RUNOFF FROM FLIGHT STRIPS[1]

By Carl F Izzard

Highway Engineer, Public Roads Administration

SYNOPSIS

This paper describes the experimental methods being used in an investigation of rates of runoff from paved and turf surfaces The project is a cooperative undertaking of the Public Roads Administration and the Soil Conservation Service to obtain data on relationship of rainfall to runoff for use in designing drainage systems for flight strips

The purpose of this paper is to describe certain experimental work which is now being conducted on rates of runoff from areas of pavement and turf on relatively flat grades. The project was undertaken because a study of existing methods of estimating runoff from areas such as those found on flight strips indicated a definite lack of experimental data to verify the coefficients which were used in the runoff formulas The Soil Conservation Service has been interested in the same subject and has conducted many experiments, most of which have been on relatively steep grades. A review of their work indicated that the technique and equipment which have been developed by the Soil Conservation Service could readily be adapted to experiments on runoff from flight strips.

Accordingly, a cooperative research project has been set up by the Public Roads Administration and the Soil Conservation Service, utilizing equipment and personnel of the latter organization, with the program under the general direction of the Public Roads Administration Briefly, the method of investigation is to measure the rates of runoff on experimental plots under simulated rainfall of fixed intensity So far, the work has been carried on at the Beltsville Research Center of the Department of Agriculture in Maryland

The rainfall simulator, which has normally been used by the Soil Conservation Service, consists of sprinkling devices mounted adjacent to a test plot 12 ft. long by 6 ft. wide. By means of special nozzles developed by Soil Conservation Service technicians at the National Bureau of Standards laboratory, water is projected upward and falls on the experimental plot in the form of drops closely resembling rain drops. The apparatus has been so devised that a reasonably uniform pattern of rainfall is obtained over the entire plot. Water also falls outside of the border plates isolating the test plot from the adjacent ground, so that the soil moisture content in the border outside the plot is practically uniform with that inside the plot

The type of nozzle consists of an alternating series of discs with small orifices, enclosed and confined to definite positions by a cylindrical shell, which in turn is screwed into a threaded base designed for mounting on standard-type fittings. The base, in addition, acts as a housing for a standardized entrance arrangement, composed of a helix mounted rigidly within an entrance tube. The entire assembly is made of brass.

The nozzles are mounted 18 in apart on a pipe line in such a manner that the nozzles are 2 ft. above the surface of the plot and 21 in outside its edge The nozzles are tilted inward 7 deg. from the vertical, this inclination having been found by ex-

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[1] Analytical data on hydrographs of runoff from the paved plot described in this paper will be presented at the 1943 meeting of the American Geophysical Union, Section of Hydrology, scheduled for the last week in April. These data presumably will be published in the proceedings of this meeting

periment to give the most uniform distribution of rainfall on the 6-ft. width of plot.

While the apparatus is being adjusted for a uniform pressure of 35 lb. per sq. in. in the pipe line, the water emerging from the nozzles is deflected by hoods into a collecting trough immediately below the pipe line. The hoods are connected to rods in such a manner that either all or half of the hoods on both sides can be operated simultaneously, thus starting or stopping rainfall. Water continues to flow through the nozzles under uniform pressure whether or not the hoods are open.

The apparatus which is now in use consists of six of the units described, enabling the measurement of runoff from plots varying in length from 12 ft. to a maximum of 72 ft. The hoods for the entire length of the plot are connected to rods in such a manner that either one-half or all of the nozzles can be operated simultaneously. With half of the hoods open, a rainfall rate of approximately 1 9 in per hour is obtained. With all of the hoods open, the rainfall rate is doubled. The entire apparatus is enclosed within a canvas tent 12 ft. wide and about 80 ft long, so as to eliminate the effect of wind.

The rate of runoff is measured by means of a carefully calibrated type H flume, which is accurate over the entire range of discharge. The depth of water flowing in this flume is determined by means of a point gage, and these depths are then converted to discharge in cubic feet per second by use of the rating table for that particular flume. The usual procedure is to take point gage readings every 10 sec. during the time when the rate of runoff is changing rapidly, and increasing the time interval to 30 or 60 sec. when the rate of runoff is changing slowly.

The crew required to operate the apparatus consists of two men to operate the hoods starting and stopping the rainfall, one man to read the point gage, and a note keeper. The note keeper has a stop watch and gives the signal to the men operating the levers controlling the hoods, so that the hoods on both sides of the plot are operated simultaneously at a predetermined instant. These men also watch the pressure gages to see that pressure remains constant, and take temperature readings of air and water.

The rainfall simulator which has been described is portable, and can be set up over any plot of ground on which it is desired to make tests. Usually it is necessary to transport water in tanks on trucks and to use portable gasoline-powered pumps to obtain the pressure required to operate the nozzles. For the preliminary tests, however, it was feasible to obtain water under pressure directly from a fire hydrant, thus simplifying the operation.

In order to eliminate some of the variables involved in investigating the hydraulics of surface runoff on turf plots, a series of tests are being conducted on an impermeable artificial plot. This plot is a wooden platform 6 ft. wide by 72 ft. long, surfaced with a mixture of finely graded sand and asphaltic emulsion. The platform is mounted on adjustable supports, so that the longitudinal slope of the plot may be changed from level to a maximum of about 3 per cent

The general procedure in making tests has been to obtain at least two runs at each rainfall intensity for lengths of plots of 72 ft., 48 ft., 24 ft., and 12 ft, and for slopes of 0.1 per cent, 0 5 per cent, 1 0 per cent, and 2 0 per cent. On all of these runs the rainfall is continued long enough so that the rate of runoff becomes constant and equal to the rate of rainfall After the rainfall is stopped, readings are continued on the rate of runoff, until runoff is reduced to a very low rate. From approximately 1 to 10 gal of water will remain on the plot, much of which is held by surface tension. This water is swept off the plot, collected in a bucket placed below the measuring flume, and weighed

Some additional runs were also made, particularly on the flatter slopes, with both rates of rainfall in the same run, in each case allowing the rate of runoff to become constant before changing the rate of rainfall. Some runs were made by stopping the rainfall before the rate of runoff had become equal to the rate of rainfall and, in a few cases, rainfall was resumed after part of the water had drained off the plot.

The point gage readings on the rate of runoff are reduced to discharge in cubic feet per second. The resulting hydrograph is then plotted on cross-section paper and the area under the hydrograph planimetered. The area under the hydrograph represents the volume of water which has drained off the plot. Theoretically, this volume plus the cubic feet of water collected in the bucket should be equal to the amount of rain which fell. The amount of rainfall cannot be measured directly, but is determined by assuming that the rate of rainfall during the entire run was equal to that occurring during that portion of the run when the rate of runoff had become constant and equal to the rate of rainfall. In comparing the volume of rainfall so determined with the volume of runoff, very close agreement has been observed on practically all of the runs on the impervious artificial plot. The difference is usually less than 1 per cent, indicating that the discharge readings are quite accurate.

A typical hydrograph showing the rate of runoff from a plot 72 ft. long by 6 ft. wide on a grade of 0.5 per cent is shown in Figure 1. The rate of rainfall in this case was 3.7 in. per hour, starting at zero minutes and ending at 9 min. The runoff began about one-half minute after the rainfall started, rapidly increasing to a rate equal to the rainfall rate at about 3½ min. The increase in rate of runoff after the rain stopped is attributed to a distinct change in the surface profile during the recession period from the shape during the period of rainfall, resulting in an almost immediate discharge of the surplus volume of water contained between these surface profiles.

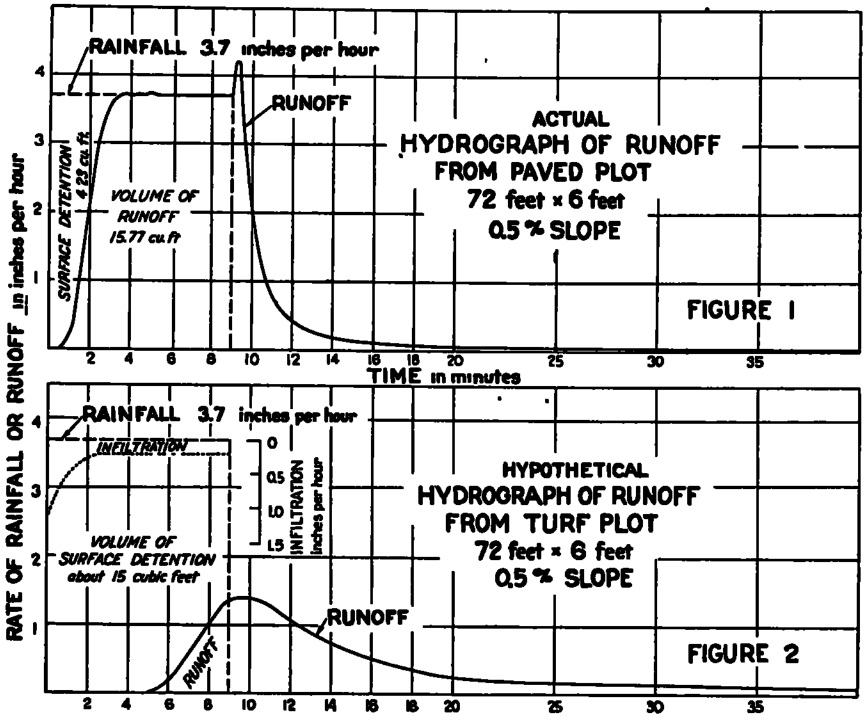
In this particular run, the volume of rainfall was about 20 cu. ft Approximately 4.23 cu. ft. of water was held in surface detention during the period that the rate of runoff was equal to the rate of rainfall This amount of surface detention can be measured either by taking the area under the hydrograph after the rain stopped, or by measuring the area between the rising side of the hydrograph and the rainfall line. The average depth of this surface detention was approximately 0.12 in. over the entire plot. The maximum depth of water at the lower end of the plot is estimated to be 0.15 in.

In contrast to the rapid rise in the rate of runoff which occurs on a paved area, Fig. 2 shows the probable form of hydrograph which will result from a rainfall of the same intensity on a plot of the same size and slope covered with turf on a relatively impermeable soil. This hydrograph is hypothetical, and is based on previous data concerning overland flow on turf plots.[2]

In this case, part of the rainfall will immediately soak into the ground. This rate of infiltration will depend, of course, upon the moisture content of the soil when the rain starts. We have assumed in this case that the soil is already moist, but not completely saturated. The rate of infiltration is measured from the rainfall line of the graph down to the dotted line and becomes constant after an interval of time. The amount of water which is available for surface detention and runoff is measured by the area under the dotted line. We have shown the runoff beginning at about five minutes and increasing very slowly. The area under the runoff hydrograph shows the amount of water

[2] A subsequent test on a turf plot has shown this hydrograph to be qualitatively correct.

which has drained off the plot. The area between the dotted line and the solid line is representative of the volume of water held in surface detention. In contrast to the amount of surface detention on the smoothly paved plot, which was 4.23 cu ft., it is estimated that approximately 24 cu. ft of water would have to be held on this plot in order to produce a rate of runoff equal to the rate of rainfall. In this case, it is estimated that about 15 cu. ft. of water would be held in surface detention at the time the rainfall ceased. This volume of water would produce a maximum rate of runoff of approximately 1.4 in. per hour. The maximum depth of flow at the end of the turf plot would be approximately 0.6 in., in contrast to the 0.15-in. depth at the same point on the paved plot.



Figures 1 and 2

To date we have not made any runs on turf plots. The same general procedure will be followed in making these runs as was used in making runs on the paved plot. Areas of turf having a reasonably uniform soil condition and as close to a plane surface as can be obtained, will be selected on grades varying from about ½ per cent to 3 or 4 per cent. The different lengths of plot from 12 ft. to 72 ft. will be tested as on the artificial plot. It is planned to complete one series of tests on a relatively impervious soil and then to repeat the entire series on a definitely pervious soil, so as to obtain a contrast demonstrating the effect of the perviousness of the soil.

In making runs on turf, it will not be possible to check the amount of runoff against the amount of rainfall, since part of the rainfall will be lost by infiltration into the soil In order to determine the rate of rainfall during a run, a calibration run will be made immediately before or after the run with an impervious covering over the plot surface, so that all of the water from the calibrated run may be collected and measured. The rate or rainfall so determined must necessarily be assumed as equal to that during the test run Care must be exercised that none of the conditions of rainfall are changed in the meanwhile—that is, the pressure on the nozzles must remain uniform and the nozzles must be clean and exactly in alinement.

Since runways are frequently designed so that the water draining off the paved runway flows across a turf shoulder, a series of tests will also be made where the upper portion of the test plot will be covered by an impermeable surface in such a manner that the water draining off this surface flows across the turf plot at the same time that the rain is falling. These tests are regarded as being especially important, since they will indicate the extent to which the peak rate of discharge from a paved surface is reduced in flowing across an area of turf. Arrangements may also be made to flood water onto the upper end of the turf plot at a known rate approximating discharge from half the width of a typical paved runway subjected to the same rate of rainfall as that occurring on the turf plot.

The data are being analyzed as rapidly as possible. Results will be published when sufficient data have been collected to enable definite conclusions to be reached

DISCUSSION ON RUNOFF FROM FLIGHT STRIPS

Mr. W. W. Horner, *American Institute of Consulting Engineers:* I would like to add a word with regard to the importance of the work Mr. Izzard has described. The data from his test, when it becomes available, will be almost an answer to prayer on the part of those engineers who have been struggling with airport drainage.

We have had to learn, as these airports became larger, that the older approaches to storm drainage, such as the Rational design, is utterly inapplicable to these cases, not only because we have no coefficients that would represent the conditions that occur on large airports, but also the principles involved do not fit the case.

We used to say, under urban drainage practice, that the maximum storm runoff would occur when all the drainage area above the point of design was contributing. The studies that have been made on large flat airports show that that critical time, measured in time of flow, does not at all govern the runoff rate, because of the persistence of the flood wave in the drains the rate of runoff from short intense rains may be larger than the mean rainfall rate for the critical time

As we got into the design of drainage for these large airports, such as the Washington National, which was the first airport that was able to support some pioneering in engineering techniques of drainage, we found the only possible approach was through a straight application of hydraulics, involving the flow and storage equations, thus evaluating the runoff after certain detention factors had taken their toll.

We were able there to make very good use of the research work of the Soil Conservation Service, both as to rates of flow and rates of infiltration. But, Soil Conservation Service had at most an academic interest in what occurred on paved surfaces, and had not carried their work into the detail necessary. When we encountered these wide runways where we had to deal with slabs of 200 to 300 ft., we had to apply hydraulics for which we did not have good basic data. We did not have any satisfactory Reynolds' Number index, so we were uncertain as to under just what conditions the flow would be laminar and under what conditions it would be turbulent. We had only friction factors measured from larger channels which were not reasonably applicable, in view of the relation of roughness to film thickness that we get in these thin sheet flows over large slabs, and we had to develop techniques for the application of the equations.

We have recognized the point Mr Izzard brought out, that the impact of raindrops will add new disturbance to the flow sheet, and undoubtedly will absorb energy to an extent greater than for undisturbed film flow, but we had no detailed information of that factor. I believe the working up of the data which he is producing in these experiments will give us adequate answers to nearly all of those needs.