CE 412 A: Water Supply & Wastewater Disposal Systems

Tutorial – 2022-23 II ● Part II: Wastewater Management

<u>TUTORIAL 2 ● Monday, March 13, 2023</u>

Exercise 2: Computation of Storm Runoff and Design of Storm Sewer

Design a system of storm sewers for the area shown in Figure 1 based on the Rational Formula for the estimation of peak runoff.

Basic Data and Assumptions

Imperviousness - Built up and paved area	0.7
Imperviousness – Open space, lawns, etc,	0.2
Inlet time -Built up and paved area (tb)	8 Minutes
Inlet time - Open space, lawns (t1)	15 Minute
Minimum velocity in sewer	0.8 mps
Minimum depth of cover above crown	0.5 m

Consider rainfall intensity for once in 5 years storm as the area is central and high priced. (Use Table 1 for the record of rainfall intensity and frequency of rainfall).

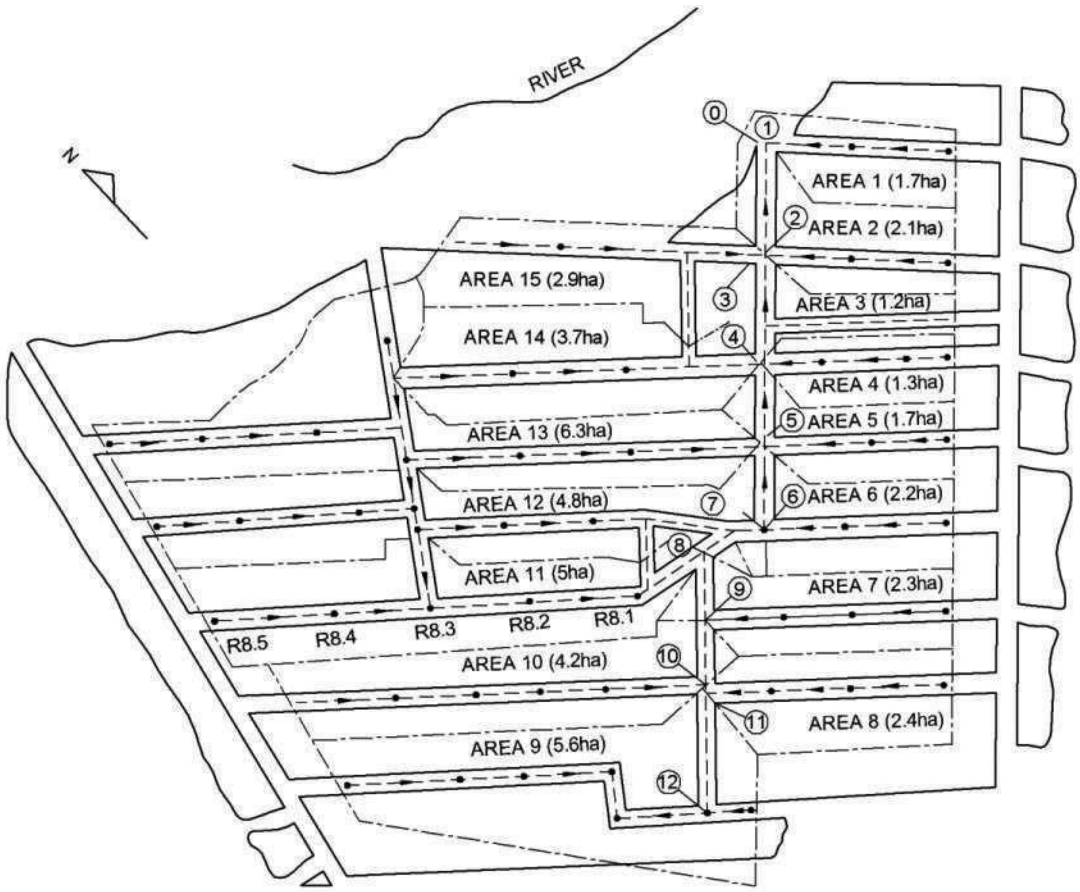


Figure 1

Procedure:

1. Quantity of storm water runoff is calculated using the Rational Formula i.e Q=10CiA; where, Q: Runoff in m^3/h; C: Coefficient of runoff; i: Intensity of rainfall in mm/h; and A: Area of drainage district in hectares.

2. Storm water runoff is determined in the following manner.

   Residential areas

- Peripheral areas – twice a year
- Central and comparatively high-priced areas - once a year to once in 5 years
- Commercial and high-priced areas – once in 5 years to once in 10 years

From the rainfall records for the last 25 years given in Table 1, the storm occurring once in 5 years, i.e. 5 times in 25 years, the time-intensity values for this frequency are obtained by interpolation and can be tabulated as per Table 2.

Table 1: Duration Versus Intensity of Storms

Duration in Minutes	**Intensity Mm/hr**	**30**	**35**	**40**	**45**	**50**	**60**	**75**	**100**	**125**
		No. of storms of stated intensity or more for a period of 26 years								
5						100	40	18	10	2
10				90	72	41	25	10	5	1
15			82	75	45	20	12	5	1	
20		83	62	51	31	10	9	4	2	
30		73	40	22	10	8	4	2		
40		34	16	8	4	2	1			
50		14	8	4	3	1				
60		8	4	2	1					
90		4	2							

Table 2: Intensity Versus Duration Data for a Storm of Given Frequency

Intensity, i mm/h	30	35	40	45	50	60
Duration, t minute	…	…	…	…	…	…

The generalised formula adopted for intensity and duration is

$$i = {}^{a}\!/_{t^n}$$

Where, i: Intensity of rainfall in mm/h; t: Duration in minutes; and a and *n* are constants. Values of a and n are to be estimated using regression analysis for above mentioned equation and data.

3. Using the regression equation i = (a / t^n), i.e., after substituting the values of a and n for different values of i for various values of t can be calculated and tabulated as follows:

Table 3: Intensity-duration Curve for Once in 5 years Storm

	5	10	15	20	25	30	35	40	45	60	80	100	120
i = a/t^n													

4. Calculation of Runoff Coefficient:

Table 4: Percentage of Imperviousness of Areas

S No	**Type of Area**	**Percentage of Imperviousness**
1	Commercial and Industrial Area	70-90
2	Residential Area - High Density - Low Density	 61-75 35-60
3	Parks and undeveloped areas	10-20

When several different surface types or land use comprise the drainage area, a composite or weighted average value of the imperviousness runoff coefficient can be computed, such as:

$$I = [(A_1 I_1) + (A_2 I_2) + \ldots\ldots + (A_n I_n)] / [(A_1 + A_2 + \ldots\ldots + A_n)] \qquad (1)$$

Where, I is Weighted average imperviousness of the total drainage basin; A_1, A_2, …., A_n are Sub drainage areas; and I_1, I_2, …., I_n are Imperviousness of the respective sub-areas.

Imperviousness of the respective sub-areas:

Residential areas

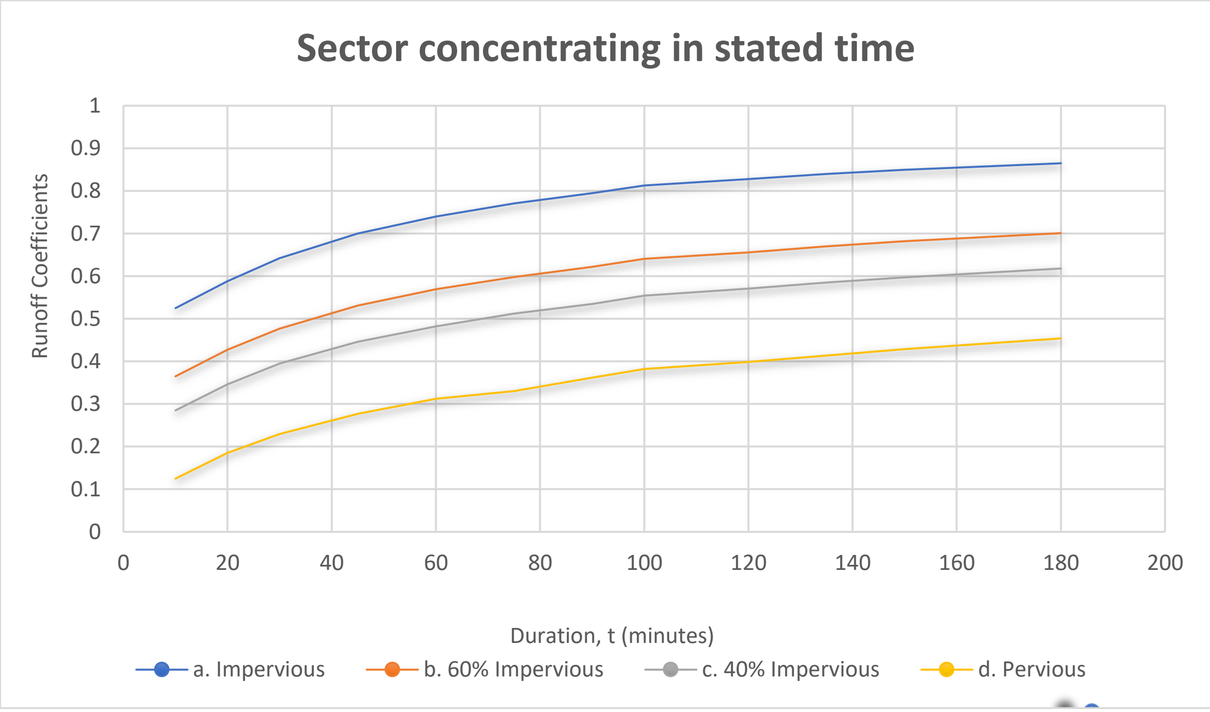
- Peripheral areas – twice a year
- Central and comparatively high-priced areas - once a year to once in 5 years
- Commercial and high-priced areas – once in 5 years to once in 10 years

Table 5: Runoff Coefficients for Times of Concentration

Duration, t, minutes	10	20	30	45	60	75	90	100	120	135	150	180
Weighted Average Coefficient												
A. Sector concentrating in stated time												
a. Impervious	0.525	0.588	0.642	0.700	0.740	0.771	0.795	0.813	0.828	0.840	0.850	0.865
b. 60% Impervious	0.365	0.427	0.477	0.531	0.569	0.598	0.622	0.641	0.656	0.670	0.682	0.701
c. 40% Impervious	0.285	0.346	0.395	0.446	0.482	0.512	0.535	0.554	0.571	0.585	0.597	0.618
d. Pervious	0.125	0.185	0.230	0.277	0.312	0.330	0.362	0.382	0.399	0.414	0.429	0.454
B. Rectangle (length= 4 x width) concentrating in stated time												
a. Impervious	0.550	0.648	0.711	0.768	0.808	0.837	0.856	0.869	0.879	0.887	0.892	0.903
b. 50% Impervious	0.350	0.442	0.499	0.551	0.590	0.618	0.639	0.657	0.671	0.683	0.694	0.713
c. 30% Impervious	0.269	0.360	0.414	0.464	0.502	0.530	0.552	0.572	0.588	0.601	0.614	0.636
d. Pervious	0.149	0.236	0.287	0.334	0.371	0.398	0.422	0.445	0.463	0.479	0.495	0.522

Source: CPHEEO, 1993

5. Another graph (Figure 2) of coefficient of runoff (C) versus rainfall duration is plotted as per values of duration of storms of interest given in Table 5.



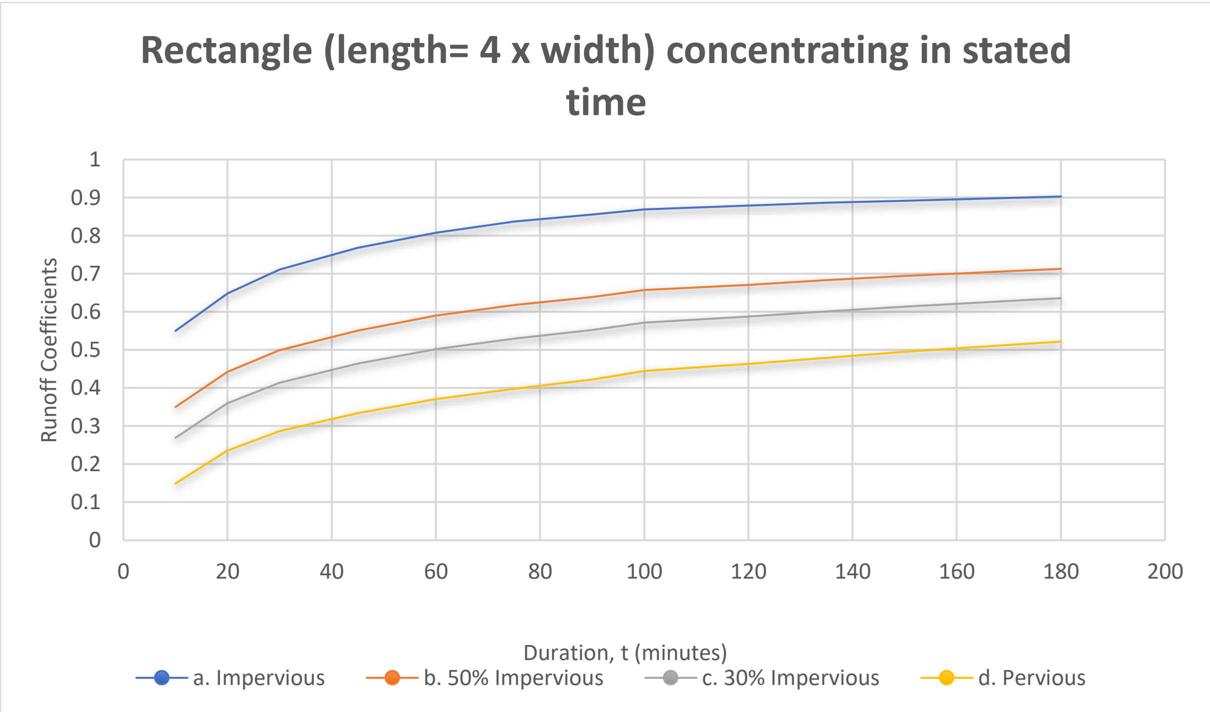


Figure 2: Coefficient of Runoff (C) Versus Rainfall Duration after Horner Area Rectangle

6. The value of 10 C i gives the rate of runoff in m^3/h per hectare of the tributary area.

DESIGN OF STORM SEWER SYSTEM – Step by Step Computations

1. Table 6 gives the various components of the storm sewer system design. Column 1-4 identify the location of drain, street, and manholes.
2. Columns 5-8 record the increment in tributary area with the given imperviousness factors. Column 9 gives the tributary area increment with weighted average imperviousness factor in column 10.
3. Column 11 records the inlet time at the upper end of line (drain).
4. Column 12 records the flow time in the drain.
5. Column 13 is the concentration time.
6. Column 14 records the Coefficient of Imperviousness corresponding to Weighted Average Imperviousness recorded in Column 10 and Concentration Time recorded in Column 13 from the data given in Table 5 or Figure 2.
7. Column 15 records the intensity of rainfall corresponding to the Concentration Time from the relation $i = {}^{a}/_{t^n}\, A$ or interpolation/extrapolation based on data recorded in Table 2 for desired frequency of storm.
8. Column 16 records the incremental storm water flow estimated using the Rationale Formula Q = 10 C i A.
9. Column 17 records the total flow which is sum of incoming flow and incremental flow (column 16).
10. Columns 18-23 record the chosen size, required grade resulting capacity, velocity of flow for each drain or line. These designs of storm sewers are computed for each required flow and maintaining a minimum velocity.
11. Columns 24-26 identify the profile of the drain. Column 19 is taken form the plan.

Table 6: Computation for Design of Storm Sewer

Line Number	Location of Drain			Tributary area (hectares) increment				Total Area	Weighted Average Imperviousness
	Street	Manhole From	Manhole To	Pervious	20 % Imperviousness	70 % Imperviousness	Impervious		
1	2	3	4	5	6	7	8	9	10
1	South St.			0	0.366	0.286	0.274	0.926	
2				0	0.488	0.167	0.214	0.869	
3	North South St.2			0	0.312	0.415	0.352	1.079	
4				0	0.36	0.358	0.324	1.042	
5	South St.			0	0.466	0.256	0.274	0.996	
6	North South St.3			0	0.492	0.230	0.260	0.982	
7				0	0.310	0.410	0.348	1.068	
8	South St.			0	0.466	0.256	0.274	0.996	
9	North South St.4			0	0.282	0.660	0.517	1.459	
10				0	0.362	0.580	0.479	1.421	
11	South St.			0	0.330	0.670	0.494	1.494	

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Line Number	Total Area	Weighted Average Imperviousness	Time of Concentration t_c			Coefficient of Runoff (C)	Intensity of Rainfall (i)	Incremental Flow/Runoff (10 CiA) m^3/h	Total Flow (Q) = Incoming Flow + Incremental Flow/Runoff lps
			Time of inlet (t_i) to upper end	Time of Flow (t_f) in Drain	$t_c = t_i + t_f$				
1	9	10	11	12	13	14	15	16	17
1	0.926		12.0						
2	0.869		13.3						
3	1.079		11.0						
4	1.042		11.5						
5	0.996		12.5						
6	0.982		12.8						
7	1.068		11.0						
8	0.996		12.5						
9	1.459		10.2						
10	1.421		10.8						
11	1.494		10.4						

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Line Number	Total Flow (Q)	Design						Profile		
	lps	Dia mm	Slope m/1000	Capacity lps	Velocity mps	Length m	Fall m	Drop in Manhole	Invert Elevation	
									Upper end	Lower end
1	17	18	19	20	21	22	23	24	25	26
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										