# A JEEP-MOUNTED RAINFALL SIMULATING INFILTROMETER

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Runoff studies done at Northern Arizona University have shown the need for a portable infiltration and runoff measuring device. An instrument designed by R.O. Meeuwig of the U. S. Forest Service was examined and an extensive literature review was made to determine the most suitable instrument for use in these studies. Subsequently a hybrid device incorporating features of ring-type flooding-infiltrometers, portable rainfall-simulating infiltrometers and a laboratory device used by V. T. Chow was designed.

## REQUIRED DESIGN CHARACTERISTICS

Runoff and infiltration studies are usually made to predict runoff resulting from natural storms. Predictions are more reliable when the instruments used closely simulate natural rainfall and runoff conditions. Portable instruments can neither exactly duplicate storm events nor can they sample watershed areas in sufficient detail to give highly reliable runoff and infiltration data. Runoff and infiltration devices must be designed to duplicate natural events as nearly as possible.

### PORTABILITY

The instrument and an adequate quantity of water for a measurement test must be sufficiently portable to be moved in the field to various test sites. Many instruments have been designed with portability as an important factor. The most portable instruments may be hand carried to reach isolated sites within a study area. Maximizing the portability aspects of the instrument requires that the amount of water and the size of the instrument carried be small. These practical considerations severely limit the size of the test plot and the duration of the test. Less portable instruments sample larger plots and give a better statistical representation of the watershed, however water requirements make them expensive to operate. These devices are generally limited to gentle terrain due to thier size.

### WATER DROP CHARACTERISTICS

Infiltrometers which simulate natural storms must produce artifical rainfall which is similar in intensity, drop size, and drop kinetic energy at ground surface to natural events. Rainfall intensity in inches per hour is usually designed to approximate intensities of near maximum storms. In the Flagstaff region storms having an intensity of two to six inches per hour are of chief interest. The rainfall simulating device must be designed to produce rainfall in the range required in the study.

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The size of the drop produced by the simulator should approximate the size of natural rain drops. Because of the relationship between drop size and terminal velocity, drop size is usually modified to give an appropriate terminal velocity. This modification usually causes the drop size produced by the simulator to be larger than the drop size in natural storms.

In natural storms water drops reach terminal velocity prior to striking the ground. The height of fall in rainfall simulators is limited and drops do not reach terminal velocity. A drop height of one meter or less is usually used in the simulators. Because kenetic energy at impact is considered to be more important than drop size, a larger drop is used in the simulator to give kenetic energy comparable to natural rain drops falling at terminal velocities.

TEST AREA

Many hand-portable infiltrometers use a test plot area of several square inches to a few square feet. A larger test area is desirable to give a more valid statistical representation of the watershed characteristics. The shape of the test area should be circular to minimize edge effects. The watershed being studied may have a variety of slopes. The test apparatus should be designed so that data may be collected on sloping test areas.

NON-DISTURBANCE OF SOIL

Soils are disturbed by water drop impact from both natural storms and simulated storms. Kenetic energy of artificial drops is regulated to reach levels of soil disturbance which are comparable to natural events. Soils are also disturbed if disruption is necessary in the installation and operation of the test apparatus. Design and placement of the test apparatus should provide for minimum disturbance of soil.

LATERAL FLOW

During natural storms the soil is wetted in large areas. Water which enters the soil surface moves downward and horizontal components of movement are minimal. Infiltrometers usually wet a limited test plot and significant edge effects may occur through lateral movement of water from the wetted area to adjacent dry areas. Lateral flow has been minimized by using infiltrometers which are designed with double infiltration rings. In the double ring infiltrometers, the outer ring is used to supply water which retards lateral flow from the inner ring. Other designs use peripheral wetting which provides water to retard lateral flow from the test plot. Significant errors may result if lateral flow is not retarded. Design of a simulator must include a means of minimizing this loss.

METHOD OF MEASUREMENT

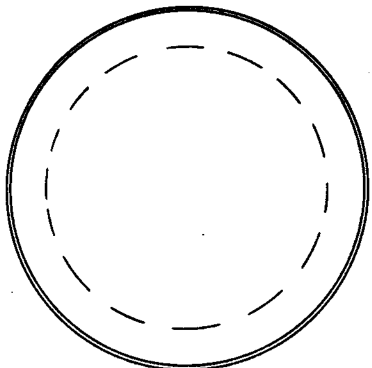
The information required from an infiltration test is the amount of infiltration or runoff as a function of time during the test. The rate of

# FIGURE I

**Sprinkler Head:**

scale: 1 in = 0.5 meters

**PLAN**

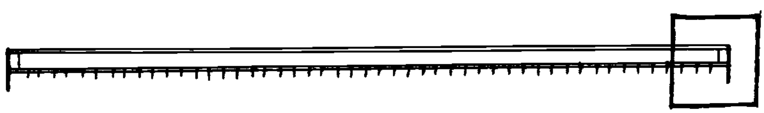


diam inner = 1.0 m

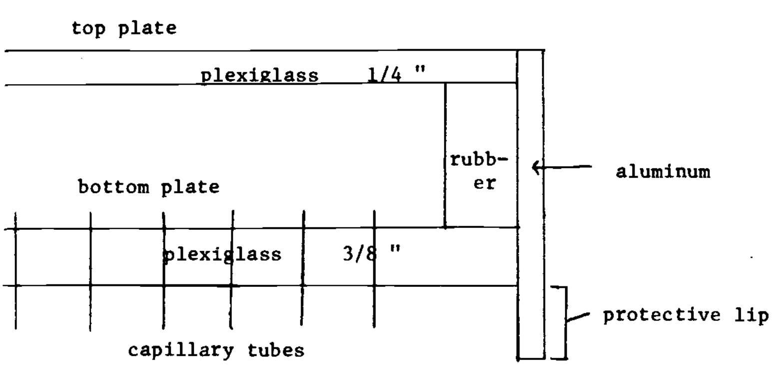
diam outer = 1.25 m

capillary tubes at 1 inch centers

**CROSS SECTION X2**




**BLOW UP - AREA B - ACTUAL SIZE**



infiltration is often measured by subtracting amounts of runoff from quantities of water supplied to the test area at various times throughout the test. Other devices measure infiltration by capturing infiltrated water.

## THE JEEP-MOUNTED INFILTROMETER

The jeep-mounted infiltrometer is believed to minimize the differences between an artificial storm-runoff event and a natural storm-runoff event and to provide adequate portability. Mounting the infiltrometer on a four-wheel drive vehicle allows the unit to be nearly as portable as a hand-carried unit. The carrying capacity of the jeep allows the equipment to be sufficiently large to test a more representative soil plot and to carry enough water to continue a test for periods longer than an hour.

### THE INSTRUMENT

The simulator consists of three basic parts; the sprinkler head, the water supply system, and the water collection system. Figures I and II are scale drawings of the sprinkler head and the unit in use. The sprinkler head is a 1.25 meter diameter cylinder constructed of plexiglass. Water drops are produced from capillary tubes which are bonded at one inch centers to the lower plate of the sprinkler head. Water is supplied to the sprinkler from a constant head reservoir which embodies a Boyle-Mariotte tube to maintain a constant pressure in the reservoir. A flow meter in the supply line between the reservoir and the sprinkler head is used to measure the discharge of the sprinkler. Drops from the sprinkler fall on the test area and are absorbed into the ground untill the infiltration capacity of the test plot has been exceeded. When the infiltration capacity is exceeded, water begins to pond and is removed through a siphon system. The amount of water removed is recorded as a function of time, thus determining runoff.

### WATER DROP CHARACTERISTICS

Capillary tubes of 0.1 inch inside diameter produce water drops which are 5 millimeters in diameter. The sprinkler head is placed at a one meter height above the test plot. Five millimeter drops falling from a height of one meter have a kinetic energy which is equal to that of three millimeter drops falling at terminal velocity. Studies by Laws and Parsons (1943) have shown that three millimeter drops are representative of the average raindrop size in storms having intensities which range from two to six inches per hour. The intensity of rainfall from the sprinkler is controlled by modifying the inflow rate from the reservoir.

### TEST AREA

Water from the sprinkler ralls in and around a collection ring which is a steel cylinder having one-eighth inch wall thickness and a diameter of one meter. The area of the test plot is the horizontal projection of the area of the soil surface within the collection ring. The area of the test plot is maximum when the ring is placed in a horizontal soil surface. When the collection ring is placed on a slope, the area becomes less and is equal to the maximum area times the cosine of the slope. Inflow to the collection ring is computed by determining the ratio of the test plot area to the area of the sprinkler which is 1.25 meters in diameter and multiplying this ratio by the inflow to the sprinkler.

### NON-DISTURBANCE OF SOIL

The soil in the test plot is disturbed by placement of the collection ring. The degree of disturbance is minimized by utilizing a relatively large test plot, one meter in diameter, and by careful placement of the ring. The soil is also disturbed through water drop impact, but because the kenetic energy of drops from the sprinkler were sized to equal the kenetic energy from natural raindrops no correction is believed to be required.

### LATERAL FLOW

Marshall and Stirk (1950) indicate that lateral flow from infiltration is most effectively minimized by peripheral wetting. Water for peripheral wetting is supplied from the 0.125 meter radial overlap of the sprinkler beyond the catchment ring. It is believed that this overlap may be insufficient if wind occurs during an infiltration test. For this reason it is recommended that the test plot be surrounded by a wind screen.

### METHOD OF MEASUREMENT

A constant measured rate of water is applied on the test plot and peripheral to the test plot from the sprinkler. Computation of inflow to the test plot was discussed on the preceding page. The rate of runoff from the test plot is variable from zero at the beginning of the test to a larger quantity later in the test. Runoff volumes are determined by siphoning all surface water from the test plot and recording the volume of siphon water as a function of time. Infiltration is computed by subtracting runoff water from inflow to the test plot.

## CONCLUSIONS

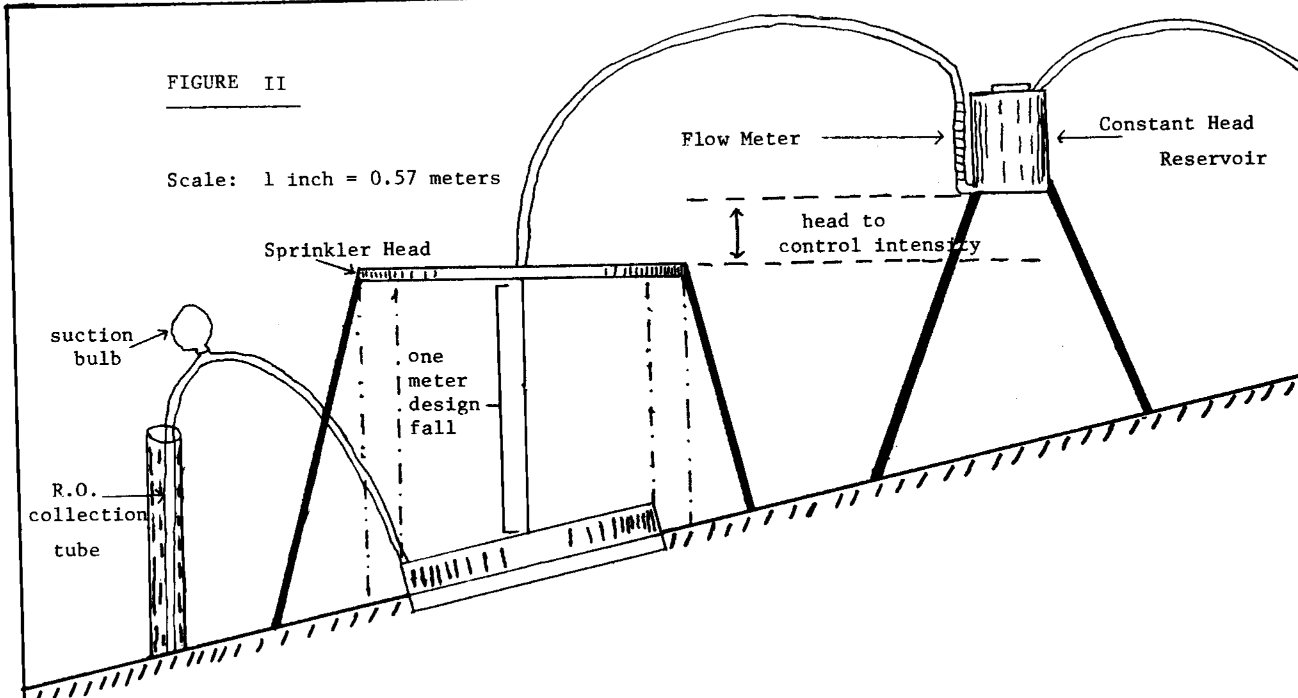
The principal conclusions from this study are:

1. The jeep-mounted rainfall simulating infiltrometer is designed to combine portability with a relatively large test plot and relatively long duration of testing. These advantages make possible more accurate predictions of infiltration rates in runoff potential studies.

2. The instrument has been designed to produce rainfall intensities of 2 to 6 inches per hour which are comparable to natural storm intensities in the Flagstaff area.

FIGURE II

Scale: 1 inch = 0.57 meters




When used on slopes, catch ring will appear as an elliptical projection on the horizontal sprinkler head.

$$Ae = \pi r^2 \cos \theta$$

$\theta$ = angle of slope

SCHEMATIC OF RAINFALL SIMULATOR

3. Capillary tubes of 0.1 inches inside diameter produce drops of five millimeter diameter. Five millimeter water drops from the simulator are equivalent in kinetic energy at impact to naturally occurring three millimeter drops travelling at terminal velocity.

4. Errors due to lateral flow are minimized through peripheral wetting.

## REFERENCES CITED

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