CHAPTER 2

QUANTITY of SANITARY SEWAGE (DESIGN FLOW RATES)

Sanitary sewage flow depends on:

1. Population: Future populations at the end of design period should be estimated. (Population forecasting methods have already been given in Enve 311 notes).
2. Water consumption:
   - Sewage flow curve is closely parallel to water consumption curve.
   - Time lag is obvious.
   - Peaks on the curve flattened due to storage space in sewers and flow time. In general, industrial countries and large communities have 300 - 400 LCD, developing countries and small communities have 150 - 250 LCD water consumption.
3. Percentage of water returns to the sewer: About 60 - 90 % (average 70%) of the consumed water. Percentage is increasing due to better sewer systems.
4. Variations in sewage flow (domestic):

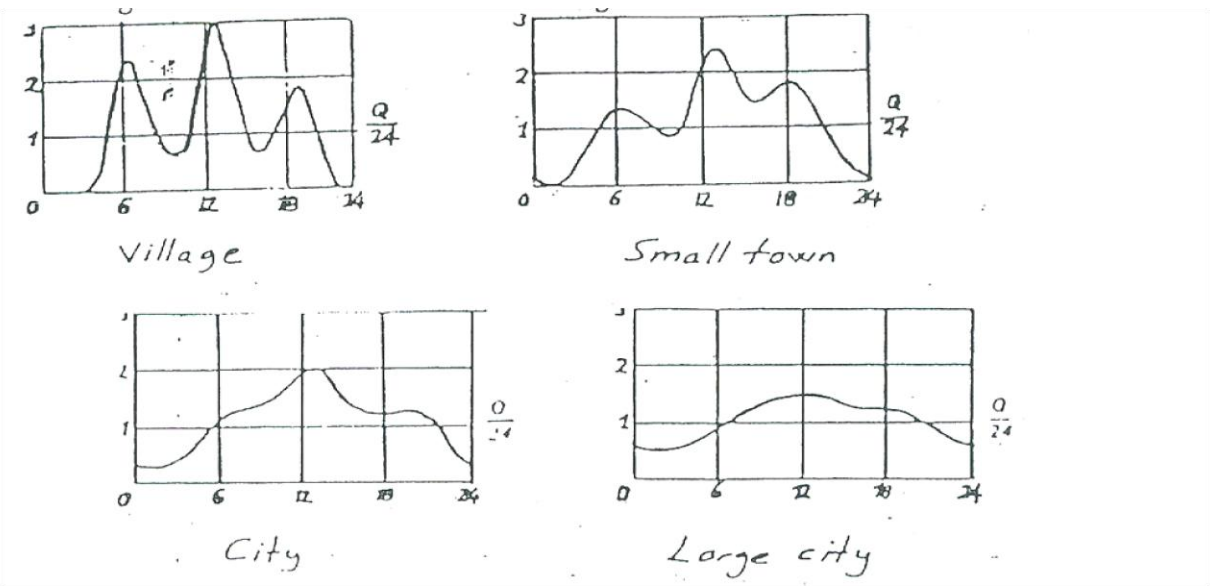


Figure 1: Sewage variations

Common ratios:

Multiply Q_ave_daily by 2.25 to convert Q_max_daily

Multiply Q_ave_daily by 3 to convert Q_max_hourly

Peak coefficient:

P.K = Peak Flow / Average Flow

To find peak flow coefficient French formula is used. French formula gives the maximum peak hourly coefficient.

By using French formula "P" is found.

$$\boldsymbol{P = a + \frac{b}{\sqrt{q_m}}}$$

Where

P: Peak coefficient

a: 1.5

b: 2.5

q_m: average flow in L/s

QUANTITY of STORM WATER

Storm water runoff is that the portion of precipitation which flows over the ground during and a short time after a storm.

The quantity depends on:

1. Surface drainage area (ha)
2. Intensity of the rainfall (L/s.ha)
3. The condition of surface (runoff coefficinet, C)

Rational Method

- This method is used to determine the storm flow.
- It can be applied anywhere, and runoff is related to rainfall intensity by the formulae:

$$\boldsymbol{Q = c.i.A}$$

Where **Q** is in L/s, **i** is in L/s.ha and **A** is in ha.

Rational Method Assumptions

1. The peak rate of runoff is a function of average rainfall intensity during the time of concentration.
2. The frequency of peak discharge is the same as the frequency of the average rainfall intensity.
3. The time of concentration is the time required for the runoff to become established and flow from the most remote part (in time) of the drainage area to the point under design.

Time of Concentration (tc)

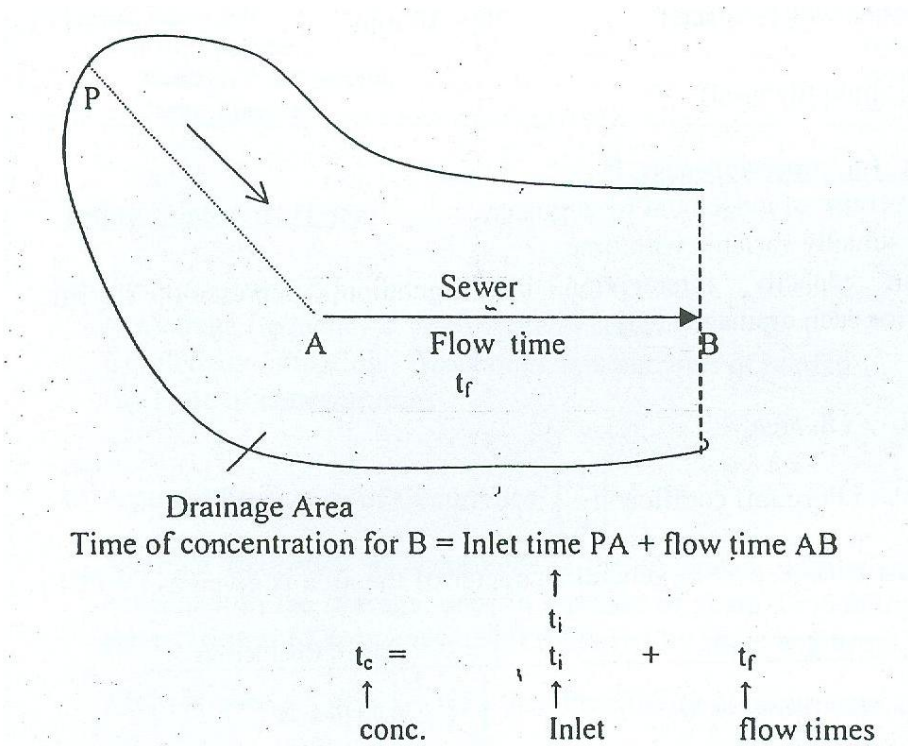
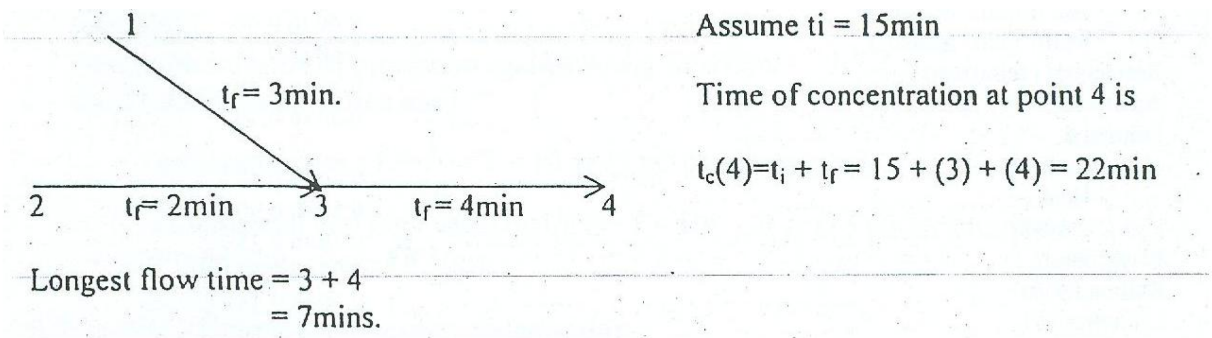


Figure 2: Time of concentration (tc), flow time (tf) and inlet time (ti).

Time of concentration for B = inlet time PA + flow time AB

tc = ti + tf

Example 1:



Time of flow (tf):

$$tf = \frac{length\ of\ pipe\ line}{velocity\ of\ flow}$$

Inlet time (ti):

- It is the time required for water to flow over ground surface and along gutters to sewer inlet.

- It is a function of rainfall intensity, surface slope, surface roughness, flow distance, infiltration capacity and depression storage.
- Common values:
  - Densely developed areas, inlets closely spaced: 5 minutes
  - Well developed areas, flat slopes: 10 - 15 minutes
  - Flat residential areas, inlets widely spaced: 20 - 30 minutes
  - 5 - 15 minutes are the most commonly used ones

<u>Runoff coefficient (C) or imperviousness (I):</u>

- It requires greatest exercise of judgement by engineer
- It is an assumed constant, actually variable with time
- It is a function of infiltration capacity, interception by vegetation, depression storage, evapotranspiration for each drainage area.

<u>Rainfall Intensity (i or r):</u>

Factors to consider:

- Average frequency of occurrence of storm
- I-D-F characteristics of rainfall
- Time of concentration

<u>*Average frequency of occurrence (f of 1/n):*</u>

If the frequency of rain is once a 5-year then f=5 or 1/n=5.

The probability of occurrence, n=0.2

Range of frequency often used:

- Residential area: f=2-10 years (5 years most common)
- Commercial and high value districts: f=10-50 years
- Flood protection: f=50 years

<u>*Intensity - Duration - Frequency (IDF) relationship:*</u>

- Basic data derived from gage measurement of rainfall over a long period.
- A rainfall height diagram obtained by a rain gage is shown in Figure 3. Slope of the curve or rain height per unit time is defined as "rain intensity".

$$i = \frac{\Delta H}{\Delta T} \left\lfloor \frac{mm}{min} \right\rfloor$$

To convert L/s.ha, use

$$i\left(\frac{L}{s.ha}\right) = 10000x0.001x\frac{1000}{60}i = 166.7i(\frac{mm}{min})$$

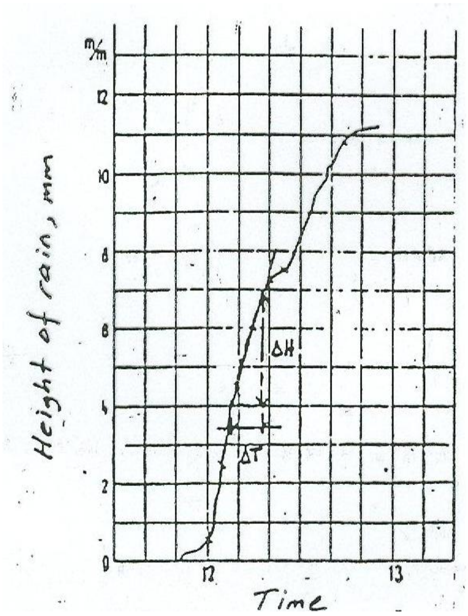


Figure 3. Rainfall height diagram.

Example 2:

An automatic rain gage record is given in table. Find the progressive arithmetic mean rate, or intensity of precipitation for various durations. The record is shown in columns 1 and 2 of table.

RAIN -GAGE RECORD				TIME-INSTENSITY RELATIONSHIP		
Time from beginning of storm (min) (1)	Cumulative rainfall (mm) (2)	Time interval (min) (3)	Rainfall during interval (mm) (4)	Duration of rainfall (min) (5)	Maximum total rainfall (mm) (6)	Arithmetic mean intensity (mm/min) (7)
5	7.9	5	7.9	5	13.8	2.76
10	15.7	5	7.8	10	27.2	2.72
15	22.4	5	6.7	15	39.1	2.60
20	34.3	5	11.9	20	46.2	2.31
25	41.4	5	7.1	25	58.1	2.32
30	53.3	5	11.9	30	65.2	2.17
35	67.1	5	13.8	45	86.8	1.93
40	80.5	5	13.4	60	97.4	1.62
45	86.4	5	5.9	80	105.8	1.32
50	93.0	5	6.6	100	112	1.12
60	97.0	10	4.0	120	116.6	0.97
80	105.4	20	8.4			
100	112.0	20	6.6			
120	116.6	20	4.6			

The intensity - duration curve of the example rain is given below in Figure 4.

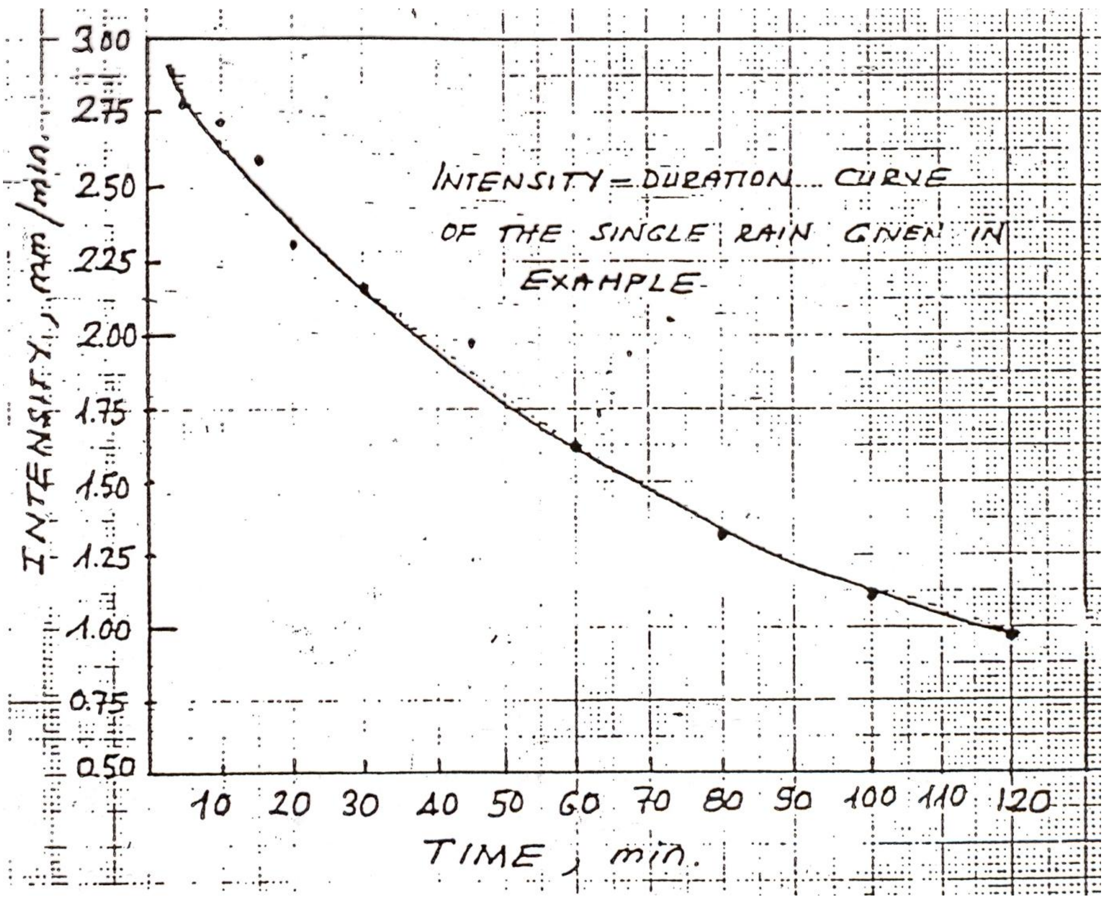


Figure 4: Intensity - duration curve of the example.

Example 3:
The number of storms of varying intensity and duration recorded by a rain gage in 45 years are listed in Table 1. Determine the time intensity values for the 5-year storm.

Table 1: Record of intense rainfalls. Number of storms of stated intensity (inches per hour) or more.

Duration min	1.0	1.25	1.5	1.75	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0
5							123	47	22	14	4	2	1
10					122	78	48	15	7	4	2	1	
15				100	83	46	21	10	3	2	1	1	
20			98	64	44	18	13	5	2	2			
30	99	72	51	30	21	8	6	3	2				
40	69	50	27	14	11	5	3	1					
50	52	28	17	10	8	4	3						
60	41	19	14	6	4	4	2						
80	18	13	4	2	2	1							
100	13	4	1	1									
120	8	2											

[1] Record for New York City from 1869 to 1913

If it is assumed that the 5-year storm is equaled or exceeded in intensity Y=9 (45/5) times in 45 years, the generalized time-intensity values may be interpolated from the summary by finding (a) for each specified intensity the duration that is equaled or exceeded by nine storms and (b) for each specified duration the intensity that is equaled or exceeded by nine storms. Interpolation proceeds along a broken diagonal line both vertically and horizontally.

The results obtained are brought together in Table 2 and Figure 5. A smooth curve drawn through them traces the course of the 5-year storm-rainfall. Similar calculations for the 1, 2, and 10-year rainfall yields the remaining members of the family of curves included in Figure 5.

Table 2. Calculation of storm frequencies (example 3).

(a)Duration (min)	5	10	15	20	30	40	50	60	80	100
(a)Intensity (in/hr)	6.50	4.75	4.14	3.50	2.46	2.17	1.88	1.66	1.36	1.11
(b)Intensity (in/hr)	1.0	1.25	1.5	1.75	2.0	2.5	3.0	4.0	5.0	6.0
(b)Duration (min)	116.0	89.9	70.0	52.5	46.7	29.0	25.7	16.0	9.3	7.5

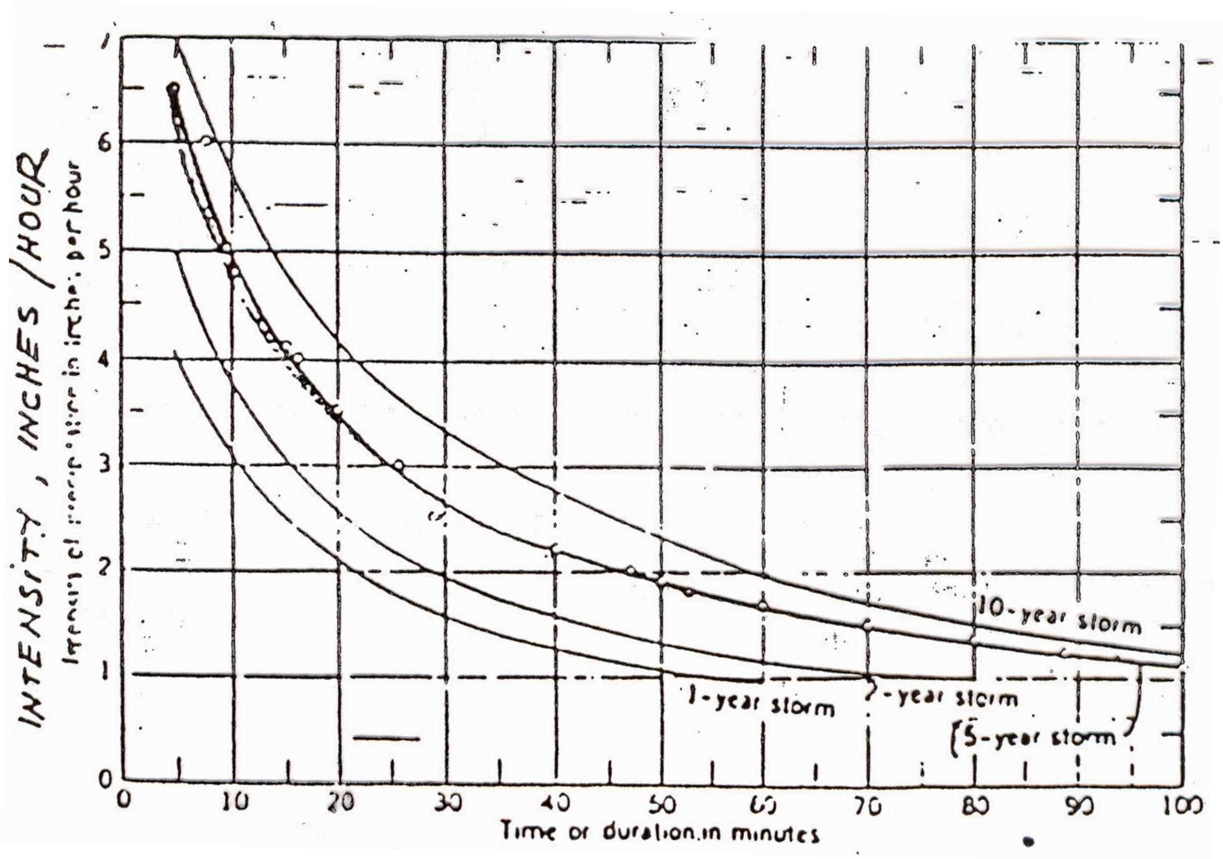


Figure 5. Intensity - Duration - Frequency of rainfalls.

Intensity - Duration - Frequency relationships may be expressed in a graphical form (as above), tabular or equation form.

<u>General Equations (for t < 2 hours)</u>

$i = \frac{A}{t+B}$; $i = \frac{A}{(t+B)^n}$; $i = \frac{A}{t^n+B}$

Constants A, B and n depend on locality and climatology [i:in/hr, t:min].

For example: $i = \frac{105}{t+15}$ for eastern USA or $i = \frac{90}{t^{0.9}+11}$ for Chicago (f=5 year).