**The Indian Geographical Journal**
Volume 96 (2) December - 2021, pp 65-83
ISSN 0019-4824

# MORPHOLOGICAL CHARACTERISTICS OF STREAMS IN EXTREME HUMID AREAS - A CASE STUDY OF THE UM-U-LAH WATERSHED, CHERRAPUNJEE

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**Abstract**

The morphological characteristics of streams are an essential aspect of all the hydrological and geomorphic processes that occur within the watershed. The present research tries to understand the morphological characteristics of the Um-U-Lah Stream, an initial stream situated in Cherrapunjee, is well known for receiving the highest rainfall in the world. Various morphological characteristics and morphometric analysis were computed using a GIS environment and manipulated for different calculations. The analysis reveals that the total number and length of the stream is maximum in the first order and decreases as the stream order increases, and the bifurcation ratio between different successive orders is almost constant. The sectional and sub-sectional division of the longitudinal profile shows a rapid changes in the stream morphology (rapids, potholes, Knick points, pools, riffles, and exposed bedrock), reflecting the influence of tectonics and structure in this area.

***Keywords :*** Stream, Stream morphology, Extremely humid areas, Climate, Rainfall.

## Introduction

A river or a stream is a body of flowing water in a channel, and its action is the most ubiquitous landscaping agency. The two basic generalisations about rivers were realised long before geomorphology emerged as an organised science. Streams form the valleys in which they flow and every river functions as a significant trunk segment fed by several mutually adjusted branches that diminish in size away from the main stem. It is generally assumed in fluvial geomorphology that the influence of climate on river morphology is through the magnitude and frequency of flood events, and the same magnitude can have a differing impact depending on the state of the channels. (Huckleberry, 1994; Hooke, 1996).

Morphometric analysis of a watershed provides a quantitative description of the drainage system, an essential aspect of characterising the watershed (Strahler, 1964). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many rivers' basins and sub-basin in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahlar, 1957, 1964; Krishnamurthy et al., 1996).

Morphological characteristics of the river are the intricate components of the river system; such characteristics, in turn, influence the hydrological response and river morphology downstream. The river morphology is determined by the valley topography and the characteristics of the river basin (geology, soil, mechanical properties). The shapes and patterns of the rivers are the results of a long history of climate change, tectonic activities, land use, and human interference. Investigating river morphology and its linkages to the catchment's physical condition provides a holistic understanding of the geomorphology and hydrology of the river system, high and low land and linkages observed in terms of channel morphology, flood, channel stability, and riverine ecology (Van Appledorn et al., 2019).

The research problem here is to understand the morphology of the Um-U-Lah Stream; an initial stream in one of the world's heaviest rainfall regions. An understanding of the structure and function of morpho-dynamics requires an analysis of not just the channel itself but of the catchment environment as well (Krzemien et al., 1999). The morphological characteristics of a river reach are a dynamic equilibrium between upstream sediment input, discharge regime and grain sizes composing the bed of the reach. A natural or artificial modification of one of these factors can produce changes in channel form at the point of the perturbation and potentially affect several kilometres downstream and even upstream by the consequence of backwater effects. The resulting transformation of the bed is the morphological adaptation toward another dynamic equilibrium corresponding to the new conditions (Benjamin et al., 2010).

Kale (2002), in his paper, emphasised that the rivers of India reveal specific unique characteristics because they undergo large seasonal fluctuations in flow and sediment load. Furthermore, the reproductive success of salmonoids and other riverine communities is influenced by the size of the sediment eroded from and deposited on the channel bed and banks (Montgomery et al., 1996). Channel morphology, a significant component of a river system, is a result of these factors. These factors can be divided into those that are enforced on the watershed (i.e., independent) and those that adjust to the enforced conditions (i.e., dependent) (Hogan and Luzi, 2010).

Stewardson (2005) stated that the variation in the river hydraulic geometry through the stream networks is central to the problem of catchment management. The river hydraulic geometry through the stream networks influences the flow and sediment routing, physical habitat and channel flood plain interaction, and the general definition of hydraulic geometry is a series of functions (normally power function) relating to channel width, water depth and mean velocity at a specific channel cross-section to discharge. Finnegan et al., (2005) applied the Manning equation and basic mass conservation principles to derive an expression for scaling the steady state, width of a river channel as a function of discharge, channel slopes, roughness, and width to depth ratio. Factors other than the character of sediments can affect the cross-sectional shapes of the channel (Millar, 1991). For example, the root system of riparian vegetation distinctly decreases bank erosion and controls channel width. In contrast, large trees that fall across the channel may increase bank erosion.

The main objective is to study the morphological characteristics of the Um-U-Lah Stream that flows down the channel would help to understand the river processes and prescribe countermeasures to address soil conservation and watershed management, flood, bank erosion, and channel avulsion problem.

**Methods and Materials:**

The study aims to understand the morphological characteristics and the processes that change the river morphology. The basin and morphological variables used in the study were derived from the Topo-sheet No: 78/O/11/SE and satellite imageries available on Google Earth, digital elevation models, and relevant maps. Further, various morphological characteristics and morphometric analyses were computed using map info software and Microsoft Excel to understand the drainage basin's geo-hydrological characteristics of the terrain, features, and flow pattern.

The Um-U-Lah stream is divided into six major sections and 31 minor sub-sections, and a cross-section of each section was surveyed. The different attributes of the stream, namely the channel shape, size, width, depth, and channel pattern, were measured and recorded using numerous instruments such as the laser distometer was used to measure the width of the river channel in the different sub-sections, the Schmidt hammer was used to measure the hardness of the rock surface at various sections and sub-sections of the Um-U-Lah Stream. The measuring tape was used to measure the length of the river from one sub-section to the other of the Um-U-Lah stream to observe the morphological characteristics of streams in extremely humid areas. The results gathered from the field survey are finally compiled and interpreted along with other relevant reports, research papers and documents.

**Regional Settings:**

The area chosen for the current work is a micro watershed locally known as Um-U-Lah located in Cherrapunjee, which stands on the southern slope of the Meghalaya plateau, facing Bangladesh. The area extends from 91.715045° east to 91.729592° east longitude and 25.284860° north to 25.268677° north latitude (Singh and Syiemlieh, 2010) and falls under the jurisdiction of the Shell-Bholaganj Community and Rural Development (C&RD) Block. The area experiences an extremely humid climate with a distinct wet season and is famous for receiving the heaviest rainfall globally. According to recent reports, the annual rainfall in Cherrapunjee is about 8101.99 mm in 2021. It has also been recorded that the highest rainfall occurs mainly in July that is greatly influenced by the southwest monsoon. The area has been deeply eroded by water due to incessant rainfall giving rise to a rugged topography and unique topographical features.

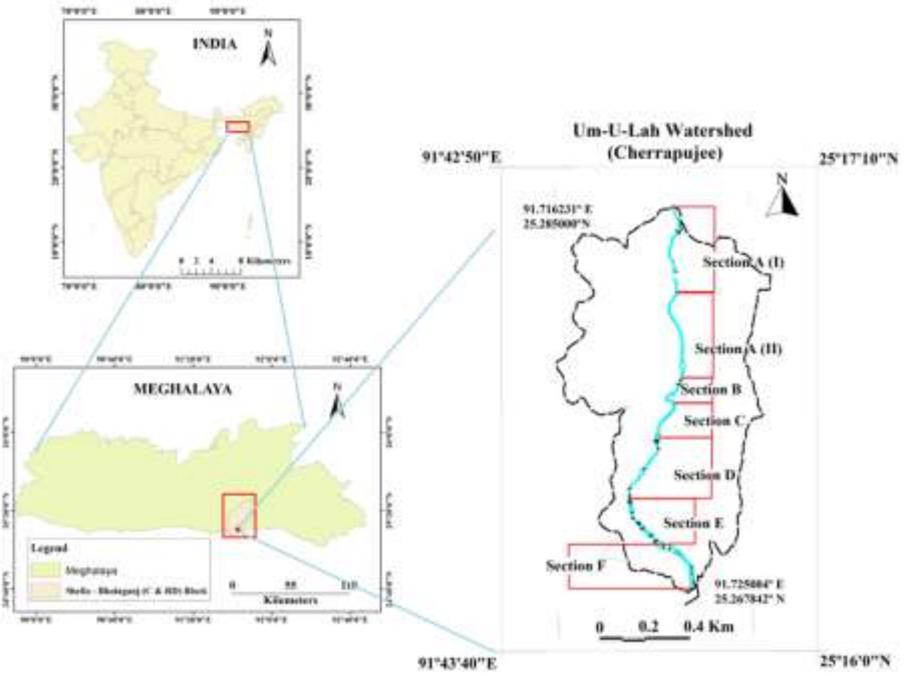


**Figure 1: Location Map of the Um-U-Lah Watershed**

## Results and Discussion:

The Um-U-Lah stream follows a dendritic drainage pattern, which is considered the most common drainage pattern found on the earth's surface. The Um-U-Lah watershed has about 18 steams in the fourth order sprawled over an area of 1.025 km, as shown in figure 2. The first order stream constitutes 7.8 per cent; the second order is 6.82 per cent, the third order is 1.95 per cent, and the fourth order is 1.075 per cent, respectively, showing a decrease in the stream frequency as the stream order increases, which indicates lower the order the higher the number of streams. The highest frequency can be attributed to flat topography and small ridges with numerous tributaries and distributaries. The Drainage Density is the highest in the first order, as shown in table 1 and decreases with increasing stream order, showing an increase in stream population concerning increasing drainage density and vice versa. Further, the highest bifurcation ratio shows the highest overland flow and discharge because of the stream's geology and lithological development.

With the help of the Topo-sheet No: 78/O/11/SE, satellite imagery, map-info software and the longitudinal profile of the Um-U-Lah stream are generated, which is seen to be slightly concaved (figure 3) that is still far from the ideal profile of equilibrium. Further, it is seen that the longitudinal profile of the stream is moderately irregular, where two knick points are observed along with the profile.

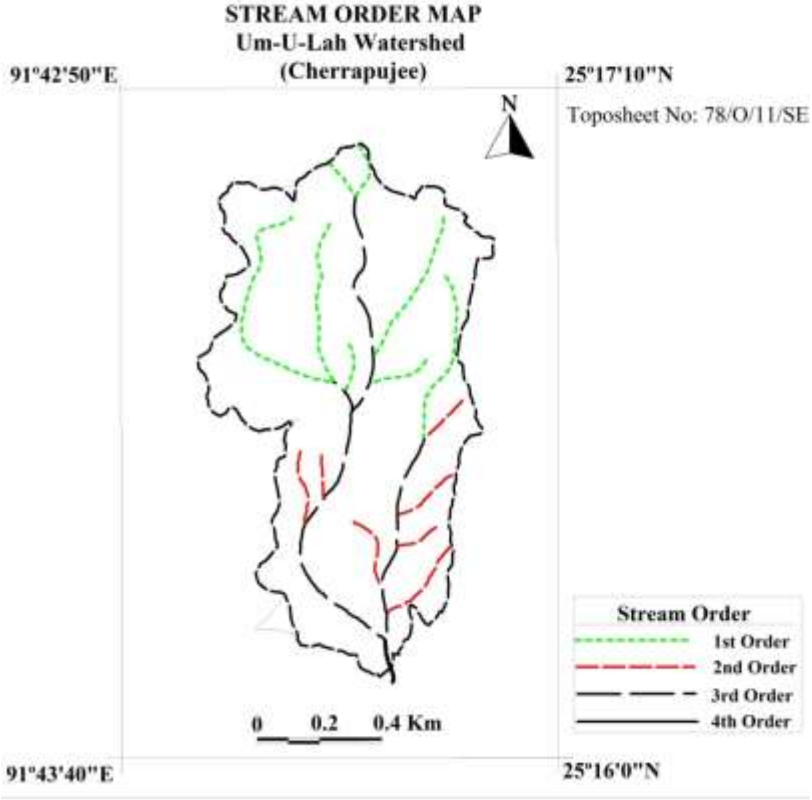


**Figure 2: Stream Order Map of the Um-U-Lah Watershed**

**Table 1. The Um-U-Lah Watershed Characteristics.**

| **Um-U-Lah Watershed Characteristics** | | | | | |
|---|---|---|---|---|---|
| **Stream Order** | **1** | **2** | **3** | **4** | **Total** |
| **No of Stream** | 8 | 7 | 2 | 1 | 18 |
| **Stream Length** | 3.215 | 2.135 | 1.791 | 0.0529 | **7.1939** |
| **Percentage of Stream Length** | 44.69 | 30.42 | 24.89 | 0.73 | **100** |
| **Drainage Density** | 3.13 | 2.08 | 1.74 | 0.71 | **7.66** |
| **Drainage Frequency** | 7.8 | 6.82 | 1.95 | 1.075 | **17.645** |
| **Bifurcation Ratio** | | 1.4 | 3.5 | 2 | |

The longitudinal profile of the Um-U-Lah stream shows an interrupted profile, especially in the upper part of the stream, with a steep gradient and dense vegetation cover. However, the stream's longitudinal profile becomes more clearly defined in the lower part of the stream, where the stream flows through grasslands and flat lands. The morphological characteristics of the Um-U-Lah stream vary from one section to the other.

The majority of the slope gradient in the area ranges between 10°-18°, with only a few areas falling under the slope gradient between 45°- 90°. Further, each section and sub-sections of the stream are characterised by varying channel width, depth and pattern and accompanied by potholes, ripples, knick points, human interference, etc., which affect the water discharge and stream equilibrium resulting in aggradation or degradation. Similarly, the river bed level changes because of the changes in land use, catastrophic floods, and tectonic or neo-tectonic activities.

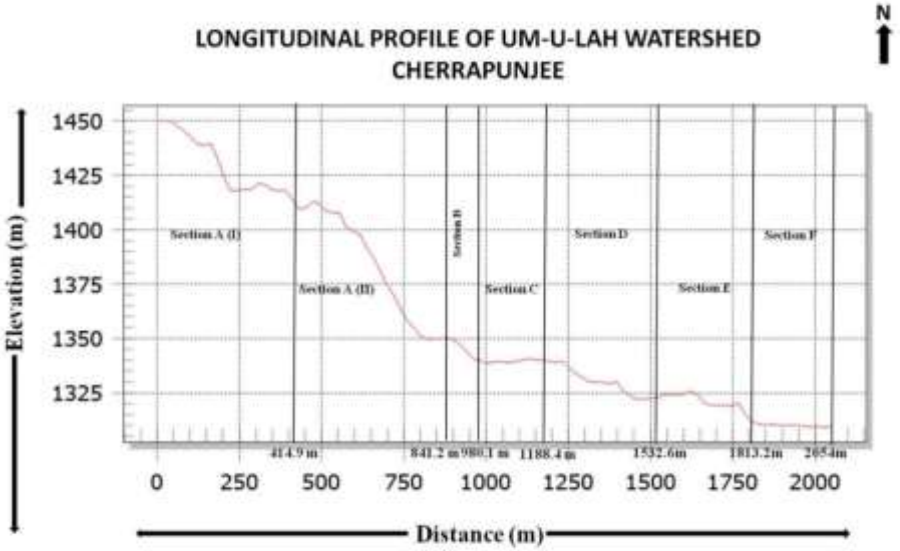


**Figure 3: Longitudinal Profile and Cross Section of the Um-U-Lah Watershed**

In the study area, the Um-U-Lah stream shows diverse morphological characteristics. The operation of the exogenetic forces at different rates over a long period has widened the channel pattern and increased the depth, width, and sinuosity, especially in the lower course of the stream. The effect of bank erosion has increased the width of the channel pattern and the sediment discharge. In such an extremely humid region, weathering also plays a significant role in influencing stream morphology. The combined effect of exogenetic forces has created a variation in the rock structure and the rock hardness. The rock hardness in this region varies from 34 to 69 R-Value (Rebound Value), which indicates that the softer and exposed rocks are easily eroded by weathering agents leaving the harder rocks behind.

The Um-U-Lah Stream is divided into 6 major sections and 31 sub-sections, and a detailed analysis of the different morphological characteristics such as the channel shape, size, width, depth, and channel of the stream are done on a section basis. Further, the morphological attributes of the different sections and sub-sections of the Um-U-Lah stream are discussed below:

**Section A (I)**

This section is the source of the Um-U-Lah stream and is further subdivided into five sections ranging from 1 to 5. Numerous small rivulets from high elevated areas joined together to form the youthful stage of the stream. Here, the stream emerges from a drain and spring, and it was modified by people for lucrative purposes. The length of the stream in this section is 414.9metres and has a moderate to moderately steep with a gently steep longitudinal profile. The general elevation of this section varies from 1410 meters to 1450 meters.

All the slopes of sub-sections vary from moderate to moderately steep, and the degree of slope ranges from 8° to 15°. There is no uniformity in the slope profile to slope angles from the hilltops to the floors of the valley in the different sub-sections. The longitudinal profile of the stream in different sub-sections is straight, but it varies significantly as the channel pattern becomes steep and flows downwards. Further, the longitudinal profile of sub-section 1 and 2 is straight and flat. Sub-sections 3 to 5 have a straight, gently sloping longitudinal profile. The length of the stream in sub-sections 1, 2, 3 and 5 varies from 1 meter to 100 meters. However, the length of the stream in sub-section 4 is considered the highest at 201.7 meters.

The channel width of this section ranges from 1.5 meters to 3.6 meters. As the channel moves downwards according to the pattern of the stream, the width tends to increase. The channel width increases mainly due to lateral erosion during the rainy season, and bank erosion is seen to be an essential feature seen along with the channel pattern in this section. In sub-sections 4 to 5, the width has increased to 3.4 meters and 2 meters due to the joining of a small rivulet from a nearby area.

The channel depth of the stream varies considerably from one sub-section to another. On one hand, sub-sections 1, 2, 4 and 5 have a channel depth of 1 meter; on the other hand, sub-section 3 has a depth of 1.5 meters. The depth of the channel is accompanied by cobbles and a small number of sand deposits brought by the stream during the rainy season.

The channel pattern of the stream in the different sub-sections is straight except for sub-section 3, where it is slightly sinuous towards the right. The river bed in this section remains dry except for sub-sections 1 and 2, where a small quantity of water flows due to human affluence. However, water in sub-sections 3, 4, and 5 flows only during the rainy season.

The people residing near the source significantly affect the stream in this section. Modifying the spring that is the source of stream and dumping different kinds of human wastes have affected the health of the stream and disrupted the ecosystem.

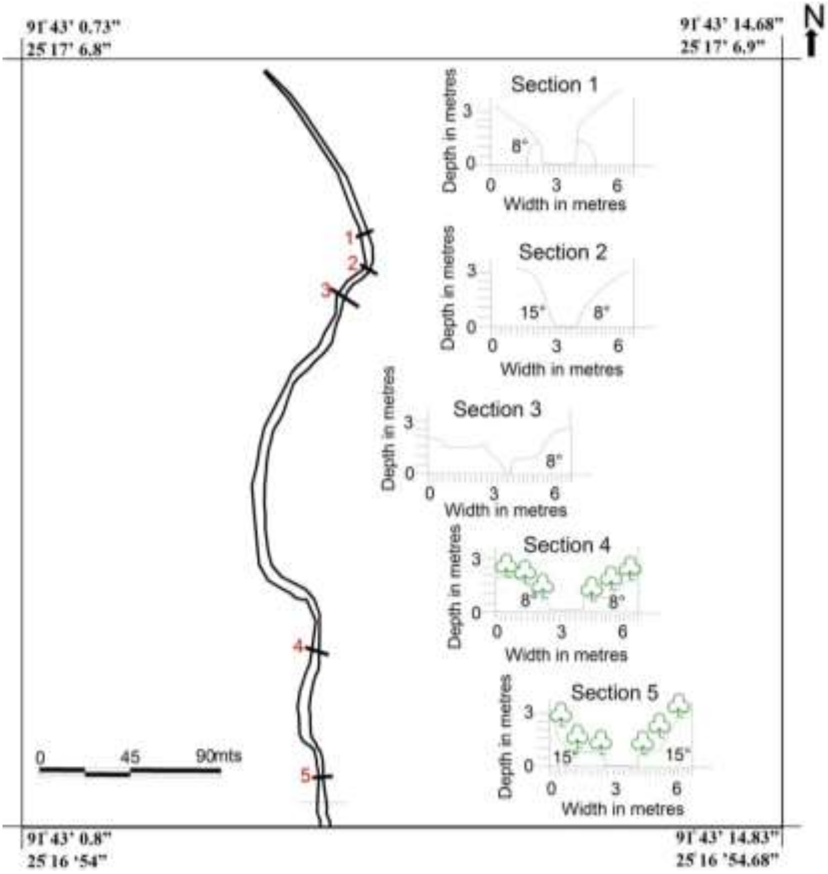


**Figure 4: Section A (I) and sub- sections of the Um-U-Lah Stream**

## Section A (II)

Section A (II) is divided into two sections: 6 and 7. The length of the stream is about 32.9 meters and has a straight and gently sloping longitudinal profile. The lithology of this section is composed of sedimentary rocks, primarily shale and sandstone, having different degrees of hardness. The slope in this section is different from one sub-section to another sub-section. This section has a moderate to moderately steep slope with a 10° slope in sub-section 6 and a 15° slope in sub-section 7.

In both sub-sections 6 and 7, there is hardly any change in the longitudinal profile. The length of the stream in sub-section 6 cannot be attained due to the inaccessibility and very steep slope of the area. However, the length of the stream is measured only in sub-section 7, where it is 32.9 meters. The channel width of this section varies from 4 meters to 5.5 meters, and it increases downwards according to the pattern of the stream flows. The width of the channel in sub-section 7 is 4.6 meters, and in sub-section 7, it is 5.1 meters, respectively.

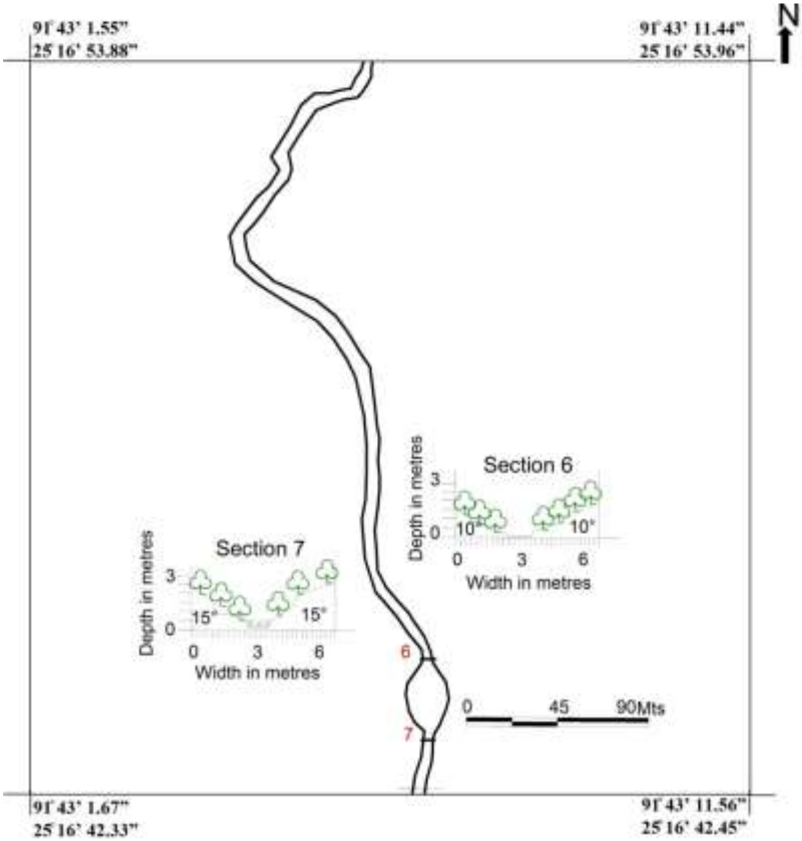


**Figure 5: Section A (II) and sub- sections of the Um-U-Lah Stream**

The channel depth of sub-section 6 is 1 meter, and in sub-section 7, it is 2 meters. The channel depth of this section is accompanied by boulders, cobbles, pebbles and a small amount of sand deposit brought by the stream during the rainy season.

The channel pattern in sub-section 6 is straight, while the channel pattern in sub-section 7 is sinuous. The variation in the channel pattern is due to the flow and discharge of the stream. The channel pattern in this section is accompanied by different erosional features of the stream, such as rapids, potholes and an alternate sequence of pools and riffles.

**Section B**

A moderately steep slope is characterised in section B. The stream length in this section is 138.9 meters, and the longitudinal profile is straight. This section is mainly composed of sandstone, shale, rocks, boulders, cobbles and pebbles of different sizes and shapes, which are the attributes of this section.

The slope of the different sub-sections in this section varies from moderate to moderately steep. The degree of slope varies from 10° to 18°, and no uniformity is observed in the slope profile. The slope is convex in different sub-sections except in sub-section 10, where the slope is concave.

The length of the stream in different sub-sections has been measured and varies significantly from one sub-section to another. The sectional division of the sub-section greatly determines the length of the stream. The stream length in different sub-sections ranges from 50 meters to 60 meters, except for sub-section 10, where the length of the stream is only 30.7 meters. Under the influence of the channel pattern and the stream's direction of flow, longitudinal profile of the stream in sub-section 8 and 9 are straight and slightly steep. However, the longitudinal profile of the stream in sub-section 10 is straight and gently sloping that allows bed-load transportation downstream.

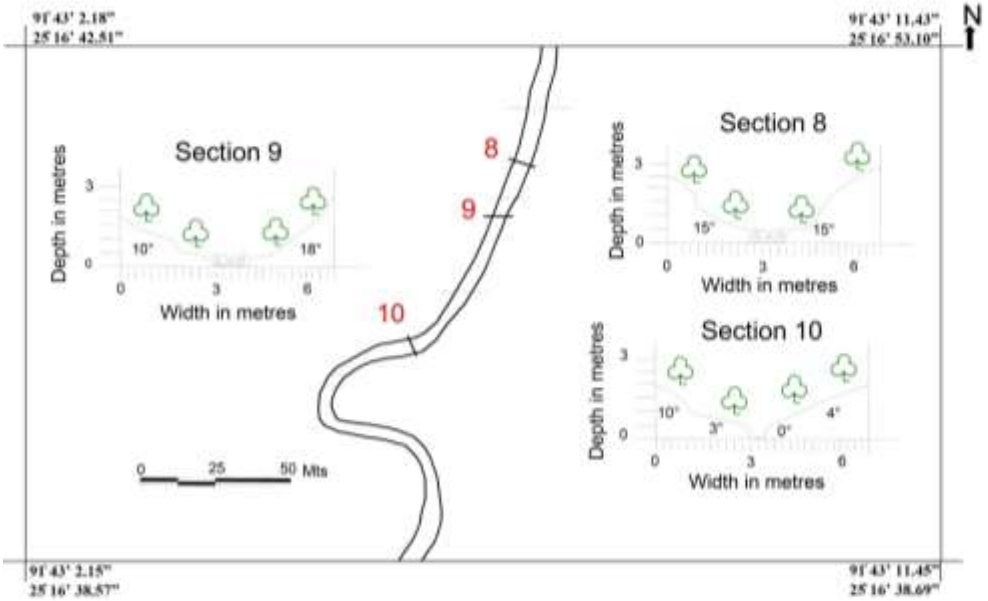


**Figure 6: Section B and sub- sections of the Um-U-Lah Stream**

The channel width in this section ranges from 5 meters to 5.9 meters. It has been observed that the width of the channel increases slowly from one sub-section to another sub-section.

The channel depth varies from 0.7 meters to 1.8 meters, and the channel depth in sub-sections 8 and 9 ranges from 1 to 2 meters, respectively. As the stream flows downwards to sub-section 10, characterised by a plain topography, the channel depth has decreased considerably to 0.7 meters. The channel depth of this section is accompanied by boulders, cobbles, pebbles and sand deposits.

The channel pattern in this section varies significantly from one sub-section to another. As the stream flows downwards, sub-section 8 and 9 are characterised by a straight channel pattern, and sub-section 10 is slightly sinuous. The channel pattern in this section is accompanied by the different erosional features such as riffles, pools, potholes and rapids. Variations in river beds have been observed in sub-sections 8 and 9, while in sub sections 10, a small volume of water flows through the channel.

Further, human interference can also be seen in this section, particularly in sub-section 10 where the people use the stream for different purposes, such as washing clothes and vehicles, which have deteriorated the water and the stream ecosystem.

**Section C**

Section C is characterised by plain topography, gentle slope, potholes, knick points, rapids, cobbles, pebbles, and fine and coarse sediments. The length of the stream in this section is 203.8 meters and has a straight longitudinal profile. The slope in section C is moderate and ranges from 2° to 10°; however, the degree of slope is not constant, and it changes from one sub-section to another. The slopes in sub-section 11, 13 and 14 are convex, whereas the slope in sub-section 12 is concave.

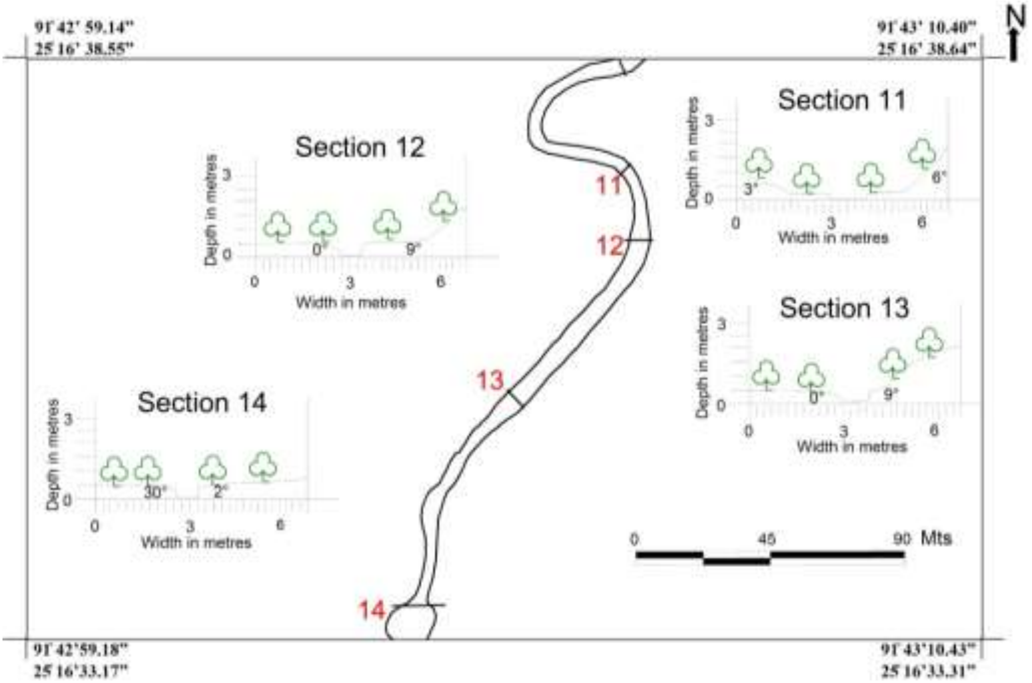


**Figure 7: Section C and sub- sections of the Um-U-Lah Stream**

In sub-sections 11 and 12, the length of the stream ranges from 1 meter to 50 meters. Similarly, in sub-sections 13 and 14, the length of the stream ranges from 50 meters to 100 meters. The longitudinal profile of sub-sections 11 and 12 is straight, while the longitudinal profile of sub-sections 13 and 14 is straight and gently sloping. Such variation in the longitudinal profile is mainly due to the flow direction and the channel pattern of the stream.

In this section, the stream's width ranges from 4.2 meters to 7 meters and varies from one sub-section to another. The channel width of the stream is high in sub-section 12, where it is 7 meters and is low in sub-section 11, where it is 4.2 meters. The channel depth of the different sub-sections that have been measured varies considerably. Sub-sections 11, 13 and 14 are characterised by similar channel depths ranging from 1 to 1.5 meters. However, in sub-section 12, depth of the channel is not deep; it is only 0.25 meters. Under a plain topography, cobbles, pebbles and sand deposits are found at regular intervals in the different sub-sections. Further, the channel pattern of sub-section 11 follows a slightly sinuous pattern, while a straight channel pattern is observed in sub-section 12 to 14.

**Section D**

Section D is characterised by a plain topography, gentle precipitous slope and knick points. The length of the stream in this section is 344.2 meters, and this section is mainly composed of sandstone and shale. This section has a straight and steep longitudinal profile. The general elevation of the area varies from 1320 meters to 1340 meters.

The slope of all the sub-section varies from gentle to steep, and the degree of slope ranges from 2° to 90°. In sub-section 15(a), the degree of slope is enormously high, precipitous and vertical that varies from 45° to 90°. Such a high degree of slope in this sub-section is due to the presence of a Knick point (waterfall), where the waterfall height is 8 meters. Sub-section 17 also has a high degree of slope, varies from 12° to 90°, and is moderately steep and wall-like. However, the slope in sub-section 15 (b) to 19 varies from gentle to moderately steep slopes ranging from 2° to 18°.

The longitudinal profile of sub-section 15 (a), 15 (b) and 16 is straight and steeply sloping. However, sub-section 17 to 19 has a straight and gently sloping longitudinal profile. The length of the stream in sub-sections 15 (a), 15 (b), 18 and 19 ranges from 1 meter to 100 meters, while the stream length in sub-section 16 ranges from 100 meters to 120 meters. The length of the stream is greater in sub-section 16, where it is 115.6 meters and lesser in sub-section 19, where it is only 9.07 meters.

The channel width of this section ranges from 4.2 meters to 10.4 meters. The variation in the channel width has been observed in the different sub-sections. The channel width is slight similar, although specific changes can be seen. Sub-section 15 (b) has a broad channel width of 10.4 meters, and sub-section 18 has a narrow channel width of 4.2 meters, respectively.

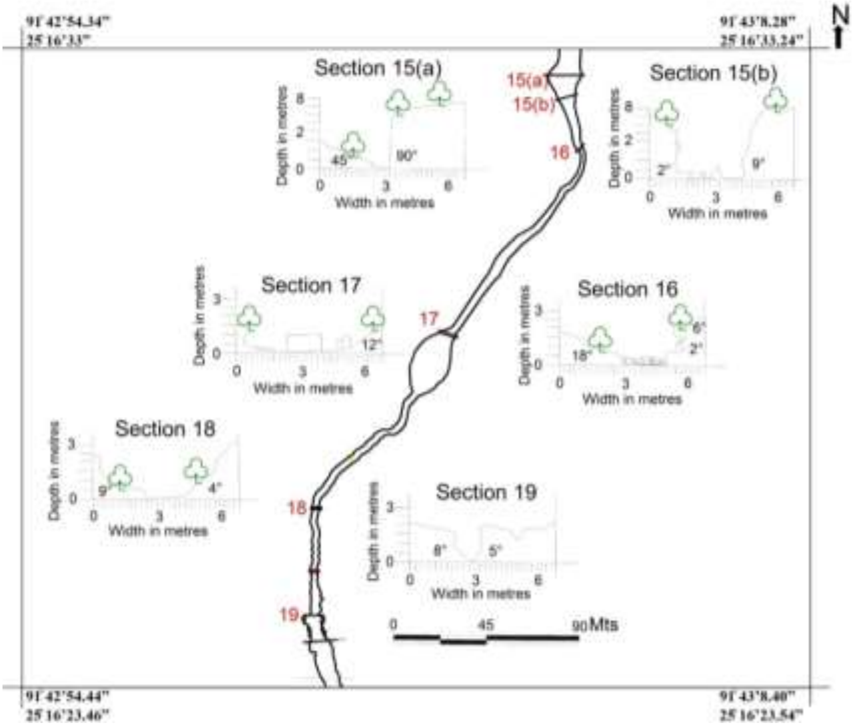


**Figure 8: Section D and sub- sections of the Um-U-Lah Stream**

The channel depth of the stream varies considerably from one sub-section to another sub-section, and it ranges from 1 meter to 9 meters, respectively. The channel depth of sub-sections 15 (a) and 15 (b) ranges between 8 meters and above, on the other hand, the channel depths sub-sections 16 to 19 ranges between 1 meter to 3.6 meters. The channel depth of this section is also accompanied by boulders, cobbles, and fine and coarse deposits.

The channel pattern of the stream in the different sub-sections is straight except for sub-section 16, where it is slightly sinuous. This section is also characterised by potholes, lateral erosion, Knick point, rapids, exposed bedrock and an alternate sequence of pools and ripples.

Moreover, the hardness of the rock has also been measured. The hardness of the rock varies significantly, and the variations are mainly caused by weathering the exposed rocks or by the geologic nature of the area. In sub-section 16, the hardness of rocks ranges from 30 to 38 R-value (Rebound value); in sub-section 17, the hardness ranges from 49 to 60 R-value; in sub-sections 18 and 19, the hardness of the rock ranges from 48 to 64 R-value.

The stream in this section has been affected by the people who are dependent on the stream. Modifying the stream by creating a dam in sub-section 17 has caused instability and disrupted the ecosystem. Furthermore, washing clothes by the people in the stream just below the dam degrades the health of the stream by affecting the flora and fauna species that thrive on it.

## Section E

Section E is characterised by moderate to steep slopes and plain topography. The stream length in this section is 298.6 meters, and the longitudinal profile is straight and gently sloping. The lithology of this section is mainly composed of sandstone, shale, rocks, boulders, cobbles and pebbles of different sizes and shapes, which are the attributes of this section.

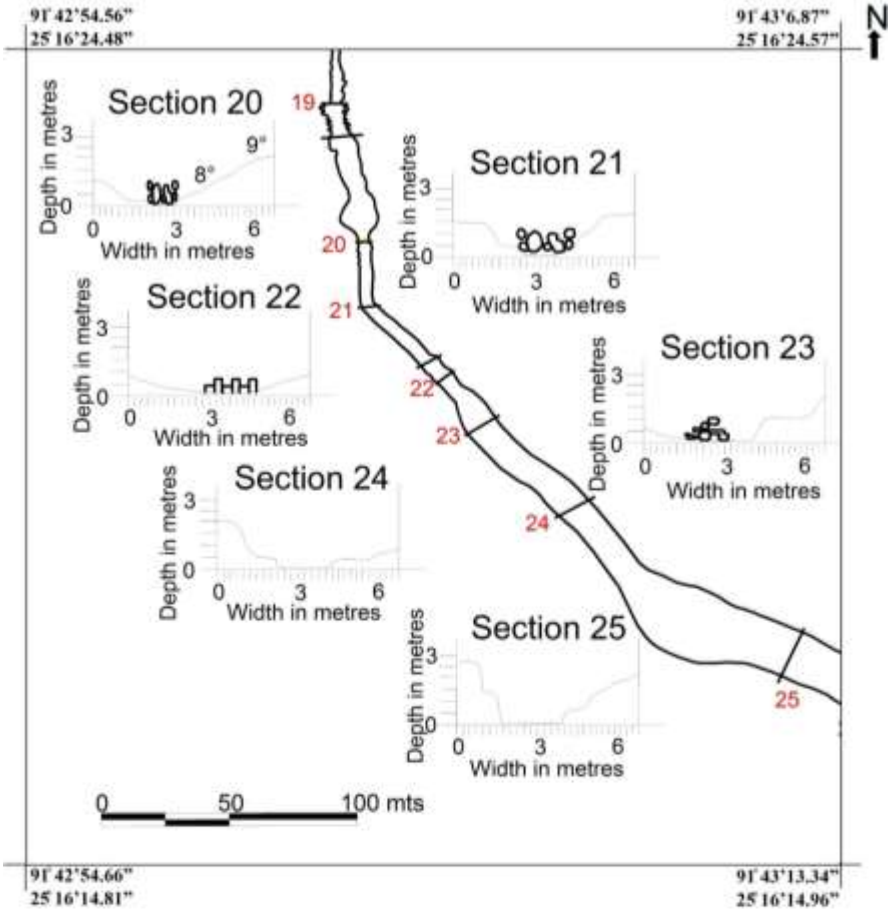


**Figure 9: Section E and sub- sections of the Um-U-Lah Stream**

The slope in this section is different from one sub-section to another sub-section. This section has a gentle to moderately slope ranging from 2° to 25°. As topography changes from hills to plains, the degree of the slope also changes from steep to gentle. The slopes in the different sub-sections are convex and concave.

The longitudinal profile of the stream is straight and gently sloping. However, the longitudinal profile varies from one sub-section to another sub-section. The longitudinal profile of the stream in sub-sections 21-24 is straight and gently sloping, whereas in sub-section 25, the longitudinal profile of the stream is straight and steeply sloping. Sub-section 22 has 24.8 meters, which is the shortest compared to other sub-sections, while the length of the stream in sub-section 24 is 102.3 meters, the longest in this section.

The channel width of this section varies from 7.4 meters to 19 meters, and it increases downwards according to the pattern of the stream flows. The width of the channel is broad in sub-section 25, where it is 19 meters and narrow in sub-section 23, where it is only 7.4 metres, respectively. Hence, the water and sediment discharge greatly influence the width of the stream.

The channel depth in this section varies from 0.25 meters to 1.6 meters. The channel depth of most sub-sections falls below 1 meter, and in sub-section 25, it is 1.6 meters. The channel depth of this section is accompanied by boulders, cobbles, pebbles and a small amount of sand deposit brought by the stream during the rainy season.

The channel pattern in all the sub-sections is straight. The channel pattern in this section is accompanied by different erosional features such as rapids and potholes. Due to low water discharge, the bedrocks are exposed in several sections.

**Section F**

Section F is characterised by plain topography, grasslands, gentle slope and barren rocks. The length of the stream in this section is 222.8 meters, and it is mainly composed of sandstone and shale. This section has a straight longitudinal profile. The attributes of the section are potholes, exposed bedrock, boulders, cobbles, pebbles, and fine and coarse sediments. The general elevation of the area varies from 1310 meters to 1320 meters.

The length of the stream in different sub-sections has been measured and varies significantly from one sub-section to another. The stream length in sub-sections 26 to 31 ranges from 1 to 50 meters. However, the length of the stream in sub-section 27 is above 50 meters. Sub-section 26 has the shortest length of 23.3 meters, while sub-section 27 has the most extended length of 54.6metres.

The sub-sections in this section vary from moderate to moderately steep, and the degree of slope ranges from 3° to 15°. In all the sub-sections of this section, the slope and its degree are similar. However, the nature of the slopes varies considerably from convex to concave.

The longitudinal profile of the stream is similar in all the sub-sections. Being dominated by highly undulating topography, the stream's longitudinal profile in all the sub-sections is straight and gentle sloping.

The channel width of this section ranges from 9.2 meters to 15.9 meters. The variation in the channel width has been observed in the different sub-sections. Sub-section 28 has a broad channel width of 15.9 meters, and sub-section 27 has a narrow channel width of 9.2 meters, respectively. The channel depth of the stream varies considerably from one sub-section to another and ranges from 0.75 meters to 2.6 meters, respectively. Sub-section 31 has a channel depth of 0.75 meters, which is relatively low, and sub-sections 27 have a channel depth of 2.6 meters, which is relatively high in this section. The channel depth of this section is also accompanied by boulders, cobbles, and fine and coarse deposits.

The channel pattern of the stream in different sub-sections is straight and somewhat similar, and all the sub-sections are characterised by potholes, lateral erosion, exposed bedrock, crumbled boulders in the stream bank, bedrock erosion and undercutting of the rock strata.

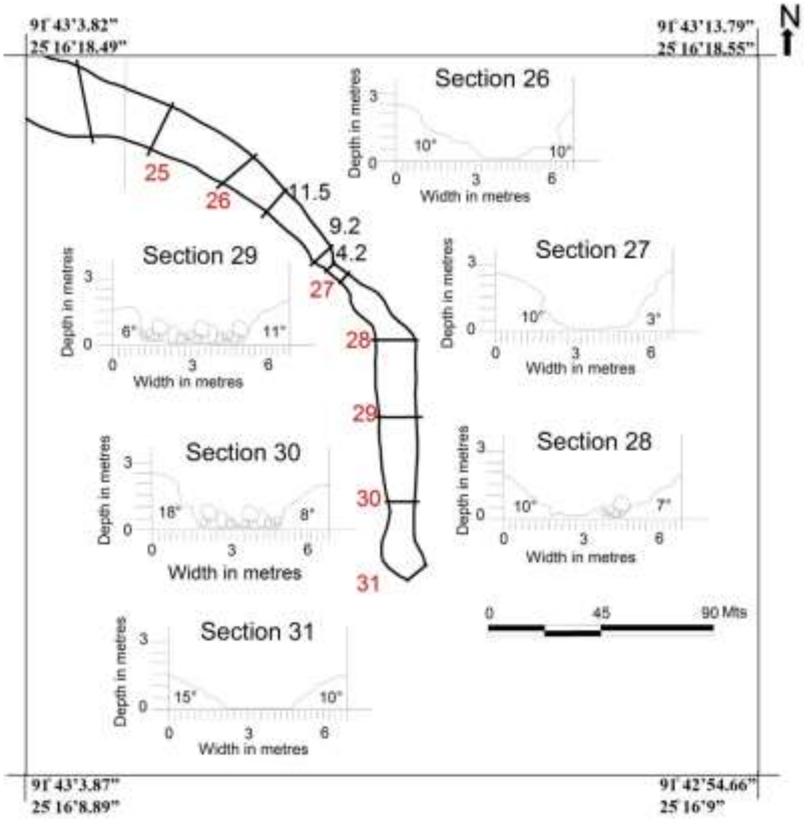


**Figure 10: Section F and sub- sections of the Um-U-Lah Stream**

## Conclusion :

Located on the southern slopes of the Meghalaya plateau and lying in the path of the South West monsoon, Cherrapunjee is characterised by heavy rainfall, especially during the monsoon season (June – September), and the atmosphere is almost saturated with water vapour with a relative humidity of 94-95%. The alternating wet-dry annual cycle with fluctuating rainfall volume between 7,000 mm to 24,000 mm is associated with intense solar radiation in the cool winter months and diurnal temperature changes in different seasons. The weathering processes operating under high fluctuating water levels lead to a considerable variation in the velocities of streams that depend primarily on the volume of rain that plays an essential role in shaping the channels of rivers and streams over old dissected landscapes and resistant rocks from time to time.

The Um-U-Lah catchment is built of limestone complexes of littoral facies. Therefore, the valley floor in those areas is marked by rising limestone mesas of 100-160 m high with a steep slope, ill-defined scarp, and typical karst topographic features like small uvals and different caves systems. The rocks are highly deformed and fractured. The catchment is characterised by rugged and hilly topography consisting of a drainage pattern controlled by the structure and a drainage network of total stream order. With drainage density of 7.6 kilometres reveals the presence of resistant permeable lithology.

The Um-U-Lah stream shows an interrupted profile with a steep gradient, especially in the upper part of the stream. However, the longitudinal profile of the stream becomes more clearly defined in the lower part of the stream, where the stream flows through grasslands and flat lands. The 39 % slope of the stream indicates that the basin streams are colluvial and a direct receiver of the sediments from slope failure and erosion. Further, the sectional and sub-sectional division of the longitudinal profile shows a significant variation in the morphological characteristics of the stream from one sub-section to the other. This is primarily due to natural processes and human interference from time to time.

## Acknowledgement

I express my humble thanks to God who had given me physical and mental strength to complete this paper. I would also like to express my gratitude to my father Late Amiya Bhuyan who had really inspired me in whatever I do.

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