HYDROGRAPH

Ch-6

HYDROGRAPH

- Hydrograph is a plot of the discharge in a stream against chronological time.
- It could be annual,monthly,daily,hourly,seasonal or flood.

Used for:-

Calculating the surface water

potential of stream

Reservoir studies

Drought studies

Analyzing stream characteristics associated with flood

Affected by

- Hydrograph is affected by all Factors affecting runoff

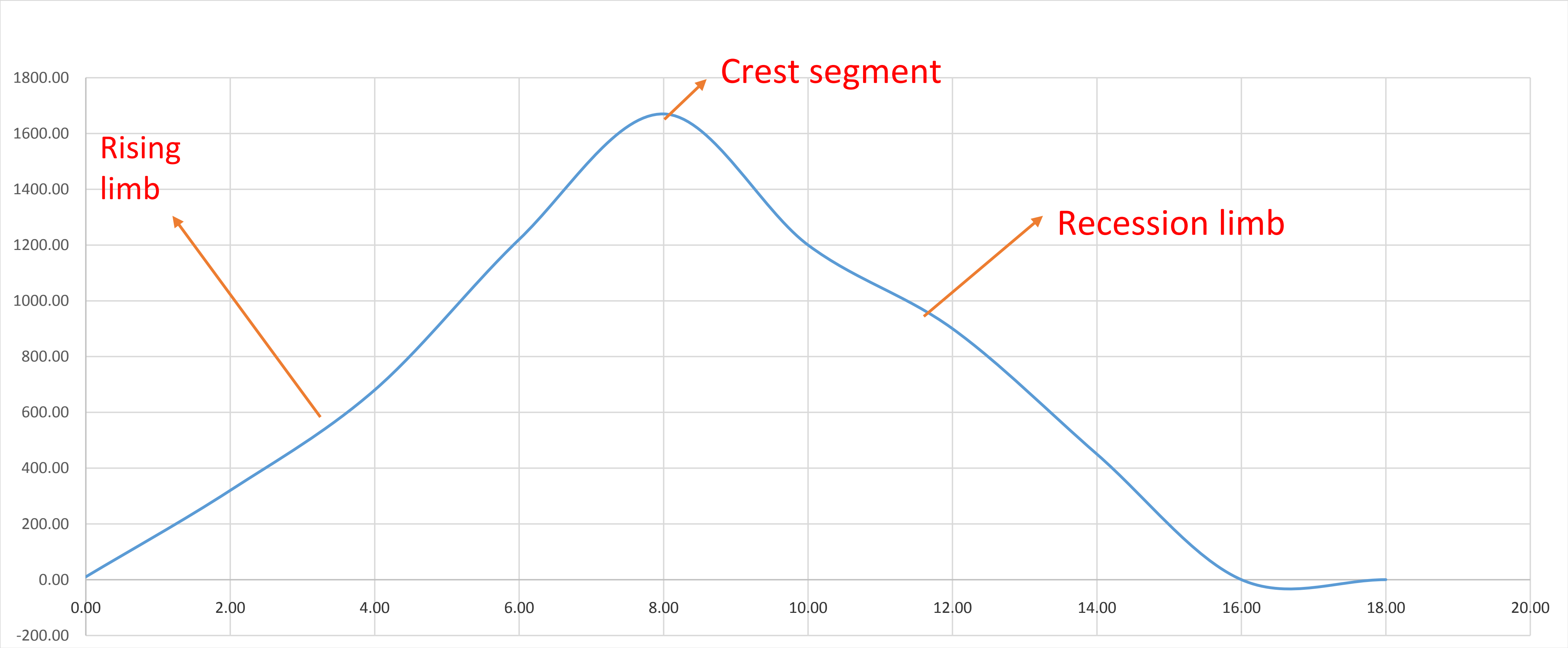
area,

slope,

land use,

climatic factors…

Components of hydrograph



Components of hydrograph

Rising limb

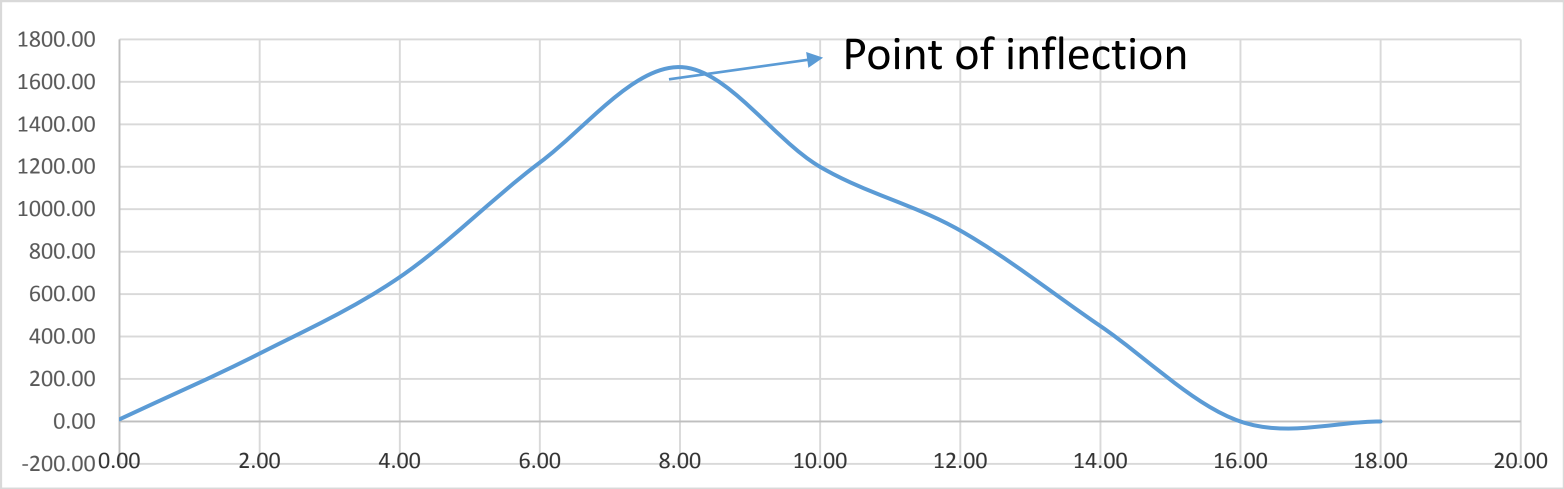
- Also known as concentration curve
- Represents the increase in discharge due to gradual building up of storage channels and over the cathchment surface.

Crest segment

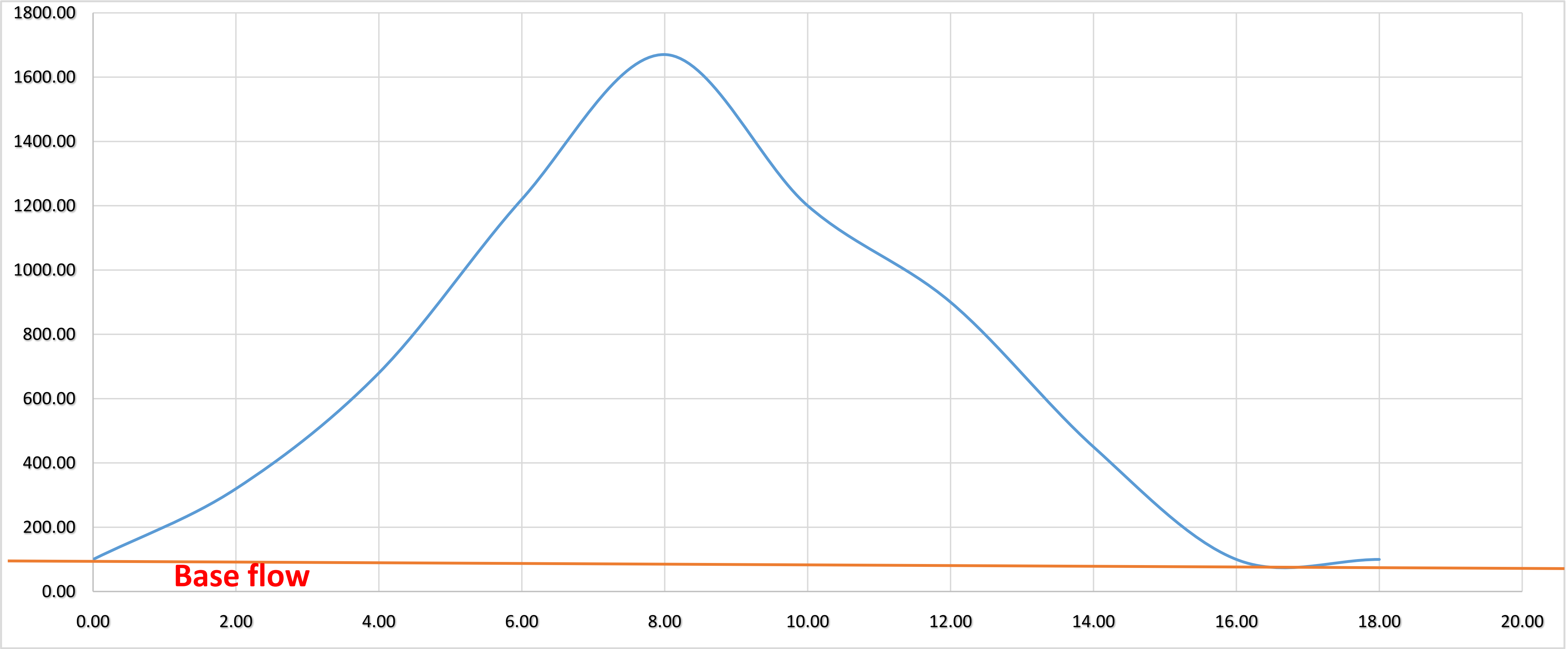
- Contains the peak flow
- Peak flow occurs when the runoff from varios parts of the cathcment simultiniously contribute the maximum amount of flow at the basin outlet.

Recession limb

- Represents the wisdrawal of water from the storage built up in the basin during early phases of the hydrograph.
- Depends entirely on basin cxtcs.



Base flow separarion

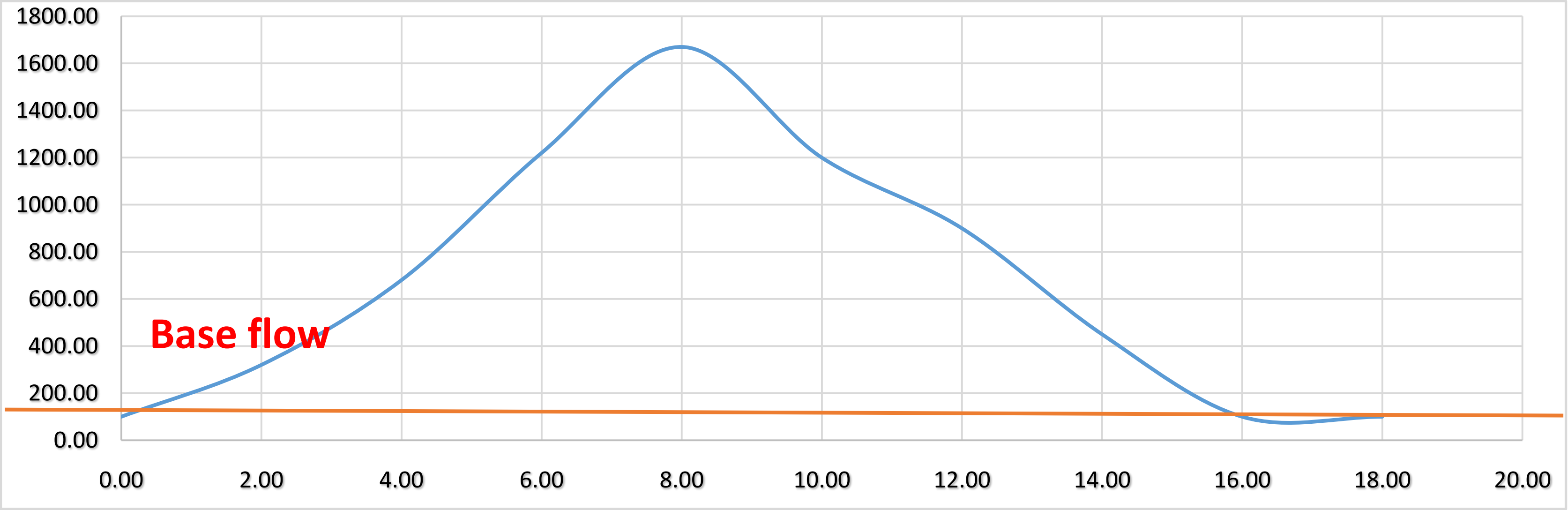


Base flow separarion

- The surface –flow hydrograph is obtained from the total storm hydrograph by separating the quick-response flow from the slow response runoff
- A variety of techniques have been suggested for separating base flow and direct runoff
- First it is necessary to identify the point in receding limb of the measured hydrograph where direct runoff ends. Generally, this ending point is located in such a way that the receding time up to that point is about 2 to 4 times the time to-peak.

The straight line method

- It involves drawing a horizontal line from the point at which surface runoff begins to the intersection with the recession limb. This is often applicable to ephemeral streams.



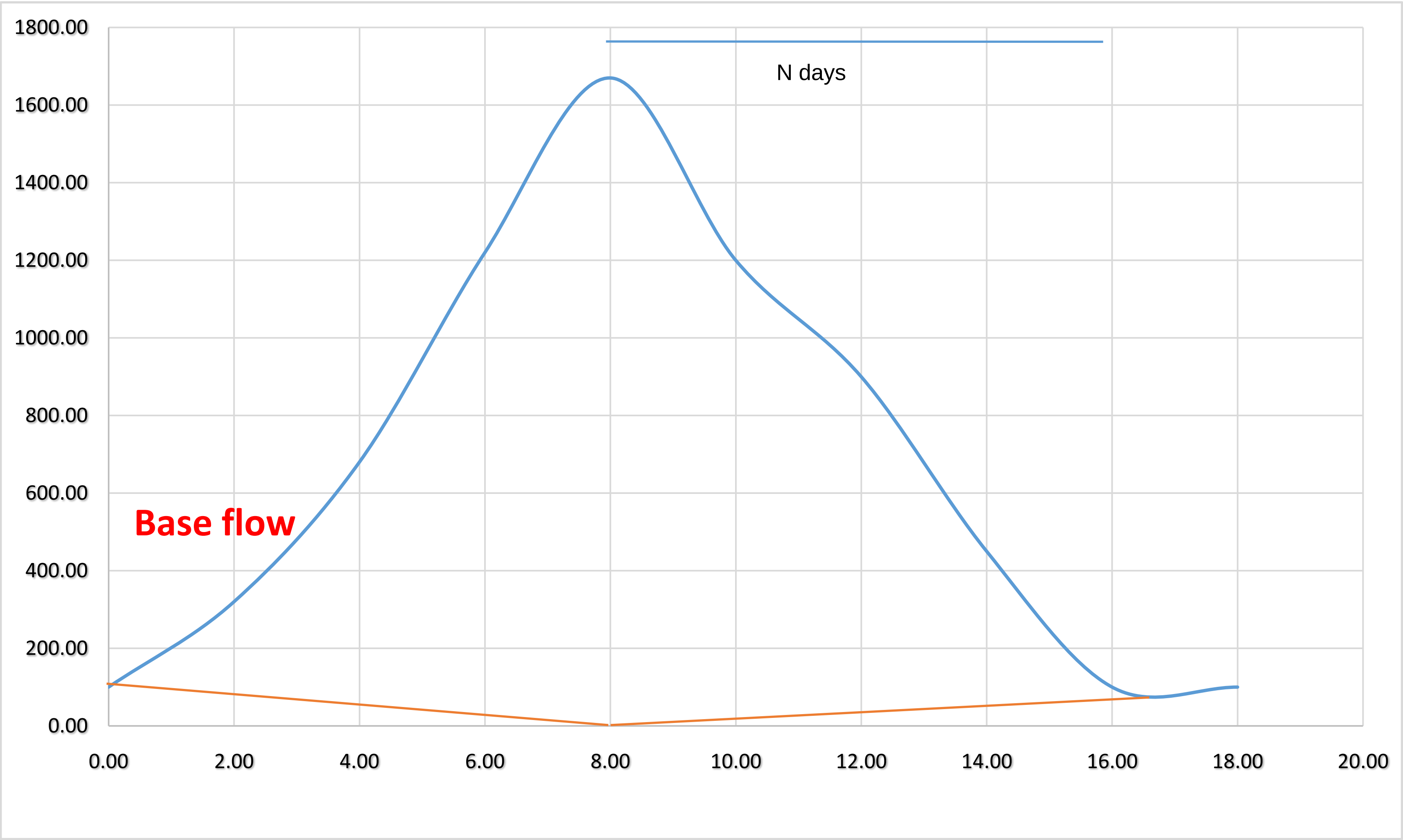
The fixed base method

- The surface runoff is assumed to end a fixed time N after the hydrograph peak.
- The base flow before the surface runoff began is projected ahead to the time of the peak.
- A straight line is used to connect this projection at the peak to the point on the recession limb at time N after the peak N can be estimated from

$$N = b\,A^{0.2}$$

Where: N = time (day)
A = the drainage area in km^2
b = 0.8.

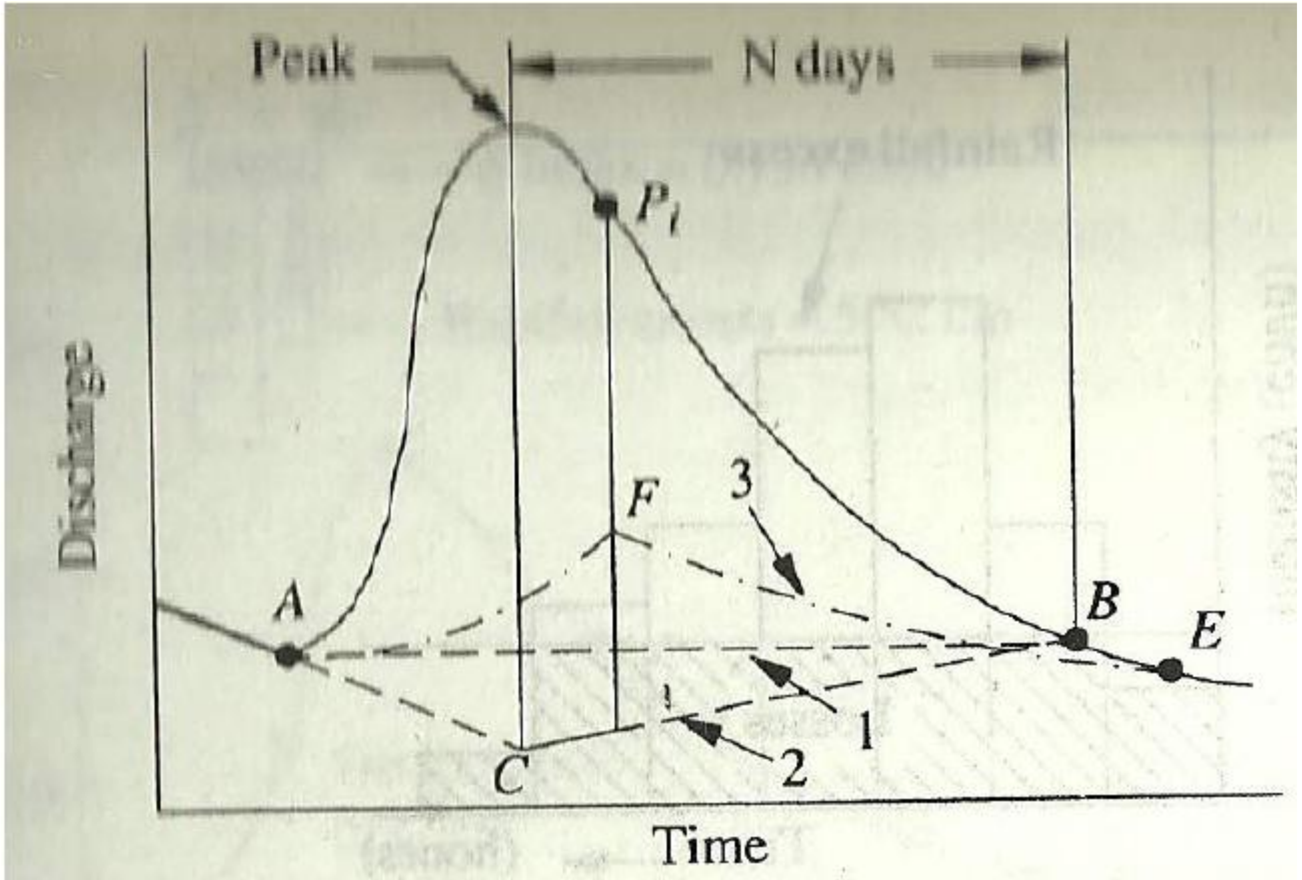
- This method may be applied for large rivers where their response is in days



N days
Base flow
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

The variable slope method

- The base flow curve before the surface runoff began is extrapolated forward to the time of peak discharge, and the base flow curve after surface runoff ceases is extrapolated backward to the time of the point of inflection on the recession limb.
- – A straight line is used to connect the endpoints of the extrapolated curves



Peak
N days
Discharge
P_1
F
3
A
B
E
1
2
C
Time

DIRECT RUNOFF HYDROGRAPH(DRH)

- The surface run off hydrograph obtained after the base flow separation.
- DRH is flow , which is produced by effective rainfall
- The effective rainfall is the rainfall that subtract the initial abstraction and infiltration losses.
- **So the main purpose of the analysis of hydrograph is to correlate effective rainfall hyetograph (ERH)[**mm/hr] **and Direct runoff hydrograph(DRH)[**m3/sec]

EXAMPLE-1

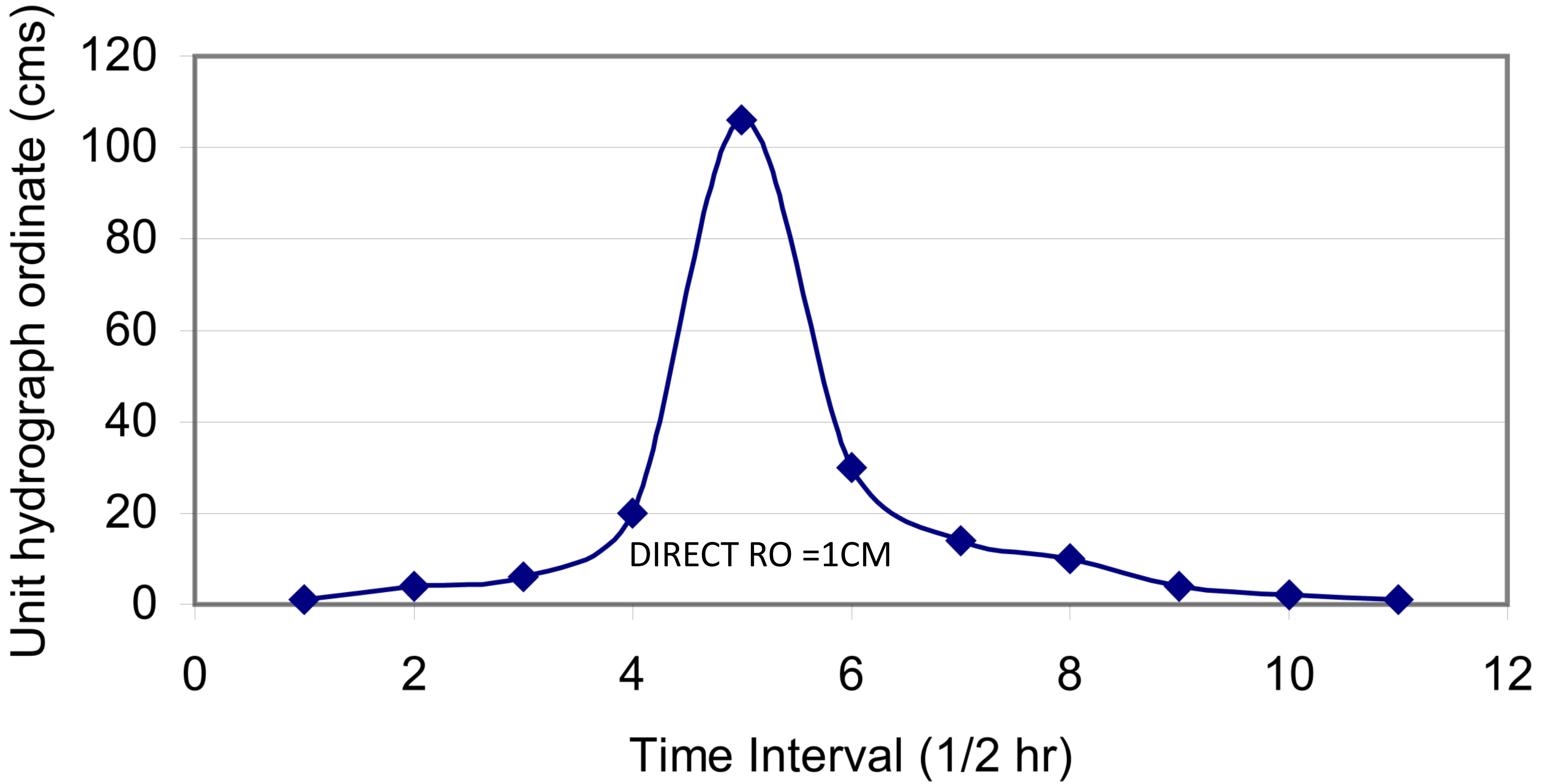
- RF magnitude 3.8cm and 2.8cm occuring on two consecutive 4h durations on a catchment area of 27Sqkm produced the following hydrograph of flow at the outlet of the catchment,estimate the RF excess and the phi index.

time of start of RF	-6	0	6	12	18	24	30	36	42	48	54	60	66
observed flow	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5

UNIT HYDROGRAPH

- A unit Hydrograph is a hydrograph of direct runoff resulting from one unit (1cm) of rainfall excess occurring uniformly over the basin and at a uniform rate for specified duration (D hours).
- A unit hydrograph is a specific type of hydrograph in that it represents the effects of the physical characteristics of the basin.

UNIT HYDROGRAPH



UNIT HYDROGRAPH

- The essence of the unit hydrograph is that since the physical characteristics of the watershed shape, size, slope etc are relatively constant over few years, one might expect considerable similarity in the shape of hydrographs resulting from similar rainfall characteristics.
- The term unit here refers to a unit depth of rainfall excess,commonly use 1cm or 1mm

UNIT HYDROGRAPH

- **Unit hydrograph represents the lumped response of the catchment to a unit rainfall excess of D-hour duration**
- **The rainfall is considered to have an average intensity of excess rainfall (ER) of 1/D cm/hr**
- **THE VOLUME OF WATER CONTAINED IN THE UNIT HYDROGRAPH MUST BE EQUAL TO THE RAINFALL EXCESS.**

UNIT HYDROGRAPH

- **Simple proportioning of the direct runoff**
  1. Separate the base flow from direct runoff,
  2. Determine the volume of direct runoff, and
  3. Divide the ordinate of the direct runoff hydrograph by observed runoff depth.

$$r_d = \frac{\Delta t \sum_{i=1}^{n} q_i}{A}$$

example

- Given the following hydrograph of a given watershed having drainage area of 104 km2 derive the unit hydrograph for the watershed

Date	Hour	Stream flow	Base flow
16-Feb	6000	11	8
	8000	170	8
	1000	260	6
	1200	266	6
	1400	226	8
	1600	188	9
	1800	157	11
	2000	130	12
	2200	108	14
	2400	91	16
17-Feb	2000	76	17
	4000	64	19
	6000	54	21
	8000	46	22
	1000	38	24
	1200	32	26
	1400	27	27

Unit hydrograph derivation by convolution method

- The process by which the design storm is combined with the transfer function (that is the unit hydrograph) to produce the direct runoff hydrograph
- It is a theory of linear superposition. it is a process of multiplication, translation with time and addition
- For a given watershed, the hydrograph resulting from a given excess rainfall reflects the unchanging characteristics of the watershed.

Assumption of convolution method

- The excess rainfall has a constant intensity within the effective duration.
- The excess rainfall is uniformly distributed throughout the whole drainage area
- The base time of the direct runoff hydrograph resulting from an excess rainfall of given duration is constant
- The ordinates of all direct runoff's of a common base time are directly proportional to the total amount of direct runoff represented by each hydrograph

Convolution equation

$$Q_n = \sum_{m=1}^{n \le M} R_m U_{n-m+1} \qquad (8.9)$$

Where: Q_n = direct runoff (m^3/s),

R_m = excess rainfall (mm),

U_{n-m-1} = the unit hydrograph ordinate ($m^3/s/mm$),

M = the number of pulses of excess rainfall, and

N = the number of pulses of direct runoff in the storm considered.

n = 1, 2, ..., N

m = 1, 2, ..., M

example

In a storm, the rainfall excess of 0.5 cm, 0.7 cm, 0.0 cm and 0.8 cm occurred in four successive hours. The storm hydrograph due to this storm has the hourly ordinates (m3/s) as given below. If there is a constant base flow of 0.5 m3/s, find the hourly ordinates of the unit hydrograph.

Time (hr)	1	2	3	4	5	6	7	8	9	10	11	12
Q (m3/s)	0.5	44.5	110.5	85.5	102.8	94	38.4	18.6	10.9	5.3	2.9	0.5

solution

- The direct runoff ordinates Qn (m3/s) are 0.0, 44.0, 110.0, 85.0, 102.3, 93.5, 37.9, 18.1, 10.4, 4.8, 2.4, 0.0.
- The depth of effective rainfall are R1 = 0.5 cm, R2 = 0.7 cm, R3 = 0.0, and R4 = 0.8 cm
- The number of unit hydrographs ordinates to be found are = *N-M+1 = 12-4+1= 9*
- Calculation fro
- Q1 = R1U1 = 0.5 x U1= 0 m3/s, U1 = 0.0 m3/s/cm
- For the second time interval,
- Q2 = R2U1 + R1U2 = 0.7 x 0.0 + 0.5 x U2 = 44.0 m3/s, U2 = 88.0 m3/s/cm
- For the third time interval
- Q3 = R3U1 + R2U2+ R1U3 =0.0 *0.05 + 0.70 *88.0 + 0.5 *U3 = 111.0 m3/s.
- U3 = 96.8 m3/s/cm
- Similarly the remaining ordinates are found U4 =34.5 m3/s/cm d as U5 =15.5 m3/s/cm, U6 =10.4 m3/s/cm U7 =-33.0 m3/s/cm U8 =0.0 m3/s/cm U9 =0.0 m3/s/cm.

example

- Following are the ordinates of storm hydrograph of river draining a catchment area of 423km2 due to 6h isolated storm.drive the ordinates of 6h unit hydrograph.

t	Q	baseflow
-6	10	10
0	10	10
6	30	10
12	87.5	10.5
18	15.5	10.5
24	102.5	10.5
30	85	11
36	71	11
42	59	11
48	47.5	11.5
54	39	11.5
60	31.5	11.5
66	26	12
72	21.5	12
78	17.5	12
84	15	12.5
90	12.5	12.5
96	12	12
102	12	12

Application of UH

- To calculate the direct runoff and stream
- flow hydrographs
- Computation of flood hydrograph for
- design of structures
- Flood forecasting models
- Comparing the catchment characteristics