INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

MORPHOMETRIC AND HYDROGEOMORPHIC ANALYSIS OF PILI RIVER BASIN EXPOSED IN PARATWADA-ACHALPUR REGION, AMRAVATI DISTRICT, MAHARASHTRA AND BETUL DISTRICT IN MADHYA PRADESH USING REMOTE SENSING AND GIS TECHNIQUES

KHADRI S. F. R, APURVA D. FULADI

IJPRET-QR CODE PAPER-QR CODE

Department of Geology, Sant Gadge Baba Amravati University, Amravati-444602 (MS)

Accepted Date:
04/08/2013

Publish Date:
01/09/2013

Keywords

Watershed,
Geomorphology,
Morphometric Analysis,
GIS Techniques

Corresponding Author
Mr. Khadri S. F. R

Abstract

The present work deals with the assessment of groundwater and morphometric analysis of Paratwada-Achalpur Region of Amravati districts of Maharashtra based on GIS approach, in which, the Arc GIS 9.3 is used. The Survey of India toposheet No. 55G/7, 55G/11 and 55G/2 on 1:50,000 scales were used. The quantitative analysis of drainage system is an important aspect of characterization of watersheds. This analysis can be achieved through measurement of linear, aerial and relief aspects of the basin and slope contribution (Nag and Chakraborty. 2003). Remote sensing data and GIS play a role in the field of hydrogeology, watershed management and groundwater occurrence. Groundwater is one of the most important natural resources required for human consumption, domestic purpose, irrigation, industrialization, urbanization etc. As groundwater is the largest available source of fresh water, it has become crucial not only to find out ground water potential zone, but also to monitor and conserve this important resource. The Morphometric analysis is mathematical calculation of the parameter likes stream order, bifurcation ratio, and drainage density and so on. Strahler (1964) stream order method is being used for stream ordering. The drainage density (D_d) of study area is 2.17 km reflecting the hydro geological conditions of the study area. The geomorphic features found in the study area are pediment, pediplain, plateau, hills, valley fill, flood plain, escarpment, denuded slope. These features are developed by erosion and deposition process of the river. On the basis of interpretation of satellite image, toposheet, and field visits, it is clear that geomorphology of the area comprises of plateau, eroded land denudation hills, residual hills, and younger alluvium. Plateau is the table like land. It is broad, elevated, and almost level. It covers southern part of the watershed along the watershed divide. This landform is easily identifiable in the satellite data due to flat top, occupying the higher altitude. The geomorphology of the watershed is having landforms features such as moderate dissected plateau, denudetional slope and alluvial pain. The hydrogeomorphological studies have demonstrated the groundwater regime of the region with identification of potential aquifer zones.

INTRODUCTION

Morphometric analysis will help to quantify and understand the hydrological characters and the results will be useful input for a comprehensive water resource management plan (Jawahar raj et al., 1998; Kumar swami et al., 1998 and Sreedevi et al., 2001). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). In India, some of the recent studies on morphometric analysis using remote sensing and GIS technique were carried out by Nautiyal (1994), Srivastava (1997), Nag (1998), Kumar *et al.* (2000), Srinivasan *et al.* (2004) and Chopra *et al.* (2005). The present report is compiled and prepared based on geomorphologic mapping done by using remote sensing and limited ground truth. In the present study, stream number, order, frequency, density and bifurcation ratio are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the topographical maps

Study area

The study area lies between the latitudes 21^0 40’30”-21^0 40’30”N and 75^0 56’25”-77^0 56’46” E long. The Survey of India top sheet No. 55G/7, 55G/11. It has an average elevation of 343 meters (1125 feet).(Fig.1).

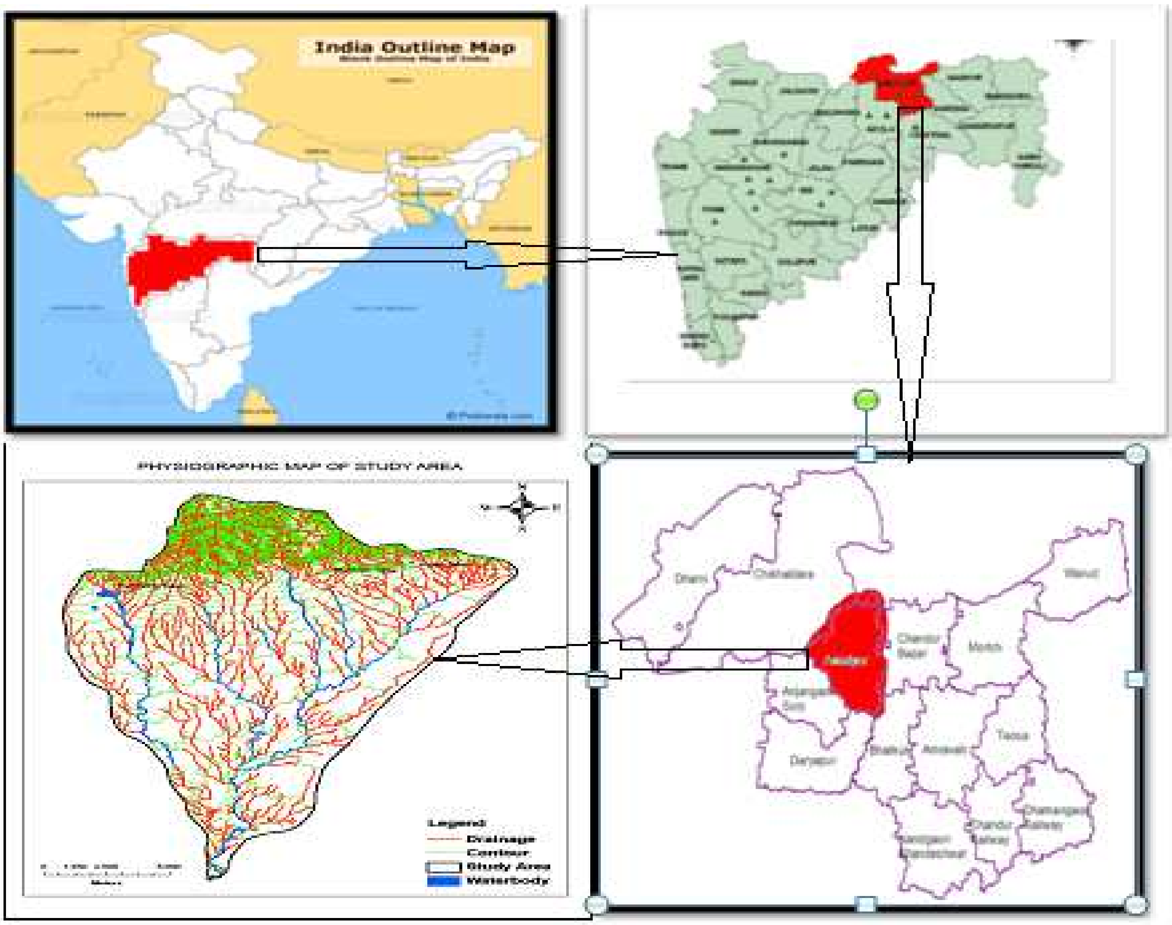

Fig 1. Location map of study area

The Climate of the study area is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e. June to September. The normal annual rainfall over the district varies from 700 mm to about 1700 mm. The intensity of rainfall during the period July to September is high accounting for the two thirds of the annual precipitation. Generally rain starts in middle of June and continues up to end of September.

Methodology

Morphometric analysis of a drainage system requires delineation of all existing streams. The quantitative approach has been adopted for the morphometric study of the area. The standard procedures suggested by Horton and Strahler [1,2] were adopted. The Survey of India Toposheet no. 55G/7, 55G/11 at the scale of 1:50000 used as base map for stream network. The goal of this study is to develop a viable methodology for producing GIS data model for preliminary location of Paratwada-achalpur region, using Arc Map 9.3, Arc GIS 9.3. The toposheet scanned for georeferenced using (Arc GIS 9.3) and stream network digitized using digitization tool and Strahler (1964) stream ordering method used for the stream ordering. The definitions of variables and their ranges are briefly outlined below. The data obtained has been incorporated in Table 2.

Geomorphology

Physiographically, the basin in marked with number of plateaus and residual hills exhibiting the flat top terraces and mesa butte features in the northern part while southern part is mainly gently sloping flood plain alluvial deposit. The basin has a total elevation different of 790 m having highest elevation of 1040 m MSL and the lowest being 350 m MSL. The Pili River is the sub-tributary of the Purna River which is an E-W elongated valley with slight convexity to the south. It has broad easterly edge but tapers towards the west. Geomorphic studies indicates that Pili River basin is a fifth order basin where the number of first order streams are much higher than higher order streams effecting rugged topography & presence of hard rock terrain in the northern portion. The tributaries of the Pili River the Bichan River & Bahiram Ki Sand River flows a master longitudinal consequent streams of exhibit, dendritic, sub parallel drainage patterns as a whole sub-rectangular & radial drainage pattern is also observed at present in hilly region. Sub-rectangular & radial Drainage pattern is also observed at places in the hilly region sub-rectangular Drainage Pattern is more prominent in the area which is overheated by joined basalt the streams are observed along the fractures / joints & are mostly oriented along the North South direction. Form factor indicates more elongate basin shape. Drainage network indicates coarse Drainage network.

Geomorphically, the study area shows structural networks Geomorphological and structural interpretation of study area have been prepared by utilizing Remote Sensing technique followed by extensive field mapping with the help of which seven distinctly different geomorphic units have been identified. They include alluvial plain, Bajada zone, Moderately Dissected Plateau, Highly Dissected Plateau, Plateau top, structural ridge and Denudetional hillock. Whereas, Bajada zone, older alluvium and younger alluvium act as storage zone. Bajada zone is also a good aquifer in the area. However, on the basis of dissection, it can be divided into following units.

Three geomorphic zones can be identified on the basis of land form assemblage, nature of its drainage, slope characters and sediment generation and deposition. These from the north to the south are-

Zone High relief:

Zone of high relief presents well-drained mature landscape with sub-dendritic to rectilinear drainage of high drainage density. Debris slopes directly terminate against the Fluve channels and pediments are usually absent. Flood plains along the streams are either absent or well developed. Area of high relief forms areas of sediment generation with very little deposition. Southern limit of the zone of high relief is marked by 20-80m high south facing scarps. Typical slope components of these scarps are a short different and steep debris slope which ends into piedmont belt below. These scarps define a sharp lineament which coincides with the E-W trending regional fault known as Gavilgarh fault, Achalpur fault.

Alluvial plain:

Alluvial plain starts from the foot of south facing scarps of the zone of high relief in the north all abuts against zone of moderate relief in the south. The Purna River flows southernly along the eastern edge of the valley and then takes an acute right turn and flows westernly as long the southern limit of the valley. Much of the drainage is from north which is sub-parallel and is of high density, following land forms are observing within alluvial plain-Older flood plain, Piedmont zone, Alluvial fans, Pediplain with alluvial cover, Inter-fans, Dissected alluvial platform.

Zone of moderate relief:

Zone of moderate relief and gentle slope occurs along the southern and eastern margins. These are plateaus drained by widely spaced, mainly north flowing sub-parallel drainage with poorly developed flood plains in many directions at any angles due to headward erosion. This is indicative of uniform response of basaltic lithology to the development of drainage network in the northern part of basin. However, in the southern part of the area sub-parallel drainage pattern is observed with the tributaries joining the Pili River at an acute angle. This reflects control of steep slopes and lineaments over the drainage (Kale and Gupta, 2001) straight stretches of stream courses developed in the field support this interference. Each of these geomorphic units is exposed at various altitudes within the basin. The highly dissected plateau covers from the northern region of the basin and is drained by first order and second order streams. The streams are controlled by small fractures in this area. The HDP is followed by MDP and drained by higher order streams. In this region, the steams are controlled by joints and fractured basalts. The Bajada zone covering an area of about 11% of the Pili river basin and forms the major aquifers in the system. Older and younger alluvial plains form the low lying area of the basin. It covers 17% and 51% of the Pili river basin. This proves the fact that the streams do not erode the massive compact basalts. The steams show recent alluvial deposits on lower region of their course. Such a classification helps us in finding the characters of the rock types combined with structures and in turn to understand the possible infiltration zone of rainwater in the basin.

Lineament Analysis:

A Lineament is a regional scale linear or curvilinear feature, pattern or changes in pattern that can be identified on satellite imagery with medium resolution. They represent structural weakness. Overall 28 lineaments are identified and mapped on the scale of 1:50,000 from IRS imageries in the basin and lineament map of Pili river basin are prepared.

Morphometric analysis:

Quantitative description of the drainage network, basin characters and landform analysis has been worked out by Morphometric analysis (Horton, 1945). Linking of geomorphic parameters with hydrologic characteristics of basin provides a simple way to understand the hydrologic behaviors of different basins (Singh 1990).

This approach has helped in characterizing the Drainage pattern, comparative study of small drainage networks and also in evaluating lithological, structural and climatic controls on the drainage in the study area. The physiographic map of the study area is shown in Fig.2 and the drainage map of Paratwada-achalpur region is shown in Fig 3.

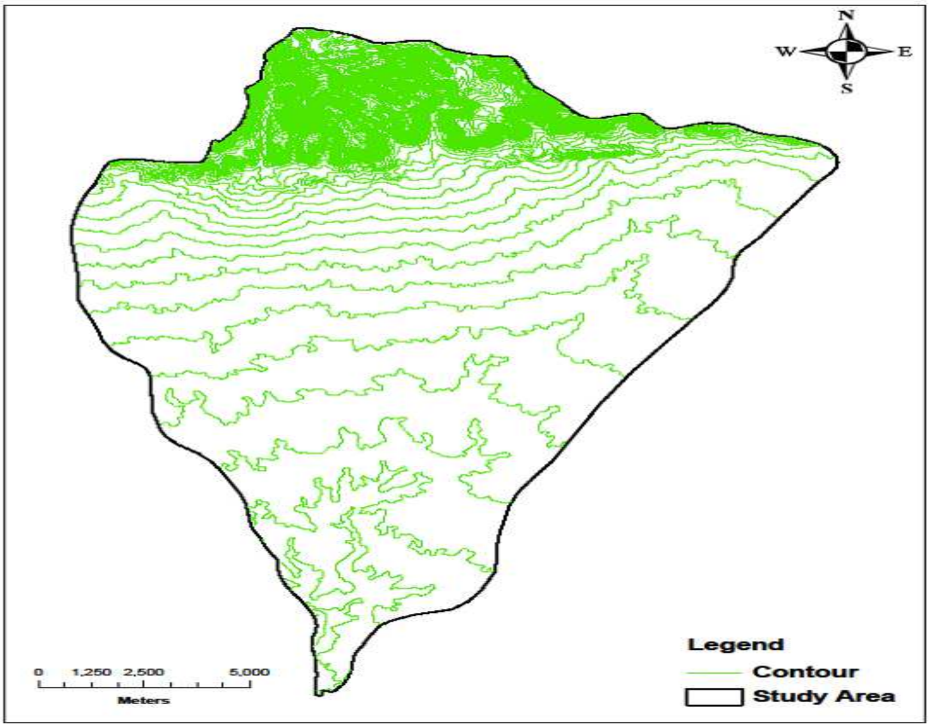

Fig.2 Physiographic map of the study area

ISSN: 2319-507X
IJPRET

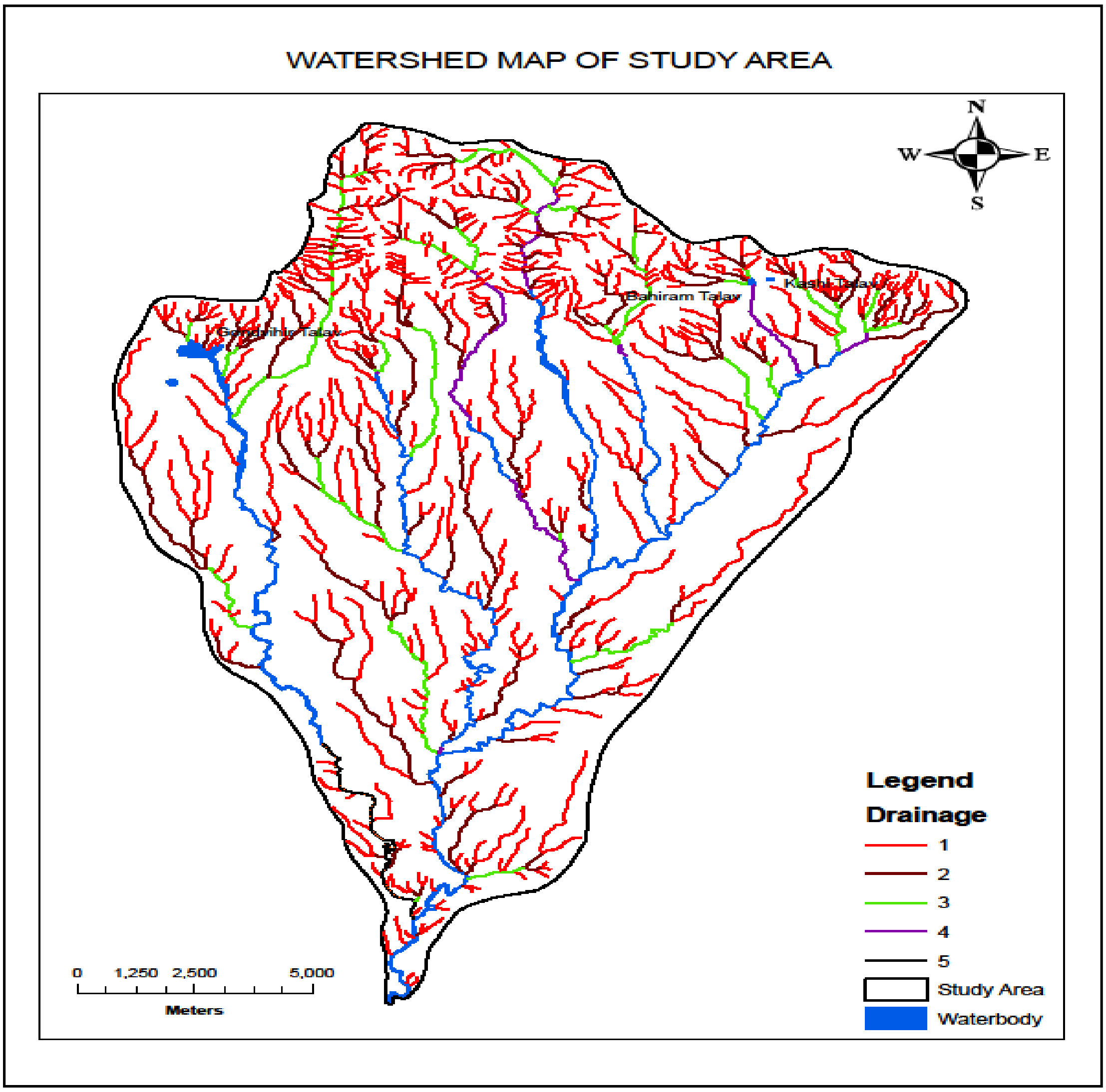

Fig. 3. The drainage map of Paratwada-achalpur region.

Morphometric studies that have been attempted are broadly classified into two groups:

A. Linear aspects

B. Aerial aspects

Linear aspects of drainage network

The linear aspects of the channel patterns of drainage network where in geomorphic characteristics of the stream segments in terms of open links of the streams are analyzed (Savindra Singh, 1998) following linear aspects are studied using method suggested by Horton (1945), Strahaler(1969), Muller (1968)as-

1. Stream Order (**µ**),
2. Bifurcation Ratio (**R_b**)
3. Stream Length (**Lu**)**,** and

Stream Order (µ)

Stream order refers to the determination of hierarchical position of the stream within a drainage basin. The first step in Morphometric analysis of a drainage basin is the designation of stream order. Stream order is defined as, 'the designation of highest order of the stream defined in the basin.' In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. Where two first order channels join, a channel segment of order 2 is formed, where two of order 2 joins, a segment of order 3 is formed; so onward. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. Ordering of the Pili River is a fifth order streams with 496 first orders, 144 second order, 41 third orders, 13 fourth order, 2 fifth order. Details of the stream order and their number (Nµ) for the Pili River and Bichan River (i.e tributary of Sapan River).

Bifurcation ratio (R_b)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total numbers of stream segments of given (Nµ) order to that of the next higher order in a drainage basin (Nµ**+**1) (Schuman, 1956). Also, It is relation between no. of streams of one order an of next higher order which was obtain by dividing no. of streams in one order by the no. of the stream in next highest order for all the orders of the stream. These calculations were also based on Strahaler method. It is expressed in terms of following equation.

$$Rb = \frac{N_u}{Nu+1}$$

Where, Nµ= numbers of stream of a given order,

(Nµ**+**1)= numbers of the next higher order.

The mean Bifurcation ratio value is for the study area in which 3.41 First order

Bifurcation ratio, 3.51 second order Bifurcation ratio, 3.15 third order bifurcation ratio, 0.54 fourth order bifurcation ratio.

Stream Length (Lμ)

According to Horton, the mean length of the stream is the ratio of the length of the stream is of the stream of each order to the stream of each order to the number of segments of the same order. In this study, it has been noticed that the length of the stream decreases with stream order indicating the characteristic size of components of drainage network and its contributing basin surface.

In the present study area, there are 537.72 Km stream length. Out of which 341.51 Km is total length of first order, 116.08 Km is the total length of second order. 54.49 Km is total length of third order, 18.10 Km is total length of fourth order and 7.54 Km is total length of fifth order.

For the study area, the stream order relationships:

Total no of stream= 696

Percentage of first order = 0.712

Percentage of second order = 0.206

Percentage of third order = 0.0589

Percentage of fourth order = 0.018

Percentage of fifth order = 0.000287

Table 1 - Linear aspects of drainage network

Stream Order (U)	Number of Streams (N_u)	Total length of Streams in km (L_u)	Bifurcation Ratio (R_b)	Mean Bifurcation Ratio
1	496	341.51	3.44	
2	144	116.08	3.51	2.66
3	41	54.49	3.15	
4	13	18.10	0.54	
5	02	7.54	-	

Areal Aspects of the Drainage Basin:

Area of a basin (A) and perimeter (P) are the important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter is length of the boundary of the basin which can be drawn from topographical maps. Basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff.

Areal Aspects of the Drainage Basin include the study of geometry of closed links. These had been studied following the Methodology suggested by Strahaler (1968) and Miller (1953). The aerial aspects of the Pili river basin such as.

1. Basin area (A)
2. Drainage Density (D_d),
3. Stream Frequency.
4. Texture Ratio (T),
5. Elongation Ratio (Re),
6. Circularity Ratio (R_c) and
7. Form Factor Ratio (R_f).
8. Basin Relief

Basin area (A):

The area of Drainage basin is another significant parameter like the length of the stream. Basin area is the direct outcome of the drainage development in a particular basin. The area of study is 247 Sq.km. Three dimensionless ratios viz., form factor, circularity ratio and elongation ratio, reflect the basin shapes.

Basin shape or Geometry of the basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998)**.**

Mathematically, **F=A/L2**

Where, F= Form Factor indicating elongation of basin shape.

A= Basin area (**247** sq. km)

L= Basin length (**26.82** km)

F=247/26.82

F =9.209

Drainage Density (D_d)

Horton (1945) defined density as "A ratio of total length of all stream segments in a given drainage basin to the total area of that basin".

It is the ratio of the total length of all streams and area of the drainage basin. The result indicate high values in the plains indicating the drainage texture, low permeability and high relief whereas it is comparatively low in the hilly terrain showing steep scraps reflecting the coarser drainage texture.

$$D_d = L_u/A$$

Where, L_u **is** total length of stream of all order which is 537.72 Km.

A is the area of study which is 247 Km^2.

Therefore, $D_d = 537.72/247$

$$D_d = 2.17 \text{ km}$$

The drainage density (**D_d**) of study area is 2.17 km.

Stream Frequency (Fs)

Stream frequency or channel frequency is the total number of stream segments of all orders per unit area (Horton, 1932).The occurrence of stream segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability Also, It is ratio of total no. of streams of any order & the area of the basin in which its lies.

Mathematically, $\mathbf{F_s = N_u/A}$

Where, Nu = Total number of streams of all orders which is 696,

A = area of study which is 247Km^2.

Therefore, $F_s = 696/247$

$F_s = \mathbf{2.81}$

Texture Ratio (T)

The term drainage texture to express the composition of drainage network as related to the drainage density and stream frequency. The drainage texture of the Pili River basin can be described as Medium to Low. It is suggested that lower the drainage density, higher is the infiltration and this is true to the Bichuan river. Similarly, low stream frequency is related to the lithological control in development of drainage network. This is also suggestive of favorable conditions for infiltration.

Texture ratio (T) is the ratio of total no. stream of any order & perimeter of the area which it lays. It is an important factor in the drainage Morphometric analysis which is depending on the underline lithology, infiltration capacity and relief aspect of the terrain.

It is expressed by the formula,

$$\mathbf{T = N_1/P}$$

Where, T is texture ratio of study area

N_1 is the total number of first order streams which is 341.51 Km,

P is perimeter of study area which is 73 Km,

Therefore, T = 341.51/73

$$\mathbf{T = 4.678}$$

Elongation ratio

Schumm (1956) used an Elongation ratio, defined as the ratio of diameter of a circle of the same areas the basin to the maximum basin length. It is very significant index in the analysis of basin shape which helps given an idea about the hydrological character of a drainage basin. It is expressed by the formula

$$\mathbf{Re = 2\sqrt{A/\pi}\; L_u}$$

Where, R_e= Elongation ratio of study area,

L_u is the total length of stream of all order which is 537.72 Km

A is the area of study which is 247 Km^2.

Therefore, $Re = 2\sqrt{247/3.14*696}$

Re = 0.67

Circularity Ratio (R_c)

Miller (1953) defined a dimensionless circularity ratio as the Ratio of basin area to the area of circle having the same perimeter as the basin. He described the basin of the circularity ratios range 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. The circularity ratio value (0.42) of the basin corroborates the Miller's range which indicating that the basin is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition. It is influenced by the length and frequency of streams, geological Structures, land use/ land cover, climate, relief and slope of the watershed.

Mathematically expressed as, $\mathbf{R_c = 4\pi A/P^2}$

Where, Rc = Circulatory ratio of study area,

$\pi = 3.14$.

A = area of study which is 247 $Km^{2.}$

P is perimeter of study area which is 73 Km.

Therefore, $R_c = 4 * 3.14 * 247 / (73)^2$

$\mathbf{R_c = 0.582}$

Form Factor Ratio

Quantitative expression of this Drainage Basin outline form was made by Horton (1932) through a form factor ratio which is the dimensionless ratio of basin area to the square basin length. Basin shape may be indexed by simple dimensionless ratios of the basic measurements of the area, perimeter and length (Singh, 1998). Mathematically expressed as, $\mathbf{R_f = A / L_b^2}$

Where, A = area of study which is 247 $Km^{2.}$

L_b = total length of basin which is 26.82 Km.

Therefore, $R_f = 247/ (26.82)^2$

$\mathbf{R_f = 0.3433}$

Basin Relief:

It is the measure of longest dimension of the basin, which is parallel to principle drainage line. The highest elevation is 1040 m and lowest elevation is 340 m indicating the Basin Relief of 690m. Areal aspect of drainage basin of the study area results have been presented in table 2.

Table 2 Areal aspect of drainage basin:

Morphometric parameters	*Formula*	Pili River Basin
Area of Basin (sq.km)	**A**	**247 sq.km**
Perimeter (km)	**P**	**73 km**
Drainage density (km / km$^{2)}$	**D = Lu/A**	**2.17 km**
Stream frequency	**$F_s = N_u/A$**	**2.81 Sq.Km**
Texture ratio	**$T = N_1/P$**	**4.678**
Elongation ratio	**$Re = 2\sqrt{A}/3.14\ L_u$**	**0.672**
Form factor ratio	**$R_{f=A/}\ L_b^2$**	**0.3433**
Basin length (km)	**L_b**	**26.82 km**
Circulatory ratio	**$R_c = 4\ \pi A/\ P^2$**	**0.582**

Summary and Conclusions

The study area can be broadly divided into alluvial plains and abrupt vertical different rising elevation which forms horizontal basalts with multiple scarps. Gondwana sediments showing large variations in geomorphic landscapes this is indicated by the structurally controlled landform showing fine to coarse drainage textures. In general, the detailed Morphometric analysis of the study area indicates the potential Hydro geological conditions of the study area which are more suitable for Ground Water exploration in the near future. Form factor 0.34 indicates more elongate basin. and drainage density indicates coarse drainage network, drainage density, stream frequency and bifurcation ratio are important for the integrated decision making process in flood management, soil erosion assessment and water resource management.

Roof rain water harvesting is suggested for the study area for the collecting and storing the rain water and also to improve ground water level. Check dams are suggested near to the water reservoir to reduce the siltation of the reservoir from the transported sediment of the river or stream. Loose boulder structures and continuous contour trenches were suggested in the high elevation and where slope of the area is steep to reduce the runoff rate and soil erosion. The land resources development plan was suggested for the utilization of soil resources for the economic and social development of the watershed. In the action plan for soil conservation, irrigated agro-horticulture with form bund and canal command which covers 60% watershed with 1-3% slope and for rest of watershed forest conservation and dry land horticulture were suggested.

The study area is characterized by the presence of shallow unconfined aquifers, which are being trapped by large diameter, dug wells and tube wells. The occurrences and distribution of groundwater is mainly controlled by geological, Geomorphological, structural and climatic condition of the region. Hydrogeomorphological study demonstrates that the area comes under hard rock terrain. It consists of Deccan basalt which shows poor, moderate and good ground water potential depending upon the intensity of weathering and presence of fracture and joints. Highly fractured, jointed basalt with amygdaloidal and vesicular horizons have proved to be potential areas for groundwater development.

Based on the field and hydrogeomorphological studies the overall groundwater potential of this zone can be classified as moderately productive. Excess of groundwater withdrawal has resulted in draw down of the aquifers, which require immediate integrated water conservation and artificial recharge methods for water resources development of the region.

REFERENCES

1. Adyalkar P.G. paleogeography, nature and pattern of sedimentation and GW potentialities of the upland alluvial valley of India

2. Dhokrikar BG (1991). Groundwater resources development in basaltic rock terrain of Maharashtra.

3. C.G.W.B. (systematic Hydro geological studies in parts of Amravati, Akola & Yavatmal districts, Purna, Godavari basin Maharashtra) By-Devendra Joshi, 1993, central region Nagpur.

4. Lillesand, T.and Kiefer, R., 1994.Remote sensing & Image interpretation. John wiley andson, Inc., NewYork, p.468

5. Strahler, A.N. (1964). Quantitative geomorphology of drainage basin and channel network, Handbook of Applied Hydrology, 39-76.

6. Sharma, S.K., Rajput, G.S., Tignath, S.K. and Pandey, R.P. 2010. Morphometric analysis and priorization of a watershed using GIS. Jour. Indian Water Resource Society, Vol. 30(2), pp 33-39.