DESIGN OF WATER TREATMENT & WASTE DISPOSAL SYSTEMS

Course Outline

- Part I: Water Supply (40 % Weightage)
- Part II: Wastewater Management (60 % Weightage)

Grading Policy

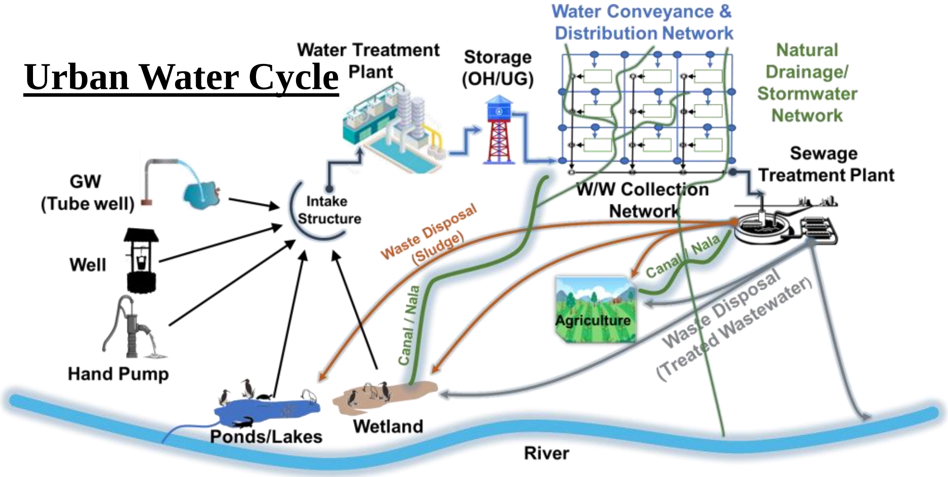
- Lectures (00 % Weightage; Attendance desirable but not mandatory)
- Tutorials (00 % Weightage; Attendance desirable but not mandatory)
- Quizzes (3 as per schedule): (15% Weightage; No makeup, zero credit for absenting)
- End Semester Examination: (45 % Weightage; Makeup as per institute policy)

Course Website
https://wl116.github.io/ce412a/

- **Visit regularly for**
  - Schedule of Lectures, Tutorials, Quizzes & Exam
  - Announcements
  - Lecture & Tutorial Material
  - Course Notes
  - Reference Materials

Planning & Design of Water Supply and Wastewater Management Systems

Urban Water Cycle



Components of Water Supply and Wastewater Management Systems

Water Supply System	Wastewater Management System
➢ Water Source: Intake Structure	➢ Wastewater Collection System → Sewerage System
➢ Water Conveyance: • Intake to Water Treatment Plant (Raw Water Conveyance) • Water Treatment to Distribution System (Treated Water Conveyance)	➢ Wastewater Treatment → • Sewage Treatment Plant (STP) • Effluent Treatment Plant (ETP)
➢ Water Distribution System (Pipe Network; Pumps; Balancing Reservoirs – Under Ground/Over Head)	➢ Wastewater Disposal System • Inland Water Bodies → Rivers/Lakes/Reservoirs/Wetlands • On land • In Ocean/Sea

Planning & Design of Water Supply and Wastewater Management Systems

Data & Information: Wastewater Quantity & Characteristics

- Design Period
- Quantity of Wastewater (Present & Final/ Ultimate/ End of Design Period)
  - Population & Per Capita Water Supply/Consumption/ Wastewater Generation
- Quality/Charasteristics of Wastewater

Planning & Design of Water Supply and Wastewater Management Systems

Design Period of Sewerage Components

S No	Component	Design Period, Years (from base year)
1	Land Acquisition	30 years or more
2	Conventional sewers	30
3	Non-conventional sewers	15
4	Pumping mains	30
5	Pumping Stations-Civil Work	30
6	Pumping Machinery	15
7	Sewage Treatment Plants	15
8	Effluent Disposal	30
9	Effluent Utilization	15 or as the case may be

(A) Typical underground sewers with manholes laid in the roads
(B) All types such as small bore, shallow sewers, pressure sewers, vacuum sewers

Storm Water & Wastewater Collection Systems (Sewerage System)

Sewerage Systems - Objectives

1. Collect and convey domestic wastewater/ sewage (mostly domestic wastewater + infiltration + some industrial waste mostly household units)
2. Collect and convey storm water.

Sewerage Systems - Types

1. Separate Sewer System → Sanitary Sewers & Storm Sewers
2. Combined Sewer

Components of Wastewater Collection Systems (Sewerage System)

- Sewers
  - Various shapes and Sizes flowing as open channel flow
  - Pressure pipes (only in some sections)
- Sewer Appurtenances
  - Manholes
  - Sump wells

Water & Wastewater Quantity

- Population & Per Capita Supply/Demand → Present and at the end of Design Period/Final/Ultimate
- Wastewater in Relation to Water Supply/Consumption:
  - Consumptive use of water is ~5% of the water supplied.
  - Water used for horticultural uses and fire fighting does not become wastewater
  - In areas with full sewer network, 80 % of remaining water supplied becomes wastewater

Population & Per Capita Supply/Demand
As per CPHEEO Manual

Wastewater Quality

Wastewater → Water + Waste

1. Water Used in Toilet: Waste → Faecal matter + Urine + Washing
   (mainly Organic Carbon, Nitrogen, Phosphorus, microorganisms)
2. Water Used in Kitchen: Waste → Waste food (raw/cooked) thrown in Basin + Cleaning Agents (Soap, detergents, etc.)
3. Water Used in Bathing: Waste → Body surface dirt + Cleaning Agents (Soap, detergents, etc.)
4. Water Used in Washing: Waste → Dirt on Clothes + Floors + Cleaning Agents (Soap, detergents, etc.)
   (mainly organic C, N and P, surfactants, salts, dirt, grit, other solid waste)

Domestic Wastewater (Sewage) = Black water + Grey water (Sullage)

Wastewater Quality

Commonly Used Terms

- **Sewage:** Sewage refers to the wastewater and solid waste that is generated by households, commercial and industrial establishments, and is carried away in a system of pipes for treatment and disposal. It typically includes wastewater from toilets, sinks, showers, bathtubs, washing machines, and other sources, as well as solid waste such as human excrement, food scraps, and other organic matter.
- **Sullage:** Sullage refers to the wastewater generated from households, kitchens, and bathrooms that is not used for flushing toilets. It typically includes wastewater from sinks, showers, bathtubs, washing machines, and other domestic appliances.
- **Sewer:** A sewer is a used to collect and transport sewage and other wastewater from homes, commercial and industrial establishments, and other sources to a treatment plant for processing.

Wastewater Quality

Commonly Used Terms

- **Septage:** Septage is a term used to describe the semi-solid and liquid waste and wastewater generated from septic tanks. Septic tanks are underground wastewater treatment systems that are commonly used in areas without access to central sewer systems. In a septic system, wastewater from homes and buildings is collected in a tank where solids settle to the bottom and liquids are treated by microorganisms. The semi-solid material that accumulates at the bottom of the tank is referred to as septage.
- **Sludge:** Sludge refers to the semi-solid material that is generated as a byproduct of water/wastewater treatment processes. It is formed when water/wastewater is treated to remove contaminants and other pollutants; the solids that settle out along with entrapped water is referred to as sludge.
- **Sewerage System:** A sewerage system is a comprehensive infrastructure that includes network of sewers for collecting, transporting, treating, and disposing of sewage and wastewater from homes, commercial and industrial establishments.

Planning & Design of Sewerage Systems

In 2023: Initial

Domestic population = 9870
Average domestic water demand =
9870. (180) = 1.78 MLD
Total temporary population = 1500
Temporary water demand = 1500.(40) =
0.06 MLD
Commercial water demand = 0.5.(1.78) =
0.89 MLD
Average wastewater production =
0.8.(1.78 + 0.06 + 0.89) = 2.18 MLD

Maximum wastewater production =
1.8 x Average = 1.8.(2.18)
= 3.92 MLD
Peak wastewater production =
3.(2.18) = **6.55 MLD**

Initial Peak wastewater production is used for checking scouring velocity in sewers

In 2053: Final

Domestic population = 12300
Average domestic water demand =
12300. (235) = 2.89 MLD
Total temporary population = 3000
Temporary water demand = 3000.(60) =
0.18 MLD
Commercial water demand = 0.5.(2.89) =
1.44 MLD
Average wastewater production =
0.8.(2.89 + 0.18 + 1.44) = 3.61 MLD

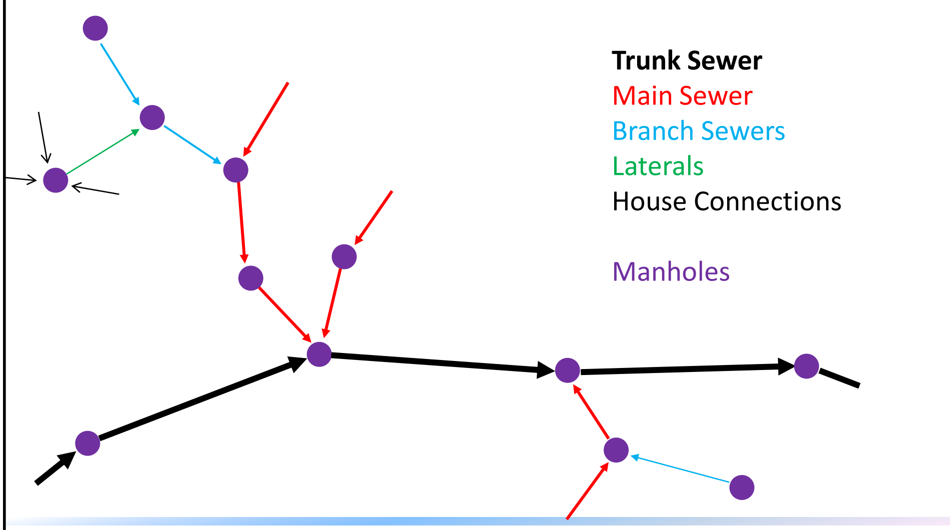
Maximum wastewater production =
1.8 x Average = 1.8.(3.61)
= 6.55 MLD
Peak wastewater production =
3.(3.61) = **10.83 MLD**

Ultimate/End of Design/Final Peak wastewater production is used for determining sewer size

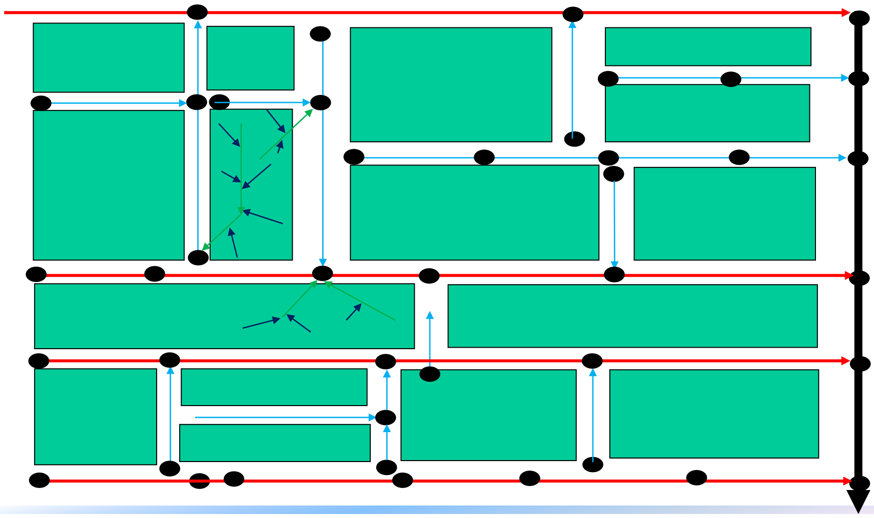
Wastewater Quantity (Initial/Present and Ultimate/Final)

- **Initial Peak wastewater production is used for checking scouring velocity in sewers and Final Peak wastewater production is used for determining sewer size.**
- **Design Periods are different for different Components**

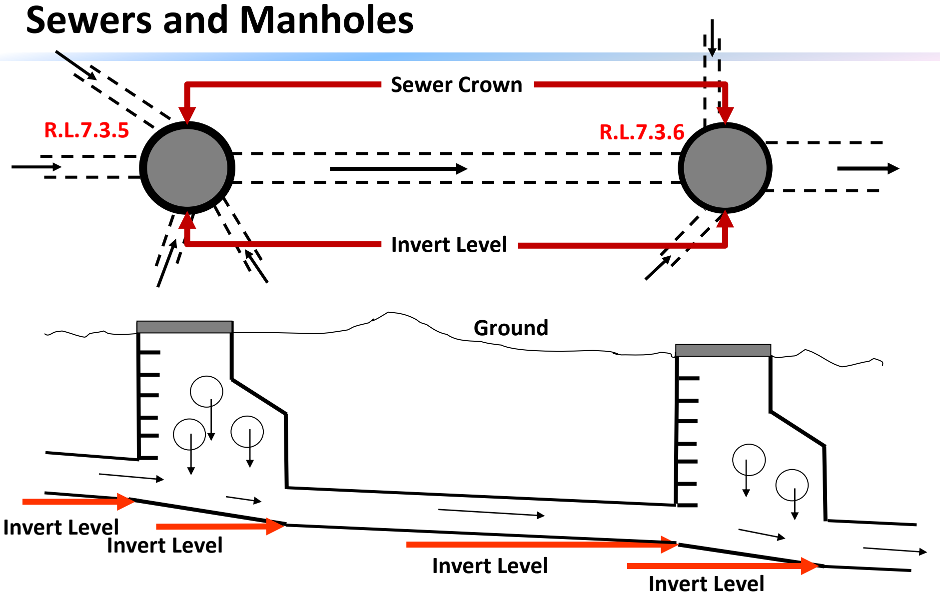
The Sewer System



Sewer Network



Sewers and Manholes



Design of Sewers

Determination of Invert level (IL) of the Upper end of a Sewer, i.e., where the Sewer Exits the manhole

1. The IL of the branch (or main) sewer, i.e. sewers joining laterally, should generally be at least 0.4 m above the invert level of the main sewer leaving the manhole. This will ensure prevention of backflow as well as dissipation of excess energy of water in the smaller sewer.

2. A minimum drop of 0.03m is provided between invert level of sewers entering (incoming sewer) and exiting (outgoing sewer) manholes.

3. The diameter of a outgoing sewer must always be greater than or equal to diameter of the incoming sewer at any manhole.

4. The top (crown level) of a incoming sewer must never be at a lower elevation than that of the top (crown) of a outgoing sewer.

Design of Sewers

1. Manholes to be provided at the junction of sewers or at every change of alignment / gradient of the sewer.
2. Branch sewers should connect to main sewers at angles ranging from 30 to 90 degrees
3. Minimum diameter of a sewer is 150 mm. Other diameters are 200 mm and higher at increments of 50 mm. Manning's coefficient 'n' for new concrete sewers is 0.013
4. Sewers should not be more than 0.8 full at ultimate peak hourly flow. Corresponding flow velocity should be between 0.8 and 3.0 m/s

Design of Sewers

6. The velocity of flow in a sewer should be at least 0.6 m/s at the initial peak hourly flow. This is required to ensure that particles are not deposited in sewers on a permanent basis.
7. Typical slopes in sewers vary from 1 in 1000 to 10 in 1000; larger diameter sewers having less slope. Slope should in general be fixed at the smallest possible value, after other design considerations
8. A sewer should be at least 1 m below ground surface

Design of Sewers

Groundwater Infiltration into Sewers

During rainy season, there is a chance of storm water infiltration into sewers, either involuntarily or on purpose.

Ground water can infiltrate in sewers through, 1) leaky joints, 2) manholes. There are three ways of estimating infiltration as per CPHEEO manual,

Unit	Minimum	Maximum
Area (L/ha.d)	5000	50000
Length (L/km.d)	500	5000
Manhole (L per day)	250	500

Design of a Sewer Section: Procedure

$$\boxed{v = \frac{1}{n}.R^{2/3}.S^{1/2}}$$

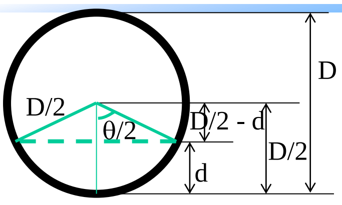
v = Velocity, m/sec
r = hydraulic radius → A/P
→ d/4 for pipe flowing full

$$\boxed{V_f = \frac{1}{n}(D/4)^{2/3}(S)^{1/2}}$$

V_f → mps, d is in mm
Q_f → lps; d is in mm

$$\boxed{Q_f = \frac{1}{n}(0.3117).(D)^{8/3}.(S)^{1/2}}$$

Design of a Sewer Section: Procedure → Partial Full



d → Depth of flow
D → Diameter of pipe

$$\text{Cos}\,\theta/_2 = \frac{D/_2 - d}{D/_2} = 1 - \frac{2d}{D}$$

$$Area = A = \frac{\pi}{4}D^2\,\frac{\pi\theta}{360} - 2\,.\frac{1}{2}\,.\frac{D}{2}\,\text{Sin}\frac{\theta}{2}\,\text{Cos}\frac{\theta}{2} = \frac{D^2}{4}\left(\frac{\pi\theta}{360} - \frac{\text{Sin}\,\theta}{2}\right)$$

$$P = \frac{\pi D\theta}{360}$$

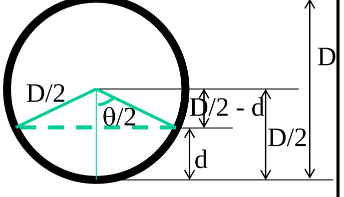
$$Hydraulic\ Radius = \frac{A}{P} = \frac{\frac{D^2}{4}\left(\frac{\pi\theta}{360} - \frac{\text{Sin}\,\theta}{2}\right)}{\frac{\pi D\theta}{360}} = \frac{D}{4}\left(1 - \frac{360\,.\,Sin\theta}{2\pi\theta}\right)$$

Design of a Sewer Section: Procedure

d/D	v/V_f	q/Q_f
1.0	1.000	1.000
0.9	1.124	1.066
0.8	1.140	0.968
0.7	1.120	0.838
0.6	1.070	0.671
0.5	1.000	0.500
0.4	0.902	0.337
0.3	0.776	0.196
0.2	0.615	0.088
0.1	0.401	0.021

Peak hourly flow (2053) = $0.30\ m^3/s = q_1$

Peak hourly flow (2023) = $0.15\ m^3/s = q_2$



Design criteria: At Q = q_1, d/D = 0.8

For a pipe flowing full, R = D/4

$$Hydraulic\ Radius = \frac{A}{P} = \frac{\frac{D^2}{4}\left(\frac{\pi\theta}{360} - \frac{\text{Sin}\,\theta}{2}\right)}{\frac{\pi D\theta}{360}} = \frac{D}{4}\left(1 - \frac{360\,.\,Sin\theta}{2\pi\theta}\right)$$

Design of a Sewer Section: Procedure

Peak hourly flow (2053) = 0.30 m^3/s = q_1

Peak hourly flow (2023) = 0.15 m^3/s = q_2

q_1 = 0.3 m^3/s; d/D = 0.8; q_1/Q_f = 0.968;

Q_f = 0.3/0.968 = 0.3099 m^3/s

n = 0.013; Putting S = 0.002, D = 0.628 m, say, 0.700 m

Corresponding to D = 0.7 m, Q_f = 0.4142 m^3/s

Design of a Sewer Section: Procedure

Therefore, q_1/Q_f provided = 0.3/0.4142 = 0.724;
actual d/D = 0.65; v/V_f = 1.100

V_f = 1.076 m/s; v (in 2038) = 1.100.(1.076)
= 1.184 m/s (okay)

q_2/Q_f = 0.15/0.4142 = 0.338; v/V_f = 0.902

v (in 2018) = 0.902.(1.076)
= 0.971 m/s (okay)

d/D	v/V$_f$	q/Q$_f$
1.0	1.000	1.000
0.9	1.124	1.066
0.8	1.140	0.968
0.7	1.120	0.838
0.6	1.072	0.671
0.5	1.000	0.500
0.4	0.902	0.337
0.3	0.776	0.196
0.2	0.615	0.088
0.1	0.401	0.021

$$Q_f = \frac{1}{n}(0.3117).(D)^{8/3}.(S)^{1/2}$$

$$V_f = \frac{1}{n}(D/4)^{2/3}(S)^{1/2}$$

Sewerage System – Management of Storm Runoff

- The sanitary sewers are not expected to receive storm water. Strict inspection, vigilance, and proper design and construction of sewers and manholes should eliminate this flow or bring it down to a very insignificant quantity.

- However, in small habitations where rainfall is almost a continuous affair, or no natural drainage network is available, or natural drainage is impaired due to alteration in topography due to infrastructural interventions, it may be necessary to include storm water in the design of sewerage systems.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- The storm runoff is that portion of the precipitation, which drains over the ground.
- Estimation of such runoff reaching the storm sewers therefore is dependent on the intensity, duration of precipitation, characteristics of the tributary area, and the time required for such flow to reach the sewer.
- The design of storm water sewers begins with an estimate of the rate and volume of surface runoff. When rain falls on a given catchment, a portion of the precipitation is intercepted by the vegetation cover that mostly evaporates, a portion hits the soil and some of it percolates down below and the rest flows over the ground.
- The higher the intensity of rain, the higher will be the peak runoff.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- The characteristics of the drainage area such as imperviousness, topography including depressions, water pockets, shape of the drainage basin and duration of the precipitation determine the fraction of the total precipitation, which will reach the sewer.
- This fraction is known as the coefficient of runoff. The time-period after which the entire area begins contributing to the total runoff, at a given monitoring point, is known as the time of concentration.
- It is also defined as the time it takes for a drop of water to flow from the most distant point to the outlet of the basin. The duration of rainfall that is equal to the time of concentration is known as the critical rainfall duration.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- The storm water flow for this purpose may be determined by using the rational method, hydrograph method, rainfall-runoff correlation studies, digital computer models, inlet method or empirical formulae.
- The empirical formulae that are available for estimating the storm water runoff can be used only when comparable conditions to those for which the equations were derived initially exist.
- A rational approach, therefore, demands a study of the existing precipitation data of the area concerned to permit a suitable forecast. Storm sewers are not designed for the peak flow of rare occurrence such as once in 10 years or more, but it is necessary to provide sufficient capacity to avoid too frequent flooding of the drainage area.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- There may be some flooding when the precipitation exceeds the design value, which has to be permitted. The frequency of such permissible flooding may vary from place to place, depending on the importance of the area. Though such flooding causes inconvenience, it may have to be accepted occasionally, considering the economy effected in the sizes of the drains and the costs.
- The maximum runoff, which has to be carried in a sewer section should be computed for a condition when the entire basin draining at that point becomes contributory to the flow and the time needed for this is known as the time of concentration (with reference to the concerned section).

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- Thus, for estimating the flow to be carried in the storm sewer, the intensity of rainfall which lasts for the period of time of concentration is the one to be considered contributing to the flow of storm water in the sewer. Of the different methods, the rational method is more commonly used as herein.
- It may be reiterated that Q represents only the maximum discharge caused by a particular storm. The portion of rainfall, which finds its way to the sewer, is dependent on the imperviousness and the shape of the drainage area apart from the duration of storm. The percent imperviousness of the drainage area can be obtained from the records of a particular district.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

The rational formula for the relationship between peak runoff and the rainfall :

$$Q = 10CiA$$

Where,

Q : Runoff in m^3 /hr

C : Dimensionless runoff coefficient

i : Intensity of rainfall in mm/hr

A : Area of drainage district in hectares

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

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

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

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

Here,

I : Weighted average imperviousness of the total drainage basin

A_1 , A_2 , ……… A_n : Sub drainage areas

I_1 ,I_2 , ……………I_n : Imperviousness of the respective sub-areas.

Sewerage System – Management of Storm Runoff

Estimation of Storm Runoff

- The weighted average runoff coefficients for rectangular areas, of length four times the width as well as for sector shaped areas with varying percentages of impervious surface for different time of concentration are given in Table on next slide.
- Although these are applicable to particular shape areas, they also apply in a general way to the areas, which are usually encountered in practice. Errors due to difference in shape of drainage are within the limits of accuracy of the rational method and of the assumptions on which it is based.

Sewerage System – Management of Storm Runoff

Rational Method - Storm Frequency

Duration, t, minutes	10	20	30	45	60	75	90	100	120	135	150	180
Weighted Average Coefficient												
1. 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
2. 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

Sewerage System – Management of Storm Runoff

Rational Method - Runoff-Rainfall Intensity Relationship

- The entire precipitation over the drainage district does not reach the sewer. The characteristics of the drainage district, such as, imperviousness, topography including depressions and water pockets, shape of the drainage basin and duration of the precipitation determine the fraction of the total precipitation, which will reach the sewer.
- This fraction known as the coefficient of runoff needs to be determined for each drainage district.

Sewerage System – Management of Storm Runoff

Rational Method

Storm Frequency

- The frequency of storm for which the sewers are to be designed depends on the importance of the area to be drained. Commercial and industrial areas have to be subjected to less frequent flooding. The suggested frequency of flooding in the different areas is as follows :

a) **Residential areas**

i. Peripheral areas → twice a year

ii. Central and comparatively high priced areas →once a year

b) **Commercial and high-priced areas once in 2 years**

Sewerage System – Management of Storm Runoff

Rational Method - Intensity of Precipitation

- The intensity of rainfall decreases with duration. Analysis of the observed data on intensity and duration of rainfall of past records over a period of years in the area is necessary to arrive at a fair estimate of intensity-duration for given frequencies. The longer the record available, the more dependable is the forecast. In Indian conditions, intensity of rainfall adopted in design is usually in the range of 12 mm/hr to 20 mm/hr or based on the actual record.

Sewerage System – Management of Storm Runoff

Table: Analysis of the frequency of storms of stated intensities and durations during 26 years for available rainfall data

Duration vs. 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							

Source: CPHEEO, 1993

Sewerage System – Management of Storm Runoff

Rational Method - Intensity of Precipitation

- The stepped line indicates the location of the storm occurring once in 2 years, i.e., 13 times in 26 years. The time-intensity values for this frequency are obtained by interpolation.

i (mm/hr)	t (min)	i (mm/hr)	t (min)
30	51.67	50	18.50
35	43.75	60	14.62
40	36.48	75	8.12
45	28.57		

Source: CPHEEO, 1993

Sewerage System – Management of Storm Runoff

Rational Method - Intensity of Precipitation

- The relationship may be expressed by a suitable mathematical formula, several forms of which are available. The following two equations are commonly used:

$$i = \frac{a}{(t^n)} \qquad\qquad i = \frac{a}{t+b}$$

Where,
i : Intensity of rainfall (mm/hr)
t : Duration of storm (minutes)
a, b and n : Constants

The available data on i and t are plotted and the values of the intensity (i) can then be determined for any given time of concentration, (t_c).

Sewerage System – Management of Storm Runoff

Rational Method - Time of Concentration

- It is the time required for the rain-water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. It is equal to inlet time (t) plus the time of flow in the sewer (t_f).
- The inlet time is dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin and may generally vary from 5 to 30 minutes. In highly developed sections, the inlet time may be as low as 3 minutes. The time of flow is determined by the length of the sewer and the velocity of flow in the sewer. It is to be computed for each length of sewer to be designed.

Sewerage System – Management of Storm Runoff

Rational Method - Time of Concentration

a) Tributary Area

- For each length of storm sewer, the drainage area should be indicated clearly on the map and measured. The boundaries of each tributary are dependent on topography, land use, nature of development and shape of the drainage basins. The incremental area may be indicated separately on the compilation sheet and the total area computed.

b) Duration of Storm

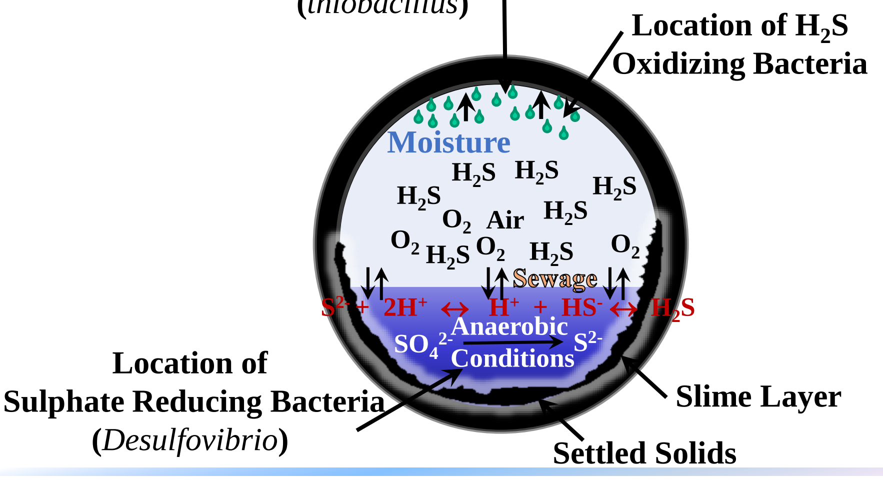
- Continuously long, light rain saturates the soil and produces higher coefficient than that due to, heavy but intermittent, rain in the same area because of the lesser saturation in the latter case. The runoff from an area is significantly influenced by the saturation of the surface to nearest the point of concentration, rather than the flow from the distant area. The runoff coefficient of a larger area has to be adjusted by dividing the area into zones of concentration and by suitably decreasing the coefficient with the distance of the zones.

Specific Issues and Special Components of Wastewater Collection Systems (Sewerage System)

- Specific Issues
  - Odor, corrosion & hazards
  - Flushing
  - Ventilation
- Special Components/Sewer Appurtenances
  - Manholes
  - Sump wells
  - Drop Manholes
  - Flushing Manholes
  - Inverted Siphons

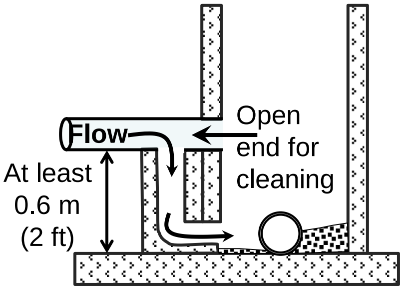
Crown Corrosion → Particularly in Concrete Pipes

$$H_2S + 2O_2 \xrightarrow[\text{(\textit{thiobacillus})}]{\text{Bacteria}} H_2SO_4 \longrightarrow \text{Corrosion}$$



Drop Manholes

These are provided when the difference in elevation of the invert levels of the incoming and outgoing sewers of a manhole is more than 60 cm.

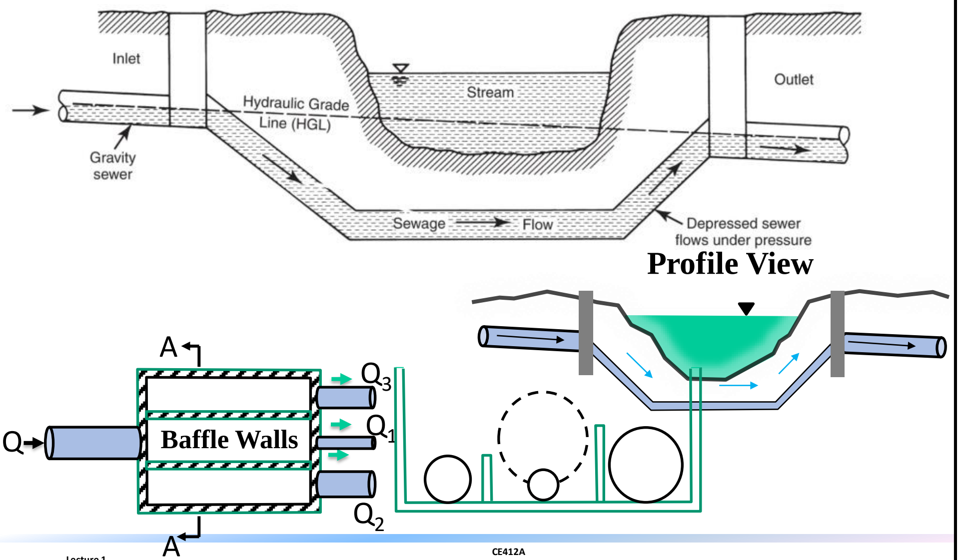


Flushing Manholes

- Generally located at the head of sewer.
- The sewers are flushed once or twice a day to wash away the solids.
- The flush is usually effective only up to 300 m.
- Is connected to water supply mains.

Slope	Q (litres)		
	200 mm	250 mm	300 mm
0.0050	2300	2500	3000
0.0075	1500	1800	2300
0.0100	1300	1500	2000
0.0200	500	800	1000
0.0300	400	500	700

Inverted Siphons/Depressed Sewer→ Crossing River/Canal



Inverted Siphons/Depressed Sewer→ Crossing River/Canal

- It is a section of sewer constructed below the hydraulic gradient line due to some obstruction (stream, subway etc.) and operates under pressure.
- No real siphon action is involved.
- Normally two or more pipes are needed
- For a siphon in order to handle flow variability, high velocity should be maintained, not less than 0.9 m/s
- Hydraulic design consists of selecting a pipe or pipes that will carry the design flow with a head loss equivalent to the difference in entrance and exit water surface elevations.
- Transition structure is generally required at the entrance and exit of the depressed sewer to properly proportion or combine the flows.

Inverted Siphons/Depressed Sewer→ Crossing River/Canal

Design Steps:

- Usually three pipes are used: 1. First Pipe to accommodate low flows; 2. First and Second Pipe to accommodate flows up to average flows; 3. Third Pipe to accommodate flows above average flows.
- Pipe Length (Same for all Pipes)= Total Length of the Pipe between Transition Structure at the Entrance and Exit of the Inverted Siphon/Depressed Sewer.
- The smallest pipe is designed to have minimum 0.9 m/s velocity.
- Velocity in other pipes of higher diameter will automatically be higher for same slope or drop in head.
- The design requires that head loss should be minimum. Head drop due to entrance and exit losses, and losses in the bents to be provided.
- Specify the Invert Levels of all incoming and outgoing pipes.

Specific Issues and Special Components of Wastewater Collection Systems (Sewerage System)

Gas Emission and Ventilation in Sewers

Anaerobic conditions develop in sewers due to emission of gases like methane, ammonia and hydrogen sulfide in sewers. There must be ample scope for ventilation of these gases. This is one of the reasons why sewers are designed to run only 0.8 full at the peak flow at the end of the design period. Hydrogen sulfide is a corrosive gas and may cause “**Crown Corrosion**” in sewers.

Solids Deposition in Sewers

- Sewage contains suspended particles which may deposit in sewers if the horizontal velocity in sewers is less than the scouring velocity of these particles. Deposition of particles in sewers results in the reduction of sewer capacity and also in the increase of the value of manning’s coefficient (n). Hence sewers are designed such that a horizontal velocity of 0.6 m/s is achieved in the sewer at least for some time every year starting from the beginning of sewer operation. If this is not possible, then sewers must be flushed manually once a year.
- Provision of Screens and grit at appropriate places.