

# The Role of Dykes in Shaping Stream Junction Angles: A Case Study of the Rangavali River Basin, Northern Maharashtra

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## Abstract

Dyke swarms frequently act as natural barriers, obstructing or deflecting stream courses. Streams tend to flow along the outcrop ridges of dykes, resulting in acute junction angles. Dykes serve as structural controls by influencing the orientation of streams. The relationship between stream junction angles and dyke orientation is a significant factor in stream confluences. Terrain plays a crucial role in directing the river's flow path and shaping its characteristics. This research paper investigates the impact of dyke orientation on stream junction angles through stream hierarchy analysis. The Rangavali River, a left-bank tributary of the Tapi River, flows for a distance of 45.65 km, crossing 21 East-West (E-W) trending dykes within a 215.95 km<sup>2</sup> basin, which forms part of the Deccan Traps. To examine the relationship between dyke orientation and stream junction angles, inputs from Google Earth imagery, LISS III images, SOI topographical maps, quadrangle maps, and Cartosat DEM were used to delineate the Rangavali basin and extract dyke features. The Rangavali River basin is a sixth-order drainage system that exhibits a superimposed drainage pattern within the Tapi dyke swarm zone. The prominent linear dyke ridges are predominantly aligned in an East-West direction (average angle N81°), with a dyke density of 0.51 km/km<sup>2</sup>. The average junction angle of streams within 100 m upstream and downstream of the dyke ridges is 81°, compared to an average of 78° in non-dyke areas. The trend of acute junction angles is attributed to the orientation of the dykes and the distance of streams from the parallel-aligned dyke ridges. This study demonstrates that dyke ridges not only redirect stream flow but also control drainage density and network development. The findings have broader implications for watershed management, flood risk assessment, infrastructure planning, and groundwater exploration in basaltic ter-

rains and contribute significantly to the understanding of fluvial-structural interactions in volcanic landscapes.

### Keywords

Deccan Traps, Tapi Dyke Swarms, Google Earth, LISS III, Cartosat DEM, Junction Angles, SOI Topographical Maps, Quadrangle Maps

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## 1. Introduction

Dykes, which are vertical or near-vertical sheets of igneous rock that intrude into pre-existing rock layers, have a significant impact on stream junction angles. As resistant geological structures, dykes are more resistant to erosion than the surrounding, softer rock [1], thereby influencing the flow and direction of streams and modifying the angles at which they meet. Dykes frequently act as natural barriers, obstructing or deflecting stream courses [2]. When streams approach a dyke, they may flow alongside or around it rather than cutting through it, altering their natural paths. This redirection often results in obtuse junction angles (greater than  $90^\circ$ ). A typical function of dykes is to divert streams, and when a stream flows parallel to a dyke and is eventually deflected into another stream, a right-angle junction may form. The sudden change in direction caused by the dyke's resistance can lead to streams meeting at nearly  $90^\circ$ . Due to their resistance to erosion, dykes cause differential erosion, where the surrounding rock erodes faster, leaving the dyke as a prominent ridge or elevated feature [3]. As a result, streams tend to flow along these outcrop ridges, forming acute junction angles. Tributary streams often follow the dykes before joining the main stream at right angles. This drainage pattern is controlled by the presence of dykes, which act as physical obstacles to stream flow, forcing tributaries to align with their orientation. Additionally, dykes are frequently associated with fault zones, which further influence terrain morphology and stream direction. Streams may follow faults or fractures parallel to the dykes, resulting in acute junction angles when tributaries are constrained by both the dyke and the fault [4].

A stream junction, also known as a confluence, is the point where two or more streams converge. Stream junctions are a fundamental component of drainage [5], influencing the overall structure and flow dynamics within a watershed. The relationship between stream junction angles and dyke orientation plays a critical role in determining confluence geometry. The terrain, which directs the river's flow path, significantly affects stream characteristics and junction behavior. The angle formed at a junction varies depending on geological and hydrological conditions [6]. Junction angles may be acute (less than  $90^\circ$ ), right-angled (approximately  $90^\circ$ ), or obtuse (greater than  $90^\circ$ ), depending on factors such as terrain slope, Stream Energy, and the presence of structural features like faults or dykes. Tributaries adjust to the main stream at a local base level and are not necessarily controlled by the terminal base level downstream [7]. Confluences influence several fluvial processes. When two or more flowing bodies of water combine to form a single chan-

nel, the resulting junction affects water discharge, sediment transport, and flood behavior. Understanding stream junction dynamics is therefore essential for interpreting drainage morphology and basin hydrology [8].

The angles and arrangements of stream junctions can provide insights into underlying geological formations and the evolutionary history of the landscape. The combination of a landscape's topography—characterized by elevations and slopes—and flowing water governs how streams carve their courses and where they intersect [9]. In regions with steep slopes, such as mountainous or hilly areas, streams typically flow rapidly and directly downslope, resulting in more acute junction angles. Conversely, in areas of low relief or gentle slopes, junction angles are generally obtuse (greater than 90°). Streams flowing through small, steep-sided valleys are often constrained by the terrain, which causes tributaries to join the main river at acute angles. The high gradient and rapid flow in such areas contribute to the formation of these sharp confluences. In contrast, as streams enter lower elevations or flat terrain, their velocity decreases, and they become more sinuous. This reduced energy allows for greater lateral movement and the development of obtuse junction angles [10]. Dendritic drainage patterns commonly emerge in regions with relatively uniform topography, such as moderate slopes and homogeneous rock types [11]. In these settings, stream junctions often occur at acute to right angles, reflecting a uniform distribution of water pathways across the landscape [12]. Streams may also encounter topographic obstacles, such as ridges or hills, which force them into structural alignments, resulting in sudden and direct confluences.

In areas of lower relief and weaker Stream Energy, streams tend to meander around structural features like dykes, leading to wider, more obtuse junctions [13]. As streams take longer, more circuitous routes before joining the main channel, their reduced flow energy allows for more extensive meandering. When dykes act as natural barriers, they further slow the water flow, promoting the formation of broad, sinuous paths and resulting in more obtuse junction angles. Topography exerts a significant influence on the geometry of stream junctions. Steep slopes and narrow valleys promote the development of acute angles, while moderate slopes and open valleys are associated with obtuse junctions. Additionally, geological structures and topographic barriers modify natural stream pathways, further affecting the configuration of stream junctions [14].

Climate has a considerable impact on stream junction angles, as it influences precipitation patterns, vegetation cover, erosion rates, and stream flow dynamics. It governs the amount and distribution of water across a landscape, which in turn affects how streams interact and converge [6]. In regions with high rainfall, streams often develop dense drainage networks. Increased water flow enhances erosional processes, enabling streams to incise more deeply and rapidly into the terrain, often resulting in acute junction angles as tributaries quickly join the main channel. Rapid surface runoff during intense rainfall events can further promote acute confluences due to high Stream Energy [15]. In climates with distinct wet and dry seasons, such as monsoonal regions, stream flow and erosion are highly seasonal [16].

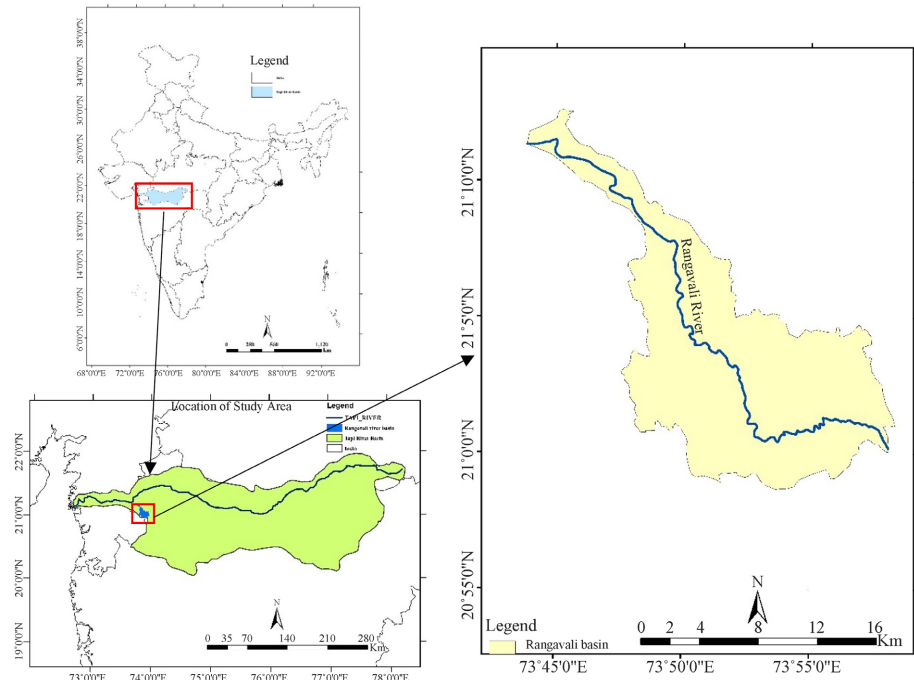
During the wet season, increased discharge and sediment transport may lead to sharper junction angles, whereas reduced flow in the dry season can result in sediment deposition, potentially widening junctions and altering their morphology over time. Vegetation also plays a key role in shaping stream junction geometry. Dense vegetation, such as that found in tropical rainforests, stabilizes soil and reduces erosion, leading to more stable and well-defined drainage networks. In such conditions, streams may exhibit more gradual and obtuse junction angles. Vegetation can also reduce the direct impact of rainfall on the soil, encouraging the formation of more sinuous stream paths and resulting in broader confluence angles [17]. Generally, humid regions with high rainfall tend to produce acute junction angles due to rapid erosion and high Stream Energy, while arid or gently sloping regions with limited rainfall foster wider, obtuse junctions as streams meander. Such studies reveal the extent to which drainage networks are modified by climatic conditions and how they interact with structural controls like dykes [18].

The primary objective of this study is to investigate how the orientation, spatial distribution, and geological characteristics of dykes influence stream junction angles within the Rangavali River Basin, a structurally controlled region of the Deccan Trap. The study aims to understand the geomorphological relationship between linear dyke ridges and the stream network by analyzing how streams respond to structural barriers, particularly in terms of changes in their confluence angles. Through the use of topographical maps, Cartosat DEMs, Google Earth imagery, and field observations, the study seeks to map and extract dyke features and drainage patterns to evaluate their spatial correlation. Quantitative analysis is carried out to measure junction angles within buffer zones of 100 meters and 500 meters from dyke ridges, with the goal of assessing variations in stream behavior in dyke-influenced versus non-dyke areas. Additionally, the study aims to assess how stream order, slope, and proximity to dykes contribute to the development of acute, right, or obtuse junction angles, thereby revealing the role of structural controls in shaping drainage networks. Ultimately, the objective is to interpret the geomorphological significance of dyke-stream interactions and provide insights into how such structural features can alter fluvial processes and influence watershed dynamics in basaltic terrains. The objective of this research is to assess how the orientation and geological characteristics of dykes influence the direction of stream flow and the resulting junction angles at confluences. It also aims to identify significant spatial patterns or variations by quantifying and comparing the junction angles of streams in dyke-affected areas with those in unaffected regions.

## 2. Study Area

The investigation pertains to the Rangavali River basin, which forms part of the east-west trending Tapi Giant Dyke Swarm. The study area extends from 20° 58' 48.0" N to 21° 12' 36.0" N latitudes and 73° 43' 52.32" E to 73° 58' 16.32" E longitudes, as shown in **Figure 1**. It is located on the northwestern slope of the Western Ghats and originates at an elevation of 680 meters. The total area of the Rangavali basin is 215.95

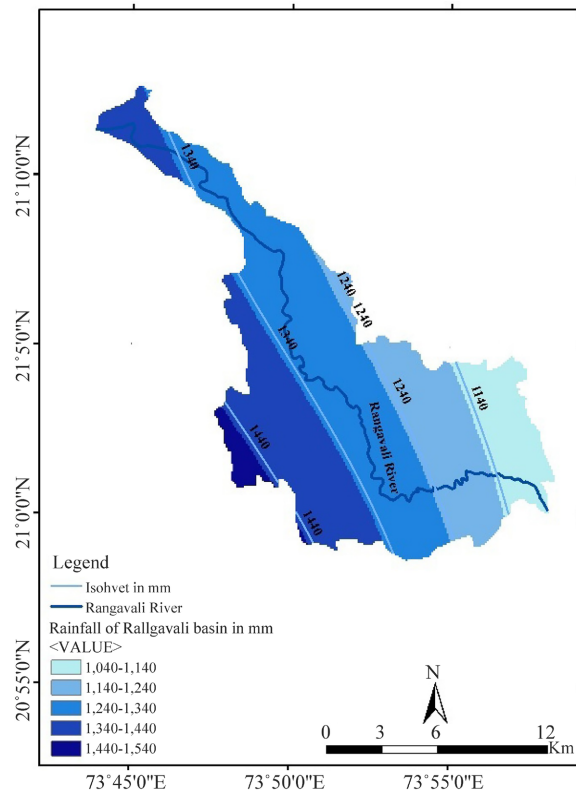
km<sup>2</sup>. The main channel of the Rangavali River has a length of 45.65 km. Gujarat accounts for 5.28% (11.39 km<sup>2</sup>) of the basin area, while Maharashtra covers 94.72% (204.55 km<sup>2</sup>). Rangavali, a left-bank tributary of the Tapi River, is influenced by the southwest monsoon and discharges into the Ukai Reservoir of the Tapi River at an elevation of 99 meters above mean sea level. The Rangavali basin, with a total relief of 680 meters, is surrounded by the Western Ghats and adjoining plateaus.



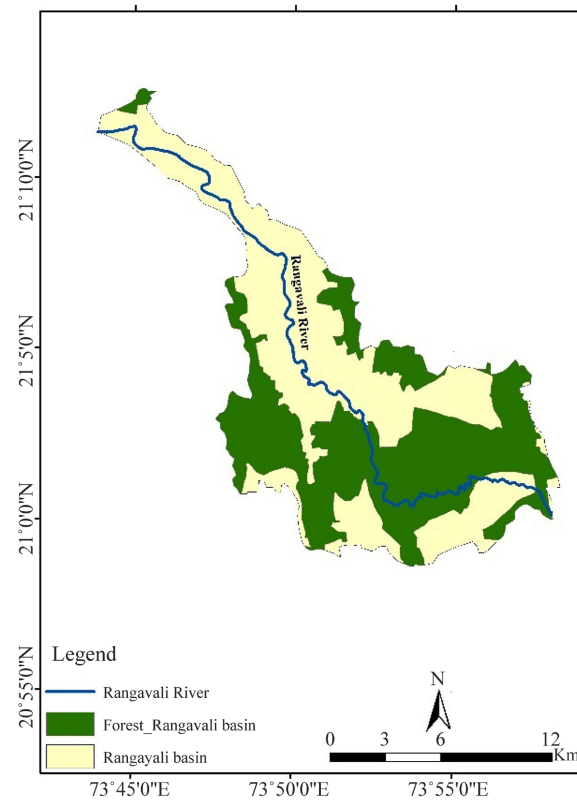
**Figure 1.** Location map of the study area depicting the relative location of the Rangavali basin with reference to India and the Tapi River basin.

It is bounded by the Girna River (a tributary of the Jhankhri River) to the south, the Panjhra basin to the southeast, and the Rayangan basin to the east. The western boundary is defined by minor streams originating from the southern side and flowing northward. The basin's slope ranges from greater than 70° to approximately 5°, with a gradient transition from steep in the southeast to gentle in the northwest. The climate is governed by the southwest monsoon, with an average annual rainfall ranging from 1,140 mm to 1,440 mm (Figure 2). Tropical deciduous forests cover an area of 101.66 km<sup>2</sup> within the Rangavali basin, primarily within the Chinchpada and Navapur Reserve Forest zones (Figure 3).

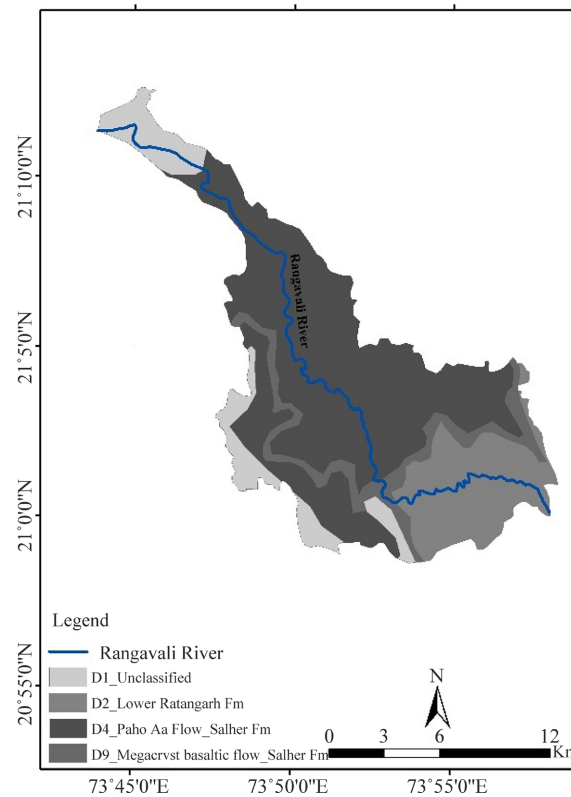
The Rangavali River basin forms an integral part of the Deccan Traps and comprises four basaltic flows extruded from fissure-type volcanoes (Figure 4). These flows are primarily of two types: *pahoehoe* and *aa*, with *pahoehoe* being more prevalent, particularly in the northern part of the basin. The basalt flows have been intruded by numerous doleritic dykes, typically ranging in width from 1 to 20 meters. Most of the dykes are aligned in an ENE-WSW direction, though a few exhibit N-S or WNW-ESE orientations [19].



**Figure 2.** Average annual rainfall distribution of the Rangavali River basin.



**Figure 3.** The forest covers the Rangavali River basin.



**Figure 4.** Geology of the Rangavali River basin.

Geologically, the Rangavali basin represents a section of the southern Tapi River region and is stratigraphically a subset of the Deccan Trap, which originated from the Sahyadri Group during the Late Cretaceous period [20]. The Ratangarh Formation, comprising both upper and lower units, forms prominent escarpments along the valley sides and contributes to the steep highland topography at the basin's source. The Salher Formation occupies the middle to lower portions of the basin.

### 3. Data and Methods

The analysis is based on two distinct datasets: the first comprises information on the properties of the dykes, while the second contains data on drainage basins and stream junction angles (Figure 5).

#### 3.1. Dyke Attributes

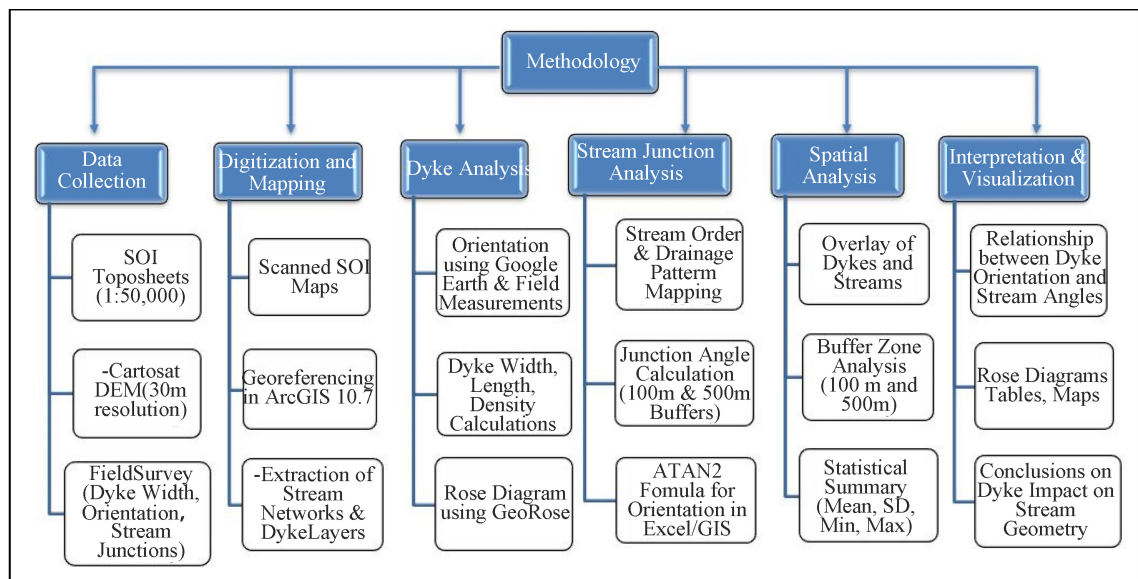
The dyke properties were traced using Geological Quadrangle Maps 46G and 46H from the Geological Survey of India, corresponding to the Rajpipla and Vansada regions at a 1:25,000 scale. Elongated contours and form lines were interpreted to indicate discontinuous linear ridges. The District Resource Maps of Nandurbar and Dhule districts were also used to identify dyke attributes. Google Earth Pro imagery was utilized to trace dyke alignments. Cartosat-1 DEM with 30-meter resolution shaded relief was employed to detect dykes and associated topographic features. Ad-

ditionally, Resourcesat-1/Resourcesat-2 LISS-III multispectral images (23.5 m resolution) were used to identify dyke features. These images were sourced from the open data archive of Bhuvan [21]. The Cartosat-1 Digital Elevation Model (CartoDEM), a national DEM developed by the Indian Space Research Organisation (ISRO), was used to extract linear ridges extending over several kilometers. The traced dykes and their geometric characteristics were analyzed to determine the trend or strike of each dyke with reference to geographic or magnetic north. Inputs from Google Earth, LISS-III imagery, and Cartosat DEM were integrated to map the locations, orientations, and dimensions of dyke swarms in the Rangavali River basin. The identified dyke swarms were digitized in a GIS environment using ArcGIS Pro 10.7 to create a spatial dataset with parameters such as length, orientation, and location.

### 3.2. Catchment Morphometrics and Stream Orientations

The drainage network of the Rangavali River basin is covered in Survey of India (SOI) toposheets numbered 46G12, 46G16, and 46H/13, published at a 1:50,000 scale. The stream network and its orientations were mapped using scanned SOI topographical maps. Quantitative parameters such as drainage basin area, stream order, stream length, basin relief, and basin slope were extracted from these toposheets. The scanned SOI toposheets and geological quadrangle maps were georeferenced using ArcGIS 10.7 software. The analysis in this study is primarily based on 30-meter resolution Cartosat Digital Elevation Model (DEM) data.

Field investigations were conducted at selected dyke locations to better understand their morphological characteristics. Some of the dykes were found to be less than five meters in height, while others were more prominently exposed at the surface. Field visits were carried out along the Rangavali River, particularly near the Navapur and Nandwan sites. Measurements of dyke width and orientation were also recorded during the survey.



**Figure 5.** Methodology chart depicting the flow of work carried out during the study.

### 3.3. Stream Junction Angles and Streams Orientation

Stream junctions are locations where two or more streams or rivers converge to form a single flow. To compute the junction angles at various confluence points—particularly near dyke swarms—manual measurements were carried out using a protractor on Survey of India (SOI) topographical maps. Stream confluences located within 100-meter and 500-meter buffer zones were selected to assess the influence of dykes on junction orientation.

In a GIS environment, the X and Y coordinates of streams within the 500-meter buffer zone were used to determine stream orientations [22]. The difference in coordinates,  $\Delta X = (X_2 - X_1)$  and  $\Delta Y = (Y_2 - Y_1)$ , was used to calculate angles in radians using the inverse tangent function:  $\theta = \text{ATAN2}(\Delta Y, \Delta X)$ .

### 3.4. Rose Diagrams

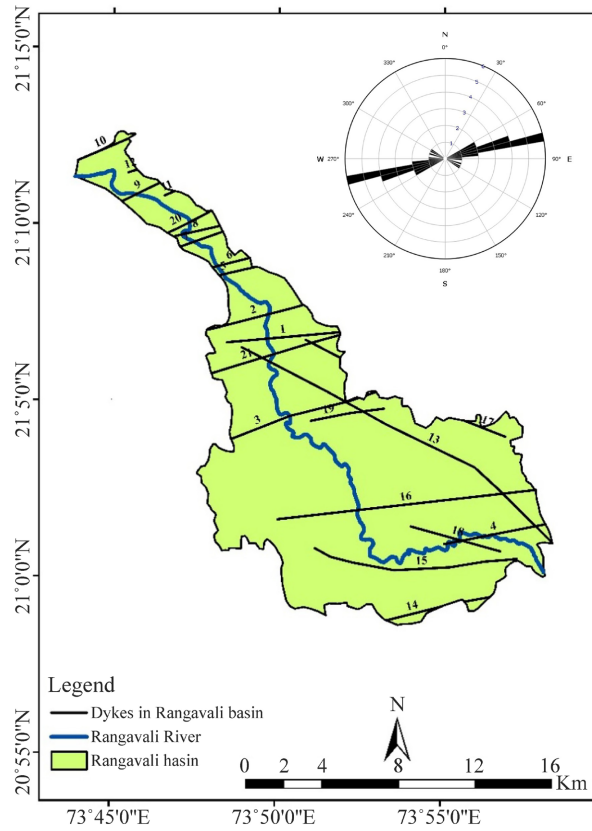
**Rose diagrams** are widely used in geology to depict the orientation or trends of geological structures such as dykes [23]. A rose diagram is a circular chart in which the circle represents 360 degrees, and the frequency or density of features in each directional bin is shown by the length of radial segments. The longer the segment, the higher the number of features (e.g., dykes) aligned in that direction.

**GeoRose** is a specialized software tool used to generate rose diagrams for analyzing and visualizing directional data, including dyke orientations, stream junction angles, and stream segment alignments [24]. These diagrams—also known as compass rose plots or circular histograms—illustrate the frequency distribution of directional data. By inputting directional information into GeoRose, users can generate rose diagrams that reveal orientation patterns of dykes and streams. These visualizations help in understanding the alignment of stream segments relative to underlying geological structures, such as dykes. In particular, rose diagrams are useful for analyzing the structural control on drainage networks by showing how stream directions correspond with the trends of dykes or other linear geological features.

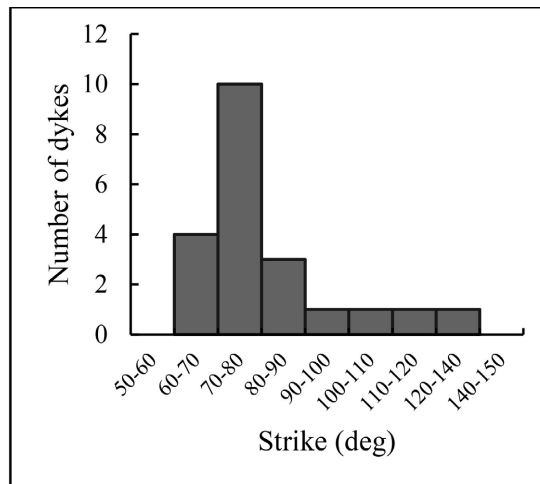
## 4. Result and Discussion

### 4.1. Spatial Distribution and Orientation of Dykes and Streams

There are 21 linear dyke segments distributed across the entire Rangavali River basin. These dykes predominantly strike in the ENE-WSW to E-W direction (**Figure 6**). The dyke ridges extend from the river's source region in the elevated eastern part of the basin to its mouth in the west, where it joins the Ukai Reservoir on the Tapi River. However, the dyke ridges are not continuous throughout their length; rather, they appear as discontinuous segments. Their spatial distribution is uneven across the basin, occurring at various elevations and distances. The preferred mean strike direction of the 21 dykes is N81°, as illustrated in the rose diagram (**Figure 6**). The range of dyke trends varies between N 63° and N 122° (**Figure 7**). The lengths of the dykes were calculated as the horizontal distance



**Figure 6.** Spatial distribution of dykes in the Rangavali River basin, in the upper right corner, the rose diagram of 21 dykes showing their trends.

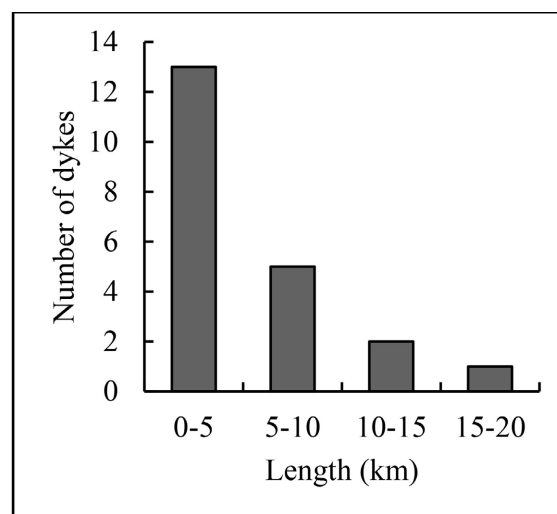


**Figure 7.** Histogram showing the 21 dykes trend.

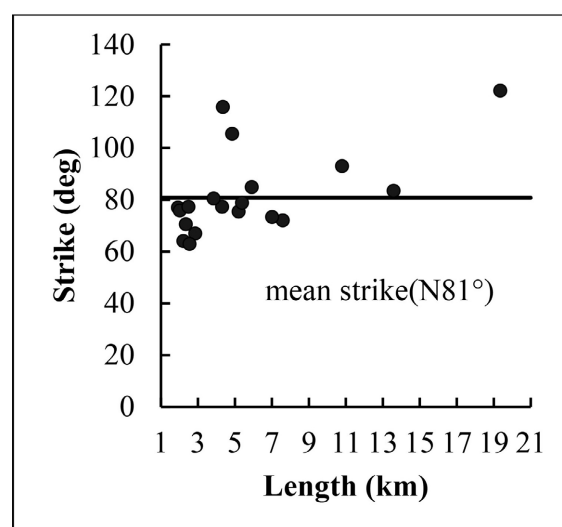
between their endpoints. Variations in dyke lengths indicate differences in the extent of the fractures through which the dykes were emplaced (**Figure 8**). The longest dyke measures 19.2 km, while the shortest is 0.5 km. The total length of all dyke segments in the basin is 109.7 km, resulting in a dyke density of 0.51 km/km<sup>2</sup> (**Figure 9** and **Figure 10**). Each dyke exhibits distinct characteristics that influence

the surrounding terrain, including the slope orientation of linear ridges and the orientation of stream segments. The slope configuration and gravitational flow direction help determine the orientation of streams on either side of the prominent dyke ridges. The fracture aperture formed during dyke emplacement corresponds to the dyke's width—wider dykes are associated with thicker intrusions, while narrower ones represent thinner intrusions within the basin.

The widest dyke observed in the Rangavali basin has a thickness of 25.41 meters, while the narrowest measures 2.89 meters (Figure 11 and Figure 12). Dyke widths were initially assessed using Google Earth imagery and further validated through field visits. During the fieldwork, measurements of dyke widths, stream junction angles, and stream orientations were recorded. The average dyke thickness across the basin is 11.32 meters (Table 1).



**Figure 8.** Bar graph showing the frequency of 21 dykes with their length.



**Figure 9.** The variation in length as a function of dyke trend indicates that mostly the E-W-trending dykes achieve lengths.

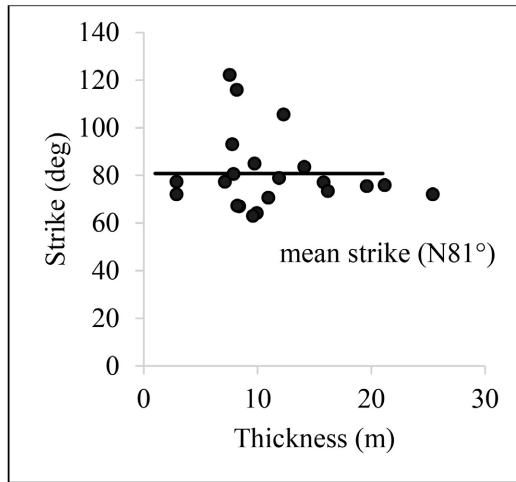


Figure 10. Thickness-strike plot.

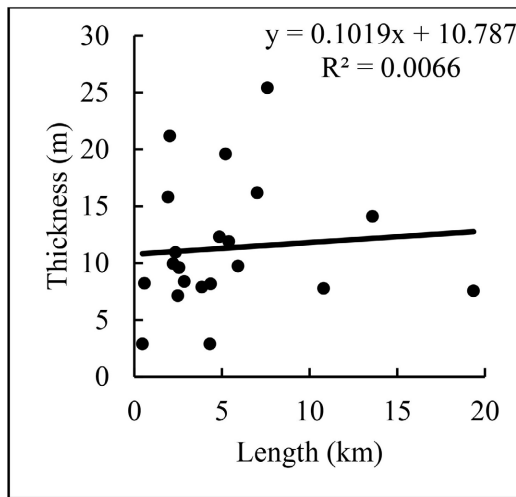


Figure 11. Thickness vs. length plot, showing a complete absence of correlation ( $R^2 = 0.0066$ ).

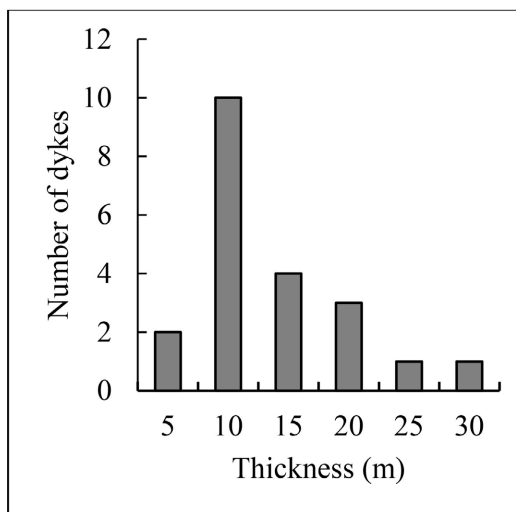
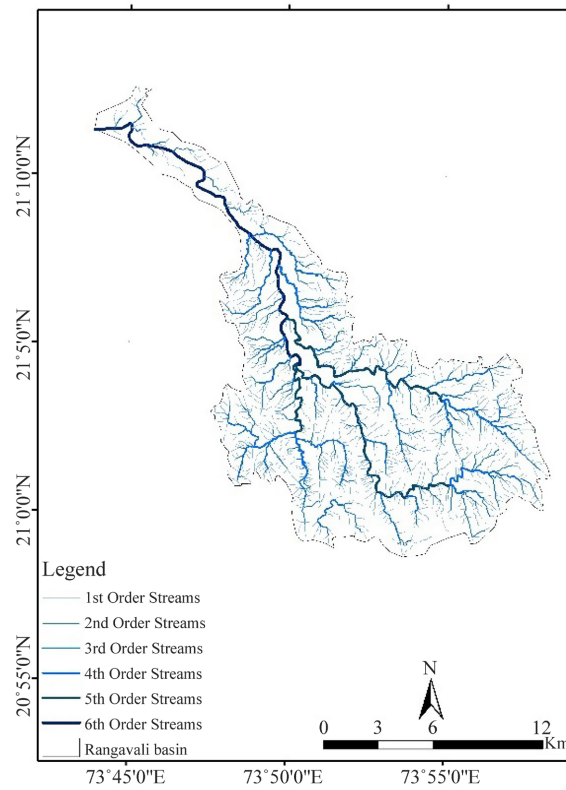


Figure 12. The thickness distribution of 21 dyke.

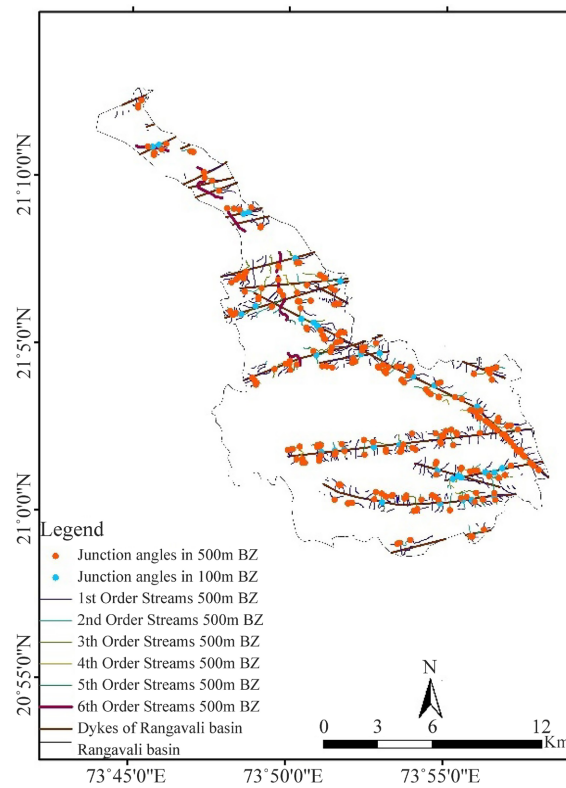
**Table 1.** Attributes of the dykes.

| Dykes No.   | Strike (N deg) | Width of Dyke (m) | Dykes Length (km) |
|---|----------------|-------------------|-------------------|
| 1   | 85             | 9.74              | 5.9               |
| 2   | 75             | 19.60             | 5.2               |
| 3   | 72             | 25.41             | 8.0               |
| 4   | 79             | 11.90             | 5.4               |
| 5   | 77             | 15.81             | 1.9               |
| 6   | 76             | 21.18             | 2.0               |
| 7   | 71             | 10.95             | 2.4               |
| 8   | 77             | 7.14              | 2.5               |
| 9   | 64             | 9.94              | 2.2               |
| 10  | 67             | 8.39              | 2.9               |
| 11  | 67             | 8.23              | 0.6               |
| 12  | 72             | 2.89              | 0.5               |
| 13  | 122            | 7.56              | 19.2              |
| 14  | 77             | 2.89              | 5.5               |
| 15  | 93             | 7.78              | 10.6              |
| 16  | 84             | 14.11             | 13.6              |
| 17  | 116            | 8.18              | 11.6              |
| 18  | 105            | 12.30             | 4.9               |
| 19  | 81             | 7.90              | 3.9               |
| 20  | 63             | 9.61              | 2.5               |
| 21  | 73             | 16.19             | 7.0               |
| <b>Avg angle = N81°   Avg width = 11.32 m   Total Length = 109.7 km</b> |                |                   |                   |

The Rangavali River, a seasonal left-bank tributary of the Tapi River, flows from the southwest to the northwest. The basin comprises 988 stream segments and exhibits a dendritic drainage pattern, reaching up to the sixth stream order (**Figure 13**). Covering a total area of 295.15 km<sup>2</sup>, the basin has a drainage density of 3.2 km/km<sup>2</sup> and a perimeter of 102.81 km. The geological configuration of dykes within the basin contributes to a superimposed drainage pattern, as evident from the alignment of stream networks along resistant dyke outcrop ridges. Buffer zones were delineated using the GIS buffer tool to assess the influence of dykes on stream orientation. The 100-meter buffer around barrier ridges reveals a pronounced influence on stream orientation, which diminishes with increasing distance from the dyke ridges. Consequently, the 500-meter buffer zone is considered representative of non-dyke-influenced areas of the basin (**Figure 14**).



**Figure 13.** Drainage network of the Rangavali River basin.



**Figure 14.** Stream junction angles with dykes' orientation in 100 m and 500 m buffer zones.

Within the 100-meter buffer zone, 245 streams totaling 143.3 km in length were identified. Of these, 79 streams (32%)—spanning various stream orders—are directly influenced by dyke orientations. In the 500-meter buffer zone, 505 streams with a total length of 285.8 km were mapped, of which 137 streams (27.13%) follow directions that align with dyke ridges. Dyke-resistant ridges in both buffer zones cause stream orientation angles to shift from acute to obtuse as stream order increases (Table 2). First-order streams, affected by parallel dyke ridges, tend to align at acute angles from the north. In contrast, higher-order streams—due to their hierarchical position in the drainage network—tend to exhibit more obtusely directed alignments.

#### 4.2. Analysis of Dykes' Orientation and Stream Junction Angles

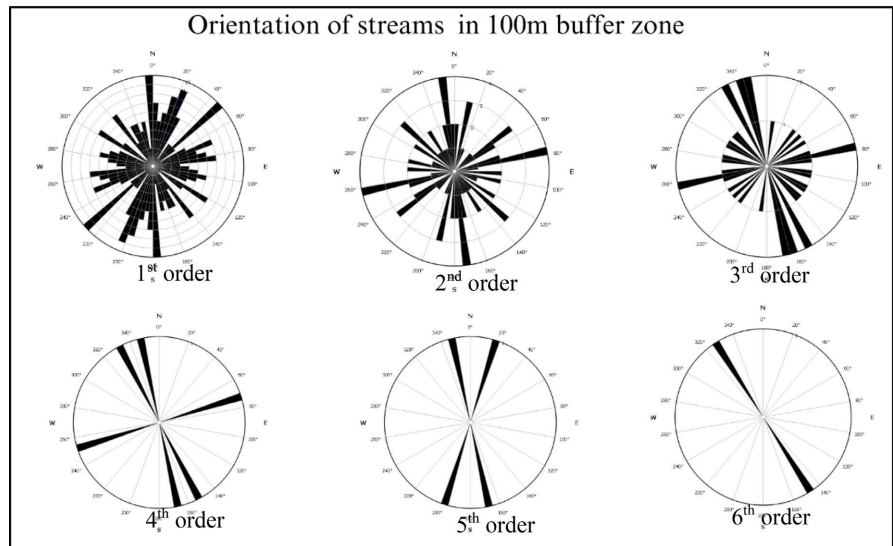
Junction angles play a crucial role in understanding stream erosion, sediment transport, and water flow dynamics. In this study, junction angles were measured using a compass protractor on the Survey of India (SOI) topographical maps. At stream confluences, these angles are primarily determined by the orientation of the joining streams (Figure 15 and Figure 16). The orientation of streams dictates their point of confluence and the resulting angle of convergence [25].

In the Rangavali River basin, stream orientations are influenced by surface topographical features—particularly dyke ridges—and prevailing hydrological processes. The average trend of the 21 prominent, linear, and parallel dykes is approximately N81°. Across the basin's total area of 215.95 km<sup>2</sup>, dyke orientations vary from a minimum (acute) angle of N63° to a maximum (obtuse) angle of N122° (Table 3).

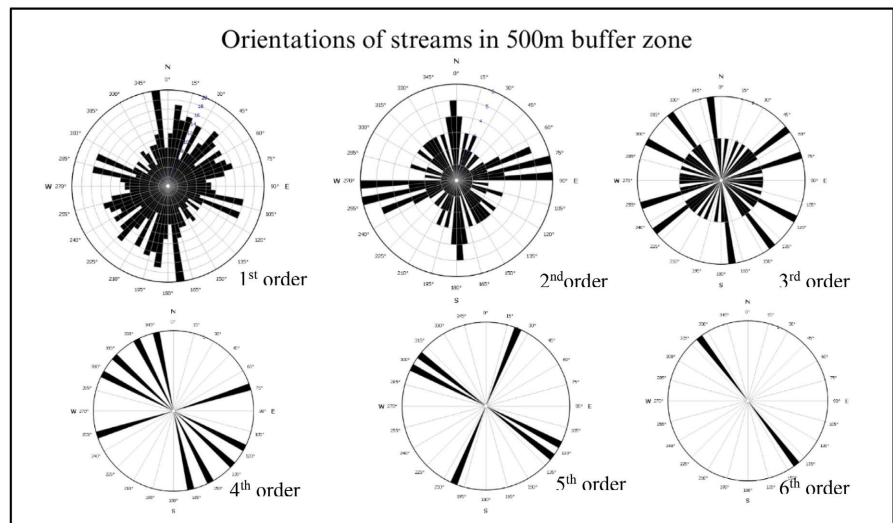
In the 100-meter buffer zone, the average junction angle between two first-order streams is 68°, whereas in the 500-meter buffer zone, it increases slightly to 70°. The average orientation angle of the dykes (81°) shows a strong correlation with the average stream junction angles in the 100-meter buffer zone (Figure 14 and Figure 16). Junction angles generally become broader with the increase in stream order at the point of confluence. For instance, the average angle at first-to-second-order stream junctions is 76°, for first-to-third-order junctions it is 95°, and for first-to-fourth-order confluences, the angle reaches 106°.

**Table 2.** Rangavali river basin streams, networks, and orientations of streams within the 100 m and 500 m buffer zones.

| Rangavali's entire basin streams |                |                   | Streams orientation in the 100 m buffer zone |                |                        |                        | Streams orientation in the 500 m buffer zone |                |                        |                        |
|----------------------------------|----------------|-------------------|--|----------------|------------------------|------------------------|--|----------------|------------------------|------------------------|
| Stream Orders                    | No. of Streams | Total Length (km) | Stream No.                                   | Avg Angle (N°) | Length of Streams (km) | Controlled Streams No. | Stream No.                                   | Avg Angle (N°) | Length of Streams (km) | Controlled Streams No. |
| 1 <sup>st</sup>                  | 776            | 415.3             | <b>172</b>                                   | 86             | 112.8                  | 57                     | <b>380</b>                                   | 84             | 164.3                  | 96                     |
| 2 <sup>nd</sup>                  | 165            | 127.32            | <b>47</b>                                    | 99             | 15.5                   | 13                     | <b>90</b>                                    | 92             | 55.8                   | 30                     |
| 3 <sup>rd</sup>                  | 36             | 72.84             | <b>20</b>                                    | 106            | 9.4                    | 8                      | <b>26</b>                                    | 95             | 33.3                   | 8                      |
| 4 <sup>th</sup>                  | 7              | 18.73             | <b>3</b>                                     | 132            | 2.6                    | 1                      | <b>5</b>                                     | 128            | 11.3                   | 2                      |
| 5 <sup>th</sup>                  | 3              | 35.2              | <b>2</b>                                     | 93             | 0.4                    | 0                      | <b>3</b>                                     | 89             | 9.1                    | 1                      |
| 6 <sup>th</sup>                  | 1              | 22.15             | <b>1</b>                                     | 145            | 2.5                    | 0                      | <b>1</b>                                     | 144            | 11.9                   | 0                      |
| <b>TOTAL</b>                     | <b>988</b>     | <b>692</b>        | <b>245</b>                                   |                | <b>143.3</b>           | <b>79</b>              | <b>505</b>                                   |                | <b>285.8</b>           | <b>137</b>             |



**Figure 15.** Rose diagram of 1<sup>st</sup> to 6<sup>th</sup> stream orders orientation in the 100 m buffer zone.



**Figure 16.** Various order streams (1<sup>st</sup> to 6<sup>th</sup>) orientation in the 500 m buffer zone.

**Table 3.** Stream orders and junction angles in the 100 m and 500 m buffer zones.

| Stream junction angles in the 100 m buffer zone |                |                                  | Stream junction angles in the 500 m buffer zone |                |                                  |
|---|----------------|----------------------------------|---|----------------|----------------------------------|
| Confluence Stream Orders                        | No. of Streams | Average Junction Angles (degree) | Confluence Stream Orders                        | No. of Streams | Average Junction Angles (degree) |
| 1-1   | 8              | 68                               | 1-1   | 55             | 70                               |
| 1-2   | 17             | 76                               | 1-2   | 82             | 77                               |
| 1-3   | 7              | 95                               | 1-3   | 36             | 81                               |
| 1-4   | 4              | 106                              | 1-4   | 12             | 83                               |
| 2-2   | 1              | 93                               | 1-5   | 12             | 87                               |
| 2-3   | 3              | 72                               | 1-6   | 5              | 80                               |

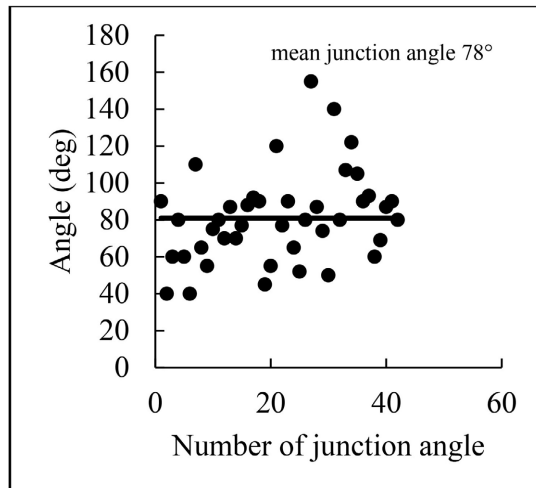
## Continued

|                  |       |    |                  |       |    |
|------------------|-------|----|------------------|-------|----|
| 2-5              | 1     | 90 | 2-2              | 17    | 82 |
| 3-3              | 1     | 80 | 2-3              | 8     | 93 |
| <b>Total</b>     | 42    |    | 2-4              | 9     | 91 |
| <b>Avg Angle</b> | 81°   |    | 2-5              | 6     | 82 |
| <b>Sd</b>        | 24.51 |    | 2-6              | 4     | 67 |
| <b>Max Angle</b> | 155°  |    | 3-3              | 1     | 40 |
| <b>Min Angle</b> | 40°   |    | 3-4              | 1     | 60 |
|                  |       |    | 3-5              | 7     | 84 |
|                  |       |    | 4-6              | 1     | 87 |
|                  |       |    | 5-5              | 1     | 29 |
|                  |       |    | <b>Total</b>     | 257   |    |
|                  |       |    | <b>Avg Angle</b> | 78°   |    |
|                  |       |    | <b>Sd</b>        | 21.25 |    |
|                  |       |    | <b>Max Angle</b> | 165°  |    |
|                  |       |    | <b>Min Angle</b> | 29°   |    |

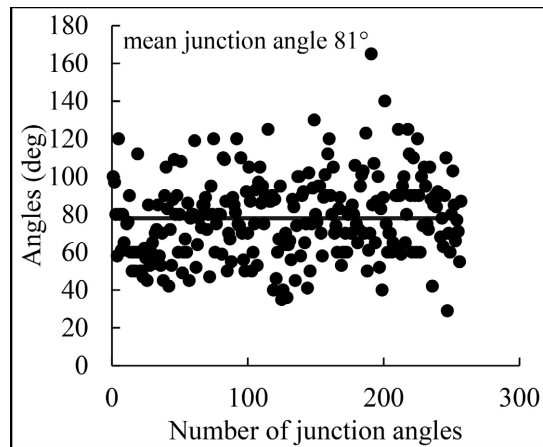
Despite the expectation of broader junctions with higher stream orders, the gentle slope in the area results in some higher-order stream junctions exhibiting relatively acute angles. The highest obtuse angle recorded within the 100-meter buffer zone is 155°, while the smallest acute angle is 40°. The standard deviation of junction angles in this zone is 24.51, indicating greater variability in the presence of dykes. By comparison, the 500-meter buffer zone, which is considered less affected by dyke orientation, shows a slightly lower standard deviation of 21.25.

A total of 257 stream junction angles were measured within the 500-meter buffer zone, representing areas presumed to be unaffected by dyke orientation. The average junction angle in this zone is 78° (Figure 17 and Figure 18), with the maximum obtuse angle recorded at 165° and the minimum acute angle at 29°. First-order streams in this buffer zone have an average confluence angle of 70°, while the confluence of two second-order streams averages 77°. Again, the gentle slope in the lower basin tends to result in more acute convergence angles in higher-order streams.

Junction angles around dyke ridges are acute angles in the lower-order streams. Overall junction angles based on actual data of 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> order streams are close to the right angle. Non-dyke locations indicate that dykes' orientation influences stream confluence patterns through a more acute angle. Stream junction angles close to the dyke parallel-oriented ridges follow the spatial arrangement of lower to middle order streams and influence the junction angles. Average junction angles near dyke ridges are similar to the orientation average angle (81°) of dykes' geological features. In non-dyke areas, the average stream junction angle is 78° acute. This suggests that the distance from dykes' prominent ridges has less of an impact on stream junction angles and stream orientation.



**Figure 17.** Plot of stream junction angles around the dyke ridges area (100 m buffer zone).



**Figure 18.** Stream junction angles distribution in the non-dykes area (500 m buffer zone).

## 5. Conclusion

This study demonstrates that the orientation and spatial distribution of dykes exert a significant influence on the geometry of stream junction angles within the Rangavali River Basin. The ENE-WSW trending dykes, with an average strike of  $N81^{\circ}$ , serve as structural barriers that modify stream flow, particularly affecting lower-order streams which exhibit more acute junction angles in proximity to these features. As stream order increases and the influence of dyke ridges decreases, junction angles tend to become more obtuse. The analysis within 100 m and 500 m buffer zones further confirms that dyke alignment correlates strongly with stream orientation and junction geometry, leading to a superimposed drainage pattern in this Deccan Trap terrain. These findings have practical implications beyond geomorphological understanding. From a management perspective, they can assist in watershed planning, particularly in predicting flow direction, erosion patterns, and sediment deposition zones. The insights gained also support flood risk assess-

ment and the identification of hydrologically sensitive areas prone to rapid runoff or localized flooding. Furthermore, the study aids infrastructure development by highlighting how dykes may redirect flow or serve as natural barriers, guiding the placement of roads, bridges, and culverts. In groundwater exploration, dyke-fracture zones aligned with stream paths may indicate zones of enhanced infiltration and recharge potential. Also, this research supports environmental planning and land use zoning by identifying structurally controlled stream behaviour that could impact development in basaltic regions. Overall, the study not only elucidates the geomorphic impact of dykes but also provides a useful framework for applied hydrology, land management, and structural geomorphology in similar volcanic terrains.

### Authors' Contributions

SBB and SSP wrote the manuscript, TPR and SDP prepared the maps and tables. All authors reviewed the manuscript.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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