

CEE3361 Water Resource Management

Solution for Assignment 3: Part A

1) Given data in Table 3.1, develop IDF curves for 2-, 5-, and 10- year return periods.

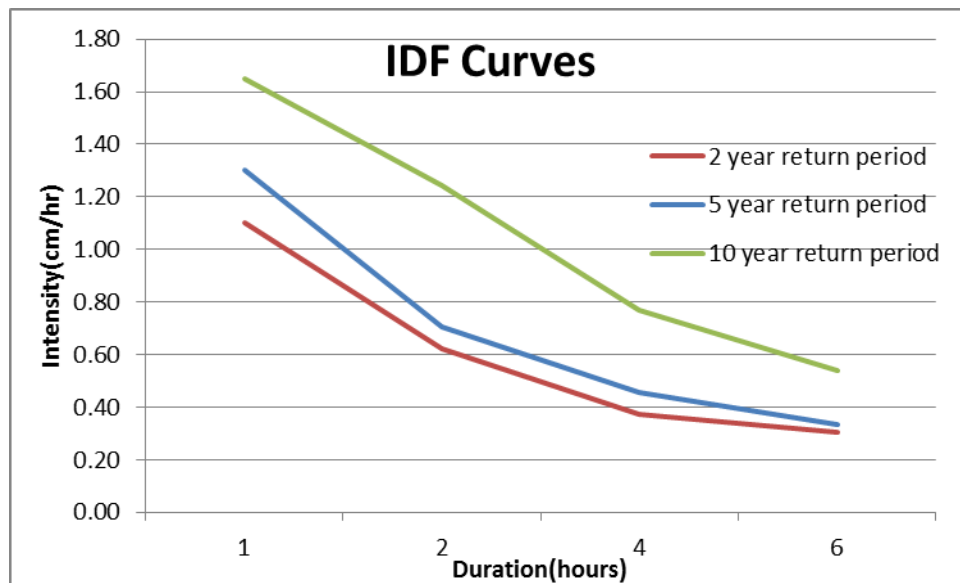
Ans1.

After rank-ordering the given data (descending order) the return period T is estimated using the following Weibull formula (n=number of years of data=20, m=the rank):

$$T = \frac{n + 1}{m}$$

Finally after linear interpolation and dividing by the corresponding rainfall durations the following results are obtained for intensity.

Return Period(year)	Duration(hr)			
	1	2	4	6
2	1.10	0.62	0.37	0.30
5	1.30	0.71	0.46	0.34
10	1.65	1.24	0.77	0.54



- 2) a. Verify that the unit hydrograph is consistent with a 1-cm rainfall excess; and
 b. Estimate the runoff hydrograph for a 1-hour rainfall excess of 3.2 cm

Ans2.

- a) The area A_h under the unit hydrograph can be estimated by numerical integration as
 $A_h = (3600)(1.8 + 6.1 + 8.4 + 6.5 + 5.2 + 4 + 3 + 2.2 + 1.6 + 1.1 + 0.7 + 0.4 + 0.2 + 0.1) = 148,680 \text{ m}^3$
 Where the time increment between the hydrograph ordinates is 60 minutes = 3600 s. Since the area of the catchment is $14.868 \text{ km}^2 = 14.868 \times 10^6 \text{ m}^2$ then the depth, H of rainfall excess is given by
 $H = 148,680 \text{ m}^3 / 14.868 \times 10^6 \text{ m}^2 = 0.01 \text{ m} = 1 \text{ cm}$
 Since the depth of rainfall excess is 1 cm the given hydrograph qualifies as a unit hydrograph.
- b) For a 60 min rainfall excess of 3.2 cm the runoff hydrograph is estimated by multiplying the ordinates of the unit hydrograph by 3.2. This yields the following runoff hydrograph:

Time(h)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
runoff (m^3/s)	0	5.76	19.52	26.88	20.8	16.64	12.8	9.6	7.04	5.12	3.52	2.24	1.28	0.64	0.32	0

3) The surface of 2-ha catchment is characterised by a runoff coefficient, C , of 0.5, Manning n for overland flow of 0.25, an average overland flow length of 60m, and an average slope of 0.5%. Calculate the time of concentration using the kinematic wave equation. The drainage channel is to be sized for the peak runoff resulting from a 10 year rainfall event and the 10 year IDF curve is given by

$$i = \frac{150}{(t + 8.96)^{0.78}}$$

Where i is the average rainfall intensity in cm/hr and t is the duration in minutes. The minimum time of concentration is 5 minutes. Determine the peak runoff rate.

Ans3. The time of concentration, t_c , is estimated by the kinematic wave equation:

$$t_c = 6.99 \frac{(nL)^{0.6}}{i_e^{0.4} S_o^{0.3}}$$

Where $n = 0.25$, $L = 60 \text{ m}$, and $S_o = 0.005$, and therefore

$$t_c = \frac{174}{i_e^{0.4}}$$

where i_e is in mm/h. Equating the storm duration to the time of concentration, then the effective rainfall rate, i_e , for a 10-year storm is given by the IDF relation as

$$i_e = C^* i = \frac{1500C}{(t_c + 8.96)^{0.78}} \text{ mm/hr}$$

Combining the latter two equations, with $C = 0.5$, yields

$$i_e = \frac{1500(0.5)}{\left(\frac{174}{i_e^{0.4}} + 8.96\right)^{0.78}}$$

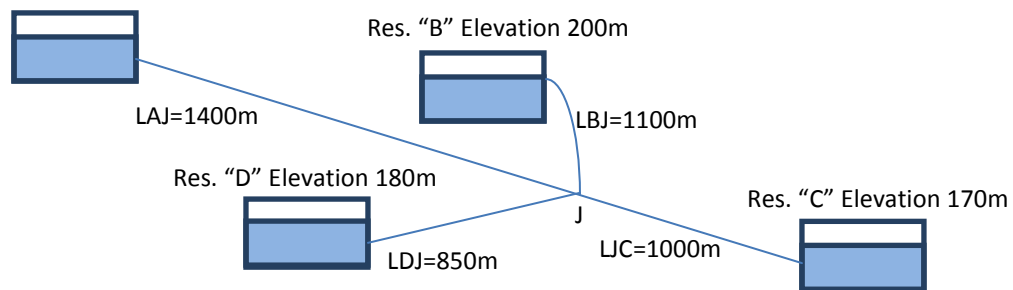
Solving by trial and error yields $i_e = 35 \text{ mm/h}$, and a corresponding time of concentration of 42 min, which exceeds the minimum allowable time of concentration of 5 minutes. The peak runoff, Q_p , from the residential development is given by the rational formula as

$$Q_p = CiA = i_e A$$

where $i_e = 35 \text{ mm/h} = 9.72 \times 10^{-6} \text{ m/s}$, and $A = 2 \text{ ha} = 2 \times 10^4 \text{ m}^2$, therefore

$$Q_p = (9.72 \times 10^{-6}) \times (2 \times 10^4) = 0.19 \text{ m}^3/\text{sec}$$

4) Reservoirs A, B and C are connected as shown in the figure below. The water elevation in reservoir A, B and C are 250m, 200m and 170m respectively. The three pipes connecting the reservoirs meet at the junction J with pipe AJ=1400m, BJ=1100m, DJ=850m and JC=1000m. The diameter of all pipes is equal to 800mm. If all pipes are made up of ductile iron and the water temperature is 20°C. Assuming turbulent flow and equivalent sand roughness $k_s = 0.26 \text{ mm}$ (ductile iron),



a) Calculate the friction factor f using the modified Colebrook equation for turbulent flows defined below

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{k_s}{3.7D} \right)$$

b) Set the energy and continuity equations for finding the flows

Ans 4.

a) Given, $D=0.80$ m, $k_s=0.26$. Substituting the values in the Colebrook equation, we get $f=0.0152$.

b) The energy equations,

$$250 - f \frac{L_{AJ} Q_{AJ}^2}{D \times 2gA^2} = 200 - f \frac{L_{BJ} Q_{BJ}^2}{D \times 2gA^2}$$

$$250 - f \frac{L_{AJ} Q_{AJ}^2}{D \times 2gA^2} = 170 + f \frac{L_{JC} Q_{JC}^2}{D \times 2gA^2}$$

$$250 - f \frac{L_{AJ} Q_{AJ}^2}{D \times 2gA^2} = 180 + f \frac{L_{DJ} Q_{DJ}^2}{D \times 2gA^2}$$

The continuity equation,

$$Q_{AJ} + Q_{BJ} + Q_{DJ} = Q_{JC}$$