16.13 A Storm Sewer Design Project

Design flows Q_{design} for various sewer sections are estimated by the rational method or the NRCS (SCS) method. The sewer design sequence is as follows:

1. For Q_{design}, and a velocity of 3 ft/sec (0.9 m/s), determine the diameter of the sewer by the continuity equation, $Q = VA$. This is the maximum size.
2. For Q_{design} and the surface grade, determine the diameter by Manning's equation. For a roughness coefficient, use Table 14.4.
3. If the diameter in step 2 is smaller than step 1, select it (rounded to a next-higher standard size) as the sewer size and the surface grade as the sewer slope.
4. If the diameter of step 2 is bigger than step 1, recompute the slope by Manning's formula, adopting the sewer diameter of step 1. In this case a steeper slope than street grade is required. In certain circumstances it is necessary to use a slope lower than this. A provision should then be made for flushing of the pipe.

An example illustrates the procedure.

Example 16.12

Design a storm drainage system for the section of a city shown in Figure 16.12 (the city for which a sanitary sewer system is designed in Example 16.4). Design for the following conditions.

1. The coefficients of runoff, C, at the time of maximum development are given in Figure 16.12.
2. The overland flow time, which can be calculated by the method of Section 16.10.5, is assumed to be 15 minutes for each inlet.
3. The system is to be designed for 5-year peak flows. The rainfall intensity in mm/hr is given by $i = 3330/(t + 19)$, where t is in minutes.
4. Manning's n is 0.013.

Solution Unlike sanitary sewers, the storm sewer line need not run through individual lots because the connections from housing units are not required. Thus the drains can be laid by the shortest route. However, the arrangement will be governed by the topography (contour pattern) of the drainage area that dictates the direction of runoff and hence the positioning of the inlets and laying of sewer lines. Also, relatively larger areas can be covered by each section of the storm drain. For the section of the city in Figure 16.12, the arrow indicates the lowest point in each block.

The general direction of flow of the block will be toward the arrow. A layout of drains has been arranged keeping this in mind. A minimum number of manholes are included. The manhole number is shown within a ❑. The drainage area tributary to each manhole (intercept) point, determined on the basis of the contours, is indicated in the figure along with the runoff coefficient, which has been taken as 0.6 for the commercial district and 0.4 for the residential area.

The design flows at each intercept point are computed in Table 16.15 by the step method of Section 16.11. To calculate the flow at manhole 3, the time of concentration needs to be determined, which involves computation of the time of travel in sewer 1–3 and sewer 2–3 (column 9). This requires a determination of the size and the flow velocity

Table 16.15 Computation of Peak Discharge

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
						Travel Time (min)				Intensity $i = \frac{3330}{(t+19)}$	
Manhole	Location	Tributary Area, a (km^2)	Coefficient, C	aC (m^2)	ΣaC (m^2)	Route	Overland	In Sewer	Total	(mm/hr)	Q (m^3/s)
1	Avenue B	0.013	0.6	7,800	7,800	TA–1[a]	15	0	15	97.9	0.212
2	Avenue B	0.016	0.6	9,600	9,600						
		0.017	0.6	10,200	19,800	TA–2	15	0	15	97.9	0.538
3	Street 3	0.018	0.4	7,200	34,800[b]	TA–3	15	0	15		
						1–3	15	1.47	<u>16.47</u>	93.9	0.908
						2–3	15	1.32	16.32		
4	Street 3	0.014	0.4	5,600	40,400						
		0.016	0.4	6,400	46,800	TA–4	15	0	15		
						3–4	16.47	1.23	<u>17.70</u>	90.7	1.180
5	Street 3	0.015	0.4	6,000	52,800						
		0.017	0.4	6,800	59,600	TA–5	15	0	15		
						4–5	17.70	0.95	<u>18.65</u>	88.4	1.464

[a] TA–1 = Tributary area to manhole 1.

[b] Col. 5 for TA + col. 6 for manhole 1 via route 1–3 + col. 6 for manhole 2 via route 2–3 = 7200 + 7800 + 19,800 = 34,800.

Table 16.16 Storm Sewer Design Computations

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Sewer Line				Surface Elevation (ft)					Design Parameters			Travel Time (min)
Manhole	From	To	Design Flow, Q_{design} (m^3/s)	Length of Sewer (m)	Upstream	Downstream	Street Slope	Maximum Diameter for Velocity of 0.9 m/s[a] (mm)	Diameter for Street Grade[b] (mm)	Diameter[c] (mm)	Sewer Grade[d]	Velocity at Full[e] (m/s)	$\left(\frac{\text{col. 5}}{\text{col. 13}} \times \frac{1}{60}\right)$
1	1	3	0.212	120	98.23	97.51	0.006	550	445	445	0.006	1.36	1.47
2	2	3	0.538	150	98.65	97.51	0.0076	875	600	600	0.0076	1.90	1.32
3	3	4	0.908	97	97.51	97.32	0.002	1135	940	940	0.002	1.31	1.23
4	4	5	1.180	93	97.32	97.04	0.003	1290	960	960	0.003	1.63	0.95
5	5	6	1.464	95	97.04	96.66	0.004	1440	990	990	0.004	1.90	0.83

[a] $D = (1.274Q/v)^{1/2} \times 1000$ (continuity equation), Q is Q_{design}

[b] $D = \left[\frac{(3.211)nQ}{s^{1/2}}\right]^{0.375} \times 1000$ (Manning's equation).

[c] Smaller of col. 9 or col. 10.

[d] If col. 9 is smaller than col. 10, recompute the slope (grade) for the diameter of col. 9 by the Manning equation. If col. 10 is smaller than col. 9, col. 12 = col. 8.

[e] $v = 1.274\left(\frac{Q}{D^2}\right)$; D in m (continuity equation).

(design) of the two sewer sections. Thus the design of each section proceeds simultaneously with estimation of design flow; the process alternates between Table 16.15 and Table 16.16. The design flows at the head of section 1– 3 (manhole 1) and section 2– 3 (manhole 2) are computed in the first two lines of column 12 in Table 16.15. For these flows, pipe sections 1– 3 and 2– 3 are designed in lines 1 and 2 in Table 16.16. This provides the average velocity of flow (column 13) and the travel time through the sewer (column 14) in Table 16.16. This time of flow is included in column 9 of Table 16.15 for manhole 3 to determine the time of concentration. The design flow is then determined for the next pipe to be designed. Thus the computation alternates in Tables 16.15 and 16.16.

The design procedure of Table 16.16 is as follows. The value in column 4 is taken from column 12 of Table 16.15. Columns 5, 6, and 7 are based on the layout plan. Column 8 is the difference between columns 6 and 7, divided by column 5. In column 9, the maximum sewer size for a minimum velocity of 0.9 m/s is determined using the continuity equation, $Q = AV$. In column 10, the diameter corresponding to the street slope of column 8 is computed from Manning's equation. The design diameter in column 11 is the minimum of columns 9 and 10 (rounded to a standard size). If this pertains to column 10, the sewer grade in column 12 is equivalent to the street grade. If the design diameter is based on column 9, the sewer grade is computed from Manning's equation. The velocity of flow in column 13 is determined by the continuity equation for known flow (column 4) and diameter (column 11). When the velocity is excessive, it is reduced to a limiting value of 5.0 m/s and for the known design flow, the diameter is recomputed by the continuity equation and the slope from Manning's equation.

Figure 16.12 Storm drains layout for a section of a city.