SCS Dimensionless Unit Hydrograph

US Soil Conservation Service (SCS), now called Natural Resources Conservation Service (NRCS), developed a Dimensionless Unit Hydrograph based on the analysis of large number of watersheds. The X-axis consists of dimensionless time units and Y-axis consists of dimensionless discharge units. The Dimensionless UH is very useful for constructing a synthetic unit hydrograph for a wide variety of watersheds. Dimensionless unit hydrographs based on a study of a large number of unit hydrographs are recommended by various agencies to facilitate construction of synthetic unit hydrographs.

A typical dimensionless unit hydrograph developed by the US Soil Conservation Services (SCS) consists of 37.5% of the total runoff volume before the peak discharge and remaining volume after the peak discharge occurs . The UH can be solved using simplified form of 'triangular' unit hydrograph. Assuming same 37.5% of the volume on left of T_p for the triangular unit hydrograph, we can solve for the T_b, which contains entire 100% volume of runoff. Therefore,

$$Tb = \frac{1}{0.375} Tp = 2.67Tp$$

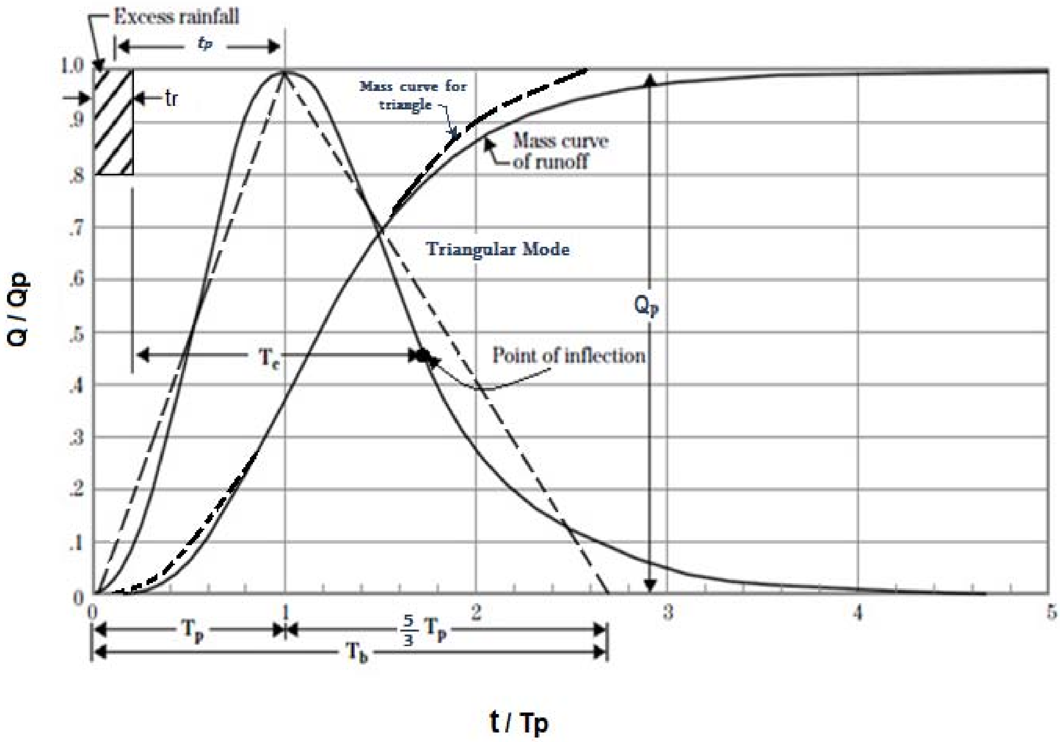


Fig.(23) ***Curvilinear UH and equivalent Triangular DUH***

SCS Triangular Unit Hydrograph

The value of *Qp* and *Tp* may be estimated using a simplified model o f a triangular unit hydrograph suggested by SCS. This triangular unit hydrograph has the same percentage of volume on the rising side as the dimensionless unit hydrograph of Fig. (23).

AS shown in Fig. (23) ,UH ordinate is *(Q/Qp)* which is the discharge *Q* expressed as a ratio to the peak discharge *Qp*, and the abscissa is (t/T*p* *)*, which is the time *t* expressed as a ratio o f the time to peak *T* . By definition, *Q/Qp*= 1.0 when *t/Tp* = 1.0. The coordinates of the SCS dimensionless unit hydrograph is given in Table (1) for use in developing a synthetic unit hydrograph shown in Fig. (24) , instead of Snyder's equations .

Table (1) Coordinates of SCS Dimensionless Unit Hydrograph

Time Ratios (t/t_p)	***Discharge Ratios*** (q/q_p)	***Time Ratios*** (t/t_p)	***Discharge Ratios*** (q/q_p)	***Time Ratios*** (t/t_p)	***Discharge Ratios*** (q/q_p)
0.0	**0.0**	**1.1**	**0.990**	**2.4**	**0.147**
0.1	**0.030**	**1.2**	**0.930**	**2.6**	**0.107**
0.2	**0.100**	**1.3**	**0.860**	**2.8**	**0.077**
0.3	**0.190**	**1.4**	**0.780**	**3.0**	**0.055**
0.4	**0.310**	**1.5**	**0.680**	**3.2**	**0.040**
0.5	**0.470**	**1.6**	**0.560**	**3.4**	**0.029**
0.6	**0.660**	**1.7**	**0.460**	**3.6**	**0.021**
0.7	**0.820**	**1.8**	**0.390**	**3.8**	**0.015**
0.8	**0.930**	**1.9**	**0.330**	**4.0**	**0.011**
0.9	**0.990**	**2.0**	**0.280**	**4.5**	**0.005**
1.0	**1.000**	**2.2**	**0.207**	**5.0**	**0.000**

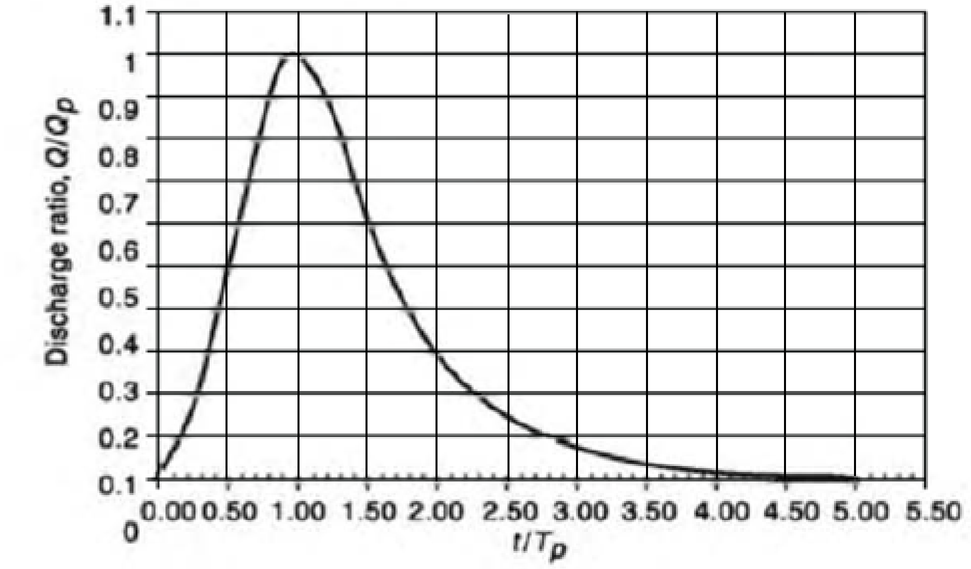


Fig. (24) Dimensionless SCS U nit Hydrograph

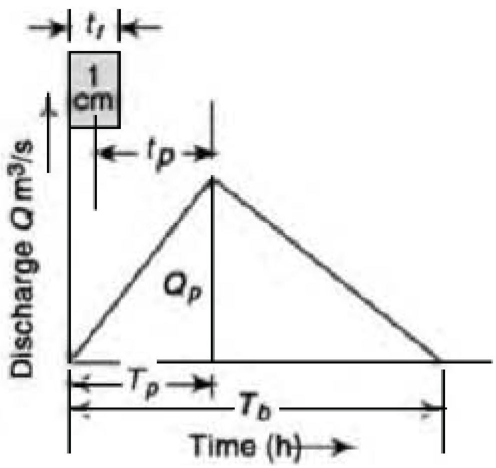


Fig. (25) SCS Triangular Unit Hydrograph

In Fig. (25):
Qp = peak discharge in m^3/s
tr = duration of effective rainfall
Tp = time of rise or time to peak
= (tr/2) + tp
tp =lag time
Tb = base length(base Time)
SCS suggests that the time of recession ;
(Tb - T p) = 1.67 Tp
Thus;
Tb = 2.67 Tp
Since the area under the unit hydrograph is Equivalent to 1 cm,
If A = area o f the watershed in km^2, thus;

$$\frac{1}{2}\ Qp \times (2.67\ \mathrm{Tp}) \times (3600) = \frac{1}{100} \times\ \mathrm{A} \times 10^4$$

$$Qp = \frac{2\mathrm{A} \times 10^4}{3600(2.67\ \mathrm{Tp})} \quad for\ 1\ cm\ \ rainfall\ depth$$

$$Qp = \frac{2.08\ \mathrm{A}}{\mathrm{Tp}} \qquad ---------------------(17)$$

Further on the basis of a large number of small rural watersheds, SCS found that;

$$tp\ =\ 0.6\ tc \qquad ---------------------(18)$$

where

tc = time o f concentration , which is defined as the time taken for a drop of water from the farthest part of the catchment to reach the outlet.

The **SCS model** ,in SI unit, used to calculate tc is;

$$tc = \frac{227L^{0.8}(\lambda + 1)^{0.7}}{10^5\sqrt{S}} \quad ----------------- (19)$$

tc in hr

in which;

L = length of divide (m),

S =average watershed slope (in percent %)

λ= curve number function, which is defined as the Potential Maximum Retention and expressed as;

$$\lambda = \frac{1000}{CN} - 10 \quad ------------------(20)$$

CN= curve number for deferent soil/land use.

Kirpich equation can be also used to estimate the time of concentration for length of travel, L and slope of the catchment, S as;

$$tc = \frac{0.01947L^{0.77}}{S^{0.385}} \quad ------------------(21)$$

tc in minutes.

Where;

L = maximum length of travel of water (m),

S = slope of the catchment = ΔH/L in which

ΔH =difference in elevation between the most remote point on the catchment and the outlet.

Thus;

$$Tp = \frac{tr}{2} + 0.6\,tc \quad ----------------(22)$$

$$tr = \frac{2}{15}\text{tc} \quad ------------------(23)$$

$$Tp = \frac{2}{3}\ tc \quad ------------------(24)$$

$$Tb = \frac{8}{3}\ Tp \quad ----------------- (25)$$

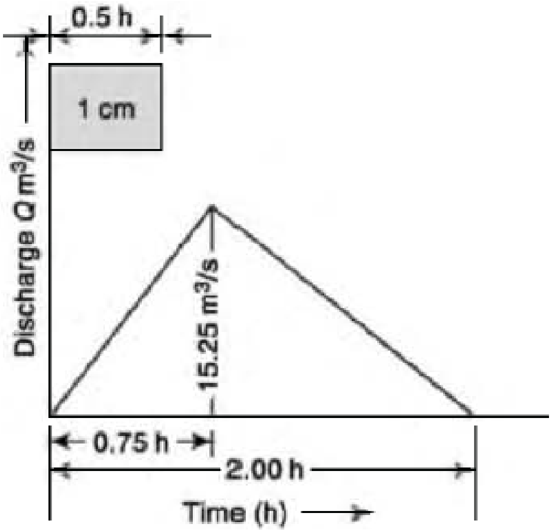
The SCS triangular unit hydrograph is a popular method used in watershed development activities, especially in small watersheds.

To use the SCS UH, one needs to determine only two things:
1. Time to peak, T_p (hr), and
2. Peak discharge, Q_p (m^3/s)

The SCS triangular unit hydrograph is a popular method used in watershed development activities, especially in small watersheds.

Example (1)

Develop a 30 minute SCS triangular unit hydrograph for a watershed of area 550 ha and time of concentration of 50 minutes.



Solution:

A = 550 ha = 5.5 km^2

tr = 30 min = 0.50 hr

tc = 50 min = 0.833 hr

lag time tp = 0.6 tc = 0.6 × 0.833 = 0.50 hr

$Tp = \frac{tr}{2} + 0.6\, tc$ = 0.25 + 0.50 = 0.75 hr

$Qp = \frac{2.08\ A}{Tp} = \frac{2.085.5}{0.75}$ = 15.25 m^3/s

$Tb = \frac{8}{3}\ Tp$ = 2.67 x 0.75 = 2.00 hr

The derived triangular unit hydrograph is shown in Figure

Example (2)

Compute the area-weighted curve number for a hypothetical watershed of two type of soils covering 1300 sq. km and 777 sq. km and exhibiting curve number 60 and 45, respectively. Slope of watershed is 0.6% and hydraulic length of watershed is 3,048 m. Net rainfall is 5.1 cm during the rainfall of 6 hr. Compute the parameters of the SCS triangular hydrograph.

Solution:

The area-weighted CN is:

$$CNavg = CN_1 \left(\frac{A_1}{A_1 + A_2}\right) + CN_2 \left(\frac{A_2}{A_1 + A_2}\right)$$

$$= 60 \left(\frac{1300}{2077}\right) + 45 \left(\frac{777}{2077}\right) = 54.38 \approx 54$$

Potential Maximum Retention (λ) is calculated as:

$$\lambda = \frac{1000}{54} - 10 = 8.518$$

The time of concentration can be computed as:

$$tc = \frac{227 L^{0.8} (\lambda + 1)^{0.7}}{10^5 \sqrt{S}} = \frac{227\ (3048)^{0.8} (8.518 + 1)^{0.7}}{10^5 \sqrt{0.6}} = 8.692\ hr$$

$$Tp = \frac{6}{2} + 0.6\ (8.692) = 8.215\ hr$$

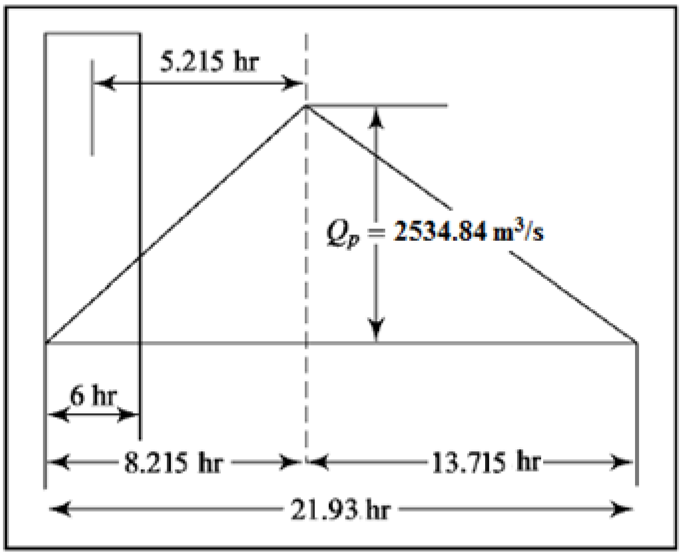
Tb=Base length of the hydrograph can be computed as:

Tb = 2.67 Tp = 2.67 × 8.215 = 21.93 hr

The ratio of Peak discharge to volume of runoff can be computed as;

$$Qp = \frac{2.08\text{A}}{\text{Tp}} \times Depth = \frac{2.08\ (2077)}{8.215} \times 5.1 = 2534.84\ m^3/s$$

The SCS hydrograph (not unit but DRH) is shown in figure below;



In reality, the shape of hydrograph cannot be a triangle. So, one can get a more precise hydrograph using Table (1) by multiplying the value of *Qp* with *Q/Qp* and *t/tp* with *tp* to plot the **SCS** hydrograph. The values in Table (1) are also sensitive to different *t/tp* values, as indicated by **SCS**. Table (1) represents only the average variation between Q and *t.*

Table of Runoff curve numbers for selected agricultural, suburban, and rural areas :

	CNs for hydrologic soil group			
Cover Type and Hydrologic Condition	A	B	C	D
Curve Numbers for Predevelopment Conditions				
Pasture, Grassland, or Range – Continuous Forage for Grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Curve Numbers for Postdevelopment Conditions				
Open Space (lawns, parks, golf courses, cemeteries, landscaping, etc.):[1]				
Fair condition (grass cover on 50% to 75% of the area)	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious Areas:				
Open water bodies: lakes, wetlands, ponds, etc.	100	100	100	100
Paved parking lots, roofs,[2] driveways, etc. (excluding right of way)	98	98	98	98
Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn):				
Fair lawn condition (weighted average CNs)	95	96	97	97
Good lawn condition (weighted average CNs)	94	95	96	97
Paved	98	98	98	98
Gravel (including right of way)	76	85	89	91
Dirt (including right of way)	72	82	87	89
Pasture, Grassland, or Range – Continuous Forage for Grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch)	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (forest litter, small trees, and brush are destroyed by heavy grazing or regular burning)	45	66	77	83
Fair (woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77