



# Environmental Engineering

Detailed notes + compact revision summary

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The notes are prepared for exam revision. Always check design values against the current IS codes before using them in real work.

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## CHAPTER 01

# Water Demand and Population Forecasting

Types of water demand, CPHEEO per capita rates, fire demand, variations in demand, design periods and population forecasting methods.

## 1.1 Types of water demand and per capita supply

The quantity of water a scheme must supply is the sum of several **demands**. The design is based on the **average daily demand** per head (litres per capita per day, **lpcd**) multiplied by the design population, and then corrected for losses, fire and peak variations.

- **Domestic demand** — drinking, cooking, bathing, washing, flushing; the largest component (about 50 % of total in a city).
- **Industrial demand** — factories, processing; depends on the type of industry (taken separately in CPHEEO practice).
- **Institutional and commercial** — hospitals, hotels, schools, offices, markets, railway and bus stations.
- **Public (civic) use** — street washing, parks, public fountains, sewer flushing.
- **Fire demand** — small in annual volume but needs a high rate for a short time.
- **Losses and wastes** — leakage from mains, faulty meters, unauthorised connections; together called **unaccounted-for water (UFW)** or non-revenue water.

### CPHEEO recommended per capita water supply (domestic + non-domestic)

| Type of community                                                  | Supply (lpcd) |
|--------------------------------------------------------------------|---------------|
| Rural water supply / towns with spot sources or public stand-posts | 40            |
| Towns with piped supply but without sewerage system                | 70            |
| Cities with piped supply where sewerage exists or is planned       | 135           |
| Metropolitan and mega cities with piped supply and sewerage        | 150           |

**Code value:** CPHEEO figures **exclude** UFW, which should be limited to **15 %**. In metro cities with large floating populations the 150 lpcd may be increased suitably.

### Break-up of 135 lpcd domestic demand (CPHEEO / IS 1172)

| Use             | lpcd | Use              | lpcd       |
|-----------------|------|------------------|------------|
| Drinking        | 5    | Washing utensils | 10         |
| Cooking         | 5    | Washing house    | 10         |
| Bathing         | 55   | Flushing WC      | 30         |
| Washing clothes | 20   | <b>Total</b>     | <b>135</b> |

**Factors affecting per capita demand:** size of city (larger city → higher demand), climate (hot dry climate → more), standard of living, industries and commerce, quality of water (good water is used more), pressure in the distribution system (higher pressure → more wastage), system of supply (continuous supply → more consumption than intermittent), metering (metered supply reduces waste by roughly a quarter), cost of water, and presence of sewerage.

**Exam tip:** Pressure, metering and continuity are favourite one-mark questions: **higher pressure and continuous unmetered supply increase per capita consumption**; metering and intermittent supply decrease it.

## 1.2 Fire demand

Fire demand is the rate of flow needed to fight fires. It is usually expressed in litres per minute for a short duration (a few hours). Empirical formulas relate it to population **P in thousands**. In Indian practice it is small compared to the total supply and is kept as a reserve in service reservoirs.

### Kuichling's formula

$$Q = 3182\sqrt{P}$$

Q in L/min; P = population in thousands

### Freeman's formula

$$Q = 1136.5 \left( \frac{P}{5} + 10 \right)$$

Q in L/min; P in thousands

### Buston's formula

$$Q = 5663\sqrt{P}$$

Q in L/min; P in thousands

### National Board of Fire Underwriters (NBFU)

$$Q = 4637\sqrt{P} (1 - 0.01\sqrt{P})$$

Q in L/min; P in thousands; for central congested areas

### CPHEEO fire demand

$$Q = 100\sqrt{P}$$

Q in kilolitres per day; P in thousands

Recommended for communities larger than 50,000

### Worked example — Fire demand by different formulas

Estimate the fire demand for a city of 2,00,000 population.

1.  $P = 200$  (thousands);  $\sqrt{P} = 14.142$
2. Kuichling:  $3182 \times 14.142 = 45,000$  L/min
3. Freeman:  $1136.5 \times (200/5 + 10) = 1136.5 \times 50 = 56,825$  L/min
4. Buston:  $5663 \times 14.142 = 80,087$  L/min
5. NBFU:  $4637 \times 14.142 \times (1 - 0.1414) = 56,303$  L/min
6. CPHEEO:  $100 \times 14.142 = 1,414$  kL/d

**Answer:** Kuichling  $\approx 45,000$  L/min; Freeman  $\approx 56,825$  L/min; Buston  $\approx 80,090$  L/min; NBFU  $\approx 56,300$  L/min; CPHEEO  $\approx 1414$  kL/d

**Exam trap:** Check the units before substituting: all the classical formulas give **L/min** with P in **thousands**; the CPHEEO expression gives **kL/day**. Buston gives the highest value of the four.

## 1.3 Variations in demand and design periods

Consumption varies with season, day of the week and hour of the day. Components must be sized for the flow that governs them: sources and treatment for the **maximum daily** flow, distribution pipes for the **maximum hourly** flow (or maximum daily + fire, whichever is more).

### Maximum daily demand

$$Q_{\max,d} = 1.8 \times Q_{\text{avg}}$$

$Q_{\text{avg}}$  = annual average daily demand

### Maximum hourly demand

$$Q_{\max,h} = 1.5 \times Q_{\max,d} = 2.7 \times Q_{\text{avg}}$$

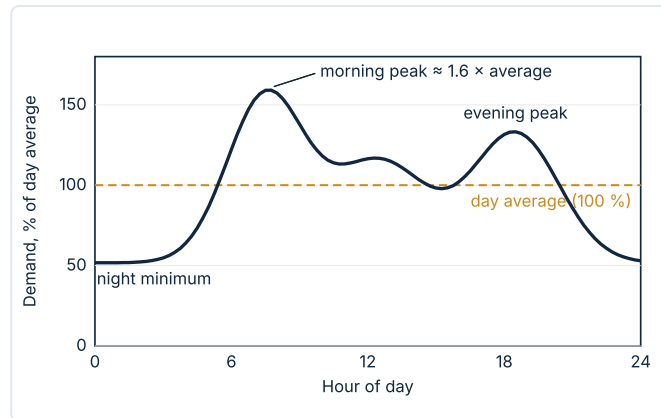
Peak hour of the maximum day

### Goodrich's formula

$$p = 180 t^{-0.10}$$

p = demand as % of annual average for a period of t days (t from 1/24 to 365)

Gives 180 % for a day, 148 % for a week, 128 % for a month



Typical hourly variation of demand on a day

### Design basis of components

| Component                                   | Designed for                                                    |
|---------------------------------------------|-----------------------------------------------------------------|
| Intake, source works, pumps, raw water main | Maximum daily demand (often + standby)                          |
| Treatment plant                             | Maximum daily demand                                            |
| Clear-water pumping and rising main         | Maximum daily demand (for the hours of pumping)                 |
| Distribution system                         | Maximum hourly demand, or maximum daily + fire demand — greater |
| Service reservoir                           | Balancing + fire + emergency storage                            |

### CPHEEO peak factors for distribution design

| Population                 | Peak factor |
|----------------------------|-------------|
| Up to 50,000               | 3.0         |
| 50,000 – 2,00,000          | 2.5         |
| Above 2,00,000             | 2.0         |
| Rural water supply schemes | 3.0         |

The **design period** is the number of years for which a component is planned to be adequate. It depends on the useful life of the component, ease of future extension, rate of population growth, cost and interest rate. CPHEEO counts it from the expected date of commissioning (base year).

### Design periods recommended by CPHEEO

| Component                                                                    | Design period (years) |
|------------------------------------------------------------------------------|-----------------------|
| Storage by dams                                                              | 50                    |
| Infiltration works                                                           | 30                    |
| Pump house (civil works)                                                     | 30                    |
| Electric motors and pumps                                                    | 15                    |
| Water treatment units                                                        | 15                    |
| Pipe connections to treatment units and other small appurtenances            | 30                    |
| Raw-water and clear-water conveying mains                                    | 30                    |
| Clear-water reservoirs at head works, balancing tanks and service reservoirs | 15                    |
| Distribution system                                                          | 30                    |

**Remember:** Short design periods (15 years) are used for items that are easy to extend in stages or wear out quickly — pumps, treatment units, reservoirs. Long periods (30–50 years) are used for items difficult to enlarge — dams, mains, distribution pipes.

## CHAPTER 06

# Distribution of Water

Methods and layouts of distribution, service reservoir capacity, pressures, network analysis by Hardy Cross and leak control.

## 6.1 Requirements and methods of distribution

The distribution system carries treated water from the clear-water reservoir to every consumer at adequate **pressure**, in adequate **quantity** and without loss of **quality**. It must also supply fire demand, be easy to repair without stopping supply to large areas, and keep leakage low.

### Methods of distribution

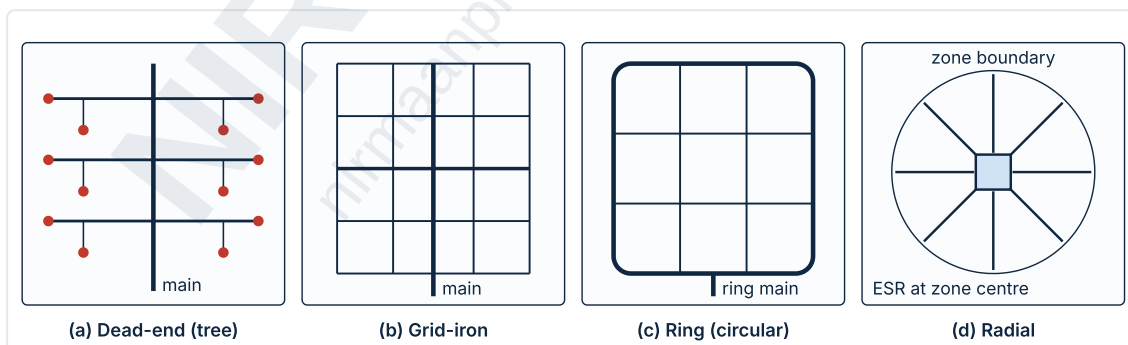
| Method                                 | Working                                                                                  | Suitability                                                               |
|----------------------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Gravity system                         | Source/reservoir at sufficient height; water flows by gravity                            | Most reliable and economical; needs a high source (hill lake, ESR)        |
| Pumping without storage                | Pumps feed mains directly; output varies with demand                                     | Least desirable — power failure stops supply; variable-speed pumps needed |
| Combined (dual) — pumping with storage | Pumps run at constant rate; excess stored in elevated reservoirs and drawn in peak hours | Most common; pumps work at best efficiency, storage meets peaks and fires |

### Continuous versus intermittent supply (CPHEEO recommends continuous 24 × 7 supply)

| Continuous (24 × 7)                             | Intermittent                                                  |
|-------------------------------------------------|---------------------------------------------------------------|
| Water always available; best for fire fighting  | Supplied only a few hours daily                               |
| Mains always under pressure — no back-siphonage | Empty mains suck polluted water through leaks (contamination) |
| Smaller pipes (demand spread over 24 h)         | Larger pipes and more storage needed                          |

## 6.2 Layouts of distribution system

The pipe network follows the street layout. Four layouts are recognised; most cities use a combination.



Layouts of distribution system (red dots = dead ends)

## Comparison of layouts

| Layout                   | Merits                                                                                             | Demerits                                                                   | Suited to                              |
|--------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------|
| Dead-end (tree)          | Simple, cheap, easy design; few valves                                                             | Stagnant water at dead ends; repair cuts off large area; limited fire flow | Old towns growing irregularly          |
| Grid-iron (reticulation) | Water reaches each point from more than one side; no dead ends; less pressure loss; good fire flow | More pipes and valves; complex design (Hardy Cross)                        | Planned towns with rectangular streets |
| Ring (circular)          | Any point fed from two directions; large fire flows                                                | More pipes and valves                                                      | Well-planned towns and roads           |
| Radial                   | Quick service, high pressure, efficient                                                            | More reservoirs needed                                                     | Towns with radial roads                |

## 6.3 Service reservoirs and balancing storage

**Service (distribution) reservoirs** store treated water near the consumers. They (i) balance the constant pumping rate against the fluctuating hourly demand, (ii) keep pressure steady, (iii) store water for fire and emergencies (pump breakdown, power failure) and (iv) allow pumps and treatment units to work at a constant, efficient rate.

- **Types:** surface (ground-level) reservoirs — usually rectangular or circular RCC — on high ground; **elevated service reservoirs (ESR)** on towers for flat areas; **standpipes** (tall tanks resting on ground) where only part of the height is useful.
- **Accessories:** inlet, outlet (above floor to trap sediment), overflow, washout/drain, ventilator, water-level indicator, access manhole, ladder and lightning conductor.
- **Capacity** = balancing (equalising) storage + fire reserve + breakdown/emergency reserve. Balancing storage is found by the **mass curve** or the **analytical (hourly tabulation)** method.

### Balancing storage (analytical method)

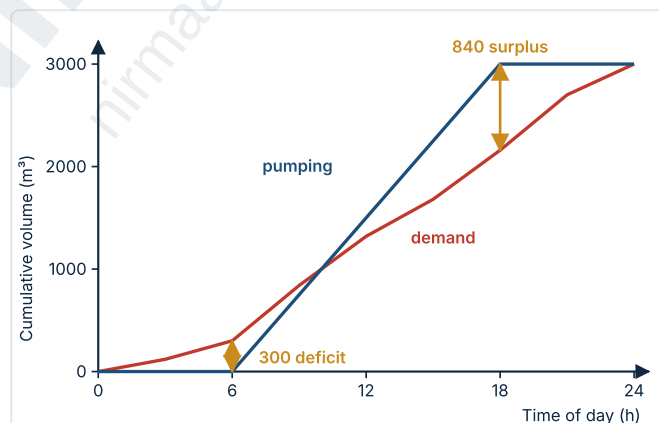
$$S = \text{max surplus} + |\text{max deficit}|$$

surplus = cumulative pumping – cumulative demand

### Staging height of ESR (approx.)

$$H_{\text{floor}} = h_{\text{residual}} + h_f + (z_{\text{critical}} - z_{\text{ESR}})$$

$h_f$  = friction loss up to the critical (farthest/highest) point



Mass curve for the worked example: storage = 840 + 300 = 1140 m³

**PART B**

# Compact Summary Notes

## Environmental Engineering

Illustrated one-page-per-topic revision sheets — read these in the last days before the exam, after studying the detailed notes in Part A.

Water Supply Engineering

page 55

Wastewater, Sewerage, Solid Waste & Pollution

page 65

20 pages of summary notes

## WATER DEMAND & POPULATION FORECASTING

### 1. Design period

- Design period is the future time for which water supply system is planned and components are designed.
- Should be based on economy, useful life of structures, scope for future expansion and uncertainty in growth.
- Generally 15 - 30 years (depending on type of component).

### 3. Common forecasting formulae

#### (i) Arithmetic increase method

$$P_n = P_o + n \bar{x}$$

where,

$P_n$  = population after  $n$  decades (or years)

$P_o$  = present population

$\bar{x}$  = average increase per decade

$n$  = number of decades

#### (ii) Geometric increase method

$$P_n = P_o \left(1 + \frac{r}{100}\right)^n$$

*Exam favourite!*

where,

$r$  = average percentage increase per decade

$n$  = number of decades

#### (iii) Incremental increase method

$$P_n = P_o + n \bar{x} + \frac{n(n+1) \bar{y}}{2}$$

where,

$\bar{x}$  = average increase per decade

$\bar{y}$  = average incremental increase per decade

$n$  = number of decades

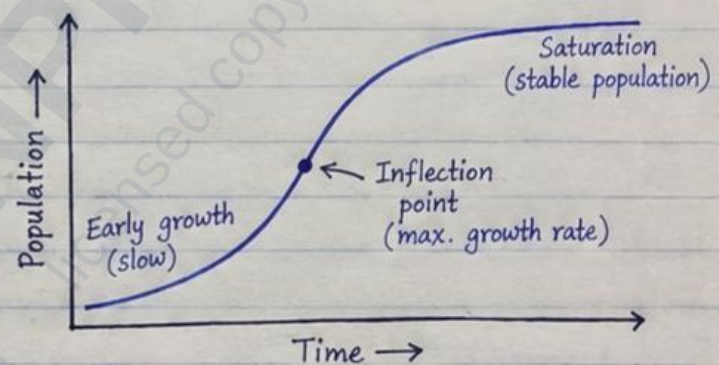
\* Population forecast → helps in estimating future water demand, size of components and cost.

### 2. Population forecasting methods

- ① Arithmetic increase method
- ② Geometric increase method
- ③ Incremental increase method
- ④ Logistic curve method (S-shaped)
- ⑤ Decreasing rate of growth method
- ⑥ Comparative / graphical method

*Important for exams!*

### 4. Population growth curve (Logistic)



- Typical urban population follows an S-shaped (logistic) curve.
- Growth is slow at first, then rapid, and finally decelerates as it approaches saturation.
- Assumes percentage growth rate becomes approximately constant in later stages.

### 5. When to use which method?

- **Arithmetic**: Suitable when population increases by nearly equal amount each decade (uniform growth).
- **Geometric**: Suitable for fast-growing towns where percentage increase is roughly constant.
- **Incremental**: Used when there is a noticeable trend in the increase (i.e. the increment itself is changing).
- **Logistic curve**: Useful for long term forecasting when saturation is expected.
- **Decreasing rate**: Used when percentage increase is gradually decreasing.
- **Comparative / graphical**: Compare with towns of similar size and development.



# ENVIRONMENTAL ENGINEERING



## ★ Handwritten Revision Notes ★

Water Supply, Wastewater, Solid Waste, Air & Noise Pollution — quick GATE / IES / PSU revision



- |                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"> <li>1. Water Demand, Source &amp; Conveyance</li> <li>2. Quality Parameters of Water</li> <li>3. Treatment of Water</li> <li>4. Distribution System</li> <li>5. Wastewater Characteristics</li> <li>6. Biochemical Reactions</li> <li>7. Disposal of Sewage Effluent</li> </ol> | <ol style="list-style-type: none"> <li>8. Sewerage System Design</li> <li>9. Sewage Treatment</li> <li>10. Solid Waste Management</li> <li>11. Air Pollution</li> <li>12. Noise Pollution</li> <li>13. Miscellaneous</li> </ol> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### LEGEND

yellow boxes = key formulas

red boxes = exam traps / quick hits

★ sketches added for easy understanding.

## ENVIRONMENTAL ENGINEERING

### 1. WATER SOURCE & CONVEYANCE



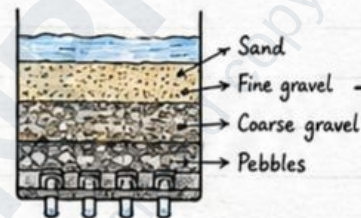
- Surface / Ground water
- Intake, Pumping
- Raw water mains

### 2. TREATMENT OF WATER



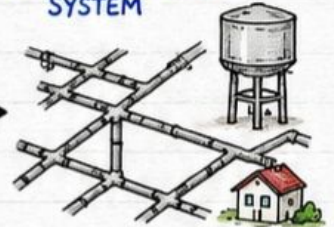
- Screening, Coagulation
- Sedimentation
- Filtration, Disinfection

### 3. FILTER BED



Removes suspended & some bacterial contaminants

### 4. DISTRIBUTION SYSTEM



- Pumps, ESR / OHT
- Pipe network
- Zoning, Valves, Meters

### 5. SEWERAGE SYSTEM



- House connection
- Laterals & Branches
- Manholes, Sewers

### 6. ACTIVATED SLUDGE PROCESS



- Aeration tank + Clarifier
- MLSS maintained
- RAS & Wasting

### 7. DISPOSAL OF SEWAGE EFFLUENT



- To land / Water bodies
- Reuse in irrigation
- Standards as per CPCB

### 8. SOLID WASTE MANAGEMENT



- Collection, Segregation
- Treatment / Recovery
- Sanitary Landfill

### 9. AIR POLLUTION



- Sources: Point, Area, Line
- Pollutants: PM, SO<sub>2</sub>, NO<sub>x</sub>, CO, HC
- Control: ESP, Bag filter, Scrubber

#### QUICK FORMULA BOX

★ Population forecasting:

$$P_n = P_0 (1 + r)^n$$

★ Water demand:

$$Q = P \times q \quad (\text{m}^3/\text{d})$$

★ Average flow (sewage):

$$Q_{avg} = 0.8 \times Q_{peak}$$

★ Detention time:

$$t = \frac{V}{Q} \quad (\text{h})$$

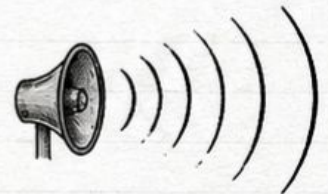
★ BOD removal efficiency:

$$\eta = \frac{S_0 - S_e}{S_0} \times 100 \%$$

#### EXAM TRAPS / QUICK HITS

- Always check units!
- $Q_{peak} \neq Q_{avg}$
- Don't mix up: BOD vs COD
- NRV essential in pump line
- Sludge age ( $\theta_c$ )  $\neq$  HRT
- Disinfection  $\neq$  Sterilization
- Landfill gas: CH<sub>4</sub> + CO<sub>2</sub>
- Air pollutants: Primary vs Secondary
- Permissible limits → CPCB / MoEF norms

### 10. NOISE POLLUTION



- Sources: Traffic, Industry, Construction, Aircraft
- Measured in dB(A)
- Control: Barriers, Enclosures, Green belts, Silencers

KEY NOTE: Understand concepts → Draw sketches → Remember formulas → Practice numericals! 😊



# End of the free preview

Environmental Engineering

## The full PDF has 74 pages:

Part A — detailed typed notes: 11 chapters, 50 pages

Part B — handwritten compact summary: 20 pages

## Chapters in the full notes

- 01 Water Demand and Population Forecasting
- 02 Sources, Intakes and Conveyance of Water
- 03 Quality of Water
- 04 Water Treatment I — Sedimentation and Coagulation
- 05 Water Treatment II — Filtration, Disinfection and Softening
- 06 Distribution of Water
- 07 Sewerage and Design of Sewers
- 08 Sewage Characteristics and Disposal
- 09 Sewage Treatment
- 10 Solid Waste Management
- 11 Air and Noise Pollution

Formula boxes with every symbol explained · IS / IRC code values in tables · labelled sketches  
Worked examples step by step · exam tips & traps · quick revision points after every chapter

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