USDA FOREST SERVICE RESEARCH NOTE NE-113
1970

FOREST SERVICE, U. S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA.

# WATERSHED MODELS FOR INSTRUCTIONAL FILMS

*Abstract.* — Watershed models, with a special sponge material that simulates soil drainage, were used to make an instructional film on subsurface flow and stream flow. Construction of the models and filming techniques are described.

Watershed models make it possible—through time-lapse photography—to study subsurface and stream flow. The models are covered with a special sponge material that simulates the drainage characteristics of soil, and are marked with dye traces and placed under a rainfall simulator. We will describe how the models were built and how they were used to make an educational film illustrating subsurface flow and stream flow.

The film, entitled "Subsurface and stream flow on watershed models," was produced by the State University of New York, College of Forestry; the USDA Forest Service; and the State University Water Resources Center. The film provides definitions, a discussion of advantages and limitations of the models in such studies, specific data recorded during the trials, and a description of the experimental apparatus.

## Watershed Models

Five models were built to evaluate the effects of slope, drainage and density, and "soil" depth (fig. 1). Characteristics of the models are shown in table 1.

In designing the models, we tried first to hold land slope and stream gradient constant by using graphs of stream gradient (as a function of distance from the mouth) and land slope (as a function of distance from the stream). But this dictated that stream gradient and land slope were automatically confounded with drainage pattern; because, on the lower

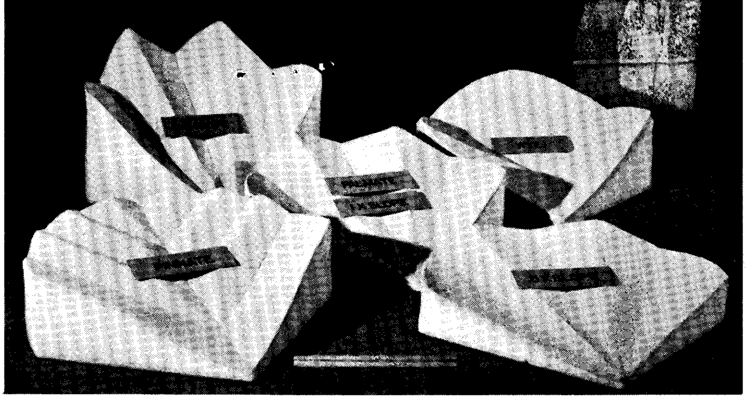

Figure 1. — The watershed models were made from ½-inch styrofoam sheets and were covered with a special sponge material that simulates soil drainage.

drainage-density models with greater distances between streams, steeper slopes could be attained. The 17- and 62-percent palmate models were built to ascertain the effect of slope.

The graphs of slope and gradient were used to locate points of equal elevation on outline maps of the models, and these were connected to create contour maps of each model. Cut apart, these maps provided templates for marking and cutting impervious 1/2-inch styrofoam sheets to form the model base. The layers were glued together and then sanded to provide a smooth surface.

Each geometric facet of the model was carefully fitted with "soil" blankets of a special 3/8-inch polyurethane sponge material (obtained by special arrangement from a commercial firm: for further information, write the authors). This particular sponge was selected to represent soil because it had (1) interconnected pores, (2) a gradation of pore sizes all less than raindrop size, (3) uniformity and dimensional stability under extremes of water content, and (4) a large retention capacity (about 25 percent).

All the models were of the common pear-shape, with a horizontal area of 3 square feet. Each model could be completely covered by the rainfall simulator, so the trials shown and the conclusions drawn apply to models completely, continuously, and uniformly covered by the rain storms.

## Rainfall Simulator

The simulator was constructed from plans developed by Chow and Harbaugh.[1] It consists of a plexiglas box 2 feet square and 1 inch deep, with an inlet for water at the top, and 576 capillary tubes (on 1-inch

[1] Chow, V. T., and T. E. Harbaugh. RAINDROP PRODUCTION FOR LABORATORY WATERSHED EXPERIMENT. J. Geophys. Res. 70(24):6111-6119. 1965.

Table 1. — Watershed model characteristics

| Characteristic | Model drainage pattern | | | | |
|---|---|---|---|---|---|
| | Wye | Palmate | Pinnate | Palmate | Palmate |
| Drainage density, in./in.$^2$ | 0.16 | 0.31 | 0.44 | 0.31 | 0.31 |
| Maximum relief, inches | 9.3 | 7.5 | 6.8 | 4.25 | 14.9 |
| Mean slope, percent | 38.8 | 31.2 | 28.3 | 17.7 | 62.1 |
| Stream gradient, log $S_g$ | *1.23+ .05$D_m$ | 1.23+ .05$D_m$ | 1.23+ .05$D_m$ | .93+ .05$D_m$ | 1.54+ .05$D_m$ |
| Land slope, log $S_1$ | 1.35+ .57$D_s$ | 1.35+ .57$D_s$ | 1.35+ .57$D_s$ | 1.10+ .57$D_s$ | 1.65+ .57$D_s$ |

*Where $D_m$ equals distance from watershed mouth, in inches; and $D_s$ equals distance from the stream, in inches.

centers) protruding from the base. When water is supplied to the unit, drops form and fall at random moments in time. A constant-head regulator and manual valve allowed adjustment of intensity (from about 2 to 12 inches per hour) and duration. All trials were run at the same intensity (6 inches per hour) and duration (2 minutes). Drops fall about 3 feet before hitting the model surface, and two small fans provide gentle turbulence that distributes the drops randomly over the models.

Water temperature affected the performance of the simulator and the models. To assure comparable results, all trials were conducted at the same water temperature.

## Dye-Spot and Filming Technique

For testing the relationships between the selected geometric properties of the watershed models and runoff parameters, runoff and its temporal distribution (not a part of the film and not covered in this report) were measured directly. Water movement under various conditions was timed, using a dye-spot technique; and the events were filmed in time-lapse sequence. Nine of these sequences were employed in the film.

Ordinary vegetable food coloring was used because it did not permanently stain the "soil" or the model base, it is soluble in water, and the colors contrast well and blend well for easy observation.

Dye spots were applied about 0.1 inch downhill from points located by straight pins. All points were located with a ruler so as to be equidistant horizontally or vertically from the outlet along the stream or ridge. Generally, two drops of dye were placed as rapidly as possible at each location on the damp "soil" blanket; and rainfall, stopwatch, and camera were started immediately. The simulator was allowed to run for about 2 minutes (about 0.2 inch of water), by which time the dye had reached the outlet of the model.

Color sequences at the outlet were noted by stopwatch time on special data forms which were cross-referenced to the film by a scene board exposed before each run. Where a model with symmetrical branches was used, yellow and blue dye spots indicated the coincidence of side branches by blending and making a green dye at the outlet. Red dye was used in the main stem; it arrived more quickly at the outlet.

After each run, the remaining dye was flushed from the entire system. About 10 minutes of drainage was allowed between successive runs; this permitted planning of the next sequence, adjusting the lights and camera, and recording the data.

The camera used was a Bolex H16T[2] fitted with a 16-mm wide-angle lens. It was located about 5 feet from the model at an angle of about 60 degrees from the main axis of the stream.

A scene board—documenting data, trial number, model number, film roll, shutter speed and opening, and time factor—was exposed at the start of each trial. All filming data were also transcribed on the trial-data form to ensure proper identification.

A 4-foot cable release was used to trip the shutter twice each second for the duration of the run. Two 650-watt color-balanced flood lights were used to illuminate the model; this lighting required an opening of f.4 for a shutter speed of 1/30 second. All trials were filmed on Ektachrome Commercial Film with a type-A filter on the camera.

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[2] Mention of a particular product should not be taken as endorsement by the Forest Service or the U. S. Department of Agriculture.