

# RIVER BASIN MORPHOLOGY



Hijam Ibeyaima Devi

The study analyses the geomorphological characteristics of the Iril River basin, which has a complex and intricate drainage system with varied rock types well exhibited by the interaction of the underlying folded structure and tectonics under the multiple cycles of fluvial erosion. The landform evolution and the geomorphological characteristics of the river basin have been analysed in the book with a focus on the land capability of the various landforms. It further outlines an integrated watershed management approach for the balanced development of the basin and its inhabitants.

Of absorbing interest and importance for the geomorphologists, geographers and earth scientists as well as planners.

**Rs. 300.00**

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Hijam Ibeyaima Devi



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## PREFACE

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The geomorphological studies have wide applications in planning and management of agricultural and horticultural landuses, crop selection with reference to soil quality and irrigation facility, development of transport and communication, industry and settlement etc. in addition to its importance, in its own right, as a well defined branch of earth sciences.

The present study of geomorphology of the Iril river basin is a modest attempt to explain the actions of running water affecting the features of the landscape termed popularly as fluvial geomorphology. The analyses of the basin characteristics reveal various litho - structures and processes of landform evolution, both natural and human induced. The basin morphometry hints at a dynamic combination of various agents *viz.*, neotectonism, intensive monsoon rain under a subtropical climatic regime and unscientific landuse practices, acting in concert to cause the evolution of a variegated polycyclic landscape in the Iril basin.

In view of the rapid progress of land degradation due to erosion of topsoil from the denuded hill slopes of the catchment, a number of landuse changes have been suggested for the Iril river basin. The size and features of the basin are ideal for its adoption as a model watershed for spatial integration of various developmental components.

I express my deep sense of gratitude to Professor R.P.Singh, ex-Head, Department of Earth Sciences, Manipur University for his guidance, supervision and unceasing encouragements during the course of my investigation. I thank him also for providing me the facilities available in the Department during my study.

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## INTRODUCTION

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The present treatise is concerned with the study on the complex fluvial geomorphological aspects of Iril basin within the Manipur basin. River Manipur is a tributary of the Myittha river of the Chindwin-Irrawaddy drainage basin of Myanmar (Burma). The Iril river originates from the south - eastern slope of the Hougdu Ching range in Ukhrul district of Manipur at a height of 2473 m. above the mean sea level (MSL) and flows over the unstable formation of the hilly tract. It is a tributary of Manipur river, which is called Imphal river in its upper part before its confluence with Khuga river. The area covered by the Iril and its distinct tributaries forms a sub - basin of the Manipur drainage basin. In the present study, the Iril sub - basin has been termed as the Iril basin accepting the drainage area as a distinct geomorphic unit. Further, Iril basin is marked by the development of a number of fluvial landforms including micro landforms of the erosional and depositional origins, which present many interesting geomorphological features related to the evolution of a variegated polycyclic landscape. Hence, the term Iril basin has been used instead of Iril sub - basin in the present geomorphological study.

### 1.1 LOCATION

An area of 1,285 sq km, covering the north eastern portion of the upper Manipur basin in the districts of Ukhrul, Senapati, Imphal East and Thoubal, forms the Iril river basin, which lies between the latitudes  $24^{\circ}40'$  N- $25^{\circ}25'$  N and the longitudes  $93^{\circ}55'$  E- $94^{\circ}20'$  E (Fig. 1.1). The total length of the Iril river from its head to the point of its confluence with the Imphal river is 144.5 km. Though the Iril basin covers a small area, it is characterised by a complex and intricate drainage system. The typical features exhibited are believed to have been produced by the interactions of the underlying folded structure, varied rocks and tectonics on the one hand, and varied geomorphological processes specially

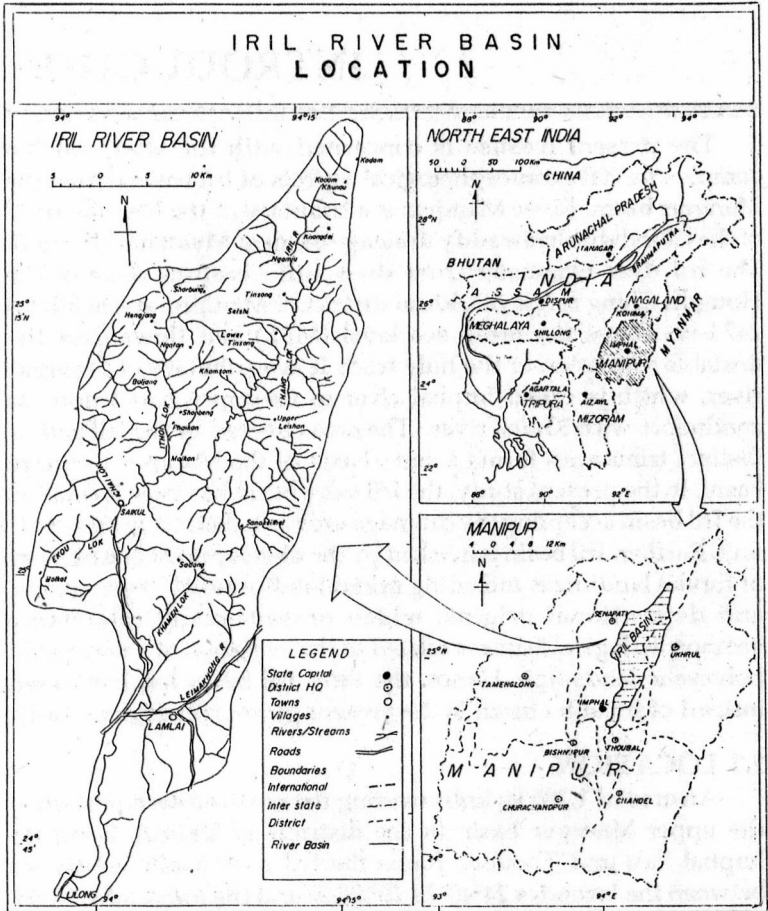


Fig. 1.1

the fluvial processes on the other.

On the west of the source of the Iril river is the water divide beyond which water is drained by the tributaries of the Barak river, which flows along the folds of the western hills of Manipur, forming a tributary of the Ganga - Brahmaputra drainage system, which finally emits into the Bay of Bengal. The long ranges of hills act as the watershed between the Imphal and Barak rivers. Beyond the water divide on the upper eastern part of the Iril river are the small tributaries such as Pei Lok that flows towards Nagaland, the neighbouring state and the Laina Lok which pools its water into Bazaru or Knobari having a big bend towards the western side. The lower parts, beyond the eastern water divide of the Iril, are drained by the small tributary streamlets of Imphal river. From a point between the heads of the Iril and the Barak rivers originate the Imphal river, one of the main rivers of Manipur. It flows southwards and receives the water of the Iril river.

## 1.2 OBJECTIVES OF THE STUDY

The present study of a small river basin in the north eastern part of Manipur state is an attempt in fluvial geomorphological analysis. The existing geological and geomorphological informations on Manipur are not adequate for evolving a valid and acceptable model for the geomorphic evolution of the catchment of the Iril river. Therefore, the present study aims to evaluate :

- a. the stratigraphic set up, tectonic and the structural conditions,
- b. the river basin morphometry,
- c. the variations and inter - relationships of the morphometric parameters of third order drainage basins,
- d. the landscape pattern,
- e. the interpretative account of the development of fluvial landforms and drainage pattern as influenced by the underlying structure and tectonics under the multiple cycles of fluvial erosion,
- f. the magnitude spectrum of the landforms correlating the drainage patterns and the structures, and

- g. the characteristic landuse pattern of the Iril river basin.

### 1.3 METHODOLOGY

The study of characteristics of landforms depends on appropriate map scale and kind of study, and needs clear understanding of the existing structural parameters. The analysis of geomorphological features involves correct interpretation of the information collected from maps and field works. The topographical maps used in the present analysis are Survey of India topographical sheets 83K/3, 4, 7 and 8; 83G/16; 83L/1; 83H/13 and 14 on the scale 1:50,000. The maps reveal the characteristic features of the study area. Topographical maps on this scale show contours at 20 meters interval which omit many minor landforms. Again geological maps of this area, except those of some parts of it, drawn by the Geological Survey of India (GSI) as a part of their field work, are not available. This creates another difficulty for the study of the structure and geology of this basin area. Other data collected for the analysis such as those on rainfall, temperature, humidity, stream discharge and reports on geological mapping are from such sources as the Meteorological Centre, at Guwahati Airport and Irrigation and Flood Control Department, Directorate of Economics and Statistics, Geology and Mining Division of Commerce and Industries Department and Department of Science, Technology and Environment, Government of Manipur.

The analysis of the structural conditions, stratigraphic set up, lithology, geological features, such as folds, faults, joints etc. is based on the geological maps drawn by the GSI. The drainage map of the study area has been drawn with the help of 1:50,000 topographical sheets published by the Survey of India.

The number of confluences, number of streams, length of streams etc. have been counted on the drainage map and shown in separate maps using the choropleth and isopleth techniques.

The isopleth maps show the pattern of the density categories while the choropleth maps depict such categories within bounds of the squares measuring one square kilometer each. The stream line surface map has also been prepared, which indicates the amount of denudation of the land surface. The stream line surface has been obtained by plotting intersections of actual contours and

main stream.

### 1.3.1 MORPHOMETRIC PARAMETERS

Morphometry deals with the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms (Clark, 1966). Drainage or fluvial morphometry, on the other hand, denotes the measurement of geometrical properties of the land surface of a fluvial erosion system. The basic form elements of a fluvial erosion landscape include linear properties such as number, length and arrangement of streams, areal properties like surface area and shape of drainage basins, and relief properties such as relief (magnitude of vertical dimension of landforms) and gradients (slopes) of ground surfaces and stream channels (Strahler, 1964).

According to Horton's Law (1945) and Strahler's system (1952) of stream order and number, the area has been divided into units of hierarchical order of different magnitudes.

#### a. Stream Order and Number of Streams

The number of streams gradually decreases with the increase in stream order. The first step in the drainage basin analysis is the determination of stream order. Stream order is a measure of the position of a stream in the hierarchy of tributaries (Leopold *et al.*, 1964). It offers a quantitative basis for the comparison of the degree of development in the drainage network of comparable size (Horton, 1945). Further, it is obvious that the number of streams is dependent on the type of lithology also.

#### b. Stream Lengths

The total lengths of the stream of different hierarchical orders and their mean values are of great importance in the study of drainage basin. Stream length is a result either of the number of stream segment or of the presence of larger segments. With every increase in stream order, its segment length tends to increase. The average length of the stream of each order in a drainage basin tends closely to appropriate a direct geometric series in which the first term is the average length of the streams of first order and constant factor is order ratio (Horton, 1945).

#### c. Length of Basin

Length of basin suggest the shape of the basin and can also show relative elongation between one basin and another.

**d. Basin Area**

Basin area and the length of streams are significantly correlated. The highest value of 3rd order basin area and the total length explains a significant linear relationship also. If length of stream is plotted against basin area, it tends to follow a distinct trend. It supports the hypothesis that the greater the value of the area, the higher will be the associated value of the total stream.

**e. Basin Relief**

Relief of a basin may be defined as the difference in altitude between the highest and the lowest points. Relief has a close relation with junction angles. Junction angle varies inversely with relief (Lubowe, 1964).

**f. Bifurcation Ratio**

Horton (1945) established a geometrical relationship among stream length, stream number and stream order. According to him, the number of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is the bifurcation ratio. Thus, bifurcation ratio is the slope of the line relating number of streams to stream order (Leopold *et al*, 1964).

The bifurcation ratio ( $R_b$ ) has been worked out as a ratio between the number of streams of a given order ( $u$ ) and the number ( $N_u$ ) of the streams of the next higher order. The following formula has been used to work out the bifurcation ratio :

$$R_b = \frac{N_u}{N_u + 1} \quad \text{Where, } N = \text{Number of streams}$$

$u = \text{Stream order}$

**g. Drainage Density and Stream Frequency**

Drainage density is the length of stream per unit area. It is expressed as follows :

$$D_d = \frac{\Sigma L}{A_d} \quad \text{Where, } D_d = \text{Drainage density}$$

$L = \text{Length of streams}$

$A_d = \text{Area of drainage basin}$

Drainage frequency or stream frequency is obtained by using the following formula :

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

Where,       $F$  = Frequency of streams  
                   $N$  = Total number of streams  
                   $A$  = Area of the drainage basin

#### h. Drainage Texture

The drainage texture means "the relative spacing of drainage lines" (Thornbury, 1957). It includes both the drainage density and the stream frequency (Horton, 1945). It is directly related with drainage density and is influenced by climate, infiltration capacity, mean available relief, geological structure etc.

#### i. Basin Shape

The stream discharge characteristics of a drainage basin can be affected by its shape. The shape of a drainage basin can generally be expressed by :

##### i. Form Factor ( $F_f$ )

$$F_f = \frac{W_b}{L_b} = \frac{A}{L_b^2} \quad [\because A = W_b \times L_b]$$

Where,

$W_b$  = axial width of basin

$L_b$  = axial length of basin

*i.e.* the distance from the measuring point to the most remote point on the basin.

##### ii. Compactness coefficient ( $C_c$ )

$$C_c = \frac{P_b}{2\sqrt{\pi A}} = \frac{P_b}{2\sqrt{\pi(\pi R^2)}} = \frac{P_b}{2\pi R}$$

Where Radius  $R$  of an equivalent circular area is given by  
 Area =  $\pi R^2$ .

Therefore, the value of  $R$  is found out.

- iii. Elongation Ratio ( $E_r$ ) is defined as the ratio of the diameter of a circle of the same area the basin to the maximum basin length (Schumm, 1956). This ratio can be expressed by :

$$E_r = \frac{2R}{L_b}$$

Where  $R$  = Radius of an equivalent circular area which is given by  $\text{Area} = \pi R^2$  and thus the value of  $R$  is found out.

$L_b$  = Length of the thalweg (the distance from the measuring point to the most remote point on the basin).

- iv. Miller (1953) used a dimensionless "Circularity ratio ( $C_r$ )" defined as the ratio of the basin area to the area of a circle having the same perimeter as the basin. This ratio can be expressed by :

$$C_r = \frac{A}{R^2} \quad \text{Where } A = \text{area of the basin}$$

Radius  $R$  of a circle of an equivalent perimeter as the basin is given by,

$2\pi R$  = Perimeter of the basin and thus the value of  $R$  is found out.

### 1.3.2 RELIEF CHARACTERISTICS

Absolute and the relative relief, various elevation groups, landscape profiles, slope categories and intensity of relief form important features of the drainage basin.

#### a. Area Height Curve

The area height curve (or diagram) represents the absolute correlative areas of land between adjacent contours (Clark, 1966). It is helpful in determining the surfaces of a region. Hypsometric curve or hypsographic curve or absolute hypsometric curve is the measurement of the interrelationship of area and altitude (King, 1966). The altimetric frequency histogram deals with the frequency of occurrences of different elevation groups in a region.

#### b. Landscape Profiles

Superimposed, composite and projected profiles of the basin landscape have also been drawn. The superimposed profile brings out surface with different slopes, corresponding to periods of

penetration and reveals significant surface forms. The projected profiles show accordant summit levels and the composite profile shows the surface ruggedness and the general skyline of the landscape.

### c. Slope

The word slope or gradient reflects many factors such as intensity and relative relief, texture and density of the drainage, tectonic structure of the particular region, climate and geology. Maps of relative relief, intensity of relief and slope category of the area have been prepared by using the methods of Smith (1935), Raisz and Henry (1937) and Wentworth (1930).

Intensity of relief has been calculated by finding out the average relief per unit area, *i.e.* per sq. km. According to Smith (1935) relative relief has been calculated by determining the difference in height between the highest contour point and the lowest points in each sq km area. The absolute relief region has also been calculated as the highest point in each sq km area.

Slope categories were determined by the average slope determination method (Raisz and Henry, 1937). Accordingly the total basin area has been divided into small regions, within each of which the contour lines have the same spacing *i.e.* the same number of contour lines per sq km. Another method of average slope determination, formulated by Wentworth (1930) was also followed. Under his scheme, the whole basin was divided into several rectangles for the sake of working convenience. The contour map of the basin area was put under an east - west and north - south transparent grid in metric scale and the total number of contour crossings along each grid line was measured and thus the average number of contour crossings per kilometre was determined. The procedure was repeated using an oblique grid over the same area and the readings of the two operations were averaged. The results were then converted into degrees and the average slope map was prepared based on the data worked out by applying the following formula :

$$\text{Slope in } \tan \theta = \frac{\text{Total no. of contour crossings} \times \text{contour interval}}{\text{Total grid length} \times \text{constant}}$$

$$\text{Average Slope} = \frac{\text{Total no. of contour crossings} \times 100}{\text{Total grid length} \times 636.6}$$

Where the constant 636.6 is adopted for metric system derived as  $0.6366 \times 1000$  (No. of metre in 1 km.) in place of 3361 (derived as  $0.636 \times 5,280$  i.e. No. of feet in mile) in FPS system. The value 0.6366 is the mean of all possible values of  $\sin \theta$  where  $\theta$  is the horizontal angle between the contour and grid line.

#### 1.4 REVIEW OF LITERATURE

The history of geomorphology can be traced back to the days of Greek, Roman and Arab philosophers and historians. However, modern geomorphology is the result of the works of the eighteenth and nineteenth century geologists and hydrologists such as Lamark and Du Buat (Kumar, 1979). However, the man who laid the foundation of modern geomorphology was the first great fluvialist, James Hutton (1795). The eighteenth century Neptunists propounded a very crude theory of erosion, one invoking great floods. But, the nineteenth century Plutonist's theory, according to which valleys originated as upper fissures during mountain upliftments and were only modified in detail by water and the forces of weathering and degradation, gained the upper hand (Hettner, 1928). However, both the theories including that of Hutton and Hettner were rejected by Lyell (1872), who took the features as products of marine action. In England, Greenwood (1857) and Beeta Jukes (1862) put forward the view that valleys had been carved out by the rivers that occupy them by the process which continued over thousands of years (Hettner, 1928).

Davis (1915) was largely responsible for classifying valleys. During the 1920s and 1930s, Walther Penck (1924) and his followers staged a minor revolt against some of Davis' idea and found some adherents (Thornbury, 1985). In the mid 1870s, Powell (1875) introduced the ideas of consequent valleys and later Davis added more nomenclatures which are rarely used nowadays. Powell attempted to classify landform with the help of geologic structures and devoted much attention to stream erosion. No one had ventured before Powell to explain the sculpturing of the land by impact of rain and stream beyond what today we would call late maturity in the geomorphic cycle. Powell recognised that the process of erosion operating undisturbed upon the land, would

eventually reduce it to a lowland somewhat above the sea level (Thornbury, 1985). Research on the relationship between geomorphic processes and resultant landforms was revived by Reiche and Keller for evaluation of the process of weathering; Hjultrem and Sundborg for fluvial action; Krumbein Zenkovich and King for marine agencies; Lozinski, Highbom and John for studies directed towards processes operating in periglacial environments; Bagnold for aeolian action; Grund, Mortel and Cvijic for karst studies; Zeuner, Pecsí and Budel for terraces in association with periglacial cycles and MacClintos, Martin, Fisk, Bryan, Ray, Hack, Throthwaite, Smith and Condra for climatic geomorphology (Kumar, 1979).

In India, the geologists have to be given credit for initiating research in geomorphology. The work of Arogyaswamy (1967), Auden (1954), Chatterjee (1968), Dunn (1929), Krishnan (1953), Radhakrishna (1952), and Wadia (1937) are noteworthy. Geographers like Bagchi (1960), Chatterjee (1945), Chibber (1953) and Singh (1958, 1969, 1972, 1981) have pioneered work in geomorphology. On account of the adequacy of records and advent of different methods of study a lot of research works by eminent geologists and geographers are in progress. The range of their geomorphological works is now becoming much wider (Chatterjee, 1968, and Vaidyanathan, 1977).

Regional geomorphological studies of different parts of India at the macro, meso and micro levels have been made by geomorphologists. The contributions of Betal (1973), Pathak (1967), Kharkwal (1968), Kumar (1969), Singh (1969), Agarwal (1972), Arunachalam (1972), Singh (1975), Mukhopadhyay (1988) etc. may be mentioned. Many of the scholars have worked on fluvial geomorphology also. Basu (1976) studied some fundamental problems of meander formation with special reference to the Bhagirathi river. Kumar (1971) made significant geomorphic interpretation of the drainage and relief of eastern Ranchi plateau. He also studied the pairwise of basin area and stream length illustration relationship from the upper Burha basin. Kumar and Pandey (1977) made a numerical analysis of small drainage basins of Hazaribagh plateau region portraying their chief characteristics. Singh (1969) discussed the drainage pattern in the highlands of Chota Nagpur and traced their evolution and denudation

chronology. Mache and Peshwa (1978) made an interesting photogeological interpretation of the controls on drainage in Gondwana and Bijawars of the Son valley, Shahdol district, Madhya Pradesh. A few works such as those of Kharkwal (1970), Satpathi (1972), Betal (1973), Sharma and Padmaja (1977), Kumar and Singh (1978) show effective use of quantitative methods in geomorphic analysis.

Studies on floods, meanders, gullies and channel characteristic and slope analysis by Radhakrishna (1964), Niyogi (1968), Mukhopadhyay (1973), Chakraborty and Ghosh (1974), Das (1975), Pal and Bagchi (1975), Basu (1976), Kumar (1976), Dikshit (1976), Mukherjee (1983), and Pal (1983) are important and deserve mention.

Many scholars have also applied the empirical laws derived by Horton (1945), Strahler (1952), Schumm (1956) and Chorley (1969) in the study of drainage basin morphometry. The parameters have mostly been collected from topographical sheets by measuring lengths, breadths, areas etc. Satpathi (1976) has made similar study of the streams of Topa and Sulpi basins of Singbhum., while Singh (1986) has studied the morphological characteristics of some selected river basins of the Middle Narmada Valley.

### 1.5 IMPORTANCE OF THE STUDY

Manipur has remained a "*terra incognita*" so far as geological studies are concerned. The only information available so far are from the accounts of Oldham (1883), Pascoe (1912), Evans (1964) and from the reports of the piecemeal exploratory works of the Geological Survey of India. Most of the works confine to geological explorations and search for minerals. However, the GSI has started studies on geomorphological aspects within the Imphal valley and Loktak lake during the past few years. The main thrusts of the geographical studies so far carried out by various experts confine to political, demographic and economic aspects. While some of the physiographic description of the state have been made by regional geographers like Ansari (1976) and Singh (1982). Mukhopadhyay (1988) has portrayed a broad spectrum of geomorphological features of the landscape of Manipur. But these investigations can, by no means, lead to the micro level geomorphic descriptions of the landforms. Fluvial geomorphology is of paramount importance in the state of Manipur because of the fact

that its surface is heavily drained by a number of intermontane river systems with potentials to bring about rapid changes in the landscape. Exposure of the land to torrential monsoon rain and heat of the sub - tropical to tropical climate on the one hand and the rapid rate of denudation of the watersheds on the other accentuate the rate of landform changes in the state. And such landform changes have tremendous implications in general ecology and environment of the hills and the central valley, the microclimate of the region and above all in the sociopolitical situations of the state. Therefore, geomorphological investigations of different river basins of the state assume importance and claim priority.

It became imperative to consider a myriad of factors before the selection of the present area of study. Nevertheless not many factors can be singled out as influencing the author's choice. The following were considered while selecting the Iril river basin for the present work :

1. The length of the river and the area of its catchment basin are ideal for a work of this nature.
2. Its tributaries and watersheds are accessible from many sides which facilitated adequate ground survey work.
3. The forest cover, land use pattern and human habitations in its catchment and along its course have introduced features representative of various disturbed and undisturbed geomorphic forms of a typical river basin.
4. The river forms the largest tributary to the Manipur river (Chindwin - Irrawaddy system), holding a fairly significant position in the drainage system of the Manipur valley and for that matter, in irrigation and water supply potentials etc.
5. Since no such work on any of the river basins of Manipur has been taken up earlier, the present work is a modest attempt at terrain evaluation, watershed management and landuse pattern.

## 1.6 DESIGN OF THE STUDY

The study is divided into seven chapters. Chapter One, including this section, highlights the conceptual frame of the fluvial geomorphology and introduces the study area - the Iril river basin

and its surroundings, besides presenting objectives, methodology, review of literature and importance of the study. Chapter Two deals with the general geology and structure of the study area, their impact on the landscape under the influence of the past and present day climate. This chapter also describes the soils, flora and fauna found in the area.

An assessment of the drainage characteristics has been presented in Chapter Three, which examines the drainage divides and their evolution, stream order and drainage pattern, stream frequency and confluence points, drainage texture and drainage density of the Iril river basin.

Chapter Four evaluates various morphometric characters of the Iril basin by studying its main tributaries such as Ithoi, Ihang, Ichai, Ekou, Leimakhong and Wari Lok etc. Order, number and length of streams, drainage texture and density, gradient, overland flow and shape of the basin have been studied in this chapter as they are intimately interrelated with each other.

Chapter Five analyses the slope and morphology of the landscape. Various methods of relief and slope analysis have been employed to verify the stability in relation to the ground level. Terrain evaluation, presented in this chapter, through different quantitative and cartographic techniques, portrays the areas of various relief region and process of basin development.

Chapter Six presents the geomorphic regions of the Iril river basin and analyses the land use pattern of the study area. Watershed management strategy for the basin has also been formulated in this part of the study.

Chapter Seven summarises the observations and findings in the concluding part of the study and suggests measures for watershed management and landuse improvements in the basin.

## SUMMARY AND CONCLUSION

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The Iril river basin lies in the north eastern part of the Manipur state. It extends between latitude  $24^{\circ}40' N - 25^{\circ}25' N$  and longitudes  $93^{\circ}55' E - 94^{\circ}20' E$  covering an area of 1,285 sq km. The basin lies within the administrative districts of Ukhrul, Senapati, Imphal East and Thoubal. Iril river originates from the south eastern slope of Hougdu Ching range in Ukhrul district at a height of 2473m above mean sea level and flows through the hill tracts of Ukhrul and Senapati districts and descends to the almost levelled tracts of Imphal East and Thoubal districts in the Manipur valley. It debouches its water into Manipur river (known as Imphal river in its upper part before its confluence with Khuga river), a tributary of the Chindwin - Irrawaddy drainage. Although Iril river basin is a sub - basin of the Chindwin - Irrawaddy system, in the present context it is termed as Iril basin accepting the drainage area as a distinct geomorphic unit. Iril basin is marked by different features of erosional and depositional origin, fluvial landforms and many other interesting geomorphological features relating to the evolution of a variegated polycyclic landscape.

Physiographically the basin is characterised by alternate hills and valleys having sharp crested ridges running NNE - SSW to NE - SW direction. The river is 144.5 km long and flows almost in the middle of the basin. It receives a number of tributaries, some of them being considerably long *viz.* Ihang Lok, Ithoi Lok, Ichai Lok, Ekou Lok, Khamen Lok, Leimakhong and Wari Lok etc.

The Iril basin can be divided into two distinct parts - the hill section and the valley portion. The greater part of the drainage basin lies in the hill section. Geologically the rocks of the basin area belong to formations of different geologic ages *viz.* Recent, Barail (upper Eocene to Oligocene) and Disang (upper Cretaceous to Eocene) The rock types associated with Recent group are alluvium, pebbles and fine soils covering the valley portions. The

Barail group of rocks are predominantly arenaceous in character with thick beds of sandstone, shale and siltstone mostly occurring at the core of the major synclines with gradational contact and marks of coarse gritty sandstone. The rock types, found in Disang group, are somewhat argillaceous in character with predominance of shale and siltstone. Siltstone beds are relatively not common. The siltstone found in the basin is generally soft and friable in nature. Major part of the basin is covered by the rocks of Disang formation.

This area has a complex history of geological evolution which is indicated by multiple folding, faulting and shearing. Three different phases of folding are observed in the Iiril basin area. The first generation of folding was in the form of localised tight isoclinal to open type of folds with NE-SW trending sub-vertical areal planes and low to moderate plunges. The second generation of folds were in the form of regional anticlines and synclines affecting the formations and showing various types of folding from open asymmetrical to tight symmetrical folds. The third generation of folds came in the form of broad warping, trending almost E-W, characterised by prominent and persistent upstanding feature of sandstone and siltstone in Mungching and the areas north, NE, NW and east of it. Many of the major strike faults have restricted the domain of different phases of folding and have also controlled the topography and drainage of the basin area. The middle part of the Iiril river itself is controlled by major fault *i.e.* the Iiril fault. Some of its tributaries too flow along the fault lines.

The type of index microfossils found in the basin also support the presence of Barail and Disang group of rocks. Landforms such as cliffs, alluvial fans, terraces and erosional surfaces are the characteristic features of the basin which are encountered in course of its downward movement. The valley portion is mostly covered by fertile alluvium, which contains deep silts deposited by the Iiril and its tributaries.

Climatically this basin area enjoys a humid to subtropical monsoon climate. However, this climate largely prevails in the relief region upto 1800m, and the higher regions enjoy more or less a temperate climate. Annual rainfall is sometime as low as 837 mm and sometime as high as 2047 mm and temperature ranges between 1.5° and 37°C.

The main soil types found in the basin area are the ferruginous red gravelly soil which belongs to the non - laterized red soil (*Ultisol*) group containing a good amount of nitrogen phosphate and potash, and the *Entisol*, formed of the materials deposited by river Iril and her tributaries, having grey to pale brown colour and containing a good proportion of potash and phosphate and moderate quantities of nitrogen and organic matter.

The Iril river basin is manifested with drainage patterns like dendritic to sub - dendritic, rectangular or angulate and radial. The river shows three different channel behaviours that is, the upper portion where its course is straight, the middle portion which is angulate in nature, and the lower plain area showing meandering courses. Although dendritic pattern generally associates with homogeneous rock type with little adjustment to underlying structure, in this basin some of the sub - tributaries show more or less straight courses which can be explained as the effect of structural control. Further, as the basin area is typified by folded structures, where evidences of superimposition are found, presence of dendritic pattern is natural. Rectangular or angulate patterns are generally associated with underlying structures, specially of the attributes of joints or faults. Therefore, it may be stated that the course of Iril river is partly controlled by the underlying geologic structure. Radial type of drainage pattern expresses erosional slope of the region. This type of drainage pattern is found at Nongmaiching, south western part of Sanakeithel and western and south eastern part of Saikul area, thus showing the presence of many erosional hill slopes/surfaces within the basin.

As the study of drainage basin reflects the geomorphic features and evolution of landforms, analyses of parameters such as number of streams, number of confluences, length of stream, bifurcation ratio, drainage density, stream frequency and basin area have been made in the present study.

The maps showing number of confluence per sq.km. by using the choropleth and isopleth methods depict the density of confluences expressing three density categories. The highest number is over ten whereas the minimum is less than two. The highest confluence density is found along the south eastern and north western portions of the basin area. The minimum number

of confluence covers 65.40 per cent, moderate 30.09 per cent and high 4.51 per cent of the total basin area. The hydrographic maps, *i.e.*, maps showing number of streams per sq. km. by choropleth and isopleth techniques, divide the basin area into three categories of the drainage texture - fine, medium and coarse covering 1.11 per cent, 66.91 per cent and 31.98 per cent of the basin area respectively. The coarse and medium texture areas are mostly confined to the southern and central portions of the basin. Fine drainage texture corresponds to the area of high relief region. As such, coarse drainage texture reveals the area of low relief. In highly dissected areas the number of streams is higher than that of the confluence points.

The studies about number of confluence and number of streams also help in analysing the texture of dissection, expressed as Thalweg length divided by area, mainly based on the length of streams. Dissection may differ in two areas having the same drainage density for the greater number of streams in one part or the other. Three categories such as fine, medium and coarse index of texture of dissection are defined from the length of stream with reference to its intervening spaces which vary in degrees. The fine or highly dissected areas are almost scattered but confine to some portions of the middle and the south western part of the basin. They cover 12.38 per cent of the total basin area showing texture of dissection index 4 to 6 km thalweg length per kilometre. The medium texture covers 59.14 per cent of the total area, which represent the valley section of the river and the lower relief tracts of the basin.

After comparing the drainage density map and the map for number of streams we can conclude that, (i) the highly dissected area has 12-16 stream per sq km or 4.6 Thalweg length per km, indicating high drainage density; (ii) in dissected areas both minor and major streams are very distinct and the total length of minor streams exceeds the total length of major streams per unit area, thus indicating highly dissected area or the area having fine drainage texture. Drainage texture is also regulated by the rate of rainfall and permeability of the mantle rock. This basin receives enough annual rainfall to run off quickly, thus creating a lot of drainage lines.

By analysing the different properties of the drainage basin we

visualize a clear picture of the basin in connection with the degree of the adjustment among the left and right bank tributaries. Some of the left and right bank tributaries, *viz.* Ithoi, Ihang, Ichai, Wari, Leimakhong and Ekou have been taken into account to analyse their morphometric characters for the understanding of the present and past forms of the landscape. In these basins Ihang (196.25 sq km), Ithoi (237.50 sq km) and Leimakhong (112.03 sq km) are the 6th order streams and Ekou (56.14 sq km), Ichai (69.02 sq km) and Wari (34.97 sq km) are the 5th order streams. By analysing the bifurcation ratios from the above drainage basins, it is observed that the average bifurcation value of this basin conforms to the values calculated by Horton and Strahler. Bifurcation ratios characteristically range between 3.0 to 5.0 for watersheds in which the geologic structures do not distort the drainage pattern. However, in this region, although the average value of each of the stream does not exceed the value calculated by Horton, some of the individual values are higher and some of them are lower, thus indicating that the basin is somewhat distorted by faults and joints. Again, the graph depicting the relation of number of streams of each order to order number shows a marked concavity at the lower end. If all the points were joined, as has been done by Horton, it indicates that geometric progression is not closely observed in the higher orders. We can further conclude that with the increase in order the number of stream decreases and this upholds the Horton's law.

By studying stream frequency of the basins a perfect interrelationship between stream order and drainage texture has been established. The values of stream frequency per sq km are high within the lower stream order which indicates the zone of fine texture. The low frequency values are found within higher order. As the stream order becomes higher, the value of frequency also becomes higher, which indicates the approaching maturity of the basin development. The higher stream frequency value in case of Ihang and Ithoi indicates a higher and more dissected terrain than other basins. Wari Lok has small basin area but the stream frequency is much higher in the first order and less mature in the advance stage, thus indicating higher scarp with dissected terrain. Leimakhong shows the lowest value of stream frequency, thus indicating mature and advance development of the basin in the higher stream order. Among all these basins, Leimakhong is

the most matured drainage basin followed by Ekou Lok.

The study of length of stream with its mean values in relation to order number are of great importance while analysing the drainage characteristics of a basin. As the stream order goes higher the length of stream also becomes higher. The cumulative mean length also shows the same pattern showing progressive increase with increase in order. The lower value of mean length for the first order streams shows that most of them are short and, therefore, indicate more dissected areas.

As estimated by Horton, the length ratio should range between 2 and 3. However, the length ratio of the drainage basin of Iril river do not totally conform to that of Horton. The number of streams is dependent on the bifurcation ratio and increases with stream order while the length per stream is dependent on the stream length ratio. Further, according to Horton, mean drainage area should form a geometric series. The mean stream length and the mean areas of the drainage basins or each order have a geometric relationship between them. In this catchment all the selected drainage basins show close relationship between the stream order and the average drainage basin area.

High drainage density shows high relief region with higher amount of rainfall. Wari basin shows the highest drainage density followed by Ithoi and Ihang. Leimakhong shows the lowest drainage density, thus showing a less dissected and lower relief region. The Ekou and Ichai basins are lower than Wari, Ihang and Ithoi, thus indicating them to be of somewhat lower gradient than the other three drainage basins.

For determining various characteristics such as hydrological regime, physiographical character and erodibility of a drainage basin, length of overland flow is one of the important independent variables. Leimakhong drainage basin shows the highest length of overland flow, which may be due to the dominant valley portion in its basin area. Due to steeper slopes and highly undulating nature of the landscape, the length of overland flow is much lower in the basins of Wari, Ithoi, Ihang, Ekou and Ichai. For observing the nature of run off, surface erosion and drainage network development, the measurement of the constant of channel maintenance is highly required. The Wari, Ihang and Ithoi sub-

basins require the minimum area for the development of drainage channel whereas the Leimakhong sub - basin needs the maximum area for the development of its drainage channel.

The morphology of an area is expressed by the appearance, dimension and magnitude of its slopes. Regional variation in slopes is associated with tectonic movement with high degree of denudational activity besides other factors such as weathering, process of erosion, transportation, etc. which have shaped the slope of the area. Average relief in different categories express the intensity of relief, which can be determined per unit area. In the Iiril basin the highest intensity of relief covers 9.73 per cent, moderate intensity 55.25 per cent and the lowest intensity 35.02 per cent of the entire basin. The area of high intensity is confined to the northern part and moderate intensity almost scattered around the central portion of the basin. The low intensity of relief covers the lower middle portion of the basin and extends upto the mouth part.

The relative relief map of the area expresses the amount of slope and nature of the surface slope. The surface with relative relief ranging from 300 m to 500 m and above covers 23.08 per cent of the total basin area mostly in northern and north eastern parts, showing a highly dissected and undulating topography. Moderate relative relief, between 100 m and 300 m, cover most parts of the basin, *i.e.* 61.51 per cent of the total basin area. It is scattered in the western most part, central and southern parts of the Iiril basin. Mapao Tangkhul and Yasmongjong villages and the southern portion of the basin have moderate relative relief. The lowest relative relief region occupies 15.41 per cent of the total basin area in the southern part around Ihang Karong, Sagolmang, Ekou Bazar and Pukhao area, besides the entire plain sector. Absolute relief can reveal the direct or indirect evidences of the genesis and evolution of the landforms.

The area of absolute relief having the height range of 1000 m - 1200 m has the largest coverage in the Iiril basin. Villages like Shongben, Phaikon, Matakhang, Mollen, Sanakeithel Bunglung Makeng, and Saikul, etc. are situated within this relief region which covers 38.69 per cent of the total basin area.

The lowest relief region with elevation below 1000 m covers

most of the southern part. It has a flat plain terrain and covers 23.01 per cent of the total basin area. The villages Sagolmang, Pukhao, Lamboikhul, Taretkhul, Nongda, Kanglasiphai, Naharup, Irilbung, Urup Arapti and Lilong are all situated within this height range. The height range of 1200 m - 1400 m covers 17.21 per cent of the basin. It is associated with high hills which have the least of human settlements. Of course, some of the villages such as Washangphung Naga, Nurathel, Mongbung, Shorbung Naga, New Ngaton and Old Ngaton, etc. are situated in this region. The region below 1200 m - 1600 m defined as medium high land area, also has some settlements, but the highest altitude zone, with above 2200 m range, has the least area covering 0.41 per cent of the basin. It is associated with high escarpments, dense forests and lack of settlements.

Dissection index of this basin can give an idea for estimating the vertical balance of erosion. The low dissection index covers 15.67 per cent of the total area and is associated with low relief region. The medium dissection index is dominant in the northern and north eastern parts covering 55.46 per cent of the basin area. About 28.67 per cent of the total basin area has high dissection index and is associated with high relief. A comparison of dissection index map with relative relief map also supports the above facts and, therefore, it can be stated that the region above 300 m is well dissected, the region between 100 m and 300 m moderately dissected and the region below 100 m less dissected.

The generalised contour map helps in reconstructing the past features of the land surface. A comparison of the past (reconstructed contour) and present maps reveal that high surfaces in the past have been destroyed by various agents of weathering, erosion, etc. and, therefore, the surfaces which show steep faces today might have been less steeper in the past. The area in between 800 m and 1000 m seems to have gained a lot of land as compared with the past. This may be due to continued destruction by the tributaries of Iril river as well as other agents. The higher surface areas have been worn down, transported and deposited in the lower relief areas. In comparison with the high and lower relief surfaces, the lower surfaces have faced the least destruction and received more areas from the higher dissected and eroded parts. The study of stream line surfaces indicates the amount of

denudation yet to be achieved. By drawing stream line surfaces, it is seen that the eastern and southern highland parts of the basin area are liable to denudation. The medium high and lowest stream line surfaces cover extensively the middle and southern parts of the basin which is an indication of land available for denudation.

By analysing the average slope the study area has been divided into three slope regions :

- |  |               |
|--|---------------|
| a. Gentle slope area                       | 8° and below  |
| b. Moderate to moderately steep slope area | 8° - 20°      |
| c. Steep slope to very steep slope area    | 20° and above |

The gentle slope area covers 6.02 per cent of the total basin area and coincides with low relief region. The moderate to moderately steep slope area covers most of the southern half of the basin forming around 29.73 per cent of the entire basin. The steep to very steep slope area covers 55.41 per cent of the Iril basin comprising mostly hilly and highly dissected tracts.

The study of hypsometric curve and hypsometric integral value reveals the stage reached by a drainage basin and the percentage of mass removed from the basin by different erosional processes. Iril river shows the hypsometric integral value of 37.77 per cent which is little above the rough limit of 35 per cent set by Strahler. However, the overall characteristic features confirm its senility and monadnock phase.

An analysis of area height curve shows that the land between 1900 m and 1600 m presents a sharp diminishing trend, thus indicating intensive erosion and deep dissection. The longitudinal profile of a number of drainages in the Iril basin reveals the break in slope and phases of their life cycles. The Iril river shows three phases in its life cycle during her journey from the source to the mouth. As most of the streams start from the high relief, they grade downward suddenly and attain the balance between erosion and deposition of a matured river within a short span (of journey).

The cross profile of the Iril landscape shows the stages in the cycle of erosion, breaks in slope, terrace formation, accordant of summit level, etc.. Here, six accordants of summit level of 1800

m, 1600 m, 1400 m, 1280 m, 1200 m and 1000 m are distinguished. The study of accordants of summit level shows erosional surfaces at the levels of 1000 m and 900 m and general relief towards NW - SE direction. The undulating hills also show that the maximum part of the basin is dissected. In addition to the cross profile of the landscape, cross or traverse valley profiles have also been drawn and the stage of maturity gained by the Iril river in its course of journey has been visualized.

An attempt has been made to classify landforms on the basis of comparison of the results of different morphological techniques applied to the different tributaries of Iril river and their basins. Five types of landform have been recognised such as :

- (a) High hills
- (b) Dissected hills
  - (i) Highly dissected hills.
  - (ii) Medium high dissected hills.
- (c) Lower valley region intermixed with residual hills, and
- (d) Lower plain region.

Out of 1285 sq km area of the Iril basin, degraded forests cover 51.53 per cent, current *jhum* 32.21 per cent, cultivated land in the valley 14.53 per cent, forest blank 1.67 per cent and the built up land 0.06 per cent. The vast extent of scrub forests have been resulted from widespread *jhuming*, wildfires and indiscriminate deforestation, etc. The lands under current *jhum* are very unproductive and environmentally unstable. The cultivated lands in the valley area are also monsoon fed and in the absense of irrigation facilities these precious lands remain fallow during winter. The too limited extent of built up land indicates less urbanisation and for that matter the backwardness of the area.

Based on the major findings of the study, landuse planning and watershed management of Iril river basin have been attempted and portrayed through maps related to potential areas for land development and spatial planning. Under an integrated approach, various suggestions have been made for treatment of degraded forests, agricultural lands and wastelands, etc. Subsidiary occupations for the local inhabitants have been identified for their

economic rehabilitation.

Large scale afforestation of the hills with timber species in upper reaches and timber, firewood and fodder species in the height range 900 - 1800m has been suggested. This must go concomitant with the practice of selective logging by banning the indiscriminate tree felling operation by the contractors.

For treatment of the degraded *jhumlands* toposequencing of crops as forest - silvipastoral horticultural - terrace cultivation downhill with various soil and water conservation measures like contour bunding, terracing, check dams, water storage cisterns, etc. have been suggested on the hill slopes between 7° and 17°.

For enhancing the yield of the wet agricultural fields in the slope range 0 - 6°, certain measures like minor irrigation, scientific rotation of crops and modern inputs like HYV (High Yielding Variety) seeds, fertilizers and pesticides have been suggested.

Reclamation of different kinds of wastelands as degraded hillslopes, undeveloped piedmont areas and the derelict wetland of Phaknung *Pat* has been proposed with the identification of appropriate landuses. These wastelands can be put to pasture development with scientific range management strategy. It has been suggested for combating the harmful effect of grazing.

Sustainable development of tribal economy can be achieved through subsidiary occupations. Therefore, livestock farming, piggery, poultry, mushroom cultivation, pisciculture and beekeeping along with various agro - based small scale industries like dairying, fruit processing, cane and bamboo works, dehydration and canning plants and rice mills have been proposed at certain vantage points.

An intensified community development programme with special components like adequate food storage system, better communication, efficient biomass energy exploitation devices, improvised agricultural and farming tools, literacy drive, environmental education, etc. have been proposed for the overall economic prosperity of the people in the river basin.

Iril river basin can be a model watershed for adoption of scientific management for environmentally sound economic development.