CASE STUDY CS-(AR) 182

HYDROGEOMORPHOLOGICAL STUDIES : DUDHNAI SUB-BASIN (ASSAM & MEGHALAYA)

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PREFACE

National Institute of Hydrology, through its regional centres has since taken up Hydrogeomorphological Studies at various basins and sub-basins of the country. Faced with the vexed problem of non availability of sufficient data from these watersheds which are mostly ungauged, the study under which measurable basinal properties or geomorphological characteristics consisting linear, areal and relief aspects are worked out, helps hydrologists to get some definite idea of flow characteristics of the basin in absence of any other information. These basin parameters have been used in the past in development of Empirical formula, Geomorphological Instantaneous Unit Hydrograph, in Regional Flood Frequency Analysis and to some extent in Hydrologic Modelling Studies.

Hydrogeomorphological parameters estimated for Dudhnai Sub-basin where the regional center, Guwahati has taken up long term representative basin studies should be useful in their future works. Results for the study were worked out by **T.R.Hans**, RA and the report was prepared by **B.C.Patwary**, Sc.'E' with assistance by **D.M.Rangan**, Technician.

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ABSTRACT

Hydrogeomorphological parameters of drainage network provide simple means, specially in mountainous and ungauged catchments to develop empirical precipitation-runoff relationships, synthesize hydrograph parameters and to develop regional Geomorphological Unit Hydrograph. Therefore, on a basin map of 1 : 50,000 scale, the geomorphological parameters consisting linear, areal and relief aspects of drainage network of Dudhnai sub-basin where long term representative basin studies are in progress, have been worked out and presented in this report.

The quantitative estimates of the geomorphological parameters for the basin would be utilised while extrapolating the results of representative basin studies to larger hydrologically similar basins and also in other future studies to follow.

1.0 INTRODUCTION :

River basins and its characteristics are controlled by nature and its hydro-climatic parameters are mostly interrelated with each other. Watershed managers require to understand and synthesize hydrologic response of such basin for which they have started looking into its basin characteristics or morphologic features and establish connection of fluvial geomorphology to hydrology. Geomorphology, the science of evolution of land forms in terms of lithology, structure , climate & other climatic factors, had been mostly qualitative in its initial stage. Now with the rational relation between the average response of a basin with given geomorphologic properties established, greater need for quantitative information is felt for. To evaluate or predict the run-off response of a river basin hydrologists are faced with the vexed problem of non availability of stream flow and precipitation data. Therefore, measurable basinal features of drainage network which have been considered and shown to have potential to describe some of the hydrograph parameters of the ungauged system have encouraged hydrologists for hydrologic simulation and applying relationships developed for gauged basins at ungauged locations through hydrograph correlations.

The geomorphological characteristics which relate to hydrology, as suggested by many investigators, consist of **Linear Aspect** of channel system dealing with one dimensional overland flow lengths & length of streams etc, **Aerial Aspect** of catchment relating to basin shape & drainage texture and **Relief Aspect** of channel network/catchment describing elevation difference etc. The first two categories of measurements are planimetric and the third category treats the vertical inequalities of the drainage basin form. Some typical catchment characteristics have also been identified which will be useful to derive unit hydrograph for the catchment. Some of the studies where quantitative geomorphological characteristics have been applied to describe hydrologic properties such as run- off response or flow hydrograph etc. are as follows:

- Development of empirical formula using geomorphological parameters
- Regional Unit Hydrograph Studies
- Regional Flood Frequency Analysis
- Development of Geomorphological Instantaneous Unit Hydrograph
- Hydrologic modelling studies.

The report attempts to estimate the various geomorphological characteristics of Dudhnai river sub-basin within North Eastern Region with the help of established laws and procedures and using survey of India map of scale 1:50,000. In absence of sufficient network of hydrologic observation sites the geomorphological parameters derived for the basin may be used for further hydrologic studies. The results of the study will also be utilized in the long term ongoing representative basin studies in the area.

2.0 METHODOLOGY :

Procedure for estimation of various geomorphological parameters of the river basin, in requirement of many hydrological studies, is described in this section. For the purpose, a large scale basin map 1:50,000 of Dudhnai sub-basin was prepared from Survey of India toposheets. Field verification of the map was made to some extent. The geomorphological parameters that are used in hydrological models and having potential to describe basin characteristics are broadly grouped under three categories.

I Linear Aspect of the Channels system
II Areal Aspect of the Catchment
III Relief Aspect of the Basin

Based on the methodology and works done by many earlier investigators like Horton (1945), Strehler (1953,1956,1964,1968), Chroley (1957), Miller (1953), Schumm (1954) , Bernard (1935), Snyder (1938), Linsey (1943), Jetter (1944), Lucas (1944) , Taylor(1952), Eaton (1954), Yonezol (1956), Muckus (1975), Nash (1960), Gray (1961), CWC (1980), Gundlach (1975) etc., the parameters under these three aspects are studied and quantified as described below:

2.1 Linear Aspect of the Channel system:

Linear aspect of basin characteristics includes overland flow lengths of channels of all orders. Usefulness of ordering channel system ~~lies~~ on the hypothesis that basin size, channel dimension and stream flows are proportional to the stream orders provided investigation is made for quite large number of water sheds. Two basins having different Linear measures can be compared with respect to corresponding points in their geometry through use of dimensionless order number . However, such comparisons should be made at locations in the two systems that have similar geometry, that is, second order stream third order streams and so forth.

2.1.1 Stream Orders:

Horton (1945) pioneered quantitative study of channel networks by classifying the channels by order in United States. This was slightly modified by Strahler (1952) . Melton (1959) explained the mathematical concepts involved. As per Strahler's scheme of ordering in a channel network map showing the intermittent and permanent flowlines located in clearly defined valleys the smallest unbranched (finger tip) tributaries are designated as **order 1**. The point at which two first order streams join a channel segment of **order 2** is formed. Where two streams of 2nd order join, a segment of **order 3** is formed and so on . The main or trunk channel carrying the entire discharge of the drainage basin upstream of basin outlet is obviously the segment of highest order. Parameters under linear aspect of channel system and their estimations are described below:

2.1.2 Length of Main Channel , (L):

This is the length of the longest water course when projected on a horizontal plan from the basin mouth to the farthest point on the basin boundary. To measure this length there are several conventional methods like pair of dividers, thread length, edge of paper strip, opsimeter and so on. This can also very well be done by Analog to Digital convertor by tracing along the main channel with the cursor which records the x and y co-ordinates of closely spaced points. The digitized co-ordinates of the main channel points are stored in computer and distance between two points is calculated from

$$\text{Distance} = \left((x^2) + (y^2) \right)^{1/2}$$

Length of the channel is the summation of all segmental distances. For the purpose a subroutine 'LENGTH' is already available at NIH. Similarly length of all streams of all orders can be found out.

However, in absence of facility, lengths of the main channel and other channels have been measured manually in the report. Bernard (1935), Snyder (1938), Linsley (1943), Jetter (1944), Lucas (1944), Taylor (1952) Eaton (1954), Yonezol (1956), Mockus (1957), Nash (1960) , Gray (1961), CWC (1980) and Gundlech (1975) considered the stream length as one of the catchment characteristics in establishing the relationship for synthetic unit hydrograph.

2.1.3 Length of the Channel between the Outlet and Point nearest to C.G., (Lc):

It is the length of the channel measured from the outlet of the catchment to a point on the stream nearest to the centroid of the basin (C.G.of the plane area of the drainage basin). The centroid is found out by cutting a card board piece in the shape of the catchment and then balancing it on a horizontal plane with a pivot. Linear measurement of the parameters is same as described in 2.1.2. This measure has been used in the studies of basin lag i.e. time between the centers of mass of effective storm input and the resulting output.

2.1.4 Total Length of Channels:

This is the total length of channel segments of all orders within the basin. Total length of channels gives an idea of overland flow and channel flow in the watershed.

2.1.5 Wandering Ratio:

This is the ratio between main stream length along the course to the straight line distance between the two extremes, outlet and farthest point in basin boundary. While this factor broadly indicates the amount of deviation of main stream from straight line path. it does not necessarily explain the meandering of the main stream.

2.1.6 Bifurcation Ratio (Rb):

The ratio number of stream segments of a given order Nu to the number of segments of the higher order Nu+1 is termed as Bifurcation Ratio, Rb.

$$Rb = Nu/(Nu+1)$$

Calculation on an average value of Rb for a given channel network can be made by determining the slope of the fitted regression of logarithm of numbers (ordinate) on order (abscissa).

This means a plot of the Log Nu vs u will approximately yield a straight line with negative slope. The magnitude of the slope is the logarithm of Rb (identical to the regression co-efficient b). If the Rb is estimated to be 3.52, this means that on the average there are 3 1/2 times as many channel segments of any given order as of the next higher order. Taking precipitation and other factors uniform, an elongated basin (high Rb) would give rise to a hydrograph of low but extended flow peak where as a round basin (low Rb) would produce a sharp peak. For a basin with a dipping rock strata where narrow valleys are confined between high ridges the Rb may be abnormally high. Strahler concludes that Rb characteristically ranges between 3.0 and 5.0 for watersheds in which the geologic structures do not distort the drainage pattern. The theoretical minimum possible value of 2.0 is rarely approached under natural conditions. The bifurcation ratio is however, not the same from one to the next order but will tend to be constant throughout the series. This is the basis of Horton's law of stream numbers.

2.1.7 Stream (Nu) :

Horton's (1945) law of stream Numbers states that the number of streams of a given order follows an inverse geometric relationship with stream number :

$$Nu = (Rb)^{k-u}$$

Where k = Order of trunk segment i.e. the highest order of the stream in the drainage basin.

u = Order of interest

From above equation it follows:

$$\log Nu = (k-u) \log Rb$$

or $$\text{Log } Nu = a-bu$$

Where, $$a = k \log Rb$$

$$b = \log Rb \text{ or } Rb = \log (b)^{-1}$$

For computing log Rb a sub - routine "REG" based on least square approach is available. The value of Rb can be used to compute the total number of streams (N) of all orders from the equation:

$$N = \sum_{u=1}^{k} Nu = (Rb^{k} - 1) / (Rb - 1)$$

These results have been confirmed many times using Strahler's ordering system.

2.1.8 Average stream length (Lu):

Mean length Lu of a channel segment of order u is a dimensional property revealing characteristic size of components of a drainage network and its contributing basin surfaces. Law of stream length (Horton, 1945) states that the average length of streams of each of the different orders tend to approximate a direct geometric series (In which the first tern is average length of first order stream) with the relation:

$$\bar{Lu} = \bar{L1} \; R1^{u-1}$$

Where $\bar{L1}$ = average length of streams of first order

$\bar{L1}$ = Average length of streams of order u
R1 = A constant called length Ratio discussed later

The validity oflaw of stream length relating R1 when Strahler ordering is used has been studied by several authors Maxwell (1960) & Melton (1957) and indicated considerable variation in segment length data from a geometric series. If it is assumed that the Horton's law of stream length is valid then the Length Ratio R1 of above equation is obtained for the watershed as the antilogarithm of regression co-efficient of a line fitted by inspection or by least square method to the plot of logarithm of stream length on order. Nroscue (1959) found that substituting cumulative mean length for average length and cumulative R1 in the equation, the geometric series was indeed obtained. Of interest to the estimation of channel storage capacity for an entire watershed, is Horton,s observation that the laws of stream numbers and lengths can be combined as product to yield an equation for the total length of channels of a given order 'u' knowing only the Rb and R1, the mean length L1 of the first order segments and the order of the trunk segment. Thus:

$$\sum_{i=1}^{N} Lui = \bar{L1}\ Rb^{k-u}\ R1^{u-1}$$

In the report Lu is calculated from the linear measurement of channel segments i.e. total length of each order is divided by the number of segments of that order such that:

$$\bar{Lu} + (\sum_{i=1}^{N} Lu) / Nu$$

2.1.9 Stream Length Ratio (R1):

This is the ratio of mean length Lu of segments of order u to mean length of segments of the next lower order Lu-1:

$$\bar{R1} = \bar{Lu} / Lu-1$$

Horton stipulated that R1 tends to be constant throughout the successive orders of a watershed. Its value is normally between 1.5 and 3.5 in natural drainage networks. It is useful in synthesizing hydrograph characteristics.

Horton gave another method for computing R1 (or also to estimate total length of channels of all orders of a watershed of order k) by introducing the term R1b (=R1/Rb)which is found from:

$$\sum_{u=1}^{k} \sum_{i-1}^{Nu} Lui = \bar{L1}.Rb^{k-1} (R1^{k} b-1)/(R1b-1)$$

Nu= Total number of streams of order u

Here RHS i.e. total stream length of all orders, $\bar{L1}$ and Rb are known and R1b can be calculated. Then R1 is calculated from:

R1 = Rb/R1b

Since the form of the above equation is non linear, solution of R1b can be obtained by technique based on Newton-Raphso-non linear optimization. For the purpose a separate sub routine, NEWTON has been developed at NIH.

2.1.10 Basin Perimeter (P):

Basin perimeter is the total length of the basin boundary or the length measured along the divide between basins and may be used as an indicator of basin size and shape. It was emphasized by Smith (1950) in his derivation of Texture ratio.

2.1.11 Fineness Ratio:

The ratio of the channel length to the lengths of the basin perimeter is termed by Melton (1957) as the fineness ratio which indicates fineness of the topography.

2.1.12 Watershed Eccentricity (T):.1s1

Black (1972) gave the expression for T as :

$$T = \left(\left((Lc^2 - W1^2) \right)^{1/2} \right) / W1$$

Where Lc = Length from the watershed mouth (outlet) to the center of mass of watershed.

W1 = the width of the watershed at the center of mass and perpendicular to Lc.

When Lc = W1 eccentricity become zero. Greater is the value of (W1-Lc) or (Lc-W1) more will be the eccentricity, lesser will be the compactness of watershed near the mouth and lower will be the flood peak.

2.1.13 Length of Overland Flow, (Lo):

Horton (1945) defined Lo as the length of flow path, projected to the horizontal of nonchannel flow from a point on the drainage divide (basin boundary) to a point on the adjacent stream channel. It is the length of overland flow of water before it joins a channel. The average length of overland flow Lo is approximately half the average distance between stream channels and is therefore approximately equal to half the reciprocal of drainage density (discussed in Areal Aspects in clause 2.2.3) such that:

$$\overline{Lo} = 1/2D$$

Horton noted that length of overland flow is one of the most important independent variables affecting both the hydrologic and physiographic development of drainage basins.

2.2 Areal Aspect of Watershed :

Areal measures of a drainage basin net works relate to many of its hydrologic characteristics. Some of these characteristics and methodology of estimation adopted by various investigators are described below:

The basin area is the plane area within the perimeter along the drainage divide. It is one of the most important characteristics of the basin reflecting the run-off process. The area of the basin of a given order u is defined as the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and including all tributaries of lower order. Thus Schum (1956) stated that the area of basin of fourth order A4 would cumulate the area of all first, second and third order basins plus all additional surface elements, known as INTER BASIN AREAS, contributing directly to a channel of order higher than first. Estimation by comparison of watershed tracing with square or rectangle of known dimension, polar planimeter, Dotgrid, strip sub division , geometric sub division, Analog to digital converter are some methods to measure basin area.

2.2.1 Law of Stream Areas: Area Ratio, (Ra):

The concept of law of stream area is same as the law of stream length and stream number. Horton (1945) stated that mean basin areas (A) of progressively higher orders should increase in a geometric sequence as do stream lengths . Schumn (1954) expressed this relationship in a law of stream areas which states that " mean basin areas of the stream of each order tend closely to approximate a direct geometric sequence in which the first term is the mean area of the first order, mathematically:

$$\bar{A}u = \bar{A}1 \quad (Ra)^{u-1}$$

Where $\bar{A}u$ = mean area of basin of order u.

$\bar{A}1$ = mean area of basin of order
RA = an area ratio analogous to R1
which follows:

$$Ra = \bar{A}u/(\bar{A}_{u-1})$$

Smart (1972) concludes that for natural basins value of Ra normally ranges from 3 to 6.

2.2.2 Drainage/ Density,(D):

Horton (1945) defined drainage density as the ratio of total channel segment lengths of all orders within a basin to the area of the drainage basin projected to horizontal and expressed as the number of miles of channels per square mile of basin area.

$$D = \frac{\sum_{k=1}^{k} \sum_{i=1}^{Nu} Lui}{A}$$

Dimensionally this ratio reduces to inverse of length (L^{-1}) and hence is a quantity dependent on the level of resolution of the map from which lengths are measured. Horton relates drainage density to the Horton numbers as :

$$D = (\bar{L}1.Rb^{k-1} .R1^{k} b-1)/(R1b - 1)$$

Drainage density characterises textural measure independent of basin site and considered to be a function of climate, Lithology, stage of development etc. In fact the drainage density is constant everywhere in the basin and the average length of contributing hill slope is approximately half the average distance between stream channels as expressed in clause 2.1.13. Various Investigators measured drainage density for different geologic and climatic conditions.

2.2.3 Constant of Channel Maintenance, (C):

Schum (1956) used this term as the inverse of drainage density i.e.

$$C = (1/D)$$

With its unit as sq. ft per foot (on a horizontal plane) the term indicates the square feet of watershed surface required to sustain one linear foot of channel.

2.2.5 Stream Channel Frequency, (F):

Stream Frequency or Channel Frequency was defined by Horton (1945) as the numbers of stream segment per unit area or

$$F = (N / A)$$

Where N = Total stream segments of all orders
A = Drainage area of the basin

Relationship between drainage density (D) and stream frequency both of which measure the drainage texture (but each treating as distinct aspect) was studied by Mellon (1958) . Although Both the terms measure different properties , Melton found a dimensionally correct equation as:

$$F = 0.694\ D^2$$

This implies that the dimensionless ratio F/D^2 approaches a constant value of 0.694 independent of scale.

2.2.5 Circularity Ratio, (RC):

Miller (1953) introduced a dimensionless circularity ratio which is defined as the ratio of the basin area to the area of a circle having circumference equal to the perimeter of the basin.

The value of this ratio approaches one as the shape of the basin approaches a circle. Miller found the value consistently in the range of 0.6 to 0.7 for first and second order basins in homogeneous shales and dolomites, indicating the tendency of small drainage basins in homogeneous geologic materials to preserve geometrical similarity. By contrast first and second order basins situated on the flanks of moderately dipping quartzite strata of Clinch Mountain, Virginia, were strongly elongated and had values of Rc between 0.4 to 0.5.

2.2.6 Elongation Ratio (Re):

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Obviously for a circular basin the value tends to unity. This ratio runs between 0.6 to 1.0 over a wide variety of climatic and geologic types. Values near to 1.0 are typical of regions of very low relief, where as value in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes.

2.2.7 Form Factor (Rf):

Horton (1932) used this dimensionless quantity which he defined as the ratio of basin area (A) to the square of the basin length (L), measured along the longest water course.

$$Rf = A/L^2$$

This is a quantitative expression of basin shape (outline form). In its inverted form, L^2 / A, this ratio was used in unit hydrograph applications by the U.S. Army Corps of Engineers.

2.2.8 Compactness Ratio (RK) :

Basin shape has been defined by an alternate descriptor based on perimeter rather than area. The compactness ratio is the ratio of the catchment perimeter to that of the equivalent circle having area as that of the basin. This leads to :

$$Rk = (0.282\ P) / A^{1/2}$$

2.2.9 Watershed Shape Factor (Rs) :

This was defined by Wu et al (1964) as the ratio of main stream length L to the diameter D of a equivalent circle having same are as the basin.

$$Rs = (L/D)$$

2.2.11 Unity Shape Factor (Ru):

Smart & Surkan (1967) used the unity shape factor to be defined as the ratio of the basin length L to the square root of the basin area (A).

$$Ru = (L / A^{1/2})$$

2.3 Relief Aspect of the Drainage Basin:

Relief morphometry of river basin describes variation of elevations between the highest and the lowest points. This is significant to study the flow phenomena in the watershed .The potential energy of flowing water from high altitude gets converted to kinetic energy which is related to slope. Various losses of water like storage, infiltration, evaporation etc. and travel time are inversely related to slope. The parameters relating to relief aspect of the drainage network are as follows:

2.3.1 Basin Relief (H):

Relief is the elevation difference between two reference points. Maximum basin relief (H) is the elevation difference between the highest point in the catchment divide and the catchment outlet. Methods of measurement of basin relief adopted by various investigators are different . Schumm measured basin relief along the longest dimension of the basin parallel to the principal drainage line. Basin relief may also be obtained by determining the mean height of the entire basin perimeter above the mouth, thus minimizing the spurious effects of sharply pointed summits.

2.3.2 Relief Ratio (Rh):

"Relief ratio is the ratio of the maximum basin relief (H) to the catchment's longest horizontal straight distance measured in a direction parallel to that of the principal water course". Schumm (1956) explained that taking vertical and horizontal distances as legs of a right angled triangle , relief ratio is equal to the tangent of the lower acute angle and is identical with the tangent of the angle of slope of the hypotenuse with respect to the horizontal .The relief ratio thus measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on slopes of the basin.

2.3.3 Relative relief (Rhp):

Melton (1957) used the term relative relief which is basically the ratio of the basin relief to the perimeter and expressed in percent as:

$$Rhp = (100\ H / 5280\ P)$$

Where,

H = Maximum basin relief in ft.
P = Basin perimeter in miles

2.3.4 Ruggedness Number (Rn):

To take into account of both slope steepness and length , a dimensionless ruggedness number has been used by Melton (1957) and Strahler (1958). It is defined as the product of relief H and drainage density D (both in same unit) i.e.

$$Rn = H \times D$$

Observed values of the ruggedness number range from as low as 0.06 in the subdued relief of the Louisiana coastal plain to over 1.0 in coast ranges of California or in badlands on weak clays.

2.3.5 Law of Basin relief:

The law postulated by Maxwell (1960) states that the mean relief of basins tends to closely approximate a geometric series and is expressed as:

$$\bar{H}_u = \bar{H}_1 \; Rh^{u-1}$$

Where,

$\bar{H}$ = Mean relief of awatershed of order u.

$\bar{H}$ = Mean relief of a watershed of order 1

Rh = Relief Ratio.

3.0 PROBLEM DEFINITION :

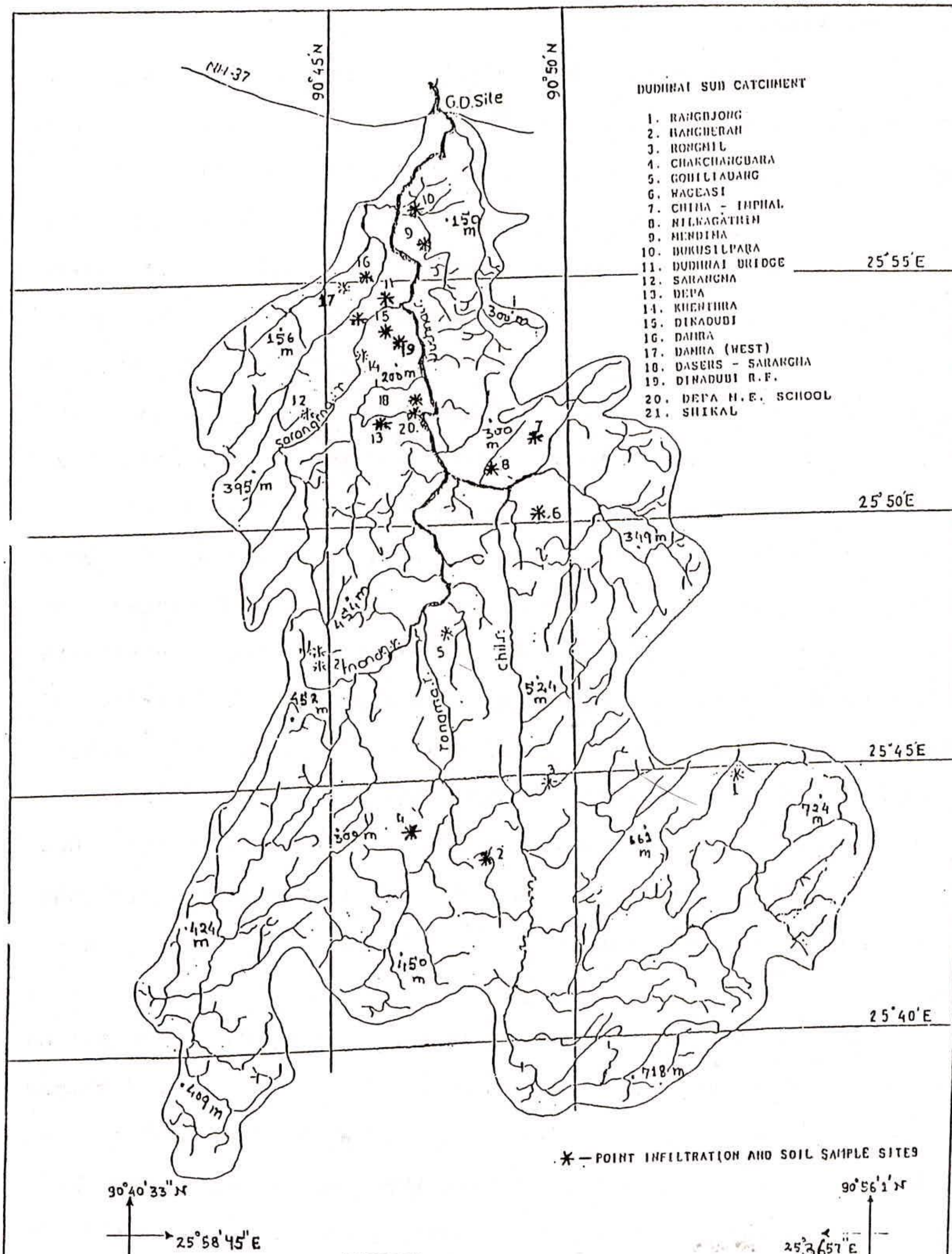
Hydrological studies in drainage basins and sub basins often suffer setbacks due to lack of various long term data. Then there is the need to extrapolate the results of few small sub systems (where only short term data are available) to other hydrologically similar regions which mostly remain ungauged for want of enormous resource and time involved in instrumentation & monitoring them. The measurable geomorphological parameters which have since been considered and shown to have potential to describe some of the hydrograph properties for ungauged basins provide simple means for hydrologic simulation, hydrograph synthesis and for development of empirical relationships to quantify some elements of flow processes.

The existing network of hydrometeorological observation in Dudhnai Sub-basin is inadequate for systematic hydrologic studies. Moreover, the channel network of the basin is very complicated. Even many of the major streams remain dry during winter and experience flash flood during rainy days. Long term representative basin studies have also been taken for Dudhnai sub-basin. Therefore, geomorphological parameters of the basin may provide comparison while extrapolating the results to larger basins.

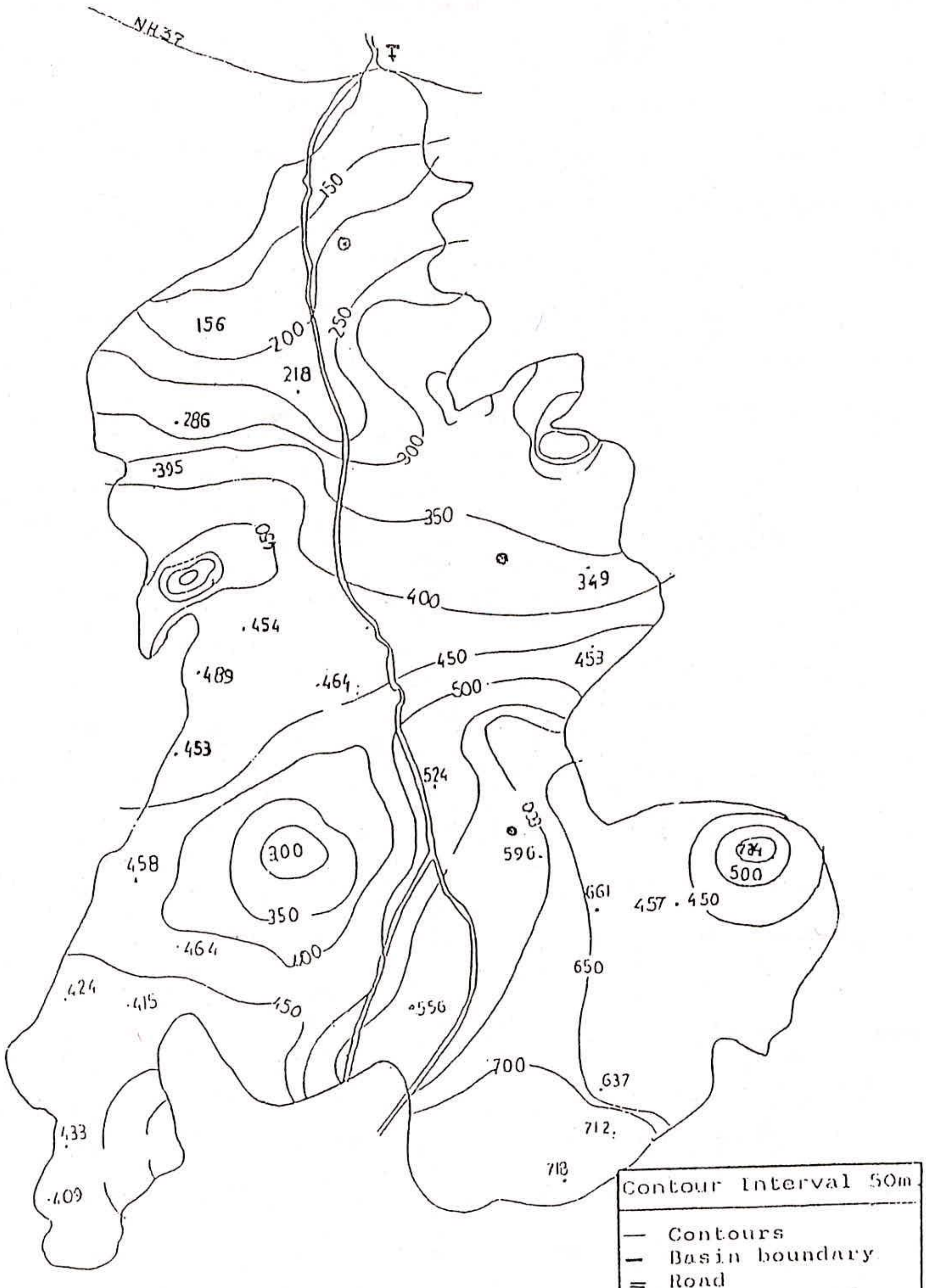
4.0 THE STUDY AREA :

The Dudhnai sub-catchment(Fig.1) in the states of Assam and Meghalaya, India selected for long term representative basin studies is situated in between latitudes 90^{o} 40' 33" N to 90^{o} 56' 1" N and longitudes 25^{o} 36' 57" E to 25^{o} 58' 45" E. The basin is bounded on the north by Goalpara district of Assam (The Brahmaputra river plain), on the east by West Khashi hills district of Meghalaya (Deosila sub-basin) and on the west & south by the East Garo hills region of Meghalaya (Krishnai sub-basin). The catchment area is about 500 sq km covered under Survey of India maps 78 K/9, 78 K/10, 78 K/13, 78 K/14 of scale 1:50,000 with its elevation varying from 100 m to 800 m above m.s.l. and basin slope from south to north. Fig.2 shows the contour map of the basin. The sub-catchment is within districts of East Garo hills in Meghalaya (83%) and Goalpara district of Assam (17%). It has been reported that soil in the lower catchment is predominantly hard reddish clay to light yellowish & light grays felspar & Mica. The basin plains are mostly new alluvium as found in riparian areas. Soil in the upper catchment is sandy loam or silty mainly comprising of quartzite & laterite.

The river Dudhnai is one of the small south bank tributaries of the river Brahmaputra. It originates from the Northern slopes of the Garo Hill ranges of Meghalaya at longitude 25^{o} 35' E at an elevation of around 400m. From here the river flows in the N.E. direction by the name Manda for a distance of about 26 km till it is joined by the river Rongma -Chichra, a right bank tributary.



1:175000
FIG.1. DRAINAGE MAP OF DUDHNAI SUB-BASIN



1 : 1,75,000

FIG.2. CONTOUR MAP OF DUDHNAI SUB-BASIN

Major part of the sub-basin is hilly terrains with a few isolated V shaped valleys developed along the course of river with undulating topography. Geomorphologically the basin can be divided into three broad limits. The first one is hilly gneissic complex, the second one the foot hill zone consisting of unsorted mixture of boulders, clay and the third one i.e. flood plains is of alluvium deposits.

Depending on the topography, river gradient and bifurcation/confluence of important tributaries of the river Dudhnai, it can be divided into the following four reaches:

1. From its origin to the joining point of Chil.
2. From the joining point of Chil to Dianadubi at the Assam Meghalaya border.
3. From Dainabubi to its confluence with Krishnai near Domani.
4. From Domani to outfall into the Brahmaputra.

The reach from its origin to confluence of Chil entirely lies in the Garo Hill ranges with altitudes varying from 100m to 400m. The whole area consists of series of hill ranges covered with forests with very small intermittent plain areas in the downstream. In this reach the river intercepts innumerable small hilly streams and rivulets which come down from the hills. However, there are only two major tributaries namely Rongma or Chichra and Chil that join the river in this reach.

The reach from the joining point of Chil to Dianadubi of the river is along the middle reserved forest area of the basin. This reach consists of the reserve forests running parallel to the river along the left bank from the confluence point of Chil to Dainadubi. The Eastern Bank is covered with dense mixed jungle. The river in this reach has got a narrow valley which generally widens as the river flows downstream. There is no major tributary joining the river in the reach.

The reach from Dianadubi to its confluence with Krishnai may be called as the alluvial or flood plain reach of the river which consists of plain area along the South Bank of the Brahmaputra. In this reach the river crosses N.H.37 at Dudhnai town.

The reach from Domani to outfall is of about 7 Km stretch (combined with Krishnai) flowing Northward in meandering loops then turning Westward near Mornai and flowing for about 2 Km before it outfall into the Brahmaputra near Dakaidal. This reach is the flood plain of the Brahmaputra.

Though the river outfall into the Brahmaputra near Dakaidal during the lean period, its outfall moves upstream near Mornai during the flood season when the Brahmaputra engulfs the part of Dudhnai river between Mornoi and Dakaidal.

The Dudhnai sub-basin falls within the climatic zone-I which comprises North and North-East India and adjoining parts of Nepal, Bhutan, Bangladesh and North Burma. In this zone the bulk of the rainfall occurs during the month of May to September. Significant rainfall occurs in May and October too. The months from November to March are generally dry.

The average annual rainfall over the whole catchment is around 1817 mm based on the records of three existing ordinary raingauge stations. It is seen that maximum rainfall occurs at

Damra where the annual average accounts for 2881 mm followed by 1326 mm and 1244 mm at Domoni and Dudhnai respectively. Of the mean annual rainfall of 1817 mm the seasonal distribution is: monsoon (June to Sept.)- 1173 mm (64.55%), pre-monsoon (March to May) - 474.60 mm (26.12%), post monsoon (Oct.to Nov.) - 140.86 mm (07.75%) and winter season (Dec. to Feb.) - 28.93 mm (01.59%).

It is seen from the regional statistics that the forest cover is comparatively more towards upper catchment in East Garo Hills(Meghalaya) which is about 38% and reduces towards the basin mouth in Goalpara district (Assam) which is about 17%.

The Gauge & Discharge site of the river Dudhnai being maintained by CWC is located at the National Highway Bridge and is in the lower reach of the river. Data are available for the period 1955-90. It is reported the average low water level at this site is 47.06m, the maximum H.F.L. observed so far is 52.150 m on 17.6.84 and the minimum low water level is 46.690m as on 1.2.57. The maximum and average flood lifts have been reported to be 5.460m and 2.960m respectively. Maximum discharge recorded is 619.433 cumecs on 15.9.60 followed by 525.871 cumecs on 21.6.74. The minimum discharge reported is 0.19 cumecs on 1.4.86 followed by 0.46 cumec on 26.5.90. The maximum annual mean discharge occurred in the year 1974 which was 51.501 cumecs and the minimum annual mean discharge recorded is 13.590 cumecs in the year 1961. It is seen that monsoon yield accounts for 70.18% of the average annual yield.

5.0 ANALYSIS AND DISCUSSION OF RESULTS:

To estimate the hydromorphologic parameters of Dudhnai sub basin the topographic map delineating the basin divide and other topographic features was prepared from toposheets published by Survey of India in the scale 1:50,000. The stream net-work has been ordered using Strahler's ordering procedure. It is principally a seven order network having 3036 first order, 910 second order, 232 third order, 72 fourth order, 25 fifth order, 5 sixth order and 1 seventh order streams contained in the drainage area under investigation of 536 Sq.Km.

From the map the basic linear parameters like basin perimeter, lengths of streams , basin length etc. were measured manually. The basic parameters of areal aspects like basin area, areas of different order streams etc. were measured from the map and other derived parameters were estimated with the relationships discussed in Chapter-2.0. To study the relief aspects of the basin a contour map of the whole basin was prepared. The number, lengths and areas of different channel segments are furnished in **Table-5.1**.

Table-5.1

Measurement of Drainage Net-work

Stream order	Stream Nos.	Stream length L, Km	Average length $\bar{L}$, Km	Area A Sq km	Mean-Area $\bar{A}$ Sq Km
1	3036	2569.20	0.846	258.40	0.086
2	0910	0968.55	1.065	115.80	0.127
3	0232	0646.65	2.782	074.08	0.320
4	0072	0296.20	4.130	034.64	0.481
5	0025	0157.05	6.280	026.50	1.060
6	0005	0044.50	8.900	015.90	3.180
7	0001	0019.00	19.000	010.75	10.750
Total	4281	4702.00	43.003	536.00	16.004

The results of the study in respect of linear, areal and relief aspects are discussed below:

5.1 Linear Aspect of Dudhnai sub Basin:

The parameters studied under this aspect and their quantitative measures are furnished in **Table-5.2.**

Table-5.2

Linear Aspect of Dudhnai Sub-Basin

S.No.	Parameters	
1.	Length of main channel, 'L'	54 Km.
2.	Length upto centroid, 'Lc'	27 Km.
3.	Total length of channel, 'Lt'	4702 Km.
4.	Length of overland flow 'Lo' (mean)	0.05 Km.
5.	Basin perimeter, 'P'	165 Km.
6.	Watershed eccentricity, 'Ew'	1.49 Km
7.	Length ratio, 'Rl'	2.01
8.	Wandering ratio, 'Rw'	1.28
9.	Fineness ratio, 'Rf'	28.49
10	Bifurcation ratio, 'Rb'	3.89

It can be seen from the **Table-5.2** that the average length (total length divided by the number) of stream increases with increasing order (from 0.846 Km to 19.00 Km). Whereas number of stream shows a decreasing trend from lower order to higher order (1 to 3036). The non dimensional parameters (i.e. bifurcation ratio and length ratio estimated), reflect the peak time characteristics of the Dudhnai sub-basin and may be used in the hydrological modeling . The measure of length upto centroid may be useful in the regional unit hydrograph studies . The other linear measures shown in **Table-5.1** for the basin will also be useful to describe the various hydrologic properties of the net work. **Fig.3** shows the variation of stream number with stream order. The negative slope of the line confirms the law of stream numbers indicating reduction of number from lower to higher orders. **Fig.4** shows a sem-log plot of the quantities of stream order vs average stream length. The plot shows the increasing trend in average length with increasing order following Horton's Law of stream length

5.2 Areal Aspect of Dudhnai sub basin:

The basinal properties of the Dudhnai drainage net-work in terms of areal measures as described in Chapter-2 have been studied and the parameters of areal aspects are estimated as presented in **Table-5.3**.

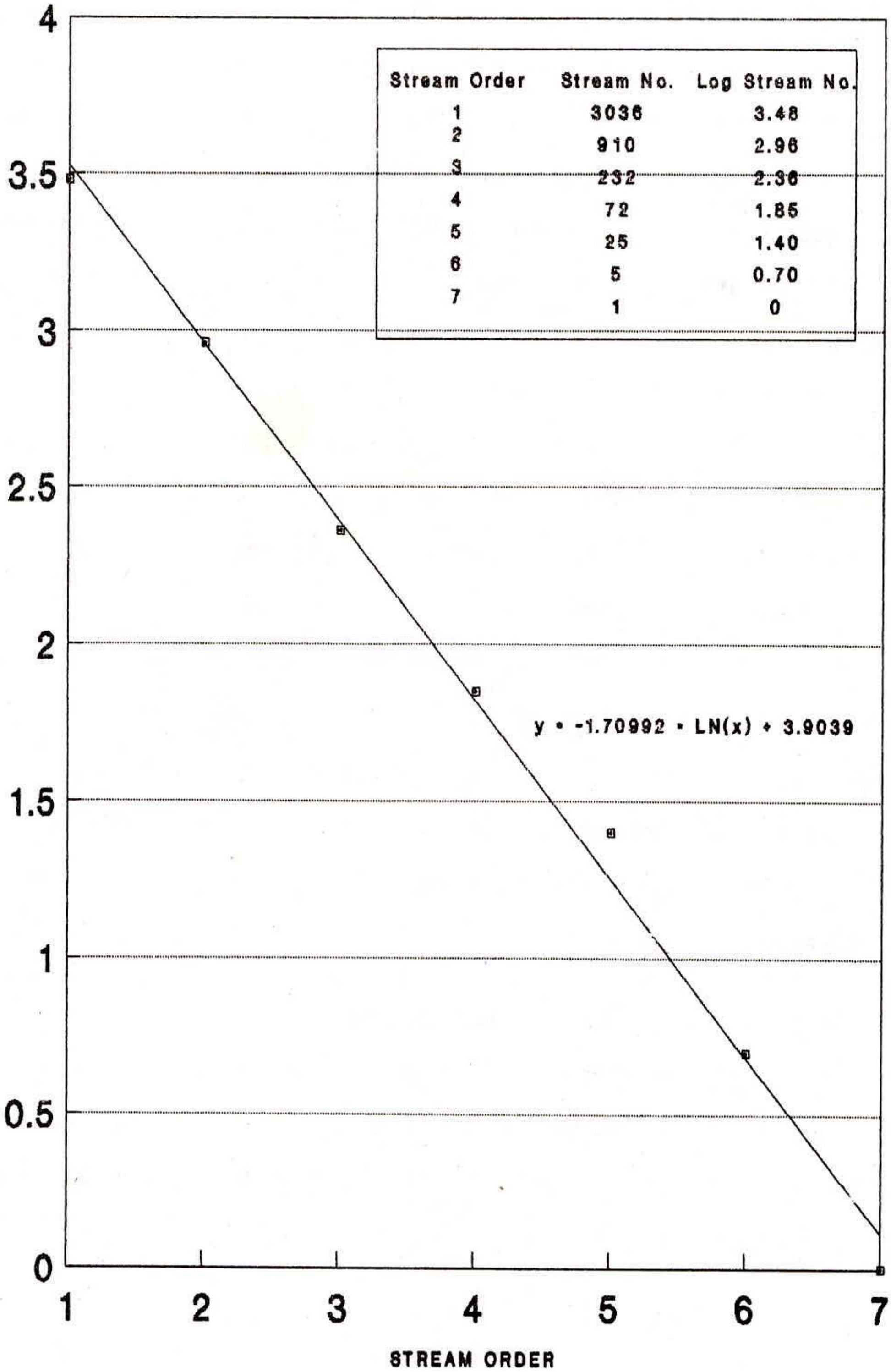


FIG.3. VARIATION OF STREAM NO. WITH ORDER

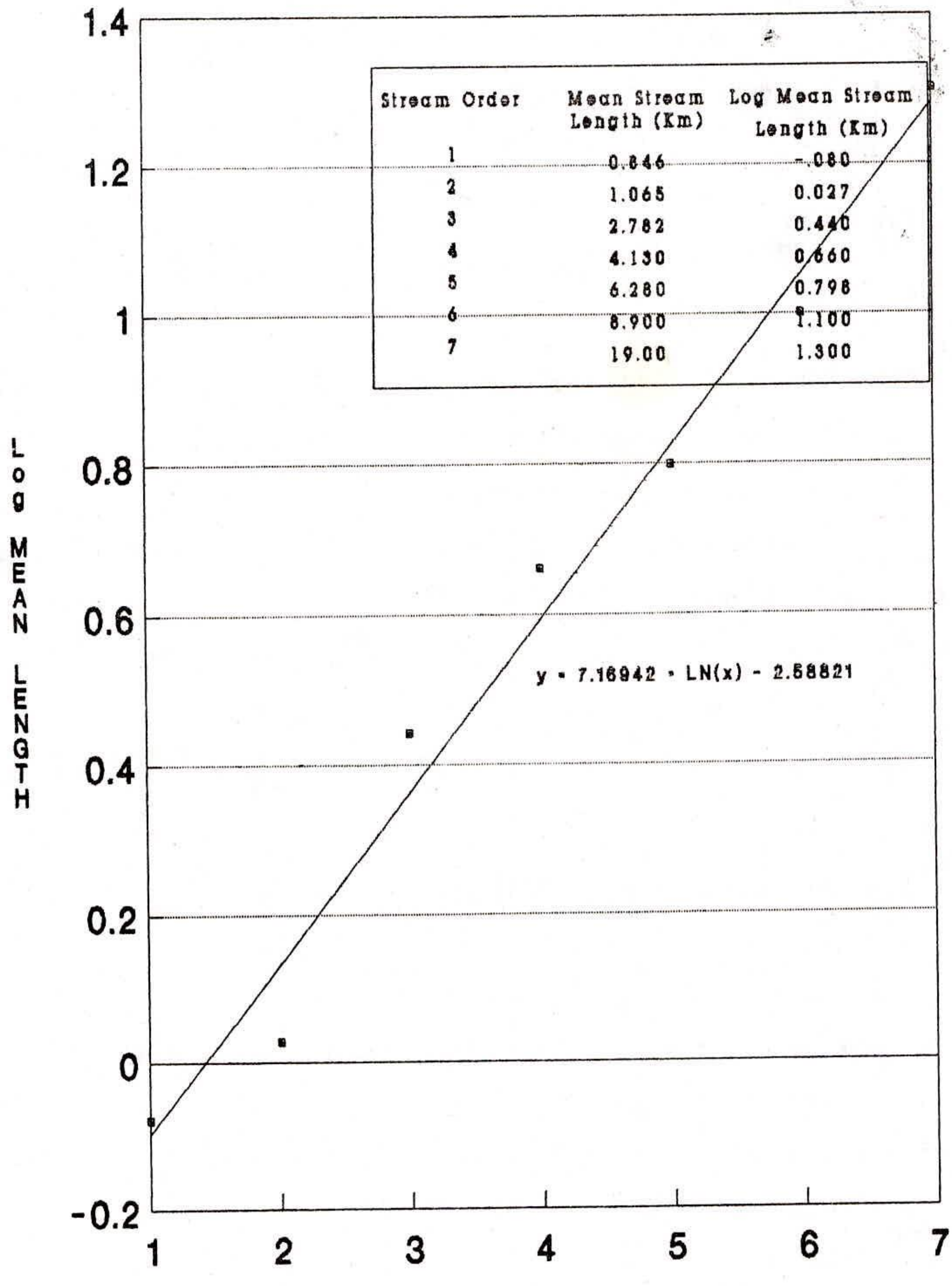


FIG.4. VARIATION OF MEAN STREAM LENGTH WITH ORDER

Table-5.3

Areal Aspect of Dudhnai River Basin

1.	Drainage Area, A	536 Sq. Km
2.	Drainage Density	8.7 km/Sq Km.
3.	Constant of channel maintenance, C	0.115 sq km/km
4.	Channel segment frequency, F	7.98/sq. Km.
5.	Circularity Ratio, RC	0.247
6.	Elongation Ration, RC	0.483
7.	Watershed shape factor, RK	3.13
8.	Unity shape factor, Ru	1.81
9.	Form factor, RF	0.301
10.	Compactness ratio, R	2.009

From Table-5.2 & Table-5.3 it is observed that there is an increasing trend in the mean areas of different order streams with increasing order which confirms the Schum's Law of stream areas as discussed Chapter-2.0. A plot to this effect between mean areas and orders is shown in **Fig.5**. The other areal measures furnished in the Table above are regarded to have effect on peak and shape of the basin hydrograph and may be used in modeling the hydrological response of the basin when flow records are not available.

5.3 Relief Aspect of Dudhnai Sub Basin:

The geomorphological parameters of interest to hydrology, under this aspect has been described in Clause-2.3 and accordingly these were estimated. The results are furnished in **Table-5.4**. The relief aspect parameters of the basin which are mostly non dimensional have significant effect on overland flow governing the flow processes.

As discussed in earlier chapter these areal descriptors are of great importance specially for a mountainous catchment like

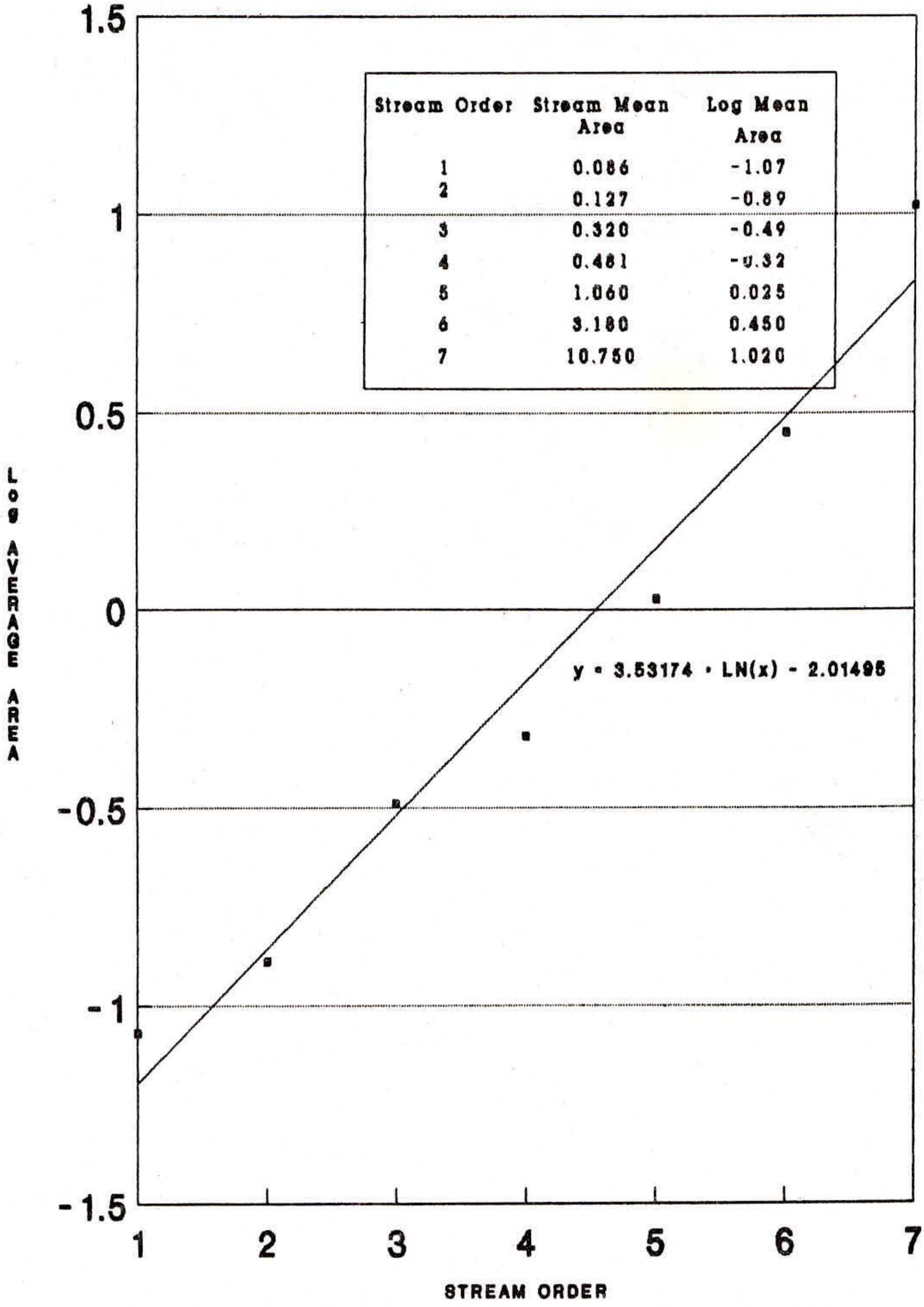


FIG.5. VARIATION OF AREA WITH STREAM ORDER

Dudhnai to understand the storage and flow characteristics, intensity of erosion processes operating on slope, comparison of basins for hydrograph synthesis etc.

Table-5.4
Relief Aspects of Dudhnai Sub Basin.

1.	Basin Relief, H	0.562 Km.
2.	Relief Ratio, RH	0.013
3.	Relative relief, RHP	0.003
4.	Ruggedness number, Rn	4.889

6.0 CONCLUDING REMARKS:

In India, not enough successful applications of geomorphological characteristics to specific hydrologic studies in a basin and then transforming the results to other basins have yet been documented. There are, therefore, many limitations in substituting the results of such applications for more traditional tools of hydrologic methods.

The hydrogeomorphological parameters have been estimated from a basin map manually which is very tedious , time consuming and prone to human error. It is felt that use of a digitizer where basic map data can be quickly, accurately and inexpensively converted into a form for automatic machine data processing would have been more helpful.

The estimated geomorphological parameters of Dudhnai sub basin covering linear, areal and relief aspects as presented in the report, will be helpful in estimating and modelling the flow process of the basin.

In the Dudhnai sub basin the existing network of hydrometeorological observation is not adequate. With the estimated geomorphological parameters of the basin it may be possible to develop synthetic Geomorphological Instantaneous Unit Hydrograph or evaluate important hydrologic model parameters like that of Nash Model (Nash,1960).

The geomorphological characteristics of Dudhnai basin will provide a simple means to compare it with other basin to regionalise the experimental results.

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