CHAPTER-III

Geomorphology
Geomorphology, the science of landforms, concerns with the study of genesis and the development of the surface features of the earth (Thornbury, 1986). The shape of the surface features is more controlled by exogenetic processes like erosion, denudation, transportation, deposition etc., and endogenetic processes resulting from internal forces like diastrophism and volcanism. The landforms and the structures associated with geomorphic features resulting from tectonic activity indicate their control over the hydrogeological conditions in the region.

The area of upper Swarnamukhi river basin is drained by the rivers Kalyani, Bheema and Swarnamukhi. The elevation in the upper Swarnamukhi river basin ranges from 180 m to 1150 m with a relief of 970 m. The northern, southern and western portions are covered by hill ranges intercepted by narrow valleys. All the hills in the area are underlain by Archaean age of rocks with intrusive bodies except a very small portion in northern and northeastern portions over lain by Cuddapah Supergroup of rocks. The foot of the hills are generally occupied by soils intercepted by outcrops of granite and dyke rocks.

3.1 SLOPE ANALYSIS

Slope may be defined as the tangent of the angle of inclination of a line or plane defined by land surface (Zavoianu, 1985). Slope map of an area provides information regarding the distribution of various slope elements. The slope elements in turn are controlled by the climatomorphogenic processes in the area underlined by rocks of varying resistance. An
understanding of slope distribution is essential, since slope map provides data for planning, settlement, mechanisation of agriculture, afforestation, deforestation, planning of engineering structures, morpho-conservation practices etc. In morpho-conservation, it is not only the slope angle which is important but also the shape of the slope namely whether they are convex or concave. The gradient reflects the control of surface materials and processes, and determines the land use.

In 1980, Finsterwald and Peuker (quoted by Baulig, 1959) independently and Wentworth (1930) solely proposed different simpler methods for calculating the mean slope of the ground surface. There are various techniques for constructing slope classification maps. In the present study, Norman Thrower and Ronald Cooke (1968) method has been adopted to measure the slope percentages making use of contour spacing. Degrees of slope computed are given in the Table-3.1. The slope map is prepared from the topographic maps of scale 1:50,000 with 20m contour interval (Fig.3.1).

Table-3.1
Slope Particulars of the Study area

<table>
<thead>
<tr>
<th>Slope Class</th>
<th>% Slope</th>
<th>Degrees</th>
<th>Lower and Upper limit of Contour Spacing in Cms</th>
<th>Covered area in Km²</th>
<th>%in Total Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0 - 3</td>
<td>0 - 1.7</td>
<td>1.33 - 4</td>
<td>107.0</td>
<td>22.5</td>
</tr>
<tr>
<td>II</td>
<td>3 - 5</td>
<td>1.7 - 2.9</td>
<td>0.8 - 1.33</td>
<td>27.4</td>
<td>5.8</td>
</tr>
<tr>
<td>III</td>
<td>5 - 15</td>
<td>2.9 - 8.6</td>
<td>0.26 - 0.8</td>
<td>126.0</td>
<td>26.5</td>
</tr>
<tr>
<td>IV</td>
<td>15 - 35</td>
<td>8.6 - 19.9</td>
<td>&lt; 0.26</td>
<td>214.6</td>
<td>45.2</td>
</tr>
</tbody>
</table>
This method is usually employed by many research organisations, institutes and scientists (Rao et al., 1995) because of the fact, that it can be done quickly and easily. From the slope analysis, the percent of slope is divided into four classes (i.e. 0-3% is class I; 3-5% is class II; 5-15% is class III; and 15-35% is class IV). Class I is level to very gentle slope. Class II is very gentle to gentle slope. Class III is gentle to moderate slope. Class IV is moderate to moderately steep slope. On level to gentle sloping land, removal of material is slow. About 22.5% of the area under study is under class I of level to very gentle slope with remnants of erosion in some places. All agricultural practices and population settlements come under this category.

About 5.8% of the area is covered under class II. Nearly 26.5% of the area is covered under class III. This class is the transition zone in between hills and plains. All the hills in the area come under class IV which occupy 45.2% of the area under report. This is a class of moderate to moderately steep slope. Class IV has coarse soils. If the soil thickness has attained any time an independent condition, the rate of net soil removal will naturally be equal to the rate at which the underlying rock is weathered into soil. Most of the area (45.2%) comes under the class IV indicating that the runoff zone is more than the groundwater rechargeable area in the basin.

3.2 Drainage

Drainage network patterns refer to “the particular plan or design that the individual stream courses collectively form” (Thornbury, 1960). Drainage pattern is determined by lithology, geological structure, topography, relief and geomorphic history of the region (Kale and Gupta, 2001). The drainage pattern of the area is dendritic (Fig. 3.2) which is a characteristic feature of
Fig. 3.2: Drainage map of the study area
Fig. 3.3a: The panoramic view of the Kalyani Dam

Fig. 3.3b: The reservoir of the Kalyani dam

Fig. 3.3c: A view of the Moolapalle reservoir constructed across the Bheema river near Moolapalle village
Since all the streams are of ephemeral nature due to the climatic and geological conditions, all these tanks are serving as percolation tanks as most of them are located in the weathered and fractured zones of granitic terrain. The downstream side of the tanks will have groundwater source in the dry seasons also which is used for irrigation.

Another main reservoir (Fig. 3.3c) is situated near Moolapalle village and the reservoir is a recent construction (not shown in SOI topographic map of year 1970), but the reservoir is noticed in the IRS-1D imagery of 2001 indicating that it has been constructed during recent years. The scrutiny of the image indicated a possible paleochannel on which the said reservoir was constructed. This has given some interest to the author to study and identify the buried channel by making through well inventory and geophysical investigations.

3.4 Morphometric Analysis

Morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its land forms (Clarke, 1967).

A quantitative statement of the geomorphic characteristics of drainage basin towards a qualitative inference of the hydraulic nature of the basin assumed considerable importance towards the middle of this century. An exhaustive study of the development and geometry of streams has been made by Horton (1945). Later Strahler (1952), Leopold and Maddock (1953) made the best inference of the hydraulic nature of streams from quantitative studies of length and slope of streams. Miller (1953) studied the geomorphic
characteristics of drainage basins in mountainous areas. The hydraulic character of streams in relation to the drainage pattern has been studied by Leopold and Miller (1956).

Evaluation of geomorphic factors and their mathematical relationships to hydrology was delayed by lack of quantitative methods and procedures measuring geomorphic characteristics. Much impetus however, was given to fluvial morphometry by Horton (1945) and suggested methods of quantitative analysis at drainage features. The present study was undertaken in an effort to establish mathematical relationships between quantitative geomorphic factors and stream flow characteristics.

For the analysis of the drainage characteristics and relief, intensive use has been made of Topographical sheets on 1:50,000 scale published by the Survey of India. The quantitative analysis of the morphometric characteristics of the basin includes linear aspects (i.e. stream order, stream length, stream-length ratio, bifurcation ratio), areal aspects (i.e. area of the basin, basin length), measures involving height (i.e. relief, relief ratio, gradient ratio), basin shape factors (i.e. form factor, compactness coefficient, elongation ratio, circularity ratio), texture and related aspects (i.e., stream frequency, drainage density, constant of channel maintenance, length of overland flow).

3.5 Linear Aspects

The linear aspects of the channel system are Stream order (U), Stream length (L_u), Stream length ratio(R_l), Bifurcation ratio (R_b).
3.5.1 Stream order (U)

The first step in the quantitative analysis of drainage basin is the designation of the stream orders. Designating a stream order is an important parameter to index the size, scale of the basin and amount of stream flow. Recognition of hierarchy of stream segments helps to determine the different morphometric and hydrologic features associated with each segment. Strahler (1964) classification of stream order system is adopted in the present study. The simple unambiguous Strahler system is now firmly established and this ordering system provides sequence of stream order numbers as \( N_1, N_2, \ldots, N_k \) which approximately is an inverse geometric series with the degree of branching or stated statistically as the antilog of the regression coefficient i.e., \( \log N_u = a - b_u \) (Chorley, 1969).

From the ordering it is obvious that the number of stream segments \( (N_u) \) of any order will be less than that of the next lower order. Thus, it follows that the total number of streams gradually decreases as the stream order increases. From the stream order analysis upper Swarnamukhi river basin is designated as 6th order stream covering an area of 475 km\(^2\). The sub-basins Kalyani and Bheema are designated as 6th order streams covering an area of 152 km\(^2\) and 151 km\(^2\) respectively. The Swarnamuki sub-basin is identified as 5th order sub-basin with an area covering 172 km\(^2\).

3.5.2 Stream Length \( (l_u) \).

Stream length of each order is measured with the help of a rotometer. The mean length \( (l_u) \) of stream channel segment of order 'U', is a parameter which reveals the characteristic size of components of drainage network and
its contributing basin surface (Strahler, 1964). In order to obtain the mean length of the streams of order \( U \), the total length of the streams is divided by the total number of streams of the same order. According to Horton's law (1945) of stream lengths, that the mean lengths of streams of each of the successive orders of a basin tend to approximately a direct geometric proportion sequence. The lengths of streams vary with the stream order in the manner which suggest a geometrical progression (Table 3.2). The same relationship is also confirmed by the linear trend shown by the logarithmic plot of the data (Fig. 3.4). From the stream lengths, the steep increase in the average length of 5th and 6th order streams may be due to their presence in the plains.

3.5.3 Stream Length Ratio \( (R_L) \)

According to Horton (1945), the stream length ratio is the ratio of the mean length of streams of one order to that of the next lower order. Order wise stream length ratios are given in the table-3.2. The law of stream length ratio states that “The mean length of stream segments of each of the successive order of a basin tend to be approximately a direct geometric series with the stream length increasing towards higher stream orders”.

47
<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
<th>1/2</th>
<th>2/3</th>
<th>3/4</th>
<th>4/5</th>
<th>5/6</th>
<th>Order wise average stream length (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalyani</td>
<td>292.5</td>
<td>91.5</td>
<td>39.0</td>
<td>34.0</td>
<td>3.25</td>
<td>17.5</td>
<td>477.75</td>
<td>3.20</td>
<td>2.35</td>
<td>1.15</td>
<td>10.46</td>
<td>0.19</td>
<td>0.45 0.66 1.18 3.09 1.63 17.50</td>
</tr>
<tr>
<td>Bheema</td>
<td>223.0</td>
<td>79.5</td>
<td>36.5</td>
<td>34.0</td>
<td>5.0</td>
<td>10.5</td>
<td>388.50</td>
<td>2.81</td>
<td>2.18</td>
<td>1.07</td>
<td>6.80</td>
<td>0.48</td>
<td>0.46 0.69 1.40 4.86 2.50 10.50</td>
</tr>
<tr>
<td>Swarnamukhi</td>
<td>282.0</td>
<td>90.5</td>
<td>53.0</td>
<td>17.5</td>
<td>29.5</td>
<td>–</td>
<td>472.50</td>
<td>3.12</td>
<td>1.71</td>
<td>3.03</td>
<td>0.59</td>
<td>–</td>
<td>0.53 0.69 2.04 2.92 29.50 –</td>
</tr>
<tr>
<td>Upper Swarnamukhi (Basin as whole)</td>
<td>797.5</td>
<td>261.5</td>
<td>128.5</td>
<td>85.5</td>
<td>37.75</td>
<td>28.00</td>
<td>1338.75</td>
<td>3.05</td>
<td>2.04</td>
<td>1.50</td>
<td>2.26</td>
<td>1.35</td>
<td>0.48 0.58 1.51 3.56 7.55 14.00</td>
</tr>
</tbody>
</table>
E-SWARMAMUKHI BASIN AS WHOLE

Stream Order (U)

Log Nu = a - bu

KALYANI

b = 0.269
RL = 1.858

BHEEMA

b = 0.258
RL = 1.811

SWARMAMUKHI

b = 0.413
RL = 2.588

BASIN AS WHOLE

b = 0.311
RL = 2.046

Fig. 3.4

b: Regression coefficient
RL: Stream length ratio
This ratio can be obtained by the following formula:

\[ R_L = \frac{L_u - 1}{L_u - 1} \]

Where \( R_L \) = Stream length ratio
\( L_u \) = Mean Stream length order U
\( L_u - 1 \) = Mean stream length of segment of the next lower order.

The stream length ratios are changing haphazardly both at sub-basin (0.19 to 10.46) and whole basin level (1.35 to 3.05). The stream length ratio has an important relationship with the surface flow discharge and erosional stage of the basin. The sudden raise in the ratios of 4/5 order stream length in the Kalyani sub-basin indicate the low erosion maturity upto 4th order streams. The sudden drop of slope to nearly level with higher thickness of weathered zone/alluvial deposits is due to structure control domination from 5th order stream. The same condition prevailed in Bheema sub-basin also.

3.5.4 Bifurcation Ratio (\( R_b \))

The ratio of number of streams of a given order to the number of streams of the next higher order in a drainage basin is known as a bifurcation ratio (Horton, 1945). The irregularities of the bifurcation ratios are dependent upon the lithological and geological development of the drainage basin (Strahler, 1971). According to Strahler, the ratio of the higher order \((N_u + 1)\) is termed as the Bifurcation Ratio \((R_b)\) (Strahler, 1964). Therefore it is expressed as

\[ R_b = \frac{N_u}{N_v} \]
The theoretical minimum possible value of bifurcation ratio is 2. But, it ranges between 3.0 and 5.0 for watersheds in which the geologic structures do not distort the drainage pattern (Strahler, 1964). According Patrick (1978), the regions of steeply dipping strata would show abnormally high bifurcation ratios. Elongated basins with high bifurcation ratio yield a low but extended peak flow, while rounded basins with low ratios produce a sharp peak. Potential flood danger increases as the value of bifurcation ratio is lowered.

In the whole basin of upper Swarnamukhi basin, the bifurcation ratios varies from 2.0-6.0. The minimum values of bifurcation ratios are between 5th and 6th order streams of Kalyani and Bheema sub-basin due to the less number of 5th order streams. High bifurcation ratio between 4th and 5th order streams of Swarnamukhi sub-basin(6.0) indicates that Swarnamukhi is a more an elongated basin than the remaining basins.

The mean bifurcation ratio (Mathematical (MR)_w) of the whole basin of upper Swarnamukhi river is 3.93 and the sub-basins Kalyani, Bheema and Swarnamukhi are 3.87, 3.56 and 4.85 respectively. All the mean values are ranging between 3.00 - 5.00 (Table-3.3).
Table 3.3
Bifurcation Ratios of the Upper Swarnamukhi Basin

<table>
<thead>
<tr>
<th>Basin/ sub-basin</th>
<th>Stream number in different orders</th>
<th>Bifurcation Ratios $R_n$</th>
<th>Mathematical mean bifurcation ratio (MR)</th>
<th>Graphical bifurcation ratio (GR)</th>
<th>Weighted mean bifurcation ratio (WR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 Total 1/2 2/3 3/4 4/5 5/6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kalyani</td>
<td>648 139 33 11 2 1 834</td>
<td>4.66 4.21 3.00 5.50 2.00</td>
<td>3.87</td>
<td>3.741</td>
<td>4.52</td>
</tr>
<tr>
<td>Bheema</td>
<td>480 118 26 7 2 1 632</td>
<td>4.14 4.46 3.71 3.50 2.00</td>
<td>3.56</td>
<td>3.548</td>
<td>4.16</td>
</tr>
<tr>
<td>Swarnamukhi</td>
<td>529 131 26 6 1 -- 693</td>
<td>4.04 5.04 4.33 6.00 --</td>
<td>4.85</td>
<td>4.764</td>
<td>4.25</td>
</tr>
<tr>
<td>Upper Swarnamukhi (Basin as whole)</td>
<td>1657 386 85 24 5 2 2159</td>
<td>4.29 4.54 3.54 4.80 2.50</td>
<td>3.93</td>
<td>3.936</td>
<td>4.30</td>
</tr>
</tbody>
</table>
The straight-line plot (Fig.3.5) satisfies Horton’s (1945) first law of stream numbers which states that “The number of streams of different orders in a given drainage basin tend closely to approximate inverse geometric series in which the first term is an unity and the ratio is the bifurcation ratio”.

The regression co-efficient of the whole basin of upper Swarnamukhi river is 0.595. The sub-basins of the Kalyani, Bheema and Swarnamukhi are 0.573, 0.550 and 0.678 respectively. These values represent the logarithm of the bifurcation ratio (Strahler, 1958). The bifurcation ratio (Graphical (GRₚ)) obtained from this co-efficient for the whole basin of upper Swarnamukhi river is 3.936 and sub-basins of Kalyani, Bheema and Swarnamukhi are 3.741, 3.548 and 4.764 respectively (Table-3.3). These values coincide well with the mathematical mean bifurcation ratios.

Strahler (1953), used a weighted-mean bifurcation ratio (WRₚ) obtained by multiplying the bifurcation ratio for each successive pair of orders by the total number of streams involved in the ratio and taking the mean of the sum of these values (Table- 3.3). These values also coincide well with the mean bifurcation ratio.

From above study, all the values bifurcation ratios calculated by Mathematical, Graphical and Weighted-mean of the upper Swarnamukhi river basin are in agreement and are between 3.0 and 5.0 indicating the homogeneous character and geologic structure.
Fig. 3.5: The linear relationship between stream order and number of streams
3.6 Areal Aspects

3.6.1 Area of the Basin (A)

The total area of upper Swarnamukhi river basin is 475 km² while the areas of sub-basins namely Kalyani, Bheema and Swarnamukhi are 152 km², 151 km² and 172 km² respectively (Table-3.4).

3.6.2 Basin length (L)

Basin length has been identified differently by different workers (Schumm, 1956, Gregory and Walling, 1973; Gardiner, 1975 and Canon, 1976). According to Gregory and Walling (1973), the basin length (L) is the longest length of the basin and end being the mouth. The length of the upper Swarnamukhi river basin is 28.0 km while the lengths of the three sub-basins of Kalyani, Bheema and Swarnamukhi are 21.50 km, 20.15 km and 28.00 km respectively (Table-3.4).
Table 3.4

Areal and Shape aspects of the Upper Swarnamukhi River Basin

<table>
<thead>
<tr>
<th>Basin/Sub-basin</th>
<th>Area Km²</th>
<th>Length (Km)</th>
<th>Perimeter P(Km)</th>
<th>Compactness coefficient (m)</th>
<th>Elongation Ratio ($R_e$)</th>
<th>Circularity Ratio ($R_c$)</th>
<th>Form factor ($R_f$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalyani</td>
<td>152</td>
<td>21.50</td>
<td>62.50</td>
<td>1.43</td>
<td>0.65</td>
<td>0.49</td>
<td>0.33</td>
</tr>
<tr>
<td>Bheema</td>
<td>151</td>
<td>20.15</td>
<td>64.00</td>
<td>1.47</td>
<td>0.69</td>
<td>0.46</td>
<td>0.37</td>
</tr>
<tr>
<td>Swarnamukhi</td>
<td>172</td>
<td>28.00</td>
<td>100.00</td>
<td>2.15</td>
<td>0.53</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>Upper Swarnamukhi (Basin as whole)</td>
<td>475</td>
<td>28.00</td>
<td>135.00</td>
<td>1.75</td>
<td>0.88</td>
<td>0.33</td>
<td>0.61</td>
</tr>
</tbody>
</table>
3.7 Measures Involving Heights

3.7.1 Relief (H)

Basin relief is an important factor in understanding the denudation of a basin. Relief is the elevation difference between reference points defined in several ways. Strahler (1952b, 1964) referred to it, as the maximum basin relief. Maximum basin relief is the elevation difference between basin mouth and highest point on the perimeter of the basin.

In upper Swarnamukhi basin, the highest point on the basin perimeter is 1150m and elevation at the basin mouth is 180m (Table-3.5). The maximum relief of the basin is 970m, while the sub-basins Kalyani, Bheema and Swarnamukhi are 970m, 769m and 759m respectively (Fig. 1.2).

3.7.2 Relief Ratio (Rh)

According to Schumm (1956), relief ratio is the ratio between maximum basin relief and basin length, measured as the longest dimension of the drainage basin. In general, the relief ratio indicates the overall slope of the basin surface (Strahler, 1957). It is dimensionless height to length ratio equal to the tangent of the angle formed by two planes intersecting at the mouth of the basin, one representing the horizontal, the other passing through the highest point of the basin.
<table>
<thead>
<tr>
<th>Basin/Sub-basin</th>
<th>Elevation in M</th>
<th>Maximum basin relief in (H-h)m</th>
<th>Longest axis 'L' Km</th>
<th>Relief Ratio (H-h/L)</th>
<th>Elevation in (m) at Source 'a'</th>
<th>Elevation in (m) at Mouth 'b'</th>
<th>Fall in Height (a-b) m</th>
<th>Length of main Stream 'L' (km)</th>
<th>Gradient Ratio (a-b/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalyani</td>
<td>1150</td>
<td>180</td>
<td>970</td>
<td>21.50</td>
<td>0.045</td>
<td>900</td>
<td>180</td>
<td>720</td>
<td>25</td>
</tr>
<tr>
<td>Bheema</td>
<td>969</td>
<td>200</td>
<td>769</td>
<td>20.15</td>
<td>0.038</td>
<td>560</td>
<td>200</td>
<td>360</td>
<td>24</td>
</tr>
<tr>
<td>Swarnamukhi</td>
<td>969</td>
<td>180</td>
<td>789</td>
<td>28.00</td>
<td>0.028</td>
<td>460</td>
<td>180</td>
<td>280</td>
<td>35</td>
</tr>
<tr>
<td>Upper Swarnamukhi</td>
<td>1150</td>
<td>180</td>
<td>970</td>
<td>28.00</td>
<td>0.035</td>
<td>460</td>
<td>180</td>
<td>280</td>
<td>35</td>
</tr>
</tbody>
</table>

Table-3.5
Relief and Gradient aspects of Upper Swarnamukhi River Basin
Relief Ratio \( R_h = \frac{H-h}{L} \)

Where \( H \) = Highest elevation on basin perimeter
\( h \) = Lowest elevation at basin mouth
\( L \) = Longest axis of the basin

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 (Strahler, 1964).

The relief ratio of the upper Swarnamukhi river basin is 0.035, while that of the three sub-basins are 0.045 for Kalyani, 0.038 for Bheema and 0.024 for Swarnamukhi (Table-3.5) indicate the high steepness and high intensity of erosion process in the Kalyani sub-basin, moderate steepness and moderate intensity of erosion process in the Bheema sub-basin and low steepness with low intensity of erosion process are present in the Swarnamukhi sub-basin.

### 3.7.3 Gradient Ratio

It is an indication of channel slope. The upper Swarnamukhi river basin has a gradient ratio is 0.008, while the sub basins, Kalyani, Bheema and Swarnamukhi are 0.029, 0.015 and 0.008 respectively (Table-3.5) indicating that the gradient is higher in Kalyani, moderate in Bheema and lower in Swarnamukhi river courses.
3.8 Basin Shape

Basin shape determines how rapidly the run off will reach the main river channel as well as the outlet. For circular basins the runoff reach quickly and for elongated basins there is longer delay in the arrival of flow after heavy rain (Kale and Gupta, 2001). According to Hack(1957), as the basins enlarge, the stream length increases and the basins become narrower and longer. Therefore, a majority of rivers have elongated basins (Mulder and Syvitsky, 1996).

Basin shape is determined from the dimensionless parameters such as form factor, compact co-efficient, elongation ratio and circularity ratio.

3.8.1 Form factor ($R_f$)

Form factor indicates the shape or outline form of drainage basin which may conceivably affect stream discharge characteristics. The long narrow basins would be expected to have accentuated flood discharge periods, whereas round basins would be expected to have sharply peaked flow discharge (Strahler,1964). According to Horton (1932), “A qualitative expression of drainage basin outline form is a dimension less ratio of basin area ($A$) to the square of its maximum length ($L_m$)”. Thus it is expressed as

$$R_f = \frac{A}{L_m^2}$$

The form factor when it is equal to the unity, the basin shape is a square, and decreases according to the extent of elongation. If the ratio is
higher than unity, the basin shape approximately is circle (Zavoianu, 1985). The form factor of the upper Swarnamukhi river basin is 0.61, while the form factors of sub-basins Kalyani, Bheema, and Swarnamukhi are 0.33, 0.37 and 0.22 respectively (Table-3.4). All values of whole basin and sub-basins are less than unity indicating elongated shape.

3.8.2 The Compactness Co-efficient ($m$)

The compactness co-efficient ($m$) has been used in the Soviet specialised literature to describe the drainage basin shape. It represents the ratio of the actual basin perimeter ($P$) to the perimeter ($P'$) of a circle of equal area (Luchisheva, 1950). Thus it is expressed as

$$m = \frac{P}{P'} \quad \text{or}$$

This coefficient is equal to unity when the basin shape is a perfect circle. In the case of square shape basins, the ratio would be increased up to 1.128. And may exceed 3.0 for very elongated basin. The compactness co-efficient ($m$) of upper Swarnamukhi river basin is 1.75, and its sub-basins of Kalyani, Bheema and Swarnamukhi are 1.43, 1.47 and 2.15 respectively. All values are greater than 1.128 and less than 3.0 indicating that the sub-basins and the whole basin are elongated in shape (Table-3.4). But comparatively Swarnamukhi sub-basin in more elongated than remaining.

3.8.3 Elongation ratio ($R_e$)

According to Schumm (1956), elongation ratio is the ratio between the diameter ($D_o$) of a circle of the same area as the drainage basin and the maximum length ($L_a$) of the basin. Higher the elongation ratio, lesser will be
the flood peak. This ratio varies between 0.6 and 1.0 over a wide variety of climatic and geologic types. Values nearing 1.0 are typical of regions of very low relief where as values in the range of 0.6-0.8 are generally associated with strong relief and steep ground slopes. Maximum value of the elongation ratio is 1.275, where as the basin shape is perfect circle. For square shaped basins the elongation ratio is 1.128 and less than this value, the basin shape comes under elongated. The ratio is obtained by using the following formula.

\[ R_e = \frac{D_e}{L_b} \]

The elongation ratio can also be written (Seyhan,1977a) as

\[ R_e = 1.129 \sqrt{\frac{A}{L_b}} \]

Where as \( A \) is the basin area, \( L_b \) is the maximum basin length.

The elongation ratios of the upper Swarnamukhi river basin and its sub-basins are given in the Table 3.4. The elongation ratio of the upper Swarnamukhi river basin is 0.88, while sub-basins Kalyani, Bheema, and Swarnamukhi are 0.65, 0.69 and 0.53 respectively indicates Kalyani and Bheema sub-basins are associated with strong relief and steep ground slopes. The low elongation ratio (0.53) of the Swarnamukhi sub-basin indicates that it is more elongated than the Kalyani and Bheema sub-basins.

3.8.4 Circularity Ratio (\( R_c \))

For the outline form of drainage basins (Strahler, 1964 and Miller, 1953) a dimensionless circularity ratio has been used as quantitative measure and is defined as the ratio of basin area (\( A_p \)) to the area of a circle (\( A_c \) having
the same perimeter as the basin. It is affected by the lithological character of the basin. It is expressed as:

\[ R_c = \frac{4\pi A}{P^2} \]

Where \( R_c \) is the basin circularity, ‘\( P \)’ is basin perimeter, ‘4’ is a constant and ‘\( A \)’ is the area of the basin.

The maximum value of ‘\( R_c \)’ is unity. When \( R_c \) is equal to unity, the basin shape is a circle. For square shaped basins \( R_c \) value becomes 0.785. The ‘\( R_c \)’ values of less than 0.785 indicate the elongated nature of the basin.

The circularity ratio of the upper Swarnamukhi river basin is 0.33, while sub-basins Kalyani, Bheema and Swarnamukhi are 0.49, 0.46 and 0.22, respectively. From the circularity ratios of the sub-basins of upper Swarnamukhi river basin (Table-3.4), three sub-basins and whole basin are elongated in shape. But, Swarnamukhi sub-basin (0.22) is the most elongated compared to the other two.

3.9 Drainage Texture

The drainage texture is used generally to evaluate the character and geometry of the drainage network, which include the drainage density and stream frequency (Horton, 1945).

3.9.1 Stream Frequency (Fs)

The Stream frequency of a basin may be defined as the ratio between the total number of segments cumulated all orders with in the basin and the basin area (Horton, 1945).
Where $F_s = \frac{\Sigma N_u}{A}$

$\Sigma N_u =$ Total number of stream segments of all orders

$A =$ Total area of the basin

The stream frequency of the upper Swarnamukhi is 4.5 and for the sub-basins of Kalyani, Bheema and Swarnamukhi are 5.49, 4.19 and 4.03 respectively (Table-3.6).

### 3.9.2 Drainage Density ($D_d$)

Drainage density is the sum of stream lengths per unit area (Horton, 1945). It is obtained by dividing the total stream lengths by the total area of the basin.

$$\frac{\Sigma L_u}{A}$$

Where $\Sigma L_u =$ Length of all order Streams

$A =$ Total area

Smith (1950) graded the drainage density and expressed the same as the drainage texture and classified the same as given below.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Drainage density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very coarse</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Coarse</td>
<td>2-4</td>
</tr>
<tr>
<td>Moderate</td>
<td>4-6</td>
</tr>
<tr>
<td>Fine</td>
<td>6-8</td>
</tr>
<tr>
<td>Very fine</td>
<td>&gt;8</td>
</tr>
</tbody>
</table>
## Table-3.6

**Drainage Texture aspects of the Upper Swarnamukhi River Basin**

<table>
<thead>
<tr>
<th>Basin / sub-basin</th>
<th>Drainage density (Dd) KmKm(^2)</th>
<th>Stream frequency (F_s)</th>
<th>Drainage Texture (T)</th>
<th>Constant of Channel maintenance ((C)) Km(^2)</th>
<th>Length of over land flow ((lo)) Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalyani</td>
<td>3.14</td>
<td>5.49</td>
<td>Coarse</td>
<td>0.32</td>
<td>0.16</td>
</tr>
<tr>
<td>Bheema</td>
<td>2.57</td>
<td>4.19</td>
<td>Coarse</td>
<td>0.39</td>
<td>0.20</td>
</tr>
<tr>
<td>Swarnamukhi</td>
<td>2.75</td>
<td>4.03</td>
<td>Coarse</td>
<td>0.36</td>
<td>0.18</td>
</tr>
<tr>
<td>Upper Swarnamukhi (Basin as Whole)</td>
<td>2.82</td>
<td>4.55</td>
<td>Coarse</td>
<td>0.35</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Both the measures of drainage density and stream frequency are most important factors that control the speed of runoff following a spell of heavy rain. The greater the drainage density and stream frequency, the faster the run off. Therefore, flooding is more in the basins with a high drainage density and stream frequency. Lithology of the area is an important control on the drainage texture and density. In the resistant hard rock terrains such as basalt, granite, gneiss, quartzite etc., the drainage is coarse textured and the drainage density is low (generally 1.5-2.5 km km^{-2}).

Upper Swarnamukhi river basin and sub-basins drainage density values range between 2.57 - 3.14 (Table-3.6) which are classified as coarse texture. The Kalyani sub-basin has the higher drainage density (3.14) and stream frequency (5.49) than the other two sub-basins, indicating the faster surface run off in this sub-basin during heavy rains.

3.9.3 Constant of Channel Maintenance (C)

According to Schumm (1956), the reciprocal or inverse of drainage density is the constant of channel maintenance (C). It is an average distance between streams.

\[
C = \frac{1}{D_s}
\]

This constant expresses the number of square kilometre of a drainage basin required to maintain one kilometre of channel. The constant of channel maintenance values are given in the table-3.6.
In dry regions and over resistant rocks the constant of channel maintenance is higher. This high constant of channel maintenance and low drainage density indicate a coarse drainage texture (Kale and Gupta, 2001).

The constant of channel maintenance of upper Swarnamukhi river basin (i.e., 0.35) and sub-basins (i.e., Kalyani, 0.32, Bheema, 0.39, and Swarnamukhi, 0.36) are strongly supporting the above conclusion.

3.9.4 Length of overland flow ($L_o$)

The study of length of overland flow is very important because it affects not only the water regime of a river network but also the long-term evolution of drainage basin. The length of overland flow depends primarily on the degree of relief fragmentation and drainage density.

The length of overland flow refer to the length of the rain water on the ground surface it gets localised into definite channel. According to Horton (1945), the length of over land flow in most cases is approximately half the average distance between the stream channels and hence is approximately equal to, half the reciprocal of the drainage density.

\[
L_o = \frac{1}{2D_d}
\]

\[D_d = \text{Drainage density of the basin}\]

Since $D_d = \frac{\sum L}{A}$ The relationship may also be written as

67
The length of over land flow of the upper Swarnamukhi river basin is 0.18 km, while sub-basins Kalyani, Bheema, and Swarnamukhi has 0.16 km, 0.20 km and 0.18 km respectively. This values (0.16, 0.2 and 0.18 km) for this basins mean that the rain water has to run over this distance before getting concentrated in stream channel and corroborates the coarse texture derived for this basin. This figure also indicates, that the basin has a scope for groundwater recharge, since water has to travel a long distance to reach the strata. This is also confirmed by the drainage density and stream frequency values. Based on the length of overland flow varies, Bheema sub-basin has more groundwater recharge than the Kalyani and Swarnamukhi sub-basins (Table-3.6).