Drainage Morphometry of Flood Prone Rangat Watershed, Middle Andaman, India- A Geospatial Approach

Shiva Shankar, Dharanirajan

Abstract: Floods is one of the wide spread global geo-epidemics frequently causing extensive loss of life and property, flood induced disease, hampering of socio-economic activity including transport and communication. Rangat watershed in middle Andaman is not an exception for that instance. Morphometric analysis of Rangat watershed using Geographic Information System (GIS) and remote sensing indicates that it is susceptible to flooding during extreme meteorological events. The watershed exhibit dentritic drainage pattern and has a perennial Rangat river of 4th order. The computed values of drainage density (2.76 Km/ Km2), stream frequency (5.66 no. streams/ Km2), drainage texture (6.26), infiltration number (15.62), form factor (0.35), elongation ratio (0.19) and Compactness constant (1.51) of the Rangat watershed articulates that it is elongated sub-circular having moderate relief and low infiltration capacity due to impervious sub-surface resulting rapid storm response giving rise to a higher runoff resulting in downstream flooding. Rangat River has the highest stream order (4th order) associated with greater discharge and higher velocity of the stream flow indicating the watershed is highly susceptible to floods during monsoon.

Key words: Floods, Drainage Morphometry, Geographic Information System, Remote Sensing, Rangat River, Andaman

I. INTRODUCTION

Flood, a natural and perennial phenomenon in many low-lying deltaic areas, can be viewed as beneficial, especially for enhancing soil fertility on flood plains, but also as a hazard – as endangering human life, property and the environment (Godschalk, 1991). In a watershed it depends upon the hydrological response of the upstream basin area. The upstream basin area may produce different amounts of runoff for a given rainfall based on its hydrologic response. Frequently flood phenomenon is a consequence of natural and anthropogenic induced causes including: climatic-hydrometeorological events, geological-geomorphological characteristics, fluvial-hydrological behaviour of the watershed, indiscriminate landuse practices.

A major prominence in geomorphology over the past six decades has been on the development of quantitative morphometric methods to describe the evolution and behaviour of surface-drainage networks (Horton 1945; Langbein et al. 1947; Strahler 1950; Leopold & Maddock 1953; Miller 1953; Schumm 1956; Leopold & Wolman 1957). These morphometric parameters have been used in understanding the geomorphology, surface-water hydrology and its relevance with flood.

Manuscript received April, 2014.

Shiva Shankar, Department of Disaster Management, Pondicherry University, Port Blair, India.

Asst. Prof. K. Dharanirajan, Department of Disaster Management, Pondicherry University, Port Blair, India.

Rangat is an administrative block of Middle Andaman, an island territory of India. It is bounded within latitude of 12º29'N to 12º34'N and longitude 92º53'E to 92º57'E covering an areal extent of 33.35sqkm. It receives an average annual rainfall of 3500mm in 138 raindays. Humidity is about 81%, with temperatures ranging between 23.9 º C and 30.2 º C. Rangat River is a perennial River in the area under investigation which swells due to copious amount of precipitation resulting in floods. Heavy rains disrupt normal life due to flooding in Parnasala, Mithila, Rangat, Sitapur, Ramapur, Janakpur and Dasharatpur hamlets of Rangat, Middle Andaman, India every year. In lieu of the reoccurrence of floods every year the present investigation was conceded to assess the hydrometeorological reciprocation of the Rangat watershed using drainage morphometry and geospatial technology. This is also note worthy to mention that it is a first of its kind research in the area under present investigation.

II. MATERIALS AND METHODS

The base maps of the watersheds were prepared based on (86D/14 and 86D/15) Survey of India Topographic Maps on a 1:50,000 scale. ASTER-GDEM 30 m (Advanced Space-borne Thermal Emission and Reflection Radiometer-Global Digital Elevation Model) was used for the drainage analysis. The drainage network was updated from the IRS-P6 LISS-IV (2011) satellite data product.

The drainage networks were digitized and the channels were classified according to stream order following Strahler (1964). Watershed was also delineated from the slope derived from ASTER-GDEM data. Watershed parameters such as area, perimeter, maximum and minimum elevation were calculated using zonal statistics tool of ArcGIS 10. Stream length were calculated using calculate geometry tool.

The morphometric parameters for the delineated watershed area are calculated based on the formula given in table 1. Morphometric parameters like stream order, stream length, bifurcation ratio, drainage density, drainage frequency, relief ratio, elongation ratio, circularity ratio compactness constant, etc., were calculated.

A ready reckoner of formulae of morphometric parameters is as tabulated in table 1.

III. RESULTS AND DISCUSSION

A. Stream Order (Nu)

The remotely sensed data was geometrically co-registered and re-sampled taking toposheets as reference.

Image enhancement techniques were a lied to extract the drainage layer from FCC (False Colour Composite) for better interpretation of the stream order. Determining the stream order is one of the initial steps in study of drainage basin (Horton, 1945). According to Strahler (1950), the smallest fingertip tributaries are designated as order 1. The confluence of two first-order channels assigns the downstream reach of order 2, and so on for the rest orders. A total of 200 streams were present in the Rangat watershed off which 102, 55, 22 & 21 streams belongs to 1^{st}, 2^{nd}, 3^{rd} and 4^{th} (Rangat River) order respectively as depicted in table 2. It is noticed that the maximum frequency is in case of first order streams followed by the second order in the area under present investigation. A drape of the stream network over the landuse and land cover as inferred from the satellite image indicate that most of 1^{st} and 2^{nd} order streams finds its origin on the hills covered by dense evergreen vegetation. The frequency decreases as the stream order increases and humans settlement have flourished around Parnasala, Mithila, Rangat, Sitapur, Ramapur, Janakpur and Dasharatpur hamlets at the confluence of the 3^{rd} and 4^{th} order streams. Hence higher stream order is associated with greater discharge and higher velocity of the stream flow (Blyth and RoDda, 1973) indicating Rangat River (4^{th} order) is highly susceptible to floods during monsoon.

B. Stream Length (Lu)

Stream length is indicative of chronological developments of the stream segments. It is measured from mouth of a river to drainage divide with the help of GIS software. This has been computed based on the law proposed by Horton (1945). The total stream lengths for different stream order were worked out viz., 1^{st} order (59.86Km), 2^{nd} order (18.93Km), 3^{rd} order (7.85Km) and 4^{th} order (11.19Km) as shown in table 2. As a thumb rule the total length of stream segments should be highest in first order streams, and it should decreases as the stream order increases. But in the present case the total stream length of the 4^{th} order stream is higher than the preceding 3^{rd} order stream. This brings out strong assumption that Rangat watershed is subjected to high rates of erosion, increased runoff and susceptible to flooding in areas around Parnasala, Mithila, Rangat, Sitapur, Ramapur, Janakpur and Dasharatpur hamlets. Also these hamlets are characterized by variation in Lithology and topography (Vittala et al., 2004 and Chopra et al., 2005).

C. Mean Stream Length (L_{sm})

Mean stream length is a distinguishing property associated to the drainage network components and its related basin surfaces (Strahler, 1964). Generally higher the order, longer the length of streams is noticed in nature. The mean stream length of the Rangat watershed were estimated as 0.58, 0.34, 0.35 and 0.53 for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} stream order respectively as enumerated in table 2. A change of stream length from one order to another order of Rangat watershed indicates the late youth stage of geomorphic development of streams in the watershed (Vittala et al., 2004 and Chopra et al., 2005). However, anomaly in the mean stream length of Rangat watershed was noticed suggesting stream extension of the higher order stream or upward extension of tributaries or inception. This exceptional change in the mean stream length of Rangat basin is also an indicator of the changes in the slope and topography, which in turn determine the age of the basin (Rudraiah et al; 2008). It also has a direct bearing on the surface flow discharge and sedimentation stage of the Rangat watershed.

D. Stream Length Ratio (R_L)

The stream length ratio has important relationship with surface flow, discharge and erosion stage of the stream (Horton, 1945). The stream length ratio of the Rangat watershed demonstrates an ideal geometric series with stream length increasing towards higher order of streams as defined by Horton (1945). It ranges from 0.59 to 1.51 (table 2) showing an escalating trend in the stream length ratio from lower order to higher order signifying their mature geomorphic stage of the Rangat watershed (Magesh et al., 2010).

E. Bifurcation Ratio (R_b)

Bifurcation ratio is considered to be an important parameter that articulates the degree of ramification of the drainage network. Its value in the study area ranges from 1.04 to 2.5(table 2) indicating that the watershed does not exercise a dominant influence of geologic structure on the drainage patterns (Strahler; 1964, Chow; 1964). The highest R_b value of 2.5 was recorded between 2^{nd} and 3^{rd} order streams indicate corresponding highest overland flow and discharge attributable to hilly and less permeable rock formation associated with high slope configuration. The relatively high bifurcation ratio indicates early hydrograph peak with a potential for flash flooding during the storm events in the areas in which these stream orders dominate. The closeness in bifurcation values within the basin on the other hand illustrates stable and similar geological set ups (Nooka Ratnam et al., 2005). The mean R_b in the present investigation reveals that the flow energy is high which in turn does not provide ample time for infiltration and groundwater recharge, as well as high probability of flooding and vice versa. Hence Parnasala, Mithila, Rangat, Sitapur, Ramapur, Janakpur and Dasharatpur hamlets are more susceptible for flooding during extreme storm events.

F. Length of Overland Flow (L_g)

Length of overland flow (Lg) is one of the most vital self-governing variables affecting hydrologic and physiographic development of drainage basin (Horton 1932; Akram Javed et al., 2011). It is inversely proportional to half of reciprocal of drainage density and is the length of water over the ground before it gets concentrated into definite stream channels (Horton, 1945). Overland flow is significantly affected by infiltration/percolation through the soil that varies in time and space (Schmid, 1997). The computed value of L_g of the study area is 0.18 (table 2) indicating a young topography. This value also indicate that runoff will take very less time to divulge into the Rangat Bay and the watershed is more vulnerable to the flash flooding during extreme meteorological events.

G. Drainage Density (Dd)

Is an expression to indicate the closeness of spacing of streams (Horton, 1932) and a key detrimental temporal factor for water to travel from source to sink (Langbein, 1947). Also, the measurement of D_d is a valuable numerical tool for a raising efficiency of the watershed's landscape dissection to remove excess precipitation inputs as runoff (Chorley et al., 1957).

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Drainage density is the result of interacting factors governing the surface runoff and in turn has a bearing on water and sediment discharge from a watershed (Chorley, 1969). D_d is known to vary with climate and vegetation (Ozdemir and Bird, 2009), soil and rock properties (Moglen et al., 1998), relief and landscape evolution processes. In general, a high D_d reflects a highly dissected drainage basin with a relatively rapid hydrological response to rainfall events, while a low D_d means a poorly drained basin with a slow hydrologic response (Strahler, 1964). The computed value of D_d of Rangat watershed was 2.76 Km/ Km^2 (table 2). An overlay analysis of the stream network, Digitial Elevation Model (DEM) and LULC of the area under investigation reveal that the human establishment have flourished in the regions with low relief (0-50m) exhibiting low D_d. Indiscriminate anthropogenic influence on land use patterns is the strong reason for comparatively low D_d in the southern part of the study area. On the contrary high D_d were observed in areas of dense vegetation with high relief. Thus high D_d in the northern parts of the study area induces a rapid storm response giving rise to a higher runoff resulting in downstream flooding of Rangat River during extreme hydrological events. Parnasala, Mithila, Rangat, Sitapur, Ramapur, Janakpur and Dasharatpur are the hamlets around the course of Rangat River susceptible to floods.

H. Stream Frequency (F_s)

Stream frequency is a vital morphometric indicator and provides additional information concerning the response of drainage basin to runoff process (Langbein, 1947; Chorley et al., 1957). F_s mainly depend on the lithology, rock structure, infiltration capacity, vegetation cover, relief, nature and amount of rainfall and subsurface material permeability of the basin (Magesh et al., 2010). It is therefore found that the F_s and D_d value of Rangat watershed is positively correlated. The F_s (5.66 no. streams/ Km^2) in the study area was categorized as a moderate (Smith, 1950) as in table 2. Moderate F_s is suggestive of moderate relief and low infiltration capacity due to impervious sub-surface as observed in the northern parts of the study area. This indicates that the increase in stream population is associated to that of drainage density resulting in faster downstream runoff making the Rangat watershed vulnerable to floods.

I. Infiltration Number (I_f)

Infiltration number plays a pivotal role in observing the infiltration characteristics of the basin (Zavoiance, 1985). It is reciprocal to the infiltration capacity of the basin. The infiltration number of the Rangat watershed is 15.62 (table 2) indicating that the infiltration capacity is very low resulting in very high runoff triggering downstream flooding.

J. Drainage Texture (D_t)

It is one of the important concept of geomorphology which means that the relative spacing of drainage lines (Rudraiah et al; 2008; Ramaiah et al., 2012). The drainage density and drainage frequency have been collectively defined as drainage texture. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Ozdemir and Bird, 2009). Also it has direct association with a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of the watershed (Smith, 1950). According to his classification the D_t (6.26) of the study area was categorized as fine (table 2). Fine D_t of the Rangat watershed indicate that it has impervious subsurface (Ramaiah et al., 2012) resulting in high runoff causing floods.

K. Form Factor (R_f)

Form factor indicates the flow intensity of a basin of a defined watershed (Horton 1945). The value of R_f would always be less than 0.7854 (for a perfectly circular basin). The computed value of form factor of the study area is 0.35 (table 2) indicating that the watershed is sub-circular and elongated (Rudraiah et al; 2008). This R_f value confirms that the Rangat watershed is sub-circular and elongated basin with lower peak flows of longer duration than the average. Flood flows of Rangat watershed are easier to manage than those of the perfectly circular basin (Nautiyal, 1994).

L. Elongation Ratio (R_e)

It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin (Schumm, 1956). Values near to 1.0 are typical of regions of very low relief and circular basin (Strahler, 1964). The R_e value of Rangat watershed is 0.19 (table 2) indicating relatively moderate relief steep slope and elongated suggesting the watershed has low infiltration capacity with high soil erosion due to high runoff (Reddy et al., 2004) is vulnerable to floods.

M. Circulatory Ratio (R_c)

Circulatory Ratio is helpful for assessment of flood hazard. The Rc value is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin (Rudraiah et al, 2008).Higher the circulatory ratio, higher is the flood hazard at a peak time at the outlet point. The R_c of the study area is 0.43 (table 2) indicating that the watershed is elongated exhibiting dentritic stage of the basin also suggesting it is moderately vulnerable to floods.

N. Compactness Constant (C_c)

Compactness constant articulates the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin (Nooka Ratnam et al., 2005). If the watershed was a perfect circle, then C_c would be equal to unity. The Rangat watershed has a Cc value of 1.51(table 2) suggesting that the watershed is elongated and has enough time for discharge.

O. RHO Coefficient (RHO)

It is an important parameter that determines the relationship between the drainage density and the physiographic development of the basin, and allows the evaluation of the storage capacity of the drainage network. It is influenced by climatic, geologic, biologic, geomorphic, and anthropogenic factors (Horton 1945). The RHO coefficient of Rangat watershed is 0.57 as depicted in table 2.

IV. RELIEF MORPHOMETRIC PARAMETERS

The relief aspects of the watershed are appreciably associated with the study of three dimensional features involving area, volume and altitude of vertical dimension of landforms to analyze different geohydrological characteristics. Some of the important relief parameters that are related to the study have been analyzed as shown in Table 2.

A. Basin Relief (H)

Basin relief is an important factor in understanding the geomorphic processes and landform characteristics. The total basin relief of the Rangat basin is 321m. The lowest basin relief of Zero is observed in the plains and highest of 321m(table 2). It has been observed that a high degree of correlation exists among relief and drainage frequency and stream channel slopes.

B. Relief Ratio (R_r)

Measures the overall steepness of a drainage basin and is an indicator of the intensity of erosional process operating on slope of the basin (Schumm, 1956). The relief ratio of Rangat basin is 32.29 (table 2) indicating moderate relief and steep to moderate slope.

C. Dissection Index (DI)

Is a factor implies the extent of dissection or vertical erosion and expounds the stages of terrain or landscape development in any given physiographic region or basin. On an average, the values of DI vary between'0' (complete absence of vertical dissection/erosion and hence dominance of flat surface) and '1' (in exceptional cases, vertical cliffs, it may be at vertical escarpment of hill slope or at seashore). DI value of Rangat watershed is unity (table 2) indicating that it is in the coastal frontier divulging itself in Rangat Bay.

D. Channel Gradient (Cg)

The altitude of the channel surface of the Rangat stream averagely falls at the rate of 20.56 m/km (table 2) in the downstream direction. In the actual field setup the greatest fall is observed in the mountainous areas dominated by lower order streams and least in the plains occupied by higher orders that indicates that down cutting is more efficient in higher altitudes and stream widening with braided channels in the plains or lower altitudes. It indicates that the mean channel slope of Rangat watershed decreases with increasing order number. This testifies to the validity of Horton's Law of Stream slopes, which states a fairly definite relationship between the slope of the streams and their orders, which can be expressed by an inverse geometric series law.

E. Basin Slope (Sb)

Basin Slope facilitates the assessment of runoff generation, direction and volume (Zavoiance, 1985). The basin has a S_b of 32.29 that reflects the relatively mountainous and plateau nature of the terrain is shown in table 2. The general slope of the basin decreases towards north to south indicating Rangat River divulges itself in South (Rangat Bay).

F. Ruggedness Index (R_I)

The topographic ruggedness index indicates the extent of instability of land surface (Strahler, 1956). It is derivative of long-standing interaction between available sharpness of local relief and the amplitude of available drainage density and other environmental parameters such as slope, precipitation, weathering, soil texture, natural vegetation etc. Ruggedness index is measured by taking into account both relief and drainage. The measured value of RI of Rangat watershed is 0.88 (table 2).

V. CONCLUSION

Morphometric analysis of river basin is found to be of immense utility in identifying flood prone watershed. Geospatial techniques are found useful for the analysis because it provides more reliable and accurate measurement of morphometric parameters of watersheds. From the present investigation it is inferred that the Rangat watershed has dendritic stream pattern facilitates more rapid concentration of runoff at or near the watershed's outlet; this increases the likelihood of downstream flooding. Rangat River has the highest stream order (4^{th} order) associated with greater discharge and higher velocity of the stream flow indicating the watershed is highly susceptible to floods during monsoon. Anomaly in the stream length between the 3^{rd} and 4^{th} order streams brings out strong assumption that Rangat watershed is subjected to high rates of erosion, increased runoff and susceptible to flooding. The exceptional change in the mean stream length of Rangat basin is an indicator of the changes in the slope and topography, which in turn determine the age of the basin. The increasing trend in the stream length ratio from lower order to higher order signifies the mature geomorphic stage of the Rangat watershed. The value of Bifurcation ratio in the study area ranges from 1.04 to 2.5 indicating that the watershed has suffered less structural disturbance and the flow energy is high which in turn does not provide ample time for infiltration suggesting high probability of flooding. The computed overland flow of the study area is 0.18 indicating a young topography with high rates of runoff resulting in flooding during extreme meteorological events. The calculated values of drainage density (2.76 Km/ Km^2),Moderate stream frequency (5.66 no. streams/ Km^2), fine drainage texture (6.26) and infiltration number (15.62) of the Rangat watershed suggesting that it watershed has moderate relief and low infiltration capacity due to impervious sub-surface resulting rapid storm response giving rise to a higher runoff resulting in downstream flooding. The form factor (0.35), elongation ratio (0.19) and Compactness constant(1.51) articulates that the watershed is sub-circular and elongated suggesting it has low infiltration capacity with high soil erosion due to high runoff indicating it is vulnerable to floods. The R_c of the study area is 0.43 indicating that the watershed is elongated exhibiting dentritic stage of the basin. It is hereby concluded that all the values derived from morphometric analysis indicate that Rangat watershed is susceptible to flooding during extreme meteorological events. Also indiscriminate landuse patterns increases the vulnerability of the watershed to flooding. It is strongly recommended that a micro watershed level morphometric analysis would help us to understand the hydrological response in detail for better mitigative measure to confront floods in future.

REFERENCES

1. Akram Javed, Mohd Yousuf Khanday, and Subah Rais (2011) Watershed Prioritization Using Morphometric and Land Use/Land Cover Parameters: A Remote Sensing and GIS Based Approach. Journal Geological Society of India. 78: 63-75.
2. Blyth K, and RoDda J. C (1973) A stream length study, Water Resource Resarch. 9:1454-1461.
3. Chopra R, Dhiman R. D, and Sharma P. K (2005) Morphometric analysis of sub-watersheds in Gurudaspur district, Punjab using Remote sensing and GIS techniques. Journal of Indian

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Society of Remote Sensing. 33(4):531–539.
4. Chorley RJ, Donald EG Malm, and Pogorzelski HA (1957) New Standard for Estimating Drainage Basin Shape. American Journal of Science. 255: 138-141.
5. Chow V. T. (Ed.), (1964) Handbook of Applied Hydrology: A Compendium of Water-Resources Technology. McGraw-Hill, New York. 1495.
6. Godschalk DR (1991) Disaster mitigation and hazard management. In Drabek TE, Hoetmer GJ (eds) Emergency Management: Principles and Practice for Local Government, 131–60. International City Management Association, Washington, DC.
7. Horton RE (1932) Drainage basin characteristics. American Geophysical Union of Transactions. 13: 350-361.
8. Horton RE (1945) Erosional Development of streams and their drainage basins, Hydrophysical Approach to Quantitative Morphology. Geological Society of American Bulletin. 56(3):275-370.
9. Langbein W.B (1947) Topographic characteristics of drainage basins. U.S. Geol.Surv. Water-Supply Paper 986 (C): 157-159.
10. Leopold L.B, and Maddock Jr. T (1953) The hydraulic geometry of stream channels and some physiographic implications: U.S. Geological Survey Professional Paper 252, 57 p.
11. Leopold L.B, and Wolman M.G (1957) River channel patterns: Braided, meandering, and straight: U.S. Geological Survey Professional Paper 282-B, 85p.
12. Magesh N.S, Chandrasekar N, and Soundranayagam JP (2010) Morphometric evaluation of Papanasam and manimuthar watersheds, parts of western Ghats, Tirunelveli district, Tamil Nadu, India: a GIS approach. Environ earth Sci Journal. 64(2): 373-381.
13. Magesh NS, Chandrasekar N, and Soundranayagam JP (2012) Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. Geoscience Frontiers 3: 189-196.
14. Miller V. C (1953) A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area, Technical report3, Department of Geology, Columbia University. 1-30.
15. Moglen GE, Eltahir EA, and Bras RL (1998) On the Sensitivity of Drainage Density to Climate Change. Water Resource Research 34: 855-862.
16. Nautiyal M. D (1994) Morphometric Analysis of a Drainage Basin using Aerial photographs: A case study of Khairakulli Basin, District Dehradun, Uttar Pradesh. Journal of the Indian Society of Remote Sensing. 22(4):251-261.
17. Nooka Ratnam K, Srivastava Y. K, Venkateswara Rao V, Amminedu E, and Murthy K.S.R (2005) Check dam positioning by prioritization of Micro-watersheds using SYI model and Morphometric analysis - Remote Sensing and GIS perspective. Journal of the Indian Society of Remote Sensing. 33(1): 25-38.
18. Ozdemir H, and Bird D (2009) Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. Environmental Geology 56: 1405-1415.
19. Prasad RK, Mondal NC, Banerjee P, Nandakumar MV, and Singh VS (2008) Deciphering potential groundwater zone in hard rock through the application of GIS. Environmental Geology 55: 467-475.
20. Ramaiah S.N, Gopalakrishna G.S, Srinivasa Vittala S, and Najeeb. Md. K (2012) Morphometric Analysis of Sub-basins in and around Malur Taluk, Kolar District, Karanataka Using Remote Sensing and GIS Techniques. Journal nature Environment and Pollution Technology. 11(1):89-94
21. Reddy O.G .P, Maji A.K, and Gajbhiye S.K (2004) Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India -A remote sensing and GIS approach. Internat. Jour. Applied Earth Observation and Geoinformatics. 6:1-16.
22. Rudraiah M, Govindaiah S, and Vittala S.S (2008) Morphometry Using Remote Sensing and GIS Techniques in the Sub-Basins of Kagna River Basin, Gulburga District, Karnataka. Journal of Indian Society Remote Sensing. 36(4):351-360.
23. Schmid BH (1997) Critical Rainfall Duration for Overland Flow an Infiltrating Plane Surface. Journal of Hydrology. 193: 45-60.
24. Schumm SA (1956) Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological Society of American Bulletin. 67: 597- 646.
25. Sherman L. K (1932) The relation of hydrographs of runoff to size and character of drainage basins, Eos Trans. AGU, 13, 332-339.
26. Smith K.G (1950) Standards for grading textures of erosional topography. American Journal of Sciences. 248: 655-668.
27. Strahler AN (1950) Equilibrium theory of erosional slopes, approached by frequency distribution analysis. American Journal of Sciences. 248: 800-814.
28. Strahler AN (1964) Quantitative geomorphology of drainage basins and channel networks section 4-2, Handbook of Applied Hydrology. Ed. Ven te Chow, McGraw-Hill, New York. 4-35.
29. Vittala S.S, Govindaiah S, and Honne G. H (2004) Morphometric analysis of sub-watersheds in the Pawagada area of Tumkur district, South India, using remote sensing and GIS techniques. Journal Indian Society of Remote Sensing. 32(4):351–362.
30. Zavoiance I (1985) Morphometry of drainage basins (Developments in water science), Elsevier Science, New York, USA.

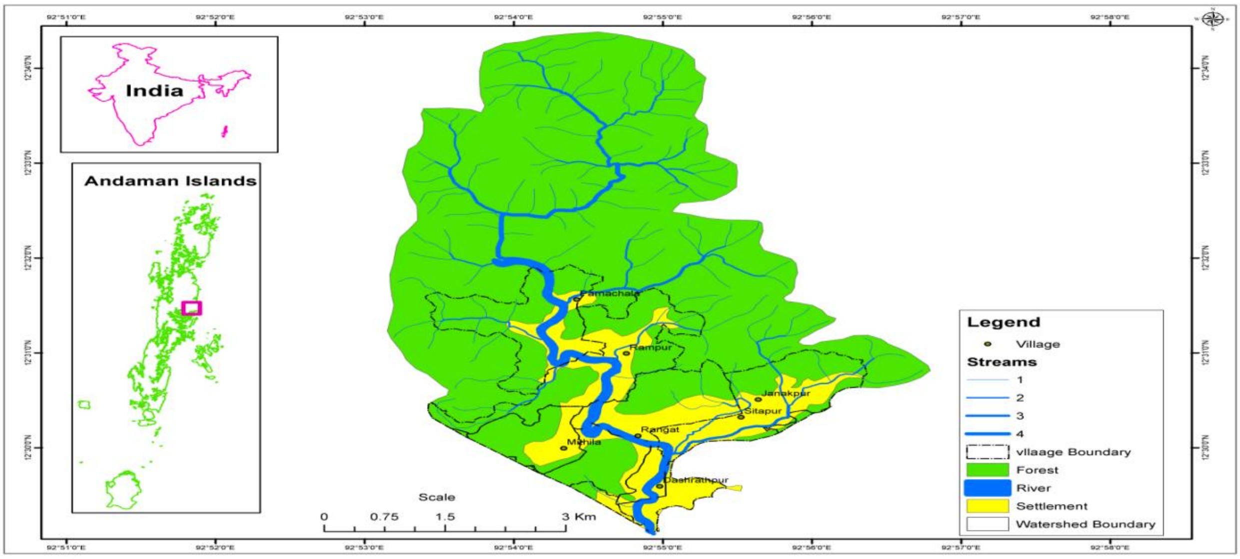

Figure 1: Study area

Table 1: Ready recknoer of Morphometric formulae

S No	Parameter	Symbol	Formula	Reference
1	Stream Order	N_u	Hierarchical rank	Strahler (1950)
2	Bifurcation ratio	Rb	Rb =Nu/Nu+1 Where, Nu =Total no. of stream segments of order'u' Nu + 1= Numberof stream segments of the next higher order	Schumm (1956)
3	Mean Bifurcation ratio	Rb_m	Rb_m = Average of bifurcation ratios of all orders	Strahler & Chow (1964)
4	Stream length	L_u	Length of the stream (Kilometers)	Horton(1945)
5	Mean Stream length	L_{sm}	$L_{sm} = L_u/N_u$ Where, L_u = Total stream length of order 'u' N_u = Total no. of stream segments of order 'u'	Strahler & Chow (1964)
6	Stream Length Ratio	R_L	$R_L = L_{sm}/L_{sm}$-1 L_{sm} =Mean stream length of a given order and L_{sm-1} = Mean stream length of next lower order	Horton(1945)
7	Length of Overland Flow	L_g	L_g = 1/2D measured inKm Where, D=Drainage density (Km/Km^2)	Horton(1945)
8	Basin Perimeter	P	P = Outer boundary of drainage basin measured in kilometers	Schumm(1956)
9	Basin Length	L_b	$L_b = 1.312 \times A^{0.568}$ Where, A = Area of the basin	Schumm(1956)
10	Basin Area	A	Area from which water drains to a common stream and boundary determined by opposite ridges	Strahler & Chow (1964)

11	Drainage Density	D_d	$D_d = L_u / A$ measured in (Km/Km^2) Where, L_u = Total length of the stream (Kilometer) and A = Area of the basin in km^2	Horton(1945)
12	Stream frequency	F_s	Fs = Nu/A Where, Nu = Total no. of stream segments of all orders and A = area of the basin(km^2)	Horton(1945)
13	Infiltration Number	I_f	If = Dd x Fs Where, Dd = Drainage density (Km/Km2) and Fs = Stream frequency	Zavoiance (1985)
14	Drainage Texture	D_t	D_t = Nu/P Where, Nu = Total no. of stream of all orders and P = basin perimeter measured in km	Horton(1945)

Table 1: Table 1: Ready recknoer of Morphometric formulae continued

S No	Parameter	Symbol	Formula	Reference
15	Form factor ($R_f < 1$)	R_f	$R_f = A/Lb^2$ Where, A= area of the basin(km^2) and L_b= basin length, km	Schumm(1956)
16	Elongation Ratio ($R_e < 1$)	R_e	$Re = \sqrt{A} / \pi / L_b$ Where, A = area of the basin(km^2) and L_b= basin length in km	Miller (1953)
17	Circulatory Ratio ($R_c \leq 1$)	R_c	$R_c = 4\pi A/ P^2$ Where, A = area of the basin(km^2) and P = basin perimeter measured in km	Miller (1953)
18	Compactness Constant ($C_C \geq 1$)	C_c	$C_c = 0.2821 P/A^{0.5}$ Where, A = area of the basin(km^2) and P = basin perimeter measured in km	Horton(1945)
19	RHO coefficient	RHO	$RHO = R_L/R_b$ Where, Rl= stream length ratio Rb= bifurcation ratio	Horton (1945)
20	Basin Relief / Relative relief	H	H = Z – z Where, Z = Maximum elevation of the basin (m) and z = Minimum elevation of the basin (m)	Sherman (1932)
21	Relief Ratio	R_r	$Rr = H/ L_b$ Where H = Basin Relief (m) and Lb = Length of basin (m)	Schumm(1956)
22	Absolute Relief	R_a	Maxmium height of relief	Hadley and Schumm (1961)
23	Dissection Index	D_I	$D_I = H/R_a$ Where, H = Basin relief (m) and Ra = Absolute relief (m)	Magesh et al.,(2012)

24	Channel Gradient	C_g	$C_g = H / \{(\pi/2) \times C_{lp}\}$ Where, H = basin relief (m) and C_{lp} = Longest Dimension Parallel to the Principal Drainage Line (Kms) =Lb	Prasad et al., (2008)
25	Basin Slope	S_b	S_b = H/Lb Where, H = Basin relief (m) and Lb = Length of basin (m)	Miller (1953)
26	Ruggedness Index	R_I	$R_I = D_d$*H/1000 Where, Dd = Drainage density and H = H = Basin relief	Strahler (1956)

Table 2 Computed morphometric values of Rangat watershed

Sl No	Parameter	Symbol	Calculated Value
1	Stream Order	N_u	I(102), II(55), III(22), IV(21)
2	Bifurcation ratio	Rb	I/II(1.85), II/III(2.5), III/IV(1.04)
3	Mean Bifurcation ratio	Rb_m	1.8
4	Stream length	L_u	I(59.86), II(18.93), III(7.85), IV(11.19)
5	Mean Stream length	L_{sm}	I(0.58), II(0.34), III(0.35), IV(0.53)
6	Stream Length Ratio	R_L	II/I(0.59), III/II(1.03), IV/III(1.51)
7	Length of Overland Flow	L_g	0.18
8	Basin Perimeter	P	31.96
9	Basin Length	L_b	9.94
10	Basin Area	A	35.35
11	Drainage Density	D_d	2.76
12	Stream frequency	F_s	5.66
13	Infiltration Number	I_f	15.62
14	Drainage Texture	D_t	6.26
15	Form factor	R_f	0.35
16	Elongation Ratio	R_e	0.19
17	Circulatory Ratio	R_c	0.43
18	Compactness Constant	C_c	1.51
19	RHO coefficient	RHO	0.57
20	Basin Relief / Relative relief	H	321
21	Relief Ratio	R_r	32.29
22	Absolute Relief	R_a	321
23	Dissection Index	D_I	1
24	Channel Gradient	C_g	20.56
25	Basin Slope	S_b	32.29
26	Ruggedness Index	R_I	0.88