Morphometric Analysis of Sukhnai River with the help of Remote Sensing Data and Arc-GIS in Bundelkhand Region, Central India

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Abstract

In the present study, Sukhnai River is selected for the morphometric study. This river is the major tributary of Dhasan River in Bundelkhand region. The morphometric parameters (linear, areal, and relief) of Sukhnai river basin were measured using Remote Sensing and GIS techniques for future development and planning of the river basin. Watershed boundary, flow accumulation, flow direction, flow length, etc; have been prepared using Arc-GIS software. Profile map of the basin is prepared through Global Mapper. The area is covered by dendritic to sub-dendritic drainage pattern. High bifurcation ratio shows that the drainage is strongly controlled by structures. Form factor (0.35) also indicates the area is having more or less elongated basin with flows of longer duration than average.

Keywords: Sukhnai River, Morphometric Analysis, Remote Sensing & GIS, Global Mapper, Dendritic pattern, Bifurcation ratio and Form factor.

Introduction:

A widely acknowledge principle of Morphometry is that drainage basin morphology reflects various geological and geo-morphological processes over time, as indicated by various morphometric studies (Horton, 1945, Strahler, 1952, Shreve, 1969). It is clear that effect of drainage morphometry is very important in understanding the landform processes, soil physical properties and erosional features. Hydrologic and Geomorphomic processes occur within the watershed and morphometric characterization of the watershed scale reveals information regarding formation and development of land surface processes (Singh, 1992). The surface runoff and flow intensity of the drainage system can be estimated using the Geomorphic features associated with morphometric parameters (Ozdemir,et al. 2009). The analysis of the drainage does not appear to be complete if it lacks the systematic approach towards the development of drainage basin in the area. Drainage lines of an area not only explain the existing three dimensional geometry of the region but also help to narrate its evolutional process (Singh 1980).

Study Area:

The Sukhnai River lies between 24°59′ 33.53″N to 25°17′ 4.03″N and 78° 52′ 23.79″E to 79°15′53.73″ E. The total geographical area of the river basin is 940.0741 km^2. It is a major tributary of Betwa river system. Sukhnai River plays an important role in increasing the catchment area of Dhasan River. It has a rocky bed almost throughout its course. Sukhnai is a fifth order stream. The highest elevation point of the basin is 347 mt. and the Lowest is 119 mt.

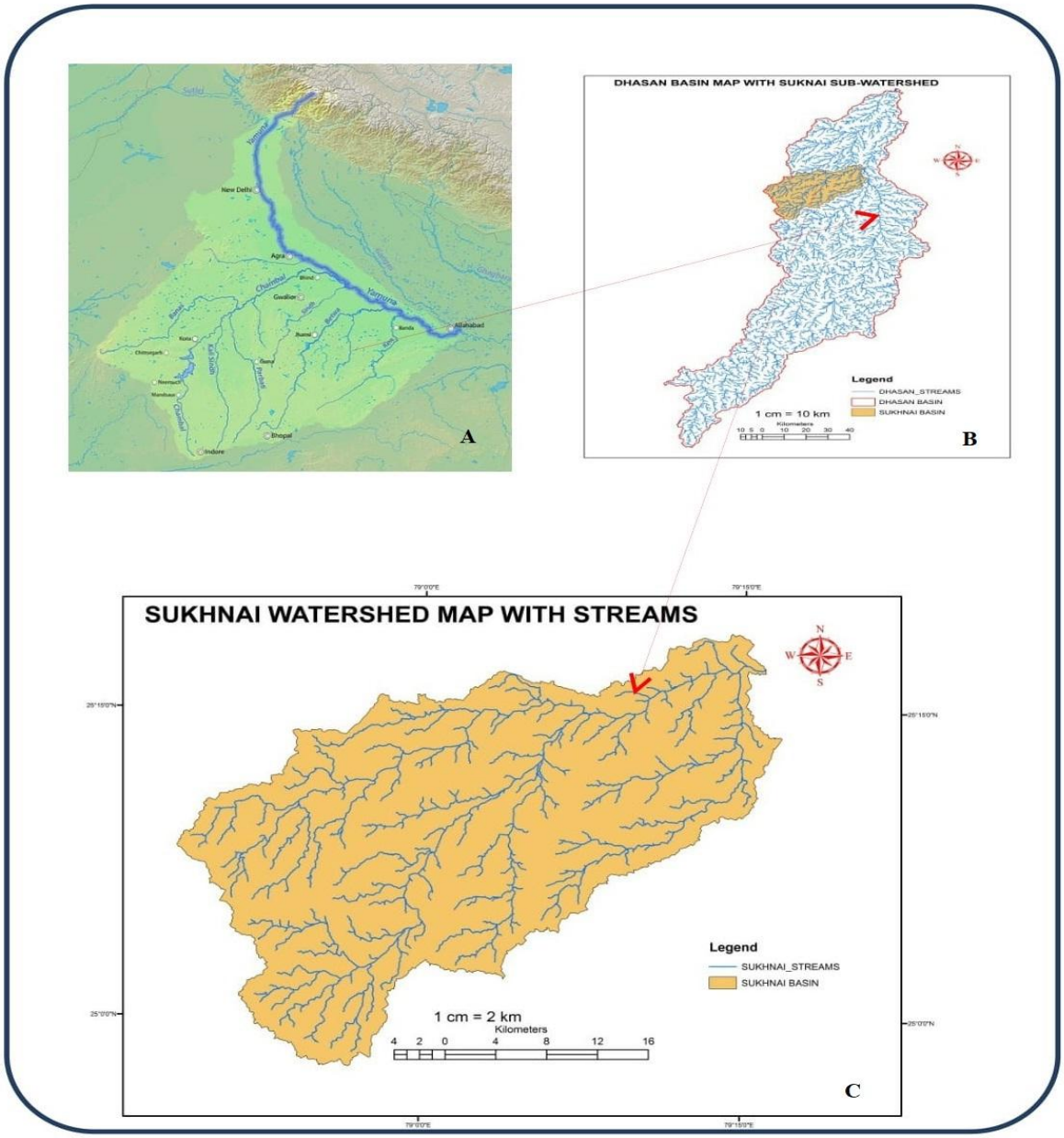
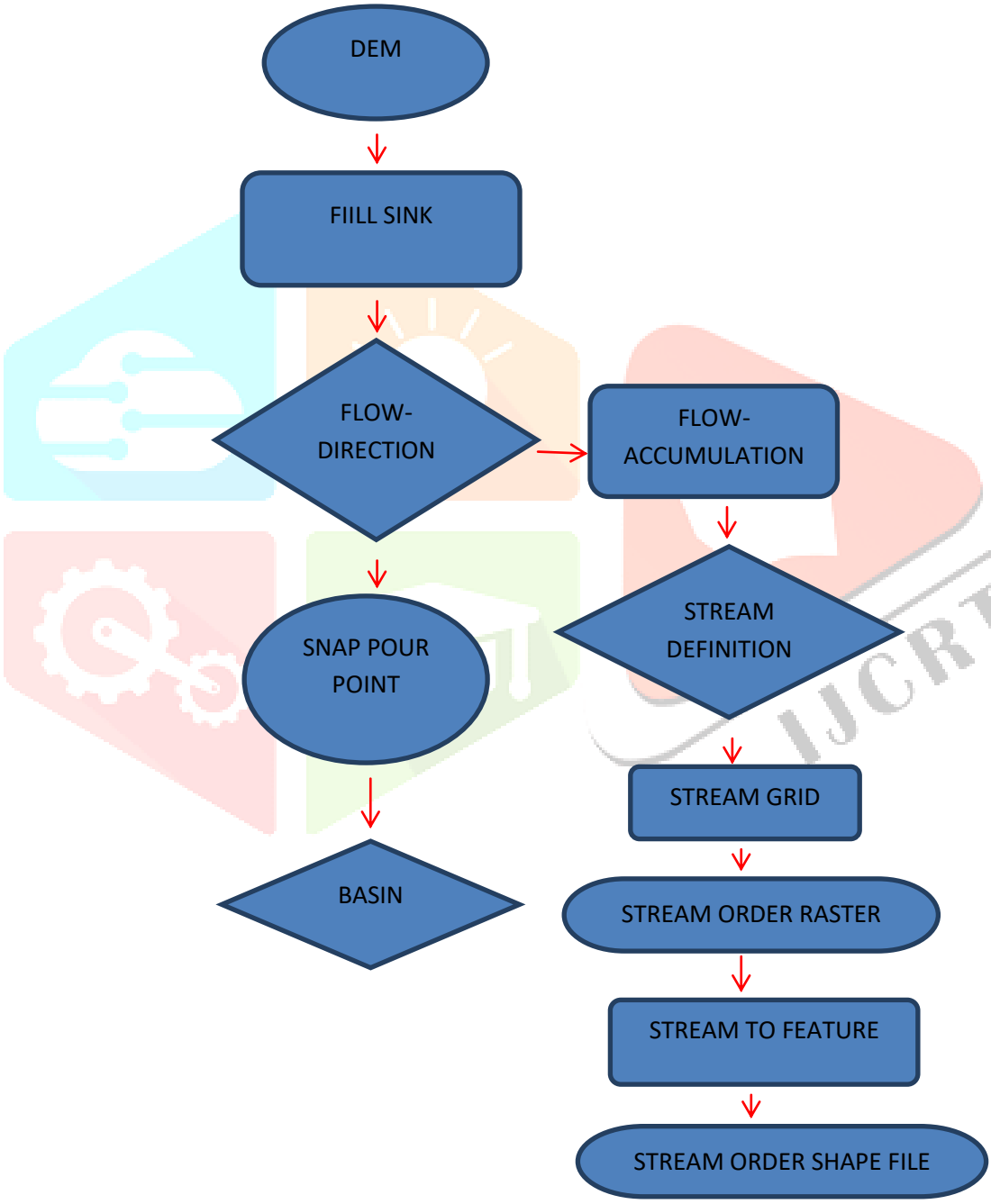


Fig 1- Location Map of Study Area

A- Betwa River, B- Dhasan River, C- Sukhnai River

Methodology:

This study is based on Cartosat-1, DEM, Stereo Data with resolution of 1 arc second downloaded from BHUVAN website http://bhuvan.nrsc.gov.in/data/download. Firstly different tiles of DEM data were mosaicked to get a complete DEM data of the study area. This DEM was processed to delineate drainage network and basin extraction in Arc GIS software using different hydrological, spatial analyst and geo-processing tools. Following steps were carried out in this process.



Flow Chart of Methodology

After analyzing the data different areal, linear and relief morphometric parameters as Basin-Area, Stream length, Stream number, Bifurcation ratio, drainage density, Stream frequency, texture Ratio, Form Factor, Circulatory Ratio and Elongation Ratio were calculated.

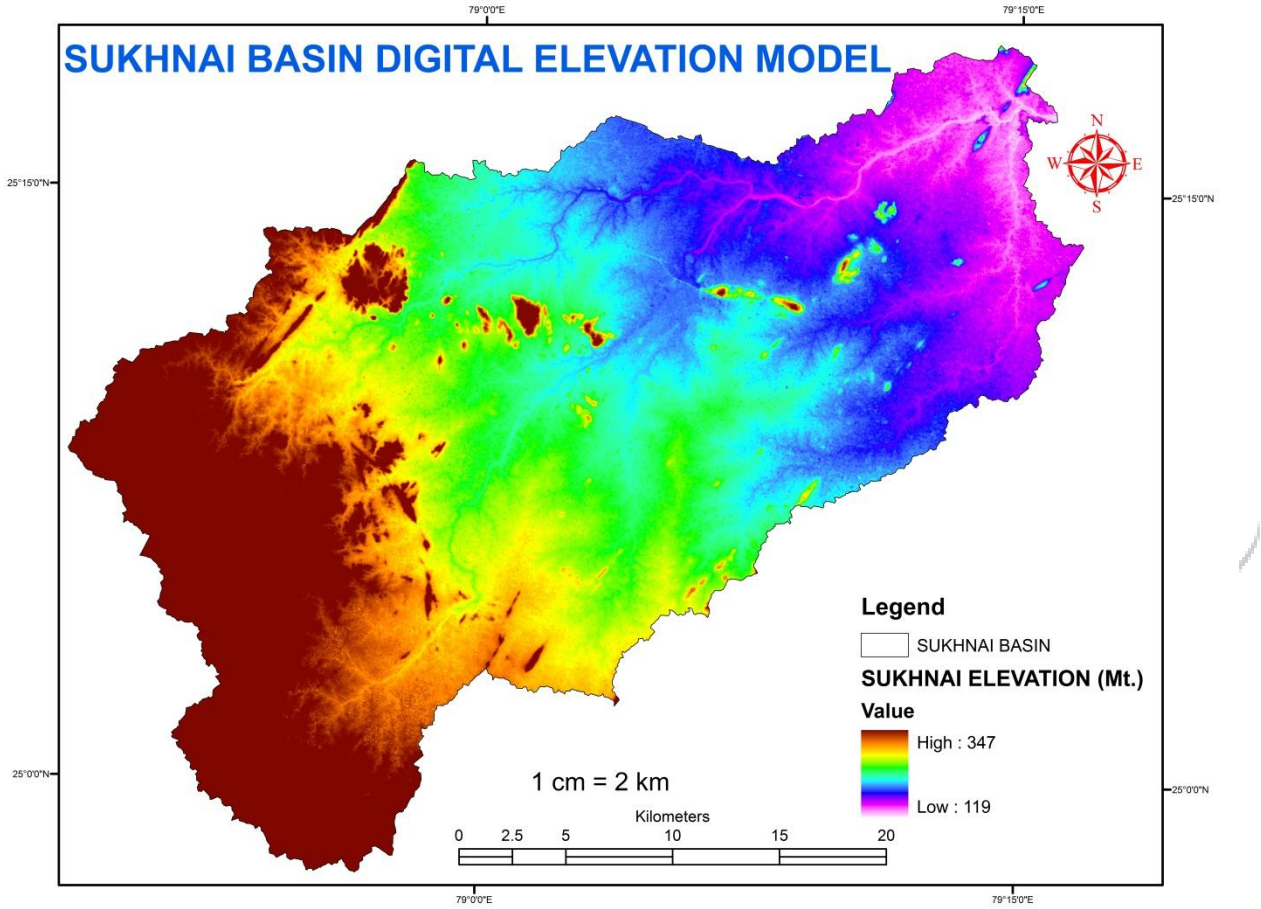
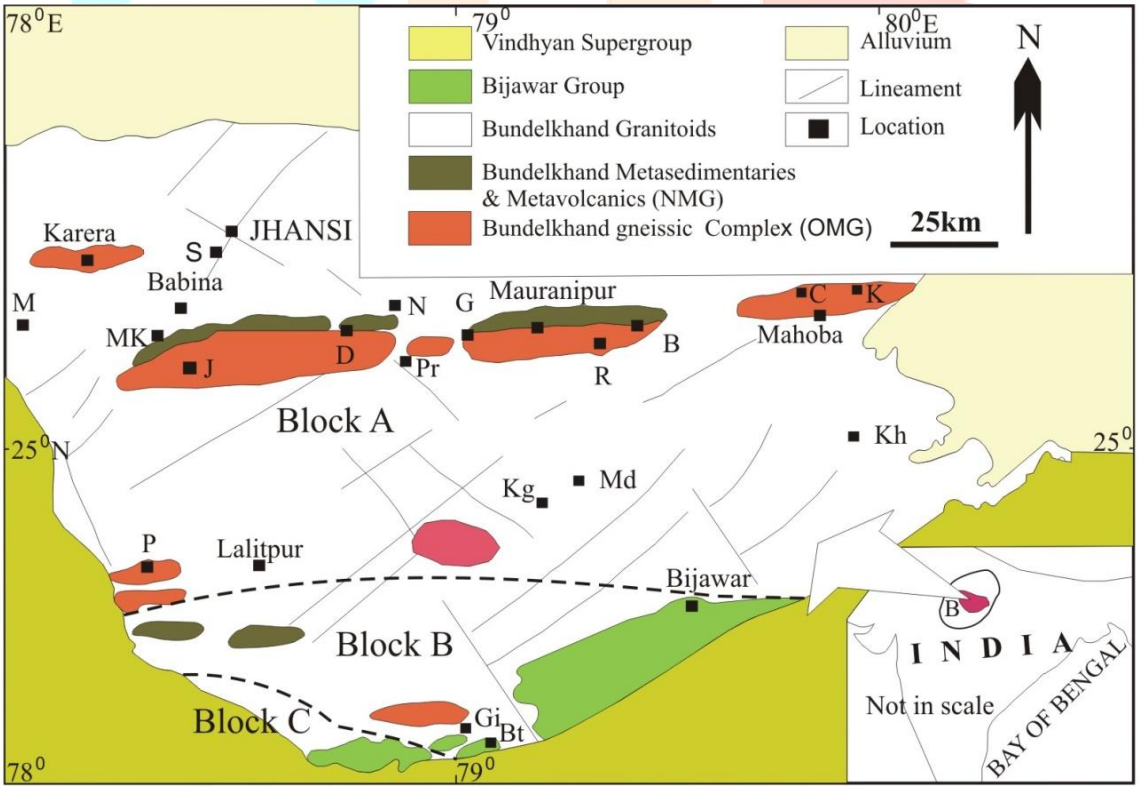


Fig 2- DEM of the study area

Geology of the Study Area:

To understand the geomorphology of the study area geology is one of the most important factor. The Bundelkhand craton lies between 24^0 15′ N to 26^0 15′ N latitudes and $77^0$45′ E to $80^0$40′ E longitudes, comprises mainly the rocks of Bundelkhand massif of Achaean and Palaeoproterozoic, succeeded by very low-grade metamorphites of Bijawar and Gwalior Groups of rocks of Late Palaeo-Proterozoic age respectively in the northwest and southeast of the massif. The sedimentary rocks of Vindhyan Supergroup (Meso-

Neoproterozoic) were deposited all around this massif. The massif comprises mainly of granitoids of different episodes, low to high-grade metamorphics of peletic, psammatic, mafic and ultramafic rocks, quartz reefs and mafic dykes swarms. Basu (1986) reviewed the geology of the Bundelkhand massif comprehensively, based on his own research and works of his contemporaries in the Geological Survey of India (GSI) and he brought out that massif consisted largely of intrusive granite and that the gneisses, metasediments and the metabasics are older and occur as dismembered lensoidal bodies within the vast mass of intrusive granitoids. The Bundelkhand craton consists mainly of granitods, migmatites, gneisses, and low grade metamorphics. The craton is delineated from Aravalli- Rajasthan craton by grate biundry fault in the west and delineated from Bastar and chhota Nagpur carton by EW trending SON-Narmada lineament in the south and south –east. The northern boundary of the massif is covered by recent alluvium. Quartz reefs are the characteristics the parallel ridge of quartz, trending NE-SW in Bundelkhand massif. They rise about 175m above the surrounding land. Mafic dykes, trending NW-SE, are more frequent near eastern and southwestern margins of the Bundelkhand massif. These dykes have a cross cut relation with the prominent NE-SW trending quartz reefs.



Geological map of Bundelkhand craton (Modified after Mondal et al. 2002, Basu 1986 and Prakash et. Al. 1975). The older Metamorphic Group (OMG) and Newer Metamorphic Group (NMG) older than Bundelkhand granitoids are mainly exposed in the central part of the massif in E-W direction. Block A, B and C are based on

topography. Abbreviations- D: Dhaurra, G: Gora, M: Mohar, MK: Mankua, S: Shivgarh, B: Baragaon, P: Panchware, R: Roni, Pr: Prithivipur, Kg: Khargapur, Md: Madla, Gi: Girar, Bt: Baraitha, Kh: khajuraho, N: Niwari, C: Charkhari, J: Jaunpur and K: kabrai. The inset shows the position of the Bundelkhand craton (B) in India.

Morphometric Analysis of Sukhnai Basin:

Stream order -

Stream ordering is the very first step of morphometric analysis of the basin area. The ordering system of stream, firstly proposed by Horton (1945), but Strahler (1952) present it with some modifications. The researcher used Strahler's method. It is observed that the first order stream has maximum frequency and decreases as the stream increases. The total stream is 336 in which first order is 266, in second order 52, in third order 13, fourth order 4, and in fifth order 1.

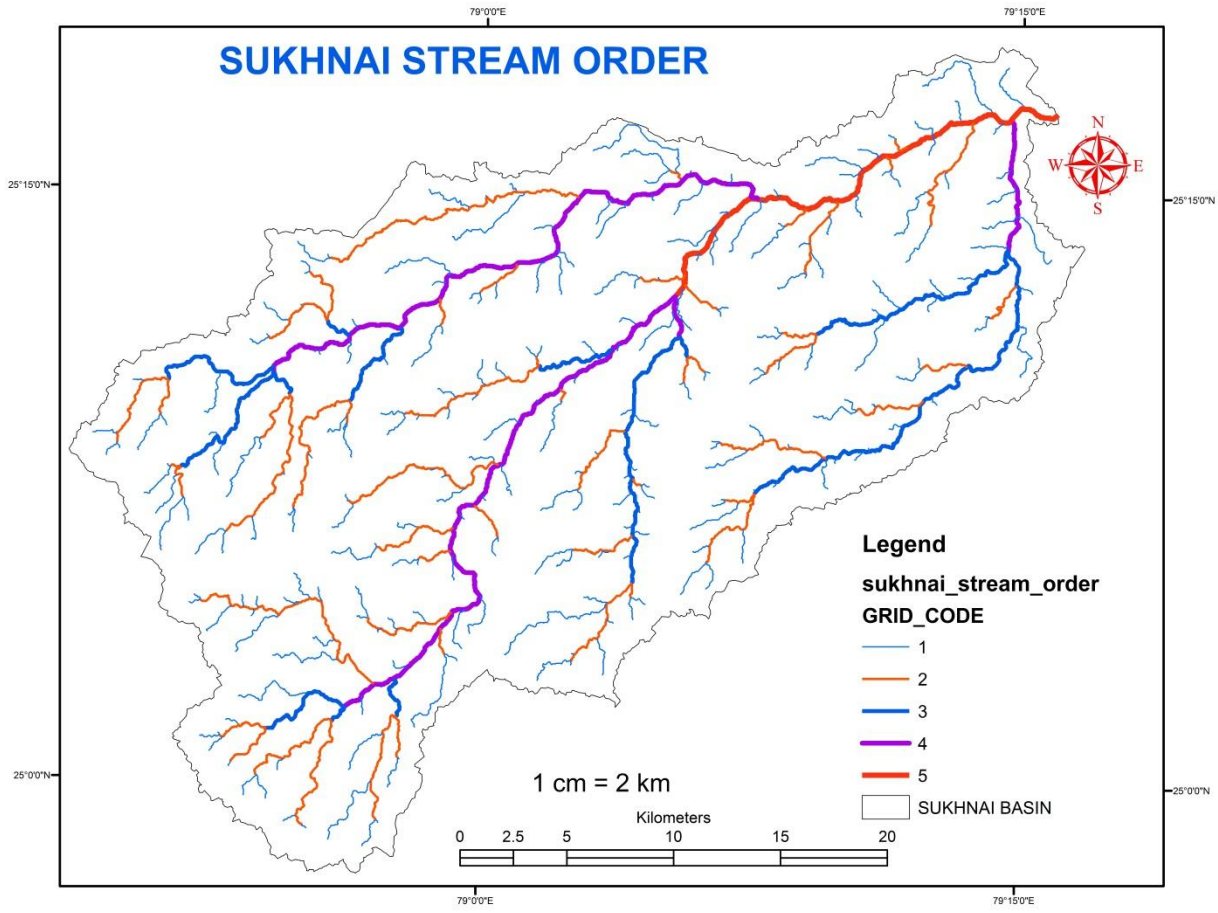


Fig 3- Stream Order Map of Sukhnai Watershed

Stream order	Stream Number	Streamlength (km.)	Meanstreamlength	Stream length Ratio	Bifurcation ratio	Mean bifurcation ratio	Stream length (km.)
1ST	266	341.957	1.285	1.701	5.115	4.091	727.925
2nd	52	201.032	3.866	2.279	4.00		
3rd	13	88.20	6.785	1.233	3.25		
4th	4	71.526	17.882	2.837	4.00		
5th	1	25.209	25.209	-	-		

Table 1- Linear Aspects of Sukhnai River Basin

Stream Number-

Stream number is the total of order wise stream segments. Horton (1945) proposed that the numbers of stream segments of each order form a reverse Geometric sequences with order number. The basin has total 336 stream numbers.

Stream Length-

The total stream length of the Sukhnai watershed has many orders, which have been calculated by Arc-GIS 9.3 software. Horton's law of stream lengths supports the theory that Geometrical similarity is preserved generally in watershed of increasing order (Strahler, 1964). The researcher is used of Horton's law of stream length. Total length of Sukhnai river basin is 727.925 km.

Mean Stream Length-

The mean stream length is calculated by dividing the total stream length of each order and the number of stream of segment of order. In the present study, it is stated that mean stream length is 2.166 km.

Stream Length Ratio-

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and having important relationship with surface flow and discharge (Horton, 1945). Changes of stream length ratio from one order to another order indicating their late youth stage of geomorphic development (Singh & Singh, 1997). Total Stream length ratio of this basin is 8.05.

Bifurcation Ratio-

The bifurcation ratio is the ratio of the number of stream segment of given order to the number of segments of next higher order. Horton (1945) considered the bifurcation ratio as index of relief and dissertation. It is a dimensionless property and generally ranges between 3.0 to 5.0. the lower value of Rb are characteristics of the watersheds, which have suffered less structurally disturbances (Strahler, 1964) and the drainage pattern has not been distorted because of the structural disturbances (Nag, 1998). In this study, the higher value of Rb shows strong structural control on the drainage pattern, while the lower value of watershed shows not affected by structural control.

Length of the Basin-

Many researchers stated basin length in many ways, as Gregory and Walling (1973), defined the basin length as the longest in the basin in which are end being the mouth. Schumm (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. The researcher is calculated basin length of the Sukhnai river basin is 51.578 km.

Basin Area-

The area of the river basin is another crucial parameter like the length of the stream drainage. Schumm (1956) established an interesting relation between the total watershed area and total lengths, which are supported by the contributing areas. The researcher is calculated the basin area using Arc-GIS 9.3 software, that is 940.071 km^2.

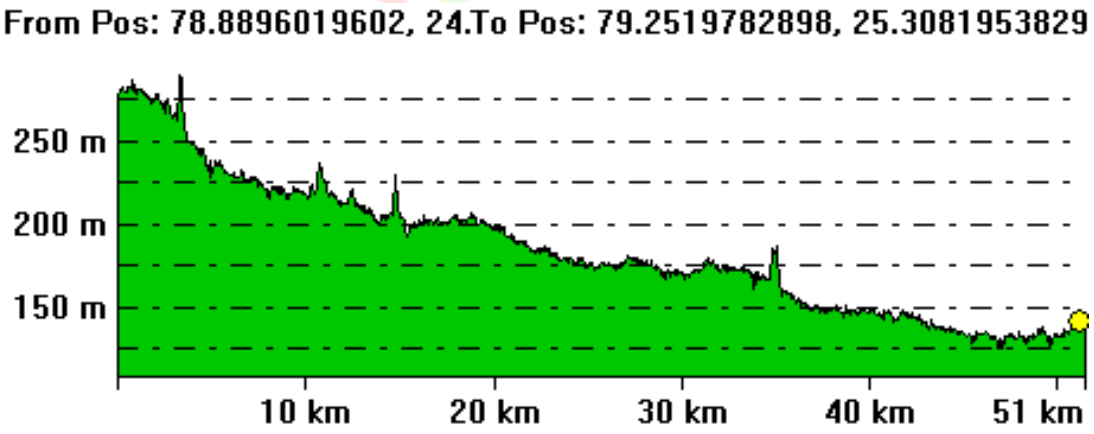


Fig 4- Profile Map of Sukhnai Watershed (prepared in Global Mapper software)

Basin Perimeter-

Basin perimeter is the outer limit of the river basin that wrapped its area. It is an indicator of the river basin size and shape. Basin perimeter of Sukhnai river basin is 192.091 km the author of this paper calculated basin perimeter by Arc GIS 9.3 software.

Form Factor-

According to Horton (1932), form factor may be defined as the ratio of basin area to square of the basin length. The value of form factor would always be less than 0.754 (for a perfectly circular basin). If river basin has high form factor value, has high peak flows of shorter duration, on the other hand with low Rf value basin has elongated shape and flow for longer duration. Form factor of this basin is 0.53.

Elongation Ratio-

According to Schumm (1965) elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Strahler stated that this ratio runs between 0.6 to 1.0 over a wide variety of climatic and geologic types. The elongation ratio of the Sukhani river basin is 7.565.

Result of Morphometric analysis:

Morphometric Parameters	**Formula/ Symbols**	**Results**
Basin Area (km^2)	A	940.074
Total Stream Length (km)	L_u	727.925
Total Stream Number	N_u	336
Basin Perimeter (km)	P	192.091
Drainage Density (sq/km)	Dd=L/A	0.774
Stream Frequency	Fs = N/A	0.357
Texture Ratio	T = N1/P	1.385
Basin Length (km)	Lb	51.578
Elongation Ratio	$R_e = 2\sqrt{(A/\pi)}/Lb$	7.565
Circulatory Ratio	$R_c=4\pi A/P^2$	0.319
Form factor	$R_f=A/Lb^2$	0.353

Basin Relief	B_h =Highest Elevation – Lowest Elevation	228
Relief Ratio	R_h =Bh/Lb	4.420
Ruggedness Number	R_n =Bh*Dd	176.472

Table 2- Linear, Arealand Relief Parametersof Sukhnai River Basin

Texture Ratio-

It is presented as the ratio between the first order streams and perimeter of the basin and depends on the underlying petrology, percolation capacity and relief aspects of the terrine. In this study, the Rt of the river basin is 1.385.

Circularity Ratio-

Miller (1953) defined circularity ratio of the basin area to the area of a circle having the same circumference perimeter as the basin. It is dimensionless and shows the degree of circularity of the basin. Rc value of the Sukhnai river basin is 0.319.

Stream Frequency-

Stream frequency presented by Horton (1932). It is known the number of stream segments per unit area. Stream frequency of Sukhnai River is 0.357.

Drainage Density-

Horton (1932) defines drainage density as the total length length of all order/ drainage area and may be an expression of the closeness of spacing of channels. It is an important quantitative expression to the dissection and analysis of landform. Drainage density of the Sukhnai river basin is 0.774.

Length of Overland Flow-

Horton (1945) defined length of overland flow as the length of flow path, projected to the horizontal of non-channel flow from point on the drainage divide to a point on the adjacent stream channel. It is approximately equal to the half of the reciprocal of drainage density. Lg of this study is 0.646.

Relief Ratio-

According to Schumm (1954) the relief ratio is obtained when basin relief 'H' is divided by the maximum basin length, results in a dimensionless ratio which is equal to the tangent of the angle formed by two plans

intersecting at the mouth of the basin called (Rh) measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on slop of the basin. Relief ratio of the basin is 4.420.

Ruggedness Number-

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. Extreme high value of Rn occurs when both variables are large, when slop is not only steep but long as well (Strahler, 1958). Ruggedness number value of the basin is 176.472.

Conclusion:

This study presents that remote sensing and GIS techniques play a crucial role to make updated and authentic drainage map which is very important for morphometric analysis. From the study it is observe that Sukhnai River is of the fifth order stream. The drainage basin presents that this basin has dendritic to sub-dendritic drainage pattern. The mean Bifurcation ratio is 4.093 and falls under normal basin category. High bifurcation ratio shows that the basin is strong structural control on the drainage. Form factor of the study area is 0.35 that shows more or less elongated basin with flows of longer duration than average.

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