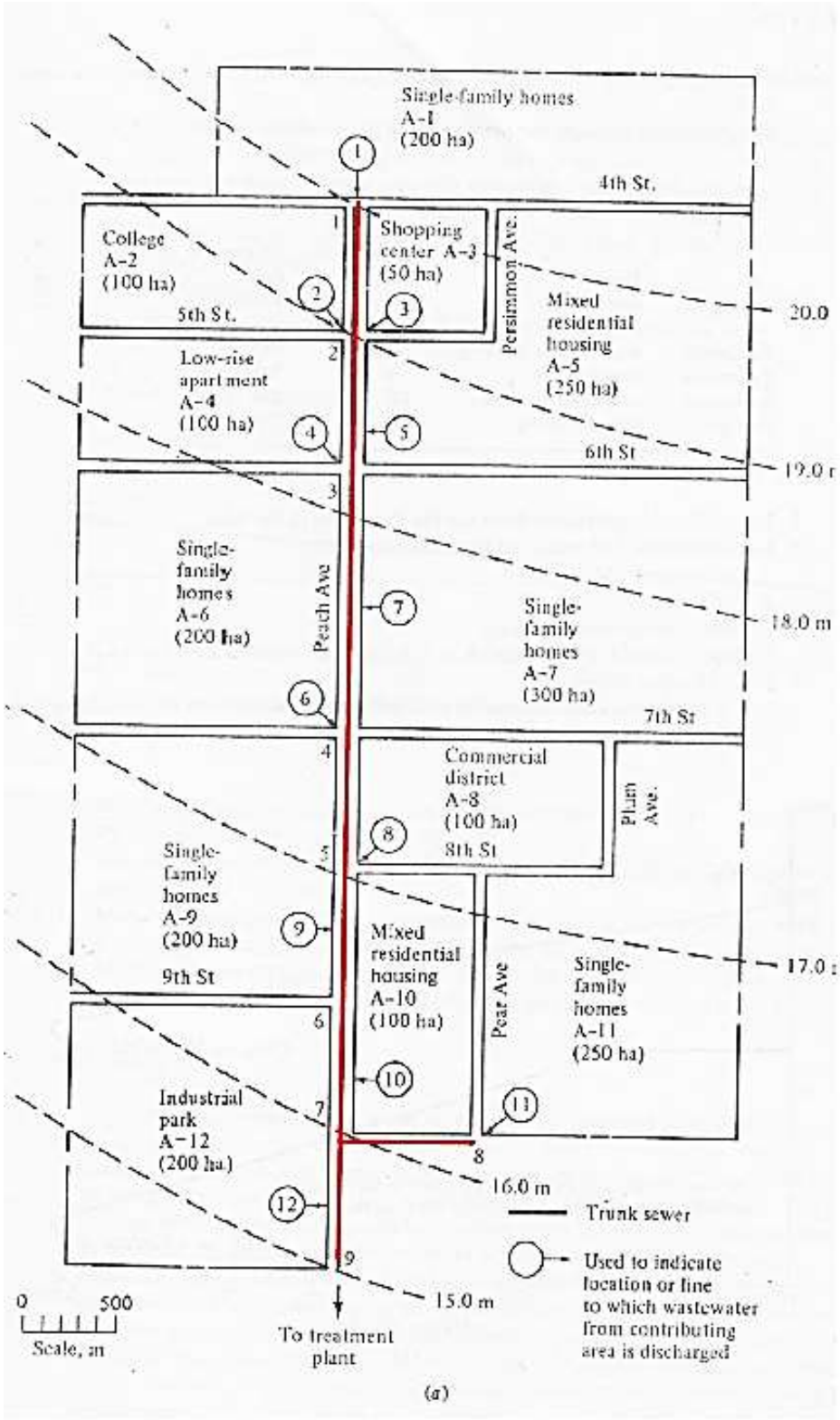
SEWER DESIGN


Single-family homes
A-1
(200 ha)
4th St.
College
A-2
(100 ha)
5th St.
Shopping
center A-3
(50 ha)
Persimmon Ave.
Mixed
residential
housing
A-5
(250 ha)
20.0
Low-rise
apartment
A-4
(100 ha)
6th St
19.0 r
Single-
family
homes
A-6
(200 ha)
Peach Ave
Single-
family
homes
A-7
(300 ha)
18.0 m
7th St
Commercial
district
A-8
(100 ha)
8th St
Plum
Ave.
Single-
family
homes
A-9
(200 ha)
9th St
Mixed
residential
housing
A-10
(100 ha)
Pear Ave
Single-
family
homes
A-11
(250 ha)
17.0 :
Industrial
park
A-12
(200 ha)
16.0 m
Trunk sewer
Used to indicate
location or line
to which wastewater
from contributing
area is discharged
15.0 m
0
500
Scale, m
To treatment
plant
(a)

Design of a gravity-flow sanitary sewer

Design a gravity-flow trunk sanitary sewer for the area shown in the accompanying figure (a). The trunk sewer is to be laid along Peach Avenue starting at 4th Street and ending at 11th Street. Assume that the following design criteria have been developed based on an analysis of local conditions and codes.

1. For design period use the saturation period (time required to reach saturation population).

2. For population densities use the data given in the following table.

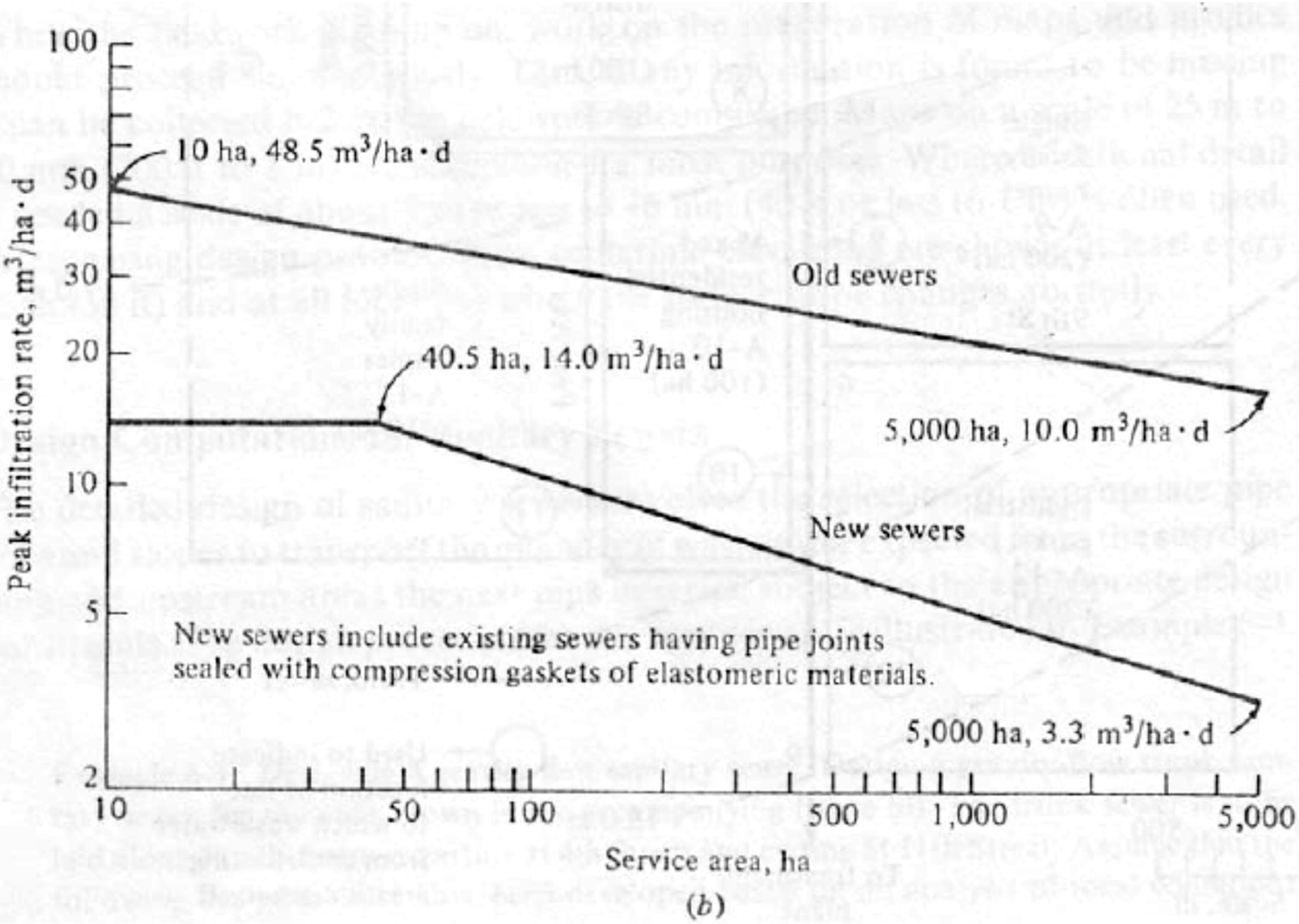
Zoning	Type of development	Saturation population density, person/ha	Wastewater flow, L/capita · d
Residential	Single-family dwellings	40	380
Residential	Duplexes	60	300
Residential	Low-rise apartments	120	220
Residential	Mixed housing	70	250

3. For residential wastewater flows use the data given in the table above.

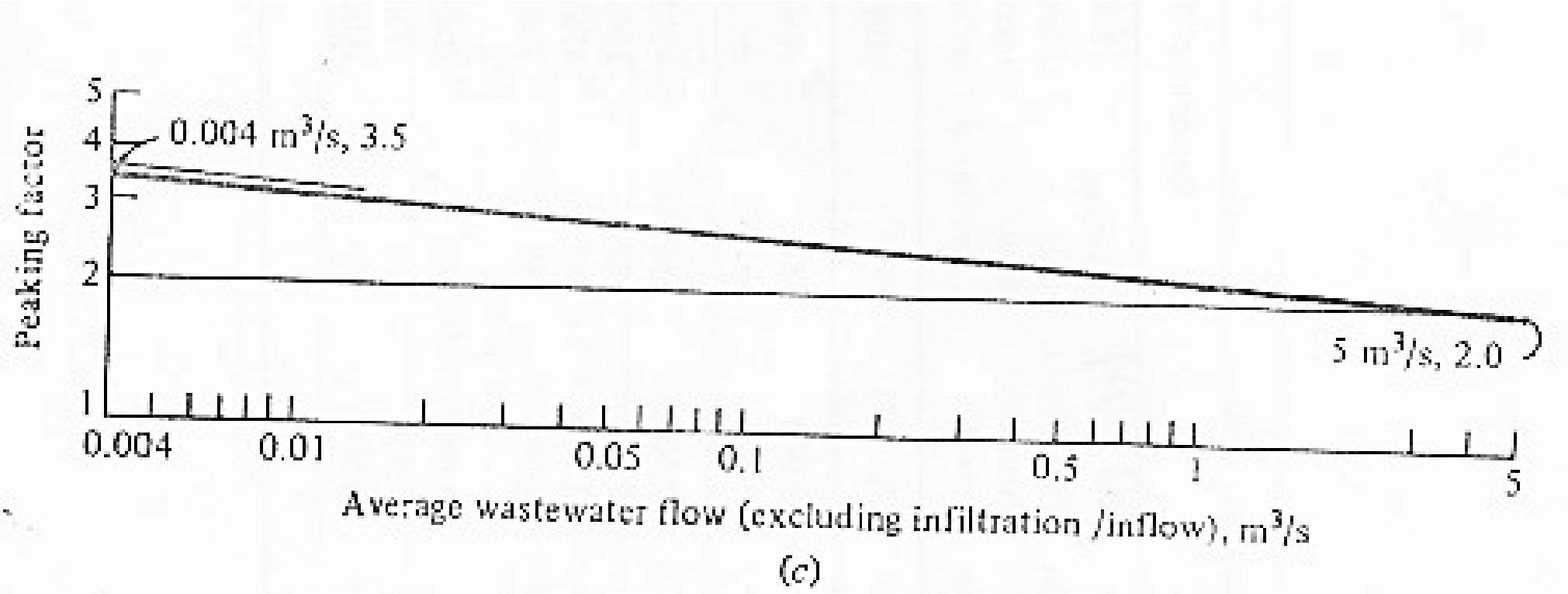
4. For commercial and industrial flows (average):
a. Commercial – 20 m^3/ha. d
b. Industrial – 30 m^3/ha . d

5. For institutional flows (average):
College – 400 m^3/d (5330 students × 75 L/student. D) /(1000 L/m^3)

6. For infiltration allowance:
a. For residential areas, obtain the peak infiltration values from the accompanying figure (b).
b. For commercial, industrial and institutional areas, also obtain the peak infiltration values from the figure (b). However, to make into account that the total length of sewers in these areas will generally be less than that in residential areas, use only 50 percent of the actual area to compute the infiltration allowance.



7. For inflow allowance assume that the steady flow inflow is accounted for in the infiltration allowance.



(c)

8. Peaking factors:

a. Residential – use the curve given in the accompanying figure (c).

b. Commercial – 1.8

c. Industrial – 2.1

d. Institutional (school) – 4.0

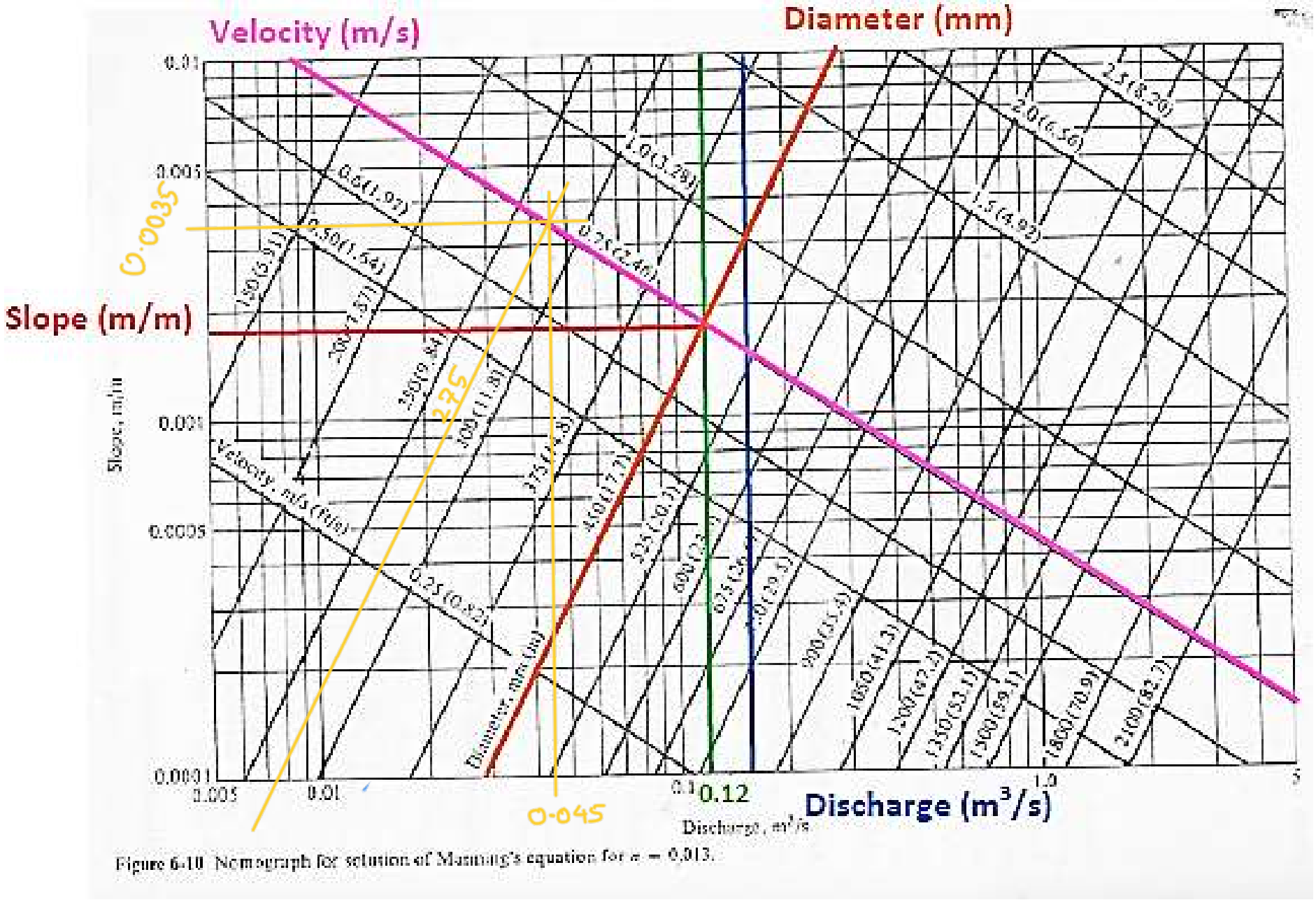


Figure 6-10 Nomograph for solution of Manning's equation for $n = 0.013$.

9. For the hydraulic design equation, use the Manning equation with an n value of 0.013. To simplify the computations, use Fig 6.10.

10. Minimum pipe size: The local building code specifies 200 mm (8 in) as the smallest pipe permissible for this situation.

11. Minimum velocity: To prevent the deposition of solids at low waste water flows, use a minimum velocity of 0.75 m/s (2.5 ft/s) during the peak flow conditions.

12. Minimum cover (minimum depth of cover over the top of the sewer): As established by the local community building code, the minimum depth of cover is 2.0 m.

Solution

1. Lay out the trunk sewer. Draw a line to represent the proposed sewer [figure (a)].

2. Locate and number the manholes. Locate manholes at (1) changes in direction, (2) changes in slope, (3) pipe junctions, (4) upper ends of sewer and (5) intervals from 90 to 120 m or less. Identify each manhole with a number. For the purpose of this problem only the manholes at the major junctions have been numbered [figure (a)]. In actual design, intermediate manholes would be located and numbered.

3. Prepare a sewer design computation table. Based on the experience of numerous engineers, it is found that the best approach for carrying out sewer computations is to use a computation table. The necessary computations for the sanitary sewer shown in figure (a) are presented in the accompanying table.

Sewer computation table

Location					Residential flows								
Line	From	To	Length of sewer, m	Subarea*	Area, ha	Population density, persons/ha	Population increment, persons [(6) x (7)]	Average unit flow, L/capita · d	Flow increment, m^3/d (8 x 9)	Cumulative average flow, m^3/d	for (10) Peaking factor	Cumulative peak flow, m^3/d (11 × 12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	1	2	707	A-1	200	40	8,000	380	3040	3,040	2.9	8,816
2	2	3	707	A-2	—	—	—	—	—	3,040	2.9	8,816
				A-3	—	—	—	—	—	3,040	2.9	8,816
				A-5	250	70	17,500	250	4375	7,415	2.7	20,021
3	3	4	1414	A-4	100	120	12,000	220	2640	10,055	2.6	26,143
				A-7	300	40	12,000	380	4560	14,615	2.6	37,999
4	4	5	707	A-6	200	40	8,000	380	3040	17,655	2.5	44,138
5	5	6	707	A-8	—	—	—	—	—	17,655	2.5	44,138
				A-9	200	40	8,000	380	3040	20,695	2.5	51,738
6	6	7	707	A-10	100	70	7,000	250	1750	22,445	2.5	56,113
7	8	7	707	A-11	250	40	10,000	380	3800	3,800†	2.9	11,020
8	7	9	707	~~A-12~~ A-12						26,245	2.5	65,613

Sewer computation table (*Continued*)

	Location				Commercial flows					Industrial flows				
Line	From	To	Length of sewer, m	Subarea*	Area, ha	Average unit flow, $m^3/ha \cdot d$	Cumulative average flow, m^3/d	Peaking factor	Cumulative peak flow, m^3/d (16 × 17)	Area, ha	Average unit flow, $m^3/ha \cdot d$	Cumulative average flow, m^3/d	Peaking factor	Cumulative peak flow, m^3/d (21 × 22)
(1)	(2)	(3)	(4)	(5)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1	1	2	707	A-1	—	—	—	—	—	—	—	—	—	—
2	2	3	707	A-2	—	—	—	—	—	—	—	—	—	—
				A-3	50	20	1000	1.8	1800	—	—	—	—	—
				A-5	—	—	1000	1.8	1800	—	—	—	—	—
3	3	4	1414	A-4	—	—	1000	1.8	1800	—	—	—	—	—
				A-7	—	—	1000	1.8	1800	—	—	—	—	—
4	4	5	707	A-6	—	—	1000	1.8	1800	—	—	—	—	—
5	5	6	707	A-8	100	20	3000	1.8	5400	—	—	—	—	—
				A-9	—	—	3000	1.8	5400	—	—	—	—	—
6	6	7	707	A-10	—	—	3000	1.8	5400	—	—	—	—	—
7	8	7	707	A-11	—	—	—	—	—	—	—	—	—	—
8	7	9	707	A-12	—	—	3000	1.8	5400	200	30	6000	2.1	12,600

Sewer computation table (*Continued*)

Location					Institutional flows			Cumulative subtotals		Infiltration			
Line	From	To	Length of sewer, m	Subarea*	Cumulative average flow, m^3/d	Peaking factor	Cumulative peak flow, m^3/d (24 × 25)	Cumulative average flow, m^3/d (11 + 16 + 21 + 24)	Cumulative peak flow, m^3/d (13 + 18 + 23 + 26)	Area, ha	Cumulative area, ha	Peak unit infiltration allowance $m^3/ha \cdot d$	Cumulative infiltration allowance, m^3/d (30 × 31)
(1)	(2)	(3)	(4)	(5)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
1	1	2	707	A-1	—	—	—	3,040	8,816	200‡	200	8.0	1600
2	2	3	707	A-2	400	4.0	1600	3,440	10,416	50†	250	7.5	1875
				A-3	400	4.0	1600	4,440	12,216	25‡	275	7.5	2063
				A-5	400	4.0	1600	8,815	23,421	250	525	7.0	3675
3	3	4	1414	A-4	400	4.0	1600	11,455	29,543	100	625	6.5	4063
				A-7	400	4.0	1600	16,015	41,399	300	925	5.5	5088
4	4	5	707	A-6	400	4.0	1600	19,055	47,538	200	1125	5.0	5625
5	5	6	707	A-8	400	4.0	1600	21,055	51,138	50‡	1175	5.0	5875
				A-9	400	4.0	1600	24,095	58,738	200	1375	4.9	6738
6	6	7	707	A-10	400	4.0	1600	25,845	63,113	100	1475†	4.8	7080
7	8	7	707	A-11	—	—	—	3,800	11,020	250	250†	8.0	2000
8	7	9	707	A-12	400	4.0	1600	35,645	85,213	100‡	1825	4.0	7300

Sewer computation table *(Continued)*

Location					Design flows		Sewer design				Sewer layout			
											Ground surface elevation		Sewer pipe invert elevation	
Line	From	To	Length of sewer, m	Subarea*	Cumulative peak flow, m^3/d (28 + 32)	Cumulative peak flow,§ m^3/s	Sewer diameter, mm	Slope, m/m	Capacity when full, m^3/s	Velocity when full, m/s	At upper manhole	At lower manhole	Upper end	Lower end
(1)	(2)	(3)	(4)	(5)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)
1	1	2	707	A-1	10,416	0.121	450	0.0018	0.121	0.75	20.00	19.00	17.50	16.23
2	2	3	707	A-2	12,291	0.142	—	—	—	—	—	—	—	—
				A-3	14,279	0.165	—	—	—	—	—	—	—	—
				A-5	27,096	0.314	750	0.0009	0.330	0.75	19.00	18.33	15.93	15.29
3	3	4	1414	A-4	33,606	0.389	—	—	—	—	—	—	—	—
				A-7	46,487	0.538	900	0.0009	0.540	0.85	18.33	17.40	15.14	13.86
4	4	5	707	A-6	53,163	0.615	1050	0.0008¶	0.770	0.87	17.40	17.00	13.71	13.14
5	5	6	707	A-8	57,013	0.660	—	—	—	—	—	—	—	—
				A-9	65,476	0.758	1050	0.0008¶	0.770	0.87	17.00	16.50	13.14	12.58
6	6	7	707	A-10	70,193	0.812	1050	0.0009	0.820	0.95	16.50	16.00	12.58	11.94
7	8	7	707	A-11	13,020	0.151	525	0.0014	0.165	0.75	16.20	16.00	12.46	13.46
8	7	9	707	A-12	92,513	1.071	1200	0.0008¶	1.100	0.98	16.00	15.00	11.79	11.22

* See figure (*a*).

† Line 7 receives flow from subarea A-11 only.

‡ 50 percent of area (see assumption 6*b*).

§ $m^3/s = (m^3/d)/(86{,}400\ s/d)$.

¶ The minimum practical slope for construction is about 0.0008 m/m.

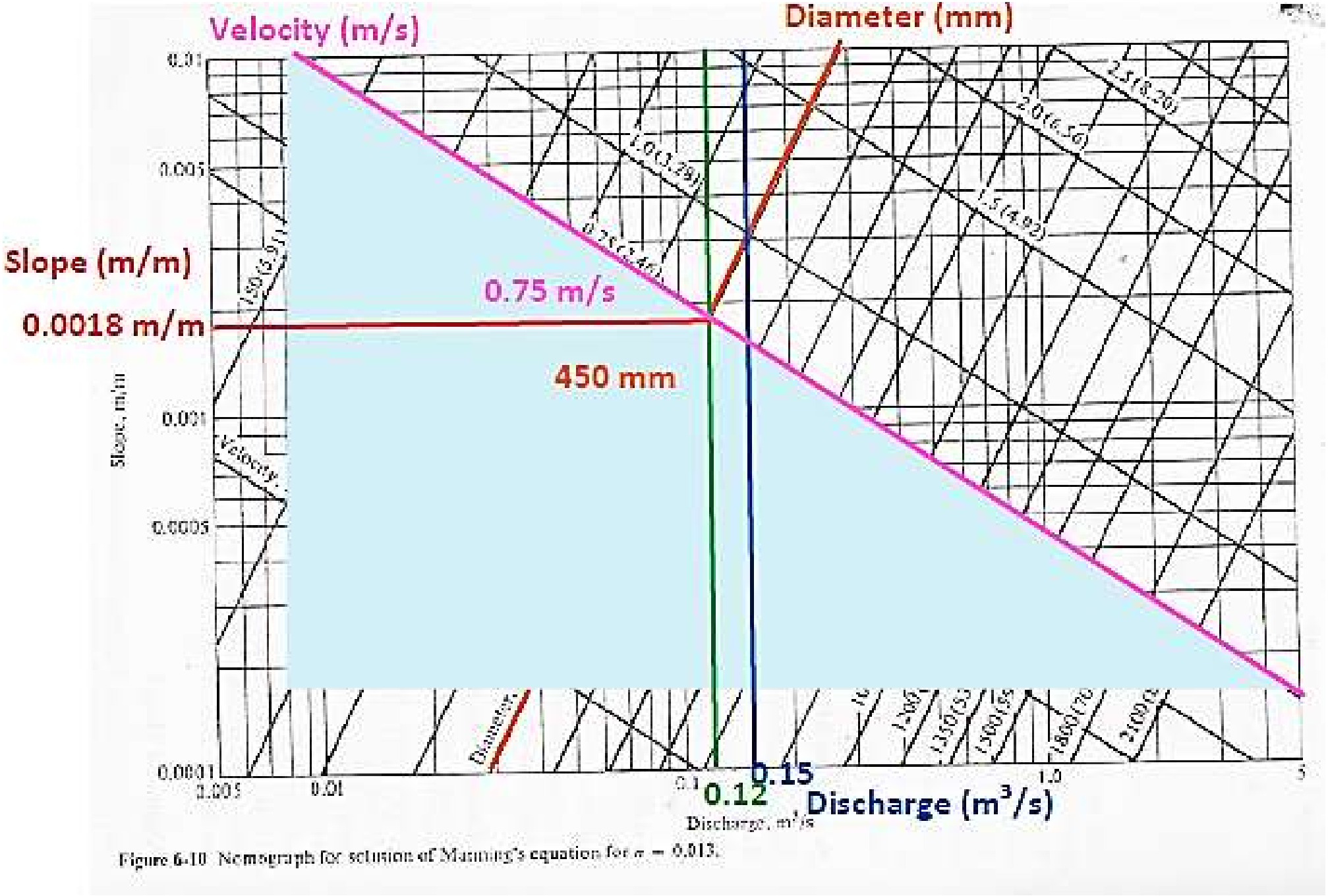


Figure 6-10 Nomograph for solution of Manning's equation for $n = 0.013$.

a. The entries in columns 1 through 5 are used to identify the sewer lines under consideration and to summarize the basic physical data from figure (*a*).

b. The entries in columns 6 through 13 are used to obtain the cumulative peak domestic flow (column 13). The area (column 6) is obtained from figure (*a*). The population density (column 7) and the unit flow data (column 9) were given. Peaking factors, obtained from figure (*c*), are entered in column 12.

c. The commercial area, the corresponding unit flow, and the cumulative average flows are entered in columns 14, 15, and 16, respectively. The given peaking factor for the commercial area is entered in column 17, and the computed cumulative peak commercial flows are entered in column 18.

d. The entries in columns 19 through 23 for the industrial flows are the same as described for the commercial flows (columns 14 through 18).

e. The institutional flows are entered in columns 24 through 26.

f. The cumulative average and peak flows are summarized in columns 27 and 28, respectively.

g. The infiltration allowance (columns 29 through 32) is determined using the curve for new sewers in figure (*b*).

h. The total cumulative peak design flow (column 33) is obtained by summing columns 28 and 32.

i. Sewer design information is summarized in columns 35 through 38. The required pipe sizes are estimated using Manning's equation with an n value of 0.013 (see Fig. 6-10). The capacity of the selected pipe and the velocity when full are tabulated in columns 37 and 38. In all cases the velocity should exceed 0.75 m/s (2.5 ft/s).

j. The necessary layout data for the sewer (columns 39 through 42) are obtained as follows: The ground surface elevations at the manhole locations entered in columns 39 and 40 are obtained by interpolation with the elevation data given in figure (*a*). The sewer invert elevations shown in columns 41 and 42 are obtained by trial and error with a sewer profile work sheet. The first step in preparing a work sheet is to plot the ground-surface elevations given in columns 39 and 40, working backwards from a convenient point. After the ground-surface profile is drawn, the next step is to begin sketching the invert and crown (inside bottom and inside top of the pipe, respectively) of each sewer section as the necessary elevation data are developed.

The method for establishing the invert elevations will be illustrated by analyzing selected sewer lines starting with line 1, which connects manholes 1 and 2. The first step is to locate the invert of the upper end of the pipe at such an elevation that the minimum cover requirement is satisfied, taking into account both the inside diameter of the pipe and its wall thickness. The upper invert elevation of the 450-mm pipe is set initially at elevation 17.5 m:

ground surface	−	depth of cover	−	pipe wall thickness	−	pipe diameter
20.00 m	−	2.00 m	−	0.05 m	−	0.45 m

The pipe thickness will vary with the type of sewer. For this example, 0.05 m will be used for all pipe sizes. The lower elevation is computed by subtracting the fall as follows:

Lower invert elevation	=	Upper invert elevation	−	Slope of sewer	×	Length of sewer

For line 1:

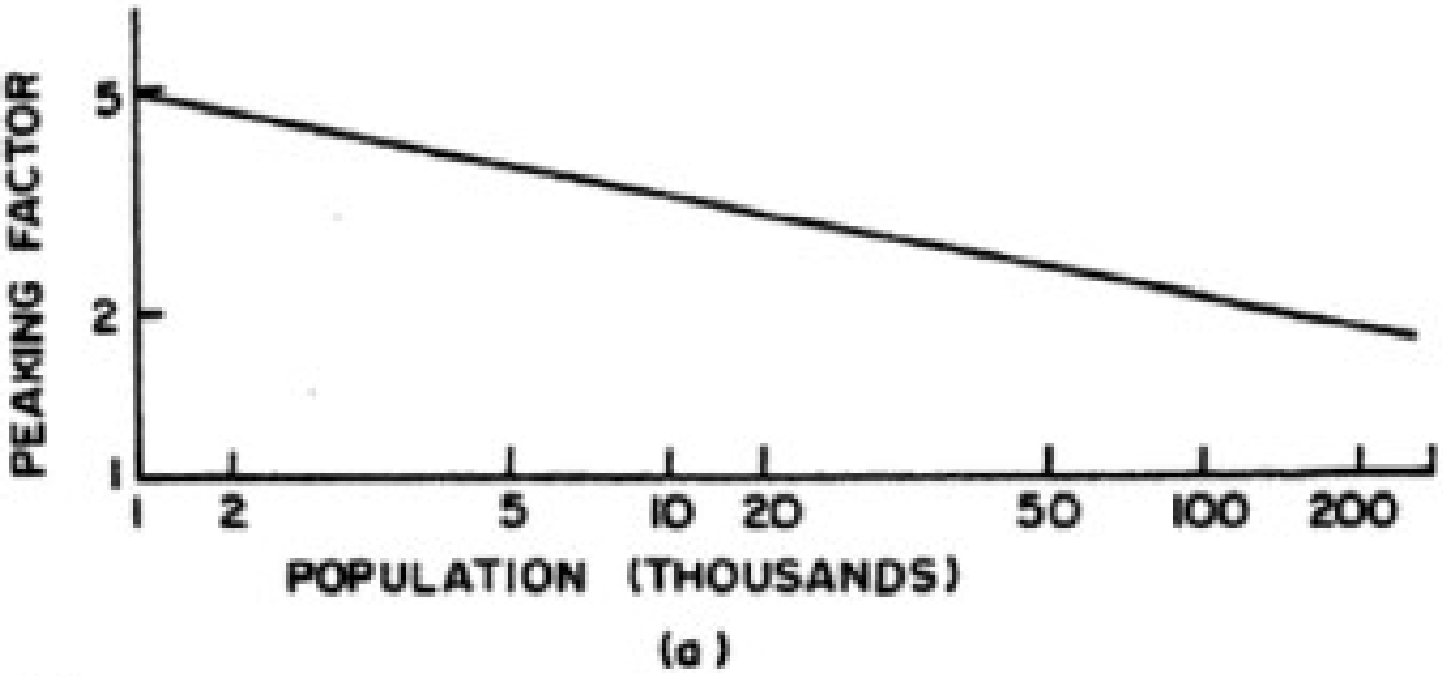
$$\text{Lower invert elevation} = 17.50\ \text{m} - (0.0018\ \text{m/m})(707\ \text{m}) = 16.23\ \text{m}$$

If the depth of cover (remember to allow for the pipe wall thickness above the crown) for any section has become too shallow, repeat the process with a lower initial invert elevation or a steeper slope for that section.

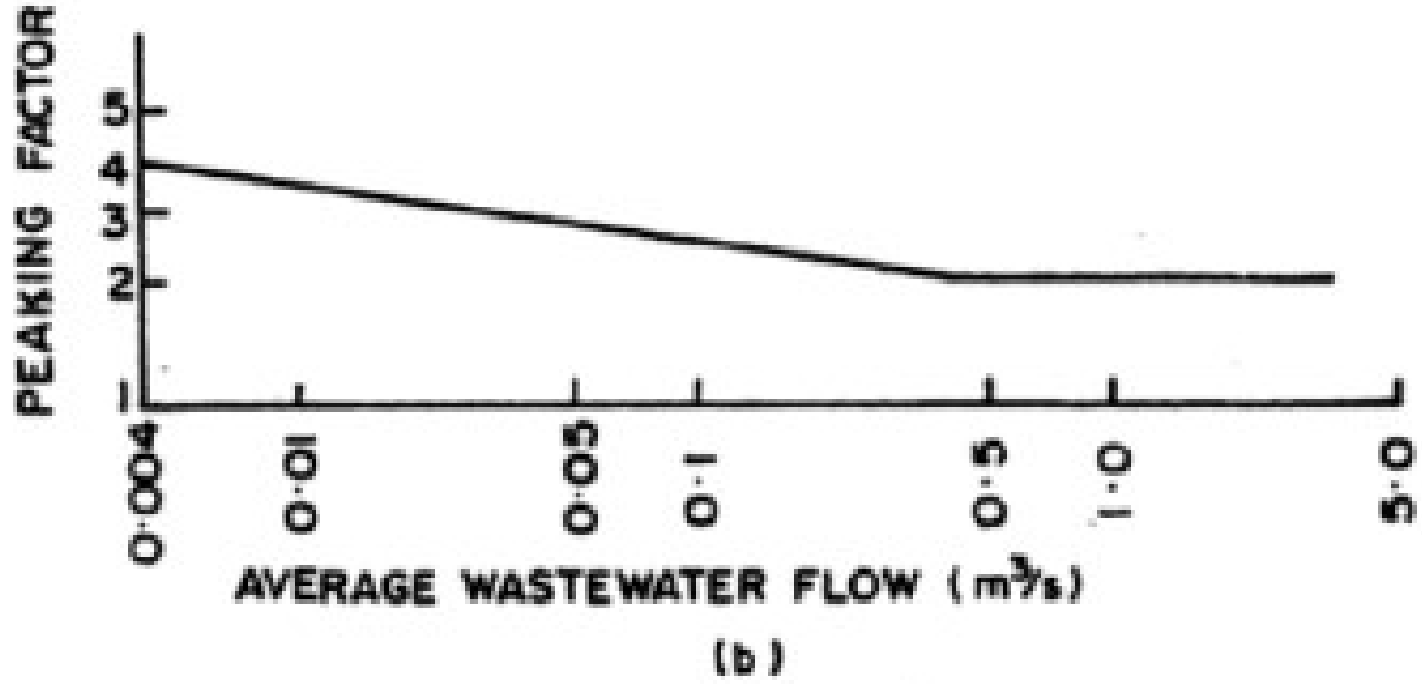
When a manhole is located at a sewer junction, the outlet sewer elevation is fixed by the lowest inlet sewer. If the pipe size increases, the crowns of the two pipes must be matched at the manhole. This is done to avoid the backing up of wastewater into the smaller pipe. An example of this situation is the increase in size from 450 to 750 mm at manhole 2. For this case, the calculations are as follows:

Lower invert elevation of the 450-mm sewer is 16.23 m.
Upper invert elevation for the 750-mm-sewer (line 2) is 15.93 m (16.23 m + 0.45 m − 0.75 m).
Lower invert elevation for the 750-mm sewer is 15.29 m [15.93 m − (0.0009 m/m) × (707 m)].
These procedures are repeated until the elevations for the entire sewer are established.

COMMENT A computation table, such as the one shown in this example, not only saves time but also is useful for summarizing both the data and the computed results in an orderly sequence for subsequent use. The specific columns in a given computation table depend on the factors that must be considered in arriving at the peak design flows. Most sanitary and civil engineering consulting firms have developed tabulation forms of their own for sewer design computations. Although the forms may differ in specific details and in the order of presentation from this table, the same information is usually presented. Some engineering firms have developed computer programs for sewer design.



(a)



(b)

FIG. PEAKING FACTORS FOR DOMESTIC SEWAGE

Contributing Population	Peak Factor
Up to 20,000	3
20,000 to 50,000	2.5
50,000 to 7,50,000	2.25
Above 7,50,000	2

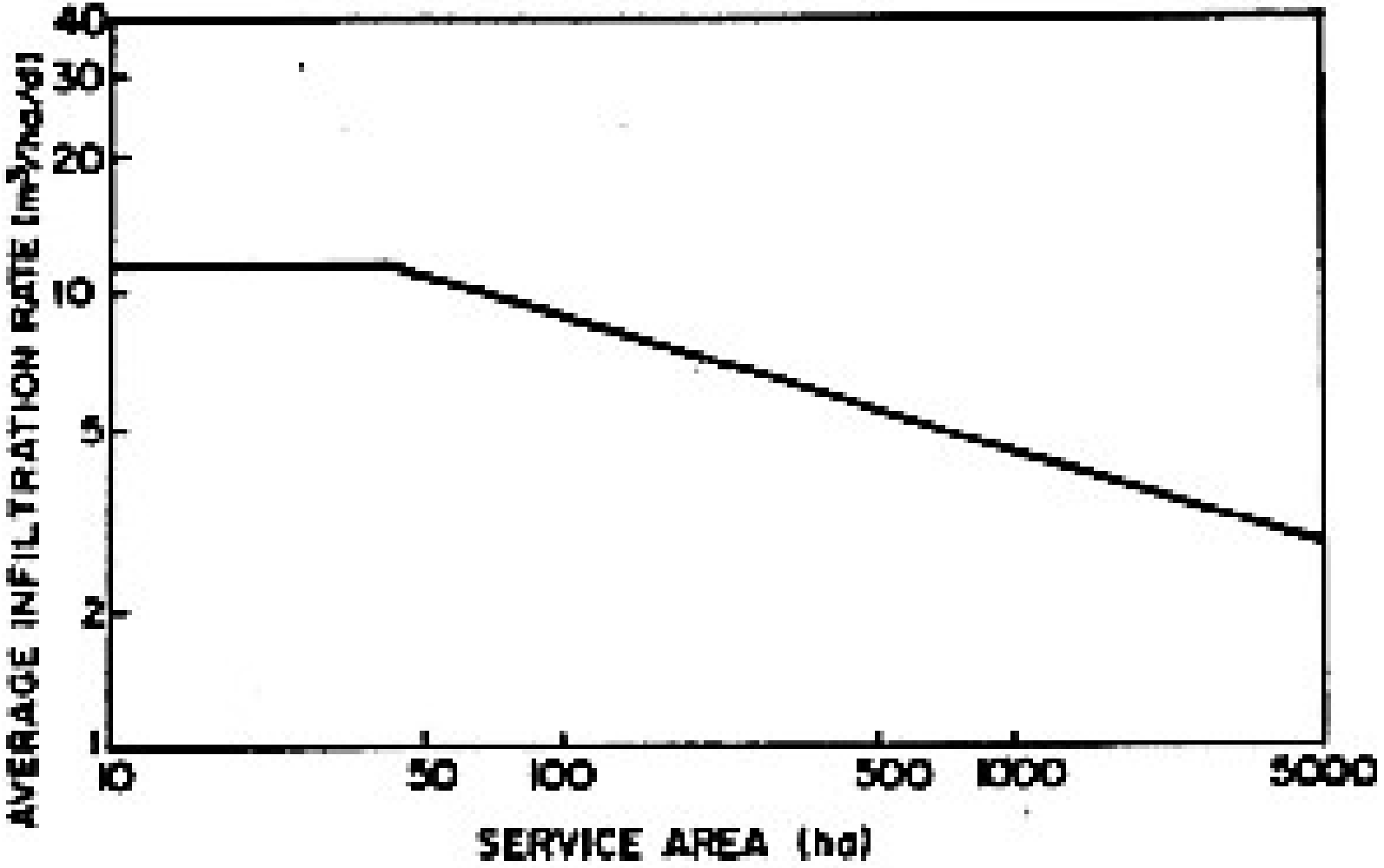
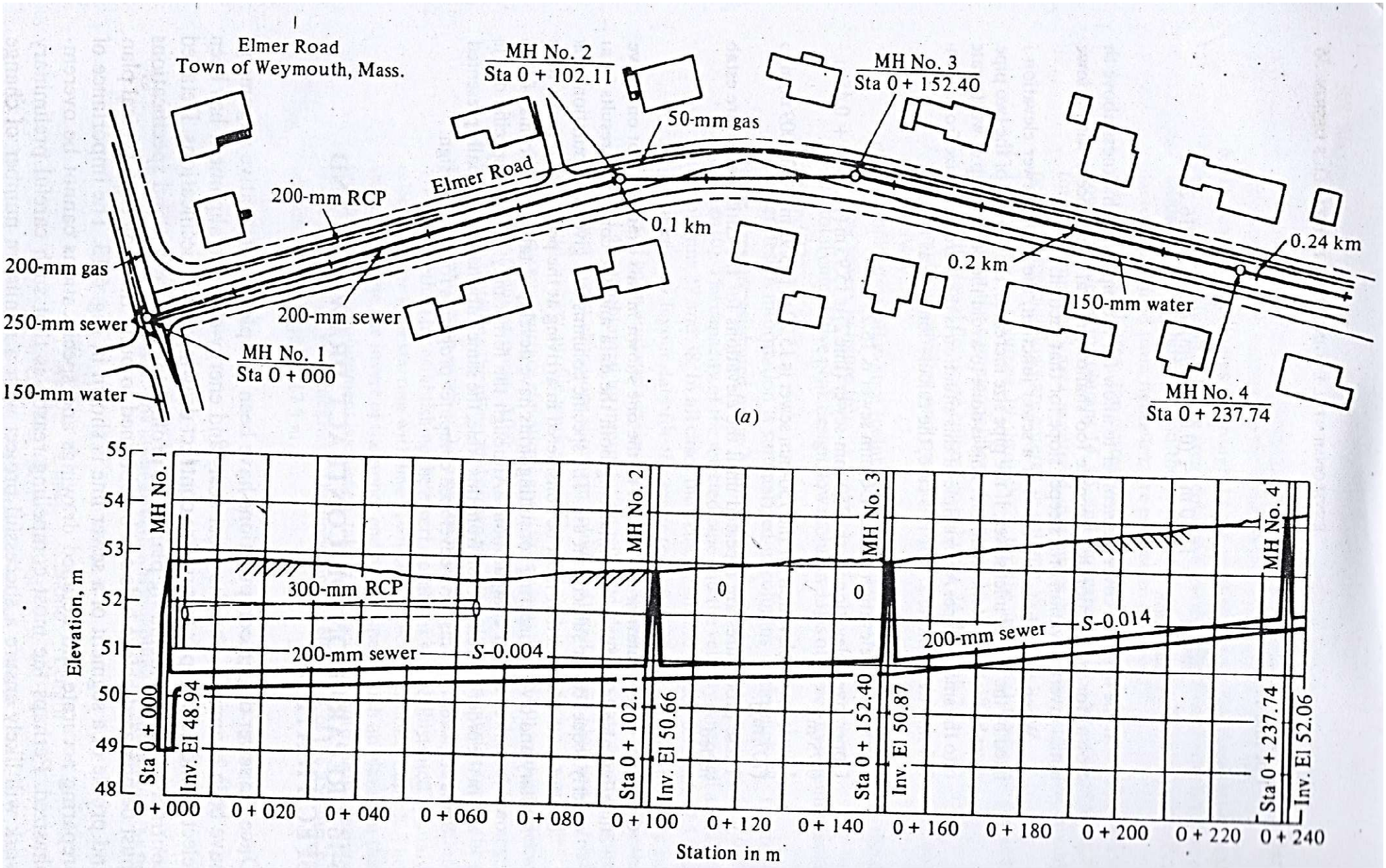


FIG. AVERAGE INFILTRATION RATE CURVE


Elmer Road
Town of Weymouth, Mass.
MH No. 2
Sta 0 + 102.11
MH No. 3
Sta 0 + 152.40
50-mm gas
Elmer Road
200-mm RCP
0.1 km
0.2 km
0.24 km
200-mm gas
250-mm sewer
200-mm sewer
150-mm water
MH No. 1
Sta 0 + 000
MH No. 4
Sta 0 + 237.74
(a)
Elevation, m
55
54
53
52
51
50
49
48
MH No. 1
MH No. 2
MH No. 3
MH No. 4
300-mm RCP
200-mm sewer — S–0.004
200-mm sewer — S–0.014
Sta 0 + 000
Inv. El 48.94
Sta 0 + 102.11
Inv. El 50.66
Sta 0 + 152.40
Inv. El 50.87
Sta 0 + 237.74
Inv. El 52.06
0 + 000
0 + 020
0 + 040
0 + 060
0 + 080
0 + 100
0 + 120
0 + 140
0 + 160
0 + 180
0 + 200
0 + 220
0 + 240
Station in m