International Journal of
Engineering, Sciences and Technologies
Published online 20 September 2014 (http://www.scienceresearchlibrary.com)

Vol. 01, No. 01, pp. 1-4

Research Article

Open Access

Physical Simulation of Rainfall-Runoff System by a Hydrology Bench

Md. Nurul Kadir[1], Taznin Naher[2] and Dr. M. Hassanuzzaman Khan [3]

[1]Research Associate, IWFM, BUET, Dhaka-1000, Bangladesh

[2]Research Fellow, IWFM, BUET, Dhaka-1000, Bangladesh

[3]Professor, Department of IWM, BAU Mymensingh-2202, Bangladesh

Received: 1 September 2014 / Accepted: 17 September 2014

Abstract

This study was conducted to simulate the rainfall-runoff system by a hydrology bench in a hydraulic laboratory. The hydrology bench consisted of a 210.8 cm long, 108.0 cm wide and 16.5 cm deep metallic tray with an overhead sprinkling system. A river network was created on the soil bed in the tray. Rainfall on the tray was simulated by supplying water by a pump through the sprinkling nozzles. There were two outlets, one to drain surface runoff and the other the subsurface runoff. Surface runoff hydrographs were developed for different rainfall durations on two different surface conditions, such as simple soil bed and gravel spread bed. The results were analyzed to verify the theories used in analysis of hydrographs, as available in relevant text books. Uniformity of rainfall distribution over the catchment was also analyzed. The results showed that the hydrology bench could simulate rainfall-runoff system quite satisfactorily. The simulation was better on the soil bed than the gravel spread bed. The rainfall distribution was not very satisfactory. However, the analysis of hydrographs showed that theories used in literature were in good agreement with the practical findings.

Keywords: Simulation, Rainfall-Runoff, Hydrograph, Hydrology bench.

*Corresponding author:

mnkseum@gmail.com, tnsabia@gmail.com, mhkhan@yahoo.com

Introduction

Rainfall duration and intensity influence the rate and volume of runoff. The rainfall-runoff simulation is the process of representing the natural rainfall-runoff system by means of an artificial simulator. A simulator may be mathematical or physical. A physical rainfall-runoff simulator consists of a metal tank that supports spray head assembly. The unit may be placed directly on the ground for field studies or used with its accessory tray for laboratory experiment. In use, water is pumped from the holding tank via a control valve to the spray nozzle to produce artificial rainfall. In a rainfall simulator, specially designed nozzles produce raindrops of various sizes falling from a desired height and are capable of producing various intensities of rainfall. The metal tank acting as a catchment can generate runoff which is also influenced by the surface condition maintained in the tank. So, these simulators can be used to study the effects of intensity and duration of rainfall and catchment conditions on the volume and rate of runoff generation. In this work, a hydrology bench was used to simulate rainfall-runoff system in the laboratory. The objective of the study was to develop and analyze runoff hydrographs for different rainfall durations on two different surface conditions of the simulator catchment.

Materials and methods

Hydrology bench

The hydrology bench consisted of a sand/soil filled metallic tray to act as a micro catchment and an over-head sprinkler device to produce rainfall on the catchment. The Metallic tray was 211.0 cm long, 108.0 cm wide and 16.5 cm deep, filled layer by layer with different textures of dry sieved soil. The top and bottom layer consisted fine soil and very coarse material to represent natural catchment and aquifer respectively. A network of micro river system was created on the top of the soil bed to represent a natural river. There was an outlet at the level of the bottom of the main channel to drain the surface runoff .Another outlet was at the bottom of the tray to drain the subsurface runoff. The tray was placed on a metallic frame which is 61cm above the ground. An over-head sprinkler system consists of two nozzles connected with PVC pipe, horizontally placed above the tray at a height of 125.0 cm. A centrifugal pump, coupled to a half horse power motor, supplied water to the pipe line. Also, 12 pots were placed in a rectangular grid system on the model catchment. The diameter and heights of the pots were 3.55 cm and 3.00 cm respectively. These pots represent as a rainfall collector.

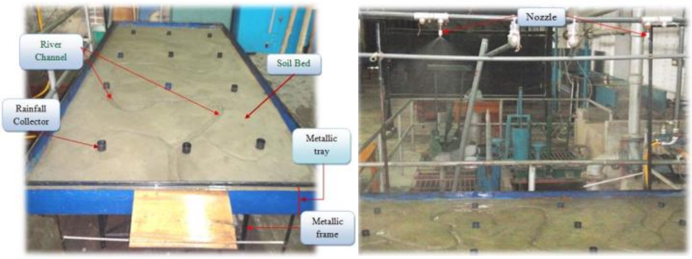


Fig. 1: Experimental setup

Experimentation

Surface runoff generation

The main experiment was started after the surface runoff due to the sprinkled water ceased. The pump was then started to produce rainfall. When the first drop of surface runoff came out, the counting time of effective rainfall began. The effective rainfall was allowed to continue for a desired period of time, say T seconds. The surface runoff due to the rain was collected in bottles at 10-sec intervals and weighed by an electronic balance and volume calculated in ml. The measured volumes were the constituents of surface runoff or effective rainfall (ER) hydrograph. The ratio of ER to total effective surface area of the model catchment represented the depth of runoff. Effective rainfall rate (ERR) was calculated by dividing the runoff depth by the effective rainfall duration, T.

Calculation of Rainfall Rate

At first the pots for rainfall measurement were emptied and placed back on the grid points on the catchment. Then the pump was started to produce rainfall. The rain was stopped after 10 minutes. Water collected in each pot was weighed and volume calculated. Depth of collected water was calculated by dividing the volume by the catch area of the pot. Average depth of rainfall on the catchment in 10 minutes was calculated by averaging the depths collected in the 12 pots. Rainfall rate (RR) was then calculated by dividing the average depth by the duration of rainfall (10 minutes).

Calculation of Runoff Coefficient

The ratio of effective rainfall rate (ERR) to rainfall rate (RR) gave the runoff co-efficient. It was dimension less.

The experiments were carried out on different surface conditions of the catchment. In the first phase, experiments were done on normal soil bed. In the second phase, fine gravels were spread on the soil bed to change the surface condition of the catchment. In each case, experiments were carried out for different durations of rainfall

Fig.2 Change of soil bed by spreading gravel

Results and discussion

The main purpose of this work was to simulate rainfall-runoff system in the laboratory. In this work, a hydrology bench was used for the simulation. Rainfall was generated for different durations and the resulting runoff volumes were collected at 10-sec. intervals. The experiments were carried out on soil bed and gravel spread bed.

Table. 1 presents features, such as time of peak (Tp), magnitude of peak flow rate (Qp) and time base (Tb).The table shows that Tp, Qp and Tb values increase with the increase of rainfall durations. Values of Tp, Qp, and Tb are maximum in 80 sec rainfall duration. The values of Tp, Qp, and Tb generally increased with increase of rainfall duration.

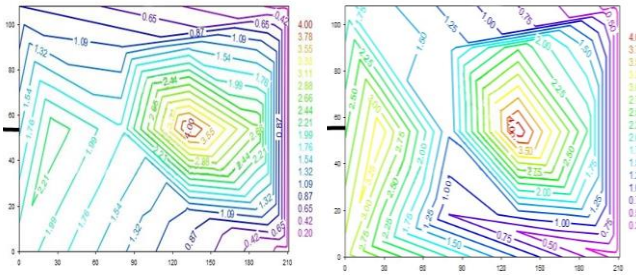
Table 1 Features of hydrographs of different durations

Rainfall duration (sec)	Time to peak (T_p) (sec)	Peak flow rate (Q_p) (ml/10sec)	Time base (T_b) (sec)
30	40	52.3	170
40	50	62.7	190
50	60	73.6	190
60	70	80.6	210
70	70	84.5	210
80	80	85.9	230

Table 2 presents the values of C obtained in different rainfall events. Experiments for rainfall durations of 40, 60 and 80 seconds were carried out on 15 July, 2012 and those of 30, 50 and 70 seconds on 18 July, 2012

Table 4.2 Runoff Co-efficient C for soil bed

Date of Experiment	Rainfall duration (sec)	Runoff Rate (mm/sec)	Rainfall Rate (mm/sec)	Runoff Co-efficient C
15-Jul-12	40	0.0045	0.0061	0.738
	60	0.0042		0.680
	80	0.0044		0.718
18-Jul-12	30	0.0045	0.0067	0.674
	50	0.0042		0.630
	70	0.0042		0.623



15 Jul. 2012 18 Jul. 2012

Fig.3 Contour of rainfall measurement data

Hydrograph Analysis

Runoff hydrographs resulting from 6 rainfall events of different durations were compared. As shown in Table 2, the runoff generation rates in the 6 hydrographs varied from 0.0042 to 0.0045 mm/sec. For comparison of hydrographs the volume of flow, represented by each hydrograph, was adjusted assuming a constant runoff rate of 0.0043 mm/sec. In Fig. 4 the 6 hydrographs are superimposed on one another. It shows that the superimposed rising limb closely resembles the rising limb of an S-curve. This is expected to happen with increasing rainfall duration.

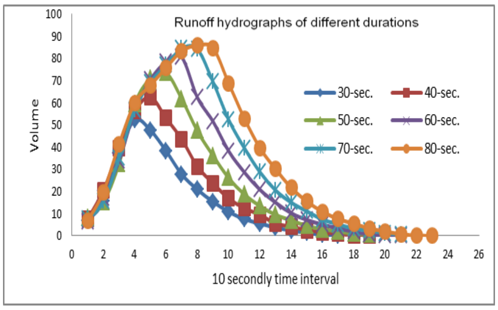
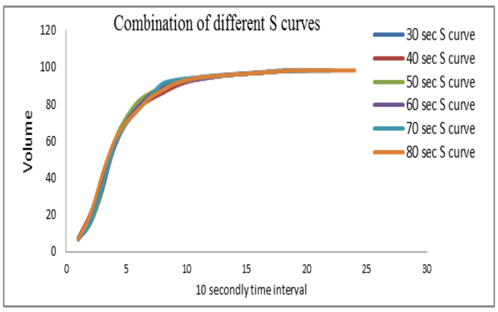


Fig. 4 Comparison of runoff hydrographs of different durations.

The six S-curves obtained from the hydrographs, are superimposed in Fig. 5. A very good match between the S-curves indicates that all of them closely represent the catchment's response due to a continuous rainfall on the catchment.



From an S-curve it is possible to construct hydrographs of any duration. In this work, 50-sec. and 70-sec. hydrographs were constructed from the s-curve. Figure 6 presents superposition of the constructed and observed hydrographs of 50 and 70 seconds durations. A very good match is seen between the constructed and observed hydrographs of both durations.

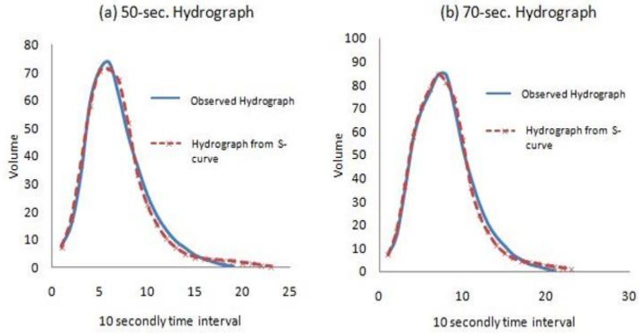
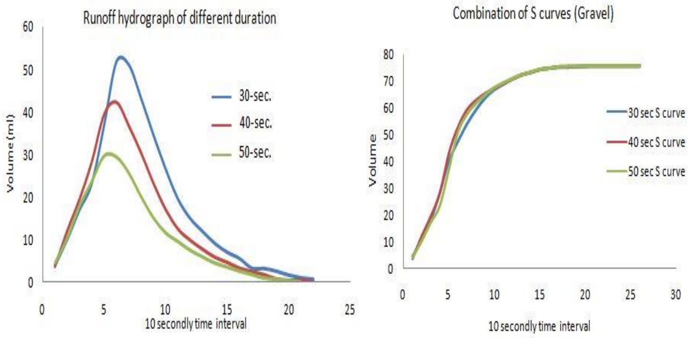
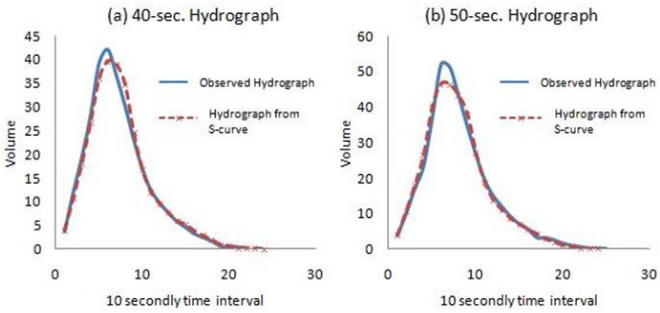


Fig. 7 Comparison of 50-sec. and 70-sec. constructed hydrographs with observed hydrographs

Same kind of practice was done for gravel spread bed.



Comparison of runoff hydrographs **Combination of different S-curves**



Comparison of constructed hydrographs with observed hydrographs

Fig.8 Hydrograph Analysis on gravel bed

Conclusion

This study was conducted to simulate the natural rainfall-runoff system by means of a hydrology bench. The main purpose of our study was to verify the theoretical assumptions by practical experiments. The results showed that the hydrology bench simulated the rainfall-runoff system quite satisfactorily. The hydrographs obtained from the tests were typical. The study revealed that the features of hydrograph of different durations were in conformity with theoretical assumptions for both soil bed and gravel bed. Also the analysis of hydrographs showed that theories used in literature were in good agreement with the practical findings.

References

Arnaez, J., T. Lasanta, P. Ruiz-Flaño, and L. Ortigosa. 2007. Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. Soil Tillage Res. 93:324-334.

Baharudin, F.B. 2007. A study on rainfall-runoff characteristics of urban catchment of SungaiKerayong. M.S. thesis:1–119

Darbandi, S., FARD, A.F., Dalir, A.H., Sadraddini, S.A. and Zadeh, D.F. 2008. Hydraulic simulation of rainfall-runoff process in Kamanaj watershed using diffusive model. Tarim Bilimleri Dergisi, 14 (3):210-216

Hamed, Y., J. Albergel, Y. Pépin, J. Asseline, S. Nasri, and P. Zante. 2002. Comparison between rainfall simulator erosion and observed reservoir sedimentation in an erosion-sensitive semiarid catchment CATENA 50:1-16.

Mardookhpour, A. 2012. Utilizing the KINFIL model for investigation of deforestation on the runoff-peak (Case study: Sepidroud catchment). International Journal of Forest, Soil and Erosion, 2(1):18–23.

Reshma, T., Kumar, P. S., Babu, M. J. R. K. and Kumar, K. S. 2010. Simulation of runoff in watersheds using SCS-CN and Muskingum-Cunge methods using remote sensing and geographical information systems. International Journal of Advanced Science and Vol. 25:31–41

Sayed, E.A. and Habib, E. 2008. Advanced technique for rainfall-runoff simulation in aridcatchments Sinai, Egypt. The 3rd International Conference on Water Res. and Arid Env. and the 1st Arab Water Forum. 1–14

Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall erosion losses-a guide to conservation planning. Agriculture Handbook Nº 537. U.S. Department of Agriculture, Washington D.C., USA.