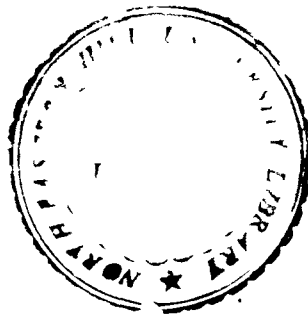


HYDROGEOMORPHOLOGICAL STUDY AROUND CHERRAPUNJEE

BY

ALMA DOHLING



A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF PHILOSOPHY IN THE DEPARTMENT OF GEOGRAPHY

NORTH EASTERN HILL UNIVERSITY

SHILLONG


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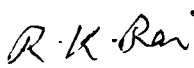
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May 2003

I Alma Dohling, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University / Institute.

This is being submitted to the North Eastern Hill University for the degree of Master of Philosophy in Geography.


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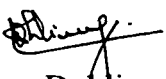
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Alma Dohling
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CHAPTER I

Hydro-Geomorphological Study around Cherrapunjee

Introduction:

Water is frequently a 'common resource', not owned or controlled by any individual or organisation and used by many (Barrow, 1987). Under conditions of relative abundance, use of a common resource is unlikely to cause difficulties. However, under conditions of relative scarcity-and such situations are becoming increasingly common in urban areas of Meghalaya, use of a common resource (water) must be regulated. If there is no such regulation users are likely to damage or destroy the water supply. Some water supplies are not recharged at a rate equivalent to the rate at which they are used.

There are regions where it is reasonably certain that the right amount of suitable quality of water will be available at the right place and at the right time. Meghalaya has substantial water resources, but their distribution over the land is uneven. While some areas are blessed with abundant water resources, many others are deprived of even minimum water to meet the basic needs. This is mainly because of the vagaries of rainfall both in space and in time. The difficulties caused by temporal variations are amplified by other rainfall characteristics.

Precipitation and availability of water for drinking, irrigation and industrial purposes are the main facets of hydrological cycle - man is most concerned today. The area under study directly faces the moisture laden atmospheric circulation funnelled from the Bay of Bengal, through the Bangladesh plains. As a result,

Cherrapunjee area receives the highest amount of rainfall in the world. Despite this, the areas paradoxically suffer from acute water scarcity.

Rainfall itself is not the only factor for uneven distribution of water resources, but landform characteristics of a particular area also develop a cause for water scarcity. The nature of lithology, structure and landform together with anthropogenic activities give rise to the dislocation and destruction of water resources. Developmental and anthropogenic activities result in the lowering of water table (e.g. agricultural practices).

In Geography, distribution, occurrence, movement and exchange of water in space and time is a study within the discipline called Hydrology. It is a Greek word of two terms; 'Hydro' means water, and 'logos' means to study. Scientists have used the term in a broad sense where they include studies, which are related with water. Wards (1967) defined Hydrology as "the systematic analysis of the distribution and movement of water in the physical environment". Where as the nature and structure of the land is specifically study in a discipline called Geomorphology. It is often described as the science of landform. Coates (1971) reiterated that the goal for geomorphic environmental studies is to minimise topographic distortions and to understand the interrelated processes necessary in restoration, or maintenance, of the natural balance. Thus, an attempt has been

made to combine the concepts of the two disciplines and their inter-relationships for micro level study of both water and land.

Survey of Literature:

Various textbooks, research papers, journals and unpublished reports and thesis related with the topic mentioned above have been surveyed. Textbooks on Geomorphology were based on a number of geomorphology texts. '*Principle of Geomorphology*', by Thorn bury (1969), and Singh's '*Geomorphology*' (1998), had in it the basic principles of the subject, and the work to be completed needs a great help of the idea presented in these two different books. The book by Clowes and Comfort (1982) '*Process and Landform – Conceptual Frameworks in Geography*' had a more recent approach through the understanding of the systems in Geomorphology. The understanding of the processes in nature seems to be better when considered along these lines. The English translation of Geology with the book by Yakushova (1983) '*Elements of Geomorphology*', gives the much-needed sensibility of the relationship between lithology and landscape.

A number of articles and unpublished papers have been consulted to augment the understanding of the geology of the regions as the whole, and research area in particular. Unpublished thesis of Panda, (1983) '*Geomorphology and Rural Settlement on Khasi and Jaintia Hills, Meghalaya*' submitted to the

Department of Geography, NEHU, Shillong (unpublished) gives detail information on the geology of the Khasi and the Jaintia Hills. Thus, it is of great help for consultation of the research work. 'Geomorphology and Agriculture in Meghalaya Plateau', a thesis submitted by Patniak to the Department of Geography, NEHU, Shillong, gives an immense help to the researcher on grounds of geomorphological studies as well as geological characteristics of the southern slopes of Meghalaya plateau, on which lies the study area, that is, Cherrapunjee.

The understanding of drainage and its related implication had been borne by such great scholars namely, Leopold, Wolman and Miller (1963) who have given much light about the nature of rivers in their books '*Fluvial Processes in Geomorphology*'. Another very significant source of help in this respect is the textbook of Morisawa (1985) '*Rivers – Geomorphological Text No.7.*' On soils, 'Tropical and Subtropical Soils Science' by Zoon (1986) gives a suitable understanding of the possible conditions that may occur in the area to be studied. USDA's Conservation of Soil and Water (1964) helped a lot to understand the soils of the region and its conservation. The Munsell Colour Chart is also be of great help in identifying the colour of the soil samples collected.

The Environment of the whole region is perhaps one of the most interesting. The micro climatic condition gives rise to a vast difference between areas of different altitudes. The book on '*Soils, Vegetation, Ecosystem-Conceptual*

Framework in Geography by O' Hare (1988) gives a good understanding of the environment and its different implications. It also helped in the simplification of some laboratory tests and the field study method. *Environmental Science - The Earth As A Living Planet* by Botkin and Keller (1982), and *The Nature of The Environment* by Gaudie (1989) touched on various aspects of different types of environment giving good support to the requirement of the present research problems.

On landuse and landuse planning, a number of books and articles have been consulted. They included papers from *Facets of Geomorphology* edited by Kumar (1985), *Exploration In The Tropic* edited by Datye (1987) and others, *Soil Geography and Landuse* by Foth and Shafer (1980) and *Physical Geography* by Gersmehl (1980) and others, were of great help in landuse studies of the area.

In addition to these, books and literatures deal with Hydrological Studies and Water Resources have been surveyed and examined. Mahajan in his book published in 1995, *Ground Water Survey and Investigation*, attempts to put forth the fundamental information about history, geology, geo-hydrology, infiltration and remote sensing application in water resources studies. This effort gives extensive data, which deals with development of land and water resources and can easily avail, the necessary information. *Ground Water Resource Evaluation* by

Walton (1983) is a text, which deals mainly with the proper planning for the development and management of ground water resources. It also focuses the basic principles, fundamental equation, and hydrological system analysis. Petts and Foster (1985) in the book '*River and Landscape*' mainly focus the study on catchment hydrology, sediment transport, lake sediments and drainage basin history besides fluvial landscape and channel morphology. The text enhances information and knowledge of fluvial system. In a book on '*Hydrogeology*' by Davis, Dewiest, (1996) opined that Hydrogeology is a companion volume to geohydrology. In Hydrogeology, the emphasis has been placed on the geologic aspects of water resources. While in geohydrology, as the name suggests, the emphasis be on the hydrologic or fluid- flow aspects of water. Combination of the two aspects helps in simplification of the two concepts. There is an attempt to bridge the gap between theory and practice by using many of the utilitarian aspects of Hydrogeology to illustrate the relevance of the basic principles.

Ward (1967) in the book, '*Principles of Hydrology*' tried to give immense information about the basic concepts of hydrology and measurement of various hydrological parameters. The importance of water resources is mainly recognised in the tropical regions for the development of agricultural activities. The author leaves some facts about this in the book '*Water Resources and Agricultural Development in the Tropics*', by Barrow (1987). The book attempts to provide a

general description on the practice and utilisation of scientific techniques of agricultural development in the tropics, concentrating on where water may be obtained, where savings might be made, or moisture better used. Irrigation methods are briefly examined, especially those which may be adopted by farmers in developing countries and problems associated with water supply. The edited book '*The Earth as Transformed by Human Action*' (Global and regional Changes in the biosphere over the past three 300 years). Edited by Turner II (1993); gives a general description of human activities on the earth surface and the transformation of terrestrial water systems.

Statement of the Problem:

It is seen that urbanisation and man's development of water as a resource distorts many aspects of the land and water ecosystem, a subject that falls within the realm of geomorphologists. Thus arises the need to have a proper study on the aspect of hydro-geomorphological characteristics of the area. Precipitation and availability of water for drinking, irrigation and industrial purposes are the main facets of hydrological cycle – man is most concerned today. Cherrapunjee area of the Meghalaya plateau at a general elevation of over 1500m above mean sea level is developing fast into urban centre, south of Shillong, the capital of Meghalaya. The area of study directly faces the moisture laden atmospheric

circulation funnelled from the Bay of Bengal through the Bangladesh plain. As a result, the area receives highest annual rainfall in the world (>11,00 cm). Despite this, the area paradoxically suffers from acute water scarcity. Infact, for more than six months the area suffers acute water shortage, even for drinking and domestic uses.

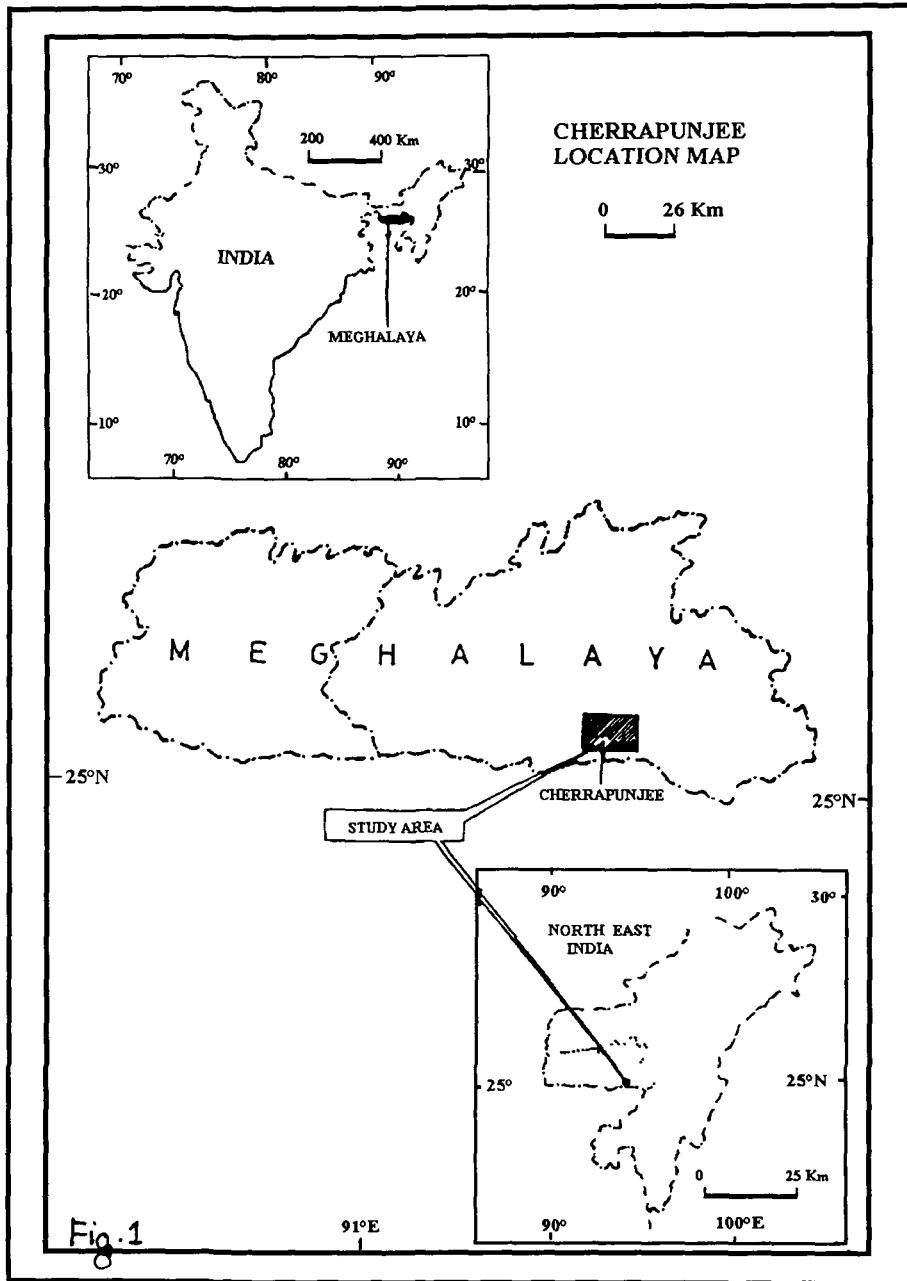
Thus, a detailed geomorphic evaluation of the area is necessary for understanding the landforms occurring in the study area, as well as to demarcate the micro watersheds of the particular area. The study on landform and water resources of the area is necessary for the careful utilisation of the land and water, both for agricultural and developmental activities. The study also has attempted to bring about hydrological assessment for optimal watershed management in the area. The present study has investigate geological, geomorphological, meteorological and landuse pattern characteristics to assess the hydrological responses in the area and devise conservatory and remedial strategies for redemption of sustainability in the area.

Hydrological studies by Central Ground Water Board (CGWB) revealed that the water level varies between 1 to 3 metres in topographic lows and within 10 metres depth in upland areas with seasonal fluctuations to the tune of 3 to 8 metres respectively. Thus, hydrological and geomorphological characteristics of the area may help in selecting the sites for tapping the ground water resource of

the area besides the distribution, which shall perhaps be beneficial in minimising the problem of water supply faced by the villages.

Study Area:

Cherrapunjee area is located on the southern region of the Meghalaya Plateau. The present area of study falls in the Survey of India toposheets nos. 78⁰/₁₁ SE and 78⁰/₁₅ SW. It lies between 24° 57' to 25° 24' 25" N latitudes and 91° 26' to 91° 45' E longitudes. The location of the study area is shown in Fig. No. 1. To the north of the study area i.e., Cherrapunjee, lies Shillong plateau and further south is the Bangladesh Plain. While to the west lies Mawsynram plateau, which also receives the highest rainfall in the world. Cherrapunjee area has substantial water resources, but their distribution over the land is uneven. While some areas are blessed with abundant water resources, many others are deprived of even minimum water to meet the basic needs. Rainfall is confined mainly to only a few months (June to September) in a year, which accounts for more than 85 percent. The precipitation in the rest of the year is insignificant. The fluvial geomorphic processes are dominating in shaping the landforms of this region. The area is composed of mainly Shillong group of rocks and Cretaceous Tertiary Sedimentary formations with huge deposits of limestone. The climate of the area also varies from sub-tropical to temperate type with highest rainfall in the world accounting



for more than 1100 cm per annum, which favours the formation of fluvial landforms and karst landscape. The area is also a typical example of plateau type of topography with isolated hills of limestone. All these unique physical settings have differentiated this area as a typical geomorphic identity.

The Cherrapunjee region selected for the present study more or less coincides with geological and physical features and possesses unique geomorphological characteristics. Again, this region is the world's wettest area with about 1200 cm of rainfall annually, which results in the formation of strong fluvial dominated landforms. The region is demarcated by Mairang Block and Umngi river valley in the north and west respectively; and in the east this region is separated from the Cherrapunjee platform by the Umiew river valley and by the Bangladesh plain to the south.

Salient features of The Region.

The general slope of the study region is to the southward direction into the Bangladesh plain. Small areas lying between different contours present a variety of morphogenetic features. On the eastern side, it gradually slopes down to the valley of river Umiew. Again, in the western part, it gradually slopes down to the valley of river Umngi and in the north it ascends gently towards the Shillong upland. Continuous weathering processes on the erosional scarp have led to the

formation of Mawsynram structural platform (1305m). Its southern part is marked with a southern lowering of the plateau surface to 1000 metres and it further gradually reduces up to a height of 50 metres near the Bangladesh plains. This southern margin of the lower plateau is a dissected hilly country with host of micro landforms viz., gorges, spurs, and divided rolling uplands, low sand hills and many swampy tracks of land.

Objectives:

Keeping in mind, the preceding paragraphs the following are the objectives of the present study:

- 1.To study the geological, geomorphological, hydrological and meteorological attributes of the study area.
- 2.To analyse the various terrain parameters and to correlate the various hydrological parameters in the area for understanding the causes of water deficiency.
- 3.To study the hydrogeomorphological characteristics of the area.

Data Base & Methodology:

The work, which was taken up, was considered on a large number of variables. The database was mainly of two kinds, namely primary and secondary. However keeping in mind the dearth of the latter, primary data was most urgently required. Thus, data generation was essential. A tentative scheme of database would be as follow:

- 1.Primary data generation by which of fieldwork and collection of samples was more appropriate.
- 2.Secondary information wherever available has been used and incorporated.
- 3.Suitable maps have been prepared to support the work on different aspects viz. geology, relief, drainage, climate, soil, vegetation etc. based on primary and secondary information.

The proposed study includes three levels of activities.

Pre-Field Phase:

In this phase all relevant literature was consulted which also helped in the further planning of the work. The main objective during this stage was collection of secondary (geological, geomorphological, meteorological, vegetation etc) data. Different micro watersheds were identified and quantitative analysis has been carried out to classify the various micro watersheds. The laboratory work was carried out to prepare relief, slope and drainage maps.

Field Work Phase:

Based on pre-field database, fieldwork was conducted in the area, to collect primary data, particularly, lithological and topographic features. During this stage, micro relief features were identified and documented. Having identified the land facets at different sites, information concerning weathering, karst features, slope characteristics were studied and analysed. The representative features were photographed for documentation.

Post Field Phase:

In this phase, all collected data were classified, tabulated and synthesised wherever necessary. The final maps were prepared depicting hydrological and geomorphological characteristics. Finally, the data was synthesised for interpretation and presentation of the results.

Tentative Chapterisation:

Keeping in mind the above stated points; a tentative chapter scheme has been prepared. Sub units in each chapter were finalised, so that the plan work comes out systematically and accordingly.

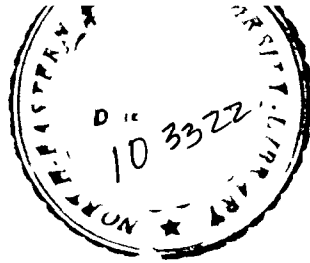
The main chapters were as follows:

- Chapter I – Geographical Characteristics of the Area.
- Chapter II – Geological Characteristics.
- Chapter III – Morphometric Analysis
- Chapter IV – Hydrological Analysis.
- Chapter V – Hydro-geomorphological Characteristics
- Chapter VI – Summary & Conclusion.

Bibliography.

People and Occupation

The study area comprises parts of Shella Bholaganj C.D Block and Cherrapunjee town. Christians, Hindus, and Khasi etc represent religion wise the people. Language wise the people can be differentiated as Khasi, Garo, Bengali, Nepali, Assamese and Hindi speaking. According to the 1991 census, Cherrapunjee town alone comprises a total population of 10086 with 4917 males and 5169 females. The working population is lower in comparison to State and district averages. The rural working population is mostly engaged in Jhuming or Shifting cultivation activities.



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CHAPTER II

GEOLOGICAL CHARACTERISTICS

The formation of Cherrapunjee region is linked up with the structural evolution of the Shillong plateau. Therefore, before going to discuss about the geology of the area under study, it is very much essential to give a brief geological account of the Shillong plateau.

The rocks of the Pre Cambrian age acutely folded mainly constitute the Shillong plateau and steeply dipping with an over turned fringe of Mesozoic and Tertiary sediments. It is regarded as geologically part of the Indian Peninsula, cut off by the intervening spread of the Ganges and the Brahmaputra alluvium. Its landscape evolution is closely linked with the Indian Peninsula. Its chronology seems to have similar sequence records as that of the Chotanagpur plateau including Rajmahal highlands. A further resemblance is seen in the marine transgression which affected the southern shores of the plateau in Cretaceous time and has left deposits, much of which lie undisturbed upon the older rocks, as do similar deposits, along the Coromandel Coast of the peninsula.

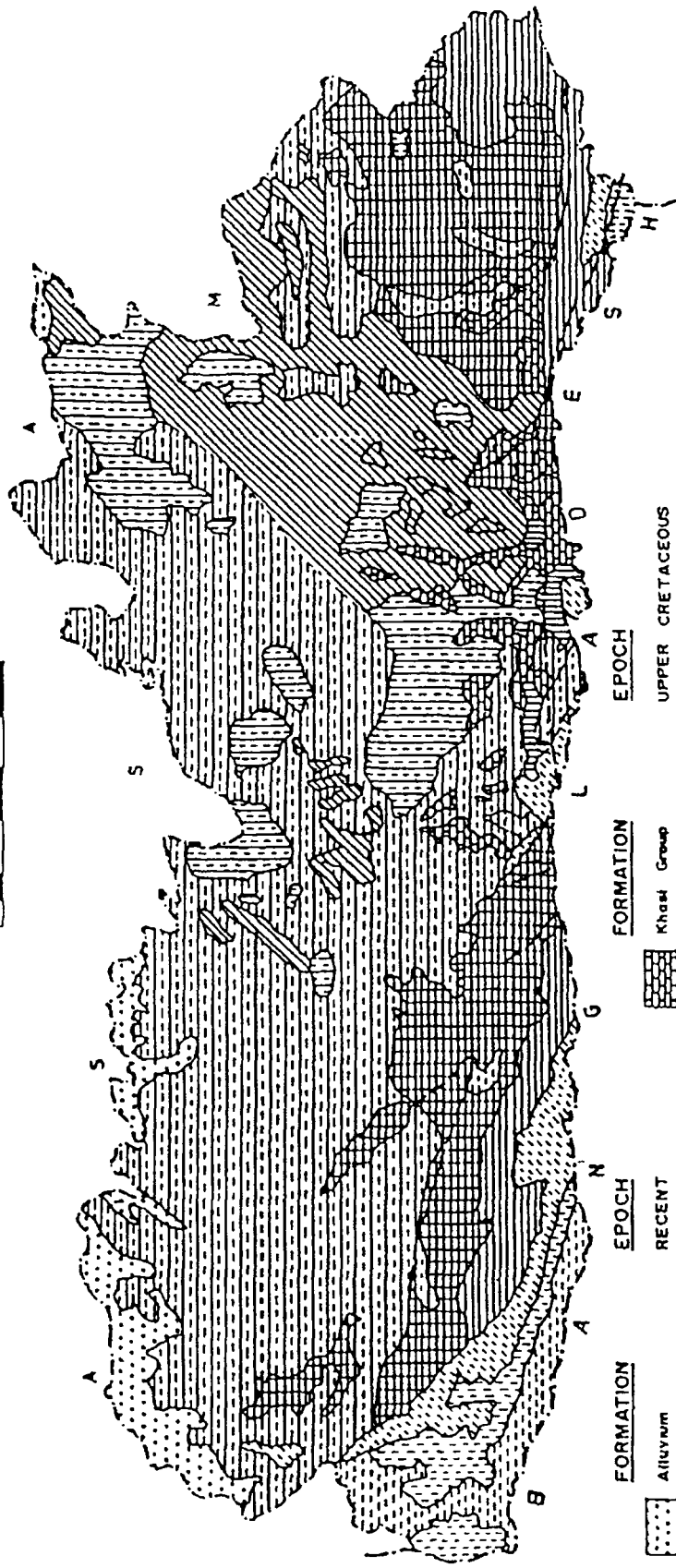
The plateau contains the ancient (Pre Cambrian) peneplaned surface, with marks of different cycles of denudation, in the central and northern part, it is hidden beneath the Mesozoic traps along the central southern fringe, southeastern and southwestern parts. The plateau is also standing as a watershed between the Surma valley of Bangladesh on the south and the Brahmaputra valley on the north.

A.C Goswami, M.K Das, S.C Talukdar, A.C Bhattacharya, G. Barman, B.K Duaran, C.Chakravarty, B.D Adhikari, K.K Sen. and S.K Srivastava have systematically mapped the self-sediments over the southern parts of the plateau during the field seasons from 1961 – 62 to 1972 – 73. Their works have led to the delineation of different litho – stratigraphic units of the tertiary self-sediments.

As a part of the Shillong plateau, Cherrapunjee region also consists of very ancient Archean and Shillong series rocks exposed in large parts along the northern and southwestern portion. These are similar to the rocks exposed in the rest of the Garo, Khasi, Jaintia and Mikir hills and like peninsula in Bengal and Bihar of which it was a part at one time. These rocks form the basements for very much younger Tertiary sediments along the southern part of the region and that of its neighboring areas too.

The region to the north and central part of the study area experienced peneplanation resulting in the formation of flat-leveled surface, one of the most remarkable sight even today. A spectacular feature of the drainage in the southern portion of Cherrapunjee area is the deep gorges, which is the result of the relatively greater upliftment of this Block; head ward erosion is massive along the joints by antecedent streams and the control exercised by the well jointed Cretaceous Tertiary sandstone cover.

MEGHALAYA GEOLOGY



FORMATION	EPOCH
Alluvium	RECENT
Daphila Series	PLEISTOCENE
Chengapara Formation	PLIOCENE
Baghmara Formation	MIOCENE
Simsang Formation	OLIGOCENE
Jamila Series	EOCENE

FORMATION	EPOCH
Khasi Group	UPPER CRETACEOUS
Sylhet Traps	LOWER CRETACEOUS
Granites	UPPER PROTEROZOIC
Shillong Group	MIDDLE PROTEROZOIC
Gneiss	ARCHAEN-MIDDLE PROTEROZOIC
Faults, Thrusts	

INTERNATIONAL BOUNDARY - - - - -
STATE BOUNDARY - - - - -

Fig. 2

The present physiographic configuration of the region has taken shape only during geologically recent times; however, it is the ultimate result of events that took place through the geological past.

Considering the general geological succession of the Shillong plateau, we can derive the sequence of lithological units of the study area, which is highlighted in Table 1 and Fig. No. 2.

Table 1.
Geological Formation

Geological Age	Group Name	Formation Name	Rock Type
1. Recent clay.	Newer Alluvium (Thickness Not Known)	(Unclassified)	Sand, silt and
~~~~~ Unconformity (Unclassified)			
2. Mio-Pliocene and	Dupi Tila Group (1050 m)		Mottled clays, felds, Pathic, sandstone  Conglomerates.
~~~~~ Unconformity			
3. Oligo-Miocene clay,	Garo group	Chengepara Formation (700m)	Sand, silt stone, Pebbles, conglomerates.
~~~~~			
4. Eocene	Jaintia Group	Kopili Formation (500m) Shella Formation (600 m)	Shale, sandstone.  Alternation of sandstone and

		Langpar Formation (100 m)	Limestone. Calcareous shale, sandstone,
limestone.			
5. Upper Cretaceous	Khasi Group	Mahadek Formation (150 m)	Arkose (glaucconitic)
Unconformity			
6. Jurassic	Sylhet Trap (600 m)		Basalt, alkali, rhyolite, acid tuff.
Unconformity			
7. Pre Cambrian	Shillong Group		Quartzite, Phyllite, Conglomerate.
Unconformity			
8. Archean		Gneissic complex	Biotite gneisses, Biotite hornblende Gneiss, migmatite, Mica schists, Biotite granulite, Amphibolites, Pyrosene granylite

### Archean

The Archean Gneissic complex is exposed in the extreme north and southwestern parts of the Cherrapunjee Block. The rocks are believed to be the northeastern extension of the Indian peninsular block, separated from it by the Garo Rajmahal trough fault. This Gneissic Complex consists of gray and pink Mica gneissic, at places traversed by quartzite veins. The rocks are composed predominantly of Gneisses, Migmatite and Meta – sedimentary bands. Rock types comes under this complex have been given in the Table 1. The contact between

the Archean Metamorphic and the Shillong series runs in a general NE - SW direction.

### **Shillong Group**

The Shillong group of rocks is predominantly composed of quartzite, usually friable, with subordinate phyllite, quartz – sericite schist, conglomerate etc. The rock generally strikes in a NE SW direction and is therefore regarded as homotaxial with Dharwar Formations of the rest of India. These rocks are composed in the extreme northeastern parts of the Cherrapunjee region, which is the southwestern extension of the central Shillong Group of the Meghalaya plateau. These rocks generally strike in NE – SW and dip either southeast or south. Current bedding is commonly noticed in these rocks. The mildly folded sediments have suffered low-grade metamorphism and are dissected by numerous faults along which the different rocks apparently moved up and down at various times during the Tertiary period. Acidic sills and dykes intrude these rocks.

### **Khasi Greenstone and Myllicm Granite**

Essentially, Khasi Greenstone is an epidiorite and consists of augite and plagioclase. In Cherrapunji region, it is specially developed in between Mawphlang and Sohra Rim. The Green stone acquires the amphibolitic

composition when it is exposed to the younger granite. These rocks also bear the intrusive relationship with the Shillong series. The granite intrusive along the axial region of the Shillong group of rocks around Myllem is termed as Myllem granite. Megascopically, it is porphyritic and fresh coloured. Microscopic studies shows that Microcline, Quartz, Orthoclase and Biotite are the essential mineral constituents of the rock type. The age of the granite does not show any sign of crustal movement like that of the older gneisses. It fixes its upper age limit as Pre Sylhet or Pre Rajmahal Trap.

### **The Sylhet Trap**

Along the southern margin of the study region occur the Trap rocks, exposed in a narrow east west strip, known as Sylhet trap, which could be seen on the way from Shillong to Cherrapunjee. The Sylhet trap is of the nature of plateau Basalt, which runs in an east west strip 80 Kms long and 4 Kms wide along the southern border of the Shillong Plateau. The maximum exposed thickness is 550 – 600 metres. They apparently overlie the eroded Pre Cambrian basements and do the Upper Cretaceous Eocene sediments overlie themselves non-conformably. The sediments and the lavas form a monocline, becoming a flexure southward; the sediments at the crest of the flexure have subsequently been eroded at places exposing the trap as sills. The flexure in the Tharriaghat – Shella sector with its

east west axis changes along its trace westward (along the Balat and Khasimorra of Mawsynram), high angle reverse fault through normal and vertical faults (Dawki Fault) and marks the exposed units of the Sylhet trap to the south. Immediately south of Raibah fault, the trap dips at  $10^{\circ}$  -  $35^{\circ}$  along the monocline or at  $50^{\circ}$  against the Dawki fault.

The Sylhet trap predominantly comprises of basalt and minor alkali basalt, rhyolitis and acid tuffs. The alkali basalt occurs as flows in the Umiew gorge. Southeast of Mawsynram near Tynger, rhyolitis also occur associated with acid tuffs in the Umiew gorge. Both within the flows and also in the immediately adjoining Archean rocks to the north, basalt dykes are common; within the trap area the dykes occurs as swamps.

### **Cretaceous – Tertiary Sediments**

The Cretaceous Tertiary sediments occupying the southern part of the study region are thick and extensive and are considered physically continuous with the Cretaceous Tertiary sediment of the Bengal Plain. These sediments are affected mostly by basement-controlled faults.

The sediments are mainly sandstone and slate, except for the three well-defined fossileferous limestone, occurs as (i) discrete outliners and (ii) a continuous narrow belt fringing the southern margin of the study region. Here the

sediments are divided into two groups (a) Khasi Group and (b) the Jaintia Group.

The Khasi group is a distinct erinaceous facies consisting of the oldest Jadukata Formation, followed by the predominantly conglomerated Mahadek Formation, of which the later formation only occur in the southern margin of Mawsynram. The Jaintia Group is a Cretaceous facies and has been divided into three formations, viz., the Langpar, the Shella and the Kopili Formations.

### **Khasi Group**

**Mahadek Formation:** - The Jadukata Formation and the bottom conglomerate Formation are overlain in turn by a coarse Arkose, usually glauconitic that is termed as Mahadek Formation on the southern Mawsynram, north of Raibah Fault. The maximum exposed thickness of the Mahadek Formation is 150 m.

### **Jaintia Group**

- (i) **The Langpar Formation:** - The Langpar Formation of the Jaintia group overlies the Mahadek Formation. The rock consists of calcareous shale, sandy limestone and fine calcareous sandstone. The deposition of these sediments marks the beginning of a table shelf condition, which was firmly established, later with the deposition of the Shella formation

(600 m thick) represented by the alternating limestone and sandstone sequence.

**(ii) The Shella Formation:** - The Shella Formation consists of three sandstone and limestone members beginning with the sandstone over the Langpar formation. These have been designed successively the lower (Tharria sandstone / Lakadong limestone), middle (Narpuh sandstone /Puriang limestone / Siju limestone) and Sylhet sandstone/limestone member in the eastern part of the plateau, looking westward along the cliff face below Mawsynram. The lower sandstone band of the Cretaceous can be seen thinning in a northerly direction.

**(iii) The Kopili Formation:** - The Kopili Formation overlies the Shella Formation and is about 500 m in thickness. The rocks are in alternation of thin sandstone and shale with rare thin fossiliferous bands of limestone. The basalt parts comprise of a dark horizon with scattered phosphoric nodules in southern part of Cherrapunjee area, it occur as crescent shape in an east west direction.

## **Garo Group**

**The Chengapara Formation:** The formation overlying conformably the Bagmara Formation consists of poorly – cemented, fine-grained micaceous sand, blue to brown siltstone and clay with a few thin beds at its base. The Dupi Tila Group consists of alternations of coarse feldspathic sandstone with beds of pebbles of vein quartz and sandy molted clay. This Group also mainly represents deltaic types.

## **Quaternary and recent Deposits**

Recent alluvium is found along the southern foothills of the study region. The alluvium consists of fine silty sand and light to dark greyish clay with rare pockets and layers of coarse sand. The fine sand at places contains abundant minute flakes of mica.

## **Tectonic and Structural Characteristics of rocks**

The Cherrapunjee area of Meghalaya shows definite relationship between the structure and topography. The rocks of the Shillong series, which includes quartzite and slates, schist and conglomerate, cover the northern part of the study area. Tertiary sediments including sandstones, limestone and shale form the southern portion. Some of the series follow the structural weak zones and the

landform in general show definite relationship with the structure. The Pre Cambrian mass experienced peneplanation till Jurassic times resulting into the formation of a flat-leveled surface preserved over the plateau till today. Since the end of Jurassic period, the southern portion of Khasi Hills experienced with eruption of plateau basalts, the Sylhet Trap. The rate of subsidence gradually showed down towards Eocene times when this area attended a stable shelf.

The southern margin of Cherrapunjee region is a sharp fracture zone formerly considered a strike slip fault but recently demonstrated to be a vertical reversed belt secondary fractured associated with the system (Murthy, 1969). The northern limit of the region is up to southern watershed zone of the Shillong plateau.

It is generally believed that Shillong plateau along with Cherrapunjee region is an autochthon of crystalline rocks that constitute the spur land of the Indian Shield and it has been over thrust from the northwest by the Himalayas and from the southeast by the Naga Hills. The general structural trend of the crystalline rocks of it, is northeast to southwest, but the variation of it occur in the south and western part of Mawsynram along the Garo Hills where the trend is east to west. The rocks are folded and lineated. The folds are generally tight and isoclinal, but these may become more metamorphosed rocks.

The folds that occur in the rocks of the Shillong series surrounding the granites are commonly known as the Myllem Granite have their axis, as nearly as possible towards the pluton. These structural relations between the rocks of Shillong Series and Myllem granite as seen around Mawphlang which is situated at the north eastern corner of Cherrapunjee region.

The Sylhet Trap, the effusion of which marked the first major tectonic event during the Jurassic period occurs along a narrow strip exposed in gorges of Umiew River along the southeastern margin of Cherrapunjee area. Their contact with the Crystalline to the north is a fault, the Raibah fault that apparently determined the limits of the traps during the effusion.

The Dawki lineament is exposed along the southern margin of the Meghalaya Plateau for about 170 km from Jadukata River in the west, to Haflong in the east. The lineament actually consists of four major east – west faults along Jadukata River and Tharriaghat.

A rectanglinear drainage pattern in NE – SW, NW - SE directions is a distinctive feature of the Mawsynram region. Some of them appear to represents fault, many of them are master joints and fractures and the whole pattern has been developed due to upliftment of this region along with Shillong Plateau during Upper Tertiary period.

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## **CHAPTER III**

## **Morphometric Analysis**

Morphometric analysis of drainage basins is of paramount significance in the domain of Geomorphology. "Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms" (Durry, 1967).

The appearance, dimension and magnitude of relief and slope depict the morphological character of the study areas. The study of relief and slope provides not only the variety of topographical features but also makes available the evidences needed for the interpretation of the complex form of landscape.

Morphometric analysis is essentially needed for the identification of geomorphic characteristics of a region like Cherrapunjee. The present analysis is based on the results of different morphometric methods, which have been applied to bring out clearly the geomorphic characteristics of Cherrapunjee region, which are responsible for the development of landforms. The study area, though occupying a small area of the earth's surface, represents a varied degree of slope, numerous streams and rivers, hills and hill ranges, which provide very wide field of investigation, interpretation and analysis of various geomorphic bondage of this small region as of a type. Morphometric techniques and methods are of great significance from the point of view of geomorphological investigation in this region.

The present study is based on the fundamental hypothesis that the system of landforms evolving from the same geomorphic unit under the similar climatic conditions and geologic materials possess a high degree of geometrical similarity, which is manifested in the geomorphic properties of the drainage basins. On the contrary, the lack of geometrical similarity in the drainage basins may result from the geological heterogeneity or climatic variations which tend to distort the basin morphometry.

The Paleo – geography of this region reveals that the plateau has been subjected to a variety of diastrophic movements since the Pre Cambrian period. The different movements recorded during these periods must have created new relief and slope forms along the line of uplift fracture zone and evolved because of plateau volcanism. The development of the drainage system thus has played a vital role in shaping the present surface features of the study areas, with their characteristic relief and slope forms.

The relief in its true meaning for the relative vertical inequality of the differences in elevation of any parts of the earth's surface collectively and individually has been studied. Sometimes, it has been misused for the altitude or absolute elevation from the sea level.

The study of the associations between morphometric variables of drainage basins is essential for proper understanding of landscape ecology and landscape

evaluation. A systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear aspects of the drainage network, areal aspects of the drainage basins and relief aspect of channel network and contributing ground slopes. In this study, the first two aspects have been discussed by selecting three small drainage basins from the study region.

Thus the use of morphometric methods and field techniques would not only lead to an ordered, systematic and scientific portrayed and varying topographical expressions, but also helps in understanding of the landforms in fact, as pointed out by Miller (1964).

This study has been divided into two main parts, viz., the linear aspects and the areal aspects. The main objective is to find out the geomorphic characteristics of these selected basins through the study of linear and areal aspects separately.

The first two properties are planimetric whereas the third one reveals the vertical inequalities of the drainage basin forms. In the present study, an attempt has been made towards the evaluation of the geomorphic significance of the drainage basins of three small streams of Cherrapunjee area, with the measurement and analysis of the linear properties of the channel network and areal properties of the drainage basins. The data for the study has been worked out from the 1: 25,000 topographic sheets bearing the numbers 78⁰/₁₁ SE, and 78-0/₁₁ SW.

The study area consists of three small drainage basins in Cherrapunjee. They are - (a) Mawsiangkabthuh, which lies between 25° 20' 15" N to 25° 17' 20" N Latitude and 91° 38' 38" E to 91° 42' 30" E Longitude (b) Umtyngiang lies between 25° 16' 10" N to 25° 19' 30" N Latitude and 91° 40' 50" E to 91° 44' 20" E Longitude. (c) Umstew lies between 25° 15' N to 25° 19' 35" N Latitude and 91° 43' 10" E to 91° 47' 30" E Longitude. Table 2 highlights the latitudinal and longitudinal extend of the selected basins, as well as the area coverage of the basins. The first three drainage basins fall within the Cherrapunjee area. The areal and linear properties of these stream basins are measured with the help of a Curvimeter. The geographical location of the selected basins is given in Table 2.

Table 2

**Geographical Location of the selected basins.**

<b>Drainage Basins</b>	<b>Latitudes (N)</b>	<b>Longitudes (E)</b>	<b>Area in Sq.Kms</b>	<b>Main village</b>
Mawsiangkabthuh	25° 20' 15" – 25° 17' 20"	91° 38' 38" – 91° 42' 30"	16	Cherrapunjee
Umtyngiang	25° 16' 10" – 25° 19' 30"	91° 40' 50" – 91° 44' 20"	15.60	Cherrapunjee
Umstew	25° 15' 00" – 25° 19' 35"	91° 43' 10" – 91° 47' 30"	27.54	Cherrapunjee

The study of linear aspects of the drainage basins includes the analysis and interpretation of stream order, stream number, bifurcation ratio and stream lengths and in areal aspect basin perimeter, drainage density, stream frequency, slope, relief, dissection index are analysed.

### **Linear Characteristics of the channel system**

The linear properties of the drainage basins portray the branching system of drainage lines regardless of their width. It includes the study of the channel patterns of the drainage network in terms of open links where in the topological properties of the stream segments are counted, their hierarchical orders are determined, the length of the stream segments are measured and various interrelationship are analysed.

### **Stream ordering & Bifurcation Ratio**

In this paper the Strahler's method of stream ordering has been applied. According to Strahler (1952) "each finger tip channel is designated 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".

The table 3 below shows the distribution of stream order and bifurcation ratio in the three drainage basins of Cherrapunjee.

Table 3

**Stream order & Bifurcation ratio**

<b>Drainage Basins</b>	<b>Stream orders</b>	<b>Stream numbers</b>	<b>Bifurcation ratio</b>
Mawsiangkabthuh	1 st order	300	5.5
	2 nd order	55	5.5
	3 rd order	10	5.0
	4 th order	2	2
	5 th order	0	0
Umtynghiang	1 st order	352	7.7
	2 nd order	46	6.6
	3 rd order	7	3.5
	4 th order	2	1
	5 th order	1	0
Umstew	1 st order	315	3.9
	2 nd order	80	3.8
	3 rd order	21	5.3
	4 th order	4	4
	5 th order	1	0

Total numbers of stream segments are counted and the Bifurcation ratio is calculated by the division of the number of stream segments of the given order to the number of segments of the next higher order, i.e.,

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

$N_u$  = number of stream segments of the order 'u'.

$R_b$  = Bifurcation ratio.

It has been established that in a region of uniform climate and rock type, the bifurcation ratios tend to remain constant in different drainage basins. It varies between 2.0 to 7.7 for river basins where the geological structure do not distorted the drainage pattern. Abnormally high bifurcation ratios are expected in regions of steeply dipping rock strata where narrow strike valleys are confined to hog bag ridges and the minor variations are due to chance variations in the watershed geometry. In the present analysis, the bifurcation ratios of all the stream networks of the drainage basins range in between 2.0 to 7.7 Table 3 shows the distribution of the bifurcation ratio indicates how many times the number of streams increase from any given order to the next lower order.

The discharges of Umtynghiang stream is being accommodated by higher order streams, indicating that there is a less likelihood of floods at any stage. In the

case of Mawsiangkabthuh, it can be interpreted from the bifurcation ratio that there is every likelihood of flood after the third order streams. The case of Umstew is also very similar. In the case of Umstew basin the third order streams have a much higher bifurcation ratio indicating that the feeder streams are much lesser in numbers than the third order streams. Hence, there is every likelihood of lower discharge levels throughout the year. In these three basins, the highest order streams may not be in a position to accommodate a total discharge.

The little higher bifurcation ratio for the Mawsiangkabthuh, Umtyngiang and Umstew streams of Cherrapunjee can be attributed to its elongated course for a long distance being confined to the deep gorges over Laitlyndop to Laitryngew villages.

The bifurcation ratio decreases towards the highest orders in all the drainage basins. They seem to have a close association with the lack of conspicuous relief and smooth topographic surface in opposition to high available relief promoting severe dissection of the landscape and favouring the development of headward eroding streams. The increasing bifurcation ratio value towards the lower reaches in any drainage basin indicated development under structural control.

### **Stream orders and Stream numbers.**

The plotting of the number of streams against order for the three drainage basins on an arithmetic graph shows the linear relationship with small deviation from the straight line. Thus, the number of streams of successively lower orders tends to approximate a geometric series beginning with the single segment or the highest order and increasing according to a constant ratio ( $R_b$ ).

### **Characteristics of Trunk Streams in three drainage basins**

#### **Mawsiangkabthuh Basin:**

This stream rises and originates from Laitlyndop village in the northern slopes of Rynngimawsaw area in Cherrapunjee. The maximum length of this river system is 6.75 kilometers covering an approximate area of about 16 Sq.Km. This stream drains some of the villages like Mawphu, Maweitksar and Laitduh. It finally joins River Umiam in the south. The drainage system of Mawsiangkabthuh lies to the northwestern part of Cherrapunjee. The river enters the study area after receiving several tributaries from the east and west direction. The streams are mostly controlled by the faults and structures in the sedimentary rocks.

**Umtynghiang Basin:**

Umtynghiang River originates mainly from the northern slopes of Laitryngew coalmines. It flows in the northern part of the study area, Cherrapunjee. The slope profile indicates that in its middle course it is interrupted by an abrupt fault forming the Nohkalikai Falls, which is one of the most beautiful sights seeing spot in the study area. This Drainage Basin covers an area of about 15.60Sq.Kms. south it further joins Pynjngithuli nala.

**Umstew Drainage Basin:**

Umstew is a stream rises from the northern slopes of Laitryngew near Laitmawrap area in Cherrapunjee. It is about 3 Kms in length covering an area of about 27 Sq.Kms. this stream drains the north eastern part of the study area and after flowing towards the south, it meets the trunk stream Wah Tymshun at an elevation of 620 metres. The most important tributary of this river is Wah Sohkhain and Umkut. The stream finally meets with Um Sohra and Wah Tymshun at an elevation of 800 metres and joins the main River Umngi, which flows, towards the Bangladesh Plains.

## DRAINAGE FREQUENCY

Drainage or Stream Frequency is the number of streams per unit area. This is one of the important morphometric analysis of the Drainage Network. Horton (1945) defines Stream Frequency as the total number of streams in a Drainage basin divided by the Basin area. It is obtained by dividing the total number of streams to the area of the same unit as follows: -

$SF = N/A$  where,

SF is the Stream Frequency per unit area.

N is the total number of streams in a unit area.

A is the unit area.

Drainage map has been prepared from the 1:25,000 topographic sheets of the study area (78 ^o/₁₁ SW, & 78 ^o/₁₁ SE,). The selected drainage basins of the study area are divided into centimeters grids, north, south and east west representing an area of one square kilometer. The value of Stream Frequency is placed in each grid following the above formula and Choropleth map is drawn.

The table 4 generated for the Drainage Frequency reveals that most of the basins exhibit in all types of categories, which shows mostly a moderate stream frequency in total. A very high rate of frequency occurs in the basins of Mawiangkabthuh, Umstew and Umtynghiang, which is more than 25 numbers of streams per Sq.Km. This category of stream frequency occurs in the central part of

Mawiangkabthuh and Umtynghiang drainage basins, whereas in the case of Umstew it appears in the northern portion of the map.

The higher frequency category covering an area of about 20 to 25 numbers of streams per unit area is highlighted in all the drainage basins. This category covers 45% of the total basin area of Mawsiangkabthuh but it is very low in the case of other basins. The map no. 4 also indicates that the streams of this category occurs in the central part of Mawsiangkabthuh drainage basin, 16.5% in the northern part of Umstew, 20% in the central part of Umtynghiang drainage basin.

The higher frequency is marked due to the high seasonal rainfall and the lithological characteristics of the Pre Cambrian and Cretaceous Tertiary sediments. Among the most important factors influencing the drainage frequency is the occurrence of a very high amount of rainfall, and the presence of joints and fractures in the rocks.

Besides this, the sedimentary rocks play important role in the development of drainage frequency. The hard rock over the Cherrapunjee area does not allow large amount of percolation and hence surface runoff is high, and large amount of small streams originate over it.

The Stream Frequency map No.4 for the selected three small stream basins clearly shows the regional variation of frequency of streams per square kilometer on its surface. It is also noticed that the area of moderate to high stream frequency

i.e., 15 to 20 and 20 to 25 number of streams per square kilometer, coincides with the areas of moderate to high stream density indicating fine texture of dissection. A detailed analysis of the different stream frequency categories and the area occupied by these categories for each stream basin and their percentage to the total area has been given in the table 4 and figure no.3

Table 4  
**DRAINAGE FREQUENCY**

No. of streams/Sq.Km	Mawsiangkabthuh	Umstew	Umtynghiang
Above 25	2.90 (18.1%)	3.11 (11.3%)	2.44 (15.6%)
20 - 25	7.20 (45.0%)	4.55 (16.5%)	3.10 (19.9%)
15 - 20	1.07 (6.7%)	7.13 (25.9%)	4.38 (28.1%)
10 -15	3.79 (23.7%)	10.23 (37.1%)	3.11 (19.9%)
5 - 10	1.04 (6.5%)	2.29 (8.3%)	2.57 (16.5%)
Below 5°	—	0.23 (0.9%)	—

Mawsiangkabthuh

### Drainage Frequency

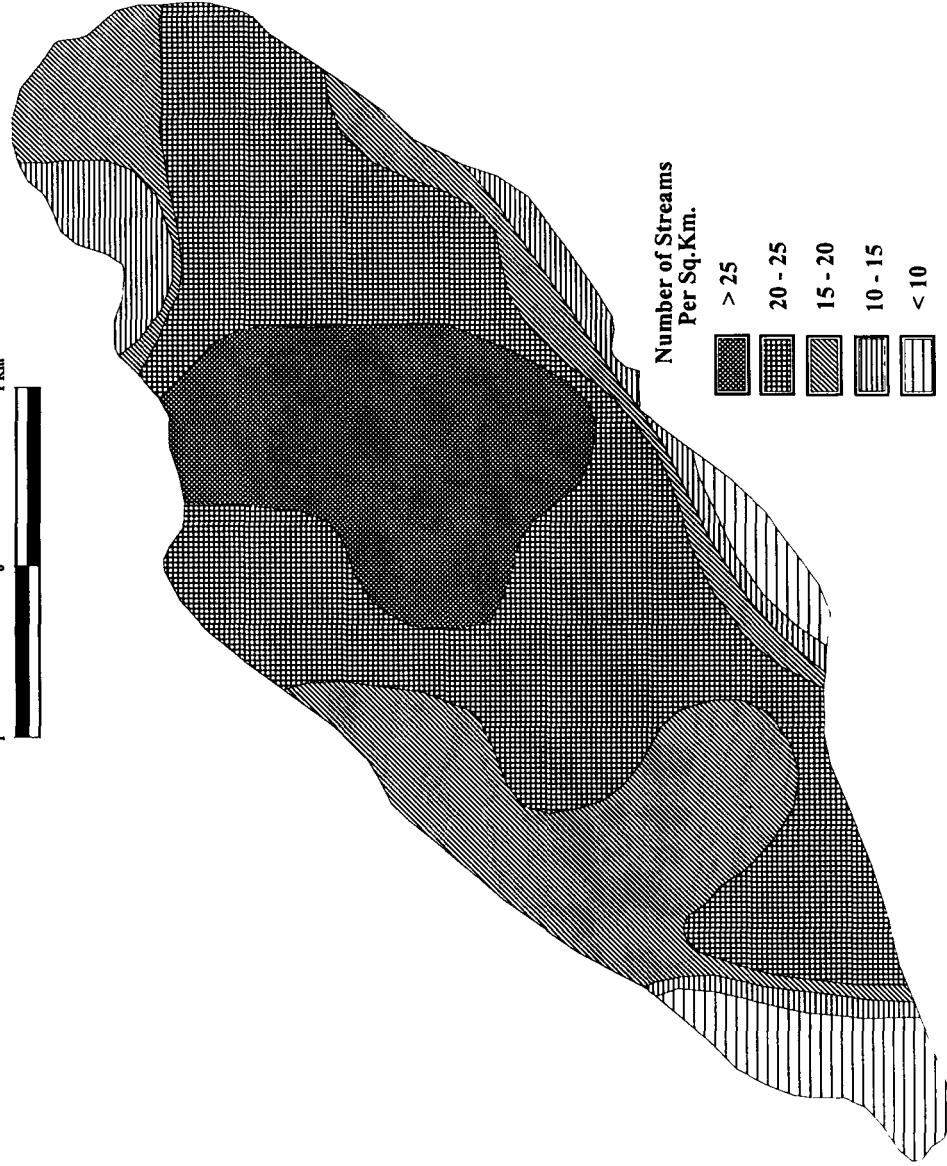
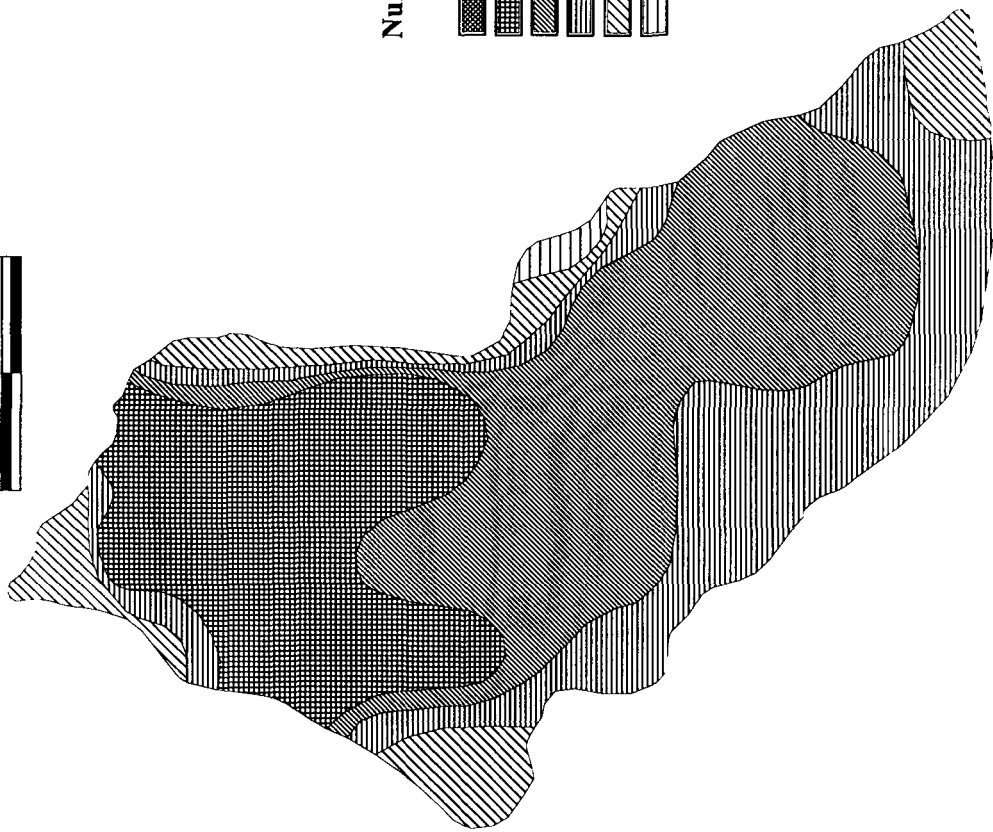


Fig. No. 3 (a)

# Umstew Drainage Frequency

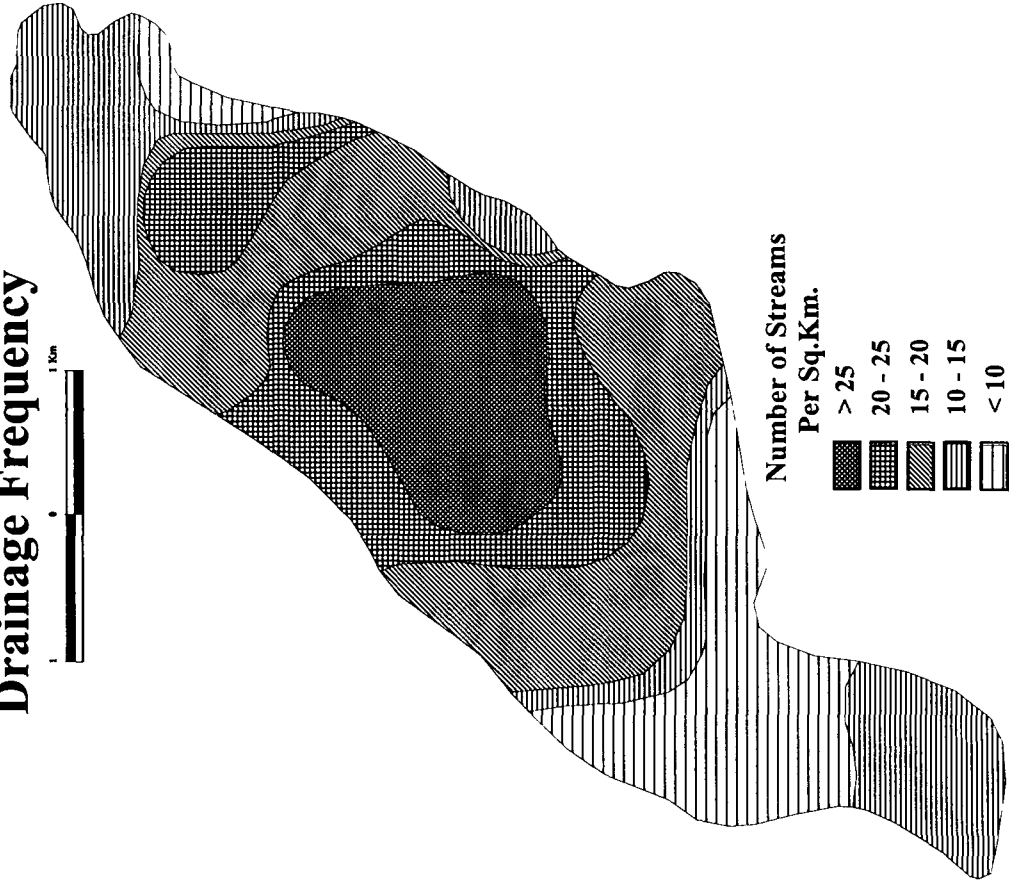


Number of Stream  
Per Sq.Km.

- > 25
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10
- < 5

Fig. No. 3 (b)

# Umtynghiang Drainage Frequency



Number of Streams  
Per Sq.Km.

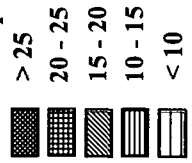
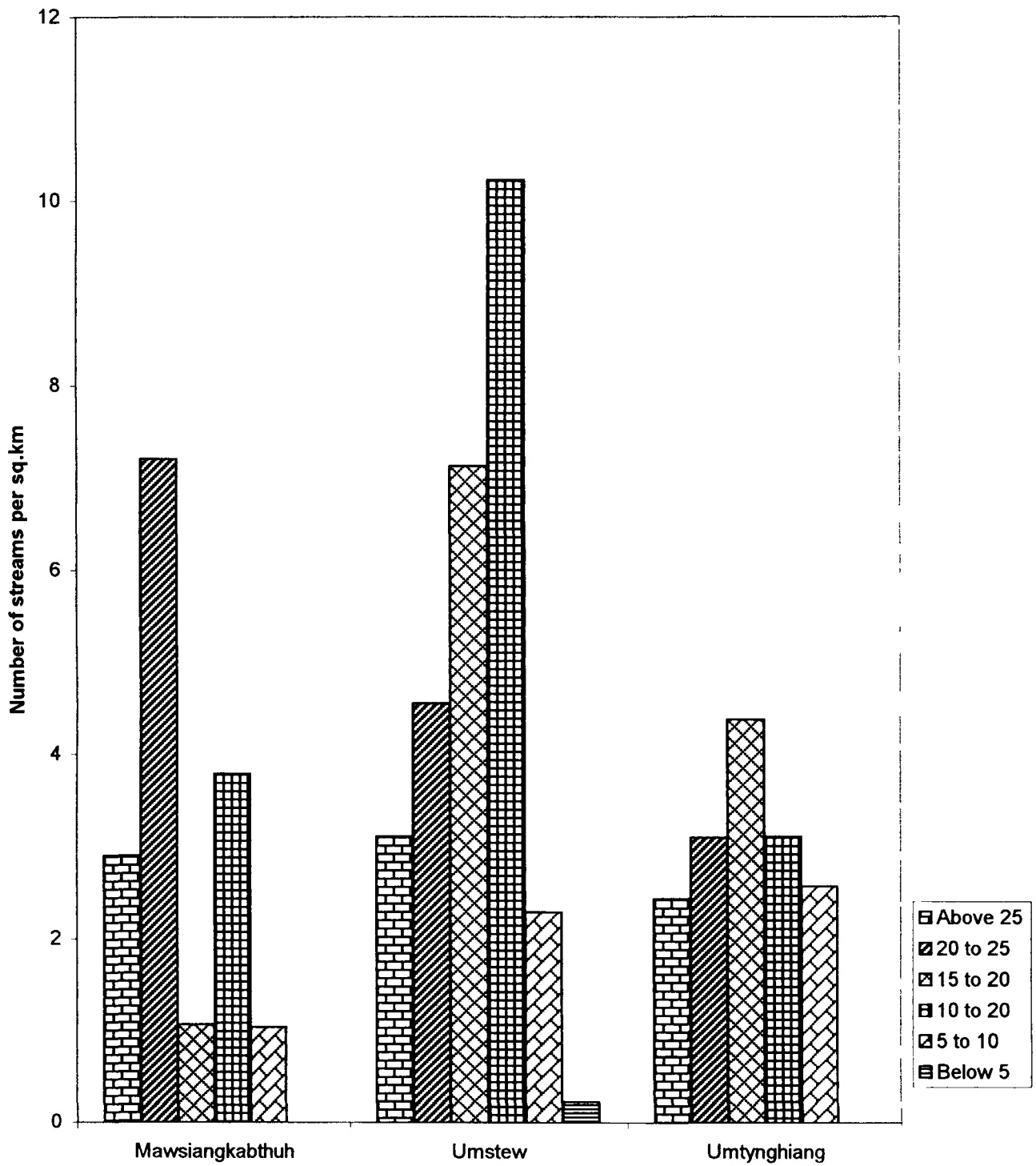


Fig. No. 3 (c)

### Drainage Frequency



Drainage Basins  
Fig 4

## **DRAINAGE DENSITY AND ITS TEXTURE**

Drainage Density is also another most important aspect of drainage analysis. Horton (1945) has used the formula to measure the drainage density, which can be obtained by dividing the total stream length, by the unit area. It can be expressed in mathematical formula as:

$Dd = L/A$  where,

Dd is the Drainage density,

L is the total stream length, and

A is the unit area.

The distribution of drainage density has been assessed qualitatively as well as in terms of statistical measures. The drainage density presented by Horton is included in hydrological studies. Grey (1965) told that the pattern and type of natural stream channels determines the efficiency of the drainage system. Drainage density is related to physiographic characteristics such as rock structures, types of rocks and shape of the basin. It is also related to the input and output of the drainage basin. The drainage density values vary according to the topography and rocks structure. It is also known that the increasing order basins contain a decreasing drainage density. Drainage density is an indication of the nature of landform dissection and closeness in the spacing of stream channels. It is also

defined as the ratio of the total stream length cumulated for all orders within a basin to a total basin area.

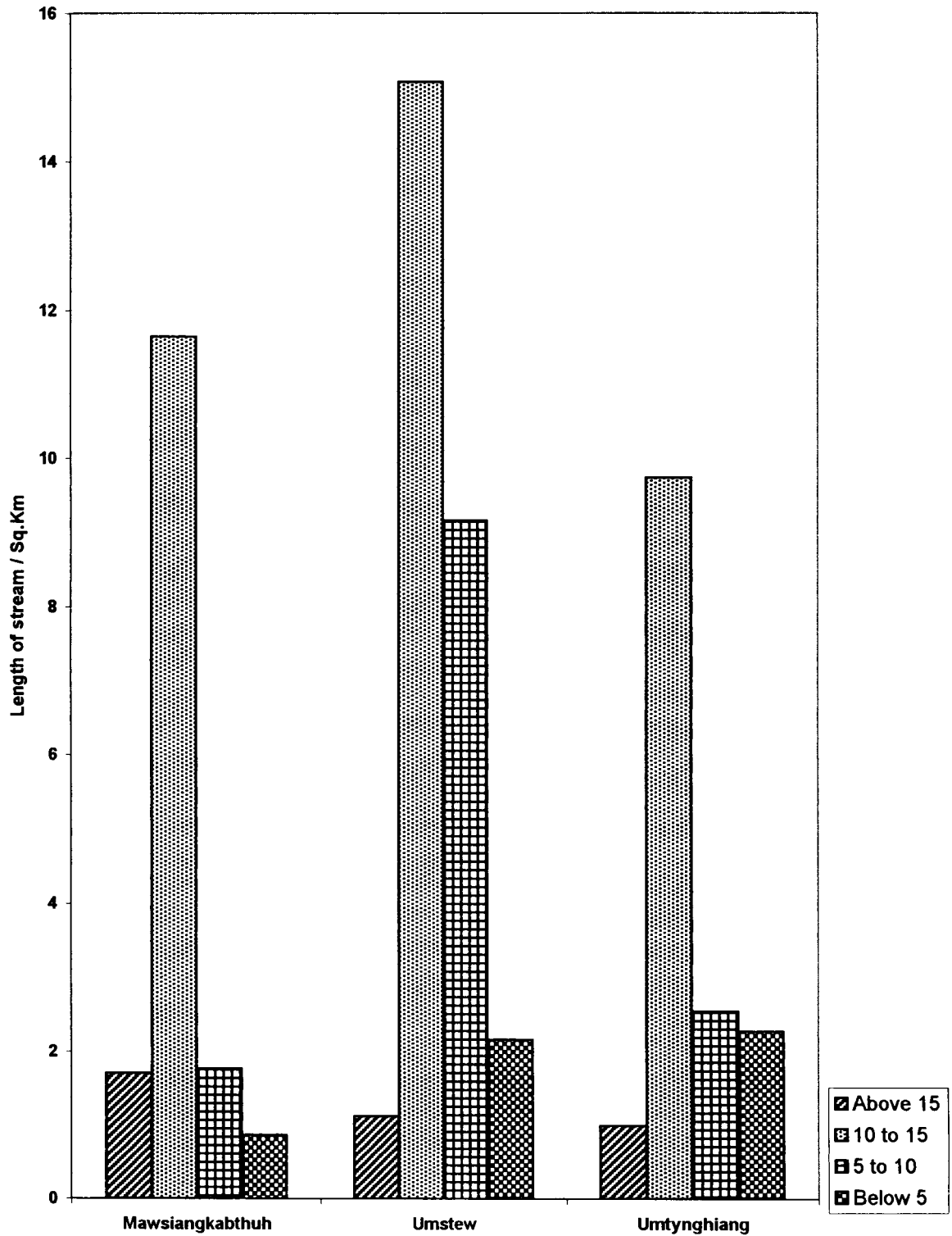
The drainage density map of the selected drainage basins in the study area has been divided into 2 centimeters grids representing 1 Sq.Km of the surface grids by using the above formula. After that, a choropleth map of drainage density is prepared. The drainage density has been classified into four categories ranging from 0 to more than 15 Km lengths of streams per square kilometer.

From the table 5 and drainage density map, it is clear that there is a wide variation in drainage density distribution in the study area. It is seen that the category of very high drainage density occurs only in the three drainage basins of Cherrapunjee (Mawsiangkabthuh, Umstew and Umtynghiang) area. The table 5 and Fig.No.6 below show the distribution of drainage density in the three drainage basins of Cherrapunjee.

Table 5  
**DRAINAGE DENSITY**

<b>Length of streams in Kms</b>	<b>Mawsiangkabthuh</b>	<b>Umstew</b>	<b>Umtynghiang</b>
Above 15	1.71 (10.7%)	1.13 (4.1%)	1.0 (6.4%)
10 – 15	11.65 (72.8%)	15.08 (54.8%)	9.75 (62.5%)
5 - 10	1.77 (11.1%)	9.16 (33.2%)	2.56 (16.4%)
Below 5	0.87 (5.4%)	2.17 (7.9%)	2.29 (14.7%)

### Drainage Density of Cherrapunjee



Drainage Basins  
Fig 6

Mawsiangkabthuh  
Drainage Density

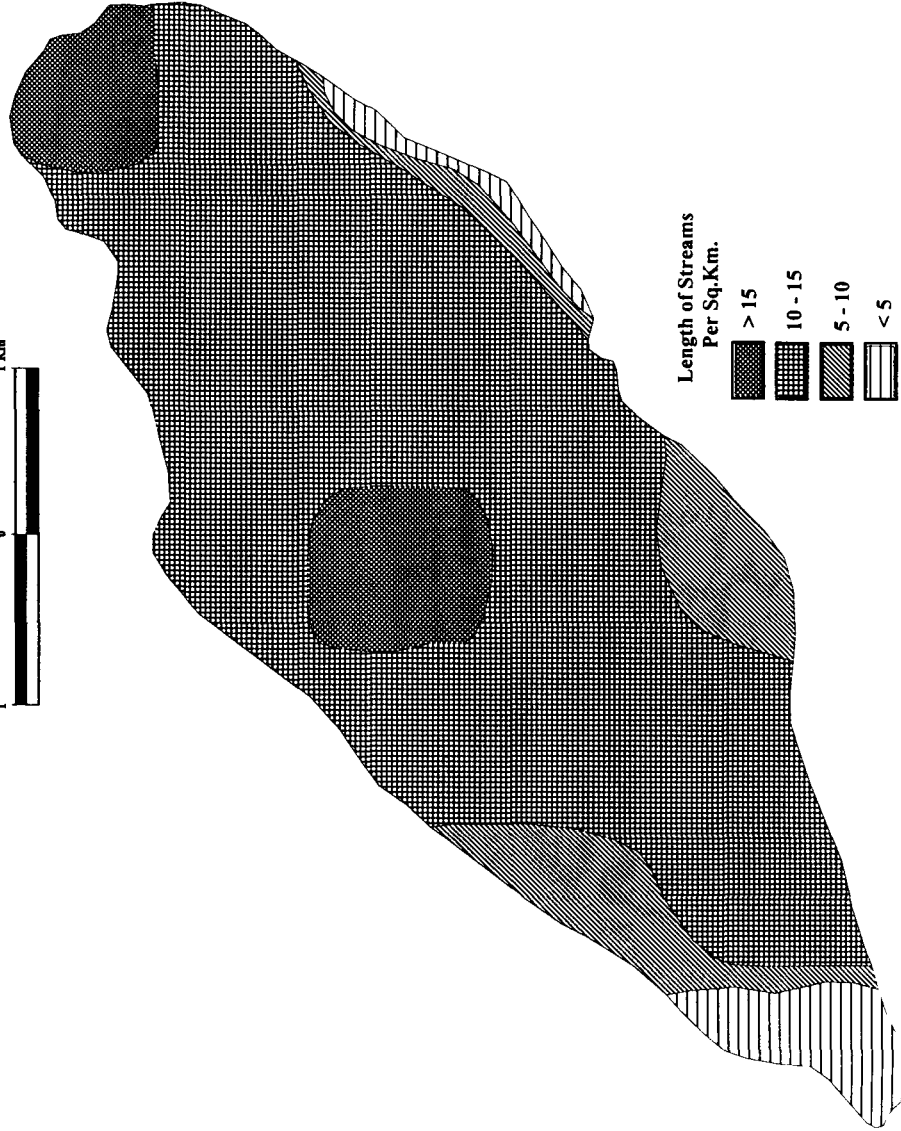
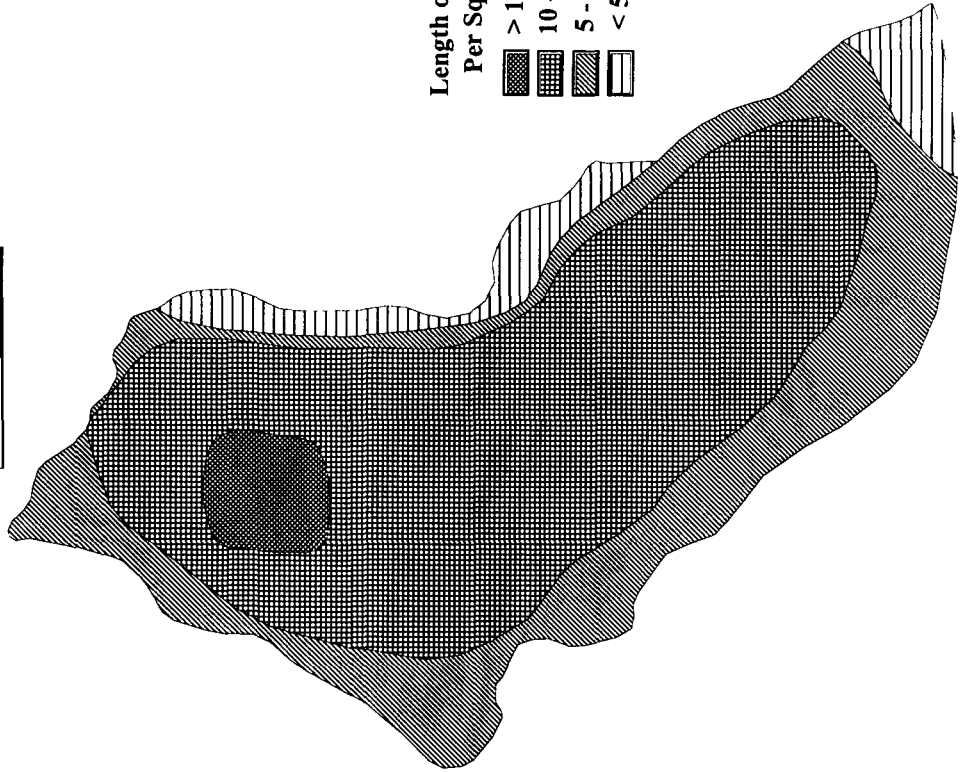


Fig. No. 5 (a)

Umstew  
Drainage Density



Length of Stream  
Per Sq. Km.

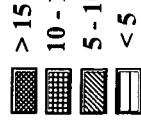


Fig. No. 5 (b)

# Umtynghiang Drainage Density

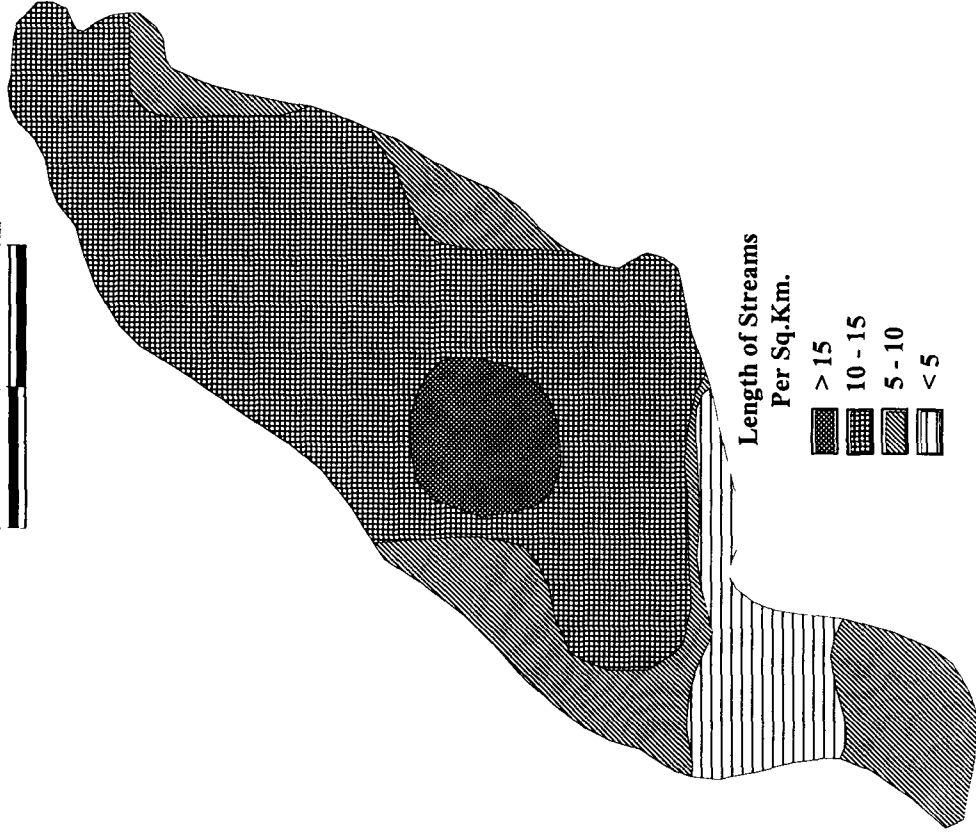


Fig. No. 5 (c)

The table 5 indicates that the category of very high rate of drainage density appears in a very low percentage in all the three drainage basins. This category is highlighted in the central and northeastern portion of Mawsiangkabthuh (10.7%), a patch of 4.1% in the northern part of Umstew drainage basin and 6.4% in the central part of Umtynghiang drainage basin. The high drainage density can be attributed to the hard resistant Achaean Complex and the Shillong group of rocks spreading over the undulating northern and highly dissected eastern, western and central part of the Cherrapunjee region, which becomes a controlling factor to the development of streams of the lower order.

The Drainage Density map No.5 and Fig. No.6 also highlighted areas under higher drainage density, which are of 10 to 15 Km lengths of streams per square kilometer. Maximum area in Mawsiangkabthuh drainage basin is covered by this category of drainage density i.e., 72.8% of its total area. This category spreads over the central region of the Mawsiangkabthuh drainage basin. This category of drainage density also dominates most of the area in the central part of Umstew and central and northern part of Umtynghiang drainage basins, which is about 53.7% in the northern part of the study area.

A moderate to high drainage density has been highlighted in all the drainage basins. This category is of 5 to 10 Km length of streams per square kilometer. A small patch in the southern part of Mawsiangkabthuh of 11.1%

comprised of this category of drainage density. 33.2% of the eastern and western portion of Umstew drainage basin is composed of this category of drainage density. Where as 16.4% of the southern part of Umtynghiang drainage basin is formed by this category of drainage density.

The low drainage density category comprises of areas, which have below five kilometer length of streams per square kilometer. This category appears in all the drainage basins of Cherrapunjee region but in a very low percentage. Only about 5.4% of the southern part of Mawsiangkabthuh drainage basin comprises of this category. The eastern most strips as well as the southern portion of 7.9% and 14.7% of the total basin area of Umstew and Umtynghiang drainage basins is marked by low drainage density.

The low drainage density is due to the fact that the basins are located in the region of highly permeable Cretaceous – Tertiary sediments with low relief features. An examination of isopleths map of drainage densities for all selected stream basins area is covered by the category of moderate to high drainage densities. This isopleths map also shows the spatial variations of drainage density over the surface at different parts of each of the three stream basin.

## SLOPE ANALYSIS

Slope, which makes up a large part of any land surface are important landforms for Geomorphologists, Pedologists as well as for Engineers. Erosion, deposition or a combination of both processes form slopes. When a stream cuts into land surface, valleys is created and slope forms that descend to the valley bottom and ascend to the upland. Slopes formed by constructional processes such as glacier deposits, wind deposits and mainly by water deposits sediments. Soon after a slope is formed, it is subjected to alternation by weathering, erosion and mass movement.

Slopes are fundamental elements of the landscape (King, 1962). The slope elements of an area reflect the evolutionary history of the existing landscape. In general, slope is often used to refer to the angle, which any element of landscape makes with the horizontal surface. Slope is also measured in grade or gradient.

Slopes are perceptible inclination visible on mountain ranges, ridges, scarps, plateau section, flanks of valleys etc. Commonly slopes are classified in terms of slope profiles, which are a slope belt of unit width extending from a drainage divide at the upper extremity, down to a lower terminus, which is commonly a stream channel or a natural discontinuity such as terrace, pediment or cliff. The primary aim of slope analysis is to identify slope elements in the study areas.

The method suggested by Wentworth (1930) for 'general and random' determination of Average Slope over an area from the Contour map is quite satisfactory, and has been adopted for the slope analysis in the area.

The formula devised by him is given below: -

**Average Slope = Tan  $\theta$  = N x CI / 3361 where,**

N is the average number of contour crossings in an area per sq.mile.

CI is the Contour Interval in feet.

3361 is a constant value.

Zakrzewska (1967) modified the above Wentworth formula as given below:

-

**Slope in degree = Tan  $\theta$  = V x N / 0.6366K where**

V is the Vertical contour interval in meter or feet.

N is the number of contour crossings per Sq.Kms or per sq.mile.

K is the constant value, 1000 for metric units and 5280 for feet and miles i.e., British units.

The area has been divided into one Sq.Km grids and the number of contours per Sq.Km i.e., per grid is counted (contour crossings per grid is divided by 4 = average contour crossing per grid). With the above-modified Wentworth's formula, average slope per grid is computed (the value obtained is converted into degree). These average slope values obtained has been classified into four

categories of 10° interval. The spatial distributions of the five categories of slope are depicted in the Average Slope map (Map No.3) of all the drainage basins. The frequency distribution of slope in the areas is highlighted in the following table 6, and its bar diagram is represented in Fig.No.8.

Table 6  
AVERAGE SLOPE IN SQ.KMS

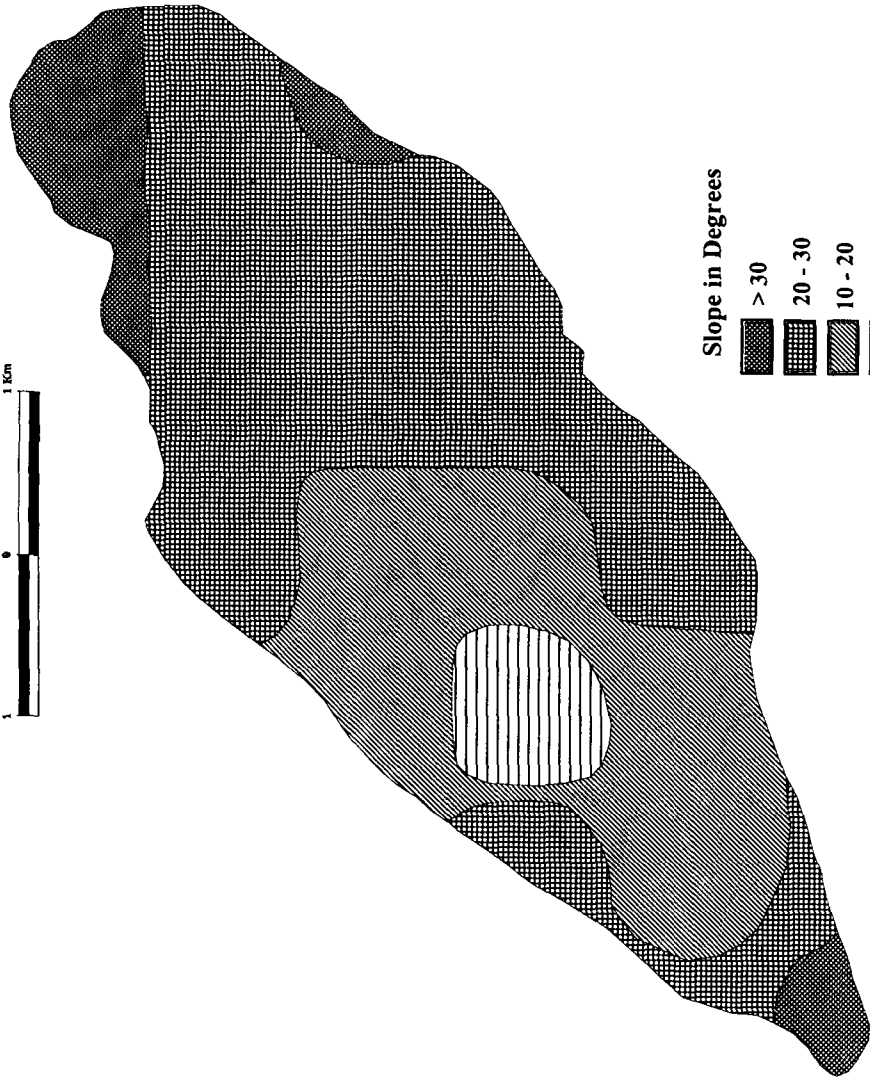
Slope in degrees	Mawsiangkabthuh	Umstew	Umtynghiang
Above 30°	1.70 (10.61%)	12.42 (45.1%)	-
20° - 30°	8.46 (52.9%)	12.54 (45.5%)	0.93 (6%)
10° - 20°	4.79 (29.9%)	2.18 (7.9%)	10.71 (68.6%)
Below 10°	1.05 (6.6%)	0.40 (1.5%)	3.96 (25.4%)

The table reveals the uneven distribution pattern of slope frequencies as per various slope categories in the areas. The category wise area slope distribution is discussed below: -

#### Level to Gentle Slope

This category comprises of areas having less than 10° of slope. It indicates low or gentle slope profile. The table 6 indicates that this category appears in a very low percentage in all the drainage basins with the exception of Umtynghiang

# Mawsiangkabthuh Average Slope



Slope in Degrees

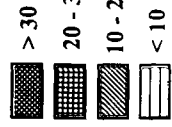


Fig. No. 7 (a)

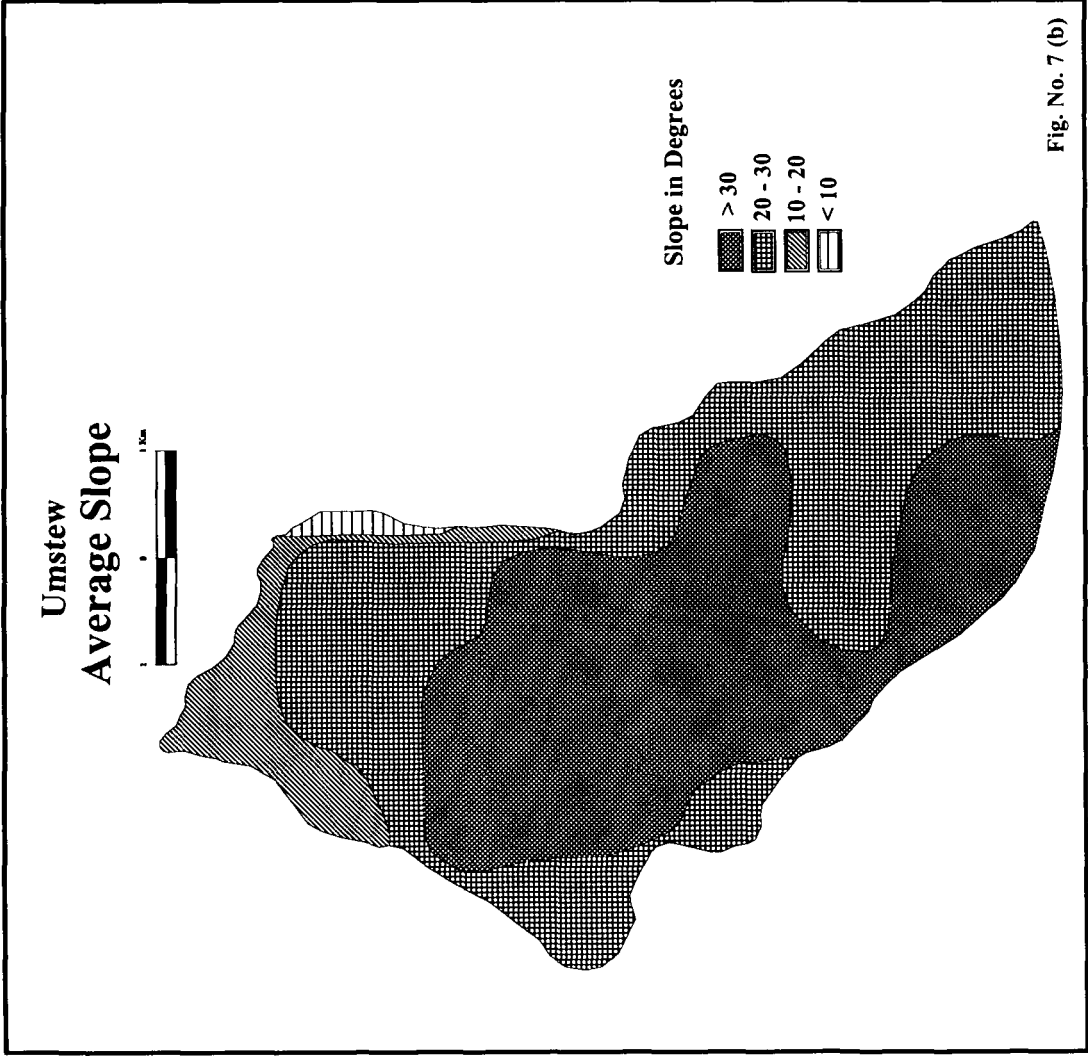
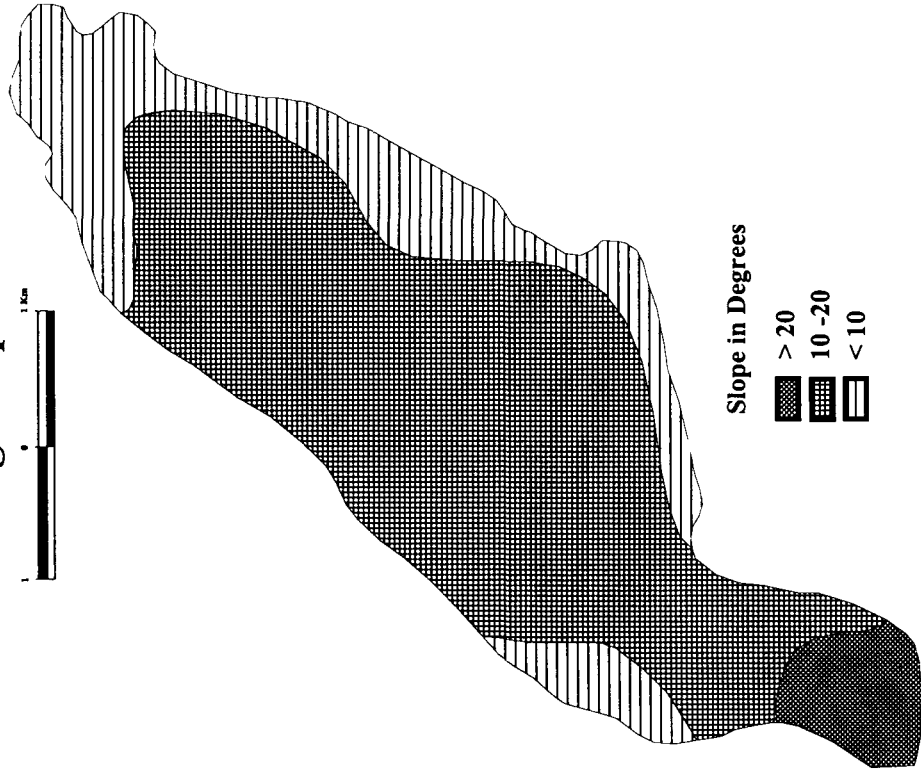


Fig. No. 7 (b)

**Umtynghiang  
Average Slope**



Slope in Degrees




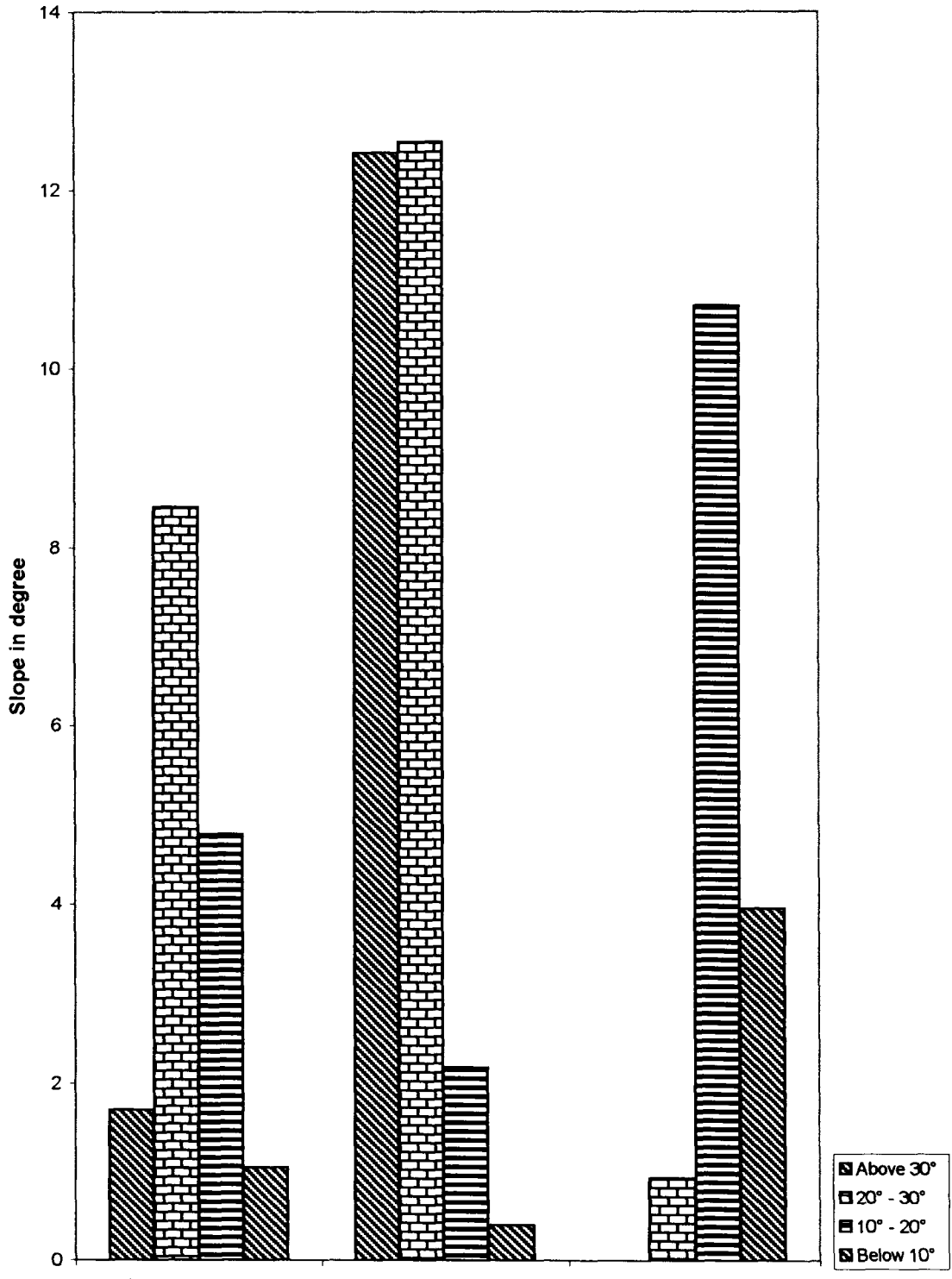
-  > 20
-  10 -20
-  < 10

Fig. No. 7 (c)

### Average Slope of Cherrapunjee



Drainage Basins  
Fig No 8

drainage basin, which is quite high. Mawsiangkabthuh drainage basin has 6.6% of its total area in the central portion that falls within this category. A very small portion of 1.5% in the northeastern part of Umstew drainage basin comprises of this category. Umtynghiang drainage basin has quite a large area of 25.4% of this category, which spreads over the extreme north, eastern and a small patch in the western corner. The area exposes mostly alluvial terraces. The conspicuous landforms in the sector are the high level terraces.

### **Moderate Slope**

The area of  $10^{\circ}$  to  $20^{\circ}$  of slopes is categorized under Moderate Slope. Moderate slopes occupy most of the area in Umtynghiang drainage basins. This category scattered over the central north and southern part of Mawsiangkabthuh drainage basin and cover about 29.9% of its total basin area. 7.9% of the upper part of Umstew drainage basin falls within this category. However, a maximum area of Umtynghiang drainage basin is highlighted to be covered by this category of slope, which is around 68.8%. The slope map itself indicates that most of the central portion of the basin area is of moderate slope. Sylhet limestone rocks are found in this category of slope.

### **Moderately Steep Slope**

This category of slope comprises of areas having 20° to 30° slope. The Average Slope table 6 reveals that most of the drainage basins of the study areas exhibits mostly of this category i.e., moderately steep slope. Cherrapunjee area composed of undulating uplands, which have moderately steep slopes varying from 20° to 30°. These undulating uplands are well drained by Mawsiangkabthuh and Umstew streams in Cherrapunjee. About 52.9% of the central and southern part of Mawsiangkabthuh drainage basin is of moderately steep slope. This category of slopes dominates most of the Umstew drainage basin area, which is of 45.5% covering the northern, eastern and southern portion of its basin area. Moderately steep slopes appear in the extreme south of Umtynghiang drainage basin and this is the highest category of slope in the case of this basin, which is 6% of the total basin area.

### **Steep Slope**

The areas having above 30° slope form this category. This category of steep slope comprises mainly of the Shillong group of rocks and it is quite thickly forested. This category spreads in about 10 to 25% of the basin areas. It covers the northernmost and southernmost parts of Mawsiangkabthuh drainage basin, covering an area of about 10.61%. This category is quite large in Umstew drainage

basin covering 45.1% of the central and southern parts of the basin area. However, this category is found to be absent in Umtynghiang drainage basin since the basin is dominated by moderately steep slope category.

### **RELATIVE RELIEF**

The relief in its true meaning is the relative vertical inequality of the differences in elevation of any of the Earth's surface, collectively or individually. The relative relief analysis has been computed from the Survey of India 1:25,000 toposheets with 10-meter contour interval. The relative altitudes give more regional character to the physical landscape than the precise altitude of single peak. The inability of the absolute relief in expressing the total morphological character of landform, and the lack of giving the sharpness of relief, leads to the investigation of still comprehensive devices to express the three dimensional forms with two dimensional medium. The 'relief energy' method, based on the difference of the highest and lowest altitudes in a unit area is one of them. This method has been used as early as 1911 and was adopted by Smith, but with connotation as relative altitude or relative relief. It presents a better index of erosion along with the stage of development.

The relative relief map of the study areas presents the vast variation and uneven distribution of relative relief categories, which varies from 100m to 700m.

The spatial and areal distribution of relative relief categories is evident from the table 7 and Fig.No.9 shown below.

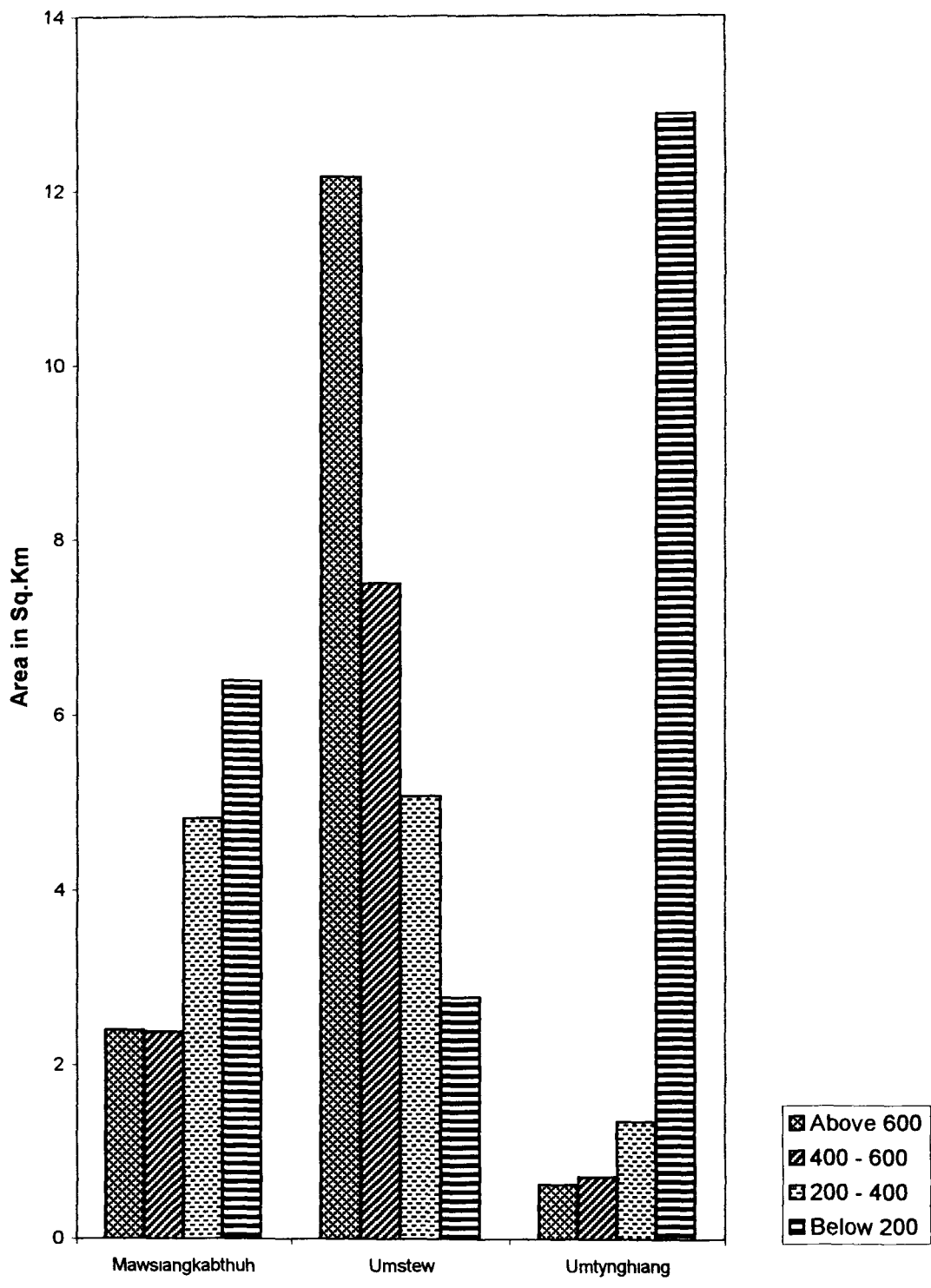
Table 7  
**RELATIVE RELIEF**

<b>Height in meters</b>	<b>Mawsiangkabthuh</b>	<b>Umstew</b>	<b>Umtynghiang</b>
Above 600	2.40 (15.0%)	12.17 (44.2%)	0.63 (4%)
400 - 600	2.38 (14.9%)	7.51 (27.3%)	0.72 (4.6%)
200 - 400	4.82 (30.1%)	5.08 (18.4%)	1.36 (8.7%)
Below 200	6.40 (40.0%)	2.78 (10.1%)	12.89 (82.7%)

Most of the drainage basins exhibit low relative relief features, which is about 40% of the northern part of Mawsiangkabthuh drainage basin. This category occupies the largest areas in these two basins, where as a small patch in the northern part of Umstew drainage basin, which is about 10%, is of low category of relative relief. This category of relief has the highest percentage, which is of about 82.7% in the Umtynghiang drainage basin occupying the whole northern and central portion of the map.

The category of 200m to 400 m is marked as Medium or Moderate Relative Relief. This category spreads over each and every drainage basin of the study areas. Relative Relief of this group prevails in the central and southern parts of

### Relative Relief of Cherrapunjee



Drainage Basins  
Fig 9

# Mawsiangkabthuh Relative Relief

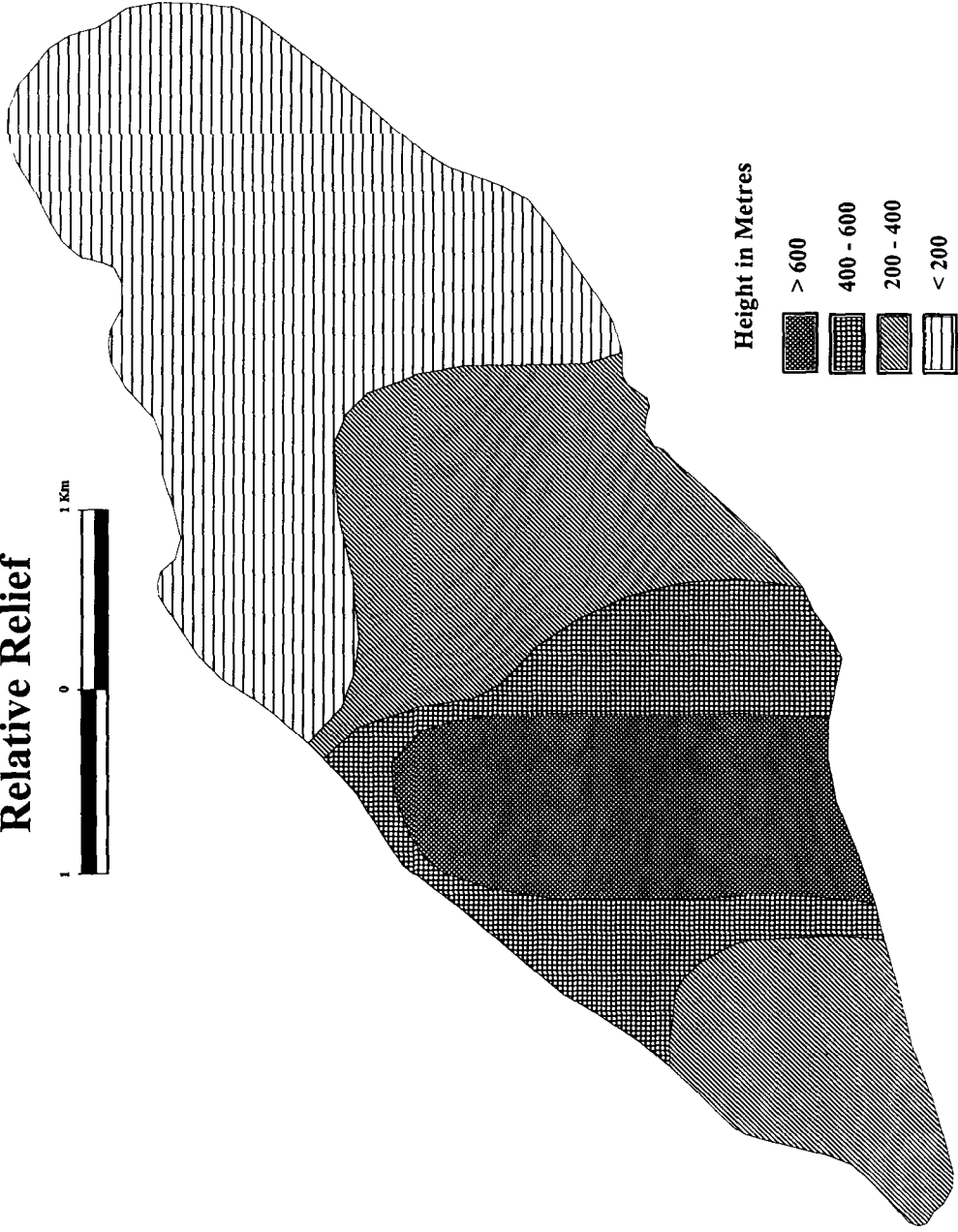


Fig. No. 10 (a)

# Umstew Relative Relief



Height in Metres

[Cross-hatched pattern]	> 600
[Vertical line pattern]	400 - 600
[Diagonal line pattern]	200 - 400
[White box]	< 200

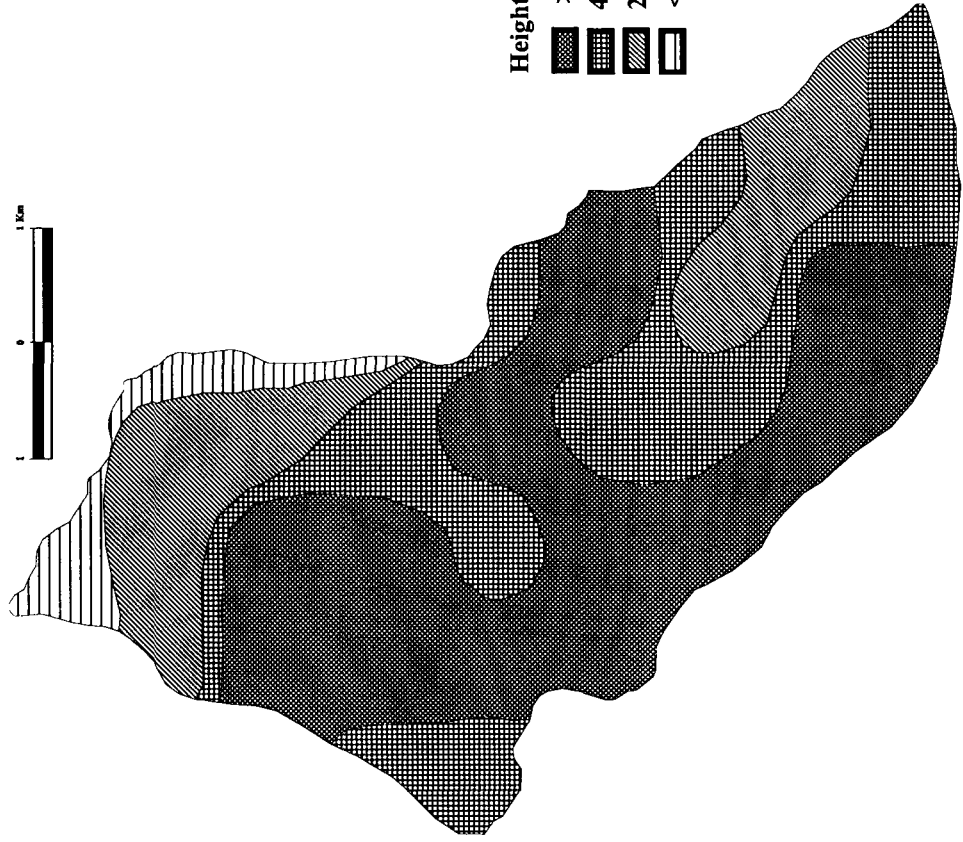


Fig. No. 10 (b)

# Umtynghiang Relative Relief

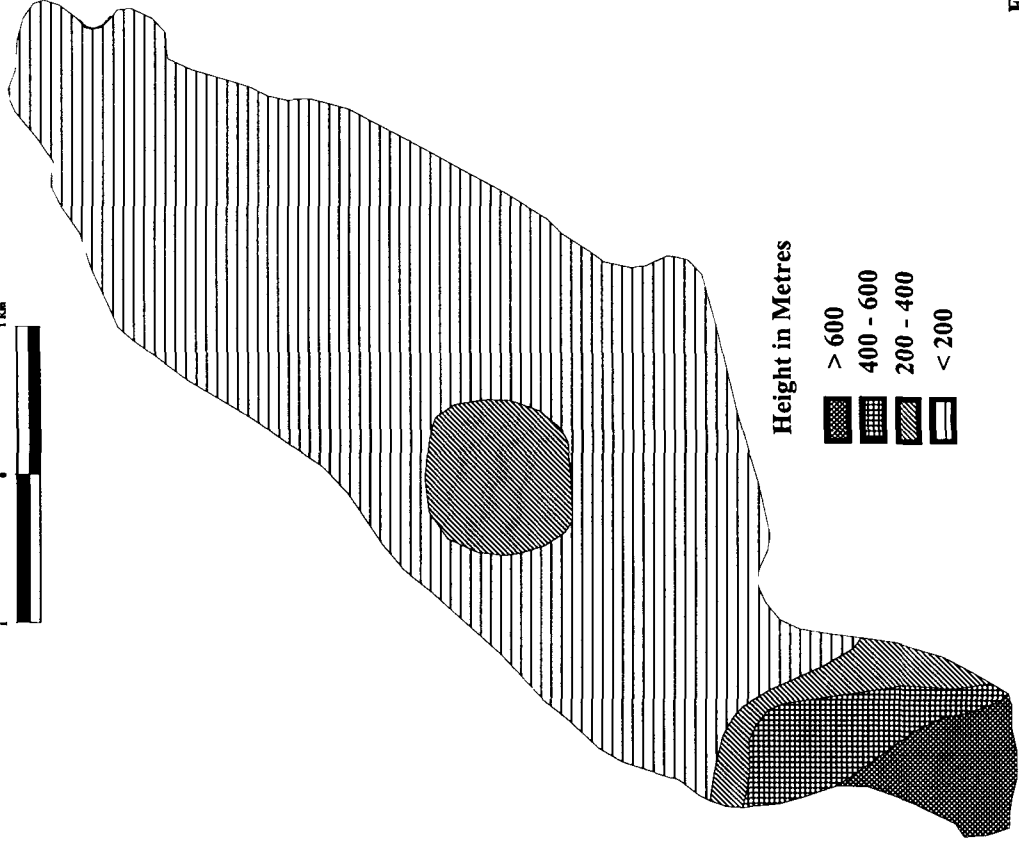


Fig. No. 10 (c)

Mawsiangkabthuh drainage basin, covering an area of about 30.1%. The northern block and southeastern corner of Umstew drainage basin is also in this category representing 18.4% of its total area. This category also occupies about 8.7% of the southern part of Umtynghiang drainage basin.

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## **CHAPTER IV**

## **Hydrological Analysis**

The study area, i.e. the Cherrapunjee region is very much influenced by various hydrological attributes, such as the climate of the region, the weather conditions, rainfall, temperature and relative humidity. All these attributes result in the occurrence of drainage systems like small streams and rivers. Thus, in hydrological analysis, apart from temperature and rainfall, drainage systems also play a very important role.

### **Climate**

Situated between the rain shadow part of the Shillong Plateau in the north and Bangladesh plains in the south, Cherrapunjee area experiences extremely varied climatic conditions mainly caused by altitudinal aspect. The area experiences tropical monsoon climate. The plateau bears the brunt of the monsoon, which begins, from May to September. The moisture bearing winds obstructed first by the scarp face of the Shillong Plateau precipitates moisture over Cherrapunjee with annual rainfall exceeding 1100 cms and becomes the rainiest region of the world. The Cherrapunjee area also experiences cold temperate climate with foggy winter months while the southern part of the terrain along the Bangladesh border experiences hot summer and cool winter months similar to that

of the adjacent plains. There is a marked seasonal variation of temperature and rainfall in the area.

The southern sandy foothill tracts experience hot and sub-humid tropical climate. With the increase in the altitude towards north, the climate changes from rainy, cool temperate to a little bit rainy, cold temperate. The most significant factor controlling the climate of Cherrapunjee is southwest monsoon and altitude. Based on the principles of Lapse Rate the areas lying below 300 m above sea level have moist tropical climate. The areas above 300 m but below 1500 m above sea level experiences rainy cool temperate climate. Higher up, the climate is rainy cold temperate up to an elevation of 3000 metres. The second most important factor affecting the climate of Cherrapunjee region is Monsoon heavy rainfall. The south facing slopes in this region is the heaviest rainfall areas of the world today. The north facing slopes fall in the rain shadow area of Shillong Plateau and are thus comparatively dry.

Climate no doubt consist of many elements like temperature, pressure, humidity, winds, rainfall, snow, fog, moist, frost, clouds, vegetation etc. Yet for our present purposes the elements of rainfall, temperature, humidity and vegetation are described here.

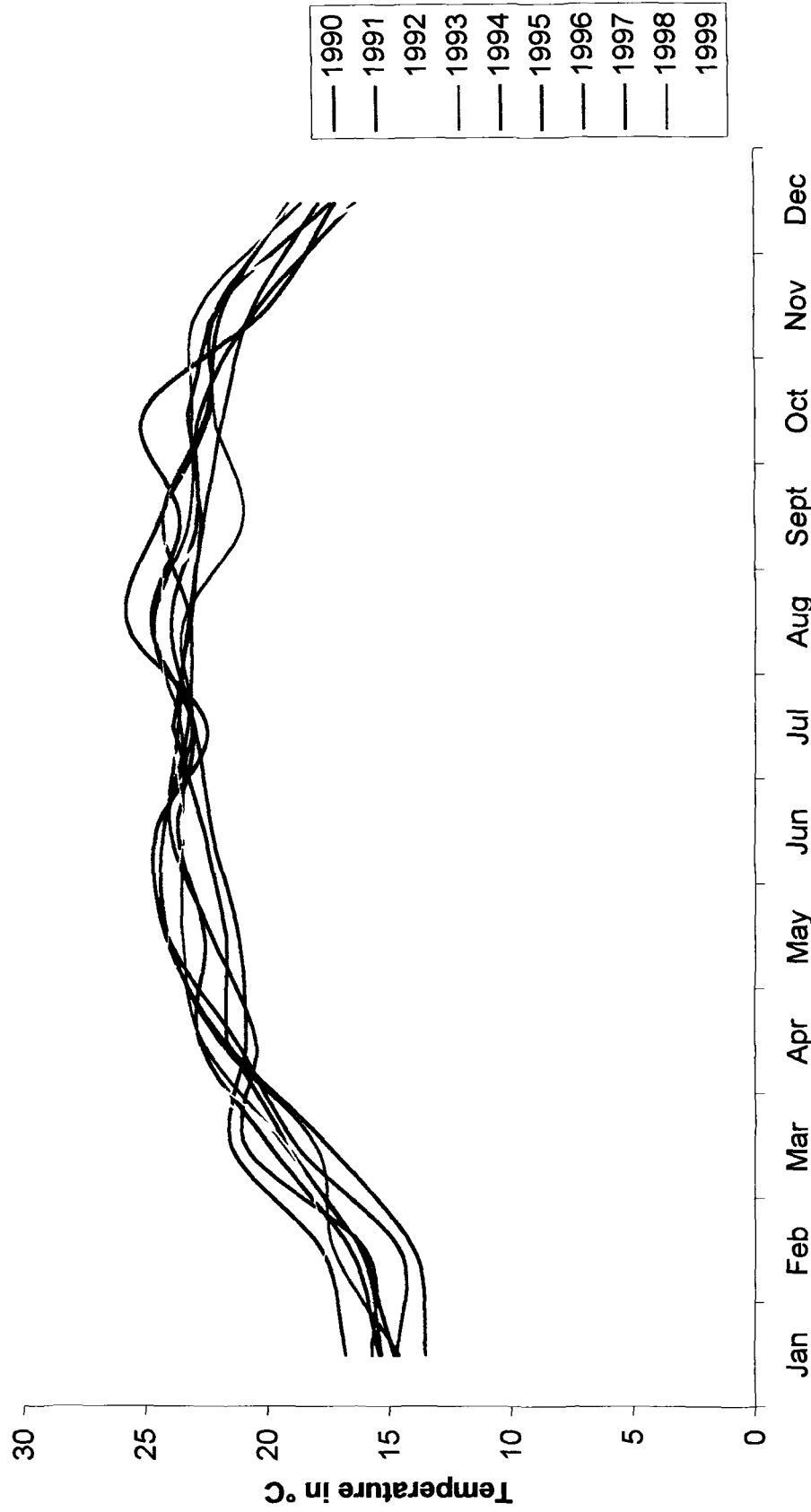
### Temperature:

With the exception of the southern slopes, normal monthly maximum temperature is recorded in this area. Temperature varies from 16°C in winter to 26°C in summer. The highest record is observed in the month of June, July and August. In general, temperature rises during the months of April to October. On set of rainy season during the same period brings down the temperature. The temperature continues to fall with the break of rains and the lowest mean maximum temperature is observed in the months of December and January. The temperature data are based on daily observations of maximum temperature.

Table No. 8  
**Mean Maximum Temperature of Cherrapunjee (in °C)**  
 1990 – 1999

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1990	13.5	14.0	17.5	21.8	24.2	24.6	22.5	25.8	24.4	22.4	22.0	17.4
1991	16.8	17.8	21.5	20.9	21.2	22.3	23.0	24.0	22.9	22.8	20.4	16.4
1992	16.0	14.5	19.8	23.5	23.7	23.4	23.5	24.8	22.7	24.8	22.7	16.2
1993	14.6	17.3	18.0	22.0	24.1	24.3	23.1	23.5	21.0	22.2	21.8	19.0
1994	14.8	16.1	19.2	21.7	21.7	22.6	23.9	23.2	22.7	23.3	22.2	19.0
1995	15.4	16.6	19.9	22.8	22.6	23.7	23.1	24.8	23.6	25.1	20.0	17.2
1996	14.7	14.6	18.8	21.3	24.1	24.3	23.3	23.2	24.3	22.5	21.8	19.1
1997	15.7	16.0	20.9	20.5	22.3	24.0	23.7	23.3	22.6	21.8	20.6	17.9
1998	15.3	16.2	19.3	22.7	23.5	23.5	23.6	24.7	23.2	23.1	22.8	18.6
1999	18.7	17.7	19.2	23.8	24.1	23.5	24.0	24.4	24.1	23.6	22.2	19.0

# Mean Maximum Temperature of Cherrapunjee 1990 - 1999



Months  
Fig 11

The table No.8 and Fig.no.11 shows that mean maximum temperature in the study area is highest in the months of June i.e. 23.6 C and August (24.2 C), and the lowest in the month of January (15.5 C). During the months of March and April the atmosphere gradually warms up and there is the advent of spring season. From the middle of April to middle of May, the temperature reaches maximum point and this may be termed as the summer season. The mean monthly minimum temperature of Cherrapunjee for the last 10 years (1990-1999) is also given in the table No.9 and Fig No.12, which are also represented in a graph. The average minimum temperature for the month of January was 6.4 ° C and December was 7.7 ° C. where as the mean minimum temperature recorded during June, July and August was 16.9 °C, 17.5 °C and 18.1 °C respectively. The table indicates that the variation between average monthly maximum and minimum is very high in the month of January. As the summer advances the difference between monthly maximum and minimum temperature seems to have narrow gap from the month of May to September.

# Mean Minimum Temperature of Cherrapunjee

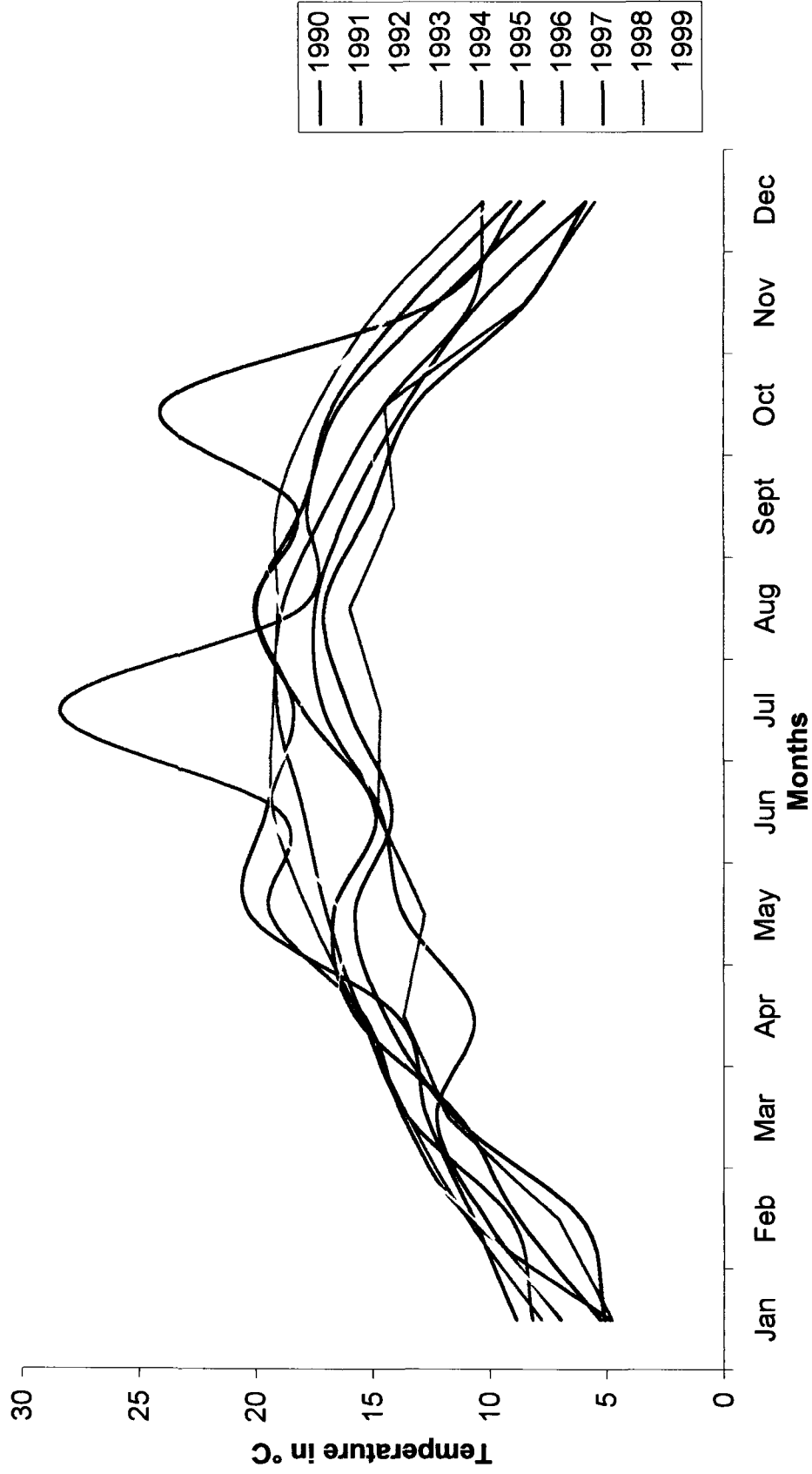


Fig.12

Table No. 9  
**Mean Minimum Temperature of Cherrapunjee (in °C)**

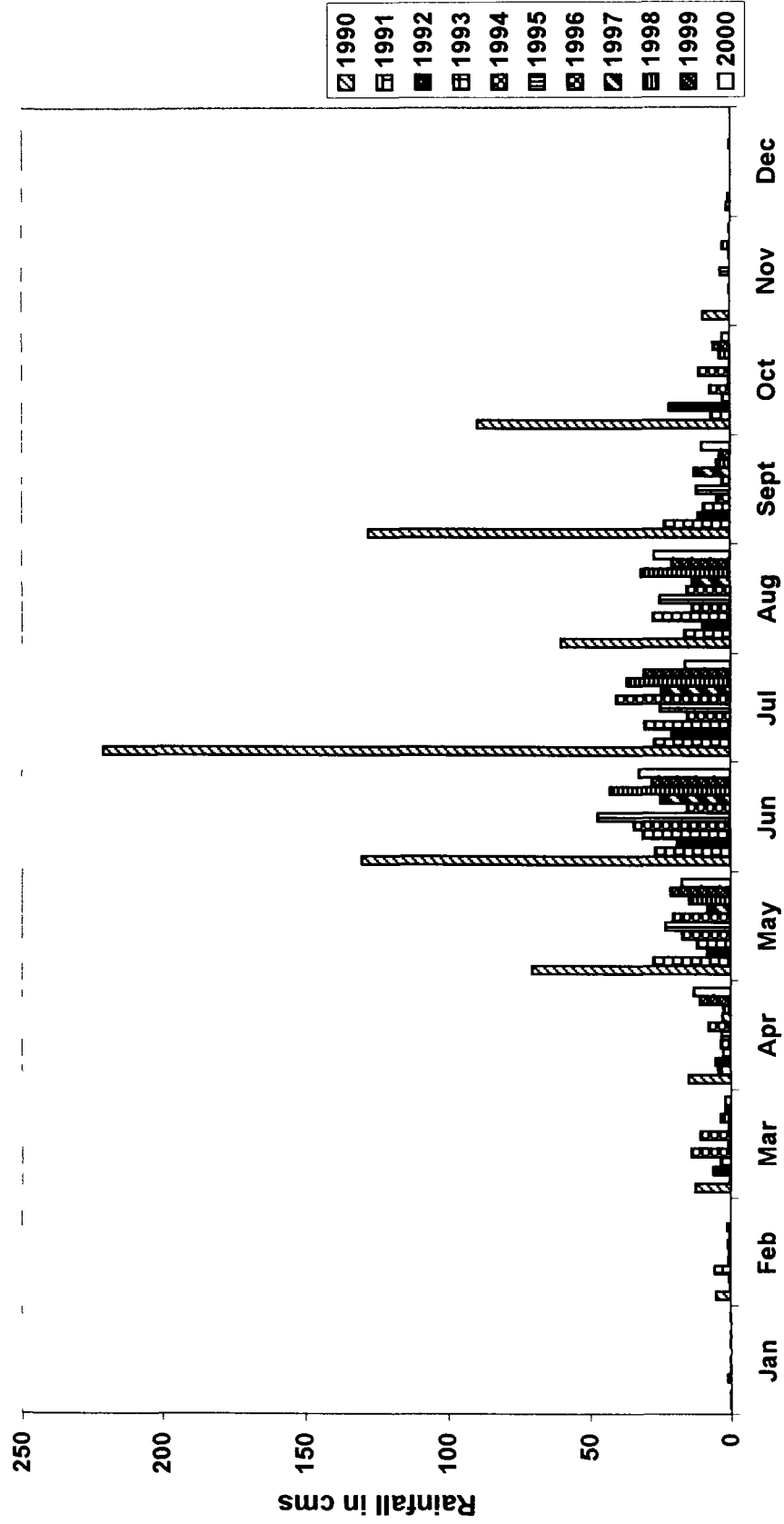
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1990	8.9	10.7	12.7	14.0	20.3	19.6	18.4	20.0	18.0	16.4	12.3	7.7
1991	7.0	10.2	12.3	10.7	13.7	14.7	17.1	17.5	16.0	13.6	10.5	5.9
1992	5.2	6.2	11.8	12.9	12.9	14.8	16.2	16.0	15.0	14.4	8.6	4.9
1993	4.8	7.1	11.8	13.7	12.8	14.8	14.7	16.0	14.1	14.5	8.5	5.5
1994	5.1	6.1	11.5	14.5	15.8	14.2	16.0	17.1	15.1	13.2	8.5	5.9
1995	5.3	8.8	11.3	15.8	16.7	14.9	18.0	20.1	18.3	24.0	12.4	8.7
1996	4.9	10.9	13.7	15.4	19.4	19.0	28.4	18.1	17.8	16.7	13.4	9.1
1997	8.2	9.1	13.5	15.5	17.0	18.0	19.1	18.9	17.0	14.5	10.8	10.3
1998	7.8	11.0	13.5	15.6	17.7	19.3	19.3	19.1	19.1	17.4	14.6	10.3
1999	6.8	10.7	15.1	16.5	16.4	19.4	18.1	19.0	20.0	18.1	13.7	9.9

## Rainfall

Generally, the amounts of rainfall received increases from the southern foothill tract of the study area towards the north, according to change in relief. The amount of rainfall decreases further north due to the effect of rain shadow.

Cherrapunjee is situated at an altitude of 1340 m. A part of Bay of Bengal monsoon enters the funnel shaped valley lying just to the south of Cherrapunjee. This may be the main cause of high rainfall in this area. In the eastern region rainfall is slightly less than the central region but definitely it is scanty in western Meghalaya.

# Annual Rainfall of Cherrapunjee



Months

Fig 13

The annual course of rainfall is typical for a monsoon climate, with a concentration from May up to September accounting for 88% of the total by volume. The mechanism of such heavy rainfall is connected with the monsoonal circulation (O'Hare 1997, Starkel and Basu 2000). The areal extent of annual rainfall of more than 10,00 cm probably does not exceed 200 Sq.Km in the Cherrapunjee region, because of its typical orography. The scarps block the humid air but it may invade deeper along the canyons. The summer monsoon reaches the plateau during late May.

The average monthly rainfall of Cherrapunji for the last 11 years (1990-2000) is given in the table No.10 and represented in the form of a bar diagram (Fig. No 13). Figures indicate that for the period of last 10 years the average annual rainfall in the area was 235.39 cm with the highest rainfall of 1356.94 cm in 1990 and minimum rainfall of 89.97 cm in 1997. It is seen that maximum rainfall occurs during the months of June to September. While very less or no rainfall was recorded during the months of December and January, highest amount of rainfall was recorded in August 1990, which amounts to 603.4 cm.

Table No. 10  
**Monthly Rainfall of Cherrapunjee (in cms)**

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1990	0.19	5.34	12.85	15.17	70.25	130.15	220.89	60.3	127.71	89.6	09.6	1.5
1991	0.18	0.21	0.51	4.44	27.57	26.96	27.24	16.54	23.57	6.94	0.03	0.89
1992	0.02	0.69	6.44	5.33	8.53	19.2	21.1	10.19	11.65	21.81	0.03	0.05
1993	1.25	5.87	3.67	2.64	12.22	31.37	30.67	27.75	9.68	2.75	0.12	0
1994	0.28	0.85	14.29	3.41	17.23	34.35	15.39	13.76	4.8	7.52	0.08	0
1995	0.17	0.68	0.97	3.32	23.24	47.11	25.15	25.31	12.19	0.55	3.51	0
1996	0.06	1.03	10.95	8.06	20.67	15.54	40.62	15.59	3.16	11.3	0	0
1997	0.19	0.38	0.73	3.13	8.5	24.9	24.79	13.64	13.01	0.21	0.12	0.37
1998	0.11	1.24	3.63	2.65	14.81	42.7	36.87	31.81	4.95	3.89	2.72	0
1999	0	0	2.12	11.08	21.52	28.13	30.95	20.9	4.02	6.27	0.01	0.04

### **Depth to Water Level below the Ground**

It is an obvious fact that Cherrapunji is declared the wettest place in the world, however the rate of water percolation is quite high due to the presence of sedimentary composition of rocks. Therefore, the depth of water level below the ground is very shallow. The table 11 below shows the depth of water level below ground in Cherrapunji:

Table No. 11

**Depth to Water Level below the Ground (m)**

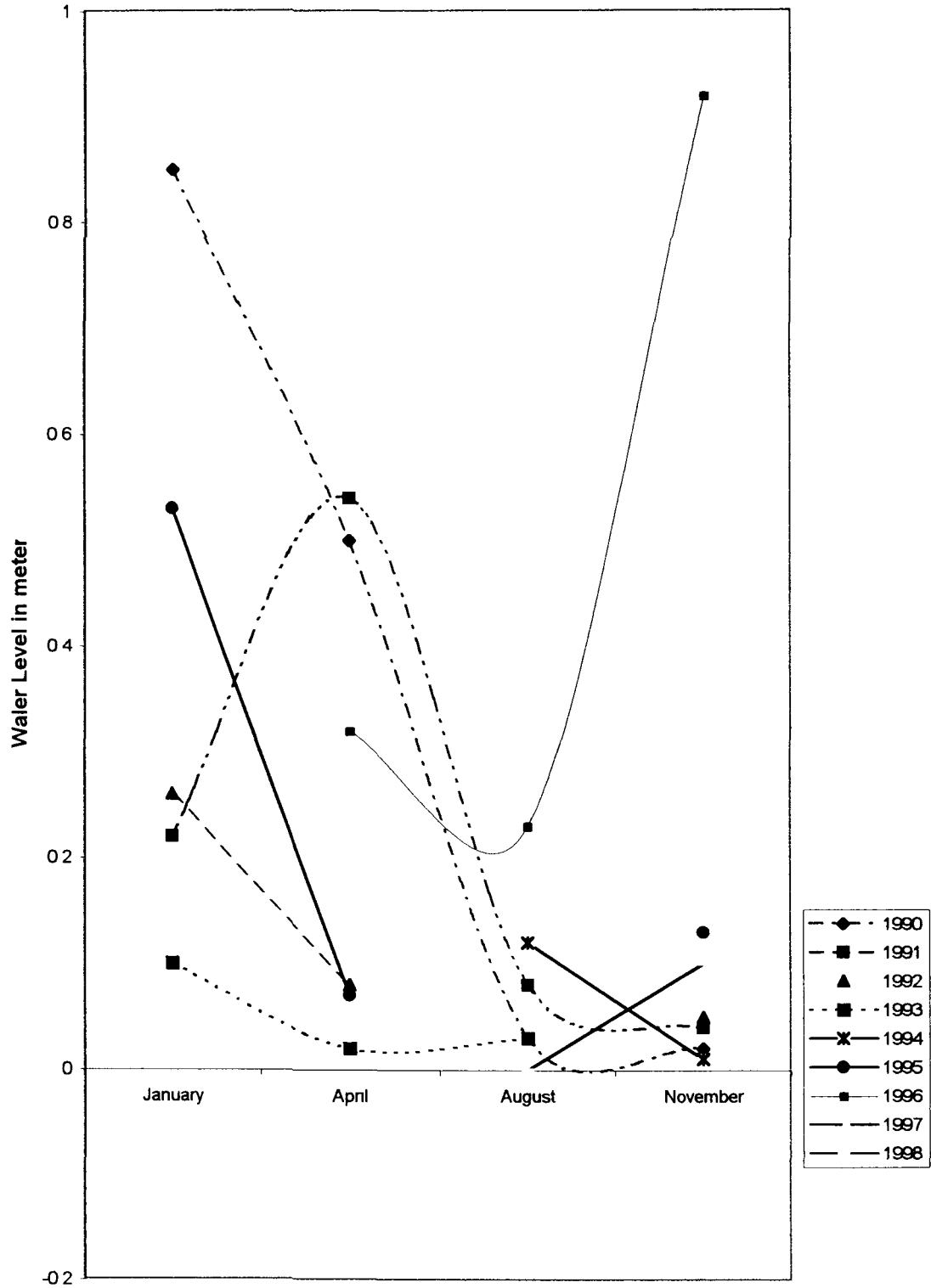
<b>Year</b>	<b>January</b>	<b>April</b>	<b>August</b>	<b>November</b>
1990	0.85	0.5	0.03 Agl	0.02 Agl
1991	0.22	0.54	0.08 Agl	0.04 Agl
1992	0.26	0.08 Agl	NA	0.05 Agl
1993	0.1	0.02 Agl	0.03	NA
1994	NA	NA	0.12	0.01
1995	0.53	0.07	NA	0.13
1996	NA	0.32	0.23	0.92
1997	0.76	NA	NA	0.18
1998	NA	NA	0	0.1
1999	0.6	0.05	0	0.11

Data Source – Central Ground Water Board, State Unit Office, Shillong.  
NA – Not Available

Agl – Above ground level

The depth of the water level in Cherrapunjee is measured by using any particular tank, well or pond, which is known as *Pung* in Khasi. If the pond is well covered or if a cement wall is constructed around it to protect the pond and its water, the measurement of the water level can be taken from the top of the cover, which is the measuring point. But in the case of an open well, the measuring point can be taken from its topsoil surface, which is known as *Ground Level*. Thus, the water level measured is below the ground surface during most of the time in a year. But measurement that is above ground level (Agl) is obtained from a tank or

### Depth of Water Level in Cherrapunjee 1990 - 1999



Months  
Fig 14

a covered well when the rise of water level could be noticed and measured from the ground level. The table No.11 and Fig. No.14 given is the measurement of water level of a particular well in Cherrapunjee.

The Hydrographs indicates that during 1990 to 1999, the depth of water level was very low during the month of January, and the water level increases with the onset of monsoon. It was only during the summer months of 1990 – 1993 that the water level appears to be above ground level.

### **Humidity:**

It is the humidity of climate whose variations appear to exercise the greatest influence on the evolution of relief. High atmospheric humidity generally associated with high rainfall favours chemical decomposition by the action of water infiltrating below the surface. It has been noticed that high humidity accompanied with high rainfall helps in chemical decomposition of the exposed sedimentary rocks in Cherrapunji.

Table No. 12  
**Relative Humidity of Cherrapunjee (in %)**  
**1990 – 1999**

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1990	82.5	77.5	70.0	72.0	64.5	92.5	95	95	91.5	77.5	75	65
1991	69.5	52.5	78.5	84.0	78.5	98.5	84	97	91.5	92.5	68	63.5
1992	72.0	63.0	88.5	74.5	74.0	92	95	88	91	88	55.5	57
1993	62.0	84.0	45.5	82.0	98.0	77.5	89.5	89	91	73	88.5	79.5
1994	81.5	58.5	89.5	87.0	85.5	99	77	88.5	77.5	82	57	72
1995	51.0	79.0	43.5	82.5	99.0	97	97.5	91.5	73.5	81.5	68	79
1996	64.5	52.5	91.5	66.5	93.5	81	98	94.5	67	55	74	83.5
1997	51.5	86.5	88.0	74.0	75.5	98	92.5	95.5	93.5	78.5	79	85
1998	82.5	79.5	70.0	72.0	61.5	95	92.5	96.5	80	80	75	65
1999	34.5	47.0	30.0	80.5	75	92	93	99	97.5	69.5	74.5	83

During the study period (1990 – 1999), the highest Relative Humidity was recorded in June 1994 and May 1995 (99%). High RH mostly occurs during the months of May to August. Based on annual record the year 1993 received the highest of humidity that was 96.85% and the year 1990 received the lowest amount (72.6%).

Table No.12 shows the variation of relative humidity over the study area during 1990 to 1999. The bar diagram of relative humidity in Fig. No. 15 indicates that it was very high during the months of June, July and August. However, it was very low during winter months.

### Relative Humidity of Cherrapunjee

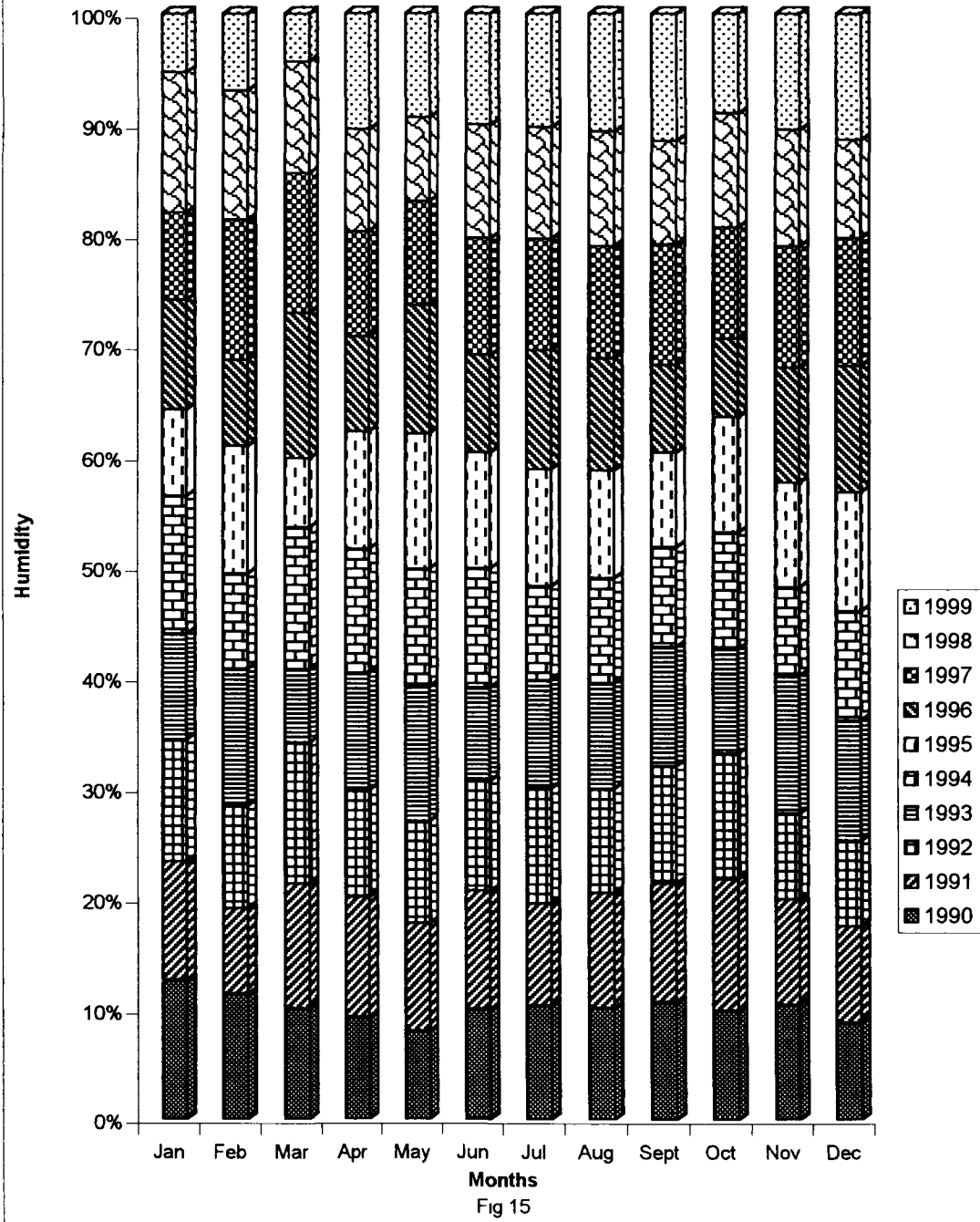


Fig 15

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## **CHAPTER V**

## **HYDRO – GEOMORPHOLOGICAL CHARACTERISTICS**

The Cherrapunjee region is relatively diversified with respect to climate and parent material (sandstone, limestone sedimentary deposits). Horizontally – bedded rocks have shallow soils compared to the upper parts of Meghalaya, which have originally 10 – 20 m thick regoliths. The spatial variations in soils reflect local relief on the landuse land cover system. The soils are coarse textured, very shallow to moderate deep but with a dominant soil depth ranging from 20-25 cms. The soils of the plateau directly exposed to heavy rainfall are extremely shallow, with gravelly pavement and occasionally large boulders on the surface. In contrast, the soils on steep slopes under dense forest vegetation are sandy loams, slightly acidic and moderately rich in organic contents.

A geomorphic unit also termed as physiographic unit is the product of various geomorphic processes acting in an area. The present area forms part of the spectacular landscape consisting of plateau and isolated hills with associated valleys. Landforms exert far – reaching influence on the pattern of human activities. Thus, the landform of the area can broadly be classified into two main geomorphic units viz., 1. Plateau which also includes (a) Gently Sloping Plateau (b) Plateau Relicts (c) Gorges (d) Stream valleys and (e) Cuesta. 2. Denudational Hills, which includes (a) Moderately Sloping Hills (b) Steeply Sloping Hills (c)

Elongated valley (d) Underground channels (e) Gorges and (f) Recent Terraces.

Detail study of these features is given in this chapter.

Geomorphological characteristics of the area depict sequence of lithological units as well as description of morphometric parameters, based on the linear and areal aspects. The study also indicates the fact that the region is of karsts topography, and this is related to lithological characters. The development of such landform depends upon lithology, rocks structure, relief, climate, height of water table and nature of drainage as well as biogenic processes.

Hydrologically the area is well drained by various streams and tributaries, of which some of the basins were discussed in detail in the previous chapter. The area is also very much influenced by various climatic attributes, such as the weather conditions, rainfall, temperature and humidity. All these results in the occurrence of drainage systems like small streams and rivers.

There is a direct relationship between landforms and hydrological attributes. One compliment on the formation of the other. Structural landform directs the condition of the fluvial system in one-way where as the later has the influence through the process of erosion, denudation and decomposition. Thus, the evolution of landforms and caves in the area is in accordance with the concentrated progress of subsurface runoff of underground drainage or water flows from fissures to

veins, which develops into the occurrence of waterfalls. Structural waterfalls are conspicuous on the banks of incised valleys of main rivers.

The total uplift of the plateau exceeds 1000 – 1200m while the aggradational plain of Bengal extends out in its foreland. The tectonic scarps of the plateau were dissected during the Neocene and Quaternary period creating river canyons up to 1000m deep. The young canyons contrast with the late mature relief of the plateau. Its Central part elevated from 1450 to 1550 m above mean sea level has undulating relief with structure – controlled monad rocks and wide flat river valleys 50 – 200m deep. A typical tableland is developed over the sedimentary rocks of the Cherrapunji region. This is inclined to the south divided by several flattening and separated by Cuesta – like scarps. Shallow valleys with many rapid and waterfalls on the resistant beds dissect it. Closer to the main tectonic escarpment over the flat valley floor are small limestone mesas 100 to 150m high with karstic phenomena.

The alternate sandstones and siltstones block gradual down cutting and thereby facilitate lateral slope retreat and the widening of river channels. The deforested slopes are built of less resistant rocks with residual lateritic crusts. On these slopes, the sliding of blocks derived from more resistant sandstone beds takes place.

Deep canyons start rapidly or in some places gradually. Over the metamorphic rocks, even the larger rivers increase valley depth gradually. Their walls 300 to 600m (Map No.13) in height over resistant limestone and sandstone are modeled by rock falls with scree talus at their base.

The proceeding chapters have crystallized the fact that every individual landform element has some definite relationship with the other. The discussion so far intended to explain the qualitative as well as quantitative measure and areal distribution pattern of rock characteristics and major morphometric attributes namely, relief, slope, drainage texture conditioned by diverse agencies.

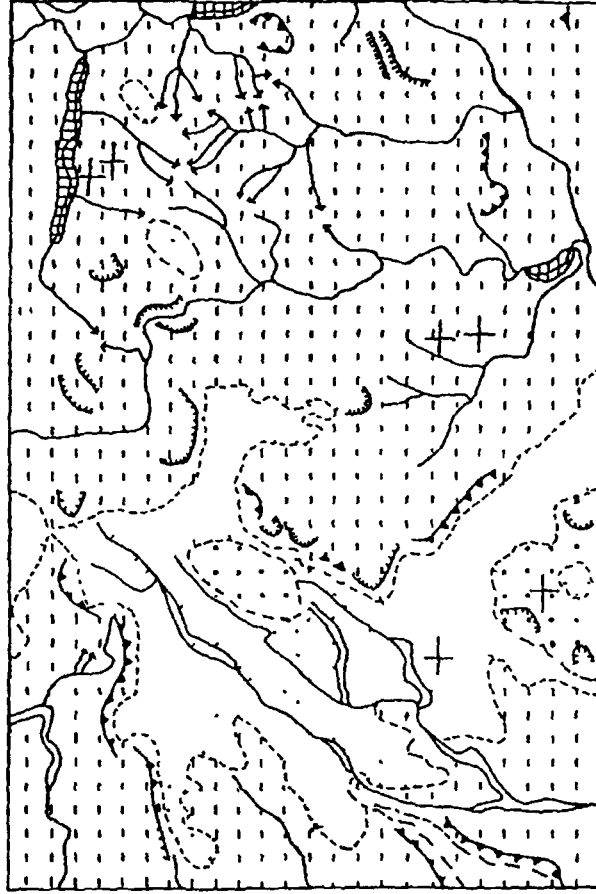
### **Landform Classification**

To evaluate the geological and geomorphological characteristics of the area detailed field studies were made. Different landforms were deciphered, classified and a geomorphic map has been prepared as shown in Fig. No. 16. Broadly, the landforms of the area could be classified into two main geomorphic domains and are described below.

### **Plateau**

The landform units of the area clearly indicate that more than 80% of the study area forms plateau domain. It is mainly composed of Khasi and Jaintia group

**CHERRAPUNJEE  
LANDFORMS**



**MORPHOLOGICAL CHARACTERISTICS**

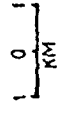


Fig No 16

of sedimentary rocks. The general elevation of the plateau rises from 800 m in the south to more than 1500 m in the north. In between dotted hills of limestone, formation may be seen. It appears major earth movements have affected this region and planation surfaces of Tertiary period may be seen. The important landform units within the plateau region are described below.

### **Plateau Relict**

These are seen as small irregular remnants confined in the dissected plateau. It represents most probably Eocene erosion surface. The most Eocene uplift of the plateau rejuvenated the terrain and a new set of terrain characteristics developed on it. The base level of streams changed resulting in vigorous down cutting and head ward erosion. Numerous waterfalls may be seen. The resultant scenario is a dissected plateau with relict of plateau surface. These relicts are seen at different levels. It is possibly because of reactivation of some subsurface structures along which differential uplift has taken place. This may be noticed in adaptation of channel network to the lineaments in the study area.

### **Gorges**

The gorges in the study area are associated with steep slopes (almost vertical) along channel segments. These gorges scooped out by the rivers are the

result of massive head ward erosion along major joints. It appears that the deep gorges are the result of intermittent upliftment of the plateau. The very heavy rainfall favours the vigorous fluvial erosion. All along southern face of the dissected plateau has the development of deep gorges.

### **Cuesta**

These are confined mostly in the north western part of the study area. These may be seen as high-level terraces along 1000m contour levels. It occurs in not very regular shape.

### **Stream valleys**

In the field photographs the nature of stream valleys usually show narrow cross-section with gentle gradient.

### **Moderately Sloping Hills**

These types of landform units are found in the central and southern part of the study area. This landform unit covers nearly 55 Sq.Km. in the area. It is mostly developed due to differential erosion and lithological variation. Some of these hills are mainly composed of sandstone and limestone rocks.

### **Steep Sloping Hills**

This landform unit is found in central and western part of the study area. These hills may be seen in sedimentary rocks. The angle of slope ranges between 20° to 40°. The altitude ranges between 1300m to 1600m. The drainage density may be moderate to high. Along streams numerous waterfalls may be seen which indicates the rejuvenation of the area in recent past.

### **Escarpmnts**

The escarpments are continued within Shillong Group of rocks forming Cuesta. The southern faces of the scarps are steeper than northern slopes. These are aligned in conformity with the trend of rock types.

### **Underground Channels**

Two examples of underground channels may be seen in the study area. These channels have developed in limestone rock formation. One may be seen near Mawmluh Cherra Cement Factory. This is quite big stream suddenly disappears and after two to three kilometers away again is seen on the surface. The other underground channel is seen near limestone caves.

## **Recent Terraces**

Recent terraces are confined by and large along the southern part of the study area and in the valley of Wah Tymshun River. These terraces are seen mostly in sandstones and limestone beds. It is comprised of coarse sand and gravels. The size of the pebbles vary from 2 cm to 4 cm. Generally, these terraces have patches rich in sand and gravel. The present riverbed shows large accumulation of boulders forming channels.

## **Hydrological Analysis**

Hydrologically, Cherrapunjee area has marked seasonal variation in temperature and rainfall. Most of the rain falls during summer (May to September) because of the effective southwest monsoon (O'Hare 1997) and orographic rainfall (Starkel, 1972). Areal variations in rainfall distribution are influenced by the relief features, as the Bengal plain at an elevation of about 100 metres receives less than 250 cm annually, while Cherrapunjee at 1320 metres in the elevation records 800 to 12,00 cm of rainfall annually. The monthly rainfall records show that Mawsynram received the highest rainfall of more than 10,00 cm in July 1974. The heavy rains frequently starts during the late evening and continues till early morning, this is so as convectional movement is coming to an end. During the daytime, there are 2 to 3 hour breaks in rainfall or periods with low intensity.

### **Circulation of water.**

In the circumstances of such a high rainfall regime, it is infiltration generation, which plays an important role where conditions of rainfall infiltration generation are concerned. An observation of stream flow fluctuation indicates that, during the rainy season and after each peak discharge, the falling stages are very sharp. This reflects the very limited retentive capacity of laterite waste cover, and the important role of overland flow in runoff generation.

The typical grain size composition and texture of the laterite waste cover are controlling factors where differences in permeability at various depths are concerned. Measurements of infiltration rate during the dry season were performed on the ground surface and at depths of 5, 10, 20 and 30 cm. The soil profile was found to capable of absorbing 100 mm of rainfall over 3 to 4 hours. It generates a hypothesis that, during the monsoon season, the threshold for the start of saturated overland flow is passed during practically each rain. The saturated dispersed overland flow and delayed returned flow is perhaps a characteristic features for slope, with the saturated sheet flow prevailing in a swampy valley bottom. The linear runoff within the gullies and along paths also plays an important role in stream flow generation. A surface storage of water may be noted over the foot of slopes in the lower part of the study area, over saturated but unpermeable thin soil cover.

The presence of an armoured layer built up of coarse materials from several mm to cm in diameter over all slope surfaces is connected with the absence of dense grass cover. Most of the finer grains have been washed out a long time ago. The finer washed materials are now closer to the river channels. In the channel itself, bare rocky beds are exposed. The limit of summer flood is marked by the presence of vegetation cover retaining finer soil particles. On the rocky benches in the channel small sandy gravely bars appear from place to place as well as single rounded pebbles of 10 to 20 cm diameters, indicating the size of particles carried during flash floods. Transportations of such materials are connected with heavy rains.

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## **CHAPTER VI**

## **Summary and Conclusion**

The Cherrapunjee plateau forms the south western part of East Khasi Hills District of Meghalaya. It is the north eastern extension of the Indian Peninsular shield. The rocks of the region have more in common with those of the peninsular region rather than those of the neighbouring Himalayan ranges of the north eastern part of India. The evolutionary history of the Meghalaya plateau is one of the recurring uplifts and down sinking during the past more than 100 million years, which have led to the formation of the spectacular landscape geometry including limestone topography. The plateau like character of the terrain is well developed within Cherrapunjee town and adjoining area. The altitude of the area ranges between 1200 m to 1530 m whereas the gorges are more than 450 m deep.

The general slope of the study region is to the southward direction into the Bangladesh plain. Small areas lying between different contours present a variety of morphogenetic features. On the eastern side, it gradually slopes down to the valley of river Umiew. Again, in the western part, it gradually slopes down to the valley of river Umngi and in the north; it ascends gently towards the Shillong upland. Continuous weathering processes on the erosional scarp have led to the formation of Mawsynram structural platform (1305 m). Its southern part is marked with a southern lowering of the plateau surface to 1000 metres and it further gradually reduces up to a height of 50 metres near the Bangladesh plains. This

southern margin of the lower plateau is a dissected hilly country with host of micro landforms viz., gorges, spurs, and divided rolling uplands, low sand hills and many swampy tracks of land.

The variety of sediments are ranging from Archean to the Tertiary period forming the region is discernable from the protruding surfaces. The evolution of Cherrapunjee plateau is closely linked with the structural evolution of the Shillong plateau. The area is full of limestone formations.

The diverse geology and geomorphic characteristics that is occurrence in the extensive undulating Shillong plateau with high hills in the east moderately high gently dipping table land in the central part and the low lying dissected hills in the west present a complex variety of landform. The Shillong group of rocks is found in the eastern part of the study area. The Cretaceous Tertiary sediments such as sandstone and limestone are lying in the western part of the study area.

The entire Cherrapunjee region is affected by frequent heavy summer rain reaching up to 12,00 cm annually. Daily rainfalls may be up to 70 cm, even if its registered intensity does not pass 40 – 60 mm per hour. Cherrapunjee is the place that receives the highest amount of rainfall in the world. It has moderate temperature during monsoon period, which further decreases towards winter months. Due to heavy rainfall and high humidity, the area is much more prone to weathering processes.

The sedimentary rocks conglomerates and sandstones are disintegrated into different blocks. The slumped blocks of coarse brown Tharia sandstone may be seen scattered along river valleys. The study of limestone of the region shows a complete dissolution of those rocks in water. During field study, it is noticed the unique development of stalactites and stalagmites deposits may be seen in limestone caves.

The different geomorphological features of an area have relief manifestation on different scale. The important relief features of the area have been analysed with the help of relative relief. In general, relief rises towards the north. The north eastern corner of the study area by and large shows higher relative relief.

Slopes are the basic features of landscape. Slope analysis reveals five categories of slope, viz., Level to gentle slope, moderate slope, moderately steep slope and steep slope categories. The steep slope category is continued in the north eastern and south eastern part of the area. On plateau top vegetation cover is almost absent except grasses.

The drainage characteristics and fluvial processes are very much important to understand the evolution of landscape in the area. The study reveals that the low drainage frequency and low drainage density prevails in the northern part of the area.

On the basis of landform, the area has been divided into two main geomorphic domains, viz., Plateau and Residual Hills. Each domain is characterised by different landforms. In plateau domain the important landforms identified are gently sloping plateau, plateau relicts, Cuesta etc. the hill domain depicts moderately sloping hills, steeply sloping hills and scarps. The recent terraces are confined along the southern part of the study area.

The Hydrograph indicates that during 1990 to 1999, the depth of water level was very low during the month of January, and the water level increases with the onset of monsoon. It was only during the summer months of 1990 – 1993 that the water level appears to be high.

The study area, i.e. the Cherrapunjee region is very much affected by various hydrological attributes, such as the climate of the region, the weather conditions, rainfall, temperature and relative humidity. All these attributes are in occurrence of drainage systems like small streams and rivers. Thus, in hydrological analysis, apart from temperature and rainfall, drainage systems also play a very important role.

In the circumstances of such a high rainfall regime, it is infiltration, which plays an important role where conditions of rainfall infiltration are concerned. An observation of stream flow fluctuation indicates that, during the rainy season and after each peak discharge, the falling stages are very sharp. This reflects the very

limited retentive capacity of laterite waste cover, and the important role of overland flow in runoff generation

## **Conclusion**

On the basis of the present study the following conclusions can be drawn.

1. The formation of Cherrapunjee Plateau is linked with the structural evolution of the Shillong Plateau. The eastern part is composed of Shillong group of rocks and the Cretaceous Tertiary sediments in the western part. The sedimentary rocks are lying in horizontal form with less undulation in topography.
2. The relief rises from the south to the north. The lowest relative relief of less than 100 metres is confined in the western part, and gives more regional character of the physical landscape.
3. Slopes are the basic features of landscape. A general pattern of the slope rises with the rise in absolute relief.
4. The drainage characteristics fluvial processes play an important role in the evolution of landscape in the area. Drainage frequency ranges from 5 to 25 numbers of stream per sq. km. Drainage density is relatively low in the eastern part and high in western part.

5. Depth of water level rises with the onset of monsoon and appears to be above ground level during summer months.
6. The limestone formation of the study area shows a complete dissolution of rocks in water. Well-developed cave deposits are seen in the area. There are well-developed stalactites and stalagmites in the caves. Near the town, good qualities of limestone deposits are used for manufacturing of cement. Rounded limestone hills are found scattered in the region.
7. The climate of the area is marked by seasonal variation in temperature and rainfall, which also favours chemical weathering, the best example of which can be seen in the limestone caves.
8. The area has distinct geomorphic domains viz, plateau and hill domains. Each showing characteristic landforms.

The Cherrapunjee spur is deforested over more than 90% of its total area, with degraded top soil armoured by stony layers at the surface. The low infiltration rate causes quick overland flow. The very low specific runoff during the dry season causes many other channels to be dry, with iron pavement forming in the rocky channel floors. In such extreme conditions of the monsoon climate after the degradation of the vegetation and soil cover, there is a distinct difference in the course of processes between the rainy and dry season.

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**Nohsngithiang falls as seen from the top**



**Laitiam and Laitduh villages lying just below the gorge culminating into a fresh water river known as Umtyngkong that drains into the plain of Bangladesh**



**Catchment Area of Wah Risaw the main source of the majestic Nohsngithiang Falls – its wide open spaces need more improvement measures**



**A rainwater harvesting structure near Cherrapunji – more of such structures are of prime importance for water conservation**



**Village Forest known as Bleibah**



**A village forest that needs more preservation and conservation of a variety of local trees and plant species**



**Small Stream in the sandstone beds**



**Mawkdok Gorge**



**Ancient Monoliths standing at the sprawling wide open spaces of Nongthymmai**