

CHAPTER 11
PREDICTION AND MODELING OF FLOOD HYDROLOGY AND
HYDRAULICS¹

JORGE A. RAMÍREZ
*Water Resources, Hydrologic and Environmental Sciences
Civil Engineering Department
Colorado State University
Fort Collins, Colorado 80523-1372, USA*

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Snyder's Synthetic Unit Hydrograph

The synthetic unit hydrograph of Snyder (1938) is based on relationships found between three characteristics of a *standard unit hydrograph* and descriptors of basin morphology. The hydrograph characteristics are the effective rainfall duration, t_r , the peak direct runoff rate, q_p , and the basin lag time, t_l . From these relationships, five characteristics of a *required unit hydrograph* for a given effective rainfall duration may be calculated (*e.g.*, Chow et al., 1988; Bras, 1990): the peak discharge per unit of watershed area, q_{pR} , the basin lag, t_{lR} , the base time, t_b , and the widths, W (in time units) of the unit hydrograph at 50 and 75 percent of the peak discharge.

Standard unit hydrograph. A standard unit hydrograph is associated with a specific effective rainfall duration, t_r , defined by the following relationship with basin lag, t_l ,

$$t_l = 5.5t_r \quad (33)$$

For a standard unit hydrograph the basin lag, t_l , and the peak discharge, q_p , are given by,

$$t_l = C_1 C_t (LL_c)^{0.3} \quad (34)$$

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$$q_p = \frac{C_2 C_p A}{t_l} \quad (35)$$

The basin lag time of the standard unit hydrograph (equation 34) is in hours, L is the length of the main stream in kilometers (miles) from the outlet to the upstream divide, L_c is the distance in kilometers (miles) from the outlet to a point on the stream nearest the centroid of the watershed area, and $C_l = 0.75$ (1.0 for English units). The product LL_c is a measure of watershed shape. C_t is a coefficient derived from gauged watersheds in the same region, and represents variations in watershed slopes and storage characteristics. The peak discharge of the standard unit hydrograph (equation 35) is in m^3/s (cfs), A is the basin area in km^2 (mi^2), and $C_2 = 2.75$ (640 for English units). As C_t , C_p is a coefficient derived from gauged watersheds in the area, and represents the effects of retention and storage.

Estimation of Model Parameters C_p and C_t . As in any model parameter estimation problem, observations of the input (*i.e.*, effective precipitation) and the output (*i.e.*, direct runoff hydrograph) must be available. In addition, the values of L and L_c must also be available (e.g., from surveys, maps, etc.). From the concurrent input-output observations, a unit hydrograph for the basin in question, a so-called *derived unit hydrograph*, can be developed. From the derived unit hydrograph of the watershed, values of its associated effective duration t_r in hours, its basin lag t_{lR} in hours, and its peak discharge q_{pR} in m^3/s are obtained. If $t_{lR} = 5.5t_r$, then the derived unit hydrograph is a standard unit hydrograph and $t_r = t_r$, $t_l = t_{lR}$, and $q_p = q_{pR}$, and C_t and C_p are computed by the equations for t_l and q_p given above (equations 34 and 35), corresponding to the standard unit hydrograph.

If t_{lR} is quite different from $5.5t_r$, the basin lag of the standard unit hydrograph for the basin is computed using:

$$t_l = t_{lR} + \frac{t_r - t_{lR}}{4} \quad (36)$$

This equation must be solved simultaneously with the equation for the standard unit hydrograph lag time, $t_l = 5.5t_r$, in order to obtain t_r and t_l . With these values of t_r and t_l , the value of C_t is obtained using equation (34) for t_l corresponding to the standard unit hydrograph; the value of C_p is obtained using the expression for q_p corresponding to the standard unit hydrograph, but using $q_p = q_{pR}$ and $t_l = t_{lR}$.

When an ungauged watershed appears to be similar to a gauged watershed, the coefficients C_t and C_p for the gauged watershed can be used in the above equations to derive the *required synthetic unit hydrograph* for the ungauged watershed.

Development of a Required Unit Hydrograph (assumes that C_b , C_p , L , and L_c are known). If a t_R -unit hydrograph is required, that is, if a unit hydrograph whose associated effective rainfall pulse duration is t_R , is required, proceed as follows.

Use equation 34 to determine the lag-time, t_l . If t_R meets the criterion for a standard unit hydrograph, that is, if $t_l = 5.5 t_R$ then the *required unit hydrograph* is a *standard unit hydrograph* and equations 34 and 35 can be used directly to estimate the peak discharge and the time to peak of the required unit hydrograph. That is,

$$t_{lR} = t_l = C_1 C_t (LL_c)^{0.3} \quad (37)$$

$$q_{pR} = q_p = \frac{C_2 C_p A}{t_l} \quad (38)$$

If t_R does not meet the criterion of equation 33 then the *required unit hydrograph* is not a *standard unit hydrograph* and equations 34 and 35 can not be used directly to estimate the peak discharge and the time to peak of the required unit hydrograph. In this case, the lag-time of the required unit hydrograph, t_{lR} , is,

$$t_{lR} = t_l - \frac{t_r - t_R}{4}$$

where t_l is obtained from equation 34, t_r is obtained from equation 33 and t_R is given.

The peak discharge of the required UH, q_{pR} , is,

$$q_{pR} = \frac{q_p t_l}{t_{lR}} \quad (39)$$

where q_p is obtained from equation 35.

Assuming a triangular shape for the UH, and given that the UH represents a direct runoff volume of 1 cm (1 in), the base time of the required UH may be estimated by,

$$t_b = \frac{C_3 A}{q_{pR}} \quad (40)$$

where C_3 is 5.56 (1290 for the English system).

As an aid in drawing an adequate UH, the U.S. Army Corps of Engineers developed relationships for the widths of the UH at values of 50% (W_{50}) and 75% (W_{75}) of q_{pR} . The width in hours of the UH at a discharge equal to a certain percent of the peak discharge q_{pR} is given by Chow et al. (1988) as,

$$W_{\%} = C_w \left(\frac{q_{IR}}{A} \right)^{-1.08} \quad (41)$$

where the constant C_w is 1.22 (440 for English units) for the 75% width and equal to 2.14 (770 for English units) for the 50% width. Usually, one-third of this width is distributed before the peak time and two-thirds after the peak time, as recommended by the U.S. Army Corps of Engineers. However, several other authors have recommended different distribution ratios. For example, Hudlow and Clark (1969) recommend a partition of 4/10 and 6/10, respectively.

Figure 11.2 illustrates the form of Snyder's synthetic UH. Note that the time lag is not the same as the time to peak. Also, note that the widths of the hydrograph at 50% and 75% of the peak flow are distributed such that the longer time is to the right of the time to peak.

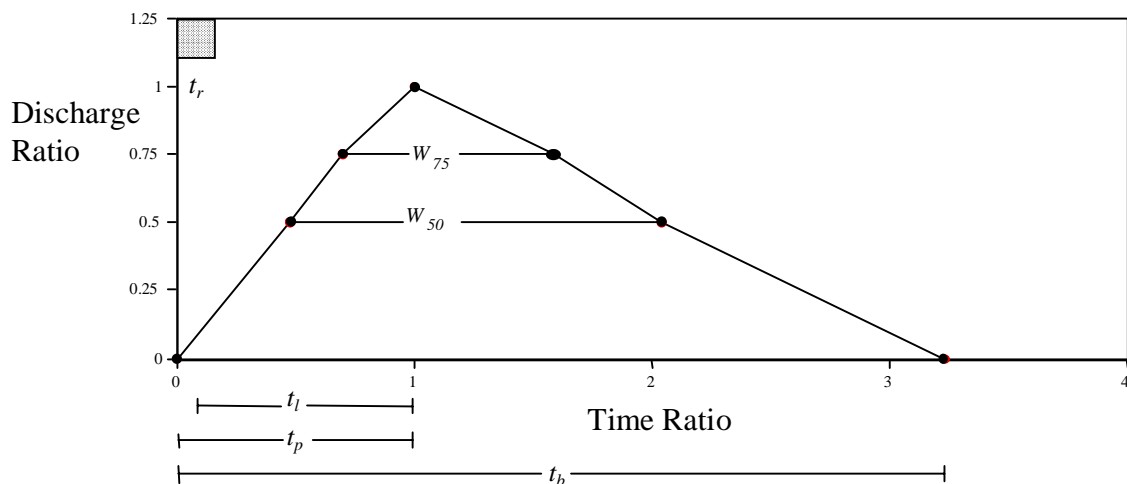


Figure 11.2: Snyder's Synthetic Unit Hydrograph

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References

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