ISSN: 2998-4459
Royal International Global Journal of Advance and Applied Research, Volume 1| Issue 1 | July 2024

Original Article

Study of Morphometric Characteristics of Karha River

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Abstract *Morphometric evaluation of any catchment area is necessary to understand the geo-hydrological response of the drainage basin to the geographical phenomenon. The morphological setup of any drainage basin have its pure impressions on behavior of the geomorphological characteristics of that drainage area. Without understanding and studying such behavior of or characteristics of drainage network linkages, planning and implementation of watershed planning is not possible. Here attempt has been made to understand the morphological behavior of Karha River Basin through morphometric delineation techniques. It will ultimately helps in planning and watershed management of present area to resolve some environmental related issues e.g. groundwater scarcity. It also give emphasis to the topographic features of the drainage basin and gives some authentic assessment of arable land and groundwater and surface water resources.*

The study area covers parts of the Purandar and Baramati tahsils in Pune District, Maharashtra. Geographic Information System (GIS) technology has been employed to generate spatial datasets, perform quantitative analysis, and present the results within a spatial framework. A range of morphometric parameters was examined to interpret the drainage pattern and basin characteristics. GIS tools were specifically used to evaluate linear, areal, and relief aspects of the basin. Such GIS-based morphometric studies are valuable for comparative analysis with other river basins that share similar geo-environmental settings.
Keywords: *Morphometric Analysis, Karha River Basin, Drainage Basin, Watershed Management, GIS Techniques, Stream Order (Strahler Method), Bifurcation Ratio*

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Submitted: 20 June 2024 **Revised:** 28 June 2024 **Accepted:** 10 July 2024 **Published:** 31 July 2024

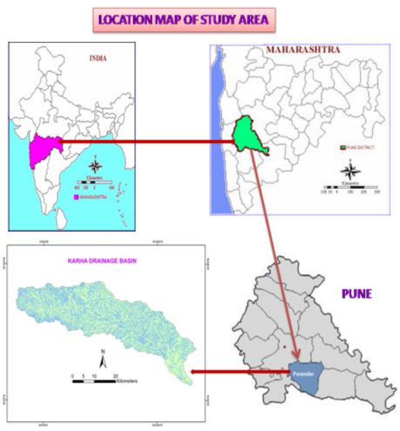
INTRODUCTION

Morphometry discusses the quantifiable measurement and mathematical estimation of the Earth's surface landforms, including the structure, dimensions and form of landforms (Agarwal, 1998; Obi Reddy et al., 2002). Over the last few decades, geomorphological research has increasingly focused on developing numerical and analytical methods to explain the development and functioning of surface drainage systems (Horton, 1945; Leopold & Maddock, 1953; Abrahams, 1984).

Earlier morphometric studies often concentrated on randomly selected areas or isolated stream segments. However, adopting the watershed as the fundamental unit of analysis provides a more systematic and meaningful approach. A watershed represents the land area drained by a stream or a group of streams and serves as a basic erosional and hydrological unit where interactions between land and water resources are clearly observable. It forms the core element of fluvial landscapes, and extensive research has examined its geometric properties, including stream network structure, drainage texture, pattern, and basin shape (Abrahams, 1984).

Study Area

The drainage basin of Karhar River located in Purandar and Baramati tahasil of Pune district, Geographically, it extends between 18°15′45″ and 18°22′48″ North latitudes, and 73°52′40″ and 74°02′00″ Eastlongitudes. The area is covered by Survey of India topographical
sheets numbered 47J/3 to 47J/12 and 47F/15.



Quick Response Code:	Access this article online
	Website: https://rlgjaar.com
	Website: https://www.doi.org DOI: 10.5281/zenodo.18906727

How to cite this article:
Gaikwad, P. P. (2024). Study of Morphometric Characteristics of Karha River. Royal International Global Journal of Advance and Applied Research, 1(1), 48–52. https://doi.org/10.5281/zenodo.18906727

Methodology

For the present investigation, toposheets of SOI, index number namely 47J/3 to 47J/12 and 47F/15 on 1:50,000 scale are utilized. Stream ordering was carried out following the method proposed by Strahler (1952). Various morphometric parameters were computed using standard mathematical formulae to analyze the drainage characteristics of the basin.

Linear Aspects

Stream Orders:

The initial stage of drainage basin analysis involves assigning stream orders to the channel network. Although several techniques are available for stream classification, the modified Strahler (1952) method has been applied in this research.

The Karha River basin has been identified as a seventh-order basin. It comprises 4,232 1st order streams, 1,084 2nd order, 255 3rd order, 93 4th order, 29 5th order, 4 6th order, and 1 7th order segment. This arrangement specifies that, number of stream sections increasingly declines as per stream order are increases, reflecting the typical hierarchical organization of a drainage network.

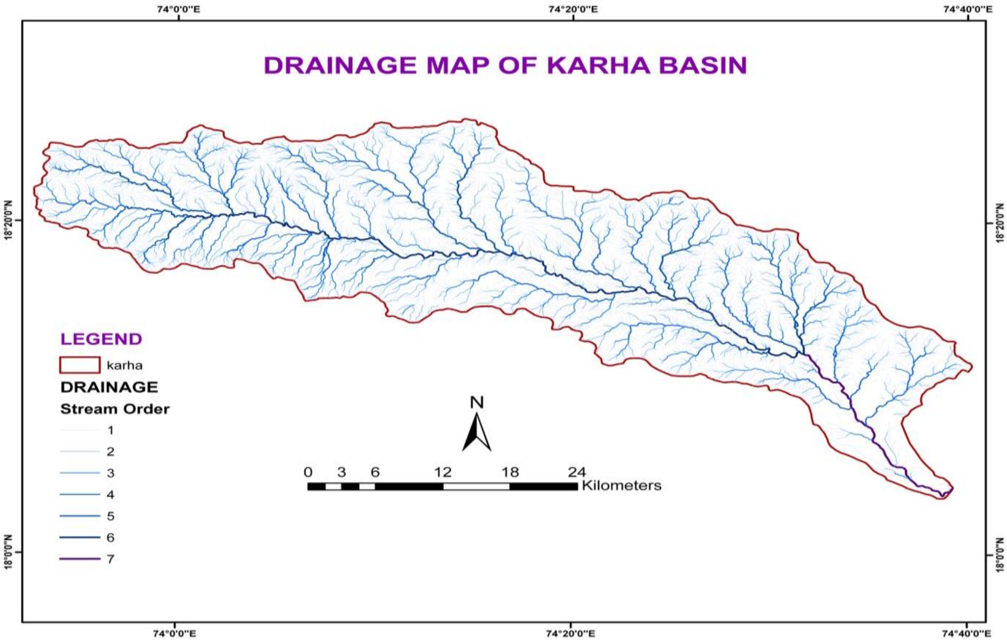


FIG-2

Bifurcation Ratio (Rb):

The ratio of stream numbers of any given stream order to the stream number of corresponding lower stream order (Horton, 1945). For the present drainage basin, bifurcation ratio is ranging in between 7.9 to 3.9. The average ratio of bifurcation for the given area is 4.2. it clearly means that 4.2 times on an average the channel is splitting in segments of next higher order channel. The given average bifurcation ratio reveals that the land under this drainage basin experiencing strong geological and structural control.

$$Rb = (N\mu / N\mu + 1)$$

Where,

(Rb) is known as Bifurcation Ratio

(Nμ) is consider as number of segments of given order

(Nμ +1) is defined as segments numbers of next conjugative higher order

Table-1)- Bifurcation Ratio

Stream Order	Total Stream Length (km)	Total No of Streams	Ratio
First	2390	4232	3.9
Second	727	1084	4.3
Third	364	255	2.7
Fourth	246	93	3.2
Fifth	112	29	7.19
Sixth	72	4	4.0
Seventh	23	1	--
TOTAL	**3936**	**5698**	25.3
		Average BR	**4.2**

Length of main channel:

It refers to the distance measured along the main channel from the outlet of the specified sub-basin to the farthest point on the catchment boundary. Different techniques can be applied to determine stream length using topographic maps. For Karha river, delineation is been carried out through the help of Global mapper 12 Software. The length measured trough the software is 111.51 kilometers from the source to confluence with Nira.

Stream lengths (Lu):

Stream length is closely associated with surface runoff characteristics. Generally, longer channels tend to delay the occurrence of floods and contribute to greater surface flow accumulation. The cumulative lengths of streams under each order are presented in Table No. 01.

Horton suggest that the average stream segment length must increases as per higher order stream in dependable quantity, which he coined the term as length ratio. It is also defined as relationship in between average stream length of any particular stream order (Lu) and next lower order stream. The (RL) is expressed as per given formula.

Ratio of the length = (Lu / Lu + 1)

The calculated LR of Given basin is 2.10, which are given in table two.

Table-2: Linear Aspects

Stream Order	Stream Number	Bifurcation Ratio	Mean Length of segment (in km)	Length Ratio
1	4232	3.9	0.5	1.2
2	1084	4.2	0.7	2.1
3	255	2.7	1.4	1.8
4	93	3.2	2.6	1.5
5	29	7.2	3.8	4.7
6	4	4.0	18.0	1.3
7	1	-	23.7	-
				2.1

Basin Perimeter:

The calculated perimeter for Karha drainage is important morphometric parameter in present assessment. It symbolizes the entire length of drainage basin boundary, which encloses total catchment. It ultimately helps in knowing the size and geographical extent of the drainage basin. In the case of the Karha basin, the calculated perimeter is 238.4 km.

Table - 3: Quantitative Information

Basin	Basin Length(km)	Basin Perimeter (km)	Basin Area Sq.Km	Relative Perimeter
Karha	89.07	238.4	1357.4	41.87

Relative Perimeter:

The relative perimeter of Karha riverhas been estimated with following equation

Relative Perimeter (RP) = (P^2 / A)

The RP of Karha is 41.87 km.

Areal Aspects

Drainage Area:

The basin area represents the cumulative result of drainage evolution within a given catchment. The Karha River basin covers an area of approximately 1,357.4 square kilometres. Among various watershed characteristics, drainage area (A) is considered one of the most significant factors in hydrological planning, as it indicates the potential quantity of runoff that may be produced from precipitation.

Drainage Density:

The measurement of drainage density (D) is considered as key morphological aspect, because hydrological responses such as surface runoff and infiltration capacity are associated with it. It is expressed as ratio in between summation of total stream length of all stream order and entire area covered by the drainage basin. It is nothing but the average length of channel per unit area. Horton particularly focuses on this parameter because it gives idea of drainage structure. It is calculated by using given formula.

$$D = (\sum Lu / Au)$$

Where as

(D) is Drainage Density

($\sum$ Lu) is total length cumulated for each stream order within a given drainage area.

The Karha basin records a drainage density (D) value of 2.90. This relatively high value can be attributed to the presence of less permeable or hard surface materials along with limited vegetation cover, which together promote greater surface runoff and reduced infiltration.

Constant of Channel Maintenance:

The Constant of Channel Maintenance, as defined by Schumm (1956), is calculated as the reciprocal of drainage density. This means that when drainage density increases, the value of the constant decreases, and vice versa. A very low value of the Constant of Channel Maintenance suggests the dominance of relatively impermeable rock formations or steep slopes that encourage rapid runoff. In contrast, a higher value generally reflects the presence of more permeable surface materials, allowing greater infiltration and reduced surface flow.

C = ($\sum$ L / A)

The Constant of Channel Maintenance for the Karha basin has been calculated as 0.34. Such a low value is characteristic of semi-arid climatic conditions, where limited rainfall and relatively impermeable surfaces tend to produce higher drainage density and reduced infiltration.

Stream Frequency:

Stream frequency denotes to summation of segments of stream, area per unit within a catchment. It is calculated by using given standard formula.

$F = \sum Nu / Au$

The Karha basin has a stream frequency value of 4.20, indicating a well-developed drainage network and suggesting a comparatively fine drainage texture.

Circularity Ratio:

The ratio of circularity is important characteristics used to analyse total shape of any given drainage basin. The ratio is nothing but direct relationship in between real catchment area with the area of circle have same perimeter as catchment. As the basin shape becomes more circular, the value of this ratio approaches 1. It is determined using the following formula:

$$RC = (4\pi A / P^2)$$

The circularity ratio calculated for the Karha basin is 0.30. Since this value is much lower than 1 and closer to zero, it indicates that the basin does not exhibit a circular form and instead has an elongated shape.

Form Factor:

Horton (1932) introduced the concept of the form factor, which is mathematically represented as:

$$F = (A / L^2)$$

A higher value of the form factor (F) generally indicates a more circular basin shape. In the case of the Karha basin, the calculated F value is 0.17, which is relatively low, confirming that the basin does not have a circular form but is instead elongated in shape.

Elongation Ratio:

The ratio of elongation expresses, relationship in between diameter of circle partaking the same area of the catchment and maximum length of catchment. As values of ratio approaches towards 1.0, indicate that the areas having high relief with very steep slopes. This ratio is calculated using the following formula:

$$Re = (2\sqrt{A / \pi}) / L$$

The elongation ratio of the Karha basin has been computed as 0.76, indicating that the basin possesses a distinctly elongated form rather than a circular configuration.

Elipticity Index:

Elipticity index (E) of drainage basin is estimated by following method:

$E = (\pi L^{2/} 4 A)$

The elipticity index (E) of Karha basin is 4.59, which suggest the eleptical shape of drainage basin.

Table -4: Areal & Relief Aspects

Basin	Stream Frequency	Circularity Ratio	Form Factor	Elongation Ratio	Elipticity Index	Ruggedness Number	Relief Ratio
Karha	4.20	0.30	0.17	0.76	4.59	2.40	9.29

Relief Aspect

Basin Relief (H):

Relief of the Basin is refers to the maximum upright difference in height in between the confluence of the dominated stream and most peak point on the watershed border. In the case of the Karha basin, the total relief (H) has been calculated as 828 meters.

Relief Ratio (Rh):

The relief ratio represents the relationship between the overall vertical relief of a basin—calculated as the elevation difference between the highest point and the basin outlet—and the basin length, which is measured along its maximum extent. It is determined using the following formula:

$Rh = (H/ Lb)$: The Rh of Karha basin is 9.29.

Ruggedness Number (Rn):

The ruggedness number is calculated by multiplying basin relief (H) with drainage density (D), ensuring that both parameters are expressed in the same units. This unit-free index integrates the effects of slope steepness and channel distribution into a single value, providing an overall measure of terrain roughness.

$Rn = (H*D)$.

Ruggedness number of Karha basin is 2.40.

Conclusions

The present study examines a range of morphometric parameters that describe the geomorphological individualities of the drainage basin, by seeing its linear, relief, and areal aspects, with the various scientific methods adopted for calculation of morphometric parameters. The Karha basin has been classified as a seventh-order basin and displays a dendritic drainage pattern.

The average bifurcation ratio is 4.2, placing the basin within the normal category. A relatively higher bifurcation ratio suggests that structural influences have played a significant role in shaping the drainage network. The drainage density indicates a coarse drainage texture. The elongation ratio of 0.76 reflects an elongated basin form, which is further supported by a circularity ratio (Rc) of 0.30, confirming the elongated shape of the basin.

Overall, the analysis highlights that morphometric evaluation is essential for understanding basin-scale fluvial landforms and interpreting the geomorphic development of the region.

Acknowledgment

The authors would like to express their sincere gratitude to [SNDT Arts and Commerce College for Women Pune, SNDT Women’s University Mumbai for providing the necessary facilities and support to carry out this research. We also thank for their valuable guidance and insightful suggestions during the course of this study.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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