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RAINFALL SIMULATION AS A RESEARCH TOOL^{1/}

K. G. Renard, SEA Research Leader^{2/}

As I approached the assignment of incorporating the comments of W. C. Moldenhauer and C. R. Amerman (who were on the original program but were unable to attend) with mine, I became apprehensive about how to accomplish such an assignment. Therefore, I have selected a few problems they point out, and have added a few of my own. Earl Neff, in his opening remarks, discussed the advantages and disadvantages of rainfall simulators. It appears that most of the participants favor the use of rainfall simulators. As Mech (1) pointed out, "It is much more popular to accentuate the positive. To point out the weakness or shortcomings of a tool so highly regarded and so widely accepted is not without real peril."

Among the factors which are difficult to emulate with a simulator, but which affect the simulation are wind, temperature, humidity, vegetative influences, soil surface and moisture, and frozen soil and snowmelt. Amerman states in his write-up (2), "To be on the safe side, one may simply state that the 'best' sprinkling infiltrometer is the one that most nearly emulates natural precipitation--drop size, kinetic energy, average intensity or intensity pattern, duration, temperature, etc." He goes on to point out that ". . . one seldom sees temperature discussed, and hydraulic conductivity is influenced by temperature. I suspect that for many field infiltrometer tests, neither water nor soil is at temperatures representative of storm conditions." Our experience in Tucson is an example of such an operating procedure. Most of our rainfall simulation work has been conducted during the fall, winter, or spring periods, yet almost all of the runoff results from summer thunderstorms where the cold precipitation (e.g., 50° F) strikes soil surfaces with temperatures well over 100° F. How important is this? I could find nothing quantitative in the literature, but I suspect it might be significant. By the same reasoning, errors introduced by this oversight might be much less than those generated by using point values to infer the spatial heterogeneity of the vegetation and soil within relatively short distances.

Most infiltrometers currently in use have not measured the effect of surface head on infiltration. We all recognize that the problem of infiltration is a two-phase flow problem (water and air). Dixon (3) showed that a parameter, which he defined as effective surface head (the difference between the surface water hydrostatic pressure and the soil air back pressure), markedly

^{1/} Contribution of the Soil, Water and Air Sciences Research USDA-SEA-AR-Western Region.

^{2/} Southwest Rangeland Watershed Research Center, USDA-SEA-AR, 442 East 7th Street, Tucson AZ 85705.

changed infiltration. He designed an infiltrometer to quantify this effect (closed top infiltrometer; Dixon (4)), and has demonstrated that infiltration rate can be changed by an order of magnitude by controlling the effective surface head. Little use of this equipment is being made by other investigators, and the idea of this pressure difference is not being actively pursued.

For some time, I have been concerned about the variation in the distribution of raindrop sizes in the wide variety of climatic provinces with which we conduct our research. Variation occurs seasonally as well as within individual storms, but most rainfall simulators are designed to reproduce the kinetic energy of some storm which may or may not be representative of the region. Moldenhauer points out other problems of simulation in his handout (5):

Simulated rain was compared to natural rain by Meyer (6). Sloneker and Moldenhauer (7) and Sloneker et al. (8), studied the effect of intermittency on soil from rain simulated by oscillating nozzles and found problems when a wide range of intensities are simulated because of recovery of soil suction during the off time. Young and Burwell (9) found, however, very comparable erosion from comparable simulated and natural storms.

A logical extension of this concept is to ask, "How much do we know about the characteristics of drop sizes in different parts of the country?" I suspect the answer is not enough, even though we had one panel address the problem. For example, the "R" term of the Universal Soil Loss Equation (USLE) is based on limited rainfall information despite limited information which has subsequently verified the Laws and Parsons (10) data.

McGregor and Mutchler (11) showed that for storms in Mississippi, the kinetic energy/rainfall intensity relationship was quite similar to the data for Washington, DC. Can we be sure that serendipity has not entered into this relationship? The scatter of data (Fig. 1) is appreciable, and may partly explain the problem encountered when efforts are made to use the USLE on individual storms. Might not experiments be warranted to define this variability across the climatic extremes of the country, and might not the envelope curves explain the wide differences in observed erosion on individual storms? Can we even design simulators to duplicate such data variability, or can we use stochastic techniques with mathematical modeling to depict such phenomenon?

Wischmeier and Smith (12) state, "The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. Median raindrop size increases with rain intensity, and terminal velocities of free-falling waterdrops increase with increased drop size. Since the energy of a given mass in motion is proportional to the velocity-squared, rainfall energy is directly related to rain intensity." Although it is difficult to question the statement, it seems intuitive that different meteorologic conditions in different parts of the country may cause the median drop size/rain intensity relationship to be more complex than postulated by Wischmeier and Smith.

Drop sizes are customarily measured using the ozalid paper, flour pan, or high-speed camera method. Recent information regarding a transducer being

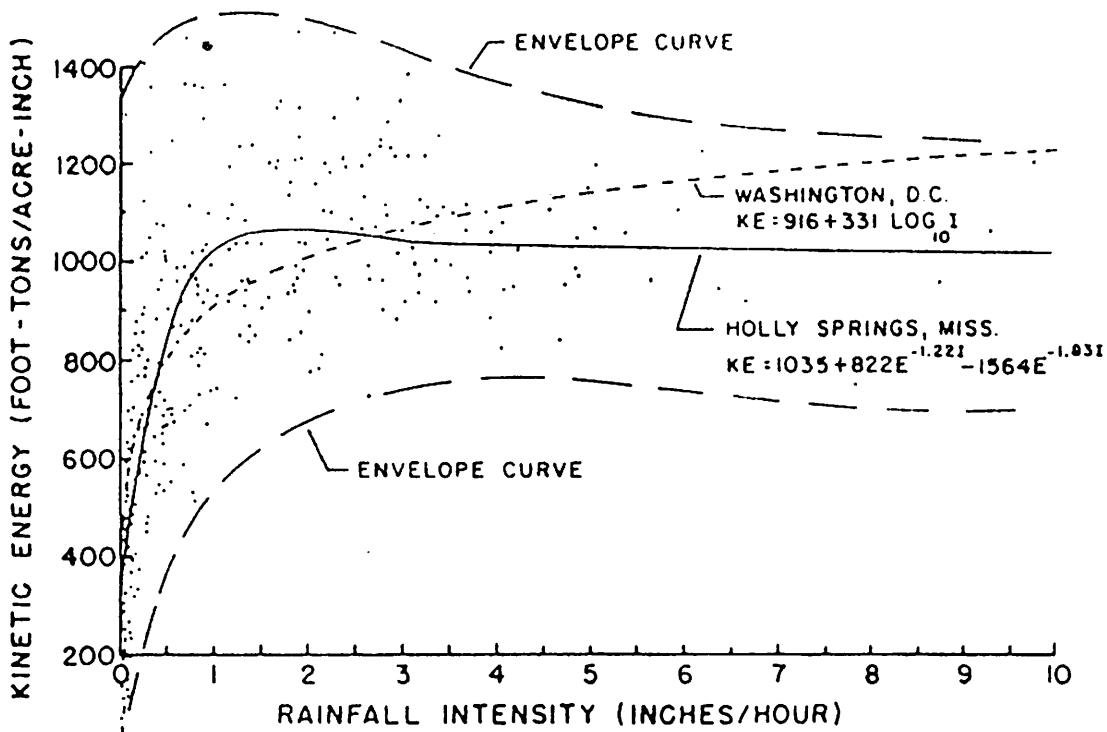


Figure 1.--Relationship of kinetic energy and rainfall intensity computed from 315 raindrop samples collected at Holly Springs, Mississippi, compared with that derived from raindrop samples collected at Washington, D.C., and extrapolated above intensities of 4 inches per hour (10.2 cm/hr) (adapted from McGregor and Mutchler, 1976).

developed by the Illinois State Water Survey illustrates one approach at improving such measurements.

Richard G. Semonin, Atmospheric Sciences Section of the Water Survey, has been working with the schematic illustrated in Figure 2, and has developed the equipment to the point of preparing a publication on the design, calibration, and some observations on the operation of the unit. Calibration requires using drops falling in a 13-meter chamber. The unit can be assembled (exclusive of the recorder) for under \$1,000 - a cost which seems reasonable.

A nationwide network of these transducers could produce the data to develop relationships between storm intensity and raindrop size (assuming a unique relation does exist), and lead to criteria for better nozzle designs for use in construction of rainfall simulators. Another opportunity might be to include a series of the nozzles reported by Don Meyer (13) in a random pattern over a large plot. With better nozzles, it should be possible to simulate a range of storm intensities using the drop sizes typical to the region in question. Furthermore, information on drop sizes in different areas of the country might afford the opportunity to modify the "R" values for use in the USLE and eliminate some problems like that of restricting the upper limit of the annual units of R in certain portions of the country.

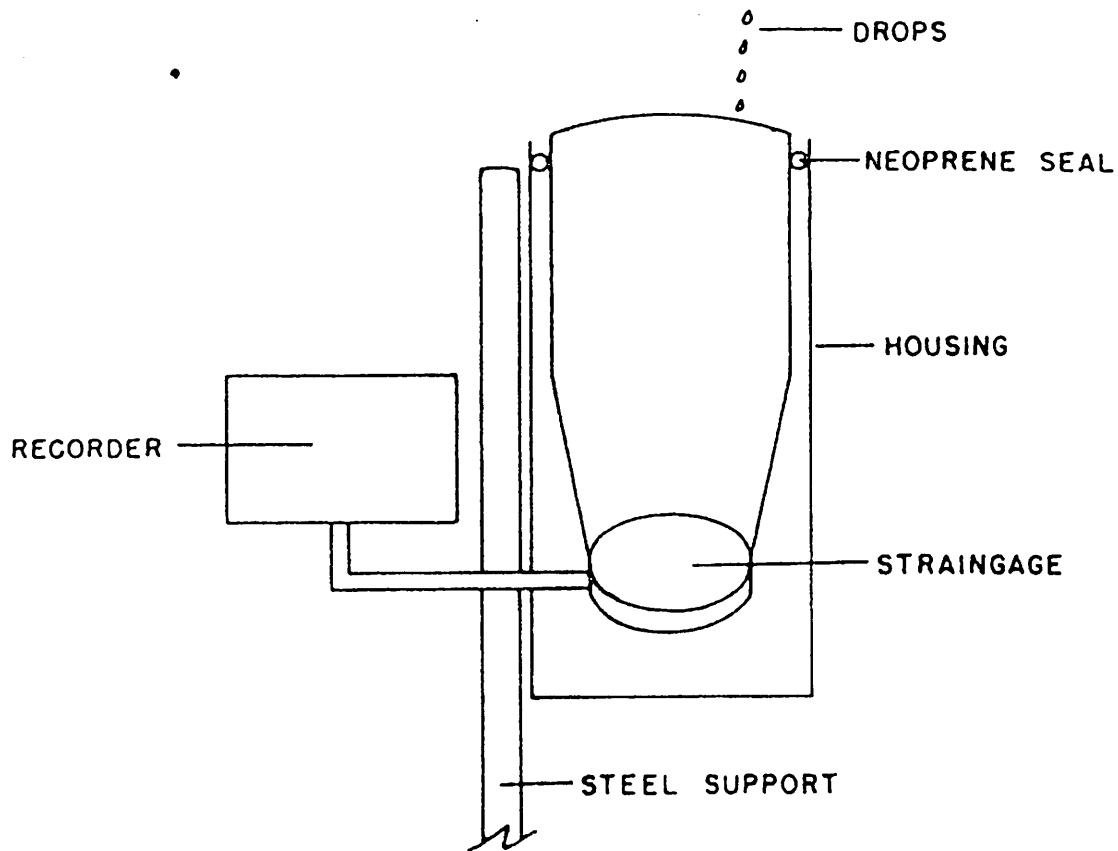


Figure 2.--Raindrop-size transducer schematic.

Rainfall simulators are valuable for infiltration and erosion research, and are the only way to answer many of the questions being asked. At the same time, we need more research to improve rainfall simulators; to see if the many simulators being used are providing compatible information; and to see if this information adequately mimics the conditions encountered in the problem area.

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