

Engineering Hydrology

Week-5

CHAPTER -2 RAINFALL-RUNOFF RELATIONSHIPS

Sisay Demeku Derib (PhD, PE)

Sisay.demeku@aastu.edu.et

Addis Ababa Science and Technology University (AASTU),

Department of Civil Engineering

February, 2025





Lecture contents of the last week (Week-4)

CHAPTER -2 Rainfall-runoff Relationships

2.4 SCS Curve Number and Time-Area Methods

2.5 Stream Flow Hydrograph

2.5.1 Factors Affecting Flood Hydrograph

2.5.2 Effective Rainfall

2.5.3 Separation of Base Flow and Runoff

2.5.4 Hydrograph Analysis



Home assignment:

I hope you are sure you are able to exercise on:

- **SCS-CN methods:** symbols, units and problem analysis
 - Compare and contrast rainfall, effective rainfall and direct runoff.
 - Relate parameters under these methods
 - Try to solve mathematical expression and problem solving on these methods for effective rainfall
- **Baseflow separation:** definitions and methods
 - What does baseflow mean?
 - Why it is important?
 - Compare and contrast baseflow separation methods graphically.
- **Hydrograph:** Factors affecting hydrograph



Lecture contents of the week (Week-5)

CHAPTER -2 RAINFALL-RUNOFF RELATIONSHIPS

2.6 The Unit Hydrograph (UH)

2.7 Applications of Unit Hydrograph

2.8 Synthetic Unit Hydrographs

2.8.1 Snyder's Method

2.8.2 Dimensionless Unit Hydrograph

2.9 Hydrology of Ungauged Catchment



Lecture Learning Outcomes

Course Learning Outcomes: After completion of this Lecture, you will be able to:

CLO-1: Apply measurement techniques of the components of the hydrologic cycle, water balance and filling of missed data;

CLO-2: Examine rainfall-runoff relationship and hydrograph;

- Apply UH
- Apply SUH
- Describe means for data transfer for ungauged watersheds

CLO-3: Examine the probability of occurrence;

CLO-4: Analyze the water movement in to, over, and through the soil surface;

CLO-5: Design capacity of reservoir;

CLO-6: Design runoff volume and time of distribution of the runoff hydrograph from urbanization effect.



Hydrograph Analysis: The Unit Hydrograph (UH)

Definition:

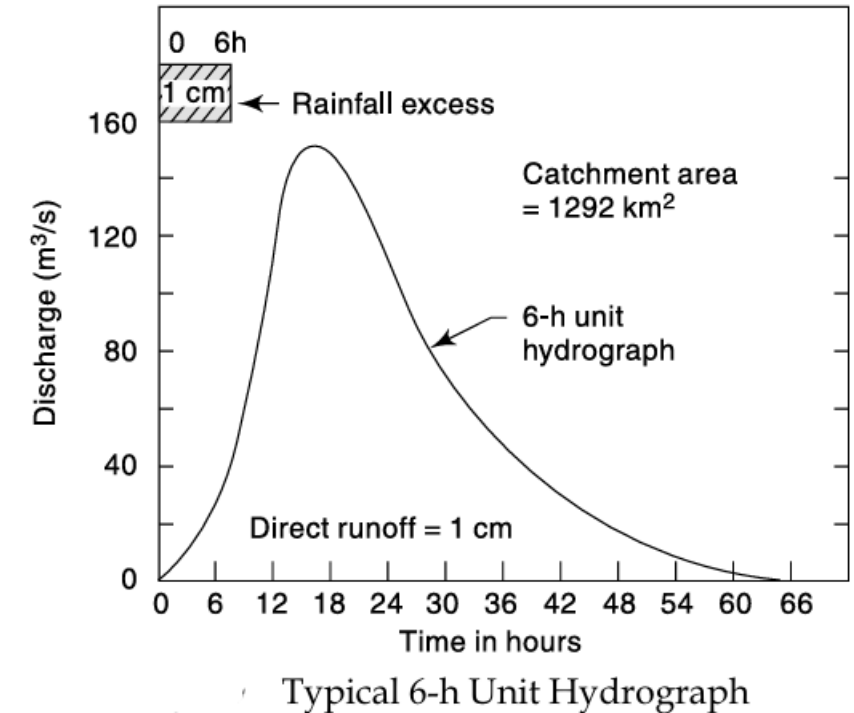
- is a direct runoff hydrograph (DRH) resulting from **1 or a unit** of effective rainfall (rainfall excess) or hyetograph (ERH)
- is **distributed uniformly** over the entire basin **at a uniform rate** during a **specified time period (or duration), D**,
- showing the interaction between ERF and RO on a watershed by viewing the watershed as a **lumped linear** system.
- Unit excess rainfall volume equaling 1 mm may be considered as a standard value since rainfall is usually measured in mm.
- However, in certain cases, UH is derived for 1 cm effective rainfall.



Hydrograph Analysis: The Unit Hydrograph (UH)

Definition:

- The intensity of the rainfall of a UH is $1/D$ cm/hr for 1 cm UH under D-h DRO.
- The area under the UH curve is 1cm over the entire area of the catchment.
- A UH shown in the figure:
 - 1cm P_{eff} in 6 hr ($D=6$ -h)
 - The hydrograph is 6-h UH
 - The DRO under the UH curve is 12.92 m^3
 - $=1 \text{ cm} * 1292 \text{ km}^2$
 - **Time invariant:** it is applied for the same 1-cm, 6-h unit hydrograph at any time of raining.



Source: Textbook, (Subramanya, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

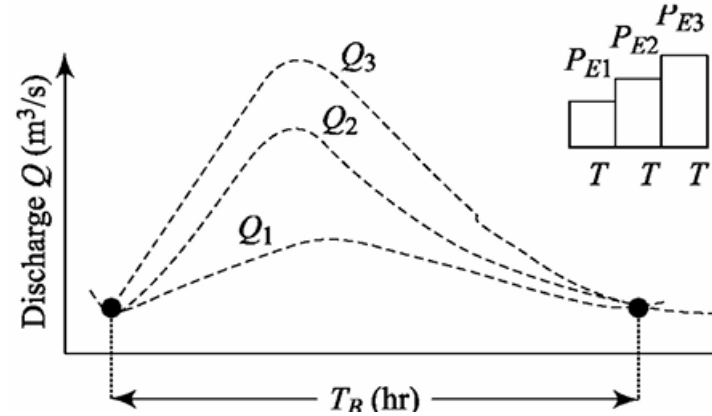
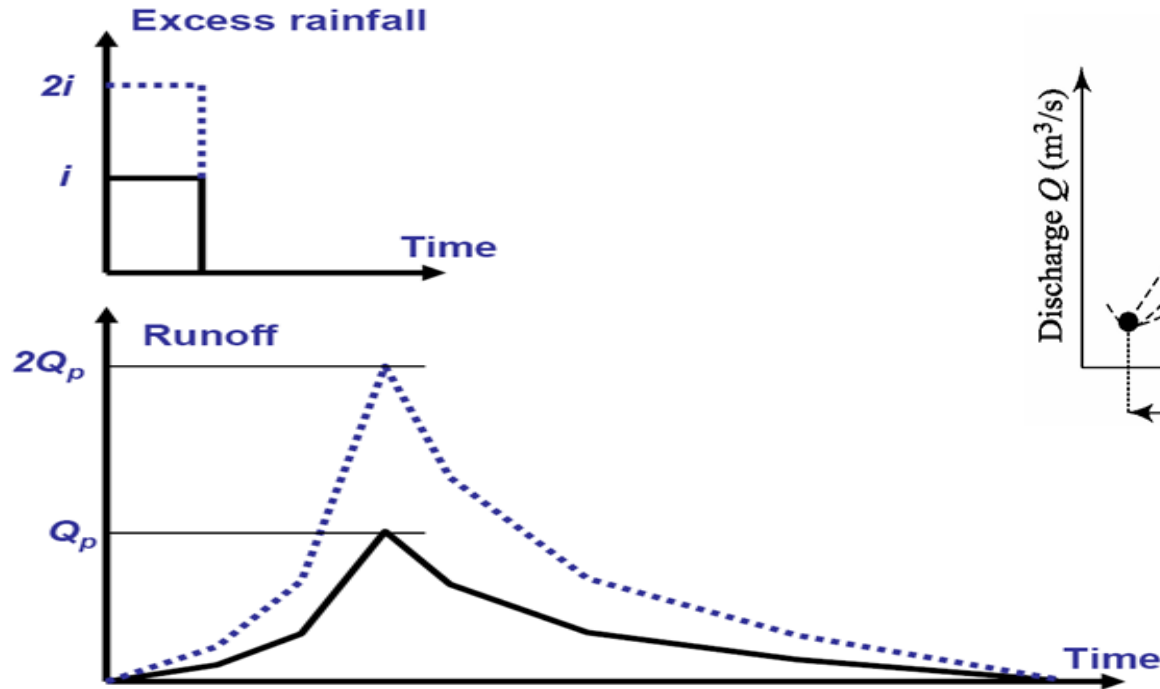
UH assumptions:

- The effective rainfall is uniformly distributed within its duration (**Temporal uniformity**).
- The effective rainfall is uniformly distributed over the whole drainage basin (**spatial uniformity**).
- The base duration of direct runoff hydrograph due to an effective rainfall of unit **duration is constant**.
- The ordinates of DRH are directly proportional to the total amount of DR of each hydrograph (**principles of linearity, superposition, and proportionality**)
- For a given basin, the runoff hydrograph due to a given period of rainfall reflects all the combined physical characteristics of basin (**time-invariant**)



Hydrograph Analysis: The Unit Hydrograph (UH)

Laws of Unit Hydrograph: 1. Law of proportionality.



$Q_{(t)}$ is proportional to the total volume of **excess rainfall**.

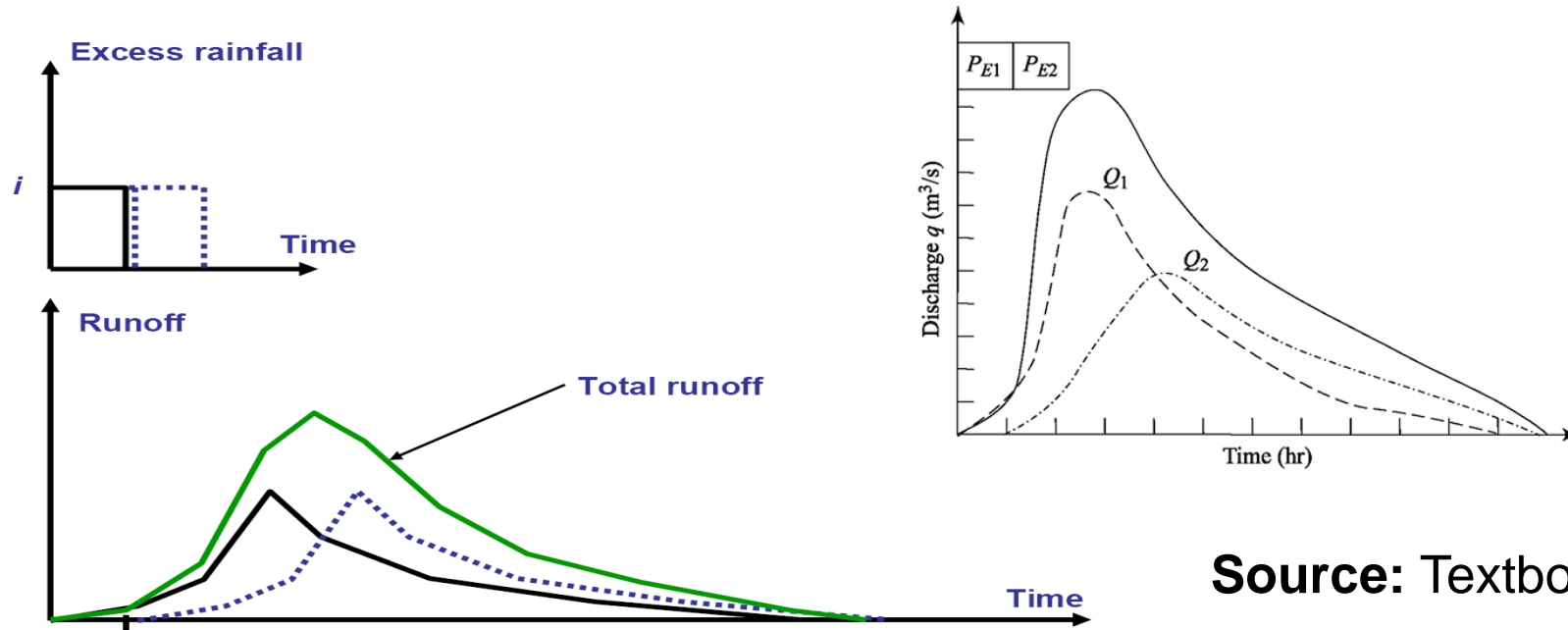
Source: Textbook, (Ojha et al, 2008)

$$\text{If } I_1 \sim Q_1 \text{ then } C \cdot I_2 \sim C \cdot Q_2$$



Hydrograph Analysis: The Unit Hydrograph (UH)

Laws of Unit Hydrograph: 1. Concurrent Flow Assumption or Law of superposition.



- The total hydrograph of surface runoff is **the sum** of the surface runoff produced by the individual portions of the excess rainfall.

Source: Textbook, (Ojha et al, 2008)

$$\text{If } I_1 \sim Q_1 \text{ and } I_2 \sim Q_2 \text{ then } I_1 + I_2 \sim Q_1 + Q_2$$



Hydrograph Analysis: The Unit Hydrograph (UH)

Laws of Unit Hydrograph:

3. Time Invariance Assumption.

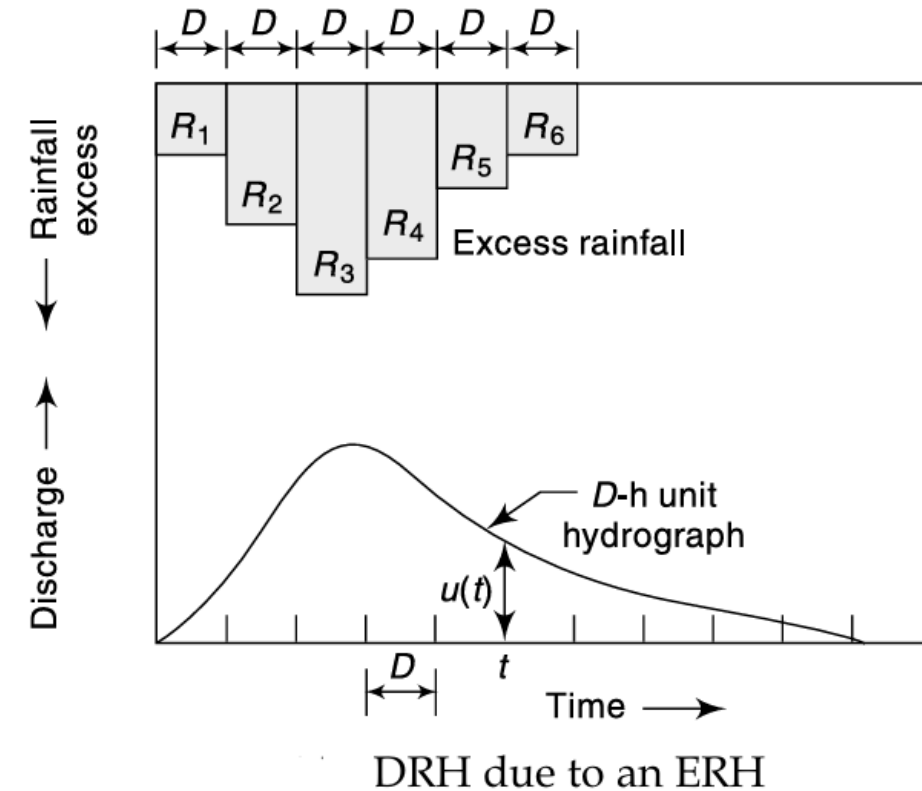
- the unit hydrograph derived for a watershed does not vary with time.
- This principle holds when:
 1. The **physical** characteristics of the watershed do not change with time and
 2. Storm **pattern** and its movement do not change with time.



Hydrograph Analysis: The Unit Hydrograph (UH)

Applications of Unit Hydrograph:

- A unit hydrograph converts the rainfall (**excess rainfall**) to runoff (**direct surface runoff**) easily.
- If D-h UH and hyetograph are available:
 - Initial and infiltration losses can be estimated and deducted from hyetograph to get $P_{eff}(R_i)$
 - This P_{eff} is divided into M blocks of D-h durations.
 - Each D-duration $P_{eff}(R_i)$ can be transformed into DRO hydrograph using the unit hydrograph developed for this duration.
 - Finally, the hydrograph of the DRO can be superimposed to the total hydrograph.



Source: Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Applications of Unit Hydrograph:

- A unit hydrograph converts the rainfall (**excess rainfall**) to runoff (**direct surface runoff**) easily.

The direct runoff due to R_1 at time t is

$$Q_1 = R_1 \cdot u[t]$$

The direct runoff due to R_2 at time $(t - D)$ is

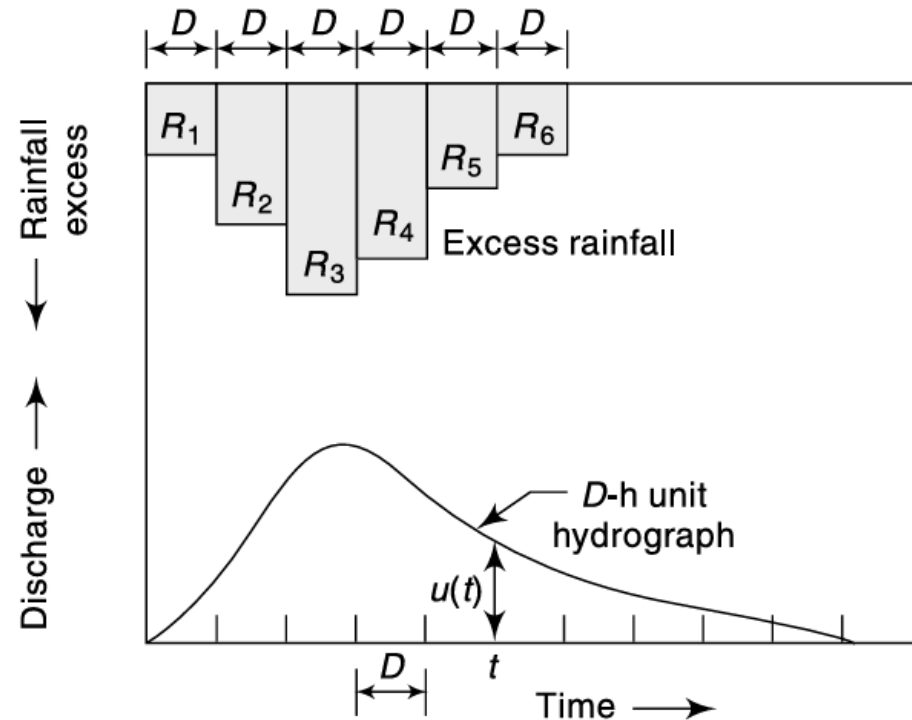
$$Q_2 = R_2 \cdot u[t - D]$$

Similarly, $Q_i = R_i \cdot u[t - (i - 1) D]$

and $Q_m = R_m \cdot u[t - (M - 1) D]$

Thus at any time t , the total direct runoff is

$$Q_t = \sum_{i=1}^M Q_i = \sum_{i=1}^M R_i \cdot u[t - (i - 1) D]$$



DRH due to an ERH

Source: Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Applications of Unit Hydrograph:

- Used to predict flood hydrographs from known rainfall events,
 - **Flood Forecasting and Prediction:** or managing flood risks and issuing timely warnings.
 - **Runoff Estimation:** dams and reservoirs, to effectively manage water resources.
 - **Design Flood Determination:** peak discharge that a dam structure must be able to withstand.
 - **Water Resource Management:** for managing water resources, including irrigation, water supply, and hydropower generation.
 - **Synthetic Unit Hydrograph:** watershed characteristics for similar watershed



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: from a single-period storm:

When a storm is of short duration and of fairly uniform intensity, UH can be derived following these procedures:

- (i) Extract hydrographs from stream-flow records
 - using observed gauge-discharge or **rating curves**.
- (ii) Separate base-flow from total hydrograph to produce direct surface runoff
 - Compute the surface runoff volume Q in mm.
 - In practice, floods of runoff volume greater than 20 mm are analyzed.
- (iii) Examine the rainfall records available for the rain gauge stations in the catchment and
 - compute average rainfall for the storm under investigation.



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: from a single-period storm:

(iv) Derive the hydrograph and the total average rainfall

- for the time period to the desired unit period of the unit hydrograph.

(v) Estimate the excess rainfall: determine the loss rate by subtracting the direct surface runoff from the total rainfall in each of the unit periods.

(vi) Unit hydrograph is a multiplying factor to convert excess rainfall to DSRO, then:

- Plot the surface runoff hydrograph.
- Determine the volume of excess rainfall, P_{Eff} , in the single unit period.
- P_{Eff} , also equals the volume of the direct surface runoff hydrograph Q_s .
- Relate the value of P_{Eff} , to the unit volume of the unit hydrograph, Q_{UH} .



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: **Examples-1:**

What does mean 1 mm unit hydrograph?

- 1 mm effective rainfall occurs uniformly over a catchment for a unit time,
- the **volume of UH** will be equal to (1 mm x area of catchment).
- If we divide **this volume** by the catchment area A , this will be just equal to 1 mm (the unit used for effective or excess rainfall).
- the term “unit volume of unit hydrograph” implies that the volume under the UH is equal to **one unit** used for effective rainfall of one unit.



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: **Examples-2:**

For a given P_{Eff} of 30 mm, derive proportionality factor (F) to get a unit hydrograph for **10 mm** unit volume.

Given: $P_{Eff} = 30$ mm, $Q_{UH} = 10$ mm.

Req.: proportionality factor (F) (-)

Solution: $F = P_{Eff} / Q_{UH} = 30 \text{ mm} / 10 \text{ mm} = 3 \dots\dots\#$

▪ **Please note that** unit volume of such UH will be equal 10 mm.

Ordinates of the UH can be obtained by dividing the direct surface runoff hydrographs by F.



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: **Examples-3:**

A thunderstorm of 6-hr duration with the excess rainfall of 154 mm produces as shown on the table. Find the ordinates of a 6-hr UH of unit volume equal to 100 mm.

Date	June 15				June 16				June 17			
Time (Hrs)	0600	1200	1800	M.N.	0600	1200	1800	M.N.	0600	1200	1800	M.N.
DSRO (m ³ /s)	10	500	1600	3500	5200	3100	1500	650	250	0	0	0

Given: $P_{Eff} = 154$ mm, $D = 6$ hr, $Q_{UH} = 100$ mm.

Req.: Ordinates of UH (can be presented using table or plot)

Solution: $F = P_{Eff} / Q_{UH} = 154 \text{ mm} / 100 \text{ mm} = 1.54 \dots\dots\#$

The ordinates of unit hydrograph are computed dividing the direct surface runoff hydrograph ordinates by the conversion factor, **1.54**#

Source: Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Unit Hydrograph Derivation: **Examples-3:**

Solution:

<i>Date</i>	<i>Time (hr)</i>	<i>Direct surface runoff (m³/s)</i>	<i>6-hr 100 mm unit hydrograph (m³/s)</i>
		<i>Q</i>	<i>Q/F</i>
June 15	0600	10	7
	1200	500	325
	1800	1600	1039
	2400	3500	2272
June 16	0600	5200	3377
	1200	3100	2013
	1800	1500	974
	2400	650	422
June 17	0600	250	162
	1200	0	0
	1800	0	0

Source:

Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Determination of DRH from Complex storm: Methods

Unit hydrograph theories used to derive multi-storm UH:

Let with given P_{ei} and Q_i , $P_{Ei} = P_{ei} * D$, where **D** is duration of the rainfall

P_{ei} = intensity of excess rainfall (mm/hr),

P_{Ei} = volume of excess rainfall (mm),

U_i = ordinates of unit hydrograph (m³/sec),

Q_i = ordinates of direct surface runoff hydrograph (m³/sec),
and

i = an integer value for an ordinate.

To determine the direct surface runoff hydrograph from P_{Ei} mm of rainfall that occurred in **D-h**:

- a **U** mm unit hydrograph of D-h duration having N unit periods (time base = N x D hrs) can be used.



Hydrograph Analysis: The Unit Hydrograph (UH)

Determination of DRH from Complex storm: Methods

For example, $T=D$

- to determine the direct surface runoff hydrograph from 4 mm of rainfall,
- that occurred in 2 hrs,
- the 10 mm unit hydrograph of 2-hr duration having 7 unit periods (time base = $7 \times 2 = 14$ hrs) is used.

$$Q_1 = 0.4 \times U_1 \quad Q_3 = 0.4 \times U_3 \quad Q_5 = 0.4 \times U_5 \quad Q_7 = 0.4 \times U_7$$

$$Q_2 = 0.4 \times U_2 \quad Q_4 = 0.4 \times U_4 \quad Q_6 = 0.4 \times U_6$$

If $P_{e2} = 4$ mm/h (2nd next period of rainfall) or $P_{E2} = 4 \times 2 = 8$ mm, the ordinates for DRO of the second period of rainfall are:

$$Q_1 = 0.8 \times U_1, \quad Q_2 = 0.8 \times U_2$$



Hydrograph Analysis: The Unit Hydrograph (UH)

Determination of DRH from Complex storm: Methods

- The equations for the combined surface runoff can be:

$$Q_1 = P_{E1} U_1$$

$$Q_2 = P_{E1} U_2 + P_{E2} U_1$$

$$Q_3 = P_{E1} U_3 + P_{E2} U_2 + P_{E3} U_1$$

$$Q_4 = P_{E1} U_4 + P_{E2} U_3 + P_{E3} U_2$$

$$Q_5 = P_{E1} U_5 + P_{E2} U_4 + P_{E3} U_3$$

$$Q_6 = P_{E1} U_6 + P_{E2} U_5 + P_{E3} U_4$$

$$Q_7 = P_{E1} U_7 + P_{E2} U_6 + P_{E3} U_5$$

$$Q_8 = 0 + P_{E2} U_7 + P_{E3} U_6$$

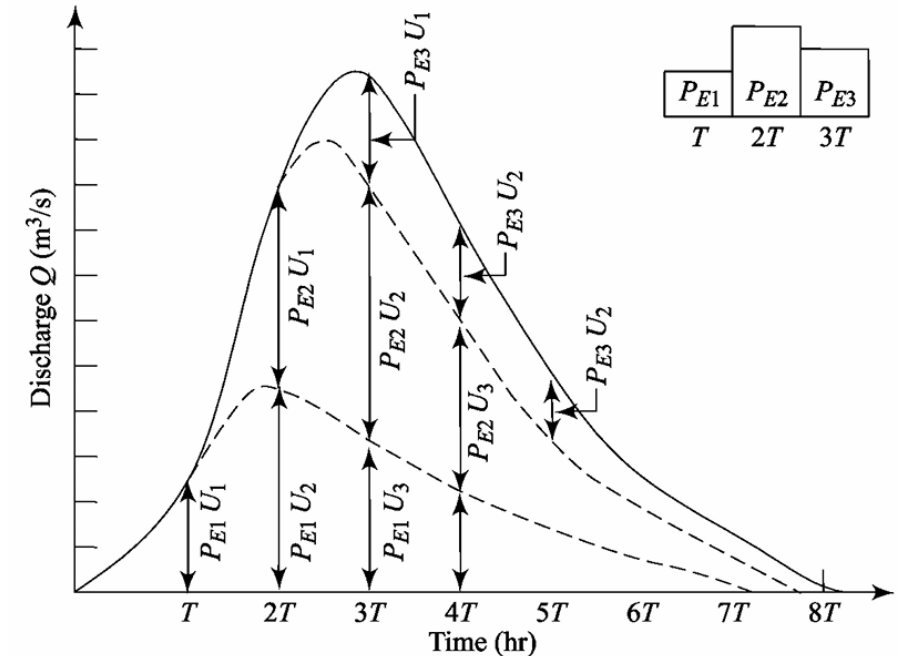
$$Q_9 = 0 + 0 + P_{E3} U_7$$

Method of Single Division: is a trial and error approach.

$$Q_1 = P_{E1} \times U_1 \quad \text{or} \quad U_1 = \frac{Q_1}{P_{E1}}$$

With known P_{E1} , U_i , and P_{E2} ,

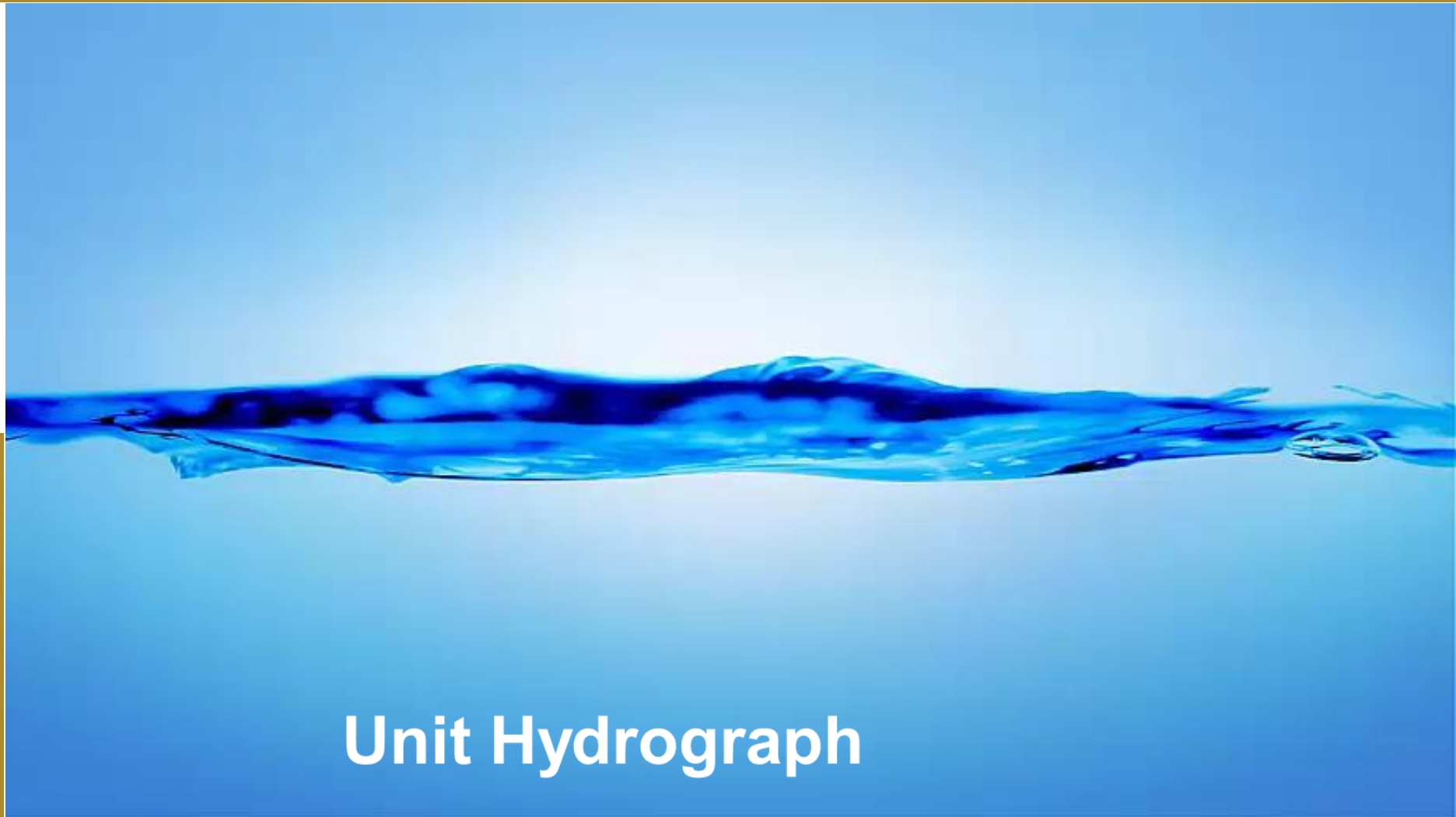
$$Q_2 = P_{E2} U_2 + P_{E2} U_1, \quad U_2 = \frac{Q_2 - P_{E2} U_1}{P_{E1}}, \quad U_3 = \frac{Q_3 - P_{E3} U_2}{P_{E2}}, \quad \text{and so on.}$$



Source: Textbook, (Ojha et al, 2008)



Break:-
for rehearsal
on:



Unit Hydrograph



Hydrograph Analysis: Synthetic Unit Hydrographs

Conceptual Models

- Detail **rainfall** and **runoff measurements** are needed to develop unit hydrograph.
- These measurements are available for **few locations**.
- **Empirical/conceptual** models can be applied to derive unit hydrograph for areal with no runoff measurements.
- These models are intermediate position between the fully physical approach and empirical black-box analysis.
- They are formulated to consider a relatively small number of components,
 - are a simplified representation of **one process** element in the system being modeled.



Hydrograph Analysis: Synthetic Unit Hydrographs

Conceptual Models for Synthetic Unit Hydrographs (SUH)

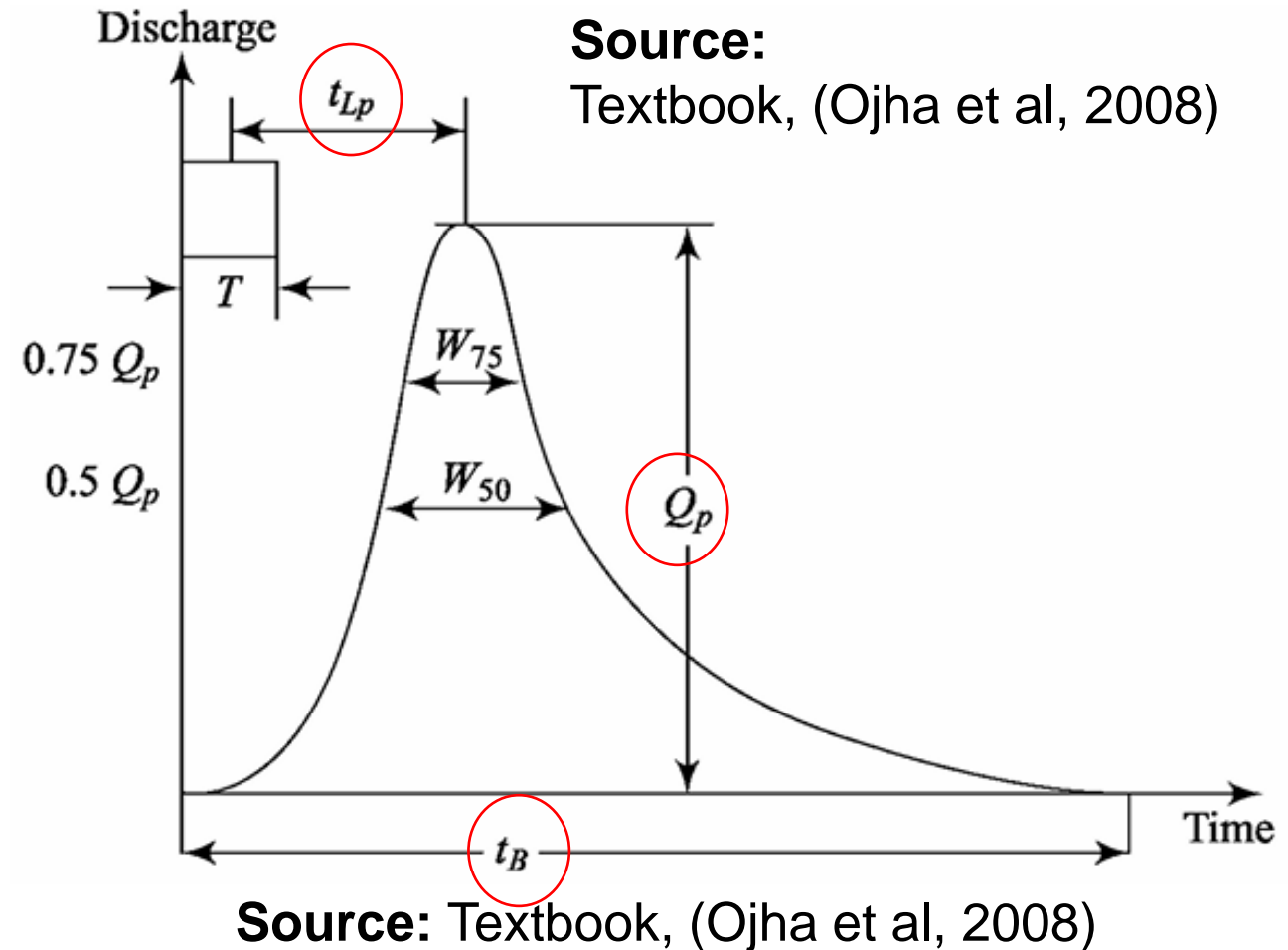
- Are used to enable the runoff from catchments to be estimated using **standard parameters** together with actual rainfall data.
- Examples:
 - Snyder's Method
 - Dimensionless Unit Hydrograph
 - SCS Method
 - Instantaneous Unit Hydrograph Method



Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method

- used **three** parameters to describe the hydrograph
 - lag-to-peak, t_L ;
 - peak discharge, Q_p ; and
 - base time, t_B ;
- Empirical relationships suggested by Snyder (1938)
- Used for large drainage basin with more **than 2 days** lag-time.



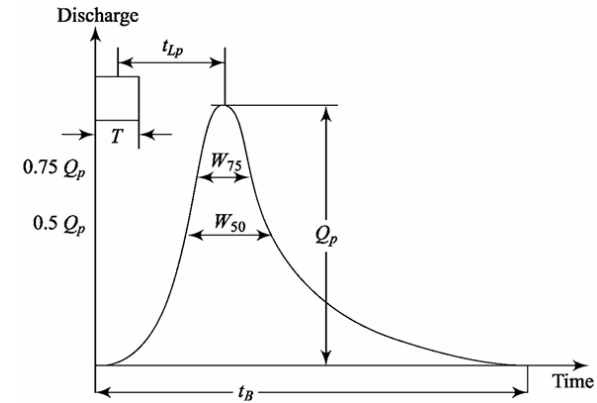


Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method

- Empirical relationships suggested by Snyder (1938)

$$t_{Lp} = C_T (L L_{CA})^{0.3}$$
$$Q_p = 640 C_p A / t_{Lp}$$
$$t_B = 72 + 3 t_{Lp}$$



where,

- L is the length of the main stream from the outlet to the catchment boundary in miles,
- L_{CA} is the distance from the outlet to a point on the stream nearest to the centroid of the catchment in miles,
- C_T is a coefficient that depends upon units and basin characteristics (it varies from 1.8 to 2.2 for FPS unit and from 1.32 to 1.65 for SI units),
- C_p is also a coefficient that depends upon units and basin characteristics (it varies from 0.56 to 0.69),
- A is the area of the catchment in square miles,
- t_{Lp} and t_B are in hrs.
- Q_p is in ft^3/s , and $Q_p = 2.778 C_p A / t_{Lp}$ (SI unit)

A is in km^2 and Q_p is in m^3/s .



Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method

- These relationships are valid for excess rainfall of standard duration, $T_{SD} = t_r$

$$t_r = \frac{t_p}{5.5}$$

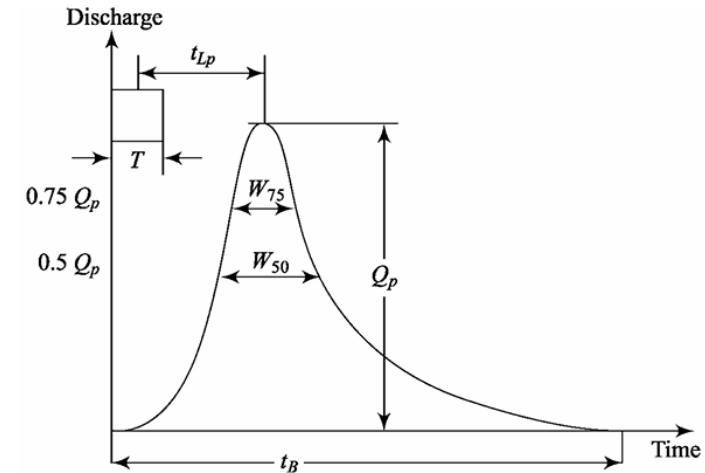
- For rainfall duration, T , not equal to, T_{SD} ,

$$t_{pR} = t_{Lp} + (T - T_{SD})/4$$

where,

- t_{pR} is the **revised lag-time** in hours, and
- T is the actual rainfall duration.
- Empirical expressions for the time base can be generalized as: $t_B = T + a A^b$
- where, a and b are the coefficient and the exponent, respectively; and A is the area of the catchment in km^2 .

$$t_{Lp} = C_T (L L_{CA})^{0.3}$$
$$Q_p = 640 C_p A / t_{Lp}$$
$$t_B = 72 + 3 t_{Lp}$$





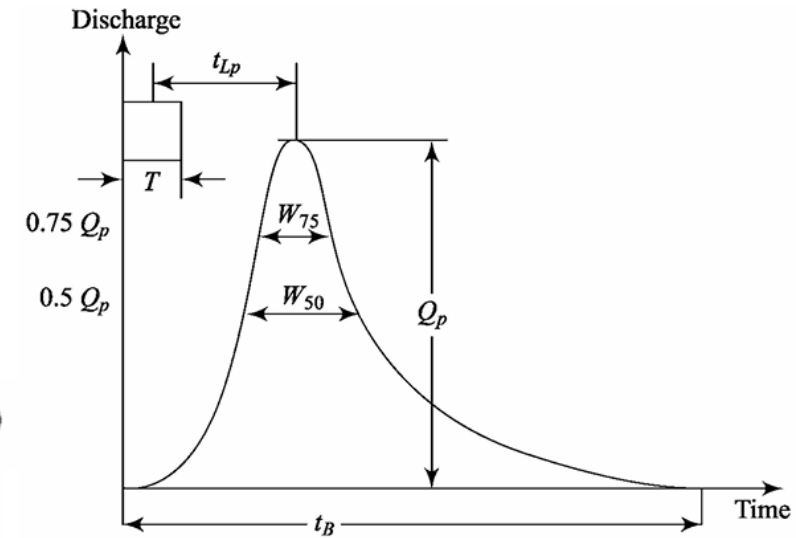
Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method

- empirical expressions are added as W_{75} and W_{50} (in hr) as functions of $q_p = Q_p/A$ in $m^3/s/km^2$, which represent the width of:
- UH at $0.5Q_p$, and $0.75Q_p$, respectively as:

$$Q_p = 2.778 C_p A / t_{Lp} \text{ (SI unit)}$$

$$t_{pR} = t_{Lp} + (T - T_{SD})/4$$



$$W_{50} = 5.6/(q_p)^{1.08}$$

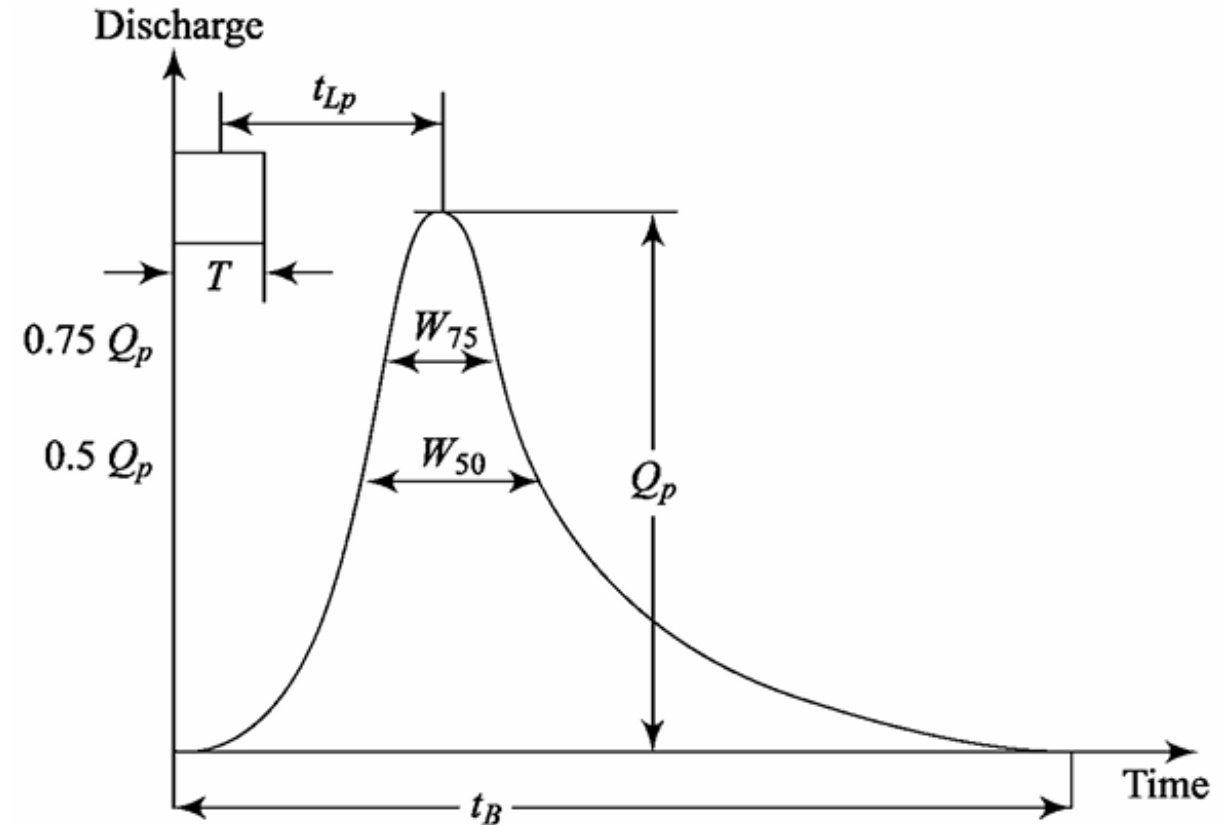
$$W_{75} = 3.21/(q_p)^{1.08}$$



Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method

- The area under the UH is has to be ensured as 1.
- Hydrograph for an ungauged watershed can be derived by determining the Snyder coefficients for the adjoining gauged watershed.



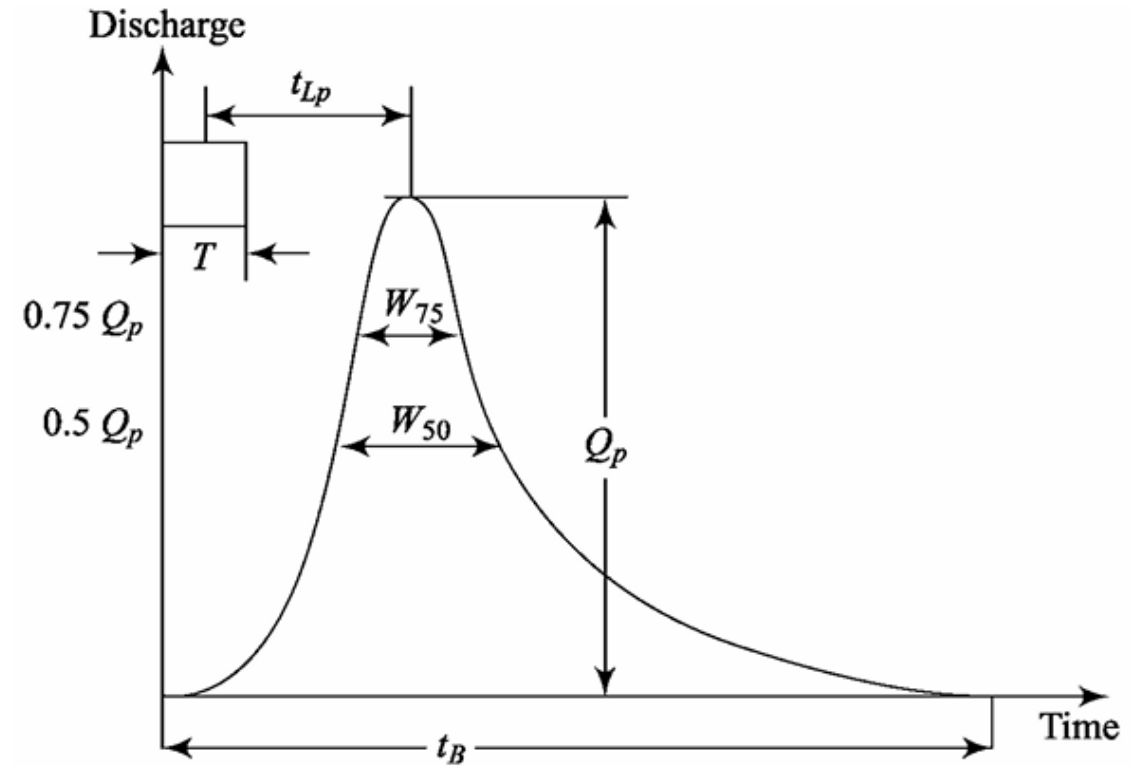
Source: Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method: Example

- The Snyder's parameters for a catchment are **given as**:
 - $C_p = 0.65$, $C = 1.5$, $L = 25$ km,
 - L , (distance from the outlet to a point on the stream, nearest to the centroid of the catchment in miles) = 12 km, and
 - catchment area, $A = 1295$ km².
- Using Snyder's method, develop a 2-hr UH for the catchment.





Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method: Example

Required:

- Q_p (m³/sec), t_B , W_{75} and W_{50} (hr).

Solution:

$$Q_p = 2.778 C_p A / t_{Lp} \text{ (SI unit)}$$

- Time-to-peak of the UH,

$$t_{Lp} = C_T (L L_{CA})^{0.3} \quad t_{Lp} = 1.5 \times (25 \times 15)^{0.3} = \underline{\underline{8.877 \text{ hr}}}$$

- Time of standard excess-rainfall duration,

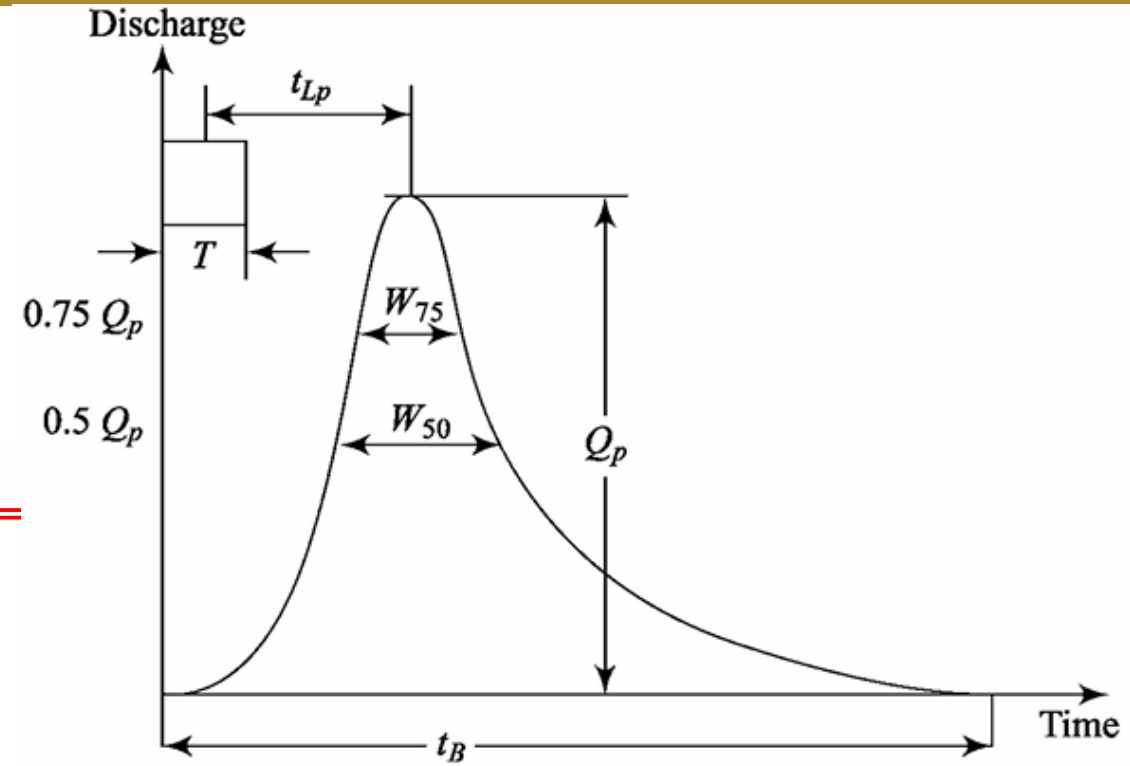
$$T_{SD} = \frac{8.877}{5.5} = \underline{\underline{1.614 \text{ hr}}}$$

$$T_{SD} \neq T (= 2 \text{ hr.}),$$

- So, calculate the adjusted time-lag,

$$t_{pR} = 8.877 + \left(\frac{2.0 - 1.614}{4} \right) = \underline{\underline{8.973 \text{ hr}}}$$

- Then, Q_p and q_p for W_{75} and W_{50} (hr) are:



$$Q_p = \frac{2.778 \times 0.65 \times 1295}{8.973}$$

$$= \underline{\underline{260.6 \text{ m}^3/\text{sec}}}$$

$$q_p = \frac{260.6}{1295} = \underline{\underline{0.201 \text{ m}^3/\text{s}/\text{km}^2}}$$

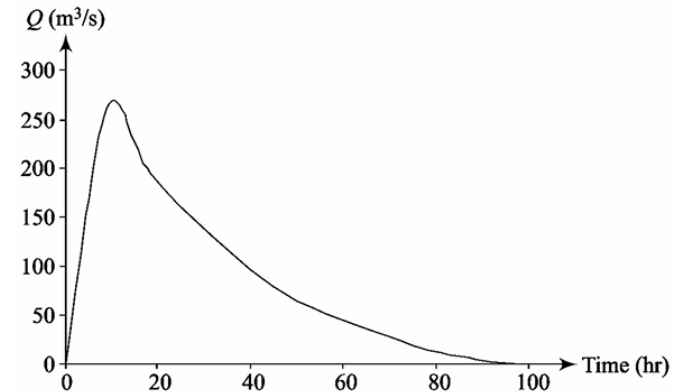
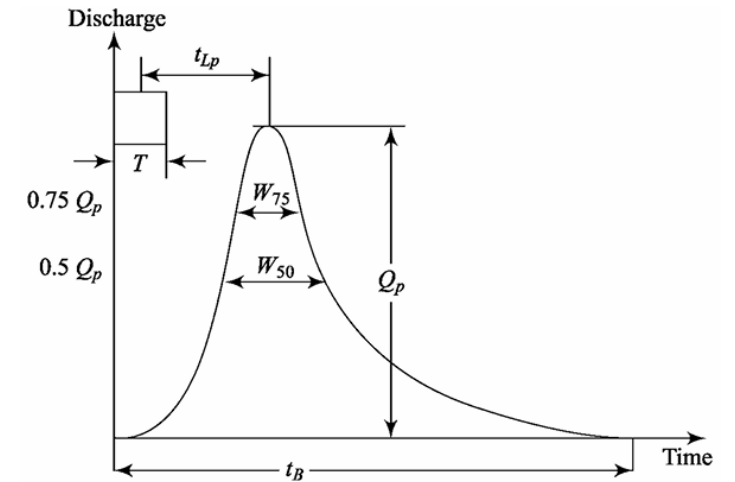


Hydrograph Analysis: The Unit Hydrograph (UH)

Snyder's Method: Example

Solution:

- Then, W_{75} and W_{50} (hr).
$$\left\{ \begin{array}{l} W_{50} = 5.6/(q_p)^{1.08} \\ W_{75} = 3.21/(q_p)^{1.08} \end{array} \right.$$
- $W_{75} = \underline{31.67 \text{ hrs}}$; $W_{50} = \underline{18.157 \text{ hrs}}$
- $t_B = 72 + 3 t_{Lp}$
- $t_B = 72 + (3 \times 8.877) = \underline{98.63 \text{ hr}}$.
- A smooth curve is drawn through these points to get a UH.

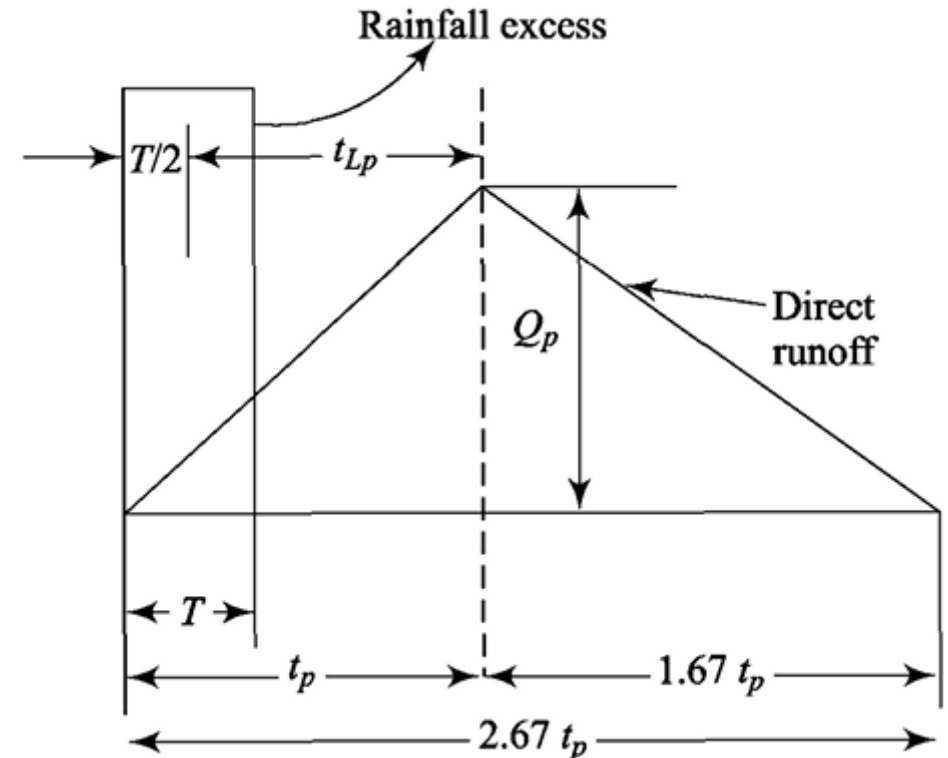




Hydrograph Analysis: The Unit Hydrograph (UH)

Dimensionless Unit Hydrograph (SCS Method)

- is widely used for estimating floods on small to medium sized ungauged drainage basins.
- SUH is determined from an average dimensionless Q/Q_p versus t/t_p hydrograph
- The time-to-peak (t_p) and peak discharge (Q_p) are computed, respectively, as:



Source: Textbook, (Ojha et al, 2008)



Hydrograph Analysis: The Unit Hydrograph (UH)

Dimensionless Unit Hydrograph (SCS Method)

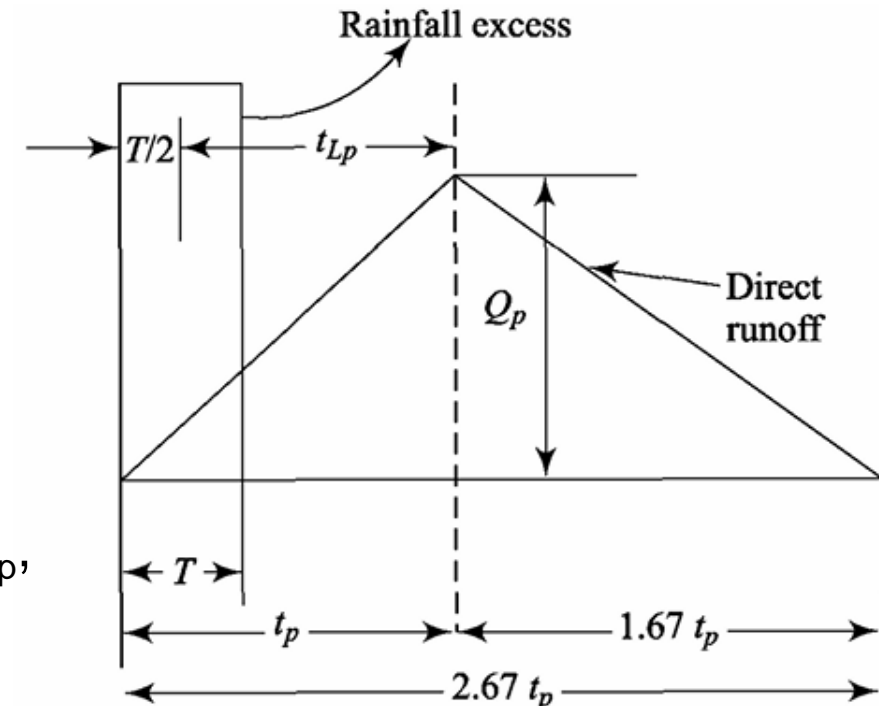
- The time-to-peak (t_p) and peak discharge (Q_p) are computed, respectively, as:

$$t_p = T/2 + t_{Lp}$$

$$Q_p = 484 AV / t_p$$

where,

- t_{Lp} is the lag-time (hr) from centroid of rainfall to peak discharge Q_p ,
 - $t_{Lp} = 0.6 t_c$, where t_c is the time of concentration.
- T is the duration of rainfall (hour),
- Q_p is in ft^3/s ,
- A is the area in square miles,
- t_p is in hour,
- V is in inches. V is the volume estimated from the rainfall which $1/2 Q_p t_B$,
- t_B is the base length of can be described as the net excess rainfall, i.e., the hydrograph and is assumed equal to $2.67 t_p$.





Hydrograph Analysis: The Unit Hydrograph (UH)

Dimensionless Unit Hydrograph (SCS Method)

- The time-to-peak (t_p) and peak discharge (Q_p) are computed, respectively, as:

$$t_p = T/2 + t_{Lp}$$

$$Q_p = 484 AV / t_p$$

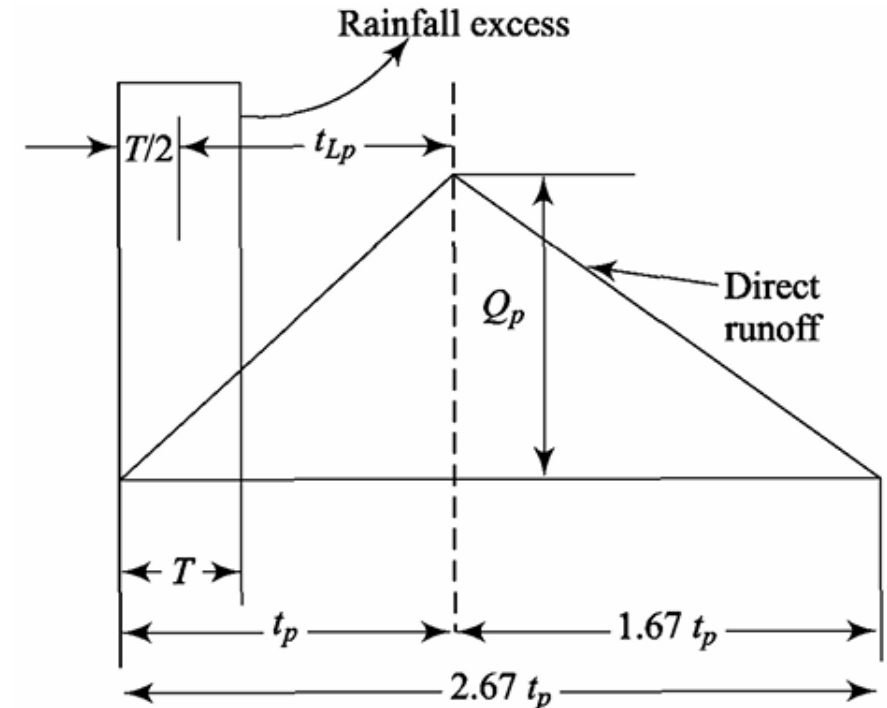
- In SI units, with Q , in m^3/s , basin size in km^2 , and V in mm ; the coefficient 484 is replaced by 0.208. The lag-time (t_{Lp}),

$$t_{Lp} = \frac{l^{0.8} (S_0 + 1)^{0.7}}{1900 S^{0.5}}$$

where,

- l is the length to divide in feet, S is the average **slope in percent**, and
- S_0 is the potential maximum **retention** derived from curve number (CN) in inches as:

$$S_0 = (1000/CN) - 10$$





Hydrograph Analysis: IUH

Instantaneous unit Hydrograph (IUH)

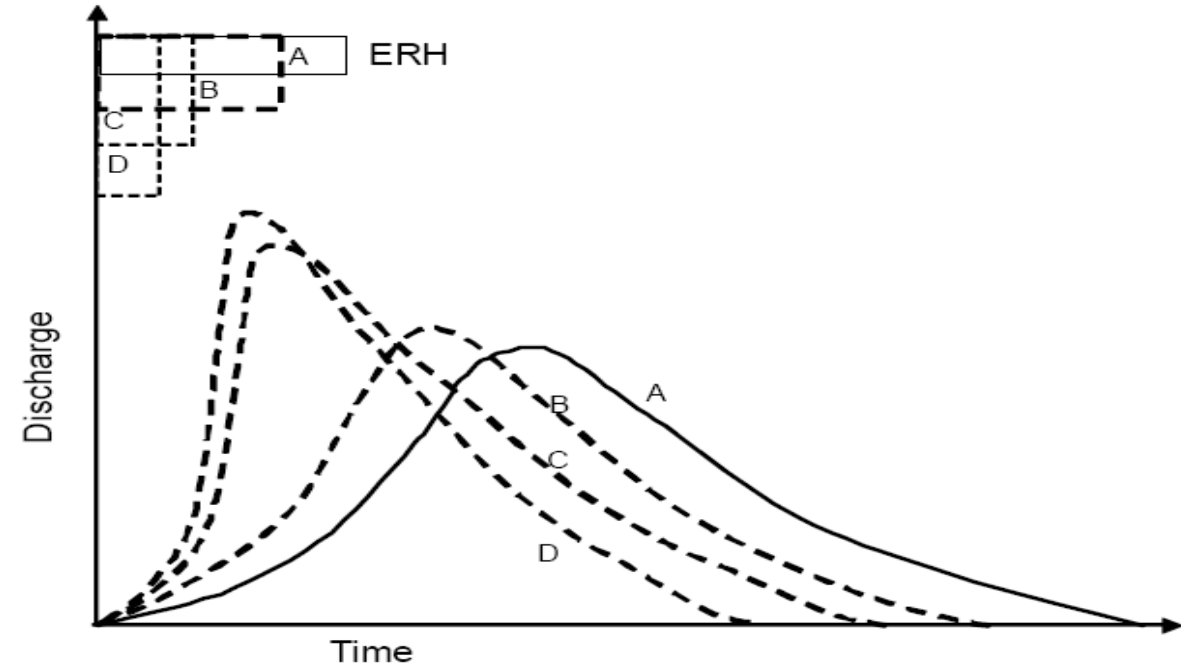
- For a given catchment a number of unit hydrographs of different durations are possible.
- The shape of these different UHs depends upon the value of effective RF duration, D .
- As the value of D is reduced, the intensity of rainfall excess being equal to $1/D$ increases and
 - the unit hydrograph becomes more skewed. A finite UH is indicated as the duration $D \rightarrow 0$.
- The limiting case of a unit hydrograph of **zero duration** is known as instantaneous unit hydrograph (IUH).



Hydrograph Analysis: IUH

Instantaneous unit Hydrograph (IUH)

1. $0 \leq u \leq u(t)$ a positive value, for $t > 0$;
2. $u(t) = 0$ for $t \leq 0$;
3. $u(t) \sim 0$ for $t \sim \infty$;
4. Time to peak = time to the centroid of the curve.



Source: Textbook, (Ojha et al, 2008)



Hydrology of Ungauged Catchment

An ungauged catchment refers to a drainage basin lacking sufficient in-situ hydrological data, such as precipitation, streamflow, and evaporation,

- difficulty of calibrating and validating hydrological models
- There are different techniques to study ungauged catchments:
- **Regionalization:** use data from gauged catchments in similar regions.
- **Hydrological Models:** simulate hydrological processes calibrated and validated using data from gauged catchments.
- **Remote Sensing:** estimate some hydrological parameters, using remote sensing data.
- **Machine Learning:**



Home assignment:

Make sure that you can do:

- **Unit hydrographs:**
 - definitions, assumptions, laws
 - UH to DRO hydrograph formation
 - UH derivations
- **Synthetic Unit hydrographs:**
 - definitions and methods
 - derivations
- **Ungauged catchment:**
 - Data transfer mechanisms



Home assignment:

Make sure that you can write, select, compare on the following topics:

- **Hydrograph:** Factors affecting, UH, SUH
 - What is UH mean?
 - Why it is important?
 - What are the assumptions behind UH?
 - Why these assumptions are needed?
 - What about the uncertainties due to these assumptions?
 - Why SUH? And what are they?
 - Drive a UH of single event rainfall given the measured hydrograph of this rainfall.
 - Try to solve mathematical expression and problem solving on UH and SUH from given effective rainfall and DRO.
- **Data transfer for ungauged watersheds**



References

Ojha, C.S.P., R. Berndtsson, and P. Bhunya, 2008. Engineering Hydrology, Oxford University Press ISBN: 978-0-19-569461-1

Subramanya, K. 2008. Engineering Hydrology, Tata McGraw-Hill Publishing Company Limited, New Delhi



Thank you very much for your active attendance!!

Prepared By: Sisay Demeku Derib (PhD, Practicing Hydraulics Engineer, Assistant Prof.)

Affiliated to: Addis Ababa Science and Technology University –AASTU, Department of Civil Engineering

[Scopus](#) [WOS](#) [ORCID](#) [ResearchGate](#) [Google Scholar](#) [LinkedIn](#) [YouTube](#)