Prediction of Runoff in Ungauged Basin using Snyder method

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Abstract— Drainage basins in the most parts of world are either partially gauged or completely ungauged. Prediction in ungauged basins is a serious challenge in hydrologic sciences, and there is still abundant work required to realize strong and reliable predictions for such basins. Errors in the prediction of hydrological parameters are seen due to unavailability of sufficient discharge data. In this research work Sub-basin of Kundalika River has been taken as the study area. Firstly we created the DEM by using the ArcGIS technique. To derive SUH we are used traditional synthetic unit hydrograph like Snyder's method. After modeling we developed the unit hydrograph of basin and we predict the discharge of basin.

Keywords: Ungauged basin, IUH, SRTM DEM, Snyder's method

I. INTRODUCTION

A drainage basin which has inadequate records of various hydrological observations in terms of both quantity and quality for analysis at the suitable spatial and temporal scales and up to a good level of accuracy for application in fields is known as ungauged basins. If the parameter of interest is not available for the required period of time for prediction, that basin is an ungauged basin with respect to that variable. Variables of interest can be rainfall, runoff, erosion rates etc. so every basin is ungauged in some respect.

Accurate and timely predictions of high and low flow events at any ungauged watershed location can provide stakeholders the information required to make strategic, informed decisions. Whenever data is not available, hydrological models are significant to establish baseline characteristics and find out long term impacts which are hard to calculate. The aim of modeling is to reduce the uncertainty in hydrological predictions.

The unit hydrograph (UH) theory is a powerful tool in watershed hydrology. The Sherman UH concept used for derives the storm hydrograph at gauged stations. This was the first tool which determines the complete shape of hydrograph instead of quantum of peak discharge only. Here the synthetic word shows the UH obtain from watershed characteristics rather than rainfall-runoff data.

The SUH models were grouped in to four types

1) Traditional models.
2) Conceptual models.
3) Probabilistic models.
4) Geomorphological model.

High resolution DEMs and advance in DEM processing software like ArcGIS, helps to extract geomorphological data which improves the practical application of models. Because of these the extraction of typical hydrological information like drainage basin and sub-basin delineation, drainage path, drainage network extraction etc. make easy, thus limiting the role of calibration parameters.

A. Objectives of Study

As mentioned above, hydrological modeling in any catchment; gauged, partially gauged or ungauged helps to understand the catchment features and its responses. The specific objectives of the present study are:

1) DEM processing by using ArcGIS
2) Extracting the geomorphological characteristics of the study area.
3) Development of SUH by Snyder's method.

II. STUDY AREA

River Kundalika is a small river which originates at longitude 73024'E and latitude 18031'N near a small village Hirdewadi, Tal. Mulshi, Dis. Pune. It originates at hills of Sahyadri mountain and flows to the Arabian Sea. The length of the river is 83.97 Km. and catchment area of the river is 786.5 Km2. Maximum elevation above means sea level is 1140m. There are five rain gauge stations Bira, Sudhagad, Roha, Sulkodi, and Alibaug.

Up to 90% of Kundalika river water is consumed by the industries. There for the hydrological study of the river catchment is important.

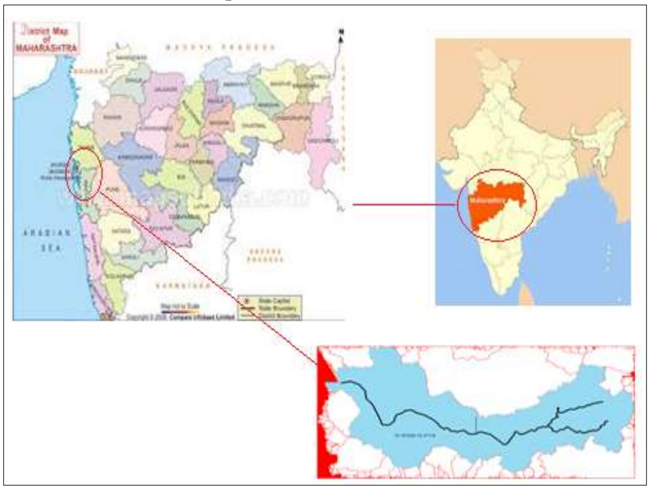

Fig. 1: Location of the study area.

III. METHODOLOGY

The following methodology is followed for developed for Snyder's method. By using this methodology, the discharge of the river is calculated. First we develop maps using ArcGIS. Then we calculate the geographical characteristics after this developed SUH using Snyder's.

A. Derivation of synthetic unit hydrograph by using Snyder Unit Hydrograph

The following methodology has been used for calculation of hydrological parameters resulting into Snyder unit hydrograph (SUH).

The Snyder standard lag time (T_{lag}) [in hours]:

$$T_{lag} = C_t (L \times L_{ca})^{0.3}$$

Where the terms,
C_t = Lag Coefficient dependent upon basin properties
L = main channel length from basin outlet to upstream watershed boundary [km]
L_{ca} = main channel length from outlet to a point opposite the Centre of gravity [km]

The duration of UH (T_r) [in hours];

$$T_r = T_{lag} / 5.5$$

As the term T_r is variable for each watershed and depends on shape and size. We propose to prepare SUH for each sub-watershed having a common time duration of 1 hour. Therefore, above calculated time duration (T_r) is not desired duration. The alternative lag time [Tlag.alt] can be computed.

$$T_{lag.alt} = T_{lag} + 0.25(T_R - T_r)$$

Where,
T_r = Previously Calculated duration [in hours],
T_R = New desired duration [in hours]

Time of Peak (T_p) [in hours]

$$T_p = (T_r / 2) + T_{lag.alt}$$

Peak Discharge (Q_p) [in m^3/s] from watershed is calculated using below equation:

$$Q_p = \frac{2.78 * A * C_p}{T_{lag.alt}}$$

Where,
A= area of sub-watershed [in km^2]
C_p= Peak flow coefficient [0.5- 0.7] that dependent upon basin characteristics.

Furthermore, Snyder proposed that shape of Unit Hydrograph is very important which has been approximated using the widths W_{50} and W_{75} at 50% and 75% of the peak discharge. The UH width at W_{50} and W_{75} can be calculated.

$$W_{50} = 756Q_P -1.081$$

$$W_{75} = 450Q_P -1.081$$

Hence, it is possible to develop the shape, standard time lag, time base, time of peak, and peak discharge of watershed.[9]

IV. RESULTS

To extract the geomorphologic features of the basin, SRTM (Shuttle Radar Topography Mission) data of 30 x 30 m resolution was used. Based on the study by Haase and Frotscher (2005) it can be stated that the SRTM data sets are of major relevance for providing terrain information in large and transboundary river basins for handling the regional environmental problems, , and could be applied in meso / macro scale river network and terrain analyses. Besides these, the application of the SRTM data is cost-efficient and informative and is web-based worldwide available and appropriately implemented into a geographic information system (GIS)-framework.[5] The DEM of Kundalika river basin (Fig. 4.1) from SRTM dataset was processed in ArcGIS to extract the basin boundaries and drainage networks.

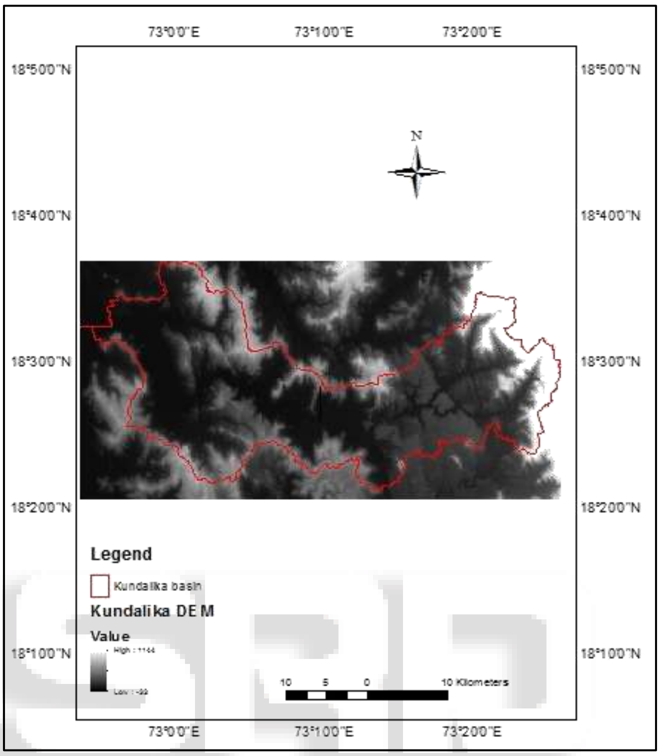

Fig. 2: Digital Elevation Model (DEM) for Kundalika River

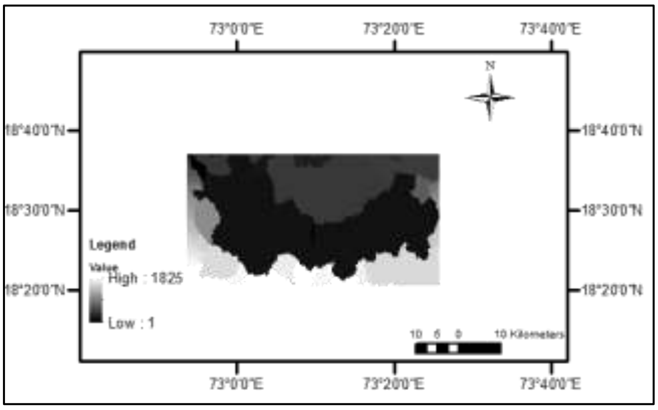

Fig. 3: River basin extracted from DEM of Kundalika River

Parameters	Value
Area of catchment(km^2)	786.5
Perimeter(km)	228.38
Length (km)	83.97
Maximum elevation(m)	1140
Bifurcation ratio	4.9
Length ratio	2.96
Area ratio	6

Table. 1: Extracted geomorphologic parameters for Kundalika River

A. Snyder's method

The regional constants C_t and C_p are calculated from geomorphological similar catchment Sawitri sub river basin. The values of C_t and C_p are 0.86 and 0.55 respectively. These values are within the range C_t = 0.3 to 6.0 and C_p = 0.31 to 0.93[5].

Sawitri sub river basin:

$T_p = 6.7$hrs
L = 57km
A= 354km^2
Q = 87.51m^3/s
L_{ca}=13km

$T_p = (T_R/2) + T_{lag,alt} = 6.7$

$T_{lag,alt} = 6.2$hrs.

$T_{lag,alt} = C_t (L \times L_{ca})^{0.3}$

$6.2 = C_t (57 \times 13)^{0.3}$

$C_t = 0.86$

Now, for calculating C_p

$$Q_p = \frac{2.78 * A * C_p}{T_{lag}}$$

$$87.51 = \frac{2.78*354* C_p}{6.2}$$

$C_p = 0.55$

Now, calculations for study area

$T_{lag} = C_t (L \times L_{ca})^{0.3}$

$T_{lag} = 0.86\ (83.97 \times 40.635)^{0.3} = 9.89 = 10$hrs.

$$Q_p = \frac{2.78*A*C_p}{T_{lag}}$$

$$Q_p = \frac{2.78*786.5*0.55}{10} = 120.25\text{hrs.}$$

$$T_b = 5(T_{lag} + \frac{T_R}{2})$$

$$T_b = 5(10 + \frac{1}{2})$$

= 52 hrs.

$$W_{50} = \frac{5.87}{q^{1.08}} = \frac{5.87}{(\frac{120.25}{786.5})^{1.08}}$$

= 44.6 hrs.

$$W_{75} = \frac{W_{50}}{1.75} = \frac{44.6}{1.75}$$

= 25.5 hrs.

Discharge from this method is Q_p = 120.25 m^3/s obtained. Time of peak T_{lag} = 10 hrs and time base is T_b = 52 hrs. W_{50} =44.6 hrs, W_{75} =25.5 hrs.

In Fig.4 X axis Indicates- time in hrs and Y axis Indicates- discharge in m^3/sec

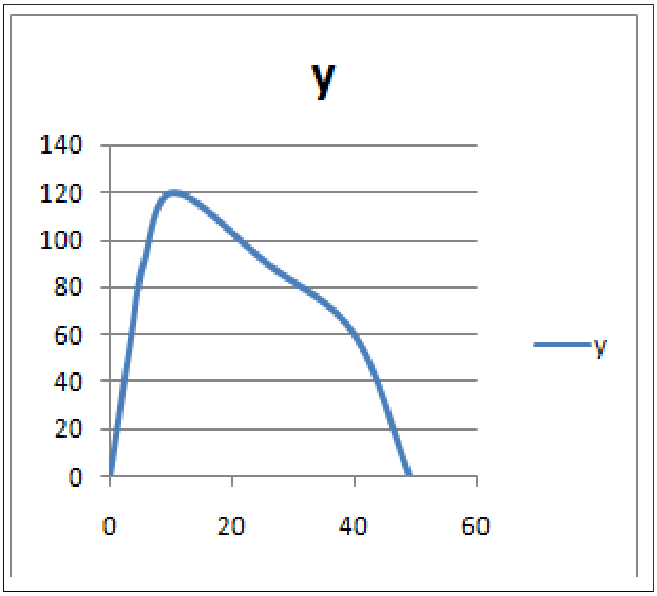

Fig. 4: Hydrograph by Snyder's Method for Kundalika River

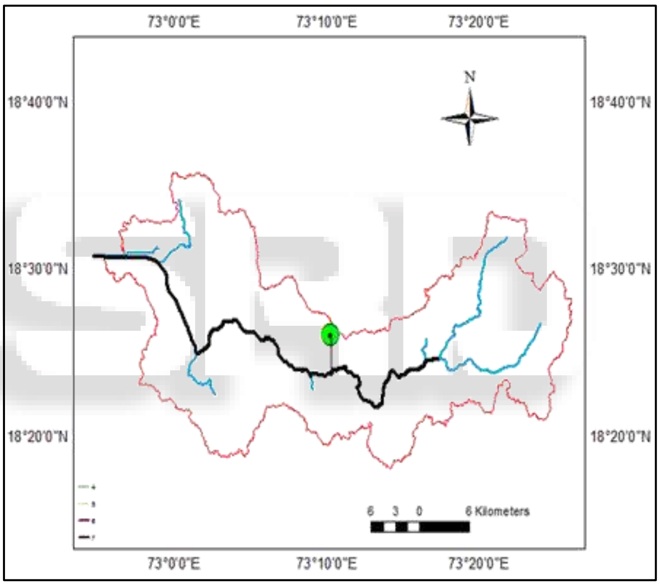

Fig. 5: Map shows calculation of L_{ca}

V. CONCLUSION

In Snyder's method, the C_t and C_p are the regional constants which are required to be extracted from the similar hydrological basin and then can be used in the study area. The topography of the study area within the first 15 to 20 km, has a very steep slope as compared to next 60 to 65 km. Using Snyder's method we get the discharge 120.25 m^3/s. The shape of unit hydrograph exerted by Snyder's method is not similar to the natural unit hydrograph.

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