6th WEDC Conference : March 1980 : Water and Waste Engineering in Africa

J OBIUKWU DURU

RUNOFF HYDROGRAPHS FROM NORTHERN NIGERIA WATERSHEDS WITHOUT STREAMFLOW RECORDS

BACKGROUND

Despite occasional criticism directed primarly at the principle of time invariance embodied in the unit hydrograph theory, the unit hydrograph has been well accepted and extensively used by hydrologists. Its appeal stems primarly from its simplicity and versatility, in the sense that it will allow the reconstruction of runoff from any storms however complex.

The derivation of the unit hydrograph as proposed by the Sherman (Ref. 1) does, however, require that the stream for which a unit hydrograph is required by gauged. But relatively few streams are gauged. Moreover, the gauging station may not be located at the point of interest for a particular application. As a result, the need was identified for methods of synthesizing a unit hydrograph.

SYNTHETIC UNIT HYDROGRAPH

All methods of synthesizing unit hydrographs aim at expressing unit hydrograph parameters - mainly peak run off rate, peak time, and total base time - as simple functions of the physical characteristics of the watershed. The unit hydrograph parameters are related to watershed geometry by empirical coefficients which have been found to be regionally sensitive. Thus, establishing a synthetic unit hydrograph for a region amounts to quantifying these empirical coefficients for that particular region. And since an exceeding few of Nigerian streams are gauged, it was felt that the synthetic unit hydrograph provides the best and, perhaps as of now, the only avenue to any useful information about the hydrology of Northern Nigeria watersheds.

USDA - SCS Synthetic Unit Hydrograph

Although many methods have been proposed for synthesizing unit hydrographs (Refs. 2,3,4) the triangular method proposed by the United States Department of Agriculture (USDA). Soil Conservation Service (SCS), (Ref. 4) was elected for this study. The better known Synder synthetic hydrograph was bypassed because it calls for a minimum base time of three days, thus making it unsuitable for basins with short runoff periods. Considering the extremely short rainfall and runoff records available, this additional constraint would have made the study totally impossible.

For a unit hydrograph, the volume of runoff (V) is given by :

$$V = (1 \text{ unit of rainfall}) (\text{watershed area})$$

From the geometry of a triangular hydrograph the volume is also given by :

$$V = \tfrac{1}{2} q_p T$$

so that

q_p = peak runoff rate

T = base time

From extensive studies by the SCS, empirical relationships

$$T = (1 + H)\, t_p$$

and

$$t_p = t_c + 0.5\, t_r$$

have been established.

In equations (4) and (5) t_p is the peak time, t_c is the time of concentration, and t_r is the duration of effective rain fall. Both and H are coefficients which need to be determined.

STUDY PROCEDURE

Records of streamflow and recording rain gauges for three drainage basins in the

Kano State were studied, and storms that reasonably satisfy the assumptions of the unit hydrograph theory were selected. Unit hydrographs for discharges corresponding to these storms were reduced to the same duration - 2 hours - via the S - curve procedure. Graphs of equations (4) and (5) were plotted on regular graph paper. The 'best' straight line for each case was fitted by eye and values of and H were determined. The values of and H were found to be 0.55 and 1.41 respectively.

Verification of the Coefficients

The coefficients and H were used to synthesize direct runoff hydrographs from one of the three basins. Similated and observed hydrographs are compared in Fig. 1.

Integrated Urban - Rural Hydrograph

Al the three basins used in the study are basically rural in character. While signs of transition to urban character are in evidence, each basin presently has less than 10 per cent surface imperviousness and the Unit Area Hydrograph (UAH) method for computing the urban runoff component of the composite hydrograph does not predict a hydrograph reliably when imperviousness drops under the 20 per cent level (Ref. 5). Thus, the basins were all treated as rural. The direct runoff hydrograph synthesized with a unit hydrograph was considered to represent the entire basin.

DISCUSSION AND CONCLUSION

The objective of, and need for, this study should attract no arguments. However, the data base is so narrow that the conclusions should not be generalised to apply to all Northern Nigeria as the title of the paper may lead one to do. Caution should be exercised in generalising the conclusion to all of Kano State as the three basins studied are not evenly distributed in the State to reflect any regional peculiarities. The scope of the study is so narrow because there are only six recording rainfall gauging stations, in addition to the National Airport, in Kano. All the six are located in the same region which is less than half of the state, and all have only been operating since 1977. And, even then, some of the six stations are considered inaccessible by the operators and no data could be obtained from them.

The coefficients and H were found to have numerical values of .55 and 1.41. For USA conditions the same coefficients have values of 0.60 and 1.67 respectively. The hydro-

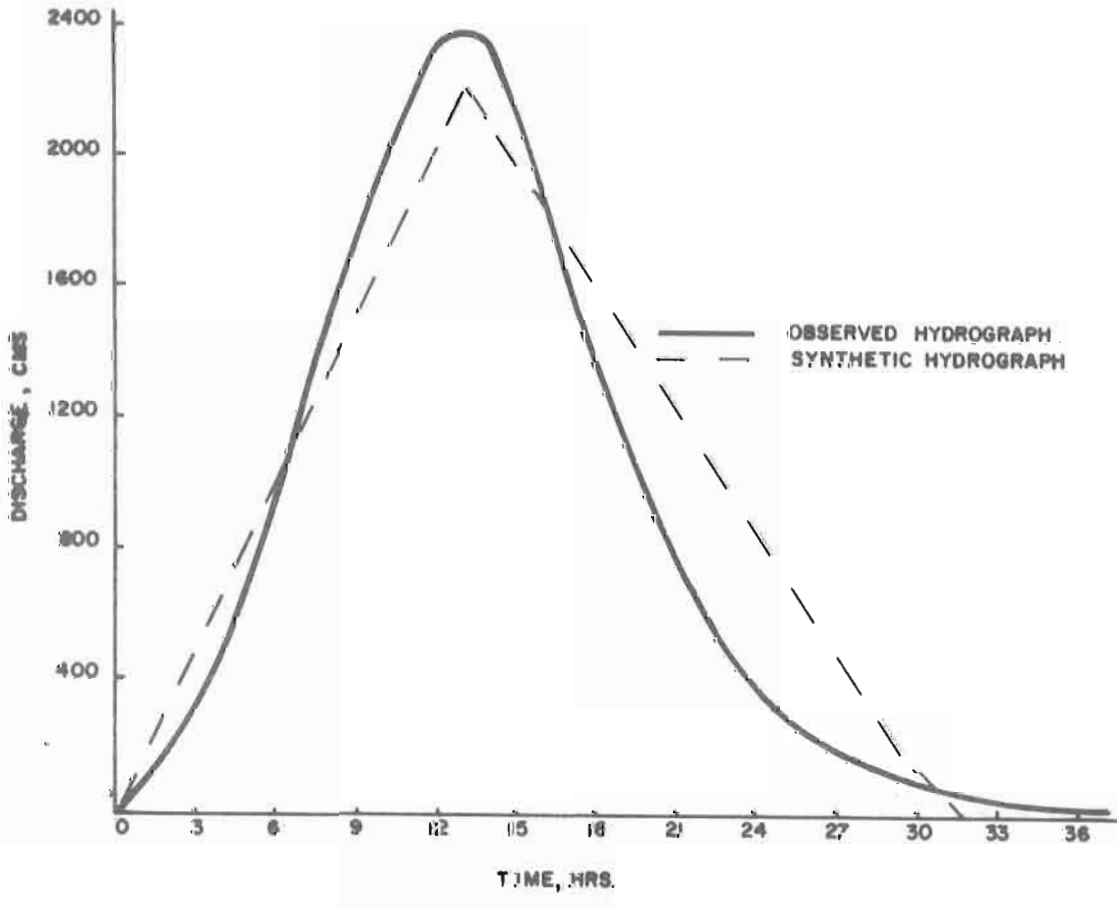

FIG. 1. OBSERVED AND SYNTHETIC HYDROGRAPHS FOR RIVER KAMANDA, AT KYARANA, JUNE 22-24, 1978

graph synthesized with = .55 and H = 1.41 (Fig. 1) does not match the observed hydrographs perfectly, though the simulation is considered reasonably good for hydrologic work. It is difficult to say at this time wether the differences between synthetic and observed hydrographs may be attributed to imperfection in the values of and H. There is another possible source of error. There is only one rain gauge near each of the watersheds studied. The lone gauge in one case is located at one corner of the basin, and in two of the three cases totally outside the basin, so that the readings may not be representative. This makes relating rainfall to runoff rather uncertain.

Perhaps a real value of this work which is as important as the findings lies in its leading the way in an important area of research, highlighting difficulties that are real, especially non-existences or inadequacy of data, and clearly exposing the need for co-operation among all persons in the water resources field. This co-operation is needed to intensify data collection effort and to insure that any data collected are relevant and in usable form. While the values of and H as determined in the study appear reasonable judging from the synthetic hydraograph the result should be considered tentative. The research base should be expanded by including many more drainage basins and using many more events from each basin. This expanded study should reaffirm the finding of this study and thus strengthen confidence in the established coefficieints or point toward a modification to achieve the desired objectives.

ACKNOWLEDGMENT

The author is grateful to the staff of the Hydrology Section of the Water Resources Engineering and Construction Agency, Kano, for making their records available and assisting the author through the work.

REFERENCES

1. Sherman L.K. Streamflow from rainfall by the unit-graph method. Engineering News Record, Vol. 108 April 7, 1932.

2. Snyder F.F. Synthetic unit graph (Trans. Am. Geophs. Union, Vol. 19 1938.

3. McCarthy G.T. The unit hydrograph and flood routing. Referenced from V.T. Chow (ed), Handbook of Applied Hydrology, McGraw-Hill Book Co. P.14-22 1964.

4. Hjelmfelt A.T. and Cassidy J.J. Hydrology for Engineers and Planners, Iowa State University Press, pp. 109 - 113 1975.

5. Duru, J.O. A Unit hydrograph concept for predicting flood hydrographs from suburban subdivisions. Proceedings, International Symposium on Urban Storm Water Management, University of Kentucky Lexington Ky - July 24 - 27 1978.