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Operational flood forecasting in *Yamuna* river by the application of Sacramento conceptual model

S. D. S. ABBI and A. K. GOSAIN*

Meteorological Office, New Delhi

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ABSTRACT. In the present paper, an attempt has been made to apply to Sacramento river forecast model to Yamuna catchment upto Kalanaur for operational purposes. For this purpose the model was calibrated using the hydrometeorological data for the years 1976 and 1977 and tested for the historical flood of September 1978 in river *Yamuna*. The six hourly peak discharge at Kalanaur on the early morning of 3 September 1978 was about 6.7 lakh cusecs as computed by the model, on the basis of six hourly mean precipitation input.

1. Introduction

Gosain and Abbi (1980) have successfully applied the Sacramento River Forecast Model to an Indian catchment which was taken to be the Yamuna catchment upto Kalanaur. The authors adapted the Sacramento model for the first time in India for the Yamuna catchment. Encouraged by their initial success the model was used for other Indian catchments with equal success.

Sacramento model is a conceptual model as it takes into consideration the physical processes taking place in the catchment. Its advantage lies in the fact that where accurate simulation of the past has been attained, a high degree of conceptuability enhances its capability of predicting the future events particularly the extreme events like severe floods not available in the past historical data. The model is already in use in several river forecast centres in USA for their operational purposes. With this in view, the authors have applied this model for the simulation of the historical flood of September 1978 in river *Yamuna*.

2. Data used

The calibrated parameters from the author's earlier study (1980), of this basin have been adapted. Values of these model parameters are listed in Table 1. Further, the six hourly rainfall data of ten stations in the upper Yamuna catchment upto Kalanaur since 1 June to 30 September 1978 have been used. The corresponding daily discharge data at Kalanaur gauge site obtained from Central Water Commission and the mean monthly evaporation data of Dehra Dun have been used.

3. Associated synoptic situation

The historical flood of September 1978 in river *Yamuna* had occurred in association with a Bay depression which affected the upper Yamuna catchment on 2 and 3 September 1978. This depression was formed in the Bay of Bengal as a deep system on 26 August 78 near Lat. 20 deg. N and Long. 89 deg. E. Moving northwestwards, it intensified into a cyclonic storm on 27 morning and same evening it crossed north Orissa coast between Balasore and Chandbali. Moving inand in a westnorthwestwards, it weakened into a deep depression on 28th morning and into a depression near Rajgarh in Madhya Pradesh on 30th morning. Moving northnorthwestwards it was centred 60 km north of Kota on 31 August. It then recurved and intensified into a deep depression on 1 September with centre about 50 km west of Agra and was centred close to Meerut on 2 September. Thereafter it weakened rapidly and moving northnortheastwards it broke over the hills of west Uttar Pradesh on 3 September.

*Indian Institute of Technology, Hauz Khas, New Delhi.

TABLE 1

Calibrated parameter values for Yamuna basin upto Kalanaur

Parameter definition	Parameter name	Value
(a) Upper zone parameters		
1. Tension water maximum capacity	UZTWM	40 mm
2. Free water maximum capacity	UZFWM	50 mm
3. Lateral drainage rate of upper zone free water expressed as fraction of contents per day	UZK	0.30
(b) Percolation parameters		
4. A factor used to define the proportional increase in percolation	ZPERC	15
5. An exponent determining the rate of change of percolation rate	REXP	2.0
(c) Lower zone parameters		
6. Maximum capacity of tension water	LZTWM	50 mm
7. Maximum capacity of supplemented free water storage	LZFSM	105 mm
8. Lateral drainage rate of supplemental free water	LZSK	0.054
9. Maximum capacity of primary free water storage	LZFPM	95 mm
10. Lateral drainage rate of primary free water	LZPK	0.006
11. The percentage of percolation water which directly enters the lower zone free water without prior claim by lower zone tension water	PFREE	0.30
(d) Direct runoff parameters		
12. Fraction of impervious basin contiguous with stream channels	PCTIM	0.009
13. Fraction of basin which becomes impervious as all the tension water requirements are met	ADIMP	0.100
14. Fraction of basin covered by streams lakes etc	SARVA	0.100
(e) Other parameters		
15. Fraction of lower zone free water not available for transpiration purposes	RSERV	0.30
16. The rate of unobserved to observed baseflow	SIDE	0.0
17. A fixed rate of discharge lost from the total channel flow	SSOUT	0.0

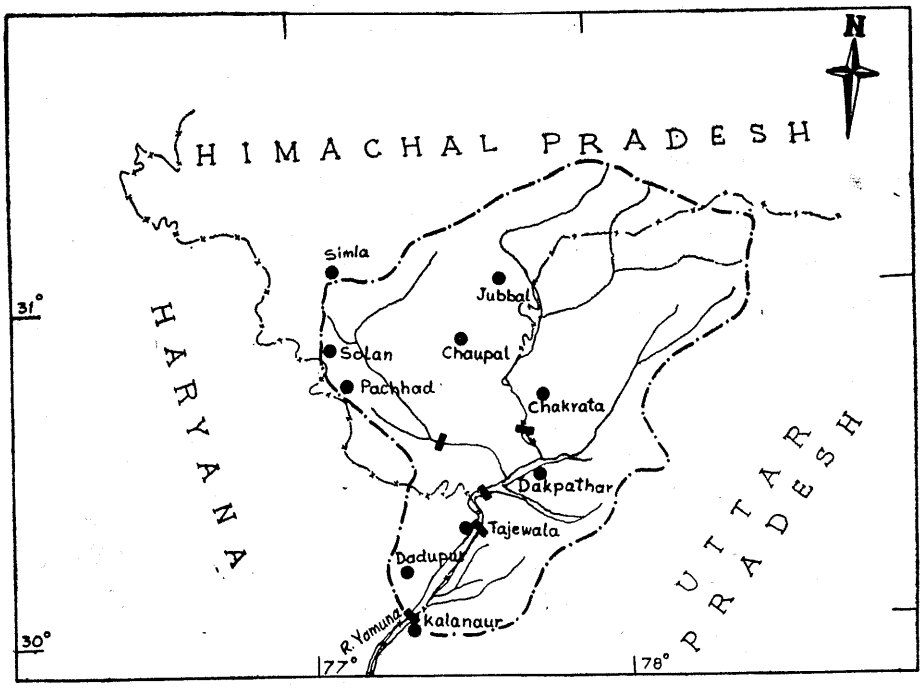

Fig. 1

It became unimportant the following day but the associated upper air cyclonic circulation, however, persisted till 6 September. Under its influence heavy to very heavy rainfall occurred over the upper catchment area of river *Yamuna* on 2 and 3 September. Some of the significant amounts of rainfall were:

Chopal 62.5 mm, Jubbal 77.0 mm, Kalsia 100.3 mm, Kotkhai 70.0 mm, Mussoorie 59.6 mm, Nayashaher 104.0 mm, Paonta 52.0 mm and Tajewala 125.1 mm on 2 Sep 1978; Chakrata 171.4 mm, Chopal 205.0 mm, Dadupur 233.0 mm, Dakpathar 147.5 mm, Jataon Barrage 209.00 mm, Jubbal 154.0 mm, Kalsia 121.9 mm, Koti 233.2 mm, Kotkhai 220.0 mm, Mussoorie 89.8 mm, Nayashahar 127.0 mm, Pachhad 223.0 mm, Paonta 225.0 mm, Tajewala 190.0 mm on 3 Sep '78. This heavy to very heavy rainfall in the upper catchment area caused unprecedented floods in river *Yamuna* and after its confluence with river *Ganga* near Allahabad, the river *Ganga* also crossed danger level at several points downstream right upto Farrakha. A map showing the upper catchment area of river *Yamuna* and the location of raingauge stations is given in Fig. 1.

4. Application of Sacramento model

The Sacramento model as adapted by the authors in their earlier paper (Gosain and Abbi 1980) for the upper Yamuna catchment upto Kalanaur gauge site has been used in the present study. This is a deterministic conceptual lumped parameter model. The model is based on a system of percolation, soil moisture storage, drainage and evapotranspiration characteristics which are intended to represent the significant hydrologic processes in the catchment in a rational manner. Model parameters representing the above processes are estimated by the inferences drawn from the rainfall and runoff record of the basin. The computational interval considered is both time dependent and volume dependent. Computations are made at six hours interval if the volume of moisture involved is less than 5 mm and the interval is divided, in case it is more than 5 mm. However, the details of this model have not been included in this paper in order to avoid the repetition. The area of catchment is 12150.0 sq. km and there are ten raingauge stations in the catchment whose six hourly rainfall data have been used for the period 1 June to 30 September 1978. The daily discharge data of Kalanaur gauge site has been

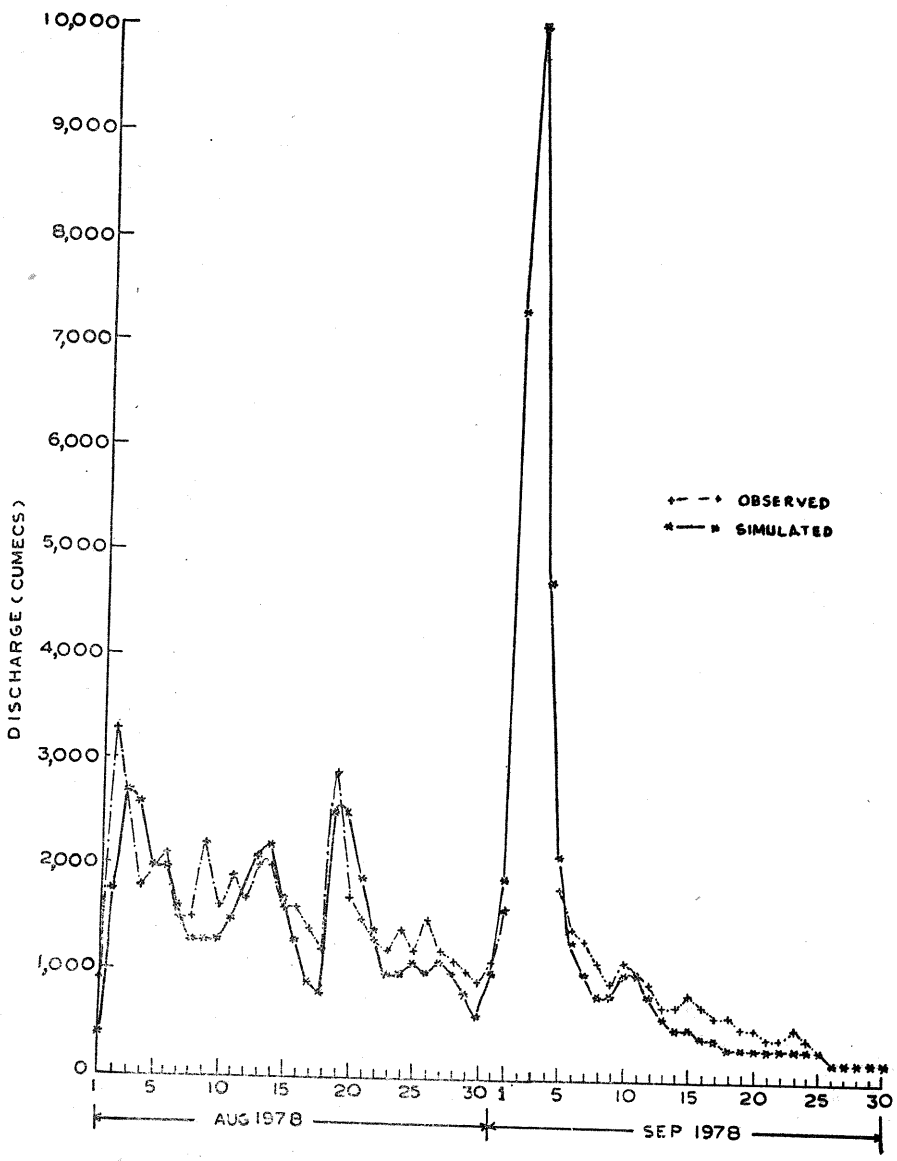

Fig. 2

obtained from Central Water Commission. For evapotranspiration demand curve, mean monthly evaporation data of Dehra Dun Agro-meteorological Observatory has been used for obtaining the daily evaporation demand curve by linear interpolation of the mean monthly evaporation values. The values of the various model parameters used for this study are the same as adopted by the authors in their earlier study (1980) and these have been listed in Table 1.

The actual and simulated discharges as plotted on day to day basis are shown in Fig. 2. It may be seen that a good agreement exist between the actual and the simulated discharge. The large peak between 1 and 3 September 1978 pertains to the historical flood which recorded its peak discharge at Kalanaur on 3 September 1979. Fig. 3 shows the hydrograph at six hour intervals as simulated by the model alongwith the available observed discharge at six hour intervals (exclud-

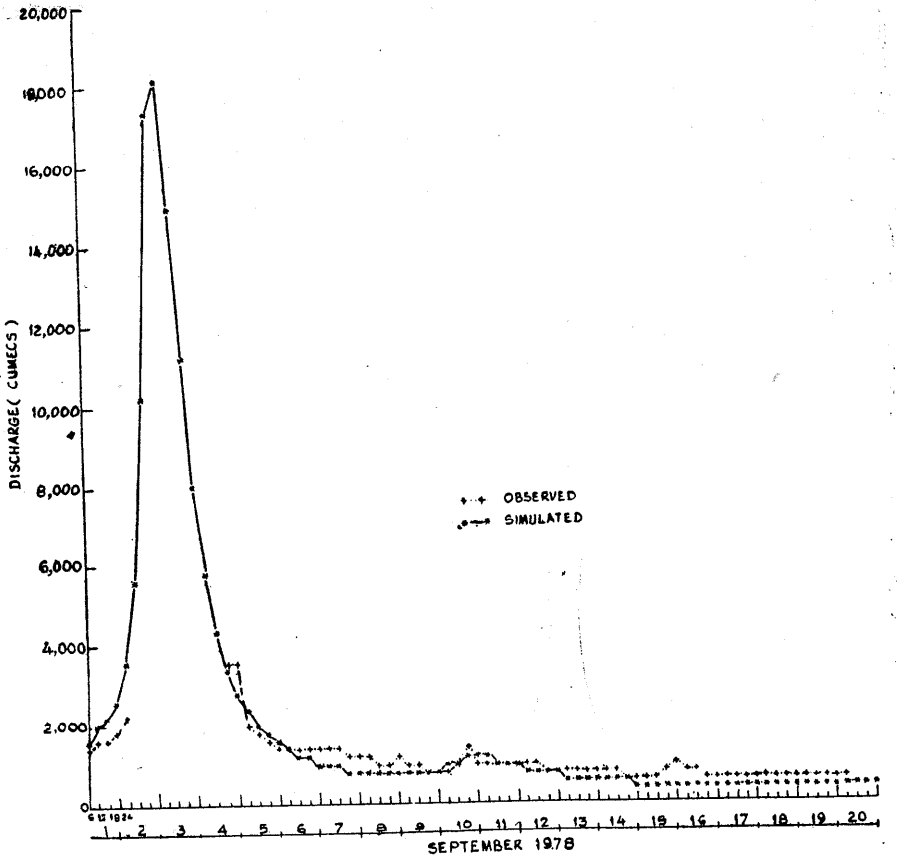

Fig. 3

ing the peak discharge values which could not be recorded). Apart from simulating the magnitude of the peak, the time of rise of the peak can also be obtained with a precision of six hour intervals.

5. Discussion on results

As may be seen from Fig. 2 that the observed discharge was recorded daily upto the morning of 2 September 1978 and thereafter the gauge was completely submerged in the flood water. The peak was reached on 3rd and as the flood water receded, the gauge reading was again recorded from 4 September 1978. No actual measurement of peak discharge on 3 September could be made. Fig. 3 shows the simulated discharge at six hour intervals as reproduced by the Sacramento model and indicates a discharge of 6.7 lakh cusecs at Kalanaur on 3rd morning of September 1978. The time of rise to this peak has been found to be 54 hours which occurred between 00 and 06 hours of 3 September 1978. Discharge as computed by Haryana Irrigation Department, for 1978 flood at an upstream station Tajewala was 7.09 lakh cusecs. Keeping this in view, the discharge of 6.7 lakh cusecs predicted by this model at Kalanaur is quite resonable. Further, considering the fact that both the rising and the recession parts of the simulated hydrograph agreed well with the actual hydrograph during the period of the flood, it is quite justified in accepting the magnitude of the peak discharge to be reasonably accurate.

6. Conclusion

Encouraged by the results yielded by Sacramento model as adapted for the Yamuna catchment, the authors are quite optimistic that this model can be used for operational flood forecasting for Yamuna catchment. Similar studies for other Indian catchments are also in progress.

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