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Progress Report

THEORY AND EXPERIMENTS IN THE PREDICTION
OF SMALL WATERSHED RESPONSE

E. F. Schulz

Office of Water Resources Research
Grant Agreement No. 14-31-0001-3264
Project B-054-COLO

ENGINEERING RESEARCH
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Acknowledgements

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Theory and Experiments in the Prediction of Small
Watershed Response

PROGRESS REPORT

This report is a summary of the progress on this project during the first three months of the experimental phases performed under OWRR Matching Grant Agreement No. 14-31-0001-3264, Project No. B-054-COLO. The analysis phases are currently underway. The period of research covered is from 1 July 1970 to 1 October 1970.

During this period the enlargement of the experimental rainfall-runoff facility was completed by adding two 6,110 square-foot plane surfaces to the 12,670 square-foot conic sector which had been constructed under a previous OWRR project. This involved moving approximately 1000 cubic yards of selected earth fill material to the lower part of the experimental watershed. These steps are shown in a number of photographs at the end of the report. This was done to cover the somewhat stoney bentonitic natural site material with a more suitable subbase for the precise grading and butyl rubber cover. The subbase surface was rolled and graded to approximately 1/2 inch below the final desired grade with a motor grader. Grade stakes were then set on a 10-foot grid network exactly to the required elevation. Sand was spread and graded precisely to the desired grade using an aluminum I-beam as a screed. The sand was sprinkled lightly with water and rolled several times with a lawn roller to achieve a smooth firm bed.

Rubber Covering The smooth plane surface is preserved by covering the watershed with a sheet of butyl rubber 0.020 inch thick. The rubber was obtained as a roll 13 1/2 feet wide and 210 feet in length. The sand

was sprinkled again before the rubber was unrolled and the 13 1/2 - foot strip was unrolled across the width of the watershed. The edge of the rubber strip was cemented securely to the edge of the previous strip. The downward capillary moisture gradient in the sand and subbase helped to create a negative pressure at the underside of the rubber. This gradient resulted in a good firm contact between the rubber and the sand bed. By again lightly rolling the rubber surface any foot prints or other blemishes in the sand surface were removed.

The outside edges of the rubber were buried in a shallow trench which was dug around the edge of the rubber covering.

Rainfall Simulator The rainfall simulator system was previously described in references (1) and (2) which are reports issued under the previous OWRR grant. There was some damage to parts of some of the simulator system caused by freezing during October 1969. This damage was repaired and eight new supply lines containing 25 sprinklers each were installed.

As presently constituted the rainfall system contains 330 sprinklers which could be individually controlled. There are an additional 75 sprinklers which could be installed but were not required during the current season.

During the current project the rainfall is uniformly distributed in space over the watershed. The rainfall is suddenly turned on and suddenly turned off after a desired interval of time. The intensity of the rainfall can be varied from approximately 0.50 inches per hour up to 4.0 inches per hour. When a rainfall intensity of 0.5 inches per hour is desired, every fourth sprinkler in alternate lines is turned on. Thus only sprinklers at every 40 - foot radius are in operation. When the

rainfall intensity of 4.0 inches per hour is required, all sprinklers are in operation. The operation of the rainfall simulators has been fully described in Reference (1). Various areas of the facility are operated independently of the other experiments. In principle any one of the sprinklers can be operated independently of the others.

Runoff The watershed response to the rainfall is measured by recording the runoff hydrograph at one or more points. The discharge is measured in an H-flume which has been calibrated in the hydraulics laboratory. Flumes have been installed at the vertex of the conic sector and at the downstream end of the two plane surfaces. The runoff from the conic sector can be discharged into an underground drain so that the runoff from the conic sector and the two plane surfaces of the watershed can be measured separately.

The stage hydrograph is recorded on a FW-1 water stage recorder which had been altered to speed up the time scale to make one revolution of the chart drum every 60 minutes. The flumes were equipped with stilling wells which are 5 inches in diameter. The floats were 4 inches in diameter. There is some evidence that the stilling well lag may be a recognizable part of the response time of the watershed.

In order to facilitate data reduction, the float shaft of the water stage recorder was also fitted with 10,000 ohm precision microtorque potentiometer. This potentiometer was part of a compensated Wheatstone bridge circuit. The electrical potential across the bridge is nearly a linear function of the stage in the flume. This signal is recorded at 10-second intervals on IBM cards. The pertinent catchment and run configuration information is also punched into IBM cards. These cards are converted by a simple computer program to a cathode ray scope image containing the following:

Run identification
Watershed area
Surface treatment
Hydrograph
Hyetograph
Dimensionless hydrograph.

This information is also stored on magnetic tape. A photocopy of the microfilm of the scope image is carefully checked. If no error or deficiencies are discovered and if the data are otherwise complete, the runoff event is transferred to a permanent magnetic tape file for further use in the data analysis.

Surface Roughness The relatively smooth rubber surface was artificially roughened by scattering uniform sized gravel evenly over the surface of the watershed. For reasons of economy, the roughness was added only to a 30° - sector of the conic watershed. The roughness elements consisted of 1-1/2 inch gravel spread at the rate of 10 lbs per square yard. At this rate of application about 15% of the watershed area was covered by stones. Experiments were also carried out when the gravel spread was increased to 20, 30, 40 and 50 pounds per square yard. At 50 pounds per square yard more than 95% of the rubber surface has been covered by stones.

The function of the stones is to retard the rate of runoff and increase the detention storage. As the detention storage increases, the roughness elements are eventually submerged in the flow. In addition, the roughness elements are eventually submerged by the flow because the area is converging. With increasing rates of application, the water in the smaller interstices appears to become inactive and more of the flow exists on top of the gravel and the effective roughness goes down.

Research Experiments A number of different research activities have been coordinated on the experimental rainfall-runoff facility this summer. These are briefly summarized:

1. Experimental verification of a Unit Hydrograph Model for predicting the flood response of a watershed.
2. Experimental verification of the kinematic wave model of overland flow on a converging section. (A cooperative project with the Agricultural Research Service USDA)
3. Influence of various concentrations of roughness elements on the surface detention volume on the watershed. (A student research project).
4. Experimental verification on a Time-Area Model for predicting the flood response of a watershed.
5. Experimental investigation of the evolution of channel network systems in a small watershed. (A cooperative project with the CSU Geology Department and the Department of the Army).
6. Experimental investigation of the leaching of pollutants from oil shale wastes. (A cooperative project with the CSU Sanitary Engineering and the Federal Water Pollution Control Agency).
7. Experimental investigation of the soil erosion due to rainfall. (A student research project).
8. A feasibility study to determine if artificial snow can be made on the experimental watershed during freezing weather.

References cited:

1. "Colorado State University experimental rainfall runoff facility - Design and Testing of Rainfall System" by M. E. Holland, Colorado State University, Fort Collins, CER69-70MEH21, November 1969.
2. Project Progress Report, "Experimental investigation of small watershed floods, Phase II," Colorado State University, Fort Collins, July 1968 to June 1969.
3. Completion Report, "Experimental investigation of small watershed floods," by E. F. Schulz and V. Yevjevich, Colorado State University, Fort Collins, CER69-70EFS-VY38, June 1970.



Fig. 1 - A layer of selected fill material was hauled into the watershed area. This provided a subbase for the final grading.



Fig. 2 - The watershed surface was graded to a smooth surface approximately 1/2 inch below final desired grade.



Fig. 3 - The rough graded surface was thoroughly compacted by rolling with a small hand-guided power roller.

Fig. 4 - Grade stakes were driven into the soil to the exact desired grade elevation. These stakes were set on 10-foot grid pattern.

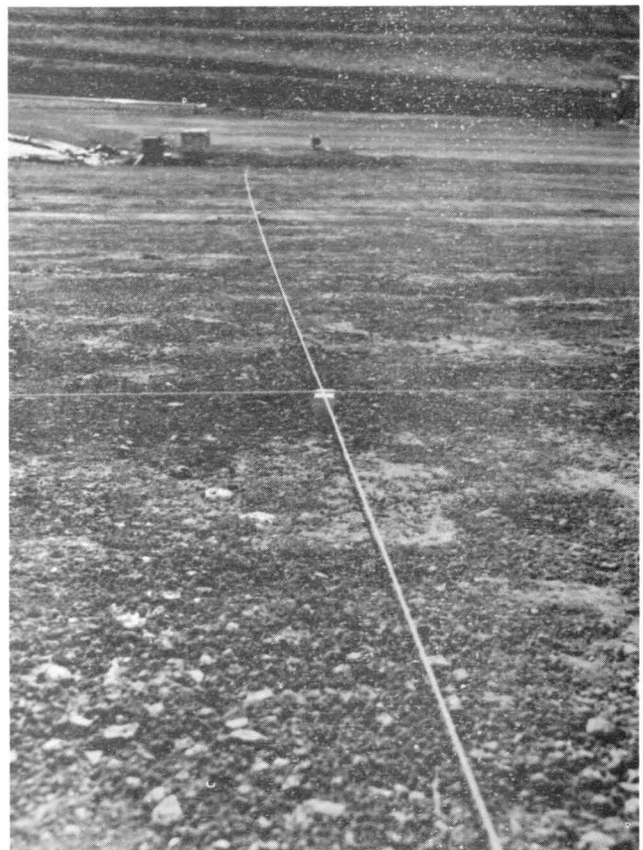


Fig. 5 - A layer of sand was spread over the watershed surface. Micrograding of the surface was accomplished with an aluminum I-beam used as a screed.

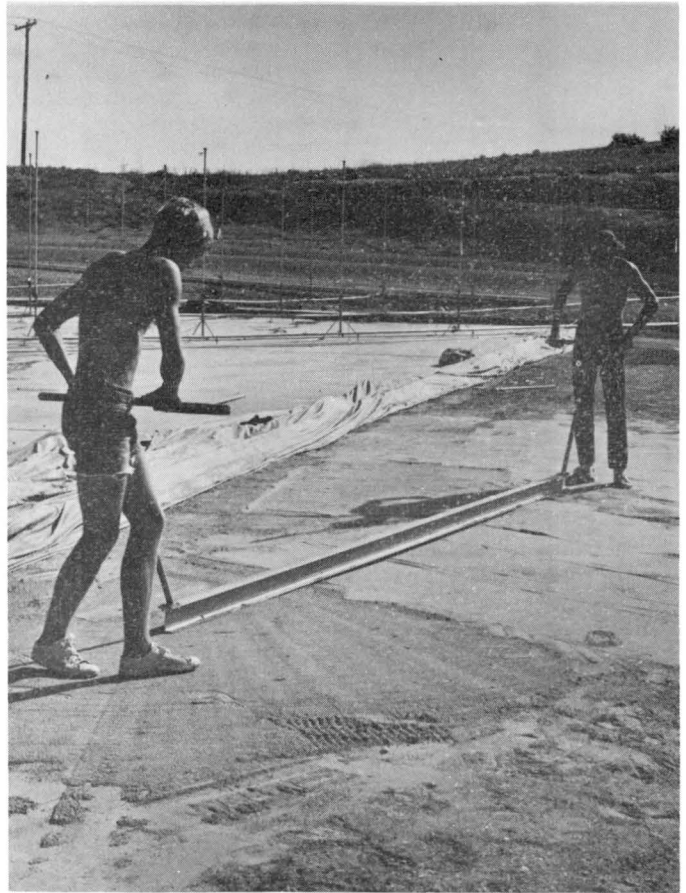


Fig. 6 - The sand layer was thoroughly compacted with a hand roller. Sand was again spread on the surface until the surface was exactly at the elevation of the grade stakes.



Fig. 7 - The 1000-pound roll of butyl rubber was unrolled from a pick up truck.

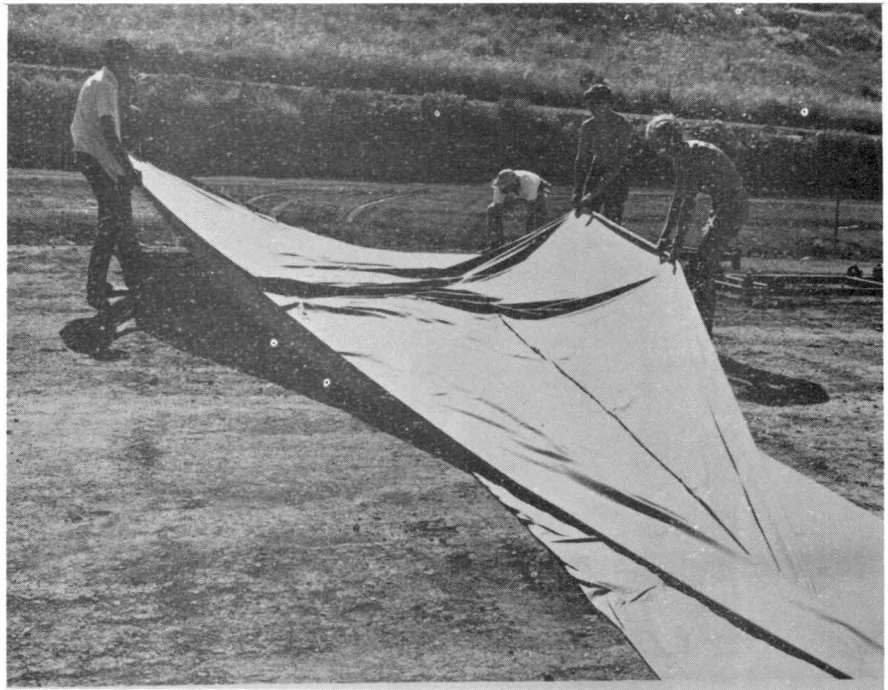


Fig. 8 - The 15 foot wide by 200 foot length of rubber was unfolded and overlapped on the previous strip.



Fig. 9 - The 6-inch wide overlapping edges of the rubber were thoroughly cleaned and treated with joint cement.



Fig. 10 - The two prepared surfaces were joined and the joint was rolled with a hand roller.



Fig. 11 - The outside of the rubber surface was buried in a small trench.

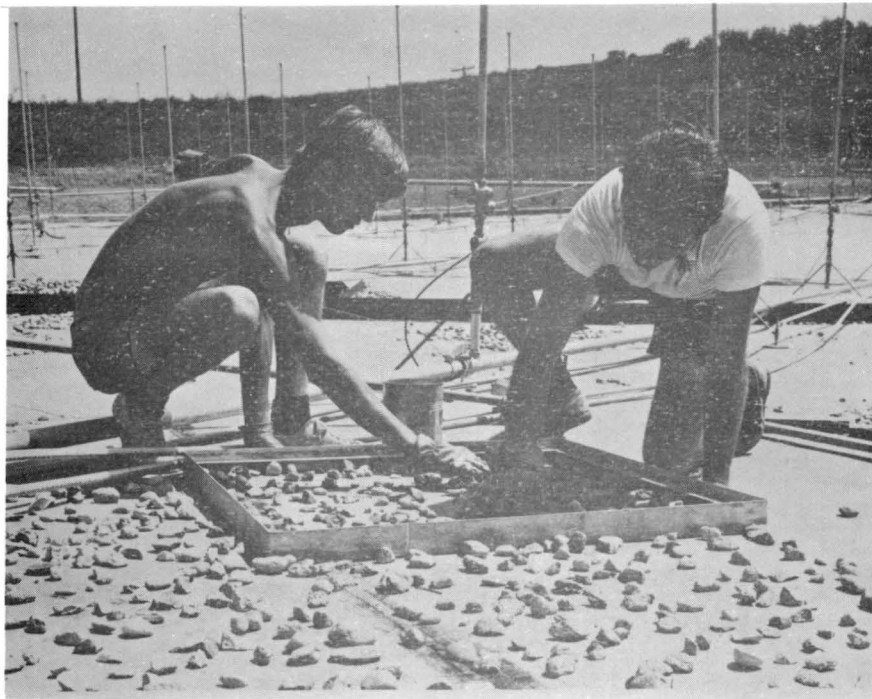


Fig. 12 - After installation of the rainfall simulators, part of the watershed surface was roughened by the addition of uniform gravel at fixed rate per square yard.

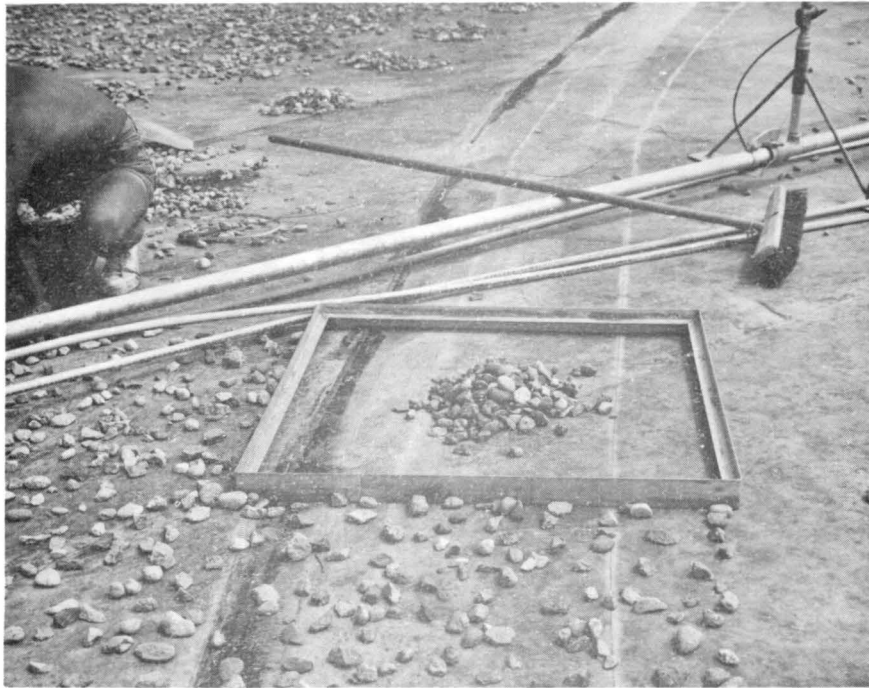


Fig. 13 - The gravel was uniformly distributed over the surface specified by the measuring frame.



Fig. 14 - The surface detention is shown draining from the gravel surface after the cessation of rainfall.

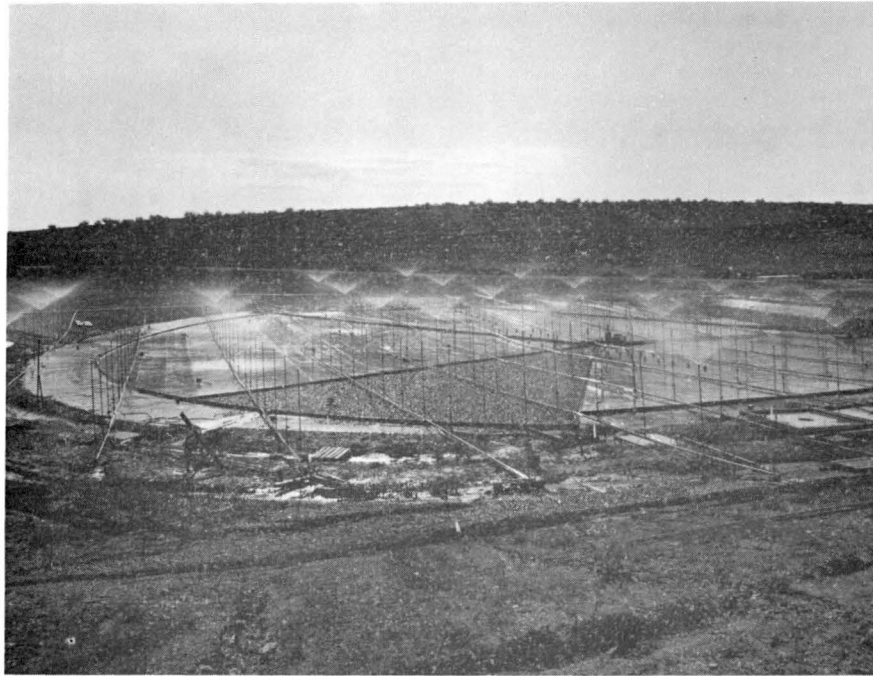


Fig. 15 - Rainfall simulators operating at the rate of 1/2 inch per hour on the upper conic part and the 30-degree gravel roughened sector.

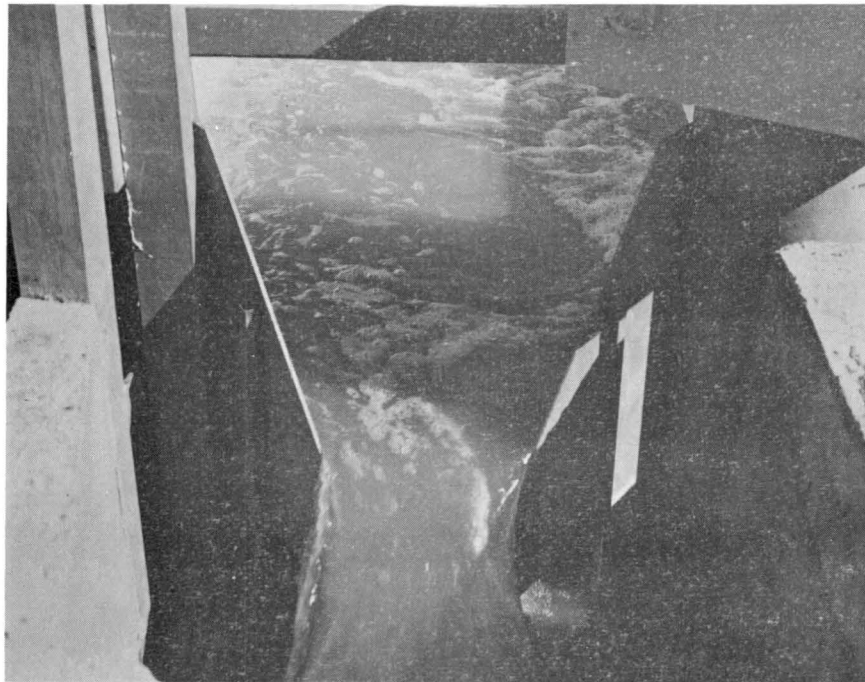


Fig. 16 - Surface runoff is measured in an H-flume where both a graphic record and IBM cards are punched.