Relating Hydrological Extremes with Area – A Case on Extreme Floods in South Central Nepal

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ABSTRACT

Flash floods, debris flows and landslide disaster on the steep sloping terraces of hilly region are so challenging that even a real time hydro-meteorological forecasting system would not be applicable for all cases in Nepal. Flash floods are localized in short ranges with respect to time and distance; and it is very difficult to measure these flash floods in time. On the other hand, such phenomena need to be assessed for sustainable design of hydro- structures and for relocating the settlements from risk areas. A study was carried out to find the suitable relationship between area and extreme flood as well as area and extreme rainfall depth. Analysis is mainly based on the case of torrential rains in July 1993 over south central Nepal, which caused floods and debris torrents those were probably the worst in the disaster history of Nepal damaging lives and properties in Nepal during the 20th century. A relation for rainfall depth and other relation for specific flood are presented in this paper.

Keywords: South-central Nepal, specific discharge, rainfall intensity, depth area duration.

1. BACKGROUND

Rainfall intensities of about 40-50 mm h^{-1} are common in the region between 300 m to 3000 m elevation above mean sea level of Nepal. The 24-hour rainfall depths of more than 400 mm are occasional events in the country. Some of the recorded events (DHM, 2000) are 431 mm rainfall at Bajura in the far-western region on August 12, 1980; 446 mm at Beluwa, in the western region on September 29; 1981, 500 mm at Ghumtang in the central region on August 25, 1968 and 473 mm at Anarmani in the eastern region on October 10, 1959. The maximum rainfall intensity of 88 mm h^{-1} was recorded in 1989 at Pokhara in western region. The 24-hour rainfall of 540 mm in 1993 broke all the previous records in Nepal; hourly peaks of the event were 70 mm and 67 mm.

Catastrophic floods have been occurring in Nepal. There was a severe flooding in 1902/03 in Bagmati River in the central region (DPTC, 1993). Floods of 1964, 1981 and 1984 in the Sunkosi River are some events in the eastern region. Doming Xu (1985) had estimated a peak flood of 15,920 m^3s^{-1} near the breached site of moraine dammed glacial lake, and 2316 m^3s^{-1} at about 50 km downstream in Sunkosi. Debris flow disaster in Nakhu Khola on September 30, 1981, and flood in Tinau River in 1981 had washed away several lives and hectares of fertile lands. A 1993-flood peak of 12,000 m^3s^{-1} (MOWR, 1993) was the highest flood assessed in Bagmati River at Nunthar having drainage area of 2720 km^2. Temporary damming at Nunthar resulted in a flood surge of 16,000 m^3s^{-1}. This flood broke the past flood records in the Bagmati River basin.

Hydrological and meteorological data collection at the organizational level had started during the sixties in Nepal. Since then attempts are being made to observe and analyze some of the extreme events. This paper focuses in establishing suitable relationships of peak discharge with catchment area for the south central Nepal.

2. STUDY AREA

Bagmati, East-Rapti and Kamala were the three major river basins severely affected by floods. The areal coverage of the physiographical feature of Bagmati River that had favored severe flooding is only about 1845 km^2. This area (Figure 1) consists of (a) 5% area as active and recent alluvial plains and sandy with cobble texture with slope less than 1 degree, (b) 4% area as river fans, ancient river terraces, and loamy texture with slope of 1 to 5 degree, (c) 11% area as moderately to steeply sloping hilly and mountainous terrain with slope 5 to 20 degree, (d) 45% area as steeply varying hilly and mountainous terrain with slope 20 to 30 degree, and (e) 35% area as steeply varying hilly and mountainous terrain with slopes greater than 30 degree.

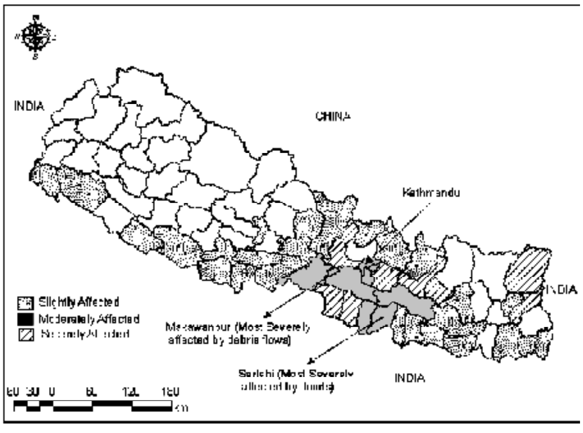

Figure 1: Location of Study Area

3. RAINFALL DATA

In 1993, monsoon entered in the eastern Nepal on June 6, four days earlier than usual, and covered the whole region by June 14. Monsoon trough that normally lies over the northern India shifted to Nepal in July 1993. These phenomena produced a torrential rain during the period from 19 to 21 July 1993. The hourly rainfall intensities (Figure 2 and 3) during that period were 70 mm per hour in Tistung, 67 mm per hour in Simlang, and 64 mm per hour at Nibuwatar in Bhainse. The 24-hour rainfall depth of 540 mm at Tistung and 482 mm at Ghantemadi were recorded in morning hours of 20th July. The 48-hour rainfall depth at Ghantemadi was 600 mm. The time lag between two rainfall peaks at Nibuwatar is 26 hours. The time lag between rainfall peaks at Tistung/Simlang and the second peak at Nubuwatar is 18 hours.

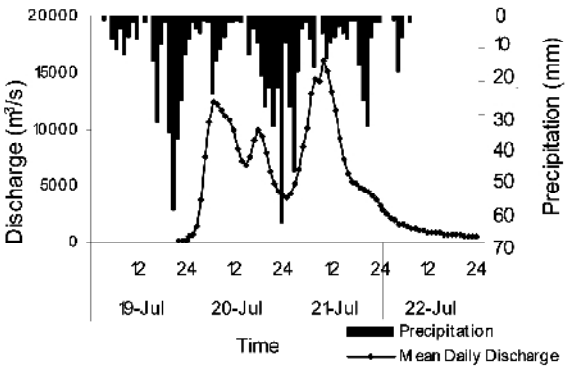

Figure 2: Observed rainfall hyetograph at Nibuwatar and flood hydrograph of Bagmati river at Nunthar

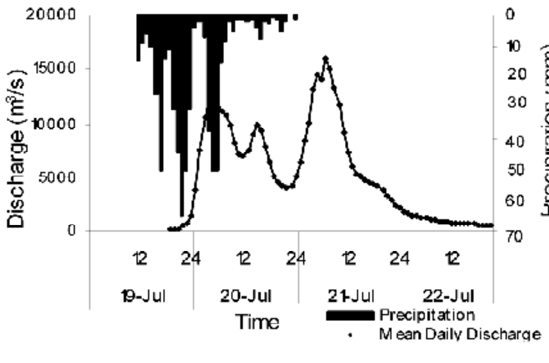

Figure 3: Observed rainfall hyetograph at Tistung and flood hydrograph of Bagmati river at Nunthar

Floods were generated due to continuous and prolonged rains before and during the peak rainfalls. Very gentle slope and wide flood plains of Bagmati

River had contributed in retarding the first flood volume while fulfilling infiltration and other requirements such as depression and bank storages. The light and moderate rains prior to the extreme event favored landslides by saturating the soil. Floods accompanied with eroded and displaced earth mass turned into debris torrents.

Different agencies (ICIMOD, 1993; JICA, 1993; Scoot Wilson Kirpatrick, 1994; SMEC/WB, 1994) got involved in assessing floods of 1993. All discharges were estimated by slope area method with appropriate roughness coefficients. The coefficient values (DHM/DPTC, 1994) varied from 0.033 for Rapti River at Bhandara, 0.06 for Bagmati, 0.07 for Kyankhola, and 0.07 for Agrakhola. The peak floods in Bagmati and in East-Rapti River were found to be 12,000 $m^3 s^{-1}$ and 6800 $m^3 s^{-1}$ respectively. In various cases, temporary damming was caused by landslides and bank erosions in most gullies and in headwaters locations. But there were no reports of floods damming in cases of larger rivers like Koshi, Narayani and Karnali.

4. ANALYSIS AND RESULTS

a) Extreme rainfall: depth area duration Isohyet contours for 24-hour and 48-hour rainfall depths were drawn; and an equation (1) for depth area duration curves of the storm was determined:

$$P = 1.5 P_0 * \exp\left\{\frac{-\ln(A)}{6}\right\} \quad (1)$$

where, A is catchment area (km^2) with P rainfall depth (mm) in 24 or 48 hours duration, and P_0 is the maximum rainfall (mm) of desired duration at the centre of the storm. In the study area, P_0 is 540 mm and 600 mm observed in 1993 in 24-h and 48-h durations respectively.

b) Extreme discharge: specific discharge and area

The results of flood assessments were summarized and correlated with corresponding drainage areas. Equation (2) is a single relationship between specific peaks ($m^3 s^{-1} km^{-2}$) versus catchment areas (km^2) for all ranges (Figure 4) of study areas. The correlation is satisfactory. The correlation coefficient is found to be 0.78

$$q = 25\sqrt{\frac{1}{\sqrt{\left(\frac{A}{\pi}+1\right)}}} \quad (2)$$

Where, q is the specific peak flood ($m^3 s^{-1} km^{-2}$), A is the area (km^2) and π is 3.141

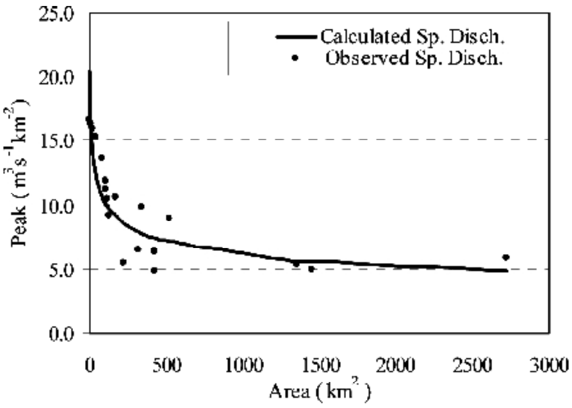

Figure 4: Specific Flood Peaks versus Area (up to 2700 km^2)

Data were then selected and divided into two groups. One relationship for each group is established. Equation (3) and Equation (4) are derived from observed peaks from areas between 90 km^2 to 700 km^2 (Figure 5), and between 90 km^2 to 2700 km^2 (Figure 6) respectively. The value of correlation coefficients in both equations is more than 0.91.

$$q = 650\left[\frac{1}{(A+1)}\right]^{0.87} \quad (3)$$

$$q = 47.5\left[\frac{1}{(A+1)}\right]^{0.285} \quad \textbf{(4)}$$

Where, q is the specific peak flood ($m^3s^{-1}\,km^{-2}$) and A is the area (km^2)

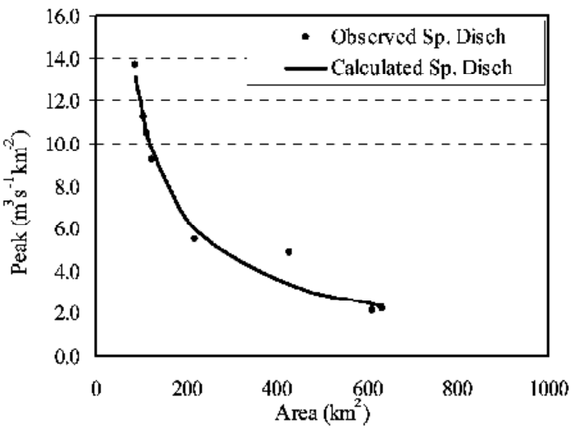

Figure 5: Specific Flood Peaks versus Area (90 to 700 km²)

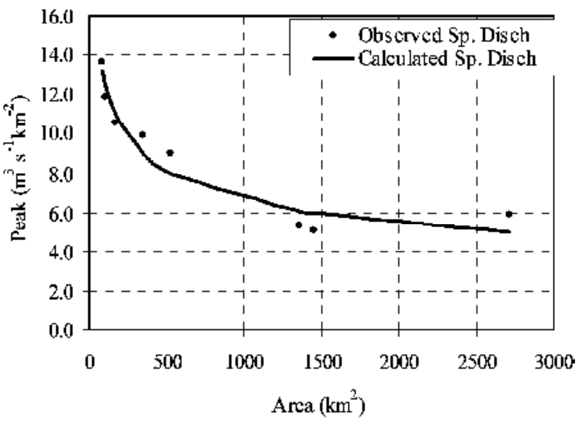

Figure 6: Specific Flood Peaks versus Area (selected data: 90 to 2700 km²)

5. CONCLUSION

The rainfall intensities of around 60 to 80 mm per hour and 400-550 mm in 24 hours are to be expected during unusual storms elsewhere in the country in the lower Mahabharat and in the Siwalik region (areas lying in altitude between 300 meter to 3000 meter) of Nepal.

The physiographic feature of a basin in combination with the rainfall duration and intensity is directly related to the scale of flooding. The specific flows range from 4 to 15 $m^3s^{-1}\,km^{-2}$ in streams having drainage areas of different sizes (100 to 3000 km^2). The streams having smaller drainage areas with less than about 100 km^2 are prone to severe flooding with debris torrents. Specific discharges have been found relatively high for smaller catchments.

Floods occurred in 1993 are of approximately 100 year recurring period. The equation (3) and the equation (4) can be recommended to apply only for areas between 90 to 700 Km^2 and 90 to 2700 km^2 respectively. However the equation (1) and equation (2) are recommended to assess extreme rainfall depths and extreme floods respectively for unguaged catchments in the south central region and similar basins of Nepal.

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