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M0rphometric Analysis of Selected Drainage Basins of the Western Palamu Upland, Jharkhand(India)

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Summary: ***Dury, G.H. (1963) states that, "subjective assessments, however, can be of very little use in comparing one drainage system with another, unless they are made by single observer, who maintains a constant standard of judgment. It is no possible to superceede subjective assesment of qualitative description by quantitative measurement." He has also defined that morphometry, " it is a measurement and mathematical analysis of configuration of the earth's surface and of the shape and dimensions of landforms."***

Fluvially eroded landscapes can be divided into a number of well-marked drainage basins. These drainage basins constitute distinct morphological regions. A greater understanding of the landscape can be, therefore, obtained by analysing the development of each drainage basin. Horton, R.E. (1945), Strahler, A.N. (1952), Morisawa, M.E. (1953) and King, L.C. (1967) have made notable contributions to the study of drainage basins and their morphometric properties. Horton, in particular, has defined certain laws of drainage compositions, which have been tested again and again. In the present analysis an attempt has been made to obtain the morphometric attributes of important drainage basins in the study-area and to assess their significance in landscape evolution.

The general characteristics of drainage such as drainage density, drainage frequency and drainage patterns have been examined previously. Ten drainage basins have been selected for a detailed examination of their morphometric attributes, their selection is based on the lithological and topographical variations of the terrains over which they flow. For example, the terrain over which the Kathdaha , Baghi, Baghlata rivers are formed entirely by Archaean granites and gneisses, including charnokites. Similarly, the drainage basins of Satbahini, Barhki and Mohanbari are formed by rocks of the Dharwar system, while these of the Sugwa, Kanarlewa, Gurgurwa and Gora rivers are composed of upper Carboniferous-Lower Triassic-Lower Gondwana rocks. All these streams originate in the heights on the higher upland .

Study-Area- The Western Palamau Upland (23039/N to 240 32/ N latitudes and 830 9/ E to 830 58/ E longitudes) occupies the northwestern part of the Chotanagpur highlands. It comprises the whole part of the Garhwa district of Jharkhand and mid-eastern part of Sonbhadra district in U.P. and Garhwa is the district headquarter. It lies between the North Koel, Kanhar drainage system. It is bounded by the middle Son river in the north, Semli-Burha hill-complex in the south, lower North Koel river in the east and lower Kandar river in the west respectively.

Its elevation varies from 140m to 849m and its area is 4104 km2. The main ranges are alinged in SE to NW direction and there are Kotam (440m), Kumbakhurd (364m), Ambakhoria (384m), Bairia (467m), Baligarh (264m), Belwadamar (598m), Karri (661m), Jogikhura (657m) pahars and Semli-Burha hill-complex. Its general height decreases to the south to the north. The topography of the area is rugged due to complex action of denudational processes. It is bounded by the Rohtas district of Bihar and Sonbhadra district of U.P. in the north, Sarguja district of M.P. in the southwest, NorthKoel valley in the east and Palamau patland in the south. The main settlement of the area is Garhwa and an important collecting centre for forest produce

The morphometric analysis of the above-mentioned drainage basins have been made with particular reference to drainage frequency, bifurcation ratio, length of streams, relief, slope, channel gradient, drainage density, valley slopes and geomorphic stage of development on the basins of hypsometric curves and integrals. The analysis of drainage frequency, bifurcation ratio and length of streams have been made on the basis of Horton's (1945) drainage order. These include the counting of streams and measurement of stream lengths for each order separately. In 1945, Horton proposed certain lows of drainage composition which assumed and orderly development of geometrical qualities of an insequent drainage system. These laws have been applied to data obtained from the morphometric measurements of the selected drainage basins. (Fig 2&3)

1. Stbahini 2. Kathdaha 3. Barkhi 4. Baghi 5. Baghlata 6. Mohnbari 7. Sugwa 8. Kanarlewa
9. Gurgurwa 10. Gora

1- Stream Frequency and Mean Stream Lengths- The first law of Horton, known as, 'the laws of stream numbers', states that, "the number of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is the bifurcation ratio." It simply means that there is a

Table 1

Order-wise Frequency of Streams in Selected Drainage Basins over Western Palamau Upland

	Drainage	Order wise Stream Frequency				
	Basins	I	II	III	IV	V
1.	Satbahini	50	23	07	02	01
2.	Kathdaha	26	15	03	01	-
3.	Barhki 33	13	02	01	-	
4.	Baghi 27	07	02	01	-	
5.	Baghlata 68	23	05	01	-	
6.	Mohanbari	33	13	05	01	-
7.	Sugwa 34	12	03	01	-	
8.	Kanarlewa	29	15	03	01	-
9.	Gurgurwa	25	12	02	01	-
10.	Gora 53	29	05	02	01	

progressive decrease in the frequency of streams as the numerical value of stream order increases. Plots of stream frequency and cumulative mean stream lengths on logarithmic scale and stream order on arithmetic scale show a straight-line relationship.

Table 2

Order-wise Streams Length in Selected Drainage Basins over Western Palamau Upland

	Drainage	Order wise Stream Length (km)				
	Basins	I	II	III	IV	V
1.	Satbahini	24.4	31.5	7.5	2.5	5.5
2.	Kathdaha	21.5	22.5	2.4	3.5	-
3.	Barhki 16.8	13.7	6.5	4.6	-	
4.	Baghi 18.6	10.8	3.8	2.4	-	
5.	Baghlata 30.5	25.4	7.8	10.7	-	
6.	Mohanbari	19.6	20.8	8.5	5.6	-
7.	Sugwa 20.5	18.6	7.9	5.5	-	
8.	Kanarlewa	12.7	16.9	2.7	6.5	-
9.	Gurgurwa	9.7	14.7	4.2	3.2	-
10.	Gora 23.7	27.2	5.0	2.2	6.7	

Table 1 and 2 show order-wise frequency and mean stream lengths, obtained for the 10 selected

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drainage basins. Plots of order-wise streams frequency for, Satbahini Barhki, Baghi, Baghlata, Mohanbari, Sugwa, Gurgurwa and Gora basins shows a straight line relationship, accordant with Horton's laws of stream numbers (Fig4.6). A slight deviation is, however, noted in the case of Kathdaha and Kanarlewa basins. In Kathdaha basin, the frequency of second-order streams is somewhat less, because they flow over the formerly peneplained surfaces composed of Archaean granites and gneisses. On the other hand , the frequency of third order streams is somewhat more because stream development has been more accelerated over the Gondwana Shales and sandstones deposited in faulted basins. Similarly plots of Kanarlewa basin indicate that the number of first order streams are somewhat more while that of the fourth order streams are somewhat less than anticipated. The higher frequency of first order streams may be explained due to rejuvenation, affecting the first order streams, during Pliocene times. In contrast, fewer number of fourth fifth order and order streams in these basins may be explained as a consequence of the old peneplained surfaces over which they continue to flow even after the rejuvenation of these surfaces. Nonetheless, the analysis confirms Horton's law of stream numbers that follow a geometric progression conforming to a negative exponential function. Mean stream length is calculated by the formula given below:

LU=L/NU

Where - LU= average length of a stream

L = total length of stream

NU =number of stream

Table 3

Mean Length of Streams in Sselected Drainage Basins over Western Palamau Upland

	Drainage	Order-wise Mean Stream Lengths (km)				
	Basins	I	II	III	IV	V
1.	Satbahini	0.48	1.36	1.07	1.25	5.50
2.	Kathdaha	0.82	1.50	0.80	3.50	-
3.	Barhki 0.50	1.05	3.25	4.60	-	
4.	Baghi 0.68	1.54	1.90	2.40	-	
5.	Baghlata 0.44	0.90	0.64	10.70	-	
6.	Mohanbari	0.59	1.60	1.70	5.60	-
7.	Sugwa 0.60	1.50	2.63	5.50	-	
8.	Kanarlewa	0.43	1.12	0.90	6.50	-
9.	Gurgurwa	0.38	1.22	2.10	3.20	-
10.	Gora 0.44	0.93	1.00	1.10	6.70	

The total length of streams of different hierarchical order and its mean values are great importance in the study of drainage basins. Stream length is a result of either the number of stream segments. With every increase in stream order, its segment length tends to increase (Fig. 4)

Plots of cumulative mean stream lengths against stream order for the selected drainage basins reveal a more perfect straight-line relationship. Accordant with Horton's law of streams lengths slight deviation are however noted in cases of the Satbahini, Kathadha, Boghlata and Kanarlewa basin. The mean stream length are somewhat more than anticipated in the case of the third order streams of the Satbahini, Kathadha, Boghlata and Kanarleva basins. This may be due to the impact of Tertiary rejuvenation affecting the areas over which these streams flow.

2- Bifurcation Ratio- The ratio between the total number of streams of one order to that of the next higher order, is known as the 'bifurcation ratio' (Schumm, S.A.,1956). It is an index of the degree of integration of streams of various orders in a drainage basin.The formula described bellow:

Rb= Nu / Nu+1

Where - -Rb = Bifurcation ratio

Nu= Number Of segment of certain order of stream

Nu+1= Number of next higher order of stream

For example, it can reveal as to how for the first order segments join the next order channels independently. Table 4 gives the bifurcation ratio of the sample basins. The bifurcation ratio between first and second order streams ranges from 2.08 to 3.85, except in the case of the Kathdaha, Kanarlewa and Gora basins which have ratios of 1.73, 1.93 and 1.82 respectively.

The ratio is high in the case of the Barhki (3.53), Baghlata (2.95), Mohanbari (2.53), Sugwa (2.83) and Baghi (3.85). This is because the first order streams are more numerous in upper parts of the northern and southern escarpment zones. The low ratio in case of the Satbahini (2.17), Kathaha (1.73), Kanarlewa (193), Gurgurwa (2.08) and Gora (1.82) basins is due to the development of peniplained surface with fever first order streams. The bifurcation ratio between the second and third order streams ranges from 2.60 for the Mohanbari to 6.50 for the Barhki, while that between the third and fourth order streams varies from 2.00 for both the Barhki, Baghi to 5.00 for the Baghlata, Sugwa and Mohanbari rivers. The ratio between the fourth and fifth order streams are obtainable for the basins of Satbahini and Gora only; these a constant value of 2.00.

Table 4

Bifurcation Ratio and Weighted Mean of Bifurcation Ratio in Sample Drainage Basins.

	Drainage	Order Ratio				
	Basins	I-II	II-III	III-IV	IV-V	Weighted Mean
1.	Satbahini	2.17	3.28	3.50	2.00	2.82
2.	Kathdaha	1.73	5.00	3.00	-	2.74
3.	Barhki 3.53	6.50	2.00	-	3.31	
4.	Baghi 3.85	3.50	2.00	-	3.62	
5.	Baghlata 2.95	4.60	5.00	-	3.35	
6.	Mohanbari	2.53	2.60	5.00	-	2.70
7.	Sugwa 2.83	4.0	5.00	-	1.30	
8.	Kanarlewa	1.93	5.00	3.00	-	2.80
9.	Gurgurwa	2.08	6.00	3.00	-	3.07
10.	Gora 1.82	5.80	2.50	2.00	2.91	

3- Weighted Mean of Bifurcation Ratio- To arrive at a more representative bifurcation number, Strahlar, A.N. (1953) used a weighted mean of bifurcation ratio for each successive pair of orders which is obtained by multiplying the bifurcation ratio for each successive pair of orders by the total number of streams involved in the ratio and then taking the mean of the sum of these values (Table 4). It is noted that the weighted mean of bifurcation ratio varies from 1.30 for the Sugwa to 3.62 for the Baghi. These variation are due to differences in the stage of their development as also due to topography variations. It is, however, noteworthy that the values for most of the drainage basins fluctuate around 3.00.

4- Stream Length Ratio- The ratio between mean lengths of streams of any two consecutive orders, known as the length ratio, has been also taken into consideration (Table 5).

Table 5

Order-wise Mean stream Length Ratio in Sample Drainage Basins over Western Palamau Upland

	Drainage	Order Wise Mean Stream Length Ratio			
	Basins	I-II	II-III	III-IV	IV-V
1.	Satbahini	0.35	1.27	0.85	0.22
2.	Kathdaha	0.54	1.80	0.22	-
3.	Barhki	0.47	0.32	0.70	-
4.	Baghi	0.44	0.81	0.79	-
5.	Baghlata	0.48	1.40	0.05	-
6.	Mohanbari	0.36	0.94	0.30	-
7.	Sugwa	0.40	0.57	0.47	-
8.	Kanarlewa	0.38	1.24	0.13	-
9.	Gargurwa	0.31	0.58	0.65	-
10.	Gora	0.47	0.93	0.90	0.16

Table 5 reveals that the ratios between first and second order mean stream lengths are somewhat similar fluctuating around 0.50 and ranging from 0.31 (Gurgurwa) to 0.54 (Kathdaha). Similarly the ratio between second and third order streams are also somewhat similar, ranging from 0.32 (Barhki) to 1.80 (Kathdaha), while that the ratios between the third and fourth order streams ranging from 0.13 (Kanarlewa) to 0.90 (Gora). The mean length ratios between the fourth and fifth order streams are obtainable from 0.16 of Gora and 0.22% Satbahin rivers. Development of first and second order streams over the upland areas account for the similarity in the mean length ratio of these streams in the various drainage basins under consideration. The mean length ratios between higher stream orders indicate independent behaviour which may be due to differences in slope and topographic conditions in the different drainage basins.

Drainage Basin Characteristics- Examination of the shape and size, relief, valley slopes, drainage density and the stage of the geomorphic development are some other aspects worthy of consideration in the study of drainage basins. Table 6 gives the drainage basins characteristics, namely (1) relief ratio,(2) elongation ratio,(3) mean channel gradient (4) and the stage in the geomorphic cycle of 10 selected drainage basins.

1- Relief Ratio- Relief is defined as the difference in elevation between the summit and the valley floor. Analysis of basin, relief has been made by obtaining the relief ratio, which is defined as the ratio between the total relief of a basins and the largest dimension of the basin parallel to the principal drainage line. Schumm, S.A. (1956) states that, "it is dimensionless height-length ratio equal to the tangent of the angle formed by the planes intersecting at the mouth of the basins, one representing the horizontal and the other passing through the highest point of the basin".Relief ratio calculated by the formula given below:

$$\text{Relief Ratio (Rh)} = H / Lb$$

Where H=Total relief of the basin

Lb=Maximum length of the basin

Table 6 reveals that the relief ratio is the highest (0.53) in the basin of Baghlata. This is because it drains a large part of the upper upland surface. In contrast, the basin of the Sugwa, Gora and Barhki have moderate relief ratios of 0.52, 0.50 and 0.43 respectively. These streams rise in the moderate height of the upper Western Palamau upland. Low relief ratio characterize the basins of the Satbahini (0.29), Kathdaha (0.15), Baghi (0.18), Mohanbari (0.15), Kanarlewa (0.31) and Gurgurwa (0.09) rivers. Large parts of these basins are formed by peneplained surfaces with residual hills of little significance.

Table 6

Drainage Basins Characteristics of the Sample Basins over Western Palamau Upland

	Drainage Basins	Relief Ratio	Elongation Ratio	Mean Channel Gradient (%)	Remarks
1.	Satbahini	0.29	0.49	0.39	Late-mature stage
2.	Kathdaha	0.15	0.42	0.62	Mid-mature stage
3.	Barhki	0.43	0.46	0.68	Mid-mature stage
4.	Baghi	0.18	0.73	0.35	Old stage
5.	Baghlata	0.53	0.42	0.15	Mid-mature stage
6.	Mohanbari	0.15	0.52	0.10	Old stage
7.	Sugwa	0.52	0.41	0.89	Mid-mature stage
8.	Kanarlewa	0.31	0.50	0.18	Late-mature stage
9.	Gurgurwa	0.09	0.53	0.19	Old stage
10.	Gora	0.50	0.45	0.57	Mid-mature stage

2- Elongation Ratio- The shape of a drainage basin is expressed in terms of elongation ratio which is the ratio between the maximum length of a stream basin, as measured for relief ratio and the diameter of a circle having the same area as that of the stream basin. It establishes a fundamental law, i.e., smaller the fraction the more elongated is the shape of the basin and vice-versa. Table 6 reveals that 6 sample basins, namely Kathdaha (0.42), Barhki (0.46), Baghlata (0.42), Sugwa (0.41), Gora (0.45) and Satbahini (0.49) have elongated shapes. In contrast the Baghi (0.73) is most circular while the Mohanbari (0.52), Kanarlewa (0.50), and Gurgurwa (0.53) are somewhat less circular.

3 -Mean Channel Gradient- Calculation of the mean channel gradient of the master streams of the sample basins shows that the Baghlata (0.15%), Mohanbari (0.10%), Kanarlewa (0.18%) and Gurgrwa (0.19%) have very low or gentle slope forms. These low values are due to the meandering nature of the streams on peneplained surfaces of very low gradient. On the other hand, streams like the Satbahini (0.39%), Baghi (0.35%) and Gora (0.57%) have moderate mean channel gradients. Existence of meanders with interlocking spurs have been noted in the upper parts of these drainage basins. The Kathdaha, Barhki and Sugwa basins have a much higher mean channel gradients of 0.62%, 0.68% and 0.89% respectively, because their upper parts are formed by the resistant Upper Carboniferous and Lower Triassic Gondwana rocks while its middle and lower parts are composed of less resistant Archaean laterites rocks.

4 -Stream Density- Stream density is the ratio of the channel length to area drained. The stream density in the sample drainage basins, ranging from 2.2 km/km2 to 3.6 km/km2. The basins of the Kathdaha, Baghi, Sugwa Kanarlewa, Gurgurwa and Gora are moderately drained; Their stream density are 3.6 km/km2, 3.1 km/km2, 3.3 km/km2, 3.2 km/km2, 3.4 km/km2 and 3.2 km/km2 respectively. Similarly the Satbahini and Barhki are well-drained, these have stream density 2.9 km/km2 respectively. The Baghlata and Mohanbari are very well-drained and its drainage density are 2.4 km/km2 and 2.2 km/km2 respectively.

5- Stream Frequency- The stream frequency in the sample drainage basins, ranging from 2.1 streams/ km2 to 4.4 streams/km2 (Table IV.11). This value is at a maximum in the late youth or early maturity. Fewer stream frequencies are indicative of the late stage in geomorphic cycle. The basins of the Kathdaha, Baghi, Sugwa Kanarlewa, Gurgurwa and Gora located in the well dissected parts of the upland, have drainage frequencies of 3.3 stream/km2, 3.2 streams/km2, 3.1 streams/km2, 3.9 streams/km2, 4.3 streams/km2 and 4.4 streams/km2 respectively. They appear to

Table 7

Texture of Drainage in the Sample Drainage Basins over Western Palamau Upland

Drainage Basins	Stream Density (Length km/km^2)	Stream Frequency (No. of streams/km^2)	Nature of Drainage
1. Satbahini	2.9	3.4	Well-drained
2. Kathdaha	3.6	3.3	Moderately drained
3. Barhki	2.9	3.4	Well-drained
4. Baghi	3.1	3.2	Moderately drained
5. Baghlata	2.4	3.0	Very well drained
6. Mohanbari	2.2	2.1	Very well drained
7. Sugwa	3.3	3.1	Moderately drained
8. Kanarlewa	3.2	3.9	Moderately drained
9. Gurgurwa	3.4	4.3	Moderately drained
10 Gora	3.2	4.4	Moderately drained

be in the mature stage of the geomorphic cycle. The Satbahini, Baghlata and Barhki with stream frequencies of 3.4 streams/km2, 3.0 streams/km2 and 3.4 streams/km2, are in the late mature stage, while the Mohanbari with stream frequency 2.1 streams/km2, appear to be in old stage.

1. a/A ('a' is the area enclosed between each pair of contours and 'A' is the total basin area) represented along the abscissa, and

2. h/H ('h' is the height of the contour above the base and 'H' is the total basin height) plotted on the ordinate

Percentage Hypsometric Curves- Percentage hypsometric curves (Strahler, A.N., 1952) have been drawn to analyse the nature and character of erosion surfaces as also to determine the stages in the evolution of the sample drainage basins. These curves show the distribution of ground surface area with respect to elevation, and are drawn by

Table 8

Hypsometric Integral of Some Selected Drainage Basins over Western Palamau

Upland		
Drainage Basins	Hypsometric Integral (%)	Remarks
1. Satbahini	45.47	Mature stage
2. Kathdaha	44.12	Mature stage
3. Barhki	36.25	Mature stage
4. Baghi	33.75	Old stage
5. Baghlata	54.37	Mature stage
6. Mohanbari	70.48	Youth stage
7. Sugwa	45.62	Mature stage
8. Kanarlewa	54.25	Mature stage
9. Gurgurwa	53.12	Mature stage
10. Gora	46.85	Mature stage

The hypsometric curves have been plotted separately for each basin (Fig 5) calculation of hypsometric integrals, expressed in percentage, have been made for each basin with the help of planimeter. The hypsometric integral is a measure of the stage because it expresses in percentage the mass of the drainage basin remaining above the basal plane of reference* (Schumm, S.A., 1956). Analysis of the hypsometric curves shows several irregularities that are represented by inflection points on the curves. These have resulted due to lithological and structural variations present in the drainage basins. Although the basin of Baghi is intirely composed of Archaean-unclassified granites and gneisses, including charnockite, its curve show many abnormalities.

This may be due to the existence of undulating and flat-topped uplands which descend steeply to the lower valley. The upper part of the curve is steep due to the presence of isolated and steep-sided hills projecting above the uplands. Lower down, the curve become concave due to the existence of gentler slopes down stream, covering most of the Baghi basin. This basin has a hypsometric integral of 33.75%, which is indicative of its old stage. The curve for the Mohanbari, a fourth order drainage is more or less a straight-line. It has developed on Archaean rocks. The middle part of the curve is convex which shows that the river flows over a variety of rock beds of different ages. The gently sloping lower part of the curve indicates its development on alluvial surfaces. The drainage basin, with a hypsometric integral of 70.48%, is in youth stage.

The curve for the Satbahini. Kathdaha, Barhki, Baghlata, Sugwa, Kanarlewa, Gurgurwa and Gora basins a fourth and fifth order drainage basins, are more or less a straight line. These have developed on

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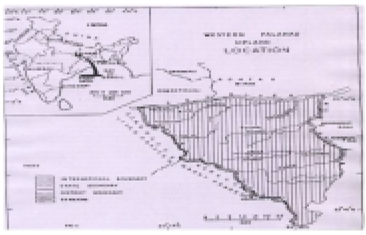
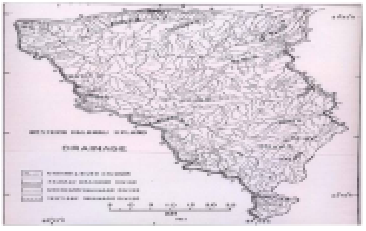
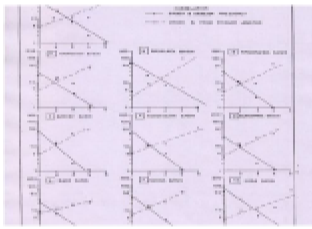
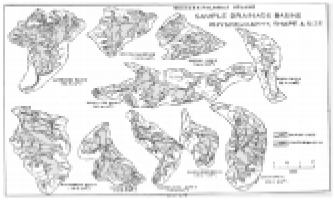
Archaean rocks. The gently sloping lower part of the curves indicates its development on peneplained surfaces. These drainage basin, with a hyposometric integral are as moderate as 45.47%, 44.12%, 36.25%, 54.37%, 45.62%, 54.25%, 53.12% and 46.85% respectively are in the late mature stage. The middle parts of the curve are concave which show that the rivers flows over variety of rocks bed of different ages.

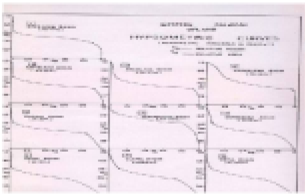
Conclusion- A detailed morphometric analysis of 10 selected drainage basins has been made and some of the laws of drainage composition tested. Plot of the cumulative mean stream length against streams orders for the selected drainage basins reveal an almost perfect straight-line relationship, accordant with Horton's law of stream length. The bifurcation rations between first and second, second and third, third and fourth, fourth and fifth order streams ranges from 1.73 to 3.85, 2.60 to 6.50, 2.00 to 5.00 and around 2.00 respectively. The weighted mean of bifurcation rations for most of the drainage basins (except Baghi), however, fluctuate around 3.00. Mean stream length ratio reveals that the ratio between first and second, second and third, third and fourth, fourth and fifth order streams ranges from 0.31 to 0.54, 0.32 to 1.27, 0.13 to 0.85 and 0.16 to 0.22 respectively. All the drainage basins are characterized by mid-mature to old stage relief ratios. The hyposometric curve for the Mohanbari in youth stage, Baghi in old stage and Satbahini, Kathdaha, Barhki, Baghlata, Sugwa, Kanarlewa Gurgurwa and Gora rivers are in mature stag











REFERENCES

1. Dury, G.H. (1963): 'The Faces of the Earth'. Pelican Books, London
2. Horton, R.E. (1945): Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. Bull. Geol. Society of America, 56: 276-370
3. King, L.C.(1967): 'The Morphology of Earth'. Oliver & Boyds, Edinburg; 275-282
4. Morisawa, M.E. (1953): Accuracy of determination of stream lengths from topographic maps. Trans. Amer. Geophys. Union, 38:.86-88
5. Schumm, S.A. (1956): Evaluation of drainage system and slope in badlands at Perth Amboy, New Jersey. Bull, Geol. Soc. Amer., 67: 597-646
6. Strahler, A.N. (1952): Hypsometric (area-altitude) analysis of erosional topography. Bull. Geol. Soc. of America, 63, November: 1117-1142
7. Strahler, A.N. (1952): 'Physical Geography; John Wiley & Sons, NewYork: 232
8. Strahler, A.N. (1953): Revisions of Horton's quantitative factors in erosional terrain; Paper read before Hydrology section of American Geophys. Union, Washington

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