# Application of Remote Sensing and GIS for Morphometric Analysis: A Case Study of Burhanpur Watershed

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**Abstract** Morphometric analysis of watershed is quantitative representation of its drainage network based on topography of a landform. Morphometric analysis-based basin attributes provide insights on drainage behavior of watershed and strengthen watershed planning, environmental monitoring and basin management activities. In broad categories these attributes are categorized as linear (length related), areal (area and shape related), and relief (elevation related) aspects of watershed. In this study Burhanpur watershed, upper part of Tapi river basin, has been selected for detailed morphometric analysis using Remote Sensing (RS) data and Geographic Information Systems (GIS) technology. The study examines about 10,585 km$^2$ drainage area for linear, arial and relief aspects of Burhanpur watershed. The values for: linear aspects (Stream order, Stream length ratio, Length of overland flow etc.), arial aspect (Drainage density, Form factor, Circulatory ratio etc.) and relief aspect (Ruggedness number, Relief ratio etc.) were recorded after analysis. This study improves the understanding of drainage characteristics and stream pattern of selected watershed and reflects potential of RS and GIS for land and water resource conservation and management with in watershed. Further study recommends the way forward in research at study area.

**Keywords** GIS · RS · Drainage analysis · Geo-morphometry analysis · Tapi basin

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# 1 Introduction

A watershed is an area which contributes the total runoff as a response to rainfall event(s) to a single common outlet point for disposal. Often it is considered similar to a drainage basin or a catchment area to a reservoir. As watershed is an integrated form of natural resources i.e., land, water, and vegetation, study of watershed and management of its natural resources is crucial for attaining the environmental sustainability (Sangma and Guru 2020; Patel et al. 2021; Kumar et al. 2021a). Watershed topography and drainage network, being the most delicate components of a landscape, greatly influences both structure and fluvial dynamics of watershed. River's flow pattern and drainage systems are dynamic in nature, changing over time and space as a result of a variety of factors such as regional geology, structural elements, vegetation, and soils (Rekha et al. 2011). Poor watershed conditions like excessive runoff generation, increased soil erosion, poor infiltration conditions, drought and floods can be overcome by a well-planned managemental techniques (Choudhari et al. 2018). Such strategies suitably provide optimal utilization of resources without any degradation and loss in sustainability (Arvind et al. 2018; Bajirao et al. 2019). In this direction the characteristics of watershed (topographical, climatic, and hydrologic) and related processes must be understood qualitatively as well as quantitatively by the decision-makers (Singh et al. 2021).

Geomorphometry is the mathematical analysis of the earth's surface that describes its topographic reliefs and drainage behavior (Pakhmode et al. 2003). According to Rastogi and Sharma (1976), a number of hydrologic phenomena are associated with the physiographic features of watersheds. Several morphometric parameters (belonging to linear, arial and relief aspects) were derived (Horton 1932, 1945; Smith 1950; Miller 1953; Schumm 1956; Hadley and Schumm 1961; Strahler 1964; Faniran 1968) and used by researches in the geomorphometric studied of watershed (Nooka Ratnam et al., 2005; Mesa 2006 and Ozdemir and Bird 2009).

## *1.1 Role of RS and GIS*

Initiation of morphometric research began in the middle of the twentieth century using a traditional methodology based on hand assessments of topographic maps (Schumm 1956). However, the traditional method of assessing river morphology is a labor-intensive and time consuming (Pande and Moharir 2017). On the other hand, with the development of geospatial and computational technology and accessibility of remotely sensed data it is now much easier to undertake exact and precise assessments with lesser time and resources. When topographic surveys are not feasible or area which are not accessible satellite terrain data such as Digital Elevation Models (DEM) are useful for geomorphometric parameterization of a watershed. DEMs give continuous data, and are simple to integrate into Geographical Information Systems (GIS) (Moore et al. 1991; Patel et al. 2022). Senthamizhan et al. (2016)

used satellite data and GIS technologies in morphometrics for constructing watershed management studies. To calculate morphometric parameters in the sub-basin susceptible to both erosion and sedimentation, a combined approach employing toposheet, remotely sensed digital elevation model, and morphometric ArcGIS toolbox has been utilized Singh et al. (2021). Moreover, RS ang GIS alone are the advance tools capable to study and manage natural resources (Kushwaha et al. 2022a; Machiwal et al. 2022; Dhaloiya et al. 2022).

## 1.2 Application of Morphometric Analysis

Geo-morphometric analysis offers the way out to investigate the geometrical and drainage characteristics of watershed based on topography. This information becomes useful to study the ungauged watersheds where information on hydrology, geology, geomorphology, and soil is limited. Forecasting of other basin features such as travel time, time to peak, and severity of erosional processes can be performed using this technique (Romshoo et al. 2012; Puno and Puno 2019). Moreover, information obtained from morphometric study of watersheds could be an important tool for managing water resources, preventing soil erosion, mapping landslide susceptibility, assessing groundwater potential, and prioritizing watersheds (Kumar et al. 2021b; Kushwaha et al. 2022b; Sharma et al. 2022).

The geomorphometric analysis along with other supplemental data such as runoff, flooding, groundwater development, soil erosion, land use and cover, socioeconomic status of the local population etc. can be used to priorities sub-watersheds (Kumar et al. 2019). It is widely used to identify changes in characteristics of drainage basin, understand the several environmental issues at watershed (Mangan et al. 2019; Choudhari et al. 2018). In general, geomorphometric analysis gives suitable information to understand the spatial and temporal behavior of watershed hydrology and related risks (Pande et al. 2018). Which are crucial for sustainable management and planning of natural resources (Karabulut and Özdemir 2019; Nitheshnirmal et al. 2019). This study is conducted with the objective to examine watershed geomorphometric characteristics using RS data and GIS technology for Burhanpur watershed at upper Tapi river in central India. Study quantifies the hydro-geo-morphic characteristics of watershed to be used in further development of management strategies for the area against several degradation processes. The study discusses in detail the different morphometric parameters, process of their quantification and importance in the context of Burhanpur watershed. Considering the previous studies, this study delivers important insights for the scholars and decision makers of the similar research area.

# 2 Materials and Methods

## 2.1 Study Area: Geography and Environment

The Tapi river system is one of the biggest west flowing river systems of peninsular India. The river originates from Multai a place of Madhya Pradesh passes through Maharashtra and falls in to the Arabian Sea near city of Surat, Gujarat. From origin to its mergence into sea it covers approx. 728 km of distance (https://indiawris.gov.in). The Tapi river system drains about total of 65,145 km$^2$ area (second largest westward draining inter-state river basin) out of which roughly 16, 79 and 5% area falls in Madhya Pradesh, Maharashtra and Gujarat respectively (Fig. 1).

The Part that is drained from Madhya Pradesh is the approximately half of Upper Tapi Basin. Burhanpur, being last district of Madhya Pradesh that is passed by Tapi river, is the outlet of the upper reach of Tapi river and a gauging station for flow measurement. Hance, this study considers Burhanpur as the outlet of watershed and distinguishes the study area as Burhanpur watershed. The river travels near about 340 km from origin to reach the outlet at Burhanpur. The spatial extent of watershed expands from 75° 55′ E to 78° 18′ 14″ E longitude and from 21° 1′ 51″ N to 22° 1′ 52″ N latitude (Fig. 1). Within this extent the watershed covers about 10,585 km$^2$ area. Topographic elevation of the area varies from 188 to 1171 m (above Mean Sea Level). The area experiences the average annual rainfall of 900 mm. Study area is predominantly having clayey to loamy clayey soils (Chandra et al. 2016) and comprises agriculture, range lands, water bodies, barren land, built-up area and forest as main land uses types.

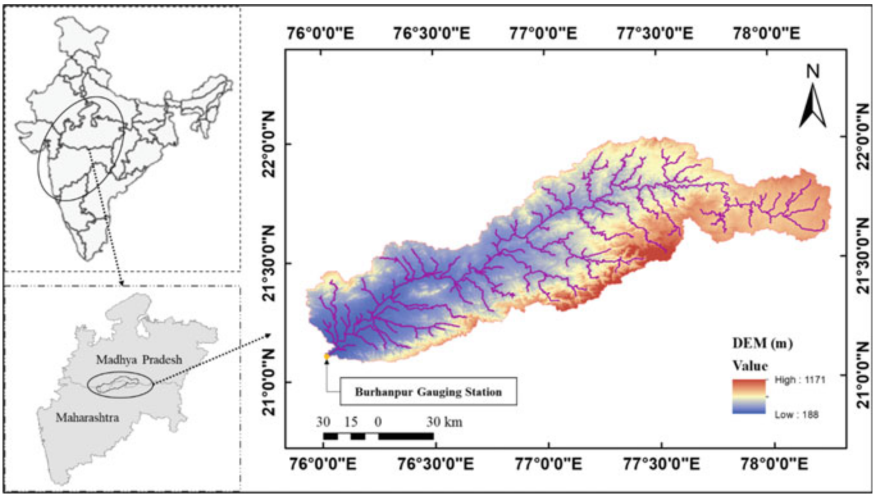


Fig. 1 Study area with DEM map and river reaches

### 2.2 Geo-morphometric Analysis: Parameter Quantification

The present study quantifies the geo-morphometric parameters of Burhanpur watershed using Remote Sensing (RS) data and Geographical Information System (GIS). The Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Digital Elevation Model (DEM) from USGS Earth Resources Observation and Science (EROS) Center archive was downloaded to get elevation and topography of study area (https://www.usgs.gov/). This RS data was used for delineation of watershed and morphometric analysis through Hydrology tool box and other spatial tools in ArcGIS (version 10.4) (Band 1986; Morris and Heerdegen 1988; Tarboton et al. 1991; Maidment 2002). In order to quantify the geomorphometry of watershed three different aspects: linear (length related), areal (area and shape related), and relief (elevation related) aspects were considered (Strahler 1964). The total 23 basic and derived aspects were analyzed to study the Burhanpur watershed as listed and described in Table 1. Linear aspect of watershed was determined using (i) *Stream order* (u), (ii) *Stream length* ($L_u$), (iii) *Number of streams* ($N_u$), (iv) *Mean stream length* ($L_{ms}$) (v) *Stream length ratio* ($R_l$), (vi) *Bifurcation ratio* ($R_{bf}$), (vii) *Mean bifurcation ratio* ($R_{bfm}$), (viii) *Basin length* ($L_b$), and (ix) *Basin perimeter* (P). Further areal aspect was analyzed through (i) *Basin area* (A), (ii) *Drainage density* ($D_d$), (iii) *Stream frequency*, (iv) *Form factor* ($F_f$), (v) *Shape factor* ($F_s$), (vi) *Circulatory ratio* ($R_c$), (vii) *Elongation ratio* ($R_e$), (viii) *Constant of channel maintenance* (C), (ix) *Drainage texture* (T), (x) *Length of overland flow* ($L_g$), and (xi) *Texture ratio* (T). Moreover, to study the morphometry through relief aspect the (i) *Basin relief* (H), (ii) *Relief ratio* (Rr), and (iii) *Ruggedness number* ($R_n$) were studied (Fig. 2 and Table 1).

In this study the linear, aerial, and relief aspects were quantified and analyzed based on the procedure suggested by Horton (1932) Horton (1945), Smith (1950), Miller (1953), Schumm (1956), Hadley and Schumm (1961), Strahler (1964), Faniran (1968), and followed by Nooka Ratnam et al. (2005), Mesa (2006) and Ozdemir and Bird (2009).

## 3 Results and Discussion

SRTM-DEM from USGS-EROS Center archive was downloaded to get elevation and topography of study at 30 × 30 m spatial resolution and used for the delineation of boundary and stream of the watershed. From the slop analysis of DEM is was found that the slope of DEM varies from 1 to 190% across watershed area (Fig. 3). The area near to the lower (west)-middle boundary of watershed is predominant with higher hill slope (>30%). Whereas the Eastern part of watershed (which is origin of Tapi river) is having lower slope value (<30%).

Figure 4 depicts the flow direction at the spatial resolution of 30 × 30 m derived from DEM. It was observed that flow is being directed in all the directions, however,

**Table 1** Aspect wise morphometric parameters

| Aspects | Quantification | Detail | References |
|---|---|---|---|
| *Linear aspects: describe of arrangement of linear elements* | | | |
| Stream order (u) | Using GIS utility | Hierarchical rank | Strahler (1964) |
| Stream length ($L_u$) | Using GIS utility | Length of uth order stream | Horton (1945) |
| Number of streams ($N_u$) | Using GIS utility | Total number of uth order stream | Horton (1945), Strahler (1964) |
| Mean stream length ($L_{ms}$) | $L_{ms} = L_u/N_u$ | Unit length of uth order stream | Strahler (1964) |
| Stream length ratio ($R_l$) | $R_l = L_u/L_{u-1}$ | Horton postulated the constant values for this ration throughout the successive orders | Horton (1945) |
| Bifurcation ratio ($R_{bf}$) | $R_{bf} = N_u/N_{u+1}$ | Higher values indicate the rockey area with sleep slope with valleys in-between | Horton (1932) |
| Mean bifurcation ratio ($R_{bfm}$) | | The average of bifurcation ratios of all orders | Schumm (1956) |
| Basin length ($L_b$) | $L_b = 1.321A^{0.568}$ | | Nooka Ratnam et al. (2005) |
| Basin perimeter (P) | Using GIS utility | Outer periphery of basin | Schumn (1956) |
| *Aerial aspect: describe of arrangement of areal elements* | | | |
| Basin area (A) | Using GIS utility | area bounded within the periphery of basin | Strahler (1964) |
| Drainage density ($D_d$) | $D_d = \Sigma L_u/A$ | The ratio between the total stream length of all ($D_d$) orders to the area of the basin | Horton (1945) |
| Stream frequency ($S_f$) | $F_s = \Sigma N_u/A$ | number of stream segments in unit area of watershed | Horton (1945) |
| Form factor ($F_f$) | $F_f = A/L_b^2$ | It indicates the flow intensity of a basin of a defined area | Horton (1932, 1945) |
| Shape factor ($F_s$) | $F_s = L_b^2/A$ | Becomes greater than 1 for basins which are elongated along some characteristic length of the basin and less than 1 for basins which are perpendicular to this characteristic length | Horton (1932) |

(continued)

**Table 1** (continued)

| Aspects | Quantification | Detail | References |
|---|---|---|---|
| Circulatory ratio ($R_c$) | $Rc = 4\pi A/P^2$ | It is influenced by the length and frequency of stream, geological structures, land use/ landcover, climate, relief and slope of the basin | Miller (1953), Strahler (1964) |
| Elongation ratio ($R_e$) | $Re = 1.128\sqrt{A}/L_b$ | A circular basin is more efficient in the discharge of runoff than an elongated basin | Schumm (1956) |
| Constant of channel maintenance (C) | $C = 1/D_d$ | Drainage area needed to generate a unit length of stream | Schumm (1956) |
| Infiltration number ($I_f$) | $I_f = D \times F_s$ | It describes about the infiltration physiognomies of the basin area | Faniran (1968) |
| Length of overland flow ($L_g$) | $L_g = 1/2D_d$ | It relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow to a large degree | Horton (1945) |
| Texture ratio (T) | $T = \Sigma N_u/P$ | The ratio between the total number of streams of all orders and perimeter of the basin | Smith (1950) |
| *Relief aspect: describe of arrangement of elevation elements* | | | |
| Basin relief (H) | $H = H_{max}\text{-}H_{min}$ | It has significant role to understand landforms development, drainage development, surface and erosional properties of area | Hadley and Schumm (1961) |
| Relief ratio (Rr) | $R_r = H/L$ | It indicates the overall steepness of a drainage basin and is an indicator of intensity of erosion processes operating on the slope of the basin | Schumm (1956) |
| Ruggedness number ($R_n$) | $R_n = (H \times D_d)/K$ | It is useful for steepness and slope of the drainage network | Schumm (1956) |

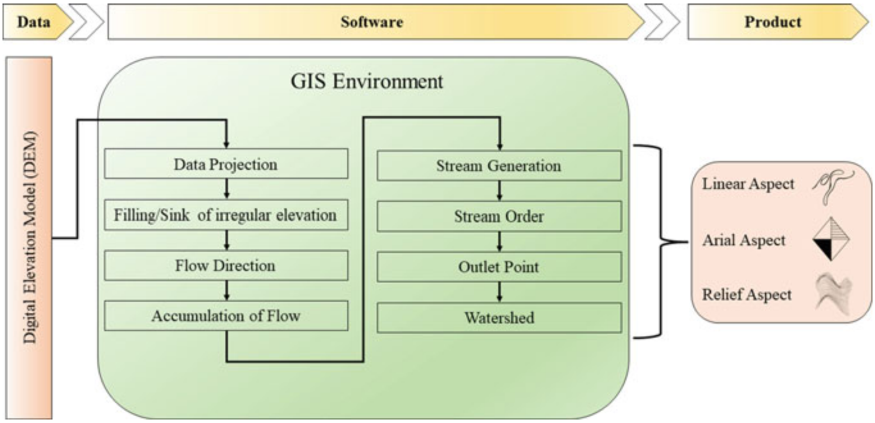


**Fig. 2** Conceptual process for watershed delineation and morphometric parameters analysis

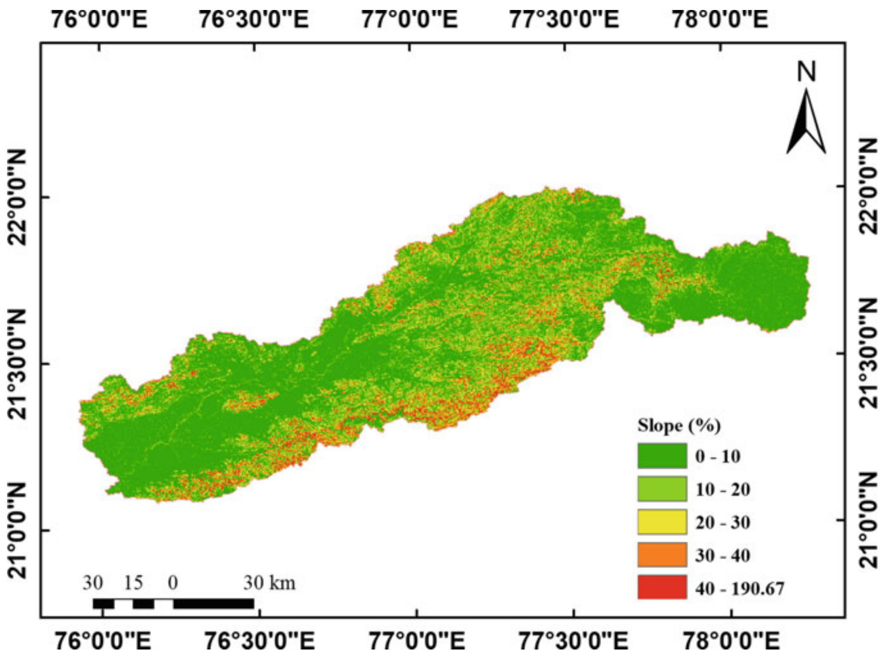


**Fig. 3** Slope map of Burhanpur watershed

the predominant direction is the West (16) with the 17.4% cells of DEM. This is followed by South (16.9%), North (15.9%) and East (11.3%).

The area of delineated watershed was 10,585 $km^2$, which is further sub divided into 18 sub-watersheds (Fig. 5). The maximum and minimum area of sub watershed are

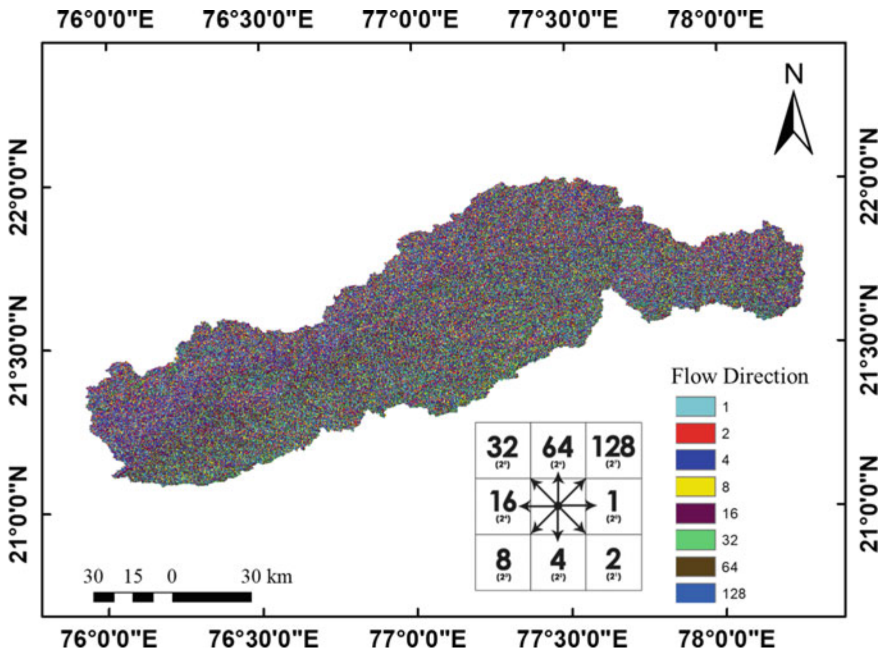


**Fig. 4** Flow direction map of Burhanpur watershed

1670.3 km$^2$ and 146 km$^2$ for SW_0 and SW_7 respectively. Perimeter of 272.1 and 79.8 km respectively.

The study area comes under the dendritic type drainage system which has widespread pattern of drainage. The network of tributes found to have highest order stream of 4th order (Table 2). Table 2 suitably depicts that delineated watershed consists 4 numbers of stream order starting from 1st order to 4th order. Total length of stream in the watershed was 2203.7 km for 281 numbers of streams. The largest sub-watershed (WS_0) covers total 43 streams (21—1st order, 10—2nd order, 11—3rd order, and 1—4th order) with stream length of 338.2 km (174.1 km—1st order, 54.5 km—2nd order, 99.0 km—3rd order, and 10.6 km—4th order).

The perimeter of sub watersheds found to be of range between 78.6 and 272.1 km. The stream orders reflect the slope of watershed, usually 1st and 2nd order streams lie on steep slopes and delivers the flow to the next order stream. The length of stream characterizes the size of different components of drainage system. It was observed from the Table 2 that the watershed has the basin length of 253.5 km whereas, among sub-watersheds, WS_0 and WS_7 have the longest and smallest sub-watershed's lengths respectively. The total length of streams of Burhanpur watershed is about 2203.7 km (accounting 1108.3, 551.9, 213.4, and 330.1 for first, second, third and fourth order of streams respectively). Whereas maximum mean stream length of 9.70 km is recorded for 3rd order stream, as 3rd order stream is not present in all sub watersheds. The highest (1.55) and lowest (0.39) stream length ratio is recorded

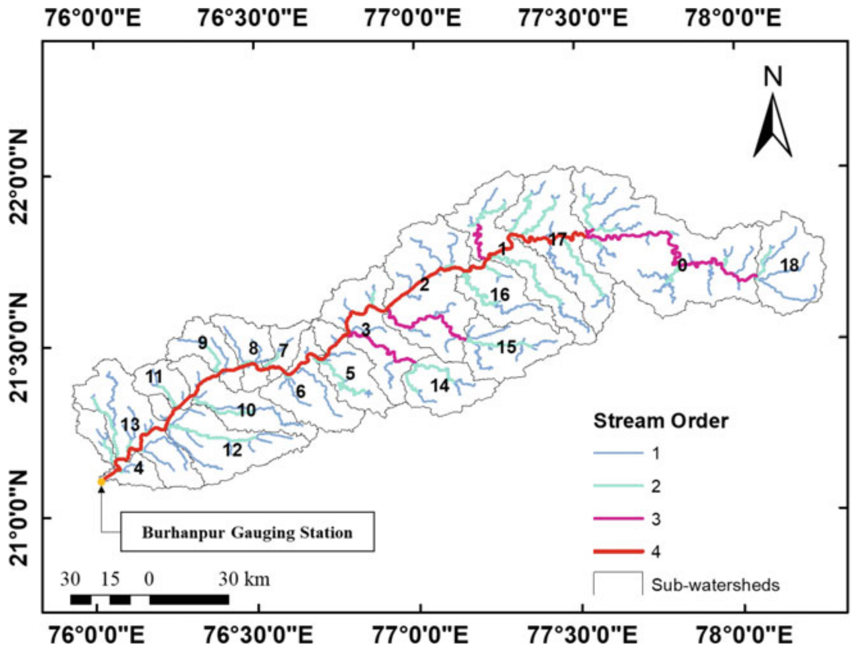


**Fig. 5** Sub-watershed wise stream order of Burhanpur watershed

between 4th and 3rd order stream and between 3nd order and 2nd order streams respectively. The stream length ratio for sub-watershed varies from 0.04 to 9.71 with in the sub watershed. Sub-watershed SW_2 has highest stream length ratio for 2nd, 3rd and 4th order streams. This variation among the stream length ratio between the successive stream orders shows the corresponding variation in the slope and topographic conditions of watershed.

The bifurcation ratio of Burhrapur watershed varies between 0.34 and 2.10 with mean bifurcation ratio of 1.77. Among sub-watersheds the highest bifurcation ratio is observed to be 4.67 for SW_0 whereas least bifurcation ratio of 0.33 for SW_3. These values are common in the basin where the drainage pattern is not influenced by the geological structure of watershed (Sreedevi et al. 2009). For bifurcation ratio less than 3 the watershed would be structurally less disturbed with less distortion in drainage pattern and geological formation (Patel et al. 2013). Higher value of bifurcation ratio also shows that watershed has steeply dipping rock strata and severe over land flow (Chandniha and Kansal 2017). The bifurcation ratio more than 3 indicates severe over land flow and low discharge to the sub-watersheds. Further, the values of bifurcation ratio also display shape of watersheds. Here the delineated sub watersheds SW_0, SW_2, SW_7, SW_10, SW_11 and SW_15 were elongated in shape whereas remaining all the sub watersheds bifurcation ratio less than 3 are normal and approximately circular in shape. The higher value of bifurcation ratio

**Table 2** Sub-watershed wise computation of morphometric parameters for linear aspect

| Sub watershed | Area ($km^2$) | Perimeter (km) | Total length of uth order streams (km) | | | | Total number of uth order streams | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| SW_0 | 1670.3 | 272.1 | 174.1 | 54.5 | 99.0 | 10.6 | 21 | 10 | 11 | 1 | 43 |
| SW_1 | 750.6 | 248.3 | 43.9 | 71.9 | 21.7 | 17.8 | 8 | 5 | 1 | 3 | 17 |
| SW_2 | 996.1 | 193.9 | 100.1 | 4.2 | 40.9 | 38.9 | 11 | 1 | 5 | 8 | 25 |
| SW_3 | 644.3 | 187.7 | 50.8 | 7.6 | 32.8 | 27.5 | 7 | 2 | 2 | 6 | 17 |
| SW_4 | 264.9 | 142.2 | 22.1 | 14.8 | | 11.9 | 5 | 3 | | 3 | 11 |
| SW_5 | 394.5 | 137.1 | 33.2 | 36.3 | | 17.5 | 6 | 3 | | 4 | 13 |
| SW_6 | 480.8 | 153.0 | 59.5 | 2.7 | | 18.9 | 5 | 2 | | 4 | 11 |
| SW_7 | 146.0 | 79.8 | 10.3 | 9.2 | | 15.9 | 3 | 1 | | 3 | 7 |
| SW_8 | 266.1 | 103.6 | 34.0 | 5.9 | | 15.7 | 4 | 2 | | 3 | 9 |
| SW_9 | 278.3 | 108.1 | 30.6 | 17.9 | | 15.6 | 5 | 2 | | 4 | 11 |
| SW_10 | 474.0 | 167.7 | 55.3 | 25.7 | | 15.2 | 6 | 2 | | 5 | 13 |
| SW_11 | 188.6 | 78.6 | 13.3 | 12.4 | | 12.2 | 3 | 1 | | 3 | 7 |
| SW_12 | 647.0 | 182.4 | 92.7 | 38.8 | | 17.4 | 8 | 6 | | 3 | 17 |
| SW_13 | 696.2 | 189.0 | 105.9 | 38.7 | | 27.6 | 9 | 5 | | 5 | 19 |
| SW_14 | 390.3 | 103.7 | 29.5 | 38.9 | 8.3 | 0.0 | 5 | 3 | 1 | | 9 |
| SW_15 | 492.5 | 133.4 | 67.9 | 29.2 | 3.9 | 0.0 | 8 | 6 | 1 | | 15 |
| SW_16 | 414.9 | 137.8 | 36.4 | 44.2 | | 18.3 | 4 | 2 | | 3 | 9 |
| SW_17 | 827.6 | 211.5 | 72.6 | 84.5 | | 49.2 | 9 | 4 | | 6 | 19 |
| SW_18 | 562.2 | 131.4 | 76.2 | 14.6 | 6.8 | 0.0 | 5 | 3 | 1 | 0 | 9 |
| **Burhanpur watershed** | **10585.0** | **1145.5** | **1108.3** | **551.9** | **213.4** | **330.1** | **132** | **63** | **22** | **64** | **281** |

| Sub watershed (SW) | SW length (km) | Mean stream length (km) | | | | Stream length ratio | | | Bifurcation ratios | | | Mean $R_{bf}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | |
| SW_0 | 88.8 | 8.29 | 5.45 | 9.00 | 10.65 | 0.31 | 1.82 | 0.11 | 2.10 | 0.91 | 11.00 | 4.67 |
| SW_1 | 56.4 | 5.49 | 14.38 | 21.75 | 5.92 | 1.64 | 0.30 | 0.82 | 1.60 | 5.00 | 0.33 | 2.31 |
| SW_2 | 66.2 | 9.10 | 4.21 | 8.17 | 4.86 | 0.04 | 9.71 | 0.95 | 11.00 | 0.20 | 0.63 | 3.94 |
| SW_3 | 51.7 | 7.25 | 3.82 | 16.39 | 4.59 | 0.15 | 4.29 | 0.84 | 3.50 | 1.00 | 0.33 | 1.61 |
| SW_4 | 31.2 | 4.41 | 4.93 | | 3.97 | 0.67 | | | 1.67 | | | 1.67 |
| SW_5 | 39.1 | 5.53 | 12.10 | | 4.37 | 1.09 | | | 2.00 | | | 2.00 |
| SW_6 | 43.8 | 11.91 | 1.35 | | 4.73 | 0.05 | | | 2.50 | | | 2.50 |
| SW_7 | 22.2 | 3.42 | 9.21 | | 5.29 | 0.90 | | | 3.00 | | | 3.00 |
| SW_8 | 31.3 | 8.49 | 2.95 | | 5.22 | 0.17 | | | 2.00 | | | 2.00 |
| SW_9 | 32.1 | 6.11 | 8.93 | | 3.89 | 0.58 | | | 2.50 | | | 2.50 |
| SW_10 | 43.4 | 9.22 | 12.85 | | 3.03 | 0.46 | | | 3.00 | | | 3.00 |

(continued)

**Table 2** (continued)

| Sub watershed (SW) | SW length (km) | Mean stream length (km) | | | | Stream length ratio | | | Bifurcation ratios | | | Mean $R_{bf}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | |
| SW_11 | 25.7 | 4.43 | 12.43 | | 4.08 | 0.93 | | | 3.00 | | | 3.00 |
| SW_12 | 51.8 | 11.59 | 6.47 | | 5.81 | 0.42 | | | 1.33 | | | 1.33 |
| SW_13 | 54.0 | 11.77 | 7.73 | | 5.52 | 0.37 | | | 1.80 | | | 1.80 |
| SW_14 | 38.9 | 5.91 | 12.96 | 8.29 | | 1.32 | 0.21 | | 1.67 | 3.00 | | 2.33 |
| SW_15 | 44.4 | 8.49 | 4.86 | 3.91 | | 0.43 | 0.13 | | 1.33 | 6.00 | | 3.67 |
| SW_16 | 40.3 | 9.09 | 22.09 | | 6.09 | 1.22 | | | 2.00 | | | 2.00 |
| SW_17 | 59.6 | 8.07 | 21.12 | | 8.20 | 1.16 | | | 2.25 | | | 2.25 |
| SW_18 | 47.9 | 15.25 | 4.87 | 6.80 | | 0.19 | 0.47 | 0.00 | 1.67 | 3.00 | | 2.33 |
| **Burhanpur Watershed** | **253.5 ($L_b$)** | **8.40** | **8.76** | **9.70** | **5.16** | **0.50** | **0.39** | **1.55** | **2.10** | **2.86** | **0.34** | **1.77** |

spectacles the mature topography and large variation between successive streams order (Sreedevi et al. 2009).

Drainage density illustrate the runoff potential, infiltration capacity, climatic conditions and vegetative cover of watershed (Horton 1932). Table 3 shows the different aerial parameters of Burhanpur watershed along with all sub-watersheds.

The drainage density of Burhanpur watershed is 0.21 which indicates that overland flow is predominate and having coarse drainage structure in the basin. Lower values of drainage density also characterize the watershed highly resistance and permeable sub soil materials with low relief and covers dense vegetation (Sreedevi et al. 2009). The drainage density of sub watershed varies between 0.17 and 0.25. For the watersheds the higher drainage density implies the weak impermeable surface, sparsely vegetated and high relief conditions for corresponding sub-watersheds. From Table 3 it was observed that stream frequency of Burhanpur watershed is 0.03 and varies between 0.02 and 0.05 for sub watershed. The lower values of stream frequency show that the area has gentle ground slope and more permeable rocks. The lower values of drainage density and stream frequency implies that Burhanpur watershed as whole has less surface runoff and flooding is likely to be less. It also gives the inference of more percolation within the watershed which shows greater ground water potentials.

Form factor is the ratio of area of the basin to the square of basin length. Generally it values less than 0.79 (0.79 is for perfectly circular watershed) (Chandniha and Kansal 2017; Patel et al. 2013). The low value of form factor confirms that the basin is elongated in shape. The form factor of Burhanpur watershed is 0.16 and for the sub watershed it varies from 0.21 to 0.29. This depicts that the sub-watersheds with high $F_f$ (circular shape) will have peak flow of short duration, whereas those have low $F_f$ (elongated shape) will be having less peak of longer duration. Hence flood can easily be managed in elongated sub-watersheds than in those which are of circular in shape. As per the Horton (1932) the shape factor of a basin always remains greater than 1 for basin which are elongated in some characteristic length of the basin Shape

**Table 3** Sub-watershed wise computation of morphometric parameters for arial aspect

| Sub watershed | L | N | $D_d$ | $S_f$ | $F_f$ | $F_S$ | $R_c$ | $R_e$ | C | If | $L_g$ | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SW_0 | 338.29 | 43 | 0.20 | 0.03 | 0.21 | 4.72 | 0.28 | 0.52 | 4.94 | 0.01 | 2.47 | 0.16 |
| SW_1 | 155.31 | 17 | 0.21 | 0.02 | 0.24 | 4.24 | 0.15 | 0.55 | 4.83 | 0.00 | 2.42 | 0.07 |
| SW_2 | 184.05 | 25 | 0.18 | 0.03 | 0.23 | 4.40 | 0.33 | 0.54 | 5.41 | 0.00 | 2.71 | 0.13 |
| SW_3 | 118.70 | 17 | 0.18 | 0.03 | 0.24 | 4.15 | 0.23 | 0.55 | 5.43 | 0.00 | 2.71 | 0.09 |
| SW_4 | 48.76 | 11 | 0.18 | 0.04 | 0.27 | 3.68 | 0.16 | 0.59 | 5.43 | 0.01 | 2.72 | 0.08 |
| SW_5 | 86.99 | 13 | 0.22 | 0.03 | 0.26 | 3.88 | 0.26 | 0.57 | 4.53 | 0.01 | 2.27 | 0.09 |
| SW_6 | 81.14 | 11 | 0.17 | 0.02 | 0.25 | 3.99 | 0.26 | 0.56 | 5.93 | 0.00 | 2.96 | 0.07 |
| SW_7 | 35.33 | 7 | 0.24 | 0.05 | 0.29 | 3.39 | 0.29 | 0.61 | 4.13 | 0.01 | 2.07 | 0.09 |
| SW_8 | 55.51 | 9 | 0.21 | 0.03 | 0.27 | 3.68 | 0.31 | 0.59 | 4.79 | 0.01 | 2.40 | 0.09 |
| SW_9 | 63.98 | 11 | 0.23 | 0.04 | 0.27 | 3.70 | 0.30 | 0.59 | 4.35 | 0.01 | 2.17 | 0.10 |
| SW_10 | 96.18 | 13 | 0.20 | 0.03 | 0.25 | 3.98 | 0.21 | 0.57 | 4.93 | 0.01 | 2.46 | 0.08 |
| SW_11 | 37.94 | 7 | 0.20 | 0.04 | 0.28 | 3.51 | 0.38 | 0.60 | 4.97 | 0.01 | 2.48 | 0.09 |
| SW_12 | 148.97 | 17 | 0.23 | 0.03 | 0.24 | 4.15 | 0.24 | 0.55 | 4.34 | 0.01 | 2.17 | 0.09 |
| SW_13 | 172.18 | 19 | 0.25 | 0.03 | 0.24 | 4.19 | 0.24 | 0.55 | 4.04 | 0.01 | 2.02 | 0.10 |
| SW_14 | 76.69 | 9 | 0.20 | 0.02 | 0.26 | 3.88 | 0.46 | 0.57 | 5.09 | 0.00 | 2.54 | 0.09 |
| SW_15 | 100.95 | 15 | 0.20 | 0.03 | 0.25 | 4.00 | 0.35 | 0.56 | 4.88 | 0.01 | 2.44 | 0.11 |
| SW_16 | 98.81 | 9 | 0.24 | 0.02 | 0.26 | 3.91 | 0.27 | 0.57 | 4.20 | 0.01 | 2.10 | 0.07 |
| SW_17 | 206.29 | 19 | 0.25 | 0.02 | 0.23 | 4.29 | 0.23 | 0.54 | 4.01 | 0.01 | 2.01 | 0.09 |
| SW_18 | 97.62 | 9 | 0.17 | 0.02 | 0.25 | 4.07 | 0.41 | 0.56 | 5.76 | 0.00 | 2.88 | 0.07 |
| Burhanpur Watershed | 2203.68 | 281 | 0.21 | 0.03 | 0.16 | 6.07 | 0.10 | 0.46 | 4.80 | 0.01 | 2.40 | 0.25 |

L = Total stream length, N = Total stream numbers, $D_d$ = Drainage density (km/km$^2$), $S_f$ = Stream frequency (number/km$^2$), $F_f$ = Farm factor, $F_S$ = shape factor, $R_c$ = Circularity ration, $R_e$ = Elongation ration, C = Constant of channel maintenance (km$^2$/km), $I_f$ = Infiltration number, $L_g$ = Length of overland flow (km), T = Texture ration

factor of Burhapur watershed is 6.07 which shows that the watershed is more or less elongated in shape.

The value of circularity ratio ranges from 0.2 to 0.8 or less than 1. The value more than 0.5 indicates that the watershed is more homogeneous in geological formation and more circular in shape whereas less than 0.5 shows that watershed is elongated in shape (Miller 1953). In circular watershed as the high flow could accumulated from whole area of watershed simultaneously circularity ratio of watershed is used for assessment of flood hazard. The circularity ratio of Burhanpur watershed is 0.10 depicting it as elongated in shape. Further emphasizes that the discharge from the watershed would be less. Whereas the circularity ration vary between 0.15 and 0.46 for the sub-watersheds. Higher value of 0.46 is for sub watershed SW_14 (relatively circular in shape) shows that it could be flood hazard zone with in the watershed. Similarly, the zones with higher circularity ration are prone to flood hazard.

Constant of channel maintenance is the inverse of drainage density of watershed. It indicates the magnitude of Sq. km of watershed surface area required to sustain the one km liner length of stream segment. The value of constant of channel maintenance for Burhanpur watershed is 4.80. Its value varies from 4.01 to 5.93 with in the sub watersheds. Overland flow is flow of precipitated water which move over the land surface leading to the stream channels which is differ from surface runoff. Overland flow is predominant in small watershed than larger watersheds. Burhanpur watershed has length of overland flow of 2.40 km, whereas its value varies between 2.01 and 2.96 km for sub-watersheds. SW_6 is more dominated with overland flow because of more relief than other sub-watersheds.

Texture ratio is also called as drainage texture which is the ratio of total no of stream segments of all order to the perimeter of the watershed. It depends on the lithological properties of basin, infiltration of the soil as well as relief aspects of the terrain (Chandniha and Kansal 2017; Shelar et al. 2022). The texture ratio of Burhanpur watershed is 0.25. The value varies within the sub-watershed between 0.07 and 0.16. Lower values of texture ratio indicate that watershed is plain with lower degree of slope. Relief ratio and Ruggedness number ($R_n$) of Burhanpur watershed observed as 3.88 and 0.2 respectively. The higher value of relief ratio characterizes the Burhanpur watershed with hilly regions (Fig. 3). Relief of the Burhanpur watershed is 983 m further indicates the mountainous area of watershed.

## 4 Conclusion

The Hydrological study of a watershed greatly relay on its geo-morphometric characteristics. No doubt, watershed delineation along with its stream network may be performed with traditional observational survey and using the maps. However, advance remote sensing and GIS technologies play a great role to provide quick yet authentic delineation of study area. Further this analysis not only helps to study hydrologic behavior but also to prioritize susceptible areas under erosion, management and utilization of land and water resources, status of landform etc. this study reviled that the Burhanpur watershed, as a whole, being elongated in shape (low form factor of 0.16 and shape factor of 6.07) and having dominant channel flow (low bifurcation ratio of 1.77) shows lesser susceptibility to erosion. Further it was found that the watershed is having low values of drainage density, stream frequency, and circularity ration of 0.21, 0.03, and 0.10 respectively, indicating that watershed, as a whole at outlet, do not contribute to instance flood hazards.

Nevertheless, when the sub-watersheds are considered, the results show the other face of a coin. It was observed that the part of watershed having sever overland flow based on bifurcation ration indicating the susceptibility under erosion problem. The fact of having low drainage density again confirms the threat of high overland flow for some sub-watersheds and their susceptibility to soil erosion. Moreover, comparative higher values of form factor and elongation ration of some sub watershed (SW_4, SW_7, SW_8, SW_9, SW_14, and SW_16) confirms their circular shapes.

In turn this indicates their capability to generate concentrated peak flow and hance susceptibility under flash flood situation. From this study it is concluded that the Burhanpur watershed is having some areas which may be under critical threat of soil erosion, sedimentation, and flash flood hazards.

The geomorphometric study being first step to understand the watershed's hydrological processes and their potential risk on resources. However, the microscopic characterization and prioritization of sub-watersheds within the watershed area is further essential for comprehensive management, detailed planning and effective implementation. Hance this study also highlights the need of further research to prioritize the sub-watershed for strategies building to promote soil conservation via control of soil erosion and on-site water harvesting via control of flash floods. Which will help the decision makers to allocate the investments to critical sub-watersheds in technically efficient and economically effective way.

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