Hydrology of Nakhu Watershed - before and after the 1981 Disaster

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The Nakhu *Khola* watershed was severely affected by debris flows on 30 September 1981. Streamflow data are available from 1963 to 1980. There was no rainfall station before 1994. The study focusses on the assessment of peak floods and an estimation of the missing annual runoff for the period from 1980 to 1994. The extreme rainfall of 1981 is seen to have been a random meteorological event (cloudburst) which occasionally happens in one part of the country or another.

Watershed Characterstics

The Nakhu *Khola* watershed lies in the central mountain region of Nepal. The area is very close to the Kathmandu Valley and is located to the south-west of Phulchowki Hill, the peak of which lies at 2,765m. The eastern and southern borders of the watershed are surrounded by hills of more than 2,000m in altitude (Fig. 1).

The longitudinal profile of the Nakhu *Khola* with its main tributaries is given in Figure 2. The percentage of area (District map 1:125,000) at different altitudes is: six per cent below 1,500m; 31 per cent between 1,500m and 1,750m (hill slopes: 8 - 40%); 44 per cent between 1,750m and 2,000m (hill slopes: 6 - 40%); and 19 per cent above 2,000m (hill slopes: greater than 50%).

The rock types are limestone, sandstone, slate, phyllite, quartzite, etc. The area is geologically categorised as part of the Phulchowki group. The area downstream from Tika Bhairav/Champi consists of alluvial deposits.

The total population in the seven major villages of the watershed over the last 30 years was 19,734 in 1971, 29,707 in 1981, and 31,738 in 1991. The low rate of population growth between 1981 and 1991 is due to outmigration, and also partly to people's awareness of the need for small families. The urbanisation of the Kathmandu Valley has now been slowly spreading to the villages of this watershed.

The land utilisation map prepared in 1984, based on aerial photographs taken in 1978, shows: forests - 37.5 per cent; sloping agricultural terraces - 23.8 per cent; shrub - 23.9 per cent; and agricultural lands as well as alluvium (including river courses and level terraces) - 14.8 per cent (Fig. 3)

The forest is exploited for fuelwood and construction materials. Boulders and gravel from the watershed are also used as construction materials and are mostly taken to the Kathmandu Valley. The stream water is used for irrigation and drinking water supplies.

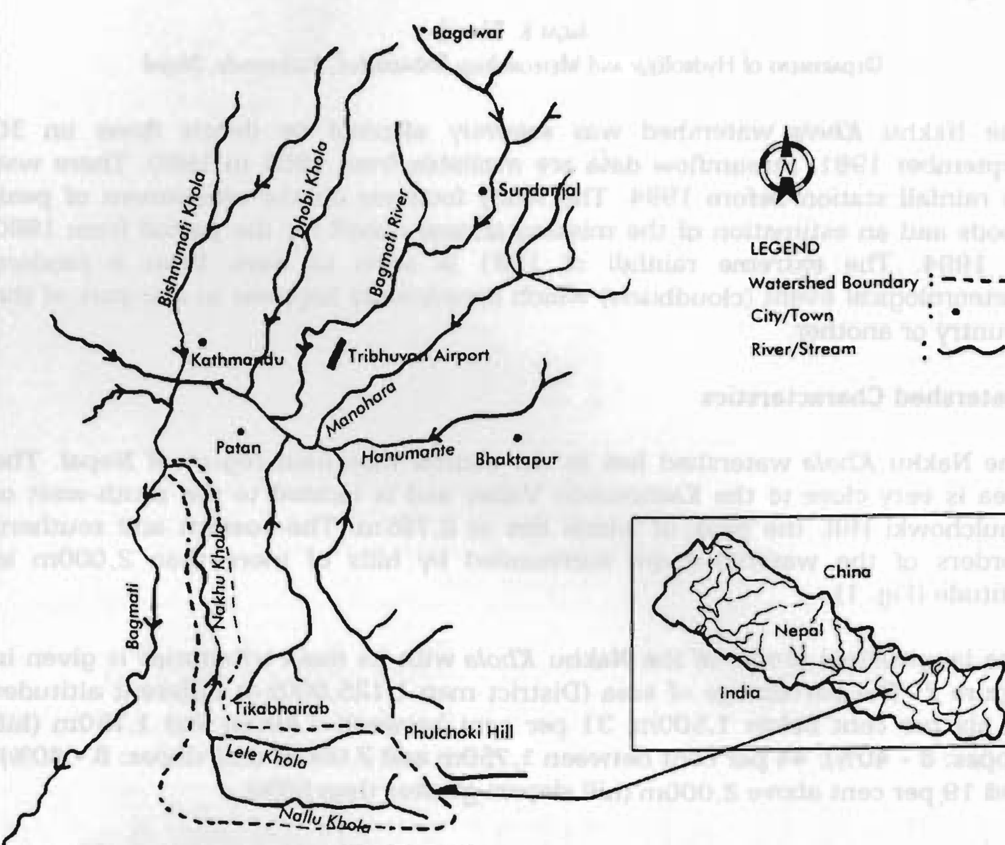

Figure 1: The Location Map of the Watershed

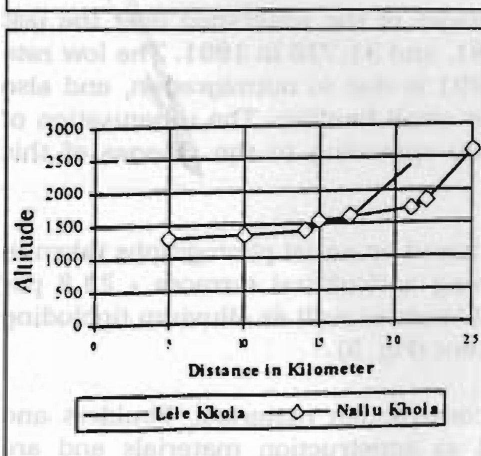

Figure 2: Stream Profile

The area is connected by motorable roads. One road passes through Bhardeo village, the most upstream area of the Nallu watershed, and another road, Bhatte *danda*, in the southern part of the watershed.

The long-term average maximum and minimum temperatures recorded at Godawari (1,400m) are presented in Table 1. The average temperature in the watershed lies around the same level.

Table 1 : Monthly Maximum and Minimum Temperatures (0°C)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max.	17.6	20.5	24.7	28.2	29.5	28.7	27.5	26.6	26.7	25.1	21.3	18.7
Mean Min.	0.4	1.9	4.5	7.3	11.1	14.1	16.8	15.8	14.9	9.4	5.1	2.4
Extreme Max.	20.8	22.2	26.4	29.2	31.6	29.3	28.4	27.8	27.2	26.5	22.5	20
Extreme Min.	-0.7	-0.7	3.5	5.4	9.0	10.6	14.5	12.5	13.0	8.5	4.0	1

Source : Department of Hydrology and Meteorology (DHM)

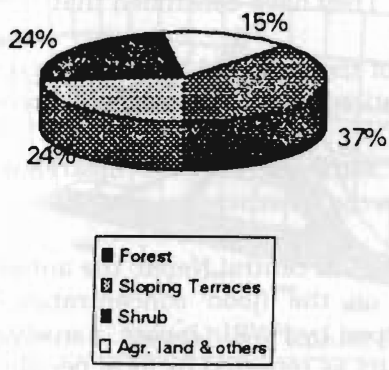

Figure 3: Land Utilisation

Precipitation

There was no rainfall station within the watershed before 1994. Therefore, the rainfall data (1971 - 1994) of two neighbouring places (Godawari and Panauti) are used to compute the basin rainfall. The long-term average of total monthly rainfall is given in Table 2.

Streamflows

The average streamflows from 1963 to 1980 of the Nakhu *Khola* at Tika Bhairav, which are listed in Table 3, were used to determine the rainfall-runoff relationship in the basin.

Table 2: Monthly Mean Rainfall (mm) (1971-1994)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Godawari	17	24	36	57	118	312	523	442	274	67	5	20
Panauti	18	19	29	50	120	246	348	264	221	68	6	13

Source: Department of Hydrology and Meteorology (DHM)

Table 3: Mean Discharges (m^3/s) [1963 - 1980]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.19	0.18	0.17	0.15	0.16	1.01	2.98	3.93	2.57	1.17	0.45	0.27
Maximum	0.70	0.52	0.96	0.46	2.50	45.2	72.8	104	34.4	23.4	1.06	0.67
Minimum	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.37	0.16	0.076	0.076	0.03

Source: Department of Hydrology and Meteorology (DHM)

Frequency Analysis

Gumble's distribution is applied to estimate the volume of discharge and the recurrence interval of annual flood peaks at Tika Bhairav, and the annually highest 24-hour rainfalls at Godawari. The results are given in Table 4. Since the hydrological station at Tika Bhairav was not equipped with an automatic water level recorder, the annual peak floods were computed from observers' records.

Table 4 : Frequency Analysis Results

Return Periods	Floods at Tika Bhairav	24-Hour Rainfall at Godawari
5-Year	84 m^3/s	130 mm
50-Year	173 m^3/s	195 mm
100-Year	200 m^3/s	214 mm

Flood/Debris Flow - 1981

Okamoto et al. (1993) made a preliminary assessment of the 1981 flood/debris flow. The flood peak estimated by a rational approach and from Manning's formula, based on the information provided by the local people, is $600m^3/s$ and $1,150m^3/s$ respectively. The result is based on the flood marks and riverbed condition shown by the local people a decade after the flood event in 1993. They have concluded that:

a) rainfall intensities in the upstream areas of the Lele and Nallu *Khola*(s) were higher than that of the Godawari station, due to localised torrential downpour; and
b) temporary ponding was caused probably somewhere in the upstream area and was breached, causing a flood surge in the downstream area.

From his experience of the flood disaster of 1993 in central Nepal, the author has revised the flood peak, using information on the flood concentration time calculated with the help of the formula developed by PWRI (Japan), namely, 2.65 hours and storm durations of three to four hours as reported by local people.

The average maximum rainfall intensity (four-hour duration) observed during the 1993 storm at Tistung was 47mm/hr [(44+65+50+30)/4], and at Nibuwatar it was 40mm/hr [(36+60+38+26)/4] (Ministry of Water Resources' Committee 1993). In 1981, the maximum 24-hour rainfall observed at Godawari was 169mm. Assuming a continuous rainfall of 40mm over four hours, the flood peak is estimated to be about $400m^3/s$. The runoff coefficient was considered to be 0.85.

Estimation of the Missing Flows

A linear regression analysis on the annual rainfall (mm) and annual discharge (mm) data (1971 - 1980) showed a very low correlation (r^2 = 0.26). A linear regression analysis on the long-term average monthly total discharge (mm) and monthly total rainfall (mm) data showed a higher correlation (Figs. 4, 5, and 6). The linear relationship in Equation 2 listed below showed the highest correlation among all types, including logarithmic and semi-logarithmic relationships. However, it fails to explain the streamflows for two consecutive dry months. The long-term average of the missing streamflows which were estimated by Equation 2 are given in Table 5 and Figure 7.

$$R_I = 0.429^* P_I + 5.95 \quad [r^2 = 0.79] \quad (1)$$

$$R_I = 0.174^* P_I + 0.312^* P_{I-1} \quad [r^2 = 0.97] \quad (2)$$

where,

R_I = Monthly total discharge (mm) for the month I

P_I = Monthly total rainfall (mm) for the month I

P_{I-1} = Monthly total rainfall (mm) for the month I-1

Table 5: Rainfall (observed) and Runoff (estimated) [1971 - 1994]

Monthly total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	18	21	32	55	120	275	438	355	250	69	6	17
Runoff (mm)	13	15	20	29	58	127	196	159	112	34	10	13
Mean monthly discharge (m^3/s)	0.21	0.27	0.32	0.48	0.93	2.11	3.15	2.56	1.86	0.55	0.17	0.21

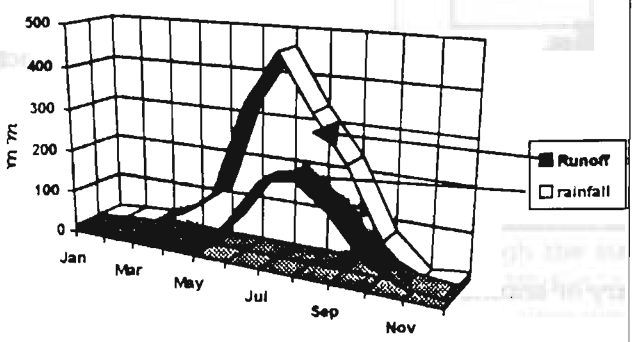

Figure 4: Rainfall and Runoff (1971-1980)

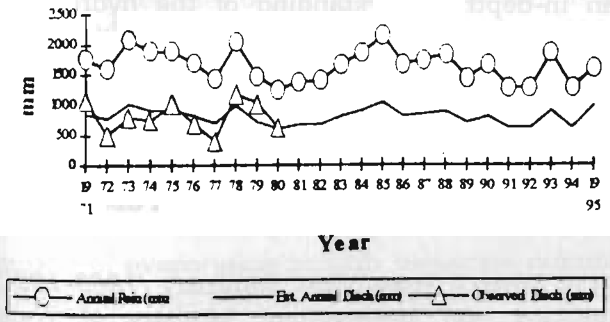

Figure 5: Annual Rainfall and Runoff

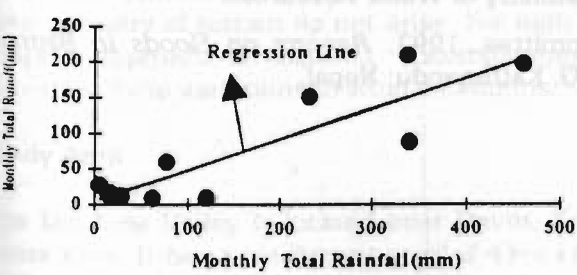

Figure 6: Rainfall and Runoff (1971-1980)

Results and Discussion

The water level and discharge data of the Nakhu *Khola* were found to be missing after 1981. Thus the observed runoff data before and after 1981 could not be compared. Change in the hydrology of the watershed could not be assessed from the estimated annual runoff only (Fig. 5).

The flood marks left by the flood event of 30 September 1981 are seen to be higher than the estimated intensity of the flood, i.e., 400m^3/s would warrant. The reason for the higher flood level on that date is that the riverbed would have been silted up and temporarily raised during the rising period and again lowered during the recession period, as the flood was heavily loaded with debris, sediments, and earth mass. The numerous landslides and gully erosion which occurred on the day of the 1981 flood in the watershed support the above fact.

The 100-year flood is 200m^3/s, which is just a half of the revised estimate of the extreme flood of 1981. All of the annual peak floods used for the frequency analysis were computed from observers' records. The floods which occur during the night are generally missed by observers in stations where automatic water-level recorders are not available. Given such limitations and incomplete data, the frequency analysis may not provide satisfactory results.

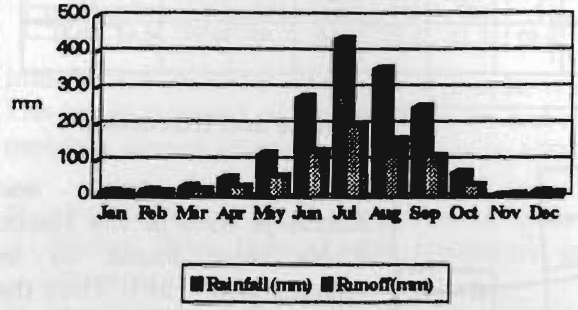

Figure 7: Rainfall and Estimated Runoff

Conclusions

The extreme rainfall on the steep and weak hill slopes of the Lele *Khola* and Nallu *Khola* watersheds produced debris torrents which resulted in loss to human life and property. The extreme rainfall of 1981 is seen to have been a random meteorological event (cloud-burst) which occasionally happens in one part of the country or another.

It is suggested that further studies, such as the water balance of the watershed and the effect of water management activities on annual runoff and sediment transport, be carried out for an in-depth understanding of the hydrological processes in this region.

References:

Okamoto A.; Bhusal, J.K; and Dhakal, A.S., 1993. Review of 1981 Flood/Debris Flow in Nakhu *Khola* Basin in Central Nepal. Kathmandu: (Publisher not given).

DHM,1985. *Hydrological Records of Nepal - Streamflow Summary (1963-1980).* Nepal: Department of Hydrology and Meteorology, Ministry of Water Resources.

DHM, *Climatological Records of Nepal (1971-1994).* Nepal: Department of Hydrology and Meteorology, Ministry of Water Resources.

Ministry of Water Resources Committee, 1993. *Reports on Floods in Bagmati River Basin, July 19 - 21, 1993.* Kathmandu: Nepal.