Chapter IV

Morphometric Analysis
The measurement and the mathematical analysis of the configuration of the land surface of the region with regard to its shape and dimension of the landforms serves quite a useful purpose.

As suggested by Strahler measurement of the shape and geometry of any landform is an essential part of the geomorphometry of an area.

In past few years a lot of work has been done by different geomorphologist in the field of geomorphometry, some of the studies are of Dury (1952a; 167), Horton (1945), Strahler (1957), Shreve (1966), Singh and Kumar (1969), Chorley (1969), Doornkamp and King (1971), Pal (1972), Kumar and Pandey (1975), Singh and Renu Shrivastava (1974), Singh and Pofali, Bhatt (1985), Vats (1985), Singh Usha (1986).

In the present study results of morphometric analysis of region are presented.

**Methodology**

The morphometric analysis of the study area is done by taking one inch topographical sheets NOS 64 A/1, 64 A/2, 64 A/5, 64 A/6, 64 A/9, 64 A/10 and the following specifications have determined. The
results have been used in the interpretation of various ramifications of land form evolutions.

1. Stream numbers
2. Stream disorders
3. Stream lengths
4. Contour crenlation
5. Drainage density
6. Drainage frequency
7. Drainage intensity
8. Bifurcation ratio

Linear, Areal and Relief aspects of the drainage basin are determined.

**LINEAR ASPECTS OF THE BASIN**

Linear aspect involves the study of linear features of the streams. Such features are number, length and order of stream segments and relationships among them at different levels. Data for such investigations have been obtained from survey of India toposheets on the scale 1:50,000. In the analysis established quantitative techniques have been adopted and the results so arrived at, have been verified during the course of field study.

Geometrical measurements and mathematical analysis of linear aspects such as number of stream, length of stream, segments of
each order, bifurcation ratio (R.b.), length ratio (RL), have been calculated.

**ORDERING OF THE STREAM**

Area of the particular basin is very important. The order of stream reflects the form characteristics and also its relation to its processes. Different geomorphologist have made different attempts to study geomorphology of the area by using different methods.

A number of methods for ordering streams have been proposed some of them, are as follows:

Gravelius (1914)
Horton (1945)
Strahler (1952)
Shreve (1966)
Woldenberg (1966)
Gregory and Walling in (1973)
Graff in (1975)
Jems and Krumbeeen (1969)
Smart (1972, 76, 78)
Smart & Wallis (1971) etc.

But the methods proposed by Horton, Shreve and Strahler are widely excepted and used. In present study the method of Strahler
MURWARA BASIN
STREAM ORDER

Stream Orders

- First
- Second
- Third
- Fourth
- Fifth
- Sixth

Source: Topographical Sheet 64A/1,2,5,6,9,10
(1957) has been adopted for the determination of stream order. This method has been preferred to other methods because of its simplicity.

In this method, the smallest of the streams without any tributaries were designated the first order streams, and those that were formed by the confluence of two such unbranched streams were assigned the second order and so on.

A second order stream is formed by the junction of two or more first order streams. A third order stream may have in addition some first and second order streams as tributaries.

In this study of the stream order of the Katni river basin has been shown in Table No. 4.1. It is found that, it is of six order stream.

Table No. : 4.1
Stream Number and Stream Order

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Stream Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1096</td>
</tr>
<tr>
<td>2</td>
<td>253</td>
</tr>
<tr>
<td>3</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 4.1 : Plot of the stream number against the stream order
STREAM NUMBER

The number of streams of every order has been counted and tabulated. The number of stream segment has plotted against the stream order on graph paper after that bifurcation ratio is calculated.

BIFURCATION RATIO

The bifurcation ratio is shortly represented by the term (Rb). It is the ratio between the number of stream segments of a given order (Nu), and the number of stream segments of the next higher number (Nu+1). This is represented by the equation

\[ Rb = \frac{Nu}{Nu+1} \]

Where: \( u = \) order

\( Nu = \) Number of streams of a given order and

\( Nu+1 = \) Number of streams of next higher order

In the study of the Katni river basin the bifurcation ratio between successive parts of orders have been found and tabulated in Table 4.2.

Bifurcation ratio is influenced by surface structure and climate etc. The bifurcation ratio remains constant if the conditions of rocks,
climate and evolution are similar. The bifurcation ratio in a drainage basin between 3 to 5 exhibits an ideal stream sequence.

The bifurcation ratio of the drainage basin under study has been derived by Hortons formula and has been shown in the Table 4.2.

### Table No. 4.2
**Number of streams present in each order in Murwara basin**

<table>
<thead>
<tr>
<th>Stream order (u)</th>
<th>Number of stream (Nu)</th>
<th>Bifurcation ratio (Rb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1096</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>253</td>
<td>4.3</td>
</tr>
<tr>
<td>III</td>
<td>61</td>
<td>4.1</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>3.5</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1433</strong></td>
<td><strong>20.3</strong></td>
</tr>
</tbody>
</table>

*Mean bifurcation ratio = 4.06*

**Weighted Mean Bifurcation Ratio**

Strahler (1953) used the term called weighted mean bifurcation ratio for the quantitative measurement of the stream character. This was the improved method of such measurement of Horton's. For determining mean weighted bifurcation ratio the following procedure is adopted.
The bifurcation ratio for each successive pairs of order is multiplied by the number of streams used in the ratio, than the total so obtained is divided by the total of number of streams used in the ratio. This provides a weighted mean bifurcation ratio of the basin. In the present study of Murwara basin the weighted mean bifurcation ratio is 4.22 whereas the mean bifurcation ratio is 4.06. These results indicate the mature stage of the basin. (According to Chandra Shekhar and Nayanna, 1983;6)

<table>
<thead>
<tr>
<th>Stream order (1)</th>
<th>Number of Streams (2)</th>
<th>Bifurcation Ratio (3)</th>
<th>Number of Streams involved in the ratio (4)</th>
<th>Product of column 3 and 4 (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1096</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>253</td>
<td>4.3</td>
<td>1349</td>
<td>5800.7</td>
</tr>
<tr>
<td>III</td>
<td>61</td>
<td>4.1</td>
<td>314</td>
<td>1287.4</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>3.5</td>
<td>78</td>
<td>273.0</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
<td>3.4</td>
<td>22</td>
<td>74.8</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>5.0</td>
<td>6</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Sum of products of column – 5 = 7465.9
Total Number of Stream used in column – 4 = 1769

Weighted mean Bifurcation ratio = \[ \frac{7465.9}{1769} \] = 4.22

STREAM LENGTH

According to the Horton’s law of length of the streams, “the average lengths of the streams of each of the different orders in a drainage basin tends closely to the approximate direct geometric series in which the first term is average length of the streams of first order
and constant factor is order ratio" (Horton Op. Cit.). To test the Horton's law to the present study area lengths of the stream segments of each order of Katni river drainage basin has been measured from toposheets. The mean length of each order of the basin has been calculated and tabulated in Table 4.4.

**Table 4.4**

*Stream lengths and length ratio in the Murwara basin*

<table>
<thead>
<tr>
<th>Order</th>
<th>Number of Stream (Nu)</th>
<th>Length of Stream (Lu) in cm.</th>
<th>Mean Length of Stream (Lu⁻¹)</th>
<th>Length ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1096</td>
<td>1226</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>253</td>
<td>571</td>
<td>2.26</td>
<td>2.01</td>
</tr>
<tr>
<td>III</td>
<td>61</td>
<td>398</td>
<td>6.52</td>
<td>2.90</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>148</td>
<td>8.70</td>
<td>1.33</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
<td>93</td>
<td>18.6</td>
<td>2.14</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>98</td>
<td>98</td>
<td>5.27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>13.65</td>
</tr>
</tbody>
</table>

*Mean length ratio = 2.73*

Length Ratio (R.L.): Stream length ratio is the ratio of the mean length of streams of a given order and the mean length of streams of the next higher order. The ratio between the mean length of stream segment of two successive orders can be termed as length ratio (R.L.) and this can be understand by following formula (Strahler, 1969)–
\[ RL = \frac{L_u}{L_u - 1} \]

where \( RL \) = Length ratio

\( L^*u = \) mean stream length of a given order

\( L^*u - 1 = \) mean stream length of immediate lower order

\( L^*u \) can be calculated by the following formula (Strahler, 1969):

\[ L_u = \frac{\sum L_u}{N_u} \]

Where \( \sum L_u = \) sum of the length of all stream segments of a given order

\( N_u = \) Number of stream segments of a given order

Stream length ratio of Katni nadi drainage basin has been shown in Table 4.4. The mean length ratio for the katni nadi basin is 2.73.

**Weighted Mean Length Ratio**

This is obtained by multiplying the length ratio by the number of streams used in the ratio.

The total of products obtained is then divided by the total number of streams used in the ratio.
The Table 4.5 show that there is gradual increase in the total stream length with the decrease the stream order. The mean length ratio for the Murwara Basin is (2.73) and weighted mean length ratio so calculated is (2.15).

<table>
<thead>
<tr>
<th>Stream order (1)</th>
<th>Number of Streams (2)</th>
<th>Length ratio (3)</th>
<th>Number of Streams involved in the ratio (4)</th>
<th>Product of column 3 and 4 (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1096</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>253</td>
<td>2.01</td>
<td>1349</td>
<td>2711.49</td>
</tr>
<tr>
<td>III</td>
<td>61</td>
<td>2.90</td>
<td>314</td>
<td>910.6</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>1.33</td>
<td>78</td>
<td>103.74</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
<td>2.14</td>
<td>22</td>
<td>47.08</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>5.27</td>
<td>6</td>
<td>31.62</td>
</tr>
</tbody>
</table>

Sum of products of column - 5 = 3804.53

Total Number of Stream used in column - 4 = 1769

Mean Length Ratio = \[
\frac{2.01 + 2.90 + 1.33 + 2.14 + 5.27}{5} = 2.73
\]

Weighted mean length ratio = \[
\frac{3804.53}{1769} = 2.15
\]

**THE AREAL ASPECT**

The areal aspect of a drainage basin includes spatial structure of stream orders and their areal expanse. The area of the drainage basin of various order stream segments is ascertained with the help
of toposheets and thereafter the average area of the basin of every stream segment is calculated.

**Analysis and determination of basin shapes** – By study of drainage density and drainage frequencies, the nature of basin shape is estimated.

**DRAINAGE DENSITY**

There are several methods of quantitative analysis of drainage systems but the method of Horton (1932; 350–361) is supposed to be the one of the best method of the study of drainage density. This is because of its simplicity. In Horton’s method the drainage density is described as the average length of stream per unit area within the basin. Expressed in the equation form:

$$Dd = \frac{L}{A}$$

Where Dd is the drainage density and

L is the total length of the stream and A is the total area of the basin

Drainage density map for area under study has been prepared by using the Horton’s method. The drainage density groups are prepared and mapped. The following groups were found–
(1) Very low density area—where length of stream is low then 0–3/sq km.

(2) Low density area—where length of stream is between 3–6/sq km.

(3) Medium drainage density area—where length of stream is between 6–9/sq km.

(4) High density area—where length of stream is between 9–12/sq km.

(5) Very high density area—where length of stream is above 12/sq km.

From the geomorphological point of view the relation of factors which influence drainage density is of particular interest. After geomorphological researchers done by Strahler (1952; 1117–42), Melton (1959; 33–35), Smith (1950; 655–68), Glock (1932; 74–83), Jhonson (1933; 293–305), Morisawa (1959; 84–86), and others, the factors which govern the drainage density have been ascertained as runoff, infiltration capacity, percentage of bare rock surface, rock type, soil relief, rainfall, slope structure, vegetational cover and scarps. Local relief also affected the drainage density.

For convenience, the said classification is converted to broad categories:
1. The low drainage density area 3-6/sq.km.

2. Medium drainage density area—6-12/sq.km.

3. High drainage density area – above 12/sq.km.

(1) **Low drainage density area**—The average length of stream in these areas lie between 3-6/sq.km.. These areas extend over Maihar, Kachhagawan, Bijeraghogarh, Kaliwara, Imlag (NW-SE) Sleemanabad, Umariya, Pipariya and Chhapra. These areas are of low frequency too.

In this area the rocks of Mahakoshal (Bijawar) rocks are found which are permeable due to presence of lime stone rocks. Therefore less water is available for surface drainage. This result in low drainage density.

(2) **Medium Drainage Density**—The average length of streams in these areas lie between 9-12 kms/sq. km. These areas extend (NE) over Dhaura, Jiwara and in central part of Katni (Murwara). This is the plane area where frequency is low. The alluvium and Vindhyans are present in this area. Due to plains and high vegetation the drainage density of the area is of medium density type.
(3) **High density area**—The average length of streams in these areas lie above 12km/sq.km. such area is NE, extend to part of Marwara basin Gopalpur, Dhaura. Here rocks of upper Gondwana and alluvium are found which favours high drainage frequency. There are frequent slopes and the area is hilly which makes the area of high drainage density. Steep slopes and hills increases velocity of water and many first order streams curve out their channels on slopes. The high drainage density is related to steep slopes and high average relief.

**DRAINAGE FREQUENCY**

The counting of number of stream segments in a unit area is called stream frequency. Horton (1945), describes the stream frequency as the total number of streams per unit area. In the present study the quarter inch drainage map was converted into one inch square grids and the drainage frequency-map was prepared by counting the number of streams on each grid.

Drainage frequency-map for area under study has been prepared and following groups were found—

1. Very low frequency → 0.3 st / 1Km
2. Low frequency → 3 – 6 st. / 1Km
3. Medium frequency → 6 – 9 st / 1Km
4. High frequency → 9 – 12 st / 1Km
5. Very high frequency → above 12 st / 1Km
MURWARA BASIN
DRAINAGE FREQUENCY

No. of Stream / 1 km
- Above 12
- 9-12
- 6 - 9
- 3 - 6
- 0-3

Source: Topographical Sheet 64A/1,2,5,6,9,10
For convenience the above said classification of stream frequency is converted in to broad categories –

1. The low drainage frequency area → 3 – 6 st / 1Km
2. Medium drainage frequency area → 6 – 12 st / 1Km
3. High drainage frequency area → above 12 st / 1Km

1. **The low drainage frequency area**

These areas lie between 3–6 st. / Sq. Km. and extend over all S.E. part and central part of the Murwara basin. This is Plain area where the frequency is low. The main factors which is responsible for the occurrence of low frequency near Katni is the presence of lime-stones about more than 61 percent of the entire area of the study region and is characterised by very low and low categories of drainage frequencies which indicate that the most part of the drainage basin under study is plain and this discourages the formation of nallahs and streams. So the factors responsible for the low drainage frequency in these areas are the comparatively plain land form surface and the coverence of thick alluvium. Because of these conditions only few streams have developed in this part of the area.
(2) **Medium Frequency**

Drainage frequency in these area lie between 6–12 st. / Km. These areas extend to central eastern part and in some parts of N.E. direction in Murwara basin. The alluvium and Vindhyans are present and medium slope found in this area. The important controlling factor is that here rocks belong to the lower Vindhyans which have the formations of variable resistance developing uneven relief. Central eastern parts of Murwara basin comprises the rocks of Bhandar series which have developed a variable relief.

(3) **High drainage frequency area**

High drainage frequency in these area lie above 12 st. / Km. has developed in many small areas mostly in the formation and the varying slopes appear to have influenced the development of drainage frequency. Such areas in S.W. extend to part of the study are Bijeraghogarh, Kailwara, imlag. Here rocks of upper Gondwana and Mahakoshal groups of rocks (Bijawar) are found which favours high drainage frequency and the area of high drainage density.
THE RELIEF ASPECT

The relief aspect of fluvial geomorphometry is taken into consideration. The study of average slope, relative relief, area, height curves, hypsometric curves, longitudinal profiles of the basin is also done.

The variety of data necessary for the aforesaid morphometric studies have been worked out from survey of India toposheets.

Relief profile

Superimposed profiles have been constructed for the analysis of the relief related morphometry. It has been noticed that the profiles are congested at the 400 metres elevation levels. They suggest occurrence of three erosion surfaces at the height of

1. 690 metres

2. 560 – 400 metres

3. 310 metres

One inch maps have been used for this purpose.

These surfaces have been discussed in Chapter Four of this thesis.
LONGITUDINAL PROFILE

Longitudinal profiles are most important and useful part of the study of geomorphological studies.

Mackin (1948), was the man to describe the importance of longitudinal profile of a stream, to describe the nature of a drainage system with regard to its segments and its effects on the velocity of the stream.

This determines the transportation capacity of the stream.

According to Strahler (1964) “the channel profiles normally show up concavity i.e. is a persistent down stream decrease ingradient”.

In study it is found that the start show elevation but it gradually shows almost straight line.

Due to low slope and low gradient the velocity of the stream is also low. Low velocity results in low kinetic energy which decreases the capacity of the stream to carry eroded material during transportation.

Longitudinal profile show that the Katni and Niwar rivers flow towards the north direction.
Longitudinal Profile of the Murwara Basin
Katni and its tributaries

Source: Toposheets 64 A/1, 2, 5, 6, 9, 10

Vertical Scale - 1" = 100 Feet
Horizontal Scale - 1" = 10 Kilometres
The broad sloping cover of laterite is found in the stream. It is estimated that this may have been the result of Deccan Trap lava flow.

The tributaries of the rivers flow radially all along due to which water flow uniformly in all directions. This character of the streams may be due to structural and volcanic nature of the land.

During investigation it is found that the Katni river is of 6 order stream. The main tributaries, Niwar, Sumrar, Bhimar, Amari, Jilhari and Koilari join to the main river i.e. Katni.

They originates from different heights (420 feet, 430 feet, 450 feet, 448 feet, 480 feet, 440 feet) and joins the Katni river almost at the same height.

This nature of tributaries of rivers give velocity to the main stream (Katni river) but maintains the uniform flow without much turbulence.
REFERENCES


Memorial Committee. Edited by V.C. Mishra, N.P. Ayyar, Pramila Kumar pp. 146.