EWCE 333 — SA

SA/L01 23/11

Waste water Engg. & Sanitation

Ref. books

2. Environmental Engg. Green/Red

8.

1.

WTP, STP, ETP

L01

23.11

book

Env. Eng - Peavey

L02

25.11

Importance and goal of
wastewater eng. and sanitation

Major components

contributions to wastewater flow

Infiltration




collection of sewage
(wastewater

wastewater treatment

preliminary treatment

~~SOIL~~ SA/L03 30/11

Wastewater chars

Sewage water chars

Physical chars of wastewater

Odor

Temperature

Density

Chem chars

BOD

Derivation BOD Eq

$$L_t = L_0 e^{-kt}$$

Limitations

SA/ LOG

02/12

BOD $BOD_t = L_0(1 - e^{-Kt})$

Example 1.

BOD for Nitrogenous OM

COD

TheoD

ThOD example

C = 12; $12 \times 12 = 144$

H = 22; $22 \times 1 = 22$

O = 11; $11 \times 16 = 176$

$$\frac{12 \times (16 \times 2)}{342}$$

Inorganic matter

Typical wastewater contamination [not impo]

Waste water treatment standards

SA/L05 07/12

## Collection of wastewater

Important terms

diff. btwn sewage, sewer, sewerage

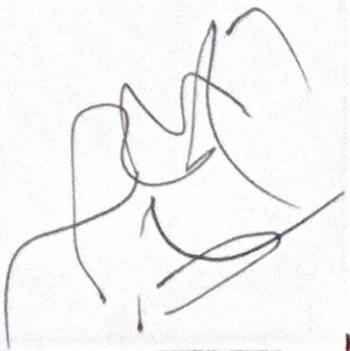
Conventional sewerage system

Basic functional elements

Types of collection system Chap 10

Three

1. Separate sewerage system
2. Combined
3. Partially combined/ separate



Rough — CT-1 13/12/2025

# Lec 01

Defn: wastewater engineering the branch of environmental engineering that uses the basic principle of science and engineering to solve the problems associated with wastewater treatment & reuse

ultimate goal → Wastewater management

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Problems associated w/ wastewater:

- Decomposition causes foul odor
- contains pathogenic microorganism that dwells in human intestine
- contains nutrients that stimulates aquatic growth.
- toxic compounds

Role of wastewater engineer:

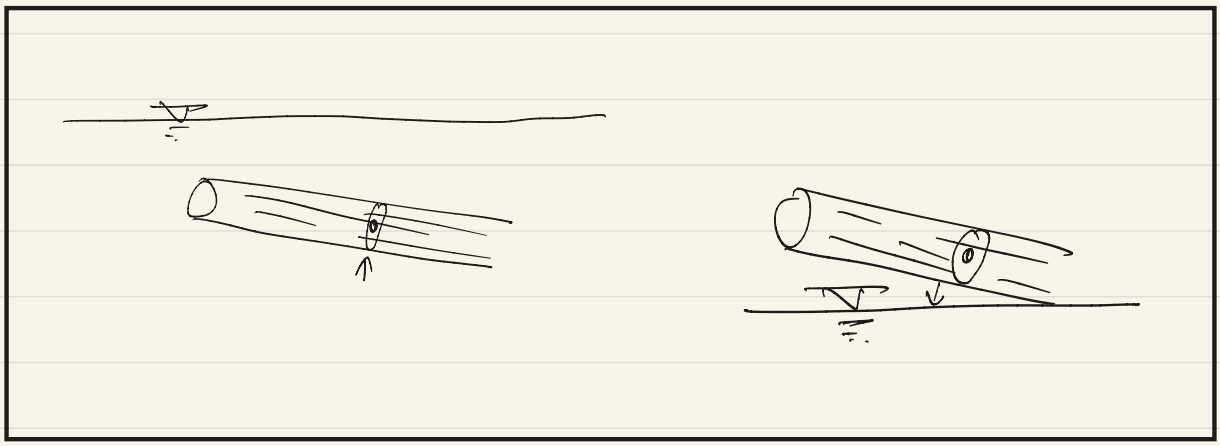
- knowledge of constituents in concern
- long term fate of those when disposed into environment
- impacts of those constituents
- beneficial use and disposal of solids generated by the treatment plant.

Sources of wastewater (major):

1. Domestic: waste from food, detergents, soap, sinks, toilet use
2. Commercial: food & toilet usage from restaurant and other shops
3. Industrial: varying types — chemical & others based on industry type.
4. Agricultural: organic waste — fertilizer, pesticides, etc.
5. Runoff from street: sand, petroleum, tars

Other contribution:

- infiltration: older sewer didnot have water tight joints water could enter in through the leakages or get out through the same



## Composition of sewage

- 99.9% liquids; 0.1% solids;
- Faeces, urine contains millions of intestinal bacteria
- organic matter contributed by per person per day —
  - 110g of of suspended solids
  - 90g of BOD

  in domestic env. & where kitchen waste is discharged into sewer system

## wastewater treatment steps (major):

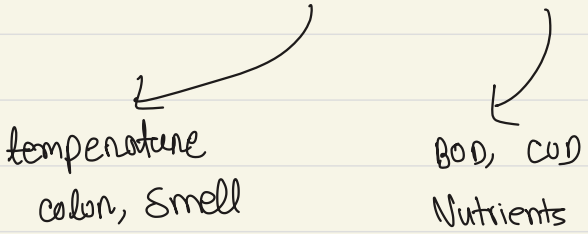
1. Preliminary: removes materials that could damage the treatment plant or would occupy treatment capacity unnecessarily
2. Primary: Removes settleable & floatable solids
3. Secondary: Removes BOD & dissolved and colloidal particles through biological action.
4. Advanced: Removes additional BOD, solids through physical, chemical, biological actions.
5. Disinfection: Removes microorganisms
6. Sludge treatment: stabilizes solids removed during wastewater treatment

Composition of sewage

- Liquid — 99.9%
- Solid — 0.1%
  - Inorganic — 30%
  - Organic — 70%
    - Protein — 40–60%
    - Carbohydrate — 25–50%
    - Fat — 10%

# Lec 02

Sewage characteristic — Physical, chemical, bacteriological




## Physical chars

- ~~total~~ solid content, odor, ~~temperature~~, density, colour and ~~turbidity~~
- freshly light grey, yellowish and no unpleasant odor
- turns to black when sewage become stale
- unpleasant odor as a result of septic or stale condition.
- temperature affect chemical & biological activities
- settleable solids, TSS, VSS affects treatment unit's size & operation

Odor — produced by gas production by decomposition & materials added.
Can be detected by portable $H_2S$ meter

Temperature — warmer than that of water supply (10 – 21°C; avg 16°C)

- Affects chemical reaction during wastewater treatment
- Affects aquatic life — oxygen solubility is higher in colder water than warmer.
- optimum temp for bacterial activity is 25 – 35°C
- Aerobic digestion & nitrification stop at ≥ 50°C methane producing bacteria at ≤ 15°C
- Nitrifying bacteria stop activity at ~ 5°C.

Density — Doesn't change significantly.

Color — fresh → light brownish grey
w/ time → dark grey
more time → black
Sometimes pink due to algae or coloring

## Chemical Characteristics

in sanitary sewage

- About 75% of suspended solids & 40% of filtrable solids are organic
- Organic compounds — C, H, O, N w/ S, P, Fe
- Protein → 40–60%; carbohydrates → 25–50%; fat → 10%
- Small amount of synthetic organic compounds — pesticides
- May also contain inorganic substances

BOD — Biochemical Oxygen Demand

Amount of oxygen required by bacteria to decompose organic matters into stable end products.

Rate of oxydation $\propto$ amount of organic matter present

$$\frac{dL}{dt} \propto -L$$

$$\Rightarrow \frac{dL}{dt} = -kL$$

$$\Rightarrow \frac{dL}{L} = -k\,dt$$

$$\Rightarrow \ln[L] = -kt$$

$$\Rightarrow \ln\frac{L_t}{L_0} = -kt$$

$$\Rightarrow \frac{L_t}{L_0} = e^{-kt}$$

$$\Rightarrow L_t = L_0 e^{-kt}$$

$L_t$ = concentration of organic matter or BOD remaining at time 't'

$L_0$ = initial concentration of om.

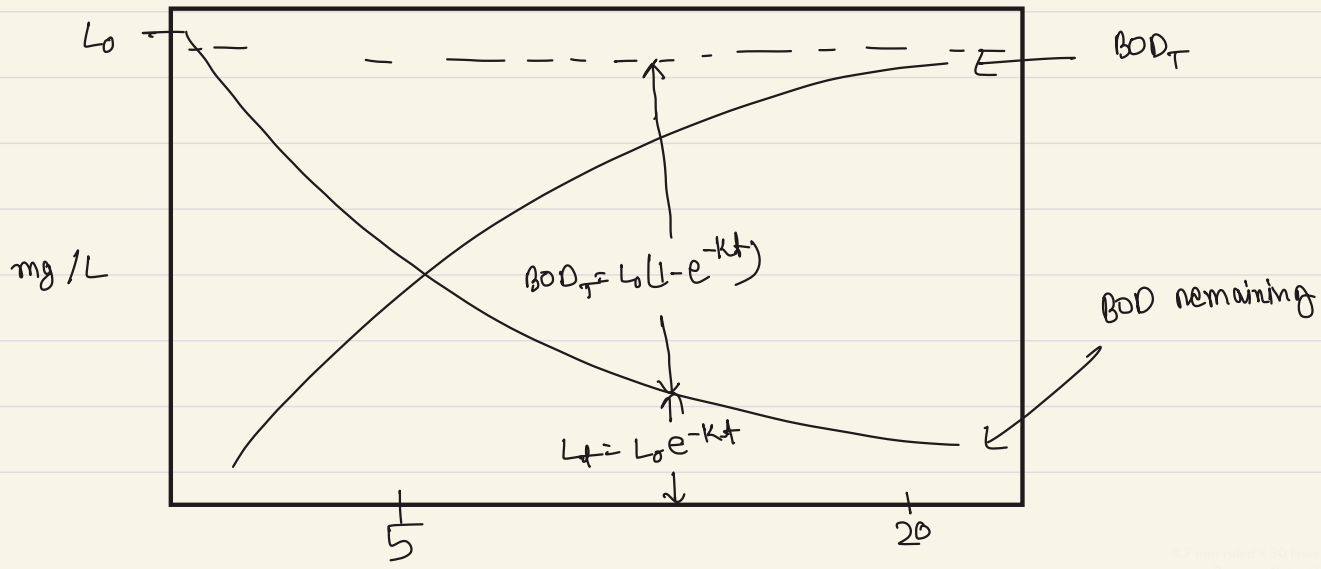
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$$y = L_0 - L_t$$

$$\Rightarrow y = L_0 - L_0 e^{-kt} = L_0(1 - e^{-kt})$$

$k = 0.23$ [per day for domestic sewage @ 20°C]

$k_T = k_{20}(\theta)^{T-20}$ [$\theta = 1.047$; $k_{20} = 0.23$]



Ex P15

$BOD_5 = 200\ mg/L$

$K = 0.23\ d^{-1}$

$BOD_5 = L_0(1 - e^{-kt})$

$\Rightarrow 200 = L_0(1 - e^{-0.23 \times 5})$

$\Rightarrow L_0 = 293\ mg/L$

$BOD_1 = L_0(1 - e^{-kt})$

$= 293(1 - e^{-0.23 \times 1})$

$= 60\ mg/L$

$BOD_5$ @ 25°C

$k_{25} = k_{20}(\theta)^{T-20} = 0.23(1.047)^{25-20} = 0.2894$

$\therefore BOD_5 = 293(1 - e^{-0.2894 \times 5})$

$= 224\ mg/L$

---

P20 $C_{12}H_{22}O_{11} + 12O_2 \longrightarrow 12CO_2 + 11H_2O$

Oxygen $\rightarrow 12 \times (16 \times 2) = 384$

Sugar $\rightarrow 12 \times 12 + 22 + 11 \times 16 = 342$

$ThOD = \frac{384}{342} = 1.123\ gO_2/g_{sugar}$

$[Sugar] = 100\ mg/L$

$ThOD = 0.1123\ gO_2/L = 112.3\ mg/L$

$TOC = \frac{144}{342} = 0.42\ g/g = 42\ g/L$

NBOD — Nitrogenous BOD

Amount of oxygen required to convert Nitrogen compounds into stable nitrates

$$NH_3 + O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^-$$

$$NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} NO_3^-$$

Theoretical NBOD → $\frac{4 \times 16}{14} = 4.57\ gO_2/gN$

Kjeldahal Nitrogen (TKN) → total concentration of organic & ammonia nitrogen

L06 21/12

Suitable conditions for seperate system (Sewen system)

→ suitable for Dhaka [for exam]

Suitable conditions for combined system

Diff btwn the two

→ define two sys
→ adv.
→ disadv.

} Prefenably in tabular format

Types of Sewers — according to use/position → name diff, func same, dia diff.

Trunk sewer or intercepting sewen may not be requine in some area

Sewen cleanout → blockage



Manhole

Design of sanitary sewen system → manning's formula

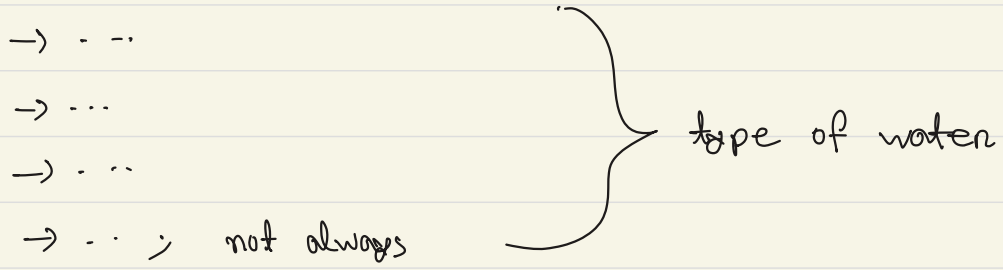
$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

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

Quantity estimation of sewage

Self cleansing velocity → Discharge ↓ → vel ↓ → deposit of solids

The sewers are designed to carry

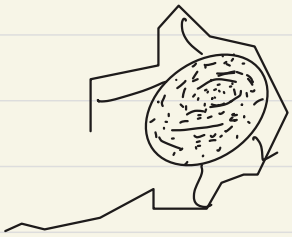



Estimation of sewage flow rate

L07 21/12

## Estimation of waste water flows

Population estimates $P = P_0[1+r]^n$



Relation to water use
Factors affecting water use

Per capita sewage flow rate



- ideally, full usage; but losses due to evapration, infil.
- very dry & arcid region — ≥ 40%
- well developed ~ 90%
- ~ 80%

Design flow

flow → wastewater flow

Peak flow
Storm water

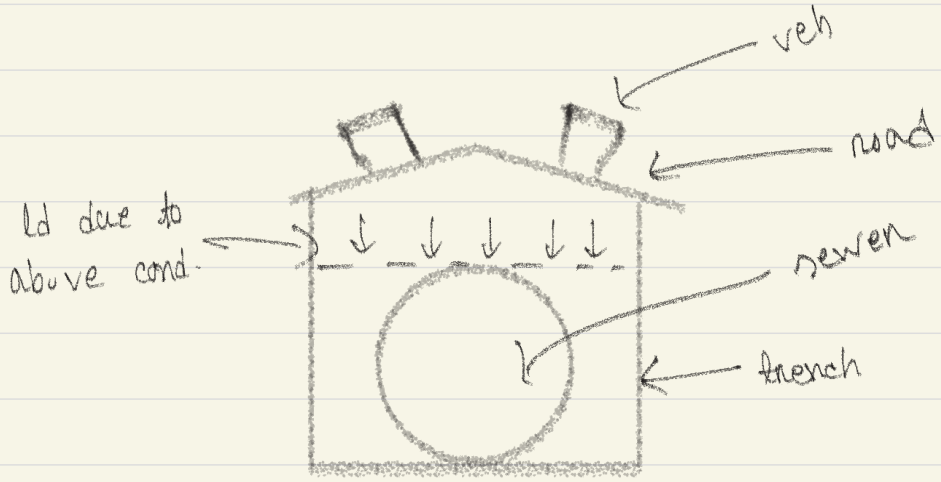
PDWF + storm contribution

Variations for all: terms → ADWF, PDWF, PWWF
Peak factor → avg dry / peak flow
variation in sewage flow

Design flow = always peak flow (not avg)

G.W. infiltration

normally not considered; should be considered




Rate of infiltration depends on,

- - -

— workmanship ⟶ workforce's skill

Max = avg flow x P.F + G.W. infil.

Quantity of storm water

depends on — ...

LO8 23/12

Estimation / Quantity of Sanitary Sewage

Storm water — separate consideration

depends on — $Q = cIA$

Catchment area

Intensity

Duration of rainfall

Nature of surface

Obstruction

Methods of estimation → Consider only that which will flow not initial seepage or absorbed

1. Rational method
2. Empirical method

Time of concentration ($t_c$)

Duration required for whole catchment to start contributing to runoff. → time of inlet + time of travel

Runoff max when rainfall duration ≥ time of conc.

Inlet time ($T_i$) → furthest point to mouth of channel

Travel time ($T_t$) → mouth of channel to outlet

## Rainfall intensity

$I = 76.2(t+10) \longrightarrow t = 5-20\ min$

$1016(t+20) \longrightarrow t = 20-100\ min$





Time of conc, $t_c = \frac{FL}{A^{0.1} S^{0.2}}$

## Runoff estimate,

Rational formula $Q = FCIA$ → factor of proportionality

## Surface drains — Requirements

- Self cleansing velocity
- not high vel to scour sides
- ...

## Estimation of design flow

Residential Commercial Industrial

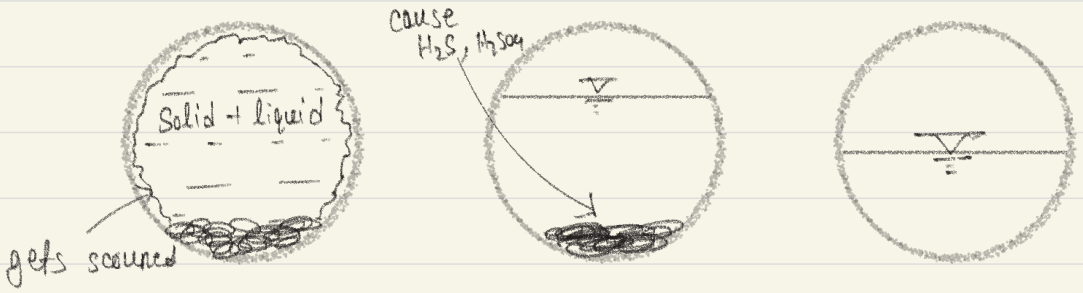
$Q = \Sigma D \cdot d + \Sigma I \cdot i$ combined system

$\Sigma D = P q_r + A_c q_c + A_i q_i$

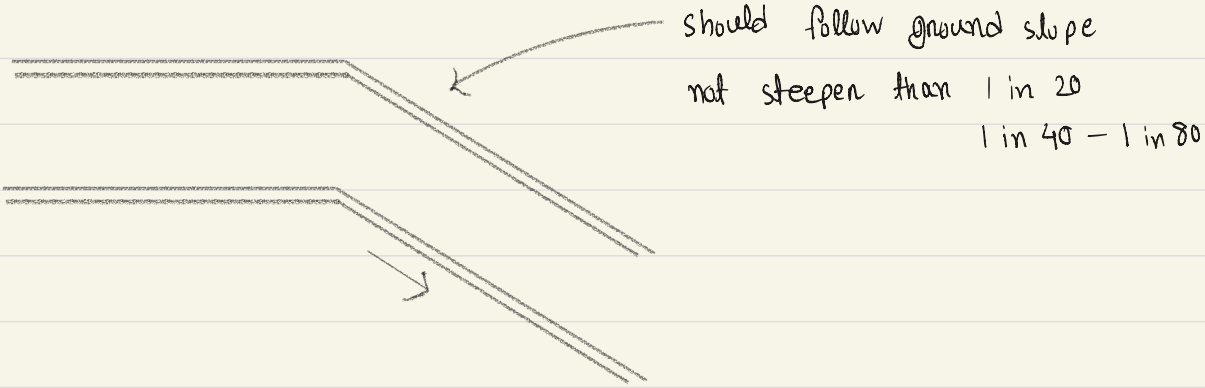
$\Sigma I = A_r K + A_c K/4 + A_i K/4$

Sewer capacity $\geq Q$

Self-cleansing velocity [avg = ... ; memo]



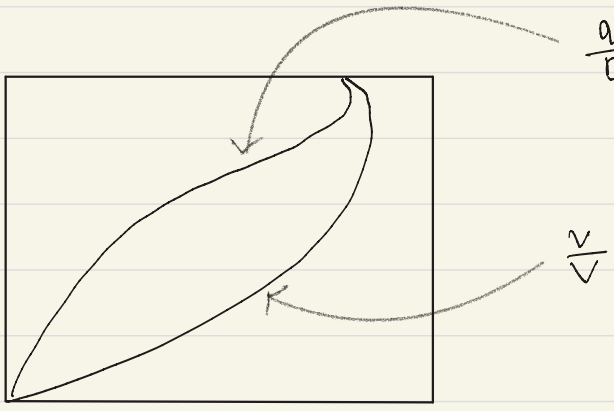

design condition actual




Manning's formula: $\frac{1.486}{n} R^{2/3} S^{1/2}$

if n not given, $n = 0.013$

Sewers flowing partly full [memo eqn] [likely graph be given]



Layout of Sewen Lines

Laying of sewen pipes

L10 30/12

Classroom code: ady6h3m

## Problem 1:

$Q_{av}$ (san) = 100% of water use = 750 × 59 = 44250 g/d = 1843.75 g/h

Infiltration = 30000 × 1.3 =

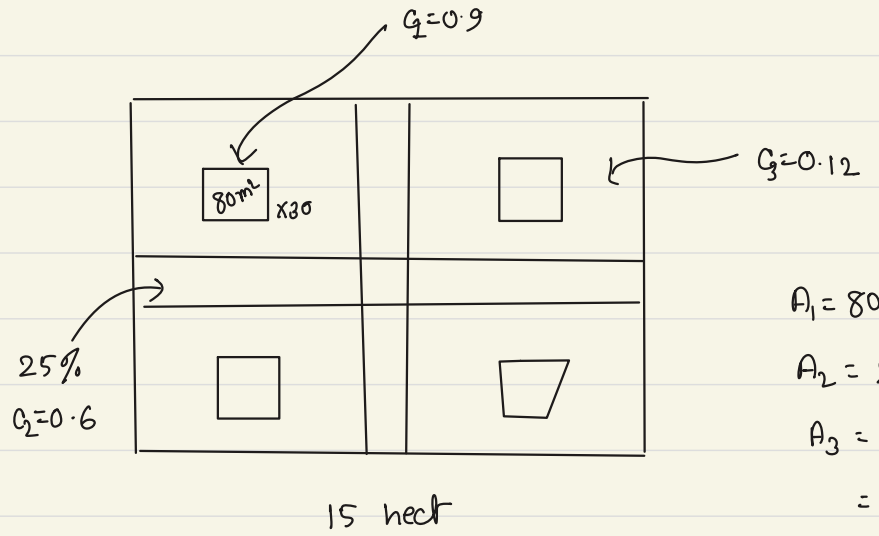
$Q_{av}$ (design) = $Q_{av}$ (san) + infiltration + storm flow ← 0 here

= 1843.75 + (30000 × 1.3 → g/h) = 83250 g/h

$Q_{max}$ (design) = 3 × $Q_{av}$ + infil

$Q_{min}$ (design) = 0.67 × $Q_{av}$ + infil

## Problem 3:




$A_1$ = 80×30 = 2160 m²

$A_2$ = 2500 m²

$A_3$ = 10000 − ---

= 5100 m²

For 1 ha,

Total pop = 300×15 = 4500

$$C = \frac{\Sigma A_i C_i}{\Sigma A} = 0.43$$

Q = FCIA = 27.8 × 0.43 × 4.5 × 15 = 807 l/s

$Q_{av}$ (s) = 80% × 4500 × 250 = 900000 l/d = 10.42 l/s

$Q_{max}$ = 2.5 × 10.42 = 26.05 l/s

Ratio → ---

For Dhaka city, which is suitable — combined or separate

Storm water example

$t_c$ →

I →

Q →

Ex. 2 (tail of earlier)

Ex. 3

## Example

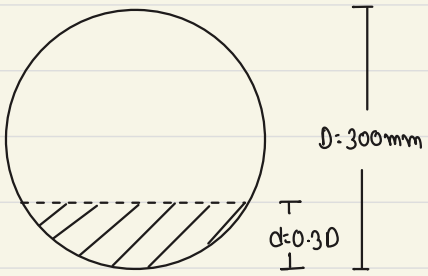
$d, q, u, S_s$

For full depth,

$$V = \frac{1}{N} R^{2/3} S^{1/2}$$

(0.9 = V; D/4 = R; S = ?; 0.013 = N)

$\Rightarrow S = \cdots = 0.0043$




$V = 0.9$ m/s $\quad d/D = 0.3$

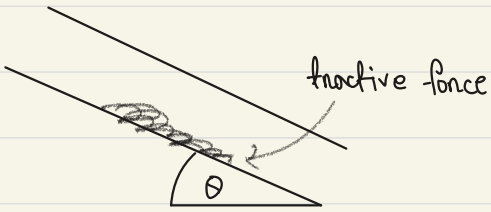
$n = 0.013 = N$

$d/D = \frac{1}{2}(1 - \cos\frac{\theta}{2}) = \theta = \cdots$

$S_s = \cdots$

$v_s = \cdots$

$q = \cdots$




$\tau = T$

$\Rightarrow \gamma_w RS = \gamma_w RS$

---

## Example

Avg water supplied $= \cdots = 0.176\ m^3/s$

Sewage production : $0.176 \times 0.8 = 0.14\ m^3/s$

max " " : $3 \times 0.176 = \cdots$

$d/D = 0.7$

$q/Q = 0.838$

$S = 1/600$

---

Problems to be solved ---

Example Nomograph — connect any two known data, then extend line

Mid ⟶ up to above prob (P15)

Limiting velocity 2.5 m/s

Self-cleansing velocity 0.6 ~ 0.9 m/s

Problem

Calculation of area, population, flow

| Type | Area | Density | Population | Flow ($m^3/s$) |
|---|---|---|---|---|
| --- | --- | --- | [Density] x [Area] | [Population] x $9.26 \times 10^{-6}$ |
| | | | 252,975 | 2.34 |

Commercial sector = $0.3 \times 2500$ ha

=

Industrial sector = $0.1 \times 250$

in K

$\frac{Q_{peak}}{Q_{ave}} = \frac{5.5}{259,975/1000} = 2.0$

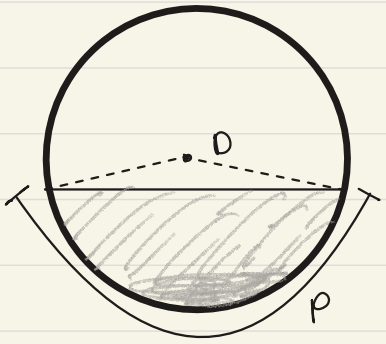
$\frac{Q_{min}}{Q_{ave}}$, . . .

. . .

Why does $H_2S$ form in sewer

$$z = 0.308 \frac{EBOD}{S_0^{0.5}} ;$$

$$B = D \sin \theta/2$$



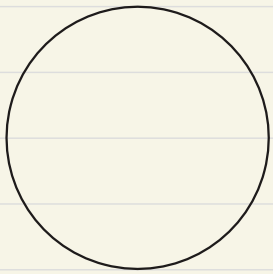

## $H_2S$ generation problem

$D = 2000\ mm = 2m$ ; $R = 1m$

Slope = 0.0015

Q = 0.—

no math → Loads on Sewer — Earth Pressure, vehicle



Load, $w = C_w B^2$ ← in m  [kg]

L13

06/01

Maintenance of Sewerage System

Sewer

- Small Bore Sewerage (SBS) System
  - diff btwn this & other
- Design criteria:
  - why self-cleansing vel not req to maintain

Simplified sewerage system

Rough / Midterm 06/01

## Terms:

Sewage: Liquid waste or wastewater produced as a result of water use.

Sewer: Physical conduit or pipe that carries sewage.

Sewerage: A system that includes wastewater collection, and conveying it to its disposal point w/ or w/o treatment.

Sanitary sewage: A.K.A black water, it is the wastewater originated from sanitary conveniences (e.g., water closet, urinals, etc).

Sullage: A.K.A greywater, it is the wastewater originated from kitchen, wash basins, etc and excluded toilet and urinal discharges.

Sanitary sewer: Conduit or pipe that only carry sanitary sewages and not designed for stormwater or groundwater.

## Conventional sewerage system

Basic elements:

1. House connections for collection
2. Sewerage system for conveying the wastewater
3. Treatment plant
4. Disposal point

## Types of collection systems

ld on tatmnt plant

Advantages & disadvantages: size, efficiency, lifting, cost, cleaning, overflow, treatment difficulty,

**Separate sewerage:** Sanitary waste and storm waste are carried separately through two diff. systems.

Advantages:

1. Smaller in size
2. Only sanitary waste is treated
3. Lifting cost is low as vol is low
4. Storm water is not unnecessarily polluted

Disadvantages:

1. High cost for two system
2. Difficulty cleaning small pipes.

**Combined sewerage:** Both sanitary waste & storm waste are carried through a single pipe.

Advantages:

1. More economical as one pipe
2. Easy cleaning large pipe
3. Sewage is diluted w/ storm water.

Disadvantages:

1. Storm water is unnecessarily polluted
2. High load on treatment plant
3. High lifting cost as vol is high
4. More difficult to treat to a higher standard.
5. Heavy rainfall may cause overflow.

Partially combined system: only one set of sewer is used for both sanitary waste and storm waste but excess water during heavy rainfall is carried separately.

Advantages:

1. Both separate & combined systems' advantages
2. Not so large conduit
3. Minimal solid deposition problem
4. Problems of storm water discharges from home simplified.

Disadvantage:

1. Increased load on pump & treatment plant
2. Flow vel may be low during dry seasons.

## Suitability — Separate system

1. Flat area;
2. Where rainfall is non-uniform yearwise
3. Near river; storm water can be open-drained
4. Not enough budget for two system, only sanitary sewerage may be installed
5. Rocky areas; large conduit is difficult to excavate
6. If sewers are laid off before actual dev. of the area.
7. Pumping is req at short interval

## Suitability — combined system

1. Rainfall is uniform
2. Pumping req for both sanitary and storm water
3. Not sufficient space for two sys.

## Suitable for Dhaka: Sepenate sewerage

1. Non uniform rainfall
2. Relatively flat
3. Lots of low lying areas and surrounded by rivers
4. Advantages of this system

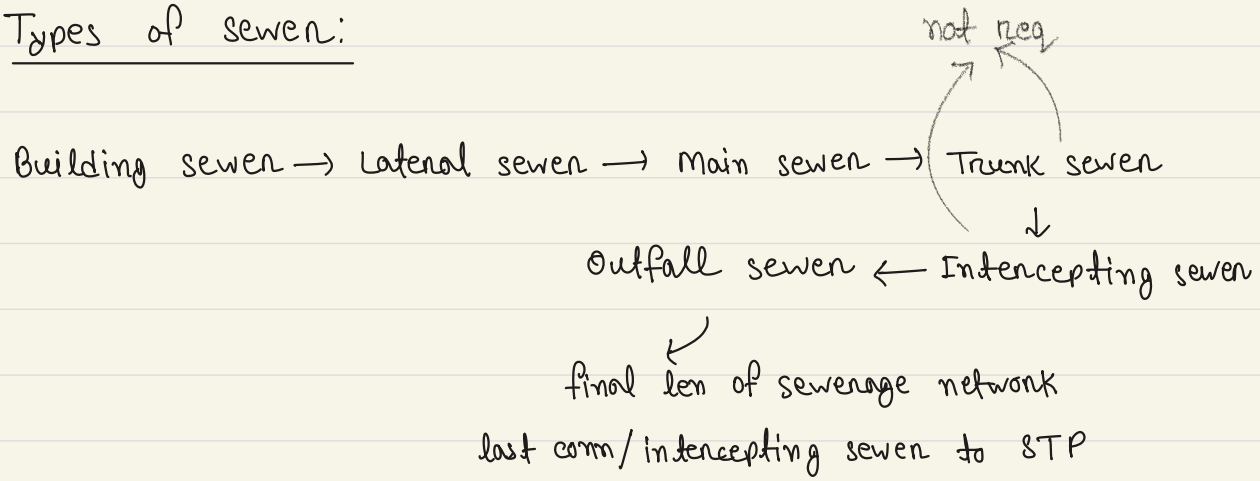
Separate vs. combined:

Separate: Two distinct set of pipes to carry sanitary sewage & storm water separately

Combined: Carries both together in a single set of sewers.

| Feature | Separate | Combined |
|---|---|---|
| No. of pipe | 2 | 1 |
| Pipe size | Small | Large |
| Pumping cost | Low | High |
| Treatment ld | Low | High |
| Cleaning | Harder | Easier |
| Env. impact | Cleaner | Riskier |

## Types of sewen:




Manhole: Opening constructed along the sewen line that allows a person to physically enter for inspection, cleaning, ... (Placed at junction)

Sewen cleanout: Smaller access point used to insert cleaning tools to clear blockage.

# Design of sanitary sewer system

Quantity estimation: v. high → non economical

v. low → flow vel < self cleansing vel

→ deposition

Sewers designed to carry:

1. Used water from community
2. GW as infiltration
3. Fraction of storm water
4. Industrial water from small establishments

Depends on,

1. Contributing pop → $P = P_0 [1 + r]^n$
2. Flow rate of sewage (per capita)

Sewage = 80% of consumption rate (conservatively)

water is lost due to

1. Evaporation
2. Seepage
3. Leakage

Design flow — carry peak flow rate

Wastewater flow varies — throughout the day and year

ADWF — Avg Dry weather Flow

PDWF — Peak Dry weather Flow

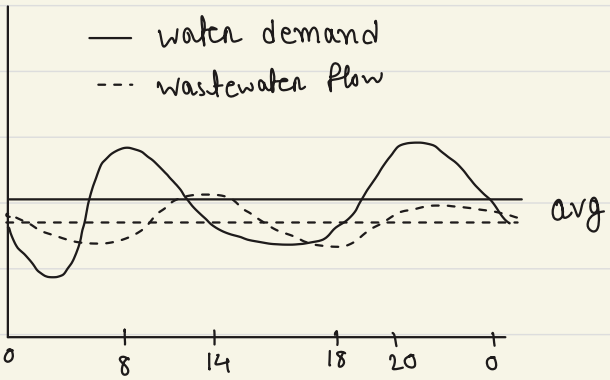
two peaks → morning, evening

Peak factor = ratio of peak to ADWF

PWWF — Peak wet water Flow

PDWF + storm water

Variation in sewage flow



## GW Infiltration

Rate of infiltration depends on,

1. Depth of sewer
2. Len of sewer under GWT
3. Materials of sewer
4. Type of soil
5. Types of joints
6. Workmanship

Peak flow rate = Avg domestic flow rate x P.F + infil. rate

## Quantity of storm water

Depends on :

1. Catchment area $\longrightarrow \uparrow - \uparrow$
2. Topography, nature of surface $\longrightarrow$ steep
3. Rainfall intensity
4. Antecedent condition
5. Extent of rainfall
6. Obstruction

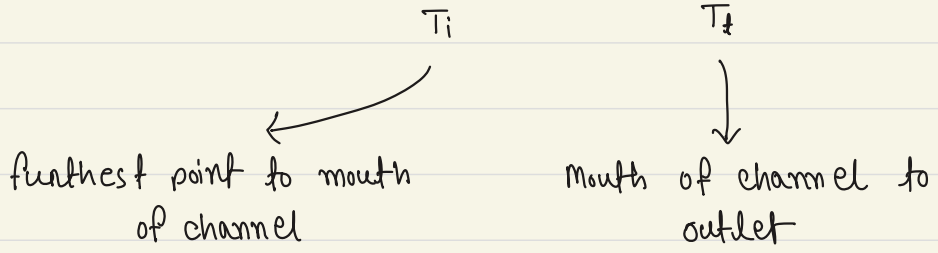
Methods :

1. Rational method
2. Empirical formulae method

Time of concentration: Duration after which entire catchment area start contributing to runoff.

Runoff max when rainfall duration = time of conc.

Time of concentration = inlet time + travel time




## Runoff estimate

$Q = FCIA$

when, $Q = l/s$, $I = cm/hr$, $A = ha$

$$F = \frac{(10)^2 \times 10^{-2}}{3600} \times 1000 = 27.8$$

## Surface drains

1. Should be inexpensive, easy to maintain
2. Develop self-cleansing vel
3. vel not too high to scour
4. Easy to clean
5. Possess structural stability
6. Smooth interior
7. Prevent weathering

## Problem 1

$Q_{av(san)} = 59 \times 750 = 44250$ gpd $= 1844$ gph

Infiltration $= 30000 \times 1.3 = 39000$ gpd $= 1625$ gph

$Q_{av(daily)} = Q_{av(san)} + \text{infil.} = 83250$ gpd

$Q_{max(hr)} = (1844) \times 3 + 1625 = 7157$ gph

$Q_{min(hr)} = (1844) \times 0.33 + 1625 = 2234$ gph

## Problem 2:

Area $= 15$ ha, 30 house/ha

roof $= 80$ m²/house, $C = 0.9$

road $= 25\%$, $C = 0.6$

$C = 0.12$

$I = 4.5$ cm/h

$\therefore$ Total area $= 15$ ha

Total roof area $= 30 \times 15 \times 8 = 36000 m^2 = 3.6$ ha

Total rd $= 0.25 \times 15 = 3.75$ ha

Remaining $= 15 - (3.6 - 3.75) = 7.65$ ha

$$\therefore C = \frac{0.9 \times 3.6 + 0.6 \times 3.75 + 0.12 \times 7.65}{15} = 0.43$$

$\therefore Q = FCIA = 27.8 \times 0.43 \times 4.5 \times 15 = 806.895$ l/m

Avg daily sewage $= 300 \times 15 \times 250 \times 0.8 = 900{,}000$ l/d $= 10.42$ l/s

$Q_{max} = 2.5 \times 10.42 = 26.05$ l/s

Ratio $= \frac{806.896}{26.05} = 31 \longrightarrow$ separate nec.

## Storm water, E1

$L = 3$ km  5 yr

$A = 7.5\ km^2$

$S = 5$ m/km

$C = 0.48$

$$t_c = \frac{FL}{A^{0.1} S^{0.2}} = \frac{58.5 \times 3}{(7.5)^{0.1} \times (5)^{0.2}} = 104 \text{ min}$$

$\therefore I = 70$ mm/hr

$$Q = FCIA = \frac{10^{-3} \times (10^3)^2}{3600} \times 0.48 \times 70 \times 7.5 = \quad m^3/s$$

E2  $Q = AV$

$$\Rightarrow 70 = \frac{\pi D^2}{4} \times \frac{1}{n} \left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$$\Rightarrow 70 = \frac{\pi D^2}{4} \times \frac{1}{0.013} \times \left(\frac{D}{4}\right)^{2/3} \times (0.001)^{1/2}$$

$$\Rightarrow D = 5.5 \text{ m}$$

v check: $V = Q/A = \frac{70}{\pi \frac{5.5^2}{4}} = 2.95$ m/s $< 3.0$ m  [OK]

P07/ Combined sewer

$A = 60\ km^2 = 6000\ ha$

Density : 185 person/ha

Avg sewage = 350 lpcd

max = 50% more

$Q_{av(sew)} = 185 \times 6000 \times 350 = 3.89 \times 10^8\ L/day = 4.5\ m^3/s$

Storm water = $12 \times 10^{-3} \times 60 \times 10^6 \times \frac{1}{3600 \times 24} = 8.333\ m^3/s$

$Q_{max} = 4.5 \times 1.5 + 8.33 = 15.08\ m^3/s$

- . -

P09/

$$V = \frac{1}{N} R^{2/3} S^{1/2}$$

$$\Rightarrow 0.9 = \frac{1}{0.013} \times \left(\frac{0.3}{4}\right)^{2/3} \times S^{1/2} \Rightarrow S = 0.0043$$

$$d/D = 0.3 = \frac{1}{2}(1 - \cos\frac{\theta}{2})$$

$$\Rightarrow \theta = 132.8°$$

$$r/R = 1 - \frac{\sin\theta}{\theta}\frac{360}{2\pi} = 0.684$$

$$\gamma_w R S = \gamma_w r s$$

$$\Rightarrow \frac{s}{S} = \frac{R}{r}$$

$$\Rightarrow s = S\frac{R}{r} = 0.0063$$

$$\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}\left(\frac{S}{S}\right)^{1/2}$$

$$\Rightarrow v = 0.846 \text{ m/s}$$

$$\frac{q}{Q} = \frac{N}{n}\frac{a}{A}\left(\frac{r}{R}\right)^{1/6} \qquad \frac{a}{A} = \theta/360 - \frac{\sin\theta}{2\pi}$$

L14

18/01

## Sewer Appurtenances

- Manholes
  - Why provided; in which situation

Lamp hole

Stormwater inlets

Sewage pumping station

## Sewer Design

[obtain a printed copy of diagram/plan]



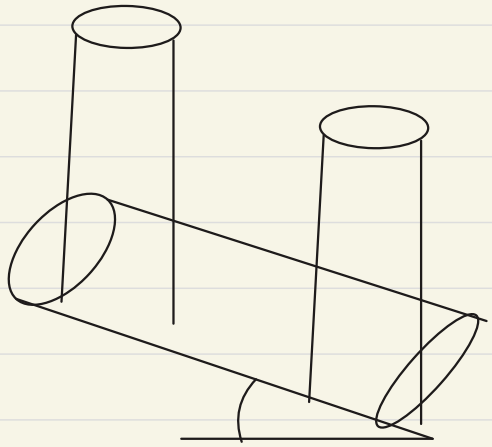
(a)

L15

20101

L16

27101



L17 15/02

Plumbing system

Scope of learning

Governing Principles of Plumbing System in a building

Design Approach IPC, UPC, BNBC

L18

17/02

Types of pipes used in Plumbing System

Drainage System – sanitary drainage sys
Storm water drainage sys
Combined

Wastewater removal

Next – Traps

Rough / CT—4 22/08

Plumbing → System of pipes
for distribution of potable water
and drainage of wastewater

Defn: Plumbing is a system of pipes, fittings, drains, valves, and fixtures installed for the distribution of potable water for drinking, heating, washing in a building and drainage of wastewater & storm water from the building.

Objectives — water supply system

1. Provision of sufficient water to serve each fixtures
2. Provision of no opportunity of backflow of used water into the system

Objectives — drainage system

1. Removal of wastewater quickly with minimum chance for stoppage of drains or leakages.
2. Prevention of entrance of sewer smell or foul smells from drainage system into the house.

Scope of plumbing

1. water supply system related
2. waste disposal related
3. Storm water management related
4. Gas supply related

## Water supply system related

1. Cold water sys
2. Hot " "
3. Chilled " "
4. Fire suppression sys
5. Water treatment for occupants
6. Garden hydrant sys
7. Pump selection, installation, maintenance
8. Swimming pool water supply
9. Fountain

## Waste disposal related

1. Plumbing fixture, pipe equip. selection, ins, maint.
2. Soil, waste, vent piping sys
3. Building sewer
4. Swimming pool waste disposal system
5. Basement pumping
6. water recycling, reuse

## Storm water management

1. Rain water collection, storage, disnf, distribution
2. Storm water drainage

## Gas supply sys.

1. Fuel gas supply in building

Governing principle of plumbing system in a Building

1. Sufficient water pressure for each fixtures
2. Must not permit back flow of used water
3. Prevent the entrance of waste gases & foul odor from waste drainage
4. Waste water should be drained quickly with minimum chances for drain stoppage on leakage
5. Shouldn't be any contamination potential due to cross-connections between water supply pipe & drainage pipe
6. Facilitate & support the storage of fire fightings
7. Pipe should be protected from damages while lying on the line
8. The pipes should be laid out as straight as possible to avoid any major head loss
9. Pipe dia should change gradually to avoid undue $h_L$
10. Pipes should not be installed as to damage structural stren of building

## Design approach

- Safety
- sanitation
- Good env
- convenience
- Comfort
- Economy
- Durability
- Legality

## Types of pipes used

1. Galvanized iron pipe → small dia
   best for services & internal connection
2. Cast iron pipe → upo 60m in dia
   doesn't echo when water goes in
3. Unplasticized PVC → 16mm to 315 mm dia
   Corrosion, chemical resistant
4. Rigid plastitite → 32 mm " 315 " "

## Drainage system

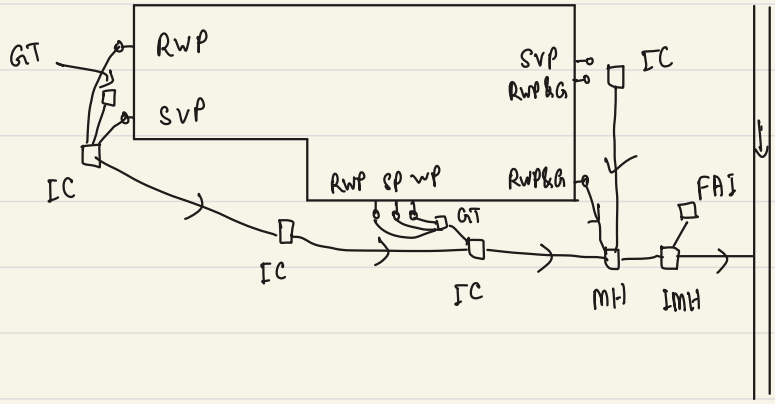
1. Sanitary drainage system
   System that drains waste water from basin, sinks, kitchen, lavatories, soil matter from toilets
2. Storm water drainage system
   Collects rain water from roofs, yards, and areaways

wastewater removal

1. wastewater carried to sanitary sewer through building drainage system of hon vent. pipes
2. They are isolated from water supply sys & must have sufficient capacity, slope, and venting + cleanouts.
3. Ideal to drain as many fixtures as pos through single main drain
4. works under gravity; no pressure

Pipings,

1. House sewer: Portion of the pipe that extends into the public sewer to about 3'-5' from house. Usually 3" in dia
2. House drain: The hon pipe into which vertical on soil, waste stacks discharge
3. Soil, waste, vent stacks:
   Soil stacks: Pipe that receives soil & sullage materials from water closet & urinals.
   Waste stack: Receives wastewater from all fixtures except water closet & urinals.
   vent stack: Allows movement of air.
4. Fixture branch: hon. pipe connecting fixture trap to vertical waste on soil stacks.


GT
RWP
SVP
IC
SVP
RWPbG
IC
RWP
SP
WP
RWPbG
FAI
GT
IC
IC
M1
HM1

L19

22/02

## Traps

- What is trap & good qualities of traps
  Types of traps
- Floor traps, Gully traps, ...

---

Loss of water traps

---

Diff btwn induced siphonage vs.
self siphonage

L20 24/02

Plumbing system — Types

Two pipe system
One pipe system
Single stack system

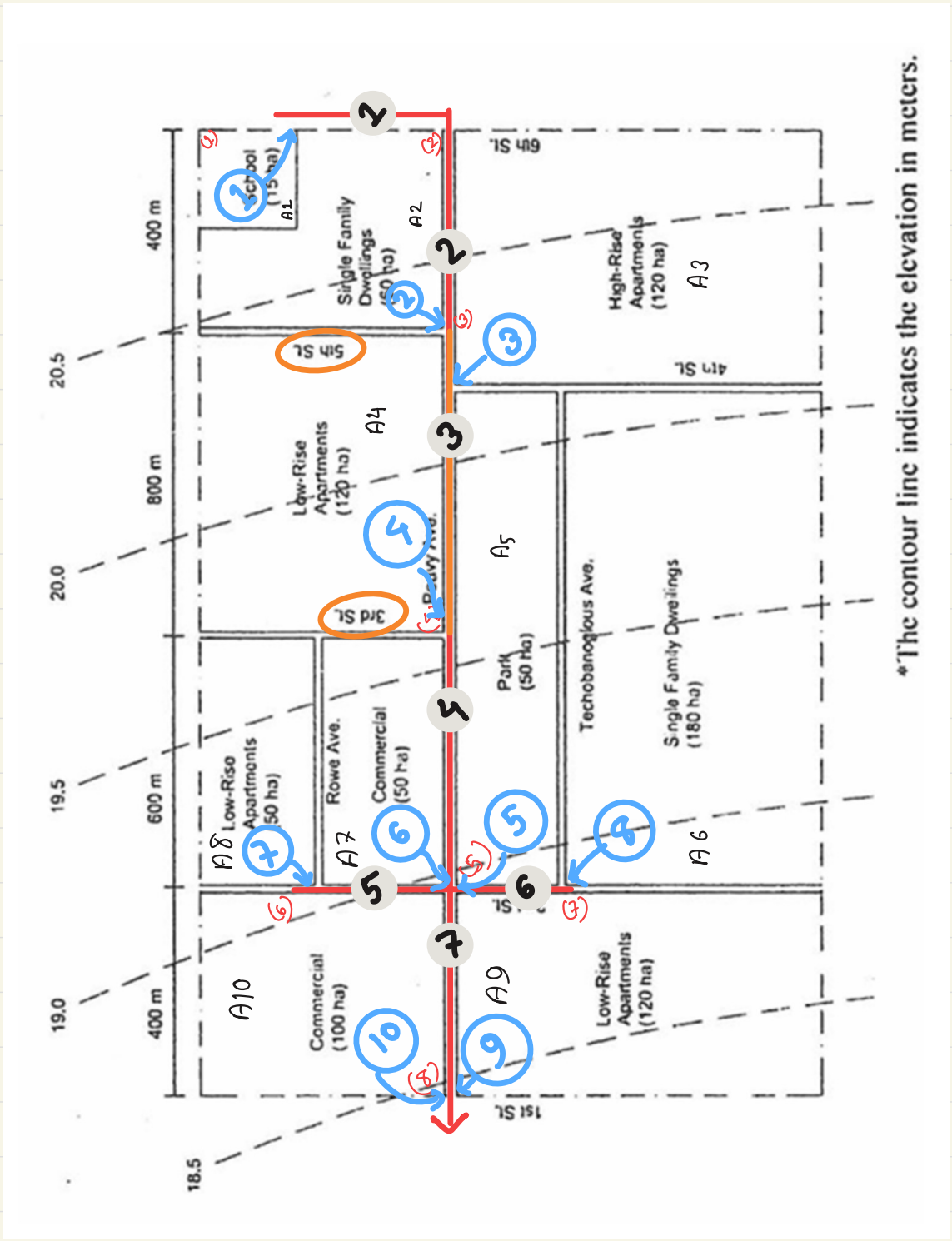
water distribution system

Up feed system
Down feed system
} diff

Plumbing fixtures

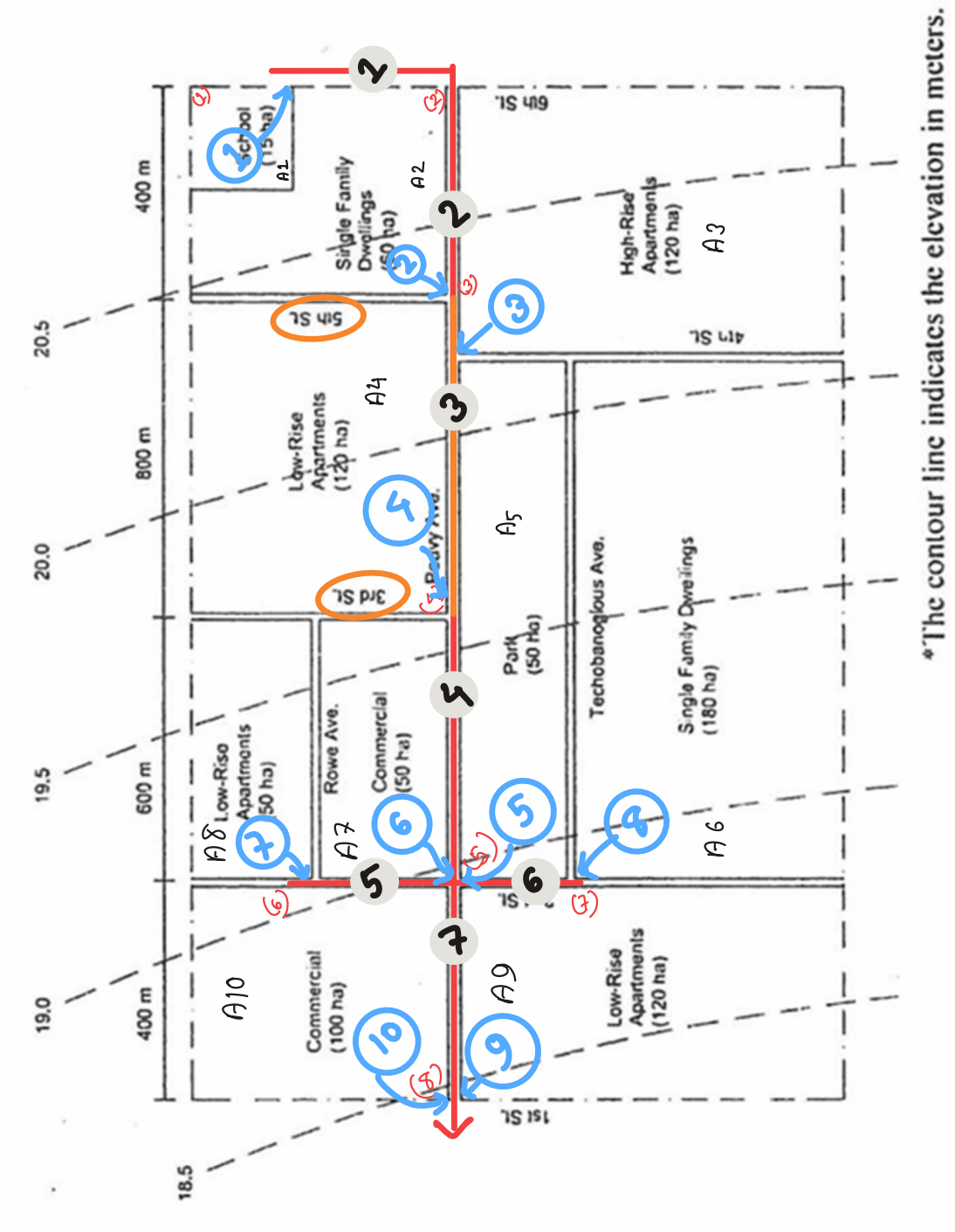
Assignment 01

28/02



Assignment 01

28/02



L21

Up Feed System
Down Feed System

Sustainable Plumbing Practices — explain

Design of water supply system

2.

2. $P = p + 0.434h + f$

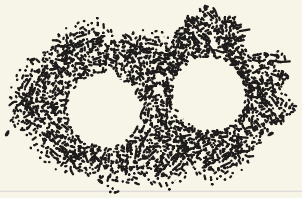
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Math # Private / Public building? matters

- — -

Graph — use value from flush valve curve (higher)

64' → assume 5 floor; 10' underground





Example problem :

$P = 0.434\,h$ ; $P$ = maximum fixture pressure

$\Rightarrow h = \frac{P}{0.434}$

Design of upfeed zone

→ See provided script

Design of downfeed zone

L23

08/03

## Sustainability of water & sanitation services

SDG 6 : Ensure access to water and sanitation for all

Ø Define sustainability with respect to water supply on sanitation sys

---

water sources software

Ø Key sustainability factors

Sustainability : Social issues

" Governance issues

L24

29/03

## Sustainability

Social issues

Governance issues

Financial issues

Technical issues

Community water management

GL
→ cleanup func
→ v4: S3,
fetch active snw
two own, one
R2

Notepad
→ evrything local + free

L25 31/03

Community based water supply

Explain the water supply management - community based

Community management → Sanitation

Fecal Sludge management (FSM)

L26 05/04

## Fecal sludge management

Onsite, offsite

Elements

Rough / Final 09/05

# Introduction to wastewater engineering

Branch of env. science in which basic principles of science & engineering are applied to solve the issues related to the disposal, treatment, and reuse of wastewater.

Sources of wastewater:

i) Domestic
ii) Commercial
iii) Industrial
iv) Agricultural
v) Street runoffs
vi) Infiltration

} major

Composition:

(i) 99.9% water
(ii) 0.01% solid, of which, 30% inorganic,
70% organic, of which 65% protein
25% carbohydrate
10% fat
(iii) Per day per person contribution ~110g of suspended solid
~90g of BOD

Physical chars:

(i) Odor

(ii) Temperature — commonly higher than clean water
Optimum range 25°C – 35°C
$O_2$ dissolves better in cold water
Aerobic activity stops after 50°C
Methane producing bacteria stops below 15°C
Nitrifying bact becomes inactive below 5°C

(iii) Density

(iv) color

(v) Turbidity

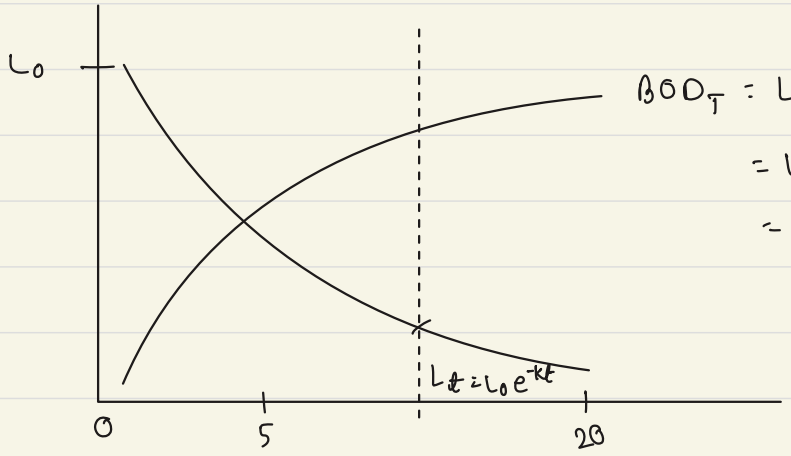
Chemical chars — BOD

Biochemical Oxygen Demand; amount of $O_2$ req by bacteria for decomposition of biodegradable organic matter.

If decomposition takes place w/ $O_2$, produces non-objectable materials

If decomp. " " w/o ", produces highly-objectable components — $H_2S$

BOD eqn:




$$BOD_T = L_0 - L_t$$
$$= L_0 - L_0 e^{-kt}$$
$$= L_0 (1 - e^{-kt})$$

$$\frac{dL}{dt} \propto -L$$

$$\Rightarrow \frac{dL}{L} = -k\,dt$$

$$\Rightarrow [\ln L] = -k(t)$$

$$\Rightarrow \ln \frac{L_t}{L_0} = -kt$$

$$\Rightarrow \frac{L_t}{L_0} = e^{-kt}$$

$$\Rightarrow L_t = L_0 e^{-kt}$$

$k = 0.23$ for domestic waste at 20°C

$k_T = k_{20} (\theta)^{T-20}$ ; $\theta = 1.047$

} $t$ in days

P15 $BOD_5 = 200\ mg/L$

$k = 0.23\ d^{-1}$

$BOS_{1,20^\circ C} = L_0(1 - e^{-kt})$

$= 60.1\ mg/L$

$T_{25} = T_{20}(1.047)^{25-20}$

$= 0.29$

$\therefore BOD_{5,25^\circ C} = L_0(1 - e^{-k_{25}t})$

$= 224\ mg/L$

$BOS_D = L_0(1 - e^{-kt})$

$\Rightarrow 200 = L_0(1 - e^{-0.23 \times 5})$

$\Rightarrow L_0 = 292.7\ mg/L$

Theoretical Oxygen Demand (ThOD)

Amount of oxygen req to oxidize an organic matter of known composition into $CO_2$ is ThOD (using stoichiometry)

P21/

$$C_{12}H_{22}O_{11} + 12O_2 \longrightarrow 12CO_2 + 11H_2O$$

$C_{12}H_{22}O_{11}$ : $12\times12 + 22\times1 + 11\times16 = 342$

$12O_2$ : $12\times(16\times2) = 384$

$\therefore$ ThOD $= \frac{384}{342} = 1.13\ g_{O_2}/g_{sugar}$

$\rightarrow 113\ mg_{O_2}/L$ (for 100 mg/L conc. wt)

$TOC = \frac{12\times12}{342} = 0.42\ g_C/g_{sugar}$

$\rightarrow 42\ mg_C/L$

---

P22/

$$\underbrace{C_5H_7NO_2}_{113} + \underbrace{5O_2}_{160} \longrightarrow 5CO_2 + 2H_2O + NH_3$$

$ThOD = \frac{160}{113} = 1.42\ g_{O_2}/g_{...} = COD = UBOD$

$BOD_5 = UBOD(1 - e^{-kt}) = \dots$

NBOD — Nitrogenous BOD

Convert nitrogen comp. into stable nitrates

TKN — Total Kjeldahan Nitrogen

Organic + ammonia nitrogen

Pop/ Sewer design

Peak flow:

$$P.F = ax^b; \quad b = -0.0785; \quad a = 2.269$$
$$= 2.269x^{-0.0785}$$

| Pipe | Subarea | Type | Area (ha) | Avg. flow ($m^3/s$) | Cum. flow ($m^3/s$) | P.F | Peak cum. flow ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1-2 | A-1 | Residential | 200 | 0.0352 | 0.0352 | 2.95 | 0.104 |
| 2-3 | A-2 | Institutional | 100 | 0.00463 | 0.0398 | 2.92 | 0.116 |
| | A-3 | Commercial | 50 | 0.0116 | 0.0514 | 2.86 | 0.147 |
| | A-5 | Residential | 250 | 0.0506 | 0.102 | 2.71 | 0.277 |
| 3-4 | A-4 | Residential | 100 | 0.0306 | 0.133 | 2.66 | 0.354 |
| | A-7 | Residential | 300 | 0.0528 | 0.185 | 2.59 | 0.479 |

Infiltration allowance:

$$I.F = ax^b; \quad b = -0.3, \quad a = 42.5$$
$$= 42.5x^{-0.3}$$

| Pipe | Subarea | Type | Area (ha) | Cum. Area (ha) | I.A ($m^3/d/ha$) | Cum. I.A ($m^3/s$) |
|---|---|---|---|---|---|---|
| 1-2 | A-1 | Residential | 200 | 200 | 8.67 | 0.02 |
| 2-3 | A-2 | Institutional | 100/2 | 250 | 8.11 | 0.0235 |
| | A-3 | Commercial | 50/2 | 275 | 7.88 | 0.0251 |
| | A-5 | Res | 250 | 525 | 6.49 | 0.0394 |
| 3-4 | A-4 | Res | 100 | 625 | 6.16 | 0.0446 |
| | A-7 | Res. | 300 | 925 | 5.48 | 0.0586 |

Design:

| Pipe | Cum. flow ($m^3/s$) | Cum. Infil flow ($m^3/s$) | Total flow ($m^3/s$) | Dia(mm) | Slope | Check discharge ($m^3/s$) | Check vel ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1-2 | 0.104 | 002 | 0.124 | 450 | 0.0019 | 0.124 | 0.78 |
| 2-3 | 0.277 | 0.0394 | 0.316 | 750 | 0.0009 | 0.334 | 0.76 |
| 3-4 | 0.479 | 0.0586 | 0.538 | 975 | 0.0007 | 0.593 | 0.79 |

## Theory for problems:

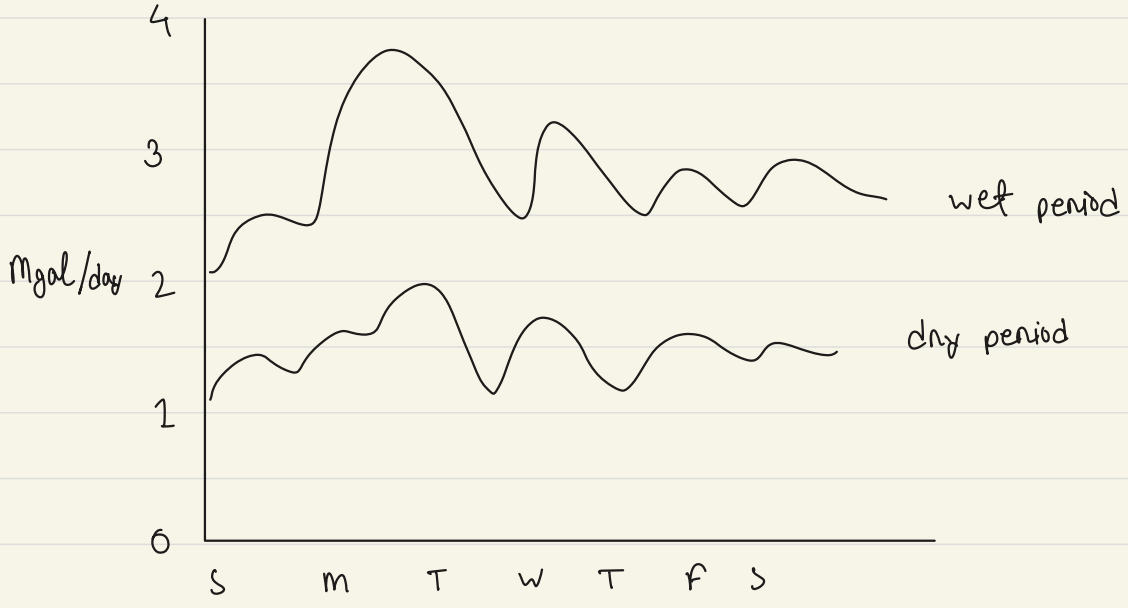
Flow ratio, to average:

max daily = 2.5x
max hourly = 3x
min hourly = 0.33x
min daily = 0.67x

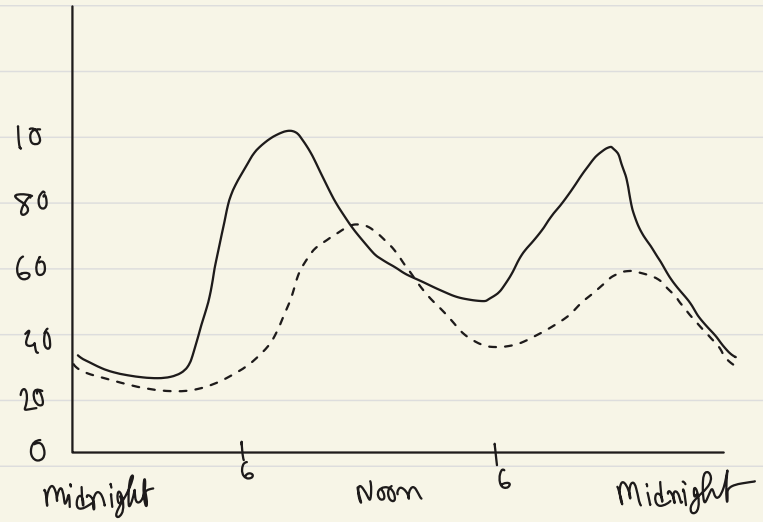
Per capita sewage flow:

Conservatively, 80% of consumption

Design flow:



Variation in sewage flow :




Max sanitary flow = avg flow x PF + infiltration flow

methods for estimation of storm water :

Rational method
Empirical method

Time of conc = inlet time + travel time

$$T_i = \left[\frac{0.8855 L^3}{H}\right]^{0.385}$$

$$T_t = \frac{Len}{vel}$$

Rainfall intensity

$$I\,(cm/hr) = \frac{76.2}{t+10} \quad ; \quad t \text{ btwn } 5 - 20 \text{ mins}$$

$$\frac{101.6}{t+20} \quad ; \quad 20 - 100 \text{ mins}$$

Time of conc.

$$t_c = \frac{f L}{A^{0.1} S^{0.2}} \quad ; \quad \begin{matrix} t \to \text{min} \; ; \; A \to km^2 \\ L \to km \; ; \; S \to m/km \end{matrix} \Bigg\} \; f = 585$$

Runoff est.

$$Q = fCIA$$

Prob 1

$$Q_{av,\,san} = 750 \times 59 = 44{,}250 \text{ gal/d} = 1844 \text{ gal/hr}$$

$$Q_{infil} = 1.3 \times 30{,}000 = 39{,}000 \text{ gal/d} = 1625 \text{ gal/hr}$$

$$\therefore Q_{av,\,daily} = 44250 + 39000 = 83{,}250 \text{ gal/d}$$

$$Q_{av,\,hr} = 1844 + 1625 = 3469 \text{ gal/h}$$

$$Q_{max,\,daily} = 2.5 \times 44250 + 39000 = 149{,}625 \text{ gal/d}$$

$$Q_{max,\,hr} = 3 \times 1844 + 1625 = 7157 \text{ gal/h}$$

$$Q_{min,\,daily} = 0.67 \times 44250 + 39000 = 68{,}648 \text{ gal/d}$$

$$Q_{min,\,hr} = 0.33 \times 1844 + 1625 = 2234 \text{ gal/hr}$$

Prob 02

Total area = 15 ha

house area = $15 \times 30 \times 80 = 36000\ m^2 = 3.6$ ha

road area = $0.25 \times 15 = 3.75$ ha

open space = $15 - 3.6 - 3.75 = 7.65$ ha

$$\therefore C = \frac{0.9 \times 3.6 + 0.6 \times 3.75 + 0.12 \times 7.65}{15} = 0.427$$

$\therefore Q = FICA = 27.78 \times 4.5 \times 0.427 \times 15 = 800$ l/s

Dry weather flow = $0.8 \times 250 \times 300 \times 15 = 900,000$ l/d

$\therefore Q_{max} = 2.5 \times 900000 = 2250000$ l/d

$\therefore$ Ratio of storm sewage to dry weather flow = $\frac{800 \times 86400}{2250,000}$

$= 30.72$

P115/ $L = 3$ km

$A = 7.5\ km^2$

$S = 5$ m/km

$C = 0.48$

$Q = FICA$

$I = \frac{76.2}{t+10}$ ; $\frac{101.6}{t+20}$

$t_c = \frac{FL}{A^{0.1} S^{0.2}}$

---

$\therefore t_c = \frac{FL}{A^{0.1} S^{0.2}} = \frac{58.5 \times 3}{7.5^{0.1} \times 5^{0.2}} = 104$ min

$I = 70$ mm/hr (from IDF curve)

$\therefore Q = FICA$

$= 1 \times \frac{70 \times 10^{-3}}{3600} \times 0.48 \times 7.5 \times 1000^2 = 70$ cumec

Follow-up example:

$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$

$\Rightarrow 70 = \frac{1}{0.013} \times \frac{\pi D^2}{4} \times \left(\frac{D}{4}\right)^{2/3} \sqrt{5/1000}\ \sqrt{0.001}$

$\Rightarrow D = 5.5$ m

$V_{check} = Q/A = \frac{70}{\pi \frac{5.5^2}{4}} = 2.9$ m/s $< 3.0$ m/s

P118/ $A = 60\ km^2 = 6000\ ha$

$Q_{av,sewage} = 350 \times 185 \times 6000 = 4.5\ m^3/s$

$Q_{max,sewage} = 1.5 \times 4.5 = 6.75\ m^3/s$

$I = 0.5\ mm/hr$

$\therefore Q = FICA = \frac{0.5 \times 10^{-3}}{3600} \times 2 \times 60 \times 10^6 = 8.33\ m^3/s$

$\therefore Q_{sewer} = 6.75 + 8.33 = 15.08\ m^3/s$

$\Rightarrow Q = AV \; ; \; V = 0.9\ m/s$

$\Rightarrow \therefore A = \ldots$

P120/ $D = 0.3\ m$

$d/D = 0.3$

$d/D = \frac{1}{2}(1 - \cos\frac{\theta}{2})$

$\Rightarrow \theta \rightarrow$ rad or deg

At full depth:

$$V = \frac{1}{N} R^{2/3} \sqrt{S}$$

$$\Rightarrow 0.9 = \frac{1}{0.013} \left(\frac{0.3}{4}\right)^{2/3} \sqrt{S}$$

$$\Rightarrow S = 0.00433$$

$$\frac{r}{R} = 1 - \frac{\sin\theta}{\theta^r}$$

$$\frac{S}{S} = \frac{R}{r}$$

$$\frac{a}{A} = \frac{\theta^\circ}{360} - \frac{\sin\theta}{2\pi}$$

$$= \frac{\theta^r - \sin\theta}{2\pi}$$

At 0.3D:

$$\frac{d}{D} = \frac{1}{2}\left(1 - \cos\frac{\theta}{2}\right) \Rightarrow \theta = 132.8^\circ$$

$$\frac{r}{R} = 1 - \frac{\sin\theta}{\theta^r} = 1 - \frac{\sin 132.8}{132.8} \frac{360}{2\pi} = 0.683$$

$$\frac{S}{S} = \frac{R}{r} \Rightarrow \boxed{S = S\,R/r = 0.00634}$$

$$\frac{a}{A} = \frac{\theta^r - \sin\theta}{2\pi} = 0.252$$

$$\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}\left(\frac{S}{S}\right)^{1/2}$$

$$\Rightarrow v = 0.9 \times (\cdots) = 0.845\ m/s$$

$$Q = av = 0.252 \frac{\pi 0.3^2}{4} \times 0.845 = 0.015\ m^3/s$$

P122/ $d/D = 0.7$

$P = 80,000$

Supply = 190 lpcd

$S = 1/600 = 0.00167$

---

$$Q_{av} = 0.8 \times 80,000 \times 190 \times \frac{1}{1000 \times 86400} = 0.141 \text{ m}^3/\text{s}$$

$$\therefore Q_{max} = 3 \times 141 = 0.423 \text{ m}^3/\text{s}$$

$$Q_{min} = 0.333 \times 141 = 0.0470 \text{ m}^3/\text{s}$$

At $d/D = 0.7$:

$q/Q = 0.83$

$v/V = 1.12$

$Q_{max}$ to be at $0.7D$

$$\therefore Q = \frac{0.423}{0.83} = 0.51 \text{ m}^3/\text{s}$$

$$\Rightarrow Q = \frac{1}{n} \frac{\pi D^2}{4} \times \left(\frac{D}{4}\right)^{2/3} \sqrt{S}$$

$$\Rightarrow D = 0.783 \text{ m}$$

$\therefore$ At $D = 0.783$ m, $d/D = 0.7$

Max discharge : 0.423 $m^3/s$ ; Full discharge = $\frac{0.423}{0.83} = 0.51$ $m^3/s$

$$\therefore V = Q/A = \frac{0.51}{\pi \frac{0.783^2}{4}} = 1.06 \text{ m/s} ; \quad \therefore v = 1.12V = 1.19 \text{ m/s}$$

min $d/s = 0.0470\ m^3/s$ ; $\therefore \frac{q}{Q} = \frac{0.047}{0.5} = 0.094$

from graph, $d/D = 0.2$ ; $v/V = 0.6$

$\Rightarrow v = 0.6 \times 1.06 = 0.64\ m/s$

P125/ $D = 0.30\ m$

$n = 0.013$

$S = 0.004$

$d = 0.075\ m$

$d/D = 0.25$

From Nomograph: $Q = 59.5\ l/s$

$V = 0.84\ m/s$

From partial flow diagram:

$q/Q = 0.12 \Rightarrow q = 7.14\ l/s$

$v/V = 0.67 \Rightarrow v = 0.56\ m/s$

P128/ $A = 25\ km^2$

$S = 0.001$

Area distribution:

Total = 2500 ha

Residential = $0.6 \times 2500 = 1500$ ha

Large slots = $0.4 \times 1500 = 600$ ha

Small single family = $0.55 \times 1500 = 825$ ha

Multi storey = $0.05 \times 1500 = 75$ ha

Commercial = $0.3 \times 2500 = 750$ ha

Industrial = $0.1 \times 2500 = 250$ ha

Population

$= 7 \times 600 + 75 \times 825 + 2500 \times 75$

$= 253575$ person

Average flow:

| Area classification | Area (ha) | Avg flow ($l/_{ha.d}$) | Avg flow ($m^3/s$) |
|---|---|---|---|
| Re: Large slot | 600 | 5600 | 0.0389 |
| Re: Small single | 825 | 60,000 | 0.573 |
| Re: multi storey | 75 | 2,000,000 | 1.736 |
| Commercial | 750 | 25,000 | 0.217 |
| Industrial | 250 | 40,000 | 0.116 |
| | | | 2.681 $m^3/s$ |

Infiltration = $1000 \times 2500 \times \frac{1}{1000 \times 86400} = 0.0289\ m^3/s$

$\therefore Q_{max,sewer} = 2.681 \times \frac{5.5}{(253.575)^{0.18}} + 0.0289 = 5.473\ m^3/s$

$Q_{min,sewer} = 2.681 \times 0.2 \times (253.575)^{0.16} + 0.0289 = 1.33\ m^3/s$

P134/ $D = 2\ m$

$S = 0.0015$

$Q = 0.6\ m^3/s$

$B = 1.414\ m$

$BOD_5 = 200\ mg/L$

$T = 30°C$

---

$$Z = 0.308 \frac{EBOD}{S^{0.5} Q^{0.33}} \frac{\rho}{B}$$

$$EBOD = BOD_5 \times 1.07^{T-20}$$

$$= 393.4\ mg/L$$

$$: 4111 < 5000$$

$$B = D \sin\frac{\theta}{2}$$

$$\Rightarrow \theta = 1.57^{c}$$

$$\rho = D\frac{\theta}{2} = 157\ m$$

Manholes: Gateway to sewer network

They are circular of rect. opening along the length of pipe provided for entrance into the sewer by a person

Provided for:

i) Maintenance: cleaning, flushing, inspection
ii) ventilation
iii) Logistics (construction)

Provided at:

i) Junction
ii) Chng in dia
iii) " " slope
iv) " " el
v) " " dia
vi) Normal length at interval

Interval: i) $D < 0.3$ m → 30 m max

ii) $D > 2$ m → 300 m max

# Design of water supply system of a building

Upfeed zone:

$P = p + 0.434h + f$

- $p$: main pressure
- $0.434h$: loss from gravity
- $h$: water meter, equips, ...
- $f$: fixture pressure

Downfeed zone:

$P = 0.434h$

---

Design step:

1. Determine zone

   Assign fixture unit to floors → total FU
   Det$^n$ demand (gal/min)
   Det$^n$ service pipe loss (psi/100')
   Det$^n$ meter loss (psi)
   Det$^n$ upfeed zone ht
   Det$^n$ per downfeed zone ht from max all. pressure
   Specify zones

2. Design upfeed zone

   Det$^n$ available pressure to overcome frictions
   Det$^n$ pressure lose per 100 ft of service pipe (70') + risen (ht of story)
   Det$^n$ pipe size following that constraint + respective floor's demand

3. Design of downfeed zone:

Consider len of hor + vert. pipe before top fixture

Det$^n$ min pressure at top fixture (f + B)

Det$^n$ allowable psi loss per 100'

Det$^n$ allowable psi loss per 100' per following storeys

Det$^n$ pipe size

Example: P263

1. Detⁿ of zoning:

Fixture units:

For 1 to 23rd floor = max(3×10, 10+2×10) + 2×2

= 34

24th to 25th floor = max(3×5, 5+2×5) + 2×2

= 19

∴ Total demand = 34×23 + 19×2 = 820 FU

→ 184 gpm

Loss in service pipe = 6 psi / 100' @ 8"

or 1.4 psi / 100' @ 4" (take)

Loss in water meter = 3.5 psi

Upfeed zone:

$$P_{=50} = 3.5 + 1.5(70+4) \times \frac{1.4}{100} + 0.434h + 15 + 1$$

$\Rightarrow h \approx 64'$ → take 5 storey + 10' main to fixture

Downfeed zone:

$P_{max} = 50 = 0.434h \Rightarrow h = 115' \rightarrow 115 - 24 = 92'$

→ take 9 storey

Required = 25 − 5 = 20 floor

Take 10' by each overhead take

Extra psi = (10−9) = 1 → 10' × 0.434 = 4.34 psi

2. Design of upfeed zone:

Available pressure for friction: $50 - 3.5 - 60 \times 0.434 - 15 - 1 = 4.46$ psi

$$\text{or, } \frac{4.43}{1.5(70+60)} \times 100 = 2.27 \text{ psi}/100'$$

| Floor | FU | Acc. FU | gal/min | Pipe dia (in) |
|---|---|---|---|---|
| 0 | 820 | 820 | 184 | 3.5 |
| 1 | 34 | 170 | 85 | 3 |
| 2 | 34 | 136 | 77 | 2.5 |
| 3 | 34 | 102 | 68 | 2.5 |
| 4 | 34 | 68 | 58 | 2.5 |
| 5 | 34 | 34 | 43 | 2 |

3. Design of down feed zone:

Tank to edge → 10'; vent. dist above 25th floor = 24'

Allowance above 25th floor = $24 \times 0.434 - 8 - 1 = 1.416$ psi

$$\therefore \frac{1.416}{1.5(34)} \times 100 = 2.78 \text{ psi}/100'$$

Allowance btwn 24th & 25th floor = $9 + 20 \times 0.434 - 16 = 1.68$ psi

$$\therefore \frac{1.68}{1.5(20)} \times 100 = 5.6 \text{ psi}/100'$$

Below 24th floor = $16 + 10 \times 0.434 - 16 = 4.34$ psi

$$\therefore \frac{4.34}{1.5(10)} \times 100 = 28.9 \text{ psi}/100'$$

| Floor | FU | Acc. FU | gal/min | psi/100' | Pipe dia (in) |
|---|---|---|---|---|---|
| 25 | 19 | 310 | 110 | 2.8 | 3 |
| 24 | 19 | 291 | 107 | 5.6 | 2.5 |
| 23 | 34 | 272 | 103 | 5.6 | ' |
| 22 | 34 | 238 | 98 | 28.9 | ' |
| 21 | 34 | 204 | ! | | ' |
| 20 | 34 | 170 | | | |
| 19 | 34 | 136 | | | |
| 18 | 34 | 102 | | | |
| 17 | 34 | 68 | | | |
| 16 | 34 | 34 | | | |

2023/ 3/c/

1. Zoning :

FU: 4 + 4 + 4 + 12 = 24 FU/ floor

= 24 × 10 = 240 FU

Demand = 73 gpm

Loss due to service pipe: 1.1 psi/ 100' @ 3"

water meter = 1.5 psi

Upfeed zone:

$$40 = 1.5 + 1.5(40+h)\frac{1.1}{100} + 0.434h + 8 + 1 \Rightarrow h = 64' \quad [5 \text{ storeys}, 10'..]$$

Downfeed zone = rest 5 storey

2. Design of upfeed:

Allowance = 40 - 1.5 - 60 × 0.434 - 8 - 1 = 3.46 psi

$$\therefore \frac{3.46}{1.5(60+40)} \times 100 = 2.3 \text{ psi}/100'$$

| Floor | FU | Acc. FU | gal/m | dia (in) |
|---|---|---|---|---|
| 0 | 240 | 240 | 73 | 2.5 |
| 1 | 24 | 120 | 50 | 2.5 |
| 2 | 24 | 96 | 43 | 2 |
| 3 | 24 | 72 | 36 | 2 |
| 4 | 24 | 48 | 26 | 2 |
| 5 | 24 | 24 | 17 | 1.5 |

3. Design downfeed:

10' tank to edge

24' above 10th floor

Allowance = $0.434 \times 24 - 8 - 1 = 1.42$ psi

$\therefore \frac{1.42}{1.5(34)} \times 100 = 2.7$ psi / 100'

Below 10th floor:

$9 + 0.434 \times 10 - 9 = 0.434$ psi

$\therefore \frac{0.434}{1.5(10)} \times 100 = 2.89$ psi / 100'

| Floor | FU | Acc FU | gal/min | psi / 100' | dia (in) |
|---|---|---|---|---|---|
| 10 | 24 | 120 | 50 | 2.89 | 2 |
| 9 | 24 | 96 | 43 | 2.89 | . |
| 8 | 24 | 72 | 36 | 2.89 | , |
| 7 | 24 | 48 | 26 | 2.89 | ' |
| 6 | 24 | 24 | 17 | 2.89 | |

Theory

Sewage: Liquid waste generated from water use

Sanitary waste: Generated from sanitary conveniences → black water

Sewer: Pipe conveying sewage

Sewerage: The system

Types of coll. system:

1. Separate: Adv. i) small dia
ii) only sanitary sewer to be treated
iii) storm water discharge w/o tstmt
iv) Less vol

Disadv. i) costly two pipe
ii) Small pipe diff. to clean

2. Combined: Adv. i) Large pipe easy to cln
ii) Less costly
iii) Dilluted sewage

Disad i) Increased ld
ii) More vol
iii) storm water mixed
iv) Min vel during dry session
v) Rain may cause overflow

3. Partially combined

Suitable cond. - separate

flat area,
when funds not avail → one sewer + drain
not-uniform rain
near river
rocky area
pumping at short interval
before actual dev

Suitable — combined

rainfall uniform
not enough space for two
pump req for both sewage & rain water

Types of sewer:

building → branch → main → trunk → intercepting
→ outfall sewer

Sewage flow less than total flow:

- evaporation
- leakage
- seepage into ground

Layout of sewer line:

House sewer → branch → main → trunk → intercepting → outfall sewer

Planning:
1. Defⁿ disposal pnts
2. Defⁿ of drainage are
3. Finalize trunk sewer
4. Pump placement

Laying of sewer:

(i) Alignment (ii) Benchmarks (iii) Grade line (iv) Excav
(v) Dewatering (vi) Bedding (vii) Laying (viii) Inspection
(ix) Backfill