



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: IV Month of publication: April 2018

DOI: <http://doi.org/10.22214/ijraset.2018.4022>

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Morphometric Analysis of Alate Nala Basin, Kolhapur District, Maharashtra, India

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Abstract: Watershed development and management is the key factor for surface and ground water conservation. To prepare a watershed development plan, it becomes important to know the topography, lithology, erosional status and drainage pattern of the area. In the present investigation various morphometric parameters of the Alate Nala basin are outlined. The Alate Nala basin is 4th order and its different morphometric parameters are found to be useful for the proper land use planning and water resources management studies in the basin. The area consists of homogeneous rock material, which is structurally undisturbed based on dendritic drainage pattern in the area.

Keywords: Morphometric parameters, Alate Nala.

I. INTRODUCTION

Morphometry is defined as the measurement of the shape and mathematical analysis of drainage (Clarke, 1996). Morphometric studies in the field of hydrology were first initiated by Horton (1940) and Strahler (1950). Pawar and Raskar, (2011) has carried out morphometric analysis of Panchaganga river basin of Kolhapur district. Yadav and Sawant, (2011) has carried out morphometric parameter estimation of Sheri Nala basin, Sangli district. Jangle and Patil, (2010) has done morphometric parameter estimation of Nalganga river, Buldhana, Maharashtra. Nageswara and et. al., (2010) has carried out morphometric analysis of Gostani river basin in Andhra Pradesh. Geo-spatial technologies, such as Geographic Information Systems (GIS) and Remote Sensing (RS), are efficient tools in delineation of watershed and drainage network for the water resources planning and management. In the present study attempt has been made to analysis the nature and structure of Alate Nala basin by applying various morphometric techniques. The morphometric analysis of the drainage basin and channel network play a important role for understanding the hydrological behavior of drainage basin and to analyze flood, geological and geo morphological structure. The morphometric parameters have been used in various studies of geomorphology and surface water hydrology, such as flood characteristics, sediment yield and evolution of basin morphology. The watershed management studies have a special importance in the field of research, due to the increasing demand of water.

II. STUDY AREA

The Alate Nala basin bounded between latitude $16^{\circ} 74' N$ to $16^{\circ} 80' N$ and longitude $74^{\circ} 36' E$ to $74^{\circ} 43' E$ in Survey of India Toposheet numbers 47 L/5 and 47 L/6 and having area of about 31.474 km² (Fig. 1). The Alate Nala is the tributary of the Panchaganga River. The study area is covered by Deccan volcanic basalt of Upper Cretaceous to Lower Eocene age. The soil cover of the study area is fertile and important for agriculture purpose. The Alate Nala basin shows well developed dendritic to sub dendritic type drainage pattern. (Fig.1). In the present paper the authors had made an attempt to morphometric analysis of Alate Nala basin.

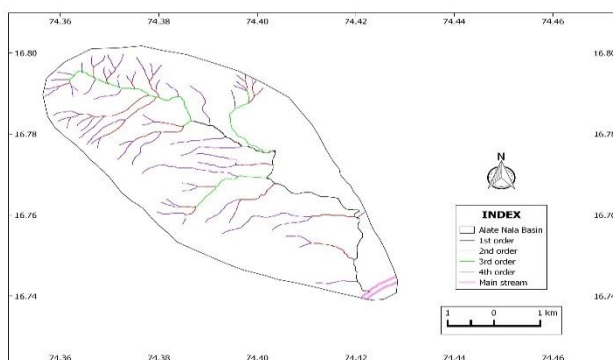


Fig. 1: Map of study area with drainage system

III.METHODOLOGY

The study area which is located in the survey of India Toposheet Nos.47L/5 & 47L/6 is present in the Kolhapur district of Maharashtra and also uses the LISS-III satellite image. The data base is created using various techniques. The maps are prepared by Geo referencing and digitization from SOI Toposheet and LISS-III satellite image using QGIS 2.6.1 - Brighton software. The Survey of India Toposheet scale 1:50,000 and LISS-III satellite image are used for preparation of the watershed boundary, drainage map. Stream ordering method as suggested by the Strahler has been employed. The different morphometric parameters have been calculated by using formulae. For stream ordering method suggested by Strahler (1957) has been used.

IV..RESULT AND DISCUSSION

The drainage characteristics of Alate Nala basin have been examined with reference to linear, aerial and relief aspects.

A. Linear Aspects of Drainage Basin

- 1) *Stream Order (Su)*: Stream ordering is the first step of quantitative analysis of the watershed. It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases. The Alate Nala basin is IVth order stream (Table No – 1).
- 2) *Stream Number (Nu)* : The total of order wise stream segments is known as stream number. Horton (1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number. Individual counting of the streams in the river basin reveals the total number of the streams. Whole Alate nala basin has 44 streams, of which the first order stream having 31 segments. The second order stream having 8 segments. Third order stream having 4 segments and forth order having 1 segment (Table No – 1).
- 3) *Stream Length (Lu)*: The total stream lengths of the Alate Nala basin have various orders, which have been computed with the help of SOI topographical sheets and QGIS software. Horton's law of a stream length supports the theory that geometrical similarity is preserved generally in watershed of increasing order (Strahler, 1964). Author has been computed the stream length based on the law proposed by Horton (1945). The total stream length in Alate Nala basin is 110.8 Km. (Table No. 1).
- 4) *Mean Stream Length (Lu m)*: Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its Contributing watershed surfaces (Strahler, 1964). It is obtained by dividing the total length of stream of an order by total number of segments in the order. Stream Length Ratio (Lur m)

The ratio in between the average lengths of successive orders is stream length ratio. (Horton, 1945). In the southern half part of basin large number of small streams are developed where the formations at upstream side and are less permeable (Manu, 2008). Stream length ratio of Alate Nala basin is given in Table No. 1.

- 5) *Bifurcation Ratio (Rb)*: The bifurcation ratio is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Horton (1945). The bifurcation ratio is not same from one order to its next order these irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler 1964). The bifurcation ratio is dimension less property and generally ranges from 3.0 to 5.0. The lower values of Rbare characteristics of the watersheds, which have suffered less structural disturbances (Strahler 1964) In the present study, the bifurcation ratio ranges from 2 to 4 (Table No. 1) indicate that the watershed are not affect by any structural disturbances.

B. Aerial Aspects of Drainage Basin

- 1) *Basin Area (A)*: Basin area is the direct outcome of the drainage development in a particular basin. The area of Alate Nala basin is about 31.474 sq.km which indicates that rain water will reach the main channel more rapidly, where the water has much further to travel.
- 2) *Drainage Density (Dd)*: Drainage density is defined as a ratio of total length of all streams to the total area of the basin. (Horton, 1932).

$$Dd = Lu/A$$

Drainage density of the any basin reveals the terrain configuration that is properties of rock of the area. In the study area as outer half part of basin shows high drainage density which indicates region having on resistant or impermeable subsurface material and mountainous relief, whereas northern half part of basin shows low drainage density which indicates region having highly resistant rock or highly permeable sub soil material and area with low relief. (Geena 2011). The overall drainage density (Dd) of the Alate Nala basin is 0.67km/sq.km.

- 3) *Stream Frequency (Fs)*: The stream frequency of the basin is the ratio of total number of stream segments of all orders to the basin area.
(Horton, 1945)

$$Fs = Nu/A$$

It is a good indicator of drainage pattern. Stream frequency has been calculated by the number of streams divided by the total area of basin in sq.km. The stream frequency value of the Alate Nala basin is 2.79. High drainage density and high stream frequency in Alate Nala basin indicate larger run off from the basin.

(Table No. 2)

- 4) *Constant of Channel Maintenance (C)*: The Constant of Channel Maintenance is the inverse of the drainage density. (Schumm, 1956). Therefore higher the drainage density lowers the constant of channel maintenance and vice versa. Regarding the Alate Nala basin, the average constant of channel maintenance is 1.49 (Table 2).
- 5) *Texture Ratio (Rt)*: It is the ratio of total stream numbers to the total perimeter of the basin. (Horton, 1945).

$$Rt = Nu/P$$

Texture ratio is an important factor in the drainage morphometric analysis which is depending upon the underlying lithology, infiltration capacity and relief aspect of the terrain (Nageswara, 2010). Smith (1950) has classified drainage density into five different textures: Very coarse (<2), Coarse (2-4), Moderate (4-6), Fine (6-8) and Very fine (>8). In the present study, the texture ratio of the Alate Nala basin is 1.96, which indicates coarse texture and area under high relief and steep slopes. (Table 2)

- 6) *Elongation Ratio (Re)*: Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956).

$$Re = \frac{2\sqrt{\frac{A}{\pi}}}{Lb}$$

It is a very significant index in the analysis of basin shape which helps to give an idea about hydrological characters of a drainage basin. The value of elongation ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions of very low relief, whereas those of 0.6 to 0.8 are associated with high relief and steep ground slope (Strahler, 1964). The Elongation ratio of the Alate Nala basin is 0.64, which indicates high relief and steep ground slope. (Table 2)

- 7) *Circulatory Ratio (Rc)*: Circulatory ratio is the ratio of basin area to the area of circle having the same perimeter as the basin (Miller, 1953).

$$Rc = \frac{4\pi A}{P^2}$$

Circulatory ratio of Alate Nala basin is 0.19, which is below 1.5 and shows a strongly elongated basin with semi-permeable homogeneous lithology. (Table 2)

- 8) *Form Factor Ratio (Rf)*: Form Factor Ratio is the dimensionless ratio of the basin area to the square of basin length (Horton, 1932).

$$Rf = A/Lb^2$$

The Form Factor Ratio value of the Alate Nala basin is 0.323 (Table No. 2), which is very near to zero and thus represents a highly elongated shape. In this elongated basin, low form factor will have a flatter peak flow of longer duration. Flood flow in long basins is easier to manage than that of the circular basins (Geena, 2011).

C. Relief Aspects of Drainage Basin

- 1) *Basin Relief (H)*: The vertical distance difference between point of maximum elevation and minimum elevation is the relief of basin. The basin relief of Alate Nala is 270 meters. (Table 3)
- 2) *Relief Ratio (Rh)*: When basin relief (H) is divided by maximum basin length (Lb) gives the relief ratio (Schumm, 1954). The relief ratio of Alate Nala basin is 32.35, which indicates that the basin has strong relief and steep slope. The higher stream frequency values show that the permeability of rocks is less at upstream to the middle portion of the Alate Nala basin. The infiltration is mainly through fracture sand joints, which are the extension of the surface joints. But the permeability of rocks increases towards downstream side where the rocks are weathered. (Table 3)

- 3) **Roughness Index (Rn):** Ruggedness number is the product relief of basin (H) and drainage density (Dd). The ruggedness number of Alate Nala basin is 745.2 (Table 3) which indicate both relief and drainage density are high.

Table No: 1- Linear aspects of the study area.

Nala basin	Stream order	No. of Streams(Nu)	Total length of Streams in km(Lu)	Mean Stream Length (MLu)	LogNu	LogLu
	I	62	51	0.82	1.79	1.7
Alate	II	18	27	1.5	1.25	1.43
	III	4	18.4	4.6	0.60	1.26
	IV	1	14.4	14.4	0.00	1.158
Total		85	110.8			

Where, Lu = Total Stream length of all orders. Nu = Total number of streams of all orders

N1=Total number of first order stream ($\pi = 3.1415$)

Table No: 2-Aerial Aspects of the study area.

Morphometric Parameters	Symbol/Formula	Calculated Value
Area (sq.km)	A	31.474
Perimeter(km)	P	44.8
Drainage Density	Dd = Lu/A	0.67
Stream Frequency	Fs=Nu/A	2.79
Texture Ratio	Rt=Nu/P	1.96
Basin Length(km)	Lb	9.856
ElongationRatio	$Re = \frac{2\sqrt{A}}{Lb}$	0.64
CirculatoryRatio	$Rc = \frac{4\pi A}{P^2}$	0.19
Form Factor Ratio	$Rf = A/Lb^2$	0.323
Constant of Channel Maintenance	C=1/Dd	1.49

Table No: 3 - Relief aspects the of study area.

Morphometric Parameters	Symbol/Formula	Calculated Value
Maximum elevation in the area(mts.)	E _{Max}	810
Minimum elevation in the area(mts.)	E _{Min}	540
Basin Relief(mts.)	H=Max.Elevation-Min. Elevation	270
Relief Ratio(Rh)	Rh= H/Lb	32.35
Roughness Index (Rn)	Rn= H x Dd	745.2

V. CONCLUSION

The morphometric study of Alate Nala Basin indicates that, the basin is forth order basin. The basin shows dendritic type of drainage pattern. Mean stream length of channel segments of a given order is greater than that of the next lower order but less than that of the next higher order. The average bifurcation ratio of the basin reveals that there appears to be no strong geological control in the development of the drainage, homogeneous nature of lithology and drainage network in study area. The elongation ratio, circulatory ratio and form factor reveals that the Alate Nala basin is highly elongated and flood flows are easier to manage than that of circulatory basins. The study also reveals that the texture of Alate Nala basin is coarse and basin is highly elongated. The drainage basin size analysis reveals that the flooding is lesser.

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