# Delineation of Groundwater Potential zones of Swarnamukhi sub watershed using RS & GIS

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*Abstract*— **Morphometric analysis using remote sensing (RS) and geographical information system (GIS), in the recent study, has become an efficient method in the assessment of groundwater potential of a river basin. The present study focused on the morphometric analysis of Makaluva Basin of Swarnamukhi River using RS and GIS techniques in the identification of groundwater potential zones for effective planning and management of groundwater resources of the basin. The study area was divided into four sub basins for the purpose of micro-level morphometric analysis. The main stream of the basin is of fourth order and drainage patterns of sub basins are mostly of dendritic and parallel type. Based on the linear, areal and relief parameters of sub basins, the groundwater potential zones of the basin were identified and the results substantiated with geomorphology map derived from RS data. The elongated shape, favorable drainage network, permeable geologic formation and low relief of the sub basins W1 and W4 make them the promising groundwater potential zones of Makaluva Basin of Swarnamukhi River. The statistical analysis and overlay analysis of the morphometric parameters also indicated the sub basins W1 and W4 as high groundwater potential zones. The thematic maps of Geomorphology, LULC, Soil, and Slope were converted to raster format and reclassified with 1 to 4 scale, representing poor, moderate, good, and very good zones of Groundwater potential. The groundwater potential map shows prioritized sub-basins and results are comparable with the compact factor analysis. The groundwater potential map supports the statistical analysis indicating the presence of groundwater potential zones in W1 and W4 sub basins.**

*Index Terms*—**Morphometry, Remote Sensing, Geographical Information System, Groundwater potential.**

## I. INTRODUCTION

Since a micro-watershed is considered as the basic unit in Hydrology, it could be appropriate to perform Morphometric analysis at micro-watershed level as it is comparatively far better than doing the analysis on a specific stream or channel or inconsistent segment area.

Morphometric analysis of a basin describes its surface characteristics and provides information regarding the region's topography and underlying geological structures. Morphometric characteristics of a watershed also indicate its formation and development since all hydrologic processes occur within the watershed.

Morphometry describes linear, areal and relief aspects of the basin. For carrying out detailed investigation and mathematical analysis, the basin is divided into sub basins. By careful evaluation of various hydrologic parameters, valuable information regarding Groundwater potential of the basin can be obtained. In recent years, extensive use of satellite Remote Sensing data along with Survey of India topographical map, collateral information and limited field checks had made it easier to establish the base-line information for Groundwater potential zones.

Many hydrogeologists studied the morphometric analysis of different basins using conventional methods (Horton 1945; Smith 1950; Strahler 1957) and using remote sensing (RS) and geographical information system (GIS) techniques (Krishnamurthy et al. 1996; Malik et al. 2011; Nag 1998; Rao et al. 2010; Rudraiah et al. 2008). Remote Sensing data enable the effective assessment of changes in drainage pattern, land use pattern and soil characteristics, GIS techniques provide flexible environment for manipulation and analysis of spatial information (Jasmin and Mallikarjuna 2011).

Sreedevi et al. (2005) studied drainage characteristics of the Pageru river basin, India using topographical maps and Landsat imagery to delineate groundwater potential zones.

The present study makes an attempt to apply RS and GIS techniques in the morphometric analysis at subbasin level for the identification of groundwater potential zones of Makaluva basin of Swarnamukhi river, India.

## II. STUDY AREA

The Swarnamukhi river originates near Chandragiri hills in Chittoor district, Andhra Pradesh, India. The Makaluva basin of Swarnamukhi River is taken up for the present study. It is located between north latitude13° 30' to 13° 45' and eastern longitude 79° 30'to 79° 45' with a total drainage of 1600 ha and maximum length of basin of 2.75 Km. it falls in Survey of India (SOI) toposheet 57 O/10. It flows in the east direction and falls into the Bay of Bengal. The drainage area is bounded by Bay of Bengal in the east, Chittoor district in the west, Nellore district in the North and Tamil Nadu in the south (Fig.1).

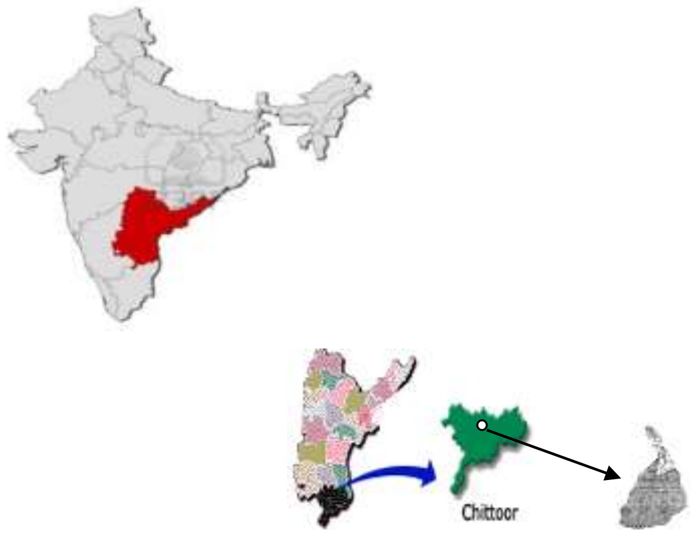


Fig.1. Location map of Makaluva basin

The soil of the area is clayey sand and the climate is semi arid. The mean monthly temperature of the basin in summer goes up to 40˚C and in winter comes down to 16˚C to 18˚C. The investigated area represents plain land and gentle slope towards southeast. The area has dendritic drainage pattern. Recharge into aquifers of the basin is mainly from precipitation, flow through river beds and water bodies.

## III. METHODOLOGY

The SOI toposheet was georeferenced with Path/Row as 141/50 and 30-m spatial resolution was geometrically rectified. The contour map at 20-m interval, created from SOI toposheet was exported to spatial analyst tool in ArcGIS from which the Digital Elevation Model (DEM) was derived. The slope map was generated from DEM using surface analysis tool which showed that 70% of the area occupies 15-45% slope, 20%, 8% and 2% of area occupies 0-1%, 1-5% and 5-15% slopes respectively.

DEM was developed and the basin was divided into four sub basins which were designated as W1, W2, W3 and W4. Each sub basin was analysed seperately. The linear, areal and relief aspects were determined in order to examine their influence in the identification of Groundwater potential zones of the basin.

### *Linear aspects*

Using Strahler's (1964) classification, the streams were classified into different orders (u). Using GIS software, the number of streams (Nu) and length of streams (Lu) (Horton 1945) were obtained. Mean stream length (Lmu) (Strahler 1964), stream length ratio (Horton 1945), bifurcation ratio (Rb) (Schumm 1956) and mean bifurcation ratio (Strahler 1957) were the other linear morphological parameters considered for the study. The number of streams of various orders in sub-basins is presented in the Table 1.

The stream length focus on surface runoff characteristics of the basin. Smaller stream lengths indicates areas with larger slopes and fine textures while longer lengths of stream indicate flatter gradient. Bifurcation ratio is the ratio of number of streams of a given order to the number of streams in the next higher order.

### *Areal aspects*

The basic parameters of sub-basins are length (L), perimeter (P), and area (A) were determined and presented in table 2.Low values of frainage density ($D_d$) of sub-basins indicate the existence of coarse to very coarse drainage structure, highly resistant and permeable sub soil with dense vegetated cover low relief. Low stream frequency ($F_s$) values indicate a very coarse drainage structure with low relief and high infiltration capacity and the existence of favorable sites for groundwater recharge.

Low drainage texture (T) values indicate very coarse drainage texture. Elongation ratio ($R_e$) greater than 0.7 of sub-basins W2, W3 & W4 indicated elongated shape of sub-basins. Circularity ratio ($R_c$) greater than 0.5 of W2, W3 & W4 indicated elongated sub-basins with moderate relief, low runoff an high subsoil permeability. Low Form factor ($F_f$) values of sub-basins indicate elongated shape resulting in longer flow duration with flatter pea leading to more groundwater recharge.

### *Relief aspects*

The relief parameters such as relief ratio ($R_r$) and ruggedness number ($R_n$) were computed and presented in table 6.4. Lower values indicate gentle slope. Low relief ratio and ruggedness numbers of sub-basins indicate the existence of promising ground water zones.

The morphometric analysis of linear, areal and relief parameters of sub-basins presented in tables 1 to 4 indicate that W4 possesses high bifurcation ratio with short streams. It is less elongated with high stream frequency causing less infiltration rate, moderate drainage density and low ruggedness number.

**Table 1. Linear parameters of sub-basins**

(a) Number of Streams and bifurcation ratio

| Subbasin | No. of streams, $N_u$ | | | | Bifurcation Ratio, $R_b=N_u/N_{u+1}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | $N_1$ | $N_2$ | $N_3$ | $N_4$ | 1/2 | 2/3 | 3/4 | Mean |
| W1 | 4 | 0 | 0 | 1 | - | - | - | - |
| W2 | 8 | 1 | 0 | 1 | 8 | - | - | 8 |
| W3 | 13 | 3 | 1 | 0 | 4.34 | 3 | - | 3.67 |
| W4 | 8 | 2 | 1 | 1 | 4 | 2 | 2 | 2.1 |
| Total | 33 | 6 | 2 | 3 | Mean | | | 4.59 |

(b) Stream lengths and stream length ratios

| Length of streams, $L_u$ (Km) | | | | Mean length of streams, $L_{mu}$ | | | | Mean stream length ratio, $L_{m(u+1)}/L_{mu}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | L4 | $L_{m1}$ | $L_{m2}$ | $L_{m3}$ | $L_{m4}$ | | | | |
| 1.2 | - | - | 2.7 | 0.30 | - | - | 2.7 | 0 | 0 | 0 | - |
| 5.3 | 2.2 | - | 2.7 | 0.66 | 2.2 | - | 2.7 | 3.32 | 0 | 0 | - |
| 5 | 2.7 | 2.5 | - | 0.38 | 0.9 | 2.50 | - | 2.34 | 2.78 | 0 | - |
| 4.2 | 1.9 | 1.7 | 0.14 | 0.53 | 0.95 | 1.70 | 0.14 | 1.81 | 1.79 | 0.08 | - |

**Table 2. Basic Parameters of sub-basins**

| Subbasin | Area($Km^2$) | Perimeter(Km) | Basin length,$L_b$(Km) |
|---|---|---|---|
| W1 | 1.5 | 7 | 2.6 |
| W2 | 4.5 | 10 | 2.2 |
| W3 | 5.5 | 10 | 2.3 |
| W4 | 4.5 | 10 | 2.75 |

**Table 3. Areal parameters of sub-basins**

| Drainage density $D_d=L_u/A$ | Stream frequency $F_s=N_u/A$ | Infiltration number $IN=D_d*F_s$ | Texture ratio $R_t=N_1/P$ | Elongation ratio $R_e=[2\sqrt{(A/\pi)}]/L_b$ | Circularity ratio $R_c=4\pi A/P^2$ | Form factor $F_f=A/L_b^2$ |
|---|---|---|---|---|---|---|
| 2.6 | 7.34 | 19.09 | 0.86 | 0.53 | 0.38 | 0.22 |
| 2.27 | 6.45 | 14.7 | 1.3 | 1.08 | 0.56 | 0.93 |
| 1.86 | 6.4 | 11.9 | 1.7 | 1.15 | 0.69 | 1.04 |
| 1.77 | 3.8 | 6.73 | 0.9 | 0.87 | 0.56 | 0.6 |

**Table 4 Relief parameters of sub-basins**

| Sub basin | Relief (m) | Relief ratio, $R_h$ | Ruggedness number, $R_N$ |
|---|---|---|---|
| W1 | 40 | 0.014 | 0.104 |
| W2 | 265 | 0.080 | 0.600 |
| W3 | 496 | 0.146 | 0.923 |
| W4 | 488 | 0.158 | 0.860 |

## IV. RESULTS AND DISCUSSIONS

The groundwater potential zones identification of sub-basins of Makaluva basin was carried out through compact factor analysis of morphometric parameters.

The compact factor analysis of morphometric parameters was carried out to prioritize sub-basins on the basis of groundwater potential availability. Rank of 1 to 4 representing poor, moderate, good and very good potential zone, were used to rank the linear, areal and relief parameters based on their contribution towards groundwater. Higher rank indicates the greater degree of ground water recharge in the sub-basin . The average rank value of the parameters of the sub basin indicates its compact factor. The compact factors 1 to 4 represent poor to very good categories of ground water potential zones. The ranks assigned and compact factors computed for the sub-basins and are presented.

The results showed that higher compact factor 3.1 of W1 sub-basin indicate good to very good of ground water potential. The sub-basin W4 with compact factor 2.9 respectively fall in moderate to good groundwater potential zones. The sub-basin W2 was identified as poor to moderate zones of groundwater potential zone. The groundwater potential zones map is shown in Figure 2.

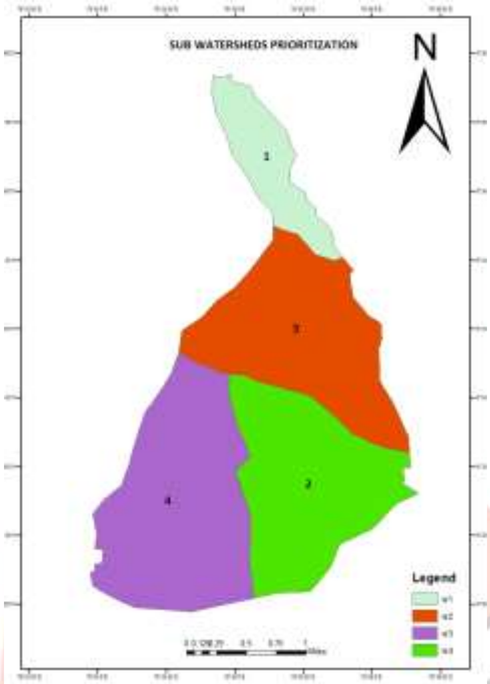


Fig.2. Prioritization of Makaluva basin

### *Overlay analysis*

The thematic maps of soil, geomorphology, LULC and slope were prepared and converted to raster format and reclassified with 1 to 4 scale representing poor, moderate, good and very good zones of groundwater potential.

The reclassified maps were combined to form corresponding aspect maps. Reclassified maps of soil, geomorphology, LULC and slope were overlayed and combined to obtain groundwater potential zone map as shown in Figure 3.

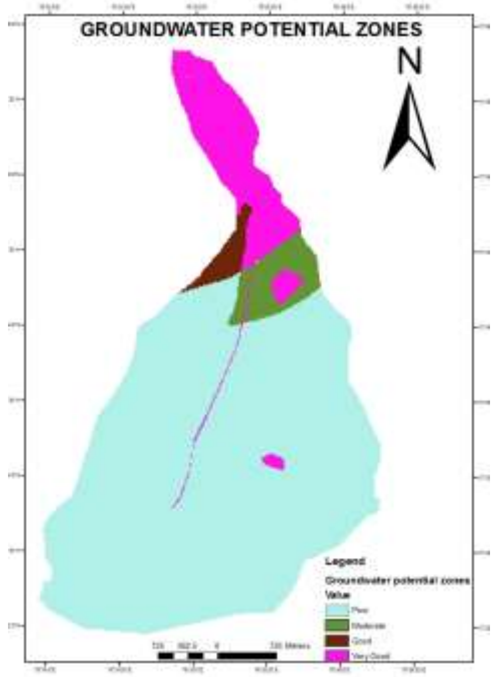


Fig.3. Groundwater potential zones

The groundwater potential map shows prioritized sub-basins and results are comparable with the compact factor analysis. It may be inferred from fig 3 that sub-basins W1 and W2 make them the promising groundwater potential zones.

## V. CONCLUSIONS

Morphometric analysis using RS and GIS is useful in basin planning and management. While high quality RS data provide recent and accurate information of various landforms and update the existing data, GIS provides a sophisticated environment to analyze and determine the morphological characteristics of a basin.

The Makaluva basin area was divided into four sub – basins for the purpose of micro -level morphometric analysis. The linear, areal and relief parameters of sub – basins were determined to identify groundwater potential zones of the basin. The compact factors of the parameters and overlay of soil, geomorphology, LULC and slope maps resulted in the prioritization of groundwater potential zones. Sub watershed (W1) was identified as good to very good category, followed by W4, W2 as moderate to good category, poor to moderate category and W3 as poor category groundwater potential sub – basins. The elongated shape, favourable drainage network, permeable geologic formation and low relief of sub – basin W1 make it the promising groundwater potential zone of Makaluva basin.

The overlay and compact factor methods of micro – level morphometric analysis are useful in the prioritization of groundwater potential zones of Makaluva basin. The approach of standardization of weights of the themes proposed during overlay analysis improves the method of groundwater potential zones delineation and these weights may appropriately be adopted for hydrogeologically similar basins.

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