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Links among Drainage Density, Frequency and Flooding in Nanoi River Basin, Assam

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ABSTRACT : *Rivers and their allied fluvial landforms are among the most universal features of earth's surface [1] with expanded nature. Drainage basin is a unique feature to understand the geomorphic process and form. Rivers have been unpredictable unit causing geomorphological changes in land and hydrological regimes. A drainage basin being the best unit for hydro-physical studies among many [2][3]), bears a great significance in today's hydro-environmental investigation of channel network and drainage morphology along with flood events and their relationship with land, water and man [3]. Hydro-geomorphic processes play key roles in creating, modifying, or destroying aquatic habitat and act as ecological disturbances that shape ecosystem characteristics. Drainage density, stream frequency, basin morphology are the chief factors to the genesis of fluvial problems like drought, flood and the size of the area affected, and the frequency of occurrence. Geographic variations of climate, physiography (geology and topography), and vegetation impart a strong regional character to river systems. Therefore, a detail investigation is required to know such types of hydro-geomorphic characteristics and its impact on flood. Quantitative applications in drainage basin are the most important tools which increasingly used in evaluation of river morphometry and hydraulic characteristics to improve the quantitative and qualitative research study of a river basin.*

Keywords: *Drainage Density, Flood, Geomorphic Process, Stream Frequency.*

I. Introduction:

Recently, considerable progress in the subject of fluvial morphology has been achieved by quantitative studies of streams, drainage basins and geology. Some of the important aspects which have evolved as a result of quantitative studies are the hydro-geometry,[4] hydro-morphometry [5] and the effect on the land form [6]. Because these studies contain basic ideas regarding quantitative data, they may be extended easily for the letter studies. The aim of this paper is to integrate the results and approaches of several investigations relating to drainage density, stream frequency and its impact on river basin and flood. Drainage texture contains different concepts of drainage system among them significant are density and frequency.

Horton [2] forwarded a measure of the amount of the dissection of the watershed which he called the drainage density, defined as the total of all stream lengths in the basin divided by the area of the basin. On the other hand stream frequency is derived by dividing the number of streams by the area of the drainage basin. Though two drainage basins may show similar drainage density, but their drainage frequency is not necessarily the same. Drainage density is higher in arid areas with sparse vegetation cover and increases with increasing probability of heavy rainstorms [7]. Drainage density also higher in highly branched drainage basins with relatively rapid hydrologic response [8].The drainage density and stream frequency train on flood peaks significant controls which can be broadly divided between direct and indirect effects. Among the important direct effects there is the control associated with the length of the stream network and hill slope path. Because flow velocity is higher in the river network it implies the increasing drainage density increasing flood flow. On the other hand, indirect effects to the role of Dd and Fs as an index of geology[9].Decreasing Dd indicates to the presence of impervious rocky structure and caused high flood peak. Sometimes due to presence of karstic topography caused the decreasing Dd. In semi arid areas like Brahmaputra valley the significant effects of soil erosion as the valley is mainly covered with alluvial soil and characterize by high Dd and and Fs and runoff production indicates high flood. The effect is clearly visible in the Brahmaputra valley where old and recent alluvial soils are characterized significantly larger Dd and Fs as result the entire valley is regularly affected by medium to high flood.

II. Objectives of the Study:

The main objectives of the study are

i) to investigate the morphological characteristics of the Nanoi river and its basin
ii) to know the drainage density and stream frequency and their relationship with flood
iii) to examine the impact of basin morphology and morphometry on river basin and environment

III.Study Area:

The river Nanoi originates from the Bhutan hill Tangchar, southern part of the Bhutan hill (1220m). The topography along the stream is such that the valley gradients decline steeply as the rivers advance from the hills to the plains of the Brahmaputra valley. Although the river originates from Bhutan hills the river Nanoi is very significant in nature .It always takes new shape and size and change her direction in Udalguri and Darrang district. So locally at the downstream part the river is known as Nanoi (In Darrang), means new river that the river is newly appeared in every direction. But at early times, before nineteenth century the river name was Digauge.

The Nanoi river basin, a part of reverine built-up plain of Brahmaputra valley composed of fine alluvial sediments, which has been washed by sheet flood causing river bank erosion and channel shifting almost every year due its hydro-geomorphic factors. The hydro-geomorphic characteristic of the river basin has caused serious geomorphic, hydrologic and environmental problem in the southern part of the Darrang district. The total length of the Nanoi River is 104.275 kilometer containing basin area of 959.460 sq km (Fig. 1). The basin extending from 26^0 $15^{/}$ $45.14^{//}$ N to 27^0 $04^{//}$ $57.84^{//}$ N latitude and 91^0 $48^{//}$ $59.66^{//}$ E to 91^0 $58^{//}$ $42.536^{//}$ E longitude. The basin area receives an annual mean rainfall of 210 cm. The relief and drainage texture plays dominant role to create contentious characteristics of environment on the land of the Nanoi river basin.

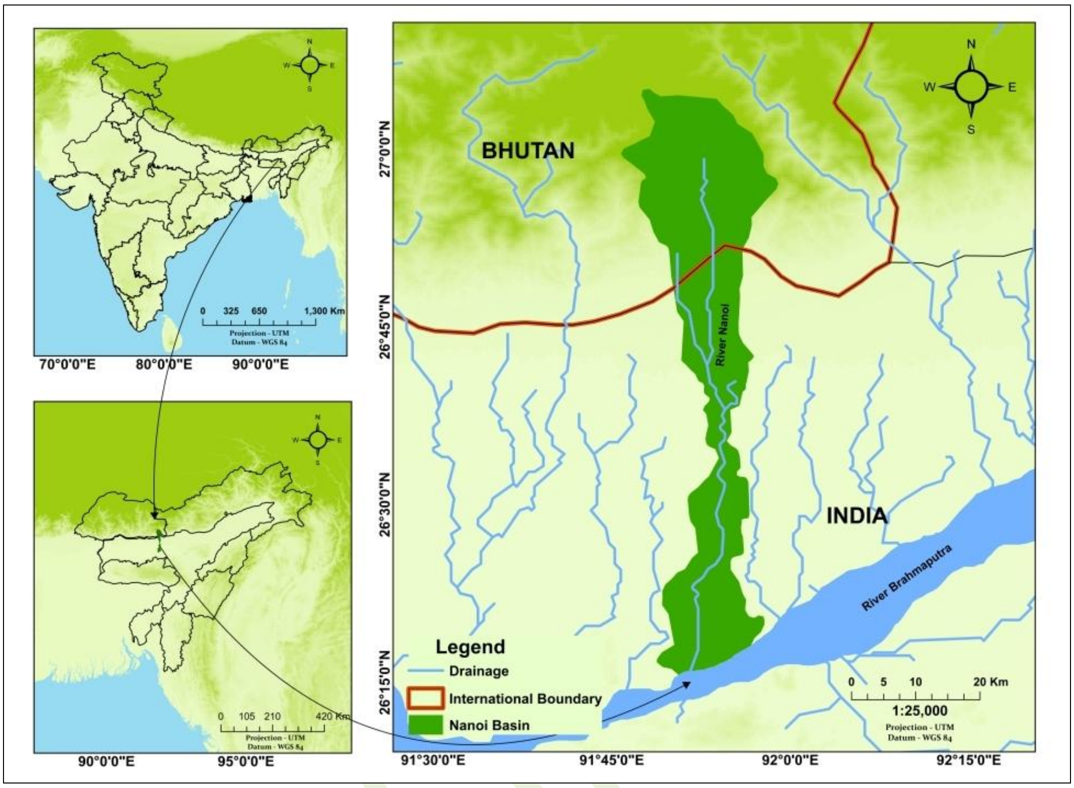

Fig.1Location Map of Nanoi River Basin

Source: Based on Primary Survey

III.Methodology:

Drainage basin analysis has been done with the help of the basin morphometric parameters such as linear and areal aspects of the river basin were determined and computed. The SOI topographical map (R.F.1:50,000) of 1972 and along with Remote sensing data like IRS LISS-III image of 2008 are used for the preparation of the basin map of the study area. The drainage networks of the basin are then digitized on the basis of the basin map. The digitization has been completed by considering the stream order followed Strahlers method. Hydrologic and morphometric characteristics along with areas of river associated problems have been done quantitatively, using different tools and techniques. Finally, all the data have been arranged and represented by appropriate maps and diagrams. Different morphometric parameters have been generated in GIS environment by using GIS software like Arc view and Erdas.

Morphometric Characteristics of the Basin

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of its landforms [10] which can be well extended in case of a drainage basin to cover up its areal, relief aspects and linear contribution [11].

a. Areal and Relief Aspects

The Nanoi river basin placed in the middle of the high hills and the grand river Brahmaputra in the south and the adjacent riverine plains in the east and west being characterized by south sloping hilly terrain in its upper part, the swelling plains in the upper middle part and flat plains on the lower middle and lower parts of the basin (Fig. 2). A number of factors right from geologic basement through topographic to fluvio-geomorphic ones have been found to be responsible for such a characteristic landform set-up. The geological basement of this fluvio-geomorphic peculiarity of the basin is such that in the Arunachal Himalayan part of the basin it is composed of tertiary sediments.

The foothills are composed of boulders, gravels, pebbles, cobles, grit and sand, while the plain part is composed of thick layers of river born alluvial deposits.

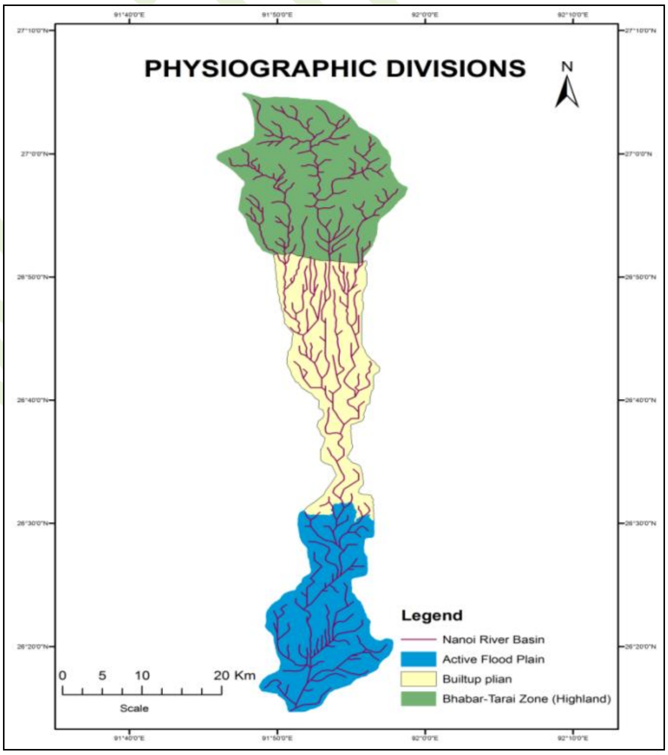

Fig.2 Physiography

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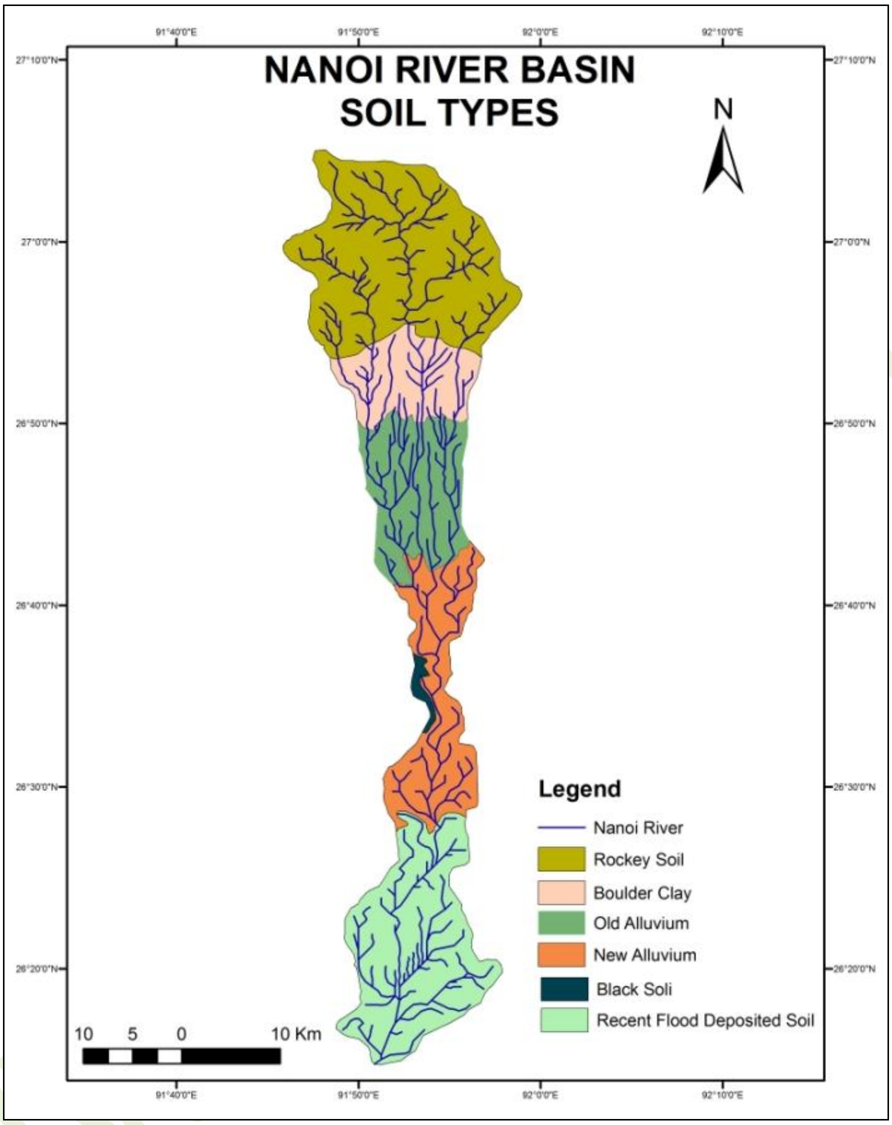

Fig-3 Soil Types

Slope analysis implies that the basin having the equal areas within slope groups of equal interval which is not uniform. It is found that below the 8^0 slopes the basin covers 68.29 percentage of the total areas while 8^0 to 23^0 has the percentage share of 16.12. Beyond 23^0 slope up to about 77^0 the basin covering as large as 25.59 percent of basin area. Such a state of slope pattern of the basin clearly indicates that there is hurriedly changing slope distribution as one goes from mountainous areas to the Nanoi river mouth in the neighborhood of the Brahmaputra.

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Table.1 Showing Channel and Basin Gradient in Different Sites

River	Total length	Segment length	Maximum channel relief	Channel gradient (m/km) of the segment	Site
Nanoi	104.27 km	26.21	1310.64 m	50.005	Foot hill
		44.04	120 m	2.725	Built-up plain
		34.025	60 m	1.763	Active flood Plain
		104.275	**1310.64 m**	**12.569**	**Entire channel**

The region is steeply downward towards the southern part. In the upstream the topography of the channel is steeply raising which create a new type of valley dimensions. So the stream is such that the valley gradients decline steeply as the stream flowing from the hill to the plains of Brahmaputra valley. After traveling through a length of about 50 kilometer from the hills their course becomes smooth, only 1.76 m/km (Table.1).

The Nanoi river basin bounded by the Bhutan Himalaya in the north and the Brahmaputra in the south has almost an elongated shape covering about 2/3rd of the areas of the basin above the middle part of the basin, while about 1/3rd lies in the lower part of the basin. The form ratio mainly concerned with the length and area. The basin form ratio is 0.088 substantiates that basin is an elongated one. It implies that the basin is mostly controlled by the structure. Shape ratio is the ratio between the basin length and basin area where in Nanoi river the ratio 9.08 indicates the sinuous shape and it implies the hard structure of the basin mainly in the upstream part as indicated by the analysis (table.2).

Table.2 Basin Geometry of Nanoi River Basin

Basin area	Basin length	Form Ratio (F)	Shape ratio (S)	Lemniscates Ratio (k)	Sinuosity index SI
959.46 km^2	104.27km	0.0882	9.088	2.272	1.116

Linear Aspect

The drainage basin restrain a common network pattern in all the geomorphic units except the hills top area (Fig. 2) as there are only 143 first order streams, 38 second order streams, 3 third, 2 fourth order and 1 fifth order streams drained to the master stream Brahmaputra totaling altogether to 187 streams identified by using Strahler's technique of stream ordering [5]. The density and frequency in the drainage basin are having slight differences among the various physiographic units. The Nanoi River of the area creates flood of high intensity and serious devastation. Bifurcation ratio of the 4thorder Nanoi basin is 2.00, there are observable deviations from the average 4.86 among the bifurcation ratios of successive pairs of stream orders. The widely varying bifurcation ratios with the increasing orders of streams specially in case of lower reaches of the basin reveals the frequently recurring flash floods as well as the strong hydraulic action as compared that in the topographically controlled up stream areas. Elongated basins have low Rb value, where circular basins have high Rb value (Morisawa, 1985).

Table.3 Linear Aspect of Nanoi River Basin

Order of streams	**Number of streams Nu**	**Bi Ratio Rb**	**Length of Streams Lu**	**Stream Frequency (Fs)**	**Drainage Density(Dd) km/km^2 & Stream Frequency (Fs) No. of stream/km^2**	**Length ratio L_R**
1st Order	143	3.76	316.13	0.15	0.62 and 0.19	0.31
2nd Order	38	12.66	100.47	0.04		0.66
3rd Order	3	1.05	66.88	0.003		0.84
4th Order	2	2.00	56.73	0.002		1.02
5th Order	1	-	58.28	0.001		-
Mean		4.86		0.04		0.71
Total	187	19.47	598.49			2.83

The streams in the basin have been marked by differential length as per topographic, hydrologic, and hydraulic control [2]. The length of the stream ranges length of the different orders of streams ranges shown in table.3 where in length ratios varies from 0.31 to 1.02 with an average of 0.71.

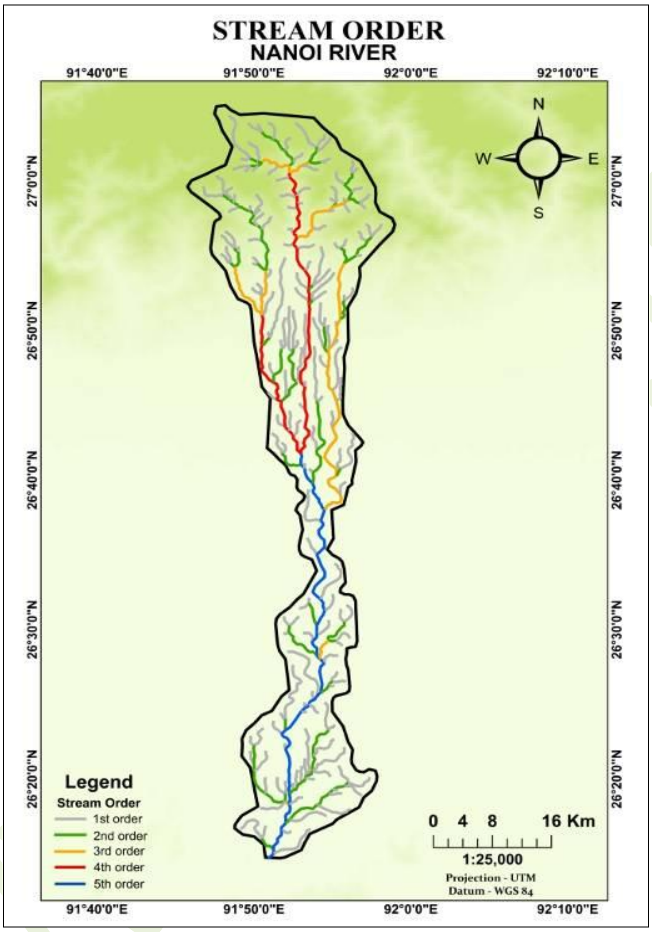

Fig.4 Stream order

a. Drainage density

Horton [2] also devised a measure of the amount of the dissection of the watershed which he called the drainage density, defined as the total of all stream lengths in the basin divided by the area of the basin. Many methods have been used to find out the Dd. Use of computer technology (GIS software) give much embracement in this process, but the method of Gardiner [12] has been widely used and accepted to calculate the Dd and Fs by using grid system. High drainage densities usually reduce the discharge in any single stream. Rivers on an alluvial fan frequently change their channel courses, the drainage pattern is redial, but the channel density is small. Channel density is larger in a flood plain than in an alluvial fan.

In Nanoi river basin the Dd is 0.62 km/sq.km. which indicates that the basin not very high and it tend to flooding. Low drainage density indicates the maximum part of the basin is covered by the permeable subsurface material, moderate vegetation cover and almost plain relief as found in the relief map. An area with high drainage density that it takes water for a while to drain to a primary stream to arrive at secondary streams so that there is basin lag. Basin lag is a natural means of adjusting the flow of water through a system. But, in case of Nanoi river the Dd is less therefore, downstream portions of the basin tend to be flooding immediately after heavy downpour as found in the discharge and water level hydrograph. In general when the Dd is very low intense rainfall events are more likely to result in high discharge to a few streams and therefore a greater likelihood of flashy discharge and flooding. Low drainage densities suggest resistant bed rock in humid areas where high Dd suggest highly erodible surficial materials.

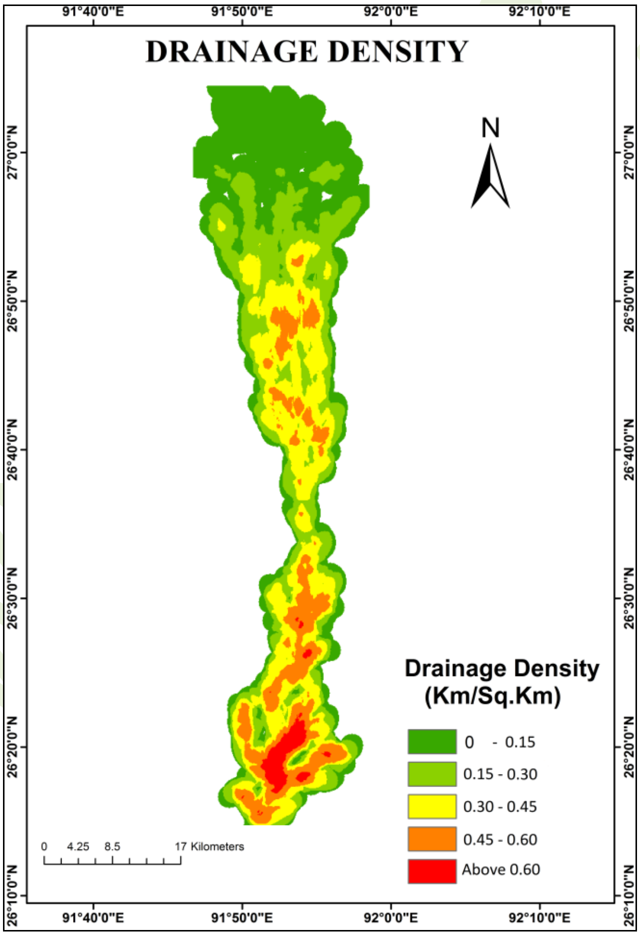

Fig. 5a Drainage Density

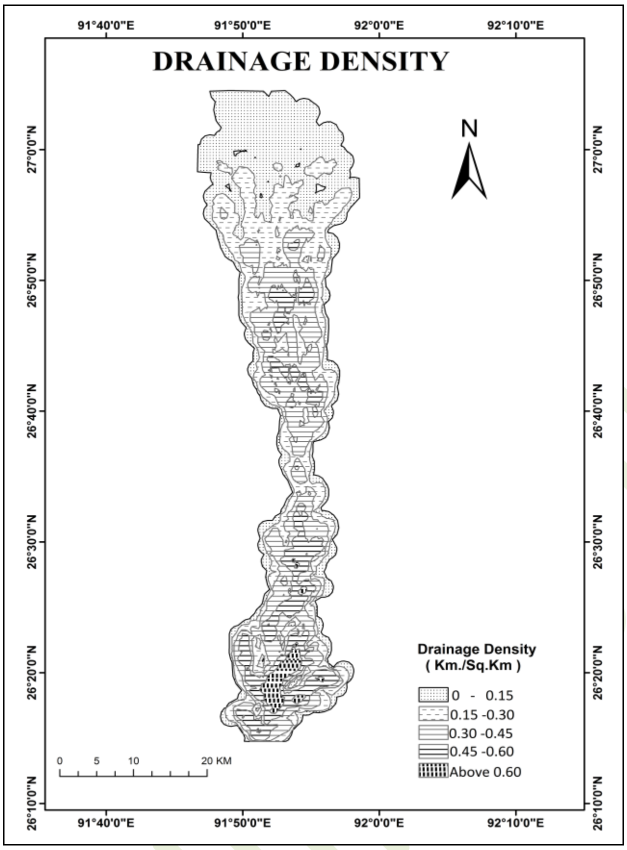

Fig. 5b Drainage Density

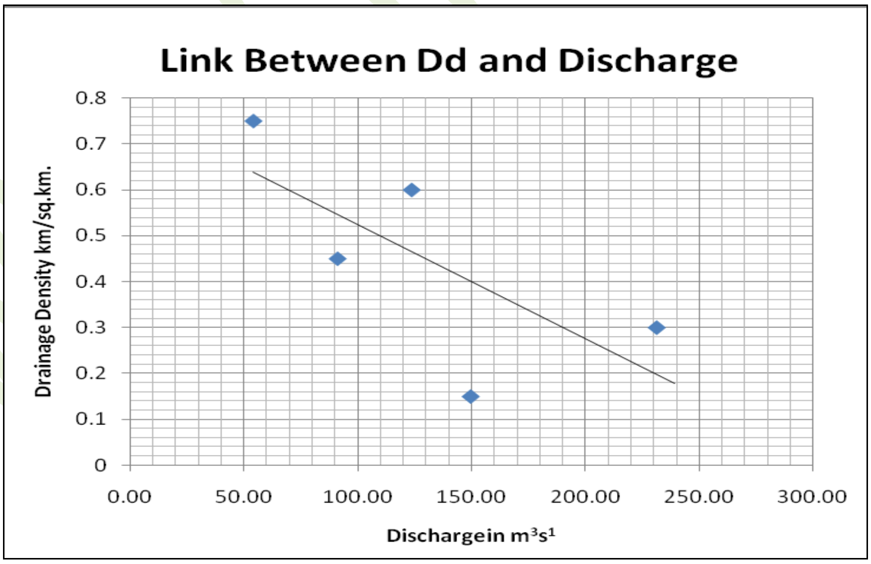

Fig. 6 Progress of Discharge depending on Dd

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Fig. 6 shows the patterns of peak discharge of 21 years of Nanoi river depending on standardized Dd that are derived from the conceptual approach. Of course, the outcome of linear model indicates that when the Dd decrease, trend of discharge have been increased. Therefore, in case of Nanoi river it is found that the decreasing of Dd in the basin highly affected by the flood specially in the high storm rainy season.

b. Stream frequency

Stream frequency is derived by dividing the number of streams by the area of the drainage basin. Although two drainage basin may show similar drainage density, their drainage frequency is not necessarily the same. In the same way, similar drainage frequency does not mean similar drainage density. Stream frequency is an index that attempts to quantity the density of natural drainage in a catchment and is derived by counting the number of stream junctions within a catchment and dividing by the catchment area in sq. kilometers. Stream frequency related to permeability, infiltration capacity and relief of the watershed. The use of stream frequency in the floodplain studies Report (NERC, 1975) was prompted by the feeling that catchment having higher stream frequency values would have larger floods, and this is borne out by the success of the stream frequency variable in flood prediction equations.

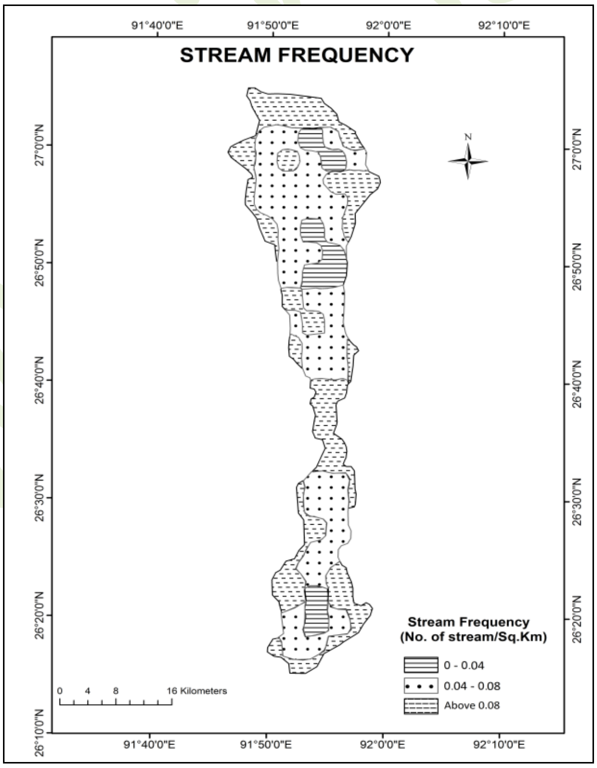


Fig.7 Stream Frequency

In case of river Nanoi the value of stream frequency indicates that the watershed shows positive correlation with increasing stream population with respect to increasing drainage density.

The basin has average stream frequency in the tune of 0.04 numbers per sq.km. however, in the hilly areas including the foothill one the stream frequency ranges from 0.05 to 0.08 per sq km., subsequently the drainage density in the basin (0.62 km/km^2) like other basin of the Brahmaputra valley or elsewhere has a good positive relation.

The details of morphometric analysis (Relating to Dd and Fs) and drainage basin characteristics of Nanoi river basin are present in table.4.

Table 4 Comparative Characteristics of Drainage Density and Frequency

Sl. No.	Morphometric Parameter relating to Dd and Fs	Formula	Reference	Result
1	Stream Frequency (Fs)	Nu/A	Horton, 1932	0.19 no./ km^2
2	Drainage density (Dd)	Lu/A	Horton, 1932	0.62 km/ km^2
3	Drainage Intensity (Di)	Fs/Dd	Faniran, 1968	0.314
4	Constant channel maintenance(C)	1/Dd	Schumm, 1956	1.61 km.^{2}/km.
5	Infiltration Number (If)	Fs*Dd	Faniran, 1968	0.11
6	Length of over land flow (Lg)	A/2*Lu	Horton, 1945	0.80 kms
7	Rho coefficient (p)	Lur/Rb	Horton, 1945	0.14

Dd and Fs has been already discussed. Drainage intensity (Di) of Nanoi river is found very low (0.314) it implies that the basin is tend to flooding, the Dd and Fs have little effect on the extent to which the surface has been eroded by different agents. As a result the discharge has been not removing quickly and highly susceptible to heavy flooding and erosion.

Constant channel maintenance (C) indicates the number of kms2 of basin surface required to develop the channel length. It indicates the relative size of landform unit in a drainage basin and has a specific genetic implication. In case of Nanoi river C vale is 1.61

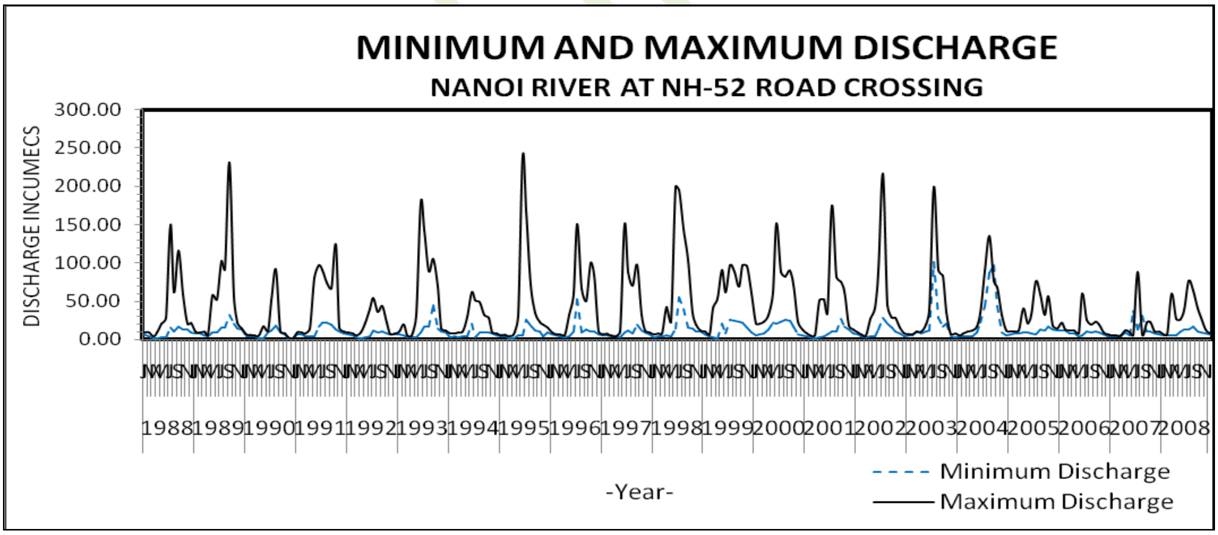
km.^{2}/km. It indicates high structural disturbance, low permeability, steep to very steep slopes and high surface runoff.

Infiltration Number (If) gives the idea of infiltration in a watershed or river basin. Higher the If value lower will be the infiltration and the higher runoff. In Nanoi river basin the value of If is 0.11.

Length of over land flow (Lg) refers to the run of the rain water on the ground surface before it is localized in to definite channels. In case of Nanoi river basin the Lg is 0.80 kms indicates the medium surface run of the study area.

Rho coefficient (p) is very important to show the relationship between drainage density and physiographic development of a river basin. Rho values of the Nanoi river basin is 0.14 implies that the medium hydrologic storage during floods and high intensity of erosion during flood.

The Nanoi River creates flood of high intensity and serious devastation. The hydrograph (Figure.9 and 10) for the river indicates that during dry period (winter) the stream flow decreased exponentially, on the other hand during heavy rainy season in the month of May is the starting month of abrupt increase of water level as well as discharge as because rainfall starts falling from May. The entire Nanoi river basin specially downstream part is severely affected by the heavy flood. The above mentioned morphometric and hydrologic analysis also substantiate the matter.



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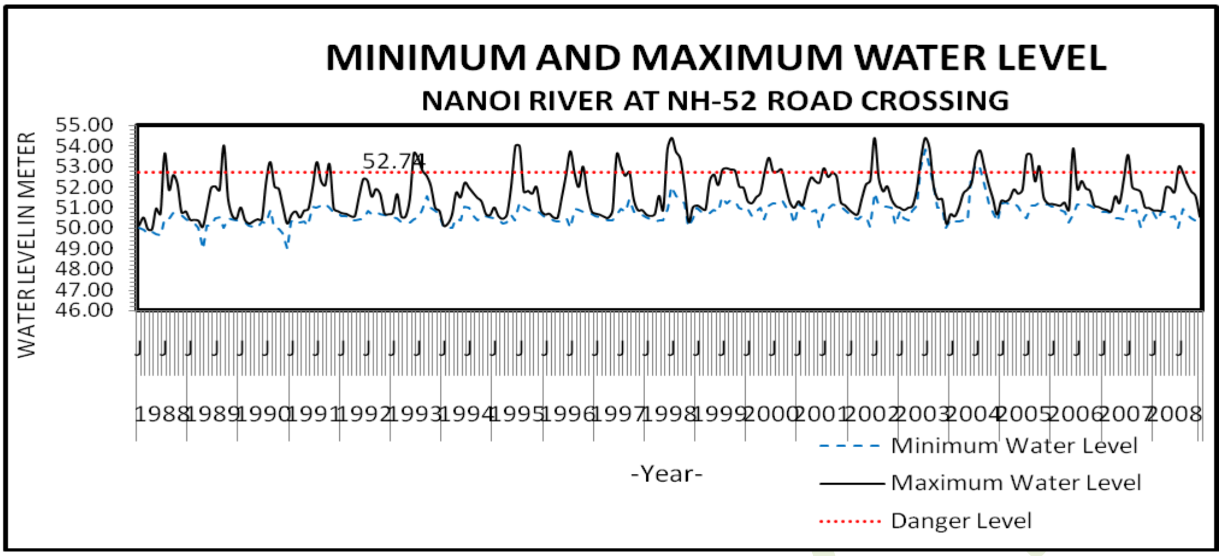

Fig. 8 and 9 Hydrographs

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V. Result and Discussion :

The study reveals that morphometric characters of the drainage basin show the dendraitic to semi dendraitic pattern of the river with moderate texture. Drainage density shows that the The bifurcation ratio in the basin indicates usual basin category, low drainage density shows it has highly permeable soil and coarse texture. The value of form basin is moderate permeability sub-soil, and coarse drainage texture. On the other hand stream frequency implies increasing stream population with respect to increasing drainage density. Shape ratio indicates the basin is elongated, whereas the basin associated with moderate to high relief and flat ground slope. The changing pattern of hydrological components of the river, augmentation and controlling of flood and its associated problems in the lower catchment area are mainly caused due to the hydro-geomorphic nature of the river basin.

VI.Conclusion :

Utilising participatory techniques in such a manner for disaster risk reduction has broadened the capacity for dialogue between impacted communities and relevant stakeholders. Besides anthropogenic process of resource development, specifically construction of road along sensitive slopes, expansion of settlement zone and agriculture on forests and upslope areas, overgrazing etc. have further rendered this entire zone prone to frequent and widespread land sliding and excessive soil erosion. The research has found that the role of community is very insignificant to mitigate and manage disasters in the Valley; as well the role of Government authorities also not satisfactory. Although by the efforts of government, in some areas retaining wall to prevent landslides have been erected, but these means are not helpful to that extent due to lack of maintenance.

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