RAINFALL-RUNOFF DATA AND MODELLING IN THE LIKHU KHOLA CATCHMENT, NEPAL

DAVID BOORMAN, ALAN JENKINS AND ROBERT COLLINS
Institute of Hydrology, Wallingford, Oxon, UK

Population growth in the Himalaya region has led to increasing demand for food which has been met by increasing use of fertilisers and expansion of agricultural land. These changes modify the quality and quantity of river flows downstream from the affected areas and therefore have a regional as well as local impact. To investigate such changes requires good quality hydrological data on the appropriate spatial scale and temporal resolution. To enable such a study, flow and rainfall, volume and quality, together with other meteorological data, have been collected from five subcatchments of the Likhu *Khola* in the Middle Hills of Nepal. This paper describes the rainfall and runoff data collected from these sites, analyses of this data, and results from a rainfall-runoff model used to simulate catchment response.

Data were collected at seven sites, listed in Table 1, between 1991 and 1994. Five of these are flow-sites where the stage and rainfall (along with other parameters) were recorded at 30-minute intervals; for these sites, a simple land-use classification of the catchment area is also shown in Table 1. At both other sites, an automatic weather station (AWS) was installed to record rainfall and other meteorological data on an hourly basis. Because not all gauges were installed at the start of the project, and there were a number of technical and operational problems leading to loss of data, the data sets are by no means yet complete.

The annual rainfall at the AWS sites for the very nearly complete year starting in October 1992 was just over 2,000mm, of which over 90% fell in the wet season between 1st April and 30th November. Note that this "wet season" corresponds to both the monsoon and premonsoon periods, and this term will be used throughout this paper to refer to this period. At the nearby, but higher, Kakani Long-term Meteorological Station, the long-term average rainfall is greater, 2,804mm for the period from 1962 to 1991, but it has an almost identical seasonal pattern.

Of the study sites the Chinniya, which is the highest site and on a north-facing hillside, has the greatest rainfall, roughly 25% more on an average than on the sites in the valley bottom. The Gerogaon site, also on the north-facing slope, receives an average of about 10% more than the other lower sites. Therefore, tentative conclusions are that rainfall increases with altitude and is greatest on the north-facing side of the valley. The latter is expected as most storms arrive at the catchment from the south or southeast. However, on other sites in Nepal, a more complex relationship of rainfall with altitude is reported.

An analysis of the rainfall data on an hourly basis shows that the sites are very similar. The following are some examples.

i. The diurnal variation of rainfall shows that rainfall is least likely between 08.00 and 12.00, and most likely between midnight and 04.00.
ii. Average storm durations are between six and eight hours, but frequently contain short periods with no rainfall.
iii. Average intervals between storms are either less than two days or greater than four days.
iv. Storms usually cause rainfall at all sites, although rainfall totals can vary greatly between sites.
v. Most rainfall occurs in low-intensity bursts, e.g. at Jogi, 80% of the rainfall occurred in bursts of less than 10mm and only 5% in bursts of 40mm or more.
vi. Within storms, there were very high-intensity bursts of short duration, the maximum being a rate of over 2mm/minute.

To derive flows from the stage records requires a stage-discharge relationship for each site. None of the sites had a formal structure and therefore these relationships had to be developed from spot gaugings. These were obtained by dilution gauging, which was ideally suited to the turbulent (well-mixed) conditions in the stream. Unfortunately, not enough high-flow gaugings were made to produce reliable stage-discharge relationships for all sites; the best was for the Bore *Khola,* with 27 gaugings.

Two features of the flow data are common to all catchments. Firstly, flows outside the wet season are very low and even fairly intense rainfall at this time causes little or no increase in flow. Secondly, during the wet season, flows are maintained at higher levels and there is a very rapid but short-lived response to all rainfall events. Clearly, at the onset of the wet season, most of the rainfall is stored by the catchment and rain falling later is on a (partially) saturated catchment and runs off quickly.

While some general conclusions can be drawn from separate analyses of these data (i.e., flow, rainfall, and potential evaporation [PE]), it is far more revealing to examine them together within the framework of a rainfall-runoff model. The disadvantage of such an approach is that it requires all three data types to be available for the same period. For three of the catchments (Bore, Chinniya, and Bhandare) the period from 3rd March 1992 to 9th October 1993 is fairly complete and has been used to help fit a rainfall-runoff model. This modelling exercise has been carried out using daily data.

The model chosen was based on the probability distributed storage principle in which the soils of a catchment are represented by a continuous set of stores with capacities ranging up to a maximum value S_{max}. Between time steps, water redistributes between stores to maintain a constant volume of water across all stores. The model has been applied successfully to data from the UK in a number of studies.

In applying the model to the catchments it became clear that there were substantial losses from the catchments. On the Chinniya catchment for example, rainfall was 4,970mm compared to the total flow of 1,746mm and potential evaporation of 1,694mm, so that even if the potential evaporation was fully satisfied, 1,530mm (30%) rainfall was "lost" from the catchment. As actual evaporation is less than the potential rate, the true losses will be even greater. While within the Bore and Bhandare catchments this loss could be through irrigation diversions onto flooded terraces, the Chinniya is a natural catchment with no such diversion and the loss is most likely through groundwater leakage. This loss was represented in the model by a drain from the groundwater component of the model. The PE, rainfall, and observed and simulated flow for the Chinniya catchment are shown in fig.1; the simulation successfully reproduces the different patterns of observed flows during the two wet seasons.

The same model can be applied to the other two catchments with the adjustment of only one parameter, the maximum soil depth Smax. The values of Smax are 314mm, 560mm, and 438mm for the Chinniya, Bore, and Bhandare catchments respectively. The lower value for the Chinniya is physically realistic since it is located on thinner soils at higher elevations than the other catchments.

It is interesting to note that simulations on the other two catchments show some underestimation of the flows for a period of some two months at the end of the wet season. A possible explanation for this is that some of the "lost" water is in fact stored on the catchment in the flooded terraces and is only returned slowly to the river channel.

Table 1. Characteristics of the Study Sites

Name (flow sites only)	Type	Altitude (m)	Aspect (facing)	Catchment Ccharacteristics			
				Area (km2)	Land Use Forest	Cultivated	Grass
Baseri	AWS	700	S				
Bhandare	Flow	700	N	1.43	9%	90%	1%
Bore	Flow	700	N	4.23	60%	39%	1%
Chinniya	Flow	1300	N	1.14	83%	17%	0%
Dee	Flow	800	S	2.64	15%	59%	26%
Gerogoan	AWS	800	N				
Jogi	Flow	700	N	2.35	2%	96%	2%

Figure 1.PE (top), rainfall (centre), observed and simulated flows(bottom, solid and dotted lines respectively) for the Chinniya *Khola* for the 575-day period from 3rd March 1992. The abscissa scale is in days, ordinate scales all in mm.