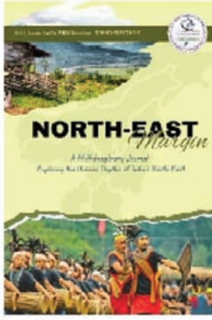

Morphometric Analysis of Chathe River Basin, In and Around Chumokukedima, Nagaland

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Abstract

Rivers are generally controlled by the geological nature of basins and their platforms, which equally influence channel slope and demonstrate erosional and depositional signs of the river. Morphometric analysis is carried out to estimate the altitude, volume, slope, and profiles of the surface and drainage basin characteristics. The present study aims to analyze the morphometric attributes of the Chathe River Basin in and around Chumoukedima, Nagaland, by detailed morphometric analyses. This study is attempted using morphometric techniques to gain insight into the geohydrological characteristics of the drainage basin to help in the identification of groundwater potential zones and overall management of the groundwater basin using GIS. The drainage network of the basin is extracted from the DEM of USGS earth explorer. Based on stream ordering, the drainage basin of the study area is designated as fifth-order basin. The total number of streams is 239, out of which 177 are first order, 46 are second order, 11 are third order, and 4 are fourth order; the main stream is fifth order. The large number of first order streams indicates that the region is undergoing the initial phase of erosion. The drainage density indicates that the subsurface is made up of permeable strata, which points to good groundwater potential. The significance of this study lies in the fact that it can help in watershed and hazard management It will also help in assessing the groundwater potential of the region and delineation of effective water-harvesting sites. Morphometric analysis thus, has a wide significance in watershed prioritization and management, soil erosion studies, groundwater potential assessment, and flood-hazard risk reduction.

Keywords:

Morphometric analysis, drainage density, permeability, groundwater potential.

North-East Margin

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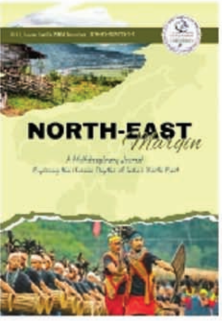


North-East Margin

1. Introduction

River basins dominate the landscape and the study of their morphology reveals important information about their formation, factors influencing their orientation over time and sedimentation yield (Dade, 2001). Rivers are generally controlled by the geological nature of the basin and its platform, which influences channel slope and demonstrates the erosional and depositional patterns of the river. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape, and dimensions of its landforms. It includes a quantitative study of the altitude, volume, slope, surface profiles, and drainage basin characteristics of the area concerned. These parameters affect catchment stream-flow patterns through their influence on concentration time (Jones, 1999). Similarly, quantitative relationships describing the nature of surface drainage networks have been used to formulate flood characteristics, sediment yield, and the evolution of basin morphology (Glennon and Groves, 2002). Castelltort and Simpson (2006) suggest that drainage networks in linear mountain ranges invariably display a particular geometrical organization, whereby the spacing between the major drainage basins is, on average, equal to half the mountain width (distance from the mountain front to the main drainage divide), which is independent of climate and tectonics. Morphometric parameters affect catchment stream-flow pattern through their influence on concentration time (Jones, 1999). The significance of these landscape parameters was earlier pointed out by Morisawa (1959), who observed that stream flow can be expressed as a general function of the geomorphology of a watershed. The assertion remains valid according to Jain and Sinha (2003), Okoko and Olujimi (2003), and Ifabiyi (2004), who reported that the geomorphic characteristics of a drainage basin plays a key role in controlling basin hydrology. In morphometry, it is possible to generate descriptive statistics of the shape of a surface or to assign a location in a landscape to an exhaustive set of features, based on the local form of the land surface (Pike, 2000). The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behaviour of a watershed directly coupled with geomorphology and ecology (Esper, 2008). The hydrologic response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density, and length of streams (Chorley and Morgan, 1962). Hence, morphometric analysis of a watershed is an essential step towards basic understanding of watershed dynamics. Morphometric analyses of drainage basins thus, provide not only an elegant description of the landscape, but also serve as a powerful means of comparing forms and processes of drainage basins that may be widely separated in space and time (Easterbrook, 1993).

Therefore, detailed morphometric analysis is carried out to determine the morphometric attributes of the Chathe River Basin in and around Chumoukedima, Nagaland.

2. Study Area

The study area, occupying an area of about 614.46 km2, lies between 25°35?30? - 25°58?30? N latitudes and 93°44?00?-93°57?30?E longitudes under the Survey of India (SOI) topographic sheet number 83G/13 and 83G/14 on 1:50,000 scale. It is located at Chumoukedima, Dimapur, Kohima, Niuland and Peren districts of Nagaland and Golaghat district of Assam (Figure 1). The Chathe River is a tributary of the Dhansiri River, which drains into the Brahmaputra River in Assam.

3. Objectives

The aims of the present study are:

i. To determine the significance of the drainage network patterns.

ii. To evaluate the different geohydrological characteristics of the drainage basin to identify groundwater-potential zones and provide information for groundwater basin management.

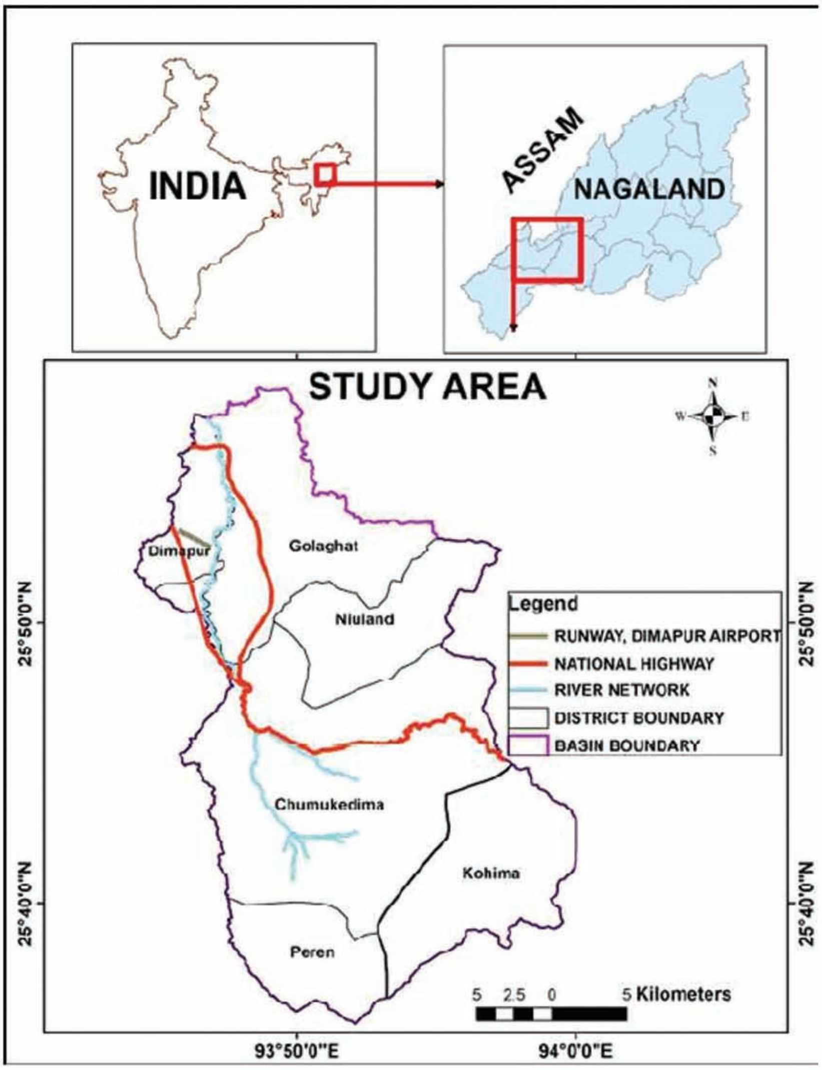
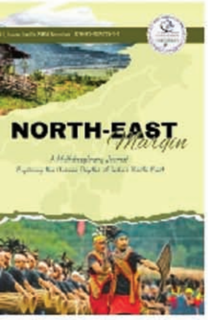


Figure 1: Location map of study area.



4. Methodology

The present study is based on the application of remote sensing and GIS techniques. Various drainage patterns are identified from SOI topographic sheets and digitized using MapInfo 7.0 software. Stream ordering is carried out with the help of spatial analyst tool of ArcMap in Arc GIS 10.8 platform.

The morphometric parameters such as stream order, stream number, Bifurcation Ratio, Drainage density (km/sq. km), Drainage (Stream) frequency, Drainage texture, the circulatory ratio, Compactness Coefficient, Elongation Ratio, Form Factor ratio are calculated based on the formula suggested by various scientists (Table 1).

Table 1: Parameters for morphometric analysis

Morphometric Parameters		Formula/symbol	Reference
Linear aspect	Stream Length	Length of the streams	Horton (1945)
	Mean Stream Length	Lsm=Lu/Nu, Where, Lsm= Mean Stream Length. Lu= Total Stream length of order u. Nu= Total no of stream segments of order u.	Hortan, 1945
	Bifurcation Ratio	R_b= Nu/Nu+1 Where, R_b= Bifurcation Ratio. Nu= Total no of stream segments of order u. Nu+1= Number segments of the next higher order.	Schumm (1956)
Aerial aspect	Drainage density (km/sq. km)	Dd=Lu/A Where, Dd= Drainage Density. Lu= Total Stream length of order u. A= Area.	Horton (1945)
	Drainage (Stream) frequency	Fs=Nu/A Where, Fs= Drainage Frequency. Nu= Total no of stream segments of order u. A= Area.	Horton (1945)
	Drainage texture	Ft=Nu/P Where, Ft= Drainage texture. Nu= Total no of stream segments of order u. P=Peri meter	Smith (1950)
	Circulatory ratio	Rc = 4* π(*A/P*) 2 Where, Rc = Circularity Ratio. A = Basin area. P= Perimeter.	Miller (1953)
	Compactness Coefficient	Cc = 0.2821 ($P/A^{0.5}$) Where,Cc =Compactness Coefficient 0.2821= Constant value. P = Perimeter. A= Basin area.	Horton (1945)
	Elongation Ratio	Re =(2/Lb) * $(A/\pi)^{0.5}$ Where Re= Elongation Ratio, Lb= Basin length A=Area	Schumm (1953)
	Form Factor ratio	Rf=A/(Lb^2) Where Rf= Form factor ratio. A=Area. Lb=Basin length	Horton (1932)
Relief aspect	Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumn,1956
	Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length	Schumn,1956
	Ruggedness Number (Rn)	Rn=Bh×DdWhere,Bh= Basin relief, Dd=Drainage density	Schumn,1956

5. Drainage Network

The drainage network of the Chathe River and its tributaries are controlled by the topography, lithology, climate, gradient, and structure over which they flow. Drainage pattern refers to the geometric forms of the drainage system and the spatial arrangement of streams in a particular area (Singh, 1998). Thornbury (1954) defined drainage pattern as a particular plan or design, which the individual stream courses collectively form. Howard (1967) defined drainage pattern as the design formed by the aggregate of drainage-ways in an area regardless of whether they are occupied by permanent streams. They are surface expressions of the variables influencing river dynamics. The behaviour of a river, changes when the character of one or more variables is altered (Matsuda, 2004). The shape and size of the drainage basin can conceivably affect stream discharge; larger basins have larger average discharge (Mulder and Syvitsky, 1996). Drainage patterns may vary greatly from area to area, depending on topography and geology of the area (Ritter, and Michael, 2006). It is also a reflection of the original slope and structure, diastrophism, and geologic and geomorphic history of the drainage basin (Thornbury, 1969). Therefore, a particular pattern bears a genetic relationship with the factors of its origin.

In the early years, drainage pattern development was studied in relation to the structure and lithology of the underlying rocks. This was essentially qualitative in nature. Subsequently, drainage patterns have been treated more as geometric patterns and attempts have been made to derive a relationship amongst them (Horton, 1945). The different types of drainage patterns identified from the drainage network map of the study area are dendritic, parallel, trellis, rectangular, and radial (Figure 2).

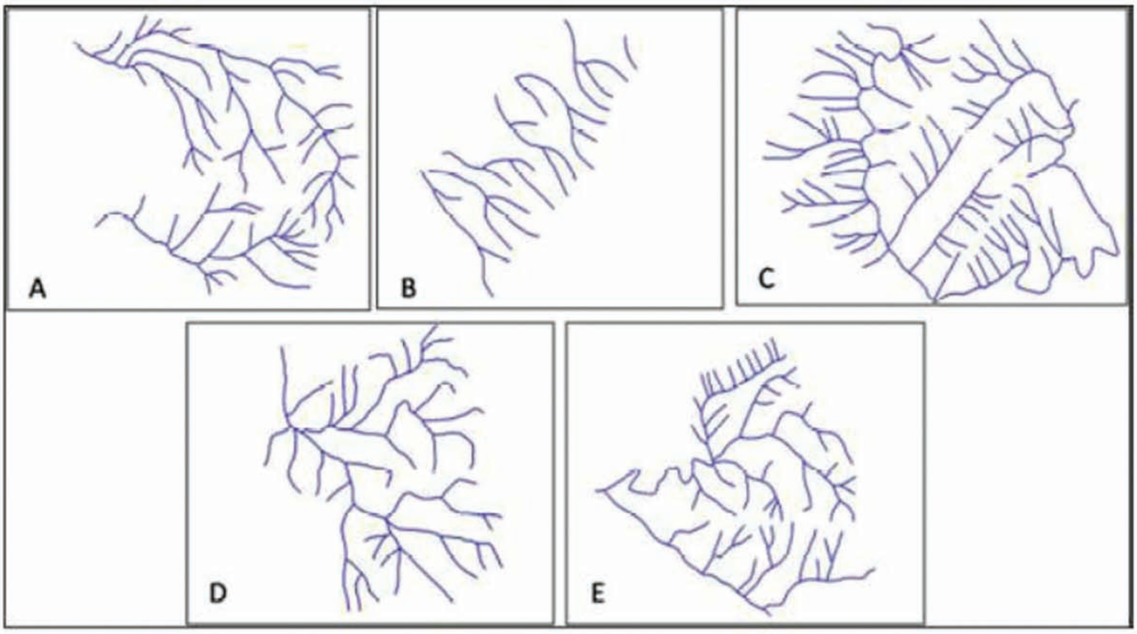
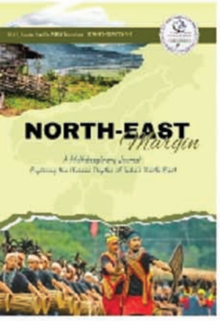


Figure 2: Drainage patterns identified in the study area: (A) Dendritic pattern, (B) Parallel pattern, (C) Trellis pattern, (D) Rectangular pattern, (E) Radial pattern.



5.1 Dendritic drainage pattern

Dendritic or tree-shaped drainage pattern is the most common and widespread pattern found on the earth's surface, where tributaries join the main river at any angle, from any direction, but less than 90°. The dendritic pattern is associated with areas of homogeneous lithology, horizontal or very gently dipping strata, and extensive flat and rolling topographic surfaces with low relief (Singh, 2014).

Dendritic patterns develop in a variety of structural and lithological environments, such as mountainous and hilly areas, and on extensive plateaus and peneplains (Singh, 2014). Hence, they tend to develop in areas of rocks with roughly equal resistance to weathering and erosion and those that are not intensely jointed. In the study area the dendritic pattern can be seen at various places (Figure 2-A).

5.2. Parallel drainage pattern

Parallel drainage patterns comprise numerous rivers or streams running parallel to each other and flowing along the regional slope. This pattern is developed on uniformly sloping and dipping rock beds such as cuestas or newly emerged coastal plains (Singh, 2014). The parallel pattern generally indicates moderate to steep slopes but is also found in areas of parallel, elongate landforms. This pattern is a transition between dendritic and trellis types (Howard, 1967). In the study area such patterns are seen in the western part of the Patkai Christian College (Figure 2-B) developed on uniformly sloping surfaces. Because of steep slopes, the streams are swift and straight, with few tributaries, all flowing in the same direction. Parallel patterns usually indicate the presence of faults that cut across areas of steeply folded bedrock.

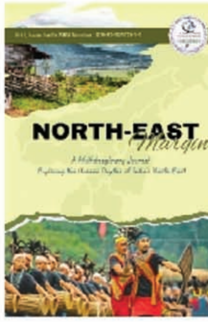
5.3 Trellis drainage pattern

Trellis drainage pattern is formed by networks of tributaries and consequent master streams, which flow along the regional slope and are well adjusted to the geological structures (Singh, 2014). Such patterns are developed in areas of simple folds characterized by parallel anticlinal ridges alternated by parallel synclinal valleys. This pattern resembles the rectangular pattern. The trellis and rectangular patterns are differentiated on the basis of spacing between the streams. If streams are closely-spaced, the resultant pattern becomes trellised, while rectangular patterns form when streams are widely spaced (Singh, 2014).

According to Howard (1967), small tributaries on either side of long, parallel subsequent streams form trellis patterns. Trellis patterns in the study area are formed by networks of tributaries and master streams, which are characterized by major streams at right angles and the secondary tributaries joining the primary ones in the same manner (Figure 2-C).

5.4 Rectangular drainage pattern

Rectangular patterns resemble trellis patterns to some degree, as tributary streams of



both patterns join their master streams almost at right angles. Rectangular drainage pattern develops along lines of weakness (e.g., fault lines, fractures and joints) and are characterized by widely-spaced tributaries (Singh, 2014).

Rectangular drainage patterns in the study area are observed at various places (Figure 2-D). The rocks may be weathered and eroded along the interfaces of joints, fractures and faults; these are usually less resistant to erosion than the bulk rock. The resulting stream system consists of streams, mainly straight-line segments with right-angled bends; tributaries join the larger streams almost at right angles (Singh, 2014).

5.5 Radial drainage pattern

Radial drainage patterns have streams diverging from central elevated tracts or isolated conical or sub-conical hills. in all directions. Such patterns are usually developed on newly formed topographic highs, such as volcanic cones or structural or intrusive domes (Easterbrook, 1969). Other geological features on which radial drainage commonly develops are batholiths and laccoliths, residual hills, small table-lands, etc. (Singh, 2014). In the study area, radial patterns (Figure 2-E) have developed due to crustal uplift (Moiya et al., 2019).

6. Morphometric Analysis

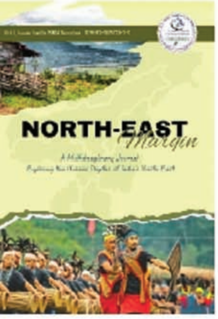
Basin morphometry includes the analysis of linear, areal, and relief aspects of fluvial drainage basins (Singh, 2014). The morphometric parameters such as stream order, stream number, Bifurcation Ratio, Drainage density (km/sq. km), Drainage (Stream) frequency, Drainage texture, the circulatory ratio, Compactness Coefficient, Elongation Ratio, Form Factor ratio are calculated based on the formula suggested by Strahler (1964), Horton (1945), Schumm (1956), Smith (1950) and Miller (1953)

6.1 Linear aspects of the basin

The linear aspects of a basin are related to channel patterns of the drainage network, which transport water and sediments of the basin through a single outlet. The size of rivers and basins vary greatly with the order of the basin. The linear aspects such as stream order, stream number, stream length and bifurcation ratio are described below.

6.1.1 Stream order (μ) and stream number (Nμ)

Stream ordering refers to the determination of hierarchical position of streams within a drainage basin; it is the first step towards drainage basin analysis. There are various systems of stream ordering (Gravelius, 1914; Horton, 1945; Strahler; 1952, 1957; Schidegger, 1970). In Strahler's (1957) system of stream ordering, modified after Horton (1945), the smallest, unbranched fingertip streams are designated as first order. The confluence of two first order streams form the second order stream, two second order streams join to form a third order stream, and so on. If a lower order joins a higher



order stream, it does not change the higher order stream. Conventionally, the highest order stream available in the basin is considered as the order of the basin. The ordering of stream segments indicates that the study area is a fifth order basin (Figure 2).

The total number of stream segments present in each order is the stream number (Nμ). A total number of 239 streams were identified, of which 177 are first-order streams, 46 are second-order, 11 are third-order, and 4 are fourth-order; there is 1 fifth-order stream (Table 2).

6.1.2 Stream length (L)

Horton's law of stream length states that the geometrical similarity is maintained in the basins of increasing orders. The length of first order is maximum in the study area (Table 2). The entire length of the streams of the study area is calculated by adding the total length of streams of all the orders. In the present study area, the total length of the streams is 557.87km.

6.1.3 Bifurcation ratio (Rb)

The bifurcation ratio (Rb) has been worked as a ratio between the number of streams of a given order and the number of streams of the next higher order. Under similar lithology, climatic condition and stage of drainage development, the bifurcation ratio remains constant. The bifurcation ratio of a drainage basin is controlled by the underlying lithology and climatic condition of the area. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. Horton (1945) considered the bifurcation ratio as an index of relief and dissection. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology is dominant. It is observed that Rb is not the same from one order to the next. These irregularities depend upon the geological and lithological development of the drainage basin (Strahler, 1964). Chow (1964) opines that Rb range of 3-5 for watersheds indicates that geologic structure does not exercise a dominant influence on the drainage pattern. For any basin, if Rb ranges from 3 to 5, it is considered an ideal stream order. The Rb between first and second order streams may be considerably higher than the Rb of higher order streams. This is indicative of a state of accelerated erosion (Verstappen, 1983). The variation in Rb values is a reflection of the differences in the shape of stream network (Ghosh and Chhibber, 1984). In the present study area, the value of bifurcation ratio ranges from 2.75 to 4.18 (Table 2).

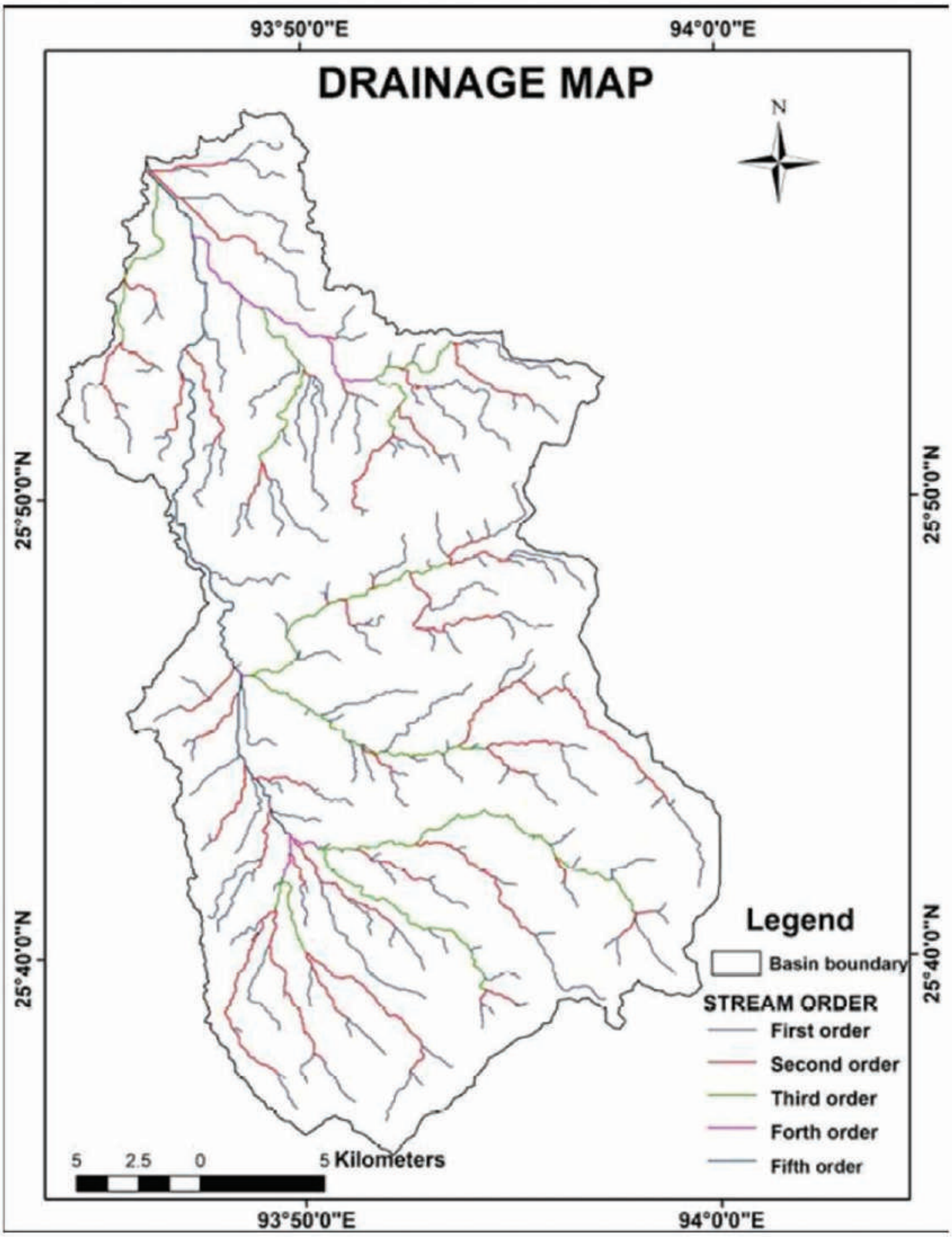


Figure 2: Drainage map of Chathe River basin.

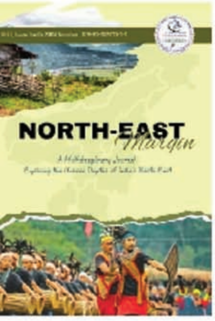


Table.2 Result of linear aspects

Stream order	Number of streams	Total length of stream (Km)	Bifurcation ratio
1st order	177	277.71	3.85
2nd order	46	149.26	4.18
3rd order	11	81.65	2.75
4th order	4	14.96	4.00
5th order	1	34.29	

6.2 Areal aspects of the basin

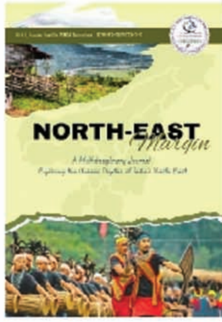
Areal aspects deal with the total projected area upon a horizontal plane that contribute flow to the stream. They include basin area (A), basin perimeter (P), basin length (Lb), drainage density (Dd), stream frequency (Fa), drainage texture (Dt), circularity index (C), constant of channel maintenance (Cm), basin elongation (Be), and basin shape (Bsh). Areal aspect values of the whole basin in the study area is presented in Table 3.

Table 3: Areal aspect values of the study area

Parameters	Values
A	614.46km^2
P	147.63km
Dd	0.9079km^{-1}
Fa	0.3889km^{-1}
Dt	3.7787
C	0.354
Cm	1.10145
Lb	40.103km
Be	0.6976
Bsh	0.382

6.2.1 Basin Perimeter, Basin Length and Basin Area

Basin area, basin perimeter, and basin length are the significant morphometric variables that determine the shape, size, and genetic aspects of drainage basins. Basin perimeter is the outer boundary of the drainage basin that encloses its area. It is measured along the divides between basins and may be used as an indicator of basin size and shape (Schumm, 1956). The perimeter of the basin of the study area is about 147.63km, (Table 3). The basin length is defined as the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956); it can also be defined as the length of the line from the basin mouth to a point on the perimeter equidistant from the basin mouth in either direction around the perimeter (Gardiner, 1975). The basin length of the study area is about 40.103km, (Table 3). The basin area (A) is a reflection of the direct effect of the drainage development in a particular basin. It is about 614.46km^2 (Table 3).



6.2.2 Drainage Density

The drainage density is expressed as the sum of the stream lengths per unit area (Horton, 1945). It depends upon climate, mainly rainfall, geology, vegetation cover, erosion, infiltration capacity and permeability of the underlying rock and soil, relief and slope aspect of the basin (Horton, 1932; Morisawa, 1968; Verstappen, 1983). It helps in identifying different categories of the surface. For instance, sandstone areas have drainage densities ranging from 3 to 4, while hard fractured rocks have drainage densities between 15 and 25; badlands have drainage densities between 200 and 400. High drainage density values suggest weak geological formations and low permeability. Low and moderate values of drainage density are characterized by gentle to moderate slopes, high relief and thick vegetation. It is a useful numerical measure of landscape dissection and runoff potential of an area (Chorley, 1969). Low drainage density is favored by low basin relief and vice versa (Strahler, 1964). It also helps in identifying different categories of land. In the present study drainage density map is prepared in the form of grid index feature (Figure 3). Drainage density values derived from grid-index feature of the study area range from 0km^{-1} - 1.4km^{-1} (Table 4); for the entire basin area it is 0.9079km^{-1} (Table 3).

Table 4: Drainage Density of Chathe River basin.

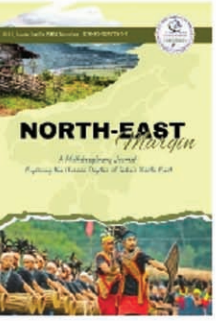
DRAINAGE DENSITY	AREA (Km^2)	PERCENTAGE (%)
0 to 0.3	21.46806	03.49
0.3 to 0.6	61.63883	10.03
0.6 to 0.8	151.8389	24.71
0.8 to 1.1	167.3342	27.23
1.1 to 1.4	212.183	34.53

6.2.3 Stream Frequency

The number of stream segments per unit area is termed stream frequency, channel frequency or drainage frequency (Horton, 1945). The stream frequency value of the entire basin area is 0.3889km?1 (Table 3). Basins with high stream frequency are characterized by very gentle to moderate slopes, moderate to high relief and moderate to sparse vegetation, whereas low-frequency basins are characterized by very steep slope, moderate to high relief and moderate to dense vegetation cover.

6.2.4 Drainage Texture

Horton (1945) defined drainage texture on the basis of stream frequency. The drainage texture depends upon several natural factors such as climate, vegetation type



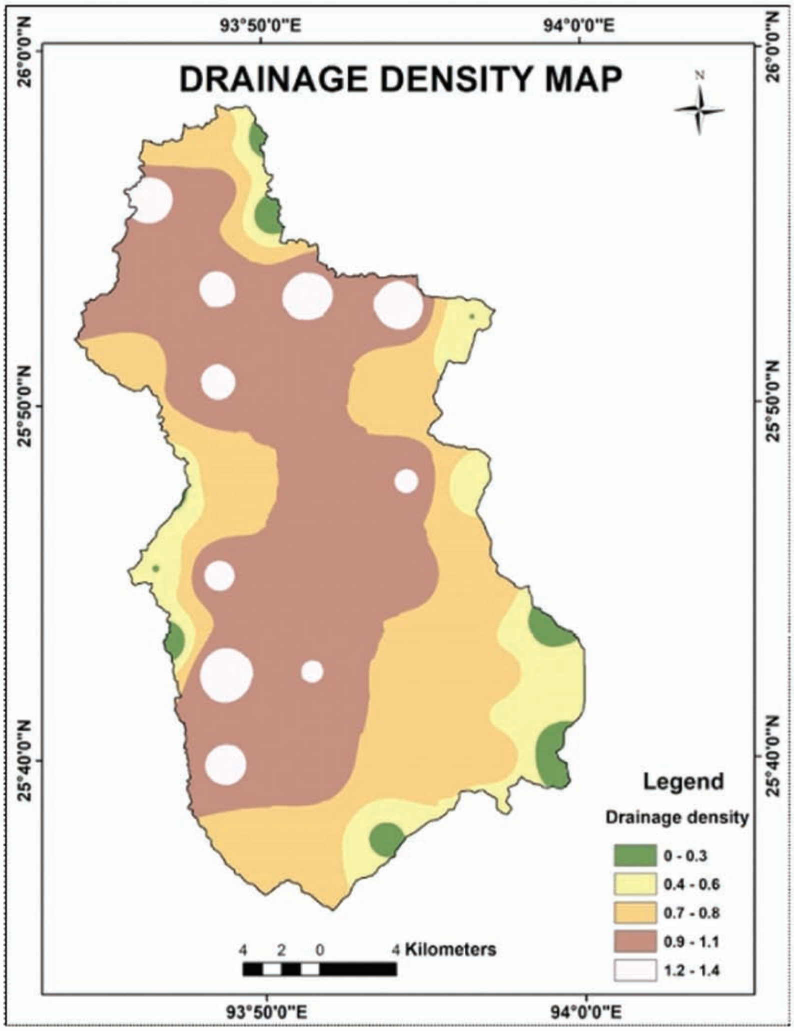


Figure 3: Drainage density map of Chathe River basin.

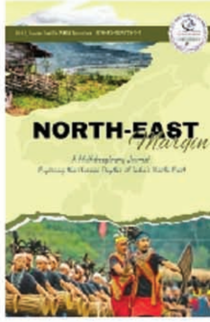
and density, rock and soil type, infiltration capacity, relief and stage of development of the basin (Smith, 1950). In the present study, the value of drainage texture is 3.7787km-1 (Table 3). Coarse drainage texture generally occurs in humid climates, heavily vegetated slopes; and highly permeable slopes; permeability of slope material may also be a result of fractures. The fine texture in the study area points to steep slopes, high-velocity stream flow, reduced infiltration, etc. favored by heavy rainfall, impermeable lithology, such as shale and clay, and sparse vegetation.

6.2.5 Circulatory Index

Circulatory index is the ratio of the basin area to the area of a circle with the same perimeter as the basin. The following relation, as suggested by Miller, (1953) has been used to calculate the circulatory index.

$$C = 4\pi A/P^2$$

The value of circulatory index in the study area 0.354 (Table 3). Areas of low values are characterized by moderate slope, moderate to high relief and moderate to dense vegetative cover, whereas areas of higher values are characterized by very gentle to



moderately high relief and dense vegetation to barren land, which may be due to erratic burning of forests for shifting (jhum) cultivation.

6.2.6 Constant of Channel Maintenance (Cm)

Constant of channel maintenance is defined as the ratio of the total drainage area of the basin to the total length of streams of all orders (Schumm, 1956). Hence, it is the reciprocal of the drainage density, that is,

$$Cm = 1/Dd$$

The values of constant of channel maintenance in the present study range from 1.10145km (Table 3). Low values of constant channel maintenance are characterized by gentle slopes, moderate to high relief and moderate to dense forest cover, whereas high values are characterized by moderately steep slopes, high relief and dense forest cover.

6.2.7 Basin Elongation

Basin elongation is the ratio of the diameter of a circle (D) to the same area as the basin, to the basin length (Schumm, 1956).

$$Be = D/Lb$$

Generally, the value of basin elongation varies from zero (highly elongated) to unity, that is, 1 (perfectly circular). The higher the value of basin elongation, the more circular the basin shape and vice versa.

In the study area, the values of the sub-basins vary from 0.6976 (Table 3). Low values of basin elongation do not bear any systematic relationship with land-use/land-cover, slope and relief. High values are characterized by vegetative cover, very gentle to moderately steep slopes and moderate relief.

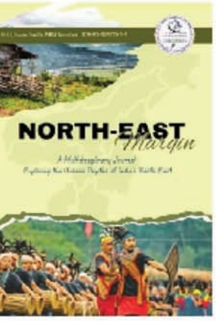
6.2.8 Basin shape

The basin shape dominantly governs the rate at which water is supplied to the main channel. Horton (1932) defines basin shape as the ratio of the basin area to the square of the basin length. It is expressed as,

$$Bsh = A / Lb^2$$

Basin shape is controlled by structure, lithology, relief, and precipitation. Basin shape values vary from zero (highly elongated) to unity, that is, 1 (perfectly circular) shape. The higher the value of basin shape, the more circular is the basin and vice versa.

The values of basin shape in the study area range from 0.382 (Table 3). Low values are characteristic of elongated basins with sparse to dense vegetation, gentle to moderately steep slopes and low to high relief. On the other hand, higher values are characterized by dense, bamboo-dominated forests, very gentle to moderately steep slopes and moderate relief.



6.3 Relief Aspects of Drainage Basin

Linear and Areal features are considered as the one- and two-dimensional aspects of a river basin. Beside these two parameters there are one more important aspects which is related to the height/elevation of the basin. This third dimension is the concept of relief. It plays an important role in determining basin drainage systems - the effectiveness of erosion, transportation, and deposition, total energy of a river etc. Relief aspect is represented by following parameters

6.3.1 Basin Relief (Bh)

Basin relief is the difference in elevation between the highest point (H) and lowest point (h) of the basin. It determines the slope of the basin. Thus, the run-off and sediment transport rate also depend on it. Low value of basin relief indicates low run-off, low sediment transport, and spreading of water within the basin. Opposite scenarios are found in basin of high relief. In the present study area, the maximum elevation is 2700m while the minimum elevation is 120m. basin relief of Chathe River is therefore 2580m.

6.3.2 Relief Ratio (Rh)

-ratio is a dimensionless parameter. It is defined as the ratio between the total relief of a basin i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumn 1956). Simply, it is the ratio between basin relief (Bh) and basin length (Lb). $Rh = Bh/Lb$. In Chathe River basin Lb =40,103m and Bh=2580m, therefore Rh=0.0643

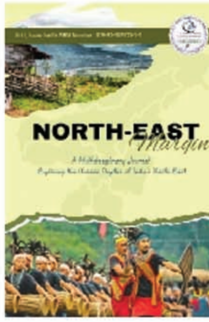
Relief ratio is directly proportional to the surface run-off and intensity of erosion. The high values of Rh indicate steep slope and high relief and vice-versa. Relief controls the rate of conversion of potential to kinetic energy of water draining through the basin. Run-off is generally faster in steeper basins, producing more peak discharges and greater erosive power.

6.3.3 Ruggedness Number

Strahler (1968) describes ruggedness number as the product of maximum basin relief (Bh) and drainage density (Dd). It usually combines slope steepness with its length. Extremely high values of ruggedness number occur when slopes of the basin are not only steeper but long, as well. The formula is $Rn = Bh * Dd$. The ruggedness number for the present study is 2.3955. River basin with high ruggedness number indicate higher drainage frequency with high channel gradient which lead to more erosion. Level of dissection is also varied in such basin.

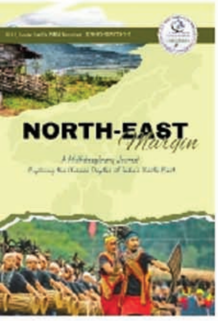
7. Conclusion

Different types of drainage patterns are identified in the study area including dendritic, parallel, trellis, rectangular and radial. The dendritic type indicates homogeneity in texture, the parallel type indicates moderate to steep slopes; the trellis type has developed in areas of simple folds characterized by alternating parallel anticlinal ridges and synclinal valleys. Rectangular drainage patterns have developed along planes of weakness, such as faults, fractures and joints; the radial types may have been caused by uplift.



Based on stream ordering, the drainage basin of the study area is designated as fifth-order basin. Of the 239 streams identified, 177 are first order, 46 are second order, 11 are third order, 4 are fourth order and 1 is fifth order. The presence of a large number of first order streams indicates that the topography is still undergoing an early phase of erosion.

The study area is characterized by gentle to moderate slope, and moderate to high relief. The drainage density reveals that the subsurface strata is permeable, which indicates good groundwater potential. In the present scenario, where water resources are becoming scarce, determination of the various attributes of drainage basin can help locate sites for artificial recharge structures. The study of the morphometric properties of the Chathe River Basin can help future watershed and hazard management programs. It can also help in assessing the groundwater potential of the region and delineating effective water-harvesting sites. Morphometric analysis thus, has a wider significance in watershed prioritization and management, soil erosion studies, groundwater potential assessment, and flood-hazard risk reduction. The morphometric parameters are also termed as erosion-risk assessment parameters and have been used for prioritization of watersheds (Biswas et. al., 1999). The linear parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture, and length of overland flow have a direct relationship with erodibility, while shape parameters have an inverse relationship with erodibility (Nooka et. al., 2005). Hence, priority of the watersheds can be carried out for giving highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters. The highest value of the linear parameter was ranked 1, the second highest value ranked 2, and so on. On the contrary, the shape parameters bear an inverse relation with linear parameters, which means that the lower their values the greater the erodibility. Sub-watersheds falling under very high priority zones are more susceptible to land degradation and soil erosion and are more susceptible to landslides because of steep slopes and deep gullies. Therefore, immediate attention towards soil and water conservation measures are required in such sub-watersheds to preserve the land from further erosion and to reduce possible hazards due to landslides. The results of the analysis of the various morphometric parameters in a GIS environment can be effectively used for prioritization of watersheds, soil and water conservation and natural resources management at the watershed level.



North-East Margin

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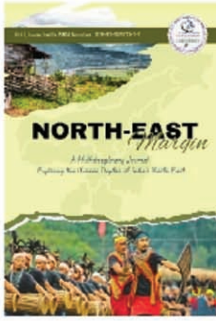

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