

# Analysing Morphometric Characteristics using Geospatial Technique: A case study of Vishwamitri Watershed, Gujarat

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## ABSTRACT

Increasing population, faulty irrigation practices, urbanization, and industrialization have pressurized water demand, especially, in developing countries. The problem gets aggravated by erratic patterns of rainfall which leads to dropping levels of the groundwater table. A watershed, therefore, acts as water supply for irrigation and water management. The management of such areas becomes more important for developing the groundwater reserve. Hence, watershed management is taken into account considering an important part of sustainable development.

Analysis of morphometry of watersheds is the evaluation of the channel network and its parameter like area of drainage, gradient and relief. Drainage basin analysis is important for the management of water, climate, geology, geomorphology, and past structural records. It helps to identify water potential zones, locations for water harvesting sites, managing water resources, overflow and nature of the drainage system. Hence, it facilitates to attain sustainable watershed management.

Morphometric analysis of watersheds is that the analysis of the channel network and its parameters like space of voidance, gradient, and relief. Such an analysis of the geographical area is vital in understanding geo-hydrological behavior and understanding some basics of climate, geology, morphology, and past structural records. It facilitates spot water potential zones, locations for water gathering sites, managing water resources, overflow and nature of the system. Hence, it facilitates to realize property watershed management.

The present study intends to quantify a range of morphometric factors viz., linear, aerial, and relief features of Vishwamitri watershed using Geospatial techniques. The result thus generated can assist decision-makers, planners and managers.

**Keywords:** Morphometric Characteristics; Quantitative Analysis, Sustainable; Watershed management; Geospatial technique

## 1. Introduction

In current situation when there is high demand and limited accessibility, it becomes more imperative to manage water resources. Also, changes in land uses have effect on rivers and its processes. (Bhatt.B, Joshi.J 2018). Quantitative Morphometric analysis of a watershed describes watershed geometry and also plays important role in evaluation of groundwater potential, management, river basin and environment. The analysis is based on systematic study of R. E. Horton in 1930s, followed by Miller (1953), Schuman (1956), Strahler (1964) and Clarke (1966).

Drainage basin morphometry makes an attempt to elucidate and predict the semipermanent aspects of basin dynamics leading to morphological changes among the basin (Thompson et al. 2001). It is additionally used in varied fields of natural science associated engineering applications as an indirect tool for estimation of soil, landslide condition mapping, predicting the movement of groundwater and analyzing topography (Pike 2000).

Basin morphometry explains and calculates the long-term characteristic of basin dynamics (Thompson et al. 2001). It is additionally also used in various fields of earth science and engineering applications as an indirect tool for estimation of soil, landslide vulnerability mapping, calculate the movement of groundwater and analyzing topography (Pike 2000).

At present geo-spatial technologies are preferred over conventional manual basin delineation as less time consuming and more accurate. Hence, much of the traditional topographic map information can now be collected and processed digitally by using GIS-based data. The technique has been increasingly used to delineate river basins and to automatically extract morphometric parameters employed in hydrologic model (Rao et al, 2010). These tools have been efficiently used for water resources assessment vulnerability to pollution and mapping of ground water quality (Bhatt.B, Joshi.J,2019). Geospatial technique have been integrated extensively by researchers for different drainage basin analysis viz., Nag(1998) Chopra et. al. (2005), Nookaratram et. al. (2005), Thakkar, et al (2007) Sreedevi et. al. (2009) ,. Magesh et al (2013), Gajbhiye, S. (2015), Dayal et al(2015) Dahiphale et.al (2016) Rai, et. al (2018),Sahoo et.al( 2019) The present study intends to quantify a range of morphometric factor viz., linear, area and relief of Vishwamitri watershed with the help of Geospatial techniques.

## 2. Study area

Vishwamitri watershed located in the Gujarat is a tributary of the Dhadhar River. It originates from Pavagadh hill at about at elevation of more than 600 meters and extends between  $73^{\circ} 7' E$  to  $73^{\circ} 33' E$  longitudes and  $23^{\circ} 2' N$  to  $23^{\circ} 33' N$  latitudes. The study is carried out for area between Pavagadh (origin and upper catchment) to Jambuva (where it leaves Vadodara city) covering length of 91km and area of about 601 sq.km.

## 3. Methodology

The drainage network has been extracted using SRTM with 90 m resolution and topographical maps (SOI sheets)(1:50,000). Watershed is demarcated using Arc GIS. Geometric characteristics of drainage basin viz., area and perimeter, length and number of streams are derived using GIS. Other parameters are derived based on the methods suggested by Horton, 1945, Strahler, 1964, Hardy 1961, Schumm 1956, Nookaratanm et. al. 2005 and Miller 1953. Spatial analyst tool is used to analyze drainage density and frequency distribution of the watershed

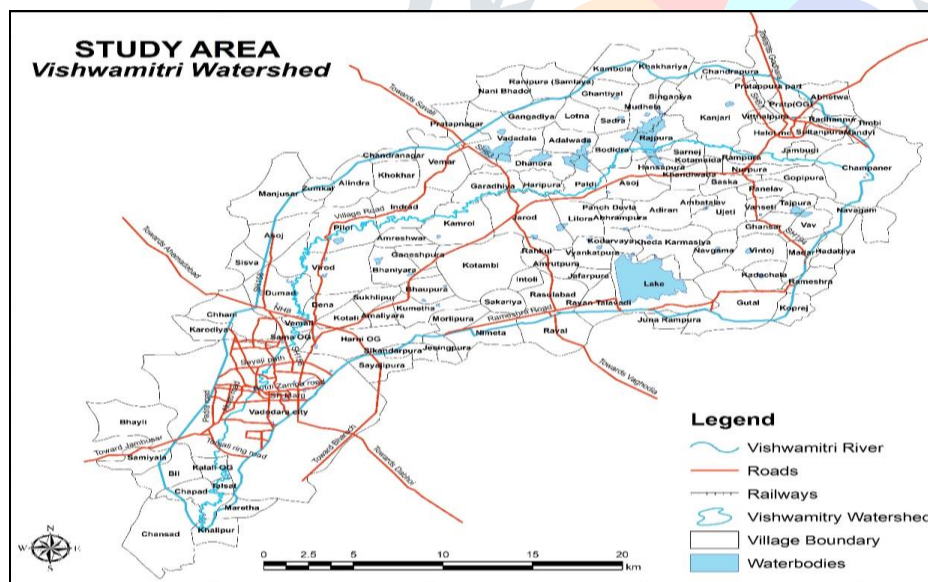


Figure 1: Study area

## 4. Results and discussion

### Estimation of linear Aspects

Table 1 linear Aspects

Stream Order	Number of stream	Total number of Stream	Length of the Stream	Total Length	Mean Stream Length	Stream Length Ratio	Bifurcation ratio	Mean Bifurcation Ratio (Rbm)	Basin Length (Lb)
1	175	238	222.553	558.13	1.27	-	3.72	3.17	49.70
2	47		119.858		2.55	2.01	3.62		
3	13		77.7815		5.98	2.35	6.50		
4	2		81.5898		40.79	6.82	2.00		
5	1		56.35		56.35	1.38	-		

**1 Stream order (Su).** The study of drainage basin starts the stream ordering. In the present study, streams are ranked according to Strahler's stream ordering method. It has observed that the first order streams are maximum and as the stream order is increasing there here is a decrease.(Table 1). The lower order streams are dominant in the study area.

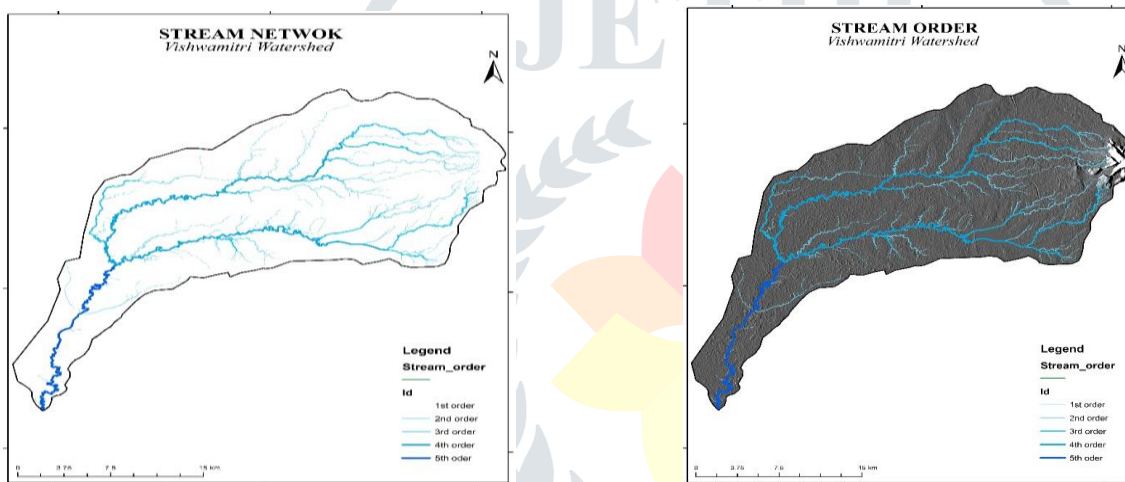


Figure 2: Stream arrangement and Stream Order in Watershed

**2 Stream Length (Lu):** Total length of the streams is 558.13 km. includes 83.160Km in 1 order, 222 Km in 2nd order, 119.858 Km in 3rd order, 77.7815 in 4th order and 81.5898 Km in 5th order respectively shown in Table 1.

**3. Mean Stream Length (Lsm):** The mean stream length of stream increases with increasing order. It was observed that Lsm was less for 1st order stream and gradually increased for the 5th order stream. This may be due to difference in slope and topography

#### 4. Bifurcation Ratio (Rb) :

It is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Nu+1). It is calculated as  $Rb = Nu/Nu+1$  (Nu: total number of stream segment of order 'u', Nu+1: number of segment of next higher order).

The bifurcation ratio for **Vishwamitri** basin ranges from 2 to 6.5 and mean bifurcation is 3.17, suggesting a very lower degree of drainage integration. Lower value of bifurcation ratio indicates plain land, permeable and soft bed rock which can act as ground water potential zone. Mean Bifurcation Ratio is arithmetic mean of bifurcation ratios of all orders. In the present study the mean bifurcation ratio of 3.17 reveals that the water shed falls within normal basin category as suggested by Strahler.

**5 Basin Length (Lb):** The basin length is the longest part of the basin parallel to the principal drainage line defined by Schumm (1956). The equation Schumm (1956) used for calculation  $Lb=1.312 \times A^{0.568}$  (A: area of the basin) Stream length that is 49.70 km.(Table 1)

**2. Estimation of Areal Aspects:** The parameters calculated under this are of stream frequency, drainage density, drainage texture, form factor, circularity ratio, elongation ratio and length of overland flow.

**Table 2: Areal Characteristics of the Watershed**

Area of Watershed sq.km	Perimeter km	Stream Frequency	Drainage Density	Length of overland flow	Elongation Ratio	Circularity Ratio	Compactness Constant
601.11	128.19	0.40	0.93	0.54	0.56	0.46	1.47

**2.1 Stream Frequency (Fs):** It is the total number of stream segments of all orders per unit area. According to Horton  $F_s = N/A$ . (Horton, 1945). Stream frequency of watershed is 0.40.

**2 Drainage density (Dd):** Drainage density (Dd) is an important indicator of the linear scale of land form elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of Km/Km<sup>2</sup>. It is calculated as  $D_d = L/A$ , where L is the total length (km) of all stream segments, A is basin area (km<sup>2</sup>). This value for watershed was found to be 0.9 km/sq.km. In the study drainage density observed very low with highly permeable sub soil materials, under dense vegetation cover and where relief is low.

**3 Length of overland flow (Lof) :** It is the length of water over the ground before it gets concentrated into definite stream channels and is equal to half of drainage density

$Lof = 1/2D_d$  where,  $D_d$ =Drainage density. The Length of overland flo in the watershed is 0.54.

**4. Elongation Ratio (Re):**It is defined as the ratio of diameter of a circle having the same area as of the basin and maximum basin length (Schumm 1956).

$Re = 2\sqrt{(A/\pi)}/L_b$  ;where, A=Area of watershed,  $\pi=3.14$ ,  $L_b$ =Basin length.

It signifies the shape of the river basin which is result of the climate and geology of the area. A circular basin is more capable in surplus discharge compared to an elongated basin (Singh and Singh, 1997). The value of elongated ratio varies between 0.6 and 1.0 typically in the regions of very low relief, whereas value between 0.6 and 0.8 are associated with high relief and steep ground slope (Strahler, 1964). The elongation ratio of Vishwamitri basin is. 0.56. The elongation value can be grouped into three categories, namely circular basin when  $Re > 0.9$ , Oval basin if Re is between 0.9-0.8, and less elongated basin when  $Re < 0.7$ . In the Vishwamitri watershed the Re value is less than 0.7 and hence the watershed is less elongated in shape.

**5. Circularity Ratio (Rc):** Circularity ratio is the ratio between the areas of watershed to the area of circle having the same circumference as the perimeter of the watershed (Miller, 1953).

$R_c = 4\pi A/P^2$  ;where, A=Area of watershed,  $\pi=3.14$ , P=Perimeter of watershed.

The value ranges from 0.4 to 0.5, greater the value more is the circularity ratio. The value low, medium and high are associated with youth, mature and old stage of the cycle. The value of 0.46 indicates an elongated basin, with a dendritic drainage pattern.

**6. Compactness Constant (Cc):** It can be represented as basin perimeter divided by the circumference of a circle to the same area of the basin. This factor is indirectly related with the elongation of the basin area.

$C_c = 0.2841 P/A^{0.5}$  | P: perimeter of basin, A: area of the basin

Lower values indicate more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion. The value of 1.47 indicates elongated shape of watershed.

### 3. Estimation of Relief Aspects

**1 Form Factor (Rf):** Horton defines the form factor as Rf dimensionless ratio of watershed area (A) to the square of the length of the watershed (L). The value of form factor would be less than 0.7854 for a perfect circular shaped watershed. For the watershed form factor is 0.24 which indicates the elongated shape of the basin.

**Table 3: Relief Characteristics of the Watershed**

Form Factor (Rf)	Texture Ratio	Basin Relief (H)	Relief Ratio (Rh)	Relative Relief	Ruggedness Number (Rn)
0.24	1.37	756	15.21	0.59	0.70

**2.Texture Ratio (T):** Texture ratio is an important parameter in the drainage morphometric analysis which depends on the original rock system, 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.  $T = N1/P$  where,  $N1$ =Total number of first order streams;  $P$ =Perimeter of watershed

In present study, the texture ratio is 1.37. The lower values of specifies that the basin is plain with lesser degree of slope.

**3. Infiltration Number (If):** Infiltration number of a drainage basin is the product of drainage density ( $Dd$ ) and stream frequency ( $Fs$ ) suggesting the infiltration character of the basin. The higher the infiltration number, the lower will be the infiltration and higher will be the run-off (Rao Liaquat et.al. 2011). The value obtained in the study is 0.37.

**4 Basin Relief (H):** Basin Relief is the vertical distance between the lowest and highest points of watershed. The elevation varies from 24 to 780 mt. The computed values for Vishwamitri river watershed indicate high basin relief 756 mt.

**5 Relief Ratio (Rh):** Total relief of the basin represents the difference in the elevation of the highest point and the lowest point on the valley floor of the river basin. The 'Rh' is the ratio between the total relief and the lengthiest measurement of the basin parallel to the main drainage line (Schumm 1956)  $Rh=Bh/Lb$ ; Where,  $Bh$ =Basin relief;  $Lb$ =Basin length In the study area, the relief ratio value is 15.21.

**6. Relative Relief (Rhp)** The maximum basin relief was obtained from the highest point on the watershed perimeter to the mouth of the stream.

$$Rh = (H*100)/p$$

The value 0.59 m indicates that basin is plane with mild slope. Therefore, the area can be mainly used for agricultural activities around stream as it is plane and has accessibility to water.

**7 Ruggedness Number (Rn) :** An extreme high value of ruggedness number occurs when both variables are large, and slope is steep (Strahler, 1956).

$$Rn = Bh \times Dd \text{ Where, } Bh = \text{Basin relief; } Dd = \text{Drainage density}$$

The low ruggedness value of watershed means that area is less vulnerable to soil erosion and have structural complexity with relief and drainage density. Calculated accordingly, the watershed has a ruggedness number 0.70 which shows that watershed less susceptible erosion

## 5. Conclusion

The quantitative morphometric characteristic of basin in the study area shows that the basin is elongated, with low relief and gentle slope.

The analysis drainage basin result shows that the basin has a dendritic pattern with fifth order stream. The maximum stream order frequency is of first-order streams and followed by other order streams. Hence, there is decrease in stream frequency and the stream order. High bifurcation ratio in study area indicates a strong control of geological structure.. The result of relief aspect shows the study area is characterized by low relief and high stream density. The mean bifurcation ratio reflects that the watershed is in normal basin category. The watershed is elongated in shape as circulatory ratio of 0.56 and elongation ratio is 0.46. As the ruggedness value is low it implies that area is less susceptible to soil erosion. In present study, value of relief ratio has been found to be 15.21. It has been

observed that an area has moderate relief and slope. Low values of relief ratios suggest the resistant basement rocks of the basin and low degree of slope.

Overall the basin falls under normal category having low to moderate relief, gentle slope, high stream density, and dendritic pattern, resistant basement rocks, less erosion, high infiltration, and low runoff.

The quantitative analysis of morphometric parameters in river basin evaluation can be very valuable in water resource management. Geographical Information System (GIS) is a competent tool to delineate drainage basin and water resources planning. The present study is valuable contributing to planning and optimal sustainable management of watershed.

### Acknowledgement

We would like to express our gratitude NRDMS (DST) for financial support (NRDMS 01/138/015(G)). Authors cordially acknowledge USGS for supplying necessary satellite imagery.

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