THE BRAHMANI BASIN

12

MORPHOMETRIC ANALYSIS: SAMPLE BASINS

- SELECTED BASINS
- MORPHOMETRIC ANALYSIS
- RELATIONSHIP OF NUMBER & LENGTH TO ORDER
- SIMPLE AND MULTIPLE RELATIONSHIP
12.1. SELECTED BASINS

A drainage basin is 'an area of the earth's surface drained by a river system and bounded by a watershed which separates it from adjoining drainage basins' (Smith, 1984, p.73) or it is 'the land area that is drained by a river and its tributaries' (N.B.K., 1979, p.238). In other words a 'drainage basin may be defined as the area which contributes water to a particular channel or set of channels' (Leopold, Wolman & Miller, 1964, p.131).

The study of drainage basins has been necessitated owing to the fact that a drainage basin is considered to be
the best unit for geomorphic investigation, particularly when we want to analyse the area in respect of the landscape evolution, processes involved therein and material's influence incurred thereupon. In a complete drainage basin one can see even the stages of landscape development.

The study area is itself a drainage basin. But to get a clear picture of drainage network in the Brahmani catchment, ten sub-basins have been selected and their drainage networks have been examined in details. The selection of these sample basins are neither random nor arbitrary. They are representing varied topography and lithology to great extent. Also two conditions were kept in mind while selecting these basins. Firstly, the selection of an equal number of basins from each side of the major stream has been made. Secondly all the basins are of 4th order streams (Fig. 12.2). While former consideration ensures a more representative sampling, the later ensures that comparison is made between basins of the same orders.

The following are the selected basins (Fig. 12.1):

1. Bagmar Nala
2. Lakdom Nala
3. Dheba Nadi
4. Saldaha Nala
5. Banjhi Amba Nala
6. Ero Nadi
SELECTED SAMPLE BASINS

1. BAGMAR NALA
2. LAKDUM NALA
3. DHEBA NADI
4. SALDAHA NALA
5. BANJHI AMBA NALA
6. ERO NADI
7. JURGURI NADI
8. BARAMASIA NALA
9. PRATAPPUR NALA
10. HARIPUR NALA
7. Jurguri Nadi
8. Barmasia Nala
9. Pratappur Nala
10. Haripur Nala

12.1.1. BAGMAR NALA

Comprising an area of 15.50 square kilometres, the Bagmar Nala sub-basin extends from 24° 17' N to 24° 20' 25"N latitudes and 87° 44' E to 87° 46' E longitudes. Bagmar Nala is a small tributary of lower Tripati river. It rises at an elevation of 104 metres and flows on Rajmahal trap. It is north of Brahmani river.

The perimeter, maximum length, maximum width and minimum width of the Bagmar Nala are 15, 5.60, 4 and 1 kilometres respectively. The elongation and circularity ratios are 0.8076 and 0.8660 respectively (Table 12.2). The gradient is about 17.67 metres per kilometre.

The sub-basin has a range of elevation from 39 - 106 metres. The relative relief ranges from 7 to 47 metres and the slope from 0.04° to 10°. The drainage pattern of the sub-basin is dendritic and the drainage texture ranges from 0 to 2.27 per kilometre in per square kilometre.
12.1.2. **Lakdom Nala**

Comprising an area of 25.30 Km$^2$ the Lakdom Nala sub-basin is situated between $24^\circ$ 20' 30" N and $24^\circ$ 24' N latitudes and $87^\circ$ 39' 30" E and $87^\circ$ 43' 30" E longitudes. Lakdom Nala is also a tributary of Tripati river and this sub-basin lies on Rajmahal trap. It is north of Brahmani river.

The river rises on an altitude of 110 metres. The gradient is about 21.47 metres per kilometre. The sub-basin has a range of elevation from 55 to 160 metres.

The perimeter, maximum length, maximum width and minimum width of the sub-basin are 13.75, 6, 7 and 1 kilometres respectively. The elongation and circularity ratios are 0.8730 and 0.7950 respectively (Table 12.2). The relative relief ranges from 8 to 75 metres. Similarly, the slope in general ranges from $0.8^\circ$ to $21^\circ$.

Dendritic is the most common pattern of the drainage everywhere. The drainage texture ranges from 0.64 to 1.60 per kilometre in per square kilometre.

12.1.3. **Dheba Nadi**

Comprising an area of 33.38 Km$^2$, the Dheba Nadi is situated between $24^\circ$ 16' 30" N and $24^\circ$ 19' 30" N latitudes and $87^\circ$ 34' 45" E and $87^\circ$ 41' 15" E longitudes. Dheba Nadi is
a main tributary of the Tripati river. It rises from the Chaksa Pahar at an elevation of 153 metres. This sub-basin also covers an area of Rajmahal trap, north of the Brahmani river. The sub-basin has a range of elevation from 56 to 144 metres.

The perimeter, maximum length, maximum width and minimum width of the sub-basin are 18, 11.20, 3.80 and 2 kilometres respectively. The elongation and circularity ratios are 0.5925 and 0.5550 respectively (Table 12.2). The gradient is about 13.09 metres per kilometre.

The relative relief ranges from 9 to 81 metres. Similarly the slope ranges from 0.17° to 16°.

Dendritic is the dominant pattern in the sub-basin. The drainage texture is fine in the middle parts. But moderately fine texture can be observed in the upper part of the sub-basin. The drainage texture ranges between 0.50 to 3.45 per kilometre in per square kilometre.

12.1.4. SALDAHA NALA

Comprising an area of 20.25 km², the Saldaha Nala sub-basin is situated between 24° 18' N and 24° 22' N latitudes and 87° 28' 30" E and 87° 32' E longitudes. The Saldaha Nala rises from the Belbuni Pahar at an elevation of 258 metres.
This sub-basin lies on both the Gondwana sedimentaries and trap area, north of the Brahmani river.

The gradient is about 33.67 metres per kilometre. The perimeter, maximum length, maximum width, minimum width are 14, 7.70, 4.30 and 0.50 kilometres respectively. The elongation and circularity ratios are 0.6770 and 0.6058 respectively (Table 12.2).

The sub-basin has a range of elevation from 95 to 303 metres. The relative relief varies from 14 to 184 metres. Similarly the slope in general is 0.13° to 18°. Radial and parallel pattern can be observed in this sub-basin. The drainage texture is moderate in the upper parts, but moderately fine in the middle parts. The drainage texture ranges from 0.62 to 3.45 per kilometre in per square kilometre.

12.1.5. BANJHI AMBA NALA

Comprising an area of 26.63 Km², the Banjhi Amba Nala is situated between 24° 24' 45" N and 24° 29' 15"N latitudes and 87° 24' 20" E and 87° 28' E longitudes. The Banjhi Amba Nala is the longest rivulet of the Gumra Nala. It rises from the Mahuagarhi hills at an elevation of 503 metres. The sub-basin has a range of elevation from 134 to 480 metres. This sub-basin lies on the Gondwana sedimentaries and trap, north of the Brahmani river.
The gradient is steep in source region. An average gradient is about 40 metres per kilometre.

The perimeter, maximum length, maximum width and minimum width of the sub-basin are 16.25, 9.50, 4.50 and 1 kilometres respectively. The elongation and circularity ratios are 0.6128 and 0.5812 respectively (Table 12.2).

The relative relief ranges from 15 to 259 metres. Similarly the slope in general varies from 0.45° to 20°. The dominant drainage pattern is dendritic. The radial and parallel patterns are also observed in the sub-basin. The drainage texture is moderately fine in the middle part and medium texture is found in the upper and lower parts. The drainage texture ranges from 0.36 to 0.95 per kilometre in per square kilometre.

12.1.6. ERO NADI

The Ero Nadi is one of the northern tributary of the Brahmani river. It rises at an elevation of 222 metres. Comprising an area of 58.01 Km², the Ero Nadi sub-basin is situated between 24° 17' N and 24° 24' 45" N latitudes and 87° 20' 25" E and 87° 28' E longitudes. This sub-basin lies on granite and gneissic terrain, north of the Brahmani river. It has a range of elevation from 99 to 328 metres.
The channel gradient is about 13.64 metres per kilometre. The perimeter, maximum length, maximum width and minimum width of the sub-basins are 31, 19.20, 5.50 and 1.60 kilometres respectively. The elongation and circularity ratios are 0.4522 and 0.3683 respectively (Table 12.2).

The relative relief ranges from 13 to 149 metres. Similarly the slope in general varies from $0.16^\circ$ to $16^\circ$.

The dominant drainage pattern of the sub-basin is dendritic. The drainage texture ranges from 0.57 to 6.67 per kilometre in per square kilometre.

12.1.7. JURGURI NADI

Comprising an area of 26.38 Km$^2$, the Jurguri Nadi sub-basin is situated between $24^\circ 18'\ N$ and $24^\circ 23'\ N$ latitudes and $87^\circ 18'\ E$ and $87^\circ 21'\ E$ longitudes. This sub-basin lies on granite & gneissic terrain, west of the Brahmani river.

The channel gradient is about 49.13 metres per kilometre. The perimeter, maximum length, maximum width and minimum width of the sub-basin are 15.25, 5, 8.80 and 2 kilometres respectively. The elongation and circularity ratios are 0.9747 and 0.7043 respectively (Table 12.2).

The relative relief ranges from 24 to 110 metres. Similarly the slope in general varies from $0.16^\circ$ to $25^\circ$. 
The sub-basin has a range of elevation from 138 to 393 metres.

Dendritic and rectangular drainage patterns are dominant in this sub-basin. The drainage texture ranges from 0.62 to 6.67 per km. in per square kilometre.

12.1.8. BARMASIA NALA

Comprising an area of 10.75 Km\(^2\), the Barmasia Nala sub-basin is situated between 24\(^\circ\) 13' 15" N and 24\(^\circ\) 15' N latitudes and 87\(^\circ\) 23' E and 87\(^\circ\) 25' 15" E longitudes. This sub-basin also lies on granite & gneissic surface south of the Brahmani river.

The channel gradient is about 48.57 metres per kilometre. The perimeter, maximum length, maximum width and minimum width of the sub-basin are 8.50, 4, 4.10 and 1 kilometres respectively. The elongation and circularity ratios are 0.9247 and 0.9957 respectively (Table 12.2).

The relative relief ranges from 20 to 35 metres. Similarly the slope in general varies from 0.16\(^\circ\) to 0.64\(^\circ\). The sub-basin has a range of elevation from 132 to 170 metres.

The pattern in general is dendritic but parallel pattern can also be observed in this sub-basin. The drainage texture ranges from 0.40 to 0.97 per km. in per sq. km.
12.1.9. **Pratappur Nala**

Comprising an area of 18.08 km$^2$, the Pratappur Nala sub-basin is situated between 24° 13' N and 24° 17' N latitudes and 87° 28' 30" E and 87° 31' 30" E longitudes. The Pratappur Nala is the southerly tributary of the Brahmani river. It rises from Karakala Pahar at an elevation of 356 metres. This sub-basin lies on Dubrajpur shales and sandstones, an undulating terrain, south of the Brahmani river.

The channel gradient is about 40 metres per kilometre. The perimeter maximum length, maximum width and minimum width of the sub-basin are 12.75, 7.50, 3 and 1.50 kilometres respectively. The elongation and circularity ratios are 0.6396 and 0.6570 respectively (Table 12.2).

The sub-basin has a range of elevation from 98 to 300 metres. The relative relief ranges from 10 to 153 metres. Similarly the slope in general varies from 0.13° to 19°.

The dominant drainage pattern of the sub-basin is dendritic. The rectangular drainage pattern can also be observed in the area. The drainage texture ranges from 0.40 to 1.35 per km. in per sq. km.

12.1.10. **Haripur Nala**

Comprising an area of 33.25 km$^2$, the Haripur Nala
sub-basin is situated between 24° 11' 30"N and 24° 14' 45"N latitudes and 87° 33' E and 87° 39' E longitudes. Upper part of the sub-basin lies on the Dubrajpur shales & sandstones while lower part on the Rajmahal trap. The Haripur Nala is a southerly tributary of the Brahmani river. It rises from the Ramgarh hills.

The channel gradient is about 21.11 metres per kilometre. The perimeter, maximum length, maximum width and minimum width of the sub-basin are 18.75, 11.30, 3.50 and 1.20 kilometres respectively. The elongation and circularity ratios are 0.5914 and 0.5952 respectively (Table 12.2).

The sub-basin has a range of elevation from 58 to 285 metres. The relative relief ranges from 3 to 102 metres. Similarly the slope on general varies from 0.08° to 12°.

The dominant drainage pattern is dendritic. The drainage texture ranges from 0.40 to 1.69 per km. in per square kilometre.

12.2. MORPHOMETRIC ANALYSIS

The morphometric analysis of the selected drainage basins is based mainly on Horton's (1945) law of drainage composition. In determining completely the composition of stream system, it is necessary to know (1) the drainage area
(2) the order of the main stream (3) the bifurcation ratio and (4) mean stream length. From these data drainage density, stream frequency and other characteristics of the drainage system are determined (Horton, 1945, pp.275-370). The morphometric analysis also includes basin shape and size, relief ratio, channel gradient, constant of channel maintenance, $F/D^2$ and geomorphic stage of development on the basis of hypsometric integrals. All these parameters have been taken into considerations following the methods discussed in the previous chapter (Chapter 6) to make an analysis of individual sub-basins as well as the Brahmani Basin as a whole.

Although the author is not confined how much help he will get from the morphometric analysis of the selected drainage basins of the Brahmani catchment in understanding the landscape evolution, he has made, however, an attempt to deduce some probable hypotheses. Hence, various morphometric parameters have been worked out and tabulated (Table 12.1).

The following are the conclusions for all the ten sub-basins:

(1) The stream number decreases as the order increases. It is an approximate geometric progression in all the selected sample basins. This follows the Horton's law (1945, p.275).

(2) Horton concludes that the bifurcation ratio ranges
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Drainage Basins</th>
<th>Total number of stream of each order</th>
<th>Bifurcation Ratio</th>
<th>Weighted Mean Bifurcation Ratio</th>
<th>Mean length of the streams: segments of each order (Km)</th>
<th>Total stream length (Km)</th>
<th>Total No. of streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bagmar Nala</td>
<td>17 5 2 1</td>
<td>3.40 2.50 2.00</td>
<td>3.93</td>
<td>0.61 1.40 2.63 1.25</td>
<td>24.00</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Lakdum Nala</td>
<td>69 16 4 1</td>
<td>4.31 4.00 4.00</td>
<td>5.18</td>
<td>0.48 0.5 2.13 4.25</td>
<td>61.00</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>Dheba Nadi</td>
<td>71 16 4 1</td>
<td>4.44 4.00 4.00</td>
<td>5.28</td>
<td>0.57 0.63 1.44 8.50</td>
<td>64.50</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>Saldaia Nala</td>
<td>47 12 2 1</td>
<td>3.92 6.00 2.00</td>
<td>5.16</td>
<td>0.55 0.96 2.00 6.25</td>
<td>47.50</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>Banjhi Amna Nala</td>
<td>73 14 3 1</td>
<td>5.21 4.67 3.00</td>
<td>5.98</td>
<td>0.69 0.77 3.67 5.25</td>
<td>77.10</td>
<td>91</td>
</tr>
<tr>
<td>6</td>
<td>Ero Nadi</td>
<td>67 12 3 1</td>
<td>7.25 4.00 3.00</td>
<td>7.66</td>
<td>0.72 1.69 4.50 10.50</td>
<td>106.75</td>
<td>103</td>
</tr>
<tr>
<td>7</td>
<td>Jurguri Nadi</td>
<td>37 10 3 1</td>
<td>3.70 3.33 3.00</td>
<td>4.49</td>
<td>0.76 1.05 2.67 2.75</td>
<td>49.25</td>
<td>51</td>
</tr>
<tr>
<td>8</td>
<td>Harmasia Nala</td>
<td>31 8 3 1</td>
<td>3.88 2.67 3.00</td>
<td>4.48</td>
<td>0.45 0.94 1.67 1.60</td>
<td>28.10</td>
<td>43</td>
</tr>
<tr>
<td>9</td>
<td>Pratappur Nala</td>
<td>38 11 2 1</td>
<td>3.15 5.50 2.00</td>
<td>4.74</td>
<td>0.63 0.91 3.00 1.75</td>
<td>41.75</td>
<td>52</td>
</tr>
<tr>
<td>10</td>
<td>Haripur Nala</td>
<td>57 14 3 1</td>
<td>4.07 4.63 3.00</td>
<td>5.07</td>
<td>0.66 1.2 4.17 2.00</td>
<td>70.25</td>
<td>75</td>
</tr>
</tbody>
</table>

**Table 12.1**

Order-wise Stream Numbers and Length in the 10 Sample Basins

<table>
<thead>
<tr>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N1/N2</th>
<th>N2/N3</th>
<th>N3/N4</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bagmar Nala</td>
<td>17</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3.40</td>
<td>2.50</td>
<td>2.00</td>
<td>3.93</td>
<td>0.61</td>
<td>1.40</td>
</tr>
<tr>
<td>2. Lakdum Nala</td>
<td>69</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>4.31</td>
<td>4.00</td>
<td>4.00</td>
<td>5.18</td>
<td>0.48</td>
<td>0.5</td>
</tr>
<tr>
<td>3. Dheba Nadi</td>
<td>71</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>4.44</td>
<td>4.00</td>
<td>4.00</td>
<td>5.28</td>
<td>0.57</td>
<td>0.63</td>
</tr>
<tr>
<td>4. Saldaia Nala</td>
<td>47</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>3.92</td>
<td>6.00</td>
<td>2.00</td>
<td>5.16</td>
<td>0.55</td>
<td>0.96</td>
</tr>
<tr>
<td>5. Banjhi Amna Nala</td>
<td>73</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>5.21</td>
<td>4.67</td>
<td>3.00</td>
<td>5.98</td>
<td>0.69</td>
<td>0.77</td>
</tr>
<tr>
<td>6. Ero Nadi</td>
<td>67</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>7.25</td>
<td>4.00</td>
<td>3.00</td>
<td>7.66</td>
<td>0.72</td>
<td>1.69</td>
</tr>
<tr>
<td>7. Jurguri Nadi</td>
<td>37</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>3.70</td>
<td>3.33</td>
<td>3.00</td>
<td>4.49</td>
<td>0.76</td>
<td>1.05</td>
</tr>
<tr>
<td>8. Harmasia Nala</td>
<td>31</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>3.88</td>
<td>2.67</td>
<td>3.00</td>
<td>4.48</td>
<td>0.45</td>
<td>0.94</td>
</tr>
<tr>
<td>9. Pratappur Nala</td>
<td>38</td>
<td>11</td>
<td>2</td>
<td>1</td>
<td>3.15</td>
<td>5.50</td>
<td>2.00</td>
<td>4.74</td>
<td>0.63</td>
<td>0.91</td>
</tr>
<tr>
<td>10. Haripur Nala</td>
<td>57</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>4.07</td>
<td>4.63</td>
<td>3.00</td>
<td>5.07</td>
<td>0.66</td>
<td>1.20</td>
</tr>
</tbody>
</table>
from 2 for a flat or rolling drainage basins to 3 & 4 for mountainous or highly dissected drainage basins.

From the analysis of the data for all the sub-basins, it is clear that the bifurcation ratio is very high between lower order streams. It increases with decreasing order upholding Horton's law of stream numbers. The ratio between 1st & 2nd order in some cases is high than ratio between 2nd & 3rd order stream segments. There are exceptions where the bifurcation ratio between 2nd & 3rd order suddenly increases as is evident in case of the Saldaha Nala, Pratappur Nala and Haripur Nala (Table 12.1). The sudden increase in the ratio may be attributed to sudden decrease of streams of higher order. This is due to undulating topography made by the Dubrajpur sandstones & shales probably.

It is also observed (Table 12.1) that the large basins have higher value of bifurcation ratio than smaller basins. These mean values of bifurcation ratio are not very helpful index in understanding the laws of drainage structure. The change of certain relationship is obviously because of time-lapse which promotes drainage integration and many of the first generation streams disappear. Thus time as a factor in the development of tributaries considerably lessens the value of bifurcation ratio as an index for comparative study of drainage networks. The structural features and age of the
basin determine how far the Horton's laws are applicable to the present study.

(3) The weighted mean bifurcation ratio calculated for each drainage basin varies from 3.93 for the Bagmar Nala to 7.66 for the Ero Nadi. These variations in the weighted mean bifurcation ratio reflect the difference in configuration, structure and climate of the drainage system. The interesting point to note here is that the values for most of the basins fluctuate around 5.

(4) It is apparent from the table 12.1 that the first order channel segments have, on the average, the shortest stream length in each drainage basin and mean length increases as the order decreases, but it is not a constant ratio. Mean lengths of the stream segments of each order show that the mean length of the first order segments is fluctuating around 0.60 Km. It is 0.76 Km. for the Jurguri Nadi as highest and 0.48 Km. as lowest for the Lakdom Nala. The mean length of channel segments of the second order ranges between 1.69 Km. for the Ero Nadi and 0.63 Km. for the Dheba Nadi. For the third order stream segments it ranges between 1.44 Km. for the Dheba Nadi and 4.50 Kms. for the Ero Nadi. In the 4th order the mean length of the stream segments ranges between 1.25 Km. for the Bagmar Nala and 10.50 Kms. for the Ero Nadi.

The data calculated for cumulative mean length of each
order have been plotted on semi-logarithmic graph paper (Fig. 12.3). It shows that cumulative mean length increases as the order increases, as an approximate geometric progression. It is also noted by Horton.

(5) The calculated average circularity ratio (C) for selected sub-basins of the Brahmani Basin stands at 0.67 whereas the entire Brahmani basin registers a low circularity ratio of 0.25.

The ratio varies from one basin to another. It is noted that it is high in case of the Barmasia Nala, Lakdam Nala and Jhurguri Nadi, but all these sub-catchments are high in elevation, and they still require more time for denudation. On the basis of the circularity ratio, these basins would be considered of mature and late mature stage; but it is not the reality. So, this parameter does not help us in understanding the landscape evolution in all the case. The ratio may deviate owing to geologic structure and other factors. So, other parameters should be kept in view before concluding anything. In case of the Brahmani Basin, however, it is close to the reality; because a major portion of the Basin is high and undulating in elevation and relief.

(6) Table 12.2 shows that the maximum value of elongation ratio (E) is obtained by the Jhurguri Nadi (0.9657), followed by Barmasia Nala (0.9247), Lakdom Nala (0.8730) and
RELATIONSHIP OF STREAM NO.  
& CUMULATIVE MEAN LENGTH 
TO STREAM ORDER

<table>
<thead>
<tr>
<th>STREAM ORDER</th>
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<th>STREAM ORDER</th>
<th>STREAM ORDER</th>
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</thead>
</table>

FIG. 12.3
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Drainage Basins</th>
<th>Circularity Ratio (C)</th>
<th>Elongation Ratio (H)</th>
<th>Channel gradient (m/km)</th>
<th>Drainage density (D)</th>
<th>Stream frequency (F)</th>
<th>Constant of channel maintenance (S4, m/m)</th>
<th>Hypsometric Integral</th>
<th>Total Area (Km²)</th>
<th>F/H²</th>
<th>Relief Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bagmar Nala</td>
<td>0.8660</td>
<td>0.8076</td>
<td>17.67</td>
<td>1.09</td>
<td>1.61</td>
<td>920</td>
<td>0.59</td>
<td>15.50</td>
<td>1.36</td>
<td>0.0121</td>
</tr>
<tr>
<td>2.</td>
<td>Lakdom Nala</td>
<td>0.7950</td>
<td>0.8730</td>
<td>21.47</td>
<td>1.86</td>
<td>3.56</td>
<td>530</td>
<td>0.42</td>
<td>25.30</td>
<td>0.96</td>
<td>0.0163</td>
</tr>
<tr>
<td>3.</td>
<td>Dheba Nadi</td>
<td>0.5550</td>
<td>0.5925</td>
<td>11.09</td>
<td>1.39</td>
<td>2.76</td>
<td>720</td>
<td>0.47</td>
<td>33.36</td>
<td>1.43</td>
<td>0.0060</td>
</tr>
<tr>
<td>4.</td>
<td>Saidaha Nala</td>
<td>0.6058</td>
<td>0.6770</td>
<td>33.67</td>
<td>1.78</td>
<td>3.06</td>
<td>560</td>
<td>0.53</td>
<td>20.25</td>
<td>0.96</td>
<td>0.0277</td>
</tr>
<tr>
<td>5.</td>
<td>Banjhi Amba Nala</td>
<td>0.5812</td>
<td>0.6128</td>
<td>40.00</td>
<td>2.20</td>
<td>3.42</td>
<td>450</td>
<td>0.59</td>
<td>26.63</td>
<td>0.71</td>
<td>0.0364</td>
</tr>
<tr>
<td>6.</td>
<td>Ero Nadi</td>
<td>0.3683</td>
<td>0.4522</td>
<td>13.64</td>
<td>1.37</td>
<td>1.78</td>
<td>730</td>
<td>0.71</td>
<td>58.01</td>
<td>0.95</td>
<td>0.0109</td>
</tr>
<tr>
<td>7.</td>
<td>Jurquri Nadi</td>
<td>0.7043</td>
<td>0.9647</td>
<td>49.13</td>
<td>1.44</td>
<td>1.93</td>
<td>690</td>
<td>0.27</td>
<td>26.38</td>
<td>0.93</td>
<td>0.0425</td>
</tr>
<tr>
<td>8.</td>
<td>Barmasia Nala</td>
<td>0.9957</td>
<td>0.9247</td>
<td>48.57</td>
<td>2.00</td>
<td>4.00</td>
<td>500</td>
<td>0.88</td>
<td>10.75</td>
<td>1.00</td>
<td>0.0395</td>
</tr>
<tr>
<td>9.</td>
<td>Pratappur Nala</td>
<td>0.6570</td>
<td>0.6396</td>
<td>40.00</td>
<td>1.71</td>
<td>2.88</td>
<td>560</td>
<td>0.34</td>
<td>18.08</td>
<td>0.96</td>
<td>0.0269</td>
</tr>
<tr>
<td>10.</td>
<td>Haripur Nala</td>
<td>0.5952</td>
<td>0.5914</td>
<td>21.11</td>
<td>1.59</td>
<td>2.26</td>
<td>630</td>
<td>0.34</td>
<td>33.25</td>
<td>0.89</td>
<td>0.0206</td>
</tr>
</tbody>
</table>
Bagmar Nala (0.8076). These high figures indicate that in comparison to other basins, these four basins are somewhat close to circular in shape. The minimum value is obtained by the Ero Nadi (0.4522), followed by the Dheba Nadi (0.5925), Haripur Nala (0.6128), which shows that these basins are comparatively more elongated in shape. Other drainage sub-basins show intermediate values ranging from 0.6396 for the Pratappur Nala to 0.6770 for the Saldaha Nala. The Brahmani Basin registers a low elongation ratio (0.41) indicating most elongated in shape. In fact, the geologic structure is responsible for these variations.

(7) Relief of the river basin is analysed by relief ratio. 'The relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on slopes of the basin' (Fairbridge, 1968, p.907). The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm, 1956, p.112).

Hence,

\[
\text{Relief Ratio} = \frac{\text{Total relief of the basin}}{\text{Basin length}} = \frac{H}{L_b}
\]

Where,

- \(H\) - total relief of the basin
- \(L_b\) - basin length
Table 12.2 reveals that the relief ratio is higher in the sub-basins of the Jurguri Nadi (0.0425), Banjhi Amba Nala (0.0364), Saldaha Nala (0.0277) & Pratappur Nala (0.0269). It indicates early mature stage of erosion. These valleys preserve steep slope with a high declivity towards the downstream catchment. The Dheba Nadi, Barmasia Nala & Ero Nadi exhibit lower relief ratio. All of these indicate the apparent gradational stage of erosion. Other basins have moderate relief ratio which varies from 0.0121 for the Bagmar Nala to 0.0163 for the Lakdom Nala indicating mature stage of erosion.

(8) The stream channel slope of the ten sub-basins has been calculated to understand channel slope characteristics. The channel gradient of these basins ranges from 49.13 m/km to 13.69 m/km. The Juruguri Nadi, Barmasia Nala, Pratappur Nala, Banjhi Amba Nala & Saldaha Nala show high value of channel gradient. They have more or less straight courses. The Dheba Nadi having high relative relief shows low channel gradient (13.09 m/km.). This is due to the meandering nature of the river which increases the stream length beyond the basin length. Remaining selected basins show comparatively lower gradient value which indicates that these rivers flow with gentle to medium channel gradient. These lower figures are due to the meandering nature of the rivers and greater rolling nature of the surface.
From the low gradient of streams it can be assumed that rivers have attained almost maturity or old stage. But this is not the case as is evident from the hypsometric integrals. These integral values range from 0.88 to 0.34 except one at the Jurguri Nadi, where integral drops to 0.27. With this value we generally infer sequential phases of landform development in a basin. But in the present study (like the Dheba Nadi and the Bro Nadi) the H.I. values are very high suggesting of the youth stage, but channel gradient values do not support the idea. It seems that structure and tectonic features have controlled over it.

(9) Drainage density, calculated for each drainage basin, ranges between 1.09 km/sq.km. for the Bagmar Nala to 2.20 km/sq.km. for the Banjhi Amba Nala. Accordingly the Banjhi Amba Nala and Barmasia Nala are graded as fine textured basins. Remaining selected basins show comparatively very coarse texture. These variations are because of lithology, structure, nature of rocks in the drainage basins and declivity together.

(10) Stream frequency calculated for each basins varies from 4.00 for the Barmasia Nala to 1.61 for the Bagmar Nala.

The relationship \((F/D^2)\) is for maturely dissected region. While evaluating this relationship of the ten drainage
sub-basins selected for the study, the author observed that in the Dheba Nadi and Bagmar Nala it approaches to 1.43 and 1.36 respectively (Table 12.2). This suggests that these basins are almost dissected compared to other basins. All basins show $F/D^2$ ratio above 0.60. On an average these high values suggest the nature of maturity of the basins.

(11) Like drainage density, the constant of channel maintenance varies from one area to another. The value is lowest in relatively more steeper portion of the major Basin on which basins like Banjhi Amba Nala, Barmasia Nala, Saldaha Nala and Pratappur Nala have developed. On these basins the value ranges from 450 sq. metres of watershed per one linear metre of channel to 580 sq. metres/metre. The high C.C.M. value is observed in the Bagmar Nala, the Ero Nadi & the Dheba Nadi, which reveals monotonous terrain condition with ground slope less than one degree. The high C.C.M. is observed near the source area (Jurguri Nadi) of the major Basin Brahmani. This high elevation planated surface has developed high C.C.M. values, while the low value of C.C.M. in the lower part of the major streams (Lakdom Nala & Haripur Nala) indicates higher slopes, though at lower elevation zone. It is either by tectonic activity or by rejuvenation processes.

(12) The hypsometric integrals calculated from the percentage hypsometric curves (Fig. 12.4) give accurate
SELECTED SAMPLE BASINS

THE BRAHMANI BASIN

HYPSOMETRIC CURVES FOR SELECTED DRAINAGE BASINS

HYPSOMETRIC INTEGRAL IN %

h/H - RELATIVE HEIGHT

a/A - RELATIVE AREA

1. BAGMAR NALA
   59%

2. LUKDUM NALA
   42%

3. DHEBA NADI
   47%

4. SALDAHA NALA
   53%

5. BANJHI AMBA NALA
   59%

6. ERO NADI
   71%

7. JURGURI NADI
   27%

8. BARMASIA NALA
   88%

9. PRATAPPUR NALA
   34%

10. HARIPUR NALA
    34%

FIG. 12.4
knowledge of the stages of cycle of dissection. These curves are the best quantitative techniques to interpret the basin form qualities and hence the geomorphic stage of development of drainage basin. Percentage hypsometric curves have its practical application in different branches of earth’s sciences, e.g. hydrology, soil erosion & sedimentation studies, military science and engineering sciences etc. (Strahler, 1952, pp. 1117-1142).

These hypsometric curves are drawn here by involving two ratios, relative height \( h/H \) and relative area \( a/A \); where \( h \) is the height of the contour above the base of the basin concerned and \( H \) is the total height of the same basin plotted on the ordinate and \( a \) is the area enclosed by corresponding \( h \). \( A \) represents the total basin area plotted on the abscissa (Fig. 12.4). The hypsometric curves drawn here show in proportionate area below the curve, termed as hypsometric integral. The following integral scales may be suggested for the recognition of the stages (Singh & Srivastava, 1976, p. 35).

<table>
<thead>
<tr>
<th>% of Hypsometric integrals</th>
<th>Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 30%</td>
<td>Old</td>
</tr>
<tr>
<td>30% to 60%</td>
<td>Mature</td>
</tr>
<tr>
<td>Above 60%</td>
<td>Youth</td>
</tr>
</tbody>
</table>

Hypsometric integrals calculated for each sample drainage basins (Fig. 12.4 & Table 12.2) separately show
that most of the basins i.e. the Bagmar Nala, Banjhi Amba Nala, Dheba Nadi and Saldaha Nala are passing through the early mature stage having integrals between 47% for the Dheba Nadi to 59% for the Bagmar Nala & Banjhi Amba Nala. The Lakdom Nala, Pratappur Nala and Haripur Nala exhibit the stage of late maturity, the integrals of which range between 34% for the Pratappur Nala & Haripur Nala to 42% for the Lakdom Nala. Only one basin, i.e., the Jurguri Nadi is passing through old stage of geomorphic development having hypsometric integrals 27%, while two basins, i.e., the Barmasia Nala & the Ero Nadi exhibit youth stage having the integrals of 88% and 71% respectively.

12.3. RELATIONSHIP OF STREAM NUMBER & CUMULATIVE MEAN LENGTH TO STREAM ORDER

It is fairly well established that number and mean length of the streams are a function of their order. In normal circumstances both the number and the mean length are exponential function of order of streams, the differences being that while the number has an inverse relationship, the mean length has a direct relationship with the order.

The ten selected sample sub-basins of the Brahmani Basin have been investigated to see whether this relationship does exist. The line drawn on the basis of regression equation
(Yc = ab^X or Log Yc = Log a + Log b X) on semi-log graph for different basins (Fig. 12.3) show the following:

(a) The regression lines do not exactly coincide with plotted points.

(b) In some cases they are parallel or almost parallel.

The regression equation representing each river basin is determined by size of the basins and the nature and degree of tributary development. The parallel lines reveals that basins of different sizes are of the same order.

12.4. SIMPLE & MULTIPLE RELATIONSHIP OF TOTAL BASIN AREA WITH GEOMORPHIC DRAINAGE NETWORK VARIABLES

The quantitative method to analyse the morphometric characteristics of the fluvial landforms was initiated by Horton (1945). Following Horton's law considerable work on the quantitative analysis of the morphometric characteristics of the drainage basins has been done in U.S.A. by Strahler (1952, 57), Schumm (1956) and Morisawa (1962) & in India by Ghose, et al (1967, 69) and Singh et al (1969-71,73). Interrelationships between quantitative geomorphic variables of the drainage basins by developing mathematical models have been established by Singh et.al. (1969-71, pp.1-11), Singh & Ghose (1973, pp.82-99), Singh (1976, pp.54-57) & Rastogi &
Jones, Jr. (1969). But there is very little work on the multiple relationships among the quantitative geomorphic variables of the drainage basins, which play a significant role in the watershed management. Keeping in view the importance of such studies Singh, Gupta & Kaith (1976, pp.151-156), Singh, Ghose, Gupta & Kaith (1977, pp.143-151) have discussed the multiple relationship among the morphometric variables.

Following some of the methods simple and multiple quantitative relationship between geomorphic variables of the selected sample drainage basins have been calculated to find out relationship, if any.

12.4.1. MEASURES OF CENTRAL & DISPERSAL TENDENCIES

The measures of central & dispersal tendencies, i.e., the range, mean and coefficient of variation of the different geomorphic variables have been worked out and given in Table 12.3.

From the Table 12.3, it is clear that there is appreciable variation in the value of range, mean and coefficient of variation of the morphometric variables. The total number of streams has the maximum range values and the number of 3rd order stream has minimum value of range. Total number of streams and number of third order streams have the highest and lowest mean value respectively. The coefficient of
<table>
<thead>
<tr>
<th>Variables</th>
<th>Range</th>
<th>Mean</th>
<th>Co-efficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total basin area in Sq. Km. (A)</td>
<td>10.75 - 58.01</td>
<td>26.75</td>
<td>46.77</td>
</tr>
<tr>
<td>Length of the 1st order streams in Km. (L₁)</td>
<td>7.72 - 48.10</td>
<td>32.74</td>
<td>46.08</td>
</tr>
<tr>
<td>Length of the 2nd order streams in Km. (L₂)</td>
<td>5.10 - 14.65</td>
<td>11.93</td>
<td>33.00</td>
</tr>
<tr>
<td>Length of the 3rd order streams in Km. (L₃)</td>
<td>2.65 - 9.50</td>
<td>7.79</td>
<td>40.04</td>
</tr>
<tr>
<td>Number of 1st order streams (N₁)</td>
<td>17.00 - 87.00</td>
<td>52.70</td>
<td>40.02</td>
</tr>
<tr>
<td>Number of 2nd order streams (N₂)</td>
<td>5.00 - 14.00</td>
<td>11.80</td>
<td>28.67</td>
</tr>
<tr>
<td>Number of 3rd order streams (N₃)</td>
<td>2.00 - 4.00</td>
<td>2.90</td>
<td>24.14</td>
</tr>
<tr>
<td>Total stream length in Km. (L)</td>
<td>16.85 - 79.35</td>
<td>42.82</td>
<td>35.56</td>
</tr>
<tr>
<td>Total number of streams (N)</td>
<td>25.00 - 103.00</td>
<td>68.40</td>
<td>40.83</td>
</tr>
</tbody>
</table>
variation is the highest for the total basin area and the lowest for the number of 3rd order streams.

Coefficient of variation suggests wide variation in area. The mean area is about 26.75 sq. km. Except three basins (Ero Nadi, Dheba Nadi & Haripur Nala) all the basins have areas less than 26.75 sq. km. It is difficult to explain such variation with the limited knowledge of geological, lithological and tectonic information. But it can be inferred that such variation is possible due to the variation of drainage development. The highest area of the Ero Nadi records the highest stream length and stream number and second highest area of the Dheba Nadi has second highest stream length. Both the streams are flowing on planated surfaces of different slopes, so it may have some impact on the area of the basin. It is likely to develop greater area after considerable lapse of time.

The length of the different orders of streams does vary considerably when we consider the C.V. of the length of different orders. The maximum variation is seen in the first order stream (46.08%) of the basin and the least variation is observed in 2nd order streams (33%), such wide variation of length between two succeeding stream orders, i.e., 1st & 2nd order may be due to differences in integration of drainage of the order concerned. The maximum variation is seen from the Ero Nadi, which has highest (62.50 kms.) among the first order
SIMPLE & MULTIPLE RELATIONSHIP

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streams. This stream is perhaps well integrated to explain such high length value although there are other considerations like joints & lithological characters.

As regards the variation of number of streams the differences are also wide, but it is between 1st order streams (40.02%) and 3rd order streams (24.14%).

12.4.2. SIMPLE RELATIONSHIP AMONG MORPHOMETRIC VARIABLES

The simple correlation coefficients, for different morphometric variables were worked out. The correlation matrix for independent & dependent variables are given in the Table 12.4.

It is observed from Table 12.4 Part I that although significant correlation exists between $LA$ & $LL_1$, $LL_2$, $LL_3$ but strongest degree of association is with the length of first order streams. On the other hand $LL_1$ is significantly correlated to $LL_2$ and $LL_3$ and also $LL_2$ is to $LL_3$.

It appears from Table 12.4 Part II that total basin area is correlated to $LN_2$ & $LN_3$, but not significantly at statistical level, while $LA$ is correlated with $LL_1$ significantly. On the other hand $LN_1$ is significantly correlated with $LN_2$ & $LN_3$ and also $LN_2$ with $LN_3$. In Part III of the Table 12.4 $LA$ and $LL$ are correlated significantly than $LN$ & $LL$. 
<table>
<thead>
<tr>
<th></th>
<th>Part I</th>
<th></th>
<th>Part II</th>
<th></th>
<th>Part III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\xi A$</td>
<td>$\xi L_1$</td>
<td>$\xi L_2$</td>
<td>$\xi N_1$</td>
<td>$\xi N_2$</td>
</tr>
<tr>
<td>$\xi A$</td>
<td>1.0000</td>
<td>0.8957*</td>
<td>0.8497*</td>
<td>0.7720*</td>
<td>1.0000</td>
</tr>
<tr>
<td>$\xi L_1$</td>
<td>-</td>
<td>1.0000</td>
<td>0.7756*</td>
<td>0.8123*</td>
<td>-</td>
</tr>
<tr>
<td>$\xi L_2$</td>
<td>-</td>
<td>-</td>
<td>1.0000</td>
<td>0.8107*</td>
<td>-</td>
</tr>
<tr>
<td>$\xi L_3$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0000</td>
<td>$\xi N_1$</td>
</tr>
</tbody>
</table>

* Significant at 1 percent probability level

** Significant at 5 percent probability level
12.4.3. MULTIPLE RELATIONSHIP AMONG MORPHOMETRIC VARIABLES

Multiple relationship among total basin area and geomorphic drainage network variables have been established and are given in Table 12.5. The Table 12.5 shows the relationships between $\ell A$ with $\ell L_1$ & $\ell L_2$, $\ell A$ with $\ell L_1$ & $\ell L_3$ and $\ell A$ with $\ell L_1$, $\ell L_2$ & $\ell L_3$. Again it shows the relationship between $\ell A$ with $\ell N_1$ & $\ell N_2$, $\ell A$ with $\ell N_2$ & $\ell N_3$ and $\ell A$ with $\ell N_1$, $\ell N_2$ & $\ell N_3$.

The order of relative contribution of $\ell L_1$, $\ell L_2$ for explaining the variances in $\ell A$ has been determined by regression equation and, coefficients of determination ($R^2$) (Snedecor & Cochran, 1968, pp.381-418) are presented in the Table 12.6.

It is seen from the Table 12.6 that the variation in $\ell A$ explained by $\ell L_1$ alone is 80.23%, while $\ell L_1$ & $\ell L_2$ jointly explain the variation of 86.19%. The relative rate of contribution of length has also been quantified by computing the rate of increment in the coefficient of determination ($R^2$). The value is small one (0.0596). Hence with the data available it may be concluded that the length of first and 2nd order streams have sufficient control on the development of the area of the basin. However, such analysis may differ when we put other variables in such analysis.
### TABLE 12.5

**MULTIPLE RELATIONSHIP AMONG MORPHOMETRIC VARIABLES**

Multiple Relationship among total Basin area and the length of the Different Order Streams

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Step up equation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Step I</td>
</tr>
<tr>
<td>1.</td>
<td>$f_A = 2.3997 + 0.7437 L_1$</td>
</tr>
<tr>
<td></td>
<td>Step II</td>
</tr>
<tr>
<td>2.</td>
<td>$f_A = -3.9880 + 0.4939 L_1 + 1.2220 L_2$</td>
</tr>
<tr>
<td>3.</td>
<td>$f_A = 1.2378 + 0.6551 L_1 + 0.5121 L_2$</td>
</tr>
<tr>
<td></td>
<td>Step III</td>
</tr>
<tr>
<td>4.</td>
<td>$f_A = -4.6153 + 0.4430 L_1 + 1.1942 L_2 + 0.3304 L_3$</td>
</tr>
</tbody>
</table>

Multiple Relationship among total Basin area and the Number of the Different Order Streams

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Step up equation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Step I</td>
</tr>
<tr>
<td>1.</td>
<td>$f_A = 1.6836 + 0.4756 N_1$</td>
</tr>
<tr>
<td></td>
<td>Step II</td>
</tr>
<tr>
<td>2.</td>
<td>$f_A = -20.5967 + 0.4981 N_1 + 1.7880 N_2$</td>
</tr>
<tr>
<td>3.</td>
<td>$f_A = 8.5903 + 0.5523 N_1 - 3.7745 N_2$</td>
</tr>
<tr>
<td></td>
<td>Step III</td>
</tr>
<tr>
<td>4.</td>
<td>$f_A = -35.3050 + 2.9328 N_1 + 18.8833 N_2 - 108.7323 N_3$</td>
</tr>
</tbody>
</table>
### TABLE 12.6

RELATIVE CONTRIBUTION OF LENGTH OF DIFFERENT STREAMS ORDERS EXPLAINING THE VARIANCE IN TOTAL BASIN AREA

<table>
<thead>
<tr>
<th>Equation</th>
<th>R</th>
<th>R²</th>
<th>Rate of increment in R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $A = 2.3997 + 0.7437 L_1$</td>
<td>0.8957</td>
<td>0.8023</td>
<td>-</td>
</tr>
<tr>
<td>2. $A = -3.9880 + 0.4939 L_1 + 1.2220 L_2$</td>
<td>0.9284</td>
<td>0.8619</td>
<td>0.0596</td>
</tr>
</tbody>
</table>
REFERENCES


REFERENCES


