ADDITIONAL ANSWER SHEET
S.S.N. COLLEGE OF ENGINEERING & TECHNOLOGY
(Affiliated to J.N.T. University, Kakinada)

Signature of Invigilator

Pg No 151 BC Punmia

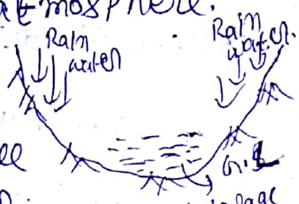
UNIT-III

Run off:

Run - means moving.
off - stoping. It means

The water moving in the soil surface. and stored in one place and the water will evaporated in the atmosphere.

Ex: Take one valley



This evaporated & infiltrated.

Run off - means the water will moving one place to another place finally stored in one place so that water is evaporated (or) infiltrated

in this catchment of water is draining into a stream or into a reservoir in that period.

This can be expressed as ~~during into~~
(i) centimetres of water over a catchment
(ii) The total water in cubic-metre (or) hectare-metre for given catchment.

As discussed earlier, the rainfall is disposed off in the following manner.
(1) Basin Recharge
(2) Direct run off (or) simply run off
(3) Percolation down to ground water (Base flow)
(4) Evaporation and transpiration.

(1) Basin recharge:- It consist of.

(i) Rain intercepted (........) by leaves and stems (.....) of vegetation (........)
Ex: more amount of water will not useful to growth of plants.

(ii) some amount of water will be stored on surface of the soil. so surface will stops moving of water so it will be recharge of the area

(iii) The water will be absorbed on the surface of soil particles.

(2) Direct run off:-

Direct runoff is that water which reaches the stream shortly after it falls of rain.
(i) surface - run off
(ii) subsurface - run off

A portion of water which travels in ground surface to nearest stream.
The surface of soil is permeable (permit water inside) water percolates into it when it become fully saturated. It flows laterally in the surface of soil to reach a stream chanel. but in this case the surface of soil is permeable but the sub-soil is relatively impermeable: so water does not percolate deep ~~so~~ ~~the~~ does not reach ground water.

(3) Percolation down to ground water (Base flow)

If the sub soil is also permeable, water percolates deep downwards to meet the ground water. It will flow and finally reach ~~sea~~ rivers (or) oceans

Some basic terms used in hydrology.
hydro → water; logy → study.

(i) Basin:-

Basin is the catchment area (or) watershed area (water storage area)
→ It can be located at highest contour (highest level)

The precipitated water collected by surface and subsurface flows and drained out ~~through a~~ collected water through a natural stream (or) river.

(ii) Stream:-

The stream natural flow channel. The stream transfer the collected water in ~~to~~ a large water body.

(iii) Over land flow:-

The rain water flows over the land surface to join the nerest stream.

(iv) Surface run off:-

The rain water and other drainage water of a basin which moves over a land surface.

(v) Stream (river) flow:-

Stream (river) flow (or) total run off means. Consist of surface flow, subsurface flow, ground water flow

This flow is will get precipitation directly falling on the stream.

(vi) Drinage density:- (D_d)

Drinage desity (D_d) is defined as the ratio of total length of all streams of the catchment divided by it's area.

$$D_d = \frac{L_s}{A}$$

where L_s = Total length of all streams in a basin.

A = drainage area of basin.

(vii) Stream density:- (D_s)

Stream density is defined as the ratio of No of streams of given order per sq. km divided by catchment area.

$$D_s = \frac{N_s}{A}$$

(viii) Centroid of the basin:-

It is the point of center of watershed.

(ix) Form factor:- (F_f)

Horton (1932) defined form factor (F_f) It is defined as the ratio of average width (W_b) divided by basin length L_b

$$\therefore F_f = \frac{W_b}{L_b}$$

The average width W_b is obtained by dividing the wetted area (A) with the axial length of the same.

$$F_f = \frac{W_b}{L_b} \Rightarrow F_f = \frac{A/L_b}{L_b}$$

$$\boxed{F_f = \frac{A}{L_b^2}}$$

(10) compactness coefficient :- (C_c)

Strahler (1964) defined as the ratio of perimeter of the basin to the circumference of a circle whole area is the area of the basin.

$$C_c = \frac{P}{\sqrt{4\pi A}}$$

$$C_c = \frac{0.2821P}{\sqrt{A}} \geq 1$$

where P = perimeter of the basin in km

A = Area of the basin in sq.km

(11) Elongation ratio :- (E_r)

Elongation ratio introduced by Schuman (1956) is the ratio of diameter of circle of the same area of the basin to the maximum length of the basin.

$$E_r = \frac{1}{L}\sqrt{\frac{A}{0.786}} \leq 1$$

(12) Circularity ratio :-

circularity ratio proposed by Miller (1956) is the ratio of area of the basin to the area of a circle having the same perimeter as the basin.

$$C_r = 12.57 \frac{A}{P^2} \leq 1$$

Factors Affecting Run-off :-

The following factors will affecting of run-off

(1) Precipitation characteristics

(2) shape and size of the catchment

(3) Topography

(4) Geological characteristics

(5) Metrological "

(6) character of the catchment surface

(7) storage characteristics.

(1) Precipitation characteristics :-

The precipitation characteristics are.

(i) intensity

(ii) duration.

(iii) Areal distribution

(iv) direction of storm movement

(v) form of precipitation and

(vi) evapo-transpiration.

(i) intensity :-

The more amount of rainfall at many Intensity of rainfall is more run off will be more intensity of rainfall is less runoff will be less and also will be last of infiltration and evaporation.

(ii) duration:-

duration means time

duration will be more time will be more runoff will be less

duration will be time will be less runoff will be more

Ex:- If u take two different areas in both areas same amount of rainfall 10 cm will be falling in 1st area 10 cm of rainfall is falling in 1 hour in 2nd area 10 cm of rainfall is falling in 2 hours. It means time will be difference

Time will be more means infiltration rate will be more and evaporation rate will be more so run off will be less.

(iii) Areal distribution:-

The rain is falling in more area result more amount of water will absorb ground and more amount of water will be evaporated. So runoff will be less

The rain is falling in less area result runoff will be more

Ex:- If u take 2 different areas in 1st area was 1 sq km 2nd area was 2 sq km. In 1st area the rain water is falling 10 cm. In 2nd area also rain water is falling 10 cm which is more runoff

1st area is less area so infiltration and absorption losses will be less and evaporation losses also will be less so runoff will be more.

(iv) direction of storm movement:-

The water will be flowing in straight direction the air also moving (or) flowing in straight direction result run off will be more

The air will be flowing in opposite to the flowing of water result run off will be less.

(v) form of precipitation:-

precipitation means rainfall

The precipitation is in the form of snow. The snow more amount of heat will be absorbed result increases it's temperature result evaporation will be more run off will be less.

(vi) evapo-transpiration:-

evapo-transpiration means loss of water plants and leaves

The evapo-transpiration will be more runoff will be less. The evapotranspiration will be less run off will be more.

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(2) shape and size of the catchment:-

The run off from a catchment also depends upon the size, shape and location of the catchment.

→ more intensity of rainfall are generally distributed over a relatively smaller area.

→ The catchment of water like curved shape or straight shape on straight shape more runoff on curved shape less run off

→ the ~~catch~~ catchment area size will more more amount of water will be absorb and evaporated. run off will be less

→ A stream collecting water from a small catchment areas is likely to give greater run-off intensity per unit area.

(3) Topography of catchment:-

Top - graphy
↓ ↓
Top~~surface~~ land

→ The top surface having a smooth surface run off will be more or the top surface having a rugged (It-means land having many rocks and ~~roughted~~ hard surface) surface run off will be less

→ If the surface is steep slope water will flow quickly and absorption and evaporation losses will be less resulting more run off

→ If the catchment of water in mountainous and the direction water on mountainous and direction of wind on the mountainous as same direction and rain also falling in same direction result intensity of rainfall will be more, and hence run off will be more

(4) orientation of water shed:-

orientation - direction.

→ orientation of water shed affects the evaporation and transpiration loss and It is effected by the amount of heat received from the sun.

→ The sun rises came in East to west direction so ~~to~~ construct the water shed in North and South orientation (direction) so watershed will not absorb the heat run off is more

→ North and South orientation of watershed affects the the melting (change solid to liquid) time of collected snow and hence the run off.

(5) Geological characteristics of basin

Geo logical
↓ ↓
earth conclusion.

If the soil and sub soil. previously seepage (water absorption) will be more. reduced the peak (large) flood and run off will be more.

→ If the surface is rocky, the absorption will be partially nil, and runoff will be more.

(6) Meteorological characteristics:-

meteorological – surroundings (study of weather)

→ The temperature, wind and humidity also effected the runoff.

→ temperature is low ground less amount of water is absorb, evaporation losses will be less so run off will be more.

→ If the temperature is high and greater wind velocity ([illegible]) more amount of hot air will meets the cool water the water will be heated and evaporation will be more so runoff will be reduces.

(7) Character of the catchment surface:-

→ The run-off also depends upon the surface conditions. It means weather the surface is drained ([illegible]) (or) undrained ([illegible]), natural (or) cultivated ([illegible]) weather it is bare ([illegible]) (or) covered ([illegible] surface cover [illegible]) with vegetation etc.

→ If the surface has no natural drainage facilities more amount of water percolated more space of earth surface so absorption losses of ground will be more so runoff will less.

→ If the more area of a catchment is cultivated surface (It means loss of top layer so infiltration will be increase) absorption losses will be more runoff will be less

* The presence of vegetal cover stops the moving of water so infiltration and evaporation will be more run off will be less.

Ex:- specially during smaller storms

(8) Storage characteristics of the catchments

→ The artificial storage such as dams, weirs etc. and natural storage such as lakes, ponds etc tend to reduce the peak flow (more amount of water flow)

→ They also give rise to greater evaporation loss

Components of Runoff:- PgNo 156 BC Punmia

The components of run-off are classified as

(1) surface run off
(2) sub surface run off
(3) Ground water run off (or) base flow

(1) surface run off:-

water flows on the land surface. and Joins in to streams rivers, which is finally reaches and Joins to the sea water

(2) sub surface run-off:-

Little amount of surface water absorb the ground infiltrates below the surface of soil. according to geological conditions (it means depending on ~~surf~~ earth surface condition) of the basin

-> so below the soil having some moisture (or) content this moisture content also moves one place to another place finally reaches to streams and rivers.

(3) Ground water run off (or) Base flow

(4)

If the infiltration water percolates (ఇంకిపోవడం) below the ground ~~surface~~ in vertical direction reach the ground water table

-> This water also moves one place to another place depending on the sub soil condition, and sloped (or) straight direction of the below ground surface

-> This water also finally Joined with ocean water.

Computations of run off - rational and SCS method.

computations run-off means measurement of run-off

The run-off can be measured (or) computed daily, monthly (or) yearly

The following methods are used to computing of run-off

(a) By linear (or) exponential regression
(b) By empirical equations and tables
(c) By infiltration method.
(d) By unit hydrograph
(e) By rational method.

(a) Run off By linear (or) exponential regression

Several factors are affecting run-off from a given rainfall. The relation b/w these two (runoff and rain fall) is quite complex. In this method Run-off can be calculated two ways.

(1) Straight line regression b/w P and R

(2) Exponential regression b/w P and R

(1) Straight line regression b/w P and R

Straight line regression method used to small are medium sized catchments

Run off can be calculated as

$$R = aP + b$$

where R = Run-off
P = precipitation.
a and b are constants.

a and b can be calculate as

$$a = \frac{N(\Sigma P \cdot R) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P)^2}$$

$$b = \frac{\Sigma R - a\Sigma P}{N}$$

and coefficient of correlation (γ).

$$\gamma = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{\sqrt{[N(\Sigma P^2) - (\Sigma P)^2] \times [N(\Sigma R^2) - (\Sigma R)^2]}}$$

(2) Exponential regression b/w P & R

Exponential regression method used to large catchment areas for measuring of run-off.

Run-off can be calculated as

$$R = \beta P^m$$

where β & m are constants

Taking the logarithms of both sides we get

$$\log R = \log \beta P^m$$

$$\log R = \log \beta + \log P^m \quad [\because \log ab = \log a + \log b]$$

$$\log R = \log \beta + m \log P \quad [\because \log a^m = m \log a]$$

$$\boxed{\log_e R = m \log_e P + \log \beta}$$

The values of β and m can be calculated by using observed the above equation of P and R values.

Problems [∵ see Note book]

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(pg No 164 BC Punmia)

UNIT-III Problems (straight line regression between P and R)

(1) Table below gives the observed values of yearly precipitation (P) and corresponding yearly run off (R) for a catchment, for a period of 16 years. Develop a linear correlation equation between P and R

Year	1970	1971	1972	1973	1974	1975	1976	1977
P (cm)	72.2	70.1	73.3	42.5	81.3	50.6	52.9	59.4
R (cm)	24.1	22.7	25.6	11.3	28.4	12.7	13.4	15.7

Year	1978	1979	1980	1981	1982	1983	1984	1985
P (cm)	60.3	64.3	68.8	56.7	77.2	40.5	44.1	65.5
R (cm)	16.2	17.7	19.2	14.9	25.4	10.6	11.7	17.9

Sol

Hear $N = 16$ [∵ Number of years 1970 to 1985 = 16 years]

Let the regression equation $R = aP + b$

The computations required for determination of a and b are done in a tabular form below.

year	P (cm)	P^2 (cm^2)	R (cm)	R^2 (cm^2)	PR (cm^2) $P\,cm \times R\,cm = PR\,cm^2$
1970	72.2	$(72.2)^2 = 5212.8$	24.1	$(24.1)^2 = 580.8$	$72.2 \times 24.1 = 1740.0$
1971	70.1	$(70.1)^2 = 4914.0$	22.7	$(22.7)^2 = 515.3$	$70.1 \times 22.7 = 1591.3$
1972	73.3	$(73.3)^2 = 5372.9$	25.6	$(25.6)^2 = 655.4$	$73.3 \times 25.6 = 1876.5$
1973	42.5	$(42.5)^2 = 1806.3$	11.3	$(11.3)^2 = 127.7$	$42.5 \times 11.3 = 480.3$
1974	81.3	$(81.3)^2 = 6609.7$	28.4	$(28.4)^2 = 806.6$	$81.3 \times 28.4 = 2308.9$
1975	50.6	$(50.6)^2 = 2560.4$	12.7	$(12.7)^2 = 161.3$	$50.6 \times 12.7 = 642.6$
1976	52.9	$(52.9)^2 = 2798.4$	13.4	$(13.4)^2 = 179.6$	$52.9 \times 13.7 = 708.9$
1977	59.4	$(59.4)^2 = 3528.4$	15.7	$(15.7)^2 = 246.5$	$59.4 \times 15.7 = 932.6$
1978	60.3	$(60.3)^2 = 3636.1$	16.2	$(16.2)^2 = 262.4$	$60.3 \times 16.2 = 976.9$
1979	64.3	$(64.3)^2 = 4134.5$	17.7	$(17.7)^2 = 313.3$	$64.3 \times 17.7 = 1138.1$
1980	68.8	$(68.8)^2 = 4733.4$	19.2	$(19.2)^2 = 368.6$	$68.8 \times 19.2 = 1321.0$
1981	56.7	$(56.7)^2 = 3214.9$	14.9	$(14.9)^2 = 222.1$	$56.7 \times 14.9 = 844.8$
1982	77.2	$(77.2)^2 = 5959.8$	25.4	$(25.4)^2 = 645.2$	$77.2 \times 25.4 = 1966.9$
1983	40.5	$(40.5)^2 = 1640.3$	10.6	$(10.6)^2 = 112.4$	$40.5 \times 10.6 = 429.3$
1984	44.1	$(44.1)^2 = 1944.8$	11.7	$(11.7)^2 = 136.9$	$44.1 \times 11.7 = 516.0$
1985	65.5	$(65.5)^2 = 4290.2$	17.9	$(17.9)^2 = 320.4$	$65.5 \times 17.9 = 1172.5$
Σ	979.7	62356.9	287.5	5654.5	18640.4

From the table

$\Sigma P = 979.7$

$(\Sigma P)^2 = (979.7)^2$

$= 959812$

$\Sigma P^2 = 62356.9$

$\Sigma R = 287.5$

$(\Sigma R)^2 = (287.5)^2$

$= 82656$

$\Sigma R^2 = 5654.5$

$\Sigma PR = 18640.4$

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P)^2}$$

$$= \frac{16(18640.4) - (979.7)(287.5)}{16(62356.9) - (959812)}$$

$= 0.4376$

$$b = \frac{\Sigma R - a\,\Sigma P}{N}$$

$$= \frac{287.5 - (0.4376 \times 979.7)}{16}$$

$= -8.826$

Hence the equation $R = aP + b$

$= 0.4376P - 8.826$

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(b) By empirical equations and tables

So many empirical equations while used to measure the run-off

(1) Run-off coefficient:-

~~coefficient~~ Co-efficient
strength

→ Any body moving in one direction the opposite forces are acting. That body while forces will act in opposite direction

Ex:- You are riding a bike on road maintain the speed 60 kmph opposite wind force will acting. Some less percent of resistance.

You are riding a lorry on same road and same speed some extra wind force will acting because space will be increasing

Like that you are passing water in smooth surface some less resistance. Rough surface some passing water in roughed surface some more resistance, after that pore in earth surface some extra more resistance. Like that quantity of water will be more means resistance force also will be more

The run off coefficient naturally depends upon all the factors like wind speed, climatic factors, temperature etc

This method is used only for small water control project, and should not be used analysis of major storms

The run off and the rainfall can be inter-related by run-off coefficient can be expressed as

$$R = KP$$

where R = run-off in cm P = rainfall in cm

K = run-off coefficient

The values of K changed depending upon the area is given below

Area	K
urban: residentials: single Houses	0.3
Garden apartments	0.5
commercial and Industrial.	0.9
Forest areas, depending on soil.	0.05–0.2
Parks, farm land, pasture (an area of land with grass where animals can feed)	0.05–0.3
Asphalt (or) concrete pavement	0.85

Barlow's table:-

T.G Barlow (1912) carried out studies of catchments under 1140 sq km in the united provinces (U.P) and gave the following values of K (in percentage) for various classified catchments.

Barlow's Table

[Draw table pg No 158 in BC Punmia]

Class	Description of catchment	Run off per cent
A	Flat, cultivated and black cotton soils	10
B	Flat partly cultivated; various soils	15
C	Average	20
D	Hills and plains with cultivation	35
E	very hilly and steep, with any hardly any cultivation	45

The above values of run-off percentage are for average monsoons (climate normal)

These values (below values) can multiplied according to the nature of season.

Nature of season	Class of catchment				
	A	B	C	D	E
(1) Light rain (upto 25 mm/day) no heavy down pour	0.7	0.8	0.8	0.8	0.8
(2) Average or varying rain fall (25–75 mm/day) no continuous down pour	1.0	1.0	1.0	1.0	1.0
(3) continuous down pour greater than 75 mm/day	1.5	1.5	1.6	1.7	1.8

(2) Strange's Tables and curves :-

W.L Strange (1928) gave tables and curves for calculating run-off from the rainfall in the plains of south India

The given below table run-off for daily rain-fall and take into account three types of catchments (i.e good, average, bad) and these surface conditions (i.e dry, damp and wet) depending upon the rain.

(3) Ingleis's formula:- C.C Inglis gave the following formulae derived from data collected from 37 catchments in the Bombay presidency

for Ghat areas (western ghats) [Ex:- Thimmala is Ghat road] (up and downs)

$R = 0.85P - 30.5$ (when R and P are in cm)

For Non Ghat areas (plain regions)

$R = 0.00394P^2 - 0.0701P$

(where R and P are in cm)

(4) Lacey's formula:-

$$R = \frac{P}{1 + \frac{304.8\ F}{PS}}$$

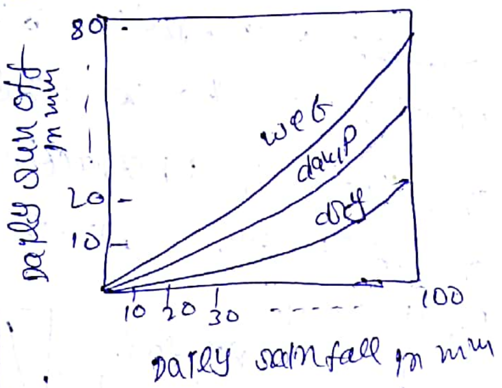
(where P and R in cm)

where S = catchment factor

F = monsoon duration factor.

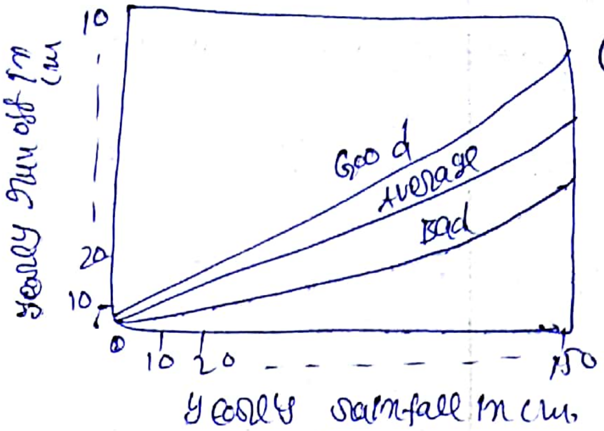
Corresponding to the five classes of catchments defined by Barlow, Lacey gave the following values of the catchment factors S

Class of catchment	value of S
A	0.25
B	0.60
C	1.00
D	1.70
E	3.45



Laceys also devided the monsoon into three class depending upon it's duration and gave the following values of monsoon duration factor.

No	class of monsoon.	Moonsoon Factor (F).
1	very short	0.50
2	standard length	1.00
3	very long	1.50



(5) Khosla's formula

$$R_m = P_m - 0.48\ T_m$$

where

R_m = monthly runoff in cm.

T = mean temperature in °C on entire catchment

P_m = monthly precipitation in cm.

The temperature is introduced in the formula. takes in to account various factors affecting losses by evaporation transpiration, sunshine and wind velocity

(6) ICAR formula (For Nilgiri hills)

$$R = 1.511\ (P^{1.44})\ (T_m)^{-1.34}\ (A^{-0.0613})$$

where A = watershed area km²

P and R = annual rainfall in cm

(7) Dhir, Ahuja and Majumdar formula:-

R = 120 P – 4945 (for chambal, Rajasthan)

R = 435 P – 17200 (for tapi, Gujrat)

R = 13400 P – 575000 (for Damodar valley, west Bengal)

$R = 34.6P - 1510$ (for Tawa, M.P)

$R = 13.18 P + 86.5$ (for Machakund, A.P)

(8) UP Irrigation Research Institute formula:-

$R = 15.45 P^{0.6}$ (for Ganga, Haridwar)

$R = 0.35 P^{1.1}$ (for Yamuna at Tejewala)

$R = 2.7 P^{0.8}$ (for Sarda at Bana Basa)

(C) Run-off By Infiltration method:-

Infiltration:- Infiltration is defined as the movement of water through the soil surface. in to the ~~so~~ below soil mass is called as infiltration

The capacity of any soil to absorb water from rainfall continuously. and infiltration rate will be decreases with minimum ~~rate of~~ infiltration water is reached.

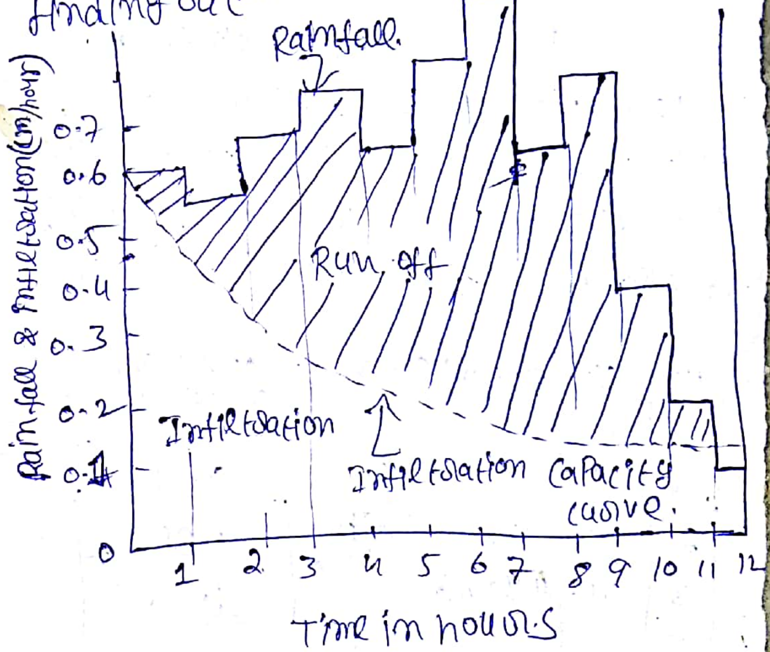
Ex:- Eat meals. 1 person will be eat 3 plates of meals at capacity. so first 2 plates will eat fastly remaining 1 plate will eat slowly. so same like. soil absorption capacity was 10 liters first 8 liters will absorb very fastly. remain 2 liters will absorb slowly. depending upon time.

→ But any instant means any condition (like heat, dry, damp) the soil which allows maximum rate of water will enters into the soil.

→ The exact infiltration rate is the rate ~~at~~ which water actually enters the soil during a storm. that is called as exact infiltration capacity of soil

→ The infiltration capacity of soil. can be determined by experimentally by plot the rainfall rates excessive infiltration capacity of soil. and measuring surface run-off

For small areas having uniform. ~~runoff~~ infiltration. run off can be calculated. to the total volume of rainfall by substracting the, volume of infiltration run-off you can finding out.



Ex:- you are buying a 1lt water bottle in 1 ltr water bottle you are drinking some water 1 person will come and ask how much amount of water you are drinking, so drinking water you can measuring not possible so you can measure the remaining water on bottle and substract the total water (1 ltr) so drinking water you can finding out same like procedure apply here. but here measure how much of water rains falling and how much of water is infiltrated substract of these two Run off you can finding out.

→ But above procedure will measure only infiltration loss of water but water will loss evaporation & transpiration also having so they introduced as infiltration Index.

Infiltration Index:-

Infiltration index is the average rate of loss ~~such that~~ (evaporation, transpiration) After finding out all the losses remaining excess amount of volume of water equal to the volume of direct runoff.

But estimating of runoff value from large areas heterogeneous infiltration (un uniform infiltration) loss so the losses can be calculated as by using infiltration. indices

These are two types of infiltration indices

(i) Average infiltration rate (or) W-index

(ii) ϕ-index.

(i) W-index:-

The W-index is calculated from the expression

$$W_i = \frac{P-R-S_R}{t_r} \quad cm/hr$$

where

S_R = surface retention

t_r = duration of rainfall in hours

(or)

$$W_i = \frac{P-Q}{t_r}$$

where P = total precipitation

Q = total run off

(ii) ϕ- index :-

The ϕ- index is defined as the average rate of rain fall

It means in 1st hour 2cm of rain fall in 2nd hour 4 cm of rain fall 3rd hour 5 cm of rain fall is having. The average of total rain fall volume equal to the run-off volume. Alternatively (or) in other words it can also defined as the average rate of loss of volume of rain fall in excess of that rate will be equal to volume of direct run off.

The run off volume above ϕ index is usually known as rain fall excess (or) effective rain fall

It means the rain water after infiltration above the ground having water after infiltration that water is known as excessive (or) effective rain fall.

$$\phi_i = \frac{P-R}{t_r}$$

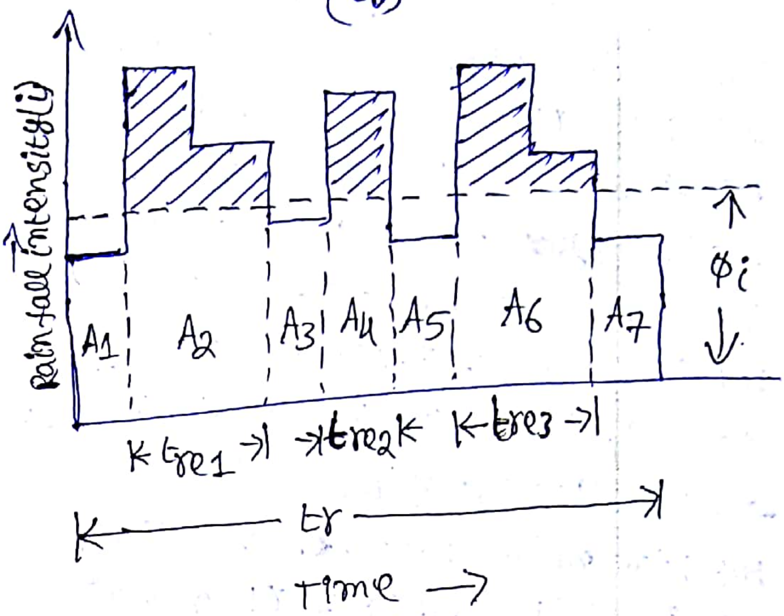
Thus we find that w-index equal to ϕ-index - surface retention (SR)

It means w-index equal to ϕ index minus average rate of retention by interception and depression storage and there fall.

$$w_i < \phi_i$$

$$\phi_i = \frac{\text{Total infiltration during periods of rain fall excess}}{\text{Total period of rain fall excess } (t_{re})}$$

(or)



$$\phi_i = \frac{A_2 + A_4 + A_6}{t_{re1} + t_{re2} + t_{re3}}$$

where A_2, A_4, A_6 are infiltration during periods of rain fall excess

$t_{re1}, t_{re2}, t_{re3}$ are individual periods of rainfall excess

and

$$w_i = \frac{A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7}{t_r}$$

where t_r = total period of rain fall.

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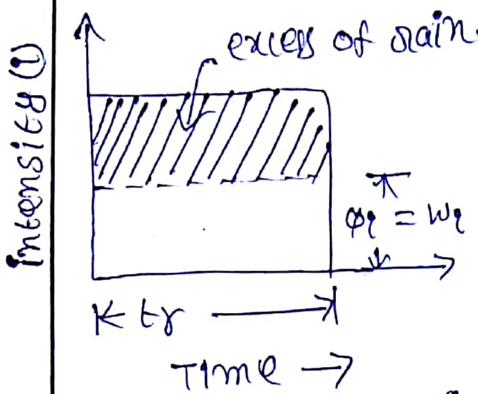
However if there is uniform rain ϕ_i and w_i would be equal.



In this case approximate index value must be derived by correlation. (connection b/w two are more things) with those factors which determine index at any time.

On this method, run off and rainfall are both are inter related (correlated) the infiltration index can be used to estimate the run off coefficient (k) from the relation,

$$k = \frac{i - w_i}{i}$$

where i = intensity of rainfall (cm/hr)

After finding of run off coefficient (k) will be used to estimate the run off as a percentage of rainfall by the relation.

$$R = kP$$

The central water commission (cwc) gave the following equation on the basis of rainfall and run-off the co-relation, for determination of ϕ index

$$R = \alpha (i)^{1.2}$$

$$\phi_i = \frac{i - R}{24}$$

where R = run off in cm. from 24 hours rainfall

i = intensity of rainfall in cm/day

α = a coefficient depends upon the type of soil

S.N	soil type.	α
1	sandy soil and sandy loam	0.17 to 0.75
2.	coastal alluvium & silty loam	0.25 to 0.34
3	Red soils, clayey loam, grey and brown alluvium	0.42.
4	Black-cotton and clayey soils	0.42 to 0.46
5	Hilly soils	0.46 to 0.5

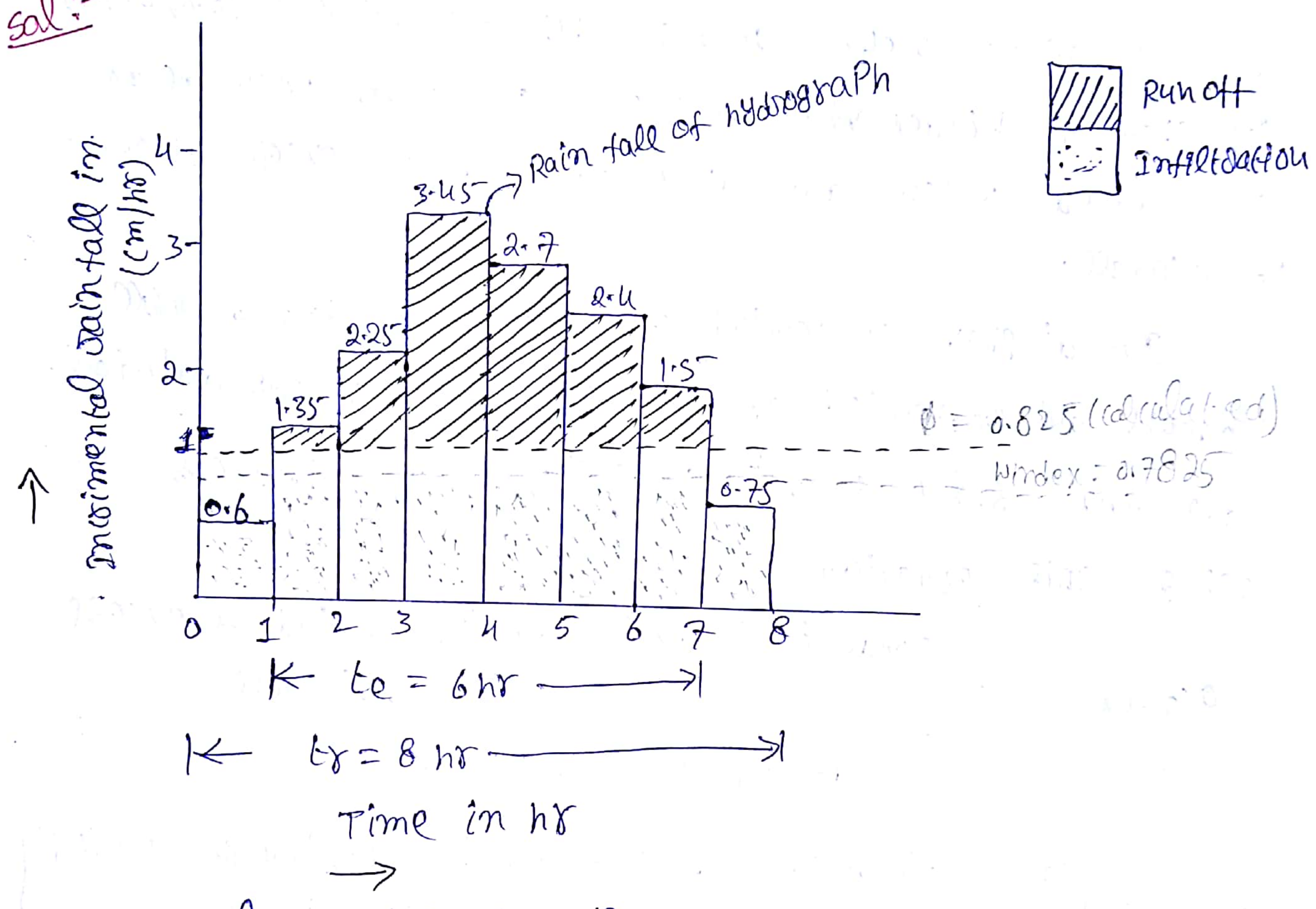
Pg No 384 (S.K. garg) UNIT - III (Problems for Infiltration method 3)

(1) A storm with a 15.0 cm precipitation produced a direct run off of 8.7 cm. The time distribution of the storm is as follows

Time from start in hr	1	2	3	4	5	6	7	8
Incremental rainfall in each hour in cm	0.6	1.35	2.25	3.45	2.7	2.4	1.5	0.75

Estimate the ϕ index of the storm.

Sol:-



Total precipitation (P) = 15.0 cm

Total run off (Q) = 8.7 cm ✓

$$W_{index} = \frac{P - Q}{t_r}$$

$$= \frac{15 - 8.7}{8} \frac{cm}{hr} \qquad [\because t_r = \text{rainfall time} = 8\,hr]$$

$$= 0.7875 \ cm/hr$$

since we know that one relation ship $W_{index} < \phi_{index}$

so ϕ_{index} has to be ~~some~~ more than W_{index} It means ϕ_{index} value is more than W_{index} value

so we can understand that 1st hour rainfall and 8th hour rainfall intensity will be less It means these two hours no excess of rainfall occur because these two rainfalls (0.6, 0.75) less than of W_{index} value 0.7875 so W_{index} below all are infiltrated water and above values all are excess amount of rainfall.

In diagram the period of t_r ~~mea~~ means total rainfall. 8 hours and the period of t_e means excess of total rainfall. 8hr − 2hr = 6hr excess rainfall occurs so in that case using this equation

$$\phi_{index} = \frac{\text{Total infiltration during period of excess rain fall}}{\text{period of rainfall excess}}$$

$$= \frac{\left[\text{Total infiltration} - \text{Infiltration during the period when no excess rain occur}\right]}{t_e}$$

$$= \frac{(15 - 8.7) - (0.6 + 0.75)}{6} \frac{cm}{hr}$$

4

$$= \frac{6.3 - 1.35}{6} \frac{cm}{hr}$$

$$= \frac{4.95}{6} = 0.825 \text{ cm/hr}$$

so The ϕindex value of line marked as a straight line. in fig. W index also markd as a straight line. in fig.
The ϕ index below ~~value~~ rainfall all are infiltrated water. above values all are excess amount of rain fall.

Hence

ϕindex = 0.825 cm/hr

Check:- Hatched area in fig is runoff which is calculated as

$[\because R = \Sigma (i - \phi i) t]$

$$R = (1.35 - 0.825) 1 hr + (2.25 - 0.825) 1 hr + (3.45 - 0.825) 1 hr + (2.7 - 0.825) 1 hr + (2.4 - 0.825) 1 hr + (1.5 - 0.825) 1 hr$$

$$= 0.525 + 1.4252 + 2.625 + 1.875 + 1.575 + 0.675 \quad [\because cm/hr \times hr]$$

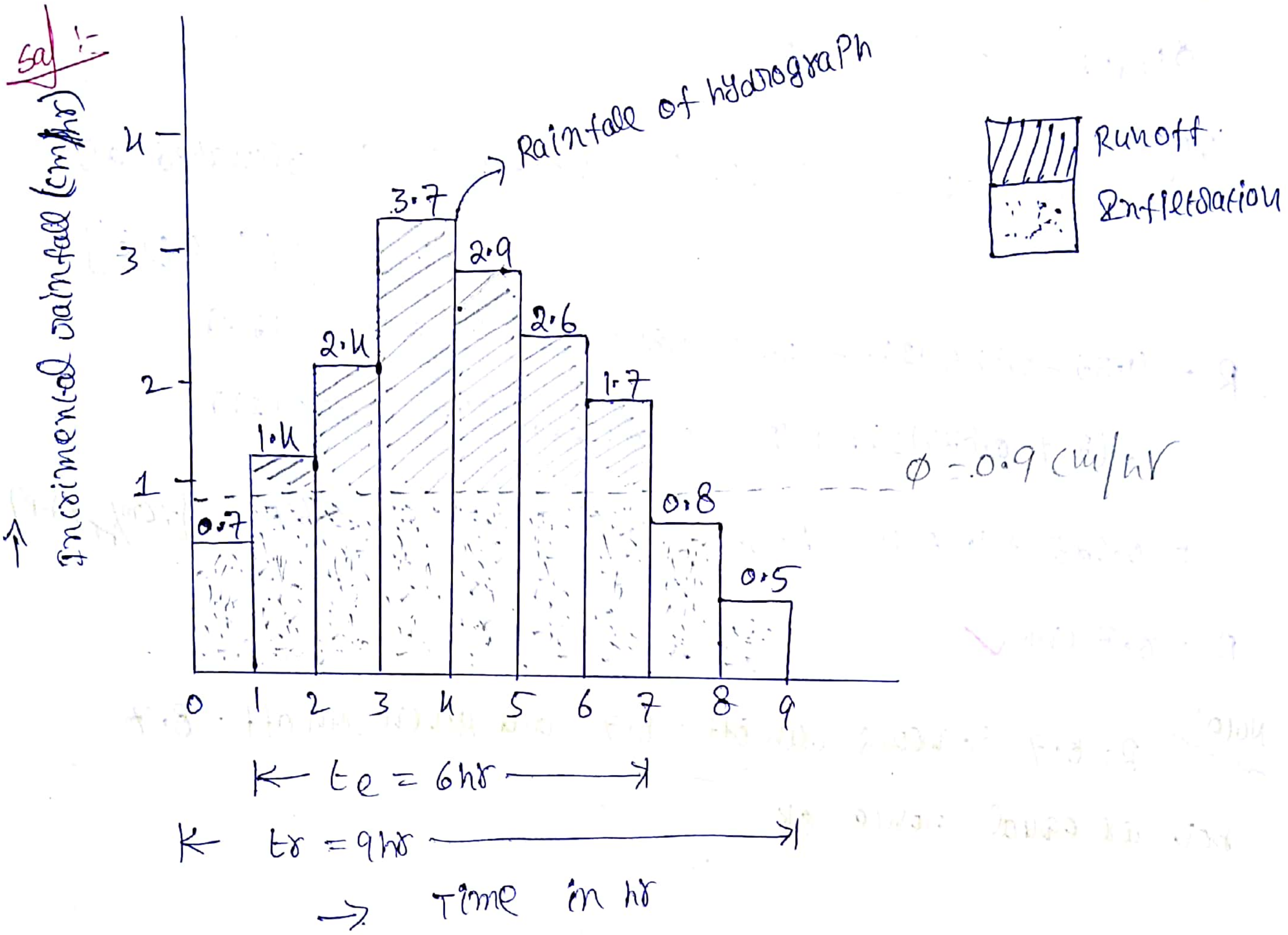
R = 8.7 cm. ✓

Note:- R = 8.7 it means run off = 8.7 and given run off = 8.7 both are equal Hence ok

(2) Table below gives the time distribution of rainfall lasting (చాలా సంవత్సరాలు) many years for nine hours. If the direct runoff is 9.3 cm determine the ϕ index of the storm and time of rainfall excess?

Time from start (h)	1	2	3	4	5	6	7	8	9
Incremental rainfall in each hour (cm)	0.7	1.4	2.4	3.7	2.9	2.6	1.7	0.8	0.5

Sol :-



Total precipitation (rainfall) $= 0.7 + 1.4 + 2.4 + 3.7 + 2.9 + 1.7 + 0.8 + 0.5$

$= 16.7$ cm

Total run off (Q) = 9.3 cm

$$W_I = \frac{P-Q}{t_r}$$

$$= \frac{16.7-9.3}{9} \frac{cm}{hr}$$

$$= 0.822 \ cm/hr$$

since we know that our relation ship windex < φindex.
so φindex has to be more than windex it means φindex value is more than windex value

so we can understand that 1st, 8th and 9th hour rain fall intensity will be less it means these three hours no excess of rain fall occur because these three values (rainfall values) (0.7, 0.8, 0.5) less than the windex values 0.822 so windex. below all are infiltrated water and above values all are. excess amount of rainfall

In diagram the period of tr means total rainfall 9 hours and the period of te means excess of ~~tot~~ total rain fall 9 - 3 = 6 hours excess rain fall occur so in this case using this equation

$$\phi index = \frac{\text{Total infiltration during period of excess rain fall.}}{\text{Period of rainfall excess}}$$

$$= \frac{\left[\text{Total infiltration} - \text{Infiltration during the period when no excess rain occur}\right]}{te}$$

$$= \frac{(16.7 - 9.3) - (0.7 + 0.8 + 0.5)}{6} \frac{cm}{hr}$$

$$= 0.9 \ cm/hr$$

So the φindex value of the line marked as a straight line. In fig ~~W index~~ the φindex below values of rainfall are infiltrated water above values all are excess amount of rain-fall.

Hence

$$\phi index = 0.9 \ cm/hr$$

Check:-

Hatched area in fig is run off which is calculated as

$[\because R = \Sigma(i - \phi i)t]$

$$R = (1.4 - 0.9)1 + (2.4 - 0.9)1 + (3.7 - 0.9)1 + (2.9 - 0.9)1 + (2.6 - 0.9)1 + (1.7 - 0.9)1 \ hr$$

$$= 0.5 + 1.5 + 2.8 + 2 + 1.7 + 0.8$$

$$= 9.3 \ cm \qquad [\because cm/hr \times hr]$$

Note:- $R = 9.3$ It means run off $= 9.3$ cm. and given in problem run off $= 9.3$ cm both are equal Hence check ok

=

(3) (Pg No 386 SK garg) 6

A catchment area of 30 km^2 has one recording gauge during a storm, the following mass curve of rainfall was recorded.

Time from start of storm (hr)	0	2	4	6	8	10	12	14
Accumulated rainfall (collection of rainfall) (mm) — Just means	0	6	17	57	70	81	87	90

If the volume of the runoff due to the storm measured $1.2 \times 10^6\ m^3$ estimate the ϕ index of the catchment ?

Sol:- Total run off (as volume) (V) = $1.2 \times 10^6\ m^3$

Catchment Area (A) = $30\ km^2$

$= 30 \times 10^6\ m^2$

1 kilo = 1000 mm

$km^2 = (km)^2$

$= k^2 m^2$

$= (1000)^2\ m^2$

$= (10^3)^2\ m^2$

$= 10^6\ m^2$

Total run off (Q) = $\frac{\text{Total run off volume (V)}}{\text{catchment area (A)}}$

$= \frac{1.2 \times 10^6\ m^3}{30 \times 10^6\ m^2}$

$= 0.04\ m$

$= 0.04 \times 1000\ mm$

$= 40\ mm$

1 m = 100 cm

= 1000 mm.

Total rainfall (P) = Accumulated rainfall difference in table.

$= (6-0) + (17-6) + (57-17) + (70-57) + (81-70) + (87-81) + (90-87)$

$= 6 + 11 + 40 + 13 + 11 + 6 + 3$

$= 90\ mm.$

$$W_{index} = \frac{P - Q}{t_r}$$

$$= \frac{90 - 40}{14}$$

$$= \frac{50}{14} \frac{mm}{hr}$$

$$= 3.57\ mm/hr$$

t_r = Total rainfall time. see in table. = 14 hr

$\left[\because \phi_{index} = \frac{90-40}{12} = 4.1\right]$

since we know that relationship $W_{index} < \phi_{index}$.

It means ϕ_{index} value little bit more than W_{index} value. 3.57 mm/hr

~~but~~ There by causing infiltration to the ground in every 2 hr interval. so ~~some water~~ it is more than 2×3.57 mm/hr = 7.14 mm/hr.

so W_{index} value = 7.14 mm/hr. The incremental rain falls in different 2 hr intervals are now worked out in the table below.

Time from start of storm in (hr)	Accumulated rainfall in (mm)	Incremental rainfall during each interval. in mm
0	0	
2	6	6 − 0 = 6 ✓
4	17	17 − 6 = 11
6	57	57 − 17 = 40
8	70	70 − 57 = 13
10	81	81 − 70 = 11
12	87	87 − 81 = 6 ✓
14	90	90 − 87 = 3 ✓
		$\Sigma P = 90$ mm.

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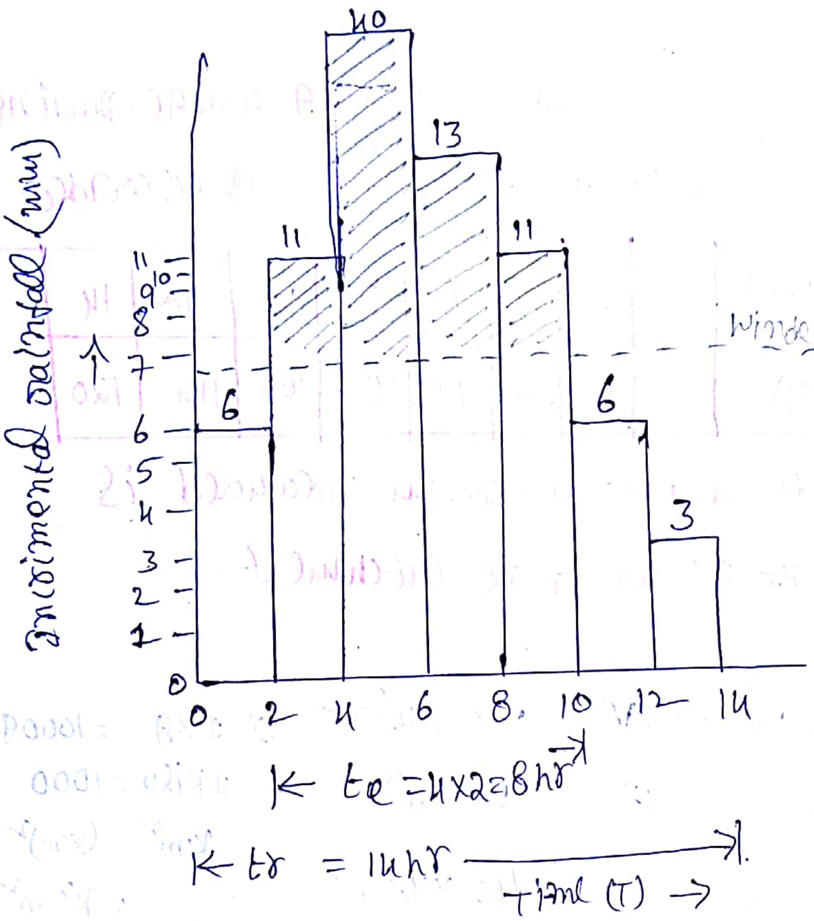
so we can understand that the incremental rainfalls are 7 intervals (7 values) in 7 intervals out of 3 intervals (3 values) below the W_{index} value it means 3 values are below ϕ_{index} value why because we know that relation $W_{index} < \phi_{index}$ (index values all are below ϕ index values.)



since W_{index} is below the ϕ_{index} so W_{index} value 7.14 mm/hr below all are infiltrated water and above values all are excess amount of rainfalls so the excess rain ~~must be~~ falls occur only 4 intervals each interval having 2hr so $4 \times 2hr = 8$ hours Hence $t_e = 8$ hours

so

$$\phi_{index} = \frac{\text{Total infiltration during the period of excess rainfall}}{\text{Period of rain fall excess}}$$

$$= \frac{\left[\text{Total infiltration} - \text{Infiltration during period when no excess rain occurs}\right]}{t_e}$$

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$$= \frac{(90-40)\,mm - (6+6+3)\,mm}{2\times 4\ hr}$$ [∵ 6+6+3 values are below 7.14 mm/hr window]

$= 35/8\ mm/hr$

$= 4.375\ mm/hr$

(Pg No 166 BC Punmia)

4) A catchment area of 40 km² has one recording gauge. During a storm, the following mass curve of rainfall was recorded.

Time from start of rainfall (hr)	0	2	4	6	8	10	12	14
Accumulated rainfall (mm)	0	8	22	74	92	105	114	120

If the value of run off due to the storm measured is $2.0\times10^6\ m^3$, estimate the ϕ index of the catchment.

Sol :-

Total run off (as volume) (V) $= 2.0\times10^6\ m^3$

Catchment area (A) $= 40\ km^2$

$= 40\times10^6\ m^2$

[∵ 1 kg = 1000 g, 1 kilo = 1000, $km^2 = (km)^2 = k^2m^2 = (1000)^2m^2 = (10^3)^2m^2 = 10^6\ m^2$]

$$\text{Total run off } (Q) = \frac{\text{Total run off value } (V)}{\text{Catchment area } (A)}$$

$$= \frac{2.0\times10^6\ m^3}{40\times10^6\ m^2}$$

$= 0.05\ m$

$= 0.05\times1000\ mm$

$= 50\ mm$

[∵ 1 m = 100 cm = 1000 mm]

Total rainfall (P) = Accumulated rainfall difference on table. 8

$$= (8-0) + (22-8) + (74-22) + (92-74) + (105-92) + (114-105) + (120-114)$$

$$= 8+14+52+18+13+9+6$$

$$= 120 \text{ mm}$$

~~so we can under standard that the Incrimental rainfall are~~

$$W_{index} = \frac{P-Q}{t_r}$$

$$= \frac{120-50}{14}$$ [$\because t_r$ = total rainfall time. see in table = 14 hr]

$$= \frac{70}{14} \frac{mm}{hr}$$

$$= 5 \text{ mm/hr}$$

since we know that relation ship $W_{index} < \phi_{index}$. It means ϕ_{index} value little more than W_{index} value. 5 mm/hr There by causing infiltration to the ground in every 2hr intervals so It is more than $2 \times 5 = 10$ mm/hr

so W_{index} value = 10 mm/hr. the incrimental rainfalls in different 2hr intervals are now worked out in the table below.

Time from the start of storm (hr)	Accumulated rainfall (mm)	Incremental rainfall during each interval (mm)
0	0	
2	8	8 − 0 = 8 mm.
4	22	22 − 8 = 14
6	74	74 − 22 = 52
8	92	92 − 74 = 18
10	105	105 − 92 = 13
12	114	114 − 105 = 9
14	120	120 − 114 = 6
		$\Sigma P = 120$ mm.

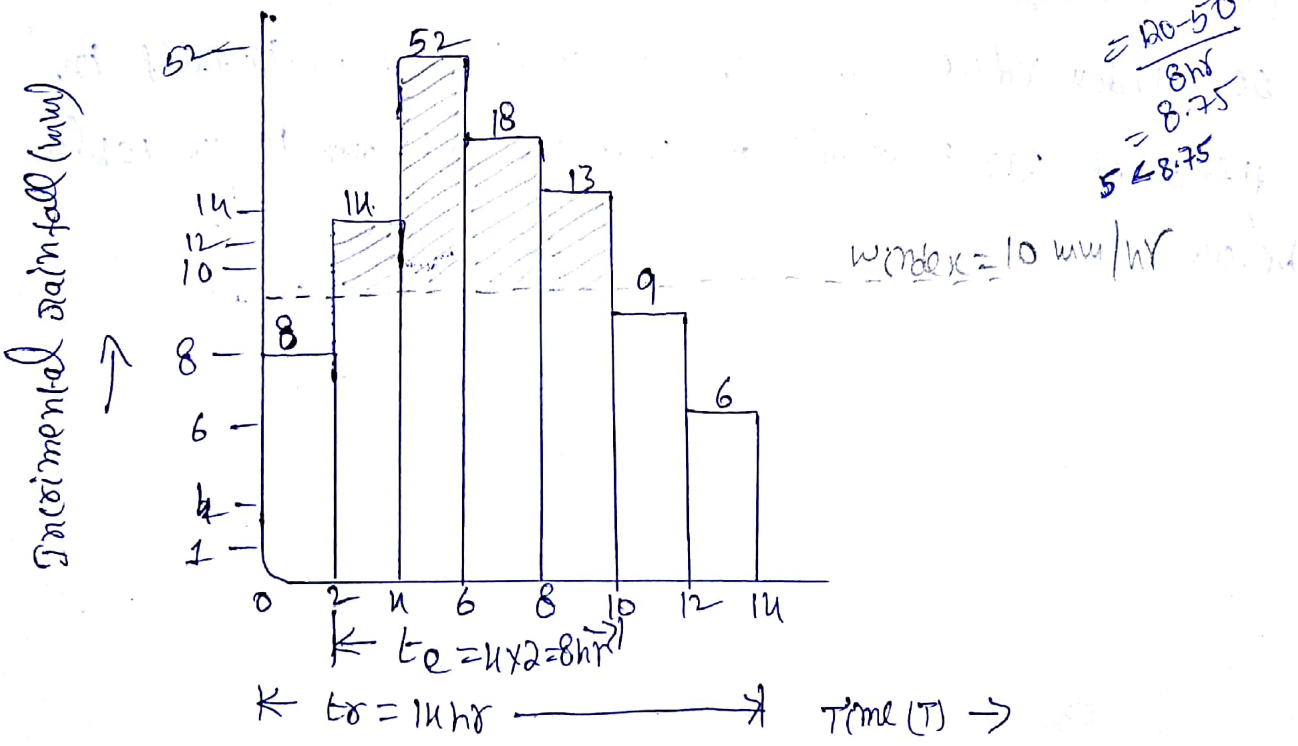
so we can understand that the Incrimental rainfall are 7 intervals (7 values) in 7 intervals out of 3 intervals (3 values) below the windex values. It means 3 values are below ϕindex values because why we know that relation windex < ϕindex (windex values all are below ϕindex values)

$\phi_{index} = \frac{P-Q}{t_e}$

$= \frac{120-50}{8hr}$

$= 8.75$

$5 < 8.75$



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since W index is below φ index so W index value ~~7~~ 10mm/hr 9 below all are infiltrated water and above all are excess amount of rainfall. so excess rainfall ~~must be~~ occur only 4 intervals each interval having 2hr so $4 \times 2\,hr = 8$ hours Hence $t_e = 8$ hours

so

$$\phi\ index = \frac{\text{Total infiltration during the period of excess rainfall}}{\text{Period of rainfall excess}}$$

$$= \frac{\left[\text{Total infiltration} - \text{Infiltration during period when no excess rain occurs}\right]}{t_e}$$

$$= \frac{(P-R) - (8+9+6)}{2 \times 4\,hr}$$

$$= \frac{(120-50) - (8+9+6)}{8\,hr} \Rightarrow \frac{47}{8}\frac{mm}{hr}$$

$$\Rightarrow 5.88\ mm/hr$$

Pg NO 166 (B C Punmia)

(5) The rate of rainfall for successive 30 minutes periods of a 4 hours storm are as follows

3.5, 6.5, 8.5, 7.8, 6.4, 4.0, 4.0, 6.0 cm/hr

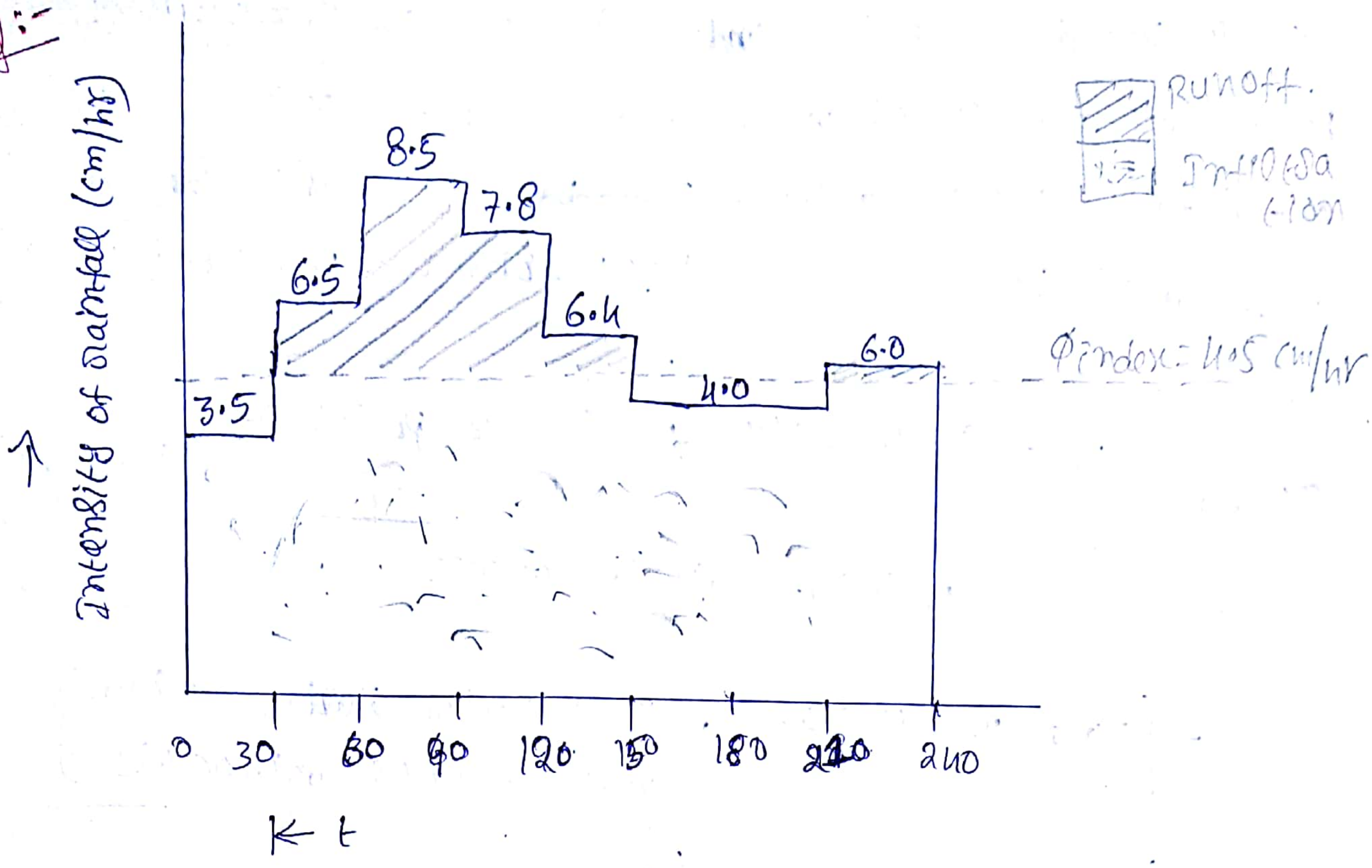
Taking a value of φ index as 4.5 cm/hr compute the following.

(a) Total rain fall.

(b) Total rain fall excess and.

(c) W index

Sol :-



(a) Total rainfall. (P) $= 3.5 \times \frac{30}{60} + 6.5 \times \frac{30}{60} + 8.5 \times \frac{30}{60} + 7.8 \times \frac{30}{60}$

$+ 6.4 \times \frac{30}{60} + 4.0 \times \frac{30}{60} + 4.0 \times \frac{30}{60} + 6.0 \times \frac{30}{60}$

$(P) = (3.5 + 6.5 + 8.5 + 7.8 + 6.4 + 4 + 4 + 6)\ cm/hr \times \frac{30}{60}\ hr$

[∵ 30 min = ½ hour

30 min $= \cancel{30} \times \frac{1}{\cancel{60}_2}$ hr

= ½ hour.

So 30 min $= \left(\frac{30}{60}\right)$ hr]

[In problem they will ask cm/hr so we can convert in hours]

= 23.35 cm

(b) Total excess rainfall = Hatched area

Excess rainfall = Run off of the rain.

[∵ R = Q = Runoff]

$R = \Sigma(i - \phi i)t$

$R. = (6.5 - 4.5)\frac{30}{60} + (8.5 - 4.5)\frac{30}{60} + (7.8 - 4.5)\frac{30}{60} + (6.4 - 4.5)\frac{30}{60}$

$+ (6.0 - 4.5)\frac{30}{60}$

$= [(6.5-4.5)+(8.5-4.5)+(7.8-4.5)+(6.4-4.5)+(6.0-4.5)] \frac{30}{60}$

$= 12.7 \ cm/hr \times \frac{30}{60} hr$

$= 6.35 \ cm.$

(c) $W_{index} = \frac{P-Q}{t_r}$

$= \frac{23.35-6.35}{(30-0)+(60-30)+(90-60)+(120-90)+(150-120)+(180-150)+(210-180)+(240-210)}$

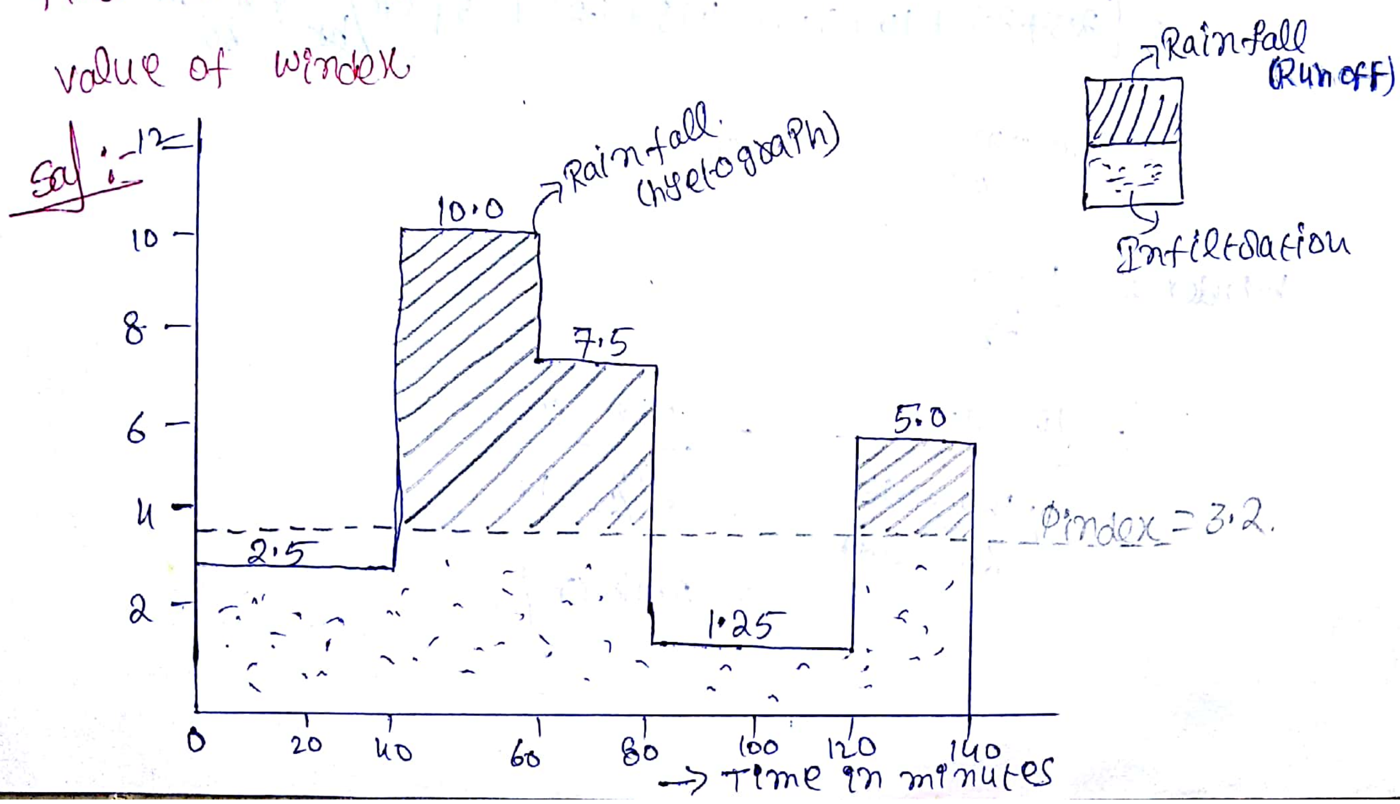
$= \frac{23.35-6.35}{240 \ minutes}$

$= \frac{23.35-6.35 \ cm.}{4 \ hr} = 4.25 \ cm/hr$

(PG NO 382 SK garg)

(6) The following are the rates of rainfall for successive 20 minutes period of a 140 minutes storm 2.5, 2.5, 10.0, 7.5, 1.25, 1.25, 5.0 cm/hr Taking the value of ϕindex as 3.2 cm/hr find out the net run off in cm, The total rainfall and the value of Windex

Sol :-



Total runoff means excess amount of water It means hatched area in the diagram.

[∵ In Problem ask cm/hr]

Total runoff (R) = $(i - \phi_i)t$

[∵ R = Q = Runoff]

$$= (10-3.2)\frac{20\text{ min}}{60\text{ min}} + (7.5-3.2)\frac{20}{60} + (5-3.2)\frac{20}{60}$$

$$= 6.8 \times \frac{20}{60} + 4.3 \times \frac{20}{60} + 1.8 \times \frac{20}{60}$$

[∵ 0 to 20 = 20 min.
20 to 40 = 20 min
difference 20 min
converted in hours
20 min = 1/3 hr
$= \frac{20}{60} = 1/3$ hr
20 min = $\frac{20}{60}$ hr]

$$= (6.8 + 4.3 + 1.8)\frac{20}{60}$$

$$= 12.9 \text{ cm/hr } \frac{20}{60} \text{ hr}$$

$$= 4.3 \text{ cm.}$$

Total precipitation (P) $= 2.5 \times \frac{20}{60} + 2.5 \times \frac{20}{60} + 10 \times \frac{20}{60} + 7.5 \times \frac{20}{60}$

$$+ 1.25 \times \frac{20}{60} + 1.25 \times \frac{20}{60} + 5 \times \frac{20}{60}$$

$$= [2.5 + 2.5 + 10 + 7.5 + 1.25 + 1.25 + 5] \text{ cm/hr} \times \frac{20}{60} \text{ hr}$$

$$= 30 \times \frac{20}{60} \Rightarrow 10 \text{ cm}$$

W index $= \dfrac{P - Q}{t_r}$

$$= \frac{10 - 4.3}{\left(\frac{140 \text{ minutes}}{60}\right) \text{1 hour}} = \frac{5.7 \text{ cm.}}{(140/60) \text{ hr}}$$

$$= 2.44 \text{ cm/hr}$$

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(PgNo 163 BC Pumnia)

(7) The rain fall rates for successive 30-minutes intervals upto 4 hours are given below. The surface run off is 3.6 cm, determine ϕ and w indices

Time (minutes)	0	30	60	90	120	150	180	210	240
Rain fall intensity (cm/hr)	0	1.3	2.8	4.1	3.9	2.8	2.0	1.8	0.9

Sol :-

[∵ In this problem were given rainfall intensity so intensity formula will be using]

(a) computation of ϕ index.

$$R = \Sigma(i - \phi_i)t$$

where i = intensity of rain fall cm/hr

t = time in hours

we know that relation $w_i < \phi_i$

so Assuming ϕ_i value greater than 1.3 cm/hr and less than 1.8 cm/hr

Note:- Just imaging ϕ_i value is will be 1.3 above and 1.8 below. between these two values ϕ_i value will be having.

so ϕ_i means excess amount of rain fall. excess amount of rain fall will be in Run off. so ϕ_i below values all are Infiltrated water so 0, 1.3 and 0.9 leave these 3 values why because ~~R = Σ(i − φi)~~ these 3 values are below ϕ_i values

$$R = \Sigma(i - \phi_i)t$$

$$3.6 = (2.8 - \phi_i)\frac{30}{60} + (4.1 - \phi_i)\frac{30}{60} + (3.9 - \phi_i)\frac{30}{60} + (2.8 - \phi_i)\frac{30}{60}$$

$$+ (2.0 - \phi_i)\frac{30}{60} + (1.8 - \phi_i)\frac{30}{60}$$

$$3.6 = \left[(2.8-\phi_i)+(4.1-\phi_i)+(3.9-\phi_i)+(2.8-\phi_i)+(2.0-\phi_i)+(1.8-\phi_i)\right]\frac{30}{60}$$

Per hour means 1 hour

$\phi_i = 1.7$ cm/hr

since this is greater than 1.3 cm/hr and less than 1.8 cm/hr

The above computations is correct

$R = \Sigma(i-\phi_i)t$

R = Runoff cm.

ϕ_i = intensity of rainfall cm/hr.

$\frac{R\,(cm)}{t} = (i-\phi_i)$

[$\because$ i = cm/hr and ϕ_i = cm/hr]

(b) computation of w-index

$$w_i = \frac{P-R-S_R}{t_r}$$

[$\because$ S_R = surface retention = 0]

$$\text{Total rainfall } (P) = (0+1.3+2.8+4.1+3.9+2.8+2.0+1.8+0.9)\frac{30}{60}$$

$$= 19.6 \text{ cm/hr} \frac{30}{60} \text{ hr}$$

$$= 9.8 \text{ cm.}$$

R = 3.6 cm given in problem $S_R = 0$ and $t_r = 4$ hr

t_r = Total rain fall time.

= 240 minutes.

= 4 hours

[$\because$ 1 hour = 60 minutes
4 hours = 4×60 minutes
= 240 minutes]

$$w_i = \frac{9.8-3.6-0 \text{ cm}}{4 \text{ hr}}$$

$$= 1.55 \text{ cm/hr}$$

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(8) The average rainfall over 45 hectare of watershed for a particular storm was as follows

Time (hr)	0	1	2	3	4	5	6	7
Rainfall (cm)	0	0.5	1.0	3.25	2.5	1.5	0.5	0

The volume of runoff this storm was determined as 2.2 ha-m. Establish the ϕ index?

Sol:- Given that

$[\because 1 \text{ hectare} = 10^4 m^2]$

Volume of runoff $(V) = 2.2$ ha-m.

$= 2.2 \times 10^4 \, m^3$

Area $(A) = 45$ hectare.

$= 45 \times 10^4 m^2$

Total runoff $R = V/A$

$= \frac{2.2 \times 10^4 \, m^3}{45 \times 10^4 \, m^2}$

$R = 0.048 m.$

$= 0.048 \times 100$ cm.

$= 4.8$ cm.

ϕ index

Trail 1 $\quad R = \Sigma (i - \phi_i) t$ $\quad$ [$\because$ Total rainfall will taken]

$4.8 = [0-\phi_i]1 + (0.5-\phi_i)1 + (1-\phi_i)1 + (3.25-\phi_i)1 + (2.5-\phi_i)1 + (1.5-\phi_i)1 + (0.5-\phi_i)1 + (0-\phi_i)1]$

$4.8 = [(0-\phi_i) + (0.5-\phi_i) + (1-\phi_i) + (3.25-\phi_i) + (2.5-\phi_i) + (1.5-\phi_i) + (0.5-\phi_i) + (0-\phi_i)]1$

$4.8 = 9.25 - 8\phi$

$8\phi = 9.25 - 4.8$

$8\phi = 4.45$

$\phi = 4.45/8$

$$\boxed{\phi = 0.55 \text{ cm/hr}}$$

sin $\phi = 0.54$ cm/hr is larger than first, second, sixth and seventh rainfall.

Trail 2

$R = \Sigma(i - \phi_i)\,t$ [∴ Excess of rainfall only.]

$4.9 = (1.0 - \phi_i)1 + (3.25 - \phi_i)1 + (2.5 - \phi_i)1 + (1.5 - \phi_i)1$

$= [(1.0 - \phi_i) + (3.25 - \phi_i) + (2.5 - \phi_i) + (1.5 - \phi_i)]1$

$4.9 = 8.25 - 4\phi$

$4\phi = 8.25 - 4.9$

$\phi = \frac{3.35}{4} \frac{\text{cm}}{\text{hr}}$

$$\boxed{\phi = 0.83 \text{ cm/hr}}$$

RgNo162 B(Purnia)

(9) A water shed has the following data.

(1) Area of water shed : 82 km^2

(2) Distance between the outlet and further most point : 12.6 km

(3) Total length of channels of various orders : 440 km

(4) Elevation difference between outlet and further most point : 656 m.

(दूरस्थ) (बिंदु)

Determine (a) Drainage density (b) Form factor (c) channel slope and (d) Average over land flow length

sol :-

(a) Drainage density $(D_d) = \frac{\text{Total channel length}}{\text{Area of basin}}$

$= \frac{440}{82} = 5.37\ \cancel{km}/\cancel{km^2}$

$= 5.37$

(b) Form factor $(F_f) = \frac{A}{L_b^2}$

$= \frac{82}{(12.6)^2} = 0.517\ \frac{\cancel{km^2}}{\cancel{(km)^2}}$

(c) channel slope (S) $= \frac{\Delta H}{L_b}$

$= \frac{656}{12.6 \times 1000} \quad \frac{m}{km}$ [∵ 1 kilo = 1000]

$= 0.05$

(d) Average over land flow length $L_o = \frac{1}{2 D_d}$

$= \frac{1}{2 \times 5.37}$

$= 0.093$ km.

$= 0.093 \times 1000$ m.

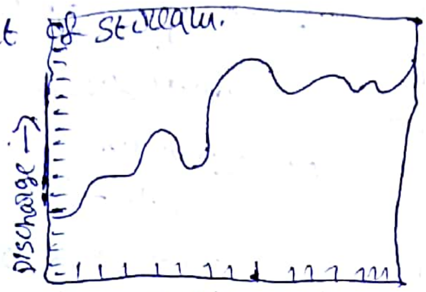
$= 93$ m

(4) UNIT Hydrograph method:-

unit hydrograph is a ~~hydrograph~~ water

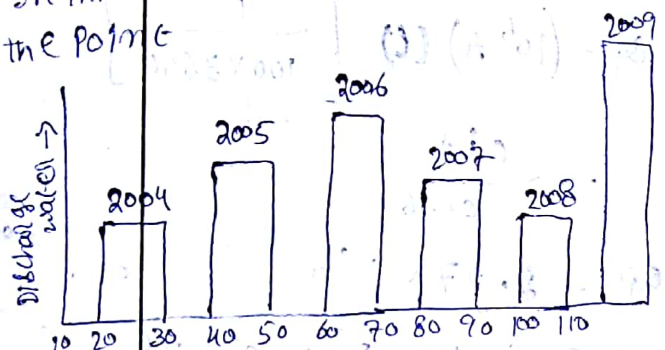
hydrograph:- PG NO 168 (BC Punmia)

A hydrograph is a graph showing variations of discharge with time at a particular point of stream. It shows the time distribution of total runoff at the point of measurement



Ex:-

It means u take one area suppose ongole. u take ~~ongole~~ if u imagine in ongole any one river will be flowing (or) u take vijayawada krishna river in that river 2004 year 10cm rain water is coming. in 2005 20cm rain is coming both are same timings in 2006 25cm and 2007 30cm. rain is coming it means the variation of discharge of water with time at a particular point (it means river flowing various cities but flood is coming mainly from vijayawada) in this water shows total runoff at the point



In simple words 1 stream is flowing in straight direction at some point the stream water will be increase in some points will be decreasing why because the area will be up and downs the water will be rise and fall. minimum level to maximum level at particular time (rain days) at particular points is called Hydrograph.

Unit hydrograph (PG NO 174 BC Punmia)

Unit Hydrograph is a graph representing 1cm (or 1 inch) run off from a rainfall of some unit duration and specific area distribution.

ఒక area లో కొంత వర్షం పడింది ఆ పడిన వర్షం లో 1cm వర్షం పడిన area ని ఆక్రమించడానికి పట్టే time లో 1cm ఆక్రమించే దాని unit hydrograph అంటారు

It means if u take some area in that area. some amount of rain is falling just u imagine we dont no how much amount of area we dont no and how much rain is falling in that area we dont no we know only. I am taking some area in that area some amount rain is falling.

The total amount of rain లో we take 1cm of rain in 1cm of rain falling and this 1cm of rain how much time is taken and how much area will be occupied is called as unit hydrograph.

Suggested values of unit time duration:-

Area of Basin	unit time duration (hours)
>2500 km^2 (1000 $mile^2$)	12 to 24 (Preferably 12)
250–2500 km^2 (100–1000 $mile^2$)	6, 8 or 12
50–250 km^2 (20 $mile^2$)	2
Small areas	one third to one fourth of the time of concentration

(Pg NO 207 B.C.Punmia)

(c) Flood discharge by Rational formula..

~~Rational formula is the~~ various types of emperical equations relations are availabul for finding the flood discharge in these formulas Rational formula is the most rational method (constant method [illegible]) of calculating peak discharge. for small catchments.

In this method calculating the peak discharge for small catchments.

In this method. assumed that the maximum flood flow produced by a certain rainfall intensity which lasts [illegible] for a time equal to or greater than the period of concentration time (t_c)

In method [illegible] maximum flood producing [illegible] area [illegible]

maximum flood [illegible] time period [illegible] maximum flood [illegible]

The maximum rate of runoff. will be coming in watershed at appeay (spreaded the water) entire area.

The runoff is generally. increases from zero to peak ones the water, will be reach in peak point in that point runoff will be constant. and rain fall. duration reaches the maximum concentration (t_c)

then, the runoff will be constant. at peak level.

The peak value of runoff is given by:

$$Q_p = F_u \, C i A$$

where

C = runoff coefficient. It represents ratio of runoff to rainfall.

$$C = \frac{\text{runoff}}{\text{rainfall}}$$

A = catchment area.

i = intensity of rainfall.

F_u = a factor which depends on expression of terms of Q_p, A and i in consistent units

Q_p = Discharge in cubic metres per second

A = catchment area in km^2

i = intensity of rainfall in cm/hour

In order to find corresponding value of factor F_u, we have

$$Q_p = (10^6 A)(C)\left[\frac{i}{100 \times 3600}\right]$$

[∵ Q = CiA

C = constant

i = cm/hr

A = $km^2 \to km^2$ $(1000)^2 m^2$

$Q_p\, m^3/sec = C \dfrac{\frac{1}{100}}{60 \times 60} \dfrac{m}{sec} \times$ i $(1000)^2 m^2$ A

$Q_p\, m^3/s = C \dfrac{i}{100 \times 60 \times 60} \times 10^6 m^2 A$

$$= \frac{CiA}{0.36}$$

$$\therefore Q_p = 2.778 \, CiA$$

Hence factor $F_u = 2.778$

If however "i" is expressed in mm/hour we have

$$Q_p = (10^6 A)(C)\left[\frac{i}{1000 \times 3600}\right]$$

$$= \frac{CiA}{3.6} \quad \therefore Q_p = 0.2778 \, CiA$$

Run off coefficient (C):-

Run off coefficient is a highly critical element.

The purpose of converting average rainfall rate in particular recurrence interval (particular places) same intensity ~~of rainfall converts peak runoff~~

It means less amount of rainfall is falling, result less runoff in that less run off will be converting more peak runoff in particular places why because in that places run off coefficient (reduction coefficient (or) water opposing capacity of soil will be less)

~~The following factors are depending.~~

This depends upon the following factors

(i) antecedent moisture conditions
(ii) ground slope
(iii) ground cover.
(iv) depression storage.
(v) soil moisture.
(vi) Shape of drainage area.
(vii) over land flow velocity.
(viii) intensity of rainfall.
(ix) geology of catchment etc

The value will be generally considered fixed for different areas depending only on the surface type.

Some typical values of "C" are indicated in table 4.28 Pg No 208 (B C Punmia)

Suppose if u take a water shed of total area A is non-homogeneous this water shed will be divided in different areas is divided into different sub areas having different values of "C" (runoff coefficient)

A weighted runoff coefficient (C_w) is computed from the following equation.

$$C_w = \frac{C_1A_1 + C_2A_2 + \cdots C_nA_n}{A_1+A_2+\cdots A_n}$$

$$= \frac{\sum_{J=1}^{J=n} C_J A_J}{A}$$

where

$A_1, A_2, A_3 \ldots A_n$ = areas of sub-zones

$C_1, C_2, C_3 \ldots C_n$ = run off coefficients for the corresponding sub-zones

Rainfall intensity (i):-

The rainfall intensity (i) corresponding to a duration t_c and desired probability of exceedance P (or return period T) is given as the following eq'n

(or)

The relationship between intensity, duration and return period

$$i = \frac{KT^x}{(t+b)^n}$$

where i = intensity of rainfall (cm/h)

Typical values of constants K, x, b and n are given in table 4.8 B C Punmia Pg No 125

SN	Place in India	Values of constants			
		K	b	n	x
1	Bellary	6.16	0.5	0.694	0.972
2	Bhopal	6.93	0.5	0.189	0.878
3	Chandigarh	5.82	0.4	0.160	0.750
4	Nagpur	11.45	1.25	0.156	1.032
5	Raipur	4.68	0.15	0.139	0.928

In the above equation.

$$i = \frac{KT^{x}}{(t+b)^{n}}$$ in this eq/n

't' is the time of concentration. (in-hours)

which can be found from the following formul by Kirpich (1940)

$$t = t_c = 0.000323\, L^{0.77} S^{-0.385}$$

Pg No 210 BC Punmia

Limitations of Rational formula:-

(1) The formula gives good result only for small catchments, having area upto 50 km^2

(2) It is applicable only if the duration of rainfall is equal to (or) more than time of concentration (t_c).

(④) ఇది ఒక time లో [illegible]

(3) The rainfall intensity (i) should be constant over entire catchment area during the time of rainfall.

(4) It assumes constant value of 'C' for given area for all storms

(5) If plot a graph b/w Qp (peak flow) and i (max intensity of rain) it is forming a straight line. is obtained ~~due to the~~

Due to the above limitations, The rational formula is generally used to estimate the peak flood (Q_P) in the design of urban drainage system, storm sewers, design of small culverts, and bridges etc.

(Pg No 215 BC Punmia)

(1) A small water shed consists of 3.2 km^2 of cultivated area with $C = 0.22$, 4.8 km^2 under forest with $C = 0.12$ and 1.8 km^2 under grass cover with $C = 0.32$. The water course, 2.4 km in length has a fall of 30 m. The intensity-frequency-duration relation for the area may be expressed by the following relation

$$i = \frac{78\,T^{0.22}}{(t+12)^{0.45}}$$

where "i" is in cm/hr, T is in years and t is in minutes. Estimate the peak rate of runoff for a 30 years frequency, using rational formula ?

[∵ $V \Rightarrow m/sec$
$V \Rightarrow L/t$
$t = L/V$
$t\ sec = L/V \; \frac{m}{m/sec}$
$t = L/V$]

Sol:- Slope of water course $(S) = \Delta H / L$

$$= \frac{30\ m}{2.4\ km}$$

$$= \frac{30\ m}{2.4 \times 1000\ m} \Rightarrow \frac{\cancel{30}\ m}{\cancel{2400}_{80}\ m}$$

$$\Rightarrow \frac{1}{80}\ m$$

velocity $= 1 : n$

$t = \frac{L}{T} \times n$

1 : n
vertical : Horizontal

Time of concentration (in-hours) $(t) = t_c = 0.000323\, L^{0.77}\, S^{-0.385}$

$$= 0.000323\,(2400)^{0.77} \times \left(\frac{1}{80}\right)^{-0.385}$$

$$= 0.6993 \text{ hours}$$

$$= 0.6993 \times 60$$

$$= 42 \text{ minutes}$$

$L = 2.4\ km$
~~= 2400 m~~
$= 2.4 \times 10^3\ m$

~~slope = m/sec~~

~~$2400\ m \times \frac{1}{80\ m/sec}$~~

~~$t\ hr = \frac{m \times sec}{m}$~~

$$i = \frac{78\,T^{0.22}}{(t+12)^{0.45}}$$

$$= \frac{78\,(30)^{0.22}}{(42+12)^{0.45}} = 27.38\ cm/hr$$

$$Q_p = 2.778\ CiA$$

$$= 2.778\ \cancel{\quad}\ i\ \Sigma CA$$

$$= 2.778 \times (27.38) \times (3.2 \times 0.22 + 4.8 \times 0.12 + 1.8 \times 0.32)$$

[∵ once converting the meter/sec in cia values dont use the 2.778 if cannot converting cia values in m/s use 2.778]

$$\cong 141.2\ m^3/sec$$

$Q \propto A \cdot V$

Discharge ∝ Area × velocity

$Q = C\ AV$ → constant

[∵ $Q_p = ciA$

$Q_p\ m/sec = c\ i\ cm/hr\ A\ km^2$

$= c\ \frac{\frac{1}{100}}{60 \times 60}\ m/sec\ (10^3)^2\ m^2$

$= \frac{ciA}{0.36} = 2.778\ ciA$]

[∵ $Q_p = ciA$

$Q_p\ m/s = c\ i\ mm/hr\ A\ km^2$

$= c\ \frac{\frac{1}{1000}}{60 \times 60}\ m/s\ (10^3)^2\ m^2$

$= 0.2778\ ciA$

(Pg No 216 BC Punmia)

(2) A small watershed has an area of 2.4 km². The slope of the catchment is 1/200 and the maximum length of travel of water is 1.8 km. The maximum depth of rainfall with a 30-year return period is given in the following table.

Duration (min)	5	10	15	20	25	30	40	50	60
Depth of rainfall (cm)	2.5	3.8	4.8	5.9	6.7	7.4	8.4	8.7	9.2

Determine the peak flow rate for a return period of 30 years. If the average runoff coefficient for the watershed is 0.25

Sol:-

The time of concentration (in hours) $t = t_c = 0.000323\ L^{0.77}\ S^{-0.385}$

~~0.000323~~

Length of travel of water (L) = 1.8 km

1 kilo = 1000

$= 1.8 \times 1000\ m$

$= 1800\ m$

Time of concentration (t) (in hours) $= t_c = 0.000323\ L^{0.77}\ S^{-0.385}$

$= 0.000323\ (1800)^{0.77} \left(\frac{1}{200}\right)^{-0.385}$

$= 0.7974$ hours $\Rightarrow 0.7974 \times 60 = 47.84$ min

For a duration ($t = t_c$) of 47.84 min, the maximum depth of rainfall can be determined from the above table by linear interpolation and is equal to (2)

interpolation form.

40 − 8.4

47.84 − ?

50 − 8.7

$$= 8.4 + \frac{8.7-8.4}{(50-40)} \times (47.84-40)$$

$$= 8.64 \text{ cm}$$

Hence average intensity $i_{av} = \frac{8.64 \text{ cm}}{47.84 \text{ min}}$

$$= \frac{8.64 \text{ cm}}{47.84/60 \text{ hr}}$$

$$= 10.83 \text{ cm/hr}$$

Hence $Q_P = 2.778\, CiA$

$$= 2.778 \times 0.25\,(10.83) \times 2.4$$

$$= 18.05 \text{ m}^3/\text{sec}$$

(or)

$Q_{P\, m/sec} = CiA$ m/sec.

$$= 0.25 \cdot \frac{\frac{10.83}{100}}{60 \times 60} \text{ m/sec} \times 2.4 \times (10^3)^2 \text{ m}^2$$

$$= 18.05 \text{ m}^3/\text{sec}$$

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Discuss the SCS-CN method :-

SCS-CN means soil conservation service-(curve number) which was developed in 1964 in U.S.A for calculating the depth of direct runoff from the depth of rain fall.

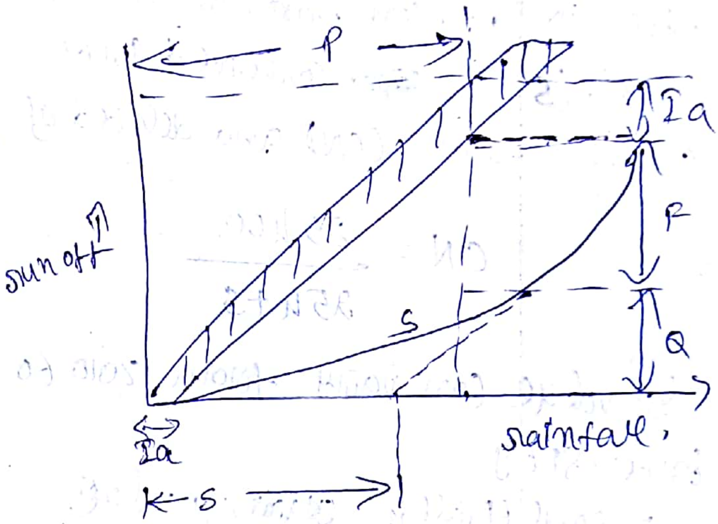
on CN method based on the phenomenon of once rain is falling some water will be initial absorption, some water beginning of runoff from the rainfall some water will be infiltration and infiltrated water will be stored. CN method is also based on actual retention (opposing) of water, loss of additional rainfall. in the form of infiltration after run has started. i.e. means the water will be flowing on river the extra water will be added to river in streams. This water will be opposing the river on this situation some water will be infiltrated. after water enter into the river.

SCS considers the ratio of actual retention to potential of maximum retention equal to ratio of actual runoff to the difference of rainfall and initial obstraction (opposing) on the below curve mathematically.

It is given by

$$\frac{F}{S} = \frac{Q}{P-I_a} \rightarrow (1)$$

where
F = Actual retention in mm
Q = collected run-off depth (mm)
P = collected rain fall depth (mm)
S = potential of maximum retention in mm
I_a = Initial obstraction in mm.



on this graph we observed that total P rain fall is falling on that rainfall Q amount of water will be runoff and F amount of water will opposing the soil. and I_a amount of water. will be absorption of soil so

$$F = P - I_a - Q \rightarrow (2)$$

By combining equation (1) and (2) we get

$$Q = \frac{(P-I_a)^2}{P-I_a+S} \rightarrow (3)$$

In this equation eliminating the variables "Ia" and "S" because of small drainage basins

It was found that $Ia = 0.2S$

There fore eq(3) becomes

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \text{for } P > 0.2S$$

The above eqn is the relationship b/w runoff and rainfall, and is used in curve number method.

The potential of maximum retention i.e means maximum opposing of water. (S) is converted into curve number (CN) and related as

$$CN = \frac{25400}{254 + S}$$

(S) value can vary from zero to intensity

Theoretically CN value ranges from 0 – 100

Separation of base flow :- Pg No 171 (B.I Punmia)

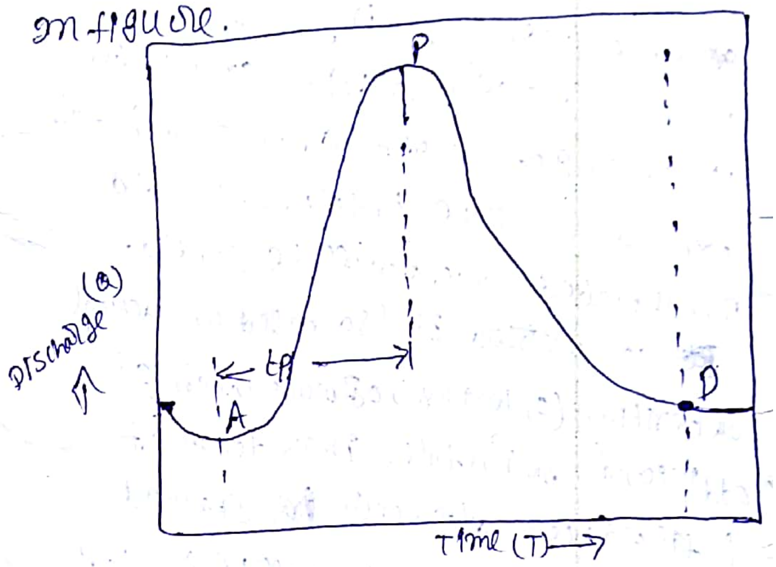
There are 3 popular methods of separation of base flow

(1) Straight line method

(2) Two lines method

(3) Curves extension method.

The direct runoff in a single peaked storm hydrograph as shown in figure.



→ The point 'A' on the hydrograph represents beginning of direct run off can be easily identified. It can be rising the Discharge slowly i.e can be rising (changing the point)

→ But the point "D" which marks the end of the direct runoff can not be easily located

So However, an empirical equations for the time interval N (days) from the peak flow (maximum flow) (P) to the point 'D' is

Scanned by CamScanner

$N = 0.827\, A^{0.2}$

where A = area of drainage basin in km²

Another empirical ~~formula~~ equation to determine N is given by

$N = a t_p$

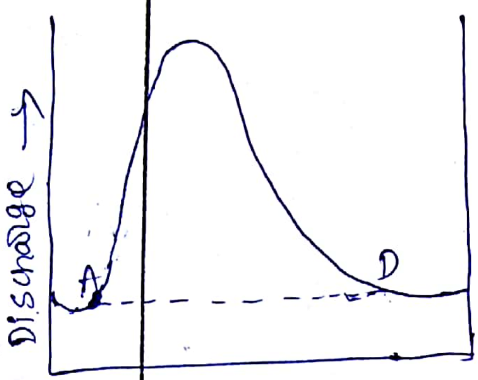
where

t_p = time to peak = time interval b/w beginning point A and peak P

a = constant whose value may be taken b/w 2 to 4 for small basins and 4 for large basins

Thus the two points where the direct runoff (i.e. point A) and direct ceases (i.e. point D) are identified

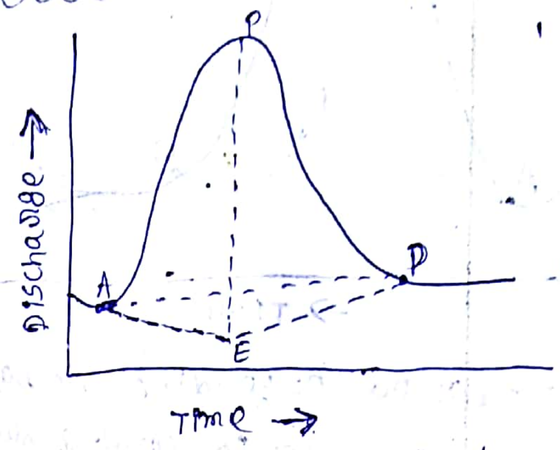
Method 1 straight line method.



In this method shows two points (i.e) A and D ~~A~~ point 'A' means beginning of direct runoff and 'D' is end of direct run off

This is the simplest method of separation

Method 2: two lines method



→ This is most used method.

The base flow is separated from direct run off by two lines

→ that is first line AE second line is ED

→ First line AE is optained by extending the base flow curve.

~~E~~ It means the rain falling 100% rain 60% rain water is run off in 100% rain 60% rain water is infilterated and 40% of rain water we dont no how much amount of water will be base flow ~~so~~

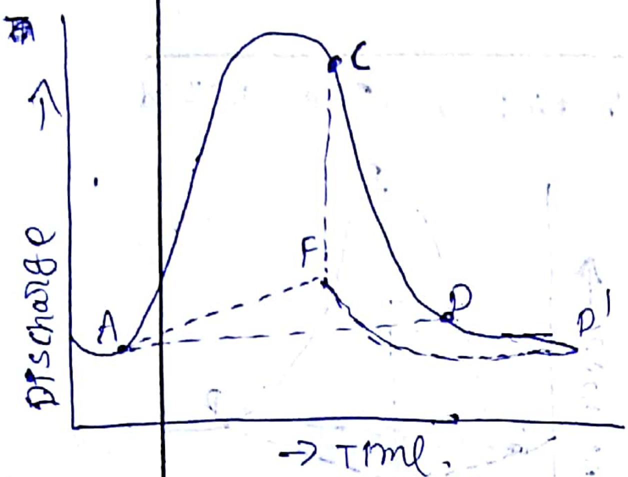
so 40% of water will be infiltrated in 40% of water draw one line (~~AE~~ AE that is AE and draw a ~~stra~~ vertical line of maximum flood P (peak flood) the vertical line PE and the line AE will be intersept one point in that point

Draw one line to join point E 'D'

This is called as base flow and direct run off

This segments marked by two line AE and ED so this method is two line method.

Method 3 :- Curves Extension method :-



In this method: extending the base flow curve on recession ([illegible]) side backward till it intersects a ~~It means the water flow peak level for maximum level [illegible] curve extend [illegible]~~ vertical line through the point of inflection (c) that is in point 'F' ~~[illegible] 100% water [illegible]~~ in. [illegible] base flow curve extend [illegible] (D to D') [illegible] some time [illegible] 1 hr [illegible] base flow [illegible] 1 hr time [illegible] extent [illegible]. [illegible] line extent [illegible] peak flow [illegible]. [illegible] point [illegible] flow discharge [illegible] point [illegible] that is point 'c' [illegible] vertical line [illegible] "D'" line and [illegible] vertical line 'C' point [illegible] intercept [illegible] that is F [illegible] F [illegible] A [illegible] smooth curve [illegible]

→ The point F and A then joined by an smooth curve. Thus the two segments marked by two curves AB and FD it shows the base flow and direct runoff.

→ This method is preferred ground water table connected and flow from ground water storage reaching the stream quickly.

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13

UNIT Hydrograph :-

[previously will be discussing]

~~Hydrograph~~ :-

(Pg No 175 BC Punmia)

Assumptions of unit hydrograph:-

→ The more amount of rainfall is uniformly distributed to the ground in specified period of time

→ The more amount of rainfall uniformly distributed throughout the whole area of the drainage basin

→ The more amount of rainfall is falling a continuously constant. The unit duration of rainfall is constant the run off will be constant

→ The ordinate of direct run off (The run off water in particular time interval) The water will be run same time interval. it means 1 hr 2cm water will run in 2 hr also 2cm of water run both the water runs in 30 minutes) as [illegible] rain falling & equal. of common base time are directly proportional to the total amount of direct run off in each hydrograph.

→ In a particular drainage basin. The run of water in a given period of rainfall reflects all the combined physical characteristics of the basin

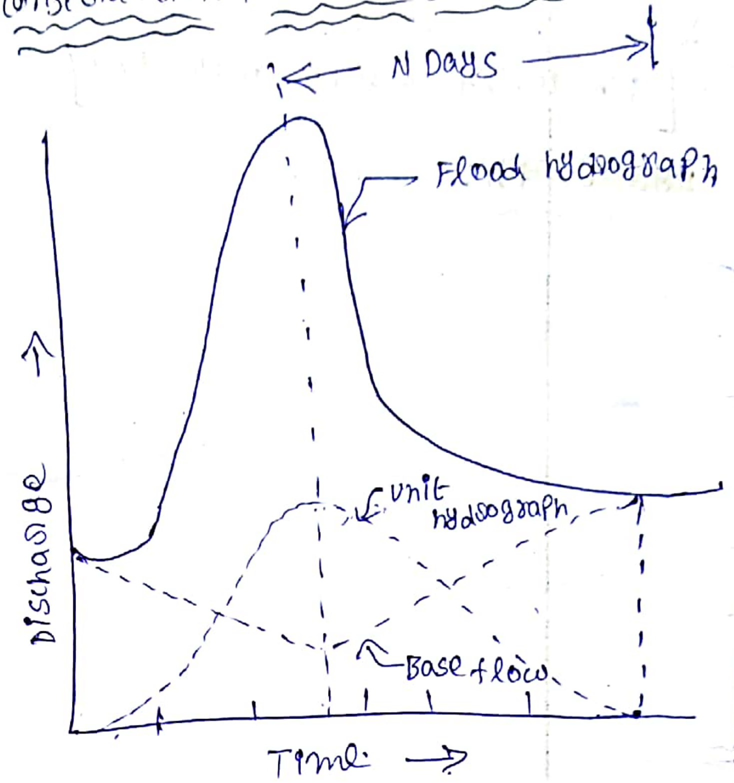
Ex:- In that basin area any obstacle is there the water will meet 11 The water will be reflected

(175 Page BC Punmia)

Derivation of unit hydrograph:-

(or)

Construction of unit hydrograph:-



(1) From the past records, select some unit period of intense rainfall duration corresponding to an isolated storm uniformly distributed over the area.

(2) From the past records of the river discharge for that storm plot the storm hydrograph for some days before and after the period of rainfall. of that unit duration.

Ex:- 25 given discharge [illegible] calculate [illegible]

(3) In this method separate the ground water flow (base flow) from the direct run-off so

(4) substracting the ordinates of base ~~flow from the~~ total ordinates to ordinates of base flow find the ordinates of direct runoff

(5) calculate direct runoff h (in centimetres) by the expression:

$$\text{Direct run-off},\ h = 0.36\,\frac{(\Sigma o) \times t}{A}\ \text{cm.}$$

where

Σo = sum of the discharge ordinates (direct run off) in cumecs

t = time interval b/w successive ordinates in hours

A = Area of drainage basin in sq. km

(6) calculate the ordinates of unit hydrograph by the relation:

$$\text{ordinates of unit hydrograph} = \frac{\text{ordinates of direct runoff}}{\text{Direct run-off } h \text{ in cm.}}$$

~~Date. Hour Total Q (cumecs) Ordinates of direct run-off (cumecs) Ordinates of unit hydrograph.~~

~~(1) (2) (3) (4)~~

Date	Hour	Total Q (cumecs)	Base flow (cumecs)	ordinates of direct runoff (cumecs)	ordinates of unit hydrograph.
(1)	(2)	(3)	(4)	(5)	(6) = $\frac{(5)}{D.R.O \text{ in cm.}}$
12 Aug.	0600	6	6.0	6-6 = 0	$\frac{0}{23.7} = 0$
	0800	8	6.0	8-6 = 2.0	$\frac{2}{23.7} = 0.08$
	1000	10	5.5	10-5.5 = 4.5	4.5/23.7 = 0.19
	1200	16	5.0	11.0	11.0/23.7 = 0.47
	1400	28	4.5	23.5	23.5/23.7 = 0.99
	1600	42	4.0	38.0	1.61
	1800	60	3.5	56.5	2.39
	2000	80	3.0	77.0	3.25
	2200	110	2.5	107.5	4.54
	2400	100	2.5	97.5	4.11
13 Aug	0200	90	2.5	87.5	3.70
	0400	80	3.0	77.0	3.25
	0600	68	3.0	65.0	2.74
	0800	56	3.5	52.5	2.22
	1000	45	3.5	41.5	1.75
	1200	35	4.0	31.0	1.31
	1400	26	4.0	22.0	0.92
	1600	18	4.5	13.5	0.57
	1800	11	4.5	6.5	0.27
	2000	9	5.5	4.0	0.17
	2200	8	5.5	2.5	0.11
14 Aug.	2400	7	5.5	1.5	0.06
	0200	6	6.0	0	0

$\Sigma O = 822$

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Area of basin = 25 sq km

Direct run-off (r) = $0.36 \frac{(\Sigma Q) \times t}{A}$

$= \frac{0.36 \times 822 \times 2 \text{ hr}}{25 \text{ sq km}}$

= 23.7 cm.

[∵ time t = 2 why because 0600 0800 difference is 2

(Pg no 177 B.C. Punmia)

Applications of the unit Hydrograph

To the construction of a Flood Hydrograph Resulting From Rainfall of unit duration.

(or)

Unit Hydrographs of different durations

→ The unit hydrograph can be used to construct a flood hydrograph resulting from rainfall of the same unit duration for which the unit hydrograph is available.

Ex: It means in a particular day we know that 1 hour duration of rainfall intensity but the rain is falling 6 hours we want 6 hr duration in this case the rainfalling 6 hr duration same intensity duration of rainfall in 6 hr same intensity so we know that 1 hr duration will be same of rainfall 2 cm in 6 hr how much rain is falling. 12 cm rainfalling

~~Area of basin~~

for based on 1 hr duration of rain fall the time will be increase in next 2 hours so construct 1 graph that is flood hydrograph.

→ The unit hydrographs selected for computing flood hydrographs

Ex: It means 1 unit of duration how much rain is falling in next hours how much rain is falling to possible ~~xxx~~ by using reference of past years so draw one graph that is flood hydrograph.

→ The unit hydrographs will be. Should be taken. However, a tolerance (Error) of as much as 25% of unit hydrograph duration can ordinarily accepted. so without much serious error.

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Date	Hour	ordinates of unit hydrograph (cumecs)	ordinates of direct runoff (4) = (3) x n	Base flow (cumecs)	Total discharge ordinates
(1)	(2)	(3)	(4)	(5)	(6) = (4)+(5)
22 August	0600	0.00	0 x 8 = 0	4.0	0 + 4 = 4
	0900	0.12	0.12x8 = 0.96	3.5	0.96+3.5 = 4.46
	1200	0.35	0.35x8 = 2.80	3.0	2.80+3.0 = 5.80
	1500	0.88	7.04	2.5	9.54
	1800	1.50	12.00	2.0	14.00
	2100	2.80	22.40	1.5	23.90
	2400	2.00	16.00	1.8	17.80
	0300	1.85	14.80	2.1	16.90
	0600	1.53	12.24	2.4	14.64
	0900	1.26	10.08	2.7	12.78
	1200	0.84	6.72	3.0	9.72
	1500	0.50	4.00	3.3	7.30
	1800	0.35	2.80	3.6	6.40
	2100	0.12	0.96	3.8	4.76
	2400	0.00	0.0	4.0	4.0

Note: Here N = 8 why because we know 24 hr rain fall.

The interval of ordinates was 0600 to 0900 3 hr interval

~~8 x 3 = 24~~ $\underset{\text{interval}}{3} \times \underset{n\,cm}{8} = 24$ duration

Direct run off ordinates = (ordinates of unit hydrograph) x n cm

PgNo 181 BC Pumnia

Constsu ction of unit Hydrograph of Different unit duration from A unit Hydrograph of some Given unit Duration:

(or)

Principle of super position :-

We want derive a unit Hydrograph (construct) (or) t_2 of unit duration t_0 hours, by using unit hydrograph unit duration T_0 (or) t_1 where $t_0 > T_0$ (or) $t_2 > t_1$ by using this relation.

This can be done by the principle of super position.

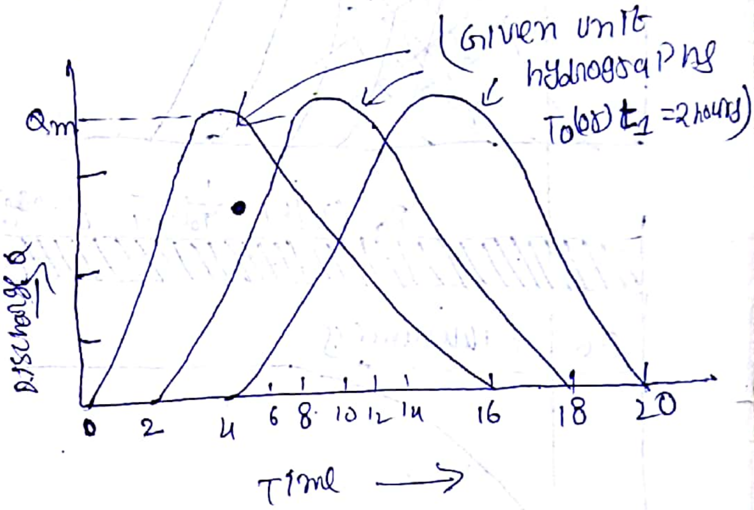
Ex:- Let we want to required to derive a unit hydrograph 6 hours unit duration ($t_2 = 6$ hours) by using a given unit hydrograph $t_1 = 2$ hours.

In this situation $t_1 = 2$ hours hydrograph but we want $t_2 = 6$ hr unit hydrograph so draw two another $t_1 = 2$ hours unit hydrographs 1 hydrograph is previously having so total 3 hydrograph. So this can be obtained sum of the ordinates of the 3 unit hydrographs of 3 hydrographs having unit duration is 2 hours and deviding sum by 3 this can be obtained by the diagram

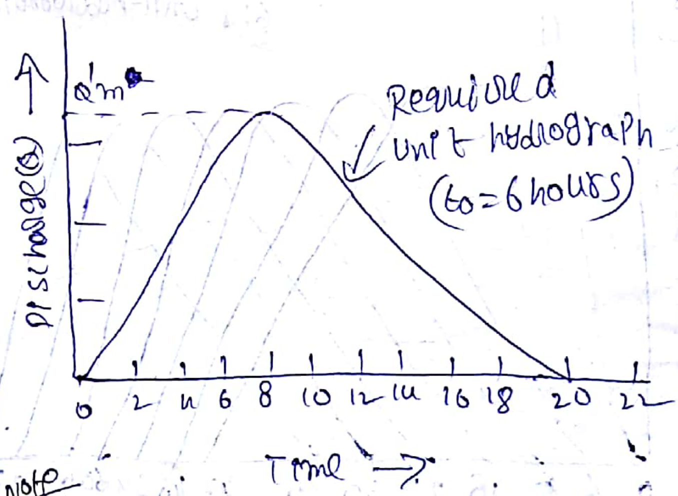
→ It is the clear that peak dischar (Q_m') of new hydrograph less than of the original hydrograph and also peak occurs later

→ ~~t_2 hydrographs are some many having t~~

→ In multiple of $t_1 = 2$ hours hydrographs are having. In this situation S-hydrograph is used.



$t_2 > t_1$; $Q_m' < Q_m$.



Note [In 1st diagram 2hr unit hydrographs combining 3 we get 6 hr unit hydrograph

(pg No 178 Ic Punmia)

S-Hydrograph methods :- (summation Hydrograph)

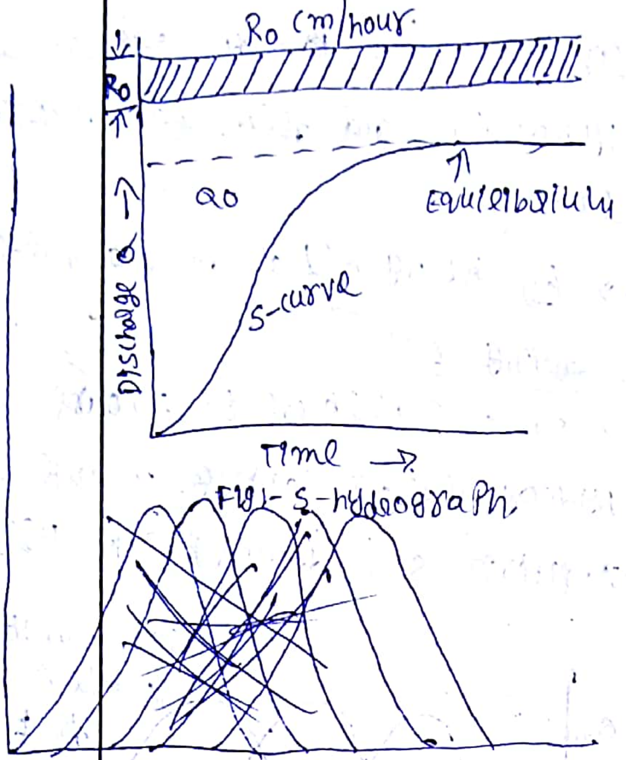


Fig:- S-hydrograph.

→ S-hydrograph (or) S-curve hydrograph. That is produced by continuous effective rainfall at a constant rate for indefinite period.

→ It is continuously rising curve. In the form of latter "S" till equilibrium is reached.

→ At the time of equilibrium is reached. on that time the water flow will be constant and rainfall will be also constant the rainfall is assume (R_0) cm/hr

→ ~~on this~~ At the time of equilibrium the S-curve will represent a run-off discharge given by

$$Q_0 = \text{Area (hectares)} \times R_0 \text{ cm/hr}$$

$$= A \times 10^4 m^2 \times R_0 \times \frac{1}{100} m \times \frac{1}{3600 \text{ sec}}$$

$$= \frac{A \times 10^4 \times R_0}{100 \times 3600} m^3/sec$$

[∵ 1hr = 3600 sec

$$= \frac{A R_0}{36} \text{ cumecs}$$

1hr = 60 mins & 60 sec = 3600 sec

where

A is the catchment area in hectares.

[∵ Discharge (Q) = Area (A) × velocity (V)]

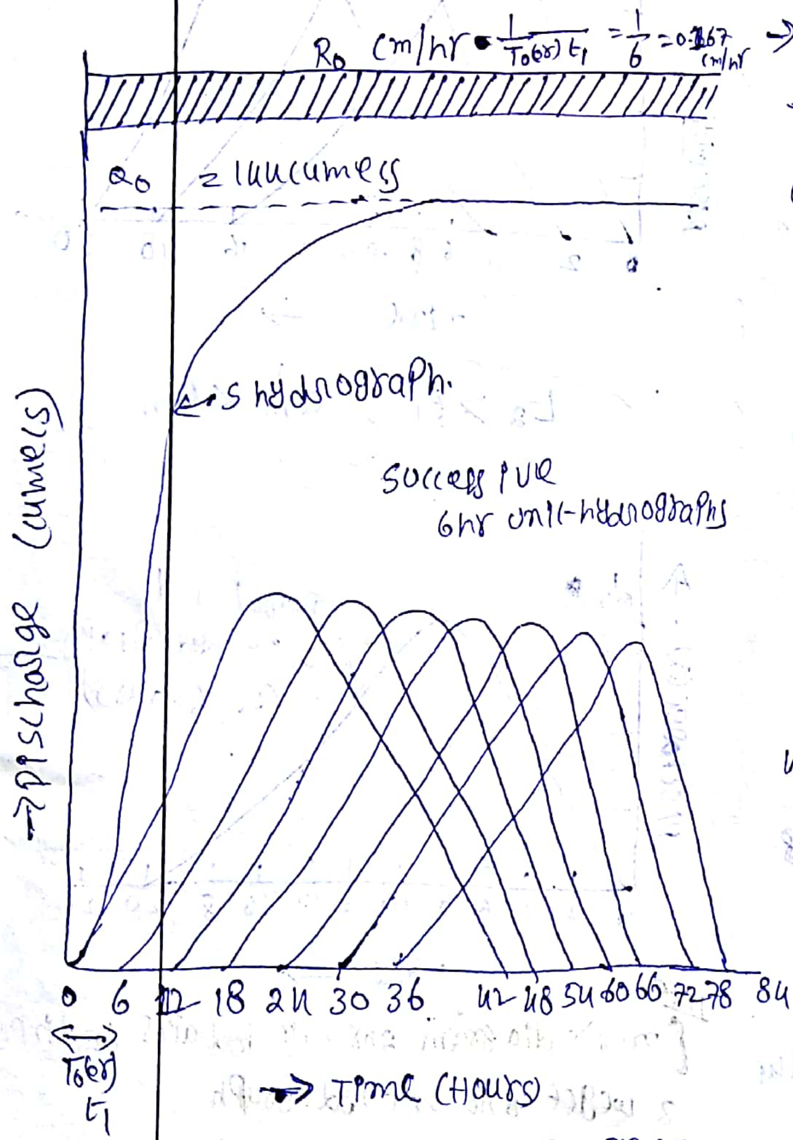


Fig:- Derivation of S-hydrograph from unit hydrograph

Suppose

If the catchment area A is in square kilometres, the discharge represented by S-curve, at the time of equilibrium is given by.

$$Q_0 = A \text{ km}^2 \; R_0 \text{ cm/hr}$$

$$= \frac{A \times (1000)^2 \text{ m}^2 \; R_0 \frac{1}{100} \text{ m}}{3600 \text{ sec}}$$

$$= \frac{A \times 10^6 \text{ m}^2 \; R_0 \text{ m}}{100 \times 3600} \text{ m}^3/\text{sec}$$

1 hr = 3600 sec = 60×60

$$= 2.778 \, A R_0 \text{ (cumecs)}$$

~~Pg No 179~~ ~~BC Punmia~~

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Pg No 179 BC Punmia

Computations for S-Hydrograph

Time	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42
Ordinates of unit hydrograph	0	9	20	35	49	43	35	28	22	17	12	9	6	3	0

Sol: Area of drainage basin A = 311 sq km.

Time	ordinates of unit hydrograph	ordinates of successive unit hydrographs						ordinates of S-hydrograph
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
00	0	–						0
03	9	–						9
06	20	0						20+0=20
09	35	9						35+9 = 44.
12	49	20	0					49+20=69
15	43	35	9					43+35+9=87
18	35	49	20	0				35+49+20=104.
21	28	43	35	9				28+43+35+9=115
24	22	35	49	20	0			126
27	17	28	43	35	9			132
30	12	22	35	49	20	0		138
33	9	17	28	43	35	9		141
36	6	12	22	35	49	20	0	144
39	3	9	17	28	43	35	9	144
42	0	6	12	22	35	49	20	144

Note:- we are taking 6hours unit hydrograph and construct a S-curve, so in column 3 leave 2 boxes why because we take 6 hours unit hydrograph same like that 4 column leave 4 boxes and 5 column leave 6 boxes 5 column leave 8 boxes same like increase 2 leaving boxes upto 8 column.

$$Q_0 = 2.778 A R_0$$

where R_0 = constant rate of continuous effective rainfall $= \frac{1}{t_1 \text{ or } T_0} = \frac{1}{6}$ cm/hr

A = Catchment in sq km = 311 sq.km.

$Q_0 = 2.778 \times A R_0$

$= 2.778 \times 311 \times \frac{1}{6}$

$= 144$ cumecs

This rate is reached in the above table 36 hours (= base period $-T_0$ hours or t_1)

Alternative method:- (PgNo 180 BCPunmia)

(18)

The alternative method is a simple method to compute ordinates of S-hydrograph.

Computations for S-hydrograph (Alternative method)

Line No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time (hours)	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42.
ordinates of 6hr unit-hydrograph	0	9	20	35	49	43	35	28	22	17	12	9	6	3	0

Sol

Line No (1)	Time (hours) (2)	ordinates of 6-hours unit hydrograph (3)	off-set ordinates (4)	ordinates of S-hydrograph ($R_0 = 1/6$ cm/hr) (5)
1	00	0	—	0
2	03	9	—	9
3	06	20	+ 0	= 20
4	09	35	+ 9	= 44
5	12	49	+ 20	= 69.
6	15	43	+ 44	87
7	18	35	+ 69.	104
8	21	28	+ 87	115
9	24	22.	+ 104.	126
10	27	17	+ 115	132.
11	30	12.	+ 126	138.
12	33	9	+ 132	141
13	36	6	+ 138.	144.
14	39	3	+ 141	144.
15	42.	0	+ 144	144

3hr } = 6hr duration } 3hr

6hr unit hydrograph

[∵ 2 boxes we leave why because 6hr unit hydrograph each box having 3hr interval) the. ⑤ Th column. 36 hours equilibrium discharge. 18 reaches 144 cumecs

some times the computed ordinates of S-curve may not fall along the. a smooth curve (the water can not fall on smooth area) in that case, smoothing is carried out and the corresponding new ordinates along smoothened curve are found (It means the extra ~~~~ column smoothened ~~curve~~ ordinates can be finding out)

~~construct sheet~~

~~construction of~~

Pg NO 18 Bc Purnima

Construction of unit hydrograph of different unit duration from a unit hydrograph of some given unit duration.

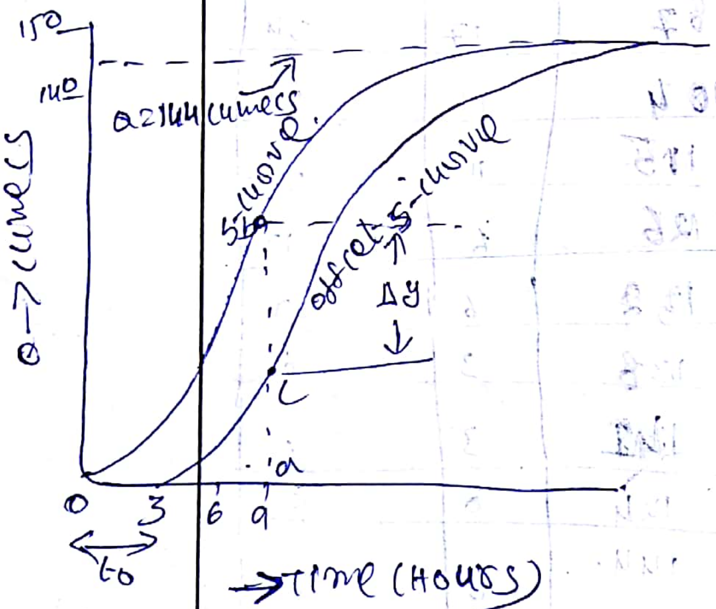
(b) Construction of ~~longer~~ shorter (or) longer period unit hydrograph from a given unit hydrograph ~~of shorter unit~~ period.

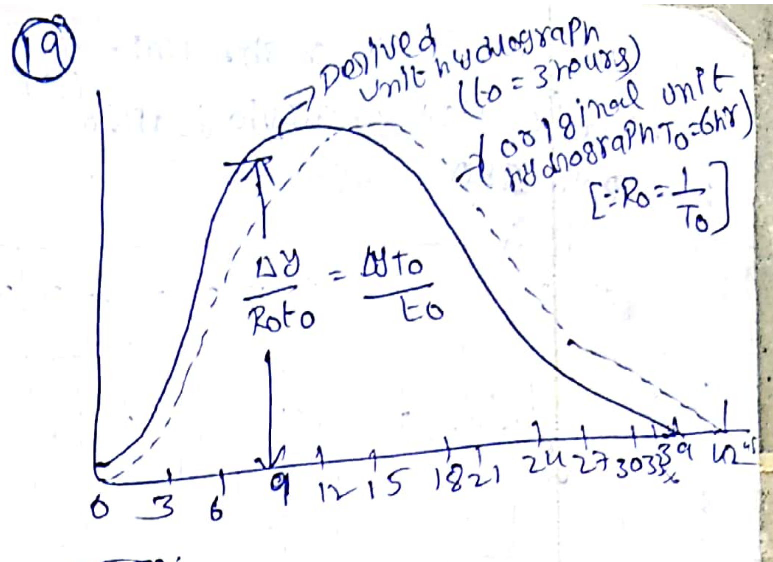
we want to ~~derive~~ required a unit hydrograph of unit period to (or) t_2 hours on entire hydrograph of unit period T_0 or t_1 hours

Ex- I want to 3 hr unit hydrograph of entire 6 hr unit hydrograph values.

→ In this situation to can be either greater (or) smaller than T_0 we dont no

For this, the S-hydrograph method described below may be used.





The given unit hydrograph of unit period T_0 the S-curve can be derived;

The S-curve will represent a constant effective rainfall of $R_0 = 1/T_0$

but we want to t_0 hours unit hydrograph so construct the offset curve is drawn by advancing (or) offsetting the position of original S-curve for a period of t_0 hours

The difference b/w ordinates of original S-curve and offset S-curve; divided by $R_0 t_0$ will give the ordinates of desired unit hydrograph.

The difference b/w ordinates of the two S-curve is Δy Then the ordinates of the desired unit hydrograph to unit period.

$$\frac{\Delta y}{R_0 t_0} \Rightarrow \frac{\Delta y}{\left(\frac{1}{T_0}\right) t_0} \Rightarrow \Delta y \cdot \frac{T_0}{t_0}$$

The unit hydrograph of 3hr unit duration can be calculated on previous table 4.21 P No 180

Time	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42
The ordinates of 3hr unit hydrograph	0	9	20	35	49	43	35	28	22	17	12	9	6	3	0

Derivation of unit hydrograph of $t_0 = 3$ hr unit duration from the one of $T_0 = 6$ hr unit duration.

Sol

$\frac{T_0}{t_0} = \frac{6}{3} = 2$ → required unit hydrograph of 3hr duration

Time (1)	Ordinates of 3hr unit hydrograph (2)	offset of 3hr unit hydrograph [∵ so leave 2 boxes] (3)	ordinates of S-curve (4)	ordinates of offset S-curve 3hr unit hydrograph (5) [∵ so leave 1 box because 3hr hydrograph]	Δy (4)-(5)=(6)	$O = \Delta y \frac{T_0}{t_0} = 2\Delta y$ (7)
0	0	–	0		0	0
3	9	–	9	0	9	9×2=18
6	20	0	20+0=20	9	20-9=11	22
9	35	9	35+9=44	20	44-20=24	48
12	49	20+0=20	49+20=69	44	69-44=25	50
15	43	35+9=44	43+44=87	69	87-69=18	36
17	35	49+20=69	35+69=104	87	17	34
21	28	43+44=87	28+87=115	104	11	22
24	22	35+69=104	22+104=126	115	11	22
27	17	28+87=115	17+115=132	126	6	12
30	12	22+104=126	12+126=138	132	6	12
33	9	17+115=132	9+132=141	138	3	6
36	6	12+126=138	6+138=144	141	3	6
39	3	9+132=141	3+141=144	144	0	0
42	0	6+138=144	0+144=144	144	0	0
					ΣO	288

$R = 0.36 \frac{\Sigma O}{A} \times t \Rightarrow \frac{0.36 \times 288}{311} \times 3 \Rightarrow 1$ cm

[∵ A = Area is assumed] 311 sq-km

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Signature of Invigilator

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~~AE~~ ~~Alama~~

Limitations of unit hydrograph("UH"):-

(i) The development of flood hydrograph for extreme rainfall for the use of design of hydraulic structure

(1) The unit hydrograph can be applied only to drainage basin with small area as the ~~aerial~~ ~~equivalent~~ distribution of rainfall over large area is less

(ii) The large portion of storm precipitation is in the form of snow, the unit hydrograph is not applicable

(iii) The base period (infilter water) direct runoff hydrograph also depends on the intensity of rainfall.

(iv) unit hydrographs are not suitable for areas less than 200 hectare

(v) the unit hydrograph does not provide batter result when the precipitation is non-uniform.

Uses of unit hydrograph:-

-> rainfall records, flood flow records can be extended

-> The development of flood hydrograph which are required for the design of hydraulic structures

-> Hydrographs are used in watershed simulation model.

Synthetic unit hydrograph:-

If the rainfall and run off values are available. The unit hydrographs can be derived

However, in the case of (values ...) ungauged rivers (...) The rainfall and runoff data are not available in some other cases, the data available may be scanty.

~~for such a catchments~~ (insufficient (or) less catchment area)

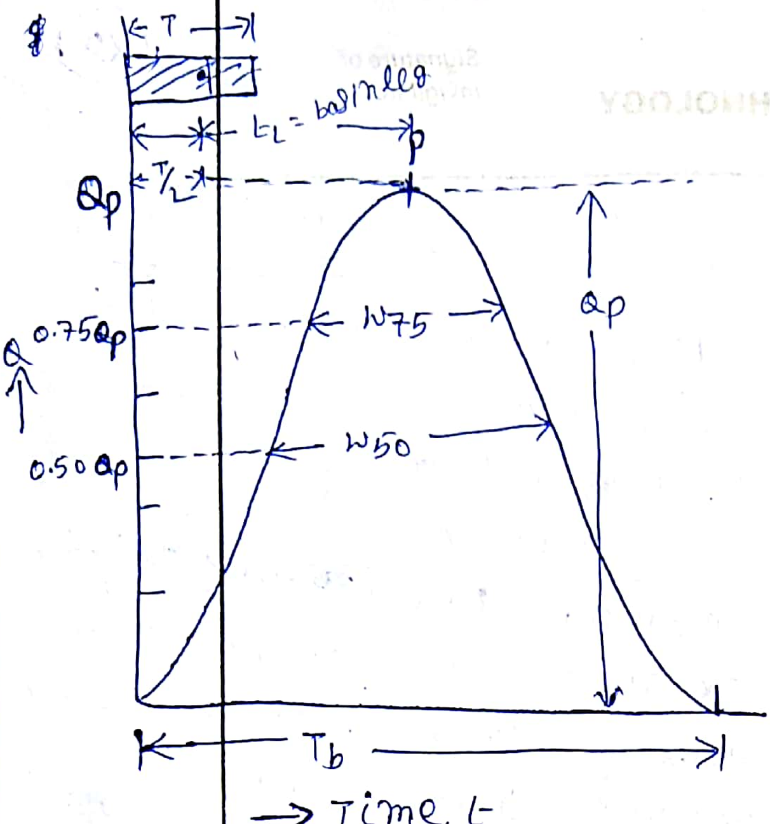
~~Small amount of less discharge~~

For such a catchments unit hydrographs are derived by relating (same thing (or) select same catchment areas (or) basin) the basin characteristics to the derived unit hydrograph shape.

The resulting hydrograph derived by using the other basin characteristics relationship is known as a synthetic unit hydrograph

There are several methods are there derive synthetic unit hydrograph.

In this methods one method was proposed by the snyder (1938) is widely used



Synder studied the data of catchments ~~of Appalachain plat~~ of Appalachian (mountains) Highlands of Eastern United States, and then developed empirical equations for synthetic hydrograph.

Synder selected three parameters of unit hydrograph.

(i) base width T_b
(ii) peak discharge Q_p and
(iii) basin lag t_L as marked in fig.

The empirical equations proposed to synder taken into account ~~catchment~~

→ catchment area
→ shape of basin
→ topography.
→ channel slopes
→ stream density and
→ channel storage

He eliminated all the parameters except the first two ~~and~~ by including them in a single coefficient (C_t)

~~The eliminating all the param~~

(మిగతా parameters ని eliminate చేసి 1st రెండు మాత్రం eliminate చేయకుండా ... coefficient (C_t) లో ...)

He deal (find) with the size and shape of the catchment by measuring the length of the main stream channel by proposing the following equation for basin lag

(i) $$t_L = C_t\,(L_{ca} \cdot L)^{0.3}$$

where

t_L = basin lag in hours

C_t = a coefficient depending upon units and discharge basin characteristics

C_t value varies b/w 1.35 and 1.65 for the applicable Highlands catchments studied by synder.

L = distance from station to catchment boundary measured along the main stream in km.

L_{ca} = distance along the main stream from raingauging station to a point opposite to the centroid of the water shed in km.

The peak discharge of Q_p unit-hydrograph of standard duration "T" is given by.

Rational formula.

(ii) $$Q_p = \frac{2.778\ C_p \cdot A}{t_L}$$

[∵ $Q_p = 2.778\ CiA$ PG NO 216

where Q_p = peak discharge.

A = catchment area.

C_p = a regional constant ~~range~~ b/w 0.56 to 0.69.

Synders adopted the standard duration (T) hours of effective rain fall given by.

$$T = \frac{2}{11} t_L$$

The duration of surface runoff (or) base ~~width~~ length T_b of unit hydrograph.

$$T_b = 3 + 3\left[\frac{t_L}{24}\right] \text{(days)}$$

when T_b is expressed in hours

$$T_b = (24 \times 3) + 3\,t_L$$

$$T_b = 72 + 3\,t_L$$

(where T_b and t_L are in hours)

UNIT - II

PG No 188 (BC Punmia)

(1) Find the ordinates of a storm hydrograph resulting from a 3 hour storm with rainfall of 2, 6.75 and 3.75 cm during subsequent 3 hours intervals. The ordinates of unit 3-hour hydrograph are given in the following table.

Hours	03	06	09	12	15	18	21	24	03	06	09	12	15	18	21	24
ordinates of unit hydrograph (cumecs)	0	110	365	500	390	310	250	235	175	130	95	65	40	22	10	0

Assume an initial loss of 5 mm, infiltration index of 2.5 mm/hour and base flow of 10 cumecs

Cumecs means a unit measurement for the flow of water equal to 1 m^3/sec

Sol :-

(i) Rainfall excess during the first three hours

$= 2cm - (2.5 \times 3)mm$ (infiltration) $- 5mm$ (initial loss)

[∵ 2cm = 20 mm]

$= 20 - (2.5 \times 3) - 5 = 7.5$ mm

$= 0.75$ cm.

[∵ initial loss having only from starting]

(ii) Rainfall excess during the second three hours

$= 6.75cm - (2.5 \times 3)$ mm

$= 6.75 - (2.5 \times 3) = 60$ mm

$= 6$ cm

(iii) Rainfall excess during the last three hours

$= 3.75$ cm $- (2.5 \times 3)$ mm

$= 37.5$ mm $- (2.5 \times 3) = 30$ mm

$= 3$ cm

Rain fall excess (increases) as the ratio of unit rainfall of 1 cm, during subsequent (continuously) 3 hours intervals are 0.75, 6 and 3.

The example has been solved in a tabular form below.

The computations (calculation) of run-off due to 0.75 cm rain fall excess (more) will start from 03 hours.

• The computations (calculation) of run-off due to 6 cm rainfall excess (mass) will start from 06 hours.

Lastly the computations of run-off due to 3 cm rainfall excess will start from 09 hours.

Time in hours	ordinates of 3-hour unit hydrograph (cumecs)	Rain fall excess cm/hours	Surface run-off from rain fall excess during successive unit periods (cumecs)				Base flow (cumecs)	ordinates Total discharge (cumecs)
			0.75	6.0	3.0	sub total 4+5+6 = 7		7+8 =
1	2	3	4	5	6	7	8	9
03	0	0.75	0			0	10	10.0
06	110	6.0	110×0.75 = 82.5	0		82.5	10	92.5
09	365	3.0	365×0.75 = 274.0	110×6 = 660	0	934.0	10	944.0
12	500		500×0.75 = 375	365×6 = 2190	110×3 = 330	2895.0	10	2905.0
15	390		292.5	500×6 = 3000	365×3 = 1095	4337.5	10	4347.5
18	310		232.5	2340	500×3 = 1500	4072.5	10	4082.5
21	250		187.5	1860	1170	3217.5	10	3227.5
24	235		176.0	1500	930	2606.0	10	2616.0
03	175		131.5	1410	750	2291.5	10	2301.5
06	130		97.5	1050	705	1852.5	10	1862.5
09	95		71.3	780	525	1376.3	10	1386.0
12	65		48.6	570	390	1008.6	10	1018.6
15	40		30.0	390	285	705.6	10	715.0
18	22		16.5	240	195	451.5	10	461.5
21	10		7.5	132	120	259.5	10	269.5
24	0		0	60	66	126.0	10	136.0
30				0	30	30.0	10	40.0
06					0	0	10	10.0

P8NO409 (SKgang)

(2)

(2) Using the 3.hr. unit hydrograph given below, find the peak flow resulting ~~four~~ from four successive 3 hour periods of rainfall producing 0.35, 0.87, 1.39 and 0.77 cm of runoff respectively from a basin

Time in hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow in m^3/s	0	16	58	173	337	440	400	285	215	165	122	90	60	35	16	0

Neglect baseflow

Sol:- The ordinates of hydrographs that would be produced by 0.35, 0.87, 1.39 and 0.77 cm of runoff, can be obtained by multiplying the given ordinates ~~of (flow in m³/s)~~ of unit hydrograph (flow in m^3/s) row values respectively.

Now, since all these 4 hydrographs are produced by successive rains, each of 3hr. unit duration, the total resultant hydrograph can be obtained by summation of the hydrographs of all the four rains each values can be entered after 3hr., successively.

Discharge = velocity x C/s area

$Q = V \times AV$

(or)

$Q = AV$

Time in hr ①	ordinates of unit hydrograph in cumecs ②	ordinates of first hydrograph in cumecs 0.35 x col② = ③ tabulated after 3hr	ordinates of second hydrograph in cumecs 0.87 x col② = ④ tabulated after 3hr	ordinates of 3rd hydrograph in cumecs 1.39 x col② = ⑤ tabulated after 6hr	ordinates of 4th hydrograph in cumecs 0.77 x col② = ⑥ tabulated after 9hr	ordinates of Total surface runoff (S.R) hydrograph ③+④+⑤+⑥ in cumecs = ⑦
0	0	0				0 5.6
1	16	0.35x16 = 5.6				20.3
2	58	0.35x58 = 20.3				60.6
3	173	0.35x173 = 60.6	0			131.87
4	337	0.35x337 = 117.95	0.87x16 = 13.92			204.48
5	440	0.35x440 = 154	0.87x58 = 50.46			290.91
6	400	0.35x400 = 140	0.87x173 = 150.51	0		315.43
7	285	0.35x285 = 99.75	0.87x337	1.39x16 = 22.24		463.42
8	215	0.35x215 = 75.25	0.87x440	1.39x58 = 80.62	0	588.47
9	165	0.35x165 = 57.75	0.87x400	1.39x173 = 240.47	0.77x16 = 12.32	771.40
10	122	0.35x122 = 42.7	0.87x285	1.39x440	0.77x58 = 44.66	**874.81**
11	90	0.35x90	0.87x215	1.39x400	0.77x173 = 133.21	853.76
12	60	0.35x60	0.87x165	1.39x285	0.77x337	774.03
13	35	0.35x35	0.87x122	1.39x215	0.77x440	721.55
14	16	0.35x16	0.87x90	1.39x165	0.77x400	589.55
15	0	0	0.87x60	1.39x122	0.77x285	419.48
16			0.87x35	1.39x90	0.77x215	304.57
17			0.87x16	1.39x60	0.77x165	210.45
18			~~0.87~~ 0	1.39x35	0.77x122	117.95
19				1.39x16	0.77x90	91.54
20				0	0.77x60	46.20
21					0.77x35	26.95
22					0.77x16	12.32
23					0	0
24						

Peak rate of discharge = 874.81 cumecs Ans

PgNo 232 (BC Punmia)
(or)
PgNo 406 (SK garg)

3

(2) The ordinates of 8-hour unit hydrograph for a drainage basin are given below

Time in hours	ordinates of 8-hr unit hydrograph
0	0.0
4	5.5
8	13.5
12	26.5
16	45.0
20	82.0
24	162.0
28	240.0
32	231.0
36	165.0
40	112.0
44	79.0
48	57.0
52	42.0
56	31.0
60	22.0
64	14.0
68	9.5
72	6.6
76	4.0
80	2.0
84	1.0
88	0

obtain 24-hour unit hydrograph by tabulation method neatly sketch it?

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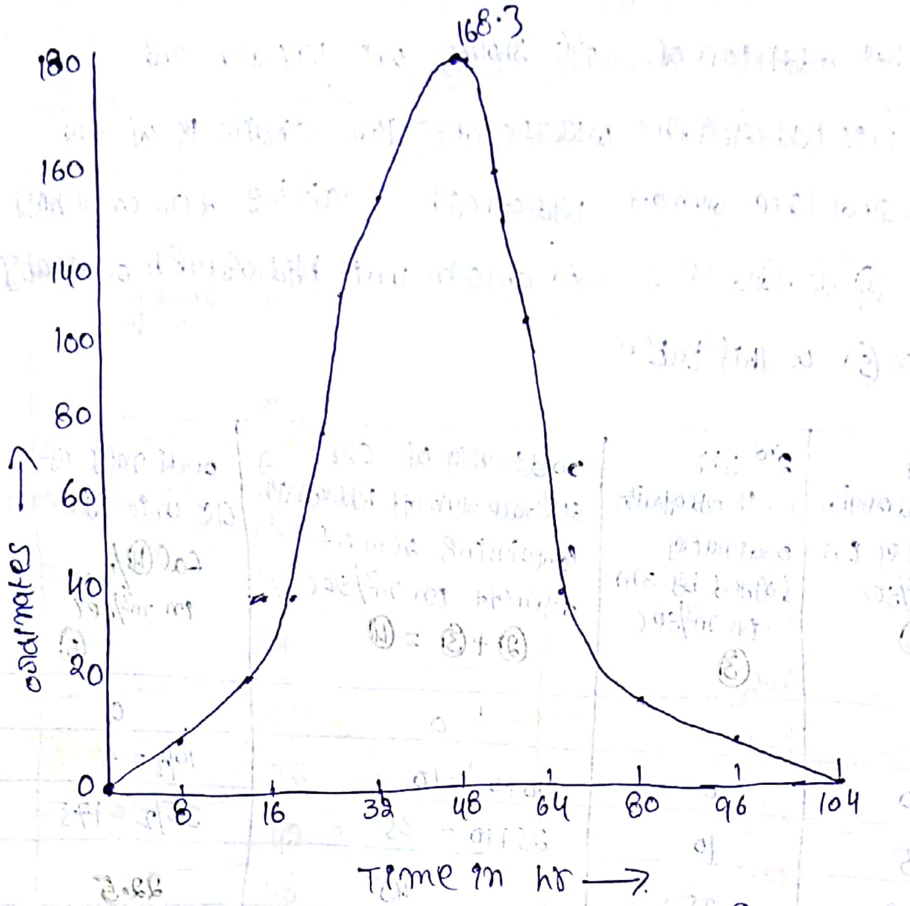
Sol:- When 3 unit hydrographs, each of 8 hours duration are added together placed at 8 hour each successively

Then we will get the ordinates of 24 hours [8+8+8] surface run off containing 3 cm of direct run off. Hence the ordinates of a 24-hour unit hydrograph are obtained by combining the 1st 8 hour + 2nd 8 hour + 3rd 8 hour unit hydrograph and deviding by 3 will give us the ordinates of a unit hydrograph of 24 hr duration.

Time (hours) ①	1st 8-hr unit hydrograph ②	2nd 8-hr unit hydrograph ③	3rd 8-hr unit hydrograph ④	Total 24 hr hydrograph of 3 cm runoff ⑤ = ②+③+④	ordinates of 24-hr unit hydrograph ⑤/3 column
0	0.0			0	0
4	5.5			5.5	5.5/3 = 1.8
8	13.5	0.0		13.5+0.0=13.5	13.5/3 = 4.5
12	26.5	5.5		26.5+5.5 = 32.0	10.7
16	45.0	13.5	0.0	45.0+13.5+0.0=58.5	19.5
20	82.0	26.5	5.5	82+26.5+5.5=114.0	38.0
24	162.0	45.0	13.5	220.5	73.5
28	240.0	82.0	26.5	348.5	116.2
32	231.0	162.0	45.0	438	146.0
36	165.0	240.0	82.0	487	162.3
40	112.0	231.0	162.0	505	168.3
44	79.0	165.0	240.0	484	161.3
48	57.0	112.0	231.0	400	133.3
52	42.0	79.0	165.0	286	95.3
56	31.0	57.0	112.0	200	66.7
60	22.0	42.0	79.0	143	47.7
64	14.0	31.0	57.0	102	34.0
68	9.5	22.0	42.0	73.5	24.5
72	6.6	14.0	31.0	51.6	17.2
76	4.0	9.5	22.0	35.5	11.8
80	2.0	6.6	14.0	22.6	7.5
84	1.0	4.0	9.5	14.5	4.8
88	0.0	2.0	6.6	8.6	2.9
92		1.0	4.0	5.0	1.7
96		0.0	2.0	2.0	0.7
100			1.0	1.0	0.3
104			0.0	0.0	0.0



This is the figure of 24hr. hydrograph.

(8) PGNO 405 (SKgarg)

(4) The ordinates of a 3 hour unit hydrograph are given below

Time in hr	0	3	6	9	12	15	18	21	24	27	30
ordinates m^3/sec	0	10	25	20	16	12	9	7	5	3	0

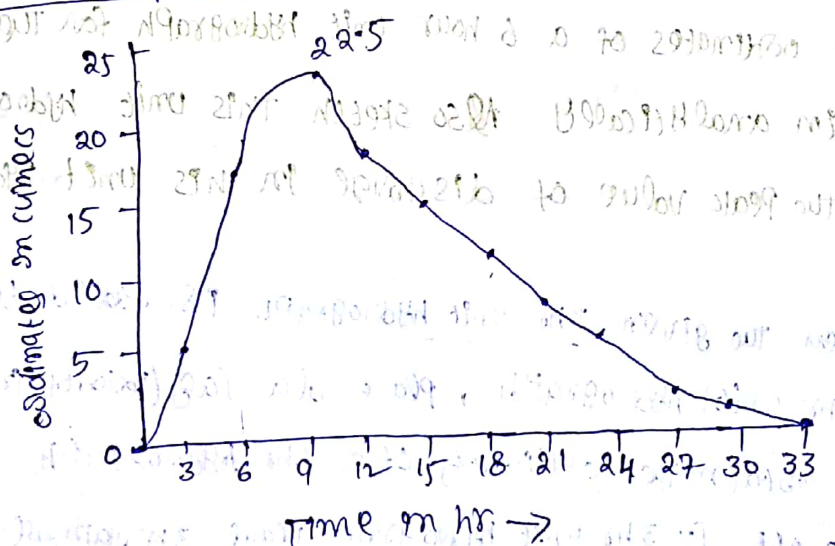
Find the ordinates of a 6 hour unit hydrograph for the same basin analytically. Also sketch this unit hydrograph. what is the peak value of discharge in this unit hydrograph?

sol:-

When the given 3hr unit hydrograph is added to the same 3hr unit hydrograph, place at a lag (period of time) 3hr, Then we obtain the ordinates of a 6hr hydrograph containing 2 cm runoff [∵ 3hr unit hydrograph means 3hr rainfall 1cm of runoff
6 hour hydrograph means 6hr " " 2 cm "]

Hence the addition of 1st 3 hours unit hydrograph and 2nd 3hr unit hydrograph will be obtation. ordinates of 6hr and surface runoff hydrograph containing 2 cm of runoff so column (4) devided by 2 to obtain unit hydrograph ordinates in column (5) of this table

Time from start in hr (1)	1st 3hr unit hydrograph ordinates in m^3/sec (2)	2nd 3hr unit hydrograph ordinates lagged by 3hr in m^3/sec (3)	ordinates of 6hr surface runoff hydrograph containing 2cm of runoff in m^3/sec (2)+(3) = (4)	ordinates of 6hr unit hydrograph col (4)/2 in m^3/sec = (5)
0.	0		0	0
3	10	0	10+0 = 10	10/2 = 5
6	25	10	25+10 = 35	35/2 = 17.5
9	20	25	45	22.5
12	16	20	36	18
15	12	16	28	14
18	9	12	21	10.5
21	7	9	16	8
24.	5	7	12	6
27	3	5	8	4
30	0	3	3	1.5
33		0	0	0



The peak value of discharge comes to 22.5 cumecs. Ans

Pg No 448 (SK garg)

(5) The ordinates of a flood hydrograph resulting from two successive storms each of 1cm rainfall excess and 6hour duration are tabulated below. Find a 6 hr. unit hydrograph

Time (hour)	ordinates of 6hour flood hydrograph (m^3/s)
0	10
6	30
12	90
18	220
24	280
30	220
36	166
42	126
48	92
54	62
60	40
66	20
72	10

Sol:-

let us assume ordinates of 6hr unit hydrograph as a, b, c, d, e, f ----etc and then ~~and~~ computing the flood hydrograph caused by two successive effective rainfalls amounting to 1 cm and 1cm respectively

The second rainfall occur at 6 hr lag (time period)

The additive (ordinates) hydrographs will be equal to the flood hydrographs ordinates − base flow, which apparently is 10 m^3/s. ~~The~~

Time in (hour) ①	Total flood graph ordinates (given) minus base flow of $10 m^3/s$ ②	Assumed ordinates of U.H m^3/s ③	Flood graph ordinates caused by 1st effective rainfall of 1cm = 1 x col ③ ④	Flood graph ordinates caused by 2nd effective rainfall of 1cm = 1 x col ③ ⑤	Total flood graph = col ④ + ⑤ = ② ⑥
0	10 - 10 = 0	0	0		0 = 0
6	30 - 10 = 20	a	a	0	a + 0 = 20
12	90 - 10 = 80	b	b	a	b + a = 80 ; b = 60
18	220 - 10 = 210	c	c	b	c + b = 210 ; c = 150
24	280 - 10 = 270	d	d	c	d + c = 270 ; d = 120
30	220 - 10 = 210	e	e	d	e + d = 210 ; e = 90
36	166 - 10 = 156	f	f	e	f + e = 156 ; f = 66
42	126 - 10 = 116	g	g	f	g + f = 116 ; g = 50
48	92 - 10 = 82	h	h	g	h + g = 82 ; h = 32
54	62 - 10 = 52	i	i	h	i + h = 52 ; i = 20
60	40 - 10 = 30	J	J	i	J + i = 30 ; J = 10
66	20 - 10 = 10	K	K	J	K + J = 10 ; K = 0
72	10 - 10 = 0	l			

The ordinates of U.H of 6 hr duration are thus determined in col ⑥ as 0, 20, 60, 150, 120, 90, 66, 50, 32, 20, 10, 0 m^3/s at time 0, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66 hr Ans

PB NO 135
(SK Garg)

5 (a) compute S-curve ordinates for the following 4hr unit hydrograph of a catchment of 300 sq km area.

Time in hr	unit graph ordinates in cumecs
0	0
1	6
2	36
3	66
4	91
5	106
6	93
7	79
8	68
9	58
10	49
11	41
12	34
13	27
14	23
15	17
16	13
17	9
18	6
19	3
20	1
21	0

(b) compute the 5hr unit hydrograph for this basin with the help of the above derived S-curve

Sol:- The given ordinates of 4hr unit hydrograph are listed in column (2) and S-hydrograph ordinates (column (4)) being the same, are written in ~~col (4)~~ column (4)

Time in hr (1)	4hr unit hydrograph ordinates cumecs (2)	Imaginary off setted S-curve (shifted by $t_1 = 4hr$) cumecs (3)	S-curve ordinates cumecs (4)	S-curve lagged by $t_2 = 5hr$ cumecs (5)	Difference Δy (4)−(5)=(6) (6)	Required ordinates of 5hr (U.H) $\Delta y \times \frac{t_1}{t_2}$ or $\frac{T_0}{T_n}$ (6) × 4/5
0	0	-	0		0	0
1	6	-	6		6	6×4/5=5
2	36	-	36		36	36×4/5=29
3	66	-	66		66	66×4/5=59
4	91	0	91	[=S-T h ordinate]	91	91×4/5=73
5	106	6	112	0	112−0=112	112×4/5=90
6	93	36	129	6	129−6=123	123×4/5=98
7	79	66	145	36	145−36=109	109×4/5=87
8	68	91	159	66	93	74
9	58	112	170	91	79	63
10	49	129	178	112	66	53
11	41	145	186	129	57	46
12	34	159	193	145	48	38
13	27	170	197	159	38	30
14	23	178	201	170	31	25
15	17	186	203	178	25	20
16	13	193	206	186	20	16
17	9	197	206	193	13	11
18	6	201	207	197	10	8
19	3	203	206	201	5	4
20	1	206	207	203	4	3
21	0	207	207	206	1	1
22	0	207	207	207	0	0

Checking Now the equilibrium discharge

$$Q_{eq} = \frac{2.78A}{t_1}$$

$$= \frac{2.78 \times 300}{4}$$

$$= 208 \text{ cumecs}$$

where A = Area in sq km.
and t_1 is in hr

(7) The ordinates of a unit hydrograph of a 6 hr. unit duration for a catchment of 5425 sq km are given below.

Time from beginning of Rainfall in hr	ordinates of unit hydrograph in cumecs
0	0 ✓
6	20
12	50
18	150
24	120
30	90
36	70
42	50
48	30
54	20
60	10
66	0. ✓

compute the ordinates of a 3 hr. unit hydrograph from this 6 hr. unit hydrograph. Using s curve method.

Sol First of all whether the given unit hydrograph contains 1 cm or 1 inch of effective rainfall. so using simpson's formula we have

$$\text{Area under graph} = \frac{h}{3}\left[\left[(\text{first}) + (\text{last ordinate})\right] + 2 \times \text{odd ordinates} + 4 \times \text{Even ordinates}\right]$$

$$= \frac{6\,hr}{3}\left[[(0+0)] + 2(0+50+120+70+30+10) + 4 \times (20+150+90+50+20+0)\right]$$

$$= 2\,hr\,[2 \times (280) + 4 \times (330)]$$

$$= 2\,hr\,[560 + 1320]\text{ cumecs}$$

$$= 2 \times 60 \times 60 \times \text{secs}\,[1880]\ m^3/sec \Rightarrow 13.536 \times 10^6\ m^3$$

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$\therefore$ Depth of water over the basin.

$$= \left[\frac{13.536 \times 10^6 \times 100}{542 \times 10^6}\right] cm \qquad [\because \text{catchment} = 542 \text{ sq km}] \text{ given}$$

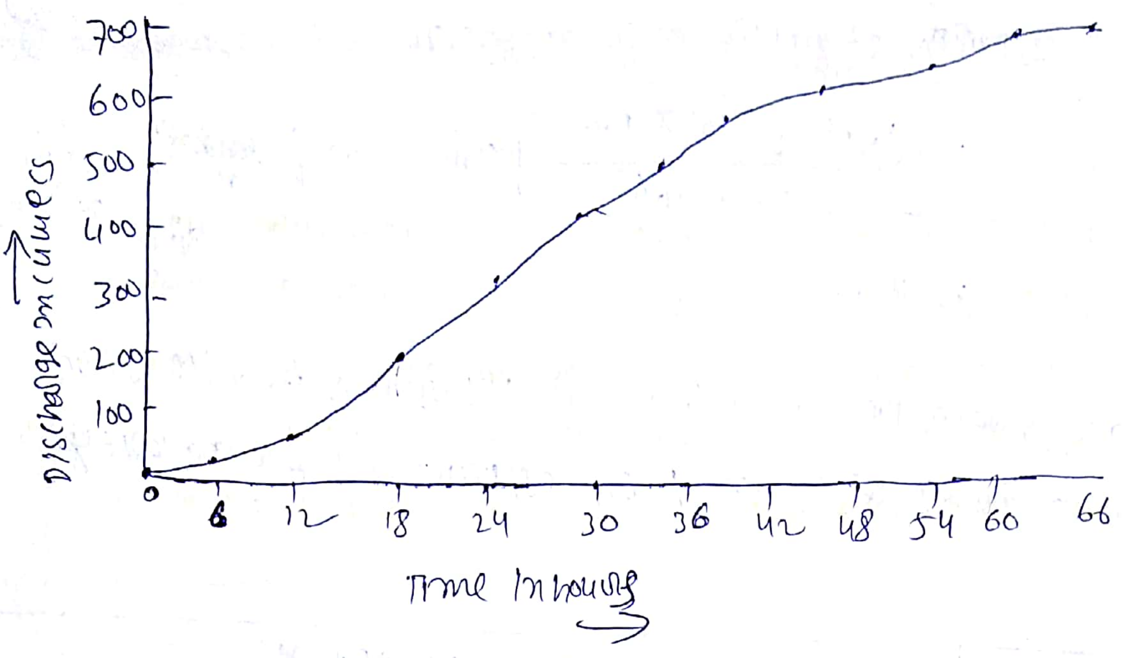
$$= 2.5 \text{ cm}$$

Now from the given 6hr. unit hydrograph, we will derive an S-curve of 2.5 cm / 6hr effective rainfall intensity

Time in hr from start (1)	Computation of S-curve from known 6hr unit hydrograph: ordinates of 6hr unit hydrograph in cumecs	Imaginary offsetted S-curve (shifted by 6hr) ordinates in cumecs	S-curve ordinates for effective rain of 2.5cm per 6hr intensity, in, cumecs
0	0		0
6	20	0 [∵6hr ordinates]	20
12	50 +	20	= 70
18	150 +	70	= 220
24	120 +	220	= 340
30	90	340	430
36	70	430	500
42	50	500	550
48	30	550	580
54	20	580	600
60	10	600	610
66	0	610	610

$$Q_{eq} = 6.94 \, A/t_1 \qquad [\because \text{for "1" U.graph}]$$

$$= 6.94 \times \frac{542}{6} \text{ cumecs} = 626 \text{ cumecs}$$


700
600
500
400
300
200
100
Discharge in cumecs
0
6
12
18
24
30
36
42
48
54
60
66
Time in hours

spect
→ The peak discharge and time to peak in a 3hr unit hydrograph derived for a basin of area 250 km² with L = 30 km and L_c = 14 km are 50 m³/s and 9 hr respectively. Assuming that snyder's synthetic unit hydrograph applies determine the coefficients, C_t and C_p. determine the 2hr unit hydrograph for the upper 180 km² of the same watershed which has L = 20 km and L_c = 11.8 km.

sol:-

Peak discharge $Q_p = 50 m^3/s$

Base width T_b = 3 hours

Basin lag in hours, t_p = 9 hours

Distance from station to catchment, L = 30 km distance along main stream from guaging station to a point opposite the centroid of watershed.

L_c = 14 km. , Area = 250 km²

The peak discharge is given by

$$Q_P = \frac{2.778\ C_p . A}{t_p}$$

$$50 = \frac{2.778 \times C_p \times 250}{9}$$

$$C_p = 0.6479$$

$$\boxed{\therefore C_p = 0.6479}$$

$$t_p = C_t (L_c . L)^{0.3}$$

$$9 = C_t (14 \times 30)^{0.3}$$

$$\boxed{\therefore C_t = 1.47}$$

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Now

$T_b = 2$ hours , $A = 180\ km^2$

$L = 20\,km$, $L_c = 11.8\,km$ given in problem.

For second drainage basin

$$t_p = C_t (L \cdot L_c)^{0.3}$$

$$t_p = 1.47 (20 \times 11.8)^{0.3}$$

$$\therefore t_p = 7.571$$

standard duration

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

$$t_r = \frac{7.571}{5.5}$$

$$\boxed{\therefore t_r = 1.37h} \cong 2h$$

NON- standard duration of rainfall of 2 hours

$$t_{pr} = \frac{21}{22} t_p + \frac{t_r}{4}$$

$$t_{pr} = \frac{21}{22} \times 7.571 + \frac{2}{4}$$

$$\boxed{\therefore t_{pr} = 7.727h}$$

Peak discharge for $t_r = 2h$ is given by

$$Q_{pr} = 2.778\ C_p \frac{A}{t_{pr}}$$

$$= 2.778 \times 0.6479 \times \frac{180}{7.727}$$

$$\boxed{Q_{pr} = 41.93\ m^3/s}$$

Peak time is given by

$$t_{peak} = t_{pr} + \frac{t_r}{2}$$

$$= 7.727 + \frac{2}{2} = 8.727h$$

$$\boxed{t_{peak} = 8.727h}$$

1 prob having in spelt

→ A basin having a drainage area of 2500 km^2 with $L = 100$ km and $L_c = 50$ km is a sub-basin of the catchment. Compute a 4 hr synthetic unit hydrograph for this sub-basin (Assume $C_t = 1.994$, $C_p = 0.545$)

Sol:

Given that

Drainage area

$$A = 2500\ km^2$$

$$L = 100\ km, \quad L_c = 50\ km$$

$$C_t = 1.994, \quad C_p = 0.545$$

Basin lag (

$$t_p = C_t (L L_c)^{0.3}$$

$$t_p = 1.994 (100 \times 50)^{0.3}$$

$$t_p = 25.67 \text{ hours}$$

Unit duration of the storm

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

$$t_r = \frac{25.67}{5.5}$$

$$t_r = 4.667 \text{ hours}$$

Synthetic unit hydrograph for $t_r' = 4$ hours is given by

$$t_p' = t_p + \left[\frac{t_r' - t_r}{4}\right]$$

$$t_p' = 25.67 + \left[\frac{4 - 4.667}{4}\right]$$

$$t_p' = 25.503 \text{ hours}$$

The modified peak discharge for $t_r' = 4$ hours is given by

$$Q_p' = \frac{2.78\, C_p A}{t_p'}$$

$$Q_p' = \left[\frac{2.78 \times 0.545 \times 2500}{25.503}\right]$$

$$Q_p' = 148.52 \text{ cumecs}$$

$$q_p' = \frac{Q_p'}{A}$$

$$q_p' = \frac{148.52}{2500}$$

$$q_p' = 0.0594.$$

Modified base period for $t_p' = 4$ hours is given by

$$T' = 3 + 3\left[\frac{t_p}{24}\right]$$

$$T' = 3 + 3\left[\frac{25.503}{24}\right]$$

$$T' = 6.188 \text{ hours}$$

width of hydrograph at 50% and 75% are given by

$$W_{50} = \frac{2.14}{(q_p')^{1.08}}$$

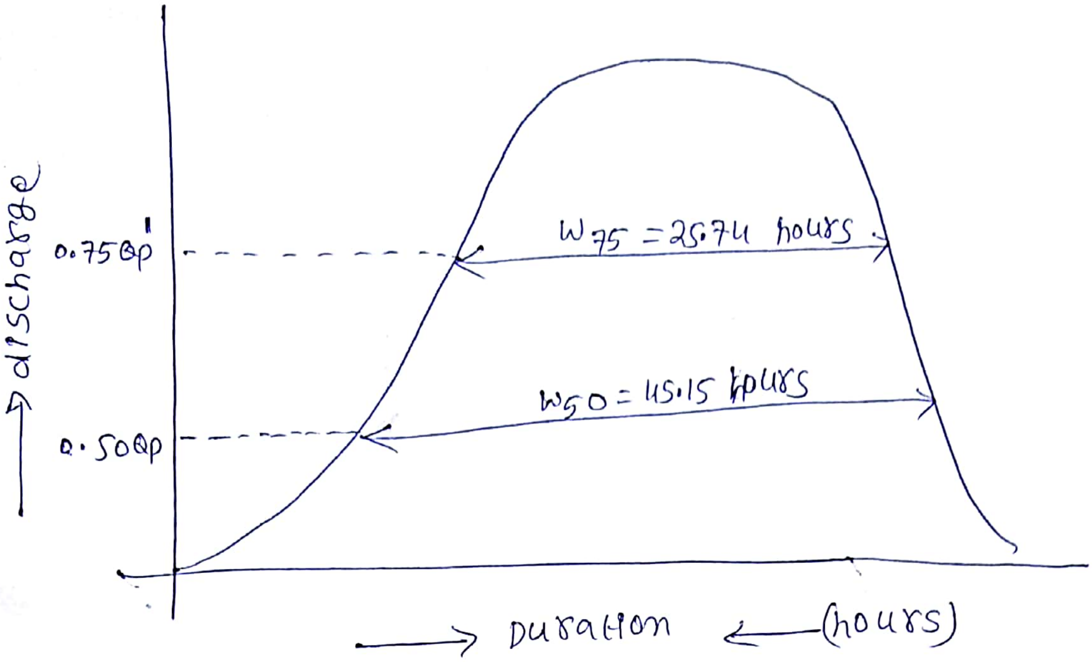
$$W_{50} = \frac{2.14}{(0.0594)^{1.08}}$$

$$W_{50} = 45.15 \text{ hours}$$

$$W_{75} = \frac{1.22}{(q_p')^{1.08}}$$

$$W_{75} = \frac{1.22}{(0.0594)^{1.08}}$$

$$W_{75} = 25.74 \text{ hours}$$



discharge
0.75Qp
0.50Qp
W75 = 25.74 hours
W50 = 45.15 hours
Duration (hours)