

**MORPHOMETRIC ANALYSIS OF
THE UPPER KALIYANI RIVER BASIN
MIKIR HILLS, ASSAM**

BY

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**DISSERTATION
SUBMITTED
IN
PARTIAL FULFILMENT OF THE REQUIREMENT
OF THE DEGREE OF
MASTER OF PHILOSOPHY**

TO



**THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG
MARCH, 1985**



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We certify that the dissertation on MORPHOMETRIC ANALYSIS OF THE UPPER KALIYANI RIVER BASIN, MIKIR HILLS, ASSAM by Mr. Bhabesh Ch. Choudhury is submitted in partial fulfillment of the Master of Philosophy Degree of this University. It is his own bonafied research work. This dissertation may be placed before the examiners for evaluation and necessary formalities.

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DECLARATION

The material embodied in this dissertation is original and has not been submitted for any other diploma or degree of any University or Institution . The contents of this dissertation are true to the best of my knowledge and belief.

Bhabesh Ch. Choudhury
(Bhabesh Ch. Choudhury)

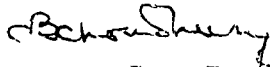
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(Bhabesh Ch. Choudhury)

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CHAPTER ONE

INTRODUCTION

Geomorphology is the study of the origin and evolution of topographic features by physical and chemical processes operating at or near the earth's surface. Geomorphology has today quite clearly and separately crystallised from a coagulated position between geology and geography. Now it stands fairly on its own principles and concepts and has developed its own methods and techniques.

The science of geomorphology has its importance not only as an academic discipline but it has more practical applications in the field of soil science, economic geology, hydrology, military geology, engineering geology and for land use planning. For the development of agricultural resources, the terrain assumes special significance. So far as agricultural planning is concerned, regional geomorphological studies have become of greater importance. In a country like India, the application of geomorphology in the field of land-utilization particularly for agriculture, horticulture, forest development, selection of sites for construction of dams,

transport and communication networks. Last but not the least, geomorphology also helps in selecting sites for human habitations.

There has been a phenomenal development in the field of geomorphological studies in the twentieth century. The early works in this field led to a variety of approaches and this registered in the development of several schools of thought. According to C.A.M. King (1966)¹, there are three major groups, (i) the first arises out of the work of Walter Penck and may be called the 'mobilistic view', (ii) the second gives priority to the effects of climate in studying the characteristics of the landscape, (iii) the third is based essentially on the idea of 'correlation by altitude' and therefore, be termed the 'eustic view'.

In the recent years considerable conceptual change has taken place in geomorphology. Sophisticated quantitative techniques have been evolved to analyse the dynamic nature of earth's form. Various morphometric techniques through statistics are becoming more and more useful to a geomorphologist to analyse the land as an open system. The studies in this aspect of research have been initiated by Horton (1945), an eminent hydrologist and Strahler (1950, 52, 54, 56, 58) and are widely published by other geomorphologists like Kesseli (1946),

¹ Leopold, L.B. (1964):

Russell (1949), Miller (1953), Schumm (1956), Melton (1958), Smith (1958), Morisawa (1962), Robinson (1963) and number of others.

Though the study of quantitative drainage analysis has advanced with rapidity in American and European countries, the follow up of this branch in India is only of recent origin. Moreover, the progress in this line is comparatively slower. Ghose, B., Pandey and Singh (1967), Sharma, V. (1968), Verma and Tandon (1971) and Pal, S.K. (1973) are a few who have published and tested Horton's and Strahler's models in different parts of this country.

Morphometry is the measurement and mathematical analysis of the configuration of earth's surface and of the shape and dimensions of its landforms.² The term morphometry is used in several disciplines to mean the measurement and analysis of form characteristics. But in geomorphology, it is applied to numerical examination of landform, which may be more properly termed 'geomorphometry'. This may be concerned with landform as a whole (general geomorphometry) or with a particular type of landform (specific geomorphometry). The most geomorphometric studies have been based upon map derived data. The drainage basin is the landform most commonly analysed in morphometry and since 1940 geomorphological literatures have included many

² Durrty, G.H. (1967) : Essays in Geomorphology, Heinmann, London, p. 235.

hundreds of studies of drainage basin form. Drainage basin morphometry is potentially a most important approach to geomorphology, since it affords quantitative information on large-scale fluvial landforms, which make up the vast majority of the earth surface.

The present work is an attempt to study the numerical indices of a particular basin and to try out the different laws propounded mainly by Horton and Strahler. These laws have been helpful not only to identify the different erosional surfaces, but they also provide materials to reconstruct a systematic geomorphic history of the basin or region. By studying the processes quantitatively the complexity of landform becomes more clear. That is why it is quoted that the application of the tools of mathematical statistics to applied geomorphology is essential if, meaningful conclusions are to be achieved.

Study Area:

The Kaliyani river basin is located in the northern part of the Mikir Hills of Assam. The Mikir hills district is at present known as the Karbi Anglong. Anglong means the hills and the Karbi is the tribe who resides in this area. Administratively this basin is under the Diphu sub-division.

Since, it is a time bound course, the upper part of Kaliyani river has taken into consideration for study (Fig.1). The upper Kaliyani river basin under study extends from

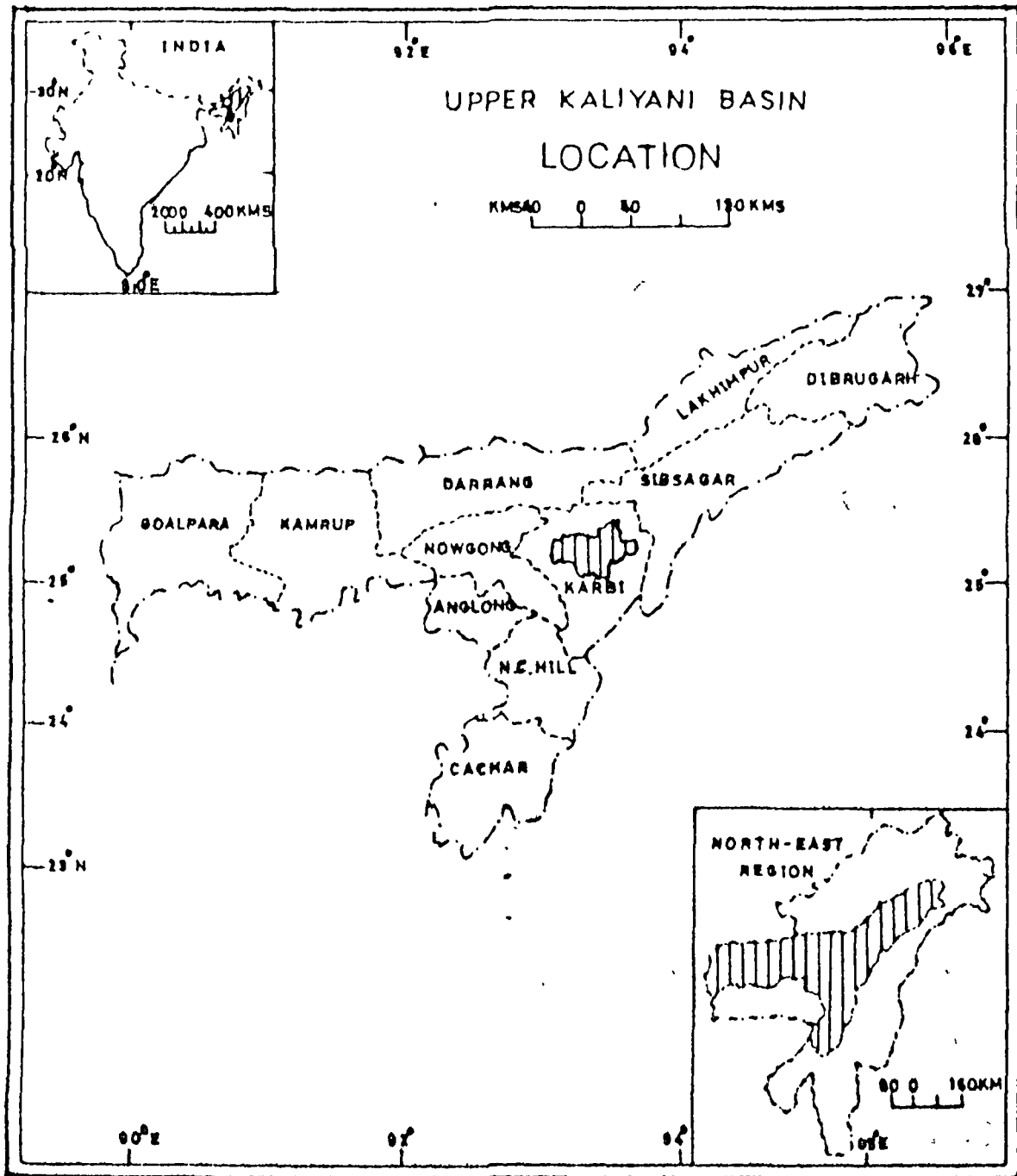


FIG.1

26°15'N to 26°28'N and from 93°15'E to 93°30'E. The river originates from the Mikir hills which is the extension of the Meghalaya plateau. It is a tributary of the Dhansiri river and finally joins in the mighty Brahmaputra. The total area of the upper Kaliyani river basin is about 380 sq.kms. The basin experiences tropical monsoon climate.

In the initial stage of study the state of Assam was taken into consideration. It thus become necessary to consider a basin of Mikir hills for detail study. On a general basis it can be safely said that not much work has been done regarding the geomorphic study of this basin as well as the whole region. It is in the light of this, that the basin (upper Kaliyani) has been selected for study. However, it must be mentioned that the geomorphic features would be useful tool for various studies.

Objectives of the Study:

This study treats quantitative landform analysis as it applies to normally developed basin in which running water and associated mass movements are the chief agents in developing surface geometry. Emphasis is upon the geometry itself, rather than upon the dynamic processes of erosion and transportation which shape the forms. Therefore, the researcher has used some of the quantitative techniques developed by Strahler (1950, 52 and 56), Horton (1945) and others.

This study will be divided into three main points viz. linear aspects, areal aspects and relief aspects. The main

objective is to find out the geomorphic characteristics of this basin through the study of linear, areal and relief aspects separately. An attempt has been made to study the relationship among the morphometric properties. Besides, an attempt has been made to analyse and interpret the morphometric characteristics of the basin which will help in the identification of geomorphic units. The present study is an humble attempt in the same direction.

Source of Materials:

The selected basin is traced from two centimeter to one kilometer (1:50,000) topographic sheet of the Survey of India. The necessary materials are collected from Survey of India, Geological Survey of India, books, journals and a number of published and unpublished research papers. The published literature and their details are given in the bibliography as well as at each page in the form of references. It was found necessary to illustrate and supplement the statements and discussions in the dissertation by figures and diagrams, which provide a clearer picture of the natural configuration of the region. To illustrate different aspects of the area under study, all the maps and diagrams of the basin have been prepared by the researcher. Moreover, extensive field work has been undertaken which is very much essential in geomorphological studies.

Method of Study:

For the present study, the researcher has used a number of morphometric methods and techniques which have been suggested

by different geographers. Some mathematical calculations have been done with the help of various data obtained from the basin parameter. The various methods used here studied under three groups as follows:

Linear Aspects of the Basin:

Linear aspects of the drainage basin include stream ordering, stream numbers, stream lengths, bifurcation ratio and sinuosity index.

Areal Aspects of the Basin:

Areal aspects of the basin include Basin perimeter, Drainage density, Stream frequency, Drainage texture, Circularity ratio, Constant of channel maintenance and Drainage pattern.

Relief Aspects of the Basin:

Relief aspects include slope, Dissection index, Altimetric frequency curve, Hypsometric curve, Hypsometric integral and relief (both relative and absolute).

The above methods have been used to compare the results and for further generalisation and correction of accuracy, considerable field studies have been undertaken.

Historical Base:

The region of Karbi Anglong lacks comprehensive historical studies. The tales and myths prevalent among the

ab-origines do not serve the purpose of arranging its historical events in chronological order.

It is, however, somewhat possible to know the earliest events of the region, though not in detail, in connection with the history of Kamarup, a Hindu kingdom, that existed during the period of fourth to seventh centuries. During the following centuries several dynasties ruled different parts of Kamarup. Among all the dynasties, the Kachari was the most powerful. The Kacharis ruled the southern part of the Brahmaputra Valley including the hill tract of North Cachar. This powerful tribe gradually declined due to successive Ahom invasions over a long period of about four centuries. The Ahom with their superior power caused a great impact upon the life and tradition of the ruling tribe of Karbis and Kacharis. When the British came, the region entered into another phase of its history. Prior to the British, there was no clear cut political boundary in the region. During British times, again, a great many changes took place, especially in regards of political boundaries and transport and communications. After independence, the hill tracts of the Karbis draw much attention of the government of India. The government ultimately decided to form them into separate hill districts. Recently, the local tribes demanded a separate union territory comprising both the districts.

The history of Kamarup deals mostly with its plain parts. Even up to the end of the 12th century, history does not give any clear and definite account of this hilly tract. It is the

beginning of the 13th century that the ruling Kachari tribe came to the notice of the Ahoms who invaded the Brahmaputra Valley from the east. The Kacharis and the Ahoms entered into rivalry for many centuries. Similarly, the Karbis and other tribes, in many occasions, came in contact with the Ahoms who used to keep systematic records of such events. Therefore, it is possible to know about the region during this period much better than the earlier. Again, as a result of British possession of India since 1826, the Ahom rule came to an end for ever. The region entered into a completely new era of western culture. Similarly, after India got independence from the British in 1947, the region again entered into another era of its history.

CHAPTER TWO

PHYSICAL SETTING

Geology:

Geology plays an important role in the study of drainage analysis. Geologically the region is closely related with the Meghalaya plateau (of Archaean origin) and the Purvachal Hills i.e. the southern part of the eastern Himalayas (of Tertiary origin). The entire area had undergone tremendous tertiary disturbances especially in the south-east causing superimposition of Tertiary rocks over the pre-cambrian basement and lot of metamorphism, folding and faulting had taken place.

The aforesaid basin, part of Diphu sub-division (East Karbi Anglong) lying north of the Jamuna river, forms a distinct unit with predominantly gneiss rocks of Archaean group and with isolated patches of gneiss and Shillong group of rocks along the western margin.

Geological Formation:

The previous literature of the area is very limited. Smith was the first officer of G.S.I. to survey the present area.

Reports of Smith (1896) and Meddicot (1898) remain as the only authentic reports till now. Chandra (1948) visited the area to study the limestones of the area. More recently Banerjee, A.K. (1954) and Barua, B.B. (1955) gave a short account of the geology of the nearby areas.

The earliest geological reference on the region was made by T. Oldham (1859). The Archaean and Pre-cambrian rocks of the region have been mapped systematically by K.Gogoi, M.M. Munshi, M.K. Das and M.G. Rao and others. Their work not only led to the delineation of the individual rock units of the Archaean and Pre-cambrian but also revealed the relationship of these two major rock groups.

The Geological succession¹ of the areas summarised below:

Quaternary-	Recent	Laterite	
	Pleistocene	Alluvium	
Tertiary-	Pliocene	Unconformity	Dihing series
	Miocene	Unconformity	Tipam series
	Lr. Miocene	Unconformity	Surama series
	Lr. Oligocene to Up Eocene	Unconformity	Barail series
	Eocene	Unconformity	Jaintia series
	Jurassic	Unconformity	Sylhet Trap Granite Shillong series
	Archaean	Unconformity	Gneissic complex

¹ Source : District Census Hand Book, United Mikir and North Cachar Hills, 1961.

Archaean Gneiss:

The Archaean Gneiss complex is the oldest group of rocks that occur in the greater part of the Karbi Anglong in the north-western fringe as isolated patches and as inliers. In this basin, the rock types show a variation from coarse grained porphyritic to foliated biotite granites associated with fine grained, strongly banded and foliated gneisses, schists and granulites. Intrusive pegmatite, quartz veins and basic sills also occur. The Jurassic rocks lie unconformably over the Archaeans in the some parts of the basin (Fig. 2).

Stratigraphy of the Study Area:

The area is composed of the following rock types :

Granites, basin intrusives, sandstones interstratified with a coal seam and clay partitions, limestone and loose sand and alluvium.

The following stratigraphic succession has been given

<u>Recent</u>	<u>Loose sands and Alluvium</u>			Jaintia series
Lower and Middle Eocene	Limestone (Fossiliferous)	Amulithic limestone or Sylhet limestone	Sylhet Stage	
Tertiary Palaeocene	Sandstone interstratified with coal, clay and shale	Cherra sandstone or Tura sandstone	Therria Stage	
Archaean	Basin intrusives (Epidiorites) Granite (granite gneiss, porphyritic granite)			

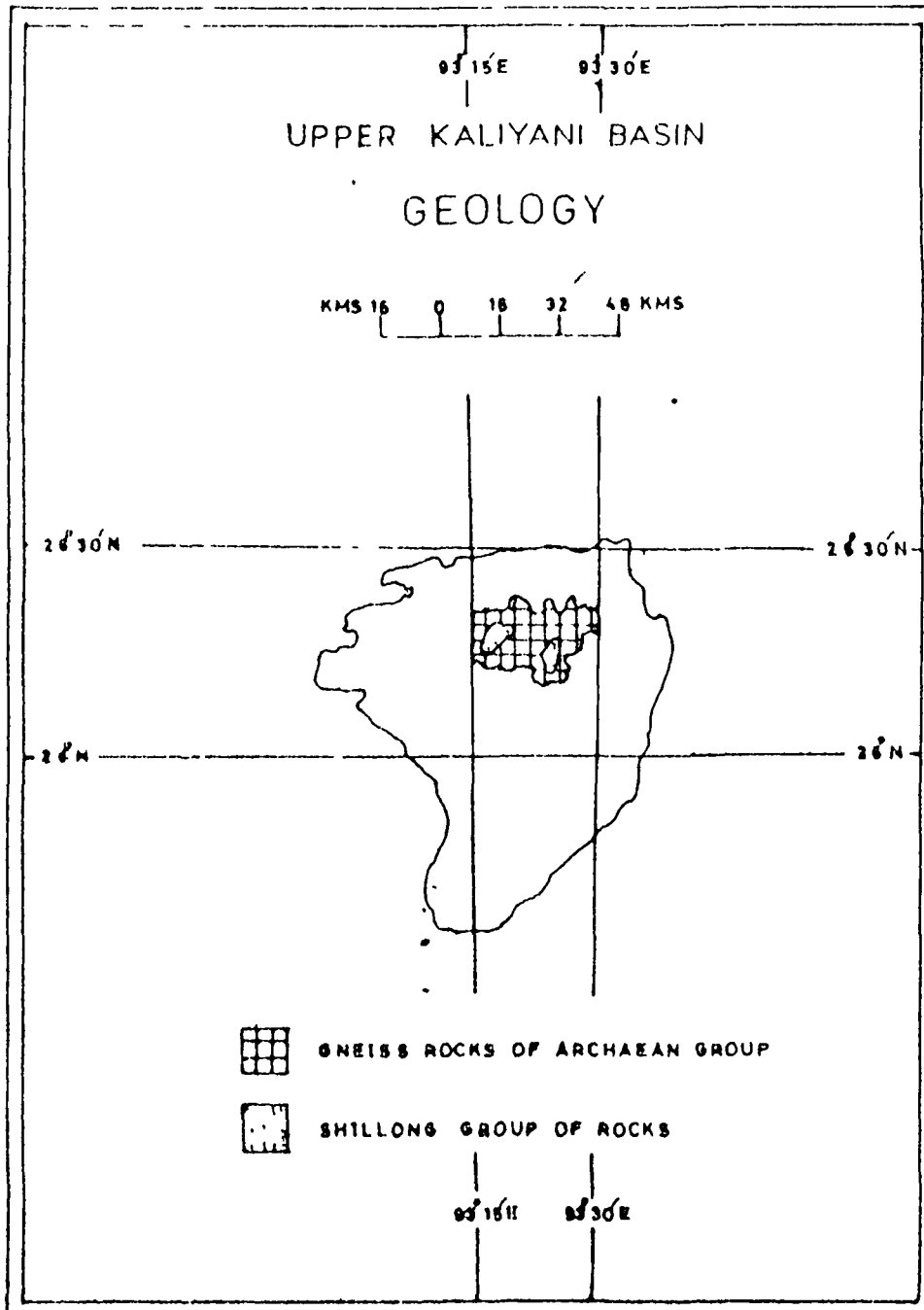


FIG:2

The oldest rock type in this area is granite. The granite of the Mikir Hills has been considered to be of Archaean age by the earlier workers (Smith, F.H., 1898, Banerjee, A.K., 1954, Barua, B.B., 1955). They are considered to have intruded into the granite during the Archaean time.

There is a complete absence of Palaeozoic and Mesozoic strata in the present area and during this long time gap the Archaean rocks were weathered and eroded. The granite is deeply weathered with most of the feldspar changed to kaolin.

On the denuded surfaces of the Archaean deposition again started, during the Tertiary era. Amongst the Tertiary sedimentaries, the sandstone was the earliest to be deposited and it was inter-stratified with coal seam and clay partitions. The sedimentaries belong to the Jaintia series (Eocene system) and are equivalent to the Disang series of Upper Assam.

Thus, in the present area, the Archaean granites and basic intrusives are directly and unconformably overlain by sedimentary strata (sandstone, coal, clay and shale and limestone) and the two are separated by a long time gap lasting throughout the Paleozoic and Mesozoic eras, involving weathering and denudation.

Sedimentary Rocks:

The sedimentary rocks occur as outlier patches in, and separated by granite and occupy a major part of the area. They include conglomerate, sandstone, a coal seam and fossiliferous

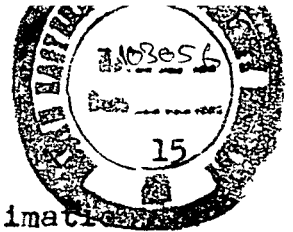
limestone. The sedimentary rock generally provides poor outcrops which are usually confined to stream cuttings.

The Mikir hills are the detached North-Eastern part of Assam plateau bounding the upper Assam Valley on the south-west. The basement of the Mikir Hills, which is a disconnected portion of the peninsular region is made up of ancient gneissic rocks belonging to Archaean or Pre-cambrian ages. The lower and middle eocene beds i.e. the Jaintia series which is extended in the form of a narrow strip from Shillong Plateau through North Cachar, Mikir Hills to near Golaghat is covered by alluvium of the plains of Lanka. This strip again reappears in the Mikir Hills. There is a close lithological similarity between the Tertiary rocks of the present area and that of Khasi and Garo Hills.

Climate :

Broadly speaking, the climate of the region is controlled by the same factors that apply to other parts of Assam, as well as Meghalaya, Manipur, Nagaland etc. But the most important factor that gives slightly different climatic phenomena from that of other parts of Assam is orography.

The Cherra-Dawki escarpment of Meghalaya, Barail range and the western border hills of Manipur obstruct easy occurs of south-west monsoon winds into the heart of the region. The condition gives a rain shadow effect to the central portion of plateau. Moreover, due to the peculiar shape of the region and



the alignment of its hills the common wealth and climatic phenomena of the Brahmaputra Valley are rarely experienced except for the border areas which come under direct influence

According to G.T. Trewartha's climatic regionilization of India, almost all the entire region comes under Caw climate. He includes Barails under Am climate. His regions could be accepted on a broad basis, but there are great local variations which perhaps are mainly due to relief on orography as stated earlier.

The climate of the study area in general is characterised by high humidity and moderate temperature. Though the area lies to the north of the tropic of cancer, yet due to occurrence of extensive water bodies and marshy tracts in the Brahmaputra Valley, the air is never devoid of humidity and hence the area supports luxuriant vegetation. The high humidity accompanied by thick cloud cover throughout the summer, the rise of temperature which seldom exceeds 90°F . During winter, the moisture content in the atmosphere condenses into fog giving rise to morning and evening fog specially in the valleys. This region presents a typical monsoon type of climatic conditions which get sufficient rains in summer season due to its location. This type of climate encourages more fluvial processes and weathering which are engaged in changing the shape of the earth surface. The temperature, rainfall and humidity play an important role in the geomorphic process.

Formally, we may define weathering as the spontaneous and essentially irreversible response of rocks conditions at the

earth's surface. The importance of weathering in the preparation of land surfaces for action by agents of landscape sculpture is recognised. However, the detailed knowledge of weathering is meagre and restricted to certain aspects. Thus, with regard to some of the principal problems of geomorphology the pertinent information regarding weathering is qualitative.

The long gap between the Archaean and the Tertiary formations indicates a period of weathering and denudation. The granites, exposed in the area, are affected by the destructive agents of weathering and they exhibit typical spheroidal weathering. The most interesting feature of the area is that at places the granites which are rich in feldspar are subjected to decomposition resulting in the formation of clay minerals some of which are of purely white in colour.

The chief agents of the weathering operated to extensively over limestones and sandstones of the area that their thickness is decreasing day by day. This is observed in the Tertiary formation of the area, because of its chemical composition, rock type under discussion is highly weathered and decomposed.

Drainage:

The drainage pattern of the Mikir Hills, in which the area under discussion is located, is most interesting and complex. The flat topped and dome-shaped hill crest of Mikir

Hills are the cause of the origin of the radial drainage. This radial drainage is of subsequent origin and develop in connection with erosion of peaks'. (Chibber, 1954).

The Kaliyani is a tributary of the Dhanshri river system in this area. The main course of the Dhanshri originates from the Thingtubum peak (6128 ft) which lies on the Assam-Nagaland boundary up to Dimapur. From Dimapur, it flows exartly north again forming the common boundary between Karbi Anglong and Sibsagar and ultimately joins the Brahmaputra at Dhanshri-mukh. Kaliyani, that originates from the height of about 3,500 ft and runs eastward, is the only big tributary within this region.

Physiography:

Relief and Drainage of the basin exhibit a high degree of relationship with its geology. The areas having hard resistant rocks of granite and gneiss etc have been standing high. The less resistant tertiary rocks have formed range but deeply cut by streams giving a complicated relief configuration of the basin.

Relief :

Relief means the ups and downs of the surface of the earth. The ups indicate the mountain whereas the down indicates the depression i.e. ocean. In other words, relief means the difference between elevations of the points. Though relief

is shown by different methods, but contours are the most important and modern means of representing relief.

For the present study, the researcher has observed that the river valley is a low lying area. The southern and northern peripheries are high in comparison to the central area (Fig. 3). Patches of isolated high relief are found in the central part. The small streams which originate in the periphery flows towards the middle of the basin to meet the main river.

Profiles of the Relief:

The profiles of the basin are drawn from the contours which are shown in the Figures. The N-S profile indicates that the southern portion of the basin is relatively higher than the northern portion. It is apparent from the Fig 4(a) that the middle portion is lower in comparison to the two extreme peripheries because the river flows through the middle in the W-E direction. The researcher has found ridges like features in the middle of the profile.

The W-E profile shows that the eastern portion is lower than the western portion because the river flows from west to east direction. It is found in the profile [Fig 4(b)] that the middle portion is higher than the two other sides forming a dome like structure. In the two extreme ends, the slope is gentle than the middle portion.

UPPER KALYANI BASIN
RELIEF MAP

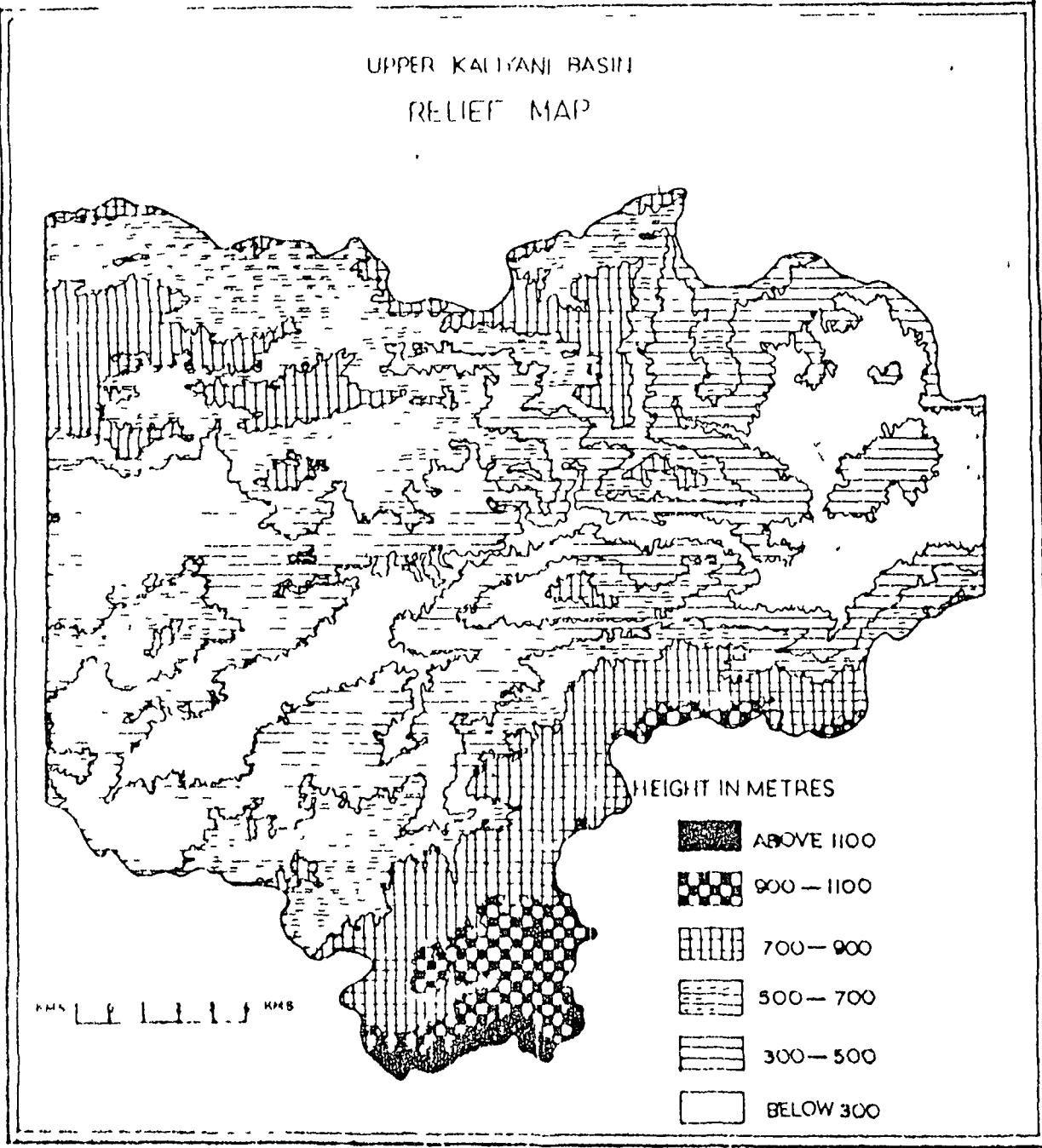
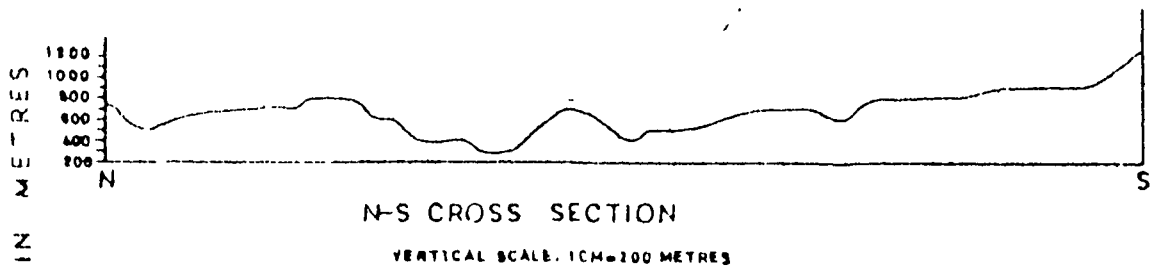


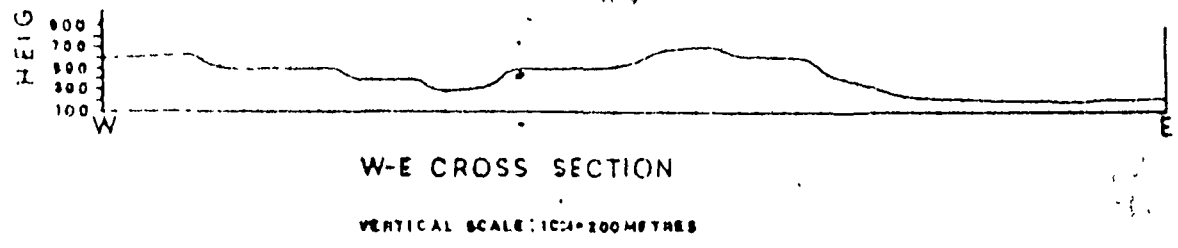
FIG.3

UPPER KALIYANI BASIN



N-S CROSS SECTION
VERTICAL SCALE: 1CM=200 METRES

FIG 4(a)



W-E CROSS SECTION
VERTICAL SCALE: 1CM=200 METRES

FIG 4(b)

Flora and Fauna:

The climate is the main factor for the growth of flora and fauna in any region. The hills and the valleys of the area are covered by dense tree forest. Xerophytes grow in abundance in some dry regions. The hillocks are generally covered with some green grasses which renders difficult in field work. The luxuriant growth of Angiospermic plants are abundant. The slopes of the hills are covered by creepers and bamboos. The vegetation is covered chiefly by cinnamom, artocarpus, nahar and bamboos and some valuable trees of economic importance.

The fauna that are fairly common in the area are elephant, rhino, buffalo, leopard, bear and wild pigs. Deer is also abundant in the area which are of different kind. Amongst them (as mentioned above) elephants and bears are most common.

CHAPTER THREE

LINEAR ASPECTS OF THE BASIN

Drainage Analysis:

The drainage basin is generally regarded as the most satisfactory basic unit for study because it is an areal unit and drainage systems can be placed in an orderly hierarchy. Interest in drainage basin morphometry has grown since R.E. Horton¹ drew attention in 1945 to certain basic laws. The work of Horton has been built upon and extended since then and knowledge of the mathematical properties of drainage basins greatly extended. In 1900, W.M. Davis wrote, 'rivers and valleys have a special place, for it is impossible to treat the development of landforms, or to describe existing forms in a rational manner, without constant reference to the valleys that have been worn in them and to the rivers by which the waste is washed along the channel in the valley floor'. Thus, in any geomorphological study, drainage analysis becomes an important part.

¹ Gregory, K. J. and Walling, D.E. (1976): Drainage Basin: Form and Process - A Geomorphological Approach, London, Edward Arnold.

Linear Aspects of the Basin:

Linear aspects of the drainage basin include the study of the channel patterns of the drainage network in terms of open links wherein the topological properties of the stream segmented are analysed. The drainage network which includes all the stream segments of a particular river, is studied in graphic terms. Where stream junctions are considered as points and streams are regarded as the lines which connect them. For this purpose, the numbers of all stream segments (N_u) are counted, their hierarchical orders are determined, the length of the stream segments are measured and various inter-relationships are analysed.

The length of overland flow (L_g) is the mean distance from the watershed to the stream of the first order having no direct channel. This length of overland flow is very significant in the study of drainage basins. Because it denotes the spacing of streams. The length of the master stream (L) from the mouth to the source is called 'mesh length'.

In the present study, the data of various attributes of linear aspects of the basin have been derived and calculated from the toposheet of two cms equal to one km.

Stream Order:

Different stream segments of a drainage basin have their definite positions in the domain of a drainage basin. They have

their distinct morphometric characteristics which necessitate the determination of their relative positions on the hierarchical scale of stream segments. Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries.²

Davis (1899) described the drainage basin as a leaf and the streams as the veins of that leaf. It was Gravelius (1914) who made the first systematic attempt to decide the hierarchical orders of the streams of a drainage basin by tracing the streams from the mouth to the source. He tried to recognise the trunk stream through greatest width, discharge, headward branching and junction angle which he allotted the position of first order. He assigned the second order to those rivers which joined the main river of 1st order and so on.

System of channel ordering have been suggested by Horton (1945) and Strahler (1952) excluding Gravelius (1914). The work of Horton marked the beginning of the concept of stream ordering and further modified by Strahler to overcome some of the limitations of Horton's ordering system (Fig. 6).

Horton defined, 'The stream order is a measure of the position of a stream in the hierarchy of tributaries'. According to him, the first order streams are those which have no

² Leopold, Wolman and Miller (1969) : Fluvial Processes in Geomorphology, p. 134.

METHODS OF STREAM ORDERING

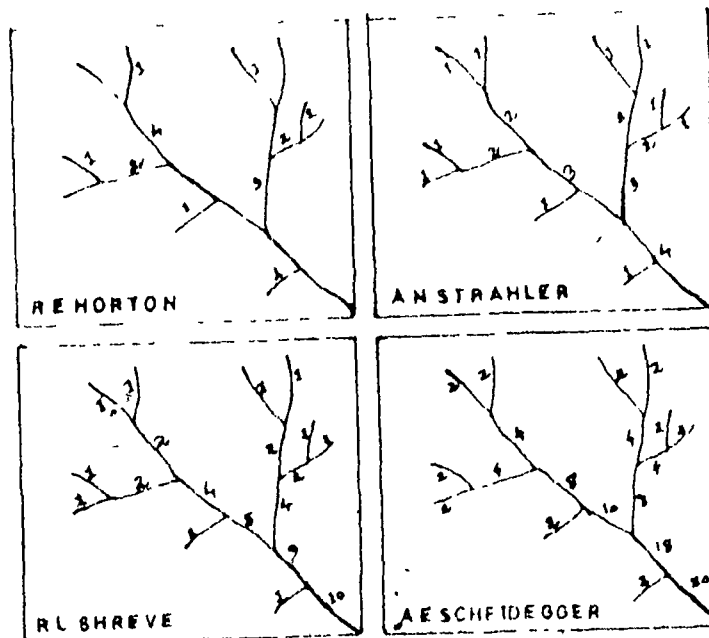


FIG. 6

tributaries, the second order streams are those which have as tributaries only first order streams receives as tributaries only first order and second order streams and so on. Horton's scheme of ordering of rivers is difficult, tedious and time consuming because it involves double phases of classification and reclassification at several times. During the second phase of renumbering some finger-tip tributaries are upgraded and others are left.

Strahler (1952, 53, 57) modified the limitations of Horton's (1945) ordering system. Strahler proposed a simple scheme out of Horton's method. In his method, Strahler retained the original definition of first order, second order streams etc. as suggested by Horton (1945). By this method, Strahler simplifies the computation but it reduces the length of the main trunk, because the method of giving order number is restricted to stream segments only.

In the present study, the researcher has applied the Strahler's method of stream ordering. According to Strahler 'each finger-tip channel is designed as a segment of the first order. At the junction of any two first order segments, a channel of second order is produced and extends down to the point where it joins another second order segment whereupon a segment of third order results and so forth.

In this study, ten small basins have been taken from the aforesaid basin. Out of ten drainage basins, Nihang is the

sixth order streams another six basin viz. Barpung, Langkangtang, Arnan, Pak, Bar, and Langterai Juri are the fifth order streams. Rest three viz Sangri, Majangri and Tarapung are the fourth order streams [Fig. 7(a) and 7(b)].

After the completion of ordering of the basins the number of all segments of each order have been counted which are represented in table 1. It is clear from the table that Arnan Langso tops the list by having the largest number of stream segments (471), whereas the bottom position is occupied by Langterai Juri (75).

It is obvious and clear from the table that the number of stream segments of any given order will be fewer than from the next lower order but more numerous than from the next higher order.

Scale of the maps used in the ordering of the drainage network plays a vital role in deciding the accuracy of the orders of stream segments. Large scale map like 1:25,000 may produce more accurate results than the small-scale maps because fingertip tributaries and rills are correctly depicted on such maps. Some geomorphologists have suggested to use contour maps for the determination of streams. The researcher has used two cm to one kilometer map in his study of stream ordering. Chance variations as well as scale variations may register departures from different laws of drainage network postulated by Horton and Strahler.

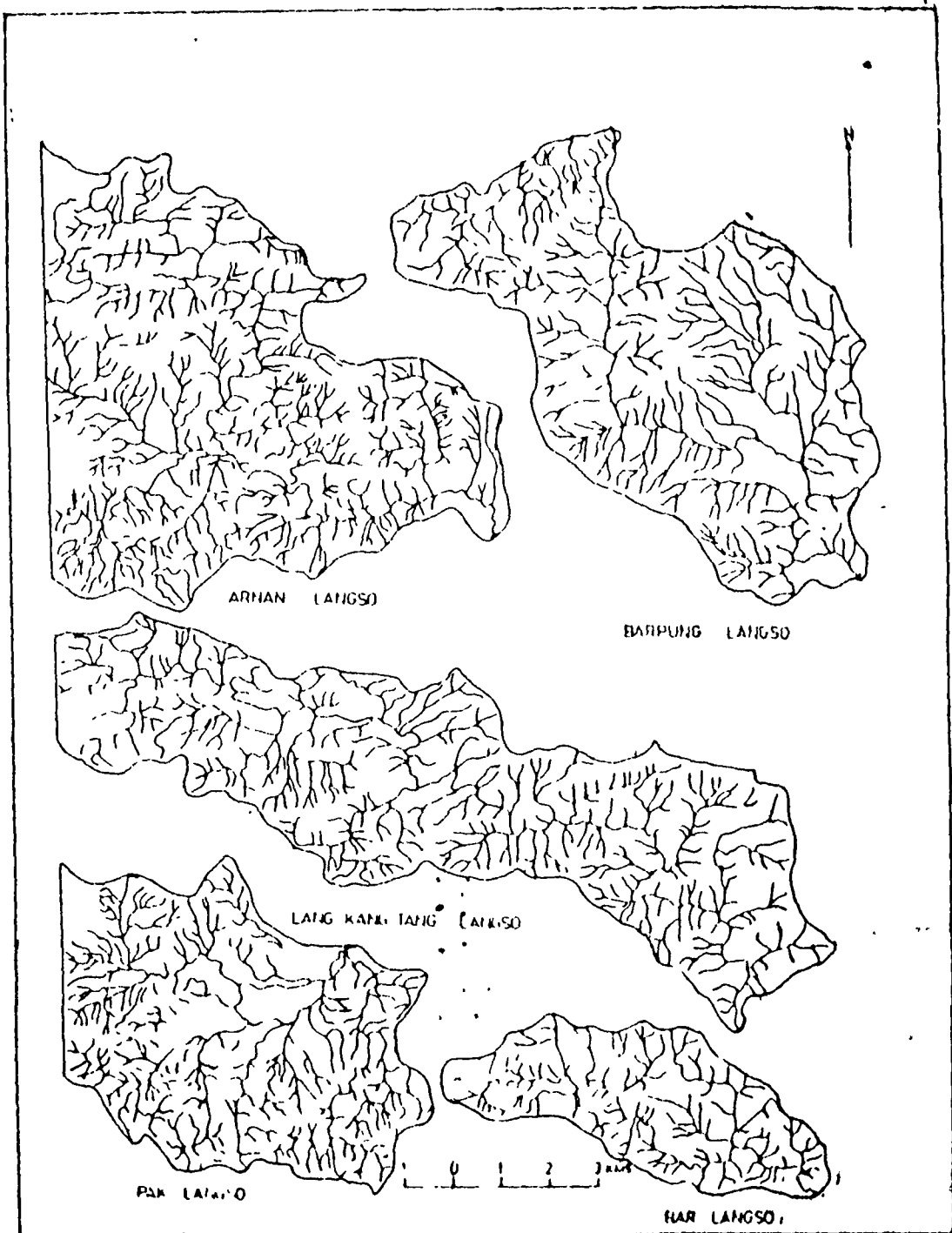


FIG 741

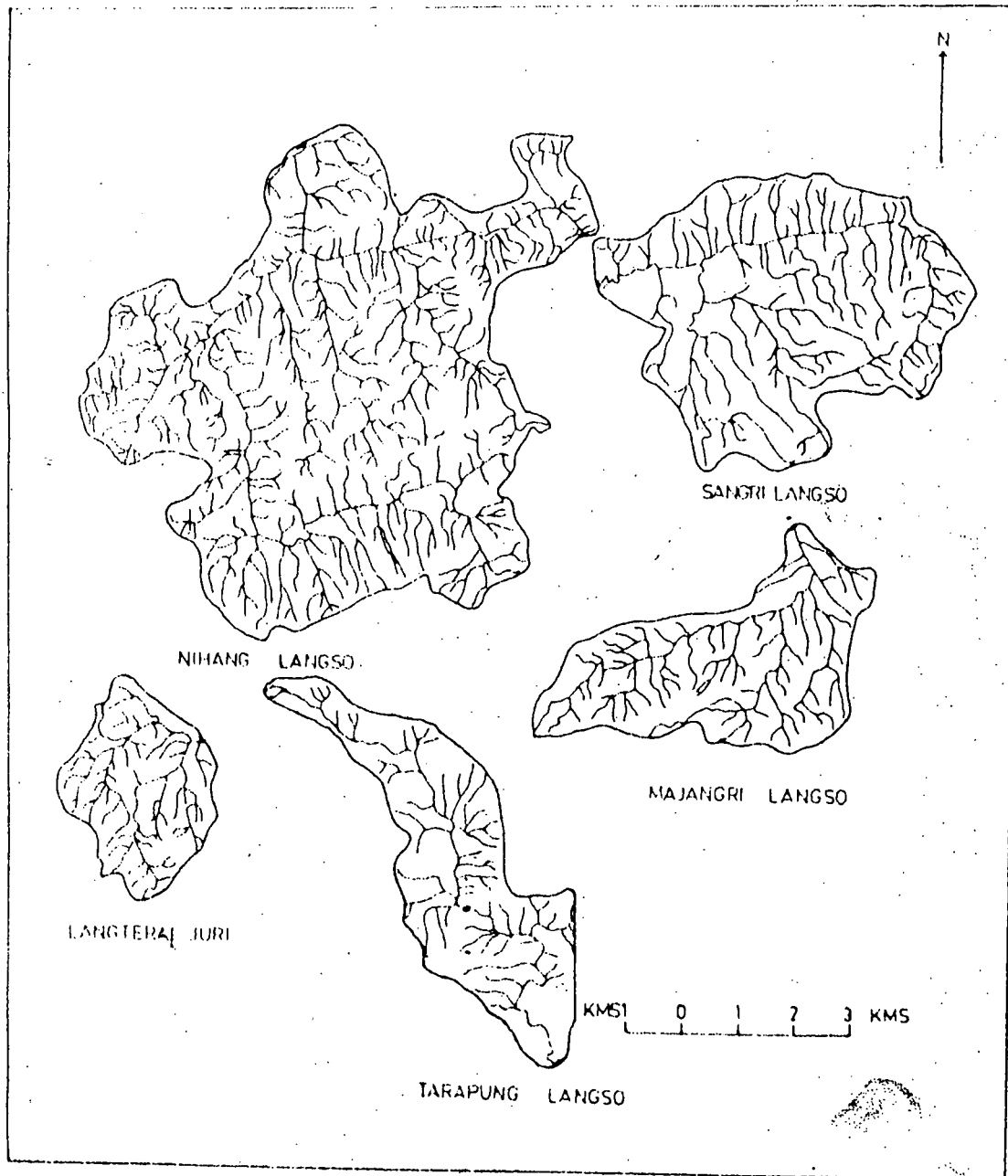


FIG 76)

Table 1
Number of Stream Segments

Sl.No.	Name of Basins	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order	Order	No. of Total Stream Segments of each Basin
1.	Mihang Langso	325	70	17	4	2	1	6th	419
2.	Barpung Langso	224	54	12	2	1	-	5th	293
3.	Langkangtang Langso	200	71	15	3	1	-	5th	290
4.	Arnan Langso	363	79	24	4	1	-	5th	471
5.	Pak Langso	233	55	16	4	1	-	5th	309
6.	Bar Langso	116	26	6	2	1	-	5th	151
7.	Langterai Juri	53	15	4	2	1	-	5th	75
8.	Sangri Langso	106	25	3	1	-	-	4th	135
9.	Majangri Langso	68	15	5	1	-	-	4th	89
10.	Tarapung Langso	59	15	3	1	-	-	4th	78

Bifurcation Ratio (Rb):

The ratio of number of segments of a given order (N_u) to the number of segments of the higher order (N_{u+1}) is termed as the bifurcation ratio (R_b) and is expressed in terms of the following equation.

$$R_b = \frac{N_u}{N_{u+1}}$$

Where, N_u = Number of streams of a given order

N_{u+1} = Number of streams of the next higher order.

Bifurcation ratio is related to the branching pattern of the drainage network. The study of bifurcation ratio in different places indicates marked seasonal variation due to the differences in climatic conditions, geological and structural characteristics, lithology, relief features and stage of basin development.

Horton (1945) recognised bifurcation ratio as one of the most important characteristic of the drainage basin. Horton has postulated that bifurcation ratio varies from 2.00 in the flat or rolling basins, 3.00 to 4.00 in the mountainous highly dissected basins. Strahler has observed that, because the bifurcation ratio is a dimensionless property and because drainage systems in homogeneous materials tend to display geometrical similarity. It is not surprising that the ratio shows only a small variation from region to region. Coate (1958) has observed that minimum possible ratio of 2.00 is seldom approached in

nature, lying between about 3.00 and 5.00 in basins without differential geological controls and only reaching higher values where geological controls favour the development of elongated narrow basins'.

The bifurcation ratio of all the ten small basins have been calculated and the same have represented in the table II.

Table II
Bifurcation Ratio (Rb)

Name of the Basins	N_1/N_2	N_2/N_3	N_3/N_4	N_4/N_5	N_5/N_6	Bifurcation Ratio (Rb)
Nihang Langso	4.64	4.11	4.25	2	2	3.4
Barbung Langso	4.15	4.5	6	2	-	4.16
Langkangtang Langso	2.82	4.73	5	3	-	3.89
Arnan Langso	4.59	3.29	6	4	-	4.47
Pak, Langso	4.24	3.44	4	4	-	3.92
Bar Langso	4.46	4.33	3	1	-	3.20
Langterai Juri	3.53	3.75	2	2	-	2.82
Sangri Langso	4.24	8.33	3	-	-	5.19
Majangri Langso	4.53	3	5	-	-	4.18
Tarapung Langso	3.93	5	3	-	-	3.98

The average bifurcation ratio of ten basins confirm the observations of the above mentioned geomorphologists. The ratios range between 3.00 to 5.00. The exceptions are the basins of Langterai Juri and Sangri Langso having the mean bifurcation ratios of 2.82 and 5.19 respectively. This departure is the result of elongated shape of the river.

Ginsti and Schneider (1965) have advocated that bifurcation ratios within a region decrease with the increasing order.

$$Rb_1 < Rb_k$$

'k' stands for successive increasing orders.

The general trend of bifurcation ratios confirm with the above hypothesis because there is a general trend of decrease in the bifurcation ratios of two basins viz Bar Langso and Langterai Juri (decreasing bifurcation ratios with increase in orders). The rest eight basins shows the mixed conditions.

Ginsti and Scheneider (1965) have further propounded that 'basins of equal order but variable areas tend to have the smallest bifurcation ratios in the smallest areas, the ratio increases with increasing areas up to a certain size beyond which the bifurcation ratios tend to become constant'. This hypothesis can be applied to these ten small basins. The six 5th order basins show that basin Langterai Juri has smallest area and also has the lowest bifurcation ratio (2.82), while the basin Arnon Langso has the largest area and its bifurcation

ratio (4.47) is the highest. The rest three 4th order basins also show the same tendency, the basin Sangri Langso has the largest area as well as highest bifurcation ratio (5.19). The 4th order basin, Majangri Langso is the only exception. This is because of not only the area, but also other factors like structural characteristics of rocks, lithology, slopes, etc. play dominant role in deciding the branching of streams. Thus it may be argued that bifurcation ratio has no dependence on basin area and may not be correlated with that variable.

Law of Stream Number:

Some definite relationship exists between the orders of the basins and numbers of stream segments. Horton and Strahler have propounded an inverse geometric series of the numbers of stream segments and orders and have stated 'that the number of stream segments of successively lower orders in a given basin tends to form a geometric series beginning with a single segment of the highest order and increasing according to constant bifurcation ratio'. They have recommended the following equation of stream number.

$$N_u = R_b (K - U)$$

Where,

N_u = Number of stream segment of a given order.

R_b = Constant bifurcation ratio.

K = Highest order of the basin.

Horton further worked out the following formula (using constant R_b) to find out the total numbers of stream segments of whole drainage basin.

$$\sum_{U=1}^K N_u = \frac{R_b^K - 1}{R_b - 1}$$

Where, K = highest order of the basin

Horton has used constant bifurcation ratio in this equation which is not possible in reality, therefore, the practical application of this rule becomes doubtful. When the numbers of stream segments of different orders are plotted on a semi-logarithmic graph paper, a straight line of regression representing negative exponential function model is obtained.

In the present study, stream numbers (N_u) have been plotted against order on semi-logarithmic graph paper using the following equation of negative exponential function model as suggested by Strahler. The regression co-efficient (b) for each plot have been calculated and the same have been represented on the graphs (Fig. 8.).

$$Y = a e^{-bx}$$

$$\text{Log}_e Y = \text{Log}_e a - bx + 1 \text{ (Epsiton)}$$

Where, Y = Number of stream segments.

x = Stream order (u)

a = Constant

and b = Regression co-efficient.

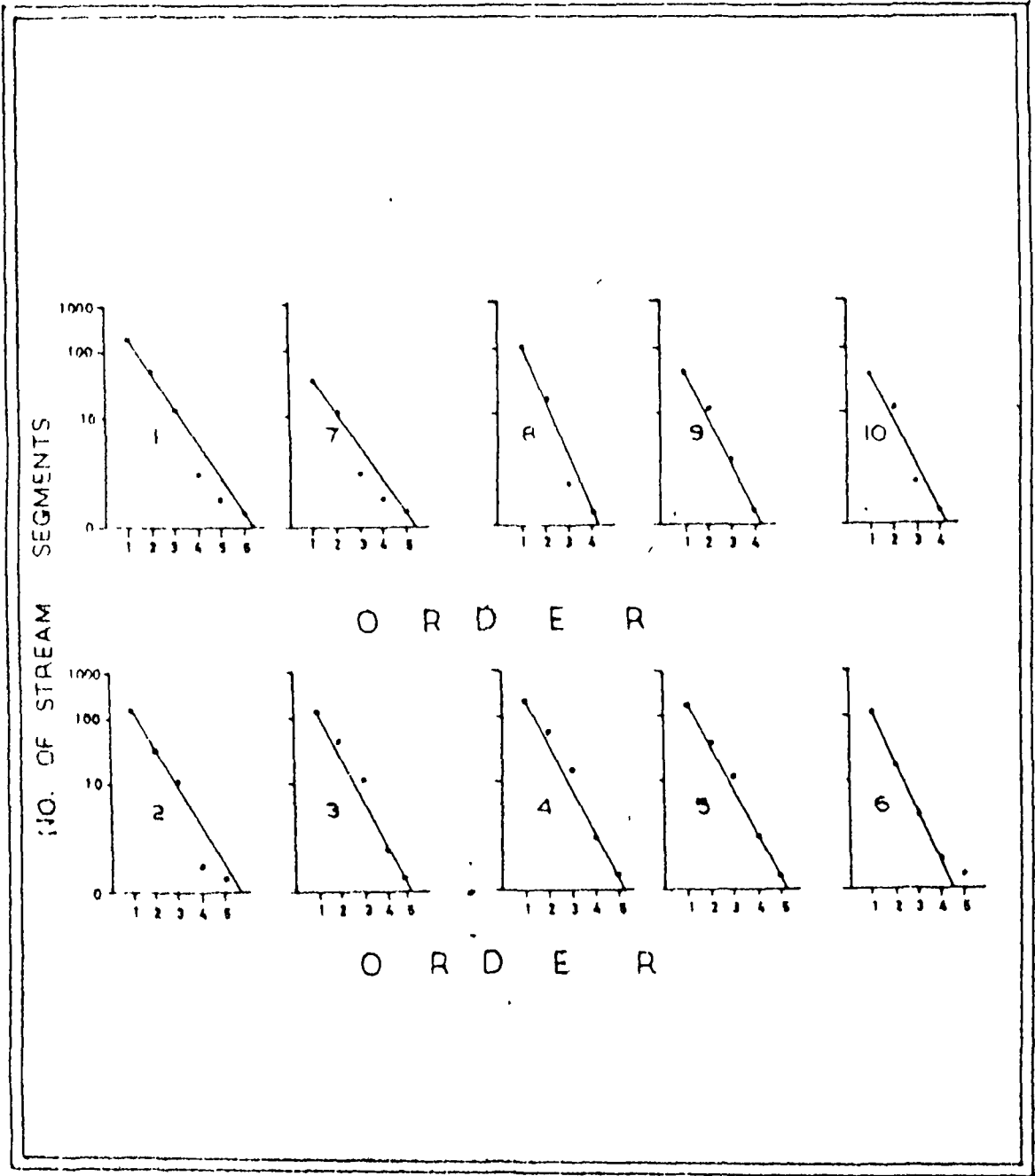


FIG 8

It is apparent from the Fig. 8 that when the number of stream segments are plotted against successive orders of the streams, the graphs for the 5th order basins show that the Pak and Bar Langso basin have indicated almost a straight line except the deviation of the 3rd and 5th orders' stream number. In other words, the number of stream segments of the various orders are proportional to the orders except the 3rd order and the 5th order of Pak and Bar Langso basins respectively.

The three fourth order basins show that, except for the Sangri Langso and Majangri Langso basins, the other basin Tarapung Langso has shown deviation on the 2nd and 3rd order and the points are not on a straight line. The only one 6th order basin Nihang Langso has made a straight line to a lesser extent except the 4th and 5th orders.

The deviation of the stream numbers from the straight line indicates the affect of various factors which caused this deviation. This deviation is due to the underlying rocks and unfavourable conditions for the development of the stream network. The surface drainage system is not well developed due to the lack of relief and relatively low rainfall. Hence, the number of streams are not found in proportion to the orders. Therefore, Barpung, Langkangtang, Arnan, Langterai etc. basins show a linear relationship, but with small deviation from a straight line.

Law of Stream Length:

The stream length is a significant morphometric parameters

of the drainage basin as it helps in the calculation of drainage density. The stream lengths of different orders of all the basins have been measured in kilometer and represented in Table III. The total length of various orders have no significance because they may not be compared. Therefore, mean lengths of each order have been calculated which have been arranged in Table IV.

Table III
Stream Length(Lu)
Length of each Order in km

Name of the Basins	Stream length (in kms)						Total Length
	1st Order	2nd Order	3rd Order	4th Order	5th Order	6th Order	
Nihang Langso	134	37	14	11	4	2	202
Barpung Langso	114	32	12	10	3.5	-	171.5
Langkangtang Langso	78	42.5	14	6	14	-	154.5
Arnan Langso	137	43	18.5	12	9	-	219.5
Pak Langso	101	24	15	6.5	2	-	148.5
Bar Langso	48	14	5	5	2	-	74
Langterai Juri	23	7.5	5.5	3	0.5	-	39.5
Sangri Langso	46	15.5	9	3	-	-	73.5
Majangri Langso	34	7	6	3	-	-	50
Tarapung Langso	33	9	4	6.5	-	-	51.5

Table IV
Mean Stream Length

Name of the Basins	Mean Length in kms					
	L ₁	L ₂	L ₃	L ₄	L ₅	L ₆
Nihang Langso	.41	.53	.82	2.75	2	2
Barpung Langso	.51	.59	1.0	5	3.5	-
Langkangtang Langso	.39	.60	.93	2	14	-
Arnan Langso	.38	.54	.77	3	9	-
Pak Langso	.43	.44	.94	1.63	2	-
Bar Langso	.41	.54	.83	2.5	2	-
Langterai Juri	.43	.5	1.38	1.5	.5	-
Sangri Langso	.43	.62	3	3	-	-
Majangri Langso	.50	.47	1.2	3	-	-
Tarapung Langso	.56	.60	1.33	6.5	-	-

Generally, the first order stream segments have the shortest mean length but the mean length increases with the increase in order. All the streams follow this postulation except some departures in certain orders of a few streams. For

example, the rivers Nihang Langso, Majangri Langso, and Langterai Juri are the exception. The Nihang Langso basin shows that the mean lengths of 4th order is higher than the 5th and 6th order. The Majangri Langso indicates the mean lengths of 1st order higher than the 2nd order. The Langterai Juri basin is also shown that the 4th order stream length is higher than the 5th order.

Horton (1945) has postulated a law of positive geometric progression between cumulative mean lengths and stream orders. Wherein the cumulative mean lengths of stream segments increase geometrically with successive increase in stream orders with constant length ratio. The model of law of stream length is called positive exponential function model and is expressed through the following equation.

$$\bar{L}_u = \bar{L}_1 R_L^{(u-1)}$$

Where, \bar{L}_1 = Mean length of 1st order

$$R_L = \frac{\bar{L}_u}{L_u - 1} = \text{constant length ratio}$$

This theoretical model may not be applicable to the natural stream system in its totality because constant length ratio seldom exists, as is evident from Table IV. Wherein significant variations in length ratios may be noted in all the drainage basins.

When the cumulative mean lengths of stream segments

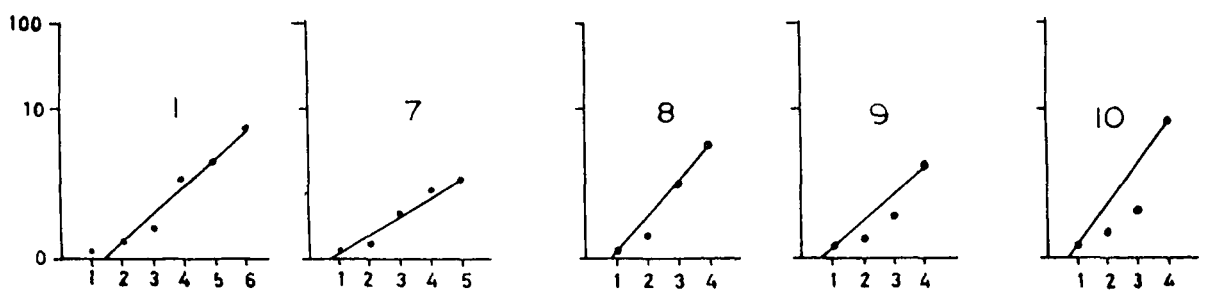
(Table V) are plotted on the ordinate against the orders on the

Table V
Cumulative Mean Stream Length
(in kms)

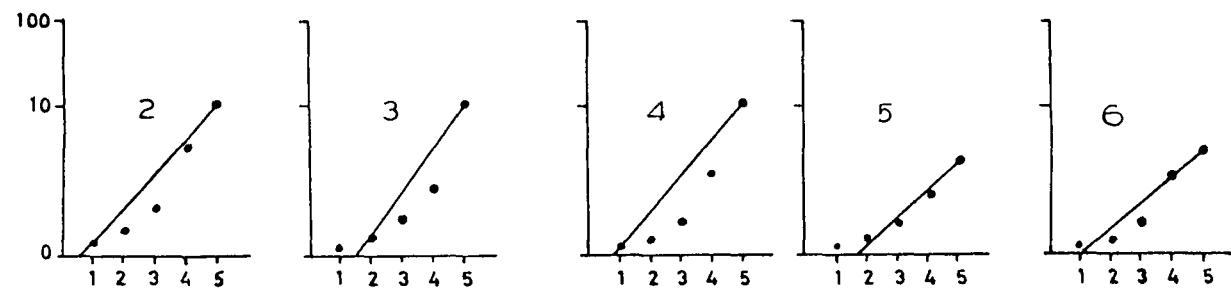
Name of the Basins	Order (u)					
	1	2	3	4	5	6
Nihang Langso	.41	.94	1.76	4.51	6.51	8.51
Barpung Langso	.64	1.23	2.23	7.23	10.73	-
Langkanglang Langso	.39	.99	1.92	3.92	17.92	-
Arnan Langso	.38	.92	1.69	4.69	13.69	-
Pak Langso	.43	.87	1.81	3.44	5.44	-
Bar Langso	.41	.95	1.78	4.28	6.28	-
Langterai Juri	.43	.93	2.31	3.81	4.31	-
Sangri Langso	.43	1.05	4.05	7.05	-	-
Majangri Langso	.50	.97	2.17	5.17	-	-
Tarapung Langso	.56	1.09	2.42	8.92	-	-

abscissa on a semi-logarithmic graph paper a straight line of positive exponential function model is derived. The regression lines for all the basins have been drawn (Fig. 9) on the basis of the following regression equation:

CUMULATIVE MEAN STREAM LENGTH (KM)



O R D E R



O R D E R

FIG 9

$$Y = a e^{bx}$$

$$\log_e Y = \log_e a + bx$$

Where,

- Y = cumulative mean length
 x = order (u)
 a = constant
 and b = coefficient of regression.

It is clear from the Fig. 9 that, when the cumulative mean stream lengths are plotted against successive orders of the streams, the graphs for the 5th order show that Pak and Langterai Juri basin indicate almost a straight line except the deviation of 1st and 2nd order and 2nd and 4th order respectively of the two basins. Rest four basins show the points are much deviated from the straight line.

The three 4th order basins also indicate same pattern. except Sangri Langso basin, rest two basins Majangri and Tarapung show their 2nd and 3rd order length, much deviation from the straight line. The Nihang Langso which is a 6th order basin shows its deviation on the 1st, 3rd and 4th order.

The deviation of the cumulative mean stream lengths from the straight line indicate the effect of various factors. Stream length data from all these ten basins illustrate that, like the first 'law' of drainage composition, geometric regularity is not maintained perfectly. The deviation from the straight line show that the valley network is not fully developed. The organizations

of fluvial hierarchies, as manifested in the laws of stream numbers is not maintained properly due to differences in geologic structure and variation in rainfall. Moreover, the stream lengths from the toposheet are measured as if projected onto a horizontal plane. This technical factor hinders the researcher to get exact lengths of various orders of stream segments.

Sinuosity Indices:

The shape of the open link in terms of geometric structure of drainage lines involves the calculation of departure of observed path (O_L) from the expected path (E_L) of a river from its source to its mouth. It is supposed that the expected path of the river will be in a straight line. The calculation of such deviations presents a great problem because 'it is not always clear where the terminating points for the observation should be located' (Magget and Chorley, 1969, p. 59). Sinuosity indices of the drainage line help in studying the effect of terrain over river course and vice-versa. The present study includes the calculation of sinuosity index of the ten small drainage basins of the whole basin.

Smart and Surken (1967, pp. 965-966) measured the systematic deviations from a straight line path and curves of considerable symmetry, whose dimensions were proportional to the size of the channel and they recognised two types of shapes of a drainage line viz (i) wandering and (ii) meandering. The wandering path may be calculated by relating the length of the observed path(O_L)

to the length of the expected path (E_L). Schumm (1956) expanded the above ideas and after measuring the deviations from a straight line path presented 5 categories of channel sinuosity viz (i) Straight ($U_L/E_L = 1.00$), (ii) transitional, (iii) regular, (iv) irregular and (v) tortuous ($U_L/E_L = > 2.00$) as shown in Fig. 10.

Muller (1968) modified the difficulties found in Schumm's method and presented his model of sinuosity index. This model explains the effects of hydraulic and topographic controls on the courses of the streams. He measured the length of the channel (CL), the length of the valley between the base of the valley walls (VL), the shortest distance between the source and mouth of the river ($Air L$) and presented his model in the form of the following equations.

$$(i) CI = \frac{CL}{Air L}$$

where CI = channel index

$$(ii) VI = \frac{VL}{Air L}$$

where VI = valley index

$$(iii) HSI = \% \text{ equivalent of } \frac{CI - VI}{CI - 1}$$

where HSI = Hydraulic sinuosity index

$$(iv) TSI = \% \text{ equivalent of } \frac{VI - 1}{CI - 1}$$

where TSI = Topographic sinuosity index

$$(v) SSI = \frac{CL}{VL}$$

where, SSI = Standard sinuosity index.

CHANNEL PATTERNS

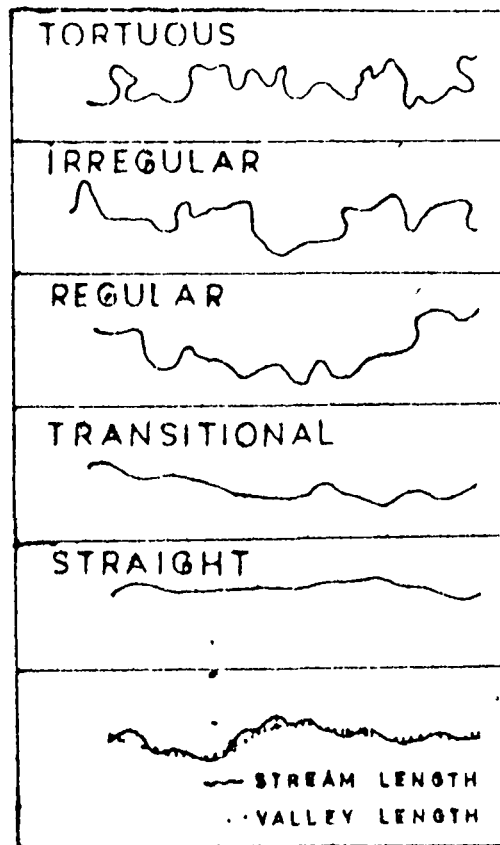


FIG:10

The present study aims at the application of Muller's model of sinuosity indices for the ten small drainage basins. The river courses are classified into three categories on the basis of the standard sinuosity index viz (i) Straight river course (SSI = 1.00), (ii) Sinuous course (SSI = 1.00-1.50) and (iii) Meandering course (SSI = >1.50).

It is clear from the Table VI that the Standard Sinuosity Indices are ranging from 1.2 to 1.62. These we can put in the second and third categories of the Standard Sinuosity Index, ranges from 1.00 to 1.50 and above 1.50 indicating Sinuous and Meandering courses respectively of the streams.

The hydraulic and topographic sinuosity indices (HSI and TSI) are the valuable morphometric tools which help in determining the stages of the basin development as well as determining the controlling factors of sinuosity. The following basins show high Topographic sinuosity Index - Nihang Langso (0.67 per cent), Barpung Langso (0.58 per cent) and Pak Langso (0.56 per cent). This indicates that these basins are in their early stages of basin development. On the other hand, the basin Sangri Langso (0.10 per cent) shows the old stage of development. While the basins Sangri Langso (0.91 per cent), Bar Langso (0.67 per cent), Langterai Juri (0.66 per cent) and Majangri Langso (0.6 per cent) show high percentage of Hydraulic Sinuosity Index (HSI). This indicates that these basins are in their mature stages of basin development.

Table VI

Sinuosity Indices

Name of the Basins	CL	VL	Air L	CI	VI	HSI (%)	TSI (%)	SSI = $\frac{CL}{VL}$
Nihang Langso	15	12.5	7.5	2	1.67	.33	.67	1.2
Barpung Langso	20	16.5	11.5	1.74	1.43	.42	.58	1.21
Langkangtang Langso	24	18	13	1.85	1.38	.55	.45	1.33
Arnan Langso	21	14.5	9	2.33	1.61	.54	.46	1.45
Pak Langso	8	6.5	4.5	1.78	1.44	.44	.56	1.23
Bar Langso	12	9	7.5	1.6	1.2	.67	.33	1.33
Langterai Langso	4.5	3.5	3	1.5	1.17	.66	.34	1.29
Sangri Langso	10.5	6.5	6	1.77	1.08	.90	.10	1.62
Majangri Langso	7.5	6	5	1.5	1.2	.6	.4	1.25
Tarapung Langso	11	9	7.5	1.47	1.2	.57	.43	1.22

CHAPTER FOUR

AREAL ASPECTS OF THE BASIN

Basin area is a significant morphometric parameter affecting the spatial distribution of a number of morphometric attributes such as drainage density, drainage texture, stream frequency, slopes, dissection index, circularity ratio etc. Therefore, Anderson (1957) termed it as a 'devil's own variable because almost every watershed characteristics is correlated with area'. The first order basins have the smallest mean basin areas and the successive higher orders show increase in the areas culminating in the largest area of the highest order of the trunk stream. The areas of the ten small basins are measured with the help of Planimeter and shown in the Table VII.

Basin Perimeters:

The areas of the drainage basins are delineated by watersheds which termed as basin perimeters. Basin perimeters can be directly correlated with the square roots of basin area and increase on decrease in the basin perimeter indicates increase or decrease respectively in the basin area. In the

Table VII
Area, Perimeter and Stream Length

Name of the Basin	Area (in sq.kms)	Perimeter (in km)	Stream Length (in km)
Nihang Langso	47.25	37	202
Barpung Langso	48	33	171.5
Langkangtang Langso	52.5	41	154.5
Arnan Langso	55.5	47	219.5
Pak Langso	35.5	23	148.5
Bar Langso	16	18	74
Langtarai Juri	7	10	39.5
Sangri Langso	22	20	73.5
Majangri Langso	12.5	17	50
Tarapung Langso	12.75	21	51.5

present study, this hypothesis is tested and has been conformed to a certain extent. Exception is the Arnan Langso and Barpung Langso basins (Table VIII). Above all, it has been found that basin perimeter and area have inter-dependent among each other.

Basin perimeter is positively correlated with channel length. The perimeter increases with increase in channel length and the former decreases with the decrease in the latter. In the present study, the coefficient of correlation is calculated

for ten basins and found to be high positive correlation.

Basin area, basin perimeter and channel length are the significant morphometric variables which determine the shape, size and genetic aspect of drainage basin.

DRAINAGE DENSITY

The density of stream network has long been recognised as a topographic characteristics of fundamental significance. This arises from the fact that network density is a sensitive parameter which in many ways provide the link between the form attributes of the basin and the processes operating along the stream course. If drainage basins were uniformed in every aspect stream flow would be proportional to the length of water course in a basin because channel flow is much more rapid than the alternative flow on or beneath slopes. As the extent and density of the network reflect topographic lithological, pedological and vegetational controls and because they also incorporate the influence of man, network density promises to be a valuable index.

Lithology, climate and vegetation cover are the major factors for the varying density. Infiltration capacity is also a important factor which is directly affected by lithology and all are closely related to climate. Chorley (1957) and Chorley and Morgan (1962) compared three lithologically similar areas from Britain and confirmed a close relationship between drainage

density and rainfall.

Horton¹ defined drainage density as a ratio of total length of all streams segments in a given drainage basin to the total area of that basin. Drainage density is quotient of the total length of all streams and the total drainage area and can be derived as given below:

$$Dd = \frac{Lu}{Au}$$

where, Dd = Drainage Density

Lu = Total lengths of all segments

Au = Total area of the basin

Drainage density, thus is expressed in terms of length of streams per unit of area. Recently Gregory and Gardinar² have developed a new method wherein the numbers of river junctions in a grid square of 4 sq.kms (2x2 kms) are counted and these values are transformed to an estimate of drainage density (Dd) by the equation, $Dd = 0.2446N + 2.0852$. This was derived from a linear regression ($n = 0.72$) of 1:10, 560 regular edition drainage density upon 1:25,000 provisional edition number of river junction³. This scheme suffers from painstaking job of unnecessary calculation with no satisfactory results.

¹ Horton, R.E. : Erosional Development of Streams and their Drainage Basins : Hydrophysical Approach to Quantitative Morphology, Bull.Geol.Ser.Amer. Vol.56 (1945),pp. 275-370.

² Gregory, K.J. and Gardiner, V : Drainage Density and Climate, Annals of Geomorphology (1975), pp. 287-98.

³ Op.cit, pp. 293-94.

The upper Kaliyani river basin occupying an area of 380 sq.kms has been divided into 380 grids of one sq.km and the Dd values for each grid have been derived and the same have been grouped as High, Moderate and Low as shown in the Fig. 11. It is apparent from the table that the drainage density of the aforesaid basin ranges from 1 to 6 kms/km². These values are grouped into below 2, 2-4 and 4-6. The moderate category of Dd occupies the maximum 60.20 per cent of the total area. While the low category occupies only 8.68 per cent of the total area. The high drainage density is found in the middle and the south western corner of the aforesaid basin and it occupies 31.12 per cent of the total area.

The variation in drainage density has been related to precipitation effectiveness, vegetation index, permeability of terrain, climatic character and to structure particularly rock type.

Table VIII
Areal Extent of Drainage Density

Sl.No.	Dd Km/km ²	Category	Area (in sq.kms)	Percentage of Area
1	<2	Low	33	8.68
2	2 - 4	Moderate	228.75	60.2
3	4 - 6	High	118.25	31.12

UPPER KALIYANI BASIN
DRAINAGE DENSITY

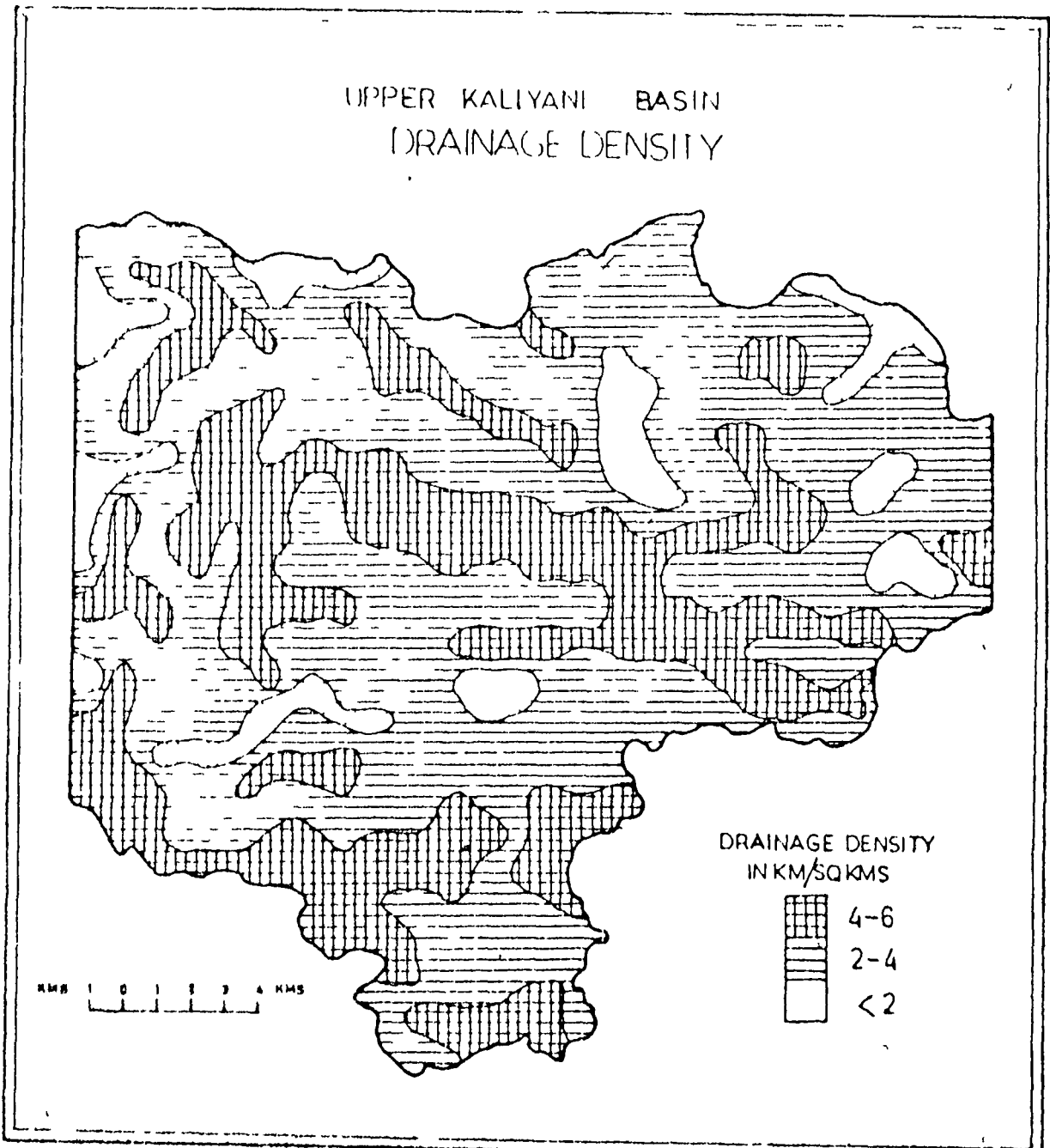


FIG.11

A rise in drainage density occurs with increasing relief. This is clear from the work of Doornkamp and King (1971). It is interesting that Peltier (1962), in a pilot study, found that there was a much steeper rise in drainage density with increasing mean slope in tropical areas than any other climatic zone.

STREAM FREQUENCY

Stream frequency is one of the most important morphometric parameter of the drainage basin. Horton (1945) introduced stream frequency (or drainage frequency) F_s as the number of stream segments per unit area. Stream frequency is calculated by the total number of streams in a drainage basin divided by the area of the basin, or the stream frequency is calculated by the total number of streams in a unit area in a given drainage basin.

$$F_s = \frac{N}{A}$$

Where,

F_s = Stream frequency

N = Total number of streams

A = Unit Area.

In the present study of stream frequency, this method is applied.

The drainage of the basin on the scale 2 cm to 1 km is first divided into two centimetres grids, thereby, making each grid to represent one sq.km. The total number of streams crossing to each grid is calculated and then put in the centre of the grids. The minimum and maximum values stand at 3 and 16 respectively. These values are classified here as coarse, moderate, high and very high groups. Then a isopleth map is drawn to the class groups. The resulting map of stream frequency brings out the regional or spatial variation clearly.

Table IX
Areal Extent of Stream Frequency

Sl.No.	Stream Frequency (Fs)	Category	Area (in sq.kms)	Percentage of Area
1	<6	Coarse	49.50	13.03
2	6 - 9	Moderate	258.25	67.96
3	9 -12	High	54.50	14.34
4	>12	Very high	17.75	4.67

It is clear from the Table IX that the moderate stream frequency covers 68 per cent area of the basin. While very high stream frequency group occupies only 4.67 per cent of the total area. The very high frequency group is seen in the southern corner of the aforesaid basin. The coarse and high

stream frequency occupy more or less the same proportion of area. The coarse group is generally found in the periphery while the high group is found as a patches here and there in the basin.

The study of the Fig. 12 reveals that the frequency of streams in the upper Kaliyani river Basin depends upon a number of variable factors, which may be divided into two categories :

- (1) Natural Factors
- (2) Map Factors

Natural Factors:

The important factors which effect the stream frequency of the basin are as follows and the relative significance of these factors varies from place to place.

- (a) Climate
- (b) Lithology and structural characteristics of rocks
- (c) Relief
- (d) Infiltration capacity and
- (e) Vegetation

Climate plays a very important role in the basin as far as the stream frequency is concerned. The average annual rainfall and the number of rainy days are quite adequate in

UPPER KALIYANI BASIN
STREAM FREQUENCY

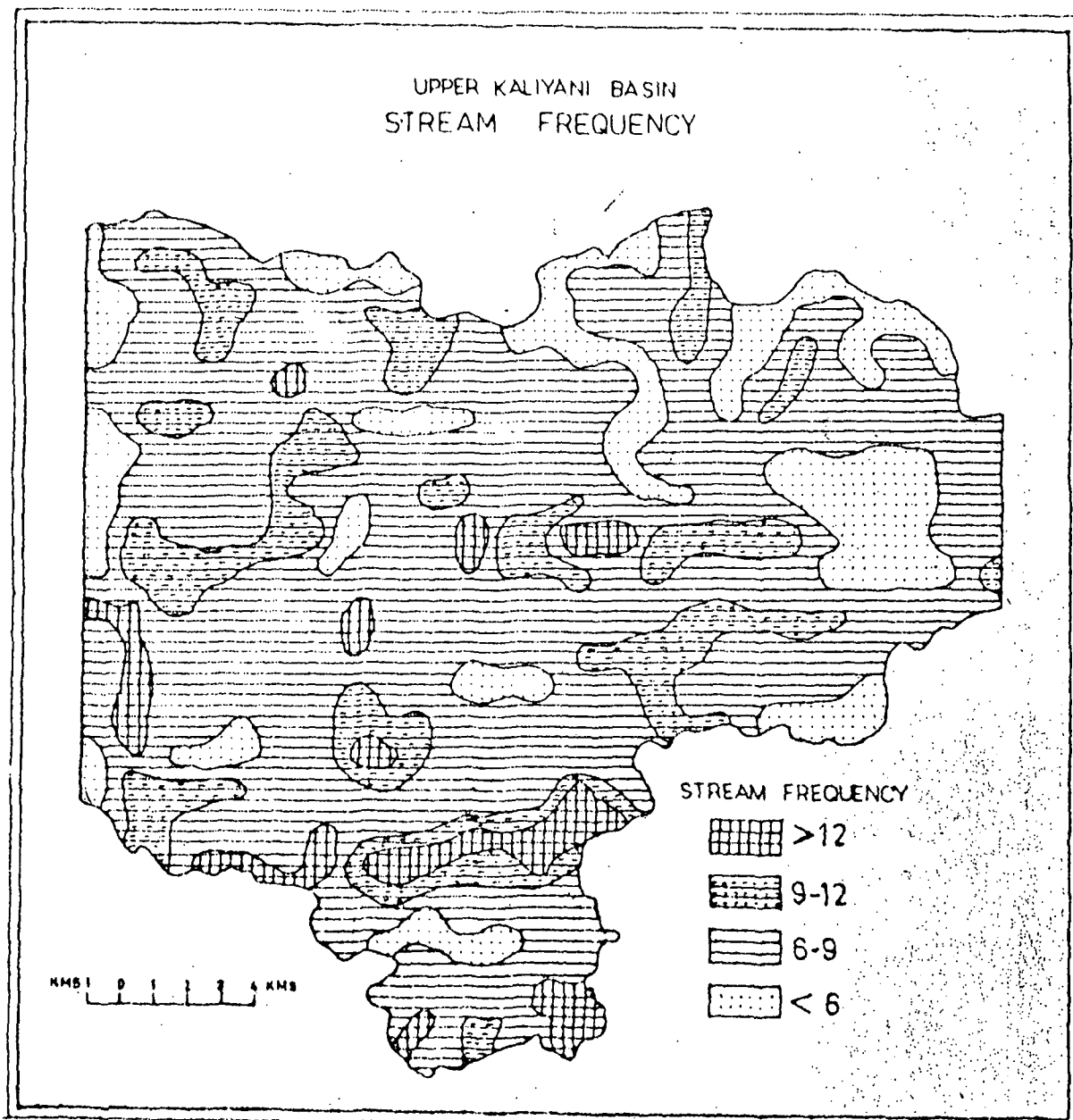


FIG.12

this basin. Thus, it is climate of this basin which accounts much for the development of the drainage system in this basin, thereby, moderate and high stream frequency is seen.

The relief and average slope play very significant role in the stream frequency of this basin. Drainage lines will develop in large number upon an irregular surface than upon one which lacks conspicuous relief.⁴ It will be seen from the relief map (Fig. 3) that the relief is low in the central area and it increases to the southern part. The central part shows moderate slope in large areas which explains the coarse stream frequency in this area. It is interesting to find that wherever the average slope is low, the stream frequency is also more or less low.

According to Thornbury⁵, Horton has called infiltration capacity, or what is more commonly referred to as the permeability of the mantle rock and bed rock, is probably the most important single factor influencing the drainage texture. Here, the basin has shown less amount of percolation and this result the moderate to high stream frequency.

Technical Factors:

The most important technical factors involved in determining the stream frequency are the scale of the map and the

⁴ Thornbury, W.D. (1971): Principles of Geomorphology, New York.

⁵ W.D. Thornbury : Principles of Geomorphology, John Wiley and Sons, London, 1954, p. 128.

accuracy of mapping. Needless to mention with large-scale maps one will get a more accurate picture of drainage frequency than from small-scale maps. In this study though the author has used the topographic sheets of the scale 1:50,000 due to the lack of larger scale topographic sheet. The aerial photograph gives a better picture of stream frequency which is not available in this area due to restriction.

DRAINAGE TEXTURE

Drainage texture is the most promising and useful variable in the morphometric analysis of drainage basin, because it is related to the dynamic nature of the network of the stream segments and the area of the basin. This variable, therefore, can be fruitfully used for the classification of drainage basin, for the spatial prediction of processes and for the interpretation of temporal changes of drainage network. It may be regarded as dependents on climate and catchment characteristics.

An important geomorphic concept is drainage texture, by which we mean the relative spacing of drainage lines.⁶ Horton (1945) defines drainage texture on the basis of stream frequency (number of streams per unit area). In fact, the term texture has been used loosely and no successful have been made to search out a quantitative parameter for its calculation. According to

⁶ Smith, K.G. : Standards for Grading Texture of Erosional Topography, American Journal of Science, Vol. 248 (1950), pp. 655-68.

Savindra Singh (1976), 'the term texture must be used to indicate relative spacing of the streams in a unit area along a linear direction'.

For the purpose the area should be divided into grids of one sq.km (1x1 km) in area. Then the numbers of stream crossing along both the diagonals should be counted and averaged. Further the numbers of stream crossing should be calculated per km length on the basis of the following formula which is given by Savindra Singh.⁷ The quotient of the unit length (1 km) and numbers of stream crossings would be the average spacing of the stream per km length. The data so derived may be classified into very fine, fine, moderate, coarse and very coarse. But the qualifying data for the classification may vary according to the scale and magnitude of grid square simultaneously the ratio may remain the same.

$$T = AS = \frac{l}{t}$$

Where, $l = 1 \text{ km}$

AS = Average Spacing

$t =$ numbers of stream crossings per km length

$$\text{when, } t = \frac{t_1 + t_2}{\sqrt{2}}$$

Where, t_1 and $t_2 =$ numbers of stream crossings along the diagonals.

⁷ Singh, S.: On the Quantitative Parameters for the Computation of Drainage Density, Texture and Frequency : A Case Study of a Part of Ranchi Plateau, National Geographer, Vol. XI, No.1(1976), pp. 21-31.

Table X
Drainage Texture

Drainage Texture (Spacing of Stream per km length in km)	Texture Category	Area (in sq.kms)	Percentage of Area
0.2 - 0.4	Fine	44.5	11.71
0.4 - 0.6	Moderate	253	66.58
0.6 - 0.8	Coarse	64.75	17.04
0.8 - 1.0	Very coarse	17.75	4.67

On the basis of the above formula, the upper Kaliyani river basin has been divided into 380 grid squares (one sq.km each) and the average spacings of the stream per km length have been calculated (Table X). The minimum and maximum values come to 0 and 1. Four classes of fine (0.2 - 0.4), moderate (0.4 - 0.6), coarse (0.6 - 0.8) and very coarse (0.8 - 1.0) at uniform class intervals have been worked out (Fig. 13). The moderate texture which secured first position covers 67 per cent area of the aforesaid basin. On the other hand, very coarse category occupies only 4.67 per cent of the area of the basin.

The spatial variations of texture in the basin are due to many factors climate, vegetal cover, infiltration capacity (permeability of the mantle rock and bed rock) and geologic

UPPER KALIYANI BASIN
DRAINAGE TEXTURE

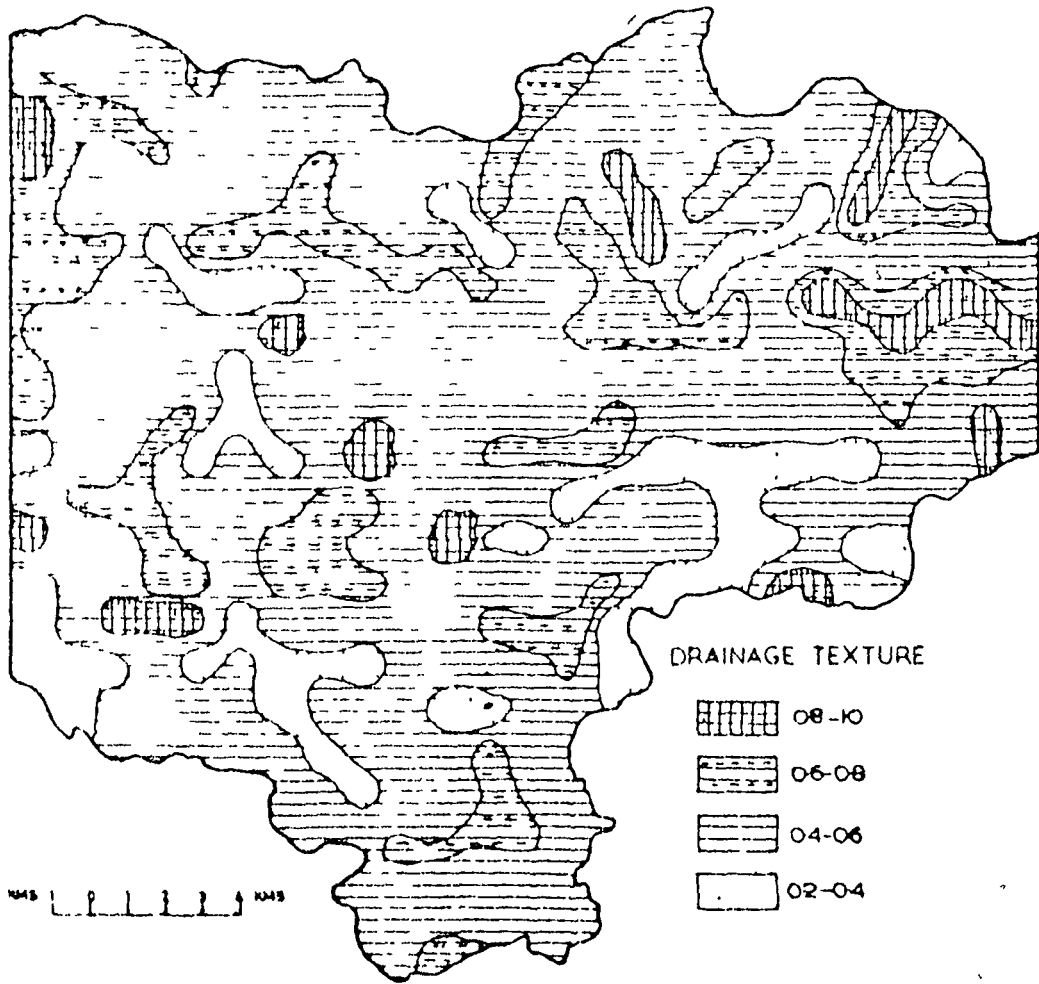


FIG 13

structure are significant controlling factors of drainage texture.

Constant of Channel Maintenance:

Schumm (1956, p. 607) used the inverse of drainage density as a property termed constant of channel maintenance (C.C.M.). Thus,

$$C.C.M. = \frac{1}{D} = \frac{A_u}{\sum_{i=1}^N L_i}$$

Specifically, the C.C.M. tells the number of square miles or kms of watershed surface required to sustain on linear mile or km of channel. This is reciprocal of drainage density.

For the present study, the C.C.M. for all the 10 small drainage basins have been calculated and represented in Table XI.

It is apparent from the table XI that the C.C.M. ranges from 0.18 to 0.34 in these basins. The basin Langkangtang Langso requires 0.34 sq.kms to maintain 1 km length of stream, which is the highest. On the other hand, the basin Langterai Juri requires the lowest amount of area i.e. 0.18 sq.km to maintain 1 km length of stream. It is interesting to note that there exist an inverse relationship between Drainage density (Dd) and constant of channel Maintenance (C.C.M.). The basins which

Table XI
Constant of Channel Maintenance (C.C.M.)

Name of the Basins	Area (in sq.kms)	Length (in km)	Dd	C.C.M. (sq.km/km)
Nihang Langso	47.25	202	4.3	0.23
Darpung Langso	48	171.5	3.6	0.28
Langkangtang Langso	52.5	154.5	2.9	0.34
Arnan Langso	55.5	219.5	4.0	0.25
Pak Langso	35.5	148.5	4.2	0.24
Bar Langso	16	74	4.6	0.22
Langterai Juri	7	39.5	5.6	0.18
Sangri Langso	22	73.5	3.3	0.30
Majangri Langso	12.5	50	4.0	0.25
Tarapung Langso	12.75	51.5	4.0	0.25

represent the highest drainage density figures are seen showing lowest constant of channel maintenance figures. This can be stated in a different way like, while it is the relief which controls drainage density i.e. higher the relief, the drainage density is high. In this case, higher the relief, lower the C.C.M. value and vice-versa. Therefore, it is confirmed that Schumm's formula for $C.C.M. = \frac{1}{Dd}$ is applicable for this study.

Circularity Ratio :

It is the ratio of circumference of a circle with same area as the basin to basin perimeter. Miller (1953) used this for the first time which is similar to elongation ratio. These values range around 1. The highest values of these basin indicates that the basin is the largest compared to other basins.

Circularity index on ratio deals with the ratio of the drainage basin area (A_b) to the area of a circle having the same perimeter. It is a quantitative approach to compare precisely, area of the actual form of the drainage basin to the area of the circle encircled by the perimeter of the same drainage basin. High, medium and low values of basin circularity are correlated with early, middle and youth stages of the drainage basins.

$$C.I = \frac{A_b}{A_a}$$

Where , C.I = Circularity Index

A_b = Drainage basin area

A_a = Area of a circle having the same
perimeter.

It is apparent from the Table XII(a) that the circularity ratio varies from 0.36 to 0.88 in the basins. These circularity indices are classified into three stages viz. Early (above 0.80), Middle (0.50-0.70) and Youth (below 0.50). The five small basin out of ten basins have attained the middle stages

Table XII(a)
Circularity Indices(CI)

SL.No.	Name of the Basins	C.I.
1	Nihang Langso	0.43
2	Barpung Langso	0.55
3	Langkangtang Langso	0.39
4	Arnan Langso	0.51
5	Pak Langso	0.84
6	Bar Langso	0.62
7	Langterai Juri	0.88
8	Sangri Langso	0.69
9	Majangri Langso	0.54
10	Tarapung Langso	0.36

(Table XII(b)).while two basins viz. Langterai Juri and Pak Langso have reached the early stage of basin development.

Table XII(b)
Circularity Indices with Stages

Stages	Number of Drainage Basins	C.I.	Percentage of the Total Area
Early	2	Above 0.80	13.75
Middle	5	0.50 - 0.70	49.84
Youth	3	below 0.50	36.41

DRAINAGE PATTERN

The process of tributary growth and 'adjustment to structure'⁸ give much significant detail to water-sculptured landscape. The adaptation of streams to the underlying structure makes the drainage pattern. A distinction can be made between the patterns of the individual streams and their spatial relationship to one another. The texture of the drainage network depends on the amount of rainfall and the proportion of runoff i.e. the perviousness of the rocks. In a basin, the drainage pattern is influenced by the slope, lithology and structure. The development of a particular drainage pattern is directly related to the stages of the cycles of erosion.

There are three types of drainage pattern recognised in this basin (Fig. 14). The fourth type i.e. the dendritic pattern is insignificant.

- 1) Radial
- 2) Rectangular
- 3) Parallel

Radial Pattern:

In this type of drainage pattern, the streams flow from the central part to all the directions. This type of drainage

⁸ Wooldridge, S.W. and Morgan, K.S. (1969) : An Outline of Geomorphology, London, Longman.

UPPER KALIYANI BASIN
DRAINAGE PATTERNS

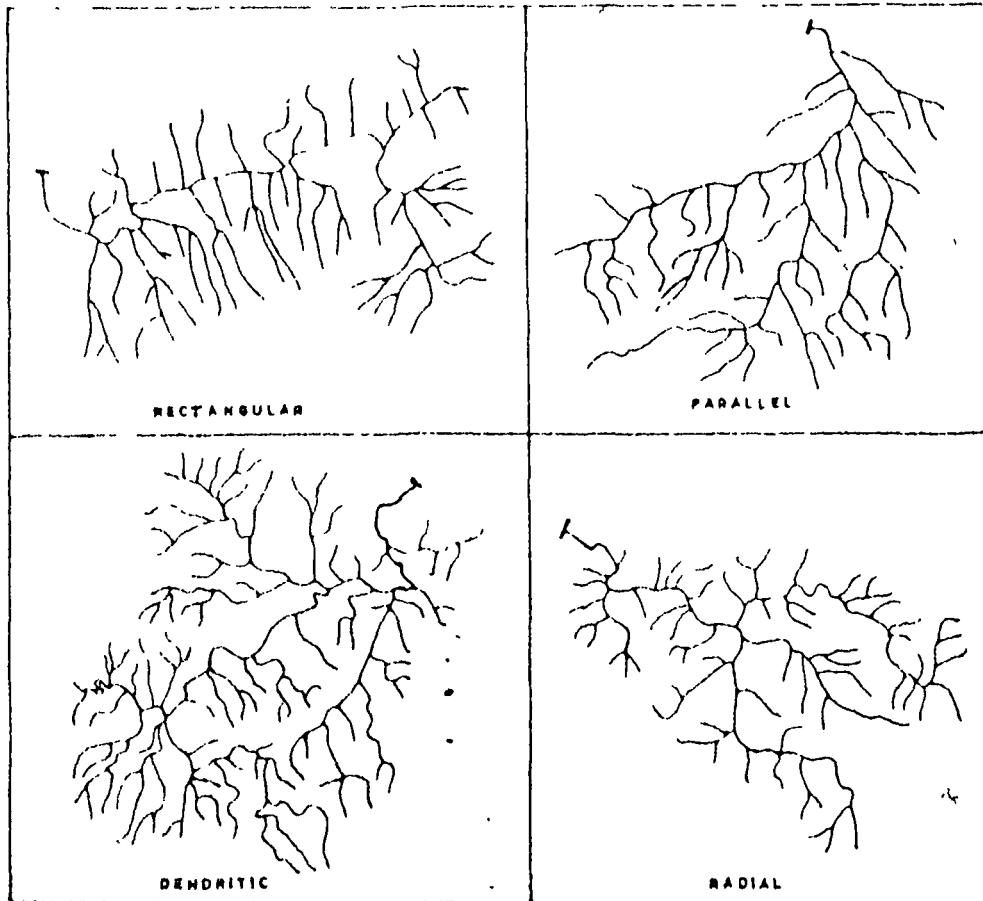


FIG 14

pattern develops on flanks of domes and volcanoes where there is no effect of differing rock resistance.⁹

It is apparent from the drainage map (Fig. 5) that there is a wide distribution of radial drainage pattern in the aforesaid basin. This may be due to the presence of isolated peaks from which the streams are directed to all sides. The radial pattern is also prominent in the north-western corner and the central part of the basin.

Rectangular Pattern:

A system of well-developed joints, fractures zones or small faults gives rise to a rectangular drainage pattern with many straight streams segments and sharp angular changes in stream direction. Geology and landforms play the most important role in the development of rectangular drainage pattern. It reflects either a regional pattern of intersecting joint systems, or a pronounced set of joints that cross belts of bed rock at a high angle.

If we examine the drainage map of the basin, we find the central portion of the basin is dominated by well developed rectangular drainage pattern. The south-eastern portion of the basin also occupies by this type of drainage pattern

⁹ Schumm, S.A. (1973): *Fluvial Geomorphology in River Mechanics, River Morphology* (Edited).

UPPER KALIYANI BASIN

DRAINAGE



FIG.5

Parallel Pattern:

Joints, cracks and regional slope play a significant role in the development of parallel types of drainage pattern. Parallel pattern of drainage is quite prominent in the entire part of the aforesaid basin. A few parallel pattern of drainage are noticed in the southern part which flows parallel to the steep slope of the terrain. For the development of parallel drainage pattern the lithology and structural controls have much role to play.

CHAPTER FIVE

RELIEF ASPECTS OF THE BASIN

Slope Analysis:

An analysis of slopes is very important for a better understanding of the processes of landform evolution. Very rarely we do find areas on the earth's surface that are absolutely level. All landform is composed of slopes, sediments of a slight gradient and sometimes of a very complex nature. Geomorphology is concerned with landform and so, an understanding of the processes which control slopes must form an important element of study.

Some slopes such as actively eroding sea cliffs or the free faces of the high valley sides may consist of bare rock. A slope may be formed by a covering of weathered rocks resting on bed rock. Another type of slope consists of bed rock forming the basal slope covered by weathered rock, often including a surface layer of soil.

Development of Slope:

The slopes develop by the different process which are acting upon the landforms. There are three important factors

which influence the development of slopes.

(a) The earth surface has relief and hence slopes because a variety of internal endogenetic processes have raised parts of it to considerable elevations above sea-level. The initial slopes caused by such movement will depend on the rapidity of the uplift and the material which is being raised. Many of the older theories of slope development envisaged separate periods of uplift followed by slope and river development.

(b) Both the weathering and transport of materials on slopes are affected by climate. In considering slopes it is important to realise the influence of ages of glaciation and periglaciations. Through out most of British isles slopes are the result of quaternary glaciation and peri-glaciation. The slope may be mantled by material deposited there by glaciers and present a form quite unlike the bed rock profile they underlie.

(c) The activity of the stream at the base of the slope is important. It removes the material conveyed to it from the surrounding slopes. It sometimes moves around the bottom of the valley and under cuts its banks. Thus, the slipping of materials on slopes and the removal of sediment from stream banks are but parts of a continuous involved in drainage basin dynamics.

(d) Man has had a considerable influence on slope development through agricultural and industrial activities.

The study of slopes in this basin will bring the nature and characteristics of development of slope profiles. The

impact of man in this basin may be noticed in the modification of slope profiles. The domination of tribal population has its own cultural impact in the practice of agriculture.

The angle of slope is a fact of geomorphic and economic significance. The nature of lithology, process of erosion, nature of tectonic movement, climate of the region and the time factor play an important role in determining slopes into straight, concave or convex surfaces. Debris accumulation are common features at the base of the steep slope.

The relationship between slopes and the flowing water is significant. A steep gradient allows a greater speed of flow, this in turn helps the stream to scour its course deeply. A zigzag course seldom occurs on such steep gradients except when it is produced by excessive over loading or due to physical obstructions in the stream. The steep slopes provide the velocity required for the transportation of all the load supplied to the streams from above. The areas without vegetations cover suffer from erosion the most. However, on the slope zones the erosional changes are continuous.

The slopes have great influence on landuse. The four slope categories may further be scrutinised and useful informations may be gather on the basis of slope sub-units for micro-regional studies. A knowledge of slope gradients is indispensable for the construction of metalled roads and rail tracks. In fact, slopes play an important role in determining how far and how fast

development can proceed.¹ The intimate acquaintance with slopes and awareness of their importance can however, only be acquired through persistent field observation.

Hill Slope Elements:

Studies on the nature of formation of hill slope elements, surficial deposits and landuse in different parts of the country had been very few and even though a few studies have been carried out by a few geographers interested in the field of geomorphology. The north-east region of India which is mainly a hilly terrain, excepting the plains of Brahmaputra with multicyclic landscapes lacks totally in such studies. In India, it is not yet fully realised by geographers the amount of useful data, one can get from a detailed study of hill slope elements, surface soils and landuse of terrain. Such type of detailed studies could be formed as a basis for the further planning of the agricultural landuse as well as for horticulture and development of forest resources and selecting favourable sites of settlements and housing.

The starting point for modern hill slope study in the analysis of hill-slope form by Wood (1942) who distinguished the four elements that appear in a fully developed slope. These are from the top:

- 1) the waxing slope

¹ Miller, O.H. and Summerson, C.H., Slope Zone Map, Geog.Review, Vol. L. April, 1960, pp. 194-202.

- ii) the free-face
- iii) the debris or talus slope and
- iv) the pediment

Each element undergoes a semi-independent evolution though, of course, on a given slope the elements to a greater or lesser extent react upon each other. Any element may be absent from a given slope profile, which is then not fully developed.

Wood's (1942) contribution is sufficiently important as it is basically uniformitarian in character for it applies to hill slopes all over the world in all stages of development, and indeed of all geological ages.

In this chapter, an attempt has been made to study the actual characteristics of hill slopes and soils of some of the hill slopes of the study area.

Hill slope elements, as discussed earlier, are broadly classified into four divisions by Wood (1942) and King (1967) and others. These are crest or convex slope, scarp or free-face, debris slope and pediment. 'The nature of slope profiles around Shillong is quite different from the Vindhyan country'². The scarp or free face is missing and the whole surface is covered by thick debris slope, in other words the scarp or free face is not fully developed or it has disappeared through time

² Rai, R.K., Patnaik, S.N., Panda, P. and Singhania, V. (1980): Landuse and Hill Slope Around Shillong, Meghalaya, p. 2.

or has been covered by debris and ultimately the free face is now totally missing.

The Waxing Slope or the Crest:

This part of the hill slope is the convex crest of a hill scarp, usually related to the zone of weathering. It is usually longest where the depth of surficial detritus is greatest e.g. where streams and rivers have recently become incised and the hill slope have not had time to adjust to new stable conditions. But, the crest is slightly convex and it is less extensive in nature here. The surface is covered with thick weathered radish laterite soil.

Debris:

The debris slope consists of detritus slipped or fallen from the free face and resting at its angle of repose against the lower part of the scarp face. As this debris is weathered to finer detrital grades, it is removed under erosion and so the debris slope retreats in essential conformity with the free face above, clearly, if the free face retreats more rapidly (after penck) the quantity of waste supplied will build up the debris slope to bury the lower scarp face so that a balance is generally struck between these two elements.

In this case, immediately below the crest, the slope gradually is covered by debris and continues to a long distance.

The angle of slope varies from 30 to maximum up to 70 degrees. It is an extensive zone of slopes profiles. In the study area, the debris surface is most active zone from farming point of view. The angle of the debris slope depends upon the rate of erosion and the accumulation of the material coming down from the crest.

Pediments :

The pediment is a broad concave ramp extending from the base of the other slope elements down to the bank or alluvial plain of an adjacent stream. Frequently its profile approximates to a hydraulic curve and it is unquestionably fashioned under the action of running water, though the cut-rock surface may often be mantled with surficial deposit.

In the slope profiles of the area the next to debris slope another slope element is pediment surface. In the study area, the pediment surface is quite important from landuse and settlement point of view. The pediment surface in this area are over Archaean granites. These seem to have been formed by sheet wash and gradual recession of the debris slope. In the present study area, the pediment surface is not well marked. Thus in comparison to Vindhyan country and Deccan Traps, the pediment surface is not well developed in this region. The sheet erosion is a main process of surface wash. The surface generally consists of heterogeneous materials of varying particles which accumulate on the lower parts of the hill slopes. The particles which have

been transported by gravity and running water have accumulated on this surface.

Method of Study:

Several methods have been suggested by Raisz and Henry, Smith, Wentworth and others to determine the average angle of slope. So, in the present study we have adopted Wentworth's method of average slope determination. It is a general and random method and hence, is simple.

First of all a contour map of the basin is prepared from the toposheet of scale 1:50,000. The basin is then divided into grid of straight lines at right angles at one mile distance. The total length of grid lines of each square is measured in miles and the number of contour crossing for each square is counted. Then by applying the Wentworth's formula, the angle of slope is determined.

$$\text{Tan } \phi = \frac{N \times I}{3361}$$

Where, N = Average number of contour crossing in one sq.mile.

I = Contour Interval

3361 = A constant figure

ϕ = Angle of slope.

In this case, ϕ gives the average angle of slopes for the whole area. As the angle of slope varies from one part of

the area to the other, the average angle of slope in each square is determined independently using the same formula. The values of the angles of slope in degree are then written down on each square and then, isolines are drawn in order to show the areas of equal angle of slope.

For the study of average slope it is always better to have a detailed map on one inch to one mile or even one inch to four miles scale. That will give a better picture of the variation in the slope. But because of non-availability of detailed topographic sheet of the basin, the present study of average slope is based on 1:50,000 sheet. So, with such a small scale map one cannot expect a very good analysis of the slope. Here an attempt has been made to visualise a general picture of the average slope of this basin.

The average slope of this basin ranges from 1.9 to 8.9 degrees. These derived values grouped into four classes viz below 3, 3-5, 5-7 and above 7. These four classes are called gentle, moderate, moderately steep and steep slopes as shown in Fig. 15.

Table XIII
Areal Extent of the Slope Unit

Categories of Slope	Slope (in degrees)	Area (in sq.kms)	Percentage of Area
Gentle	Below 3	4	1.05
Moderate	3 - 5	137.75	36.25
Moderately Steep	5 - 7	207.75	54.67
Steep	Above 7	30.5	8.03

UPPER KALIYANI BASIN
AVERAGE SLOPE

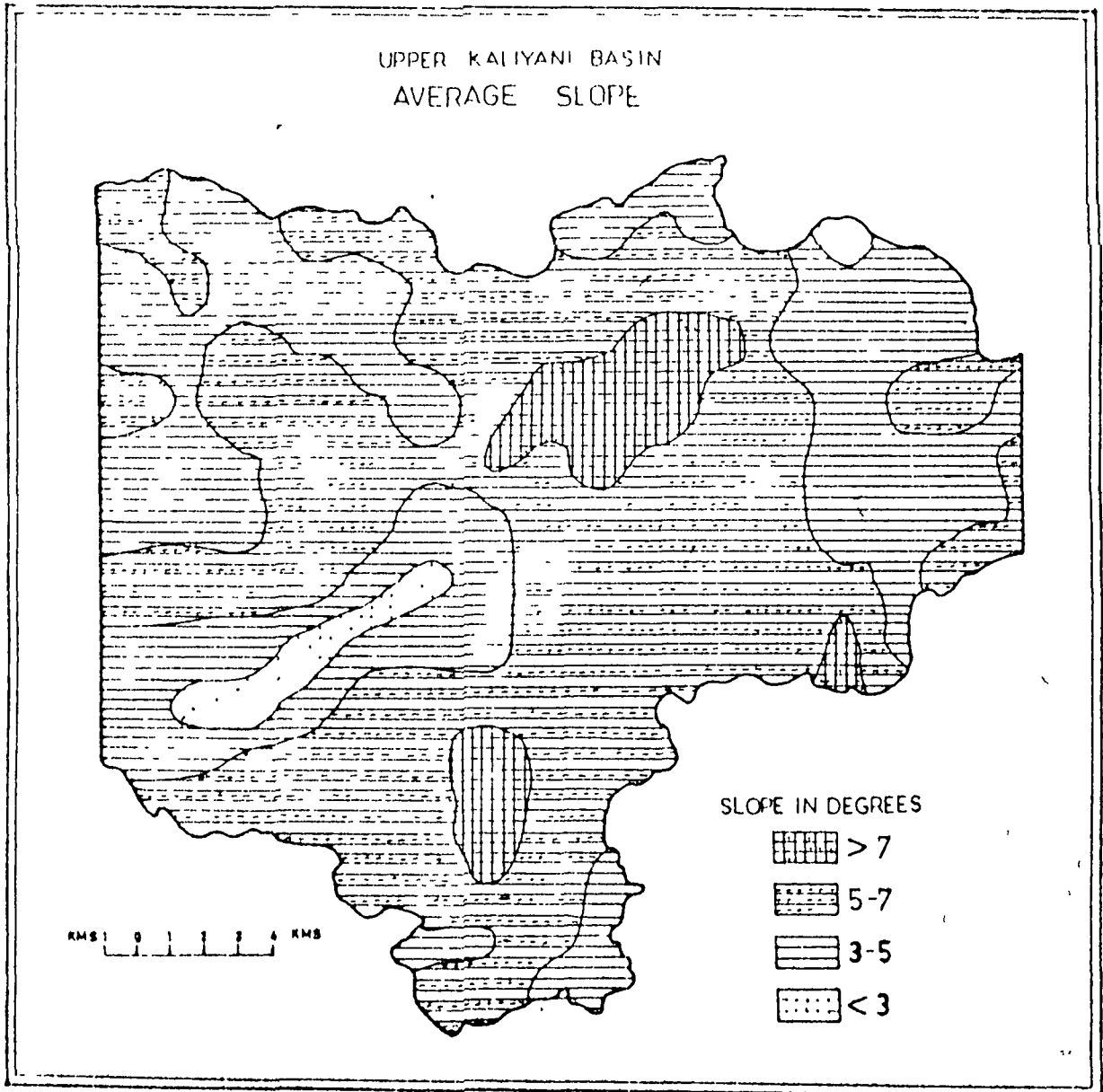


FIG 15

Gentle Slope (Below 3°):

This slope category is found between 0 to 3 degrees. Only two small patches of gentle slope are available in this basin. One patch is found on the south-west corner and the other is on the north-east corner of the study area. The area under gentle slope is only 1.05 per cent. The slopes having 0 to 3 degree gradient are suitable for agricultural purposes and encourage permanent settlement in this basin.

Moderate Slope (3° - 5°):

The second category has a gradient between 3 to 5 degrees. This moderate slope occupies 36.25 per cent of the total area. The western part of the basin is dominated by this category of slopes. The eastern part also shows the moderate slope. This slope category is also considered to be a good site for housing and agricultural purposes.

Moderately Steep Slope (5° - 7°):

The third category of slopes varies generally from 5 to 7 degrees. It is apparent from Table XIII that moderately steep slope occupies 54.67 per cent of the total area. At this gradient tractors can not be used in the field and ploughing is quite arduous.³

³ Macgregor, D.R. : Some Observation on the Geographical Significance of Slopes, Geography, Vol.43,1957,pp. 167-73.

Steep Slope (Above 7°):

The fourth category has a gradient above 7 degrees. It indicates undulating uplands. Walking in the slope of this gradient requires considerable efforts. Steep slope occupies only 8 per cent of the total area. It is found in the middle of the basin as patches. These areas are well drained by small and large streams and rivers with its numerous tributaries. This part is thickly forested.

The researcher has found that due to long geological history of the basin, the topographic and structural characteristics of landforms are quite complex. The basin exhibits the multicyclic landscape of isolated rounded hills varying in height.

Dissection Index:

Dissection Index is now one of the probabilistic models for morphometric analysis of the stage of development of not only cyclic landscape of Davisian concept but also the landscape built-up under shallow water conditions or in the big river valleys in the geological past. The present study is an attempt to find out intensity, spatial pattern and the probable causes of dissection and its effect on the landform of the aforesaid basin. It is assumed that the heterogeneity of the existing landscape has much effect on the dissection pattern of the landscape. It is also assumed that the

dissection is more in the vicinity of rivers and it is less away from them especially in the regions of local depression.

Dissection Index deals with the relationship of the real area to the projected area between contours and is calculated as proposed by Slauctajas. But this scheme does not give a vivid picture of dissection of a particular region in detail. Dissection Index, therefore, is expressed in terms of ratio between maximum relative relief and maximum absolute relief. Dissection is directly related to the stage of cycle of erosion. Very high values of dissection closely correspond to youthful stage whereas low values are related to penultimate stage. The trend of the values of dissection index in the valley tends to decrease from early stage to youth stage.

Method of Study:

For the study of this morphometric characteristics dissection index, the basin is divided into 2.56 sq.kms grids. This helps to compute the dissection indices and to find out the relative relief of each grid square. Isopleth maps are drawn for the dissection indices (Fig. 16). For better understanding of the areal pattern of the morphometric characteristics a distribution table showing the dissection indices with percentages of areas are prepared.

It is apparent from the table XIV, that the Dissection

UPPER KALIZANI BASIN
DISSECTION INDEX

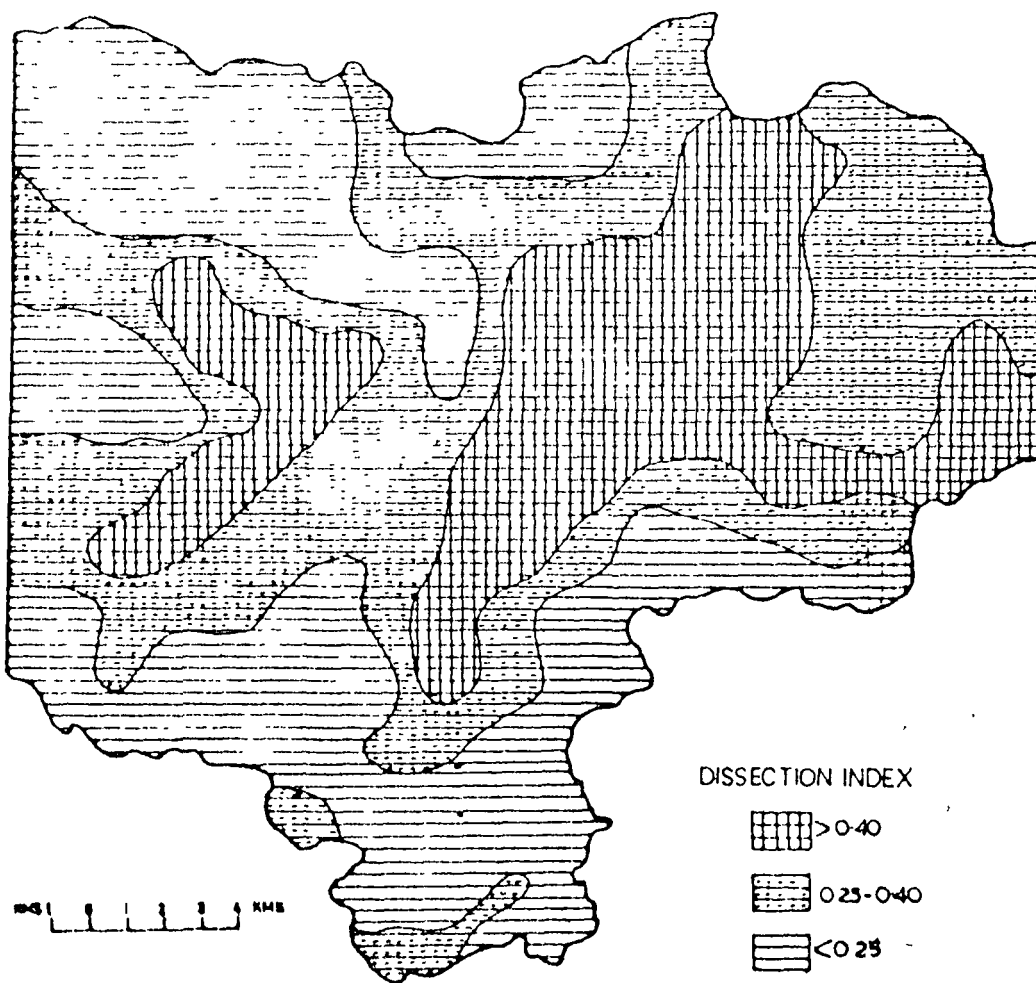


FIG:16

Table XIV
Dissection Indices

Dissection Index	Types	Percentage of Areas
Below 0.25	Youth	36.25
0.25 - 0.40	Middle Youth	41.38
Above 0.40	Early Youth	22.37

Index varies from 0.11 to 0.67 in this basin. The middle youth stage occupies 41.38 per cent areas of the total areas. While early youth covers only 22.37 per cent areas.

The present study of dissected landform of the afore-said basin reveals a complex response of structure, process, form and stage to this sub-tropical basin. Investigation shows that the spatial pattern of dissection varies with the varying conditions of structure, process and forms. Though the study reveals that the fluvial agents are the main sculptor of the dissected topography of this basin, other agents may also be responsible for curving out the land surface.

Relative Relief:

The term 'relative' as used by geomorphologists differs from the concept from used by climatologists or statisticians. In fact, the current usages of the two terms of relief and relative relief imply that these two are synonymous. Therefore,

the concept of relative relief in morphometric analysis is facing problem. Smith (1935) observed : 'The difference in elevation between highest and lowest points within a limited area may be regarded as the absolute or local relief of that area..... The expression 'relative relief' is here used to imply regional comparison, therefore, the relation between areas and the delineation of regions with similar relief become important objectives'. Thus, the maximum height difference in each grid square is its absolute or local relief and, as the isopleths on the basis of such values show the relation of each area to adjacent regions of lesser or greater relief, it becomes relative relief. Thus, local relief and relative relief are practically the same both in expression and magnitude. Thauer also considers the difference in elevation between the highest and lowest points in a grid as its relative relief. The general definition of relative relief is the difference in the altitude between the highest and lowest points within a limited area is regarded as its relative relief.

The relative relief varies from 100 metres to 400 metres in this basin, and these are classified into three groups as high (above 250 m), medium (150 - 250 m) and low (below 150 m). The central portion of the basin is dominated by the high relative relief. While the periphery of the basin is occupied by low relief. A comparison of two isopleth maps of Relative relief (Fig. 17) and Dissection Index (Fig. 16)

UPPER KALIYANI BASIN
RELATIVE RELIEF

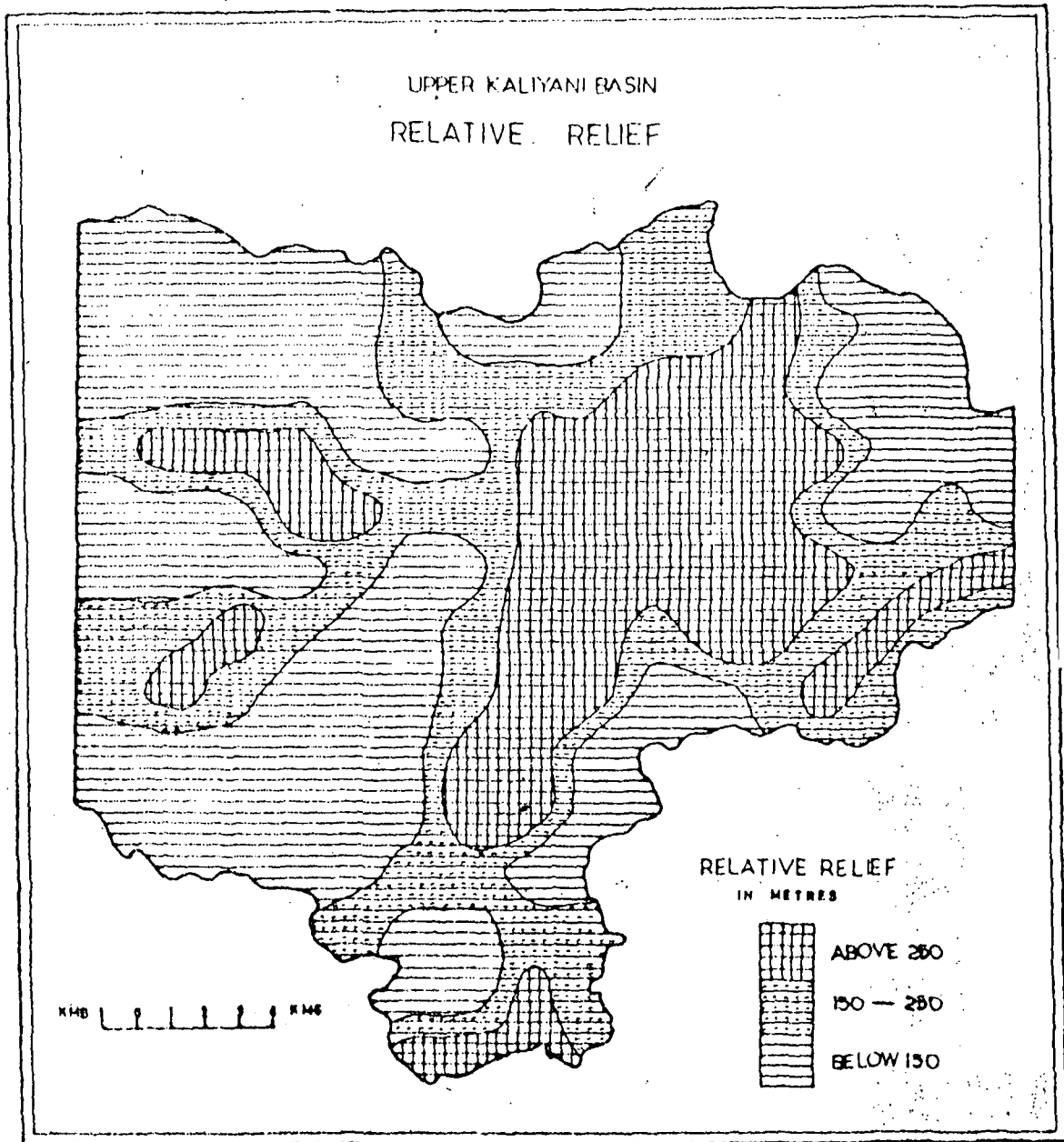


FIG.17

reveals that a high relative relief shows a high degree of dissection index. Thus, it indicates a high positive correlation between the relative relief and dissection index.

Altimetric Frequency Curve:

It is a fact that the highest parts of the landscape will be the last to lose remnants of the former erosion surfaces because the dissection spreads later along the river valley. So, with the help of altimetric frequency curve, the remnants of former erosion surfaces can be recognised.

It is clear from the Fig. 18, that the maximum frequency occurs at the height of 700 to 800 metres. On the other hand, above 800 metres, the frequency decreases continuously. Again at the height of 400 to 500 metres, the frequency increases to 63. This altimetric frequency curve study suggests that this surface is only in the developing stage and marked only along the river valleys.

Longitudinal Profiles:

From 2 cm equal to 1 km map, the length of upper Kaliyani river has been measured and with a vertical scale of 1 cm to 100 metres and horizontal scale of one cm to one km, the longitudinal profile of this river has been drawn. The vertical scale is exaggerated by ten times here.

It is apparent from the Fig. 19 that there is no major

UPPER KALIYANI BASIN
ALTIMETRIC FREQUENCY CURVE

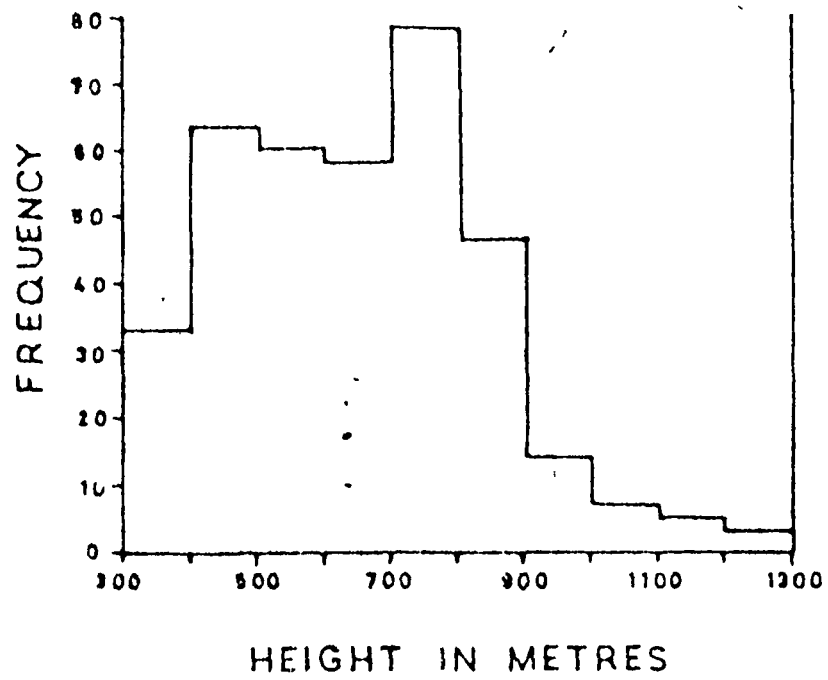
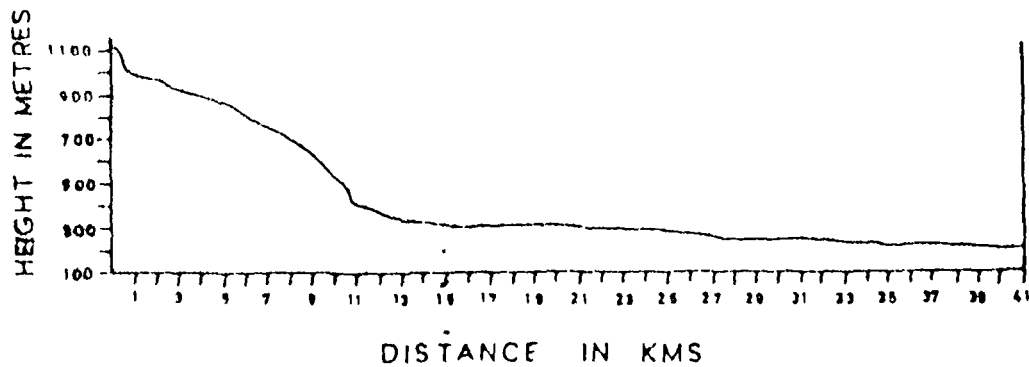


FIG:18

UPPER KALIYANI BASIN
LONGITUDINAL PROFILE



VERTICAL SCALE: 1CM = 100 METRES

HORIZONTAL SCALE: 1CM = 1KM

FIG:19

knick points in the profile. The profile between 400 and 1100 metres height, show a steep slope which indicate the possibility of rapids. The slope is gentle between 200 and 400 metres height which covers the maximum area. The lateral erosion is predominant in this area. The vertical erosion is more above the height of 400 metres.

Hypsographic Curve:

In 1940, Holmes used a hypsographic curve to show the proportions of the earth's solid surface above or below different altitudes. This familiar technique shows that most of this surface is at two main levels, the continental and the deep sea platforms. The curve is a summary or model of the whole surface of the earth. This is most conveniently done by using contour lines for the heights. The most accurate way to measure the area of an irregular shape is to use a polar planimeter.

$$a/A$$

Where, A = Total area

a = Total area - area below the
required contour

The hypsographic curve presents a generalisation of the surface character along with the areas incorporated in different height group. It is apparent from the Fig. 20 that due to the increase of height, the area under each group is decreasing in this basin. The maximum area is found between 300-500 metres group.

UPPER KALIYANI BASIN
HYPSOGRAPHIC
CURVE

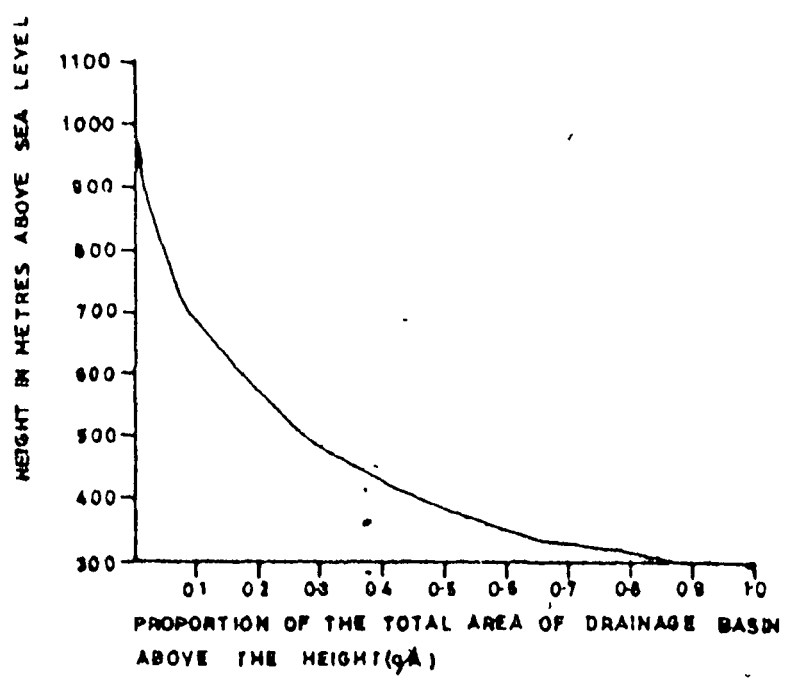


FIG:20

Hypsometric Curve and Integral:

In order to study the relief aspects of the area, hypsometric curve following Strahler's suggestion (1952) were constructed for the representative second, third, fourth and fifth order basins. To find the hypsometric integral, a hypsometric curve is constructed by reducing the real heights of the contours to a dimensionless ratio between 0 and 1. To do so, the difference between the highest point on the watershed and local base level is found out.

According to Strahler (1952), the hypsometric integral above 60 per cent, in between 60 per cent and 35 per cent and below 35 per cent are indicative of youthful, mature or equilibrium and old stages respectively.

Since, the hypsometric integral is 24 per cent in the aforesaid basin, it indicates that the basin is in the old stages of the cycle of erosion (Fig. 21).

UPPER KALIYANI BASIN
HYPSOMETRIC CURVE

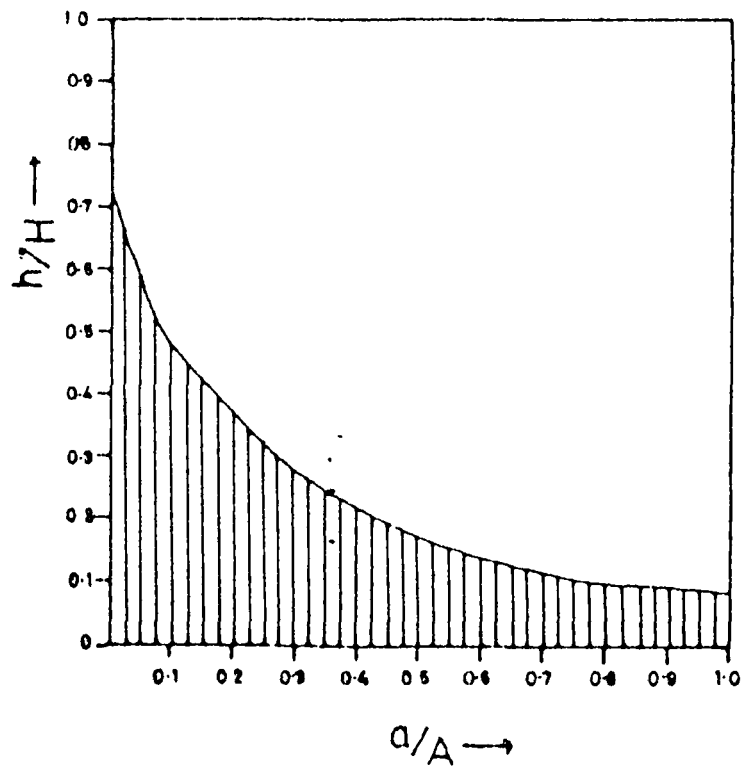


FIG:21

CHAPTER SIX

RELATION AMONG THE MORPHOMETRIC PROPERTIES AND CLASSIFICATION OF LANDFORMS

There are varying degree of complexity associated with geomorphological data. The simple way is to analyse a single characteristic of certain landforms. In many instances, however, the geomorphologists need to know the relations between two variables. This requires the use of bivariate statistics. But, when there are more than two variables to be analysed, it requires the use of multivariate statistics. In the present section an attempt has been made to study the relationship between the morphometric properties of six selected 5th order drainage basins of the upper Kaliyani river basin. The bivariate analysis is used in this study because the number of basins are few for the multivariate analysis.

Data Base and Method of Work:

The data which have been used for the present analysis fall into two distinct groups. Some of them are

obtained directly by measuring from the map. These include basin area, length of different order streams, number of streams under different orders etc. Other variables are derived from such direct measurement and include drainage density, stream frequency, bifurcation ratio, etc.

The toposheet which is used for the analysis is 2 cm to 1 km topographical map of Mikir Hills of Assam (Sheet No. 83 $\frac{K}{7}$) published by the survey of India. Areas are measured from this map by Planimeter. Length and distances are all measured by map measurer. These measurements are the horizontal equivalents of ground lengths. As a result of these measurements the available data for analysis consists of 20 variables as shown in the Data Matrix (Table XV), either measured or derived from those measured for the six-fifth order basins - Barpung Langso, Langkangtang Langso, Arnan Langso, Pak Langso, Bar Langso and Langterai Juri.

The relationships between the above mentioned morphometric properties have been obtained by simple correlation coefficient technique. Students 't' test was applied to determine the significant 'r' values at 0.05 level of significance.

Analysis:

The bivariate analysis of the 20 variables of the six 5th order basin reveals that some variables show positive relationship and the other variables show negative relationship. The area of the basin and other variables such as

Table XV

Data Matrix

Variables Basins	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Barpung Langso	48	114	32	12	10	3.5	0.51	0.59	1.0	5	3.5	224	54	12	2	4.16	3.6	1.21	0.55	33
Langkangtang Langso	52.5	78	42.5	14	6	14	0.39	0.60	0.93	2	14	200	71	15	3	3.89	2.9	1.33	0.39	41
Arnan Langso	55.5	137	43	18.5	12	9	0.38	0.54	0.77	3	9	363	79	24	4	4.47	4.0	1.45	0.51	37
Pak Langso	35.5	101	24	15	6.5	2	0.43	0.44	0.94	1.63	2	233	55	16	4	3.92	4.2	1.23	0.84	23
Bar Langso	16	48	14	5	5	2	0.41	0.54	0.83	2.5	2	116	26	6	2	3.2	4.6	1.33	0.62	18
Langterai Juri	7	23	7.5	5.5	3	0.5	0.43	0.5	1.38	1.5	0.5	53	15	4	2	2.82	5.6	1.29	0.88	10

Index to Table XV

<u>Serial No.</u>	<u>Variables</u>	<u>Unit</u>
1	Area of the basin	sq.kms
2	Length of 1st order stream	kms
3	Length of 2nd order stream	kms
4	Length of 3rd order stream	kms
5	Length of 4th order stream	kms
6	Length of 5th order stream	kms
7	Mean length of 1st order stream	kms
8	Mean length of 2nd order stream	kms
9	Mean length of 3rd order stream	kms
10	Mean length of 4th order stream	kms
11	Mean length of 5th order stream	kms
12	Number of 1st order stream	-
13	Number of 2nd order stream	-
14	Number of 3rd order stream	-
15	Number of 4th order stream	-
16	Bifurcation Ratio	-
17	Drainage density	kms of stream length/sq. kms
18	Standard sinuosity index	-
19	Circularity index	-
20	Perimeter	kms

length of 1st order stream (0.88), length of 2nd order stream (0.98), length of 3rd order stream (0.89), length of 4th order stream (0.81) and length of 5th order stream (0.75) show a significant positive relationship. There is a significant positive relationship between the basin area and mean length of 5th order stream (0.75). The basin area shows a high positive relation with the number of 1st order stream (0.87), number of 2nd order (0.97) and number of 3rd order stream (0.86). It is interesting to observe a high positive relationship between area of basin and bifurcation ratio (0.95). The relationship between area and Standard Sinuosity Index (0.23) is insignificant though it is positive. All the length of different stream orders show an insignificant positive relationship with the Standard Sinuosity Index. The bifurcation ratio shows a highly positive relationship with the number of 1st order (0.95), number of 2nd order (0.93), number of 3rd order (0.91) and number of 4th order streams (0.64). There is a significant positive relationship between drainage density and circularity indices. The basin area shows a very highly significant relationship with perimeter (.96). When basin area increases the perimeter also increases. This hypothesis is proved in the basin.

Another interesting significant positive correlation is seen between number of 1st order stream and number of 2nd order and 3rd order streams (0.75 and 0.84). This can be explained by the established fact that as the order number increases there

is a positive decrease of the streams in subsequent orders.¹ There exist a positive relationship between lengths and number of streams.

The area of the basin is negatively correlated with mean length of 1st order stream (-0.60), mean length of 3rd order stream at 95 per cent level of significance. The basin area shows a negative relationship with circularity index. There exists a negative relationship between the basin area and the drainage density which indicates that as the area increases the variable drainage density tends to decrease in a particular proportion. The drainage density and bifurcation ratio show a negative relation with each other. The circularity index has a significant negative correlation with bifurcation ratio (-0.58) and Standard Sinuosity Index (-0.55). In general, it can be noted that the drainage density is related inversely to almost all variables except the mean length of 3rd order streams and circularity index.

Classification of Micro-Geomorphologic Units:

For the classification of geomorphic regions, two points need to be borne in mind - the basis of classification and the factors to be considered. The basis of classification depends upon the size of the region under study, the areal distribution of various structural, lithological, topographical and climatical elements. When large areas of continents and sub-continents size are considered, the climate become the chief

¹ Strahler, A.N. (1969): Physical Geography, New York, John Willy and Sons.

factor for classification. But for smaller region, geological structure, lithology, relief features and erosional peculiarities are taken into consideration. While in still smaller area morphometric properties as slope, form of the ground, quantitative properties of streams and surface morphology are used as important criteria of micro geomorphic divisions.

It is already mentioned that the upper Kaliyani basin experienced the tropical monsoon climate. Being a small area, there is not a well-marked difference of climate. Therefore, this factor can not be used in demarcating the geomorphic regions. On the basis of the lithology, relief features, degree of dissection, slope and stream peculiarities, this basin can be divided into three geomorphic units.

1. The Central Low Land Section of the Basin
2. The Hilly Section of Southern Periphery
3. The Low Hilly Section of Northern Periphery.

The central low land section of the basin is a rolling plain which can be divided into two micro-geomorphic units

- (i) The western low land area
- (ii) The eastern low land area

The western low land area is composed of mainly by the Shillong group of rocks. The degree of dissection is from poor to medium type. The slope is also low to moderate. The stream frequency and drainage density are moderate category in

this geomorphic unit.

The eastern low land area is formed by the gneiss rocks of Archaean group. In the extreme end of this unit, the laterite soils are found. The drainage pattern is dendritic in nature. The maximum height of this unit is 300 metres. The degree of dissection is moderate to high. The slope is also moderate to moderately steep. Both the drainage density and stream frequency are medium in this unit.

The Hilly section of southern periphery shows the maximum height of this unit is 1200 metres. All the streams and rills originate in this unit flow to the low land of the middle of upper Kaliyani basin. The drainage pattern is parallel in this unit. The dissection index and slope are poor to medium in nature. The drainage density is high. Whole the unit is covered by a dense mixed jungle.

The third unit i.e. the low hilly section of northern periphery shows the maximum height of 800 metres. It is interesting to note that there is some hillock in this unit with high relief. The entire unit is dominated by the rectangular and parallel drainage pattern. The dissection index is poor to moderate. The average slope varies from moderate to moderately steep. The moderate category of drainage density dominates this unit.

CHAPTER SEVEN

CONCLUSION

The upper Kaliyani river basin is a part of the Mikir Hills which is considered as the extension of Meghalaya Plateau. The geologic and geomorphic history of this region is long and very complex.

The quantitative analysis of ten small basins reveals that there is a direct relationship between area and number of stream segments, while the area has no relation with the length of the stream. The hypothesis, that 'bifurcation ratios within a basin decreases with the increasing order' has been confirmed. The five basins Barpung Langso, Langkangtang Langso, Arnan Langso, Sangri Langso and Tarapung Langso are the exception. The Standard Sinuosity Index indicates that nine streams flow in a sinuous course while only Sangri Langso flows in a meandering course. The Nihang Langso, Barpung Langso and Pak Langso basins with a high Topographic Sinuosity Index (TSI) indicate that these basins are still in their early stages of development. On the other hand, the basins Sangri Langso, Bar Langso, Langterai

Juri, and Majangri Langso show a high hydraulic simosity index (HSI) which indicate that these four basins are in their late youth stage of basin development.

The study of drainage density brings out an interesting relationship with the relief. It has been found that a rise in drainage density occurs with increasing relief (superimposing relief map upon drainage density map). The increase in relief is supported with steep slopes and total precipitation also effect the drainage density of the basin. More than 60 per cent areas of the basin is covered by the medium drainage density. The drainage density and constant of channel maintenances show an inverse relationship between each other i.e. the basins which are having high drainage density have low C.C.M. figures. The stream frequency of the aforesaid basin varies between below six to above twelve streams per 4 sq.kms. It is found that the variation in stream frequency is directly influenced by the topography and structural controls due to the differences in rock resistance to erosion which are expressed in the landforms themselves. Climate plays a very important role in this basin as far as the stream frequency is concerned. The average annual rainfall in this basin is 1300 mm. Thus, it is the rainfall, relief, structural and lithological characteristic of rocks and average slope of this basin which accounts much for the development of stream frequency. The drainage texture groups are inversely related to density groups viz. very coarse texture is related to low density, very fine texture is related to very

high density and so on so. The circularity ratios indicate that the five small basin reach the middle stages and three basins reach the youth stages. The drainage patterns of this basin reflects the influence of initial slopes, inequalities in rock hardness and structural controls. There are four types of drainage patterns found in the aforesaid basin. Among these, the parallel and rectangular patterns of drainage system are found extensively over this basin.

The average slope of this basin varies from 1.9 to 8.9 degrees. The spatial variation in slope is directly influenced by the topography and lithological and structural characteristics of the underlying rocks. It is interesting to note that the slopes have greater influence on landuse. The four slope categories viz. gentle, moderate, moderately steep and steep may further be scrutinised and useful informations may be gathered on the basis of slope sub-units for micro regional studies. The association of particular soils with distinct slopes will demarcate different zones for landuse also. The dissection indices of the basin are grouped into youth, middle youth and early youth. It is directly related to the stage of cycle of erosion. A hypothesis may be formulated that a high relative relief shows a high degree of dissection, thereby indicating a high positive correlation between these two variables. The hypsometric integral in this basin is 24 per cent which indicates that the basin reaches the senile stage.

The drainage analysis of the upper Kaliyani river basin reveals the fact that the branching of streams has been largely controlled by geologic structure, lithological characteristics, slopes and rainfall intensity. The basin possessing homogeneity in the above factors closely correspond to the different laws of drainage network but marked variation in the above factors has upset the normal functioning of drainage system. It is, therefore, dangerous to relate the morphometric properties of drainage network to the stages of basin development in Davisian style. The different mathematical models of Horton and Strahler related to the drainage network may not be applied in totality but linear relationship is very much validated.

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Soil erosion by waters unchecked is erosion of life at length.



Small settlements, nay, all great human civilisations happen to have grown on river banks .



Rivers at meandering stage brings beauty and bounty to raise.



Sadentary agriculture in the level land.



A side view of Dakmoka Inspection Bungalow.



A part of Dakmoka reserved forest.



Rocks and grates on river bed show slow and steady race,



Elephants are used for carrying logs in the forest areas.



Will man go a silent spectator
of the fury of rivers ?



Surface features eroded by sheet
erosion.



Domesticating wild elephants are
sign of man's prowess to master
wild nature.



A part of a Forest Beat House near
the pak Langso river.