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# DERIVATION OF SYNTHETIC UNIT HYDROGRAPH FOR RANGANADI BASIN AND DIKRONG RIVER BASIN IN ASSAM-ARUNACHAL

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## ABSTRACT

*A hydrograph is a continuous plot of instantaneous discharge v/s time. It results from a combination of physiographic and meteorological condition in a watershed and represents the integrated effects of climate, hydrologic losses, surface runoff, interflows and groundwater flow. The unit hydrograph represents the lumped response of the catchment to a unit rainfall excess of D-hr duration to produce a direct runoff hydrograph In order to construct a unit hydrograph in areas where detailed information are not available, unit hydrograph can be synthetically generated using some relationships. Various researches were done before to generate synthetic unit hydrograph where data is not available. Natural Resource Conservation Service NRCS dimensionless unit hydrograph model and Snyders unit hydrograph model is used for this study in two river basins in North East India. This paper elucidates the use of Remote Sensing and GIS technology for the evaluation of the required parameters necessary for the generation of 1 hr unit hydrograph. The slope map and the delineated watershed are generated in ArcGIS*

***Keywords: Hydrograph, GIS, NRCS, Remote Sensing, unit hydrograph***

## I. INTRODUCTION

A hydrograph is the representation of the water surface in a stream with time. The hydrograph is the response of a given catchment of a rainfall input. It consists of flow in all the three phases of runoff i.e surface runoff, interflow and baseflow. Hydrographs are of paramount importance from engineering point of view. Hydrographs are necessary for the design of reservoir, capacity of spillway etc. In watershed evaluation hydrographs are important on effect of land uses with the change in peak discharges and volume runoff. The unit hydrograph method is the most widely used method for the computation of flood hydrograph. To develop unit hydrographs to a catchment, detailed information regarding the rainfall and resulting flood hydrograph is necessary. However there are large numbers of catchments where the data would normally be scanty. In such cases relationships among various watershed parameters are used for the generation of unit hydrographs. The unit hydrographs derived from such relationships are known as synthetic unit hydrographs.

A number of researches have been done in this field. Salami (2009) [2] developed unit hydrographs using Snyder, NRCS, Grays method for the catchment of lower Niger River. Choudhury(2012) [3] uses NRCS model to derive 1-hr UH for Madhura and Ghagra watersheds located in Barak basin in India.Sule and Alube (2013) [1] used synthetic unit hydrograph method to generate storm hydrograph for Awun river basin in Kwara

state,Nigeria. Snyder (1938) [10] derived some relationship among the watershed parameters required for the generation of unit hydrograph .Further studies were done by Taylor and Schwarz (1952) [8] developed some empirical relationships to develop unit hydrograph.

## II. NRCS DIMENSIONLESS UNIT HYDROGRAPH

The NRCS previously known as SCS [7] developed a dimensionless unit hydrograph in the 1950's based on analyses on many unit hydrographs for gauges watersheds varying widely in size and location. The NRCS dimensionless unit hydrograph continues to be widely applied throughout the world. Its popularity is largely due to its simplicity and use. The watershed area A and lag time $t_L$ are the only parameters required and they can be estimated for ungauged watershed. There are curvilinear and triangular version of NRCS synthetic unit hydrograph.the curvilinear is more realistic, but triangular is simpler.

## III. SNYDERS SYNTHETIC UNIT

Snyder gave some empirical relationships which relate the watershed characteristics. He gave the three basic parameters of the unit hydrograph i.e, $t_L$=lag time (hr), $Q_p$= peak discharge ($m^3/s$) and $T_b$=base time(hr).For the derivation of these parameters watershed characteristics like area of the watershed, length of the main stream and the distance from watershed outlet to a point on the main stream nearest to the centre of the watershed. The unit hydrograph can be generated using the basic parameters. The Us Army Corps of Engineers developed empirical equations between width of unit hydrograph at 50% and 75% of $Q_p$ i.e $W_{50}$ and $W_{75}$ respectively as a function of $Q_p$ per unit area ($q_p$). From these data the unit hydrograph can be derived in an easier way with less ambiguity.

## IV. STUDY AREA

For the present study two river basins, Ranganadi basin and Dikrong basin of North East India is taken. The Ranganadi originates from the Dafla hills in the Arunachal Himalaya. It is situated between 27 and 27 $^0$46' N latitude and 93$^0$ 16' E and 94$^0$ 10' E longitude. In the hills the Ranganadi is known as Panir river. After traversing a distance of 28.5 km through Kameng district of Arunachal Pradesh and Lakhimpur district of Assam, it outfalls at river Subansiri. During its long journey it receives water from the meandering streams like the Singra, Pabha, Boka and the Gerale etc. And about 6 km northeast of Badati it debouches into the Subansiri. The total catchment area of the Ranga is about 2500 sq km, of which about 700 sq km falls in Assam. The average width of the river is 112.5 m.

The other major tributary of Subansiri is the Dikrong river which originates at an elevation of about 2899 m in the Dafla hills of Arunachal Himalayas. In the hills, it is called the Par Nadi. Before it debouches into the plains near Daimukh, the river traverses a distance of about 80 km in the Arunachal Himalayas. From the foothills to the confluence, it follows a long winding course and ultimately a southerly course. The distances covered by the above segments are approximately 11, 13, 17 and 3 km respectively. It receives the water of the Garela river at a point about 5 km south of Niz Laluk. Out of the total catchment area of 1528 sq.km, 270 sq. km lies in Assam and the remaining 1258 sq. km in Lower Subansiri district of Arunachal Pradesh. Its average width is 102 m. It

discharges 566.34 cumec of water at 1.6 km downstream of National highway, NH 52. The river changes its course in the last leg of its journey. The old course which is now called Mora Dikrong used to join the Subansiri near Dikrongmukh.

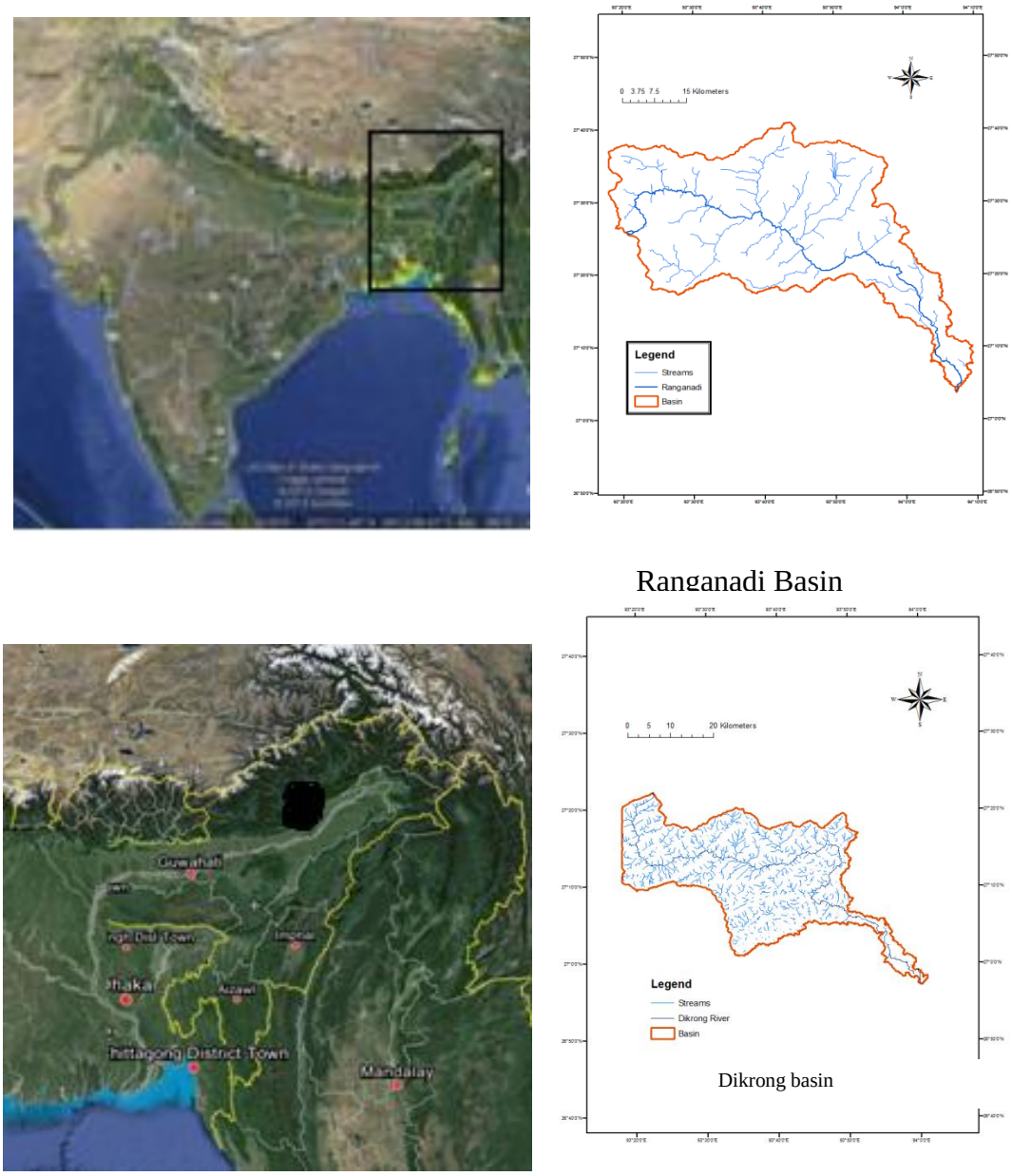


**Figure 1: Study area of Ranganadi basin and Dikrong basin**

## V. DATABASE

For the study Digital Elevation Model (DEM) Shuttle Radar Topographic Mission (SRTM) with 90m resolution is used. The downloaded DEM for the watersheds is used with GIS software ArcMap to delineate watershed area and to develop slope map, drainage network map, etc. Using DEM flow direction and flow accumulation

maps for the watersheds are developed. Watershed geomorphological parameter,delineation is done in ArcGIS. The parameters are then used in NRCS model to derive the unit hydrograph.

## VI. METHODOLOGY

### 6.1 Development of NRCS unit hydrograph

The NRCS dimensionless unit hydrograph method is the most widely used method to derive Synthetic Unit Hydrograph. The synthetic unit hydrograph is derived which is based on a dimensionless hydrograph which relates ratios of time to ratios of flow. For the generation of Triangular Unit Hydrograph the following equations are used as recommended by NRCS.

$T_p=(\frac{tr}{2}+t_L)$

(1)

where $T_p$ = the time to peak (hr); $t_r$= the duration of rainfall (hr); $t_L$=the lag time(hr) Time to peak is the time it takes a stream of water to build up to it peak. It is important in flood prediction and basin management and controlled by basin length, length of mainstream, slope and others. The lag time can be derived by the following equation:

$t_L= 0.6t_c$

(2)

where $t_c$= the time of concentration (hrs)

The time of concentration can be derived from Kirpich formula. Kirpich (1940) is a well known relationship useful in estimating time of concentration for a watershed.

$t_c=0.0195 \quad L^{0.77}S^{-0.385}$

(3)

where tc = Time of concentration (min); L = Length of main river (m); S = the watershed gradient or slope (m/m).

### 6.2 Development of Snyders unit hydrograph

$T_p=C_t(LL_{ca})^{0.3}$

(4)

Where $T_p$=basin lag in hours,L= basin length measured along the water course in km, $L_{ca}$= distance along the main water course from the gauging station to a point opposite to the watershed centroid in km, $C_t$=a regional constant representing watershed slope and storage effects. The value of Snyder ranged from 1.35 to 1.65.However various studies reveal that $C_t$ varies from 0.3 to 6. A value of 0.4 is adopted in this study for both the catchment as they lie on the same river basin.

Snyder adopted a standard duration $t_r$ hours of effective rainfall given by-

$t_r=\frac{Tp}{5.5}$ (5)

The peak discharge $Q_p$ ($m^3/s$) of a unit hydrograph of standard duration $t_r$ is given by-

$Q_p=2.78\ C_pA/T_p$ (6)

Where A=catchment area in $km^2$ and $C_p$=a regional constant which is considered as an indication of the retention and storage capacity of the watershed. A value of 1.5 is taken for both the catchment.

If a non standard duration $t_R$ h is adopted the value of basin lag is affected. The modified basin lag is given by

$T_p' = T_p + t_R - t_r/4$ (7)

Where $T_p'$=basin lag in hours effective duration $t_R$ h. The value of $T_p'$ is used instead of $T_p$. The Peak discharge is given by-

$Q_p = 2.78\ C_p A / T_p'$ (8)

The time base of a unit hydrograph is given by-

$T_b = 3 + T_p'/8$ days $= (72 + 3\ T_p')$ hours (9)

The widths of the unit hydrograph corresponding to 50% and 75% of the peak discharge given by the US Army Corps of Engineers are given by-

$W_{50} = 5.87/q^{1.08}$ and $W_{75} = W_{50}/1.75$ (10)

Where $W_{50}$ = width of unit hydrograph in h at 50% peak discharge

$W_{75}$= width of unit hydrograph in h at 75% peak discharge; $q = Q_p/A$=peak discharge per unit catchment area in $m^3/s/km^2$

## VII. RESULTS AND DISCUSSIONS

The Digital Elevation Model of the two river basins are shown in the figure. Figure shows the DEM of Ranganadi .It shows the elevation values varies from 3726m to 71m.Figure shows the DEM of Dikrong River basin. The elevation varies from 2899m to 72m.

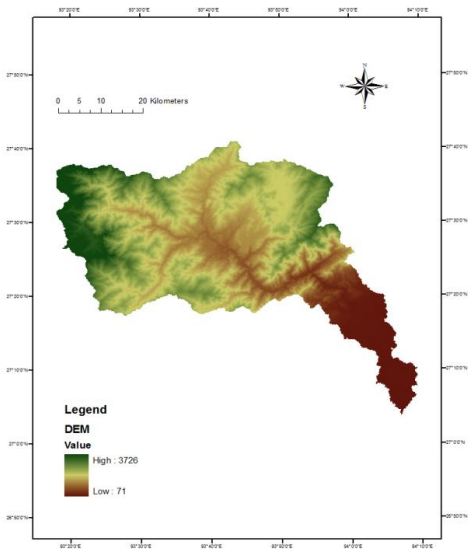


**Figure 2: Ranganadi DEM**

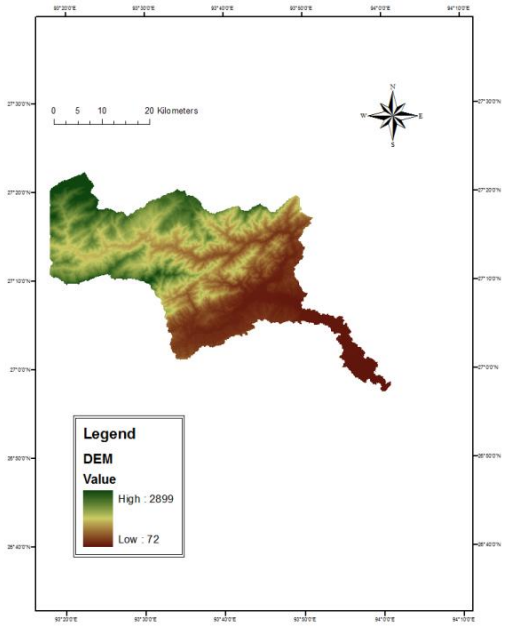


**Figure 3: Dikrong DEM**

Figure shows the slope maps of Ranganadi basin and Dikrong river basin. The slope in Ranganadi varies from 0-57.93 degrees whereas for Dikrong river the slope varies from 0-53.41 degrees.

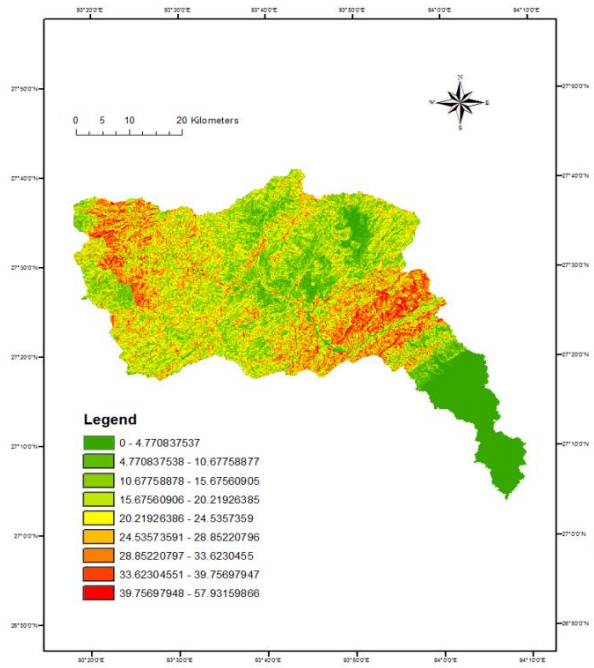


**Figure 4: Slope map of Ranganadi**

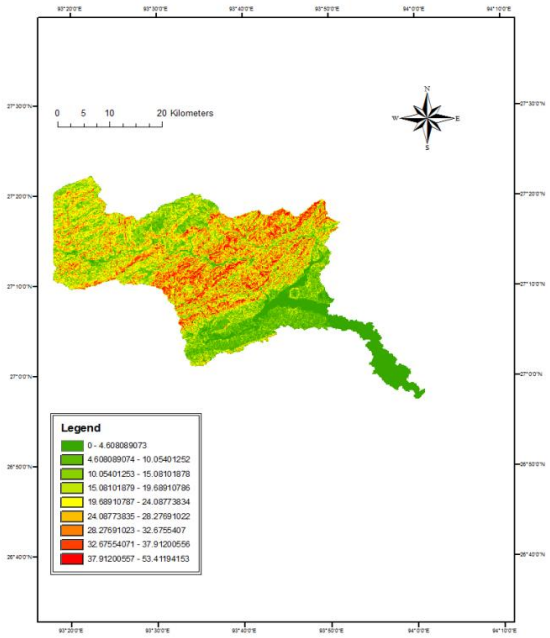


**Figure 5: Slope map of Dikrong**

### 7.1 NRCS Unit Hydrograph

**Table 1: NRCS parameters of unit hydrograph**

| Watershed | Length of the flow channel,(km) | Slope of the basin,(m/m) | Area of the basin, (sq km) | Lag time,$t_L$ (hr) | Time of concentration $t_c$(hr) | Peak time,$T_p$ (hr) | Peak discharge,$Q_p$ ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| Ranganadi basin | 156.317 | 0.023 | 2468.38 | 8.316 | 13.86 | 8.816 | 582.37 |
| Dikrong river basin | 152.423 | 0.0185 | 1295.69 | 8.874 | 14.79 | 9.37 | 287.49 |

Figure 6 shows the 1 hr NRCS curvilinear and equivalent unit hydrograph for Ranganadi basin.The peak discharge is found to be 582.37 $m^3/s$ and the base time is found to be 23.5 hrs for triangular unit hydrograph.

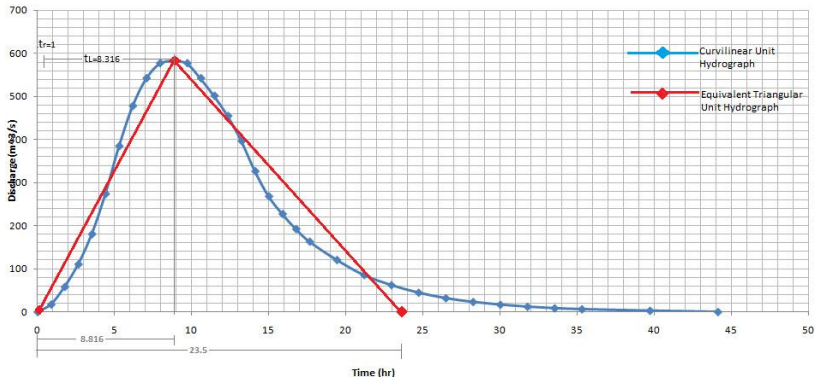


**Figure 6: NRCS unit hydrograph of Ranganadi basin**

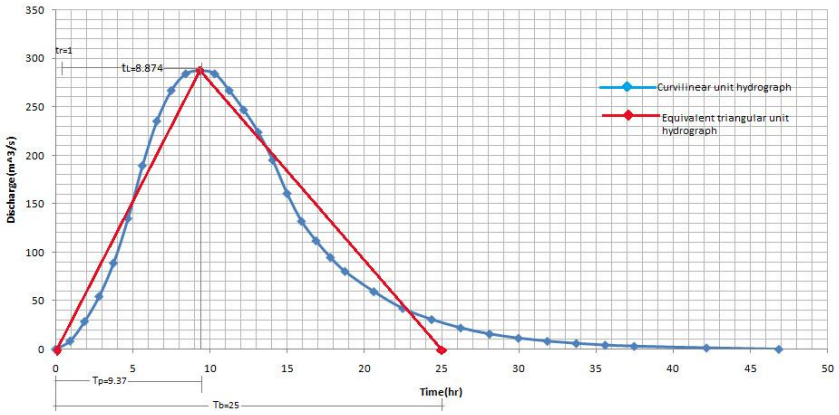


**Figure 7: NRCS unit hydrograph of Dikrong river basin**

The unit hydrograph derived for Dikrong river shows a peak discharge of 287.49 $m^3/s$ and a base time of 25 hrs for triangular unit hydrograph.

### 7.2 Snyders Unit Hydrograph

The Snyder's parameters are shown in the Table 2

**Table 2: Snyders parameter for derivation of 1 hr unit hydrograph**

| Basin | Peak Time, $T_p$ (hr) | Peak Discharge, $Q_p(m^3/s)$ | Base Time, $T_b$(hr) | Width at 50% discharge, $W_{50}$(hr) | Width at 75% discharge, $W_{75}$(hr) |
|---|---|---|---|---|---|
| Ranganadi | 7.03 | 526.68 | 93.09 | 31.18 | 17.82 |
| Dikrong | 6.97 | 287.84 | 92.21 | 30.84 | 17.62 |

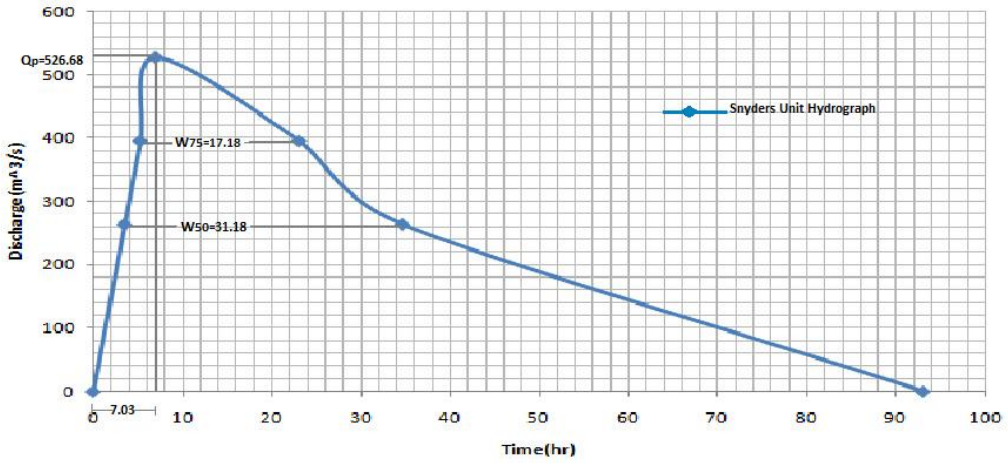


**Figure 8: Snyders 1 hr unit hydrograph for Ranganadi Basin**

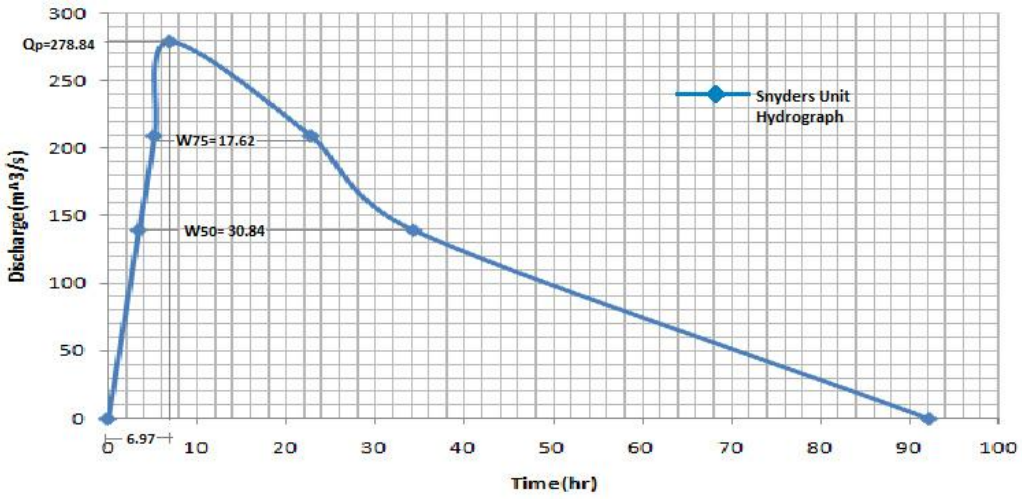


**Figure 9: Snyder's 1 hr unit hydrograph for Dikrong River Basin**

### 7.3 Comparison of the Models

**Table 3: Comparison of both the models**

| Watershed | NRCS Peak Discharge, $Q_p(m^3/s)$ | NRCS Peak Time,$T_p$ (hr) | SNYDER Peak Discharge, $Q_p(m^3/s)$ | SNYDER Peak Time,$T_p$ (hr) |
|---|---|---|---|---|
| Ranganadi | 582.37 | 8.816 | 526.68 | 7.03 |
| Dikrong | 526.68 | 9.37 | 278.84 | 6.97 |

## VIII. CONCLUSIONS

In this study NRCS model and Snyder method is implemented to derive 1 hr unit hydrograph for Ranganadi and Dikrong river basin. These methods are useful to generate hydrograph for ungauged watershed. For the generation the parameters are estimated using GIS. Watersheds are delineated and slope maps are extracted in

ArcGIS using SRTM 90m resolution DEM .For the derivation of NRCS triangular unit hydrograph Kirpich formula is used for the determination of time of concentration. The comparison study between both the models revels that the peak discharge is almost same for both the river basin. Further study can be carried out by generating storm hydrograph from unit hydrograph. Storm hydrograph of a basin is very essential to carry out design of any proposed structures.

## IX. ACKNOWLEDGEMENTS

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