of grazinglands and has reinforced and expanded the concept of multiple use. Society is challenging traditional grazingland uses as destructive and is demanding improved water quality, reduced erosion, new management alternatives, restoration of degraded lands, and more accurate soil erosion and water supply prediction techniques. Competitive demands for grazingland resources by livestock, wildlife, recreation, mineral exploration and off-site water users far exceed the available supply. The result is that there is a critical need to understand grazingland watersheds with respect to: (1) soil erosion and water quality, (2) water yield, (3) evapotranspiration, and (4) effects of global climate change.

The Soil and Water Resources Conservation Act of 1977 identified reduction of erosion and improvement of water quality and quantity as two of our nation's highest resource priorities. Since the need for clean water is critical and grazinglands comprise vast watershed areas in the United States (899.08 million acres in the 17 western states; 401.6 million acres are non-federal), it is of prime importance that policies and activities are formulated and implemented to arrest resource degradation. With increasing concern over quantity and quality of surface and groundwater supplies, judicious management of this natural resource is essential to the future well being of the Nation. The Natural Resources Conservation Service's (NRCS) mission is to provide leadership in the conservation and wise use of our natural resources.

In natural plant communities, the hydrologic condition of a site is the result of complex interactions of soil and vegetation factors. Natural plant communities are not homogeneous, even within seemingly continuous unbroken expanses of grass. Mosaic patterns and patchiness prevalent in most natural rangeland plant communities are spatially heterogeneous and temporally dynamic. The kind and amount of vegetation influences many hydrologic processes including interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and deposition of sediment. Also, spatial and temporal variability of soil and vegetation characteristics strongly influence grazingland hydrology and erosion.

Research has demonstrated a significant correlation between kinds of vegetation, plant cover, and soils to erosion, infiltration, and runoff (Pearse and Woolley 1936, Mazarak and Conrad 1959, Osborn 1950, Dee et al. 1966, Rauzi et al. 1968, Blackburn and Skau 1974, Blackburn 1975, Hanson et al. 1978, Blackburn 1984, Gifford 1984, Swanson and Buckhouse 1984; Blackburn et al. 1986, Synman et al. 1986, Johnson and Gordon 1988, Thurow et al. 1988, Gifford 1985, Wilcox and Wood 1989, Spaeth 1990, Blackburn et al. 1990, Blackburn et al. 1992a,b). In some regions, vegetation can be manipulated to increase water quantity and quality from grazingland watersheds (Heede 1979, Richardson et al. 1979, Blackburn 1983, Hibbert 1983, Thurow et al. 1988, Griffin and McCarl 1989). However, caution must be used when predicting which grazingland watershed areas are capable of producing significant increases in water yield by vegetation manipulation.

Why Study Watershed Management on Grazinglands:

There are many reasons for studying watershed management on rangelands, pasturelands, woodlands, etc. Watershed management on grazinglands is concerned with the protection and conservation of water resources, but also considers that vegetation resources are managed for the production of goods and services (Brooks et al. 1991). Few grazingland watersheds are managed solely for the production of water. Likewise, managing grazinglands for the sole purpose of livestock production is not environmentally appealing to the public and economically sound for the landowner. On Federal public lands, society and Federal land use policies desires a multiple-use philosophy. On private lands, ranchers find that the sale of products such as hunting privileges, wood gathering, horseback riding, fishing, camping etc. are economically appealing, while "it is seldom possible to maximize the benefits from any single use under the multiple-use concept" (p. 396, Holechek et al. 1989).

Why become astute in understanding the fundamentals of hydrology and how they are related to planning and management on grazinglands? By having knowledge of hydrologic principles and processes and how these processes are affected by vegetation, vegetation management practices, and structural practices (engineering activities), the conservationist or land manager can integrate their thinking about how all the various activities in a given area effect the water cycle. Aside from managing the forage resource, other objectives or goals may also be equally important, such as maintain and/or improve water quality, maintain and/or improve water yields, regulate timing of stream flow, control excess soil erosion, and excessive runoff. The outcome of management decisions on upland environments must be understood because they directly impact the health and welfare of people and other living organisms downstream.

Why Use Rainfall Simulators:

Since the 1940's rainfall simulators have been used in hydrologic research to emulate natural rainfall in experimental plots. A primary advantage for the use of small plot rainfall simulators in NRCS is to obtain field data which can be used to compare relative differences between treatments (grazing, range improvement practices etc.) or vegetation types.

Rainfall simulators can also provide information to validate model estimates and predictions of interrill soil loss, sedimentation, and water quality. Information from field data, whether it comes from rainfall simulations, instrumenting small watersheds, or permanent plots, is essential to meet the planning needs at NRCS field office level on up through the regional planning applications.

The science of erosion research in the United States has developed as a result of efforts to maintain long-term production of America's lands (Renard 1985). Early erosion research was concerned with finding practical solutions to erosion problems while current research takes a more analytical approach and is directed toward predicting the outcome of management decisions. Current research also emphasizes a multidisciplinary approach. Natural ecosystems are complex biologically, ecologically, and physically; therefore, biophysical models may be the only practical and economic means to understand the hydrologic response of natural ecosystems (Carlson 1992). In the early 1800's Humbolt (1807) wrote that everything was somehow interconnected and interdependent. Eventually this theory became known as the "holocoenotic concept" (hologoen is equivalent to ecosystem) which states that no single environmental factor can be isolated and used to explain the distribution or abundance of a plant species. The holocoenotic concept can also be extended to hydrology. No single environmental factor or plant growth form is consistent in its effect on hydrologic processes.

Objectives for Performing Rainfall Simulations on Grazinglands:

1) To identify, predict, and model the interrelationships of infiltration, runoff, and sediment yield (hydrologic assessments). Correlate vegetative and soil factors such as above ground biomass, root biomass, plant height, percent canopy cover, bulk density, soil texture, and organic matter, etc. with hydrologic assessments.

2) Validate current methodologies for estimation of runoff, erosion, and sedimentation.

3) Evaluate conservation practices (nonstructural or structural) and their effect on hydrology. Use this information in developing, creating, supporting, and implementing programs which address water quality and quantity on grazingland watersheds [i.e., Great Plains Conservation Program (GPCP), bioremediation of depleted range watersheds, Rural Conservation and Development (RC&D) projects, Public Law (PL-566) watershed programs, river basin studies, and targeted projects such as restoration of springs and seeps].

4) Update hydrologic information for use in range site descriptions. The concept of "benchmark" sites (Franks et al. 1993) can also be used to provide initial hydrology information for similar range sites on similar soils where hydrology data are not yet available.

5) Evaluate and correlate the concepts of ecological range condition and hydrologic condition on a site specific basis. These concepts are not necessarily correlated (Spaeth 1990).

Solutions to existing or potential problems involving the relationship between water and land uses can be physical, economic, or regulatory. Conservation strategies on grazingland watersheds can be classified as preventive or restorative. Usually, most situations are a combination of the two. Preventive strategies and sound management plans are equally as important as the more dramatic and sometimes more politically visible restorative actions. For every watershed and site within the watershed, there exists a critical point of deterioration due to surface erosion. Beyond this critical point, erosion continues at an accelerated rate which cannot be overcome by the natural vegetation and soil stabilizing forces until a new equilibrium is achieved. Areas that have deteriorated beyond this critical point continue to erode even when man-caused disturbance is removed (Satterlund 1972).

Preventing losses of soil, desirable vegetation, wildlife habitat, and losses of forage production are much less costly than achieving the same benefit from a degraded situation by restoration. Depending on the severity of resource and watershed degradation (which includes water, soil, plant, animal, air, and human resources), restoration may not be feasible from an ecological and/or economic perspective. The results of grazingland watershed degradation can be serious and irreversible.

> Heede states: In semiarid and arid areas, the balance between healthy and dying vegetative cover is very delicate. It takes only a slight trigger, exerted either by a natural event or man, to upset it. Depletion of the original sparse vegetation and/or conversion from desirable to undesirable plant species follows over-use rather quickly. The results are well known [documented]: reduction of vegetative cover causes increased surface runoff because infiltration [rates and capacity] decreased (Dortognac and Love 1961, Meiman 1975). Increased surface runoff, in turn often leads to soil erosion, since larger flow concentrations cause higher flow energies that may exceed the threshold value for safe flow conveyance [detachment and transport of soil particles]. Rills and gullies develop, giving rise to still larger flow concentrations and erosional energies. Dissection of the land surfaces by gullies produces lower ground water tables, and, in combination with decreased infiltration of rainfall and snowmelt, leads to lower streamflows. Lag times for flow concentrations decrease drastically and peak flows rise sharply, causing floods in lands below [the lower drainage basin]. Depletion of ground-water storage can also cause perennial streams to become ephemeral, thus adding to the impairment of plant growth (p. 271, Heede 1979).

Common Problems and Issues of Grazingland Watersheds:

Certain common problems, issues, and situations are recurring with respect to grazingland watersheds. A summary of the most common situations are:

- interrelationships: plant/soil complexes—ecological—environmental—hydrology
- modelling hydrologic processes,
- validation of hydrology and erosion prediction models,
- trampling impacts and effect of grazing treatments on watersheds,
- water quality with respect to grazingland use,
- range improvement practices and their effect on hydrology,
- riparian management and hydrologic implications,
- enhancement of surface water, groundwater, and aquifer recharge in response to vegetation manipulation,
- climatic shifts—vegetation response—and the hydrologic cycle,
- deficient water supplies,
- flooding,
- polluted surface waters—reduced fish and wildlife habitat,
- degraded fish habitat due to temperature fluctuations and siltation,
- economics of watershed restoration,
- erosion and sedimentation from grazingland watersheds,
- energy shortages—hydroelectric power projects,
- food shortages—maintenance, restructuring, and developing resources, and
- sludge and animal waste applications on grazinglands.

Hydrology Defined:

- Hydrology is the science dealing with the occurrence of water on the earth: its physical and chemical properties, transformation, combinations, and movements especially with the course of water movement from the time of precipitation on land and movement to the sea or atmosphere.

- Hydrology involves the movement of water over and under the land surface and includes a variety of geomorphic, geochemical, and biologic processes that depend upon the storage and movement of water (Dunne and Leopold 1978).

- Hydrology is an earth science. It encompasses the occurrence, distribution, movement, and properties of the waters of the earth and their environmental relations (Viessman 1989).

- Hydrology is the study of the interrelationships and interactions between water and its environment in the hydrological cycle (Gordon et al. 1992).

- Rangeland hydrology, or rangeland watershed management, is the study of hydrologic principles applied to range ecosystems (Branson et al. 1981).

- Grazingland hydrology, which is founded on basic biological and physical principles, is a specialized branch of range science which studies land use effects on infiltration, runoff, sedimentation, and nutrient cycling (hydrologic assessments) in natural and reconstructed ecosystems.

Watershed Management Defined:

- The management of land for the optimum production of high quality water, the regulation of water yields and for maximum soil stability along with other products of the land.

Field Procedures for Hydrologic Information:

Rainfall simulators were conventionalized for hydrologic research in the late 1930's (Cook and Stubbendieck 1986). Concentric ring infiltrometers were used prior to this time and are still used today. The common features of rainfall simulators are: 1) rainfall rates and amount can be controlled; 2) portability; and 3) research areas can be established in accordance with an experimental design. Neff (1979) lists many of the advantages and disadvantages of rainfall simulators and summarized that the advantages outweigh the disadvantages. However, it is important to keep in mind that in many instances, the use of rainfall simulators is the only practical method to obtain hydrologic information in a reasonable amount of time (Renard 1985). Also, rainfall simulations, in accordance with a sound experimental design, provide fundamental information about hydrologic processes and the many associated variables which affect the hydrologic cycle. Rainfall simulators have, and will continue to play an important role in hydrologic and erosion research and in the development and validation of predictive models. On grazingland areas where natural rainfall is temporally and spatially variable and unreliable. It takes years and/or decades to obtain information relevant to todays technological needs. Rainfall simulation experiments can alleviate this problem.

Methods and Operating Procedures for Small Plot Rainfall Simulators

Rainfall Simulators:

Two types of portable rainfall simulators are currently available to NRCS: 1) a drip needle rainfall simulator[1] (Meeuwig 1971, Blackburn et al. 1974), and 2) a stationary single nozzle simulator[2] (Wilcox et al. 1986). Both types of simulators have advantages and disadvantages.

The drip type simulator which is currently in use in Texas and Nevada is equipped with a four legged tubular frame which can extend to two meters in height. The plexiglass applicator module contains 3600 needles on 1.27 cm centers with a surface area of 0.58 m^2. Rainfall intensity is controlled through a flow meter located between the plexiglass module and the overhead water storage unit. Flow rate must be regulated to maintain a constant rainfall intensity. A water storage tank (minimum 190 liters) is regulated to supply the water used during the simulation or greater. An advantage of this simulator is that water drops are very evenly distributed over the soil surface. Disadvantages are that the plexiglass module is delicate and the needles tend to clog and hard water can be a problem. A thin wire (0.2 to 0.40 mm diameter) can be used to unclog needles, but this can be very time consuming. Another disadvantage is that the velocity of the droplets are about 65% of terminal velocity at 2.5 m. An average sized raindrop ($\approx$ 2.5 mm in diameter) reaches terminal velocity at approximately 7.4 to 8.0 m.

There are many designs available for the single nozzle rainfall simulator. One simple design is given by Wilcox et al. (1986), which is currently being used in Texas, South Dakota, Wyoming, Utah, and California. The simulator contains three telescoping legs

[1] For simulator information, contact Dr. Robert Knight, Department of Rangeland Ecology and Management, Texas A&M University, College Station, Texas, 77843. (409) 845-5557.

[2] For simulator information, contact Dr. Ronald Sosebee, Department of Range and Wildlife Management, Texas Tech University, Lubbock, Texas, 79409. (806) 742-2841.

[3] At 2.9 psi (20 Kpa) pressure the 10 SS 1/4 GG Fulljet nozzle (manufactured by Spraying systems Co., Engineers and Manufacturers in Wheeton, Illinois) produces 15.24 cm/hr) and an average droplet size 2.4 mm in diameter. The 5 SS 1/8 GG Fulljet nozzle produces 10.16 cm/hr at 5.5 psi (40 Kpa). To convert from psi to Kpa (Kilo Pascal) multiply by 6.9.

and a single stationary nozzle which can be placed two meters or higher above the plot. A water tank (378 to 560 liters) is needed to supply water to the simulator. Molded plastic tanks that fit between the wheel wells of pickup trucks are available at farm and ranch supply stores. Rainfall intensity and droplet velocities can be controlled by altering the type of nozzle[3] and pressure. Advantages are durability of equipment, simulations can be conducted on steep slopes, and no clogging problems as experienced with the needle type simulator. One disadvantage is that droplet distribution can vary slightly with particular nozzles; however, any error associated with droplet distribution remains constant from plot to plot.

Number of Rainfall Simulations Needed Per Study Site:

As a general guideline, a minimum of five simulation runs per treatment is required to ascertain variability and minimize erroneous results. For experimental purposes, more replications are required and the number depends upon the experimental design. Range hydrology studies must be carefully planned. Clear and explicit objectives need to be defined and documented before any field work begins. A soil scientist should be consulted to identify the soil series, provide the taxonomic soil classification, characterize the soil profile, and investigate any microsite differences that may be present.

Prewetting Procedure:

Dry and wet rainfall simulations can be conducted on the same plot. If a dry run is desired, soil moisture samples should be collected at 2.54 cm, 7.6 cm, and 15 cm. Dry runs data can be used to evaluate unsaturated infiltration, runoff, and erosion for initially dry conditions. However, dry run rainfall simulations have greater variance because soil moisture is not constant from plot to plot and location to location. After the dry run, the plot can be covered with plastic for the next day's wet run to minimize evaporation.

To reduce variability of antecedent moisture between plots, locations, and sample dates, plots should be prewet approximately 12 to 24 hours prior to the simulated rainfall event. If only a wet run is desired, the site must be prewetted and covered with plastic the day before. The soil surface (to a depth of 15 cm) at the onset of a wet run simulation should be at field capacity.

Using a mist nozzle, gently prewet plots with approximately 100 liters the day before the simulation and cover with plastic. The wetted area should encompass a buffer area of at least half the distance of the plot length. Care should be taken when applying the water so that the soil surface is not disturbed and erosion is created by the process. On sites where bare ground is >30%, a fabric (burlap, cloth, towel etc.) should be placed on the soil surface to avoid scouring or disturbance during the wetting process. Anchor the plastic on the edges with rebar rods and pins. Depth of wetting on sandy loams, loams, etc. should be to about 15 cm. On clayey or lithic soils, the wetting front may be approximately 5 to 10 cm. After prewetting, the actual simulation should be performed approximately 24 hours later.

Alternative Method for Prewetting:

Plot frames may be placed in the ground and wetted inside and around the outside of the plot frame. The frame and buffer area should be covered as directed above.

Simulator Plot Size:

Plot size should be based on the following criteria:

- The objectives of the simulation can dictate plot size (e.g., studying the hydrological dynamics of a particular shrub, etc).
- The steel frame should completely fit under the simulator and receive equal amounts of rainfall.
- The suggested plot size for the single nozzle simulator is 0.5 m^2 (70.71 cm x 70.71 cm x 12.7 cm). The steel should be about 3 to 4 mm thick.
- A buffer area surrounding the plot frame (at least 0.25 m on each side of the plot) is required. The buffer strip should also receive equal amounts of rainfall as the sample area.
- The suggested plot size for the dripper simulator should not be less than 0.0929 m^2. Again wet the buffer area around the plot.
- On stony or rocky sites a pliable frame should be used. Use pliable steel or aluminum flashing; about 13 cm is recommended.

Simulator Plot Installation:

The plot outlet should be oriented downslope. All contacts between frame and soil should be tamped down gently by hand and sealed with moist clay (caulking) and/or a soil seal solution where needed. When using the single nozzle simulator, it is easier to set up and level the simulator first. Secure the feet of the simulator with steel stakes. When the hose is attached to the simulator, the simulator has a tendency to tip over if the legs are not securely staked to the ground. Once the simulator is in place, use a plumb bob to center the plot with the nozzle opening. The centered frame is then driven approximately 5 cm into the ground. To calibrate the simulator, place an aluminum pan, the exact dimensions of the plot, over the steel frame and run the simulator for a minimum of 5 minutes. Measure the volume in ml and calculate the application rate (see calibration procedure in Appendix A). The needle dripper simulator is usually secured into a frame which has four legs. Center the plot frame so that there is even overlap of the plexiglass module needles and the plot frame.

Rainfall Application:

No one rate is acceptable for all areas. Generally, 6.35 cm/hr is a minimum rainfall simulation rate (Note: the National Range Study Team simulator is set up to apply 6.35 cm/hr and 12.7 cm/hr of simulated rainfall). A rainfall rate should insure that a terminal infiltration rate is achieved. For example, the Texas Agricultural Experiment Station near Sonora, Texas, Thurow et al. (1988) used a 9.05 in/hr (20.3 cm/hr) rate for 30 minutes to insure that runoff and terminal infiltration rate occurred on their research plots. They also chose this rate because this storm intensity occurred every year or two. In rainfall simulation experiments in the northern desert resource area in New Mexico, Balliette et al. (1986) used a 4.2 in/hr (10.7 cm/hr) rate for 45 minutes in 1 m^2 plots. This rate was chosen to insure runoff and this intensity was similar to a short-duration convectional thunderstorm that typically occurs during August through September. A rainfall simulation study on the Texas Experimental Ranch near Throckmorton, Texas, Wood and Blackburn (1981) used a 7.0 in/hr (17.7 cm/hr) rate for 30 minutes on 0.5 m^2 plots. The simulated rate of 17.7 cm/hr rate has a natural storm period more than 100 years and was chosen to ensure runoff from all sites. Bedunah and Sosebee (1985) conducted a simulation study on a transition area between the southern short grass plains of the Llano Estacado and the Red Rolling Plains of Texas. They chose a simulated rainfall rate of 5.5 in/hr (14 cm/hr) for 30 minutes on 0.64 m^2 plots to insure that runoff occurred on all treatments and plots. This rate was also consistent with storm intensities for the area which are strongly convective--most of the rainfall occurs within 5 to 15 minutes.

Check Technical Paper No. 40, Rainfall Frequency Atlas of the United States for rainfall durations of 30 minutes to 24 hours and return periods from 1 to 100 years. Also, obtain local rainfall intensity data. Understanding the storm dynamics of the area and obtaining rainfall intensity data of short time intervals is essential.

A simulated rainfall rate can be used which approximates rainfall intensities that cause damage and erosion to the site. In the case of the single nozzle simulator, the pressure should be checked periodically so that it remains constant. Fluctuations in pressure will change raindrop size. Differences in raindrop size and kinetic energy will confound the results of the simulation. On coarser textured soils, or on some range sites in good to excellent condition, a rate of 12.7 cm/hr or more may be needed to insure runoff.

Raindrop size should be near 2.5-mm in diameter, the approximate size of a natural raindrop. Laws and Parsons (1943) reported that average drop sizes for several storm intensities were 1.25 mm diameter (0.127 cm/hr, 1.8-mm diameter (1.27 cm/hr), and 2.8 mm diameter (10 cm/hr). A falling raindrop attains a terminal shape of a hemisphere or oblate shape (Chow and Harbaugh 1965, Riezebos and Epema 1983). An airborne raindrop traveling at terminal velocity (7.4 to 8.0 m/s) over 1-mm in diameter will disrupt the soil surface on impact, whereas drops smaller than 1-mm in diameter are significantly less disruptive (Moss and Green 1987, Moss 1989). Gravity drops, about 5-mm in diameter, are erosive because they are large and fall almost vertically.

As a guideline, run rainfall simulations for a minimum of 30 minutes. If a steady runoff rate has not been achieved at 30 minutes, continue the simulation for a total of one hour. If a steady state rate has not been achieved at one hour, consider increasing the rainfall application rate. The influence of interception on mid and short grass plots is usually not a significant source of water loss. However, on tall grass and shrub sites, interception losses may be significant. Prior to the simulation run, soil moisture samples should be taken at 2.54 cm, 7.6 cm, and 15 cm. The gravimetric method can be used to calculate mass wetness (w):

$$w = \frac{(wet\ weight)-(dry\ weight)}{dry\ weight} = \frac{(wet\ soil + can\ wt.) - (dry\ soil + can\ wt.)}{(dry\ soil - can\ wt.)}$$

<u>Collection of Runoff</u>:

Runoff should be collected at periodic intervals throughout each 5 minute collection period. Do not let water backup on the plot during the simulation. Record time when 50% ponding occurs and when runoff starts. Runoff water can be pumped directly to a one or four liter plastic graduated cylinder and measured in milliliters at 5 minute intervals. The contents are then emptied into a larger open plastic container.

Runoff water can be collected by pumping directly from:

1) the nipple on the receiving frame;
2) from a secondary collection point--a sump located below the nipple of the receiving frame (A plastic container may be used for collection); or
3) water may be pumped directly from a completely walled plot frame. This procedure is recommended on very flat slopes where runoff does not occur in one direction. In this case, care must be taken to insure that the suction hose does not come in direct contact with the soil. Strips from waxed cardboard milk cartons can be cut and pinned to the soil with wire. The suction hose is then placed on this surface and anchored with a curved piece of wire.

Calculation of Infiltrability:

Hillel (1982) proposed the term infiltrability to replace "infiltration capacity" which has several shortcomings. Infiltrability "designates the infiltration flux resulting when water at atmospheric pressure is made freely available at the soil surface" (p. 212).

For specific time intervals, soil infiltrability (in/hr or cm/hr) is calculated as follows:

$$f = i - S_r$$

where:

f = Infiltrability (cm/hr)
i = Rainfall intensity (cm/hr)
S_r = Runoff rate (cm/hr)

This assumes that rainfall is constant. A small standard rain gauge should be attached to the back of the plot to record total rainfall.

Sediment Concentration and Sample Collection:

Sediment samples are collected from runoff every 5 minutes by obtaining a 1-liter subsample. Be sure not to overfill the bottles. Be consistent in filling the bottles to the 1 liter level to avoid error. Pour the remaining volume of water into a 115 liter plastic container. As a minimum, runoff collection periods are 5-, 10-, 15-, 30-, and 60-minutes. After 1 hour, thoroughly agitate the total runoff volume and take a 1-liter total cumulative subsample.

About 5 ml of superflock[4] should be added to the sample and be allowed to stand overnight. The sample is filtered through a funnel containing a tared Whatman No. 1 paper filter and oven-dried and weighed in grams. This weight is expressed as sediment concentration (g/liter).

Other techniques can be used such as evaporating the water in the plastic liter runoff sample bottle in a drying oven after the superflock solution has been added. Be sure that the plastic bottles are rated to withstand temperatures of 49° C.

Sediment concentration can be expressed as an instantaneous value (i.e., sediment concentration at some specific time interval, or as a cumulative measure at specific time intervals).

4. A source of Superfloc is American Cyanamid Co., P.O. Box 32787, Charlotte, NC 28232, (800) 438-5615. Superfloc 16, 0.2% solution (w:v). Dissolve two grams of Superfloc 16 in 1 liter of distilled deionized (DDI) water. Do not shake the mixture as this breaks the polymer chains of the Superfloc. Gently swirl the mixture occasionally over several days until the Superfloc is completely dissolved in the DDI water.

Interrill Erosion:

Interrill erosion is calculated as follows:

$$E = \frac{\dfrac{(C_i)(R_i)}{1000\,\frac{g}{kg}}\left(10{,}000\,\frac{m^2}{ha}\right)}{P}$$

where:

E = Interill erosion from plot (kg/ha) for the time interval of interest
Ci = Sediment concentration from a specific time interval (g/l)
Ri = Total runoff volume from a specific time interval (liters)
P = Plot size (m^2)

Calculations: Example 1

Five grams of oven-dried sediment were obtained from a liter subsample at between 10 and 15 minutes. Total volume of runoff measured during this 5 minute period was 5 liters. The plot size used is 0.5 m^2.

Ci = 5 grams
Ri = 5 liters = 5,000 cm^3
P= 0.5 m^2 = 5,000 cm^3

To convert kg/ha to lbs/ac multiply by 0.893

$$E = \frac{\dfrac{(5g/l)(5\ell)}{1000\,\frac{g}{kg}}\left(10{,}000\,\frac{m^2}{ha}\right)}{0.5m^2} = 500\,\frac{kg}{ha}$$

$$500\,\frac{kg}{ha}(0.893) = 446.5\,\frac{lbs}{ac}$$

Calculations: Example 2

In a 3.5 ft^2 plot, a 1-liter subsample bottle was collected from cumulative runoff at 60 minutes. The subsample, 1-liter bottle, contained 3.5 grams of oven dry sediment. Total runoff at the end of a 60 minute run was 33.83 liters.

Convert ft^2 to m^2 = (3.5 ft^2)(.0929) = 0.3251 m^2

$$E = \frac{\dfrac{(3.5 g/l)(33.83 l)}{1000\dfrac{g}{kg}}\left(10{,}000\dfrac{m^2}{ha}\right)}{0.325 m^2} = 3643.23\frac{kg}{ha} = 3253.41\frac{lbs}{ac}$$

Vegetation and Soils as Related to Hydrology

The amount of data or variables that can be used to predict hydrological assessments (infiltration, runoff, and sediment) are infinite. Predicting infiltration from vegetative and soil variables (from field measurements such as percent cover, above ground biomass, root biomass, bulk density, soil texture, etc.) can be more tedious than measuring infiltration itself. Infiltration and runoff can be determined directly; however, this approach provides no information about how the plant/soil complex affects hydrologic relationships.

Vegetation in the Simulator Runoff Micro-plot:

Measure plant height in centimeters, clip, and bag plants by species. Standing dead height and mass should also be collected. Mulch or litter on the soil surface should be collected separately. Label paper bag (site, species, date), and bag separately. Air dry or oven dry weights by species are recorded on the field sheet.

Record canopy cover in the micro-plot for each species to the nearest percent. Canopy cover can be estimated using a point cover frame or by the ocular method. Point cover and random roughness can be done simultaneously. Perform necessary calculations for total weight and composition by species. From the micro-plot, record average number of canopy layers [e.g., tall-or-mid-grass overstory (first layer), forb understory (second layer), and shortgrass understory (3rd layer) equals three layers]. Also record percent bare ground, percent of the soil surface covered by litter or mulch, percent rock cover, and percent cryptogam cover. Describe rock fragment size and record percent rock fragments on the soil surface. Other site information included on the hydrology field sheet should also be completed.

Collection of Vegetation Data in a Macroplot Around the Simulation Frame:

Establish a 375 m^2 (approx. 0.1 acre) circular plot [72 ft, (21.8 m) diameter] around the area of the hydrology plot. Collect this data the day before or after the simulation run. If this data is collected the day before the simulation, be careful to rope off the simulation area so that no disturbance or footprints occur in or near the simulation plot. If the data is collected after the simulation, designate and mark off the macroplot area so that no traffic occurs in this area. The 0.1 acre macroplot will be used to further verify (quantify and identify) that the sample area is an actual representation of the respective range site. In the 0.1 acre macroplot, estimate percent canopy cover to the nearest percent and percent composition by weight for all plant species. Estimates of canopy coverage classes can also be used: T = trace; (1) 1 to 5%; (2) 5 to 25%; (3) 25 to 50%; (4) 50 to 75%; (5) 75 to 95%; and (6) 95 to 100%. If the canopy cover class is near the high or low end, use the symbols + or -, respectively (e.g., 2+ if the canopy cover class is closer to 25%). If + or - is not designated, use the mean value for the class (e.g., cover class 2 is 15% cover). Canopy cover can exceed 100 percent, especially if there are several canopy layers (e.g., shrub—grass canopies). The plant species data from the 0.1 acre macroplots will be used for range watershed models, establishing range condition class, and calculating other ecological attributes for range site descriptions.

Canopy Coverage Estimation Guide:

Dimensions of Plant Canopy for Various Canopy Cover Classes in a 375 m^2 Circular Plot

Plot	% Area	Diameter meters	Diameter ft.
375.00 m^2	100.00	21.85 m	71.69 ft
93.75 m^2	25.00	10.92 m	35.84 ft
37.50 m^2	10.00	6.91 m	22.67 ft
18.75 m^2	5.00	4.88 m	16.03 ft
3.75 m^2	1.00	2.18 m	7.17 ft
1.87 m^2	0.05	1.54 m	5.10 ft
0.375 m^2	0.01	0.69 m	2.26 ft
0.0375 m^2	0.001	0.22 m	0.71 ft

Root Samples:

Plant species are not equitable with respect to root morphology and how the roots affect the hydrological dynamics of a site (Weaver and Albertson 1956, Estes et al. 1979, Richards 1986). A circular sample, 30.5- cm diameter by 10.2- cm depth root sample should be taken in the sample plot during the time the vegetation in the plot is clipped. Use subjectivity without preconceived bias when locating the sample. The root sample can be stored in sample bags. To prepare a root sample for washing, soak the soil/root samples in water with calgon solution (water softener). Overnight soaking is usually adequate. A 30.5- cm diameter 2 mm sieve is sufficient to screen the root sample. Wash the soil from the roots with a gentle stream of water from a garden hose. A clayey sample generally takes about 20 minutes. Place washed roots in a sample bag and air dry for at least 2 weeks. Oven drying is preferable (60° C for 48 hours).

Calculations:

A 12 in (30.5 cm) circular frame was used, radius = 6 in (15.25 cm)

$$Area = \pi r^2$$

$$3.14159(6 inches^2) = 113.097 inches^2$$

Convert in^2 to ft^2, 144 in^2 = 1 ft^2

$$\frac{113.097 inches^2}{144} = 0.785 ft^2$$

96/N = 0.785 ft^2; where N = conversion factor gms to lbs/ac

N = 96/0.785 = 122.231

The oven dried root sample = 50 g.
(122.231)(50 g) = 6111.55 lbs/ac root biomass for a 4-inch depth.

To convert lbs/ac to kg/ha multiply by 1.12

6111.55 lbs/ac (1.12) = 6844.94 kg/ha

Random Roughness:

Soil microrelief, cross slope and down slope, within each plot is measured using a microrelief or pinpoint frame (Kuipers 1957, Kincaid and Williams 1966, Simanton et al. 1987). Soil roughness is calculated as the standard deviation of pin height from a zero point representing a level surface. The pinpoint frame needs to be long enough to fit over the width of the plot frame. The frame must be leveled up, down, and across the slope. For small plot work, the distance between pins should be 6 cm. For a 0.5 m^2 plot, about 50 horizontal points are satisfactory. For more detailed investigations and research, read random roughness horizontally and vertically in the plot. Random roughness can be read to the nearest millimeter. Random roughness, point cover, and leaf area index can be read at the same time.

Collection of Soils Data

Soils data is a valuable component in range hydrology studies and models. Soil variables can be classified as quantitative and qualitative. Particle size analysis (percent sand, silt, and clay) is a quantitative measure whereas soil structure is a qualitative measure.

All soil samples for analysis should be taken inside the simulation plot. Document whether the sample was taken on or between basal plant crowns. Be consistent on all plots. Generally in bunchgrass grassland vegetation, soil samples are collected between the grass basal crowns. In stands where there are sod or mat forming species, sample soil randomly. If there is a specific reason to sample on a basal crown, document why.

In shrub communities, the soil sample area needs to be carefully thought out and should correspond to the objectives of the investigation. Blackburn et al. 1992b found significant spatial differences with respect to soils on five soil surface cover types in a sagebrush plant community. They designated the five cover types as shrub coppice dune, moss-grass associated with the coppice dune, moss-interspace, bare ground, and vesicular crust.

Other soil characterization should be done within the 375 m^2 macroplot. Since the upper soil surface is more correlated with hydrologic response (infiltration, runoff, and erosion) during a short simulation run (one hour or less), it is important to collect more detailed samples from the soil surface. It is recommended that soil samples be collected at 0 to 3.8 cm, 3.8 to 7.6 cm, 7.6 to 15 cm, and > 15 cm, depending on the objectives of the investigation. Spaeth (1990) found no hydrologic correlations with some soil physical properties at a sample depth of 0 to 7.6 cm. However, correlations of hydrologic variables with some soil physical properties were found when the samples were split into two depths (0-3.8 and 3.8 to 7.6 cm).

All hydrology sites should be correlated with a soil scientist. Each site should be characterized, with special attention given to the surface horizons. Samples can be sent to the National Soil Survey Lab (NSSL). Some pertinent analyses relevant to hydrology are given in Appendix B. Work through Area and State Soil Scientists to request these analyses from the NSSL (SCS 1992). Attach an NRCS-SOI-232 to the soil sample with a cover letter explaining the analyses desired. Several helpful references on soil analysis concepts and procedures are given in Appendix B.

Each horizon selected for complete characterization will be sampled following the Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey (Soil Survey Staff 1984). Where applicable, three clod samples will be taken and coated with saran for laboratory determination of bulk density (where possible). When a clod or core sample for bulk density cannot be extracted without crumbling, measure bulk density in the field at two depths, 0 to 2.5 cm and 2.5 to 10 cm with the compliance cavity technique (Grossman 1992) or the ASTM rubber balloon method (ASTM 1984a).

Literature Cited

American Society of Agronomy, Soil Science Society of America. 1986. Methods of soil analysis, part I and II. Arnold Klute (ed.). Number 9 in the series Agronomy. Amer. Soc. of Agron., and Soil Sci. Soc. Amer. Inc. Madison, Wisconsin.

ASTM. 1984a. American society for testing and materials: standard test method for density and unit weight of soil in-place by the rubber balloon method. Annual Book of ASTM Standards, Vol. 04.08.

ASTM. 1984b. Annual book of ASTM standards. Vol. 04.08, Soil and rock; Building stones. American Society of Testing and Materials, Philadelphia, Pennsylvania.

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

Bedunah, D.J., and R.E. Sosebee. 1985. Influence of site manipulation on infiltration rates of a depleted west Texas range site. J. Range Manage. 38:200-205.

Blackburn, W.H. and C.M. Skau. 1974. Infiltration rates and sediment production of selected plant communities and soils of Nevada. J. Range Manage. 27:476-480.

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

Blackburn, W.H. 1975. Factors influencing infiltration and sediment production of semi-arid rangelands in Nevada. Water Resources Research 11:929-937.

Blackburn W.H. 1984. Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses, p. 927-983. In: Developing strategies for rangeland management. National Research Council/National Academy of Sciences. Westview Press, Boulder, Colorado.

Blackburn, W.H., T.L. Thurow, and C.A. Taylor. 1986. Soil erosion on rangeland. Symposium on the use of cover, soils, and weather data in rangeland monitoring, Orlando, Florida, February 12, 1986. Texas Agr. Exp. Sta., TA-2119.

Blackburn, W.H., F.B. Pierson, and M.S. Seyfried. 1990. Spatial and temporal influence of soil frost on infiltration and erosion of sagebrush rangelands. Water Resources Bulletin 26:991-997.

Blackburn, W.H., F.B. Pierson, C.L. Hanson, T.L. Thurow and A.L. Hanson. 1992a. Variations in rangeland hydrologic/erosion processes. Presented at the ASAE Summer Meetings, Albuquerque, New Mexico, June 16-23. Paper No. 912019.

Blackburn, W.H., F.B. Pierson, C.L. Hanson, T.L Thurow, and A.L. Hanson. 1992b. The spatial and temporal influence of vegetation on surface soil factors in semiarid rangelands. Transactions of the ASAE 35:479-486.

Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. Rangeland hydrology. Kendall Hunt Publ. Co. Dubuque, Iowa.

Brooks, K.N., P.F. Ffolliott, H.M. Gregersen, and John L. Thames. 1991. Hydrology and the management of watersheds. Iowa State University, Ames, Iowa.

Carlson, D.H., T.L Thurow, and C.A. Jones. 1992. Biophysical simulation models as a foundation of decision support systems. In J.W. Stuth (ed.). Decision support systems for grazed ecosystems, UNESCO-MAB Book Services, Parthenon Press, Manchester, England.

Chow, V.T., and T.E. Harbaugh. 1965. Raindrop production for laboratory experimentation. J. Geophysical Res. 70:6111-6119.

Cook, C.W., and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society for Range Management, Denver, Colorado.

Corson, W.H. 1990. The global ecology handbook. The Global Tomorrow Coalition. Beacon Press, Boston.

Dee, F.F., T.W. Box, and E. Robertson. 1966. Influence of grass vegetation on water intake of Pullman silty clay loam. J. of Range Management 19:77-79.

Dunne, T., and L. Leopold. 1978. Water in environmental planning. W.H. Freeman and Co., San Francisco, California.

Environmental Protection Agency. 1992. The quality of our Nation's Water: 1990. EPA 841-K-92-001, June 1992. Office of Water, Washington, DC.

Estes, J.R., R.J. Tyrl, and J.N. Brunken. 1979. Grasses and Grassland Systematics and Ecology. Univ. of Oklahoma Press, Norman, Oklahoma.

Franks, C., L.C. Brockman, M. Whited, and S.W. Waltman. 1993. Using the benchmark site selection process to enhance modeling. In: F.B Pierson and K.E. Spaeth (eds.). Predicting rangeland hydrologic and erosion processes. Proceedings of a Symposium, February 16, 1993. The 46th Annual Meeting of the Society for Range Management Albuquerque, New Mexico, February 14-19, 1993.

Gifford, G. F. 1984. Vegetation allocation for meeting site requirements. In: Developing Strategies for Rangeland Management. pp. 35-116. National Research Council, National Academy of Sciences. Westview Press, Boulder, Colorado.

Gifford, G.F. 1985. Cover allocation in rangeland watershed Management (a review), p. 23-31. In: B. Jones and T. Ward (eds.). Watershed management in the eighties: Proc. of a Symposium, Denver, Colorado, Apr. 30 - May 1, 1985. ASAE, St. Joseph, MI.

Griffin, R.C., and B.A. McCarl. 1989. Brushland management for increased water yield in Texas. Water Resources Bulletin 25:175-186.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream hydrology. An introduction for ecologists. John Wiley and Sons, New York, New York.

Grossman, R.B. 1992. Compliance Cavity Technique for Bulk Density Determination. USDA-Soil Conservation Service, Midwest National Technical Center, Lincoln, Nebraska.

Hanson, C.L., A.R. Kuhlman, and J.K. Lewis. 1978. Effect of grazing intensity and range condition on hydrology of western South Dakota ranges. South Dakota State University Agr. Exp. Sta. Bull. 657.

Heede, B.H. 1979. Deteriorated watersheds can be restored: A case study. Environmental Management 3:271-281.

Hibbert, A.R. 1983. Water yield improvement potential by vegetation management on western rangelands. Water Resources Bulletin 19:375-381.

Hillel, D. 1982. Introduction to Soil Physics. Academic Press, Inc., California.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1989. Range management principles and practices. Prentice Hall, Englewood Cliffs, New Jersey.

Humbolt, A. von and A. Bonpland. 1807. *Essai sur la geographie des plantes*. Paris, France.

Johnson, C. W., and N. E. Gordon. 1988. Runoff and erosion from rainfall simulator plots on sagebrush rangeland. Transactions of the American Society of Agricultural Engineers 31:421-427.

Kincaid, D.C., and G. Williams. 1966. Rainfall effects on soil surface characteristics following range improvement treatments. J. Range Manage. 19:346-351.

Kuipers, H.A. 1957. A relief meter for soil cultivation studies. Netherland J. Agr. Sci. 5:255-262.

Laws, J.O., and D.A. Parsons. 1943. Relation of raindrop size to intensity. Trans. Am. Geophy. Union 24:452-460.

Mazarak, A.P., and E.C. Conrad. 1959. Rates of water entry in three great soil groups after seven years in grasses and small grains. Agron. J. 51:264-267.

Meeuwig, R.O. 1971. Infiltration and water repellency in granitic soils. USDA-Forest Service Intermountain Forest and Range Exp. Sta., Ogden, Utah. Research Paper INT-111.

Moss, A.J. 1989. Impact droplets and the protection of soils by plant covers. Aust. J. Soil Res. 27:1-16.

Moss, A.J., and T.W. Green. 1987. Erosive effects of the large water drops (gravity drops) that fall from plants. Aust. J. Soil Res. 25:9-20.

Neff, E.L. 2979. Why rainfall simulation? p. 3-7. In: Proceedings rainfall simulator workshop. USDA-SEA ARM-W-10.

Osborn, B. 1950. Range cover tames the raindrop. A summary of range cover evaluations, 1949. Soil Conservation Service, Fort Worth, Texas.

Pearse, C.K., and S.B. Woolley. 1936. The influence of range plant cover on the rate of absorption of surface water by soils. J. For. 34:844-847.

Population Reference Bureau. 1989. 1989 World population data sheet. Washington, DC.

Quigg, P.W. 1976. Water: The essential resource. International Series No. 2. National Autobon Society.

Rauzi, F., C.L. Fly, and E.J. Dyksterhuis. 1968. Water intake on midcontinental rangelands as influenced by soil and plant cover. USDA Tech. Bull. No. 1390.

Renard, K.G. 1986. Rainfall simulators and USDA erosion research: history, perspective, and future. p. 3-6. In: L.L. Lane (ed.). Erosion on rangelands: emerging technology and data base. Proceedings of the rainfall simulator workshop, January 14-15, 1985, Tucson, Arizona. Society for Range Management, Denver, Colorado.

Richards, J.H. 1986. Root form and depth distribution in several biomes. p. 83-96. In: D. Carlisle, W.L. Berry, I.R. Kaplan, and J.R. Watterson (eds.). Mineral exploration: biological systems and organic matter. Rubey Vol. V. Prentice-Hall, Englewood Cliffs, New Jersey.

Richardson, C.W., E. Burnett, and R.W. Bovey 1979. Hydrologic effects of brush control on Texas Rangelands. Transactions of the ASAE 22:1113-1122.

Riezebos, H.TH., G.F. Epema. 1983. Drop shape and erosivity. Part II: Splash detachment, transport and erosivity indices. Earth Surface Proc. and Landforms. 10:69-74.

Satterlund, D.R. 1972. Wildland watershed management. Ronald Press Co., New York, New York.

Simanton, J.R., L.T. West, M.A. Weltz, and W.G. Wingate. 1987. Rangeland experiments for water prediction project. ASAE, International Winter Meetings Paper, No. 87-2545.

Soil Survey Staff. 1984. Procedures for collecting soil samples and methods of analysis soil survey. Soil Survey Investigations Report No. 1. USDA-SCS. U.S. Government Printing Office, Washington, DC.

Soil Survey Staff. 1992 (Draft). National Soil Handbook. USDA-SCS, Lincoln, Nebraska.

Spaeth, K. E. 1990. Hydrologic and ecological assessments of a discrete range site on the southern High Plains. Ph.D. Dissertation, Texas Tech. Univ., Lubbock, Texas.

Swanson, S.R., and J.C. Buckhouse. 1984. Soil and nitrogen loss from Oregon lands occupied by three subspecies of big sagebrush. J. Range Manage. 37:298-302.

Synman, H.A., and W.L.J. Van Rensburg. 1986. Effect of slope and plant cover on run-off, soil loss and water use efficiency of natural veld. Grassl. Soc. sth. Afr. 3,4:153-158.

Thurow, T.L., W.H. Blackburn, and C.A. Taylor. 1988. Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. J. of Range Manage. 41:296-302.

USDA-Soil Conservation Service. 1992. Soil survey laboratory manual. Soil Survey Investigations Report No. 42, Version 2.0, August 1992. National Soil Survey Laboratory, Lincoln, Nebraska.

Viessman, W., G.L. Lewis, and J.W. Knapp. 1989. Introduction to hydrology, third edition. Harper and Row, New York, New York.

Weaver, J.E., and F.W. Albertson. 1956. Grasslands of the Great Plains. Johnsen Publ. Co., Lincoln, Nebraska.

Wilcox, B.P., M.K. Wood, T.T. Tromble, and T.J. Ward. 1986. A hand portable single nozzle rainfall simulator designed for use on steep slopes. J. Range Manage. 39:375-377.

Wilcox, B.P., and M.K. Wood. 1989. Factors influencing interill erosion from semiarid slopes in New Mexico. J. Range Manage. 42:66-70.

Wood, M.K., and W.H. Blackburn. 1981. Grazing systems: their influence on infiltration rates in the rolling plains of Texas. J. of Range Manage. 34:331-335.

Wood, J.C., and M. Karl Wood. 1988. Infiltration and water quality on a range site at Fort Stanton, New Mexico. Water Res. Bull. 24:317-323.

Appendix A

Calibration

The rainfall simulator rate should be calibrated prior to the run by collecting runoff water from a simulation run for at least 5 minutes. Several rain gauges or a pan (the same dimensions as the plot) can be used. Measure the 5-minute volume in milliliters.

Calculations: Example 1

$1 cm^3 = 1$ ml
$1 ft^2 = 0.0929 m^2$
$3.5 ft^2$ plot frame $= 0.32515 m^2 = 3251.5 cm^2$

To solve for rainfall intensity (x). A 5-minute run produced 2753 ml of runoff was collected from a the $3251.5 cm^2$ catchment pan.

$(3251.5 cm^2)$ (x) $= 2753 cm^3$ or ml

$$x = \frac{2753 cm^3 \text{ of runoff}}{3251.5 cm^2 \text{ surface area of plot}}$$

x = 0.8467 cm/5 minutes. 0.8467 x 12 (conversion from 5 min to 1 hour) = 10.16 cm/hr or 4.0 in/hr rate of application.

Calculations: Example 2

A 5-gal plastic bucket (cylindrical with straight sides) was placed under the drip needle simulator. The diameter of the container opening was 11.25 in.

(11.25 in)(2.54 cm/in) = 28.575 cm, radius = 14.2875 cm
Area $= \pi r^2 = (3.14)(14.2875 cm^2) = 641.302 cm^2$

The rainfall simulator was run for 5-min with the flow gauge setting on 10. The measured volume of runoff was 545 ml.

$$\frac{545 cm^3 \text{ volume of runoff}}{641.302 cm^2 \text{ surface area of container}} = 0.8498 cm \text{ application rate } 5 \min$$

(0.8498 cm) (12) (conversion from 5 min to 1 hour) = 10.2 cm/hr or 4.0 in/hr

Appendix B

Particle-size Analyses (notations given are NRCS-National Soil lab codes):

- **GC205**, Coarse gravel fragments 5 - 20 mm
- **GC52**, 2-5 mm gravel fragments
- **SAND**, Total Sand 0.002 - 0.05 mm
- **VFSAND**, Very fine sand 0.5 - 1 mm
- **FSAND**, 0.10 - 0.25 mm
- **MSAND**, 0.25 - 0.5 mm
- **CSAND**, 0.5 - 1.0 mm
- **VCSAND**, 1.0 - 2.0 mm
- **SILT**, Total silt, 0.002 - 0.05 mm
- **FSILT**, Fine silt, 0.002-0.02 mm
- **CSILT**, Coarse silt, 0.02 - 0.05
- **CLAY**, Total clay, < 0.002 mm
- **FCLAY**, Fine clay, < 0.0002 mm
- **CO3CLY**, CO3, Carbonate clay (calcareous samples only)

Fabric-related Analyses:

- **DOD**, Bulk density, oven-dry from clods
- **D3**, Bulk density, 1/3 bar suction
- **LEWS**, Linear extensibility, whole soil, 1/3 bar to oven dry
- Water retention differences (WRD)
- **WP3**, 1/3 water bar, clods, weight percent
- **W15AD**, 15 bar water on air dry soil, weight percent

Cation Exchange and Extractable Bases:

. **SUMBSE**, Sum of NH4OAC (Ammonium acetate) extractible bases

. **BSESAT**, NH4OAC base saturation

. **CECCLY**, Ratio CEC/Clay

. **ACIDX**, NH4OAC extractible acidity at pH 8.2

. **ALX**, KCL extractible aluminum (only when pH < 5.2)

. **CEC7**, NH4OAC cation exchange capacity (CEC)

. **BSECAT**, NH4OAC base saturation by sum cations (Cation exchange capacity by summing base and acidity)

. **SUMCAT**, Sum of cations

. **CAX**, NH4OAC extractable calcium (where applicable)

. **MGX**, NH4OAC extractable magnesium

. **NAX**, NH4OAC extractable sodium

. **KX**, NH4OAC extractable potassium

Soluble Salt:

. Electrical conductivity where salts suspected and the following analyses made if salt detected

. **ECSX**, Electric conductivity, saturation extract

. **TESALT**, Total estimated salt

. SAR, Sodium adsorption ratio

Other Chemical Analyses:

- **OC**, Walkley-Black organic carbon
- **Total C** (surface layer)
- **N**, Kjeldahl nitrogen
- **P**, Extractable phosphorous
- **NO3SX**, Nitrate, saturation extract
- **NO22CGH**, Nitrite, saturation extract
- **FEDITH**, Dithionite-citrate extractible Iron, Fe
- **ALDITH**, Dithionite citrate extractable Aluminum, Al
- **MNDITH**, Dithionite citrate extractable Manganese, Mn
- **PH1H2O**, pH, 1:1 soil-water suspension
- **PH2CC**, pH, 1:2 soil-CaCl2 suspension
- **CACO3**, Carbonate, < 2mm fraction (where applicable)
- **CACO32**, Carbonate, 2 - 20 mm fraction (where applicable)
- **GYPL2**, Gypsum, < 2mm fraction (where applicable)
- **GYPG20**, Gypsum, 2 - 20 mm fraction (where applicable)

Mineralogical Analyses (total clay fraction):

- X-ray diffraction analysis and interpretation (qualitative to semi-qualitative)
- Differential scanning calorimetry
- General interpretation of mineralogy
- Volcanic glass content of very fine sand or silt fraction if glass is suspected

Other Analyses:

- Modulus of rupture
- Moisture release curves
- Aggregate stability by sieving (National Soil Survey Lab methodology)

Study Site Soil Characterizations by Soil Mechanics Laboratory

The following analyses are available through the NRCS Soil Mechanics Laboratory, Lincoln, Nebraska on samples maintained at field moisture content. These analyses will include:

a. Atterberg limits (ASTM, 1984b);

b. Unconfined compressive strength (ASTM, 1984b);

c. Direct shear strength at low confining pressure;

d. Pin-hole test for dispersion/erodibility (test ran with distilled water and the water used for the field rainfall simulation) (ASTM, 1984b);

e. Middleton dispersion ratio (modification of ASTM, 1984b);

f. Volume change under variable 1-dimensional applied loads for saturated and unsaturated conditions; and

g. Saturated hydraulic conductivity.

Other Study Site Measurements

During site characterization, record depth of root penetration of the surface horizons. In a shrub community, determine depth of root penetration in the coppice and interspace areas.

Appendix C

Suggested reading and references on rangeland hydrology and rainfall simulation

Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. Rangeland hydrology. Kendall Hunt Publ. Co. Dubuque, Iowa.

Cook, C.W., and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society for Range Management, Denver, Colorado.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1989. Range management principles and practices. Prentice Hall, Englewood Cliffs, New Jersey.

Peterson, A.E., and G.D. Bubenzer. 1986. Intake Rate: Sprinkler Infiltrometer. p. 845-867. In: A. Lute (ed.). Methods of soil analysis, Part I, physical and mineralogical methods 2nd. ed. Agronomy No. 9, Am. Soc. Agron., Inc., Madison, Wisconsin.

USDA-Agricultural Research Service 1979. Proceedings of the rainfall simulator workshop Tucson, Arizona, March 7-9, 1979. ARM-W-10/July 1979.

USDA-Agricultural Research Service 1982. Proceedings of the workshop on estimating erosion and sediment yields on rangelands Tucson, Arizona, March 7-9, 1981. ARM-W-26/June 1982.

USDA-Agricultural Research Service 1985. Erosion on rangelands: emerging technology and data base. Proceedings of the rainfall simulator workshop. January 14-15, 1985, Tucson, Arizona. Society for Range Management, Denver, Colorado.

USDA-NATURAL RESOURCE CONSERVATION SERVICE: Grazingland Hydrology Field Worksheet

Data by ____________________ Date of simulation ________________ Date of Prewetting _______________

[illegible] Name ______________________ Mapping Unit Name _______________ Soil Series ____________________

Slope ________________ Elevation ________________ Aspect ________________ (______________ deg.)

Location of site:

Describe Rock Fragment Size (Stones, Cobbles, Gravels):

Describe Soil Crusts, Desert Pavement, Vesicular Crusts, Cryptogamic crust makeup etc. if present:

Describe location of hydrology plot: Shrub coppice, interspace, tree understory, grass stand etc.

Plot Data: Plant Name (Sci. Symbol/Common Name)	Avg. Height (in)	%Canopy Cover	Clipped Weight (g)
Standing Dead			
Root Sample	xxxxxxxxxxxxxxxxx	xxxxxxxxxxxxxxxxx	

Average Number Canopy Layers	% Bare Ground	% Soil Surface Litter Cover	% Rock Cover	% Cryptogam Cover

Calibration Area _______ cm^2; Water collected in 5 min. _______ ml; Rainfall Simulation Rate _____ in/hr; _____ cm/hr

Simulation start time _______; Simulation end time _______ ; Plot size _______ ft^2; _______ m^2; Plot shape _______

Time 50% ponding _______; Time of Runoff _______; % Soil Moisture _______ 0.0 to 1.0 in; _______ 3.0 in; ______ 6.0 in;

Wind Speed _______; Wind Direction _______; Notes ____

Time	Runoff (ml)	Runoff (ml)	Runoff (ml)	Sediment Bottle No.
0 - 5 min				
5 - 10 min				
10 - 15 min				
15 - 20 min				
20 - 25 min				
25 -30 min				
30 - 35 min				
35 - 40 min				
40 - 45 min				
45 - 50 min				
50 - 55 min				
55 - 60 min				
			Cumulative Sediment	

Note: Attach a Site Specific Soil Profile Description with Taxonomic Classification.

Worksheet for Plant Data: Range Hydrology Investigations

Kind of Land:

Describe Use History and Grazing Systems (if any):

Kind of Animals:

Season of Use:

Fire History: Unknown, Rarely burned, Occasionally burned, Systematically burned, Accidently burned

Specify Fire Frequency and Purpose:

Brush Management History:

Type of Brush Control: Mechanical, Biological, Chemical, Fire

Describe Previous Year and Current Growing Season Status:

Vegetation in 0.1 Acre (72 ft diameter) macroplot

Plant Name Scientific Symbol/Common Name	% Canopy Cover	Estimated Weight lbs/ac	% Composition by Weight	% Climax by Weight
Totals				

Canopy coverage class T = trace; (1) 1 to 5%; (2) 5 to 25%; (3) 25 to 50%; (4) 50 to 75%; (5) 75 to 95%; (6) 95 to 100%

evaluated by changing parameter inputs to reflect various conditions.

Worksheet for Plant Data: Range Hydrology Investigations

Kind of Land:

Describe Use History and Grazing Systems (if any):

Kind of Animals:

Season of Use:

Fire History: Unknown, Rarely burned, Occasionally burned, Systematically burned, Accidently burned

Specify Fire Frequency and Purpose:

Brush Management History:

Type of Brush Control: Mechanical, Biological, Chemical, Fire

Describe Previous Year and Current Growing Season Status:

Vegetation in 0.1 Acre (72 ft diameter) macroplot

Plant Name Scientific Symbol/Common Name	% Canopy Cover	Estimated Weight lbs/ac	% Composition by Weight	% Climax by Weight
Totals				

Canopy coverage class T = trace; (1) 1 to 5%; (2) 5 to 25%; (3) 25 to 50%; (4) 50 to 75%; (5) 75 to 95%; (6) 95 to 100%

evaluated by changing parameter inputs to reflect various conditions.