

# Low flows in the Middle Mountain watersheds of the Hindu-Kush Himalayas (HKH)

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## Abstract

*In the middle mountain areas of the Hindu-Kush Himalayan region population growth is rapid. Agricultural intensification is also getting high and more water is needed for increased crop productions. Shortages of water for irrigation followed by drinking were found to be the major issues in the areas of middle mountain region of Hindu-Kush Himalayan region. During the monsoon season there is a lot of rain and water everywhere but most of the remaining time is dry causing scarcity of water. The People and Resource Dynamics Project (PARDYP), a regional research for development watershed management project has been operating in five watersheds across the Hindu-Kush Himalayas (HKH), one in Pakistan-Hilkot watershed, one in India-Bhetagad watershed, two in Nepal-Jhikhu Khola watershed and Yarsha Khola watershed and one in China-Xizhuang watershed. The main aim of this study is to analyse and compare the low flow characteristics for better understanding and use in future water management activities. Different low flow characteristics including rainfall, specific discharge, runoff coefficient, low flow frequencies, base flow index and low flow index were analysed for the five PARDYP watersheds and compared. Hilkot watershed is found to be critical watershed in terms of low flow characteristics amongst the five watersheds. The potential for the water resource in Hilkot watershed is very limited. Bhetagad watershed comes to the second critical watershed after Hilkot watershed. Yarsha Khola and Xizhuang watersheds are found to be good watersheds in terms of water availability compared to the other watersheds. Jhikhu Khola watershed is found to be in the middle, in terms of water resource potential compared to five watersheds.*

**Key words:** Low flow, middle mountains, watershed, HKH

## Introduction

Water remains the major issue in the middle mountain areas of the Hindu-Kush Himalayas (Merz et al., 2003). The demand for water is rising due to increasing population and agricultural intensification. Seasonal variability in rainfall distribution with distinct monsoonal climate causes water scarcity during dry seasons. Shortages of irrigation water followed by drinking water are the major key issues of the study area. Analysis of hydro-meteorological data is important to understand the hydrological regimes for proper management of water resources of the region. This study is focused on the low flow characteristics on a watershed level and conducted under PARDYP project. PARDYP is a regional research for development watershed and natural resources management project implemented in five watersheds of the four countries: China, India, Nepal and Pakistan. The project has generated considerable amount of hydro-meteorological data. Few low flow characteristics were analysed and the results are presented and discussed.

## Study area and methodology

The study area is the five PARDYP watersheds across the Hindu-Kush Himalayas (HKH): Hilkot in Pakistan, Bhetagad in India, Jhikhu Khola and Yarsha Khola in Nepal and Xizhuang in China, Figure 1.

The area of the watersheds ranges from 35-110 km<sup>2</sup> and the elevation ranges from 800-3000 masl. The major land uses are agriculture, forest and grass. All the watersheds have maize and wheat dominated rainfed agriculture and rice dominated irrigated agriculture.



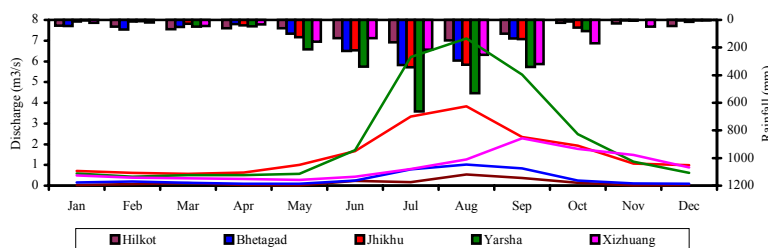
**Figure 1: Location of study sites**

PARDYP project has established monitoring network of hydrological and meteorological stations in its five watersheds. The station network was set up according to nested approach principles in all the five watersheds as described in detail in Hofer (1998). Data is generated at: plot level, sub watershed level, watershed level and regional level. Rainfall and discharge data at the watershed scale has been considered for this study. Manual and automatic or semi automatic instruments were used to record the rainfall and water level data. Discharge measurements were taken at different water levels using current meters, salt dilution technique and tracer depending upon the site. With the water level records the discharge data was determined using the rating curve in HYMOS software. All the collected data were managed and processed in this software. Common methodology is applied in all the watersheds. The available and complete daily time series data was taken for the analysis for the period of three years: 1999-2001 for Bhetagad, Jhikhu Khola and Xizhuang watersheds, 1998-2000 for Yarsha Khola watershed and 2000-2002 for Hilkot watershed. This study is based on the main hydrological stations at the outlet of the watershed and main meteorological stations (watershed representative) of each five watersheds.

## Result and Discussion

### Rainfall and discharge

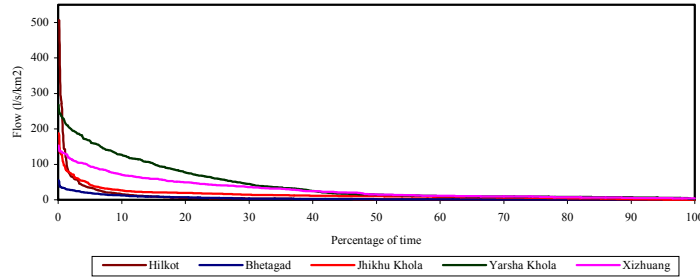
All the five watersheds are influenced by skewed rainfall with the excessive rainfall during monsoon season and very low rainfall during rest of the year, Figure 2. The monthly rainfall amounts are higher in Yarsha Khola watershed. The monthly rainfall and discharge is higher during July and August, except Xizhuang watershed in September. Comparatively, winter rainfall is higher in Hilkot and Bhetagad than in other watersheds. May to October significant rainfall occurs in all the watersheds. Very low amount of rainfall occurs during November to April. The discharge is lowest around April and May in all the watersheds. Yarsha Khola and Xizhuang watersheds towards east receive more and Hilkot watershed towards west receives less annual rainfall comparatively, Table 1. The average annual specific discharge and runoff is highest in Yarsha Khola watershed and lowest in Bhetagad watershed, while runoff coefficient is highest in Xizhuang and Yarsha Khola watersheds and lowest in Bhetagad watershed.



**Figure 2: Rainfall and discharge pattern**

### Flow duration curve

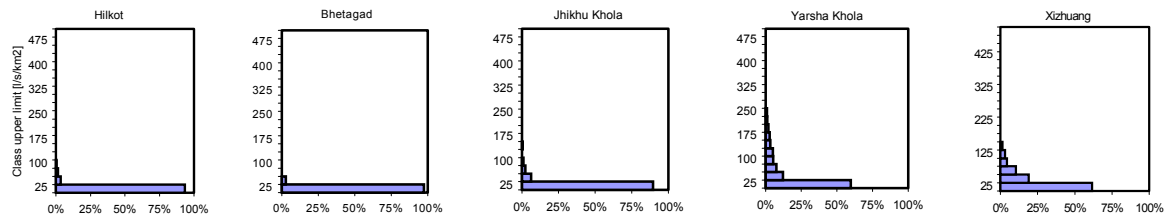
The flow duration curve showed that the flow is comparatively more variable in Hilkot and Jhikhu Khola watersheds, Figure 3. Yarsha Khola, Xizhuang and then Bhetagad watersheds have comparatively stable flow with flat curves. It is obvious that more than 50% of the time is occupied by the low flow situations in all the watersheds.



**Figure 3: Flow duration curve**

### Frequency distributions

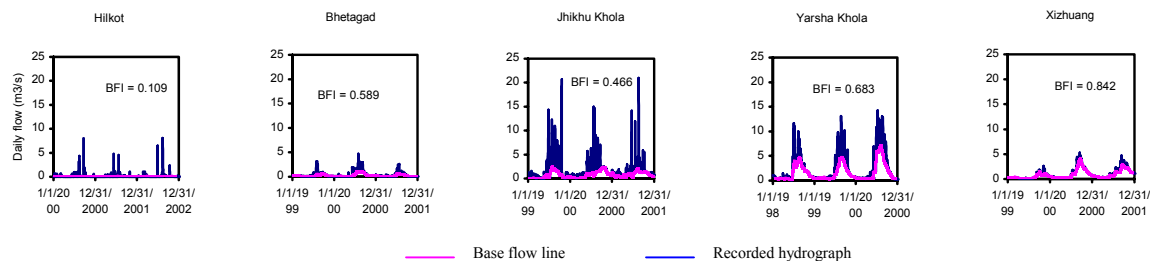
The frequency distribution analysis showed that in Hilkot, Bhetagad and Jhikhu Khola watersheds about 90% of time is occupied by the low flow discharge with class upper limit of 25 l/s/km<sup>2</sup> while in Yarsha Khola and Xizhuang watersheds it is about 60% Figure 4. Comparatively Yarsha Khola and Xizhuang watersheds have relatively better distribution of different class upper limit discharge. This result shows that the low flows are more dominant in Bhetagad, Hilkot and Jhikhu Khola watersheds compared to Yarsha Khola and Xizhuang watersheds.



**Figure 4: Frequency distributions**

### Base flow index (BFI)

Base flow index was analyzed according to the report no 108, Institute of Hydrology, 1992, Figure 5. Xizhuang watershed has highest base flow index of 0.842 and Hilkot watershed has lowest base flow index of 0.109, Table 1. It is difficult to see the base flow line of Hilkot watershed because of the very low discharge comparative to other watersheds. Yarsha Khola watershed has second higher base flow index of 0.683 but it is to be noticed that the magnitudes of the base flow is higher in Yarsha Khola than in Xizhuang watershed. Higher the base flow index higher is the storage capacity of the watershed, which mainly depends on geology and watershed characteristics. Jhikhu Khola watershed has more fluctuations in the hydrograph. Xizhuang and Yarsha Khola watersheds have stable base flows comparatively.



**Figure 5: Base flow index**

### Low flow index (LFI)

The low flow index was calculated as described in the report of Institute of Hydrology, Wallingford, 1980. The low flow index can be computed as a measure of comparison of the base flow. The result of low flow index (LFI) Table 1 showed that the low flow index is higher in Yarsha Khola then in Xizhuang watersheds and lowest in Hilkot watershed. As already mentioned above in the section of base flow index, that the base flow magnitudes are higher in Yarsha Khola watershed than in Xizhuang watershed however the base flow index (BFI) was higher in Xizhuang watershed. Therefore from this analysis it can be proved that the low flow index (LFI) can be a measure of comparison of the base flow as described in the report, which seemed to be true in all the watersheds.

**Table 1: Summary of the analysis**

Watershed	Specific discharge (l/s/km <sup>2</sup> )	Rainfall (mm)	Runoff (mm)	Runoff coeff.	Base Flow Index (BFI)	Low Flow Index (LFI) (m <sup>3</sup> /day/ha)
Hilkot	8.626	911	272	0.3	0.109	0.05
Bhetagad	4.574	1360.7	144.3	0.11	0.589	0.56
Jhikhu Khola	14.358	1231.7	452.8	0.37	0.466	1.53
Yarsha Khola	42.815	2276.6	1350.2	0.59	0.683	5.44
Xizhuang	29.354	1546	925.7	0.6	0.842	4.03

### Conclusion

Based on the overall analysis, it was found that Hilkot watershed, in Pakistan is the most critical one in terms of low flow characteristics and therefore has limited potential for developing water resources, followed by Bhetagad watershed in India. Yarsha Khola and Xizhuang watersheds in Nepal and China respectively are found to be good in terms of water resources potential comparatively. Jhikhu Khola watershed in Nepal is slightly better compared to Hilkot and Bhetagad watersheds.

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