TUTORIAL-3

UNIT HYDROGRAPH DERIVATION BY CONVENTIONAL METHODS

(a) Thunder storm of one hour duration with volume 20 mm resulted the direct surface Runoff hydrograph which ordinates are given below. Find out the unit hydrograph of one hour duration with volume 1 mm.

Time (hrs)	Direct Surface Runoff Hydrograph (m^3/s)	Time (hrs)	Direct Surface Runoff Hydrograph (m^3/s)
0	0	12	91.6
1	61.0	13	61.4
2	314.6	14	40.6
3	561.0	15	26.4
4	673.4	16	17.0
5	645.0	18	11.0
6	584.2	19	7.0
7	475.0	20	4.4
8	365.4	21	2.8
9	269.8	22	1.6
10	192.8	23	1.0
11	134.4		

(b) Using the data of rainfall-runoff for the storm of Tutorial 2, Findout the second trial unit hydrograph using Collin's Method,

Solutions :—

(a) Computational steps involved in the derivation of one hour unit hydrograph are : (Ref. Table T 3.1)

(i) Enter the ordinates of the given direct surface runoff in column (3).

(ii) Enter the volume of excess rainfall in column (2) for the single unit period (one hour). The volume of excess rainfall also equals the volume of the direct surface runoff hydrograph).

(iii) Relate the single unit period excess rainfall to the unit volume required in the unit hydrograph. For this example, the unit volume is 1 mm. Therefore, the same excess rainfall block is considered. The proportionality factor (F) used to convert the surface runoff hydrograph ordinates to unit hydrograph ordinates is :

$$F = \frac{P_e}{Q_{UG}} = \frac{20}{1.0} = 20$$

(iv) Divide the surface runoff hydrograph ordinates by F and this gives the unit hydrograph ordinates in column (4),

Table T 3.1 Derivation of Unit Hydrograph From A Single Period Storm

Time (hours)	Excess rainfall (mm)	Direct surface Runoff (m^3/S)	Unit hydrograph (m^3/S)
(1)	(2)	(3)	(4)=(3)/20
1	20	61.0	3.05
2		314.6	15.73
3		561.0	28.05
4		673.4	33.67
5		645.0	32.25
6		584.2	29.21
7		475.0	23.75
8		365.4	18.27
9		269.8	13.49
10		192.8	9.64
11		134.4	6.72
12		91.6	4.58
13		61.4	3.07
14		40.6	2.03
15		26.4	1.32
16		17.4	0.85
17		11.0	0.55
18		7.0	0.35
19		4.4	0.22
20		2.8	0.14
21		1.6	0.08
22		1.0	0.05

(b) Computational steps involved in unit hydrograph derivation using collins Method are : (Ref. Table T 3.2)

(i) Enter the time period in hours in column (1).

(ii) Enter the excess rainfall blocks, determined from analysis of recorded rainfall and runoff in Tutorial 2, in the column (2).

(iii) Determine the values of excess rainfall adjusted for unit volume of unit hydrograph and enter them in the column (3). Here unit volume of unit hydrograph is assumed to be 1 mm.

(iv) Estimate the first trial unit hydrograph ordinates. The no. of periods (ordinates) in the hydrograph is determined from the general equation for the base length relationship.

Periods in Unit hydrograph Base = Periods in surface runoff Base-Number of Rainfall periods + 1 = 18—3 = 1 = 16.

The first trial assumes a uniform unit hydrograph and this is determined as follows :

Calculate Total surface Runoff (from volume under hydrograph) by addition of ordinates
$=2331.32$ cumec hour
$=2331.32 \times 3600 m^3$
$=8.392752 \times 10^6 m^3$
Catchment area $=823.62$ Sq. km
$=923.62 \times 10^6 m^2$
For unit runoff of 1 mm
unit hydrograph volume $=323.62 \times 10^6 \times 10^{-3} m^3$
$=823.62 \times 10^3 m^3$

Excess Runoff in hydrograph $= \dfrac{8.392752 \times 10^6}{0.82362 \times 10^6} = 10.19$ mm

$P_{E1} = 3.58$ mm $\therefore \dfrac{P_{E1}}{1} = 3.58$ mm

$P_{E2} = 4.07$ mm $\therefore \dfrac{P_{E2}}{1} = 4.07$ mm

$P_{E3} = 2.54$ mm $\therefore \dfrac{P_{E3}}{1} = 2.54$ mm

Total $= 10.19$ mm

Fist trial assume constant flow in unit hydrograph. Therefore. First trial average

$$U = \frac{823.62 \times 10^3}{16 \times 1} \text{ m}^3/\text{hour}$$

$$= \frac{823.62 \times 10^3}{16 \times 1 \times 3600} \text{ m}^3/\text{sec}$$

$$= 14.34 \text{m}^3/\text{sec}$$

(v) Enter the first trial unit hydrograph in column (4) to (19) as shown in Table T 3.2

(vi) Apply the first trial unit hydrograph to all periods of rainfall excess except the maximum and determine the hydrograph that would result. Refer to Table T 3.2 and it illustrates what this application gives. See column (20).

(vii) Estimate the runoff from the maximum rainfall P_{EMAX} after deducting the sum of P_{E1} and P_{E3} runoffs from the actual surface runoff hydrographs. The actual surface runoff hydrograph ordinates are entered in column (21).

(viii) Dividing the resulting hydrograph ordinates from step (vii), we get another estimates of the unit hydrograph ordinates. Enter these ordinates in column (22).

(ix) Compare these unit hydrograph ordinates with the original trial unit hydrograph ordinates. U_1^1 for P_{EMAX} occurs at the same time as P_{EMAX}.

(x) If the comperison is not reasonable, average the unit hydrograph ordinates of the first trial and those derived at step (viii) as follows and enter in column (23).

$$\overline{U_i} = \frac{MU_i + NU_i^1}{M+N}$$

where $M=6.12$ mm

$N=4.07$ mm

(xi) Determine the second trial unit hydrograph by adjusting the unit hydrograph obtained from step (x) for the unit runoff volume corresponding to that required. These values are entered in column (24).

(xii) Repeat step (v) to (xi) until the adjusted hydrograph agree with the trial unit hydrograph

Note

$$\overline{U} = \frac{U_{trial} \times M + U^1 \times N}{M + N}$$

Here M=6.12; N=4.07

$\overline{U}_{adjusted} = \overline{U} \div$ Factor so that volume=1 mm.
In example 228.78=1 mm.

Table T 3.2 Collin's Method (Example calculations)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Time	P_E	For	TRIAL (1) UNIT HYDROGRAPH—$m^3/^5$										
(Hons)	(mm)	UH	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9	U_{10}	U_{11}
		Excess rain mm	14.30	14.30	14.30	14.30	14.30	14 30	14.30	14.30	14.30	14.30	14.30
1	3.59	3.58	51.20										
2	4.07	4.07	—	51.20									
3	2.54	2.54	36.32	—	51.20								
4				36.32	—	51.20							
5					36.32	—	51.20						
6						36.32	—	51.20					
7							36.32	—	51.20				
8								36.32	—	51.20			
9									36.32	—	51.20		
10										36.32	—	51.20	
11											36.20	—	51.20
12												36.32	—
13													36.32
14													
15													
16													
17													
18													
	10.19	10.19											

(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
U_{12}	U_{13}	U_{14}	U_{15}	U_{16}	$P_{Ei} \times U_1$	(m^3/s)	$U_i = q - P_{Ei}$ P_{EMAX}	U_i U ($m^{3/5}$)	$\bar{U}$ (adjusted for 1 mm volume ($m^{3/5}$)
14.30	14.30	14.30	14.30	14.30					
					51.20	0	—	—	—
					51.20	47.37	0.94	8.20	7.94
					87.52	111.06	5.78	10.89	10.54
					87.52	369.74	69.34	36.32	35.17
					87.52	413.42	80.07	40.61	39.32
					97.52	337.11	61.32	33.11	32.06
					87.52	215.79	31.52	21.19	24.52
					87.52	214.47	31.19	21.06	20.39
					87.52	153.16	16.13	15.03	14.55
					87.52	126.84	9.66	12.44	12.05
					87.52	115.53	6.88	11.33	10.97
51.20					87.52	84.21	-0.81	8.26	7.99
—	51.20				87.52	52.89	-8.51	5.18	5.02
36.32	—	51.20			87.52	31.58	-13.74	3.08	2.98
	36.20	—	51.20		87.52	20.26	-16.53	1.97	1.91
		36.32	—	51.20	87.52	13.95	-18.08	1.348	1.31
			36.32	—	36.52	12.63	- 5.82	6.26	6.05
				36.32	36.32	11.32	—	—	—
						2331.32		236.37	Factor
								223.78	=1.0327