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Quantitative analysis of Drainage and Morphometric characteristics of the Karha river basin of Western Maharashtra using Geospatial technology

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ABSTRACT

In this paper, an attempt has been made to study the morphometric characteristics of the Karha river basin which is a left-bank tributary of the Nira River in Maharashtra. The Alos Palsar DEM data having a spatial resolution of 12.5 meters and SOI Toposheet 1:50000 scale were used for quantification of morphometric parameters. The Karha valley is considered to have a 7th order trunk stream according to this study. It has a total of 5096 streams whose total stream length is 3781.7 km. The mean bifurcation ratio is 3.71. The basin area of the Karha River is 1342.65 Km2 which is covered by hard massive and vesicular amyloidal basalt rocks. Its circulatory ratio is 0.28, the form factor is 0.11, elongation ratio is 0.30, and drainage density is 2.82. The relief aspect of the Karha river watershed revealed that the relief ratio is 0.0074, absolute relief is 830M, ruggedness number is 2.34, and the channel gradient is 2.36. It is observed that the Karha watershed has a dendritic type drainage pattern. It is highly eroded and elongated in a shape manner.

Keywords: Morphometric analysis, GIS, GPS, Linear aspect, Areal aspect, Relief aspect.

INTRODUCTION

The morphometric analysis of the drainage basin requires measurement of the linear aspects, aerial aspects, and slope. These factors influence the movement and occurrence of water within the basin. Morphometric analysis of watersheds involves analyzing land surface configuration parameters such as size, shape, landform dimension, etc. (Clarke, 1996). Planners and researchers can characterize watersheds and prioritize development for optimal utilization of natural resources based on their linear, aerial, and relief characteristics. Geology, structural components, soil, and vegetation influence the development of drainage systems in a given area over time and space.

There are a number of important hydrologic characteristics that can be related to the physiographic characteristics of drainage basins, including size, shape, slope of drainage area, drainage density, and size and length of the contributors (Rastogi et al. 1976).

STUDY AREA

The watershed area of the Karha river is 1342.63 Km^2. The Karha river originates from the Purandar hill range near Saswad town (Pune). The study area is basaltic rock type. The geographical extent of the basin is 18^0 00' N to 18^0 30'N latitude and 73^0 50'E to 74^0 45' E longitudes (Figure 1). The Karha River flows from the West to the south-east direction till it falls into the Nira river at Songaon village (Baramati Taluka, Pune District). In the present study, the outlet was selected at Songaon just before it joins the Nira river. The rainfall in this region is near 300-400mm annually, and it has a semiarid type of climate. More than 70 percent of the population in the basin area is engaged in primary services, and agriculture is the main occupation.

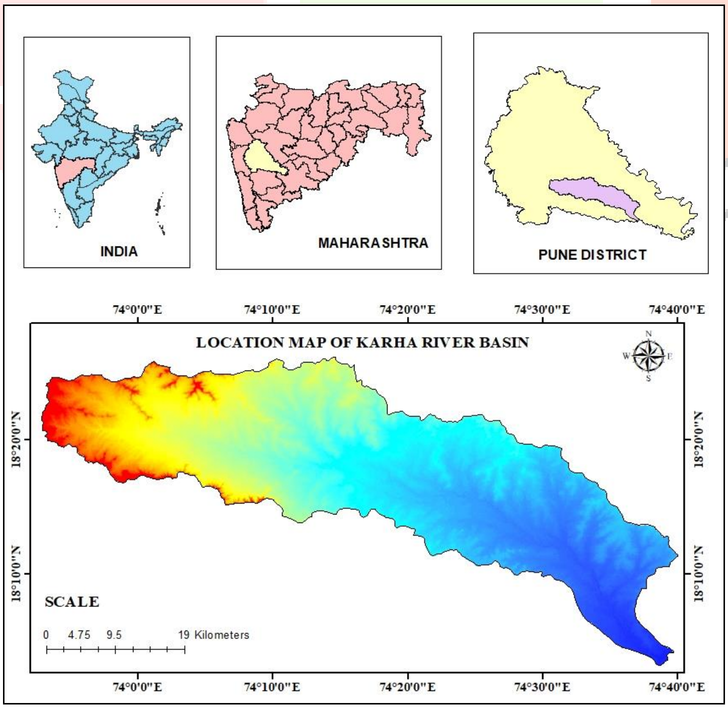


Figure 1. Location Map of the Karha river basin.

MATERIALS AND METHODOLOGY

The morphometric analysis of the Karha river watershed was carried out by using Alos Palsar DEM of 12.5m spatial resolution and Survey of India topographical maps No 47 F/15, 47 J/3, 47 J/4, 47 J/7, and 47 J/8 of 1:50,000 scale. The lengths of the streams, areas of the watershed were measured by using ArcGIS-10.2 software and stream order has been generated using Strahler's (1953) system and Arc Hydro tool in ArcGIS-10.2 software.

A linear, aerial, and relief aspect study has been conducted using the following formulas (Table 1). Stream and basin networks are projected to the regional projection (WGS-1984, UTM zone 43N).

Sr. No.	Morphometric Parameters	Formula	References
I- Linear Aspects			
1	Stream Order (U)	Hierarchical rank	Strahler, 1964
2	Stream Number	The total order wise stream segments are known as stream number.	Horton, 1945
3	Stream Length (Lu)	Length of the Stream in km	Horton, 1945
4	Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = Total stream length of order 'u'; Nu = Total no. of stream segments of order 'u'	Horton, 1945
5	Stream Length Ratio (RL)	RL= Lsm / Lsm-1 Where, Lsm=Mean stream length of a given order ; Lsm-1= Mean stream length of next lower order	Horton, 1945
6	Bifurcation Ratio (Rb)	Rb = Nu / Nu +1 Where, Rb = Bifurcation Ratio ; Nu = No. of stream segments of a given order ; Nu +1= No. of stream segments of next higher order	Schumn, 1956
7	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders.	Strahler, 1957
8	Length of the main channel (Lm)	Length along longest water course from the outflow point of to the upper limit of catchment boundary.	Horton, 1945
Sr. No.	**Morphometric Parameters**	**Formula**	**References**
9	Basin Perimeter (P)	Length of the watershed divides which surrounds the basin.	ArcGIS tool
10	Sinuosity Indices	The degree of deviation of its actual path from expected theoretical straight path.	Schumm,1963

11	Rho Coefficient	**P**= RL/ Rb Where, RL= the stream length ratio and Rb= the bifurcation ratio	Horton, 1945
		II- Arial Aspects	
1	Basin Area or Drainage Area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges.	Horton, 1945 & Strahler, 1964
2	Drainage Density (Dd)	Dd = Lu/A Where, Dd = Drainage Density (1/km) ; Lu = Total stream length of all orders ; A = Basin Area (km2)	Horton, 1945
3	Stream Frequency or Drainage frequency (Fs)	Fs = Nu/A Where, Fs = Stream Frequency ; Nu = Total no. of streams of all orders and ; A = Area of the basin (km2)	Horton, 1945
4	Drainage Texture Ratio (T)	T = Nu /P Where, Nu = No. of streams in a given order ; P = Perimeter of basin (km)	Horton, 1945
5	Form Factor (Ff)	Ff = A/Lb2 Where, A = Basin Area; Lb = Basin length	Horton, 1945
6	Constant Channel Maintenance (C)	C = 1/ Dd Where, Dd = Drainage Density	Horton, 1945
7	Circulatory Ratio (Rc)	$Rc = 4\pi A/ P^2$ Where, A = Basin area (km2) ; P= Perimeter of the basin (km)	Miller, 1953
8	Compactness Coefficients (Cc)	$Cc = 0.2821\ P/A^{0.5}$ A = Basin area (km2), P = basin perimeter (km)	Horton,1945
9	Elongation Ratio (Re)	$Re= \sqrt{A / \pi} / Lb$ Where, A= Basin area (km2) ; Lb= Basin length (km)	Schumn, 1956
10	Length of Overland Flow (Lof)	Lof = 1/ 2 * Dd Where, Dd = Drainage Density	Horton, 1945
11	Infiltration Number (In)	In = Dd × Fs Where, Dd = Drainage density ; Fs = Drainage frequency	Faniran, 1968
12	Shape index (Sw)	Sw=1/Ff, Where, Ff = Form Factor	Horton, 1932
Sr. No.	**Morphometric Parameters**	**Formula**	**References**
13	Drainage Intensity (Di)	Di= Fs/Dd Where, Fs = Stream frequency, Dd = drainage density	Faniran, 1968
		III- Relief Aspects	
1	Basin / Watershed Relief (Bh)	Bh=H-h Vertical distance between the lowest and highest points of watershed	Schumn, 1956
2	Relief Ratio (Rr)	Rr= H / Lb Where, H = Basin Relief (km) ; Lb = Basin length (km)	Schumn, 1956

3	Ruggedness Number (Rn)	Rn = H x Dd Where, H = Basin Relief (km) ; Dd = Drainage Density	Patton & Baker, 1976
4	Dissection index	DI = H /Ra Where, H = basin relief (m) Ra = Absolute relief (m)	Magesh et al., 2011
5	Channel gradient	Cg = H/{(Pi)*Cp} Where, H= Basin relief (m) Cp= logest dimension parallel to trunk drainage line	Prasad et al.,2008
6	Basin Slope (Sb)	Sb = H / Lb Where H and Lb= given above	Miller, 1953

Table 1 Formulae for computation of morphometric parameters

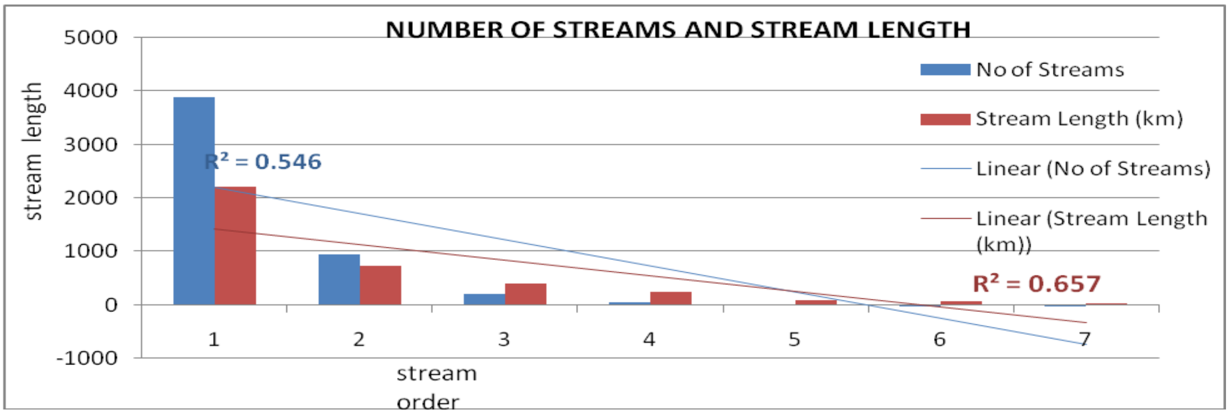
Stream Order	No of Streams	Stream Length (km)	Mean Stream Length (km)	Stream Length Ratio	Bifur-cation Ratio	Basin Perimeter (km)	Main stream length (km)	Rho Coefficient
1	3880	2219.83	0.57	0.74	4.12	244.56	112.64	0.15
2	941	726.73	0.77	0.40	4.57			
3	206	394.27	1.91	0.39	4.12			
4	50	246.55	4.93	0.81	3.13			
5	16	97.82	6.11	0.17	8.00			
6	2	72.35	36.18	1.50	2.00			
7	1	24.11	24.11	--	--			
Total	5096	3781.66	--	4.01	25.94			
Mean	--	--	--	0.57	3.71			

Table 2 Linear aspects of the study area

I- LINEAR ASPECTS

1. Stream Order (Nu) –The stream ordering map (Figure 1) shows that the Karha river basin is a seventh order stream. The maximum frequency is found in first order streams and its decreases from higher order to lower order stream.

2. Stream Number - The Karha basin contains total of 5,096 streams in which first order streams are 3,880 followed by second (941), third (206), fourth (50), fifth (16), sixth (2), and seventh (1) order streams (Table 2). A strong negative correlation was observed between stream order and the number of streams (R2=0.546).



Graph 1: Stream number and stream length relation with stream order

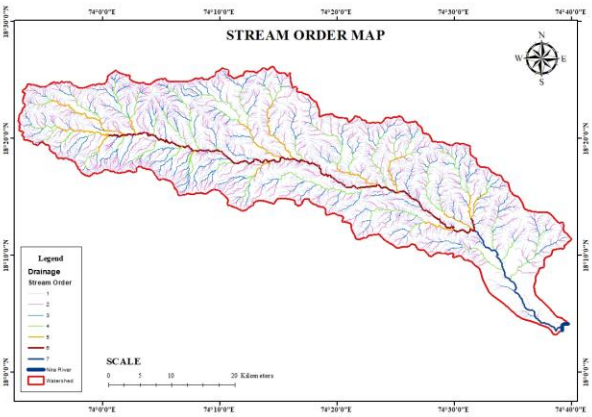


Figure 1 Stream Order Map

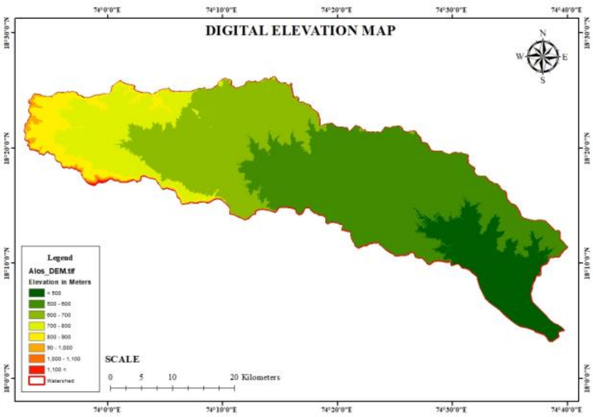


Figure 2 Digital Elevation Model

4. Mean Stream Length – The mean stream length of the different order streams of the study area is presented in Table 2. The order-wise mean stream length varies from 0.57 km to 36.18 km.

5. Stream Length Ratio – The stream length ratio of different orders of the Karha basin is presented in Table 2. Within the study area, the stream length ratio ranges between 0.17 and 1.50.

6. Bifurcation Ratio (Rb) – According to Table 2, the bifurcation ratios of the different streams in the Karha river basin have a constant nature and range between 2 and 8.

7. Mean bifurcation ratio (Rbm) –The mean bifurcation ratio of the Karha is 3.71 indicates it is a hilly dissected basin.

8. Length of the main channel (Lm) - The main channel length measured in ArcGIS-10 software, which is 112.64 Km (Table 2).

9. Basin Perimeter (P) - According to the toposheet, the perimeter of the Karha River basin has been measure. The basin perimeter of the drainage basin is 244.56.7 km (Table 2).

10. Sinuosity Indices – Sinuosity is calculated by dividing channel length by down valley distance. Sinuosity indices of the Karha River are 1.18, which indicates a transitional stage.

11. Rho Coefficient (ρ) - The computed value of the Rho coefficient for the study area is 0.15 (Table 2).

II- AREAL ASPECTS

A drainage basin's two-dimensional properties describe its area. This study examines the relationship between watershed area and length of a stream as well as how the area of a watershed relates to discharge characteristics and basin shapes (outline form).

Parameter	Value
Basin Area in (km2)	1342.63
Form Factor	0.11
Circularity Ratio	0.28
Elongated Ratio	0.3
Drainage density (km/km2)	2.82
Stream frequency (streams/km2)	3.8
Drainage Texture	20.83
Constant Channel Maintenance (C)	0.35
Compactness Coefficients (Cc)	1.88
Length of Overland Flow (Lof)	1.41
Infiltration Number (In)	10.72

Table 3 Areal aspects of the study area

1 Basin Area or Drainage Area (A) - The drainage basin area of the Karha River is 1342.63 km^2 (Table 3).

2. Form Factor (Ff) - The form factor ratio of the Karha River basin is 0.11 (Table 3) it indicate elongated basin.

3. Circularity Ratio (Rc) - The circularity ratio of the whole Karha river basin is 0.28 (Table 3).

4. Elongation Ratio (Re) - The elongation ratio of the basin is 0.30 (Table 3).

5. Drainage Density (Dd) - Stream length per unit area is the measure of drainage density (Horton, 1945). The drainage density of the Karha River basin is low i.e. 2.82 km/km^2 (Table 3.3).

6. Constant Channel Maintenance (C) - The value of constant channel maintenance of the Karha River basin is 0.35 (Table 3).

7. Stream Frequency (Fs) - The drainage frequency of the Karha River basin is 3.8 $streams/km^2$ indicating moderate stream frequency (Table 3).

8. Drainage Texture (T) -. The drainage density value of the Karha River basin is 2.82 and the drainage texture value is 20.83 indicating coarse drainage texture.

9. Compactness Coefficient (Cc) - The Karha basin value of compactness coefficient is 1.88 indicating a less hazardous basin (Table 3).

10. Infiltration number - The infiltration number of river Karha is 10.72 (Table 3).

11. Drainage Intensity (Di) - According to this study, the drainage intensity for the Karha river basin was only 1.34 (Table 3).

III- RELIEF ASPECTS

The above mentioned Linear and Areal features are considered as the one and two dimensional aspects of a river basin mainly deals with the length and

12. Length of Overland Flow (Lo)- The length of the overland flow of the Karha River basin is 1.41 km (Table 3).

width related parameters. Besides these two parameters one more important aspect is related to the height/elevation of the basin.

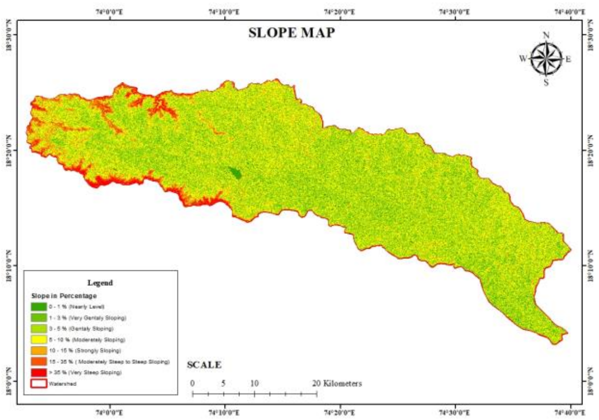


Figure 3 Slope Map

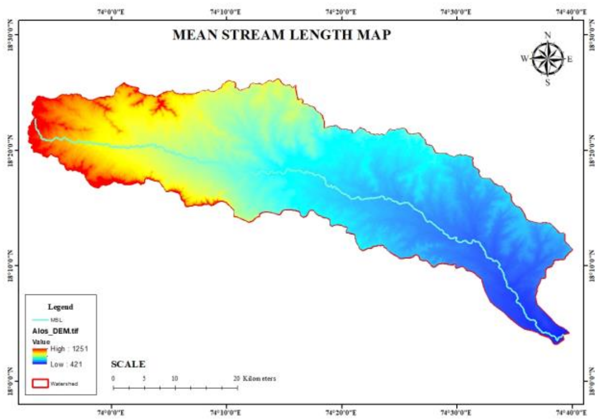


Figure 4 Stream lengths Map

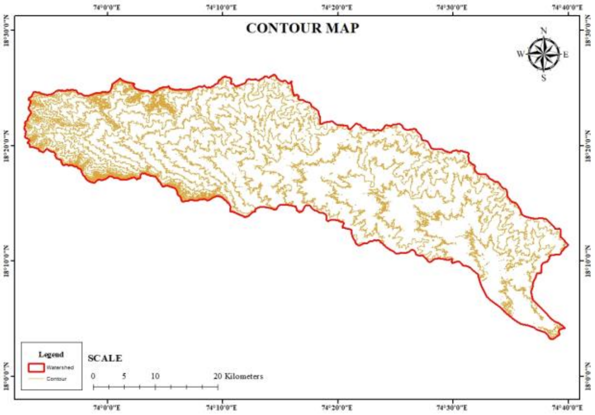


Figure 5 Contour Map

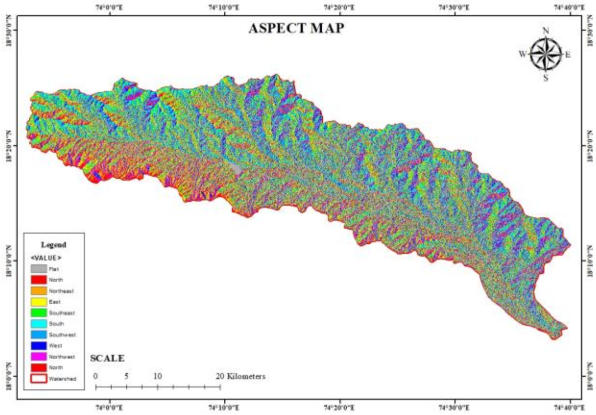


Figure 6 Aspect Map

1. Slope analysis or Gradient - A slope map is prepared using the spatial analyst tool of ARC GIS 10.2 (Figure 3). Contour generates using spatial analysis tools in

2. Aspect analysis - The aspect of the basin provides the direction of the slopes. The direction of the slope (east to south east) on the entire relief of the Karha River basin is illustrated in the aspect map (Figure 6).

3. Channel gradient - Channel Gradient of the Karha river basin is 2.36.

4. Basin relief (R) - Difference in elevation between highest and lowest points in a basin is called basin relief. Basin relief of the Karha river basin is 830 Meters.

arcGIS software with the help of Alos palsar DEM image (Figure 2). Karha River basin's topography is undulating, and its average slope is 0.549 percent.

5. Relief Ratio - The value of the relief ratio of the Karha river basin is the value of 0.0074 km.

6. Profile Analysis - The profile shows altitude against distance downstream. The longitudinal profile of the Karha River basin is created using Alos Palsar DEM data of 12.5m spatial resolution in Global mapper software and shown in Figure 3.8. Cross-section profiles were shown as follows from A to E.

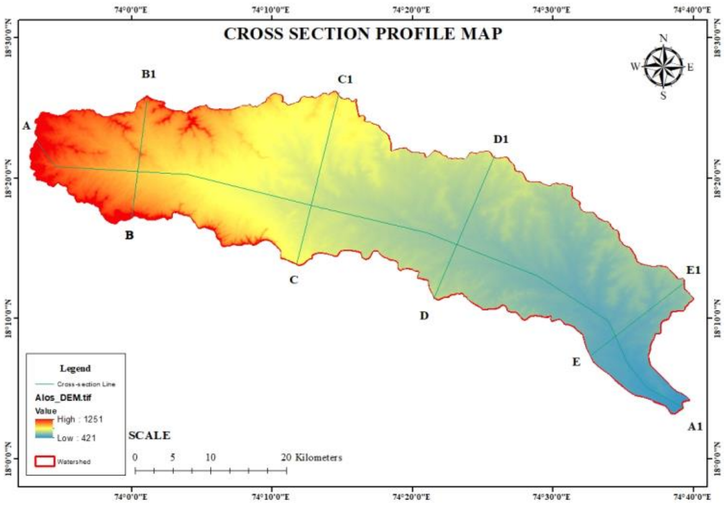
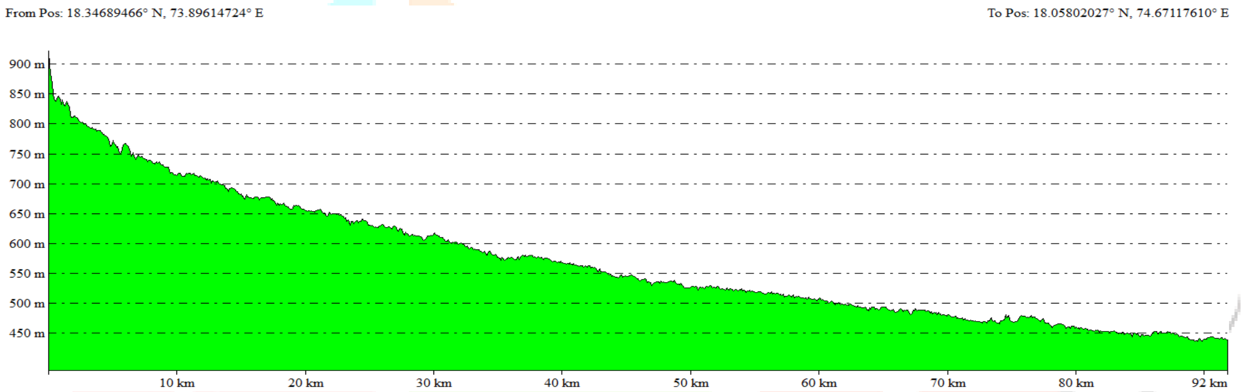
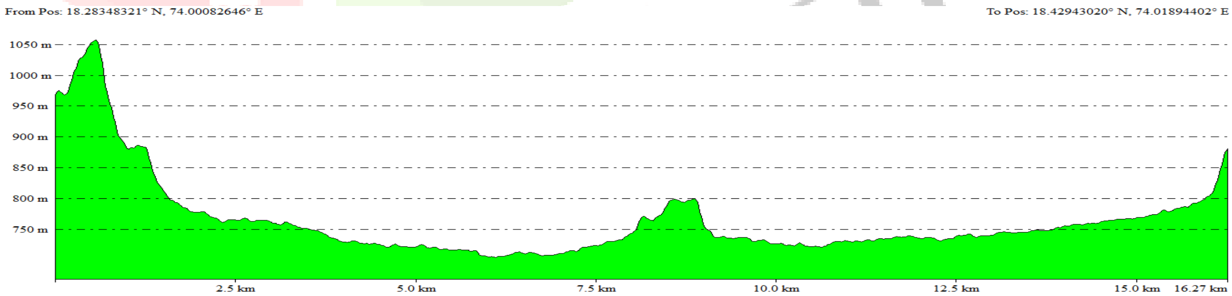


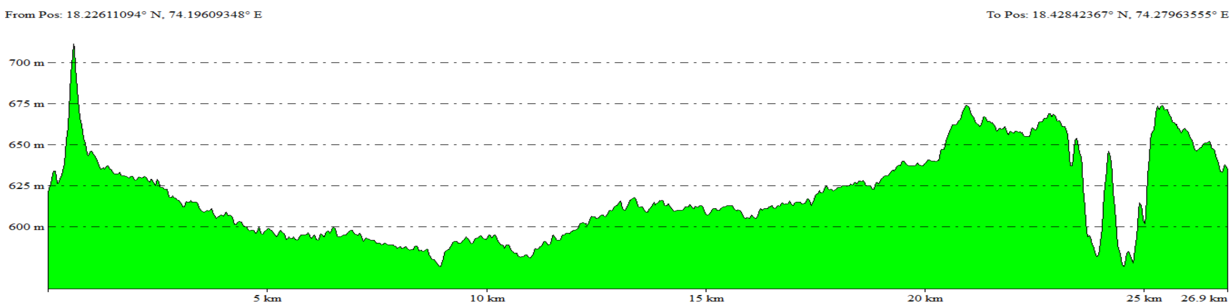
Figure 3.8 Cross-section profile of the Yerla river basin.



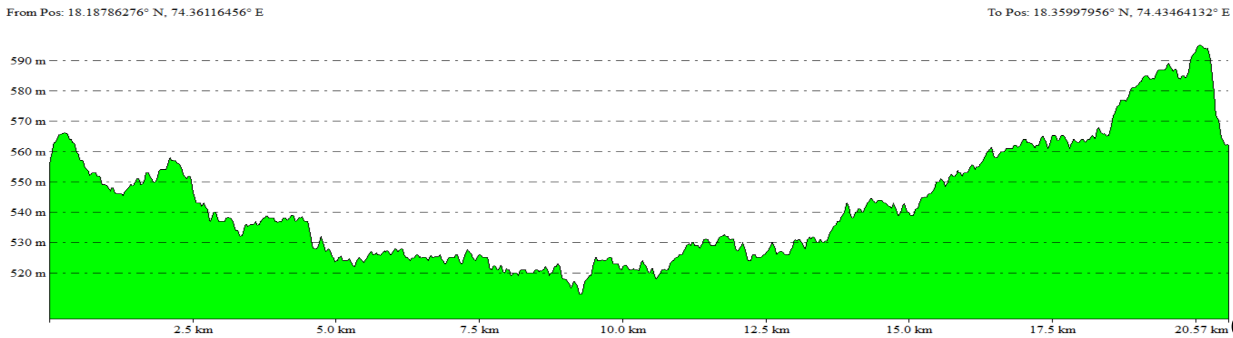
Cross-section of A to A1 line



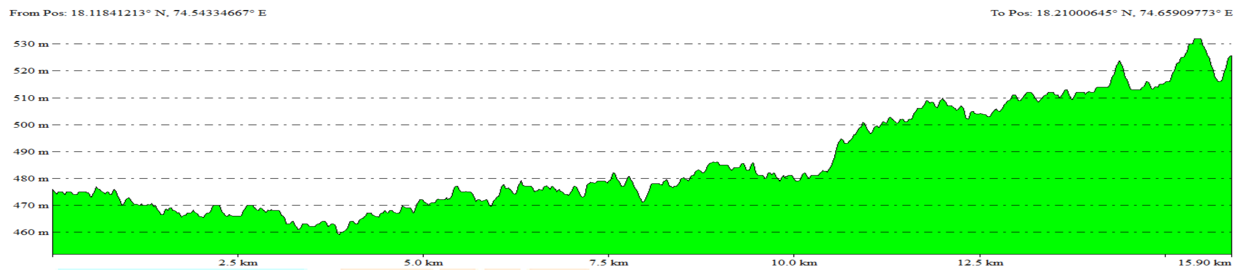
Cross-section of B to B1 line



Cross-section of C to C1 line



Cross-section of D to D1 line



Cross-section of E to E1 line

Figure 3.7 Longitudinal profile of the Yerla river main stream channel (North-South-D-D1).

7. Ruggedness number - In the study area, Ruggedness number is 2.34.

8. Dissection index (DI) - The Karha river basin has a DI value of 0.66.

CONCLUSION

The Karha river watershed is the largest of the left bank feeders of the Nira River on the Deccan Traps. The shape of the drainage basin affects the stream discharge development in a particular basin. An important conclusion of the morphometric study of the Karha river basin is as follows;

·Using GIS allows easy and accurate analysis of drainage basins based on morphometric analysis.

·Many researchers found that GIS based approach in analysis at river basin is more appropriate than the conventional methods.

GIS based analysis with morphometric parameters gives a relationship between hydrological aspect, geological, topographical, pedological which is useful for planning & management of soil and water conservation structures.

Use recharge priority maps developed by the department of groundwater surveys and development agency government of Maharashtra for suitable site selection for soil and water conservation structure.

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