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Flood study of the Himalayan tributaries of the Ganga river

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A flood study of the Himalayan rivers has been attempted on the basis of gauge/discharge data from 27 sites on major tributaries of the Ganga between 1986 and 1999. This study has shown that the Ghaghra, Gandak, and Kosi are the most important tributaries of the Ganga and their flood waters should be harnessed for developmental purposes to save the Indo-Gangetic plains from the recurrence of yearly floods. It was also found that some of the sites on these rivers have recorded floods more than 100 to 150 times during the 14-year period.

1. Introduction

India has a large network of rivers which are spread out over the country. They are a great source of prosperity and energy if properly harnessed. The river Ganga is one of the three great rivers of the sub-continent, the other two being the Brahmaputra and the Indus. The Ganga drains the Indo-Gangetic plains of northern India between the Himalayas in the north and the Vindhya-Satpura mountain ranges in the south. The northern tributaries of the Ganga, which originate in the Himalayas, contribute much more than the southern tributaries. According to Rao (1975) the total catchment area of the Himalayan tributaries of the Ganga is approximately 420,000 km^2 while that of the southern tributaries is 580,000 km^2. Due to heavy precipitation over the Himalayas, especially during monsoon months, the normal annual runoff from the northern tributaries is about 25 times more than what it receives from the southern tributaries. The average annual flow of the Ganga at Farakka (Figure 1) before entering Bangla Desh is 459,040 million m^3 (Rao, 1975).

In this paper a study has been made of the flood characteristics of the Himalayan tributaries of the Ganga based upon the available flood data of the monsoon periods of the 14-year period from 1986 to 1999 using the gauge/discharge data observed at about 27 sites on these tributaries (see Figure 1).

A flood is defined here as and when at a gauge/discharge (G/D) site the flood waters flow above a certain level which is called danger level (D.L.) or warning level. Danger levels at G/D sites are normally fixed by the State Engineers and they indicate the level above which flood waters will start inundating the areas along the river.

2. Himalaya mountain range as a great source of water

The Himalayas stretch from Nanga Parbet (8126 m) in the west to Namche Burva (7756 m) in the east in the form of an arc with convexity towards the south. This great mountain chain, whose length is about 2400 km from west to east and which has a north to south width varying between 250 and 300 km, has not only witnessed the evolution and progress of the Indian civilization from time immemorial but also has provided enough water through its tributaries to feed the millions living in the Indo-Gangetic plains to the south of this great mountain barrier.

The Himalayas start in the west at 35°N and extends south-eastwards to 27°N. In other words, its central and eastern sections come nearer to the equator by about 760 km and hence are warmer than its western sector. As a result, there is a greater accumulation of snow and glaciers in the western section than in its central or eastern sections. The total number of glaciers in the Himalayas has been estimated by Vohra (1981) to be about 15000 and total ice volume was found to be 14000 km^3. Upadhyay *et al.* (1989) have estimated that the glaciated area in the three main river systems of the Indian sub-continent as follows:

- 14,050 km^2 in the Indus basin in the Western Himalayas.
- 5,957 km^2 in the Ganga basin in the Central Himalayas.
- 3,083 km^2 in the Brahmaputra basin in the Eastern Himalayas.

It is clear that the Indus basin has the largest glaciated area in the Himalayas. From the available studies made in the Western Himalayas it is found that the discharge of about 0.084 to 0.112 m^3 sec^{-1} (3 to 4 cusecs) is generated from each square metre of glaciated area.

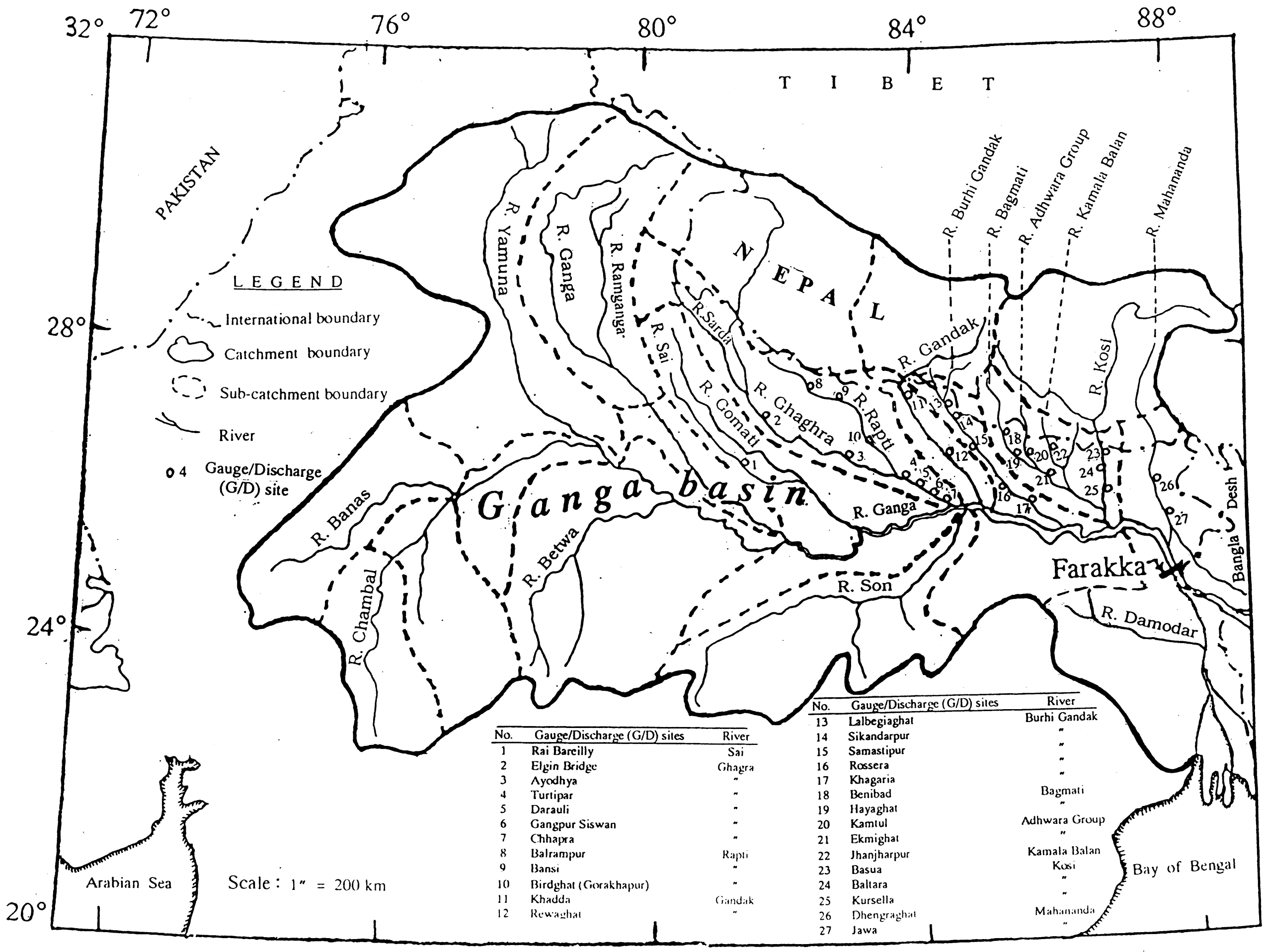

Figure 1. *Ganga river basin showing its major Himalayan tributaries and gauge/discharge (G/D) sites.*

The Himalayas have been referred to as the abode of snow and ice which has accumulated through millions of years on its lofty peaks and high ranges. This is partly due to the eastward track of western disturbances and also because of heavy precipitation caused by summer or the south-west monsoon when the entire Himalayan region receives copious amounts of rain and snow from the highly moisture-laden winds from the neighbouring seas. These winds are blocked by this mountain barrier of 6 to 8 km in height and most of the moisture is shed over the Himalayan ranges. As a result, the Tibetan plateau to the north of the Himalayas is semi-arid.

3. Ganga river and its major Himalayan tributaries

The main Ganga river, whose source is in the Garhwal Himalayas, debouches into the Indian plains at Hardwar in north-west Uttar Pradesh. Besides the main Ganga river, there are more than half a dozen major and medium-size rivers with their numerous tributaries which have their origin in the snow and glacier fields of the Himalayas. A few tributaries of these rivers have their sources in the glaciers of the trans-Himalayan region located in southern Tibet. These south-flowing Himalayan tributaries of the Ganga, after cutting deep gorges in the great Himalayan ranges of Garhwal-Kumaon and Nepal Himalayas, join the main Ganga river at different locations in the north Gangetic plain. The important Himalayan rivers of the Ganga are (a) Yamuna, (b) Ramganga, (c) Gomati with its sub-tributary the Sai, (d) Ghaghra along with sub-tributaries of the Sarda (or the Kali) and the Rapti, (e) Gandak, (f) Burhi Gandak, (g) Kosi along with its sub-tributaries of the Bagmati, the Adhwara Group, the Kamla Balan and (h) Mahananda (see Figure 1).

Although the Yamuna rises in the Punjab-Garhwal Himalayas and is the westernmost tributary of the Ganga, it flows to its south and joins the Ganga at Allahabad. As most of its tributaries flow into the Yamuna, to a large extent their flow originates from the western and central Indian region. Therefore, in this paper the Yamuna has not been considered as a northern tributary of the Ganga.

Brief information about the major Himalayan rivers of the Ganga and their tributaries – sources, catchment areas, average annual flow, etc. – is given in Table 1. From this table it is apparent that the Kosi, Ghaghra and Gandak are the principal tributaries of the Ganga and that these three tributaries mostly drain the Nepal Himalayas and its neighbourhood from the north (see Figure 1). Annual maximum discharge of some of the important Himalayan tributaries of Ganga is given in Table 2 by way of information (Sinha & Jain, 1998).

4. Meteorological situations causing heavy precipitation in the Himalayan rivers

The Himalayan mountains receive the bulk of their precipitation during two main seasons: winter (November to March) and the summer (south-west monsoon period, June to September – or occasionally to mid-October). Most of the winter precipitation is associated with the extra-tropical 'western disturbances' whose frequency per month during the winter varies from 3 to 5 on average. These western disturbances are mid-latitude extra-tropical low pressure systems whose origin is somewhere around the Caspian Sea, and these disturbances travel from west to east along the Himalayan latitudes after moving through Iran, Afghanistan and Pakistan during November through March. As these disturbances travel inland they encounter the Western Himalayas and the neighbouring plains where they contribute the bulk of the winter precipitation in the form of snow and rain.

Most of the precipitation that the Himalayas receive (especially its central and eastern sections) occurs in the summer monsoon months of June to September. During these months monsoon disturbances traverse the Indian sub-continent from east to west in the form of low pressure areas, depressions or cyclonic storms. They cause the bulk of precipitation over the Himalayas especially when they are moving in a north-westerly direction and then recurve towards the north or north-east after traversing the plains of West Bengal, Orissa, Bihar and their surrounding areas.

During the monsoon months, especially in July and August when the axis of the monsoon trough shifts from its normal position over the Indo-Gangetic plains to the foothills of the Himalayas, the 'Break' monsoon usually occurs. At this time the Himalayan region gets heavy to very heavy rainfall while the Indo-Gangetic plains to the south of the Himalayas experience negligible amounts. Also if an active western disturbances also happens to move from west to east along the Himalayan latitudes, the synchronisation of the two systems (tropical as well as extra tropical) can cause heavy rainfall (Dhar *et al.*, 1982) and most of the Central and Eastern Himalayan tributaries are in high flood. This particular weather situation during the monsoon season occurs almost every year. In August 1954 widespread and devastating floods were caused by the Kosi in north Bihar by a weather situation similar to the one mentioned above (Dhar & Narayan, 1966).

Table 1. *Information about major Himalayan tributaries joining the Ganga river.*

Name of river	Name of major tributaries	Source	Total length (km)	Catchment area (km^2)	Point of confluence with the	Ganga Mean annual flow (million m^3)
Ramganga	–	Lower Kumaon Himalayas at an altitude of 3110 m near about Nainital (Dist. Garhwal).	596	32,493 (India)	At Kanuj (Uttar Pradesh)	15,258
Gomti	Sai	3 km east of Pilibhit (Uttar Pradesh) at an elevation of 200 m.	940	30,437 (India)	Near Tarighat (Uttar Pradesh)	7,390
Ghaghra	Sharda, Rapti	Trans-Himalayan Tibet near Lake Mansarovar and flows through Western Nepal.	1080	1,27,500 (Total) 57,578 (India)	Near Chapra (Bihar)	94,400
Gandak	–	At an elevation of 7620 m in Tibet (trans-Himalayan origin).	425	46,300 (Total) 7,620 (India)	Near Patna (Bihar)	52,200
Burhi Gandak	–	In Champaran district of Bihar at an elevation of 300 m.	320	10,150 (India)	Opposite Monghyr town (Bihar)	NA
Kosi	Bagmati, Adhwara Group, Kamla Balan	Formed by the confluence of three main rivers of east Nepal: Sun Kosi, Arun Kosi and Tamur Kosi. Rise in Tibet (trans-Himalayan origin) .	NA	74,500 (Total) 11,000 (India)	Near Kursella (Bihar)	61,560
Mahananda	–	In the hills of Darjeeling district at an elevation of 2100 m.	NA	20,600 (Total) 11,530 (India)	At Godagiri (Bangla Desh)	NA

Table 2. *Annual maximum discharge of some of the tributaries of Ganga (data for the river Ghagra is not available).*

River	Maximum discharge ($m^3\ sec^{-1}$)	Year
Gandak at Triveni	12423	1975
Gandak at Dumariaghat	13745	1981
Burhi Gandak at Champatia	2810	1986
Burhi Gandak at Sikandarpur	3787	1975
Burhi Gandak at Rossera	2234	1975
Bagmati at Dhang	3033	1975
Bagmati at Hayaghat	2617	1975
Kamla Balan at Jaynagar	2012	1975
Kamla Balan at Jhanjharpur	1503	1985
Kosi at Birpur	14833	1987
Kosi at Baltara	10682	1988

It is clear that the weather situations mentioned above cause heavy precipitation over the Himalayas resulting in severe floods in the Himalayan rivers. Unlike the peninsular rivers of India, the Himalayan rivers are perennial as they are also fed by the glacier and snow melt all through the year, whereas the rivers of central India and the Indian peninsula depend upon the monsoon precipitation and therefore are not perennial in nature.

5. Highest recorded floods and flood frequency of the Himalayan tributaries of the Ganga

Dhar & Nandargi (1998) prepared a catalogue of severe floods of the Indian rivers using available flood stage data up to 1997. In the present study, data for 14 years from 1986 to 1999 have been used. A list of highest floods that have occurred in the Himalayan tributaries of the Ganga (outside the Yamuna) is given in Table 3. This table is based upon the data reported in the Central Water Commission's Flood News Letters (CWC, 1986–1999). A close scrutiny of the data shows that the highest floods in the Himalayan rivers at different gauge/discharge (G/D) sites occurred mostly in August. In a few cases highest floods also occurred in July (i.e. in the rivers of Kosi and Bagmati).

The number of occurrence of floods in the Himalayan tributaries of the Ganga is given in Table 3 for the period 1986 to 1999. It shows that there are ten Himalayan rivers which contribute their flow into the main Ganga river.

On examining Table 3, it is clear that the number of floods at G/D sites in the Himalayan rivers is much less in the Uttar Pradesh region in comparison with the Bihar region. Among the Himalayan rivers which flow through the Uttar Pradesh region, only the Ghaghra at its three G/D sites (Elgin Bridge, Ayodhya and Turtipar) experienced 50 to 80 floods whereas almost all the Himalayan rivers flowing through the Bihar region experienced more than 50 floods during the last 14-year period. The highest number of floods were recorded at Baltara G/D site on the Kosi and at the Jhanjharpur site on the Kamla Balan which were of the order of 150 and 104 respectively.

It is also evident from Table 3 that all these G/D sites recorded flood deviations of 2.5 to 3.0 m above their respective danger levels (D.L.s). The Jawa site on the Mahananda recorded the highest flood deviation of about 4.45 m in August 1996. Next to it are Samastipur and Rossera sites on the Burhi Gangak and Hayaghat site on the Bagmati which recorded a flood deviation of more than 3 m.

In Table 4 a list of ten G/D sites on seven Himalayan rivers is presented. It indicates the highest flood deviations at these sites in the period 1950–85. A comparison of the highest flood deviations recorded at each G/D site during the 14-year period with earlier record shows that there are 10 G/D (out of 27) sites whose flood records of highest deviations have not yet been surpassed (see Table 4).

It was also observed that the Ghaghra at Turtipar, Kamla Balan at Jhanharpur and Kosi at Baltara experienced floods during every monsoon season of the 14-year period, and Baltara site (Kosi river) experienced the highest number of floods of all the 27 sites. In 1999, this site recorded 19 floods during the four monsoon months of June to September (i.e. an average of 4 floods occurred in each monsoon month at this site).

The Baltara G/D site on the Kosi river has experienced 150 floods and it appears to be the most flood-affected site as far as the Himalayan rivers of the Ganga are concerned (see Table 3). Even considering the major floods (i.e. >1 m above their respective D.L.), the Baltara site has experienced the highest number of major floods (67) compared with other sites during the 14-year period. In this connection it may be mentioned that at an old G/D site on the Kosi in Nepal Terai at Barakkshetra, the flood deviation from D.L. was 7.14 m on 24 August 1954 which corresponded with a peak discharge of $2.4\times10^6\ m^3\ s^{-1}$ (8.55×10^5 cusecs) (Dhar & Narayan, 1966). In another devastating flood in the Kosi, the deviation was 11.29 m above the D.L. at Barakkshetra site on 5 October 1968 (Rao, 1975).

Besides heavy rain and snow, floods in the Himalayas are also caused by man-made activities such as deforestation on hill slopes, shifting cultivation and overgrazing by domestic animals. These factors cause quick runoff from the steep hilly slopes, and flash floods are often caused by the sudden descent of landslides into downstream reaches. Such floods occurred in the Alaknanda in 1970, in Bhagirathi in 1978 and in Bagmati in 1983. In August 1998 a flash flood in the Kali (Sarda) river, caused 200 pilgrims on their way to

Table 3. *Highest recorded floods in the major Himalayan tributaries joining the Ganga river from the north at different gauge/discharge sites (1986–1999) (Data source: CWC, 1986–1999).*

River	Gauge site	State	Danger Level (m)	Highest flood level (m)	Date of occurrence	Deviation from D.L. (m)	Total frequency of floods (major floods ≥ 1 m)
Sai	Rai Bareilly	Uttar Pradesh	101.00	102.07	20–21.08.88	1.07	3 (1)
Ghaghra	Elgin Bridge	”	106.07	106.77	19.08.88	0.70	56 (-)
	Ayodhya	”	92.73	93.64	21.08.88	0.91	58 (-)
	Turtipar	”	64.01	65.95	29.08.98	1.94	80 (7)
	Darauli	”	60.82	61.82	18.08.98	1.00	17 (1)
	Gangpur Siswan	”	57.04	57.97	20.09.93	0.93	26 (-)
	Chhapra	”	53.68	54.75	11.08.88	1.07	5 (1)
Rapti	Balrampur	”	104.62	105.07	16.07.89	0.45	5 (-)
	Bansi	”	84.90	85.73	21.08.98	0.83	15 (-)
	Birdghat (Gorakhapur)	”	74.98	77.38	24.08.98	2.40	32 (13)
Gandak	Khadda	”	96.00	96.85	14.08.96	0.85	41 (-)
	Rewaghat	”	54.41	55.34	18.09.86	0.93	6 (-)
Burhi Gandak	Lalbegiaghat	Bihar	63.20	64.74	14.08.87	1.54	15 (6)
	Sikandarpur	”	52.53	54.29	15.08.87	1.76	23 (4)
	Samastipur	”	46.02	49.38	16.08.87	3.36	45 (22)
	Rossera	”	42.63	46.35	16.08.87	3.72	54 (26)
	Khagaria	”	36.58	38.45	18.09.87	1.87	56 (20)
Bagmati	Benibad	”	48.68	49.72	06.07.99	1.04	90 (2)
	Hayaghat	”	45.72	48.96	14.08.87	3.24	47 (18)
Adhwara	Kamtul	”	50.00	51.38	18–24.7.96	1.38	63 (6)
Group	Ekmighat	”	46.94	49.27	14.08.87	2.33	52 (14)
Kamala Balan	Jhanjharpur	Bihar	50.00	52.67	12.08.87	2.67	104 (34)
Kosi	Basua	”	47.75	48.94	28.07.98	1.19	69 (1)
	Baltara	”	33.85	36.66	20.07.98	2.81	150 (67)
	Kursella	”	30.00	32.04	06.09.98	2.04	80 (28)
Mahananda	Dhengraghat	”	35.65	36.85	11.09.91	1.20	56 (6)
	Jawa	”	31.40	35.85	15–21.8.96	4.45	52 (10)

Table 4. *List of highest ever recorded flood deviations at some gauge/discharge (G/D) sites on the Himalayan tributaries joining the Ganga river (Data source: CWC, 1950–85).*

River	Gauge site	State	Danger Level (m)	Highest flood level (m)	Date of occurrence	Difference in flood level (m)
Ghaghra	Elgin Bridge	Uttar Pradesh	106.07	107.88	1950	1.81
	Gangpur Siswan	”	57.04	59.21	17.08.80	2.17
Rapti	Balrampur	”	104.62	105.90	23.08.69	1.28
	Bansi	”	85.00	87.44	1965	2.44
Gandak	Rewaghat	”	54.41	57.38	01.08.77	2.97
Burhi Gandak	Lalbegiaghat,	Bihar	62.19	66.00	02.08.75	3.81
	Khagaria	”	36.58	39.66	19.08.78	3.08
Adhwara Group	Kamtul	”	50.00	52.38	1975	2.38
Kosi	Kursella	”	30.00	32.55	10.07.80	2.55
Mahananda	Dhengraghat	”	35.65	38.09	1965	2.44

Tibet to be washed away. The Himalayas are certainly no longer the green wall they used to be.

6. Summary and conclusions

From the foregoing it is seen that among all the Himalayan rivers joining the Ganga from the north, the major contributions come from the Kosi, Ghaghra and Gandak and their tributaries joining the Ganga along its course through the Gangetic plains. This bulk of water, and its load of heavy silt, causes flooding in the main Ganga during the monsoon months in the states of East Uttar Pradesh, Bihar and West Bengal. The historical flood records show that there are ten G/D sites out of 27 whose flood records of highest deviation have not been surpassed so far.

To utilise the enormous volume of flood water from the Himalayan rivers, it is suggested that multi-purpose water resources projects should be undertaken to conserve the flood waters and use them for agriculture, industry and hydro-power generation during the lean dry months. This can be achieved only by building multi-purpose dams across these rivers within the Himalayas or at suitable sites where they debouch into the plains. In this respect the full co-operation and participation of the Nepal government with the neighbouring Indian states is considered to be essential.

Since all these Himalayan rivers are perennial in nature due to their source being in glaciers and ice caps, they can be utilised for power generation wherever the necessary drop in water level is available. In the Himalayas a good number of such sites are available especially in the Karnali river in Nepal. The progress and prosperity of this country is closely linked to the harnessing of the waters of the main Himalayan rivers, the Kosi, Ghaghra and Gandak.

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