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Derivation of Unit Hydrograph and S Curve of Suvarnamukhi Watershed

K. Ranjitha[1], Shivakumar J. Nyamathi[2]
[1]*Assistant Professor, Department of Civil Engineering, Vivekananda Institute of Technology, Bengaluru, India*
[2]*Associate Professor, Department of Civil Engineering, Vivekananda Institute of Technology, Bengaluru, India*

***Abstract*: Unit Hydrograph (UH) is the most popular and widely used method for analyzing and deriving flood hydrograph resulting from a known storm in a basin area. However, the non-availability of flood runoff details due to poor network of stream gauges in flood prone Indian River basins is a major concern. Traditional techniques for design flood estimation use historical rainfall-runoff data for unit hydrograph derivation. For ungauged catchments, unit hydrograph are derived using either regional unit hydrograph approach or alternatively Geomorphological Instantaneous Unit Hydrograph approach. Central Water Commission (CWC) derived the regional unit hydrograph relationships for different sub-zones of India relating to the various unit hydrograph parameters with some prominent physiographic characteristics.**

In the present study, unit hydrograph and S curve has been derived. Unit hydrograph is derived using the regional relationships as proposed by Central Water Commission (CWC), for Kaveri basin subzone-3(i). Unit hydrographs and S curve of watersheds are tried to analyse with the help of dimensionless Unit Hydrograph and dimensionless S curve to understand the parameters of unit hydrograph for watershed area.

***Keywords*: Dimensionless Unit Hydrograph, Dimensionless S curve, Ungauged Watershed, CWC-method.**

1. Introduction

Urbanization increasing the variability and intensity of extreme flood events. Floods are the most common and widespread of all natural disasters. Current measures to mitigate flood impacts specifically for urban environments no longer provide optimal solutions for previously planned flood risk intervals. In terms of victims, floods are responsible for more than half the deaths caused by natural catastrophes. As flood events appear to be rapidly increasing world-wide, an advanced and universal approach to urban flooding and how to manage becomes imperative to reduce flood impact. The increasing trend of natural disasters is related mainly to population growth and occupation of risk areas (floodplain and coastal); economic development leading to pressure on the environment and urbanization; and the effects of climate variability and change on the hydrologic cycle. In recent years, 90% of natural disasters have been related to climate conditions (Cap-Net-2011).

The unit hydrograph characteristics such as peak discharge (Q_p), time to peak (t_p), width of hydrograph at 50% of peak volume (W50), width of hydrograph at 75% of peak volume (W75), width of the rising side of unit hydrograph in hours at ordinate equal to 75% of UH peak (WR75), time base (TB), etc. has been computed on the basis of physiographic features. These regional formulae enable computation of unit hydrograph for ungauged watersheds of the subzones (CWC, 1986).

Dimensionless unit hydrograph developed by United States soil conservation service (SCS) provides a shape to the unit hydrograph and therefore leads to more reproducible results than the Synder method. The plotting positions of the SCS dimensionless unit hydrograph are expressed as the ratios t/t_p and Q/Q_p. t_p is the time to peak Q_p is the peak discharge. S-curve hydrograph may be defined as the hydrograph of direct runoff resulting from a continuous effective rainfall of uniform intensity 1/D cm/h (Chow, 1964).

2. Study area details

The study area is located between Latitude 12º40′54″ N and 12º53′18″ N and Longitude 77º29′24″ E and 77º33′52″ E as shown in figure 1 The study area covers an area of 210.12 km^2 and its elevation vary from 933m to 679m. SOI Toposheet Nos: 57 H/5, 57H/6, 57H/9 and 57H/10 of 1:50000 scale. Length of the longest stream L= 33 km. Length along the stream nearest to Cg, Lc =14 Km.

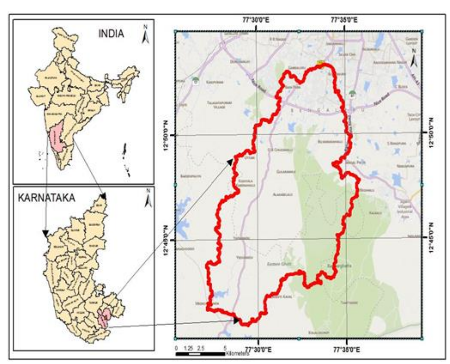

Fig. 1. Study area, Suvarnamukhi watershed

3. Materials and methods

A significant effort over the years went into determining design floods at ungauged locations. The Central Water Commission (CWC, 1983) under the long-term hydrological plan for water resources development and management, divided the country into 26 hydro meteorologically homogeneous zones and carried out analysis of selected concurrent rainfall and flood data for the gauged catchments to derive unit hydrographs of mostly 1-hour duration on the basis of rainfall data, gauge and discharge data collected during the monsoon season. Representative unit hydrographs are obtained for each of the gauged catchments. The characteristics of the catchments and their unit hydrographs, prepared for several catchments in a sub-zone, are correlated by regression analysis and the equations for synthetic unit hydrograph for the sub-zone are derived for estimating design flood for ungauged catchments. Studies are also carried out by the CWC to arrive at suitable recommendations for estimating loss rate and base flow for ungauged catchments (Jha et.al. 2008).

Hydrographs or some elements of them, such as peak rates, are used in the planning and design of water control structures. They are also used to show the hydrologic effects of existing or proposed watershed projects and land use changes. CWC derived the regional unit hydrograph relationships for different sub zones of India relating to various unit hydrograph parameters with some prominent physiographic characteristics. Area, length, stream slope, Lc are the parameters required for the derivation of CWC Unit hydrograph. The extraction procedure is adopted which is shown in below flow chart that is in Fig. 2.

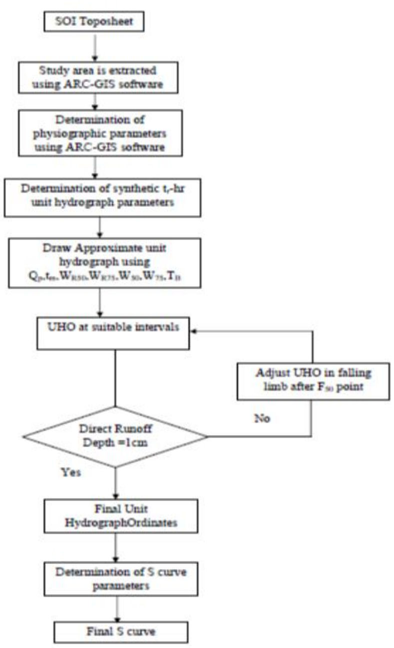

Fig. 2. Methodology adopted to derive a CWC Unit Hydrograph Ordinates and S-curve

4. Conclusions

The values for dimensionless unit hydrograph and S curve are obtained by the above methodology and plotted as shown in the fig. 3 and fig. 4.

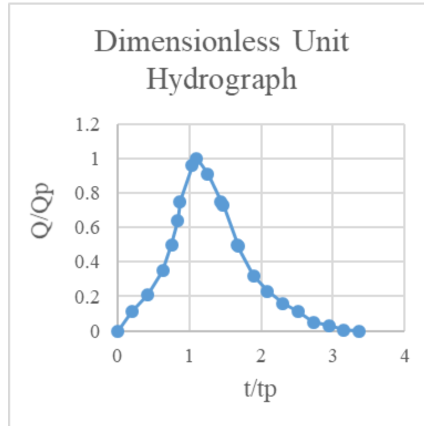

Fig. 3. Dimensionless Unit hydrograph

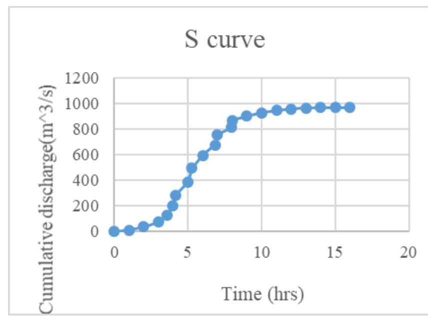

Fig. 4. S curve

Table 1
Dimensionless Unit hydrograph and S curve parameters

Time 't' (hrs)	Discharge 'Q' (m^3/s)	t/t_p	Q/Q_p	Cumulative Discharge
0	0	0	0	0
1	12	0.20	0.11	12
2	23	0.42	0.21	35
3	38	0.63	0.35	73
3.59	55.03	0.75	0.5	128.03
4	70	0.84	0.64	198.03
4.16	82.54	0.87	0.75	280.57
5	106	1.04	0.96	386.57
5.26	110.06	1.10	1	496.63
6	100	1.25	0.91	596.63
6.84	82.54	1.44	0.75	679.17
7	80	1.47	0.73	759.17
7.97	55.03	1.67	0.5	814.2
8	54	1.68	0.49	868.2
9	35.4	1.89	0.32	903.6
10	25.2	2.09	0.23	928.8
11	18	2.30	0.16	946.8
12	11.6	2.52	0.11	958.4
13	6.4	2.73	0.05	964.8
14	4.2	2.94	0.03	969
15	0.6	3.15	0.005	969.6
16	0	3.36	0	969.6

- Time to peak and peak discharge of one-hour unit hydrograph computed for Suvarnamukhi watershed are tabulated in Table 1. Now, keeping in mind the methodology adopted in this case, it is clear that the method namely CWC regional relationships are purely based on regional relationships. Since, CWC approach is independent of

Table 2
Parameters of t_r- hr. Unit Hydrograph for Suvarnamukhi Watershed

t_p (hr)	q_p m^3/sec/km^2	W_{50} (hr)	W_{75} (hr)	W_{R50} (hr)	W_{R75} (hr)	T_B (hr)	Tm (hr)	Q_p m^3/sec
4.76	0.52	4.38	2.68	1.67	1.10	15.82	5.26	110.06

climatic parameter (i.e. dynamic flow velocity) and geomorphologic characteristics other than the slope, drainage area and length of mainstream; therefore, the resulting UH may have computational error.

- Dimensionless unit hydrograph Parameters are tabulated in table 1 where maximum $Q/Q_P = 1$ is obtained for the $t/t_p = 1.10$.
- Cumulative Discharge obtained is 969.6 and S curve is plotted as in fig. 5.
- The shape of recession curve of CWC Unit Hydrograph may vary from person to person as trial and error method is adopted for its derivation. This needs real time measured flood runoff data, such that it may be possible to derive a general relationship based on hydro geomorphological study.

A. *Equations*

- $t_p= 0.553(LL_c/\sqrt{s})^{0.405}$
- $q_p = 2.043/(t_p)^{0.872}$
- $W_{50}= 2.197/(q_p)^{1.067}$
- $W_{75}= 1.325/(q_p)^{1.088}$
- $W_{R50} = 0.799/(q_p)^{1.138}$
- $W_{R75} = 0.536/(q_p)^{1.109}$
- $T_B = 5.038(t_p)^{0.733}$
- $T_m = t_p+(t_r/2)$
- $Q_p = q_p x A$
- The parameters got in the above table 2 were plotted to scale on a graph paper. The points were joined to fit a trial synthetic unit graph.
- Considering the Q_p, R_{50}, R_{75}, F75, F50 and T_B the graph is plotted manually and the methodology is carried out.
- The location of these points depends on the values of physiographic parameters that are obtained for the study area. R_{50} and R_{75} are the points corresponding to discharges at 50% and 75% of peak discharge ordinates on the rising limb of Unit graph. Q_p is another point corresponding to time t_m. F75 and F50 are the points corresponding to discharges at 75% and 50% of peak discharge ordinates on the falling limb of Unit graph. Values of these points are obtained as below:
    - $R_{50}= t_m-W_{R50} = 5.26 - 1.67 = 3.59$ hr
    - $R_{75}= t_m-W_{R75} = 5.26 - 1.10 = 4.16$ hr
    - $F_{75} = R_{75}+W_{75} = 4.16 + 2.68 = 6.84$ hr
    - $F_{50} = R_{50}+W_{50} = 3.59 + 4.38 = 7.97$ hr
- From the plotted graph the required values are taken and the trials are taken to plot the Unit hydrogrph as shown in Fig. 5.

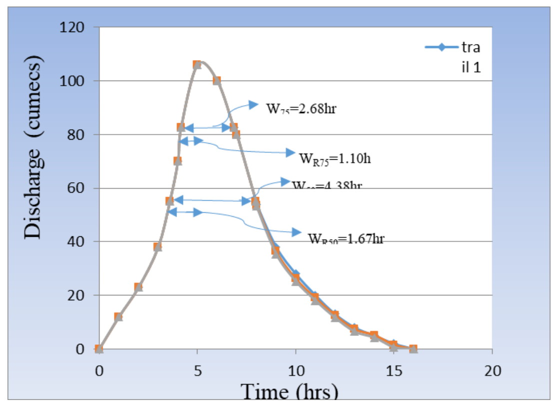

Fig. 5. CWC Unit Hydrograph for the Suvarnamukhi watershed

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