Journal of Nepal Geological Society
Vol. 6, 1989, 11 to 20

MORMPHOMETRIC ANALYSIS OF THE BAGMATI RIVER IN KATHMANDU VALLEY

S.R. BAJRACHARYA*, V.K. VERMA**

ABSTRACT

The oval shaped Kathmandu valley stretches 30 km E-W and 25 km in N-S direction encompasing an area of about 647 sq. km. The valley is drained by 10 different tributaries of the Bagmati river forming a typical Centripetal drainage system. The drainages consisting of Dhobi khola from Shivapuri Range, Bishnumati khola from Shivapuri and Nagarjung ranges, Hanumante and Manohara kholas from Nagarkot range, Nakhu, Kodku and Godawari Kholas from Phulchowki range and Balkhu and Bosan kholas from Chandragiri range, have originated from different directions.

Bagmati, Dhobi, Balkhu and Bosam kholas form the 4th order network whereas the remaining drainages form the 5th order network and the Kathmandu Valley as a whole is taken into the 6th order network.

INTRODUCTION

The near circular amphitheatre - like Kathmandu Valley, stretching about 30 km in E-W and 25 km in N-S directions encompasses an area of about 647 sq. km. with an altitude ranging from 2000 m to 2800 m above mean sea level. The valley falls in Lat between 27 32' 34" to 27 49' 11" north and in Longitude between 85° 11' 10" E to 85° 31' 10" E. The valley is floored with fluvial and lacustrine sediments at an average altitude of 1350 m with slopes inwards to the centre.

The valley is surrounded by spurs of the Lesser Himalaya and Mahabharat Ranges. It is demarcated by Shivapuri Lekh (2732 m) on the north Nagarkot (2166 m) on the east, Phulchowki (2765 m) on the south, and Dhilachowk (Chandragiri 2550 m) on the west. There is only one exit on the south at Chovar through which the Bagmati River drains the amphitheatre. The trunk river Bagmati along with its tributary Dhobi khola originates from Shivapuri Range near the watershed boundary, and Bishnumati River from Shivapuri - Nagarjun Range, Hanumante and Monohara Rivers from Nagarkot Range. Nakhu khola and Godawari khola from Phulchowki Range, and Balkhu and Bosan Kholas from Chandragiri Range.

The ten different tributaries constitute ten different sub-basins with 1767 large and small channel segments. Next 152 segments flow directly to the trunk channel making a total of 1919 channel segments in the Kathmandu Valley.

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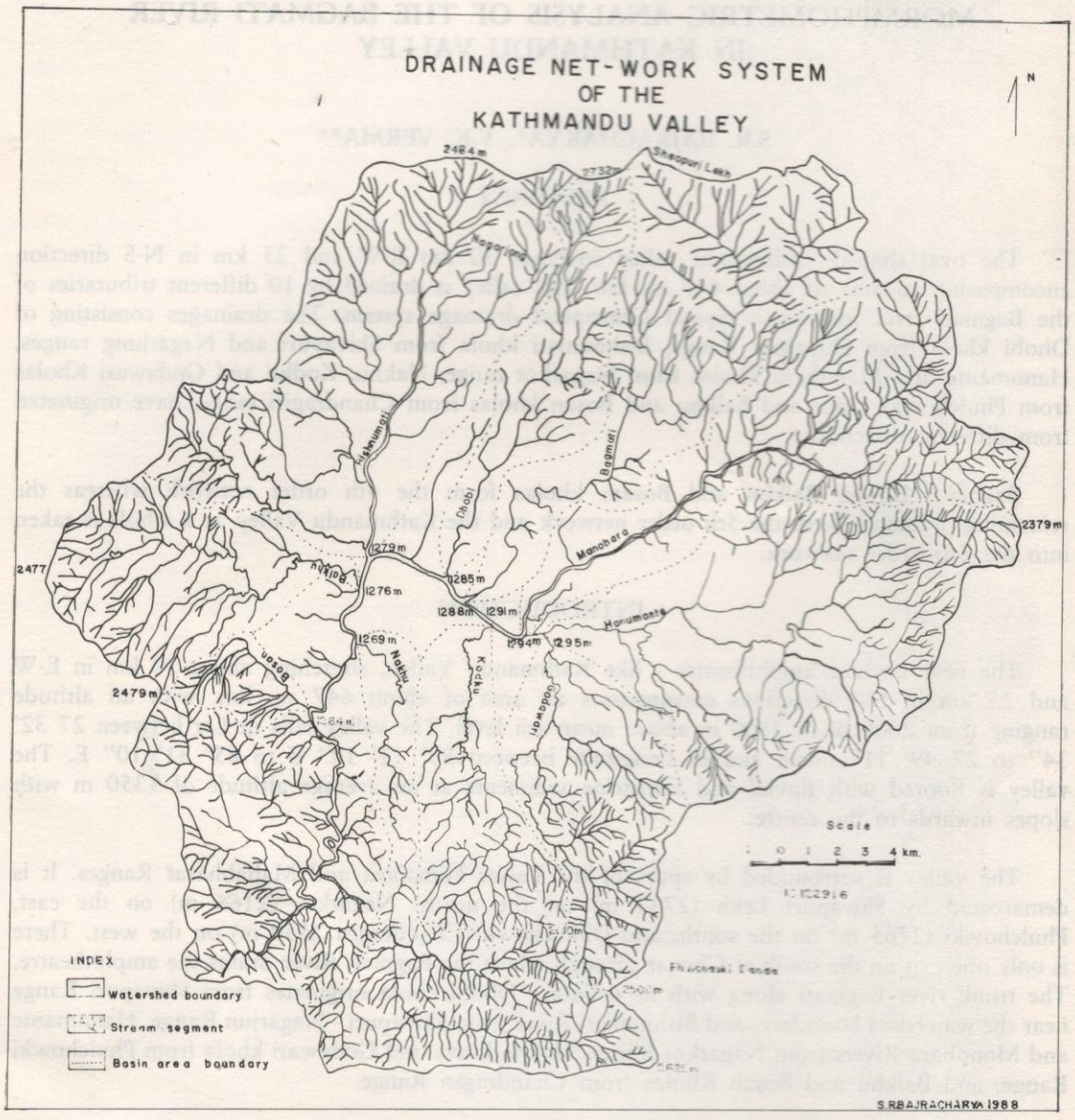
DRAINAGE NET-WORK SYSTEM
OF THE
KATHMANDU VALLEY
N
2484 m
2732m
Shesppuri Lake
Bagmati
Dhobi
Manohara
2379m
2477
1279m
1276m
1285m
1288m
1291m
1294m
1295m
Hanumante
1269m
Nakhu
Kodku
Godawari
Bagmati
2479m
Scale
0 1 2 3 4 km.
1:102916
INDEX
Watershed boundary
Stream segment
Basin area boundary
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The longest channel segment is of Hanumante River with the total length of 208.189 km and the shortest channel segment is of Bosan khola with only 33.65 km length. The total length of the channel segments of all the kholas in the Kathmandu Valley is 1472.719 km.

METHOD OF INVESTIGATION

The base map used for the morphometric analysis was in the scale of 1:50,000, which was prepared from the 1 inch equal to 1 mile scale topographic map of Survey of India. The map was enlarged by the H.M.G., Survey Department, Topographical Survey Branch, Kathmandu. The stream orders that were designated are based on the law of Horton (1945) as modified by Strahler (1956).

MORPHOMETRIC PARAMETERS

Kathmandu Valley consists of 10 main sub-basins formed by 10 different tributaries of Bagmati River. These sub-basins have been further sub-divided into 79 third order sub-basins. Out of these 75 third order sub-basins have been formed by 10 different tributaries and the remaining 4 sub-basins are formed by 4 different kholas which directly join the trunk river.

The morphometric parameters investigated for each sub-basins include the linear, aerial and relief aspects. Among the linear aspects, the relationship of various stream orders (Horton 1945, modified by Strahler 1956) with the number of channels and stream lengths have been investigated. The smallest finger tip tributaries are designated as **first order.** When two first order channels join, a channel segment of **second order** is formed. In the same way when two second order segments join, a **third order** segment is developed, and so on. The trunk stream through which all discharge of water and sediments pass is therefore, the stream segment of highest order.

The ratio of number of segments of a given order Nu to the number of segments of the higher order Nu +1 gives the **bifurcation ratio** Rb. **Weighted-mean bifurcation ratio** (Strahler, 1953) is obtained by multiplying the bifurcation ratio for each successive pair of orders by the total number of streams involved in the ratio and by taking the mean of the sum of these values. This is more useful than the bifurcation ratio of chance variation birfurcation ratio between successive pairs of orders which differs within the same basin and therefore, the weighted-mean bifurcation ratio gives more representative value.

This **mean channel length** of the segments is the cummulative lengths of all the channel segments of an order divided by the number of segments of that order.

An important indicator of the linear scale of landform elements in stream-eroded topography is the drainage density, introduced by Horton (1945). **Drainage density** is simply the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area as projected on the horizontal plane. He also introduced **Stream Frequency** (F) as the number of the stream segments per unit area.

Amongest the relief aspects the **channel gradient** and **maximum basin relief** (elevation difference of heighest and lowest points of a basin) ratio have been calculated. The **relief ratio** is defined as the ratio between the total relief of a basin (maximum basin relief) and the longest dimension of the basin parallel to the principal drainage line.

Figure 2 BIFURCATION RATIO OF SUB BASINS VS STREAM ORDER

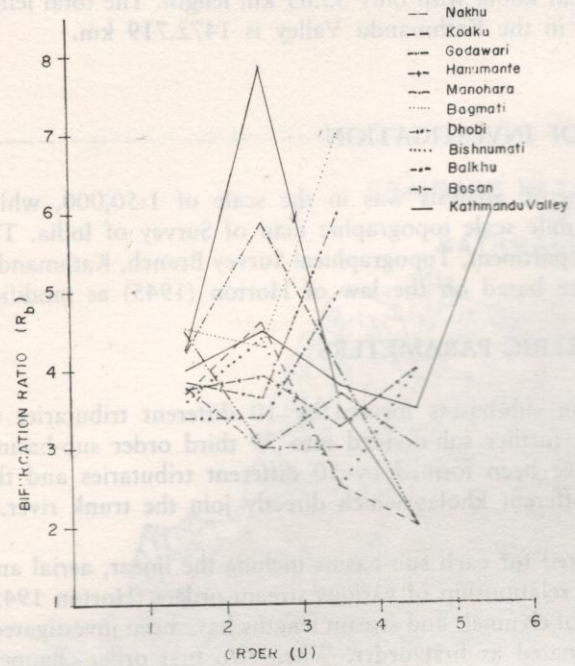


Figure 4. NUMBER AND ORDER OF STREAMS

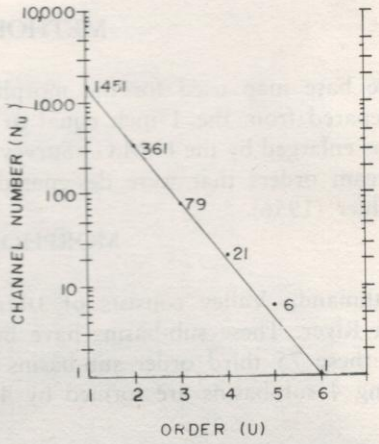
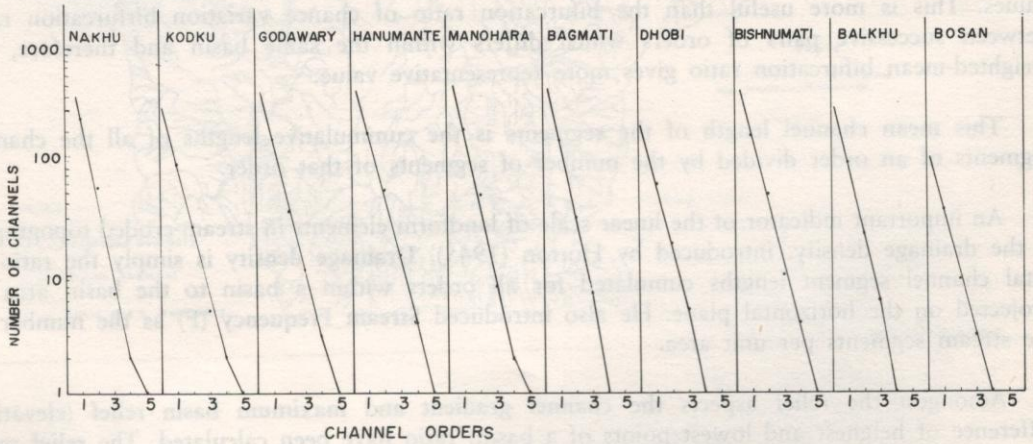


Figure 3. RELATION BETWEEN NUMBER OF CHANNELS AND CHANNEL ORDERS

(KATHMANDU VALLEY)



DRAINAGE

The drainage network of the Valley constitutes a centripetal drainage system. Among the numerous tributaries 10 different tributaries are considered for the sub-basins of Kathmandu Valley. They are Nakhu, Kodku, Godawari, Manohara, Hanumante, Bagmati, Dhobi, Bishnumati, Kalkhu and Bosan sub-basins. Among these Bagmati, Dhobi, Balkhu and Bosan form the 4th order network, whereas the remaining tributaries form the 5th order sub-basins. So the Bagmati river itself belongs to the 6th order sub-basin.

The morphometric parameters determined for the above sub-basins are given in the table 2. The bifurcation ratio of 3rd order basin of Nakhu khola has very high value and is moderate in Manohara khola (fig. 2) whereas in 4th order basins of Bagmati, Balkhu and Dhobi kholas in decreasing order show the higher bifurcation ratios. The 6th order trunk river (Bagmati river) also shows high value. The high birfurcation ratio is attributed to the immature nature of the sub-basin. The weighted mean birfurcation ratio of the 4th and 5th order basins ranging between 3.502 and 4.858, do not show any remarkable difference. The highest value is for Nakhu khola basin and the lowest of Dhobi khola basin. The length of 4th order basin of Bosan khola is 4.75 km which is the shortest one whereas the longest basin length is 19.2 km which belongs to Bagmati river. The sudden termination of Bagmati basin is less than the length of the 4th order stream channel. The drainage densities range from 2.02 to 3.808. In general the variation of densities depends on the differences in lithology. Hard rocks ten to give lower values of drainage density as compared to softer rocks.

ANALYSIS OF DRAINAGE CHANNELS

The numbers of streams of each order are plotted on a logarithmic scale on the ordinate against the order numbers on an arithmetic scale on the abscissa.

The graphs of the channel order versus number of channels of various sub-basins are shown in fig. 3. Out of the ten sub-basins, seven sub-basins like Godawari, Hanumante, Bagmati, Dhobi, Bishnumati, Balkhu and Bosan show linear relationship for all the orders in confirmity with the terms of Horton's First Law (1945), the Law of Stream Number. Next, three sub-basins like Nakhu, Kodku and Manohara show a linear relationship only for the smaller order streams, the higher order streams slightly deviated forming a concavity upwards at the lower end, which tend to equlibrium with Horton's First Law. But total number of channel versus channel order (fig. 4) shows a slightly concavity downward at the lower end.

The graphs of average length against channel order (fig. 5) do not show the linear relationship well. But in some cases they are even randomly distributed. As per the Second Law of Horton, the Law of Stream Length regarding the composition of stream order are not followed satisfactorily by the streams of the valley. On the other hand the total length and mean length versus order number (fig. 6) show linear relationship adopting Horton's Second Law of Stream Length. This may indicate near stability in the basin. The Godawari, Hanumante, Bagmati, Dhobi, Bishnumati, Balkhu and Bosan kholas have reached the position to follow Horton's Laws, whereas the Nakhu, Kodku and Manohara khola have nearly reached to the equilibrium position to follow Horton's Laws.

Figure 5. RELATION BETWEEN AVERAGE LENGTH AND CHANNEL ORDER

(KATHMANDU VALLEY)

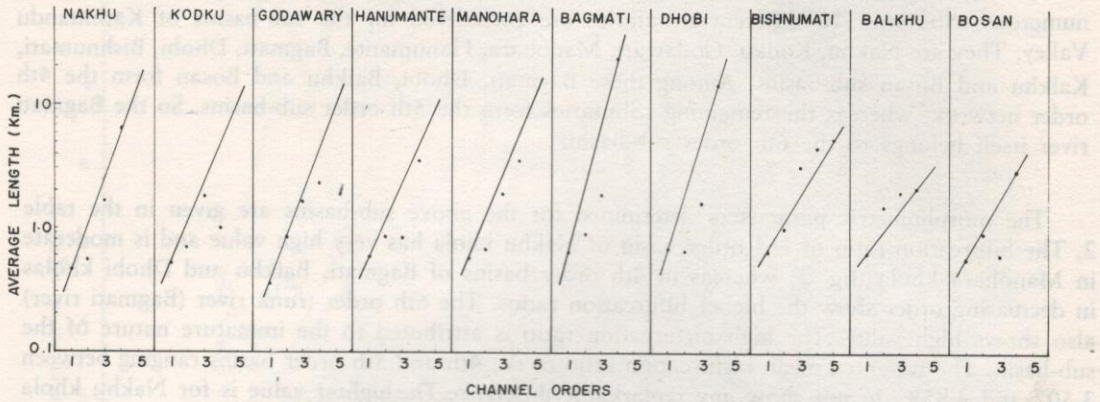
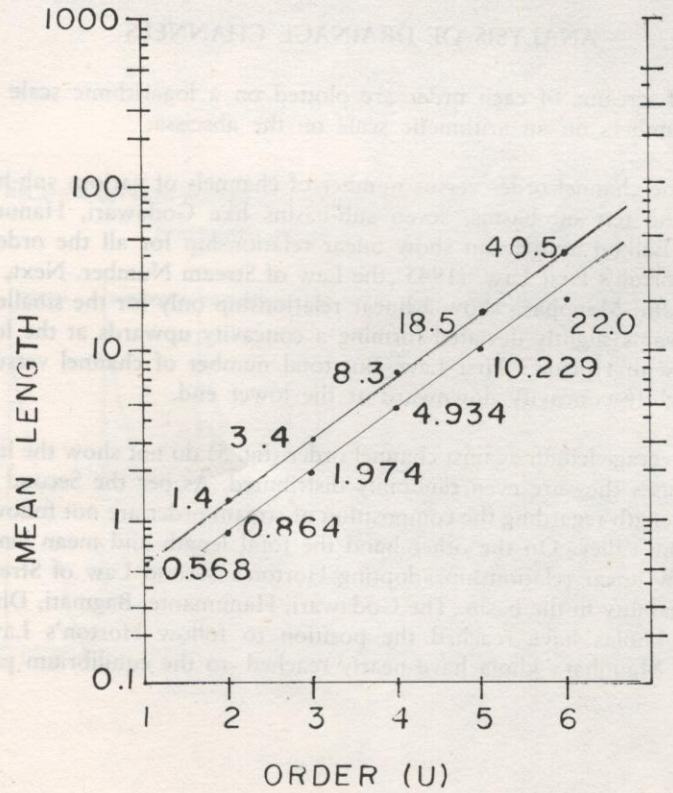


Figure 6. ORDER AND MEAN LENGTH OF STREAMS



CONCLUSIONS

The 3rd order sub-basins of Nakhu khola show more immature nature than the 3rd order sub-basins of Manohara khola.

The 4th order sub-basins of Bagmati, Balkhu and Dhobi kholas in decreasing order also show immature nature.

The 6th order basin of Bagmati River (Trunk river) is attributed to immature nature.

Hard rocks tend to give lower values of drainage density as compared to the softer rocks.

Godawari, Hanumante, Bagmati, Dhobi, Bishnumati, Balkhu and Bosan kholas have reached stability in their respective basins. Nakhu, Kodku and Manohara kholas have nearly reached to stability to follow the equilibrium position of Horton's Law.

ACKNOWLEDGEMENTS

The authors are grateful for the invaluable support from the Central Department of Geology, Tribhuvan University, in particular from Dr. M.P. Sharma (Chairman). The authors are also thankful to Dr B.N. Upreti, Chairman of Department of Geology, Tri-Chandra Campus, Tribhuvan University for offering constant help during the preparation of this paper.

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Table 1. DRAINAGE NETWORK OF KATHMANDU VALLEY

	Ist Order		2nd Order		3rd Order		4th Order		5th Order		6th Order		**Total**	
	No.	Length (km)	No	Length (km)	No	Length (km)	No	Length (km)	No	Length (km)	No	Length (km)	**No**	**Length (km)**
1. Nakhu	236	107.065	55	30.428	7	11.48	2	13.0	1	13.75			**301**	**175.723**
2. Khodu	85	44.891	23	15.943	5	9.4	2	2.0	1	10.0			**116**	**82.234**
3. Godawari	149	56.123	33	28.632	11	16.95	3	7.0	1	10.5			**197**	**119.201**
4. Hanumante	191	114.322	51	45.015	13	24.35	4	14.625	1	9.875			**260**	**208.187**
5. Manohara	200	124.0	47	33.161	8	15.0	2	7.0	1	11.75			**258**	**190.911**
6. Bagmati	137	88.904	30	28.0	7	12.9	1	21.75					**175**	**151.554**
7. Dhobi	58	41.78	17	11.688	5	7.8	1	13.5					**81**	**74.768**
8. Bishnumati	159	109.0	44	45.7	10	32.2	4	19.5	1	5.5			**218**	**211.9**
9. Balkhu	85	54.468	22	32.0	6	12.1	1	2.25					**114**	**100.818**
10. Bosan	34	20.25	9	8.5	3	1.9	1	3.0					**47**	**33.65**
Total Kathmandu Valley	1451	824.303	361	305.456	79	155.96	21	103.625	6	61.375	1	22.0	**1919**	**1472.719**

Table 2. MORPHOMETRIC PARAMETERS

Channel order	No of Channel	Bifurcation Ratio	Stream length Ratio	Total length (km)	Average length (km)	Total length of the stre (km)	Weighted mean Bifurcation Ratio
Sub-basin A (Nakhu Khola)							
1	236	4.291	3.519	101.065	0.454		
2	55	7.857	2.651	30.428	0.553		
3	7	3.5	0.883	11.48	1.64		
4	2	2	0.945	13.0	6.5		
5	1			13.75	13.75	175.723	4.858
Sub-basin B (Khodu khola)							
1	85	3.696	2.816	44.891	0.528		
2	123	4.6	1.696	15.943	0.693		
3	5	2.5	4.7	9.4	1.88		
4	2	2.0	0.2	2.0	1.0		
5	1			10.0	10.0	82.234	3.777
Sub-basin C (Godawari khola)							
1	149	4.515	1.960	56.123	0.377		
2	33	3	1.689	28.632	0.868		
3	11	3.667	2.421	16.95	1.541		
4	3	3	0.667	7.0	2.333		
5	1			10.5	10.5	119.205	4.168
Sub-basin D (Hanumante khola)							
1	191	3.745	2.54	114.322	0.599		
2	51	3.923	1.849	45.015	0.883		
3	13	3.25	1.665	24.35	1.873		
4	4	4.0	1.481	14.625	3.656		
5	1	-	-	9.875	9.875	208.187	3.758
Sub-basin E (Manohara)							
1	200	4.255	3.739	124.0	0.62		
2	47	5.875	2.211	33.161	0.706		
3	8	4.0	2.143	15.0	1.875		
4	2	2.0	0.596	7.0	3.5		
5	1			11.75	11.75	190.911	4.508
Sub-basin F (Bagmati)							
1	137	4.567	3.175	88.904	0.649		
2	30	4.286	2.171	28.0	0.933		
3	7	7.0	0.593	12.9	1.843		
4	1			21.75	21.75	151.554	4.61
Sub-basin G (Dhobi)							
1	58	3.412	3.575	41.78	0.72		
2	17	3.4	1.498	11.688	0.688		
3	5	5	0.578	7.8	1.56		
4	1			13.5	13.5	74.768	3.502

Total drainage area (sq.km)	Drainage density	Length of the basin (km)	Maxm Basin relief (m)	Stream frequency	Elongation ratio	Relief ratio	
							086
56.924	3.087	14.25	1356.06	5.288	0.596	0.095	11
							54
35.962	2.287	10.5	728.472	3.226	0.660	0.69	
44.962	2.651	12.1	1204.26	4.381	0.625	0.1	
94.749	2.197	16.75	1084.784	2.744	0.656	0.065	
75.764	2.520	18.0	1084.784	3.405	0.546	0.06	
75.312	2.012	19.2	1443.56	2.324	0.510	0.075	
33.425	2.237	15.1	1446.428	2.423	0.432	0.096	

Sub-basin H (Bishnumati)						
1	159	3.614	2.385	109.0	0.686	
2	44	4.4	1.419	45.70	1.039	
3	10	2.5	1.651	32.2	3.22	
4	4	4.0	3.545	19.5	4.875	
5	1			5.5	5.5	211.9
Sub-basin I (Balkhu)						
1	85	3.864	1.702	54.468	0.641	
2	22	3.667	2.645	32.0	1.455	
3	6	6.0	5.378	12.1	2.017	
4	1			2.25	2.25	100.818
Sub-basin J (Bosan)						
1	34	3.778	2.382	20.25	0.596	
2	9	3.0	4.474	8.5	0944	0.944
3	3	3.0	0.633	1.9	0.633	
4	1			3.0	3.0	33.65

3.653	101.673	2.084	13.95	1204.9	2.144	0.815	0.086
3.93	43.186	2.335	10.85	1200.8	2.64	0.623	0.111
3.567	8.837	3.808	4.75	1204.88	5.319	0.706	0.254