

# **SHILLONG AND ITS ENVIRONS A STUDY IN URBAN GEOMORPHOLOGY**

**ABSTRACT**



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*Thesis*

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## **Introduction to the Study Area and Statement of the Problem**

During the past three decades, Meghalaya has experienced an increasing trend towards urbanisation that has been at the same time both rapid and uneven. This growth pattern is consequent to the movement of people and jobs to the urban areas. The result has been the evolution of urban communities from villages into towns or urban region as in the case of Shillong. This growth has brought forth a vast array of goods and services, an ever expanding spatial distribution of people, as well as a host of urban problems.

The inexorable trend toward very large, extremely complex and urban places is a result of forces whose origin lie in the political, economic and social systems of our society. Of particular significance that promote or sustain growth, two forces emerge. These are (a) population growth (b) the expansion of public investment. The linkages between the two are demand and development.<sup>1</sup>

The resulting effects of these two factors are demand for and pressure on land. Impacts on land result also from changing use of land as it is converted from natural areas to agriculture, and, or suburban, commercial and industrial uses. These can be termed as direct impact. Indirect impacts result from the promotion of growth, development and urbanisation.<sup>2</sup>

With mounting concern over the impacts on natural environment, particularly from urbanisation, it has become apparent that an objective, analytical strategy is necessary to assess the subtle but far reaching impacts of geomorphological forms and processes, because such a strategy could profit from interdisciplinary modelling experiences and findings. It is in the light of this context that the city of Shillong has been selected as an area for study

### **History on the Evolution of Shillong**

The evolution of Shillong from small and scattered hamlets into a big city of today started in 1863 when the British acquired lands on lease for the purpose of creating a civil station and sanatorium.<sup>3</sup> In 1874 it was made the capital of Assam with some interruptions till 1973. And from 1970 till today it has become the capital of Meghalaya. Through the formative years Shillong steadily grew and expanded in size. Its present geographical area is approximately 120 square kilometres. Its population in 1881 was a mere 3,737 and today over a hundred years later its population soared to above over a half million (2001 Census).<sup>4</sup>

As it grows it is also beset with problems of space resulting in the mushrooming growth of unplanned settlements plus a host of other problems like sanitation, water supply, narrow roads, traffic jams, etc. This unprecedented growth of population with limited urban facilities and amenities has led to a tremendous pressure on land. As such this is another

point which needs attention for remedial measures in proper planning and management of the land with due emphasis on geomorphic characteristics

Because of the complexity and urgency of urban problems, an urban geomorphological approach can be adopted to provide a comprehensive and interdisciplinary approach model to aid in studying the complicated nature of our cities.<sup>5</sup> An urban geomorphological approach can be adopted as geomorphology being the science of landforms, falls within the broad framework of geography, which is concerned with the interaction between man and environment.

### **Review of Literature**

Many articles and books have been written on the evolution, history and scenic beauty of Shillong but no relevant literature existed or been written on urban geomorphology of Shillong though scanty literatures on geology, climate, vegetation and its people are available.

However, some geomorphic studies of Meghalaya existed and have been undertaken by workers such as R.K. Rai (1985),<sup>6</sup> P.C. Panda (1985),<sup>7</sup> G.C. Panda (1987),<sup>8</sup> M. Agarwal (1993),<sup>9</sup> H.J. Syiemlieh (1997)<sup>10</sup> and I. Cajee (2002).<sup>11</sup>

Elsewhere, in other parts of the world, studies in urban geomorphology have gained ground. Notable studies on this line worth mentioning are "Geomorphology and Urban Development in the Manchester Area" by Ian

Douglas.<sup>12</sup> This work underlined the impact of geomorphology on river dynamics, urban growth, glacial deposits, subsidence, sewer collapse and ground conditions. Then another notable work “Aspects of Urban Geomorphology – Ground Movements in parts of Salford and Bury” by C Harrison and J.R. Petch,<sup>13</sup> traced and explained the history of ground movements and landslips. It was a pioneering work in so far as ground movements affect urban growth and development. There are also other works such as *Urban Geomorphology in Dry Lands* by R.G. Cooke *et al*<sup>14</sup> This study was undertaken as a consequent of serious soil erosion, landslides and widespread flooding where hundreds of people were killed and thousand of homes ruined. The dominant environment processes responsible for this crisis are geomorphological problems, problems relating to the nature of land surface and the forces that act upon it.

In India the study of urban geomorphology, first appeared in 1988 This study was *Mussoorie and Its Environs* by H. Prasad.<sup>15</sup> This study underlined the impact of geomorphology in identifying areas for establishment of new settlements.

As stated earlier, Shillong covering an area of over 120 square kilometres has elevations ranging from 1000 metres to above 1900 metres above mean sea level. So with a height difference of 900 metres the city thus has diverse topographical features consisting of undulating topography,

moderate to steep slopes, cliffs and a fair amount of isolated flat lands. In such a topographical set up, settlement patterns have been greatly controlled by geomorphic forms. This, therefore, calls for a need to understand the geomorphological forms and processes so that planning and proper management and decision-making policy in urban development can be undertaken and executed.

### **Objectives of the Study**

The main objectives of the study are:

- (i) Analysis of geomorphic characteristics.
- (ii) Identification and delineation of geomorphic provinces and their distribution.
- (iii) Identification of morphometric parameters related to the study such as slopes, relief, drainage, etc.
- (iv) Delineation of high, medium and low-density settlements and their patterns.
- (v) Identification of roads and water supply their impact on landuse and problems.
- (vi) Identification of sewage disposal problems and their impact on the environment.

## **Data**

The data for this study has been generated primarily by extensive fieldwork and secondary sources where toposheets are used extensively.

## **Methodology**

The methodology adopted were as follows:

(i) Pre field work; (ii) Field work; (iii) Post field work.

Chapter-II deals with six different physical aspects of the study area and is arranged as follows:

(i) Geology; (ii) Climate; (iii) Topography; (iv) Drainage; (v) Vegetation; (vi) Soils.

In order to highlight the geology of the area, a general description of the state is first given and is based on published data of the Geological Survey of India.<sup>16</sup>

Regarding the geology of the study area, the geological formation and tectonics have been inferred basically on the collection of fossils and identification of exposed rocks in the field. Tectonic activity has been inferred from the exposed topographical features like escarpments of the Dymmiew area and the structural adaptation of streams to lithology. Examples of such streams are Umkhrach, Umshyrpi, Wah Tamdong, Umshing and Wah Shala.

Climate of the study area has been assigned as sub tropical monsoon climate and also referred as humid mesothermal climate<sup>17</sup> in empirical classification. The factors influencing the climate of Shillong are (i) existence of protected forests in the northern face of Shillong Peak-Kynton Sngi range, (ii) the Barapani reservoir; (iii) increasing built up area.

Shillong, though small in area, it has a range of differences regarding precipitation and temperature. These differences occur within short distance and at varying elevations. These differences has been ascertained from the weather column of *Shillong Times*.<sup>18</sup>

Topographically Shillong is comprised largely of escarpments, denuded hills, undulating topography, steep slopes and isolated flatlands.<sup>19</sup> In terms of area, the undulating topography covers 124 sq kms and occupies the central part of the study area. Escarpments are seen in the *Dymmeu*<sup>20</sup> and Wah Tamdong, precipice on the western edge of Shillong and Umkhen valley.

The drainage systems in the study area is comprised of twelve streams with proper names and terminologies these are Umjapung, Umshing, Umladew, Wah Tamdong, Wah Shala, Wah Umbah, Wah Mawlynrei, Umkhrah, Umshyrpi, Umdiengpun, Wah Umiam and Umkhen.

Chapter III has been divided into two parts – (i) Physical Environment and (ii) Social Environment.

Under Physical Environment a geomorphometric analysis of rock groups, slopes, drainage systems, relief and geomorphic provinces have been dealt with in detail by using standard techniques adopted by geomorphologists

In the Social Environment demographic characteristics, analysis of socio-cultural and economic factors and their impact on urban growth, infrastructural network analysis and settlement characteristics have been highlighted.

The Geo-environmental problems of the study area relating to deforestation, water resources, topographical constraints, urbanisation and environmental degradation have been dealt with in Chapter IV

A thorough analysis on the population growth and urbanisation of the study area with special emphasis on its decadal and rate of urbanisation and development have been carried out in Chapter V.

Finally, in Chapter VI the emergent of geo-environmental issues have been brought out and some remedial measures have been suggested

### **Findings and Conclusion**

The topography such as steep slopes and escarpments deter the expansion of urbanisation. However, the most suitable areas for urban development as derived from the various geomorphometric analyses is apparent at elevations between 1400 to 1600 metres.

The trend of population growth upto 2001 shows an increase in population resulting in demand and pressure on land. This is amply demonstrated by the inclusion of another village, Nongmensong, to form the Shillong Urban Agglomeration.

With the rapid growth of population and urbanisation leading to an increase in various man-made activities, large quantities of pollutants and wastes are being continuously released into the city environment. Thus in the race for progress and development, the people of Shillong might lose the race for healthy survival, if answers are not found to the twin spectres of over population and environmental degradation.

Random expansion without taking geomorphic studies into consideration leads to infrastructural and environmental problems. As a practice in geomorphological studies, delineation of geomorphic provinces for any type of landuse is indispensable.

On the basis of these and other findings, it may be derived that similar conditions may prevail in other hill stations of the country as well.

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A STUDY IN URBAN GEOMORPHOLOGY**

**DISSERTATION SUBMITTED IN PARTIAL  
FULFILMENT FOR THE  
DEGREE OF DOCTOR OF PHILOSOPHY**

**BY**



**DONDOR GIRI NONGKHLAW**

**TO**

**THE DEPARTMENT OF GEOGRAPHY  
SCHOOL OF HUMANITIES & ENVIRONMENTAL SCIENCES  
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SHILLONG  
2003**

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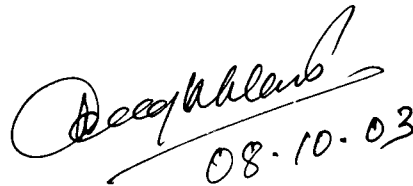
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I, *Dondor Giri Nongkhlaw*, hereby declare that the subject matter of the thesis is the record of the work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody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

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Dated: 8<sup>th</sup> October 2003

**(DONDOR GIRI NONGKHLAW)**

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## Chapter I

### INTRODUCTION

The Science of Geomorphology as the study of landforms, has aroused much interest amongst scientists, scholars and laymen alike since time immemorial. This is so because the understanding of this branch of knowledge leads us to straight thinking in terms of the interactions and relations of man and the landforms around him. Landforms like mountains, for example, are the storehouses of minerals and at the surface the landforms nurture living organisms like vegetation and animals, including man and provide a platform for all kinds of human activities.

Geomorphology, as the science of landforms, stems from the Greek terms, *Geo*, meaning 'Earth', *Morphe*, meaning 'form' and *Logos* meaning 'discourse'; literally it means, 'a discussion on earth forms'. The study of geomorphology is based on the principle that all landforms can be related to a particular geologic process and that the landforms thus developed may evolve with time through a sequence of forms dependent in part on the relative time a particular process has been operating.

As landforms are the most widespread geologic phenomenon, speculation as to their origin has gone on since the days of ancient philosophers. A discussion on the development of scientific ideas began

with the Greek and Roman Philosophers. We could in fact very well omit discussion of their ideas as to the development of landforms, for what little they had learned was largely forgotten during the Dark Age and had to be relearned, but it will help us to get a more complete picture of the evolution of geomorphic ideas and thought if we want to consider the views of Herodotus, Aristotle, Strabo and Seneca.

During the many centuries that followed the decline of the Roman Empire, there was little or no scientific thinking in Europe. Such knowledge as survived was largely in monasteries but it was not natural science. Some survival of learning persisted in Arabia and we find certain ideas expressed there that have a modern flavour.

Abicenna (980-1037) held views upon the origin of mountains who divided them into two classes, those produced by “uplifting of the ground such as taking place in earthquakes” and those, “which result from the effects of running water and wind hallowing out valleys in soft rocks”. Thus, the concept of mountains and its forms resulting from differential erosion was expressed.

With the coming of Renaissance, the occasional and increasing alliance of philosophy and technology fostered afresh the urge to know why and how things happened and landforms were largely explained in terms of the prevailing philosophy of Catastrophism. By his unsurpassed

and versatile genius, Leonardo de Vinci (1452-1519) firmly established the pattern of combining philosophy and technology. He recognized that landscapes are sculptured and worn away by erosion; that the fossil shells found in the limestones of the Appenmines are the remains of various organisms.

The development of geomorphology on modern lines is said to have its beginnings in the work of James Hutton (1726-1797) and he is considered to be the originator of modern geomorphic ideas who laid down the groundwork of the long and slow development of geologic thinking by propagating the philosophy of Uniformitarianism into modern geomorphic thought. In 1785, he presented a Paper before the Royal Society of Edinburgh, in which he propounded the "Theory of the Earth". This theory is better known as the "Doctrine of Uniformitarianism". Thus, the 'science of geomorphology' was born in Edinburgh in March 1785. This theory is based on the hypothesis that the "present is the key to the past."

After Hutton, the development of geomorphology took place in different directions in Europe and America. In the wake of new ideas and principles, the concept of ice age, marine erosion and, later, river erosion came into existence. Thus, it can be safely stated that geomorphology had established itself as a branch of geology by the end of the 19th century in

Europe, though the word geomorphology had not come into vogue and instead the word "Physiography" was commonly used.

In Europe, the French scholar, Buffon (1771-1788) stated that rivers were a powerful agent of erosion and their capacity to erode was so great that they could destroy land surface. Targioni Tozzetti of Italy (1712-1784) also recognized the erosive power of streams. He was the first to suggest the concept of differential erosion.

Another French scholar, Dasmarest (1725-1845) has shown with reference to specific examples that the valleys through which the rivers of Central Europe flow have been in fact carved by them. He was the first to understand the evolution of landscape in successive gradual stages.

The area of study of De Saussure of Switzerland (1740-1799) was the Alps. He laid great stress on the power of streams to erode the mountains and put forward the view that the river valleys in the Alpine mountains are the creation of the rivers that flow through them.

Another contemporary of James Hutton also deserve mention. He was the founder of modern Russian geomorphology and geology. He was the first to suggest that the landscapes are the result of interactions between internal and external forces and that these processes are universal in nature.

In North America, the maximum development of geomorphology took place between 1875 and 1900. This is known as the Heroic Age in American geomorphology, as it was during this period that the most important geomorphological theories were propounded. The names of J.W. Powell (1834-1902), G.K. Gilbert (1843-1918) and C.E. Dutton (1841-1912), are particularly noteworthy as these were the people who showed the way and it was basically on the foundation of concepts formulated by them that later on, W.M. Davis built his 'Theory of Geomorphic Cycle'.

If Hutton is considered as the founder of geomorphology, then W.M. Davis is undoubtedly the father of American geomorphology. The impact of W.M. Davis on geomorphology was greater than any one man. Based on the works of his predecessors, Davis synthesized many geomorphic ideas and moulded them into a unified system for the study of landforms. W.M. Davis recognised that the origin and evolution of topography was dependent upon geologic structure, geomorphic processes and stages of development. The concept was based on the work of running water, which, according to Davis was the process of normal erosion. This concept, therefore, provides the framework for interpretative geomorphology and, thus, its understanding is imperative to the students of geomorphology.

During the last 30 years or so there has been a considerable progress in all branches of sciences. On a modest scale, the part time science of geomorphology, has achieved a great deal during this time and the geographers, geologists, hydrologists and specialists from other fields who all contributed to the study of geomorphology have become aware of the comparative suddenness of change within the context of landform studies. This suddenness of change was affected by the recognition of anthropogenic presence in nature where man is identified as the most potent and powerful agent of destruction.

The impact of man's activities became more and more pronounced leading to environmental degradation by anthropogenic acts such as establishing a squatter settlement on a steep hillslope, construction of dams, road, railways, industries, etc. Therefore, the application of geomorphic knowledge in ameliorating damages from natural and man made hazards and in the management of the environment has been incorporated and integrated leading to the emergence of a sub-field of geomorphology, known today as Applied Geomorphology.

In applied geomorphology landforms are studied in relation to human and economic aspects such as population, settlements and environment. A mere qualitative description of the landforms is no longer sufficient to fulfill the requirements of applied geomorphology.

Applied geomorphology has diverse applications over a large area of human activity. According to Verstappen (1968) applications of geomorphology can be grouped into the following:

- (i) Application in the fields of earth sciences, thematic mapping and resource studies.
- (ii) Application in the field of environmental studies in the survey of natural hazards, landslides, avalanches, earthquakes, land subsidence, floods and droughts.
- (iii) Application in the field of rural development and planning emphasizing landuse, erosion control, conservation and river basin development.
- (iv) Application in engineering including assessment for communication network, river and coastal engineering.
- (v) Application in the field of urbanization for urban extension, site selection or mining.

It is in the light of the above ideas that Shillong and its environs was chosen for making a detailed study in the field of urban geomorphology. The importance of this study lies in highlighting the significance of geomorphological studies related to the problems of urbanization.

### **Statement of the Problem**

Man's impact on the landscape is manifold. One of the direct impacts of man in the environment is the establishment of a settlement. The inexorable trend towards very large, extremely complex urban places is a result of forces whose origin lies in the political, economic and social systems of our society. Of particular significance that promote or sustain urban growth two forces emerge, these are (i) population growth and (ii) the expansion of public investment. The linkage between the two is demand and development.

The resulting effects of these two factors are demand for and pressure on land. Impacts on land result also from changing use of land as it is converted from natural areas to agriculture and to sub-urban, urban, commercial, industrial uses. These can be termed as direct impacts. Indirect impacts result from the promotion of growth, development and urbanization.

The significance of these impacts, direct and indirect, has been stated explicitly by Robert H. Twiss (1974), "Environmental impacts are seldom important solely in terms of their direct physical effects. That is, if a road is built into a new area, the soil erosion and visual scars are important but not as important as the 'bombaret' effect at the end of the road that generates new housing followed eventually by the need for

many other services. Most of the people involved recognize that the question is not whether we should treat indirect effects, but rather, given that indirect effects are the most important of the two, how we compute and weigh them”.

With mounting concern over the impacts on natural environment, particularly from urbanization, it has become apparent that an objective analytical strategy is necessary to assess the subtle but far reaching impacts of geomorphological forms and processes, because such a strategy could profit from interdisciplinary modelling experiences and findings. It is in the light of this context that the city of Shillong has been selected as an area for study.

The evolution of Shillong from small and scattered hamlets into a big city of today started in 1863 where the British acquired lands on lease for the purpose of creating civil station and sanatorium. In 1874, it was made the capital of Assam, with some interruptions, till 1972. And from 1972 till today it has become the capital of Meghalaya. Through the formative years, Shillong, steadily grew and expanded in size. Its geographical area is 174 sq. kms. according to the Shillong Master Plan 1991-2011. Its population in 1881 was a mere 3,737 persons and today over a hundred years later, its population soared to over two lakhs (2001 Census).

As it grows it is also beset with problems of space, resulting in the mushrooming growth of unplanned settlements plus a host of other problems like sanitation, water supply, narrow roads, traffic jams, etc. This unprecedented growth of population with limited urban facilities and amenities has led to a tremendous pressure on land. As such, this is another point which needs attention for remedial measures in proper planning and management of the land with due emphasis on geomorphic characteristics.

Because of the complexity and urgency of urban problems, an urban geomorphological approach can be adopted to provide a comprehensive and interdisciplinary approach model to aid in studying the complicated nature of our cities.

An urban geomorphological approach can be adopted as geomorphology, being the science of landforms, falls within the broad framework of geography which is concerned with the interaction between man and environment.

### **Review of Literature**

Many articles, papers, news, tourist pamphlets and books have been written on the evolution, history and scenic beauty of Shillong but no relevant literature existed or been written on urban geomorphology

though scanty literature on geology, climate, vegetation and its people are available.

However, some geomorphic studies of Meghalaya existed and have been undertaken by R.P. Singh (1968), R.K. Rai (1985), P.C. Panda (1985), G.C. Panda (1987), M. Agarwal (1993), H.J. Syiemlieh (1997), L. Cajee (2002). So far no work has been undertaken on urban geomorphology in any part of the state.

Elsewhere, in other parts of the world, studies on urban geomorphology have gained ground. Notable studies on this line worth mentioning are “*Geomorphology and Urban Development in the Manchester Area*” by Ian Douglas (1990). This work underlined the impact of geomorphology on river dynamics, urban growth, glacial deposits, subsidence, sewer collapse and ground conditions.

Then another notable work, *Aspects of Urban Geomorphology - Ground Movements in Parts of Salford and Bury* by C. Harrison and J.R. Petch (1990), traced and explained the history of ground movements and landslips. It was a pioneering work in so far as ground movements affect urban growth and development.

There are also other works worth mentioning such as “*Urban Geomorphology in Dry Lands*”, undertaken by R.G. Cooke, D. Brunsten, J.C. Doornkamp and D.K.C. Jones (1985). This study was undertaken as

a consequent of serious soil erosion, landslides and widespread flooding where hundreds of people were killed and thousands of homes were ruined. The dominant environmental processes responsible for this crisis are geomorphological problems, problems relating to the nature of the land surface and the forces that act upon it.

In India, the study of Urban Geomorphology first appeared in 1988. The study was, "Mussoorie and Its Environs" undertaken by H. Prasad (1988). This study underlined the impact of geomorphology in identifying areas for establishment of new settlements.

Other works related to geomorphology and urban and environmental problems brought about by urbanization processes have been undertaken by various other workers such as, "Geomorphology and Engineering", by D.R. Coates (1985). This study emphasized the need for geomorphological mapping and morphological mapping to aid in roads and building construction.

Then there are other works on water supply to urban areas such as *Water Resources Distribution, Use and Management* by John R. Mather and *Perspectives on Water* edited by David H. Speidel.

Environmental pollution arising out of urbanization have been well documented in a study, *Environmental Chemistry* by A.K. De.

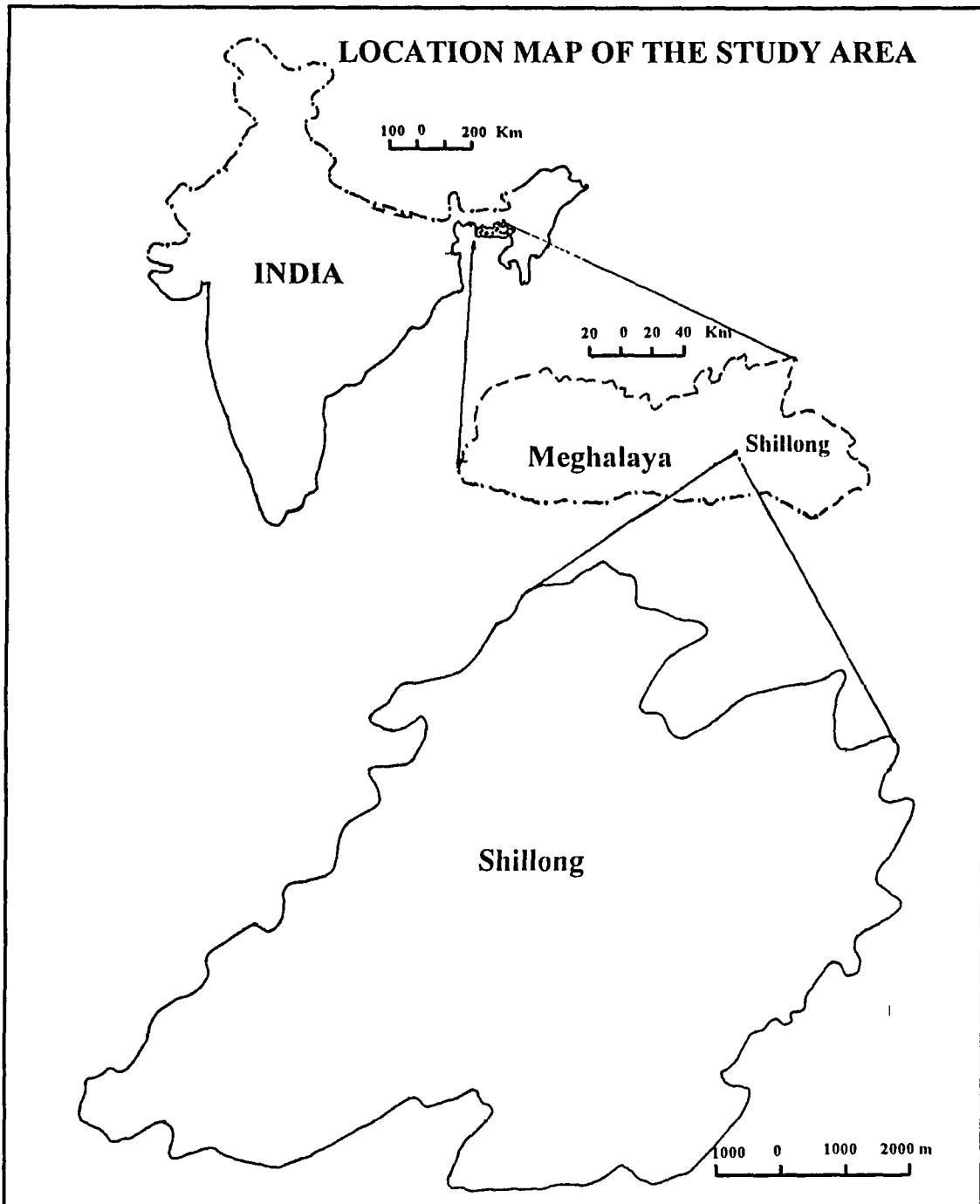


Fig. - 1.1

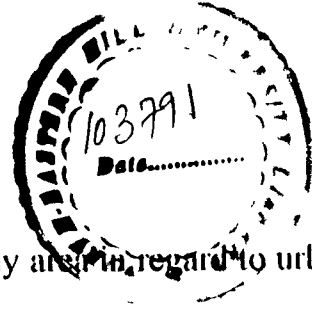
Besides the above works, other works appearing in some journals have been read and consulted in order to give a better picture and clearer understanding on the relevance of geomorphology in urban studies. Such works worth mentioning are “Morphological Aspects of Kundaetivanka River Basin” by T.S. Rao (1996) appearing in the *Indian Journal of Landscape Systems and Ecological Studies*. Then another paper “Paradigm Shifts in Geomorphology: Trends and Implications” by K.R. Dikshit (1999) which discussed about a sequence of paradigm shifts in geomorphology from uniformitarianism of the late 18<sup>th</sup> century to one of dynamic geomorphology of the last century.

### **Study Area**

Shillong, the capital of the State of Meghalaya, adopted as an area of study is located at 25°34' North latitude and 91°53' East longitude and a height of 1496 metres above mean sea level (Fig.1.1). Originally, during the British Raj, Shillong covered only the Shillong Cantonment and Shillong Municipality. When the British took the lands on lease from the Nongkhlaw clan, the Kurkafang clan, the Sohtun clan and Kharkongor clan, boundaries, with numbered pillars were erected and this gives us an idea of the size of Shillong then.

The name “Shillong” is derived from “U SHULONG” meaning “One who exists by himself”. The name is used in reference to God who, as believed, has His abode on the highest mountaintop of Meghalaya, named U LUM SHYLLONG. The original name “Shulong” got corrupted into “Shillong” to suit the British way of spelling and pronunciation.

The evolution of Shillong from small and scattered hamlets into a big city of today owes its origin to the British Administration of Assam. Today, Shillong is a growing city, as it grows it is beset with problems of space resulting in the mushrooming growth of unplanned settlements plus a host of other problems like sanitation, water supply, narrow roads, traffic jams, etc. However, the jovial and jolly character of its citizens offsets all these. Its reputation as a centre of learning, as a health resort and centre of social and intellectual interactions spread far and wide. Many world famous dignitaries and celebrities have visited and lived here, like Pope John Paul II who visited Shillong in 1986, Verrier Elwin, the anthropologist who lived and died here, E.P. Gee the naturalist, C.V. Raman the Nobel Laureate Physicist, Rabindranath Tagore, the Nobel Laureate Poet. Even the modern science of Seismology owes its origin to the thorough studies of the Shillong earthquake, 1897, by famous geologists such as R.D. Oldham.



The demarcation or delineation of the study area in regard to urban areas has always been a problem. In the case of Shillong, the problem is further compounded by the absence of official notification of its limits and extent. The Census of India in 1971 has declared Shillong as an Urban Agglomerate comprising of Shillong Municipality, Shillong Cantonment, Nongthymmai, Madanring, Mawlai and Pynthorumkhrah. But again the expansion of Shillong in terms of size, as it is today, is credited to its inhabitants who construct houses and settlements with the consent and permission of the local traditional durbars, which in most cases the Government, has no say on the matter, except by extending infrastructure like roads, electricity, telephone lines and postal services. The hitherto villages surrounding the Shillong Urban agglomeration has, of now, attained urban character such as Mawshbuit, Laitkor, Mawpat, Mawlynrei, Umlyngka, Mawiong and Upper Shillong.

Such random expansion in unplanned and haphazard manner is rather confusing when demarcation of the study area is warranted. As a practice in geomorphological studies, the watershed or drainage basin of an area is always considered and treated as one geomorphic unit where many environmental and cultural factors come into play, which in most cases are related and interdependent. This is one problem where there is no conformity between the geomorphic and cultural set up of an area.

Gulick (1958) analyzed the problems of urbanization as “Urbanization in and of itself, as a pattern of life, increases the dependence of our culture on the natural resources”.

Besides, Shillong being located on a high seismic zone where earth tremors like the Shillong earthquake of 1897 destroyed it, a clear and rationale approach can be pursued by understanding the geomorphology, and the forces that play, on which it is located so that urban expansion can be carried on with disaster management in mind.

### **Objectives of the Study**

From the discussion as appeared in the study area, it is apparent that Shillong is dynamic as far as the spread of urban sprawl is concerned which is going on without interruption even at this moment. Such dynamism produce impacts, these impacts are (i) modification of the environment; (ii) influence of the physical environment on urban form, functions and growth and (iii) continuous feedback in the city from man, culture and physical environment. Keeping the above points in mind, the main objectives of the study are:

- (i) Analysis of geomorphic characteristics.
- (ii) Identification and delineations of geomorphic provinces, geomorphic characteristics and their distributions.

- (iii) Identification and delineations of morphometric parameters like slopes, tilt, relief, etc.
- (iv) Delineations of settlements and their patterns.
- (v) Identification of roads and water supply, their impact on landuse and problems.
- (vi) Determination of gravity flow of drainage and identification of sewage disposal problems and their impacts on the environments.

### **Data**

The data for this study has been generated primarily by extensive fieldwork and secondary sources. Primary data are acquired by fieldwork (the researcher is a professional surveyor and cartographer), where data of slope, rock types and rock exposures, forest cover, soils and landuse are derived and collected in the spots where these occur.

Secondary data were collected from various sources to supplement the requirements of the study for a better and clearer understanding of the complexities and realities of physical and cultural parameters. The main secondary data, however, that has been used as base for mapping the relief, drainage and landuse was the use of toposheets of the Survey of India on scales varying between 1:63360, 1:50,000, 1:10560, 1:10000 and 1:5000.

These toposheets are also used to compare changes of the physical and cultural parameters that determined the evolutionary history and growth of Shillong into its present form.

### **Methodology**

The methodology adopted is the standard methodology adopted by geomorphologists. The parameters worked out include (i) the linear aspects like stream order, stream number, stream length and bifurcation ratio and length ratio; (ii) the areal aspects which include basin area, basin length, form factor, circularity ratio, elongation ratio, drainage density and stream frequency; (iii) the relief aspects such as basin relief, relief ratio and ruggedness number.

The significance of morphometric characteristics in various sub-basins and for the whole basin has been highlighted. Collection of data relating to vegetation cover, landuse and extent of urbanization and types of environmental degradation have been undertaken to obtain a clear understanding of the impact of urbanization on landforms and environment.

All the quantitative descriptions given above have been converted into maps in order to display and highlight the spatial distributions as found in the ground.

In view of the above, it is apparent that the study in all its entirety and completion can be grouped into three phases, namely, (i) Pre-field work; (ii) Field work and (iii) Post-field work.

(i) Pre-field Work Phase: This is the first stage. It includes the collection of relevant literature and involves the thorough study of meteorological data, geological and topographical maps so as to evolve a strategy for the research work. In this stage morphometric data were extracted and were used to prepare, relief, drainage and slope maps. Diagrams such as long profiles, superimposed profiles, area-height curves, etc. have been prepared to help visualizing the nature of landscape.

(ii) Field Work Phase: As the term implies, fieldwork means hands on and visual contact with the phenomena under study. On reaching the study site, identification of rock types, soil characteristics, slope characteristics, landuse and vegetation cover etc. were noted, measured and mapped and photographed.

Pinpointing or benchmark location of rock types, slopes vegetation cover, types of landuse expansion of urban sprawl has been done in the field by using surveying instruments and available toposheets. By the method of insertion and deletion, a standard method adopted by the Survey of India, for updating of topographical maps by ground

verification has been used as the investigator is himself a professional surveyor.

The field work stage is also gratifying in the sense that the parameters under study have been captured by means of photographs and are attached along with this study.

(iii) Post-Field Work Phase: This phase included the final preparation of maps, diagrams, interpretation and presentation of the findings. This phase is comprised of the following activities:

(a) The morphometric data extracted from toposheets have been used for statistical analysis such as correlation and regression analysis, significance test, scale ratios, linear and non linear equations to arrive at fairly accurate results in landscape analysis.

(b) Using the morphometric data and field data and other informations, a descriptive account of geology, landform, soil, vegetation, landuse and extent of urbanization has been undertaken.

(c) All the above data are then analyzed and cartographic representations have been done.

### **Plan of Work**

The entire study is divided into seven chapters with appropriate headings as given below:

Chapter-I deals with an introduction to geomorphology and its relevance to the study of urban areas in terms of applications of geomorphological knowledge and techniques. In this chapter the following have been included, these are:

- (a) Statement of the problem
- (b) Study area
- (c) Objectives of the Study
- (d) Survey and Review of Literature
- (e) Data base and Methodology.

Chapter-II, deals with the physical aspects such as geology, topography, drainage systems, climate and vegetation. The topographical features like undulating landscape, isolated flat lands and slopes and toponyms as appeared in the landscape have been discussed. Toponyms mostly of Khasi origin when interpreted sometimes give us explanations on the nature of landscape.

Drainage systems complete with stream ordering and patterns as well as their sources have been discussed. Stream ordering also known as *Ki Kyrdan Wah* in Khasi, assigned as first, second, third, fourth and fifth order streams exist. However, instead of grading the streams into different orders, the Khasi concept of stream ordering appear in the form of terminologies of Khasi fluvial morphology and hydronyms.

Interpretation of the meaning of these terminologies and hydronyms give us the characteristics of the streams.

The geological set up has been discussed in the light of rock exposures at different localities of Shillong. The rocks seen in around Shillong are the Khasi green stones seen at Mawiong and Umkhen river valley. The quartzites are seen exposed at many localities, particularly at Laitkor, Umkhen, Demthring, Noh Kalia and Shyiap. The sandstones are seen as overlies of quartzites at many localities. Conglomerates are found at two locations, one at Lawsohtun the other at Elephant's Falls in Upper Shillong. Granites are seen south of Shillong Peak. All the above rocks in geological literature are known as 'Shillong Group of Rocks'.

Fossilized remains of plants are found in a layer of sandstone south of Shillong Peak. Ripples marked rocks are found at Mawblei. Both the fossilized remains of plants and the ripples marked rocks have been found by the investigator himself in the course of his fieldwork. A petrified wood is also found by the investigator near the N.E.H.U. Campus Nongthymmai.

Soils in terms of characteristics and thickness have been discussed. Climatic factors like rainfall, wind, and temperature have been discussed and shown in tables and diagrams. Vegetations that are still seen in and

around Shillong, have been discussed. The important species along with Botanical names and Vernacular names are also given.

Chapter-III deals with the morphology of Shillong urban environment in terms of linear, areal and relief aspects.

Chapter-IV deals with geo-environmental problems brought about by urbanisation in terms of deforestation, water supply, topographical constraints and environment degradation.

Chapter-V deals with the growth and increase of population at different decades. In this respect census data for many years were collected and tabulated so that the rate of urbanization can be determined.

Chapter-VI deals with emerging geo-environmental issues and suggestions for remedial measures to mitigate the current geo-environmental issues prevailing as a result of the absence of a master plan for overall development of Shillong.

Chapter-VII deals with an overview of the entire study where general summary and conclusions are presented.

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## Chapter II

### PHYSICAL SET UP

#### **Geology of Meghalaya**

The Garo, Khasi and Jaintia hills of Meghalaya and the detached mass of Karbi Anglong of Assam together make up the hills of the peninsular part tapering into a wedge like mass of ancient gneiss and schist rocks towards the north-eastern corner of the country. The Rajmahal hills of Bihar and the Shillong Plateau are thus apparently continuous underneath the Gangetic alluvium.

According to Murthy *et al.* (1976) and Mazumdar (1986) Meghalaya massif is a geomorphic arch bounded on all sides by faults. The southern fault is the famous Dawki fault. The northern fault is marked by the Brahmaputra lineament. To the west the massif is detached from the main Indian shield by the north-south trending Rajmahal-Garo lineament. The eastern fault is marked by a NE-SW lineament separating the massif from the sediments of Bengal-Assam shelf. As such the Meghalaya massif is a horst, forming a plateau region block uplifted to its present height about 600 metres to 1900 metres above mean sea level.

Broadly speaking Meghalaya consists of five geological formations, viz., the Archaen Gneissic complex, the Shillong group of



rocks, the Lower Gondwana rocks, the Sylhet traps and the Cretaceous Tertiary sediments (Fig.2.1).

The Archaen Gneissic complex occupies the greater part of the northern Meghalaya and is composed of gneiss rocks with granitic rocks strewn here and there over the central region. The Shillong series of sub-metamorphic partly intervenes the gneissic rocks of the northern Jaintia Hills. These have broken into a number of irregular outlying hills and hillocks in some cases on the northern border.

The Shillong group of rocks in the central region consists of quartzite bands overlying the schists. The gneiss is covered by sub-metamorphic rocks. Intensive granitic and diorite rocks are found in the central part of the plateau with conglomerate and Khasi Green stone folded up in some places. The Khasi Green stone include amphibolites, dolerite and epidiorites.

The Lower Gondwana rocks occur in the western part of Garo Hills in the Singrimari area within 4 km. of Indo-Bangladesh border. The outcrop extends over a length of 1 km. and a width of 400 m. just east of Manikachar road. It includes pebble – beds, sandstone and shale.

The sub-metamorphic of the central region is in contact with the outburst of volcanic trap (of Meghalaya) described as the *Sylhet Trap* and is close to the *Shella-Dawki Fault* (the basaltic lava flows of the Deccan

is found to spread over vast areas which have produced terrace or step like topography. Hence, it is called a *trap*). The overlies eroded the Precambrian basement and are themselves overlain by the Upper Cretaceous Eocene Sediments. The Sylhet Traps consists mainly of basalt and rhyolites.

The cretaceous-tertiary sediments which occupy the southern part of the state are very thick more than 300 metres and plunge steeply below the tertiaries and alluviums of the Bangladesh plains. The chief rocks include sandstone, shale and limestone. The formations are divided into three groups:

- (a) The Khasi Group
- (b) The Jaintia Group
- (c) The Garo Group

(a) The Khasi Group

The Khasi Group represents the cretaceous section of the pile and is represented by Jadukuta formation, Bottom Conglomerate formation and Mahadek formation. The Jadukata formation non-conformably overlies the Sylhet Traps and represents an arenaceous facies comprising conglomerate at the base overlain by pebbly sandstone, coarse grained sandstone with carbonaceous streaks.

Table 2.1

## General Stratigraphic Sequence of Geological Formation in Khasi and Jaintia Hills

Geological Age	Group Name	Formation	Rock Type
Recent	Newer Alluvium (Thickness not known)	Unclassified	Sand, Silt and Clay
UNCONFORMITY			
Pleistocene	Older Alluvium (Thickness not known)	Unclassified	Sand, Clay, Pebbles, Granite, Soulder deposits
Eocene	Jaintia Group	Simsang Formation 1150 m. Shella Formation 600 m. Langpar Formation 100 m	Siltstone, Sandstone alteration Alteration of Sandstone, Limestone Calerian Shale, Sand-stone, Limestone
Upper Cretaceous	Khasi Group	Mahadek Formation 100 m Bottom Conglomerate 25 m Jadukata Formation 140 m	Arkose (Glaucouitic) Conglomerate Arkose Sandstone Conglomerate Alteration
Jurassic	Sylhet Trap	Jadukata Formation 600 m	Basalt, Alkali Basalt Rhyolite Acid-tuff
Proterozoic	Pre-Cambrian	Intrusive Acid and Basic	Porphyrite, Coarse Granite Apatite, Quartz Veins Epidorite Basalt
		Khasi Greenstone Shillong Group	Basic Sills & Dykes mostly within the Shillong Goup Quartzite, Phylite and Conglomerate
	Archaen	Gnessic Complex	Biotite, Grains Biotite Hornblende, Gneiss magnetite, Mirca Schist, Biotite Granite, etc

Source Geological Survey of India, 1975, Geology and Mineral Resource of the Survey of India, Part IV, Misc Publication No 30, pp 69-79

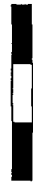
(b) The Jaintia Group

The Jaintia Group marks the onset of change in depositional environment. It is best developed in Cherrapunji area. Its vestiges are found as north as Um Raleng lying west of Umiam Lake in Khasi Hills and Darugiri in Garo Hills. It represents commencement of calcareous facies deposited in a stable shelf segment of the basin. This group is

Shillong and its Environs  
GEOLOGICAL MAP







Scale

1000 0 1000 2000 III



INDEX

Rock Groups

-  Khasi Green Stones
-  Conglomerates
-  Siltstone Shale Phyllite
-  Sandstone Phyllite Quartzite
-  Shear Zone
-  Fault

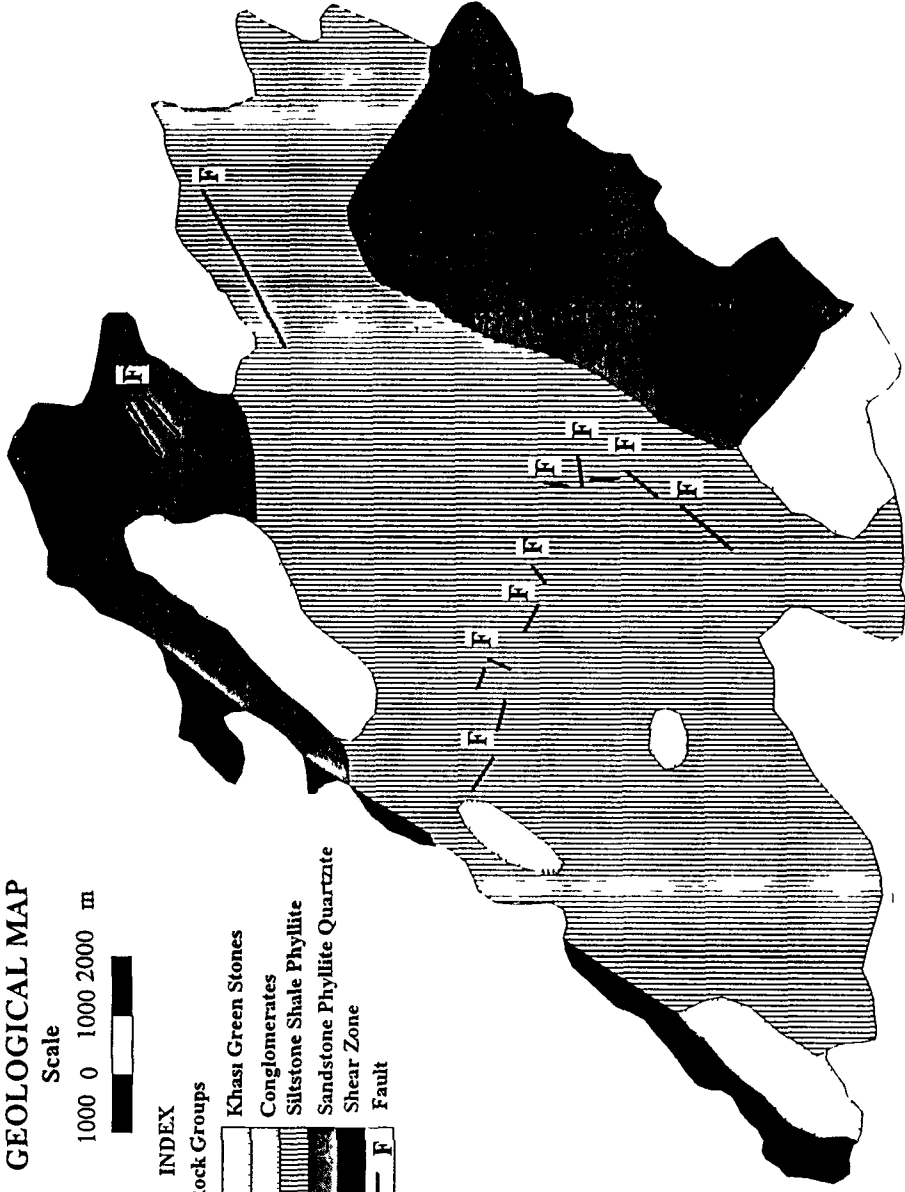


Fig - 22

divisible into three formation, viz., Langpar Formation, Shella Formation and Kupili Formation.

(c) The Garo Group

The Garo Group represents the Upper Tertiary sequence and is well exposed in Garo Hills. It is divisible into three formations, viz., Simsang Formation, Baghmara Formation and the Chengapara Formation. Lithologically and faunal assemblage wise these three formations are akin to the Barail Surma and Tipam Formation of Assam-Arakan Basin.

### **Geology of Shillong**

Shillong, the study area, forms part of the well-known Shillong Plateau, which is also referred to as the Meghalaya plateau. Shillong city is located in the centre of the plateau. The core of the plateau is an ancient mass of gneiss, which was intruded by coarse granite. The gneiss and granite are concealed beneath cretaceous and tertiary deposits.

The rocks seen in and around Shillong city have been assigned by geologists as the Shillong Series or the Shillong group of rocks (Fig.2.2).

### **Distribution of Geological Formations**

In order of antiquity, the Khasi greenstones are the oldest groups of rocks and are confined within the Shillong group of rocks. The Khasi name for greenstone is Mawiong. From the investigator's field work in

his study of toponyms, he discovered that wherever a toponym “Mawiong” exists, Khasi greenstones invariably occur. One locality known as Mawiong located at an altitude of 1340 metres, in the northern part of the study area testifies to this. The Khasi greenstones in this locality are overlaid with thick red soils. The other locality where Khasi greenstones occur stretches between Mawblei and Umphyrnai in the upper reaches of the Umkhen valley and extend upto Mawlyngngad. Khasi greenstones are also seen along the Phud Umshing stream near Mawiong. The Khasi greenstones in the Umkhen valley, however, are overlaid by siltstone-shale-phyllite unit and appear to be deep seated. In the Mawiong and Phud Umshing, the Khasi greenstones occur as detached bases running parallel to the meta-sedimentaries. These greenstones are represented in the above localities in the form of epidiorite, metadolerite, metagabbro etc. In mineral content it is composed of hornblende, plagioclase, chlorite, opaques, biotite, etc.

The siltstone-shale-phyllite group of rocks occurs as exposed rocks, sometimes overlaid, at places, with thin brown soils, these rocks are seen in the Umladew basin, in the Happy Valley area of Umkhen and Wah Umbah basin and at Lawsotun area. These rocks exhibit small scale fracturing and crushing which may have been brought about by tectonic activity. These rocks represent the argillaceous facies of the

Shillong group and in composition it is similar to that of the sandstones. Due to local metamorphism within the Shillong group of rocks itself slates are formed by the process of compaction and recrystallisation of the quartz grain that composed these rocks. The phyllite member of this rock group varies in colour from yellow grey to light green whereas the *siltstone member is light brown to brown.*

The other group of rocks belonging to and confined within the Shillong group of rocks are the sandstone phyllite-quartzites. This group is the most dominant of all groups in the study area and has two variations - the sandstones and quartzites. In most cases, as seen in the field, the sandstones are observed as resting conformably on the quartzites. These rocks, particularly the quartzites exhibit a crestal type of fold pattern with steep dips near the crestal parts as seen in the northern face of the Shillong Peak-Kynton Sngi range and shallow dips in the intervening adjacent parts. The trend of folding of these rocks is NE-SW and the folding takes the assymetrical to isoclinal folds as seen at many localities particularly in the sub basins of the study area wherever parallel pattern of drainage are seen.

Most of the cliffs and precipitous slopes, which are perpendicular and where waterfalls occur, are composed predominantly of well-bedded quartzites. The dip and strike of the Shillong quartzites along the granite

boundary on the left of the Umiam river in the west to the south of Shillong peak are independent of the granites. The folding of the quartzites has been effected before the granitic intrusions. Mazumdar (1986) has traced the folding pattern of the Shillong quartzites and encountered S-shaped folds and reclined folds on many occasions at different localities.

The conglomerates which included the cemented fragmental rocks containing rounded fragments such as pebbles, gravels and boulders are found to occur as detached lensoid beds at Ummawlong, 1563 metres. However, the conglomerates found exposed as outcrops cover the whole of Nongpiur, 1678 metres, in the Upper Shillong area to west of Mawiong, 1280 metres. These conglomerates are seen compacted together by the process of metamorphism. At Ummawlong the sandstone-phyllite-quartzite group appears to rest conformably over the conglomerates. These conglomerates, therefore, have also been assigned as basal conglomerates.

The geology of the study area is further complicated by the occurrence of the Tyrsad-Barapani Shear zone which is very prominent in the remote sensing imagery. This shear zone runs in a NE to SW direction and follow the axial plane of the folds. The shear zone appears to be a manifestation of deep-seated basement controlled tectonic fracture. This

shear zone displaced and deformed the adjacent rocks and brought an unstable phenomenon known locally and called by the villagers of the area, where this zone runs, as *Dew Theh* and *Khylliam Boit*. *Dew Theh* means, “poured debris materials” and *Khylliam Boit* means “unpredictable mass wasting”.

### **Tectonics**

From the examination and interpretation of fossils and rock types, which were collected, the tectonics and geological set up of Shillong can be inferred. Plant fossils were collected at an altitude of 1852 metres, one kilometre south of Laitkor. These fossilized remains of plants were found in a layer of metamorphosed rocks inclined at an angle of 40°. Rippled-marked rocks have been found in a thick layer of red sandstones at Mawblei, 1850 metres. Petrified piece of wood have been discovered in a depression overlain by sandstones at a depth of three metres near the North-Eastern Hill University Campus at Nongthymmai.

The most striking discovery is the exposures of conglomerates located at Ummawlong area of Lawsohtun. Field observations indicate that the quartzites of the Dymmiew apparently overlie these conglomerates.

The geological evidence, that is, the plant fossils, the ripples marked rocks, the petrified wood, conglomerates and perpendicular cliffs show that the physical landscape of Shillong city had a slow and sometimes occasional violent evolution spanning a period of about 4000 million years.

From the evidences presented above, a stratigraphic sequence on the geological set up of Shillong city is given below:

**Table 2.2**  
**Stratigraphic Sequence of the Study Area**

Geological Age	Group Name	Rock Types
1. Tertiary	<i>Langpar formation</i>	<i>Brown Sandstones and Shale</i>
2. Upper Cretaceous	Khasi group	Sandstones and Conglomerates
3. Pre-Cambrian	Shillong group	Quartzites, Conglomerates
4. Achaean	Gneissic complex	Gneiss, Hornblende etc.

From the stratigraphic sequence given above, it is seen that the Archaean gneissic complex is exposed in the central part of Shillong plateau and is composed of gneisses, granites, hornblende etc.

The Pre-Cambrian or the Shillong group of rocks comprising quartzites, conglomerates and Khasi greenstones are seen exposed widely in and around Shillong. Current bedding is noticed in these rocks. The Shillong group of rocks lies unconformably over the gneissic rocks with a thick bed of conglomerates like those seen at Ummawlong. These rocks usually strike in a Northeast-Southwest direction. The newly folded

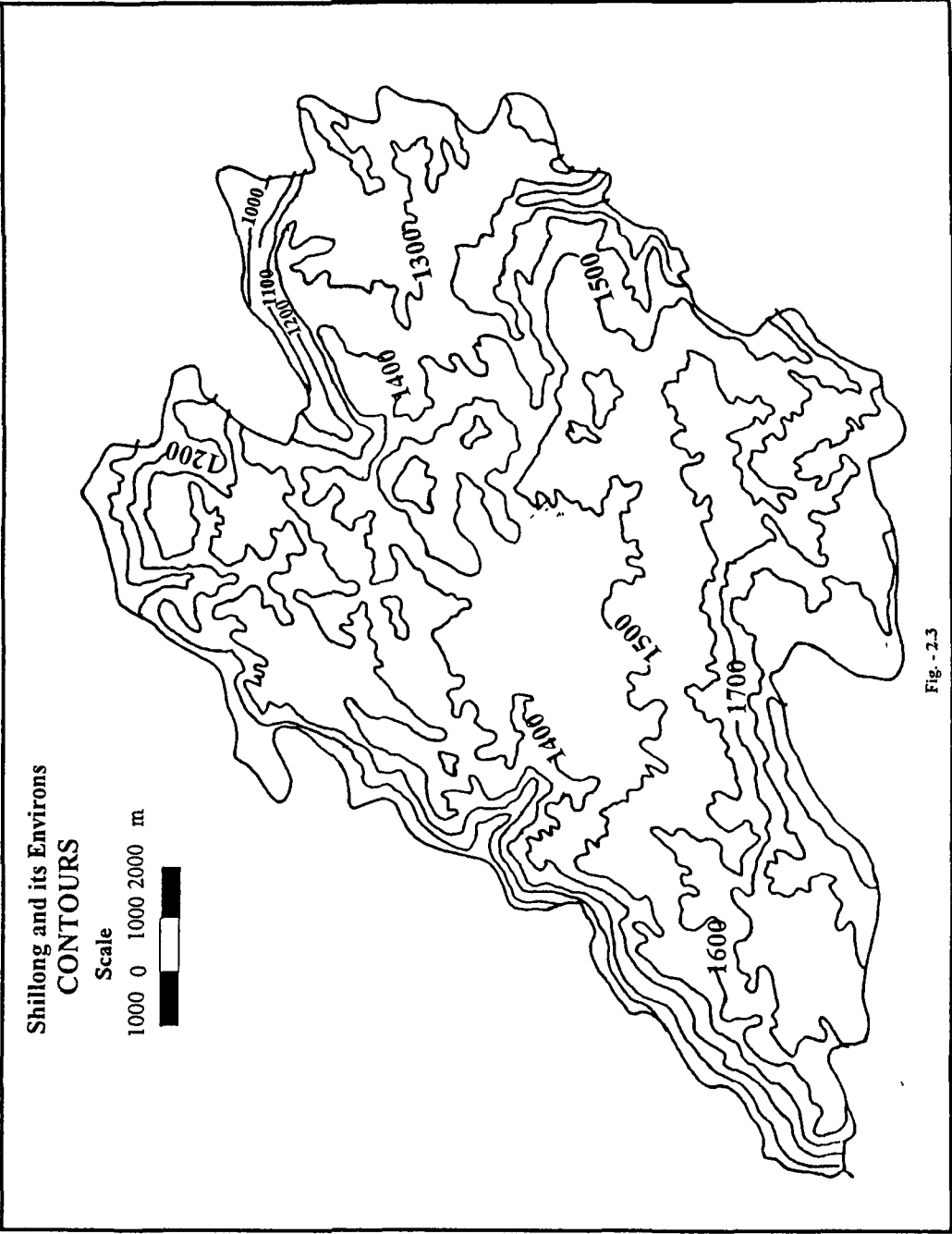


Fig. - 2.3

sediments have suffered low-grade metamorphism and are dissected by numerous faults, like the Umpling fault, the Dymmiew fault and the Wah Roro fault. The different lithological blocks move up and down at various times during the tertiary period.

The Shillong group of rocks were intruded by igneous rocks of basic to ultra basic composition along the axial region around Myllem and thus termed as Myllem granites. Sedimentation occurring 65 million years ago gave rise to the emergence of brown sandstones and shale.

### **Topography**

The study area forms part of the Shillong Plateau which is known today as the Meghalaya Plateau. The topographical features have been identified with the help of (a) contour maps (Fig.2.3), (b) field verification and (c) Khasi place names. The study area is comprised of different categories of relief such as undulating topography with uniform slopes to steep slopes. The relief of Shillong has an altitudinal variation of between 1000 metres to 1900 metres. In the field when viewed from Diengie Peak, Shillong appears to have a mountainous character but when viewed from the Shillong View point, the view gives one the impression that Shillong is located on a bowl-like shape valley.

Topographically, Shillong, is comprised of flat lands, flat mountaintops, precipitous slopes, mounds and undulating topography, and is located on a deeply dissected central uplands of the Meghalaya plateau. The highest mountain range, the Shillong Peak-Kynton Sngi Range of the Plateau is located just one kilometre areal distance from the city and forms a great watershed. Flat mountaintops are seen in the Mawpat ridge, 1687 metres, and at the Shillong-Peak-Kynton Sngi Range at 1960 metres forming the southern and central watersheds of Shillong.

Precipitous slopes are seen in the northern face of Shillong Peak-Kynton Sngi Range at different elevations ranging between 1680 metres at Riat Kut, 1767 metres at Riat Malki, 1865 metres at Riat Laban and 1896 at Riat Tynrah. The Khasi word *Riat* means 'Cliffs'. Therefore, the precipitous nature of this belt can be known only from this word *Riat*. Thus the precipitous topography extends from Riat Kut to Malki, Lumparing, Riat Laban and Riat Tynrah. This whole area is known as *Ka Dymmiew* which conforms to Khasi ecological and geomorphological terminologies. In the heart of Shillong, on the left bank of Umkhrah stream, downstream, the precipitous nature is seen at Riatsamthiah, 1436 metres. Another precipitous topography is seen from near the confluence of Umshyrpi and Umkhrah, known as Riat Sunapani and extends interruptedly upto Riat Khwan in the Barapani reservoir. The precipitous

nature is also seen at the right bank of Umġam river extending from the confluence of the Umġam and Umbah streams to the Barapani reservoir. This particular stretch of precipitous topography has a total length of 18 kilometres and run in south-south west to north-north east direction.

Another precipitous landscape is seen on the banks of Umshing stream from Mawġong area northwards till it meets the Umġam river. The Khasi name for steep riparian sides is known as *Pynden*. The precipitous nature, which continues to Riat Sunapani, is seen from the Iron bridge across the Umshyrpi.

The precipitous topography is also seen in the northern face of a ridge starting from the headwaters of Wah Tamdong running up to 7 kilometres in length. The precipitous topography is further seen in the riparian sides of the Umkhen river from Mawpdang in the east to Umphymai in the south west having a total length of 14 kilometres. The Umbah stream a tributary of the Umkhen river also has steep riparian sides.

The undulating topography covers the whole of Mawlai right from Lummawsing, 1382 metres to ĩewrynghep and Nongkwar to Nonglum. From Nonglum and Mawroh, the topography descends gradually to form the flat level lands of Pynthor Umkhrāh, Pynthorbah and Langkyrding covering an area of 3 square kilometres. The flat nature of the topography

is known from the name of the place itself where the Khasi word *Pynthor* means “flat level lands”.

From Langkyrding and Nongmensong 1545 metres the topography ascends gradually to form another undulating topography covering Mawpat 1612 metres across Umpling 1419 metres and Rynjah 1546 metres to Happy Valley 1581 metres.

Another undulating topography covers the southern part of Jaïaw 1440 metres to Mawkhar, Pinemount, Cricket ground, the Military hospital and the European ward areas.

In fact the land between Umshyrpi and Umkhrah streams is highly undulating, except in the Jail Road areas. This stretch of land is referred to as *KA PYRDI* or “land between rivers”.

In the proposed satellite town or New Shillong, towards the east of the Mawpat ridge, the area is highly undulating. This undulating nature of the land in this part is known from the Khasi name of the place Mawdianglydiang or Mawdiangdiang, meaning an area of low mounds.

Even to the south of the Shillong Peak-Kynton Sngi mountain range, the area is highly undulating and at this height average 1800-1900 metres, the area is known in Khasi as *Ka Rngi*, meaning Dry and Sunny.

From 6<sup>th</sup> Mile, at a height of 1714 metres towards the south-west extremity of Shillong, the land is highly undulating.

Shillong and its Environs  
**TOPOGRAPHICAL FEATURES**

Scale  
1000 0 1000 2000 m

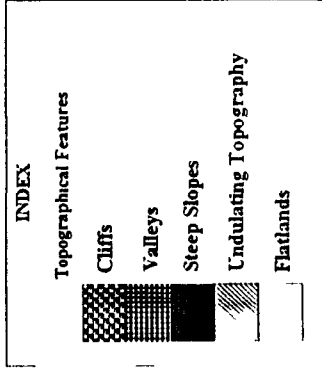
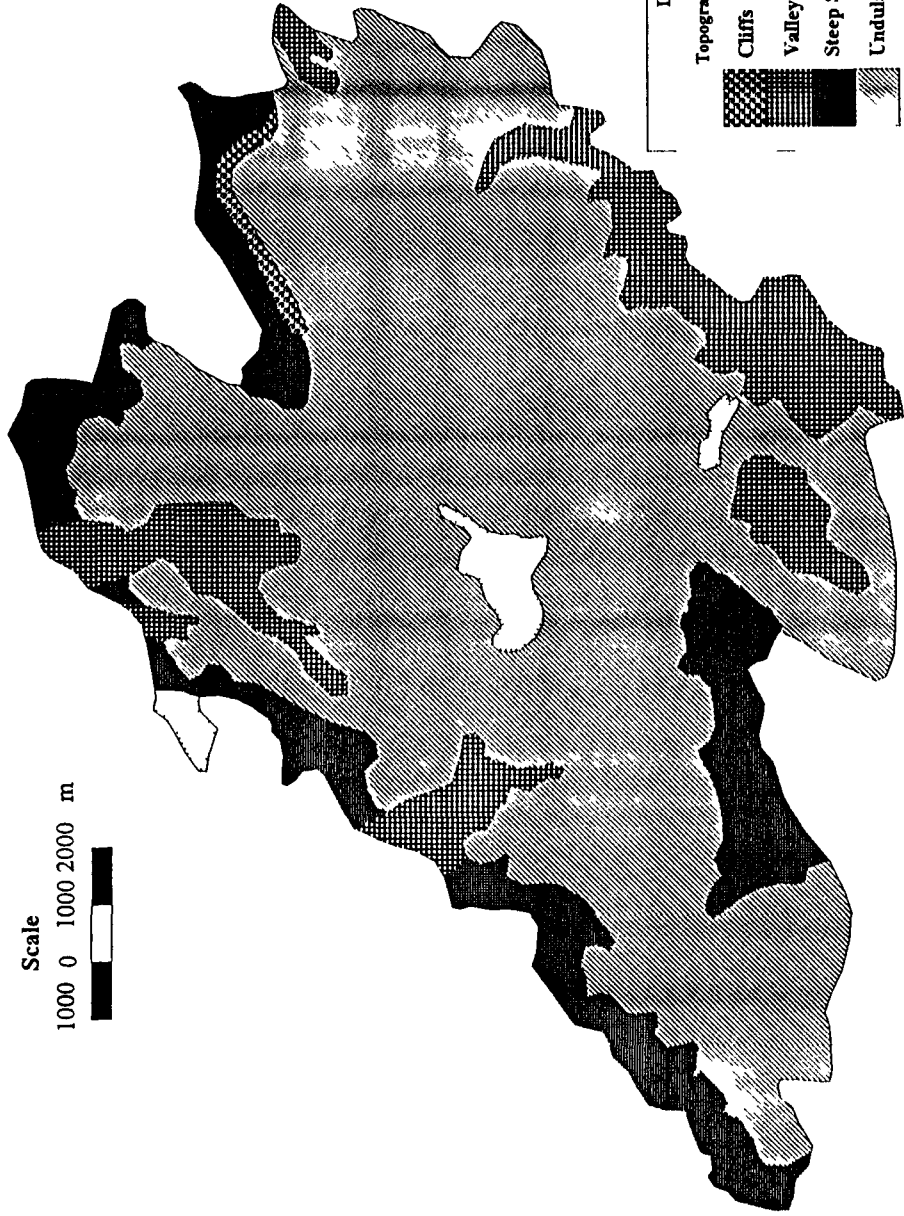


Fig - 2.4

The Mawprem area 1460 metres, north of Bara Bazaar is characterized by moderate to steep slopes. The Nongkseh and Lummawbah area across the Umshyrpi on its left is also comprised of moderate slopes, whereas Umlyngka is highly undulating.

Another area, which is highly undulating, is the Lawsohtun area upto Madan Laban, Kench's Trace and Bishnupur. The whole of Malki, Risa Colony and Cleve Colony the area is comprised of steep slopes and moderate slopes respectively.

The Nongthymmai area along with Madanrting can be said to be comprised of moderate to steep slopes. Mawshbuit, 1760 metres to the south of Happy Valley is located on a flat mountain top with steep slopes all around. Mawiong, in the north of Shillong, is also characterized by moderate to steep topography.

Thus Shillong, the study area, is comprised of cliffs, precipices, moderate to steep topography and undulating nature. These are known by physical verification in the spot as well as from the Khasi names such as *Ka Dymmiew*, *Ka Rngi*, *Ka Pyrdis*, *Ka Pynthor*, *Diang-Lydiang*. The break-up of each topographic feature (Fig.2.4) as described above have been tabulated as follows:

**Table 2.3**  
**Topographical Features**

Topographic Feature	Area Covered (sq.km.)	Percentage from the Total Area	Total Geographical Area of Shillong (sq.km.)
1. Cliffs	6.743	3.87	174
2. Valleys and Steep Slopes	40.191	23.10	
3. Undulating topography	124.304	71.44	
4. Flat lands	2.762	1.59	

### Drainage Systems

There are two main streams in Shillong proper (Fig.3.1), namely the Umshyrpi, meaning “flowing along as one stream” and the Umkhrach meaning “gurgling stream”. These two streams meet together at a steeply dipping junction known in Khasi as *Sdad Umkhrach* or Umkhrach Confluence. From this confluence it is known as *Wah Roro* till it meets the Umiam river meaning “Weeping River”. The sources of these streams are located high in the northern face of Shillong Peak-Kynton Sngi Range at an average elevation of 1900 metres. There are nine small streams flowing northwards down the slopes of *Dymmiew* to form the Umshyrpi streams. These nine small streams, though having separate and unique hydronyms, are collectively known locally as *Ki Khyndai Umdih* or The Nine Drinking Waters. There are many small waterfalls in the small streams, the notable one being the *Kshaid Risa* or Risa Waterfalls which the British call it the Crinoline Falls.

The Umkhrach has its source at Nan Syiem, 1900 metres and flows down the steep slopes of Nongthymmai under the name of Demthring meaning “the stream where storks used to rest” in their southward annual migration. At Rynjah, the Demthring meets the smaller streams such as Wah Tepthoh and Ummawdamob of Happy Valley and Phudbri, Phud Pambriew and Umkoi of Nongrah. From the Rynjah junction the Demthring then flows by another name called Umpling. From Demthring bridge downstream the stream flows on a quartzite bed. The Umpling stream, from the Rynjah junction, has a rectangular course and apparently, flows on rectangular fault line where it receives two other smaller streams, Wahnuid and Umshyngiar and cascading into a waterfall known locally as *Kshaid Nohkaliar*, which the British called it the Spread Eagle Falls. From this falls, the Umpling flows directly north in a straight line for about 500 metres, indicating the strong presence of a fault. Beyond the falls downstream, the Umpling receives another small stream known as Wah Kdait. From this point, the Umpling take an almost circular course and then along a ‘U’-shaped meandering course. From this point downstream, it then flows under the name of Umkhrach where it receives the waters of a small stream, Wah Langkyrding, which has its source in the southern face of Mawpat hillock, 1687 metres, and Ummawroh. Both these small streams drain the flat level lands of

Pynthorbah, Langkyrding, Pynthor Umkhras and Golflinks area. From a place call Sawphorlong, the Umkhras flows on a straight course for about 1 kilometre. From the Pasteur Road bridge the Umkhras has the same pattern of flow as the Umpling, meaning that the Umkhras also flows on a fault line in a rectangular manner.

From Madan Weiking, the Umkhras then flows in a meandering manner across the Mawlai bridge cascading into a waterfalls and rapids known as *Kshaid Sunapani*, which the British called it the Beadon's falls. The waters of the Sunapani Water falls was tapped for the generation of electricity by the Shillong Electric Company in 1910, and is the second oldest hydro-electric plant in India.

The Umshyrpi stream starts from the junction of the smaller streams, Umkashi and Wahdienglieng. The Umshyrpi, unlike the Umkhras, has a tortuous winding course and has an almost complete circular path before it debouches downstream into two waterfalls, the Bishop and Gunner's Falls.

The Umiam river running in a south-south west to north-north west direction form the western boundary of Shillong from Umbah to the Umshing confluence. There are many waterfalls on the tributaries flowing to Umiam such as Kshaid Umdiengpun or Elephant's Falls, Elysium Falls and the Umsaitsning Waterfalls.

In the south, that is south of Shillong Peak-Kynton Sngi range are the headwaters of Umfiew river and in the south east there is the Umkhen river with its source at Wiehkhlich. This river also meanders in a circular manner before it debouches into the flat lands of Happy Valley. The tributaries of this river are Umsohlwai, Umphyrnai, Umweiar, Umshawshaw of Umphyrnai and Laitkor areas. Another tributary is Ka Wah Rting and Wah Dita of Madanrting.

To the East, on the New Shillong area, the streams are Wah Tamdong, Wah Shala and Wah Umbah. Wah Tamdong has its mouth in the northeasterly direction. Another stream, to its north, is the Umjarasong which meets the Wah Tamdong at Kleng village.

The Umbah stream has its source in the Itshyrwat Protected forests and its other sources are Phud Raimut and Phud Synran and Wahkyiaïñ. The main source of Wah Shella is the Umsawli stream that rises from the eastern face of Mawpat ridge at Diengiong and Lyngkien villages.

Another stream in the north is the Umshing stream that rises from the western face of the Mawpat ridge. From its source to a distance of 4 kilometres, the Umshing flows through flat lands and undulating topography, but from Mawiong downstream the banks are very steep and precipitous till it meets the Umiam.

About two kilometres east of Umshing, there is another stream known as Umladew, it has its source at Umsaw village.

### **Soils**

Soil is the dynamic layer in which many complex chemical, physical and biological activities are going on constantly. Therefore an understanding of soil characteristics is indispensable. In geomorphology, soil is a three dimensional body of the earth's surface which supports plants and generally produced out of alteration of weathered materials so that a distinct layer of its mineral and organic components appear. Yakushova (1983) stated that "Soil is the surface layer of the earth restricted to land with the fertility characterized by the organic and mineral composition and a profile type of structure that it alone possesses, the soil emerged and developed as a result of combined activity upon the rocks by water, air, solar energy, plant and animal organisms; hence the properties of soils reflect the local characteristic features of the environment and managing the activity of man.

From the above statement it is clear that there are factors at work responsible for soil formation and the chief of them is climate. Therefore, the study of soils logically follows the study of climate. The type of soils

that are formed in a particular area depends on parent materials, climate, living organisms, particularly vegetation, topography and time.

In this respect, Shillong, the study area, has a humid climate with temperatures ranging between 19°C to 25°C on the average, which is much lower than other humid areas experience. Therefore, development of soils would very much correspond to other humid areas of the world where weathering reaction are greatly reduced but at the same time allowing soil formation.

In order to highlight the relationships of soils to parent materials, soils to physiography, soil samples were collected from different elevations and a relationship between soil and physiography to geological structure was attempted as follows:

### **Relationship between Soils and Physiography**

From the topographical map  $78\frac{0}{14}$  it is seen that Shillong has a relative relief of 920 metres ranging from 1000 metres along the precipitous slopes of the right bank of the Umiam to 1920 metres on the Rngi area of Laitkor on the Shillong-Kynton Sngi range. Analysis of topographic features reveal that Shillong possess five types of relief: (i) Cliffs, (ii) Precipitous slopes, (iii) Flat level lands, and (iv) Undulating topography, (v) Valleys (Fig.2.4).

On the top of cliffs the soil depth is only about 10 cms with gravels, on the precipitous slopes the soil depths however varies between 15 cms to 25 cms. On the flat level lands the soil depth is 150 cms to 300 cms such as in the Pynthor Umkhrah area; and on the undulating topography the soil, though sandy, has an average thickness between 40 cms to 90 cms.

### **Relationship between Soils and Rock Types**

Soil reactions vary from strongly acidic to acidic in nature. The acidic nature of soils of Shillong is attributed to the prevailing climatic factors and the reason for low pH may be assigned to the heavy leaching of bases under complex exchange of matter under the prevailing high rainfall conditions. Thus, the relationships between soils and parent materials or rock types can be recognized and is given below:

1. Soils over Pre-Cambrian Rocks: As per the stratigraphic sequence, the rocks of the Pre-Cambrians are mostly quartzites. These quartzites are seen exposed at many localities at different elevations. The soil derived from these rocks is mostly medium to fine textured. The colour also varies from dark tan to dark reddish. Texturally, it is loamy to clayey non-sticky and non-plastic. It is gravelly and sandy at

places. In areas where forest covers are seen the topsoil is rich in humus.

2. Soils over Shillong Group of Rocks: Soils that have been formed of the rocks of Shillong group range between medium to fine textured. Leaching occurs where bases of mineral components are leached out. Soils that have been formed from such rocks are generally homogeneous, granular, and loamy to clayey. The soil colour varies from dark grayish brown to yellow to brownish yellow. Due to presence of evergreen forests, the topsoil is rich in humus.
3. Soils over Khasi Greenstones: Soils over Khasi greenstones is typically lateritic having a reddish brown colour. The soils developed from such rocks are clayey to loamy, moderately fine and granular.

The significance of the soil types as shown above is that each soil type is related to significant materials and a particular gradient and position in the landscape.

### **Climate**

The climate of Shillong is controlled by seasonal winds, the southwest monsoon, and altitudes. In general the climate of Shillong is different from its adjoining places on account of three factors. These factors are the (i) presence of the Barapani reservoir, (ii) the existence of

protected forests on the northern face of Shillong Peak-Kynton Sngi Range facing Shillong city and (iii) Increasing built up area.

Though the central uplands of Meghalaya has been assigned, climatically, as a subtropical mountainous monsoon climate, it is also referred as having a 'humid mesothermal climate in empirical classification. The seasons of Shillong are as follows:

1. Spring – March to middle of May (Pre-Monsoon).
2. Summer – the rainy seasons from middle of May to middle of September (Monsoon).
3. Autumn – Middle of September to November (Post-Monsoon).
4. Winter – December to February-March (Cold season).

In this chapter more attention is given to the climatic elements like temperature and precipitation with specific reference to their annual activities. These phenomena play an important role in weathering and fluvial processes.

Climatically speaking, Shillong though with a small total geographical area of 174 sq kms only, has a range of differences regarding precipitation and temperature (Tables 2.4, 2.5, 2.6). These differences occur within short distances, horizontally and at varying elevations, vertically. The uplands of Shillong have a sub-tropical mountainous monsoon climate, whereas the areas at elevations of 1200

metres and down to 1000 metres have a temperate humid climate resembling the warm sub-tropical type.

Table 2.4

## Meteorological Data of Shillong for 1997

Temp (degrees)	Max.	Jan	Feb.	Mar.	Apr	May	June	July	Aug	Sept	Oct.	Nov	Dec
	Min.	4.8	13.7	14.9	20.7	19.9	33.9	24.1	23.9	24.3	23.0	21.1	19.0
Humidity	Mor.	62.9	55.8	60.4	79.6	75.7	76.2	88.0	91.2	84.0	63.8	63.0	60.0
	Eve.	86.1	79.0	66.2	76.0	25.6	84.3	86.3	86.2	87.2	90.0	87.0	93.0
Rainfall (mm)		16.0	33.4	59.0	278.1	192.9	301.0	516.1	352.5	282.8	53.3	9.9	18.0

Table 2.5

## Meteorological Data of Shillong for 1998

Temp (degrees)	Max	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct.	Nov	Dec
	Min	5.3	14.3	17.3	19.2	22.7	23.9	23.6	24.0	24.1	24.0	22.6	20.6
Humidity	Mor.	68.0	51.0	68.2	65.0	77.0	81.0	74.0	88.0	69.0	92.0	76.0	43.0
	Eve.	98.0	80.0	83.6	77.0	84.0	93.0	82.0	91.6	91.0	88.0	96.0	95.0
Rainfall (mm)		12.0	0.0	112.0	213.5	109.9	93.2	439.1	500.3	270.2	169.3	85.6	0.0

Table 2.6

## Meteorological Data of Shillong for 1999

Temp (degrees)	Max	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	Min.	6.6	16.4	21.2	22.9	25.2	22.9	24.2	23.5	25.7	23.3	21.6	18.9
Humidity	Mor.	25.0	23.0	58.0	68.0	74.0	96.0	57.0	95.0	81.0	89.0	46.0	56.0
	Eve.	67.0	59.0	76.0	72.0	60.0	93.0	78.0	81.0	91.0	85.0	85.0	97.0
Rainfall (mm)		7.8	0.0	4.4	13.8	515.1	221.8	717.5	323.8	130.3	31.8	9.7	2.1

The differences of temperature at different elevations but at short distances of 3 kilometres are being made known to the public in the weather column of *Shillong Times*, the city English premier daily. For example, the weather conditions in terms of rainfall and temperature for three days, 27, 28 and 29 July 2003 are given in Table 2.7.

Table 2.7

## Temperature and Rainfall Variations of Upper Shillong and Shillong for Three days

Date	Temperature & Rainfall		Upper Shillong (1860 metres)	Shillong (1496 metres)
27.7.2003	Temperature (in degrees)	Maximum	25.4	25.8
		Minimum	17.4	17.4
	Rainfall (in mm)		5.4	Nil
28.7.2003	Temperature (in degrees)	Maximum	25.4	26.8
		Minimum	17.4	18.8
	Rainfall (in mm)		5.4	Nil
29.7.2003	Temperature (in degrees)	Maximum	22.8	24.0
		Minimum	17.5	17.0
	Rainfall (in mm)		10.4	Nil

Temperature

With the exception of the Shillong Peak-Kynton Sngi Range, normal monthly maximum temperature is recorded in Shillong. The highest monthly maximum temperature is observed during the month of August upto 28°C. Thereafter on the onset of rainy season brings down the temperature. The temperature continues to fall with the break of rains and the lowest monthly temperature is recorded in the month of January.

The above tables show that mean maximum temperature in the study area is the highest, 26°.5C and lowest in the month of January 13°.6C. The mean minimum temperature varies from 5°.2C in January to 17°.9C in August. The variations between monthly maximum and monthly minimum is very high in the month of April when maximum is 23°.1C and minimum is 13°.1C. From May to December the range between monthly maximum and minimum temperature appears to be

narrowing down and is again rose which clearly indicate that there is fluctuation in monthly temperature.

### Rainfall

The amount of rainfall received at Shillong annually, on the average, is 2200 mm and decreases northwards according to change of relief known as the rain shadow effect. The rainfall normally begins to fall by the third week of April and continues to rain upto the end of September after which it gradually diminishes. The intensity of rainfall is noticed in the month of June as high as 544.60 mm but is less than one-fourth of rainfall received by Mawsynram, 50 kms south-west of Shillong.

### Humidity

Humidity remains high throughout the year. Except in the month of March the relative humidity is always more than 60 percent. During the rainy season when the winds are blown mostly from the south-west the relative humidity is as high as 75 to 85 percent

### **Seasonal Weather Conditions**

The general weather conditions of the different seasons with characteristics are given below:

### Spring

This season is also known as Pre-monsoon lasting from the month of March to middle of May. It is a season when temperature starts rising, after a cold winter, as high as 20°C coupled with high relative humidity. Winds are quite strong in this season and blows from the west. In the Khasi concept of climate relating to wind, spring is the season where *Ka Er Kyllang*, a local cyclonic type of wind, is active. This wind is particularly strong in the month of April where trees and even houses are sometimes uprooted. The weather conditions during this season change suddenly and sometimes abruptly, as a result low intensity rainfall, thunderstorms and hailstorms occur. Cloudiness of the sky also starts appearing during this season.

### Summer

This season is also known as the rainy season or the monsoon season. This season, by virtue of the intensity of rainfall is also referred to as a “season of relatively long summer”. In the Khasi concept of climate relating to rain, summer is a period of intense rainfall known as *Ka Aiom Slap*. During this season rain fall intermittently for days together sometimes upto a stretch of nine days. Cloudiness is a common

phenomenon; the nights are quite cold after rainy days. Flash floods on the headwaters of streams are commonly seen during this season.

### Autumn

This season is also referred to as the post-monsoons. Weather conditions during this season are characterized by short period of sunshine and less cloud cover. This is the period when monsoon winds have retreated; as a consequence there is less or no rainfall at times. The temperature in the mornings and evenings are cooler and winter sets in gradually. This season is the shortest season. It starts from the middle of September to early December.

### Winter

This season starts by early or sometimes middle December; and lasts upto middle March. Though the weather conditions are generally cold and dry, thunder showers known locally as *Lap Pyniapiong* or the rain that kill plants occur with.

### **Weathering**

Weathering is the breakdown and alteration of rocks exposed at the earth's surface to products that are more in equilibrium with newly imposed physico-chemical conditions. All rocks were originally formed

at high temperature, and high pressure. Weathering, in a large part, is in fact a response to low temperature and low pressure.

The area under study is formed generally of metamorphic rocks like quartzites and sandstones, with granites and greenstones at some localities. It has been found that the agents of denudation like surface water; rain and change of temperature have played a dominant role on the rock types in moulding the landscape of the area. Far more important in this respect are weathering and erosion processes, which under the subtropical mountainous monsoon climate exert a significant influence on the landscape.

In weathering activity, the physical, chemical and biological agents actively co-operate with one another. Shattering requires stresses powerful enough to overcome the strength of the materials, but the strength is gradually reduced by the progressive action of decomposition. Shattering in turn provides increased opportunities for further penetration of chemical agents. Everywhere full advantage is taken of joints and of bedding and foliation planes, which together with the cracks newly formed, admit air, water and rootlets down to considerable depths. Thus, although the processes of weathering may be considered separately, it must not be forgotten that the actual work done is the resultant effect of several processes acting together in intimate cooperation.

The materials ultimately produced are broken fragments of mineral and rocks; residual decomposition products, such as clay and soluble decomposition products, which are removed in solution. The products of weathering differ widely in different places according to the climatic conditions and the relief and configuration of the surface.

Weathering has been found to be active in the study area. It is noticed that rocks of the Shillong groups have varied resistance to weathering and erosion, thus forming a ridge and valley sequence at places. On the other hand, granites appear to have more resistance to weathering but are susceptible to the action of temperature and water.

Deep weathering also has been taking place in the study area. This is inferred from the observations made at various pockets of Shillong where foundations of building as deep as 2 metres to 6 metres are more of sand.

### **Mass Wasting**

Mass wasting is also an important process of weathering seen in the study area. Once a particle is loosened by weathering, it ceases to be bedrock and becomes regolith. Because it is loose, it becomes loose materials that move down slope under the influence of gravity. In mass wasting, water plays an important role. This is the main reason why some

mass wasting activities are commonly seen in the slopes of the study area after long rains.

In 1997, due to incessant rainfall, a cliff-like topographic feature collapsed and slide downslope carrying with it large tracts of soil and trees and erode everything that lies on its path. This took place in the area about 1 km south-west of the North-Eastern Hill University Campus, Nongthymmai.

### **Vegetation**

Vegetation, consisting of trees, shrubs, vines, herbs and grasses, as stationary objects possessing distinctive physical properties are an element of the landscape just as soils, landforms and water bodies. The physical form of individual plants and of their assemblage varies in some systematic way with altitude, slopes, soils and climate.

In this chapter we are concerned with natural vegetation, i.e. vegetation that develops without the interference and modification by man, more so with the vegetation of Shillong.

From the study of remnants of protected plant life such as those still seen today at the Shillong Botanical gardens, the Ward's Lake, and the Government protected forests on the northern slopes of Shillong Peak-Kynton Sngi Range, known as Laitkor Protected Forests, Riat

Laban Protected Forests, the Upper Shillong Protected Forests and the Riat Khwan Protected Forests, the type of vegetation that was prevalent in Shillong during its early evolutionary can be ascertained.

Vegetation cover in the landscape reduces the rate of soil erosion; it traps the moisture-laden winds and provides habitats for quite a number of living organisms. As such, Shillong is endowed with varied and rich natural vegetation. The richness and variety of vegetation ranging from sub-tropical to tropical is due to diverse topography and variations in rainfall, soils and temperature.

However, vegetation cover in Shillong has changed over time. In 1863, almost the whole of Shillong except in the Pynthorumkhrah area, the vegetation cover was about 85 percent. By 1925, according to the topo map of Shillong on R.F.I. 10560 the vegetation cover of Shillong comes down to 82 percent In 1933, the vegetation cover, according to a revised edition of the same map, was more or less stable at 80 percent Then in 1996, the vegetation cover comes down to 28 percent

According to the above-mentioned maps pine forests are seen at an elevations of 1000 metres and above. At 1500 metres and above, dense mixed forests occurred. Therefore, the vegetation of Shillong can be classified as sub-tropical pine forests and the evergreen forests.

The main trees seen in Shillong are pines (*Pinus kesiya*). On the northern slopes of Shillong Peak-Kynton Sngi Range, we see plants such as oaks, rhododendrons, *cinnamomum* spp., *Schima khasiana*, *Myrica esculenta*, *Bucleandia populnea*, *Betula alnoides*, *Schima wallichii*, *Castanopsis indica*, etc. But today (2003) vegetation cover in and around Shillong is reduced to about 22 percent only and this attributed to deforestation and urbanization.

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### Chapter III

## MORPHOLOGY OF SHILLONG URBAN ENVIRONMENT

Measurement of the shape or geometry of any natural form – be it plant, animal or relief features – is termed morphometry (Strahler, 1969). But in geomorphology, “morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth’s surface and of the shape and dimensions of its landforms (Clarke, 1970). In fact morphometry, incorporates quantitative study of the area, altitude, volume, slope profiles of the land and drainage basin characteristics of the area concerned (Singh, 1978).

Morphometry has two aspects. These are (i) relief morphometry and (ii) fluvial morphometry. Relief morphometry deals with the study and analysis of the relief of any area under study and includes area-height curves, altimetric frequency histogram, hypsometric curve and profiles; whereas fluvial morphometry deals with the study and analysis of a drainage basin and includes three broad aspects. These are the (i) Linear aspect; (ii) areal aspect and (iii) relief aspect. Linear aspect deals with the hierarchical order of streams, numbers and lengths of stream segments, their relationships and morphometric laws. The areal aspect deals with the analysis of basin perimeters, basin area, stream frequency, drainage

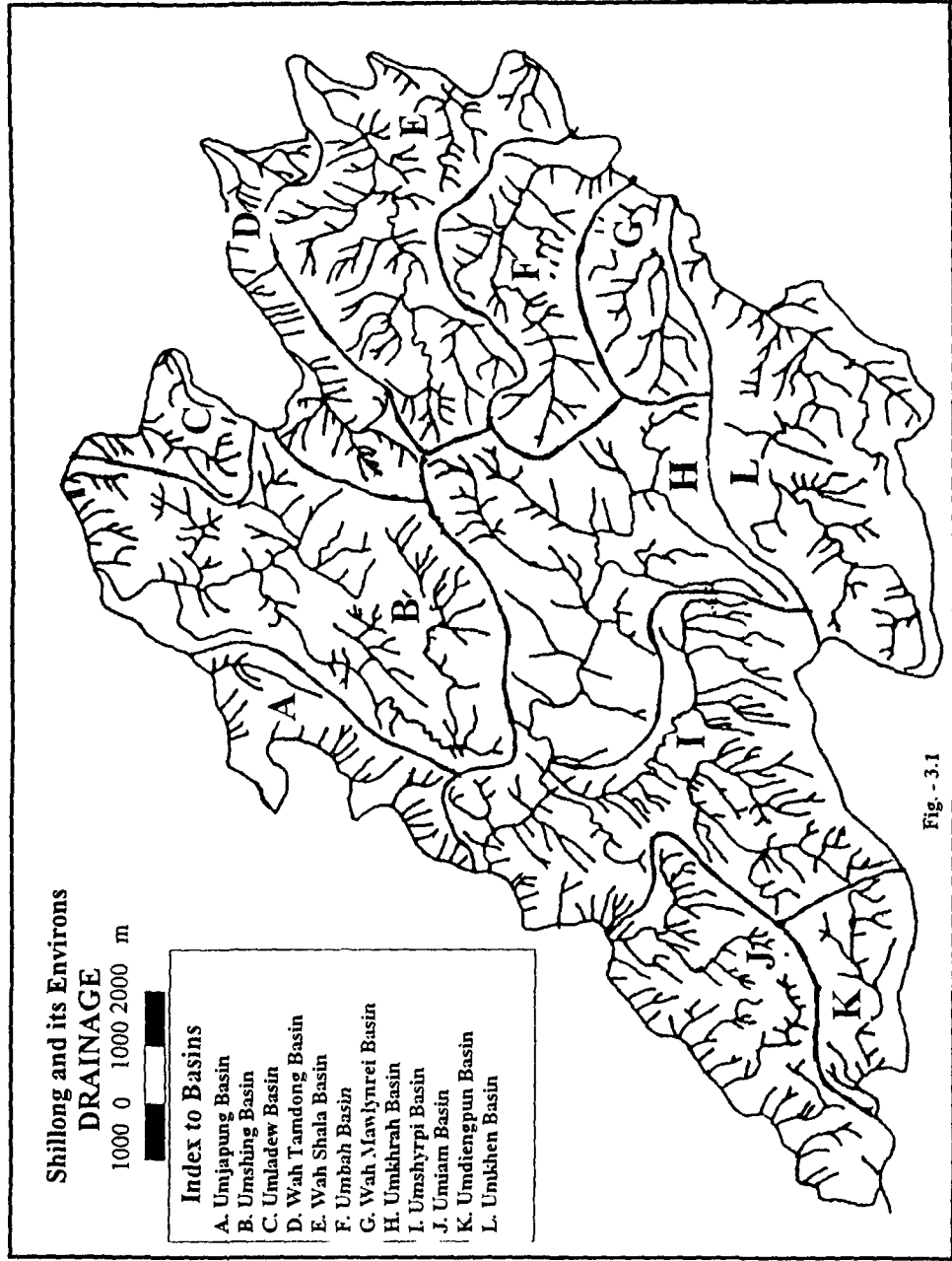


Fig - 3.1

density and drainage texture. The relief aspect studies and analyse absolute relief, relative relief, relief ratios, average slope etc.

### **Drainage Divides**

The drainage divides or watershed (Fig.3.1) have been delineated from toposheet no 78 $\frac{O}{14}$ , twelve sub-basins emerged from this exercise, these are the Umjapung basin, Umshing basin, Umladew basin, Wah Tamdong basin, Wah Shella basin, Wah Umbah basin, Wah Umkhrah basin, Umshyrpi basin, Umdiengpun basin, Umbah basin, Umkhen basin and Wah Mawlynrei basin.

A study of the drainage basins of the study area reveals that the drainage systems and patterns are to a great extent controlled by the structural platforms running in a north-west direction as in the case of Umshyrpi, Umdiengpun and Umkhrah basins and in a north east direction for other basins. This clearly shows that the whole study area has been subjected to tectonic activity, faulting and upliftment.

### **River Basins**

The drainage divides of the study area have outlined many river basins which are twelve in number.

1) The Umjapung Basin: This basin is characterised by the existence of very steep slopes. The master stream in this basin is the

Umñam into which all the first and second order streams flow. The basement rocks as seen are mainly quartzites which are overlaid by thick layer of debris rock materials. This basin is significant only due to the existence of Riakhwan Reserved Forests. There is no human activity whatsoever in the basin area, this is explained by the precipitous nature of topography. There are 33 first order, 5 second order streams in this basin and covers an area of 7.442 square kilometres only (Table 3.1).

**Table 3.1**  
**Linear Aspects of Umjapung Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	33	6.6	15.5	0.47	-
2	5		2.4	0.48	0.01
Total	38		17.9		

2) The Umshing Basin: The Umshing stream, a master stream of the basin, rises from the western flank of Mawpat ridge. For about 5 kilometres it flows in a zigzag manner directly west then it turns north to the north-east along a precipitous valley. The Umshing basin has a trellised pattern of drainage and it flows on the landscape which is alternately composed of sandstones and quartzites. This stream is joined by the other smaller streams, the Umjaraiñ, Umsaw, Umlummawblei.

Human activities such as settlements are seen at Umsaw, Lumdawblei, Mawiong, Mawtawar, Mawkynroh and parts of Mawlai. The Guwahati-Shillong road runs along the Umshing valley or Phud Mawiong. The rocks seen in this basin are the Khasi green stones which are overlaid by a thick layer of red soils. Quartzites are also seen in the basin area along with sandstones. There are 63 first order, 22 second order, 6 third order and 2 fourth order and 1 fifth order stream in an area of 25.494 square kilometers (Table 3.2).

**Table 3.2**  
**Linear Aspects of Umshing Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	63	2.86 3.66 3.00 2.00	46.48	0.74	-
2	22		12.52	0.57	0.77
3	6		10.98	1.83	3.21
4	2		3.57	1.79	0.98
5	1		1.48	2.15	1.20
Total	94		75.03		

3) The Umladew Basin: The Umladew stream rises north of Umsaw village. Right from its source upto two kilometres this stream has perpendicular cliffs. The whole basin is rugged and comprised of steep slopes. There are 22 first order streams, 6 second order streams and covers an area of 3.941 square kilometres only. On account of rugged

nature of topography, no settlements are seen in this basin. The whole area, however, have been used for agriculture (Table 3.3).

**Table 3.3**  
**Linear Aspects of Umladew Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	22	3.66	12.35	0.56	-
2	6		3.25	0.54	0.96
Total	28		15.60		

4) The Wah Tamdong Basin: Wah Tamdong rises north of Mawpat ridge, 1687 metres, and flows in a north easterly direction. Its right bank is highly precipitous and at the top the precipices culminate into perpendicular cliffs which run to about more than four kilometres. This stream is watered mostly by first order streams. There is altogether 47 first order, 10 second order and 3 third order streams in an area of 8.564 square kilometres. On account of precipitous topography, human settlements exist in the form of isolated hamlets and homesteads (Table 3.4).

**Table 3.4**  
**Linear Aspects of Wah Tamdong Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	47	4.70	18.98	0.40	-
2	10	3.30	5.24	0.52	1.30
3	3		3.25	1.08	2.07
Total	60		27.47		

5) The Wah Shala Basin: The Shala stream originated from Lyngkien and Diengiong villages. In its upstream course, it is known as Phud Lyngkien meaning, "Flood waters". The topography of this basin is characterised by a gentle to moderate slopes. However, its course for about three kilometres is highly crooked in a meandering form. The topography is composed of sandstones overlying the crystalline quartzites. This basin has 89 first order, 22 second order, 5 third order and 2 fourth order stream in an area of 21.025 square kilometres only (Table 3.5).

**Table 3.5**  
**Linear Aspects of Wah Shala Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	89	4.50	40.25	0.45	-
2	22		15.25	0.69	1.53
3	5	4.40	4.20	0.84	1.21
4	2	2.50	5.60	2.80	3.33
<b>Total</b>	<b>118</b>		<b>65.30</b>		

6) The Umbah Basin: The Umbah stream rises from the Itshyrwat Reserved Forests. Its right bank is characterised by the existence of perpendicular cliffs for about 5 kilometres, whereas the topography on its left bank is moderate to undulating. The Umbah stream drains Mawdiangdiang on its left and Mawlynrei on its right. There are 44 first

order, 10 second order, 3 third order in an area of 11.742 square kilometers (Table 3.6).

**Table 3.6**  
**Linear Aspects of Umbah Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	44	4.40	19.62	0.44	-
2	10		5.38	0.54	1.22
3	3	3.30	6.04	2.01	3.72
Total	57		31.04		

7) The Wah Mawlynrei Basin: This small stream drains the area between Mawlynrei and Happy Valley. Throughout its course, till it meets the Umkhen river, this stream flows on steep riparian sides comprised mostly of cliffs which is a clear indication that the geology and tectonics of this basin is that composed of quartzites and subjected to upliftment. From the summit of the perpendicular cliffs the topography ascends and tapers gradually to form a highly undulating landscape with a highest point of 1622 metres. There are 18 first order stream, 4 second order streams, 1 third order streams in an area of 6.543 square kilometres only (Table 3.7).

**Table 3.7**  
**Linear Aspects of Wah Mawlynrei Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	18	4.50	9.96	0.55	-
2	4		3.96	0.99	1.80
3	1	4.00	2.75	2.75	2.77
Total	23		16.67		

8) The Umkhras Basin: This stream has its source at Laitkor, 1840 metres. From its sources till Nongthymmai for 2 kms it flows on a steep gradient. From this point for over 10 kms its gradient falls gradually from 1500 metres to 1400 metres till the Sunapani falls at the rate of 1 metre per kilometre. This river in its higher courses is known as Demthring and is joined by smaller streams notable are Umjynriew, Wahkdait and Umlangkyrding. From Umpling it flows along L-shaped minor faults composed of quartzites, till it cascades down to form the Sunapani waterfalls. The topography on which this stream flows ranges from steep to undulating and flat lands.

The Umkhras basin is the most significant of all the basins of the study area as it is related to the origin and evolution of Shillong and can be considered as the central part of Shillong. This basin has 65 first order, 15 second order, 4 third order, 2 fourth order and 1 fifth order streams in an area of 25.494 square kilometer (Table 3.8).

Table 3.8

## Linear Aspects of Wah Umkhrab Basin

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	65	4.33 3.75 2.00 2.00	37.17	0.57	-
2	15		11.94	0.79	1.38
3	4		6.38	1.59	2.01
4	2		5.24	2.62	1.64
5	1		1.97	2.67	1.02
Total	87		62.70		

9) The Umshyrpi Basin: This basin is drained by the Umshyrpi and rises just below the Shillong Peak, 1964 metres. It consists of 96 first order, 22 second order, 7 third order, 2 fourth order and 1 fifth order streams in an area of 22.963 square kilometres.

The first order streams of this basin are designated as parallel type of drainage pattern. From its source upto two kilometres downstream and height of 1600 metres it flows on steep slopes, from this elevation it flows on, a more or less, gentle gradient till it culminates in the formation of two waterfalls, the Gunner's falls and Bishop's falls. The parallel pattern of its first order stream is due to the isoclinal folds of rocks which are alternately composed of sandstone and quartzites. Other rocks seen in this basin are the conglomerates found at an altitude of 1600 metres. The basin is further characterised by the existence of four notable cliffs

known as Riat Kut, Riat Malki, Riat Laban and Riat Tynrah. About 40 percent of the basin is occupied by cultural features, the rest 60 percent is under the Upper Shillong, Riat Laban and Laitkor Protected forests (Table 3.9).

**Table 3.9**  
**Linear Aspects of Umshyrpi Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	96	4.36 3.14 3.50 2.00	50.62	0.53	-
2	22		17.02	0.77	1.45
3	7		7.98	1.14	1.48
4	2		5.98	2.99	2.62
5	1		1.37		
Total	128		82.97		

10) The Umiam Basin: This basin is characterised and occupied by first order and second order streams only and joins the Umiam river directly. The whole basin is highly dissected and is comprised of isoclinal folds. In the Nongpiur settlement at a height of 1700 metres there are large exposures of conglomerates on the surface which indicate that the basin had been uplifted. This is inferred from the precipitous bank of the Umiam into which all streams empty their waters. The basin has 73 first order streams, 17 second order, 3 third order streams in an area of 14.302 square kilometres only (Table 3.10).

**Table 3.10****Linear Aspects of Umiam Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	73	4.29	29.24	0.40	-
2	17	5.66	14.07	0.82	2.05
3	3		2.08	0.69	0.84
Total	93		45.39		

11) The Umdiengpun Basin: In terms of stream number, this basin is the smallest in the study area. It comes to only 6.381 square kilometres with 19 first order, 4 second order and 1 third order streams. It is the most frequented basin on account of scenic beauty of Shillong Peak and the Elephant's falls tourist spots. The basin in its highest part is composed of sandstones as overlies on the quartzites. The complexity of the geology of this basin appears just below the Elephant falls where the quartzites seem to rest over the conglomerates (Table 3.11).

**Table 3.11****Linear Aspects of Umdiengpun Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	19	4.75	8.88	0.47	-
2	4	4.00	3.02	0.75	1.59
3	1		2.38	2.38	3.73
Total	24		14.28		

12) The Umkhen Basin: The Umkhen rises south of Laitkor from a height of 1848 metres. It flows on somewhat gentle gradient right from its sources. The river bed on which it flows is composed of quartzites, and Khasi greenstones. The topography of the basin in the Laitkor area is highly undulating. Due to lithological control, this river has two meanders. The banks of this river starting from a height of 1700 metres downstream are very steep. Between Madanrting, Umphyrnai, Mawshbuit and Mawlynggad of the basin exhibit a highly dissected topography with steep slopes. The break in the course of Umkhen river is the knick point where there are two waterfalls known as Sweet falls and Kshaid U Ram.

**Table 3.12**

**Linear Aspects of Umkhen Basin**

Stream Order	Stream No.	Bifurcation Ratio	Stream Length (in kms.)	Average Stream Length	Length Ratio
1	61	4.06 3.00 2.25	31.98	0.52	-
2	15		10.67	0.71	1.36
3	5		7.31	1.46	2.05
4	2		1.12	0.56	0.38
Total	83		51.09		

i

The areal aspects and relief aspects of the sub-basins have been separately tabulated in Tables 3.13 and 3.14.

Table 3.13

## Areal Aspects of Basins

Basins	Circularity Ratio	Area (in sq kms.)	Basin Length (in kms.)	Elongation Ratio	Drainage Density	Form Factor	Stream Frequency	Basin Perimeter (km.)	Basin Axis (km.)
Umjapung	0.2935	7.442	2.02	0.11	2.40	1.82	5.10	17.85	6.50
Umshing	0.5134	25.494	14.32	0.57	2.96	0.12	3.69	24.98	9.35
Umladew	0.4962	3.941	2.49	0.25	3.95	0.63	7.10	9.99	6.10
Wah Tamdong	0.2332	8.564	3.48	0.16	3.20	0.70	7.00	21.48	7.35
Wah Shala	0.3914	21.025	8.73	0.34	3.10	0.27	5.61	25.98	7.60
Wah Umbah	0.5052	11.742	8.01	0.46	2.64	0.18	6.55	17.09	5.85
Wah Mawlyncei	0.7249	6.543	4.01	0.38	2.54	0.40	3.51	10.65	3.75
Wah Umkbrah	0.1258	25.494	13.48	0.45	2.48	0.14	3.41	29.56	9.35
Umshyrpi	0.4271	22.963	8.01	0.31	3.55	0.36	5.53	25.99	7.35
Umiam	0.5085	14.302	4.01	0.21	3.17	0.89	6.50	18.80	7.60
Umdiengpum	0.4102	6.381	5.25	0.38	2.23	0.23	3.76	13.98	4.10
Umkhen	0.4542	20.185	10.00	0.42	2.53	0.20	4.11	23.63	9.55

1. The areal aspects considered in the above table are:

- Basin area which has been calculated by curvimeter.
- Basin length has been calculated by rotometer.
- Elongation ratio has been derived by the formula

$$\text{Elongation Ratio} = \frac{\text{Max length of main stream}}{\text{perimeter area}}$$

(d) Drainage density has been calculated by the formula:

$$DR = \frac{\text{Total length of stream}}{\text{area}}$$

(e) Form factor has been calculated by Horton's formula:

$$F' = \frac{A}{L^2} \text{ where } F' = \text{Form factor, } A = \text{basin, } L = \text{Basin length.}$$

(f) Stream frequency has been calculated by the formula:

$N.S. = \frac{\sum N_u}{A}$  where  $N.S.$  = Stream frequency;  $\sum N_u$  = Total number of streams;  $A$  = Basin area.

(g) Perimeter area has been derived by using a rotometer.

(h) Basin axis or length axis is derived by measuring from one extreme to the other on the longest axis of the basin.

2. The Relief aspects considered are as follows:

(a) Absolute relief has been derived by noting the highest points such as form lines, spot height, bench-marks and triangulation stations.

(b) Relative relief has been calculated by finding the difference of heights at source and at the lowest point of a stream.

(c) Relief ratio has been derived by the formula:

$$Rr = \frac{\text{Maximum elevation} - \text{Minimum elevation}}{\text{Longest axis of the Basin}}$$

(d) Ruggedness number has been derived by using the formula:

$$R.I. = \frac{\text{Drainage density} \times \text{relative relief}}{1000}$$

(e) Gradient ratio has been calculated by the formula:

$$G.R. = \frac{\text{Height at source} - \text{Height at lowest point}}{\text{Basin length}}$$

The above relief aspects have been tabulated in Table 3.14.

**Table 3.14**  
**Relief Aspects of Basins**

Sl No	Basins	Absolute Relief (m)	Relative Relief (m)	Relief Ratio	Ruggedness Number	Gradient Ratio
1	Umjapung	1400	420	0.067	0.0100	0.168
2.	Umshing	1560	660	0.070	0.0171	0.040
3	Umladew	1360	380	0.062	0.0150	0.152
4	Wah Tamdong	1687	747	0.101	0.0239	0.174
5	Wah Shala	1600	440	0.057	0.0142	0.050
6	Wah Umbah	1600	400	0.068	0.0105	0.049
7	Wah Mawlynrei	1660	460	0.122	0.0116	0.104
8	Wah Umkhrah	1880	880	0.094	0.0198	0.060
9	Umshyrpi	1921	861	0.117	0.0305	0.104
10	Umiam	1780	700	0.092	0.0221	0.174
11	Umdiengpun	1920	460	0.112	0.0102	0.087
12	Umkhen	1860	620	0.060	0.0156	0.061

### Analysis of Sub-Basins

The whole study area has been divided into 12 sub-basins. Analysis of the linear, areal and relief aspects of these sub-basins have been divided in two parts (a) statistical, and (b) interpretation of tabulated data.

In the statistical part morphometric variables like stream number, stream length and stream orders only are considered and the statistical computation results are presented in Tables 3.15, 3.16, 3.17, 3.18, 3.19, 3.20, 3.21, 3.22, 3.23, 3.24, 3.25. 3.26.

**Table 3.15**  
**Linear Regression of Umjapung Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	r <sup>2</sup>
Stream length vs. Stream order	$y=2.22 - 0.08x$	-1	1
Stream number vs. Stream order	$y=0.74 - 0.04x$	-0.1	-0.01

**Table 3.16****Linear Regression of Umshing Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	r <sup>2</sup>
Stream length vs. Stream order	$y-3.52 - 0.04x$	-1.14	0.3
Stream number vs. Stream order	$y-3.94 - 0.05x$	-3.08	0.8

**Table 3.17****Linear Regression of Umladew Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	r <sup>2</sup>
Stream length vs. Stream order	$y-2.36 - 0.11x$	-1	1
Stream number vs. Stream order	$y-2.34 - 0.06x$	-1	1

**Table 3.18****Linear Regression of Wah Tamdong Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	r <sup>2</sup>
Stream length vs. Stream order	$y-3.00 - 0.11x$	-2.4	0.8
Stream number vs. Stream order	$y-2.10 - 0.005x$	-0.13	0.02

**Table 3.19****Linear Regression of Wah Shala Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	r <sup>2</sup>
Stream length vs. Stream order	$y-3.64 - 0.07x$	-0.86	0.8
Stream number vs. Stream order	$y-3.39 - 0.03x$	-0.86	0.8

Table 3.20

## Linear Regression of Wah Umbah Basin

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-3.14 - 0.11x$	-1.6	0.7
Stream number vs. Stream order	$y-0.48 + 0.08x$	-1.56	1.7

Table 3.21

## Linear Regression of Wah Mawlynrei Basin

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-2.77 - 0.10x$	-2.97	0.9
Stream number vs. Stream order	$y-3.33 - 0.24x$	-0.94	0.9

Table 3.22

## Linear Regression of Wah Umkhras Basin

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-4.25 - 0.10x$	-2.9	0.7
Stream number vs. Stream order	$y-3.87 - 0.05x$	-2.5	0.7

Table 3.23

## Linear Regression of Umshyrpi Basin

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-3.77 - 0.03x$	-10.9	0.76
Stream number vs. Stream order	$y-4.16 - 0.07x$	-2.5	0.7

Table 3.24

**Linear Regression of Umiam Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-3.10 - 0.07x$	-1	1
Stream number vs. Stream order	$y-2.93 - 0.03x$	-0.9	0.9

Table 3.25

**Linear Regression of Umdiengpun Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-4.19 - 0.25x$	-2.2	0.8
Stream number vs. Stream order	$y-2.80 - 0.10x$	-0.8	0.9

Table 3.26

**Linear Regression of Umkhen Basin**

Relation between Parameters	Regression Equation / Linear Regression	Level of Significance 't'-test	$r^2$
Stream length vs. Stream order	$y-3.78 - 0.10x$	-3.25	0.8
Stream number vs. Stream order	$y-3.12 - 0.03x$	-1.51	0.5

**A. Analysis of the Areal Aspects of the Sub-Basins**

Analysis of the areal aspects considered are area, basin length, form factor, elongation ratio, drainage density and stream frequency.

i. Basin area: Analysis of basin size reveals that Umjapung, Umladew, Wah Tamdong, Wah Mawlynrei and Umdiengpun are small size basins which indicate that these basins receive less rainfall, thus less flooding; whereas other sub-basins which are big size receive more rainfall and thus are prone to flooding.

ii. Basin Length: Basin lengths have been given different meanings by different workers such as Gregory and Walling (1973), Gardiner (1975) and Cannon (1976). As seen in Table 3.1 Umjapung has a basin length of 2 kilometres only whereas Umshing has the maximum basin length of 14.32 kilometres followed by Wah Umkhrah with 13.48 kilometres.

Basin length indicates only the longest length of the basins, one end being the mouth.

iii. Elongation Ratio: Analysis of the elongation ratio reveals that the basins have flatter peak flows and the resultant flood flows are easier to manage. From the tabulated data obtained it is evident that the sub-basins are moderately elongated in shape. The highest value recorded is that of Wah Umbah with a value of 0.46.

iv. Form Factor: The form factor values indicate that all basins, except Umjapung, are elongated in shape and hence flood flows are easier to manage.

v. Drainage Density: Analysis of the drainage density of the sub-basins reveals that the size of the mean annual flooding to be more in Umladew, Wah Tamdong, Wah Shala, Umshyrpi and Umñiam basins and thus have a greater possibility of flash flood occurrences.

vi. Stream Frequency: The stream frequency values of the sub-basins calculated show that the drainage networks are characteristic of drainages found in hilly region where first and second order streams are well developed and are larger in number.

vii. Circularity Ratio: This is a dimension of the basin shape. A value of 0.0 indicates a circular shape, 0.5 indicates a semicircular shape and 1.0 elongated. Its low, medium and high values are indicative of youth, mature and old stages of the cycle of the tributary basins of the study area.

The high value circularity ratio of Wah Mawlynrei indicates the late maturity stage of topography and the other sub-basins reveal nearly mature stage of topography. This anomaly is due to diversity of slope, relief and structural conditions prevailing in the basin.

#### **B. Analysis of the Linear Aspects of the Sub-Basins**

Analyses of the linear aspects of the sub-basins considered are stream order, stream number, bifurcation ratio, stream length, and length ratio. Each of these aspects have been analysed as follows:

i. Stream Order: the method of stream ordering used is that developed by Horton (1945). The area under investigation comprises of 630 first order, 152 second order, 38 third order, 10 fourth order and 3 fifth order.

ii. Stream number: The area under investigation comprises of 833 streams from first order to fifth order. It is observed that the first and second order streams constitute almost 95 percent of the total number of streams.

iii. Bifurcation Ratio: Bifurcation ratio values between 3 to 5 are characteristics of watersheds which have suffered less structural disturbances and those whose drainage pattern have not been distorted because of structural disturbances (Nautiyal, 1994). The bifurcation ratio values obtained for the sub-basins reveals that the drainage have not been affected by structural disturbances and is in a well-developed stage.

iv. Stream-Length and Length Ratio: Stream-Length has an important relationship with the surface flow discharge, the longer the length the slower is the appearance of flood and larger the surface flow. Stream-Length ratio has an important relationship with the erosional stage of the basin. The values of length ratios vary from 0.01 to 3.73. A glance at these values reveals that the length ratios change haphazardly in the sub-basins. The following relationships are noted between stream-

lengths and stream orders (i) Total stream length of 1<sup>st</sup> order is inversely related to stream order, i.e., total stream length decreases from lower order to successive higher orders; (ii) there is positive relationship between mean stream-length and basin order, i.e., mean length increases with successive orders.

### **C. Analysis of the Relief Aspects of the Sub-Basin**

Relief is an important attribute of a terrain in general and the drainage basin in particular. According to Strahler (1968), these relief measures are indicative of the potential energy of the drainage system because of its elevation above the mean sea level. The relief aspects considered for the sub-basins include basin relative relief, relief ratio, ruggedness number and gradient ratio.

i. Relative Relief of Basin: The relative relief of the sub-basins computed exhibit differences of the elevations between the source and mouth of the drainage. Relative relief is an indication of the vertical distance varying with horizontal distance which gives a rough idea of the steepness of the terrain on which the stream flows.

ii. Relief Ratio: When basin relief is divided by the horizontal distance on which it is measured it results in a dimensionless relief ratio. Relief ratio measures the overall steepness of a drainage basin and is an

indicator of the intensity of erosion process (Schumm, 1954). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin have been suggested by Schumm who found that sediment loss per unit area is closely correlated with relief ratio. According to Schumm, generally the basins with low relief ratio values exhibit a characteristic feature of the less resistant rocks and the high relief ratio values indicate a characteristic feature of the least resistant rocks. The relief ratio values of the sub-basins exhibit a relief ratio between 0.060 to 0.122. Four sub-basins have a higher relief ratio. These are Wah Tamdong, 0.101, Wah Mawlynrei, 0.122, Umshyrpi, 0.117 and Umdiengpun 0.112 whereas the other eight sub-basins have much lower relief ratio values. Overall, the whole study area exhibit that the sub-basin is characterised by less resistant rocks.

iii. Ruggedness Number: To combine the qualities of slope steepness and length of stream, a dimension, ruggedness number is formed. Analysis of the ruggedness number data reveals that slope steepness is more in the upper reaches of Umshyrpi. This is accounted by the existence of isoclinal folds.

iv. Gradient Ratio: Gradient ratio is an indication of channel slope determined by differences in elevation of drainage at source to that of its mouth or confluences at lower elevations. The gradient ratio values

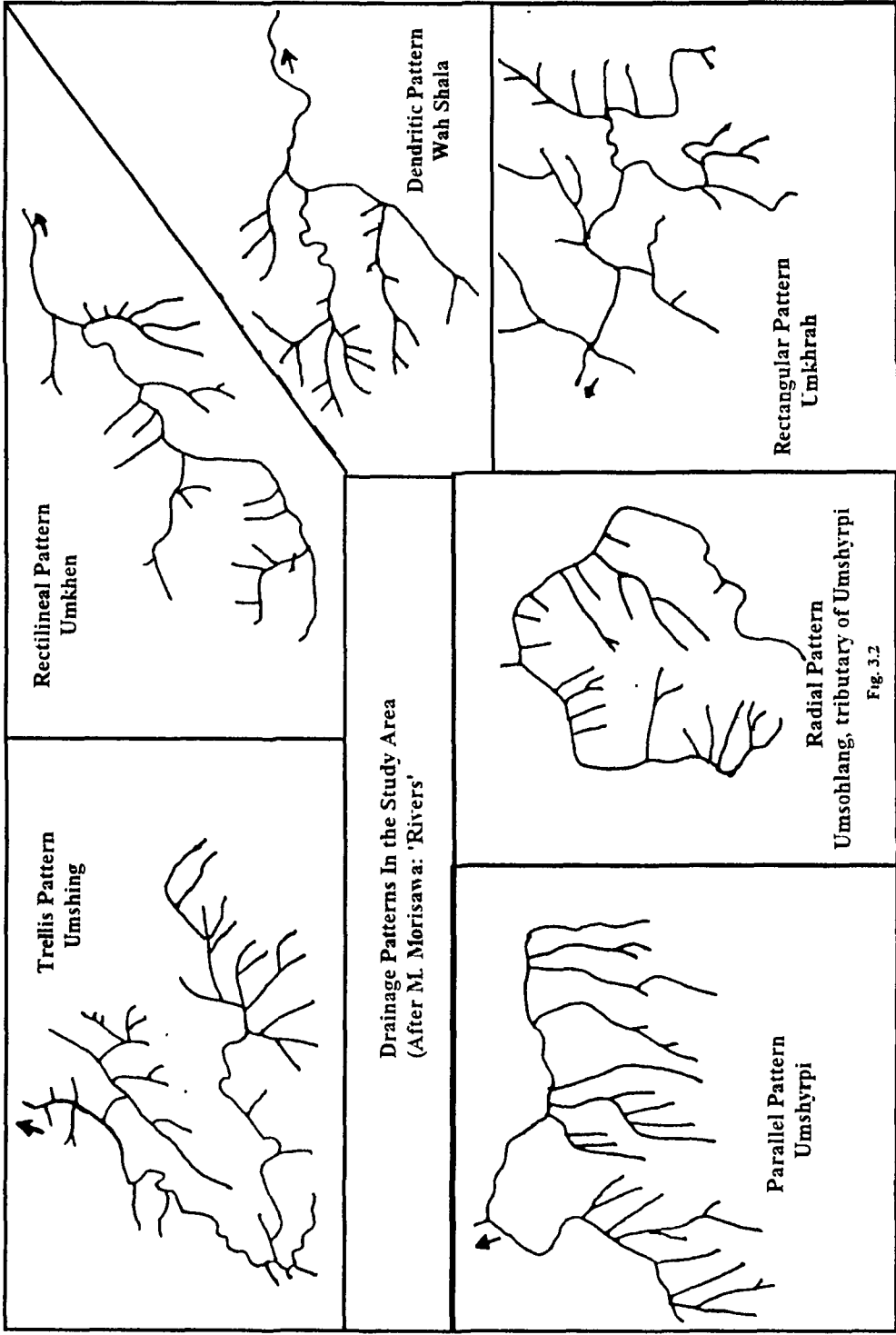


Fig. 3.2

calculated for the sub-basins show that the gradient ratio ranges between 0.040 to 0.174 which indicate that the channel slope of the basins has a more or less regular drop in elevation.

### **Drainage Pattern**

Delineation of the study area into sub-basins defines varying orders of stream system. An analysis of the composition of each type of basin brings out distinctly the pattern of drainage. Drainage pattern refers to the particular plan or design which the individual stream courses collectively form. The pattern of drainage is one of most revealing features of landscape and casts light on the rock type, geological structure and stage in drainage evolution. The drainage network of the study area reveals the following type of drainage pattern (Fig.3.2).

- (i) Trellis Pattern
- (ii) Annular Pattern
- (iii) Dendritic Pattern
- (iv) Rectilinear Pattern
- (v) Parallel Pattern
- (vi) Radial Pattern
- (vii) Rectangular Pattern.

The arrangement of the drainage lines or network pattern has been observed to have been so greatly influenced by geologic structure and lithology that the drainage pattern is often used to interpret structure and

general rock type (Table 3.27). As the stream cut into the underlying rocks, the resistance to erosion varies and gives rise to characteristic patterns. These types of drainage pattern seen in the study area can be correlated with the description and rock control as derived after Morisawa.

**Table 3.27**  
**Adaptation of Streams to Lithological Control**

SI No	Type	Description	Control	Observed in
			Tilted or Folded	
1	Trellis	A dominant drainage direction with a secondary direction perpendicular to it	Hard/soft sediments	Umshing Basin
2	Annular	Main rivers have circular pattern with subsidiary channels at right angles	Eroded done in alternate hard/soft rocks	Umladew Basin
3	Dendritic	Spreading tree like arrangement	Lack of structural control on rocks of uniform resistance	Wah Shala Basin
4	Rectilineal	Stream bends and junctions are approximately at right angles	Controlled by well developed joints or small faults	Umkhen Basin
5	Parallel	Main channels are regularly spaced and parallel to each other	Steeply sloping surface on isoclinal folds	Umshyrpi Basin
6	Radial	Stream flow outward from centre	Domes	Umshyrpi Basin
7	Rectangular	Drainage forms a perpendicular net with the two directions equally developed	Joints or faults	Umkhrah Basin

Source: Morisawa, M *Rivers*, Vol 7, Geomorphology Texts

## GEOMORPHOMETRY OF THE STUDY AREA

After analysing the areal, the linear and relief aspects of the sub-basins, the geomorphometric characteristics will now be considered for the whole study area in relation to stream orders, stream numbers, bifurcation ratio, drainage density, stream frequency, absolute relief,

relative relief, area height, hypsometric analysis, altimetric frequency, dissection index, profiles and average slope analysis.

## **LINEAR ASPECTS OF THE STUDY AREA**

### **Stream Orders**

Stream ordering is another aspect of linear fluvial morphology. According to Leopold (1953) stream order is the measurement of its position in a stream network system. To avoid multiple difficulties in stream ordering system, Horton's method is used to evaluate the structural control in drainage development. In this system each of the finger tip channel is designated as the segment of the first order, at the junction of any two first order segment the channel represent the second order which extends downstream upto the point where it again joins another second order channels, where upon a third order segment resulted and proceeds on higher order. Figure 3.1 gives the varying orders of stream in the study area.

### **Stream Number**

Horton (1945), a noted hydraulic engineer has formulated "a law of stream number" where he stated that "the numbers of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with a single segment of the highest order and increasing

according to a constant bifurcation ratio". The area under investigation has a total of 630 first order, 152 second order, 38 third order and 10 fourth order and 3 fifth order streams, totalling to 833 number of stream from first to fourth order. The number of stream of different orders are presented in Table 3.28.

**Table 3.28**  
**Showing Different Non-Linear Parameter of Streams**

Stream Order	Stream Number	Bifurcation Ratio
First	630	4.14 4.00 3.80 3.30
Second	152	
Third	38	
Fourth	10	
Fifth	3	

### **Bifurcation Ratio**

The term bifurcation ratio expresses the ratio of the number of streams of any given order with the number of streams of next higher or lower order. The relationship between the stream order and stream number follows a geometric progression.

In the present analysis the bifurcation ratios of all the stream orders range between 3.30 to 4.14 (Table 3.28). The  $R_b$  values indicate how many times the number of stream increase from any given order to the next higher order.

### Stream Length

The stream length of various order of the basin of the study area has been measured by rotometre and the average length of each order was computed and is presented in Table 3.29.

**Table 3.29**  
**Stream Length**

Stream Order	Stream Number	Stream Length (kms)	Average Length (kms)	Cumulative Length (percentage)
First	630	321.03	0.50	63.51
Second	152	104.70	0.68	20.72
Third	38	53.35	1.40	10.56
Fourth	10	21.51	2.15	4.26
Fifth	3	4.82	1.61	10.95

The average length increases orderwise in direct proportion. Strahler (1957) pointed out that the stream length of given order are inversely proportional to the stream order.

The average length has been derived by formula =  $\frac{\text{Stream length}}{\text{Stream number}}$

## AREAL ASPECTS OF THE STUDY AREA

### Drainage Density

In addition to the "Law of Stream Number", Horton (1945) suggested the concept of drainage density as a measure of dissection where he defined drainage density as the total length of the streams (L) in

**Shillong and its Environs  
DRAINAGE DENSITY**

Scale

1000 0 1000 2000 m

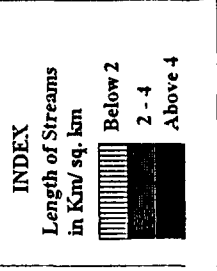
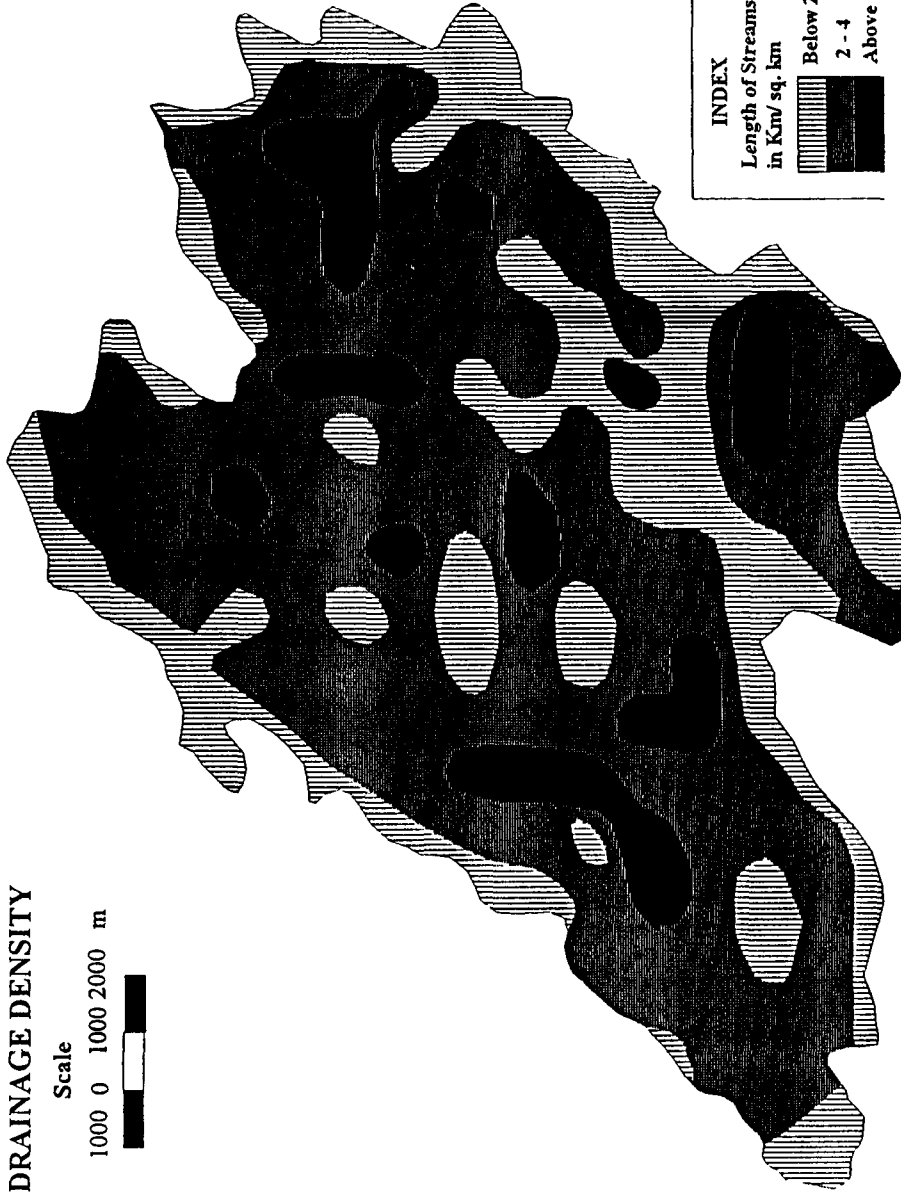


Fig. - 3.3

a given drainage basin divided by the area of the basin (A), the drainage density then is simply a length per unit and is expressed as

$$Dd = \frac{L_k}{A_k}$$

where  $L_k$  = total lengths of all stream segments of a basin

$A_k$  = total area of basin.

The simplest way to calculate drainage basin, which is adopted in this study, is to calculate drainage density on a regional scale and to divide the basin into grid squares of one square kilometre each and by measuring the total stream lengths in each grid square and grouping the derived data into drainage density categories, then an isopleth map (Fig. 3.3) of drainage density has been prepared as per the tabulated data (Table 3.30).

**Table 3.30**  
**Drainage Density**

Drainage Density (km/km <sup>2</sup> )	Grid Frequency	Percentage of Grid Frequency	Area (sq. kms.)	Area (percentage)	Cumulative Area (percentage)	Category
Below 2	86	40.95	40.005	22.991	22.991	Low
2 - 4	100	47.61	110.939	63.758	86.749	Moderate
4 above	24	11.42	23.056	13.250	100.00	High

An analysis of the drainage density map shows the spatial distribution of drainage density per km<sup>2</sup>. Three major categories of drainage density emerge from the map. The high drainage density is seen

**Shillong and its Environs  
STREAM FREQUENCY**

Scale  
1000 0 1000 2000 m







<u>INDEX</u>	
No. of Stream / sq. Km.	
	Below 4
	4 - 8
	8 - 12
	Above 12

Fig. - 3.4

in the Wah Tamdong, Wah Shala, Umkhen, Umkhrak, Umshyrpi and Umdiengpun basins where the surface is formed of softer and less resistant rocks like sandstones and in the case of Umdiengpun basin it is formed of conglomerates and shale. These basins show a density of 4 kms drainage length per square kilometre. The moderate to low drainage density categories is confined to the hard resistant group of rocks known as quartzites.

The above analysis of drainage density is in conformity with the drainage pattern table given earlier. Strahler (1961) was of the view that the hard and resistant group of rocks tends to give lower drainage density, while softer and less resistant rock give higher drainage density.

### **Stream Frequency**

Stream frequency shows the number of streams per unit area. For this study, in computing the stream frequency, the basin is divided into grids of one square kilometre each. The number of streams in each grid is counted, tabulated and quantified. The data derived is thus classified into four categories and shown in Figure 3.4 and Table 3.31.

**Table 3.31**  
**Stream Frequency**

No. of Stream Crossing	Frequency of Grids	Percentage of total frequency	Area (sq. kms.)	Area (%)	Cumulative Area (percentage)	Category
Below 4	70	33.33	35.376	20.331	20.331	Low
4 - 8	102	48.57	100.457	57.733	78.064	Moderate
8 - 12	36	17.14	36.564	21.013	99.077	High
12 above	2	0.95	1.603	0.921	100.00	Very High

In analysing the stream frequency map, it exhibits that the second stream frequency category is rated as moderate and the category occupies the biggest percentage of stream frequency of 57.7 percent of the total study area ranging between 4-8 streams per square kilometre.

The areas of very high of 12 and above stream per square kilometre are seen only in the Umshyrpi basin. The above measure of stream frequency shows that the drainage of the basin is generally coarse and is fairly drained.

## **RELIEF ASPECTS OF THE STUDY AREA**

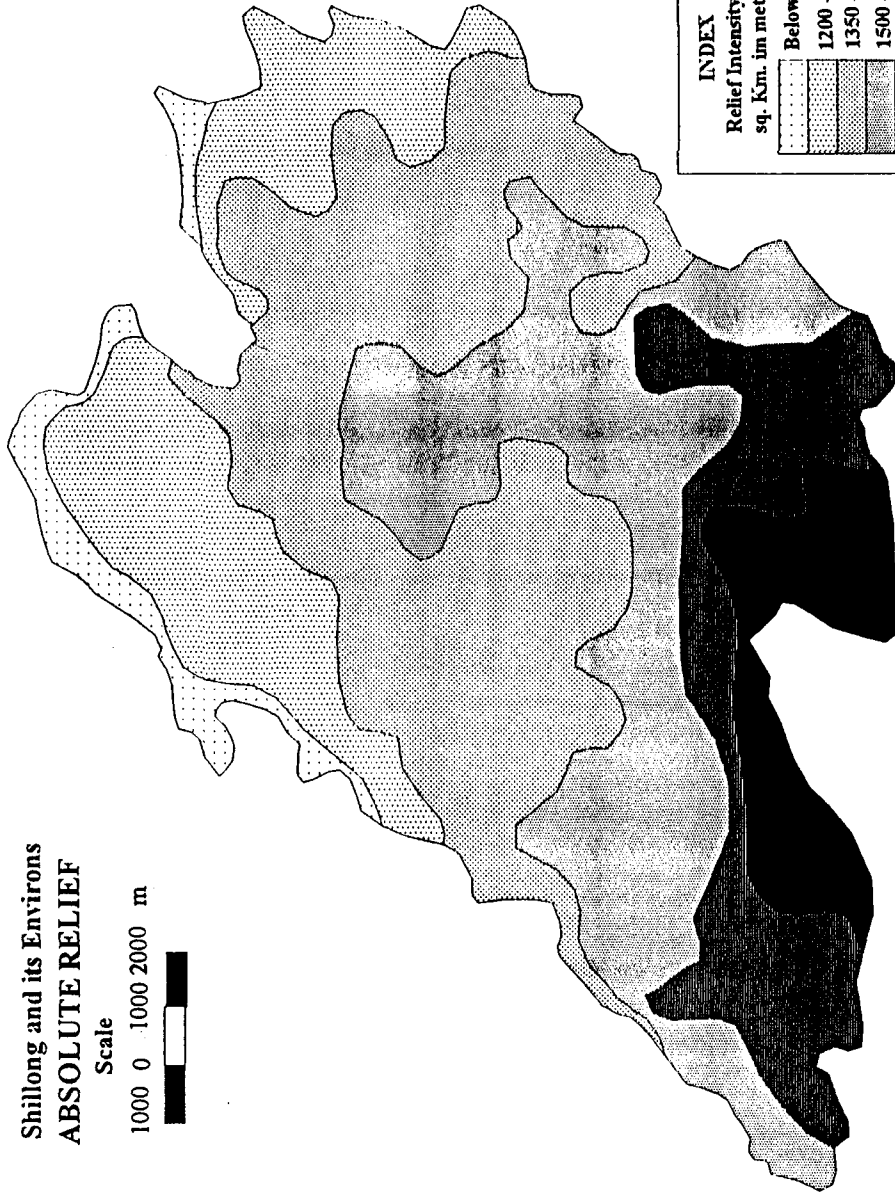
### **Relief Analysis**

Relief refers to the relative heights of points on surfaces and lines with respect to the horizontal base of reference. Relief properties can be thought of as relating to the third dimension, perpendicular to the horizontal base on which planimetric measurements are made. One group

Shillong and its Environs  
**ABSOLUTE RELIEF**

Scale

1000 0 1000 2000 m



INDEX	
Relief Intensity /	
sq. Km. in metres	
Below 1200	[Dotted pattern]
1200 - 1350	[Horizontal line pattern]
1350 - 1500	[Vertical line pattern]
1500 - 1650	[Diagonal line pattern]
1650 - 1800	[Dark grey shading]
Above 1800	[Black shading]

Fig. - 3.5

of form elements is a study of relief study itself defined as the difference in elevation of any given two points. Another group of form elements in this class consists of the gradients or slopes of ground surfaces and stream channels. Such measurements tell the rate of drop of the run off and are measures of the intensity of the processes of erosion and transportation.

The term relief, however, have been misused for the altitude or absolute elevation from the mean sea level. In this study an attempt has been made to analyse and evaluate the quantitative characteristics of relief features of the study area in terms of absolute relief, area height analysis, hypsometric analysis, altimetric frequency analysis, profile analysis.

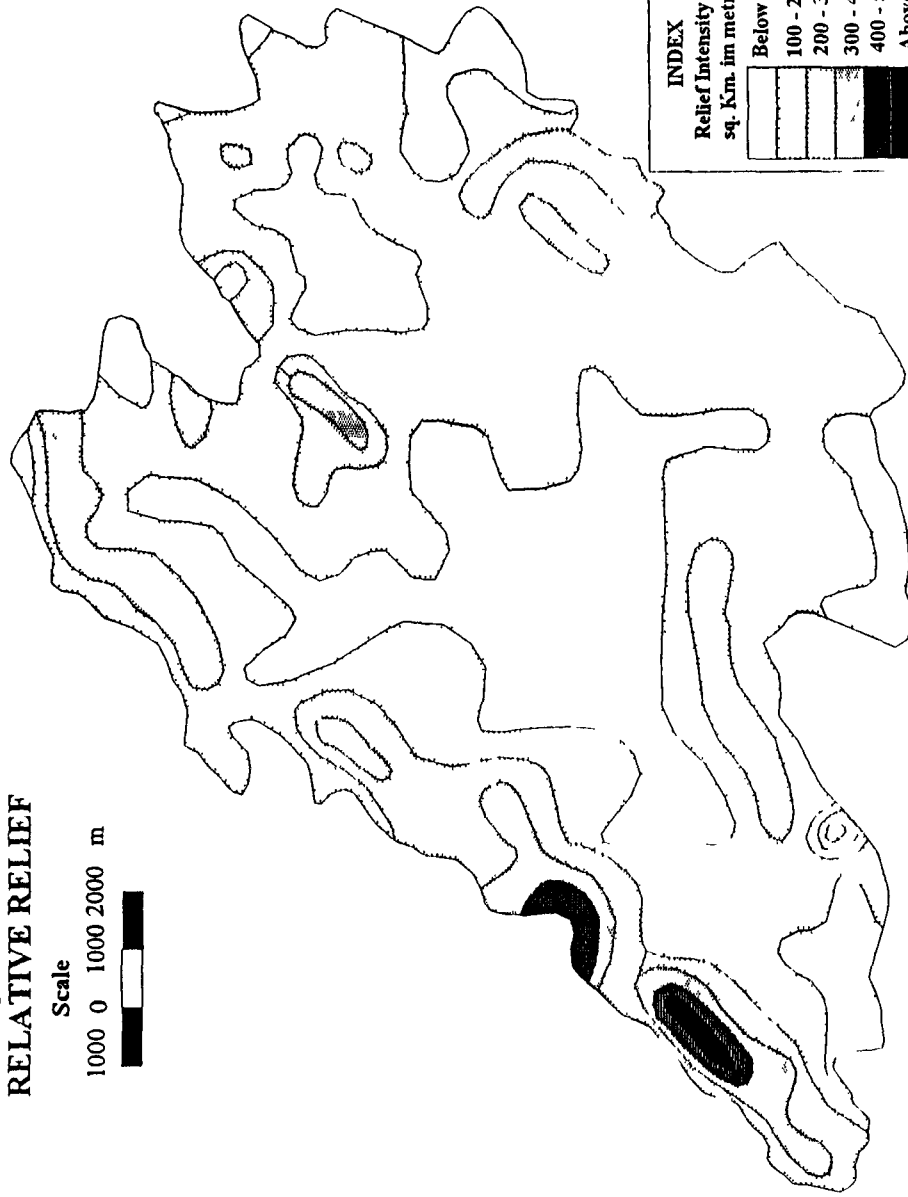
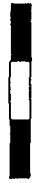
### **Absolute Relief**

Absolute relief provides clues to estimate the intensity of forces operating in an area. In this study, absolute relief has been derived by dividing the area into one square kilometre grids. The highest point on each grid has been plotted for the preparation of an absolute relief map. The absolute relief map (Fig.3.5) has been categorised into six different height categories at interval of 150 metres and is given in Table 3.32.

**Shillong and its Environs  
RELATIVE RELIEF**

Scale

1000 0 1000 2000 m



**INDEX**

Relief Intensity /  
sq. Km. in metres

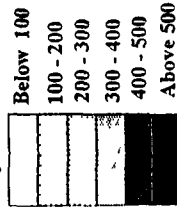


Fig - 36

**Table 3.32**  
**Absolute Relief Category**

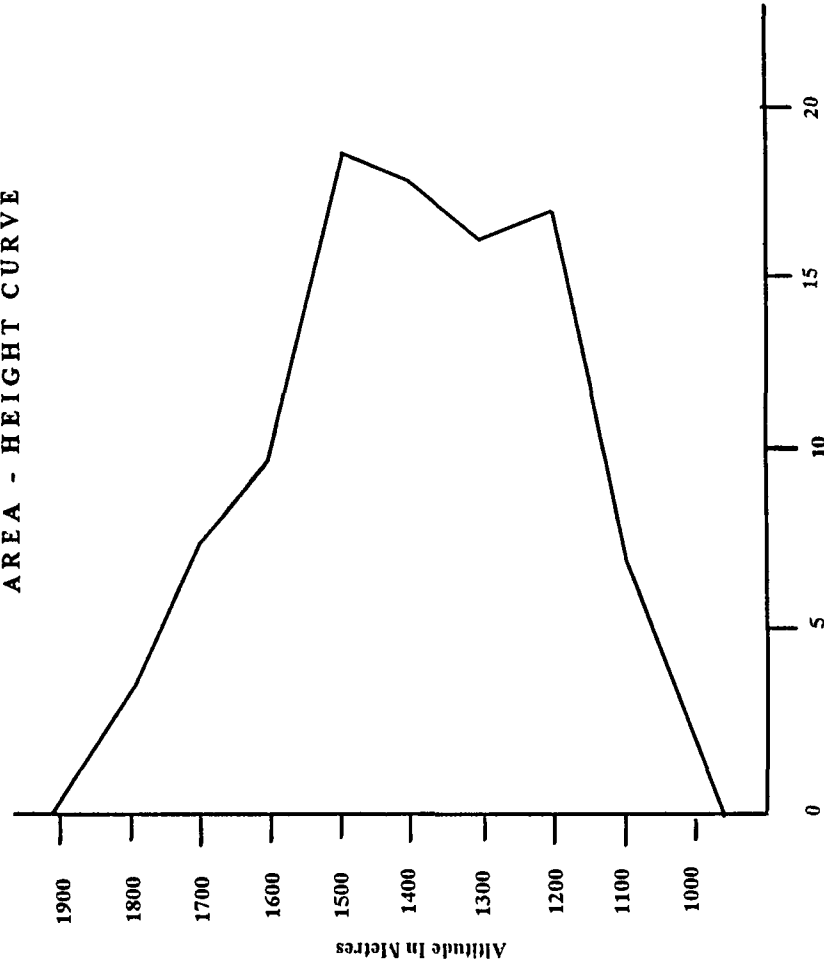
Absolute Relief (in metres)	Frequency of Grids	Percentage of total frequency	Area (in sq kms )	Area (in %)	Cumulative Area (in %)	Category
Below - 1200	16	7.61	7.85	4.51	4.51	High
1200 - 1350	36	17.14	30.06	17.27	21.78	
1350 - 1500	60	28.57	57.42	33.00	54.78	Moderate
1500 - 1650	49	23.33	42.90	24.65	79.43	
1650 - 1800	28	13.33	22.57	12.97	92.40	Low
1800 above	21	10.00	13.56	7.79	100.00	

### Relative Relief

Relative relief is also termed as local relief and is defined as the difference in height between the highest and the lowest points in a unit area. Relative relief is a very important morphometric variable which is used for the overall assessment of morphological characteristics of terrain and degree of dissection. Relative relief has been developed by Melton (1957) as a result of the inability of the absolute relief to express the total morphological character of landforms in terms of sharpness of relief.

The study area has been divided into 1 square kilometre grids and relative relief for each grid has been calculated on the basis of highest and lowest elevation and the data so derived are tabulated and classified as given in the Figure 3.6 and Table 3.33.

# AREA - HEIGHT CURVE



Area In Percentage

Fig. - 3.7

**Table 3.33**  
**Relative Relief**

Relative Relief (in metres)	Frequency of Grids	Percentage of total frequency	Area (in sq kms.)	Area (in %)	Cumulative Area (in percentage)	Category
Below 100	93	44.285	52.929	30.418	30.418	High
100 – 200	68	32.380	89.056	51.181	81.599	Very High
200 – 300	32	15.238	21.842	12.552	94.151	Moderately High
300 – 400	10	4.761	7.001	4.023	98.174	Moderate
400 – 500	6	2.857	2.446	1.405	99.579	
500 above	1	0.476	0.726	0.417	100.00	

### Area-Height Curve

Area-height curve represents the absolute or relative areas of land between two contours. This curve indicates actual areas between contours and hence horizontal axis represents area in terms of percentage and the vertical axis represents heights. Area-height curve gives only the relationship between altitudinal zones and corresponding areas. In this study the area between two contours have been calculated by curvimeter and the data so derived is presented in Figure 3.7 and Table 3.34.

**Table 3.34**  
**Area-Height**

Contour Class Interval (in metres)	Frequency of Grids	Percentage of total frequency	Area (sq. kms.)	Area (in %)	Cumulative Area (percentage)	Category
Above 1900	7	3.333	1.044	0.600	0.600	Low
1800 – 1900	14	6.666	6.547	3.762	4.762	
1700 – 1800	18	8.571	13.324	7.657	12.019	
1600 – 1700	21	10.000	16.833	9.674	21.693	Moderate
1500 – 1600	36	17.142	32.511	18.684	40.377	
1400 – 1500	41	19.523	31.261	17.966	58.343	
1300 – 1200	32	15.238	27.950	16.063	74.406	High
1200 – 1100	25	11.904	29.582	17.001	91.407	
1100 – 1000	11	5.238	11.846	6.808	98.215	
Below 1000	5	2.380	3.102	1.782	100.00	

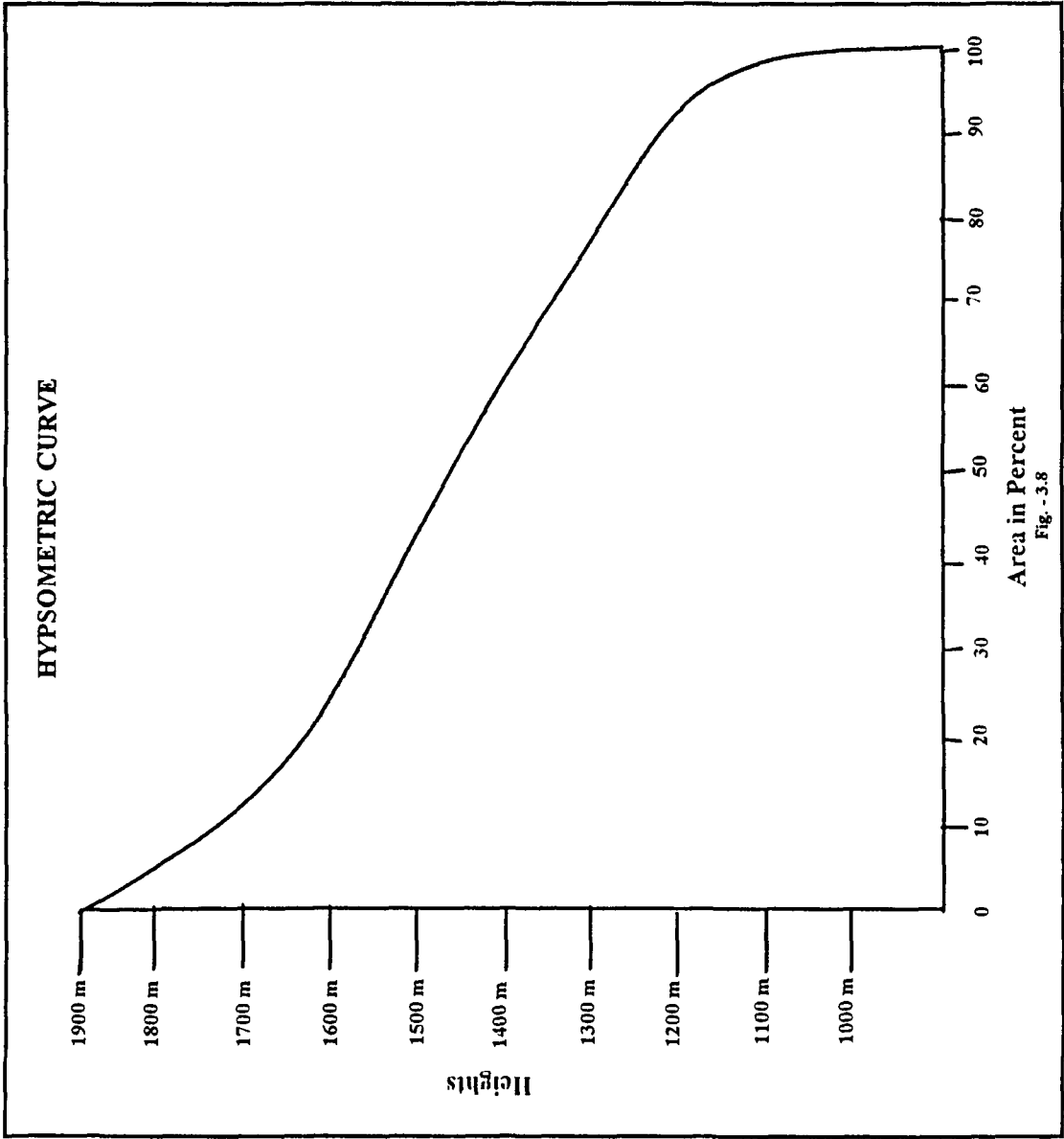


Fig. - 3.8

The area-height curve as given in the Figure 3.7 exhibits a bimodal distribution of lands, first mode is observed at a height of 1200 metres and the second mode at a height of 1500 metres. The land between 1200 metres and 1400 metres appears to have been subjected to severe erosion and dissection which coincide with the absolute relief of the study area.

### Hypsometric Curve

Hypsometric curve is a device to measure the interrelationships of area and altitude. It generally shows the proportion of area at various elevations. The hypsometric curve of the study area has been prepared by using two variables, elevations or heights and area. The data for the hypsometric curve is given in the Table 3.35 and the area in this curve has been represented by cumulative percentage and plotted on graph in Figure 3.8.

**Table 3.35**

### Hypsometric Curve Analysis

Contour Class Interval (in metres)	Area (in sq kms)	Area (in %)	Cumulative Area (in percentage)
Above 1900	1 044	0 600	0 600
1800 – 1900	6 547	3 762	4 362
1700 – 1800	13 324	7 657	12 019
1600 – 1700	16 833	9 674	21 693
1500 – 1600	32 511	18 684	40 377
1400 – 1500	31 261	17 966	58 343
1300 – 1400	27 950	16 063	74 406
1200 – 1300	29 582	17 001	91 407
1100 – 1200	11 846	6 808	98 215
Below 1000	3 102	1 782	100 00

Analysis of the hypsometric curve, though does not reveal the actual profile of the study area, show that the trend of the curve is almost uniform from the height of 1200 metres till the height of 1600 metres. From the height of 1600 metres the curve starts rising to the vertical and culminates at a height of 1900 metres. This decline or departure of the trend line indicates that the areal coverage on the higher altitude is due to the occurrence of precipitous slopes and cliffs that culminates into the mountaintop of Shillong Peak. Similarly, areal coverage at 1200 metres and lower show a vertical characterising the presence of precipitous slopes. The hypsometric curve when compared to the longitudinal and superimposed profiles of the study area appears to be similar. Hence, the area is perfectly marked out as a geomorphic unit with distance homogeneity.

The land surface between 1200 metres to 1600 metres is extensive and covers about 77 percent of the total geographical area of the study area and roughly coincide with the low relative relief surface of the central part of the study area.

As can be seen as illustrated, the hypsometric curve exhibits the relationship between area, altitude and nature of topography.

### ALTIMETRIC FREQUENCY HISTOGRAM

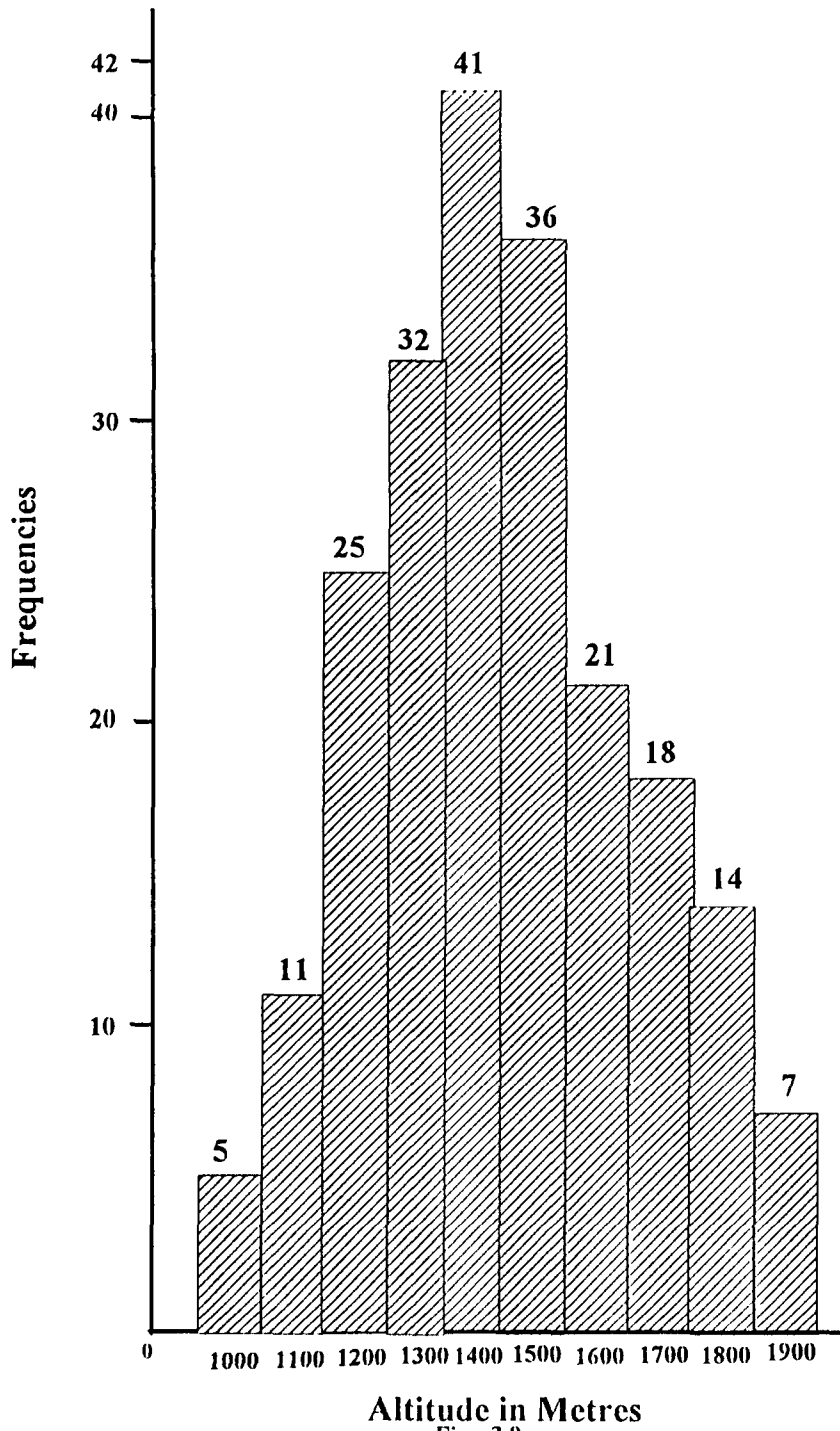


Fig - 3.9

### Altimetric Frequency

Altimetric analysis is utilised in order to know the old erosion surfaces. H. Baulig (1935) was convinced of the occurrence of flats and shoulders on valley sides and was the first to adopt this technique. In this study, the altimetric frequency histogram (Fig.3.9) is used to depict and show the frequency of occurrence of different elevation in the study area.

The altimetric frequency histogram has been prepared by finding the highest point in a grid of one square kilometre and counting the number of spot heights, highest points, and triangulation stations. The number of frequency of the highest points per grid and their percentage tabulated in Table 3.36.

**Table 3.36**

#### Altimetric Frequency Analysis

Contour Class Interval (in metres)	Frequency of Grids
Above 1900	7
1800 – 1900	14
1700 – 1800	18
1600 – 1700	21
1500 – 1600	36
1400 – 1500	41
1300 – 1200	32
1200 – 1100	25
1100 – 1000	11
Below 1000	5

The altimetric frequency histogram reveals that the land surface at the heights of 1400 and 1500 metres is dominant and occupies 37.3 percent of the area in the central part of the study area. This shows that the land surface at 1400-1500 metres coincide with the zone of relative relief. The histogram shows that the relief in the study area has flat summits.

### **Dissection Index**

Dissection Index, a ratio of the maximum relative relief to the maximum absolute relief is an important morphometric indicator of the nature and magnitude of dissection of the terrain. The term 'Dissection Index' itself defines the roughness of the surface created by numerous valleys and ravines present and operating in an area.

Dov Nir (1957) states "As a perfect criterion of relief expression, the concept of relative altitude is not entirely satisfactory. Equal relative altitudes are not always of equal importance since their absolute altitudes may differ. The picture gained from relative altitudes only is static as it fails to take into account the vertical distances from the erosional base that is the dynamic potential of the area studied".

In emphasizing the importance of dissection Index, Dov Nir further states that "it is an index of the degree to which the dissection index has

advanced.” According to Dov Nir the value of this index always lie between 0 and 1 denoting the complete absence of dissection and vertical cliffs.

In the present study, the study area has been divided into grids of one square kilometre and dissection index values were computed for each grid. The formula used in this study as has been expounded by Dov Nir is given as follows:

$$D.I = \frac{R_r}{A_r}$$

where *D.I* = Dissection Index

*R<sub>r</sub>* = Relative Relief

*A<sub>r</sub>* = Absolute Relief

The computation of dissection index by using the above formula has been tabulated and grouped in Table 3.37.

**Table 3.37**

**Dissection Index**

D.I. Category	Frequency of Grids	Percentage of total frequency	Area (sq. kms.)	Area (%)	Cumulative Area (%)	Category
Below 0.1	127	60.476	103.879	59.700	59.700	Low
0.1 – 0.2	60	28.571	58.357	33.538	93.238	Moderate
0.2 – 0.3	20	9.523	10.587	6.084	99.322	High
0.3 above	3	1.426	1.177	0.676	100.00	Very High

**Shillong and its Environs  
DISSECTION INDEX**

Scale

1000 0 1000 2000 m

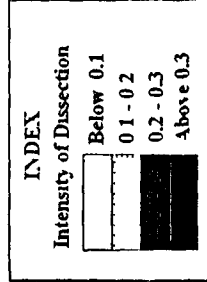
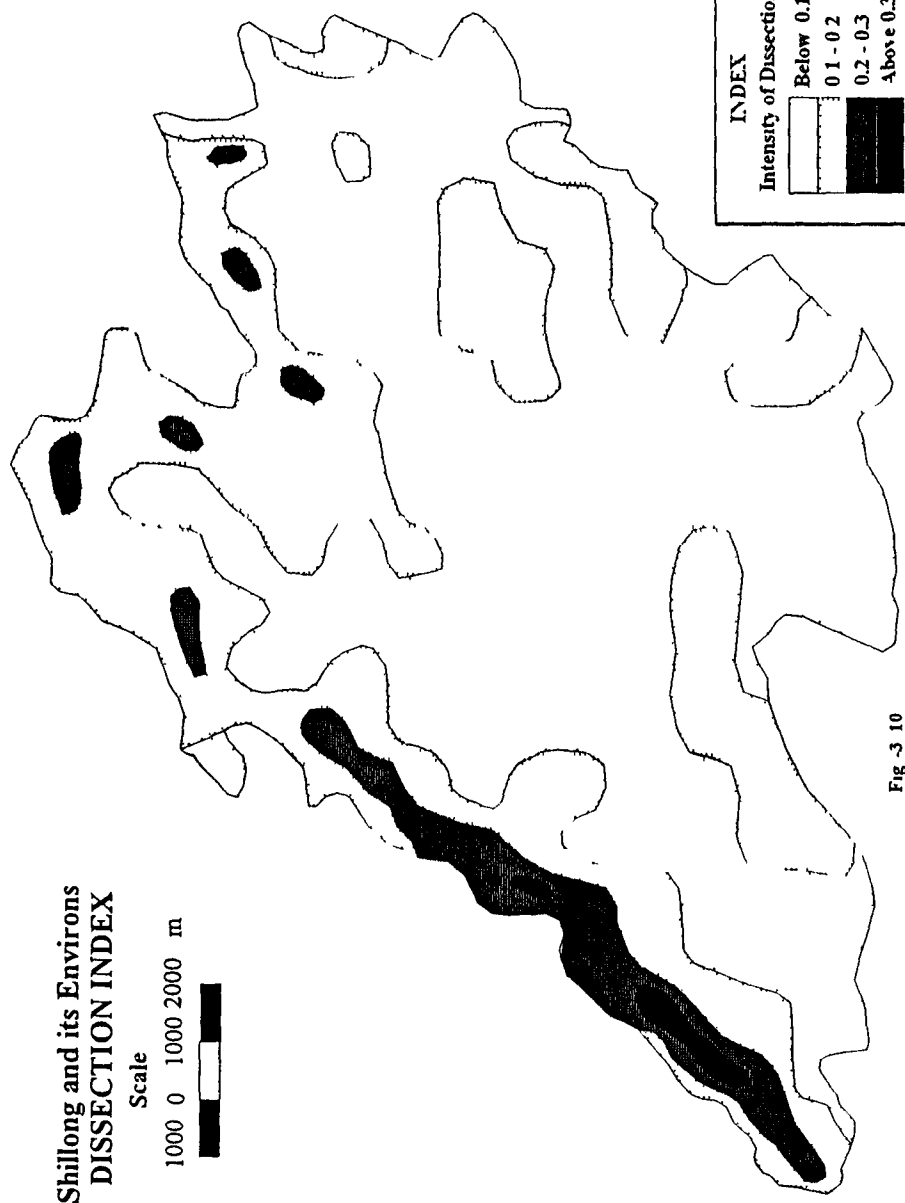
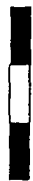
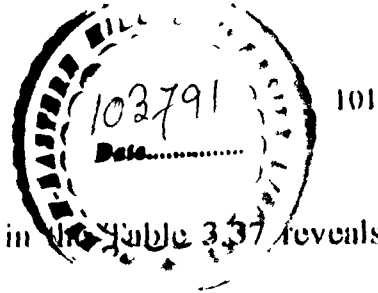


Fig-3 10



Analysis of the dissection index given in the Table 3.37 reveals that the maximum frequency and area lies in the extremely dissection index category occupying 51.744 percent, whereas the low to moderate dissection index category occupies 47.493 percent and the very high dissection index category having only 0.760 percent.

Analysis of the dissection index as given in the table and map gives us the following conclusions:

1. The low dissection index category occupies 59.700 percent of the total study area and coincides to the height groups of 1200 to 1500 metres. This relationship is established by superimposing the dissection index map (Fig.3.10) on the contour map. The areal distribution of dissection index has the same general spread and coverage as the relative relief of the study area. This can be seen by superimposing the dissection index map on the relative relief map.

The low dissection index in this category is due to the widespread occurrence of sandstone which rest as overlies on the quartzites.

2. The moderate dissection index category occupies 33.538 percent of the study area at varying elevations such as between 1400 metres to 1600 metres, 1600 metres to 1700 metres, 1100 to 1400 metres and 1600 metres to 1900 metres. This category seems to be similar in

spread to the relative relief of the study area as seen when superimposed to dissection index map on the relative relief map.

The low to moderate dissection index in this category is due to isolated exposures of quartzites and Khasi greenstones in different localities occupying the peripheral areas outside the low dissection category.

3. The high dissection index category covers only 6.084 percent of the study area and occupies the western flank of the study area as the D.I. map shows. They appear at two localities on the right bank of the Umiam.

4. The very high dissection index seen in the two patches can be attributed to the existence of large surface exposure of conglomerates covering the entire Nongpiur area in the Upper Shillong parts. This category occupies only 0.676 percent of the study area.

### **Profiles Analysis**

Profiles are outlines or drawings of the terrain drawn with measurements from a scaled contour map. Profiles give a better picture of the terrain and surface configuration of the landscape in addition to the contour map. Profiles are of great help to geomorphologists in analysing the relief and provide a visual perception of the actual nature of terrain.

LONGITUDINAL PROFILES

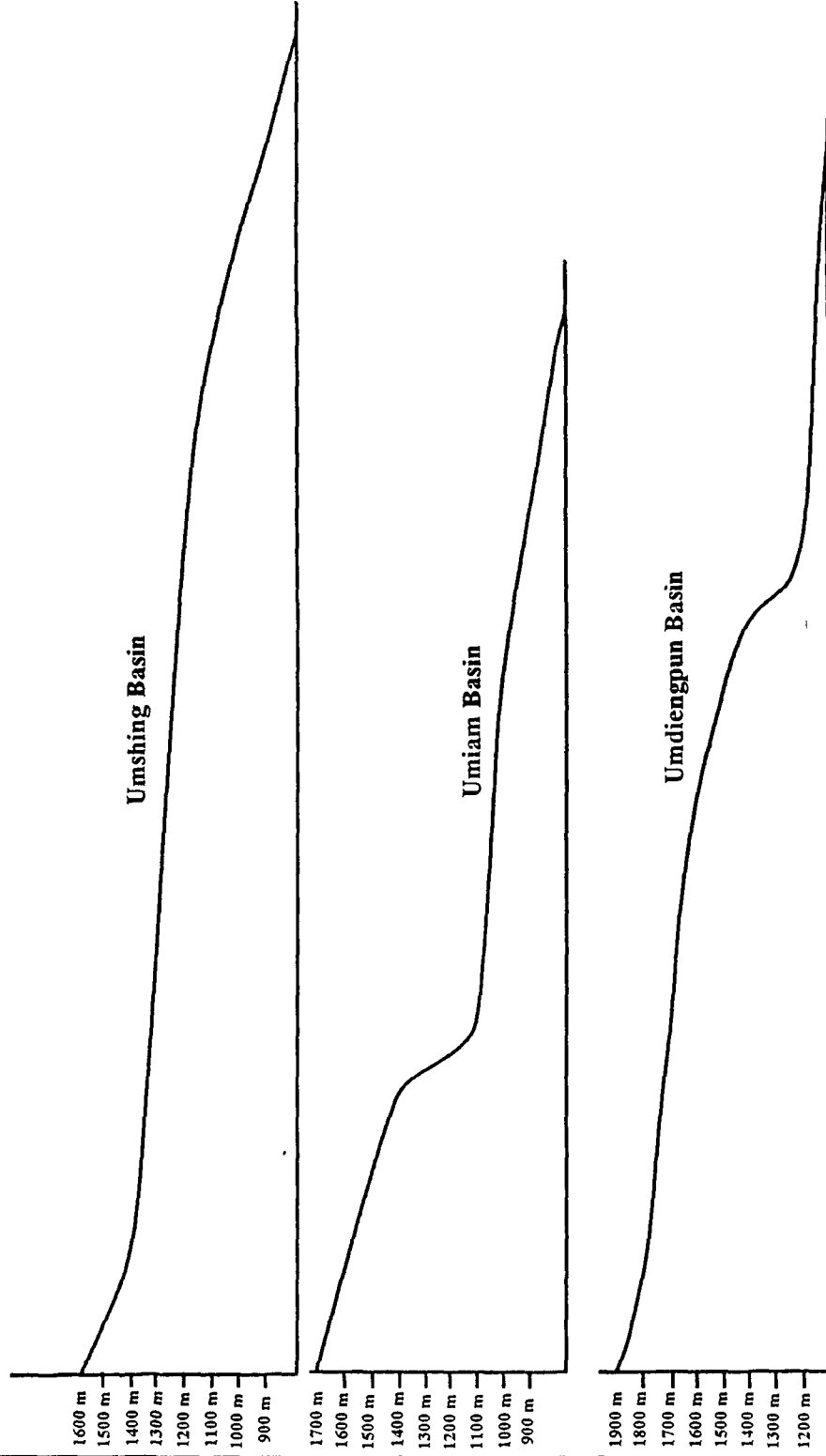
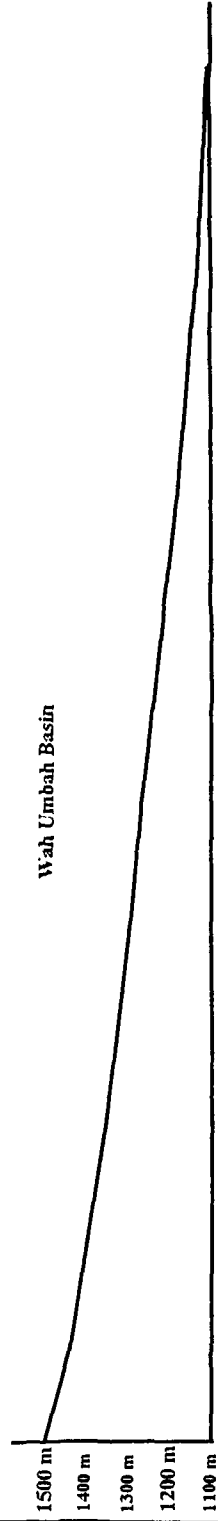
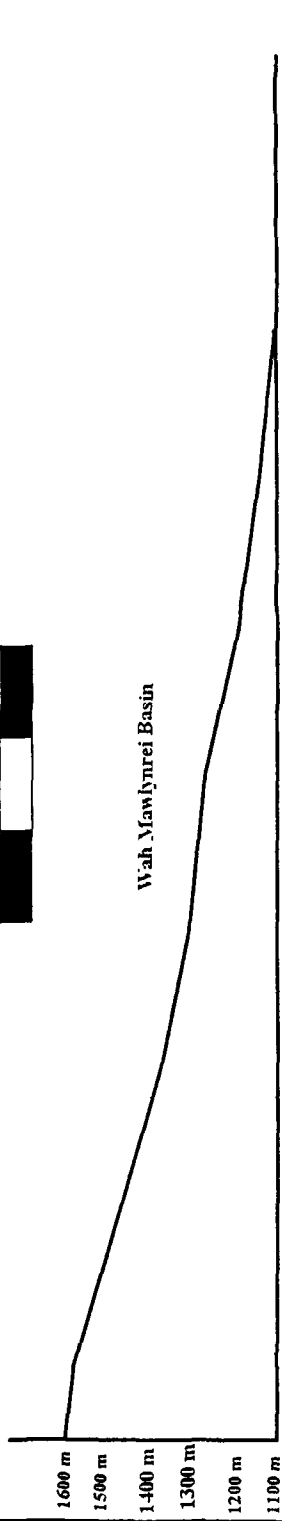


Fig. - 3.11

# LONGITUDINAL PROFILES

Scale

1000 0 1000 2000 m



Vertical Scale Exaggerated 4.5 Times

Fig. - 3. 12

# LONGITUDINAL PROFILES

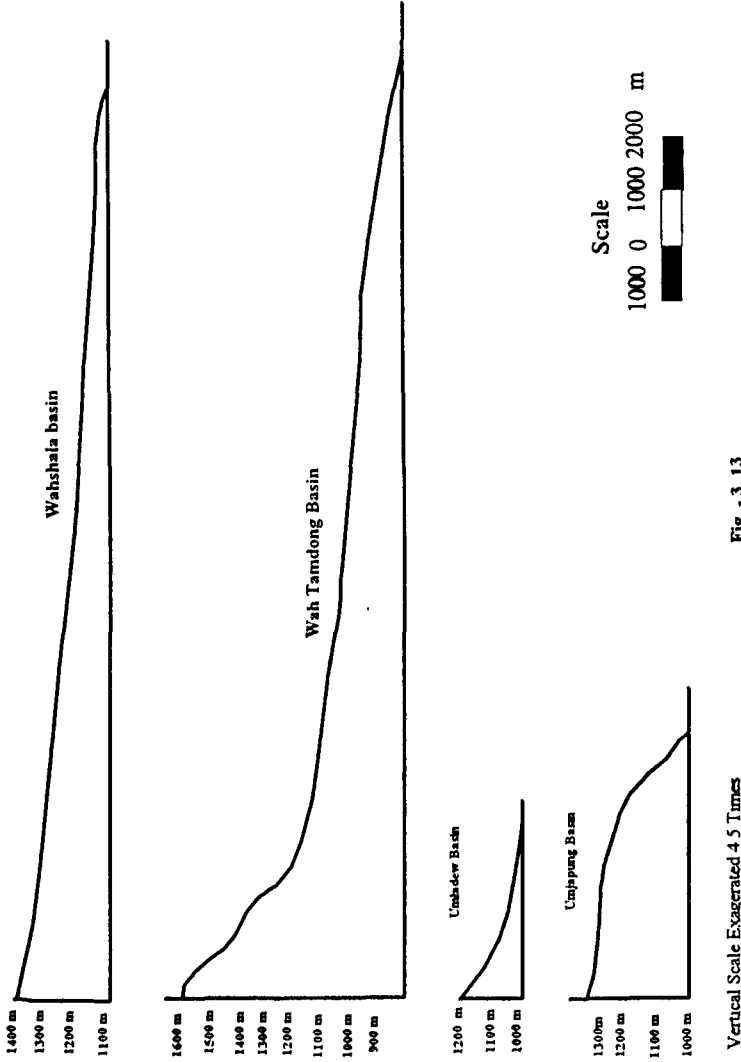


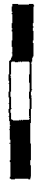
Fig - 3. 13

Vertical Scale Exaggerated 4.5 Times

**LONGITUDINAL PROFILES**

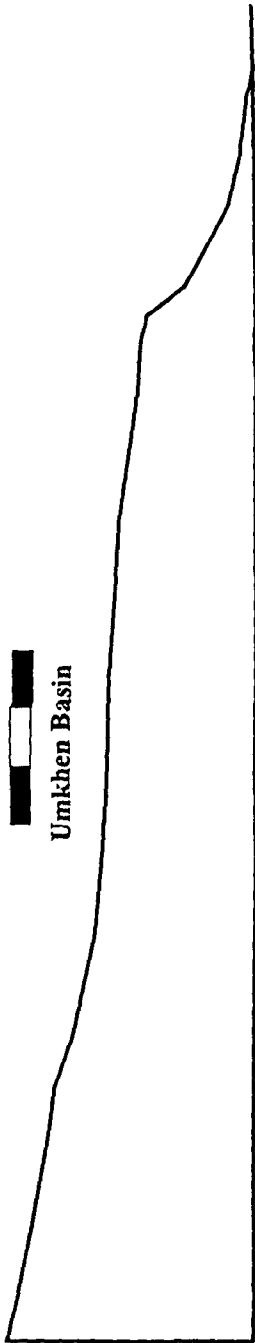
Scale

1000 0 1000 2000 m



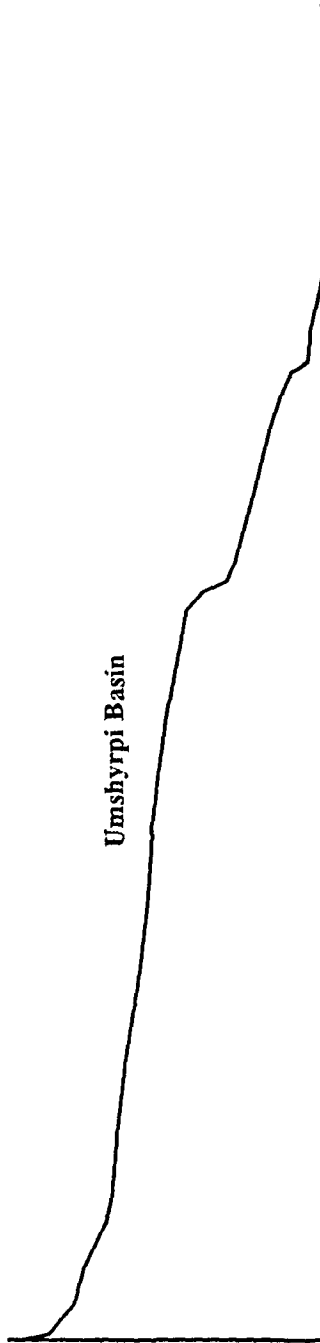
**Umkhen Basin**

1800 m  
1700 m  
1600 m  
1500 m  
1400 m  
1300 m  
1200 m  
1100 m



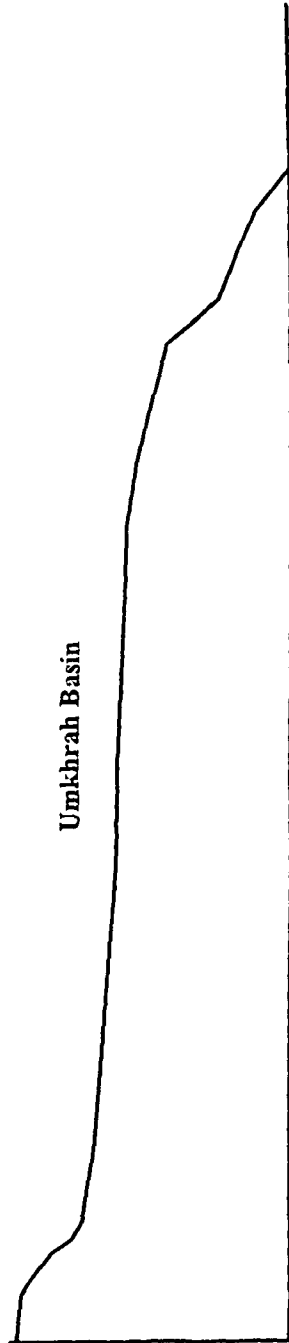
**Umshyrpi Basin**

1900 m  
1800 m  
1700 m  
1600 m  
1500 m  
1400 m  
1300 m  
1200 m  
1100 m  
1000 m



**Umkhrab Basin**

1800 m  
1700 m  
1600 m  
1500 m  
1400 m  
1300 m  
1200 m  
1100 m  
1000 m  
900 m



Vertical Scale Exaggerated 4.5 Times

Fig. - 3. 14

Profiles are of two types (i) river profiles and (ii) terrain profiles. River profiles comprises of (a) longitudinal profile, and (b) transverse profiles. Terrain profiles are classed as (a) serial profiles, (b) superimposed, (c) projected, and (d) composite profiles.

River profiles, especially longitudinal profiles give the geomorphologists a clear picture of breaks in the river which may indicate knick points or heads of rejuvenation and thus help in analysing the polycyclic nature of landform development.

Profiles such as the superimposed profiles help in determining the different levels of planation surfaces. Projected profiles give a panoramic view of the entire landscape or any area under study. Composite profiles represent the highest parts of the summit levels.

The longitudinal profiles (Figs.3.11, 3.12, 3.13, 3.14) of all twelve basins give a general impression of the altitudes of surface at various levels with break in slope. The longitudinal profile of Umjapung indicates the steep nature in its upper reach. The longitudinal profiles of Wah Mawlynrei, Wah Umbah and Wah Shala show that the gradient of the river is somewhat gentle and is an indication of the undulating topography on which their first and second order streams flow. The longitudinal profile of Umshing indicates a break in slope and this accounted by the existence of waterfalls known as Kshaid Thum Thum at

### SERIAL PROFILES

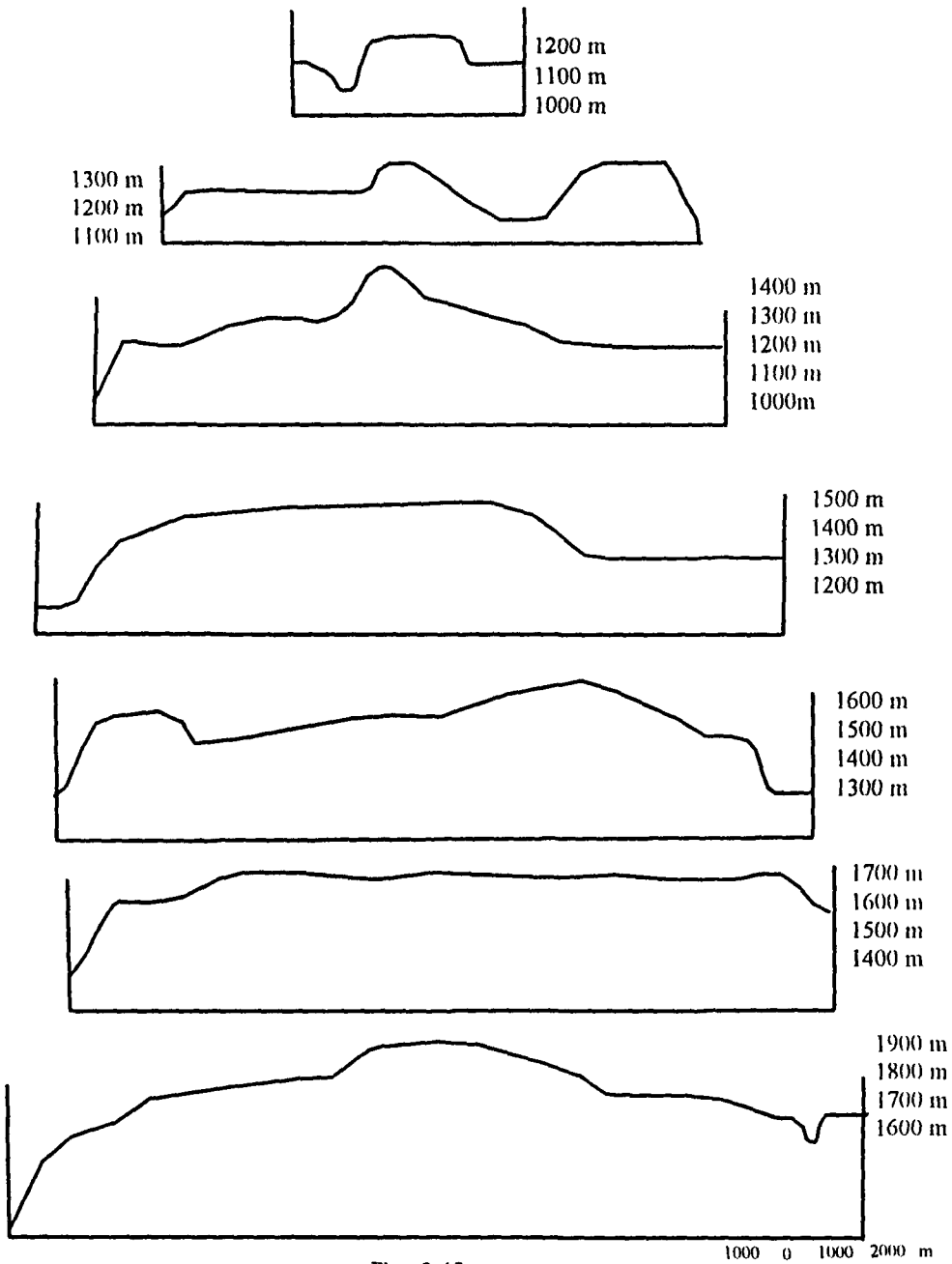
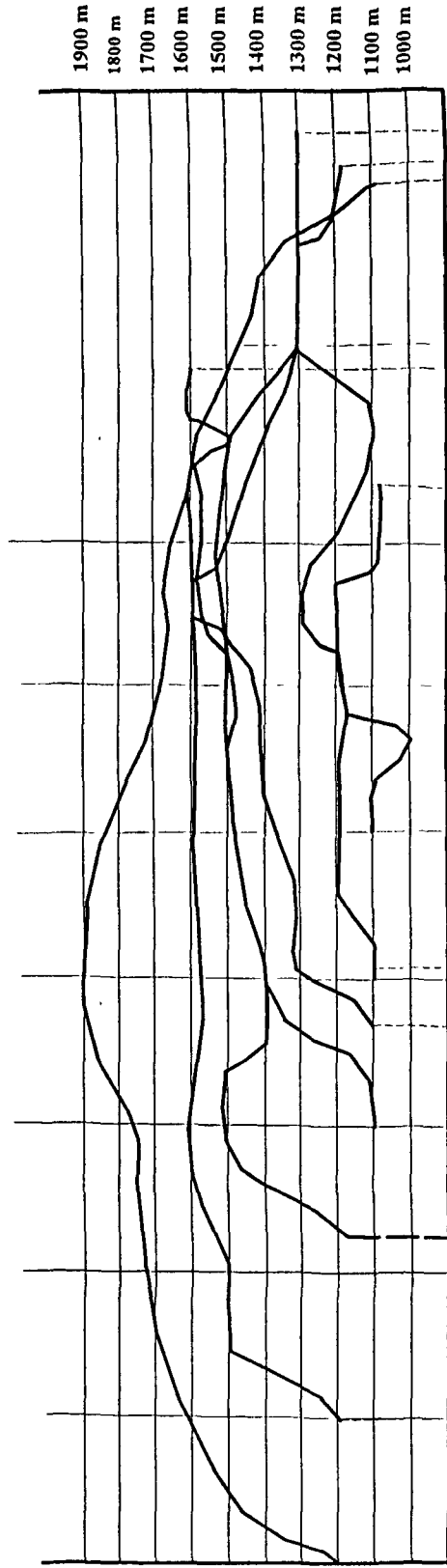


Fig. - 3. 15

SUPERIMPOSED PROFILES



HORIZONTAL SCALE 1: 50, 000  
VERTICAL SCALE EXAGGERATED 4.5 TIMES

Fig - 3.16

1360 metres. The longitudinal profile of Umladew also shows a break in slope at 1100 metres. The longitudinal profile of Umkhrah indicate a break in slope at 1600 metres and 1300 metres depicting the sites of waterfalls known as Kshaid Risa and Kshaid Umshyrpi. The longitudinal profile of Umkhen show a break in slope at 1660 metres and 1380 metres.

From the analysis of the longitudinal profiles that the break in slope of all the streams in the study area is located between 1300 metres to 1600 metres. This clearly indicates that the study area is affected by tectonic disturbances which consequently lead to the structural adaptation of stream to lithology, three streams in particular that show such structural adaptation is the Umkhrah, the Umshyrpi and Wah Tamdong; this is inferred from the existence of minor faults derived when drainage map is superimposed on the geological map of the study area.

Relief profiles (Fig.3.15), seven in number, have been prepared serially from the north to the south covering elevations between 1000 metres to 1900 metres. When these serial profiles are superimposed (Fig.3.16) three distinct pictures emerged. Peneplanation surfaces are encountered at varying elevations. One peneplaned surface is located at 1200 metres, the second at 1300 metres and the third at 1600 metres. Another feature that is seen in the superimposed profiles is the undulating topography ranging between 1300 metres to 1600 metres. Whereas at

elevations of 1650 metres the land surface appears to have been affected by upliftment. Valley development is also seen to be active at 900 metres and 1500 metres.

### **Slope Analysis**

In the study of landforms, slopes and relief are recognised as two basic but separate concepts. In geomorphology, the term 'slope' denotes the declivity of some portion of land surface with respect to the horizontal plane and is defined as angular inclinations of terrain between hilltops and valley bottoms. The development of slopes has been attributed to various factors including geologic, tectonic, climatic, vegetation cover, etc. Slopes are important landforms for geomorphologists, pedologists and engineers.

A slope is formed by erosion, deposition or a combination of both processes. As soon as it is formed, it is subjected to the vagaries of weathering, erosion and mass movement. With the understanding of the above in mind, this section attempts to evaluate and analyse the morphological expression and general characteristics of the slope features and their spatial distribution in the area under study.

## Average Slope

Since the very beginning of geomorphological studies, slope analysis and its categorization have received remarkable attention. However, the scientific and systematic approach in the study of slopes started only during the 20<sup>th</sup> century. Several commendable contributions towards the study and analysis of slopes have been provided by Walder (1980), Ric (1916), Wentworth (1930), Riasz and Henry (1937), Smith (1939), Monkhouse (1953), Strahler (1956), Miller and Summerson (1960), Eyles (1965) and others.

Amongst the various techniques developed for the evaluation and analysis of slopes by the above mentioned workers, the techniques, known as 'Average Slope Analysis' developed by Wentworth (1930) is much easier and involves lesser measurements and calculations. Wentworth devised his technique of the calculation of average slopes in degrees by dividing the contour map into grids of one mile or one kilometre as applicable today. The average number of contour crossings per square mile or kilometre is then computed and is expressed by the

formula as: 
$$\text{Average slope} = \tan \theta = \frac{N \times CI}{633.6}$$

where N is the number of contour crossings per kilometre length, C.I. is the contour interval and 636.6 is constant value in the metric system.

**Shillong and its Environs  
AVERAGE SLOPE**

Scale  
1000 0 1000 2000 m

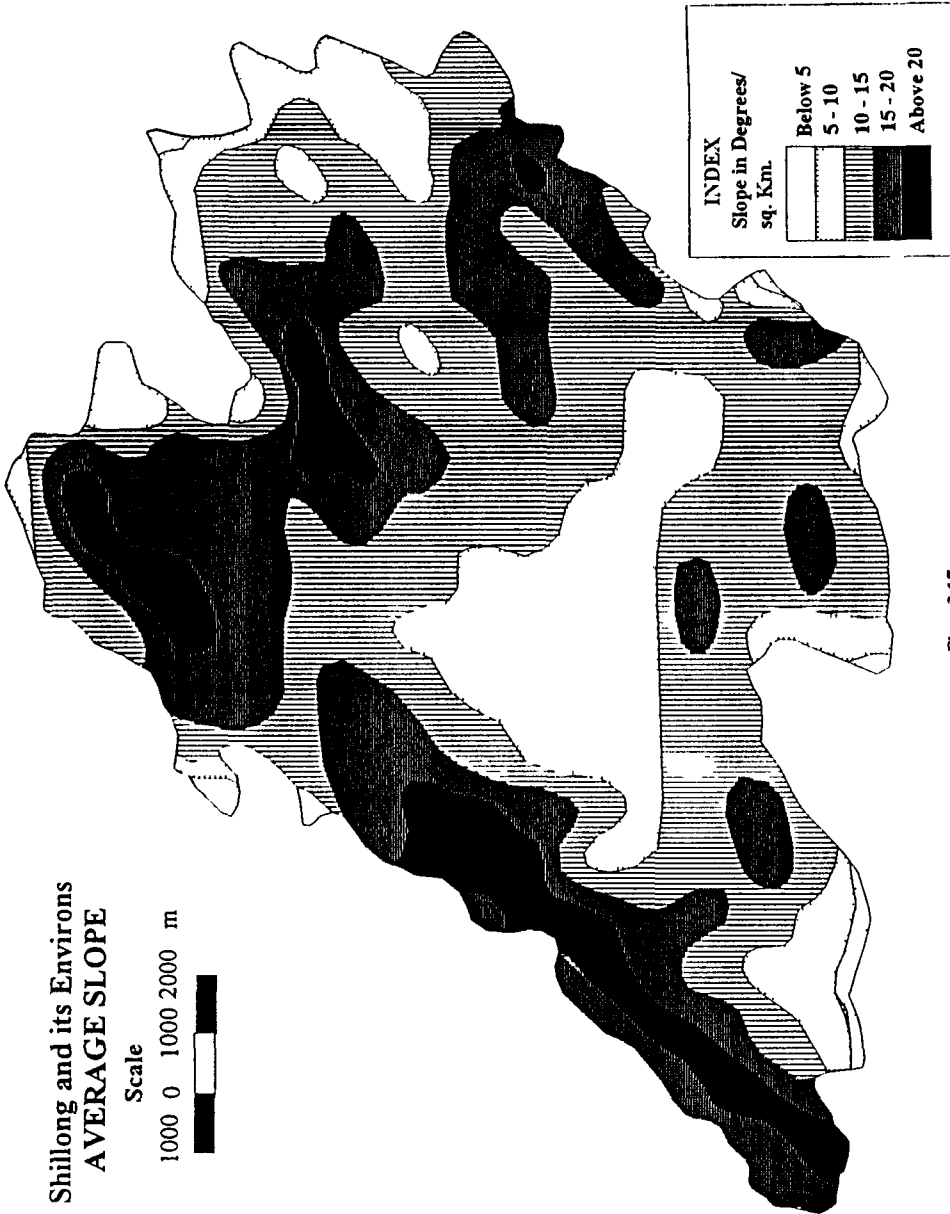


Fig. - 3.17

Thus, in the present study, the average slope method of Wentworth is used and the data derived from employing this technique is tabulated in Table 3.38 and represented in the average slope map (Fig.3.17).

**Table 3.38**  
**Average Slope**

Average Slope (degrees)	Frequency of Grids	Percentage of total frequency	Area (sq. kms.)	Area (%)	Cumulative Area (%)	Slope Category
Below 5	13	6.190	2.135	1.227	1.227	Gentle
5 - 10	59	28.095	37.996	21.836	23.063	Moderate
10 - 15	64	30.476	71.464	41.071	64.134	Moderately Steep
15 - 20	51	24.285	48.422	27.828	91.962	Steep
20 above	23	10.952	13.983	8.036	100.00	Very Steep

Analysing the table and map of the average slope of the study area, the following observations are made:

Gentle to Moderate Slope: The gentle slope category of 0° to 5° covers an area of 2.135 square kilometre which is 1.227 percent of the study area and are found in five extreme isolated pockets in the northern, southern, eastern and western extremities of the study area at varying elevations. The general appearance in the field looks somewhat like flatlands. The soils seen in these five gentle slopes vary in colour and thickness. The soils at Upper Shillong where there is gentle slope of 5°, appears brownish in colour and the whole area is occupied by the

Government farm where plantation experiments of crops, like potato, maize, tea and paddy are undertaken in the gentle slope area.

The moderate slope category of  $5^{\circ}$ - $10^{\circ}$  of average slope occupies 37.996 square kilometres of area and is seen occupying the major parts of the central portion of the study area and at five different localities in the periphery of the study area. The soils in this slope category are as deep as 3 metres and rest as overlies on the sandstones. The trend of the slopes follows the pattern of the gentle folded quartzites on which sandstones are overlaid. The famous Polo Ground, the Shillong Football Ground and the Golf Course are all located in this slope category.

Moderately Steep to Steep Slope Category: The moderate steep slope occupies 71.464 square kilometres of the area. The trend of this slope category appears to follow the lines of the main drainages. This slope category overlaps between the moderate land steep slopes. Therefore, it covers a wide area and divides the moderate slope from the steep slopes. The steep slope category covers an area of 48.422 square kilometres. The major part of this slope zone is seen in the northern, western and eastern portions of the study area. In the southern part this zone is seen spreading at four localities only. The major part of this zone was forested till recently. During rainy season this slope zone very often witness the occurrence of landslide and debris flow.

Very Steep Slope Category: This slope zone covers an area of 13.393 square kilometres and is seen along the western flank of the study area only. The very steep nature of this zone can be attributed to the works of denudation as in this zone the surface rocks that are exposed comprise mainly of conglomerates.

The study of slopes reveals the various zones of varying magnitude. The study shows that the undulating and low relief topography coincide with the zones of gentle to moderate slopes.

Thus the analysis of the linear, relief and areal aspects of the sub-basins and the study area as a whole brought out the characteristics of the drainage network. The quantitative analysis has helped to understand some useful hydrological characteristics. The numerical data has further provided scope for comparison the various drainage characteristics of the study area. The results obtained can serve as useful inputs for a comprehensive water management and urban management plans.

## **GEOMORPHIC PROVINCES**

In the foregoing chapters we have examined the geology, climate, topography and morphometry of slopes and drainage. This section, therefore, seek to classify and to delineate the geomorphic provinces or

morpho units on the basis of various morphometric variables which had been discussed.

A geomorphic province may be defined as that part of the earth's surface with recognisable geomorphological qualities showing homogeneous geomorphic unity. The study area, no doubt, is in itself a part of the geomorphic province of the Shillong plateau but within the study area there occur variations in materials, forms and processes operating on its exposed surfaces.

Works on the delineation of geomorphic provinces or morpho units had been carried out by many workers such as Powell (1896), Davis (1899), Gannet (1902), Bowman (1911), Blackwelder (1912), Fenneman (1916), Linton (1951), Hammond (1954), Wood and Snell (1960) and Weaver (1965). All of them have attempted to classify the landscape into geomorphic provinces of varying orders.

The objective of the present study is to classify the study area into geomorphic provinces as a basis for urbanisation, future planning and management. The basic concept underlying such classification is obtained from regionalization principle which is the main concern of the geomorphologists. The most useful type of classification relate to those classes which permit the widest range of generalisations. Therefore, the best mode of classification is that based on origin, processes and forms

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**Shillong and its Environs  
GEOMORPHIC PROVINCES**

Scale  
1000 0 1000 2000 m



**Fig. 3.18**

Shillong and its Environs

**MORPHO UNITS**

Scale

1000 0 1000 2000 m

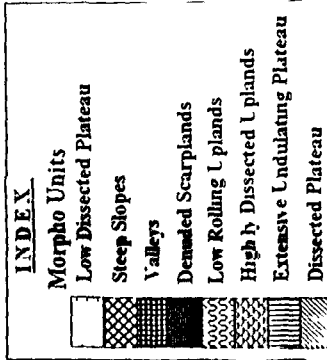
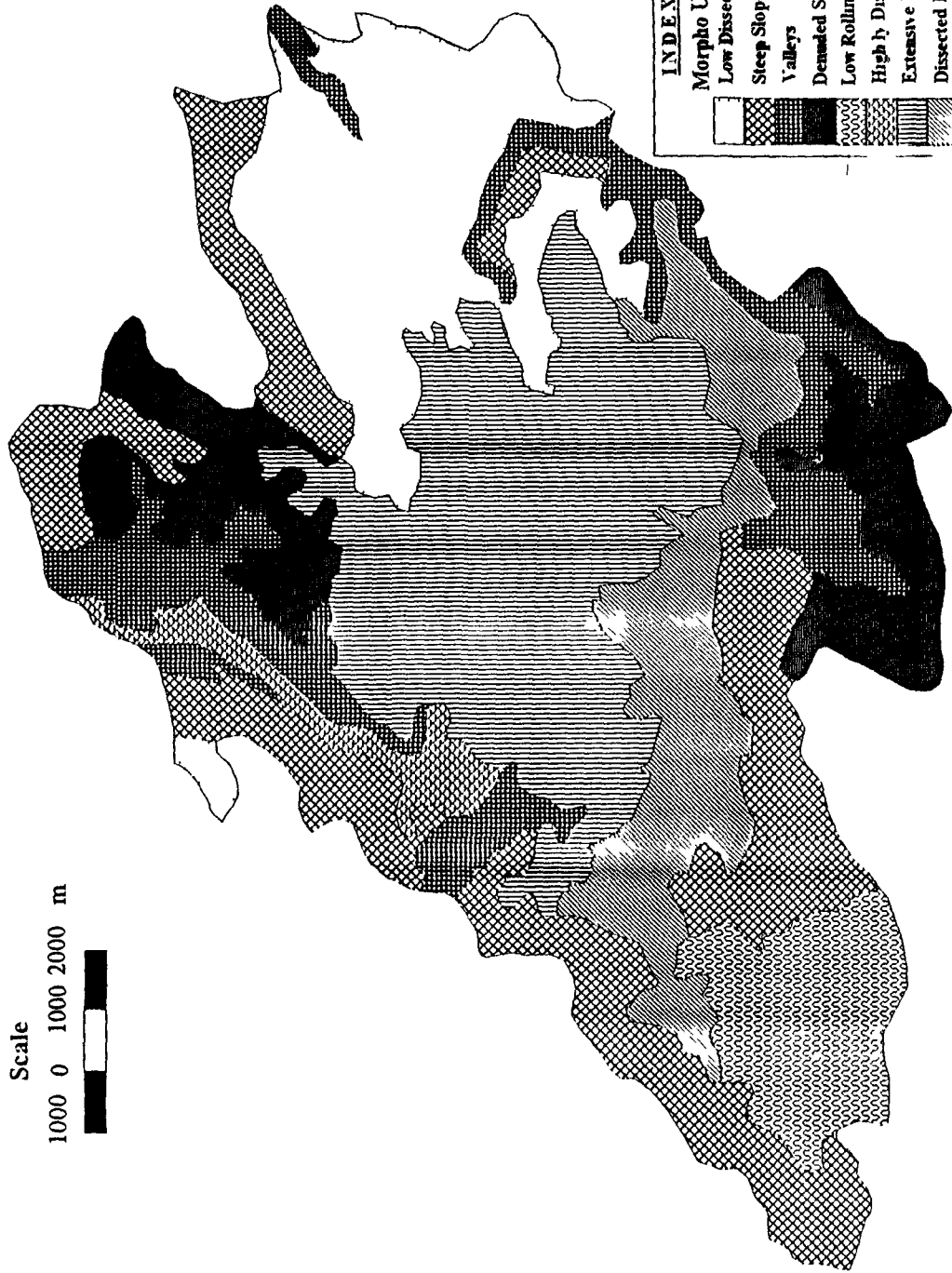


Fig.-3.19

and this is achieved by keeping the number of geomorphic provinces to a reasonable minimum and at the same time ensuring that each is internally homogeneous and distinct from others.

The objective of the present study is to delineate the study area into geomorphic provinces and morpho units as a basis for urban expansion, future planning and management. The delineation of geomorphic provinces and morpho units were based on homogeneity of morphometric attributes, i.e. drainage density, stream frequency, dissection index, absolute and relative relief and average slope.

For the purpose of delineation all the above morphometric maps are superimposed on a single frame and the most coinciding lines or points of contact were marked so that delineation of geomorphic provinces and morpho units can be drawn. Besides the geomorphic delineation, ground checks were made and correct delineation is then done by the insertion method with the help of plane table, clinometre and other surveying accessories.

By adopting these methods, the primary and secondary landforms were marked and mapped (Fig.3.18) for geomorphic provinces and morpho units (Fig.3.19) were prepared which then facilitated the need for preparation of landuse and settlement map (Fig. 3.20).

## **Analysis**

The study area has been differentiated into two primary landform units — valleys and plateau.

### **Valleys**

The valley provinces occupy the northern, eastern, southern and western margins of the study area. This province is characterized by valleys with high dissection values of 0.2 and above with average slopes of  $10^\circ$  to above  $20^\circ$  per sq. km., relative relief of 300 metres and a low stream frequency of 4 to 8 kms. per sq. km.

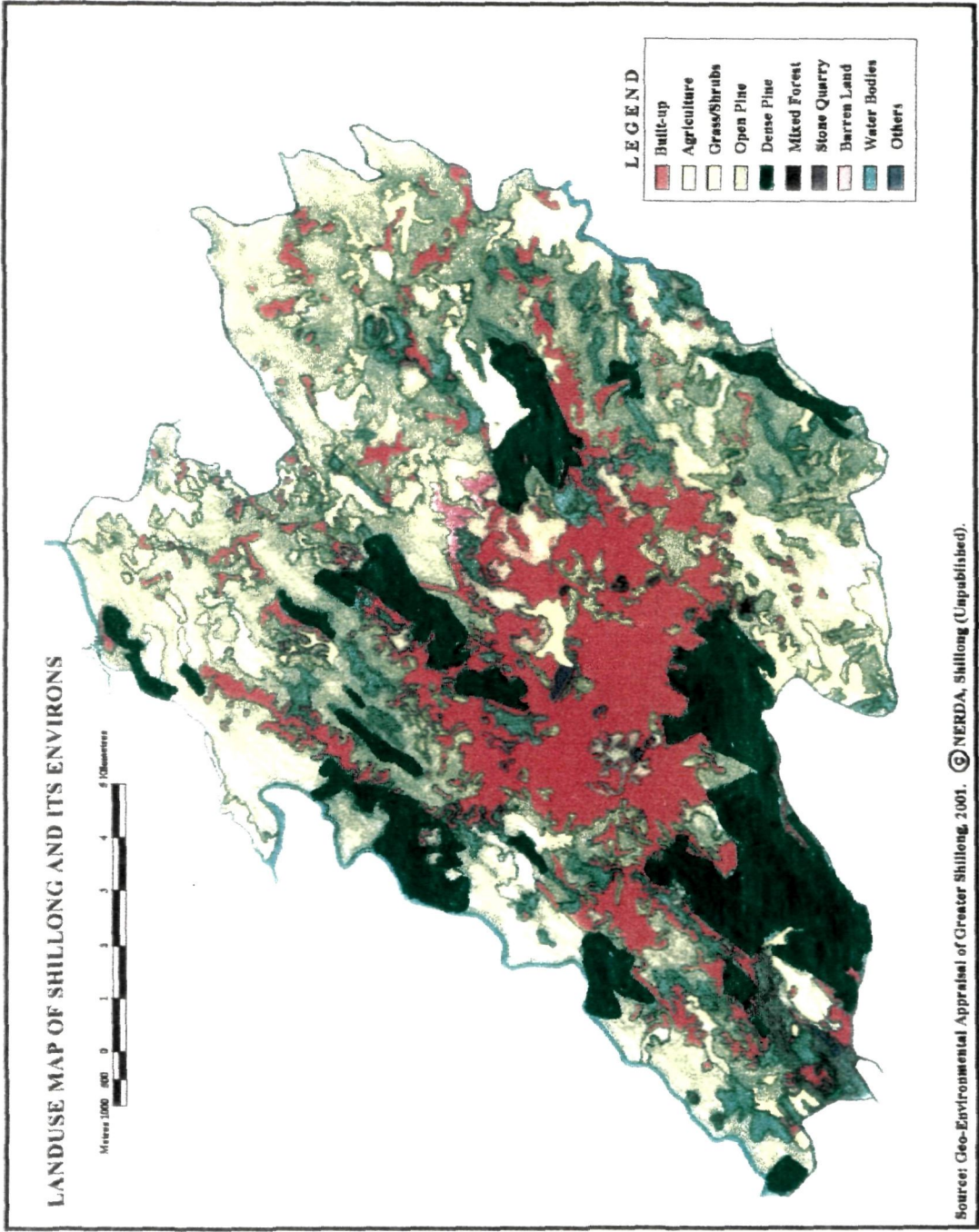
### **The Plateau Province**

This is an extensive geomorphic unit and covers 73 percent of the study. This domain is characterized by slopes below  $15^\circ$  relative relief of 200 metres with low dissection values of 0.1 only. The stream frequency ranges between 4 to above 12 kms. per sq. km.

The secondary landforms designated as morpho units delineated on the basis of morphometric attributes and ground observation have been classified as:

1. Low Dissected Plateau located on the north-eastern part of the study area with dissection values of 0.1-0.2, average slopes of  $10^\circ$ - $15^\circ$  per sq. km. and stream frequency of 8-12 km. per sq. km.

2. Steep Slopes located on the four margins of the study area with dissection values of 0.2 and above, average slope of  $15^\circ$  and above per sq. km. Geologically, the western end of this morpho unit falls under the Tyrsad-Barapani shear zone and is greatly disturbed tectonically. Stream frequency in this unit is below 4 streams per sq. km.
3. Valleys: the deep valleys are located at Wah Roro, Umjapung, Wah Shala, Umbah, Wah Mawlynrei and Umkhen with dissection values of 0.2 and above, average slope of  $15^\circ$  and above.
4. Denuded Scarplands are seen only at two pockets, i.e., in the north and south of the study area. The dissection values are in the range of 0.1 to 0.3, average slope of  $10^\circ$  and above.
5. Low Rolling Uplands are located in the south-western part of the study area with low dissection values of 0.1 and average slope of below  $10^\circ$ . Stream frequency in this unit is below 8 km. per sq. km.
6. Highly Dissected Uplands are located along the G.S. Road, north of Mawlai to Mawiong. This unit is characterized by high slopes of  $15^\circ$  with high dissection values of 0.2 and above. Stream frequency ranges between 8-12.
7. Extensive Undulating Plateau covers largely the central part of the study area. This unit is characterized by low dissection values of



Source: Geo-Environmental Appraisal of Greater Shillong, 2001. ©NERDA, Shillong (Unpublished).

Fig. 3.20

below 0.1, average slope below  $10^\circ$ . Stream frequency in this unit is below 8 km. per sq. km.

8. Dissected Plateau is located just south of the extensive undulating plateau with dissection values of 0.2 and average slopes of  $15^\circ$  and stream frequency of 4-12.

### **Landforms and Settlements**

To understand the existing landuse (Fig.3.20) particularly settlement on how the people have adjusted to geomorphic forms, a further stage of study is necessary, that of relating or superimposition of the morphometric attributes to the requirements of different kinds of landuse. In the field it has been observed that there is a close relationship between the decision of the people and the vagaries of nature. In most cases as has been observed in the field all the 35 villages in the Shillong Master Plan area exhibit the wise decision of the people in establishing their settlements as evident from the location of these villages at varying elevations and along the undulating patches of the landscape.

The localities where settlements occur usually are located at areas with low dissection of 0.1 to 0.2. The average slopes where these settlements are located ranges between  $10^\circ$  to  $15^\circ$ . Shillong Urban Agglomeration, however, has an average slope of  $5^\circ$ - $15^\circ$  and low

dissection of 0.1 only. Thus the area available for urban expansion is about 77 percent with low dissection of 0.1 to 0.2 and average slope between 5° to 15°.

Analysis of other morphometric parameters reveal that areas with slopes of 15° to 20° and above having a high dissection value of 0.2 and above greatly restricted the establishment and other activities. The areas with average slopes of 15° and above are heavily forested such as those seen on the western flank of the study area and around the Wah Tamdong, Wah Umbah and Umkhen Valleys (Plate 3.1).

Except the Shillong Urban Agglomeration, the built up areas in all the basins are scattered. Currently there is a tendency of villages crowding on road junctions and this give an impression that these villages have a linear pattern.

Drainage is another factor influencing settlement and landuse. Most of the villages except Mawlynrei and Laitkor have sufficient number of springs from which people derive their water supply.

In conclusion, it can be mentioned that geomorphic attributes directly or indirectly determine landuse in the study area. At present there is a trend that people from the Shillong Urban Agglomeration are gradually migrating to the surrounding villages. Therefore, utilization of

land in the Shillong Master Plan area should be properly planned and managed to achieve sustainability.

### **Settlement Characteristics**

A settlement is a territorially integral and compact area where population is concentrated with all the necessary conditions and facilities for people to live, work and rest. A settlement is a complex geographic object. And yet from the standpoint of population geography and in all cases when settlement problems, settlement patterns and networks are studied, a settlement is regarded as an elementary object lying at the basis of all constructs and serving as the main unit of observation in the geography of population and settlement.

The complexity of this geographic object consists in the fact that a settlement is simultaneously the site of enterprises and offices being the sphere of employment. Among the necessary structural elements of a settlement are: transport and the service sphere as juxtaposed with the residential area. In social and economic geography and regional economics, the scientific interests in the settlement is due above all to its role as places of settling, as the site of production location and as a point in a certain transport network. The category of settlement has many typological and classification varieties.

Historically, the first division of settlements into different types had to do with a major division of labour which led primarily to the separation of industrial and commercial from agricultural labour and hence to the separation of urban and rural. This division is retained till today; all settlements are divided into two main types rural and urban.

Accordingly, a country's entire population is divided into urban population and rural population. The functions of settlements are extremely varied and there may be several functional typologies, there is no need to dwell on them because this question has been profoundly examined in several literatures. Yet, one of the typologies can be mentioned, since its terminology has to do with the present work/study of Shillong. This typology is based according to the geographical location of some settlements in a given local system.

A central settlement is a settlement whose organising function, economic and administrative, extends to the surrounding areas with at least one or two more settlement to the central one where the expression 'service centre' is often used.

Periphery settlement is one which is situated in the sphere of influence of the central settlement and subordinated to the latter. An intermediary position between central and periphery settlement is

occupied by the satellite town providing for the development of class labour, cultural and everyday ties.

Using this system of terminology, the settlements which are not included in the about category may be designated as rural settlement. Thus, it can be said that Shillong, the study area either in terms of Urban Agglomeration or Master Plan area fits perfectly to the above characteristics of settlements (Fig.3.20).

In the case of Shillong, the central settlements are the Shillong Municipality and Shillong cantonment which for over 100 years has served as centre of administration and defence of the erstwhile state of Assam and N.E.F.A. (North East Frontier Agency).

The periphery settlements grown out of the sphere of influence of the Shillong Municipality and Shillong cantonment are today, Nongthymmai, Mawlai, Pynthorumkhrak, Madarting and Nongmensong.

The satellite settlement is the proposed new township in the Master Plan area. The other type of settlements seen around the periphery settlement is the isolated homesteads and small hamlets located in the most inaccessible and remote parts of the Master Plan area.

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## **Chapter IV**

### **GEO-ENVIRONMENTAL PROBLEMS**

Shillong, initially, was developed to cater to the needs of the British administration of Assam. The British never envisioned that Shillong would continue to grow and expand as it is today. Shillong was once famous for its salubrious climate with picturesque landscape, sparkling streams, waterfalls, meadows, wooded mountains and animals. It was even termed 'the Scotland of the East' and it enjoyed this distinction till the late sixties. However, within a span of four decades, Shillong has lost all its grandeur due to environmental degradation on land, air and water bodies.

With the rapid growth of population and urbanisation leading to an increase in various man-made activities, large quantities of pollutants and wastes are being continuously released into the city environment. Thus in the race for progress and development, the people of Shillong might lose the race for healthy survival, if answers are not found to the twin spectre of over population and environmental degradation. This chapter, therefore, gives an overview of some aspects of environmental degradation as follows:

**1. Problems of Deforestation:** Extensive deforestation in the study area could be attributed to several factors such as:

- (a) Urban proliferation (Plate 4.1) has taken a heavy toll of the surrounding forests. Most new localities have come up subsequent to forest clearing. Even slopes of 10° have not been spared to make way for new settlements and timber logging.
- (b) The traditional practice of *BUN* cultivation which involves cutting and burning of vegetation cover is destructive (Plate 4.2).
- (c) Deforestation (Plate 4.3) has also been brought by stone and sand quarrying (Plates 4.4 & 4.5).

Urban proliferation into the forest areas was done by (a) private land owners and (b) the government. In the case of private lands, the owners have no qualms in destroying the environment for their gains. Proliferation into the forest areas, particularly, in the government protected forests by the government started right from the mid-sixties when the then government of undivided Assam constructed and allotted residential quarters for its officers in areas now known as Motinagar, Risa Colony and Cleve Colony. The proliferation into protected forests by the then Government is that the government does not own enough lands in Shillong and further the government, then and even now, have no say on how private land owners utilize their lands.

Deforestation continued to be carried in the wooded areas to make way for the indigenous *BUN* method of cultivation especially in the fringe areas of the city.

Quarrying of stone and sand, which is carried on currently with much intensity further degraded the already fragile environment to meet the ever increasing demand of stones, pebbles and sands for building constructions. Of late, mechanical stone crushers have been installed at the quarry sites to meet the ever-increasing requirements for blacktopping of road networks.

All the above factors lead to complete stripping of vegetational cover from the landscape. When the land is laid bare it is then either utilized for construction of building or left to the vagaries of nature to forces of denudation and erosion.

Impact of Deforestation: The impact of deforestation is seen on land and on water bodies and leads to loss of vegetational cover which leads to loss of aquatic life. The impact of deforestation on land is viewed as loss of original landscape and replaced by cultural landscapes or man-made activities. The remaining deforested landscape is then left to the forces of denudation and erosion which ultimately leads to soil erosion.

The impact of deforestation is also seen in the streams and water bodies and is primarily associated with water stagnation in the worked up areas and addition of different types of pollutants.

Impact of Quarrying: The impact of quarrying is seen in the form of production of fine silt and sand which are deposited in the nearby streams. There are twenty-two stone and sand quarries and mechanical stone crushers around Shillong city. From these quarries alone, an estimated 160-180 tonnes of fine sands and silt are added annually to the streams of Shillong, thereby destroying aquatic habitats and life forms.

**2. Problems of Water Resources:** Two developments arising out of urbanisation which have an impact on water resources of Shillong are (a) deterioration of water catchment areas and (b) deterioration of stream basin. From the standpoint of both water supply and water quality, the conditions of a catchment or river basin is determined largely by the flora on the upper portions of the basin. The high, often, steep portions of the basin usually receive a large proportion of the rainfall and the flora on these slopes is critically important in determining the quality and flows of water throughout the basin.

A continuous mantle of vegetation in the upper portions of a basin has many benefits. The vegetation breaks the fall of the raindrops, absorbing the kinetic energy before it can dislodge soil particles. The

vegetation also slows the run off and enhances the absorptive properties of the soils. Where vegetation is present over the upper portions of a river basin, the basin's water is generally well regulated and clean.

Thus, this was the picture of water catchment areas of Shillong forty years ago. Today, the water catchment areas of the Umkhrach stream, the Umbah stream, the Umiam river, the Umkhen river, the Tamdong stream, the Umshing stream, the Umsawli stream have been greatly disturbed by human interference in the form of urban expansion, quarrying and deforestation as seen in the catchment areas of aforementioned streams. Some of the water catchment areas especially in the fringe areas of Shillong can be regenerated and conserved, whereas some water catchment areas that have been urbanised can no longer be conserved. As of today, all these water catchment areas are devoid of vegetation cover.

In the absence of vegetation cover in the water catchment areas rain flows off a basin's steep upper slopes. The full kinetic energy of the raindrops is available to dislodge soil particles. A relatively unobstructed surface accelerates the run off, producing greater flood peaks downstream. A classic example of such downstream floods is the occurrence of annual flooding of the Pynthorumkhrach area because as it is seen today the headwaters and sources of Wah Umkhrach is proliferated by

settlements and extensive deforestation. The kinetic energy of the enhanced floods tears away river banks, broadened channels, damages and destroys settlements, bridges, even roads and pavements along side a stream as was seen in the Umkhrach stream in the rainy season of 2001.

As a result, the removal of vegetation especially forests from the upper portions of river basins and catchments increases erosion, reduces water quality and reduces the water availability during the dry season. Deforestation and urban proliferation are the most serious causes of deterioration of catchment and river basins of the once freshwater systems of Shillong.

The practice of *BUN* method of cultivation that expose the soils for long periods is expected to increase in many areas around Shillong over the next few years, contributing further to catchment deterioration. These practices intensify the extreme of floodings and aridity of reducing soil porosity and water storage, by reducing organic matter and by increasing compaction. In soils that are frequently burned, as is the case with *BUN* method of cultivation, and continuously cultivated can become sufficiently depleted to cause soil drought. Without the absorbant properties of these organic materials, soils are less able to retain moisture and shifts on vegetation types occur. The vegetation able to survive in such soils is typical of climates that are more arid than actual rainfall

indicates. Much further deterioration of the water retaining properties of soils can be anticipated on the basis of population and food supply.

Therefore, in the near future, further and acute deterioration of water catchment areas of Shillong would be adversely affected. Today though different localities of Shillong receive drinking water from various sources such as springs, streams, deep tube wells, hand pumps, the Greater Shillong and Umkhen Water Supply Schemes of the P.H.E., there is an acute shortage of water supply in the dry season.

To justify the above statement on the problems of water resources, Maybeck (1976) studied particulate and dissolved matter export and erodibility before and after deforestation. Dissolved substances were approximately twice as much as particulate matter in the forests of the catchment areas but rose to eight times as much during the first two years following deforestation. Erosion increases after two years and particulate matter output rises sharply from 2.5 metric tons per square kilometre per year to 38 metric tons per kilometre square per year.

**3. Urbanisation and Environment Degradation:** The process of a society's transformation from a predominantly rural to a predominantly urban population is known as urbanisation which means two things, an increase in the number of people living in urban settlements and an increase in the percentage of population living in urban settlements. This

distinction is important. The increase in the number of urban residents is a function of the total population increase in the society. As the population of the country grows, it is inevitable that some of those additional people will live in urban settlements.

At the same time urbanisation means an increase in the percentage of urban dwellers and a corresponding decrease in the percentage of rural residents. The percentage distribution is a function of the economic structure of the society.

Urbanisation, demographically, refers to the process of redistribution of population in some specific areas called urban. Geographers analyse the process as spatial concentration of people and activities in favourable location as a direct outcome of the structural shifts in the economy of a region.

The Registrar General of India defines, "urban areas in the census of India (Series 1, Paper 2 of 1991 Census) as follows: (a) It must have a municipality/corporation/cantonment/Board or notified town area committee; (b) It must have a minimum population of 5000 persons with at least 75% of male working population engaged in non-agricultural pursuits and a density of population of at least 400 persons per square kilometre.

Shillong fulfils the above conditions and fall under the category of urban centre. However, Shillong has also been referred as Shillong Urban Agglomeration. The urban agglomeration of Shillong forms a continuous urban spread and normally consists of a town and its adjoining urban outgrowth or two or more physically contiguous towns together with contiguous well recognised outgrowth. Today, Shillong Urban Agglomeration consists of six contiguous towns, these are Shillong Municipality, Shillong Cantonment, Mawlai, Nongthymmai, Pynthorumkhrah, Madanrting and Nongmynsong.

In view of the fast expansion of Shillong Urban Agglomeration particularly during the last two decades many villages located in the fringe areas of the city now forms part of Shillong Urban Areas. As such the government has prepared a master plan to include another 32 villages in and around Shillong covering a total geographical area of 174 sq. kms.

Almost half of the total developed area covered by the Master Plan is under residential use. It is 2662.78 hectares or 15.30 percent. At present the trend of urbanisation has spread in three directions along the three major arteries or National Highways, towards Mawiong in the north, Upper Shillong in the south-west and Madanrting in the south. The present trend of urbanisation is seen today towards Nongrah, Mawlynrei and Mawdiangdiang in the east.

This trend of urbanisation towards the different directions as shown above is determined by (a) Road network such as the Gauhati-Shillong Road, the Shillong-Cherrapunjee Road, the Shillong-Silchar Road; (b) undulating nature of the topography as seen in the Nongrah-Mawlynrei and Mawpat areas and (c) due to non-availability of buildable land within the main Shillong urban areas.

**4. Environmental Degradation:** As the term implies, it means the degradation of some or all the elements of the environment brought about by anthropogenic processes. Anthropogenic activities include, amongst other things, all activities of man such as constructions of settlements, roads, bridges, places of worship, market places, recreational playgrounds, educational institutions, administrative buildings etc. All these activities are imprinted on the geographical landscape by man's cultural activities.

In the light of the above statement, Shillong urban agglomeration today is imprinted with diverse cultural landscapes. Such landscapes that are seen in Shillong today are the military landscape, the administrative landscape, residential and slums landscape, religious landscape, commercial landscapes, recreational landscape, linguistic landscape, landscape of the dead such as cemeteries/graveyards/burning ghats,

industrial landscape, agricultural landscape, forest landscape tourist spot landscapes.

All the above urban cultural landscapes, in one way or the other, create an impact on the physical environment. The physical environment, which was untouched or virgin thirty years ago, now is being replaced or occupied by cultural landscapes. In most cases, these landscapes appear as scars. The impact of these various landscape as a result of urbanisation manifest itself in the form of environmental degradation which can be categorised as land degradation including soil, water pollution and air pollution.

These anthropogenic activities alter air and water quality, modify weather, produce solid waste, noise, radiation, hazardous substances, change the soil, hydrology, climate, plant and animal communities and use considerable fossil fuel energy.

**a) Land Degradation:** The first aspect of land degradation seen in Shillong is the clearing of the forest areas or deforestation. The land once it is deforested for timber logging it is then utilised for agricultural purposes, for house construction etc. or left it as it is. And if the rock outcrops are exposed more on the surface, whether quartzites or sandstones, they are quarried. These quarries leave a permanent scar on

the physical landscape and unlike water or forest resources, the rocks once removed can never be replaced or renewed.

Today, large tracts of land in and around Shillong are devoid of forests. A large part of deforested lands are used for agricultural purposes. In most cases due to illiteracy and poverty of the individual land owners, the deforested lands are then left unattended and are exposed to the vagaries of natural forces which more often lead to soil erosion and inorganic pollution of the streams around Shillong.

**b) Water Pollution:** The surface water drained out from the various income households includes sewage, waste water and rain water. Sewage is the liquid waste water discharged from domestic premises and consists of effluents from kitchens, bathrooms and toilets. Sewage in Shillong is generally discharged into street drains or locality drains and consequently makes its way to the nearby streams.

Residential domestic waste form the bulk of waste produced in the city. Household wastes also include both organic and inorganic materials like tins, cans, papers, old newspapers, polythene bags, food scraps, iron scraps, worn out furniture, broken toys, old appliances, a variety of plastic bottles, utensils, glasses and a host of other items. Residential domestic waste is estimated to form a greater proportion of all sources of solid waste produced in the city. Due to rapid population growth of 49.75

per cent during 1981-2001, the problem of waste management has become severe.

Due to uncivilised nature and lack of civic sense all the organic and inorganic wastes produced from the city's households are always dumped into the nearest drain or streams. This is the main reason for water pollution of the streams which caused the death of its freshwater systems.

In order to assess the surface water quality of the streams of Shillong, the Meghalaya Pollution Control Board carried out some investigations in 1997 to 2000. Similarly, other workers, Roy and Tandon (1990), Nath and Gupta (1992) carried out their investigation on the organic pollution of the streams of Shillong and are presented Tables 4.1, 4.2, 4.3.

**Table 4.1**  
**Water Quality of Umshyrpi during 1997, 1998, 1999 and 2000**

Sampling Time	pH	DO mg/l	CON umho/cm	TDS mg/l	NO <sub>2</sub> mg/l	NO <sub>3</sub> mg/l	BOD mg/l	CoD mg/l	TC MPN 100 ml	FC MPN 100 ml
Nov 1997	7.0	5.0	258.0	180.5	0.20	9.6	79.5	130.0	94000	49000
Mar 1998	7.6	4.3	262.4	185.8	0.30	10.0	84.7	140.5	100000	54000
Apr 1999	7.4	2.9	290.0	200.4	0.45	12.50	90.8	150.0	1100000	60000
May 2000	7.2	7.9	134.0	-	0.10	-	40.0	68.4	35000	22000

Source: Meghalaya Pollution Control Board (2003), Shillong

**Table 4.2**  
**Water Quality of Wah Umkhrak during 1997, 1998, 1999 and 2000**

Sampling Time	pH	DO mg/l	CON umho/cm	TDS mg/l	NO <sub>2</sub> mg/l	NO <sub>3</sub> mg/l	BOD mg/l	CoD mg/l	TC MPN 100 ml	FC MPN 100 ml
Nov 1997	7.0	3.0	290.0	220.5	0.50	12.5	94.5	178.5	160000	110000
Mar 1998	7.1	2.5	285.0	210.8	0.40	13.2	96.0	189.0	179000	115000
Apr 1999	7.6	-	360.0	279.2	0.62	14.5	112.5	210.0	200000	130000
May 2000	7.2	7.9	221.0	-	0.14	-	43.2	70.5	90000	50000

Source: Meghalaya Pollution Control Board (2003), Shillong

**Table 4.3**  
**Water Quality of Lakes and Reservoirs (1990-1991)**

Parameters	Ward's Lake	Umiam Reservoir
1. Temperature °C	15.0 – 24.0	17.5 – 25.6
2. Turbidity (NTU)	3.9 – 17.2	1.6 – 13.6
3. Conductivity (umho/cm)	50.0 – 92.0	34.0 – 74.0
4. pH	6.0 – 7.3	6.2 – 7.5
5. Total solids (mg/l)	54.0 – 121.0	45.0 – 136.0
6. Alkalinity (mg/l)	19.6 – 32.0	8.0 – 58.0
7. Hardness (mg/l)	6.8 – 60.8	5.0 – 38.3
8. Chloride (mg/l)	6.8 – 45.2	-
9. Nitrate + Nitrate N	Trace 1.3	Trace 0.3
10. NH <sub>3</sub> -N (mg/l)	0.6 – 2.0	1.3 – 3.0
11. Kjeldahl-N (mg/l)	1.4 – 5.6	1.1 – 9.2
12. Sulphate (mg/l)	10.4 – 53.0	3.4 – 14.4
13. Iron (mg/l)	0.4 – 9.0	Nil – 1.2
14. Phosphate (mg/l)	1.4 – 9.0	0.3 – 0.6
15. Dissolved Oxygen (mg/l)	3.0 – 6.2	3.7 – 8.4
16. C.O.D. (mg/l)	4.8 – 29.8	4.9 – 13.4
17. B.O.D. (mg/l)	1.0 – 4.2	0.8 – 6.0
18. Total Coliform (mPN/100 ml)	22 – 2400	Nil – 2400
19. Faecal Coliform (mPN/100 ml)	22 – 540	Nil - 23

*Source:* Meghalaya Pollution Control Board (1991), Shillong

From the observation in the above tables, it is evident that the waters of these streams of Shillong are totally unfit for human use and pose serious health hazards. It is observed that even during the monsoon, with maximum dilution the B.O.D. values are normally more than 30 mg/litre, exceeding even the maximum permissible limits of B.O.D. concentration in industrial effluent for discharge in inland surface water bodies.

The investigations clearly indicate the serious degraded condition of the water quality in these streams of Shillong. Still, a large number of

people living in the tenements on the stream banks regularly use these waters for bathing, washing of household utensils and laundrying.

**c) Air Pollution:** Air pollution is a concentration of one or more of the rare elements at a greater level than found in normal air. The most common pollutants, worldwide, are carbon monoxide, sulfur oxide, nitrogen oxides, hydrocarbon and particulates. Concentration of these pollutants in the air can adversely affect the health of humans, animals, plants and the condition of property and products with value to people.

Three types of activities generate most of the air pollution in Shillong. These are motor vehicles, bakeries, burning of coal in private homes, restaurants and dust and particulate matters from stone crushers. Of the above mentioned sources of emissions, vehicular pollution is the major source of the urban environment of Shillong. A large number of cars, buses, trucks etc. including those from outside the state ply through the city, release obnoxious and harmful gases into the city environment.

The Meghalaya Pollution Control Board made a preliminary study on the exhaust emissions from petrol driven and diesel driven vehicles during January and February 1990 and in September 1999 and November 2000. The findings are given in Tables 4.4 and 4.5.

**Table 4.4****Petrol Driven Vehicles Emitting Gases at Higher Levels than Permissible**

Year	Total No. of Vehicles Monitored	No. of Vehicles Complying with Standards	No. of Vehicles not Complying with Standards
February 1990	1228	776	452
September 1999	1058	641	417
November 2000	1397	925	472

*Source:* Meghalaya Pollution Control Board (2003), Shillong.

**Table 4.5****Diesel Driven Vehicles Emitting Gases at Higher Levels than Permissible**

Year	Total No. of Vehicles Monitored	No. of Vehicles Complying with Standards	No. of Vehicles not Complying with Standards
February 1990	1709	641	1068
September 1999	1585	1100	485
November 2000	1930	846	1084

*Source:* Meghalaya Pollution Control Board (2003), Shillong

From the two tables above, it is found that petrol and diesel driven vehicles emit smoke (Plate 4.6) more than the prescribed standards. This can be attributed to the speed of vehicles moving in the city because these vehicles are not designed for Shillong as these vehicles are required to move at a very slow speed due to (i) the city's hilly terrain; (ii) and the phenomenal traffic snarl which occurs daily.

Vehicle movement in the city is active from 0800 hours to 2000 hours daily, especially during working days where most establishments and institutions remain open. On Sundays and holidays vehicle movement

is relatively low. Another factor for vehicular pollution is that the NH 40 and NH 44 pass through the city, therefore, interstate transport vehicles ply on these roads at specified time of the day and throughout the night.

In order to monitor the ambient air quality trends in Shillong, air samples were collected and tested from two selected stations of the city in 1990-91 and from six selected stations in February-March 2000 and are given in Tables 4.6 and 4.7.

**Table 4.6**  
**Ambient Air Quality at Two Locations**

Location	Year	Concentration in $\mu\text{g}/\text{Nm}^3$ 24 hours Average		
		NO <sub>x</sub>	SO <sub>2</sub>	SPM
1. State Central Library	1990-91	92.6	16.0	115.5
2. Motinagar	1990-91	71.0	3.3	90.0

*Source:* Meghalaya Pollution Control Board (2003), Shillong

**Table 4.7**  
**Ambient Air Quality at Six Locations**

Location	Year	Concentration in $\mu\text{g}/\text{Nm}^3$ 24 hours Average		
		NO <sub>x</sub>	SO <sub>2</sub>	SPM
1. Nongthymmai	Feb./Mar.2000	44.9	30.6	347.2
2. Dhankheti	Feb./Mar.2000	42.1	11.8	400.8
3. Barik	Feb./Mar.2000	28.1	10.6	227.3
4. Police Bazar	Feb./Mar.2000	30.8	9.2	259.9
5. Bara Bazar	Feb./Mar.2000	37.9	4.2	234.9
6. Mawlai	Feb./Mar.2000	43.2	19.2	349.8

*Source:* Meghalaya Pollution Control Board (2003), Shillong.

The ambient air quality in other busy and congested areas can become even worse than the situation reflected in the above tables, especially during the peak hours.

Thus, it is evident from the above findings that:

- (i) by and large most surface water sources in and around Shillong have been grossly polluted due to various anthropogenic activities.
- (ii) Air quality in Shillong is being continuously and increasingly deteriorated.
- (iii) The environment is degrading rapidly, thereby accelerating environmental pollution.

In view of the vehicular pollution, the Transport Department, Government of Meghalaya, just recently, 2002, has prepared a scheme known as "Pollution Under Control (P.U.C.)" where emissions testing stations to check vehicular pollution would be set up throughout the urban areas of the state and would be run by private agencies with proper licenses to be issued by the Transport Department, but sadly this proposal still awaits cabinet approval (*Shillong Times*, Shillong, Wednesday July 30, 2003).

**d) Noise Pollution:** Another aspect of pollution prevalent in Shillong is 'noise' pollution. Vehicular traffic is attributed to be the main source of noise pollution in Shillong. The main factors of level of noise pollution in Shillong are (i) the existence of roadside high-rise buildings, narrow roads and reflection of noise due to hilly nature of the topography of Shillong.

### Topographical Constraints

According to the Shillong Master Plan 1991-2011, Shillong covers an area of 174 square kilometres. The breakup of the present existing landuse falling in the master plan is given in Table 4.8.

**Table 4.8**

#### Landuse of Shillong

Sl.No	Landuse	Area	Percentage to total area
1	Developed area	5994 10	31 58
2	Undeveloped area	1573 88	9 04
3	Developed area	5077 02	29 18
4	Urban agriculture	803 07	4 62
5	Forest and Water Bodies	4431 93	25 88
Total area		174 sq km	100 00

*Source:* Directorate of Urban Affairs, Government of Meghalaya

From the table, it is obvious that developed area covers 31.58 per cent as per the official figure. The areas covered under urban agriculture, forests and water bodies constitute 4.62 per cent and 25.58 per cent respectively. Ground verification of the above type of land use reveals that these are very much controlled by topography. Even by interpreting the topographical set up of the different land use it is seen that precipitous slopes account more than 20 per cent of the areas and a further 15 per cent by valleys and cliffs and 65 per cent by undulating topography. Therefore, topography acts as a constraint, and has to be overcome if the developable lands have to be developed.

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## **Chapter V**

### **POPULATION GROWTH AND URBANISATION**

The study of population had been largely neglected by geographers in comparison to other branches of human geography such as agriculture, industry and settlement which have a long established tradition of systematic analysis. But in recent years man's impacts on environment and problems of food supply have become issues of great importance, there is now a growing awareness of the importance of population studies within the broad framework of human geography. Today the study of population has rapidly advanced from a peripheral position to the stage where it has been claimed that "numbers, densities and qualities of the population provide an essential background for all geographical studies."

#### **Sources of Population Data**

One of the most difficult problems in the study of population is the varied quality of data. In India the main source of population data is acquired only from the census of India which is considered as the national registers where economic activities, literacy, religion, languages etc. are recorded. The Census of India, therefore is the only reliable source of population data in the country.

## Distribution of Population

In order to understand the distribution of population of Shillong, the study area; an overview of the population of the state of Meghalaya is deemed necessary at this juncture (Table 5.1).

**Table 5.1**

### **Growth of Population of Meghalaya and Population of Shillong 1901-2001**

Year	Total Population of Meghalaya	Growth Rate	Population of Shillong	Percentage of Urban Population
1901	3,40,524		9,621	2.83
1911	3,94,005	15.71	13,639	3.46
1921	4,22,403	7.21	17,203	4.07
1931	4,80,837	13.82	26,536	5.52
1941	5,55,820	15.59	38,192	6.87
1951	6,05,674	8.99	58,512	9.66
1961	7,69,380	27.03	1,17,483	15.27
1971	10,11,699	31.50	1,47,170	14.55
1981	13,35,819	32.04	1,74,703	18.06
1991	17,60,626	31.80	2,23,366	18.69
2001	23,06,069	30.98	2,67,881	19.63

From the above table (Table 5.1), it is seen that in 2001 the total population of Meghalaya was 23,06,069 in an area of 22,429 sq. km. A glance at population data of Meghalaya for any decade reveals that primary concentration of population is confined to East Khasi Hills alone. This is attributed to the location of Shillong in this district as it was the capital of the State of Assam and now of Meghalaya and headquarters of

many central government offices. The secondary distribution of population in the state is seen in the West Garo Hills, this is also attributed to the fact that Tura was the headquarters of the entire Garo hills then.

### **Influences on Population Distribution**

From a brief examination of population of Meghalaya it is tempting to conclude that inaccessibility and rugged topography of the state are the essential influence upon population distribution. However, closer consideration shows that physical factors provide no more than a partial and deterministic explanation; this is so because man is by no means passive in his choice of areas for settlement and everywhere demonstrates an ability to exercise some control on his environment. Therefore, analysis of population distribution whether local, regional or national, must inevitably take into account various social, demographic, economic, political, historical and physical influences.

### **Economic, Social and Political Influence on Population**

In the modern day world it can be implied that the density of population in a particular area depends to a large extent on the type of scale of economic activity in an area. Economic and technological advances are usually associated with changes in population density and

distribution. Political influences are also another factor affecting population patterns. The evolution of Shillong into a big city of today can be attributed to the political exigency of the 19<sup>th</sup> century in this part of the country when the British held sway over the whole of India. Later with its administrative and political functions, the commercial scenario also changed where the traditional Khasi market held once in eight days gradually developed into a daily affair and now became the state's biggest market place. Slowly the spread of the main bazar area expand into what is known now as the Police Bazar.

Economic activities also followed closely with construction work, both governmental and private. The arrival of the motor cars or vehicles, a development of modern technology, leads to the construction of roads and this leads to crowding of the people from the rural areas to Shillong as well as employment seekers from other parts of the country.

### **Components of Population Change**

Distribution patterns and density of population represents a starting point in the study of population. However, the dynamic aspect of population changes and their interaction processes like birth, death and migration also form part of population study.

Since records of births and deaths are never properly maintained, even in the municipal office, the natural increase of population in the study area cannot be ascertained. Therefore in order to understand the change in population structure only migration aspect can be discussed here.

### **Migration**

Migration is defined as a movement of population involving a change of permanent residence of substantial duration. Migration can also be interpreted as a spontaneous effort to achieve a better balance between population and resource. One of the major effects of migration in any area refers to a change in the total volume of population. Thus an area gains or loses population through in-migration or out-migration. In other words, migration is a major factor in changing the size and structure of population.

A study by Nengnong (1999) of the patterns of migration to the state of Meghalaya reveals the following salient features:

- a) A very high proportion of the immigrants is confined in the East Khasi Hills district only, where Shillong, the study area, is located.

- b) Migration from the districts of Meghalaya appears to be closely related to the size of the urban segment of the population in the districts.
- c) The size of migration and redistribution of population is of intra state origin and accounts for a very high share of the total migrants.

**Table 5.2**

**Distribution of Migrants Classified by Streams 1991**

District	Total Migrants	Rural to Rural	Urban to Urban	Rural to Urban	Urban to Rural	Diversity Index
Jaintia Hills	25,019	19,421	1,542	2,772	1,284	0.37
East Khasi Hills	1,28,047	49,676	14,167	28,786	35,418	0.71
West Khasi Hills	16,079	22,635	830	1,588	537	0.21
East Garo Hills	29,464	25,001	1,216	2,113	1,134	0.27
West Garo Hills	83,423	61,544	3,007	14,168	4,704	0.42
<b>Meghalaya</b>	<b>2,91,543</b>	<b>1,78,277</b>	<b>20,762</b>	<b>49,427</b>	<b>43,077</b>	<b>0.57</b>

*Source: Census of India, 1991.*

From the above table (Table 5.2), it is seen that the trend of rural-urban migration appears to be very well developed in East Khasi Hills district and fairly developed in West Garo Hills district. This migrant segment is largely drawn from villages in close spatial proximity.

### **Sex Ratio**

Sex composition is an index of socio-economic conditions prevailing in an area and is a useful tool for regional analysis. In itself,

**sex ratio is a function of the basic factors of sex ratio at birth, differential in mortality of the two sexes at different stages of life and sex selectivity among the migrants. In its own turn sex ratio has a profound effect on other demographic elements like growth of population, marriage rates, occupational structure, etc. The knowledge of sex ratio helps in understanding the employment and consumption patterns and social needs. Sex ratio is significant in the sense that there is a relationship between change in sex ratio and trends in socio-economic health of an area.**

As per 1991 census the total population of Shillong was 2,23,366, 1,17,372 are males and 1,05,993 are females, i.e. the male-female ratio is 100:90.3. The sex ratio of urban area like Shillong is determined by factors like migration trends of working force, housing condition, health care, etc.

### **Literacy**

The term literacy refers to a cultural fact pertaining to the development of a society's capability to make use of writing for various specific purposes. For a population researcher literacy is that qualitative attribute of population which is a fairly reliable index of the socio-economic development of an area. The trends in literacy are indicative of

the pace at which a particular society is getting transformed. Literacy is essential for eradicating poverty and mental isolation. The lack of literacy on the other hand detracts man from his dignity, keeps the population economically poor and isolated. It acts as a deterrent on the social development, economic progress and political maturity of a society. Thus literacy is essential for economic development, social advancement and democratic growth of an area. Literacy also influences various other demographic attributes like fertility, mortality, etc.

The level of literacy recorded in 1991 was 37,764 males and 70,581 females and the ratio is 100:187. The percentage of literacy was 48.51% of the total population in 1991.

Literacy, however, is closely linked to education and educational institutions. As per 1991 census there were 109 primary schools, 52 junior secondary and middle schools, 64 secondary schools, 20 colleges, 20 vocational centres and one university in Shillong alone.

### **Economic Characteristics of Population**

The economic characteristics of a population not only influence demographic attributes like quality, behaviour and thinking of the people but also are influenced by a variety of demographic attributes. An analysis of the livelihood patterns of an area unfolds its diverse economic,

demographic and cultural attributes and provides a background knowledge for formulating plans for its social and economic development. The size of labour force, its distribution into various occupations, sex-wise participation rates by age, literacy and residence are indices of the physical resource base and nature of economy prevailing in an area. Similarly, the trends in working force and industrial composition that an area undergoes are associated with the overall changes in the physico-socio-economic set up of an area.

The source of data into occupation, labour force, industrial set up etc. for the study is derived from the census of India.

### Work Force

Since data on workforce for 1991 and 2001 are not available at hand, the data of 1981 is used in order to analyse the composition of workforce as given in Table 5.3.

**Table 5.3**  
**Shillong Urban Agglomeration: Structure of Workforce, 1971**

Division	Total	Culti- vators	Agril Labou- tors	Liv- stock, Fores- try, Hun- ting, etc	Mining & Quarry- ing	House- hold Indus- tries	Others	Con- struc- tion	Trade & Com	Trans- port	Other Servi- ces
Shillong Sub- division	100	1.78	2.04	2.09	0.30	1.89	10.95	5.82	16.13	9.17	50.92
Shillong Police Station	100	3.39	4.45	0.77	0.25	1.29	3.04	1.39	24.4	3.05	58.08
Total	100	2.09	2.50	1.84	1.02	1.78	8.74	4.97	17.73	8.04	52.29

Source: Census of India, 1971.

Table 5.3 shows overwhelming concentration in the tertiary sector, particularly trade and commerce, transport, communication and administration. The economy of Shillong has large tertiary sector. The tertiary sector alone accounts for about 87 percent of the total workforce while manufacturing and industrial sector accounts for only 9 percent. Within the tertiary sector itself trade and commerce constitutes a significant segment of the working force. Other services also account for as high as 54 percent of the working population. This can be compared in Table 5.4.

Table 5.4

## Shillong Urban Agglomeration: Structure of Workforce, 1981

Divisions	Total	Cultivators	Agricul. Labourers	Household Industry	Other Workers
Shillong Urban Agglo.	100	1.34	2.19	1.45	95.00
Shillong Municipality	100	0.65	0.22	1.59	97.52
Shillong Cantonment	100	0.98	0.00	1.12	98.77
Total	100	1.05	1.39	1.54	96.04

*Source:* Census of India, 1981.

### Occupational Structure

The study of workforce gains added significance when its occupational structure is studied in detail. Occupation refers to a person's trade or profession or the type of work one is engaged in. The study of occupational structure is significant in the sense that it reveals (i) whether a region's economy is agricultural, industrial or semi-industrial; (ii) its

level of economic development, and (iii) the direction which the entire process of planning a region or area could follow.

Occupational structure of any society is related to a number of factors. These factors are basic foundation as laid by nature and a variety of physical resources like good land for agriculture, vast cover of forests for forestry, rich mineral resources, etc. and these determine the structure of occupation. Commercialization in the use of these resources diversifies the occupational structure. Industrialization also brings in further diversification by creating additional jobs. Industrialization and technological advancement together create a new urban culture requiring more and more services, thus changing the pattern of occupational structure considerably.

The index of economic development on the basis of occupational structure has been measured by demographers differently in different countries. In India occupational structures have been classified into nine categories. These are cultivators, agricultural labourers, livestock, forestry, fishing, hunting and plantation workers, mining, quarrying, manufacturing, processing, servicing, repairs and household industries, construction, trade and commerce, transport, storage and communication, other services and marginal workers.

In the case of Shillong Urban Agglomeration, the number of total main workers was 75,698 according to 1991 census and the break-up of the occupations is given in Table 5.5.

**Table 5.5**  
**Number of Workers, 1991**

Workers	Number
Cultivators	937
Agricultural Labourers	1,373
Livestock, Forestry, Fishing, etc.	1,368
Mining and Quarrying	573
Manufacturing and Repairing Services	6,692
Construction	4,421
Trade and Commerce	15,241
Transport, Storage and Communication	5,155
Other Services	39,938
Marginal workers	902
Non workers	1,54,543

*Source:* Census of India, 1991.

From the break up of the occupational structure as presented in Table 5.5, it is seen that the number of workers is the highest in the trade and commerce category. This can be attributed to the fact that Shillong being the capital city, it also serves as a commercial centre for the rural areas.

### **Industries**

Shillong does not have any major industry. It is observed that most of the industrial activities taking place in the city are secondary small-

scale units which cater to meeting the local consumption requirements.

Table 5.6 gives a picture of the industrial situation in Shillong:

**Table 5.6**

**Small-Scale Industries: Numbers, Investments and Employment in 1986-87**

Industries	No. of Units	Investment in Plants and Marketing	No. of Persons Employed (in percent)
Motor Repairing	8.20	7.56	10.12
Wooden Furniture	9.35	3.75	7.71
Leather based Industry	1.24	0.15	0.92
Bakery	11.21	6.46	10.28
Flour and Rice Mills	5.98	6.03	3.75
Printing Press	3.36	6.14	4.88
Knitting and Embroidery	6.85	1.40	2.90
Seed based Industry	3.11	5.56	4.16
Type Works	2.11	4.03	1.98
Saw Mills	3.74	14.06	7.86
Stone Crushers	1.37	5.05	2.08
Cane and Bamboo works	4.36	0.10	2.24
Tailoring	7.60	1.11	6.89
Lime making	0.74	2.34	1.53
Household	19.45	31.48	22.67
Others	11.22	5.93	10.42

*Source:* Directorate of Industries (Meghalaya).

It is observed that motor repairing and automobile workshops are the dominant industrial activity generating industrial effluents. Most of these units are small and are concentrated in congested residential areas on the roadside with no provision of effluent treatment facilities.

The number of factories registered in the State can be observed in Table 5.7.

**Table 5.7**  
**Number of Registered Factories, 1989**

Districts	Number of Units	Percentage	Persons Employed	Percentage
Jaintia Hills	-	-	-	-
East Khasi Hills	49	84.40	2,630	85.20
West Khasi Hills	-	-	-	-
East Garo Hills	3	5.10	210	6.10
West Garo Hills	6	10.50	288	9.70
Total	58	100.00	3,128	100.00

*Source:* Directorate of Industries, Meghalaya.

It is seen from Table 5.7 that the number of industries is the highest in the East Khasi Hills district with 84.40 percent of registered factories and 85.20 percent of persons employed. From this table, it can be said that there is an additional pressure on land and producing considerable solid and liquid wastes into the city environment.

All the above parameters, i.e. migration, sex ratio, literacy and the economic characteristics of population such as workforce, occupation structure, trade and commerce and industries indicate the types of activity and structure of population of Shillong. The magnitude of the above parameters would not have arisen if Shillong remains a small town. However, due to the pull factors such as trade and commerce, job opportunities and education, the population of Shillong is increasing. The decadal growth of population of Shillong can be seen in Table 5.8.

**Table 5.8**  
**Population Growth of Shillong, 1901-2001**

Year	Population
1901	9,621
1911	13,639
1921	17,203
1931	26,536
1941	38,192
1951	58,512
1961	1,17,483
1971	1,47,170
1981	1,74,703
1991	2,22,273
2001	4,52,612

### **Decadal Growth of Population**

In tracing the urban growth of population over space and time, it is necessary to study the pattern of population growth of the State of Meghalaya, because urban growth is found to be intimately linked to the fortunes of the surrounding rural areas.

The average growth of population in Meghalaya as given in the Table 5.1 from 1901 to 2001 was 21.47. Throughout the eleven decades or for over 100 years there have been fluctuations between the decades 1901 to 1911, 1911 to 1921 from 15.71 percent to 7.21 percent. This can be attributed to countrywide plague which took a heavy toll on population. Another significant drop in decadal variation occurred during

1931 to 1941 and 1941 to 1951 from 15.59 percent to 8.97 percent. This is attributed to the award of large tract of lands from the then United Khasi-Jaintia Hills district as a result of partition in 1947.

However, the growth rate has been persistently rising from 1951 onwards and is significantly brought out during the decade of 1961-1971 when it registered an increase of 31.50 percent. This high growth rate can be explained in terms of increasing birth rate and higher expectancy of life due to malaria eradication and social welfare programmes, and large-scale immigration from neighbouring states for job and economic activities. In the decade between 1971 to 1981 there is a slight increase of 1.46 percent only, accounting for 32.04 percent. Then from 1981 till 2001 there is a gradual decrease in the growth rate and can be explained by the agitational programmes and increasing militancy in the state.

### **Consequences of Population Growth on Shillong Urban Agglomeration**

The consequences of population growth are manifold even in a small but expanding city like Shillong. Population growth has been supposed to be an obstacle to economic development. Rapid population growth increase the pressure on land and resources and lead to mass unemployment. Even the need to provide social infrastructure tends to divert public expenditures from directly productive assets. There is

greater pressure on educational and health facilities which are not adequately met.

Rapid growing population necessitates large investments in social infrastructure. In a small state like Meghalaya particularly a small city like Shillong due to scarcity of resources, it is not possible to provide health, educational, medical, transport and housing facilities to the entire population. There is overcrowding everywhere. As of today, one of the many problems that are faced by the people of Shillong is water supply. The shortage of water supply is most acute during the months of February, March and April.

The density of population in Shillong is the highest in the Shillong municipal area as the central business district (C.B.D.) is located here. It is in the C.B.D. that migrants get casual work both in the formal and informal sectors of the economy. This leads to a sharp rise in land values making it more difficult for the poor to acquire or build a house. It was to such a factor that today squatter settlements and slums are seen in many localities of Shillong.

Currently, the social fabric of Shillong have undergone great changes owing to large scale migration from rural areas and from outside the state. Today Shillong can be considered as “mini India” of the north-east. People with varied cultures, belief, customs and languages are

encountered; thus we can see today many Punjabi, Bihari, Madrassi, Bengali, Assamese, Tibetans, Sikkimese, Bhutia, Chinese, Oriya, Malayali, Telegu, Kannada and Hindi speaking people, apart from the tribals of the north-east.

Another effect arising out of growing population is unemployment which ultimately leads to the emergence of social ills. Today, Shillong no longer retain its peaceful and beautiful character, militancy, extortion, gambling, etc. had become the order of the day.

However, the most prominent feature of growing population in Shillong today due to migration of rural poor is the emergence of slums. The pace and magnitude of intra state migration capitulated with an influx from outside the state has left authorities concerned. As of today the Government of Meghalaya had identified and declared 23 slums pockets within the Shillong Master Plan area with a population of 76,730 dwellers during 1991.

### **Characteristics of Slums**

Unlike the slums in the plains or in other parts of India, the slums in Shillong are less bleak due to its societal structure, topographic advantage and low level of industrialization. Slum dwellers are not

pushed to or compelled to occupy unfit or undesired marginal land but are occupying the land as common city dwellers.

Most of the slums in Shillong are developed in private lands; the Government of Meghalaya owns only 3.02 sq. kms. of land comprising of the main municipal area. Table 5.9 gives an idea of localities, population and number of slum dwellers in Shillong.

**Table 5.9**

**List of Identified Slums in Shillong, 1991**

Sl.No.	Localities	Population	No.of Household
1	Naspatighari	1747	349
2	Qualapatty	2153	431
3	Harijan Colony	817	163
4	Polo Bazar	3358	672
5	Jail Road	2955	591
6	Sweeper Lane	1250	169
7	Laitumkhrah	3129	520
8	Demseiflong	500	77
9	Malki	9826	1638
10	Madan Laban	5838	1167
11	Riat Laban	4323	720
12	Lumparing	7645	1390
13	Lower Mawprem	7375	1229
14	Upper Mawprem	3113	518
15	Wahingdoh	3221	644
16	Barapathor	3145	629
17	Wahthapbru	1300	236
18	Laban	7062	1405
19	Lama Villa	250	45
20	Riatsamthiah	450	90
21	Umsohsun	500	111
22	Jhalupara	3028	505
23	Pynthorumkhrah	3750	750
	Total	76,730	14,044

*Source: Directorate of Urban Affairs, Government of Meghalaya, Shillong. Shillong Master Plan, 1991-2011.*

The inhabitants on the above mentioned slums have a tendency of associating between those having the same linguistic affinity only. The problems of slum areas in Shillong identified in the Shillong master plan are lack of basic civil amenities such as water, drainage, lighting and sanitary facilities, overcrowding, unlivable housing units, unemployment, deprivation of educational facilities and health contingencies.

### **URBANISATION**

In the modern era, the principal feature in human settlement is urbanisation. Urbanisation is manifested in the growth and spreading of urban settlements with cities becoming the nuclei of an overwhelming majority of economic regions. Peter Hagget (1972) defines city as a “large number of people living together at very high densities in a compact swarm”. B.S.Khorev (1971) an expert in economic geography states, “the set of specific living conditions and their consequences or the style of life, which while being typical of modern large cities is becoming a feature of small cities and numerous rural settlements”. According to Khorev, the factors that stimulate and increase urbanisation are:

- (i) Ongoing process of division of labour.
- (ii) Concentration of production.
- (iii) Technology becoming an immediate productive force.

Urbanisation can further be defined as a process which leads to concentration of people in urban place where they perform specialized functions. Urbanisation can also be defined as a social and economic process which has become intensified in the age of rapid advances of science and technology and is manifested in the growth of urban settlements. Urbanisation is also a reflection of the indepth shifts in the economy and social life in the modern period.

Urbanisation and urban growth are two distinct and independent processes which lead to urban development. Urban development in the developing countries is very rapid but lacks the necessary ingredients of urbanisation, India also is one example of this, particularly the state of Meghalaya.

### **Spatial Pattern of Urban Growth**

The extent of urban development can be determined partially by two attributes (i) percentage of urban population to total population, and (ii) density of population in urban centres.

From Tables 5.1 and 5.10, it can be understood that out of a total population of 23,06,069 persons, 4,52,612 persons live in urban areas or in others, 80.37 percent of the population live in the rural areas and a meagre 19.63 percent live in urban areas.

When we observe the break up of population data of urban areas for 2001, it is seen from Table 5.10 that East Khasi Hills district has a higher proportion of urban population and thus, it can be said that there is more urban development in East Khasi Hills district than the other six districts of the state.

**Table 5.10**

**Townwise Population, 2001**

City/Town	Area in Km <sup>2</sup>	Population	District
Shillong Urban Agglomeration	27.42	2,67,881	East Khasi Hills
Cherrapunjee	-	10,086	East Khasi Hills
Tura	18.30	58,391	West Garo Hills
Resulbelpara	-	17,652	West Garo Hills
Jowai	7.80	25,023	Jaintia Hills
Nongstoin	76.00	22,003	West Khasi Hills
Mairang	-	11,517	West Khasi Hills
Nongpoh	-	13,165	Ri Bhoi
Baghmara	8.80	8,643	South Garo Hills
Williamnagar	9.72	18,251	East Garo Hills

The density of population in the Shillong Urban Agglomeration townwise is 6228.2 per square kilometre for Mawlai, 11,675.4 per square kilometre for Nongthymmai, 8,267.3 per square kilometre for Madanrting, 12,825.9 per square kilometre for Shillong Municipality, 6,730.9 per square kilometre for Shillong Cantonment, 10,477.7 per square kilometre for Pynthorunkhrah and 5,624.7 per square kilometre

for Nongmensong. Analysis of the density of population in Shillong Urban Agglomeration indicates the high concentration of population in towns leading to heavy congestion in Nongthymmai, Shillong Municipality and Pynthorumkhrah.

From 1901 onwards till 1921 there was only one town in Meghalaya, the Shillong Municipality. By 1931 to 1951 there were two towns, Shillong Municipality and Shillong Cantonment. By 1961, there were 5 towns, namely, Shillong Municipality, Shillong Cantonment, Mawlai, Nongthymmai in East Khasi Hills district and Tura in West Garo Hills district. The progress in the number of towns increases with an increasing number of newly formed districts. According to the Census of India 2001, in addition to the above towns, there are 10 other towns namely Nongpoh, Baghmara, Cherrapunjee, Mairang, Resubelpara, Nongstoin, Jowai, Williamnagar, Tura and Nongmensong. The above analysis reveals that the overall growth in the number of urban centres in Meghalaya is very low and it can be attributed to a low degree of industrialisation.

### **Rate of Urbanisation and Development**

In order to know and understand the rate or levels of urbanisation in Meghalaya, it is necessary to compare the growth rate of the different

towns in a given point of time by taking five specific attributes such as urban density percentage of secondary workers to non-primary workers, percentage of tertiary workers to non-primary workers, percentage of literacy to literate population and number of hospitals per 1000 population.

The density of urban population, as an attribute has been selected to know the degree of concentration of people in a town. The second and third attributes have also been taken because different levels of non-primary activities are observed in the town under this study, whereas the fourth and fifth attributes have been chosen randomly to highlight the rate and extent of urban development.

The method adopted to understand the levels of urbanisation, is the composite rank method and is based on the census data of 1971, as covering six towns of three districts of East Khasi Hills, Jaintia Hills and West Garo Hills. Table 5.11 shows the percentage of secondary and tertiary workers.

**Table 5.11**  
**Percentage of Secondary and Tertiary Workers, 1971**

Towns	Percentage of Workers in the Secondary Sector	Percentage of Workers in the Tertiary Sector
Shillong Municipal	10.64	86.34
Nongthymmai	5.04	90.83
Mawlai	11.36	56.66
Shillong Cantonment	21.97	77.35
Jowai	18.86	71.56
Tura	6.32	88.48

*Source.* Census of India, 1971.

## Methodology

A very simple approach to arrive at a composite index is done by ranking the variables in ascending order to reflect the maximum observation so that the variable having the maximum observation get the highest score. The series or rank that has been arranged can be summed up and then divided by the number of variables to arrive at the final index of composite ranks in which the maximum score will reflect the highest level of urbanisation, and the lowest score gets the minimum level of urbanisation as tabulated below.

**Table 5.12**  
**Composite Rank of Variables**

Town	Density	% of Secondary Workers to Non-Primary	% of Tertiary Workers to Non-Primary	% of Literates to Total Literates	No. of Hospitals per 1000	Composite Rank Index
Shillong Municipal	8461	10.97	89.03	62.25	0.11	4.40
Nongthymmai	5496	5.85	94.15	11.64	0.06	3.60
Mawlai	2322	16.70	83.29	7.82	0.07	3.00
Shillong Cantonment	2571	22.12	77.88	2.83	0.63	3.60
Jowai	1144	20.86	79.14	4.80	0.33	3.00
Tura	1704	6.67	93.33	10.66	0.32	3.40

Analysing the composite index values that has been derived by this simple exercise, three levels of urbanisation emerged and can be grouped as under:

- (a) 3.00 – 35 = Low level of urbanisation.
- (b) 3.50 – 4.00 = Medium level of urbanisation.
- (c) 4.00 and above = High level of urbanisation.

The table reveals that high level of urbanisation is seen in Shillong Municipality. This is quite natural as it is a commercial and administrative centre for over 100 years with adequate urban facilities and services.

The medium level of urbanisation is observed at Nongthymmai with considerable degree of connectivity. Other towns like Mawlai, Tura and Jowai can be considered to be having low level of urbanisation.

### **Processes of Urbanisation**

From the foregoing discussion, it is apparent that population growth is closely related to urbanisation. However, a closer look on the processes facilitating expansion of Shillong can be undertaken here and is given as follows.

### **Extent of Urban Facilities**

Playgrounds: Thirty years ago, there was only one main playground in the whole of Shillong and one small playground each in Nongthymmai, Laitumkhrah, Malki, Mawlai areas. Today in the Nongthymmai area there are three playgrounds. Playgrounds also have

come up at Madanrting, Upper Laban, Nongkseh and at other localities. In some case playgrounds have proliferated into the forest areas even in the protected forests.

Roads: Shillong is well served by black-topped roads but road width are very much restricted with no proper or adequate drainage. Wherever *katcha* roads are constructed, settlements followed suit, thus leading to further expansion of urbanisation process.

Cemeteries and Graveyards: Since a large proportion of the population of Shillong are Christians proliferation of church building and graveyards into the surrounding areas of Shillong are observed. Muslims burial grounds and Chinese graveyards are also seen in Shillong but burning *ghats* is very less when considering the size of the Hindu population in the Shillong Urban Agglomeration.

School and Colleges: Shillong has been traditionally a centre of education not only of the State of Meghalaya but also for the entire North-East. Today there is a mushrooming growth of school and colleges in Shillong.

The number of educational facilities in Shillong and surrounding areas are given in Table 5.13.

**Table 5.13****Educational Facilities in and around Shillong, 2001**

Sl. No.	Towns	Colleges	Poly-technic	Vocational Institutions	University	High Schools	Junior Secondary Schools	Primary Schools
1	Shillong Municipality	11	-	14	-	47	28	67
2	Shillong Cantonment	1	-	-	-	3	3	3
3	Mawlai	1	1	2	1	7	5	12
4	Nongthynmai	5	-	2	-	6	6	14
5	Pynthorumkhrah	-	-	1	-	1	4	5
6	Madanring	-	-	1	-	2	4	5

*Source: Meghalaya Pollution Control Board, 2003. The State of Environment of Shillong City.*

Central and State Government Office Complex: Shillong is the only city in the north-east that has the headquarters of many central government offices. These are Meteorological Seismological Observatory, Survey of India, Geological Survey of India, Anthropological Survey of India, Botanical Survey of India, Zoological Survey of India. Besides these, there are the complexes of the Atomic Energy Department, National Power Grid, etc. As already stated the government has no lands of its own, so these office-cum-residential complexes have to acquire lands for the purpose. Some of these office-cum-residential complexes are seen in the periphery of the Shillong Urban Agglomeration like the North-Eastern Hill University at Umshing basin, the North-East Indira Gandhi Regional Institute of Medical

Sciences in the Umbah basin. In the near future, it is probable that many other such big complexes like engineering colleges, medical colleges, etc. will come up.

Banking Facilities: The economic health of an urban area can be assessed by the number of banks operating in an area which leads to capital formation and involves three steps: (i) increase in the volume of real savings; (ii) mobilisation of savings through financial and credit institutions and (iii) investment of savings. Historically, the first bank in Shillong was the Imperial Bank of India established on 1<sup>st</sup> April 1926, the New Standard Bank on 2<sup>nd</sup> December 1934. The thirties and forties of the 20<sup>th</sup> century saw many branches coming and going. Following the nationalisation of 14 major commercial banks in June 1969, the spectacular march of banking in Shillong began. The banks and their branches operating in Shillong today are State Bank of India, United Commercial Bank, Punjab National Bank, Bank of Canara, Central Bank, Indian Bank, Indian Overseas Bank, Syndicate Bank, Vijaya Bank, etc.

In deposit mobilisation, the Meghalaya Apex Cooperative Bank gets about 60 percent of the total deposits from Shillong alone as indicated Table 5.14.

Table 5.14

**Meghalaya Credit Deposit Ratio of Scheduled Commercial Banks  
1985-89**

Banks	Years				
	1985	1986	1987	1988	1989
State Bank of India	0.33	0.31	0.24	0.33	0.41
Nationalised Banks	0.32	0.24	0.20	0.25	0.38
Regional Banks	0.43	0.43	0.52	0.55	0.52
Other Banks	0.16	0.17	0.14	0.29	0.26

*Source:* Yearly Balance Sheet, Reserve Bank of India, North-Eastern Zonal Office, Guwahati.

At present nearly all the banks mobilised their deposits in the form of loans for housing, car loans, etc. Thus the people in turn utilise the loaned money for investment in land purchase, construction of houses, etc., furthering urban growth.

The above are the different aspects of the urbanisation process in Shillong today. This trend indicates that Shillong is expanding. The impacts of such urbanization processes in and around Shillong are of course environmental degradation. Analysing the foregoing discussion it is apparent that the population of Shillong is growing which ultimately leads to expansion of urbanisation. The demographic characteristics like migration, sex ratio, literacy, workforce and occupational structures clearly demonstrates the type of choices and responses made as revealed by the extent of urban facilities and these directly or indirectly have great impact on the city's environment.

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## Chapter VI

# EMERGENT GEO-ENVIRONMENTAL ISSUES AND REMEDIAL MEASURES

Humans are an integral part of any ecosystem but human activity is a more pervasive force than is the case with other organisms. Maintenance of a quality environment requires action to be perceived in the light of their effects on the internal dynamic and regulating mechanisms of those ecosystems. Human divert energy, water and other materials from the natural system in order to create unstable artificial environments distinguished by high energy inputs and turnover rates and in most cases lowered species diversity and low stability. In brief many of human system or cultural landscapes are typical of simple early developmental stages of succession.

Humans have greatly modified their physical environment by large-scale removal of plant cover via filling, logging (Plate 6.1), burning, land drainage, earth moving and resource extraction. In many cases the devegetated land is then covered with concrete or other rock-like materials, resulting in greatly increased heat-holding capacity and reduced porosity. Such practices can increase ambient heat energy and surface water run off rate, conditions already aggravated by devegetation

and fossil fuel combustion respectively. Other often-mentioned impacts include lowering of ground water levels, reduction in exposed water surfaces like marshes, wetlands, ponds, etc. and weather and climate modification where lower humidity, reduced radiation and increased frequency of rainfall are observed.

But the most talked about impacts are those resulting from the practice of dumping into the air and water organic and inorganic, natural synthetic, bio-degradable and non-biodegradable substances which often disrupt or accelerate many of the processes so vital to ecosystem functions.

Clearly the ultimate source of impacts on the environment is the growth in the number of people and growth in the amount of resources required by each person. This growth of population even in a small city like Shillong as it is seen today has brought forth a vast array of goods and services, an ever-expanding spatial distribution of people as well as a host of urban problems.

The inexorable trend towards Shillong urban expansion is a result of forces whose origin lies in the political, social and economic system of our society. Of particular significance that promote or sustain urban growth two forces emerge. These are (i) population growth and (ii)

expansion of public investments. The linkage between the two are demand and development.

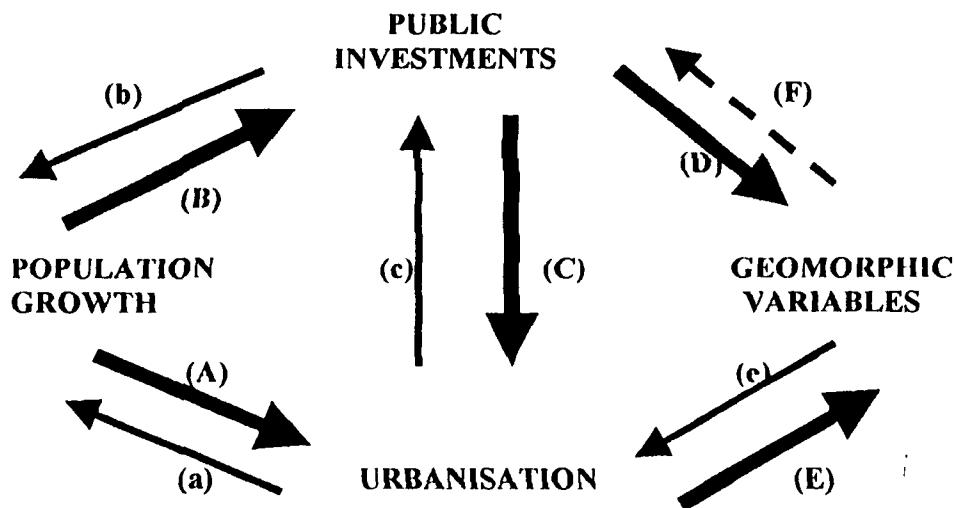
The resulting effects of these two factors are demand for and pressure on land. Impacts on land result from changing use of land as it converted from natural areas to agriculture and or sub-urban, commercial and industrial uses. These can be termed as direct impacts. Indirect impacts result from the promotion of growth, development and urbanisation.

The significance of the impacts, direct and indirect has been stated explicitly by Robert H. Twiss (1974) "Environmental impacts are seldom important solely in terms of their direct physical effects. That is if a road is built into a new area, the soil erosion and visual scars on the landscape are important, but not as important as the 'receiving end' effect that generates new housing followed eventually by the need for many other services. Most of the people involved recognise that the question is not whether we should treat indirect effects but rather given that indirect impacts are the most important of the two, how we compute and weigh them".

With mounting concern over the impacts on natural environment, particularly from urbanisation it is necessary to demonstrate here an

urban geomorphological approach, developed during the course of this study, so that impacts and geo-environmental issues can be assessed.

**FIG. 6.1: INTERACTION MODEL OF URBANISATION PROCESSES**



In the above illustration the fundamental component of the urban geomorphological approach is the process of urbanisation. This approach focuses on the reciprocal nature of population growth, public investments and urbanisation as well as the impact urbanisation has on the environment – in this case geomorphic forms and processes.

From the above diagram it can be inferred that

- (i) population growth enhances urbanisation **(A)** and at the same time urbanisation may influence population growth **(a)**;
- (ii) as population grows and increases **(B)**, capital formation grows and more people migrate to urban areas **(c)**. Population growth then places demand on government machinery for

provision of roads, electricity, water supply, etc. this is known as public investments;

- (iii) the continuing process of urbanisation through population creates a demand for facilities while the facilities enables the urban area to accommodate more people. This results from the interaction of population growth and urbanisation that has direct and indirect impacts on the environment;
- (iv) the facilities created through public investments have direct and indirect impacts (**D**) on the environment, in this case geomorphic variables like land forms, topography, drainage, climate, etc.
- (v) urbanisation induced by population growth and expanded provision of facilities produces secondary impacts (**E**). These impacts are the focus of this study. Similarly, geomorphic variables determine the extent of urbanisation (**e**).
- (vi) a missing link (**F**) between urbanisation through public investment and geomorphic variables requires the interaction between engineers, planners, geomorphologists and others.

In so far as geo-environmental issues are concerned. Berry *et al.* (1974) reviewed the relation between environmental quality and the type

and density of population in which he noted changes in environmental quality that accompany planned and unplanned development.

In this respect an urban area with its built up suburbs can be regarded as an ecosystem – a functional ecosystem, importing food, water, fuel, raw materials etc. and on the other hand, exporting, sewage, combustion products and solid and liquid wastes.

Wolman (1967) has already described the changes in a three-stage time square following urbanisation of a basin. According to him these are:

Stage 1: Pre-urban Conditions – During this stage natural vegetation, stream channels and other natural system are found to be well adjusted to ambient conditions.

Stage 2: Construction and Development Activities – This stage is a brief period where due to developmental works, vegetation and soil structure are disturbed and destroyed.

Stage 3: New Urban Landscapes – The original site or area existed in Stage 1 has been replaced by built up areas like buildings, roads, parking lots, etc.

From the above description of changes by Wolman it is clear that any perturbation to any part of the environment will have repercussions throughout the environment. Life on earth depends on flow of energy and

the cycling of materials through the ecosystem. The abundance of organisms and the complexity of their relationships are all controlled by these factors. Disturbances, whether large or small, affecting these relationships by man's interference may disturb the functions of the environment as a whole.

Again, according to Wolman, the effects of urbanisation is heightened when:

- (i) Urbanised drainage basin is small in area.
- (ii) A significant portion of the basin is urbanised.
- (iii) The basin has some relief.
- (iv) The sediments brought to stream channels is coarse and large in amount.
- (v) The rain frequently falls with high intensity.

Applying the above characteristics to the study area, it is seen that:

- (i) The Shillong Urban Agglomeration is located in two small basins, the Umkhras basin and Umshyrpi basins. Covering an area of 25.494 sq. km. and 22,903 sq. kms. respectively.
- (ii) The relative height is 300 metres ranging from 1300 metres to 1600 metres above mean sea level with undulating topography, flatlands and steep slopes.

- (iii) Rainfall is intense during rainy season and sediments in the stream channels are coarse and large in amount.

The manifestation of urbanisation leads to the emergence of some well known geo-environmental problems which is summarised as follows:

- a) Large areas are covered by impervious areas that intercept precipitation and increase run off.
- b) Concrete drainage systems increase run off.
- c) Large number of septic tanks pollutes shallow aquifers.
- d) Wastes disposal pollutes streams.
- e) Urbanisation encroaches on stream banks.
- f) Accelerated erosion and sediment production from construction, quarrying and deforested sites.
- g) Increased slope failure.
- h) Flooding and changes in the stream channels.

The emergent geo-environmental concerns arising out of urbanisation as underlined above that are also seen in the study area, can be categorised into the following:

Quarrying: The increasing quarrying activities for economic exploitation of rocks and sands in the vicinity of Shillong has resulted into extensive degradation of significantly landforms relics of parts of the

Shillong plateau and this process is continuously shrinking the green cover of Shillong. It is estimated that on the average about 1000 workers per day are engaged in quarrying activities in the twenty existing quarries of Shillong (Plate 6.2). With regard to the socio-economic benefits, quarrying has proved to be potential source of employment. But the conventional method of quarrying adversely affects the health of workers.

Some of the impacts of quarrying on the environment is air pollution, water pollution and disturbance of flora and fauna (Plate 6.3). Air pollution occurs in the form of dust particles during blasting, loading and unloading. Water pollution occurs in the form of water stagnation, addition of dust particles and innumerable pollutants (Plate 6.4). The other types of pollution arising out of quarrying in the study area are solid waste disposal land degradation and soil erosion.

Landslides: The encroachment of urbanisation process on hill slopes affect slope processes and mass movement of rock wastes. Construction of roads, buildings, laying out of water pipelines, laying of electric high tension power lines, construction of sewers etc. on higher hill slopes decrease the resisting force of slope materials. Since such construction activities are not properly planned, slope failures and landslides occur (Plate 6.5). Landslides in Shillong, of late, have become a recurring phenomenon where, sometimes, several lives are lost in areas

like Mawblei, Jaïaw, Laitumkhrach and Nongrimmaw. These landslides occur due to combined anthropogenic and intense rainfall and we frequently see during the rainy season. It is also observed in several parts of the study area even areas with slopes in the category of  $5^{\circ}$ - $20^{\circ}$  are severely affected by landslides but fortunately such landslides occur mostly in the uninhabited parts of the study area (Plate 6.6).

However, the magnitude of the occurrence of landslides when compared to other urban areas like Mussoorie is much less, most landslides in Shillong are of localised nature and small in extent.

Mudflow: Of late, the occurrence of mudflow is noticed in areas in the average slope category of  $15^{\circ}$ - $20^{\circ}$ , particularly in the Riat Laban, Upper Shillong and Laitkor reserved forests. This phenomenon also occurs only during the rainy season and affects the valley sides of the parallel streams.

Soil Erosion: Soil erosion in the study area can be attributed mostly to anthropogenic processes. Human activities in the study area affecting and accelerating soil erosion is preceded by deforestation where large tracts of wooded landscape are cleared and felled for timber logging resulting in a landuse changes (Table 6.1).

Rai (1995) has highlighted the effects of damages due to deforestation in the Barapani area on the outskirts of Shillong Urban Agglomeration. According to Rai, this area as a whole is extremely susceptible to large-scale soil erosion.

**Table 6.1**  
**Landuse Changes in the Study Area (1910-11 and 1966-67)**

Landuse	1910-11 Area (sq km)	1966-67 Area (sq km)
Forest	38.5 – 26.9	35.5 – 24.8
Agriculture	11.3 – 7.9	-
Shillong Township	4.3 – 3.0	9.9 – 6.9
Completely deforested	11.0 – 7.7	-
Lake	-	10.0 – 7.0

*Source:* R.K. Rai, “Geomorphic Processes and Environmental Degradation”, Department of Geography, NEHU, Shillong, 1995.

Another aspect of geo-environmental concern is the waste disposal aspect. Rapid urbanisation has resulted in creating numerous waste dumps in and around the study area often in close proximity to human habitations and thus posing a grave threat to public health (Plate 6.7). These wastes dumping sites automatically become the breeding sites of various disease vectors like flies, mosquitoes and rats which in turn can transmit diseases such as typhoid, cholera etc. On the average, the present population of Shillong Urban Agglomeration generate around 210 tons of waste per day.

Another aspect of waste is the domestic sewage comprising of human body wastes (faeces and urine). The residential houses in Shillong generally use septic tanks and ordinary pit latrines. Besides, the tendency today is to construct houses along stream banks and the city dwellers discharge their domestic sewage directly into such water bodies. All these contribute to unsanitary and severe pollution of streams in and around Shillong.

But by far the utmost geo-environmental issues prevalent in Shillong today are:

- a) Accelerated soil erosion.
- b) Permanent loss of water sources.
- c) Loss of nature aquatic life.

### **Geo-Environmental Issues**

1. Accelerated Soil Erosion: Slow removal of soil is part of the natural geological process of denudation and is both inevitable and universal. On the other hand accelerated soil erosion refers to the increased rate of erosion covered by various landuses effected by man. Erosion and sedimentation under natural conditions are part of any denudation system and do not cause any significant problem except some catastrophic events but accelerated erosion caused by human activities

results into several environmental problems which adversely affect plant and animal life.

In the long history of agriculture in the study area little change has taken place in traditional methods of agriculture. Most of the systems are followed without soil and water conservation measures and consequently there is a heavy soil loss in the study area.

One the traditional methods of agriculture are the *Bun* method of cultivation that is prevalent in the study area (Plate 6.8). Table 6.2 gives an idea of soil erosion in the study area.

**Table 6.2**  
**Soil Erosion from Traditional and Forest Landuse System, 1995**

Landuse	Soil Erosion (tonnes/ha./year)	Remarks
Forest	0.04 to 0.5	Low erosion
<i>Bun</i> method of cultivation	40.0 to 50.0	Soil erosion as high as 5.1 to 170.2 tonnes/ha./year

*Source: Singh, A. (1995), Environmental Degradation and Its Control, ICAR Research Complex, Shillong.*

Unscientific agricultural methods and deforestation are the main factors of soil erosion in the study area.

### **Loss of Water Sources**

Shillong was once famous for its springs, waterfalls, sparkling streams and its fresh water systems. Today all its water systems have

been polluted into such magnitude that the Government of Meghalaya has banned people from using its streams for washing and bathing. However, the most serious is the loss of water sources. The loss of water sources is primarily due:

- (i) Deforestation which then led to the growth of settlements (Plate 6.9).
- (ii) Quarrying at the water source sites (Plate 6.10).
- (iii) Construction of houses right over the water sources (Plate 6.11).
- (iv) Seepage of human coliform from graveyard sites.

It is an accepted fact that vegetation cover helps infiltration of rainwater and that water can be retained more quantitatively for longer periods in the geological strata. Depletion of vegetation cover ultimately leads to loss of water sources such as springs. Some of the streams in the study area whose sources have been affected in the manner prescribed above are Umshyrpi and Umkhras. Similarly, other water sources in the other basins have also been affected in much the same way. Most of the water sources have a flow of water only during the monsoons, whereas during the months of February, March and April are all dried up.

Quarrying of sandstones and quartzites also is another form of anthropogenic act leading to loss of water sources. Demthring water

source of Umkhrah at Nongthymmai (Plate 6.12) have been destroyed by quarrying of quartzites and the changed landscape in the quarry sites have been replaced by settlements.

In areas like Madanrting where the topography is steep, the forested land is being consistently encroached by settlement. The water supply to Madanrting from one of the water sources located upslope is affected by the existence of five graveyards just about 100 metres upslope from the water source. During monsoons the rainwater seeps into the graveyard pits then percolates down to the water sources bringing with it a number of human coliform bacteria and pathogenic organisms that arise from the decomposition of human corpses in the pits.

Another geo-environmental issue of grave concern is the loss of aquatic life in all the streams in the study area particularly Umkhrah and Umshyrpi basins. Organic pollution of urban freshwater bodies result chiefly from the entry of untreated sewage, domestic wastes and effluents. As a consequence there is increased bio-chemical oxidation, depletion of dissolved oxygen and increase in nutrient loads. These in turn, result in 'Fish-kills' and leads to the elimination of a variety of fishes and bring changes in biotic composition such as profuse growth of slimy sewage fungus, blue-green algae and undesirable insects like flies and gnats.

The consumers of such polluted water face a high risk of suffering from various water borne diseases like hepatitis, typhoid fever, dysentery etc.

### **Remedial Measures**

Thus geo-environmental problems and issues in the study area as seen is rapidly increasing. The situation will further worsen beyond rehabilitation within the next few years unless appropriate preventive measures are taken to keep the situation under control. It is, therefore, desirable that concerned authorities should take up some short-term and long-term remedial measures to partly or wholly address these problems.

#### **Short-Term Remedial Measures**

The short-term remedial measures suggested are:

- a) Prevention of environmental degradation in and around the study area by stopping or restricting sand and stone of quarrying and indiscriminate felling of trees.
- b) Banning construction of any establishments like houses, offices, tea stalls with or without toilets on the banks of rivers and streams.

- c) Undertaking of a comprehensive solid waste collection and disposal scheme for Shillong Master Plan area with people's participation.
- d) Development of urban settlements with minimum facilities for transport, education, medical care, markets, etc.
- e) Creation of an appropriate administrative authority covering the Shillong Master Plan area for effective management of different facilities.
- f) Burial grounds like cemeteries, graveyards and burning *ghats* should be relocated to remote and unproductive landscapes to prevent seepage of human coliforms to the water sources.

However, the most effective means of environmental management is through education which should aim at understanding the adverse effects of activities like directly discharging wastes into any sources of water, prevailing poor sanitation, etc. This can best be done through mass media for which concerned authorities should adopt some long-term measures.

### **Long-Term Remedial Measures**

The long-term remedial measures are:

- a) Introduction of conservation oriented education policy at appropriate levels and improvement of environmental education and training.
- b) Adoption of a natural resource conservation strategy.
- c) Incorporation of environmental consideration into all public and private development planning.
- d) Strengthening of programmes for environmental manpower development.
- e) Development of environmental management systems and implementation of environmentally sound sustainable projects.

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## **Chapter VII**

### **SUMMARY, SUGGESTIONS AND RECOMMENDATIONS**

From the discussion in the preceding chapters it is seen that there are relationships between landforms and landuse, particularly between population and urban growth. Thus the whole study has been summarised as follows:

- (i) The study area is physiographically a part of the Meghalaya plateau. The rock formations seen in the area are predominantly the Shillong group of rocks identified as the Khasi greenstones, siltstone-shale phyllites, sandstone-phyllite quartzites and conglomerates.
- (ii) That the area is disturbed tectonically by the processes of upliftment as seen in the southern parts of the study area and is evident from the interpretation of super-imposed profiles and ground occurrence of isoclinal folds leading to the development of cliffs and very steep slopes.
- (iii) The existence of a shear zone geologically known as the Tyrsad-Barapani Shear Zone in the western margins of the study area indicating the manifestation of a deep seated

basement controlled tectonic fractures creating an unstable geological phenomenon known locally as '*Khylliam Boit*'.

- (iv) Topographically, the study area is predominantly occupied by five topographical features, i.e., cliffs, valleys, steep slopes, undulating topography and flatlands. The undulating topography has the highest coverage of 124.304 sq. kms.
- (v) The elevation in the study area ranges from 1000 metres above mean sea level to above 1900 metres.
- (vi) The study of drainage systems in the area reveals that there are 12 sub-basins with varying total geographical areas from 3.941 sq. kms. of Umladew basin to 25.494 of Umkhrah basin.
- (vii) The study of drainage pattern reveals six types of drainage pattern; these are the trellis pattern of Umshing drainage system, rectilinear pattern of Umkhen drainage system, dendritic pattern of Wah Shala drainage system, rectangular pattern of Umkhrah drainage system, parallel pattern of Umshyrpi and radial pattern of Umsohlang, a tributary of Umshyrpi.
- (viii) The lineaments guide the streams of the basin and exhibit strong lithological control of geology on stream flow.

Climatically, it is seen that the climate of Shillong though affected by the monsoon, the local controlling factors are (a) presence of Barapani Reservoir; (b) existence of Government protected forests and (c) increasing built-up area.

- (i) Comparison of climatic data of 1997, 1998, 1999 with the climatic data for 2003 reveals that the climate of Shillong is changing and these climatic variations may have a bearing on the operations of physical processes like weathering, landslides and mass wasting processes.
- (ii) The relief differences also suggest variations in rainfall pattern.

Pedologically, the soils of the study area in terms of depth and colour vary showing affinity that each soil type is related to significant parent rock materials.

The quantitative analysis of drainage basins through linear analysis method reveals that:

- (i) there is a noticeable drop in the mean length of the third order streams and unequal mean length for the third and fourth order streams;
- (ii) the high bifurcation ratio and length ratio indicates strong lithological control and guide the flow of streams. This

lithological control is also very prominently seen in satellite imagery. The rise in the values of these ratios shows an indication of high relief and heavy rainfall in the southern part of the study area and not affected by structure disturbances;

- (iii) the geometry of the twelve basins reveal that tectonic activity was active in a south-south west to north-north east direction.

The quantitative analysis of landforms in terms of areal aspects reveals the following:

- (i) There is variation in the sizes of the basins; the small sized basins indicate that they receive less rainfall while the big sized basins receive more rainfall and flooding.
- (ii) High elongation value recorded is that of the Wah Umbah and is an indication of high elongation in relation to its size. The elongation ratio values for other basins indicate that they have flatter peak flows and flood flows can be managed.
- (iii) Drainage density reveals that mean annual flooding is more in Umladew, Wah Tamdong, Wah Shala, Umshyrpi and Umiam.

- (iv) Stream frequency values show that the drainage networks are characteristics of drainage found in hilly regions due to large number of first and second order streams.
- (v) The high circularity ratio of Wah Mawlynrei reveals the mature stage of its basin.

The quantitative analysis of the relief of the study area reveals that:

- (i) Comparison of absolute and relative relief provide a coherence in their distribution.
- (ii) Study of area height relationship shows that the land surface between 1200 metres and 1600 metres is dominant and is restricted to the low dissected plateau and extensive undulating plateau.
- (iii) Study of the hypsometric curve reveals that the proportion of area between 1200 metres and 1600 metres is dominant. The trend of the curve is almost uniform from the height of 1200 to 1600 metres. From the height of 1600 metres the curve rises sharply to a height of 1900 metres. This is attributed to the occurrence of precipitous slopes and coincides with ruggedness values of the area.

- (iv) Study of the altimetric frequency histogram reveals that the maximum frequency of erosional surfaces is located between 1200 metres and 1500 metres of elevation.
- (v) The study of dissection values indicates that low dissection is dominant at elevation between 1200 metres and 1500 metres in the extensive undulating topography/plateau.
- (vi) The study of average slopes reveals five zones of slopes between 5 to 20 degrees.
- (vii) The interpretation of super imposed profiles reveal three small peneplaned surfaces at varying elevations, i.e. one at 1200 metres, the second at 1300 metres and third at 1600 metres. Valley development is dominant at 1000 metres.
- (viii) The interpretation of relief ratio exhibits that the basins are characterised by less resistant rocks.
- (ix) Analysis of the ruggedness number reveals that the steepness is more in the upper reaches of the Umshyrpi stream where isoclinal folds at 1600 metres and above are encountered.

The classification of landforms into geomorphic provinces and morpho units reveals the following findings:

- (i) The study area has been differentiated into two primary geomorphic provinces and eight secondary morpho units.

The primary provinces are valley and plateau domains. The valleys domain occupy about 37 percent of the area and the rest is occupied by the plateau domain.

- (ii) The secondary morpho units reveal eight categories of morpho units. These are low dissected plateau, steep slopes, valleys, denuded scarplands, low rolling uplands, highly dissected uplands, extensive undulating plateau and dissected plateau.

From the classification of landforms it is apparent that out of the eight secondary landforms only three classes of landforms are found to be suitable for urban expansion. The land surface between 1200 metres and 1600 metres is extensive and coincide roughly with the low relative relief surface of the central part of the study area. Thus it can be seen that the land surface available for future urban expansion of Shillong is located in the elevation between 1200 metres to 1600 metres. Therefore, utilization of land in the Shillong master plan area should be properly planned and managed to achieve sustainability.

Analysis of population growth of the study area reveal that the population is increasing with an urban percentage of 2.83 in 1901 to 19.63 in 2001. This decadal increase is attributed to natural increase and migration from the rural areas as well as from other states of the country.

Other demographic characteristics such as sex ratio, workforce, occupational structure and literacy; and economic factors such as industries and banking, reveal that:

- (i) an overwhelming concentration of workers in the tertiary sectors accounting for about 87 percent of the total workforce;
- (ii) the occupational structure of the working population in trade and commerce sector is dominant;
- (iii) capital formation by banking institutions and mobilisation in recent years is rising with regional banks having the highest shares;
- (iv) literacy rate is 87 females per 100 males and the total percentage of literacy in 1991 was 48.51 from the total population of the city;
- (v) analysis of industries as seen in the Table 5.6 production in all sectors is meant for local consumption only. This clearly shows a low level of industrialisation in the study area.

From the study of population, it is clearly evident that migration and other demographic characteristics have a profound effect on the population growth of the study area.

- (i) Migration combining with natural increase brings in an increase of population in the study area. Sex ratio analysis can also reveal the employment and consumption patterns and social needs.
- (ii) Analysis of literacy reveals that it influences fertility, mortality and economic patterns and is an important parameter in eradicating poverty, and enhances economic development.
- (iii) The study of workforce and occupational structure gives an added significance as these are considered as indices of development.

Thus it can be concluded that population growth and its characteristics are indicators showing the degree in the level of development and in furthering development processes and urbanisation.

The impacts of population growth in the study area can be assessed as follows:

- (i) Population growth enhances urbanisation.
- (ii) Population growth place demands and pressure on land.
- (iii) Urbanisation induced by population growth and expanded urban facilities impacts the environment.

Analysis on the levels of urbanisation indicates that a high level of urbanisation takes place in Shillong municipality followed by Nongthymmai. This trend shows that in the near future the levels of urbanisation will spill over to the surrounding areas of Shillong Urban Agglomeration.

The impacts of urbanisation on the city's environment via population growth are the environmental degradation in terms of land degradation, water pollution and air pollution.

- (i) Quarrying and deforestation are the most serious forms of land degradation leading to rapid loss of vegetation and soil cover leading to drying up of water sources.
- (ii) Water pollution analysis show that the water bodies are highly polluted. The investigations undertaken by various agencies clearly indicate the serious degraded condition of the water quality in the streams of Shillong.

Air pollution is increasing due to increasing number of vehicles coupled with traffic jam and narrow roads.

Another aspect of pollution is the noise pollution and is attributed to increasing number of vehicles.

In conclusion, it can be stated that Shillong is expanding both in terms of population and urban growth. Urbanisation creates demand and

pressure on land leading to congestion and overcrowding of people and urban facilities, thereby leading to serious geo-environmental concerns.

### **Suggestions**

In order to have a healthy and sustainable urban set up in the city, the following suggestions are made:

- (i) The authority concerned should take the planners, engineers, geo-morphologists, geologists and social scientists into confidence before any urban developmental work is undertaken.
- (ii) Future urban development should undertake to study the areas available before urbanisation, so that environmental impact assessment can be made.

### **Recommendations**

In order to get a better and clearer picture of the study area in terms of urbanisation, population growth and future expansion, it is recommended that detailed researches should be undertaken by bringing together a team of researchers drawn from allied disciplines which should:

- (i) develop a comprehensive check list of the potentially available and needed information to determine the

geomorphic units, the ecological units, social structure, economic functions, urban growth, etc;

- (ii) identify the natural forces producing change in the geomorphic variables and processes as well as existing source of human interventions;
- (iii) perform the necessary analyses to describe the existing dynamic aspects of the environment, urbanisation and population with particular emphasis on the projection of changes that will occur naturally and socially.

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1.1 View of the Study Area



3.1 Proliferation of Settlements in the Umkhen Valley



4.1 Proliferation of Medical Complex of the North-East  
Indira Gandhi Regional Institute of Medical Sciences  
in the Umbah Basin



4.2 *Bun* Cultivation



4.3 Deforested Landscape



4.4 Quarrying of Quartzites



4.5 Quarrying of Sandstones



4.6 Smoke Emission from Old Vehicles



6.1 Timber Logging



6.2 Quarrying Activities at Demthring



6.3 Water Pollution



6.4 Water Stagnation Due to Accumulation of Gravels



6.5 Landslides on a Hillside Facilitated by Quarrying



6.6 Landslides Near the Stream



6.7 Solid Waste Dumps at ĩewduh



6.8 *Bun* Cultivation on Steep Deforested Landscape



6.9 Deforestation and Growth of Settlement at Mawpat



6.10 Quarrying of Quartzites at Demthring Water Source



6.11 Construction of Office Complex at Lapalang Water Source

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