PARAMETER INFLUENCE ON RUNOFF MODELING

by

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INTRODUCTION

In hydrologic analysis and design, it is quite often to estimate runoff from rainfall data, because rainfall data are generally available for much broader areas than are runoff data. Any quantitative estimation of runoff through rainfall requires mathematical modeling. The accuracy of estimation is dependent not only on the completeness of the model, but also on the selection of the corresponding model parameters. The objective of this paper is to investigate the influence of some model parameters on runoff simulation. The model parameters considered here include space and time increments, rainfall input, and channel roughness.

Two kinds of indicators are used for measuring the effect of model parameters. The first kind of indicator is the factor related to surface runoff, i.e., the peak rate of flow. The second kind is the time factor associated to a flow. Here the length of time from the beginning of a storm to the peak of surface runoff is used as the indicator.

THE RAINFALL-RUNOFF MODEL

A distributed system model including simulations of overland flow, channel flow and flow through channel junctions has been used in this analysis.

WATERSHED REPRESENTATION

The natural complexities of a watershed to be modelled are represented by a group of subcatchments, which are linked together by a number of prismatic channels.

The rainfall input to each subcatchment is assumed to have a spatially uniform distribution. It may vary, however, in a completely unrestricted manner between adjacent elements. The surface cover and ground slope within each subcatchment is also assumed to be uniform. Runoff occurred on the subcatchments is considered as overland flow. It is apparent that the runoff water from one subcatchment is a source of inflow to its adjacent downstream channels.

SIMULATION OF OVERLAND FLOW

The dimensionless hydrograph derived by Morgali and Linsley (1965) is used in this study. The overland flow hydrographs resulting from rainfall input with finite duration can be easily obtained by use of the method of offset hydrograph (Chow, 1959).

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SIMULATION OF CHANNEL FLOW

The simulation of channel flow is based on the hydrologic routing approach which uses a depth-discharge relationship incorporated with the equation of continuity. According to the theory of continuity, the difference between inflow I and outflow 0 of a section is equal to the rate of change of storage within that section. The mathematical equation can be expressed as:

$$I - 0 = \frac{\text{Change of Storage}}{\text{Unit Time}}$$

The inflow to a section is the summation of lateral overland flow within that section and the outflow from the immediate upstream channel section. The outflow from a section is approximated by a uniform-flow formula, namely, the Manning's formula.

The channel flow model has been tested in a one-acre experimental watershed. The shape of the synthesized hydrographs is about the same as the observed ones. On average, the error involved in volume is about 4 percent, and in peak rate, 3 percent.

SIMULATION OF FLOW THROUGH CHANNEL JUNCTIONS

Flow through a channel junction is a phenomenon that involves many variables, such as the number of the adjoining channels, the direction and discharge of flow, the shapes and slopes of the channels, etc. In general, junctions in this study are assumed to behave as a reservoir with a horizontal surface. The net discharge into a junction is equal to the change in reservoir storage. If the total inflow to the junction exceeds the allowable carrying capacity for the channel reach immediately below the junction, the storage at the junction will be increased and the steady backwater will be formed in the inflow channels above the junction. The allowable carrying capacity for the channel reach below the junction is computed by means of Manning's formula. The calculation procedures for simulation of flow through channel junctions are similar to that of channel flow.

RUNOFF SIMULATION PROCEDURES

A computer program has been written to handle the simulation of runoff. Procedures of the runoff simulation are described by the flow chart diagram as shown in Figure 1. The overland flow from a subcatchment is computed first. After the computations for all subcatchments and channels related to a channel junction are completed, the flow depth and discharge in each branch channel of the junction are computed. These steps are repeated until all the channel junctions are finished. Details of the computer program are given by Kao (1973).

DISCUSSION OF RESULTS

As mentioned previously, the model parameters considered in this study are space and time increments, rainfall input and channel roughness. The effect of various parameters on runoff simulation is discussed under appropriate heading.

SPACE AND TIME INCREMENTS

Usually, the smaller the time and space increments, the more accurate the simulation. However, results of this analysis indicate that the improvement of accuracy is very small. In general, the variation on peak flow due to different space increments is less than 5 percent; while on time to peak, less than 1 percent. On the other hand, the variation on peak flow due to different time increments is less than 3 percent; while on time to peak, less than 1 percent. The importance of time and space increments is that the ratio of time increment and space increment has to be small enough to guarantee a stable solution. In this study, the solution has been found stable as long as the ratio is less than one.

TIME DISTRIBUTION OF RAINFALL INPUT

Three sets of rainfall input are used to examine the effect of time distribution of rainfall excess on hydrograph simulations. The volumes of the three inputs are equal, yet the time distributions are different. As shown in Figure 2, the first input is a rainfall excess with uniform intensity, and second is a hyetograph with an increasing intensity, and the third input is similar to the second one except that the shape is more nonuniform. Figure 3 is a plot of the hydrographs resulting from these three inputs. The rate of peak flow from input one is about 7 percent lower than that from input three, and the difference between time to peak is 10 minutes. The peak flow from input two is only 1.7 percent lower than that from input three, and the difference between time to peak is only 2 minutes. For all practical purposes, therefore, input two is just the same as input three.

CHANNEL ROUGHNESS

The variation on flow hydrographs due to different values of Manning's n has also been examined in this study. Generally, the variation on peak flow and time to peak is less than 1 percent. In other words, the outflow hydrographs generated by the hydrologic routing model are not too sensitive to channel roughness. This finding coincides with Linsley's (1971) conclusion. However, as illustrated in Figure 4, the flow depth resulting from different values of Manning's n has a significant variation. The value of Manning's n should be carefully selected if the objective of the simulation is to predict the depth of flow at various points of a watershed.

SUMMARY

In view of the above results concerning the parameter influence on runoff modeling, the effect of time and space increments, time distribution of rainfall input, and channel roughness on runoff simulation appears to be very small. However, the influence of channel roughness on flow depth is significant.

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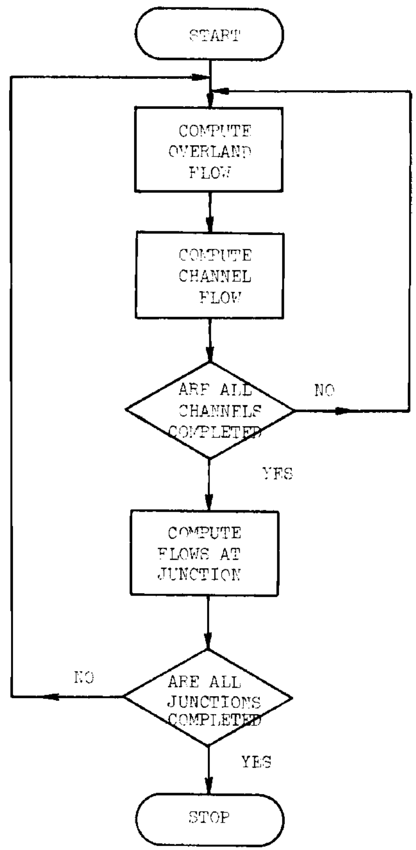


Figure 1 Flow Chart Diagram for Runoff Simulation

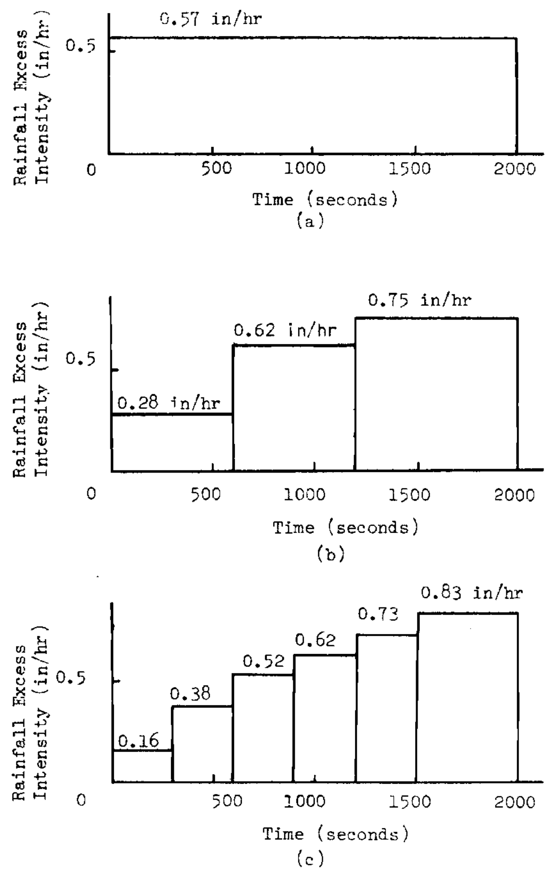


Figure 2 Rainfall Inputs

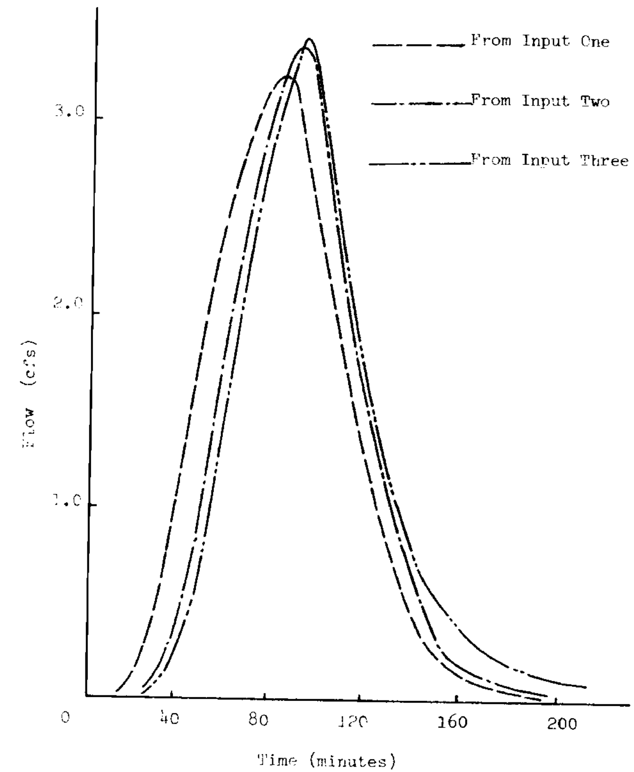
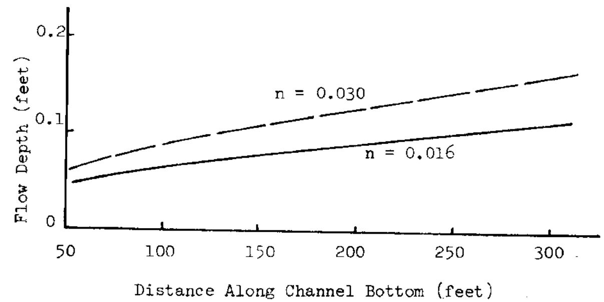
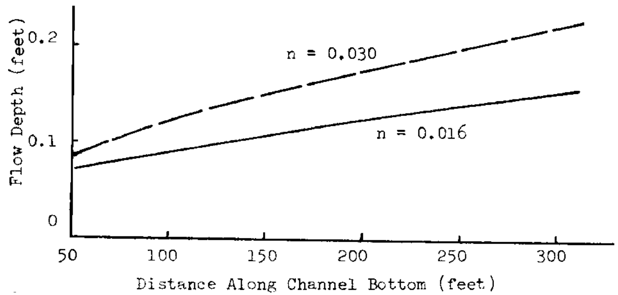


Figure 3 Effect of Rainfall Inputs on Flow Hydrographs.



(a) Flow Profile at t = 1000 Seconds



(b) Flow Profile at t = 2000 Seconds

Figure 4 Effect of Manning's n on Flow Depth