

RESEARCH ARTICLE**DELINEATION OF MORPHOMETRIC CHARACTERISTICS FOR THE IDENTIFICATION OF ZONES FOR ARTIFICIAL RECHARGE STRUCTURES IN MATHADI VAGU BASIN OF ADILABAD DISTRICT, ANDHRA PRADESH, INDIA****¹Kamal Das., K. ^{1*} Santhosh Kumar, S., ²Sundaraiah, R., ²Laxman Kumar, D and ¹Muralidhar.M**¹Department of Geology, Osmania University, Hyderabad, Andhra Pradesh, India²Department of Geochemistry, Osmania University, Hyderabad, Andhra Pradesh, India**ARTICLE INFO****Article History:**Received 14th, April, 2014Received in revised form 26th, April, 2014Accepted 15th, May, 2014Published online 28th, May, 2014**Key words:**

Morphometry, drainage basin, recharge structure, mathadi vagu basin.

ABSTRACT

Morphometric studies are carried out keeping in view that the immediate need of a suitable plan of groundwater investigation, development and management to improve socio-economic status of the local people of the Mathadi vagu basin, Adilabad district.

The evolution of systematic and scientific research work for utilizing it for the development of farmers to improve the irrigation facilities, an attempt is made for the identification of zones for artificial recharge structures to improve the groundwater potential zones and their optimization in the study area.

The geological formations covered in the study area are Deccan traps, limestones and granites. In these three formations, with Deccan trap being common geological formation, which is associated with hard rock and soft rock formations in close by neighboring areas will form an ideal case for over all study of morphometric features and their correlation will give better understanding of impact of lithology on drainage characteristics.

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INTRODUCTION

Hydrology of a basin is directly related to total stream length, basin area and first order stream frequency and inversely related to stream gradient calculations and relief ratios (Morisawa, 1962).

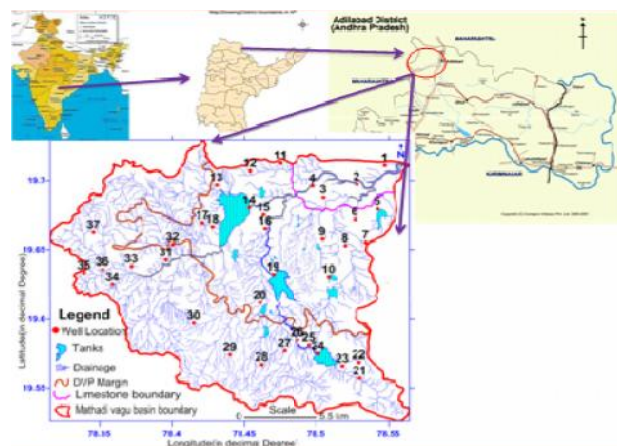
Geomorphic factors such as basin shape and slope depend on geology, structure, intensity of runoff and discharge in an area. Stream density and bifurcation ratio effect discharge. Such drainage pattern features are the typical characteristic of hard rock areas.

Morphometry is the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landforms (Thorn bury, 1969). Drainage pattern provides information on the topography and underlying geological structure. Drainage density varies with relative age, differing geology, drainage area etc and enables comparisons of basins and streams (Faisal Zaidi, 2011). An attempt is made for the identification of zones for artificial recharge structures to improve the groundwater potential zones and their optimization in the study area.

Study Area

Mathadi vagu basin is located in the northern part of Adilabad District, Andhra Pradesh, India (Fig-1). The study area is in the Western part of Saathnala River which is a tributary of the Penganga River. The area is covered in the Survey of India toposheet Nos 56 I/06, 56I/10 and lies between latitudes 19°50'28"-20°13'35" North and Longitudes 78°28'25"-78°58'00" East. The basin trends NW-SE covering the total

geographical area of 525 Sq Kms with 43 villages in 4 mandals of the Adilabad district.

**Fig.1** Location map of the Mathadi vagu basin

Adilabad, Thamsi, Thalamadugu and Gudihatnoor mandals of the area consists of three formations with Thalamadugu area being the central part. The entire hilly terrain and the reserve forest cover up to 47 percent of total geographical area. Mathadi vagu and ephemeral streams and a few ephemeral streams and natural springs are only water sources, which get dried up during summer.

Hydrogeological studies of micro level and drainage aspects i.e. basin wise morphometric analysis is much useful for understanding of the groundwater occurrences and also in the selection of certain zones for recharge structures.

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Geological and Geomorphological Units of the Area

The area predominantly contains of granites and gneisses in the central part, Penganga limestones in the northeast and Deccan traps to the southeast. About fifty percent of the area is covered by Deccan traps. When correlated lava flows in the study area with the flows in adjoining areas, numbers of lava flows with varying thickness are found ranging from 2 to 5kms. Tectonic activity and denudation in the geological past resulted in structural features favoring for groundwater occurrences (Fig-2). The major geomorphic units covered in the area are highly dissected plateau, moderately weathered pediplain, pediment, residual hill and structural hill etc.

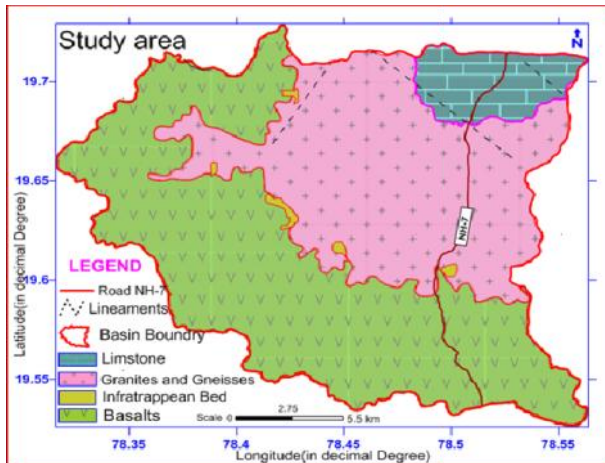


Fig. 2 Geological map showing various lithounits of the Mathadi vagu basin

Drainage Aspects and Methodology

A drainage basin is defined as a portion of the earth's surface, which is bound by topographic slopes that divert all run off to one drainage outlet. The physical boundary of the drainage basin is defined by the direction in which surface runoff will drain and follows the ridgeline between hydrologic units. The boundary is called the drainage divide (Vijay Singh, 1997).

The Mathadi vagu basin is a part of Saatnala river basin, saathnala is a tributary of Penganga River, and it is a part of the Godavari river basin.

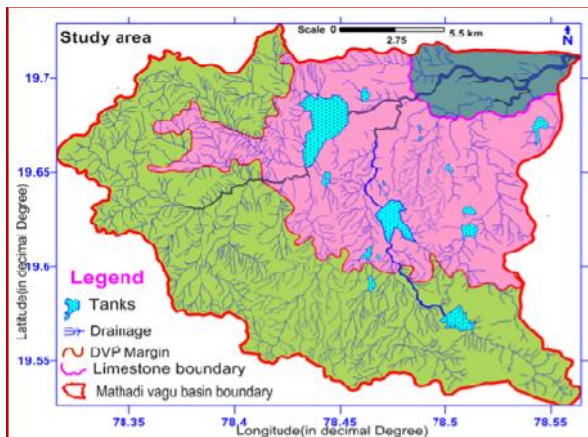


Fig.3 Drainage map of the Mathadi vagu basin

Most of the study area is hilly and covered by forest. The area exhibits dendritic to subdendritic drainage pattern in general. Drainage pattern in the central part exhibits radial to sub-radial covering Devapur, Bharampur, Umdam and Waghapur

converting to parallel & sub-parallel drainage patterns locally at places due to different geological formations. The drainage pattern of the area is given in Fig-3.

Hilly areas of study area mostly generate preliminary drainage of 1st, 2nd and 3rd order streams only. There are a few springs in Kappardevi and Jhari areas. The extreme western part of the area has sub-dendritic drainage with a few sharp bends and a couple of streamlets joining at 90°. Around Ponna village (Northeast and East) parallel drainage is also observed (Fig-4A). In the NE of Batti Samargam village the streamlets join in obtuse angle.

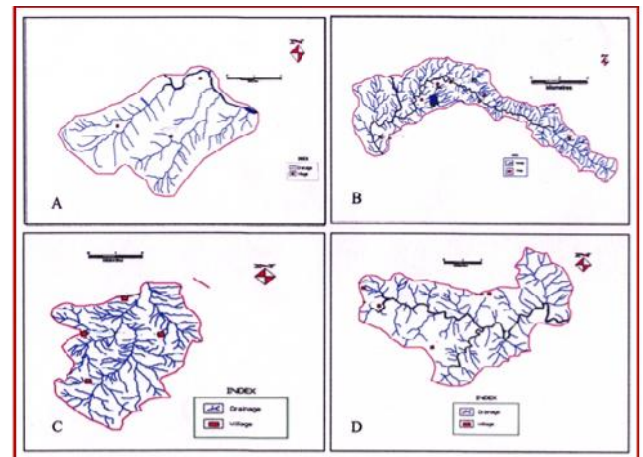


Fig.4 Drainage pattern of Mathadi vagu basin

Even a relatively higher order Mathadi vagu shows 90° sharp bends, and also to the South of Somarpet repeated sharp bends at short distances, giving rise to rectangular pattern drainage (Fig-4B). Dominant drainage flow directions are West to East in the area. Mainstream flow at Umdam and Sunkidi is towards WSW, taking a sharp bend between Waijapur and Waghapur before joining the main stream, which flows towards north. Whereas, in the eastern part general flow direction is from west to east is maintained. The drainage pattern at Dahegam, Umri, Kappardevi and Dorli (Fig-4C) strongly suggest evolution of youthful drainage system under process, largely controlled by underlying geology and structures. To the south of Kottur, Mathadivagu stream shows two "V" bends, reflecting tectonic control. The disproportionate size and shape of the drainage pattern to the east of study area suggests "Misfit" stream (Fig-4D). The complete drainage system observed in the area indicates:

- Structural control, such as faulting of the strata and the joint pattern
- Geological boundaries and contact between different flows.
- Contact between lava flows and the basement granite rock.

Drainage basin geometry is understood properly by the analysis of drainage network; its stream channel system requires measurement of linear aerial and relief aspects with ground slopes. First two parameters are derived by measurement with plan meter and the third parameter is by vertical variation. The analysis shown in this work is done on 1:50,000 scale drainage map, and for convenience presented in 1:250,000. The drainage channels were classified into different orders using Strahler's 1964 classification. Basin parameters such as Stream Order, Stream length, Shape of the Basin, Area of the basin, Drainage

density, Drainage texture, Constant of channel maintenance, Stream frequency, Circularity ratio, Form factor ratio are all delineated.

RESULTS AND DISCUSSIONS

Linear Aspects of Drainage System

Stream Order

In the present study, Strahler's (1964) and Strahler's (1957) method of stream ordering has been adopted. Stream order (u), total number of streams of each order (Nu) and bifurcation ratio (Rb) are computed for three formations and one basin area and are presented in Table-1. It can be seen that the number of stream segments decrease with the increase of stream order. The stream segment of any given order will be less than the stream segments of next lower order and more than the stream segment of higher order. Further it is observed that bifurcation ratio (Rb) with respective different stream orders vary as follows for the basin. The Mathadi vagu basin variation of bifurcation ratio is 2.00-7.00, Mean bifurcation is 4.44.

Table-1 Stream order, Number of streams and Bifurcation ratio of Mathadi vagu basin

Stream Order	No. of Streams (Nu)	Total length of streams in km (Lu)	Log Nu	Log Lu	
1	1129	337.5	3.052	2.528	
2	274	122.5	2.437	2.088	
3	49	57	1.690	1.755	
4	14	49	1.146	1.690	
5	2	12.5	0.301	1.096	
6	1	10	0	1	
Total	1469	588.5			
Bifurcation ratio Rb					
1 st /2 nd order	2 nd /3 rd order	3 rd /4 th order	4 th /5 th order	5 th /6 th order	Mean Bifurcation
4.12	5.59	3.5	7	2	4.44

The bifurcation ratios (Rb) will not be the same for different stream orders on account of variation in the geometry of the basin. Horton's law of stream numbers, states that the number of stream segments of each order forms an inverse geometric sequence with stream order number.

$$R_b = N_u / N_{u+1}$$

Where, Nu= Total number of stream segments of order 'u'; Nu+1 = Number of segment of next higher order, Rb=Bifurcation ratio; U=number of stream order.

Stream length

Stream length is more influencing hydrological parameter, along with stream order and stream number in a basin or watershed. The Horton's (1945) analysis of mean length of stream orders, characterize the size of the component that comprise the drainage net channel lengths of each stream order (Lu). All the segments of a given stream order within the specified drainage network are measured without pause and the cumulative length is read on the dial of the map measurer. Morisawa (1957) stated that the length measured represents the true length, slightly shortened by projection upon horizontal plane and the mean length of stream channel (Lu) of order (u) is a dimensional property, which is obtained by dividing the total length (Lu) by the number of segments (Nu) of that order and is calculated by the formulae,

$$R_L = L_u / L_{u-1}$$

Where "length ratio" (RL); Lu= Total stream length of order; Lu-1=Stream length of next lower order.

The total length of the stream is measured using the (planimeter) map measurer. The stream length of the Mathadi vagu basin Environs comes around 588.5 km. given in Table-1.

Features of drainage basin

Area, shape and drainage texture of a basin in morphometry, throw more light in understanding its nature.

Area of the basin

Drainage basin area is defined as the area of the curve obtained by projecting the catchment boundary on a horizontal plane. Area measurement on a map of known scale is done by counting number of squares covered by the drainage basin boundary on a plain graph paper and also by using planimeter or mechanical digits or scanning techniques. Total study area is 525 sq. km. Perimeter of total study area is 62 km.

Sediment yield per unit area has been observed to decrease as catchment area increases in accordance with stream flow. Rate of erosion and runoff per unit of drainage area is inversely proportional to area of basin or watershed. Multiple regression analysis of sediment data for Missouri basin, Loess hills and for Columbia River basin indicated that the sediment production rate varies as 0.8 power of drainage area, while other researchers found sediment production to vary from 0.6 to 1.1 power of the drainage area.

Shape of the Basin

Stream discharge characteristics depend on the shape of the drainage basin. The elongated basins have high bifurcation ratio whereas, it approaches to minimum for rounded basins. The study area has bifurcation ratios between 2 and 7, considered to be of normal category according to Strahler (1964) norms.

Drainage density

This expression was introduced by Horton (1932) to indicate the closeness of spacing of channels. Mathematically it is expressed as the ratio of total channel segment lengths cumulated for all orders to the basin area. Further, combining the law of stream numbers and lengths, the drainage density can be computed by the formula,

$$D = L_u / A$$

Where D = Drainage density in km/sq.km; L = Mean stream length of 1st order; Lu= Total length of basin in km; A = Total area of the basin in sq.km.

Drainage density of Mathadi vagu basin obtained by the above formula, 1.12 km/sq. km.

Table-2 Classification of Drainage density (Smith, 1950)

Drainage Density	Texture
<2	Very Coarse
2-4	Coarse
4-6	Moderate
6-8	Fine
>8	Very fine

The drainage density of the Mathadi vagu basin is 1.12 km/sq.km, and classified as coarse (table-2) in texture indicating thick vegetation, high infiltration, and permeable rock strata in the present case. Other contributory factors for

coarse drainage texture are infiltration capacity and structural features.

Drainage density measurements made over variety of geologic and climatic types are given in table-3. Drainage density is controlled by various factors like rainfall, type of rocks, relief, infiltration capacity, vegetative cover (forest) and surface roughness under the influence of runoff intensity index. The amount and intensity of precipitation directly influence the quantity and character of surface runoff. Other factors being equal, areas with high intensity of precipitation, such as thunder shower, loses greater percentage of rainfall as runoff, resulting in soil erosion and more surface drainage channels. Hilly terrains with steep slopes, as in the study area, with high order of precipitation also results in more number of drainage lines with short stream lengths. Density and kind of vegetation and rainfall absorption capacity of soils also influence the rate of surface runoff and affects the drainage texture of an area. Areas having similar litho logy, geologic structures with semi arid climatic regions have fine drainage texture than tropical to sub tropical climatic regions. Low drainage density generally results in areas of highly resistant or permeable sub soil material, dense vegetation and low relief. High drainage density is resultant of weak or impermeable sub surface material. Low drainage density leads to coarse drainage texture, while high drainage density gives rise to fine drainage texture.

Table-3 Morphometric parameters, Symbol/formula and Results of Mathadi vagu basin

Morphometric parameters	Symbol/formula	Results
Area(sq km)	A	525
Perimeter(km)	P	64
Drainage density(km/sq.km)	$D=L_u/A$	1.12
Stream frequency	$F_s=N_u/A$	2.79
Texture ratio	$T=N_1/P$	18.20
Basin length(km)	L_b	588.5
Constant channel maintenance	$C=1/D_d$	0.892
Circularity ratio	$R_c=4 A/P^2$	53.21
Form factor ratio	$R_f= A/L_b^2$	0.44

L_u =Total stream length of all orders; N_u =Total no .of streams of all orders; N_1 =Total no.of 1st order streams; $=3.14$.

Drainage texture

Drainage texture also requires to be studied to understand geomorphology concept. Drainage lines are numerous over impermeable area rather than permeable area. Horton (1945) observed that the study of drainage texture includes both drainage density and stream frequency.

Constant of channel maintenance

Schumm (1956) defined "constant of channel maintenance" as inverse of drainage density. The amount of drainage area needed to maintain one unit of channel length was termed as Constant channel maintenance by Schumm (1956). Formula given in table-3.

$$C=1/D_d$$

i.e. C= Area of the basin/Total stream length of all order

Constant channel maintenance= $1/1469=0.892$.

The drainage density of the Mathadi vagu basin is calculated and the value is 1.12km/Sq km. The inverse of it is 0.892 Sq km. Hence the Constant channel maintenance comes to 0.892 Sq km. Indicating impermeable nature of sub surface formation.

Stream frequency

Stream frequency or channel frequency (F) defined by Horton (1932), is the ratio of number of streams to the area of the basin. Hypothetically it is possible to have basins of same drainage density differing in stream frequency and basins having same stream frequency differing in drainage density. Formula given in table-3.

$$F=N_u/A$$

F= Total number of stream segments of all orders/Total area of the basin

Stream frequency of Mathadi vagu basin is 2.79 /km².

Texture ratio

Texture ratio defined by Horton (1945), Formula given in table-3.

$$T=N_1/P$$

Where: N_1 = Total number of first order stream; P = Perimeter of basin.

Texture ratio of the Mathadi vagu basin is 18.20.

Circularity ratio

Circularity ratio Formula given in

$$R_c=4 A/P^2$$

Where: A=Area of watershed; $=3.14$; P=Perimeter of watershed.

Circularity ratio of Mathadi vagu basin is 53.21.

Form factor ratio

Form factor ratio defined by Horton (1932), Formula given in table-3.

$$R_f= A/L_b^2$$

Where: A= Area of watershed; L_b = Basin length

Form factor ratio of Mathadi vagu basin is 0.44.

CONCLUSIONS AND SUGGESTIONS

The area is covered by streams up to 5th and 6th order with 1469 streams measuring 588.5 km length with an average mean length ratio of 0.149. The average drainage density of the basin of the area is 1.12 km/ sq.km indicates coarse drainage texture caused by resistant geological formations, structural disturbances and dense forest.

The average constant channel maintenance of the area is 0.44 sq. km indicates that 0.44 sq.km area is needed to support each linear kilometer of channel. The average length overland flow is computed as 0.23, stream frequency as 2.79 stream segments/sq.km.

In the drainage pattern study and the morphometric analysis deduces that the area is of high intensity of precipitation with high run off resulting in more number of surface drainage channels due to steep slope of hilly terrain.

Drainage aspects and basin wise morphometric analysis in this area results that the area is characterized by dendritic to subdendritic drainage pattern with sub-parallel drainage pattern at places. Drainage density of the Mathadi vagu basin and the sub-basins reveals that the nature of sub-surface strata is permeable as the drainage density values are less than 5. Such type of drainage density values constitutes a characteristic feature of coarse drainage and shows good potential for the

construction of artificial recharge structures.

The mean bifurcation ratio of the Mathadi vagu basin is about 4.44 indicating that the drainage pattern is not much influenced by geological structures.

Suitable scientific steps are needed for arresting part of the huge run-off by taking up rainwater harvesting structures in areas of poor groundwater potential particularly in massive trap plateaus. Due to good rainfall, steep slope and accelerated run-off, low cost artificial recharge structures do not withstand. Hence, taking up wide earthen structures at specific locations, and need based masonry structures.

However, a comparison of all the four sub basins shows that near Ponna village (Fig-4A) and to the south of Kottur, Mathadivagu stream shows two "V" bends (Fig-4D), reflecting tectonic control which are much suitable for the construction of recharge structures since they offer lowest drainage density.

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