



Research Paper

Drainage Network and Topographic Characteristics of the Pasighat Area, East Siang District, Arunachal Pradesh, India: A GIS-Based Assessment

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Abstract

The present study examines the drainage network and topographic characteristics of the Pasighat area in East Siang District, Arunachal Pradesh, using a drainage and contour map prepared from a 30 m Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) (Farr et al., 2007), Survey of India topographical maps, and GIS techniques. The drainage network was classified according to the Strahler stream-order system (Strahler, 1957). The mapped drainage system contains 499 stream segments with a cumulative length of 427.41 km, distributed from first- to fifth-order streams. First-order streams dominate the network, accounting for 312 segments and 186.45 km, while only six fifth-order streams are mapped, with a combined length of 22.19 km. The mean bifurcation ratio calculated from successive stream orders is approximately 2.69, indicating a systematically branching drainage network with limited evidence of strong structural distortion at the network scale. The average stream length increases progressively from approximately 0.60 km for first-order streams to 3.70 km for fifth-order streams. The map also demonstrates a marked topographic gradient, with low-elevation terrain concentrated toward the Brahmaputra/Siang valley and higher terrain toward the surrounding uplands. The drainage pattern is predominantly dendritic to sub-dendritic, although local variations appear to reflect differences in relief, lithology, slope and structural conditions. The results indicate that the Pasighat landscape is strongly controlled by Himalayan relief, fluvial incision, and the transition from mountainous terrain to the low-lying river valley — consistent with the region's documented tectonic and fluvial history (Jayangondaperumal et al., 2017). The study provides a useful baseline for watershed planning, flood-risk assessment, soil-erosion management and sustainable land-use planning in the Pasighat region.

Keywords: Pasighat, East Siang, drainage network, stream order, morphometry, contour, SRTM, GIS, Arunachal Pradesh, Brahmaputra

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I. Introduction

Drainage networks are important indicators of the interaction between topography, geology, climate, surface runoff and geomorphic processes. The arrangement and hierarchy of streams provide valuable information about the evolution of landscapes and the hydrological behaviour of drainage basins. Quantitative analysis of drainage systems was substantially developed through the work of Horton (1945), who demonstrated that stream order, stream length, drainage density and bifurcation ratio can be used to characterize drainage-basin geometry.

Strahler (1957) subsequently developed a systematic approach to quantitative watershed geomorphology in which drainage networks are ordered according to their hierarchical relationships. This approach permits comparison of stream numbers, lengths, bifurcation ratios, relief and other basin characteristics.

Modern Geographic Information System (GIS) techniques have significantly improved drainage analysis because digital elevation models can be used to derive elevation, slope, flow direction, flow accumulation and drainage networks. The SRTM mission provides global elevation data at approximately 30 m resolution (Farr et al., 2007), making it particularly useful for regional-scale terrain and drainage studies.

The Pasighat region is particularly suitable for such an investigation because it occupies an important geomorphic transition between the eastern Himalayan foothills and the extensive fluvial landscape associated with the Siang–Brahmaputra system. East Siang District is characterized by considerable topographic variation, while Pasighat itself lies at approximately 155 m above mean sea level (East Siang District Administration, n.d.). The Siang flows through the region before becoming part of the Brahmaputra system farther downstream. Previous geological research has also identified Pasighat as a geomorphologically significant area associated with the Siang antiform and Quaternary alluvial fans and river terraces (Jayangondaperumal et al., 2017). These features indicate the combined influence of fluvial processes and tectonic activity on the regional landscape. Despite the importance of the region, detailed interpretation of the drainage hierarchy and topographic organization of the Pasighat area remains useful for understanding watershed behaviour and supporting environmental planning. Therefore, the present study evaluates the mapped drainage network and associated elevation characteristics of the area.

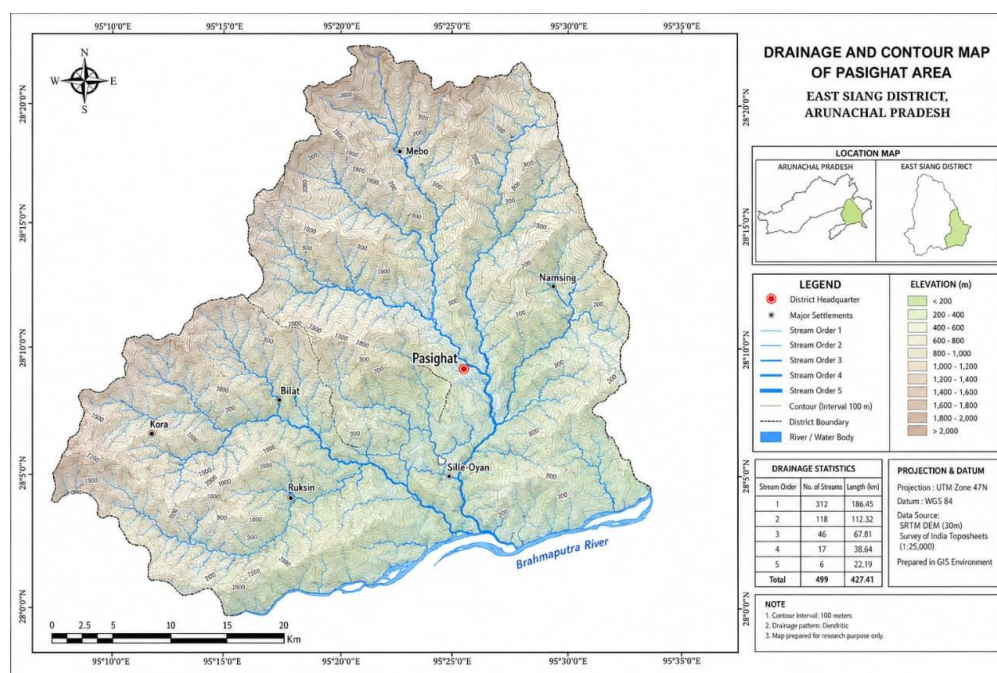


Figure 1. Drainage and contour map of the Pasighat area, East Siang District, derived from SRTM DEM and Survey of India toposheet data.

II. Objectives

- To analyse the drainage network of the Pasighat area using GIS-based mapping.
- To classify the drainage network according to the Strahler (1957) stream-order system.
- To determine the number and cumulative length of streams belonging to different stream orders.
- To calculate the bifurcation ratio and examine the hierarchical organization of the drainage network.
- To examine the relationship between drainage development and topographic variation using contour information.
- To identify the major geomorphological characteristics controlling drainage development.
- To discuss the implications of the drainage network for watershed management, erosion control and flood-related planning.

III. Study Area

The study area is located around Pasighat in East Siang District, Arunachal Pradesh, northeastern India. Pasighat is the headquarters of East Siang District and is situated near the eastern Himalayan foothills. The district extends approximately between 27°43' and 29°20' N and 94°42' and 95°35' E and covers approximately 3,603 km² (East Siang District Administration, n.d.).

The study map covers the Pasighat region and adjoining areas containing settlements such as Mebo, Namsing, Bilat, Kora, Ruksin and Sille-Oyan. The drainage network ultimately connects with the major river system along the southern margin of the mapped area, identified on the map as the Brahmaputra River. The terrain shows a pronounced transition from relatively low-lying valley and plain areas in the south to elevated and dissected terrain toward the north and western portions of the map. The contour interval shown on the map is 100 m, allowing the major relief and slope trends to be interpreted.

East Siang experiences substantial rainfall, with district-level annual rainfall reported to vary considerably across the mountainous and plain environments. A district irrigation plan reports annual rainfall generally ranging from about 1,500 to 5,000 mm and identifies the region as part of the Siang basin agro-ecological zone (Water Resources Department, Government of Arunachal Pradesh, n.d.).

The combination of high rainfall, steep slopes, dense stream networks and low-lying valley floors makes the area important for hydrological and geomorphological investigation.

IV. Methodology

4.1 Data Sources

The drainage and contour map supplied for this study identifies the following principal data sources:

- SRTM DEM, 30 m resolution (Farr et al., 2007)
- Survey of India toposheets, 1:25,000 scale (Survey of India, n.d.)
- GIS-based drainage and contour analysis
- Projection: UTM Zone 47N
- Datum: WGS 84
- Contour interval: 100 m

SRTM provides approximately 30 m elevation data in its 1-arc-second global product and is widely used for terrain and hydrological analysis (Farr et al., 2007).

4.2 Drainage Extraction

The drainage network was represented as a hierarchy of stream segments. Streams were classified according to the Strahler (1957) system:

- A stream without a tributary is designated first order.
- When two first-order streams join, they form a second-order stream.
- Two second-order streams joining produce a third-order stream, and so forth.

This method follows the established quantitative drainage-basin approach developed by Strahler (1957), building on the earlier hydrophysical framework of Horton (1945).

4.3 Quantitative Analysis

The following parameters were evaluated:

Stream number

The number of streams belonging to each order was obtained directly from the drainage statistics shown on the map.

Stream length

The cumulative length of streams within each order was used to determine the contribution of each stream order to the total drainage length.

Bifurcation ratio

Following Horton (1945) and Strahler (1957), the bifurcation ratio was calculated as the ratio between the number of streams of a given order and the number of streams of the next higher order. The bifurcation ratio is an important indicator of drainage-network organization and possible structural influences.

Mean stream length

Mean stream length for each order was calculated by dividing the total length of streams of that order by the number of streams of that order (Horton, 1945).

Drainage density

Drainage density is normally calculated as the ratio of total stream length to basin area (Horton, 1945). Because the supplied map does not state the numerical area of the mapped drainage basin, a defensible drainage-density value cannot be calculated from the supplied information alone. The total district area of 3,603 km² should not be substituted because the mapped study area is only a portion of the district.

V. Results and Findings

5.1 Drainage Network Characteristics

The drainage statistics presented on the map show a total of 499 stream segments with a cumulative stream length of 427.41 km.

Table 1. Stream-Order Characteristics of the Pasighat Drainage Network

Stream Order	Number of Streams	Total Length (km)	% of Total Streams	% of Total Length
1 st	312	186.45	62.53%	43.63%
2 nd	118	112.32	23.65%	26.28%
3 rd	46	67.81	9.22%	15.87%

4 th	17	38.64	3.41%	9.04%
5 th	6	22.19	1.20%	5.19%
Total	499	427.41	100%	100%

The first-order streams clearly dominate the drainage network, representing approximately 62.5% of all mapped stream segments. This is characteristic of a highly dissected terrain in which numerous small tributaries develop on hillslopes and converge into progressively larger channels.

The number of streams decreases systematically with increasing stream order:

312 → 118 → 46 → 17 → 6

This inverse relationship between stream order and stream number is consistent with the hierarchical organization expected in natural drainage networks (Horton, 1945; Strahler, 1957).

5.2 Bifurcation Ratio

The calculated bifurcation ratios are:

Stream-Order Pair	Bifurcation Ratio
1 st /2 nd	2.64
2 nd /3 rd	2.57
3 rd /4 th	2.71
4 th /5 th	2.83
Mean	2.69

The mean bifurcation ratio is approximately 2.69.

The relatively consistent values between approximately 2.57 and 2.83 indicate that the drainage network has a reasonably regular hierarchical organization, in line with the expectations set out by Horton (1945) and Strahler (1957). There is no strong numerical anomaly in the stream-order progression that would, by itself, demonstrate major structural control.

However, bifurcation ratio should not be interpreted independently of geological and geomorphological information. Local structural features, lithological variations and tectonic processes may influence individual tributaries even when the overall drainage network remains relatively systematic (Jayangondaperumal et al., 2017).

5.3 Mean Stream Length

The mean stream length increases with stream order:

Stream Order	Mean Stream Length (km)
1 st	0.60
2 nd	0.95
3 rd	1.47
4 th	2.27
5 th	3.70

This progressive increase demonstrates the expected tendency for higher-order channels to be longer and to occupy larger valleys (Horton, 1945).

The ratio between successive mean stream lengths is approximately 1.54–1.63, showing a relatively regular increase in channel length with stream order.

VI. Topographic and Geomorphological Findings

The contour map demonstrates a strong relationship between elevation and drainage development. The higher portions of the study area are characterized by closely spaced contours and a dense network of small tributaries. Closely spaced contours generally indicate steeper slopes, and the large number of first-order streams in these areas suggests substantial surface runoff concentration and channel initiation.

In contrast, the southern and southeastern portions of the map contain broader, lower-elevation terrain associated with the major river valley. The drainage channels become progressively larger toward this lowland environment. The elevation classes shown on the map range from less than 200 m to more than 2,000 m. Pasighat is located in the relatively low-elevation portion of the landscape, while surrounding upland areas reach considerably greater elevations (East Siang District Administration, n.d.).

The general pattern therefore indicates:

high-elevation dissected terrain → numerous small tributaries → progressively larger streams → major valley drainage

This reflects the strong influence of regional relief on the organization of the drainage system.

VII. Discussion

The drainage network of the Pasighat area displays a clear hierarchical organization dominated by first-order streams. Such dominance is expected in mountainous and dissected terrain, where numerous small channels develop on hillslopes before joining to form larger streams.

The mean bifurcation ratio of approximately 2.69 indicates a relatively organized drainage network. Horton (1945) and Strahler (1957) demonstrated that stream number and drainage hierarchy can be used to characterize the geomorphic organization of drainage basins.

The progressive reduction in stream number with increasing order suggests that the drainage network is naturally hierarchical rather than consisting of randomly distributed channels. The progressive increase in mean stream length from approximately 0.60 km for first-order streams to 3.70 km for fifth-order streams further supports this interpretation.

The spatial relationship between contours and streams provides additional geomorphic information. Areas with greater relief and steeper slopes contain numerous short tributaries, whereas low-relief valley areas are dominated by larger drainage channels. This relationship is consistent with the expected effects of topography on runoff concentration and channel development.

The geomorphological setting of Pasighat is especially important when interpreting these results. Palaeoseismic research on the region has identified the Pasighat area as being located near the hinge zone of the Siang antiform, with preserved Quaternary alluvial fans and multiple fluvial terraces along the Siang/Brahmaputra system, and has documented a co-seismic surface rupture associated with the 1950 Tibet-Assam earthquake along the eastern Himalayan front at Pasighat (Jayangondaperumal et al., 2017).

Therefore, the drainage pattern should not be attributed solely to rainfall and topography. The modern drainage network reflects the combined influence of:

- Regional Himalayan relief
- Fluvial erosion
- Slope and elevation
- Lithological differences
- Quaternary sedimentation
- Tectonic processes
- High seasonal rainfall

The high rainfall environment is particularly significant. District-level information indicates substantial annual precipitation, with much of the rainfall occurring during the monsoon period (Water Resources Department, Government of Arunachal Pradesh, n.d.). High rainfall combined with steep slopes can enhance runoff, soil erosion, channel incision and sediment transport.

The low-lying river-valley areas are consequently important from a flood-management perspective, while steep upland areas require attention to erosion, landslides and slope instability.

VIII. Hydrological and Environmental Implications

The results have several practical implications.

8.1 Flood management

The concentration of numerous tributaries into larger downstream channels means that rainfall occurring over upland areas can rapidly contribute runoff to major rivers. Low-elevation areas close to major channels therefore require careful flood-risk assessment.

8.2 Soil erosion

The high number of first-order streams indicates substantial surface dissection. Steep terrain combined with intense rainfall may promote soil erosion, particularly where vegetation cover is disturbed.

8.3 Watershed management

Small first-order and second-order watersheds should be considered important units for soil and water conservation. Measures such as vegetation restoration, contour-based land management and small-scale runoff-control structures may reduce erosion and improve infiltration.

8.4 Land-use planning

Development in valley-floor areas should consider flood susceptibility, while infrastructure construction in steep terrain should account for slope stability and drainage concentration.

8.5 Water-resource planning

The hierarchical drainage system provides a framework for identifying tributary catchments that could be investigated for local water-resource management, although site-specific hydrological and hydrogeological investigations would be required before implementation.

IX. Limitations of the Study

The present analysis is based primarily on the supplied drainage and contour map. Consequently, several parameters normally included in a complete morphometric study (cf. Horton, 1945; Strahler, 1957) could not be calculated reliably. In particular:

- the exact study-area/basin area is not provided;
- drainage density cannot therefore be calculated;
- basin perimeter and basin length are unavailable;
- relief ratio cannot be calculated;
- elongation ratio and circularity ratio cannot be calculated;
- geological and lithological datasets were not supplied;
- rainfall records were not spatially integrated with the drainage analysis;
- field verification of mapped channels was not undertaken.

These limitations should be addressed before submission to a journal that requires a complete quantitative morphometric analysis.

X. Conclusion

The present study demonstrates the usefulness of GIS-based drainage and contour analysis for understanding the geomorphological characteristics of the Pasighat area of East Siang District, Arunachal Pradesh.

The mapped drainage network contains 499 stream segments with a total length of 427.41 km, ranging from first- to fifth-order streams. First-order streams are strongly dominant, accounting for approximately 62.5% of the total number of streams and 43.6% of the total stream length. Stream numbers decline systematically with increasing order, while mean stream length increases from approximately 0.60 km for first-order streams to 3.70 km for fifth-order streams.

The mean bifurcation ratio of approximately 2.69 indicates a relatively systematic drainage hierarchy, consistent with the classic Horton–Strahler framework (Horton, 1945; Strahler, 1957). The contour pattern demonstrates a strong relationship between topography and drainage development, with densely dissected, higher-elevation terrain feeding progressively larger channels toward the lower river valley.

The geomorphology of Pasighat is further influenced by its position within the active eastern Himalayan environment and the Siang–Brahmaputra fluvial system. Existing research identifies evidence of tectonic activity, alluvial fans and river terraces in the Pasighat region (Jayangondaperumal et al., 2017), emphasizing the importance of considering both tectonic and fluvial processes in interpreting the drainage network.

Overall, the study indicates that the Pasighat drainage system is controlled by a combination of relief, slope, runoff, fluvial processes and regional geomorphic structure. The results can provide a baseline for watershed prioritization, erosion-control planning, flood-risk assessment and environmentally sustainable development.

For a fully quantitative morphometric paper, future work should incorporate the exact watershed area, geological and lithological data, slope analysis, drainage density, drainage texture, relief ratio, elongation ratio, circularity ratio, hypsometric analysis and field verification.

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