EXPERIMENTAL INVESTIGATIONS OF SMALL WATERSHED FLOODS

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EXPERIMENTAL INVESTIGATION OF SMALL WATERSHED FLOODS

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ABSTRACT

KEY WORDS: Rainfall-runoff relationships, rainfall simulators, small watersheds.

An experimental facility for generating artificial storms over a one-acre catchment is under construction. The catchment has been shaped into an approximation of a typical small watershed by combining a conic section upstream of two intersecting planes. The conic section can be measured separately and either diverted under the plane sections or allowed to join the channel flow between the planes. The rainfall system is based on a system of towers with large nozzles spraying into the air more than 30 feet above the catchment. The final design of the system is not complete. Runoff can be measured at two points by H-flumes equipped with chart recorders. The rainfall gaging system is designed to automatically record rainfall at 27 locations on the basin. The gages utilize a capacitance system indicating accumulated depth of rainfall. The catchment surface is to be covered by a butyl material to provide an impermeable, erosion-resistant surface. Current activity is focused on bringing the conic section into operation to test the full-scale system before the lower areas are finished.

LIST OF FIGURES

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Although this report was prepared in November, it is based on the period ending June 30, 1968, and developments that occurred between July and November are not presented here. They will be discussed in the project reports for Phase II of the study.

This report consists of two parts. Appendix 1 is a publication describing the project in a manner appropriate to an annual report. The report texts briefly summarize the main points of that report and present developments not included in Appendix 1, which was published several months before the end of the project period. Part III of Appendix 1 was developed in a different, but closely related project.

OBJECTIVES

The research supported by matching Grant B-005-COLO is an experimental investigation of small watershed runoff response. The objective of the experimental investigation is to provide the physical facilities to substantiate mathematical models so as to merge them into the mathematical-physical models of small watershed responses to various storms, under various river basin conditions. This objective may be divided into two separate parts:

(1) The design, construction and instrumentation of the experimental facility; and,

(2) The collection, compilation and analysis of experimental data.

The collection of experimental data cannot begin until part (1) is essentially complete. It was originally expected that some experimental data could be acquired during the period of this project, which represents the first phase of a planned three-phase investigation. However, as will be discussed below, the construction and instrumentation of the facility are not complete and no data suitable for analysis of watershed runoff has yet been compiled.

The accomplishment of the objective of design, construction and instrumentation of the experimental facility will be presented under four major headings. Each of the four endeavors could be and was pursued with only limited reliance on developments of the other features of the project. The first step in the research investigation was a definitive statement of the long-range philosophy of approach and objectives that should be kept in mind during the design and construction phase of research. The second line of effort to be discussed is the design and construction of the basin and main water supply stream. The third aspect is the design and construction of the rainfall-generation system, and the fourth topic is the instrumentation for measuring the rainfall and runoff on the facility.

Statement of Long-Range Objectives

The philosophy of approach and objectives of the long-range utilization of the experimental facility influence the criteria for the current design. Therefore, a definitive statement of objectives was formulated early in the project. This statement is contained in Part I of "An Experimental Rainfall-Runoff Facility," which is included as Appendix 1 of this report. Some conclusions are presented here.

The experimental facility can be used for three general types of studies -- rainfall-runoff relationships, travel and dissipation of chemical pollutants, and soil erosion. The facility will supplement data from natural watersheds and results from small-scale laboratory studies. The facility is not a model, but a prototype with the major variables controlled. It can serve as a prototype for evaluating and improving mathematical models and scaling criteria for scale models.

The requirements for the control and instrumentation cannot be completely determined. The experimental facility lies between the natural watershed and the laboratory system in degree of control to be achieved and instrumentation required. The greater the degree of control provided, the less stringent are the instrumentation requirements. A uniform distribution of rainfall is desirable, but complete uniformity is not required. The ability to reproduce the initial state and input conditions is more important. This has led to the selection of an impervious surface with no vegetation for the initial design.

Design and Construction of the Catchment

The design and construction of the catchment and the main water supply system have been essentially completed. Minor changes are expected to occur as the rainfall generation system is completed, and surface treatment must be delayed until the other components of the system are installed. But provisions have been made for these items and this part of the effort is considered complete.

The design and construction of the catchment involved three efforts: (1) the design and installation of the main water supply system, (2) the design and shaping of the basin geometry, and

(3) the treatment of the surface of the catchment. The first two efforts are complete and are described in Part II of Appendix 1, "An Experimental Rainfall-Runoff Facility."

The water supply system consists of a pumping plant with an intake on the large supply line from Horsetooth Reservoir to the Colorado State University Engineering Research Center laboratories and a loop of 10-inch pipe supplying the facility. The supply line lies outside the catchment except at the upper end where soil conditions made it necessary to go under, rather than around, the basin. Therefore, most of the supply line can be reached without disturbing the catchment.

The selection of the basin geometry was based on a study of a sample of the small watersheds in the Research Data Assembly File of the Hydrology Program. The typical slope was found to be about 5% and the typical shape approximated a lemniscate. The desire for additional versatility for the facility and for simplicity of mathematical description of the catchment shape led to an approximation of the typical shape by a conic section and two intersecting planes. This shape is shown in Fig. RR1 on page 16 of Appendix 1. The slopes are designed to create a 5% slope in the direction of flow on each surface. The use of the geometry makes it possible to isolate the conic section, which represents overland flow on a converging section. A flume was installed to measure the runoff from the conic section.

The treatment of the catchment surface was given considerable study. The use of plastic or rubber to cover it was initially rejected because of the cost of the materials. Soil cements were tested, but resulted in surface cracking. A paraffin-base liquid was also tested, but results were not conclusive. Near the end of the project period the availability of some butyl material at a reduced cost made the rubber a feasible alternative. Some butyl was provided by a related project that will be using the results of the experimental tests on the facility. An additional quantity of butyl has been ordered for Phase II of the experimental facility project. At the end of the project period, preparation was underway for the installation of part of the butyl.

Rainfall Generation System

The rainfall generation system is perhaps the most important component of the experimental facility. This is the feature that distinguishes the present facility from the experimental watershed concept used in the past. The artificial application of rainfall permits a condensation of the time history of rainfall over a basin. Because the rainfall system is considered to be so important and because no previous facility of this size has utilized such a system, the decision on the exact system has been delayed to allow full consideration of alternatives.

As a result of surveying the literature on artificial rainfall systems of various sizes for a variety of uses, it was decided that a system of towers and large nozzles offered the most promising solution. A number of fire nozzles were acquired from government surplus and were tested individually for distribution patterns using a simple support structure. One such test is illustrated in Fig. 1. The next stage in the testing involved mounting several nozzles on a single tower. The tower was supported by a crane for testing (Fig. 2) and the directions of the nozzles were varied (Fig. 3) to obtain various patterns. When these results appeared satisfactory, the preliminary design shown in

Fig. RR10 of Appendix 1 (page 24 of the Appendix) was established, and a prototype tower constructed.

The preliminary towers must be located on the basin and require high pressures to operate effectively. An alternative system that could overcome these faults utilizes large irrigation nozzles located on the periphery of the basin. As the project period ended, the towers for these nozzles were being constructed and four nozzles were obtained to be tested on part of the basin.

The final selection of the rainfall system has not been made during the project period. This is the most significant point in which the objectives of the research for this phase were not accomplished. When the final design is made, it will not take long to bring the system into operation.

Instrumentation

The automatic recording data network planned for the facility is described in Part II of Appendix 1. Because of the number of recording raingages planned, automatic digital recording for computer analysis was considered necessary. To record from 27 raingages using the one analog-to-digital converter requires running through a cycle for reading each gage in sequence. This can only be done effectively by using a gage that measures cumulative rainfall, instead of rainfall rate. Therefore, the standard tipping-bucket gage was not acceptable.

A measurement system based on a capacitance gage had been developed for measuring flow in some flumes in the hydraulics laboratory and this system was tried for the experimental facility. A bread-board model of the raingage using the capacitance concept was tested in the field and after some modification was found to perform satisfactorily. When the prototype gages were installed in the field in the Spring of 1968, they were found to be more sensitive to temperature than the preliminary testing had indicated. The actual cause of the sensitivity was being investigated at the end of the project period.

The difficulties with the raingage system are not considered to be as important as the delays on the rainfall system. Standard raingages with chart recorders are available commercially and the charts can be converted to digital records with equipment that has recently become available at the Colorado State University Engineering Research Center. Therefore, until the electronic gages are operating properly, a smaller number of chart-recording gages can be substituted.

The capacitance gage was also considered for runoff measurements, but was rejected because sediment interfered with the gage. Since the facility is likely to be used for erosion studies in the future, a standard chart recorder, with a float in the stilling well has been selected for the runoff measurement.

CONCLUSIONS

Because the facility is not yet in operation, it is not appropriate to list conclusions. One of the observations that was made in statement of objectives in Appendix 1 is that many features of the response of the facility can only be determined when the full-scale system is operated. This has been confirmed by the few tests made on the nearly completed facility.

The other factor to bear in mind is that the rainfall system is the most important component of the facility because no equivalent system has been used before. All available equipment was designed to serve other kinds of demands for uniformity in time and space and for area covered. This is the component for which conclusions are most eagerly sought.

LIST OF PUBLICATIONS FROM THE PROJECT

Dickinson, W. T., M. E. Holland and G. L. Smith, "An Experimental Rainfall-Runoff Facility," Colorado State University Hydrology Paper No. 25, September, 1967.

Holland, M. E., "Discussion of 'Laboratory Study of Watershed Hydrology,' by V. T. Chow," Proceedings of International Hydrology Symposium, September 6-8, 1967. Fort Collins, Colorado, Vol. 2, pp. 212-215.

(Original photos are not available for a clearer reprint)

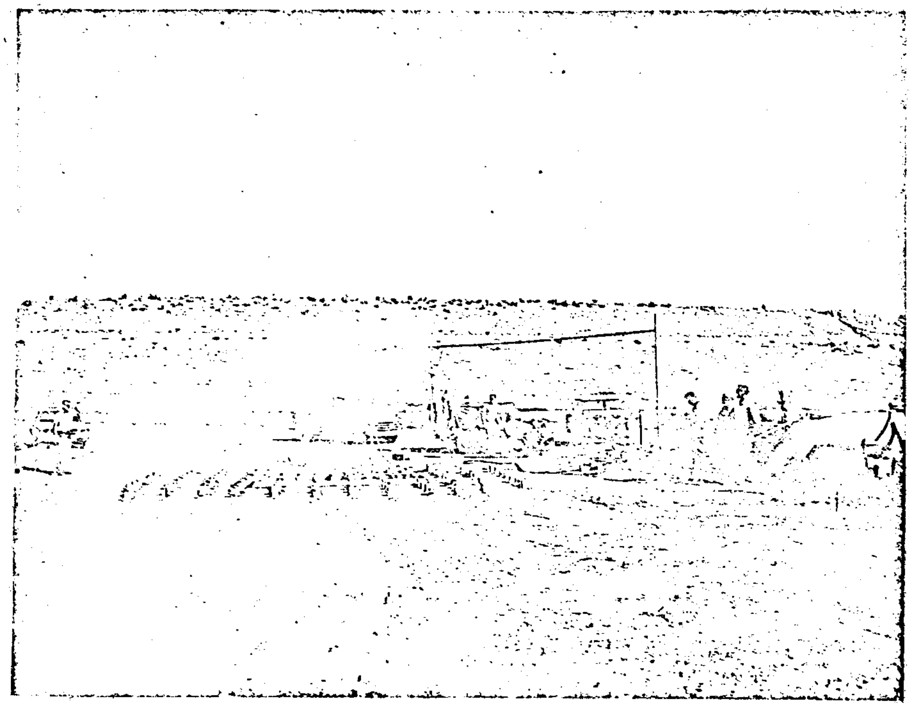

Fig. 1 Preliminary testing of the distribution pattern of rainfall from a nozzle directed horizontally.

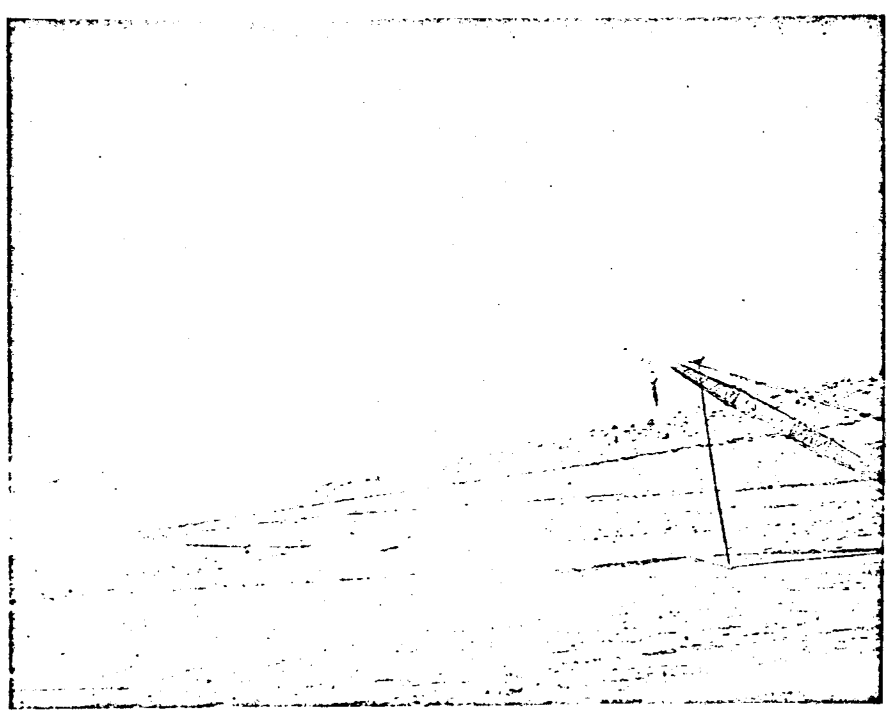

Fig. 2 Test of rainfall pattern from three nozzles on a tower supported by a crane.

(Original photos are not available for a clearer reprint).

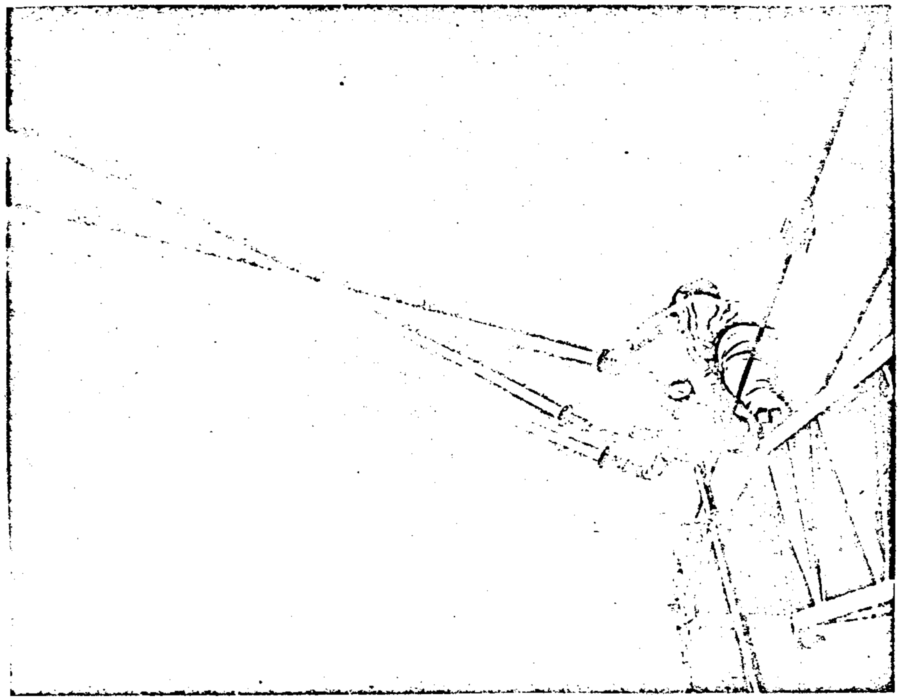

Fig. 3 Adjusting the directions of discharge for the nozzles on the tower of Fig. 2.