Design of Wastewater Conveyance System
(Sanitary Sewer System)

Introduction:

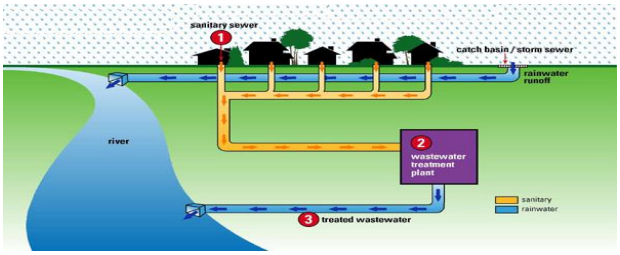
The basic functional elements of a conventional sewerage system includes -

1. House connections- collect wastewater from houses,
2. Network of sewer systems- for collection and conveying the wastewater and
3. Treatment plant- for processing the wastewater, and
4. Receiving environment (water or land) for disposal of the treated wastewater

Depending on the type of sewage carried by the conveyance system, sewage collection can be categorized into three types-

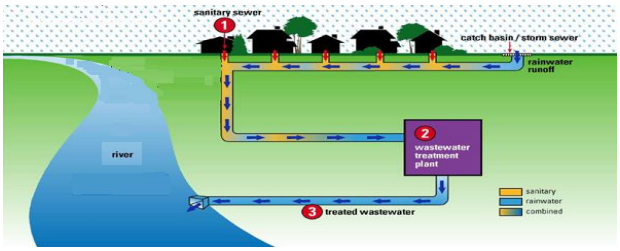
1. Separate sewerage system

Sanitary sewage and storm waste are collected and conveyed separately through two different systems.
Storm water can be discharged without treatment; only sanitary sewage is treated but very costly option.



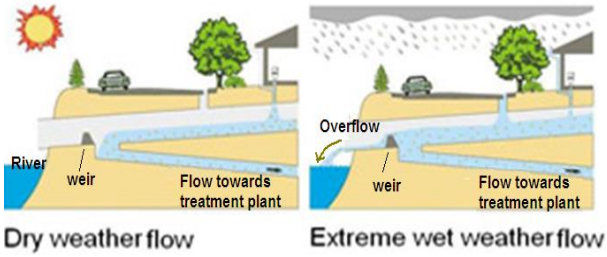
2. Combined sewerage system

Both sanitary sewage and storm water are collected and carried together through a single set of sewers.
Economical, large size makes it easy to clean but however increases waste load in treatment plant, difficulties in maintaining minimum flow during dry season.



3. Partially combined or partially separate system

Only one set of sewers is laid to carry sanitary sewage as well as storm water during low rainfall. During heavy rainfall excess storm water is carried separately e.g., through open drains to natural channels



Sanitary Sewer Systems

3 types of sanitary wastewater collection systems based on hydraulic characteristics and purpose:

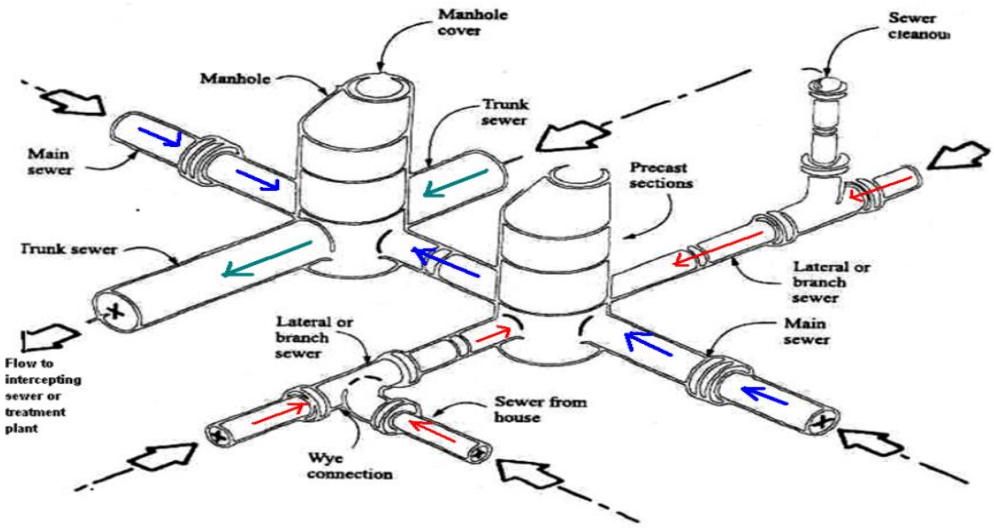
1. Gravity
2. Pressure
3. Vacuum

Gravity type is the most common where wastewater is transported by gravity. However conveyance capacity allowances must be made for groundwater infiltration and unavoidable inflow. A pressure sewer system is made up of a network of fully sealed pipes which are fed by pumping units located at each connected property.

Second method is often used in areas when the landscape is either very hilly or very flat, in areas that regularly flood or have high water tables, or where it is impractical to install other types of sewerage systems.

In vacuum sewerage system wastewater initially collected in a pre-tank. While the pre-tank being filled, an electronic sensor opens the interface valve where it is mixed with air and leaves the valve flowing into the vacuum pipe network as a water-air mixture.

Types of Sewer Pipes in a Typical Separate Sanitary Collection System



Sanitary sewers must be laid near all occupied buildings in order to collect wastewater.

- **Building Connections:**
  It connects the building plumbing to the public sanitary wastewater collection system and conveys wastewater from the buildings to lateral or branch sewer, or any other sewer except another building sewer. It normally begins outside the building foundation.
- **Lateral or Branch Sewers:**
  Lateral or branch sewers form the first element of a wastewater collection system. It usually collects wastewater from one or more building sewers and conveys it to a main sewer.
- **Main Sewers:**
  Main sewers are used to convey wastewater from one or more lateral sewers to trunk sewers or to intercepting sewers.
- **Trunk Sewers**
  Trunk sewers are large sewers that are used to convey wastewater from main sewers to treatment or other disposal facilities, or to large intercepting sewers.
- **Interceptor Sewers**
  Intercepting sewers are large sewers that are used to intercept a number of main or trunk sewers and convey the wastewater to treatment or other disposal facilities

  - In our class we will design the trunk sewer(s) only for the industrial village

Components of a Community's Wastewater

1. *Domestic (sanitary) wastewater* – wastewater discharged from residences and from commercial, institutional and similar facilities.
2. *Industrial wastewater* – wastewater in which industrial wastes predominate.
3. *Infiltration/Inflow* – extraneous water that enters the sewer system from the ground through various means, and storm water that is discharged from sources such as roof leaders, foundation drains, and storm sewers.
4. *Storm water* – runoff resulting from rainfall. Storm sewers are always gravity-flow systems due to large quantities of storm water. Storm sewers collect storm water from streets, roofs and other sources.

   - For this class we will exclude storm sewer system design assuming all storm runoff will be carried by surface drains

➢ Conveyance capacity allowance must include groundwater infiltration and unavoidable inflows.

Inflow to Sanitary Sewer Systems

Inflow is basically water entering a sewer system from surface sources such as- leaking manhole covers, directly connected roof gutters, yard and area drains, street wash water etc.

Infiltration to Sanitary Sewer Systems

Groundwater/percolating water in the subsurface entering a sewer system through- defective pipes, leaking pipe joints, cracked manhole walls etc. is considered as infiltration flow towards sewer pipe.

Calculation/ estimation of infiltration/inflow for new construction can be obtained using the following figure:

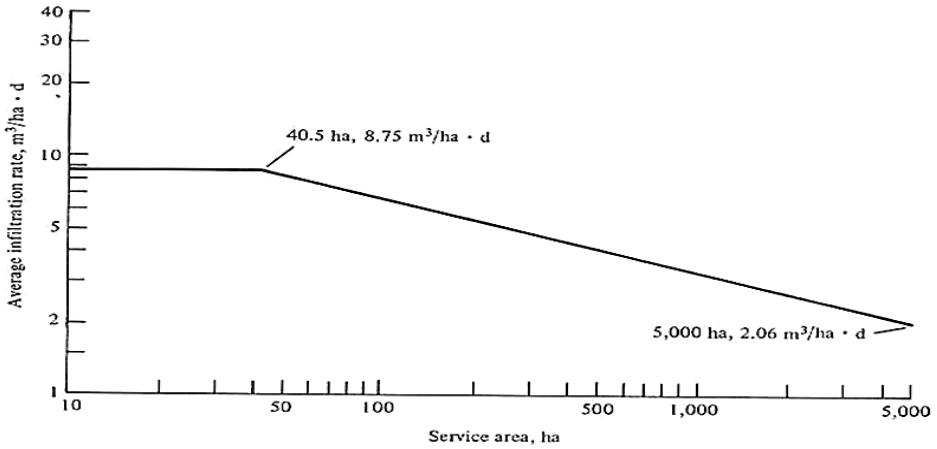


Figure 5 : Average infiltration rate allowance for new sewers. Note: ha × 2.4711 = acre; m³/ha·d × 106.9 = gal/acre·d.

Average Wastewater Flows:

Estimation of "design flow" is important because it ultimately determines the sizes of the sewers to be provided. Amount of average wastewater flow from any area depends on the amount of average water demand/consumption of that area and also on the type of that area. e.g., for industries without internal reuse programs - approximately 85 to 95% of water used will be returned to the sanitary sewer system.

In this class the following percentage of average water demand for different types of area will be used:

Table-1: percentage of avg. water demand to be considered as avg. WW generation

Category	% of avg. water demand as avg. ww flow
Industrial	95 -85
Residential	80-70
Institutional	80-70
Commercial	80-70

Peak wastewater flows

Components of waste water flow include:

1. Peak flows from residential (use fig-6)
2. Peak discharge for institutional and commercial zone
3. Peak discharge of industrial waste water
4. Peak infiltration and inflow allowance (use fig-5)

Peak factors for industrial, institutional and commercial wastewater is given in table- 2:

Table-2: Peak Factors for Different Facilities	
Category	**Peak Factor**
Industrial	2.1
Institutional	4.0
Commercial	1.8

Peak factor for residential wastewater – use figure-6:

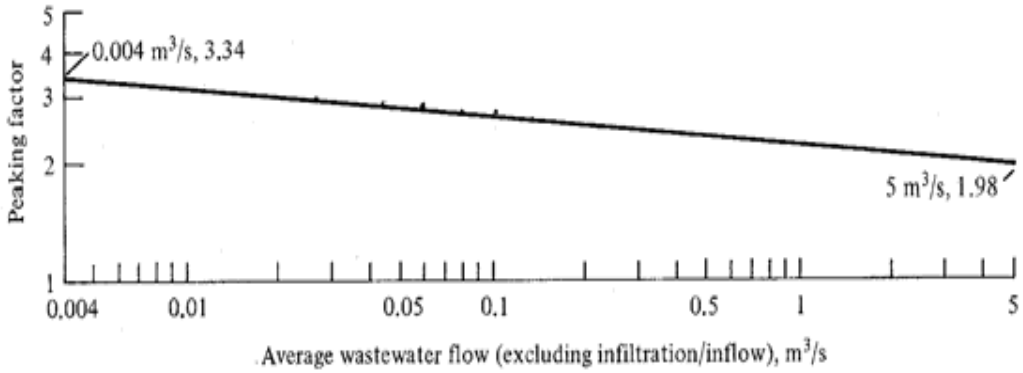


Figure-6: Peaking Factor for Residential Wastewater Flows

Sanitary Sewer: Basic Design Considerations

It includes:

- Wastewater flow from -industrial, commercial, institutional & residential.
- Use of hydraulic-design equation for pipe design (manning's equation)
- Sewer pipe materials (e.g. – concrete)
- Minimum pipe sizes
- Minimum and maximum velocities
- Slopes and cover
- Evaluation of alternative alignments or designs
- Selection of appropriate sewer appurtenances

Hydraulic Design Equation

The Manning equation is commonly used for sewer design. Roughness co-efficient "n" in Manning's equation should not be less than 0.013 for new sewers made of PVC, Vitrified clay or concrete.

- Pipe sections should not be less than 5 feet long
- For new constructions assume first class construction with true and smooth inside surfaces etc.

Sewer Pipe Materials

Most commonly used materials are –

- Ductile Iron
- Reinforced Concrete
- Pre-stressed Concrete
- Polyvinyl Chloride
- Vitrified Clay
- Glass Reinforced Plastic

Pipe Sizes

- Consider minimum pipe size 8 inches (200mm). However if wastewater volume is low pipe size at least 6 inch is allowed.
- Smallest sewers should be larger than the building sewer connections in general use in the area
- Most common size of building connection is 6 inches but connections of 5 or 4 inches have been used successfully in some areas

Flow Velocities

During sewer pipe design two critical velocities are considered –

i) Self cleansing velocity –

- It is the minimum velocity required to be attained at least once in a day to prevent solid deposition along sewer.
- Minimum allowable velocity is 2 ft/sec (0.6 m/sec) at one-half full or full depth.
- If access for cleaning is difficult, the minimum velocity should be 3 ft/sec (1 m/sec).

ii) Non-scouring velocity

- It is the maximum limit of velocity to prevent scouring/ damage to sewer wall by solids in wastewater.

- Its value depends on the type of sewer pipe materials.
- Maximum allowable velocity:
  - 2.5-3.0 m/sec for concrete sewer
  - 3.0-3.5 m/sec for vitrified sewer
  - 2.0-2.5 m/sec for brick sewer
  - 3.5-4.0 m/sec for cast iron sewer

Sewer Pipe Slopes

- Sewers with flat slopes may be required to avoid excessive excavation where surface slopes are flat or the changes in elevation are small. In such cases, the sewer sizes and slopes should be designed so that the velocity of flow will increase progressively, or at least will be steady throughout the length of the sewer.
- The following table shows the minimum gravity sewer pipe slopes based on manning's equation with a minimum velocity of 0.6 m/s. Where practicable steeper slopes should be used.

Table-3: Gravity Sewer Minimum Pipe Slopes

Size in inch (mm)	Slope m/m	
	n = 0.013	n = .0.015
8 (200)	0.0033	0.0044
10 (250)	0.0025	0.0033
12 (300)	0.0019	0.0026
15 (375)	0.0014	0.0019
18 (450)	0.0011	0.0015
21 (525)	0.0009	0.0012
24 (600)	0.0008	0.0010
27 (675)	0.0007*	0.0009
30 (750)	0.0006*	0.0008
36 (900)	0.0004*	0.0006

*The minimum practicable slope for construction is about 0.0008.

Sewer Appurtenances

Primary appurtenances for sanitary sewers:

- Manholes
- Drop inlets to manholes
- Building connections
- Junction chambers

Manholes

The number of manholes must be adequately spaced so that the sewers can be easily inspected and maintained.

Manhole Size:

- Manholes in small sewers are usually about 4 feet in diameter when the sewers have circular cross sections
- In large sewers, larger manholes may be required to accommodate larger cleaning devices

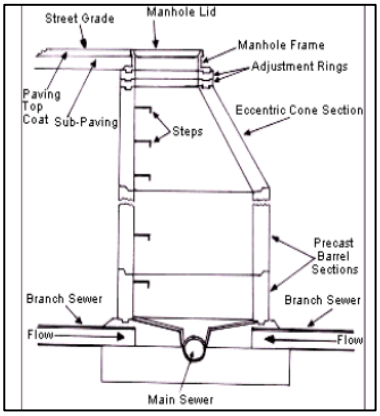
Placement: For sewers that are 48'' and smaller, manholes should be located –

- at changes in size,
- at changes in slope or
- at changes in directions
- at changes in length of pipe
- For larger sewers, these changes may be made without installing a manhole.

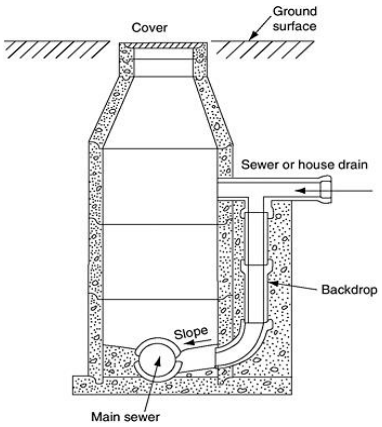
Spacing:

- Sewers < 24 in (600mm) - Place manholes at intervals not greater than 350 ft (100m).
- Sewers 27 – 48 in (700-1200mm) - Place manholes at intervals not greater than 400 ft (120m).

- Sewers > 48 in (1200 mm) - Manholes may be placed at greater intervals depending on local conditions like breaks in grade, location of street intersections, etc.



Vertical section of a typical manhole



Drop Manhole

Drop Manhole:

A drop manhole is used in areas with a steep slope when one or more of the inlet pipes has an invert elevation significantly higher (> 2 ft) than the invert of the outlet pipe.

Sewer pipe cover

- A minimum soil cover is required to keep sewer pipe below service connection as well as to prevent contamination and leakage.
- For Trunk sewer assume 2 m minimum soil cover from ground surface for this case. For highly porous soil the cover must be increased.

Crossing between Sanitary Sewers and Water Lines

A minimum separation between water and sewer pipes must be maintained to assure protection of a water supply.

Common Trenches and Sewers Parallel to the Water Line

- Do not install a sewer directly above or below a water pipe
- Do not construct a sewer within 5-feet from the outside wall and below the invert of the water pipe.
- Locate the sewer at least of 1 -ft away from the outside wall of a water pipe.

STEPS FOR DESIGN OF TRUNK SEWER

(Sanitary Wastewater only)

1. From the plan of the Industrial Village prepare the layout of wastewater sewer network. Identify and mark all the junctions (nodes) of branch sewers/main sewers with the Trunk sewer.
2. Calculate each sub area or service area (in hectors) contributing to each junction/node for determining infiltration rate allowance for each sub area (as shown in figure- 7).
3. Calculate population/unit used under each sub area
4. Calculate total average daily water consumption (Lpd) for each sub area
5. Calculate average wastewater flow per day for each type of unit
   Average ww flow (per day) = multiplying factor (from table-1) x water consumption rate of the unit per day
6. Calculate peak ww flow per day for each unit
   Peak ww flow per day = avg. ww flow per day x peaking factor (PF- from table-2 or figure-6 for residential ww flow)
7. Calculate infiltration allowance (m^3/ha-d) for each sub area using calculated size of the sub area (Use figure-5)
   Infiltration and in flow (l/l) = infiltration allowance (m^3/ha-d) x area (ha)

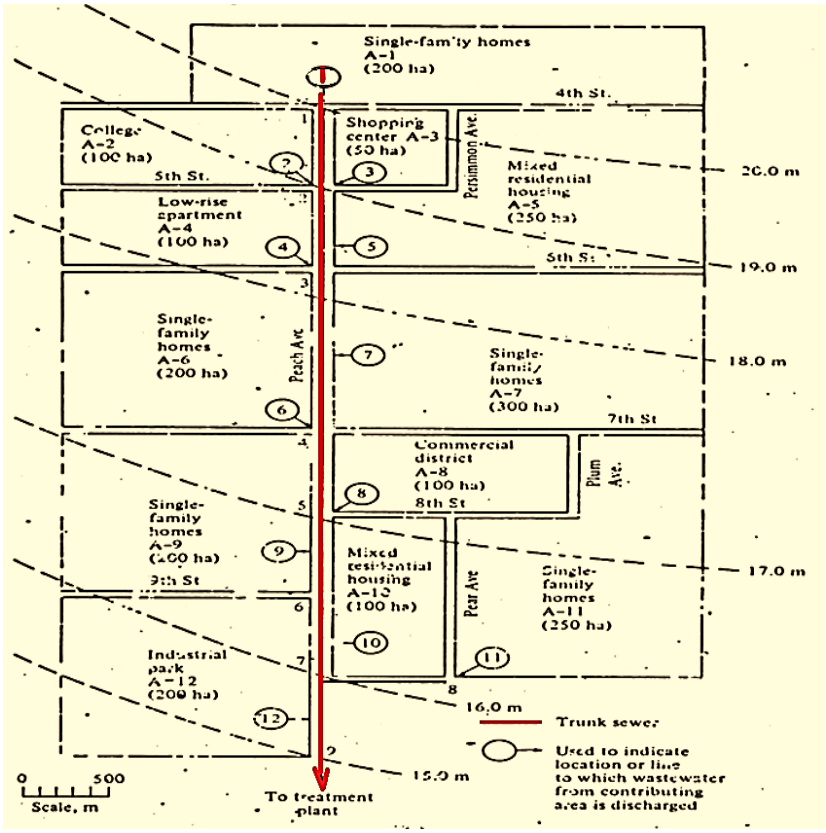


Figure -7: A typical contour diagram of a sub-urban area

8. Calculate Cumulative Peak flow contributing to each node

Total Flow, Q (m^3/sec) = total peak ww flow towards each node + Infiltration and inflow

Design of Trunk Sewer

9. Determine size of the pipe segment in between two successive nodes using manning formula.

Assume,

- Pipes are flowing full
- Slope of pipe = 0.0033 in/in (minimum slope for smallest available size – table -3)
- n = 0.013 (for new concrete/ pvc pipe)

Using Manning's equation,

$$\text{Pipe Diameter, D (m)} = 1.548\,[\,nQ / \sqrt{S}\,]^{0.375} \quad \text{------- (1)}$$

Use next larger size as pipe diameter **(D_{actual})** if the calculated diameter doesn't match with standard available pipe sizes.

10. Calculate "Q_{Full}" using D_{actual} in eq-1

11. Calculate velocity, V_{Full} using manning's equation

$$V_{Full} = \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

- Check with V - minimum (self-cleansing velocity) and V –maximum (non-scouring velocity). Revise diameter/ slope to satisfy this factors.

12. Calculate $\left(\frac{Q}{Q_{Full}}\right)$. Using Hydraulic element Diagram (figure-8) , Find out –

$\left(\frac{d}{D_{Full}}\right)$, $\left(\frac{V}{V_{Full}}\right)$

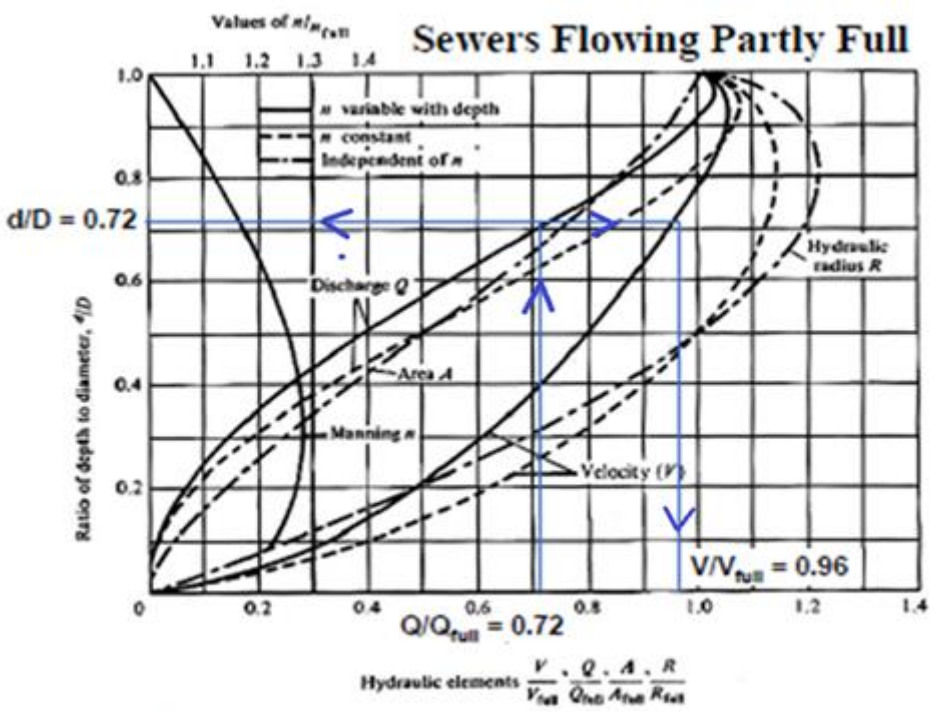


Figure 8: Hydraulic elements for circular sewers [10].

13. Determine actual V. Check with V - minimum (self-cleansing velocity) and V –maximum (non-scouring velocity). Revise if needed.

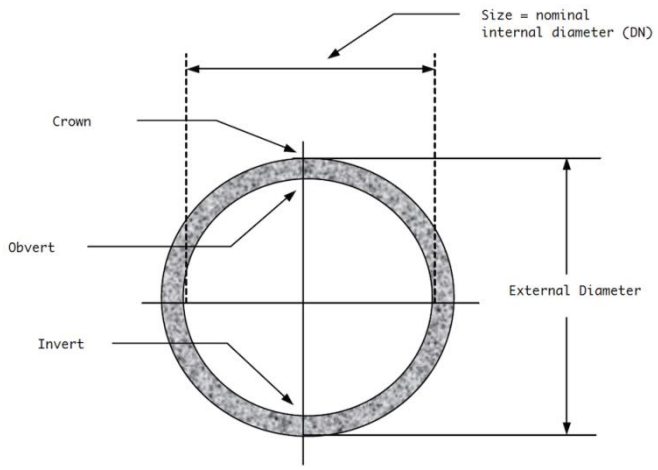
14. Prepare sewer design computation tables as shown in class.

15. Prepare longitudinal Profile of the Trunk sewer

- From contour diagram of the area find out ground surface elevation at each node along the trunk sewer trench line.
- Calculate sewer pipe invert elevation at each end (upper and lower) for each segment of pipe-
  Invert elevation of sewer pipe at upper end = Ground Elevation – 2 m cover – Pipe thickness (50 mm) – Diameter of the pipe

- Calculate sewer pipe Crown elevation at each end-
  Crown elevation of sewer pipe at upper end = Invert Elevation + Diameter of the pipe

- When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient.
- Draw the longitudinal profile showing details of ground elevation, tentative position of manholes, invert crown etc. for all nodes



Profile of Trunk Sewer should include:

1. Lay out the trunk sewer.
2. Locate and number the manholes. Identify each manhole with number.

Manhole should be located at

- ✓ Changes in direction
- ✓ Changes in slope
- ✓ Pipe junctions
- ✓ Upper ends of sewer
- ✓ Intervals from 300 ft or less

Vertical Profile

- Prepared for each Trunk Main
- Horizontal scale of 1:500 or 1:1000
- Vertical scale of 1:50 or 1:100