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Morphometric analysis of the Catchments of Himayatsagar and Osmansagar Reservoirs - Hyderabad

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Abstract— The linking of the geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of the different basins particularly of the ungauged basins because the hydrologic and geomorphic effects of natural and human process with in a catchment are focused at its outlet. The development of morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network. The geomorphological properties which are important from the hydrological studies point of view include the linear, aerial and relief aspect of the watersheds. In the present study morphological study has been carried in the catchments of Himayatsagar and Osmansagar reservoirs. The catchments of Himayatsagar and osmansagar reservoirs cover the area of 1315.14 and 748 km within the elevation rang of 575 to 715 and 585 to 705 m resepectively.the drainage pateern varies from dentric to subdentric. They are 5^{th} and 4^{th} order drainage basins respectively. The stream length and stream areas to stream number relation follows the Hortons laws. Stream density shows low value for all stream orders. The bifurcation ratio is high for Osmansagar reservoir catchment. This is due to the variation in stream frequencies in successive orders. Lower value of drainage density and stream frequency indicates the region of highly permeable subsoil strata and the catchment will not generate runoff soon. The length of overland flow and time of concentration for the catchments of Himaytsagar and osmansagar is estimated to be .68, .70 and 16.74, 15.81hours resepectively. From the values of Circularity ratio, elongation ratio, form factor, and compactness coefficient of the catchments of Himayatsagar and Osmansagar reservoirs it is expected that the catchment is highly irregular, strong relief, steep ground slope and elongated hydrograph. The high ruggedness number of the catchment of Himayatsagar and Osmansagar reservoir shows the high roughness or unevenness.

Keywords— *Drainage network, Morphometric Analysis*

1. Introduction

Hyderabad is the fifth largest city in India is facing with severe water shortage on account of growing population with the rate of more than 5% and depleting water resources. At present, only one-half hour to two hours every alternate day in MCH area and one hour every alternate day in surrounding municipalities of Hyderabad and in summer even this little supply is in alternate days. For over a 6.8 million population of the city, the actual requirement is at the rate of 290 Million gallons per Day (Mgd) but the present water availability is 270Mgd (Hyderabad city plan).

Himayatsagar and Osmansagar are the two oldest reservoirs supplying the water to the city apart from Manjira and singur dams. Over the years the inflows to the Osmansagar and Himayatsagar are slowly decreasing in spite of the average annual rainfall is more or less the same for the past 46years (Dr.B.Venkateswara Rao, 2009). This shows the importance of Hydrogeological studies in these areas.

2. Location And Description of the Study Area

The study area for the present work consists of catchment areas of Himayatsagar and Osmansagar reservoirs (Fig.1). The Himayatsagar reservoir was constructed on Esa river in 1925 and is located 9.6 km in southwest direction from the city and Osmansagar reservoir was constructed on Musi river in 1922, and is located 9.6 k.m. from Hyderabad in western direction. The Himayatsagar catchment covers 153 villages and spread over 1315 km^2 area with a slope range of 575 m to 715 m Where the Osmansagar catchment area consists of 748 km^2 with a slope varies between 585 m to 705 m and covers 93 villages. The two reservoirs are supplying drinking water to Hyderabad city, which is extending from 17^0 10' to $17^0$50' of North latitude and 78^0 10' to $78^0$50' of East longitude.

Both the catchments of Himayatsagar and Osmansagar reservoirsis shows flat to gently undulating topography except for few hillocks and valleys. The region is mainly underlain by a peninsular gneissic complex that includes a variety of granites, magmatites of various phases and enclaves of older metamorphic rocks belonging to the Archean age. These are intruded by various acidic (pegmatite's, aptite, quartz veins/reefs) and basic intrusives of dolerite and gabbros. Major dykes of dolerite composition cut across the country rocks in different

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directions. The predominant soils in the basin are sandy loam, clay loam, black cotton soils and rocky soils**.** The riverbed is mostly deposited with sandy soils**.** Ground water occurs under Unconfined to Semi-confined conditions in weathered and fractured formations respectively. Three seasons prevail in the basin: summer (March – May), monsoon/ rainy (June – November) and Winter (December – February). The mean annual rainfall is around 800 mm. 75% of rainfall occurs during the monsoon period. The minimum and maximum temperatures vary between 12^0 C and 43^0C.

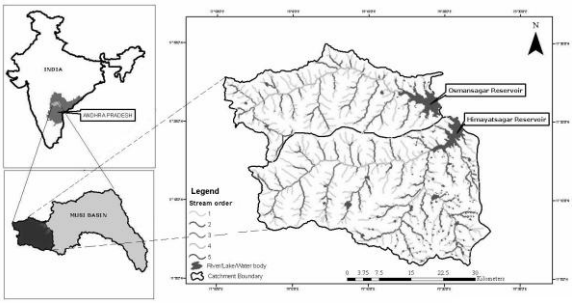

Fig.1 Location map of the study area

3. Literature Review

The development of morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network. These parameters are useful in characterizing river basins and comparing their characteristics. For the first time it was proposed by Horton (1945). Later it was modified by Strahler (1957). Naithani & Rawat **t**he Morphometry parameters could be categorized into two major groups namely; the measured parameters such as basin area, axial length etc. and the calculated parameters like drainage density, stream frequency,etc. Sandeera et al (2007). studied the quantitative description of the geometry of the Kotmale reservoir and its network and compared the characteristic of several drainage networks and examining the effect of variables such as lithology, rock structure, rainfall etc. Yasuo Shimano (2005) analyzes the composition of stream networks of 180 drainage basins in the entire country of Japan and discuss the characteristics of drainage basins in the Japanese Islands. P.D.Sreedevi (2004) carried out morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain of total area of the Pageru River basin.

4. Methodology

To estimate the morphometric features of catchments of Himayatsagar and osmansagar reservoirs, the drainage network is drawn with the digital elevation model in arc GIS software by using the toposheet of 1:2, 50,000 scale.

Stream oreder: The first step in drainage basin analysis is to designate the stream order. Stream order is introduced by Horton. Later it is modified by Strahler. The smallest streams of the network, which have no tributaries, are called first order streams. When two first order streams coalesce they form a second order stream and further along its course this stream may join another second order channel to form one of the third order and so on. A lower order stream, such as one of the first order joining another higher order does not alter the rank of the latter. The relevant numbers were entered into the attribute table of the drainage network using GIS software.

Axial length of the basin (Lb km): It is the distance from the outlet to the most remote point on the basin

Mean length (Lu km): Mean length of channel Lu of order U the total length is divided by the number of segments Nu of that order

$$Lu= \sum Lu/Nu$$

Stream length ratio (Rl): It is the ratio of the meanlength of segments of order U to the mean length segment of the next lower order.

$$Rl=Lu/Lu-1$$

Drainage basin area: Drainage basin area Au is defined as the total area projected on a horizontal plane contributing overland flow to the channel segments of the given order including all the lower orders. The stream areas or derived by using DEM model in GIS software.

$$Au=(\sum A1+\sum A2+\sum A3\ldots\ldots\ldots\ldots+\sum Ao1)+ +\sum Ao2 +\sum Ao3\ldots\ldots\ldots\ldots +\sum Aou)$$

Drainage density: Drainage density Dd is introduced by Horton. It is the ratio of the total length of all stream channels in the basin to the total area of the basin.

$$Dd= \sum Lu/Au$$

Constant channel maintanace (Cc): According to Schumm Constant channel maintanace is the inverse of the drainage density.

$$Cc=1/Dd$$

Stream frequency (Fc): Horton introduced stream frequency Ds as the number of stream segments per unit area.

$$Ds=\sum Nu/Ak$$

Length of overland flow (Lg): According to Horton definition length of overland flow approximately equal to half of the reciprocal of the drainage density.

$$Lg=1/2Dd$$

Time of Overland flow: This equation is suggested by Kirpich for time of overland flow is

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$$Tc=0.0195L^{0.77}S^{-0.385}$$

Where Tc is in minutes, L is the maximum length of travel of water along the water course in meters and S is the slope expressed as the ratio of the difference in elevation between the remotest point and the catchment outlet to the length L.

Circularity ratio (Rc): According to Miller circularity ratio Rc defined as the ratio of basin area Au to the area of circle Ac having the same perimeter as the basin.

$$Rc=Au/Ac$$

Elongation ratio (Re): Schumm defined the elongation ratio Re as the ratio of diameter of a circle of the same area as the basin Dc to the maximum basin length Lb

$$Re=Dc/Lb$$

Form factor (Ff): Horton defined the form factor Ff which is the ratio of basin area Au to the square of basin length Lb.

$$Ff= Au/Lb^2$$

Compactness factor (Cc): The compactness factor was obtained from the ratio of the perimeter of the watershed P to the total drainage basin area. (Gupta, 1999)

$$Cc=P/2\sqrt{\prod A}$$

Laminscate ratio: It is the ratio of square of the length of the basin to the four times of the basin area

$$Lb^2/4Au$$

Maximum basin relief (R): It is defined as the higtht difference between the maximum elevation on the watershed Zm and the elevation of the Gauging station Zo

$$R=Zm-Zo$$

Relief ratio (Rh): Schumm measured relief ratio Rh as the maximum basin relief to horizontal distance along the longest dimension of the basin parallel to the principle drainage line.

$$Rh=R/Lb$$

Relative relief (Rhp): It is the ratio of the maximum basin relief to the perimeter of the basin (Shivapur, A.V., 2006)

$$Rhp=R/P$$

Ruggedness number (Rn): This is the product of Drainage density and Catchment relief.

$$Rn=Dd*R$$

5. Results and Discussions

The main or trunk stream and its tributary streams that drain the basin area collectively form the stream network. The spatial arrangement of a river and its tributary streams in a drainage network of Himayatsagar reservoir catchment and Osmansagar reservoir catchment is referred to as dentric too sub-dentric drainage pattern of a basin. Figure 1 illustrates the stream network of catchments of Himayatsagar reservoir and Osmansara reservoir, the stream orders of Himayatsagar reservoir catchment order, varied from 1 to 5 and the total number of stream segments of all orders recorded was 423. stream network indicated 335 of 1st orders, 72 of 2nd Orders of 12 of 3rd order, 3 of 4th order and 1 of 5th order streams where The catchment of osmansagar reservoir stream orders varied from 1 to 4 and the total number of stream segments of all orders recorded was 274. Orders of stream network indicated 219 of 1st order, 44 of 2nd order, 10 of 3rd order and1 of 4th order streams.

The mean length and mean areas of the streams shows an increasing trend with stream order (Table1and table.2). The number of streams, stream order and stream areas follows the Hortons laws, i.e, it has been observed that the logarithm of number of streams decreases with increasing stream order. This is Hortons I law. Logarithm of the mean length of stream increases with increasing stream order this is Horton II law. Logarithm of mean area of stream increase with increasing stream order. This is Horton III law.

According to Gregory & Walling (1985) almost every watershed characteristics is correlated with the catchment area. Kale and Gupta (2001) stated that the larger basins have large average discharge. The areas of the catchments

Table.1 Stream parameters of the Catchment of Himaytsagar Reservoir

Stream order(U)	No. of streams (Nu)	Length of Streams (Lu)	Areas of the Streams (Au)	Log Mean stream length (logLu)	Log Mean stream area (LogAu)	bifurcation ratio (R_b)	strem length ratio (R_L)	Stream density
1	335	554.4406	911.79	0.21	.43			.60
2	72	231.8466	1048.92	0.50	1.16			.74
3	12	103.41	1226.92	0.93	2.00	4.652778	1.9456198	.72
4	3	50.71596	1284.28	1.22	2.63	6	2.6762409	.732
5	1	21.87	1315.15	1.34	3.11	4 3	1.9616883 1.2941749	.731

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Table.2 Stream parameters of the Catchment of the Osmansagar Reservoir

Stream order(U)	No. of streams (Nu)	Length of Streams (Lu)	Areas of the Streams (Au)	Log Mean stream length (logLu)	Log Mean stream area (LogAu)	bifurcation ratio (R_b)	strem length ratio (R_L)	Stream density
1	219	280.86	483.34	.10	.34	4.97 4.40 10.00	.49 .40 .99	.58
2	44	140.03	602.8	.50	1.13			.69
3	10	56.02	633.49	.74	1.80			.75
4	1	55.90	748.14	1.74	2.87			.71

of Himayatsagar and Osmansagar are 1316 km^2 and 748.14 km^2 respectively.

The length and slope of the catchment effects the lag time taken for the water to reach the reservoir from its longest distance in the catchment after the rainfall. The length and maximum basin relief of the catchments of Himayatsagar and Osmansagar are 58 km, 140 m and 53.8 km, 120 m respectively. From Fig.2 it shows that there is a decrease in slope with the length along the stream towards mouth of the drainage basin.

The bifurcation ratios of the Himayatsagar reservoir catchment varies between 3 to 6. This shows that the geologic structures with in the catchment do not distort the drainage pattern. It also indicates that a basin is a mature topography due to the result of the process of drainage integration. Where the osmansagar reservoir catchment varies between 4 to10. These high bifurcation ratios are the result of large variation in stream frequencies in successive orders and The structural control encourages the development of elongate narrow drainage basins.

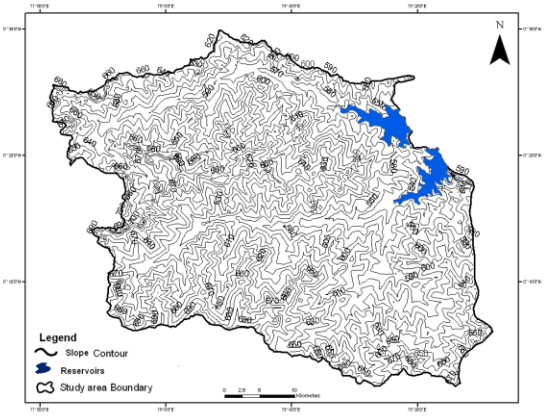

Fig.2 Slope Map of the Study Area

The drainage density is indicative of the closeness of spacing of channels thus providing a quantitative measure of average length of stream channel for the whole basin. It also indicates about the physical properties of the underlying rocks. The drainage densities of the catchments of the Himayatsagar and osmansagar is .731 km per km^2 and .71 km per km^2 indicates region of highly subsoil strata and coarse texture (Smith,1950 and Strahler, 1957). This coarse texture gives more time for overland flow. The stream frequency also shows the low value of .321number of streams per km^2 and 0.36number of segments per km^2. This is shows the catchment will not generate runoff soon and low sediment production. This is evident from the values of length and time of overland flow which is 1.36 km and 16.7 hours.

We know that the pattern of flow hydrograph and its time variance depends on shape of the basin flow response to catchment precipitation and its topography. The important parameters that describe the shape of the basin are circularity ratio (Rc), elongation ration (Re) compactness coefficient and form factor (F_f). From the values of Circularity ratio, elongation ratio, form factor, and compactness coefficient of the catchments of Himayatsagar and Osmansagar reservoirs it is expected that the catchment is highly irregular, strong relief, steep ground slope and elongated hydrograph (Table.3). It also shows the basin is matuture and old. It is evident from the relief ratio value of the catchment. From The high ruggedness number of the catchment of Himayatsagar and Osmansagar reservoir shows the high roughness or unevenness. High relative relief shows high region or low relative relief shows paddy plain and valley.

6. Conclusions

The catchments of Himayatsagar and osmansagar reservoirs cover the area of 1315.14 and 748 km within the elevation rang of 575 to 715 and 585 to 705 m resepectively.the drainage pateern varies from dentric to subdentric. They are 5^{th} and 4^{th} order drainage basins respectively. The stream length and stream areas to stream number relation follows the Hortons laws. Stream density shows low value for all stream orders. The bifurcation ratio is high for Osmansagar reservoir catchment. This is due to the variation in stream frequencies in successive orders. Lower value of drainage density and stream frequency indicates the region of highly permeable subsoil strata and

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Table.3 Morphometric Parameters of the Catchments of Himayatsagar and Osmansagar Reservoirs

S.No.	Paraameter	Himayatsagar	Osmansagar
1	Area of catchment in km^2	1315.70	748.14
2	Perimeter in km	174.69	151.06
3	Axial length in km	58.02	53.80
4	Breadth in km	30.83	19.97
5	Drainage density	.73	0.71
6	Constant channel maintanance	1.36	1.40
7	Stream frequency	.32	0.36
8	Length of overland flow	.68	0.70
9	Time of overland flow (hr)	16.74	15.81
10	Circularity ratio	.54	0.41
11	Elongaton ratio	.70	0.57
12	Form factor	.39	0.25
13	Compactness factor	1.35	1.55
14	Lminscate ratio	.63	.96
15	Max water shed relief	140	120
16	Relief ratio	2.41	2.23
17	Relative relief	.80	0.79
18	Ruggedness number	102.39	85.46

the catchment will not generate runoff soon. The length of overland flow and time of concentration for the catchments of Himaytsagar and osmansagar is estimated to be .68, .70 and 16.74, 15.81hours respectively. From the values of Circularity ratio, elongation ratio, form factor, and compactness coefficient of the catchments of Himayatsagar and Osmansagar reservoirs it is expected that the catchment is highly irregular, strong relief, steep ground slope and elongated hydrograph. The high ruggedness number of the catchment of Himayatsagar and Osmansagar reservoir shows the high roughness or unevenness.

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