Morphometric Analysis of a Phulambri River Drainage Basin (Gp8 Watershed), Aurangabad District (Maharashtra) using Geographical Information System

Tribhuvan, P.R. and Sonar, M.A.

Govt. Institute of Science, Nipat Niranjan Nagar, Caves Road, Aurangabad, Maharashtra, India

Publication Date: 27 June 2016

DOI: https://doi.org/10.23953/cloud.ijarsg.62

Abstract

Geographical information system (GIS) has emerged as a professional tool in demarcation of drainage pattern and ground water potential and its planning. GIS and image processing techniques can be utilized for the identification of morphological characteristics and investigating properties of basin. The present study deals mainly with the geometry, more importance being given on the evaluation of morphometric parameters such as stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), and form factor ratio (Rf) etc. Study area is Phulambri river basin located in Aurangabad district of Maharashtra state in India. The GIS based Morphometric analysis of this drainage basin revealed that the Girja-Purna is 6th order drainage basin and drainage pattern mainly in dendritic type thereby indicates homogeneity in texture and lack of structural control. Total number of streams is 1616, in which 895 are first order, 391 are second order, 196 are third order and 97 are fourth order streams and 36 of the fifth order and 1 of the sixth order. The length of stream segment is maximum for first order stream and decreases as the stream order increases. The drainage density (Dd) of study area is 0.030 km/km².

Keywords

Morphometric Analysis; Girija-Purna Basin; GIS; Aurangabad District; Maharashtra

1. Introduction

The present paper describes the drainage characteristics of Phulambri area in Aurangabad district obtained through RS GIS based morphometric analysis. It is felt that the study will be useful to understand hydrological behavior of basin. The area under study is located in Girja-Purna river basin in Aurangabad district, Maharashtra, situated between North Latitude 20°10’ and 75°25’, and East Longitude 20°0’ and 75°30’ (Figure 1a & b). It covers an area of 227.5 sq.km. The average annual rainfall in this area is about 500mm to 840mm and temperature goes up to 40°C in summer and comes down to 10.3°C in winter season. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the tributaries etc. (Rastogi et al., 1976). Remote sensing data can be used
in conjunction with conventional data for delineation of characterization, problem identification, assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selection of sites for check dams and reservoirs etc., (Dutta et al., 2002).

Figure 1a: Location Map of Phulambri River Area Showing GP8 Watershed
2. Materials and Methods

2.1. Geology

The whole area is covered by Deccan trap lava flows of upper cretaceous to lower Eocene age (Figure 2). The basaltic lava flows are covered with thin alluvial deposits along the Kham and Sukhna River. These flows belonging to the Deccan trap is the single major geological formation present in Aurangabad. The flows are gently inclined or nearly horizontal and each flow has two different components. The upper portion is made up of vesicular and amygdaloidal basalt whereas the lower portion is of compact basalt. The lava flows individually diverse in their ability to receive as well as hold water in storage and to transmit it. The difference in productivity of ground water in various flows occurs as a result of their inherent physical characters such as porosity and permeability. The ground water is present in the zone of saturation and is mostly controlled by the extent of its secondary porosity i.e. thickness of weathered rock and spacing of joints and fractures. The highly weathered vesicular basalt and lower jointed and fractured compact basalt contains the ground water potential zone (Water Res. Rep., 2015).

2.2. Methodology

The total study area is demarcated from Survey of India toposheets no. 46 p/8, 46 p/12 and 47 m/5 on 1:50000 scale with the help of Arc-GIS-10. Morphometric analysis of a drainage pattern needs the demarcation of all the existing streams. Digitization of the drainage basin was carried out for morphometric analysis in GIS environment using Arc GIS-10 software. The attributes were allocated to generate the digital data base for drainage layer of the river basin. Various morphometric parameters
such as linear aspects and aerial aspects of the drainage basin were computed. Digitization work was carried out for complete analysis of drainage morphometry. The diverse morphometric parameters have been determined as shown in Table 4.

3. Results and Discussion

The subsequent subsections illustrate the substantial significance of various morphometric parameters. Further values of these parameters are obtained as per methods proposed by various researchers for the study area and indicated in respective descriptions. The morphometric analysis of the Gp-8 watershed was carried out on the Survey of India topographical maps. The lengths of the streams, areas of the watershed were measured by using ArcGIS-10 software, and stream ordering has been generated using Strahler (1953) system, and in ArcGIS-10 software. The linear aspects were studied using the methods of Horton (1945), Strahler (1953), Chorley (1957), the areal aspects using those of Schumm (1956), Strahler (1956, 1968), Miller (1953), and Horton (1932), and the relief aspects employing the techniques of Horton (1945), Melton (1957), Schumm (1954), Strahler (1952), and Pareta (2004). The average slope analysis of the watershed area was done using the Wentworth (1930) method. The Drainage density and frequency distribution analysis of the watershed area were done using the spatial analyst tool in ArcGIS-10 software.

3.1. Linear Aspects

3.1.1. Stream Order (Su)

There are four different system of ordering streams that are available (Gravelius, 1914; Horton, 1945; Strahler, 1952; Schideggar, 1970). Strahler’s system, which is a slightly modified of Hortons system, has been followed because of its simplicity, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the stream segment of highest order. It is found that Godavari river tributaries are of 6th order. In all 1616 streams were identified of which 895 are first order, 391 are second order, 196 are third order, and 97 in fourth order and36 of the fifth order,1of sixth order. Drainage patterns of stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control. The properties of the stream networks are very important to study basin characteristics (Strahler, 2002).
3.1.2. Stream Length (Lu)

The stream length (Lu) has been calculated on the basis of the Horton's law. Stream length is one of the most important hydrological characters of the area as it gives information about surface runoff characteristics. The river of fairly smaller length is characteristics of regions with steep slopes and better textures. Rivers having longer lengths are commonly suggestive of smoother slope. In general, the total length of river section is highest in first order stream and the length is inversely proportional to the stream order. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. The length of first order stream is 407.7 Km, second order stream is 135.2 Km, third order stream is -67.7 Km, and fourth order stream is 41.5 Km, fifth order stream 39.25 Km, and sixth order stream 30.8 Km. The change may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes (Singh, 1997). The examination of stream order validates the Horton's law of stream number i.e. the number of stream segment of each order forms an inverse geometric sequence with order number.

![Stream Length Vs Stream Order](image.png)

3.1.3. Mean Stream Length (Lum)

The mean stream length is a characteristic property related to the drainage network and its associated surfaces (Strahler, 1964). The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of stream. The mean stream length of first order stream is 455.5 Km, second order stream is 346.0 Km, third order stream is 345.5 Km, and fourth order stream is 428.2 Km and 1090.3 Km, 30872 Km. The mean stream length of stream increases with increase of the order.

3.1.4. Stream Length Ratio (Lurm)

Horton (1945, 291) states that the length ratio is the ratio of the mean (Lu) of segments of order (So) to mean length of segments of the next lower order (Lu-1), which tends to be constant throughout the successive orders of a basin. His law of stream lengths refers that the mean stream lengths of stream segments of each of the successive orders of a watershed tend to approximate a direct geometric sequence in which the first term (stream length) is the average length of segments of the first order (Table 2). Changes of stream length ratio from one order to another order indicating their late youth stage of geomorphic development (Singhand Singh, 1997).
Table 1: Stream Order, Streams Number, and Bifurcation Ratios in Gp-8 Watershed

<table>
<thead>
<tr>
<th>Su</th>
<th>Nu</th>
<th>Rb</th>
<th>Nu-r</th>
<th>Rb * Nu-r</th>
<th>Rbwm</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>895</td>
<td>2.28</td>
<td>1286</td>
<td>2,932.08</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>391</td>
<td>1.99</td>
<td>587</td>
<td>1,168.13</td>
<td>2.126</td>
</tr>
<tr>
<td>III</td>
<td>196</td>
<td>2.02</td>
<td>293</td>
<td>591.86</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>97</td>
<td>2.69</td>
<td>133</td>
<td>357.77</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>36</td>
<td>1.63</td>
<td>58</td>
<td>94.54</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>2.126</td>
</tr>
<tr>
<td>Total</td>
<td>1616</td>
<td>10.63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Su: Stream order, Nu: Number of streams, Rb: Bifurcation ratios, Rbm: Mean bifurcation ratio*, Nu-r: Number of stream used in the ratio, Rbwm: Weighted mean bifurcation ratios

Figure 2: Map Showing Drainage Orders in GP-8 Watershed Area
### Table 2: Stream Length, and Stream Length Ratio in Gp-8 Watershed

<table>
<thead>
<tr>
<th>Su</th>
<th>Lu</th>
<th>Lu/su</th>
<th>Lur</th>
<th>Lur-r</th>
<th>Lur*r-Lur-r</th>
<th>Luwm</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>407.70</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>135.29</td>
<td>0.34</td>
<td>0.75</td>
<td>542.99</td>
<td>3,676.04</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>67.73</td>
<td>0.34</td>
<td>1</td>
<td>203.02</td>
<td>1,374.44</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>41.53</td>
<td>0.42</td>
<td>1.23</td>
<td>109.26</td>
<td>739.69</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>39.25</td>
<td>1.09</td>
<td>2.59</td>
<td>80.78</td>
<td>546.88</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>30.87</td>
<td>30.87</td>
<td>28.32</td>
<td>70.12</td>
<td>474.71</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>722.37</td>
<td>33.51</td>
<td>33.89</td>
<td>1,006.17</td>
<td>6,811.76</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>6.77*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Su: Stream order, Lu: Stream length, Lur: Stream length ratio, Luwm: Mean stream length ratio

#### 3.1.5. Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumm, 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is not the same from one order to its next order. In the study area mean Rb varies from 1.63 to 2.28; the mean Rb of the entire basin is 2.126. Usually these values are common in the areas where geologic structures less disturbing the drainage pattern.

#### 3.1.6. Weighted Mean Bifurcation Ratio (Rbwm)

To arrive at a more representative bifurcation number Strahler (1953) used a weighted mean Bifurcation ratio obtained by multiplying the bifurcation ratio for each successive pair of orders by the total numbers of streams involved in the ratio and taking the mean of the sum of these values. Schumm (1956, 603) has used this method to determine the mean bifurcation ratio of the value of 2.12 of the drainage of Perth Amboy, N.J. The values of the weighted mean bifurcation ratio this determined are very close to each other (Gp-8 watershed) Table 1.

#### 3.1.7. Rho Coefficient ($\rho$)

The Rho coefficient is an important parameter relating drainage density to physiographic development of a watershed which facilitate evaluation of storage capacity of drainage network and hence, a determinant of ultimate degree of drainage development in a given watershed (Horton, 1945). The climatic, geologic, biologic, geomorphologic, and anthropogenic factors determine the changes in this parameter. Rho value of the Gp-8 watershed is 3.19. This is suggesting higher hydrologic storage during floods and attenuation of effects of erosion during elevated discharge.

### 3.2. Basin Geometry

#### 3.2.1. Length of the Basin (Lb)

Several people defined basin length in different ways, such as Schumm (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. Gregory and Walling (1973) defined the basin length as the longest in the basin in which an end being the mouth. Gardiner (1975) defined the basin length as the length of the line from a basin mouth to a point on the perimeter equidistant from the basin mouth in either direction around the perimeter. The author has determined length of the Gp-8 watershed in accordance with the definition of Schumm (1956) that is 25.80 Kms.
3.2.2. Basin Area (A)

The area of the watershed is another important parameter like the length of the stream drainage. Schumm (1956) established an interesting relation between the total watershed areas and the total stream lengths, which are supported by the contributing areas. The author has computed the basin area by using ArcGIS-10 software, which is 227.5 Sq kms.

3.2.3. Basin Perimeter (P)

Basin perimeter is the outer boundary of the watershed that enclosed its area. It is measured along the divides between watershed and may be used as an indicator of watershed size and shape. The author has computed the basin perimeter by using ArcGIS-10 software, which is 96.97 Kms.

3.2.4. Length Area Relation (Lar)

Hack (1957) found that for a large number of basins, the stream length and basin area are related by a simple power function as follows: \( \text{Lar} = 1.4 \times A^{0.6} \)

3.2.5. Lemniscates (k)

Chorely (1957), express the Lemniscate’s value to determine the slope of the basin. In the formula \( k = \frac{Lb^2}{4 \times A} \). Where, \( Lb \) is the basin length (Km) and \( A \) is the area of the basin (km²). The Lemniscates (k) value for the watershed is 0.03 which shows that the watershed occupies the maximum area in its regions of inception with large number of streams of higher order.

3.2.6. Form Factor (Ff)

According to Horton (1932), form factor may be defined as the ratio of basin area to square of the basin length. The value of form factor would always be less than 0.754 (for a perfectly circular watershed). The watershed will be more stretched because the value of form factor reduces. The watershed with excessive form factors have elevated crest flows of lesser period, but lengthened watershed having minimal form factor varies from 2.03 representing them to be stretched out in shape and flow for longer period.

3.2.7. Texture Ratio (Rt)

According to Schumm (1965), texture ratio is an important factor in the drainage morphometric analysis which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. The texture ratio is expressed as the ratio between the first order streams and perimeter of the basin \( \text{Rt} = \frac{N_l}{P} \) and it depends on the underlying lithology, infiltration capacity and relief aspects of the terrain. In the present study, the texture ratio of the watershed is 9.22 and categorized as moderate in nature

3.2.8. Elongation Ratio (Re)

According to Schumm (1965, 612), elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Strahler states that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5). The elongation ratio of Gp-8 watershed is 0.60 which is represented the watershed is less elongated.
3.3. Drainage Texture Analysis

3.3.1. Stream Frequency (Fs)

The drainage frequency introduced by Horton (1932, 357 and 1945, 285) means stream frequency (or channel frequency) Fs as the number of stream segments per unit area. In the present study, the stream frequency of the Gp-8 watershed is 7.90.

3.3.2. Drainage Density (Dd)

Drainage density is the stream length per unit area in region of watershed (Horton, 1945, 243 and 1932, 357; Strahler, 1952 and 1958; Melton, 1958) is another element of drainage analysis. Drainage density is a better quantitative expression to the dissection and analysis of landform, although a function of climate, lithology and structures and relief history of the region can finally use as an indirect indicator to explain, those variables as well as the morphogenesis of landform. Author has calculated the drainage density by using Spatial Analyst Tool in ArcGIS-10, which are 3.53 Km/Km² indicating moderate drainage densities (Table 5). It is suggested that the moderate drainage density indicates the basin is moderate permeable sub-soil and thick vegetative cover (Nag, 1998).

3.3.3. Constant of Channel Maintenance (1/D)

Schumm (1956) used the inverse of drainage density or the constant of channel maintenance as a property of landforms. The constant indicates the number of Kms² of basin surface required to develop and sustain a channel 1 Km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957). Channel maintenance constant of the watershed is 0.28 Kms²/Km.

3.3.4. Drainage Intensity (Di)

Faniran (1968) defines the drainage intensity, as the ratio of the stream frequency to the drainage density. This study shows a low drainage intensity of 2.23 for the watershed. This low value of drainage intensity implies that drainage density and stream frequency have little effect (if any) on the extent to which the surface has been lowered by agents of denudation. With these low values of drainage density, stream frequency and drainage intensity, surface runoff is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides.

3.3.5. Infiltration Number (If)

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and given an idea about the infiltration characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher ran-off. The study shows 27.88 infiltration.

3.3.6. Drainage Pattern (Dp)

In the watershed, the drainage pattern reflects the influence of slope, lithology and structure. Finally, the study of drainage pattern helps in identifying the stage in the cycle of erosion. Drainage pattern presents some characteristics of drainage basins through drainage pattern and drainage texture. It is possible to deduce the geology of the basin, the strike and dip of depositional rocks, existence of faults and other information about geological structure from drainage patterns. Drainage texture reflects climate, permeability of rocks, vegetation, and relief ratio, etc. Howard (1967) related drainage patterns to geological information. Author has identified the dendritic pattern in the study area. Dendritic pattern is most common pattern is formed in a drainage basin composed of fairly homogeneous rock without
control by the underlying geologic structure. The longer the time of formation of a drainage basin is, the more easily the dendritic pattern is formed.

3.3.7. Length of Overland Flow (Lg)

Horton (1945) used this term to refer to the length of the run of the rainwater on the ground surface before it is localized into definite channels. Since this length of overland flow, at an average, is about half the distance between the stream channels, Horton, for the sake of convenience, had taken it to be roughly equal to half the reciprocal of the drainage density. In this study, the length of overland flow of the Gp-8 watershed is 73.78 Kms, which shows low surface runoff of the study area.

3.4. Relief Characterizes

3.4.1. Relief Ratio (Rhl)

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the total relief of the river basin. 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). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by Schumm who found that sediments loose per unit area is closely correlated with relief ratios. In the study area, the value of relief ratio is 11.70. It has been observed that areas with low to moderate relief and slope are characterized by moderate value of relief ratios. Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope.

3.4.2. Relative Relief (Rhp)

The maximum basin relief was obtained from the highest point on the watershed perimeter to the mouth of the stream. Using the basin relief (302m), a relief ratio was computed as suggested by Schumm (1956), which is 11.70 Melton's (1957) relative relief was also calculated using the formula: \[ R_{hp} = \frac{H \times 100}{P}, \] where \( P \) is perimeter in meters. This comes to 311.4 for Gp-8 watershed.

![Figure 3: Slope Map of GP-8 Watershed Area](image)
3.4.3. Ruggedness Number (Rn)

Strahler’s (1968) ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. Calculated accordingly, the Gp-8 watershed has a ruggedness number of 1.06. The low ruggedness value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

3.4.5. Melton Ruggedness Number (MRn)

The MRn is a slope index that provides specialized representation of relief ruggedness within the watershed (Melton, 1965). Gp-8 watershed has an MRn of 21.12. According to the classification of Wilford et al. (2004), this watershed is debris flood watersheds, where bed load component dominates sediment under transport.

3.4.6. Gradient Ratio (Rg)

Gradient ratio is an indicator of channel slope, which enables assessment of the runoff volume (Sreedevi, 2004). Watershed has an Rg of 11.70 which reflects the mountainous nature of the terrain. Approximately 83% of the main stream flows through the plateau and the relatively low values of Rg confirm the same.

3.5. Hypsometric Analysis (Hs)

Langbein et al. (1947) appear to have been the first to use such a line of study to collect hydrologic data. However, again Strahler (1952) popularized it in his excellent paper. According to Strahler (1952) topography produced by stream channel erosion and associated processes of weathering mass-movement, and sheet runoff is extremely complex, both in the geometry of the forms themselves and in the inter-relations of the processes which produce the forms. In topographic profile, the nature of hypsometric curve and the value of the integral are fundamental elements. It shows remarkable differences in areas conflicting in phase of evolution and geologic formation, since the phase of youth hypsometric integral is large but it decreases as the landscape is denuded towards a stage of maturity and old age (Strahler, 1952, 118). The author used the percentage hypsometric curve method, and calculated the hypsometric integral (Hi). In late mature and old stages of topography, despite the attainment of low relief, the hypsometric curve shows no significant variations from the mature form, and a low integral results only where monadnock remain. After monadnock masses are removed, the hypsometric curve may be expected to revert to a middle position with integrals in the general range of 40 to 60 percent. (Strahler, 1952B, 1129-1130.) In the present study hypsometric integral (Hi) is 50.00, which indicate that the basin is in early mature stage.

Table 3: Hypsometric Data of Hypsometric Integrals

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Altitude range (m)</th>
<th>Height (m) h</th>
<th>Area (Km²) a</th>
<th>h /H</th>
<th>a /A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>900</td>
<td>301</td>
<td>7.5</td>
<td>0.006</td>
<td>0.03</td>
</tr>
<tr>
<td>2.</td>
<td>800</td>
<td>181</td>
<td>62.5</td>
<td>0.59</td>
<td>0.27</td>
</tr>
<tr>
<td>3.</td>
<td>700</td>
<td>81</td>
<td>50.6</td>
<td>0.26</td>
<td>0.22</td>
</tr>
<tr>
<td>4.</td>
<td>680</td>
<td>61</td>
<td>54.7</td>
<td>0.20</td>
<td>0.24</td>
</tr>
<tr>
<td>5.</td>
<td>660</td>
<td>41</td>
<td>40</td>
<td>0.13</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Where, Maximum Height of the Basin = (Z) m, Height of Basin Mouth= (z) m Total Basin Relief=(H)m

**Figure 4: Hypsometric Curve of the Study Area**

### 3.6. Comparison of Drainage Basin Characteristics

The details of the morphometric analysis and comparison of drainage basin characteristics of Gp-8 watershed is present in Table 4.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Morphometric Parameter</th>
<th>Formula</th>
<th>Reference</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stream Order (Su)</td>
<td>Hierarchical Rank</td>
<td>Strahler (1952)</td>
<td>1 to 6</td>
</tr>
<tr>
<td>2</td>
<td>1st Order Stream (Suf)</td>
<td>Suf = N1</td>
<td>Strahler (1952)</td>
<td>895</td>
</tr>
<tr>
<td>3</td>
<td>Stream Number (Nu)</td>
<td>Nu = N1+N2+...+Nn</td>
<td>Horton (1945)</td>
<td>1616</td>
</tr>
<tr>
<td>4</td>
<td>Stream Length (Lu) Kms</td>
<td>Lu = L1+L2+...+Ln</td>
<td>Strahler (1964)</td>
<td>722.37</td>
</tr>
<tr>
<td>5</td>
<td>Stream Length Ratio (Lur)</td>
<td>see Table 1</td>
<td>Strahler (1964)</td>
<td>0.7 to 28.3</td>
</tr>
<tr>
<td>6</td>
<td>Mean Stream Length Ratio (Lurm)</td>
<td>see Table 1</td>
<td>Horton (1945)</td>
<td>6.77</td>
</tr>
<tr>
<td>7</td>
<td>Weighted Mean Stream Length Ratio (Luwm)</td>
<td>see Table 4</td>
<td>Horton (1945)</td>
<td>2.12</td>
</tr>
<tr>
<td>8</td>
<td>Bifurcation Ratio (Rb)</td>
<td>see Table 4</td>
<td>Strahler (1964)</td>
<td>1.6 to 2.6</td>
</tr>
<tr>
<td>9</td>
<td>Mean Bifurcation Ratio (Rbm)</td>
<td>see Table 4</td>
<td>Strahler (1964)</td>
<td>2.12</td>
</tr>
<tr>
<td>10</td>
<td>Weighted Mean Bifurcation Ratio (Rbwm)</td>
<td>see Table 4</td>
<td>Strahler (1953)</td>
<td>2.12</td>
</tr>
<tr>
<td>11</td>
<td>Rho Coefficient (ρ)</td>
<td>ρ = Lur / Rb</td>
<td>Horton (1945)</td>
<td>3.19</td>
</tr>
<tr>
<td>B</td>
<td>Basin Geometry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Basin Length (Lb) Kms</td>
<td>1.312*A^0.568</td>
<td>Schumm(1956)</td>
<td>25.80</td>
</tr>
<tr>
<td>13</td>
<td>Mean Basin Width (Wb)</td>
<td>Wb = A / Lb</td>
<td>Horton (1932)</td>
<td>7.91</td>
</tr>
<tr>
<td>14</td>
<td>Basin Area (A) Sq Kms</td>
<td>GIS Software Analysis</td>
<td>Schumm(1956)</td>
<td>227.5</td>
</tr>
<tr>
<td>15</td>
<td>Basin Perimeter (P) Kms</td>
<td>GIS Software Analysis</td>
<td>Schumm(1956)</td>
<td>96.97</td>
</tr>
<tr>
<td>16</td>
<td>Relative Perimeter (Pr)</td>
<td>Pr = A / P</td>
<td>Schumm(1956)</td>
<td>2.10</td>
</tr>
<tr>
<td>17</td>
<td>Length Area Relation (Lar)</td>
<td>Lar = 1.4 * A^0.35</td>
<td>Hack (1957)</td>
<td>34.06</td>
</tr>
</tbody>
</table>
4. Conclusion

GIS softwares have demonstrated that they have great significance in the morphometric analysis of the drainage basins. On the basis of the drainage orders, the Phulambri river Basin has been classified as sixth order basin. The mean Rb indicates that the drainage pattern is not much affected by geological structures. Drainage density (Dd) and stream frequency (Fs) are the most important criterion for the morphometric categorization of drainage basins which unquestionably control the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. The Dd and Dt of the basin reveal that the nature of subsurface strata differs from fairly permeable to permeable. This is a distinctive element of drainage basin having Dt varying from fine to course as the texture value is 16.66. The study reveals that the drainage areas of the basin are passing through premature stage of
the fluvial geomorphic cycle. Lower order streams mostly control the basin. The developments of stream segments in the basin area are more or less affected by rainfall. Rc, Ff and Re show the somewhat elongated shape of the basin, having low degree of runoff and low relief of the terrain. It is observed that stream sectors up to 3rd order pass through parts of the high altitudinal regions with high virtual relief, which are characterized by steep slopes, while the 4th, 5th and 6th order stream segments occur in comparatively average relief regions in which maximum penetration of runoff occurs; these are main spots for constructing check dams. The outcome of our study illustrates the rocks in a region shows advantageous condition and good water bearing characteristics which might be useful for groundwater investigation.

Acknowledgements

The authors are thankful to Dr. A.K. Joshi, Head, Regional Remote Service Centre, Nagpur for providing a training in Remote Sensing and GIS and extending the lab facilities to the first author for this work. Further, the authors are also grateful to Dr. M.D. Babar, Dnyanopasak College, Parbhani for his critical remarks and suggestions on morphometric analysis. Dr. P.L. Salve, Deputy Director, G.S.D.A. Marathwada region for providing relevant literature is gratefully acknowledged.

References


Reddy, P.R., Vinod Kumar, K. and Seshadri, K. *Use of IRS-1C Data in Ground Water Studies. Current Science.* Special session: IRS-1 C. 1996. 70 (7) 600-605.


