

**SAMPLE STUDY MATERIAL**

Postal Correspondence Course  
**GATE, IES & PSUs**  
**Civil Engineering**



**Environmental Engineering-A**  
**Water Supply**

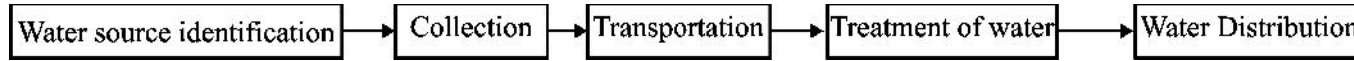


**CONTENT**

1. WATER DEMAND.....	3-11
2. SOURCES OF WATER .....	12-27
3. CONDUITS FOR TRANSPORTING WATER.....	28-35
4. QUALITY CONTROL OF WATER SUPPLY.....	36-42
5. PURIFICATION OF WATER SUPPLY.....	43-58
6. DISTRIBUTION SYSTEM.....	59-69
7. PRACTICE SET-I [ENVIRONMENTAL ENGINEERING] IES .....	70-75
8. PRACTICE SET-II [WATER SUPPLY (OBJECTIVE TYPE QUESTIONS...]	76-80
9. CONVENTIONAL PRACTICE QUESTIONS.....	81-82
10. FAQ-INTERVIEW QUESTIONS.....	83-83
11. GLOSSARY.....	84-85
12. GATE PAPER [1999-2013] WITH SOLUTION.....	86-107

**CHAPTER-1****WATER DEMAND**

Major components of a water supply scheme are:

**Classification of water demand for a city****1. Domestic water Demand:**

- As per IS: 1172-1993, the minimum domestic consumption for a city with full flushing system should be **200l /h/d** (*litre per head per day*) or *lpcd*(*litre per capita per day*) and for economically high section and LIG colonies it can be reduced to 135 *lpcd*.
- The domestic water consumption usually amounts to 50-60% of the total water consumption.

**2. Industrial Water Demand:**

- The water demand depends on the number and type of industries present in the city.
- In industrial cities, water demand may be 450 *lpcd* and in case of small-scattered industries it may be as low as 50 *lpcd*.

**Water Demand of Certain Important Industries**

S.No.	Name of Industry and Product	Unit of production of Raw material used	Approximate quantity of water required per unit of production/raw material in kilo litres
1.	Automobiles	Vehicle	40
2.	Distillery (Alcohol)	Kilo litre	122—170
3.	Fertilizer	Tonne	80—200
4.	Leather (Tanned)	Tonne	40
5.	Paper	Tonne	200—400
6.	Special Quality paper	Tonne	400—10000
7.	Straw board	Tonne	75—100
8.	Petroleum Refinery	Tonne (Crude)	1—2
9.	Steel	Tonne	200—250
10.	Sugar	Tonne (Crushed cane)	1—2
11.	Textile	Tonne (goods)	80—140

**3. Institutional and Commercial water demand:**

- Water requirement for institutions like hospitals, hotels, railway stations, school, offices come under this category.
- In general, water demand for it is 20 lpcd which may go up to 50 lpcd for highly commercialized cities.
- Water demand for certain institutions and commercials:
  - Offices: 45-90 lpcd (l/h/d)
  - Schools: 45-90 (Day scholars) lpcd
  - 135-225 (Residential) lpcd
  - Hotels: 180lpcd (per bed)
  - Airports: 70 lpcd
  - Hospitals (including laundry) :350 (per bed)(No. of beds < 100)
  - : 450 (per bed) (No. of beds > 100)
  - Cinema Halls: 15 lpcd (per seat)

**4. Demand for public uses:**

- This includes the water requirement for public utility purposes.
- Generally, water demand for it is taken as 10 lpcd.
- Water demand in this category is normally taken as a nominal value not exceeding 5% of total consumption.

**5. Fire Demand:**

- Fire hydrants are usually fitted in the water mains at about 100-150m apart and minimum water pressure available at fire hydrant should be 100 KN/m<sup>2</sup> – 150 KN/m<sup>2</sup> and should be maintained even after 4-5 hrs. of constant use of it.
- The per capita fire demand hardly amounts to 1 lpcd and hence it is generally ignored while computing the total per capita water requirement of a city.

**Formulas for calculating rate of fire demand**

**a. Kuichlingformula:**

$$Q = 3182\sqrt{P} \quad \text{Where, } Q = \text{water demand (l/min)}$$

➤ P = Population (in thousands)

**b. Free man formula:**

$$Q = 1136 \left[ \frac{P}{10} + 10 \right]$$

**c. National Board of Fire under writers formulas:**

(i) For a central congested high valued city

$$Q = 4637\sqrt{P} \left[ 1 - 0.01\sqrt{P} \right] \quad \dots\dots\dots \text{If population}$$

$P \leq 2,00,000$

$Q = 54,600 \text{ L/minutes}$  with an additional provision of



+ ..... If  $P > 2,00,000$   
 (9,100 – 36,400)l/minutes for a second fire

(ii) For a residential city

: Small or low buildings,  $Q = 2,200$  litres/minutes (l/min.)

: Large or higher buildings,  $Q = 4,500$  (l/min.)

: High value residence, apartments, tenements,  $Q = 7,650$  to 13,500l/min.

**d. Buston’s formula:**

$$Q(l/min.) = 5,663\sqrt{P} \quad \text{where } P:(\text{in thousands})$$

For Indian condition only 2-3 hours storage is fairly adequate, while 5-10 hrs. Storage is considered as minimum requirement is USA.

➤ All the above formulas are not related to different type of district served and hence it gives equal results for industrial and non-industrial areas.

**6. Water required to compensate losses in theft and wastes:**

➤ This quantity may be as high as 15% of the total consumption.

**Per Capita Demand (q):**

➤ It is defined as the annual average amount of daily water required by one person including water for domestic use, industrial and commercial use, public use, wastes etc

$$\therefore q(l/h/d) = \frac{\text{Total yearly water requirement of the city (v)}}{365 \times \text{Design population}}$$

➤ For an average Indian city, as per IS recommendation, the value of q is 335 lpcd.

**Break up of per capita demand (q) for an Average Indian City**

Use	Demand in l/h/d
Domestic use	200
Industrial use	50
Commercial use	20
Civic or public use	10
Wastes and thefts, et	55
	Total = 335 ( Per Capita Demand (q))

**Factors Affecting Water Demand:**

I. Size of city

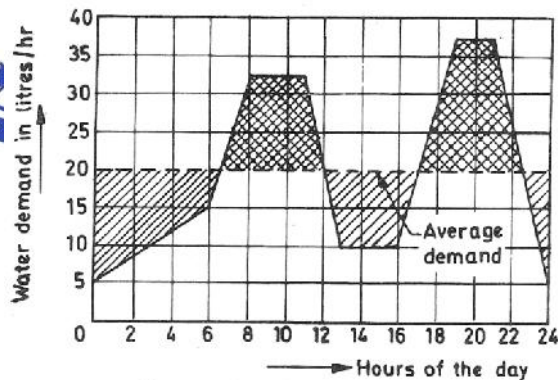
**Variations in per capita demand with population in India**

S.No.	Population	Per Capita Demand in litres/day/person*
1.	Less than 20,000	110
2.	20,000—50,000	110—150
3.	50,000—2 lakhs	150—240
4.	2 lakhs—5 lakhs	240—275
5.	5 lakhs — 10 lakhs	275—335
6.	Over 10 lakhs	335**—360

Above figure are liable to variation up to about 25%.

- II. Climatic condition
- III. Habits of people
- IV. Industrial and commercial activities
- V. Water quality
- VI. Pressure in distribution system
- VII. Development of sewerage facilities
- VIII. System of water supply
- IX. Policy of metering and method of charging

**Variation in demand (or Draft)**



Showing hourly rate of water consumption.

**(i) Maximum daily Consumption:**  $q_{max}$

$$q_{max} = 1.8 \times q_{avg.}$$

Where,  $q_{avg.}$  = Average daily demand or Annual Average daily demand.

**(ii) Maximum hourly consumption:**  $q_{h-max}$  or Peak demand

$$q_{h-max} = 1.5 \times \text{Average hourly consumption of maximum Daily}$$

$$= 1.5 \times \left( \frac{q_{\max}}{24} \right) = 1.5 \times \frac{(1.8 q_{\text{avg}})}{24}$$

$$\therefore \boxed{q_{h-\max} = 2.7 q_{\text{avg}}}$$

**(iii) Goodrich Formula:**

Used to find out the ratio of peak demand to their corresponding means.

$$\boxed{p = 180.t^{-0.1}}$$
 Where, p: % of the annual average draft for the time 't' (in

days)

t: Time (in days) from 1/24 to 365.

**(a) Based on this, for t = 7 days (weekly variation)**

Maximum weekly demand = 1.48 × average weekly demand

$$\left[ p = 180 \times 7^{-0.1} = 148\% \right]$$

**(b) For t = 30 days (Monthly variation)**

Maximum monthly demand = 1.28 × Average monthly demand

$$\left[ p = 180 \times 30^{-0.1} = 128\% \right]$$

**Coincident Draft:**

➤ For general community propose:

Total draft (demand) = Maximum of

(a) Sum of maximum daily demand and fire demand

**OR**

(b) Maximum hourly demand

Where, the summation of maximum Daily demand and fire demands are known as *coincident draft*.

**Recommendations for designing the capacities of different components of water supply scheme:**

- The source of supply may be designed for maximum daily consumption or sometimes for average daily consumption.
- The pipe mains may be designed for maximum daily consumption.
- Filter and other units of a water treatment plant and pumps for lifting water may be designed for maximum daily consumption.
- The distribution system, including the pipes carrying water from service reservoir to distribution system may be designed for maximum hourly draft of the maximum day or coincident draft, whichever is more.
- The service reservoir is designed to take care of the hourly fluctuations, fire demand, emergency reserve etc.
- **Water supply projects, under normal circumstances are designed for a design period of 30 years.**

## GATE, IES & PSUs ( 2015-16)

S.No.	Item	Design period in years
1.	Storage by dams	50
2.	Infiltration works	30
3.	Pumping	
	pump house	30
	electric motors and pumps	15
4.	Water treatment units	15
5.	Pipe connections to the several treatment units and other small appurtenances	30
6.	Raw water and clear water conveying	30
7.	Clear water reservoirs at the head works, Balancing tanks, and Service reservoirs (over head or ground level)	15
8.	Distribution system	30

### Population forecasting methods:

- Some of the following methods are used when design period is small, and some are used when the design periods are large.
- These methods are based on the laws of probability.

#### 1. Arithmetic Increase Method:

- Based on the assumption that the population increases at a constant rate.

$$P_n = P_0 + n.\bar{x}$$

Where,

$P_n$  = Forecasted population after 'n' decades from the present

$P_0$  = Population at present (i.e. last known census)

$n$  = Number of decades between present and future

$\bar{x}$  = Average (*Arithmetic mean*) of population increases in the known decades.

It is suitable for old cities.

#### 2. Geometric Increases Method:

- Here, % decadal growth rate ( $r$ ) is assumed to be constant.
- This method is also known as “*uniform increase method*”



$$P_n = P_0 \left( 1 + \frac{r}{100} \right)^n$$

Where,  $P_n, P_0$  have same meaning as mentioned in (1)

$r$  = Assumed growth rate (%)

➤ Method of determining assumed growth rate ( $r$ )

$$r = \sqrt[t]{\frac{P_2}{P_1}} - 1$$

Where,  $P_2$  = Final known population       $P_1$  = Initial known population

$t$  = Number of decades (period) between  $P_1$  and  $P_2$

$r_i = \frac{\text{Increase in population}}{\text{original population}} \times 100$  are computed for each known decade,

i.e.  $r_1, r_2, r_3, \dots, r_n$

Hence average value of ' $r$ ' is found as:

(a) Arithmetic average method: (Preferred)

$$r = \frac{r_1 + r_2 + r_3 + \dots + r_n}{n}$$

(b) Geometric average method:

$$r = \sqrt[t]{r_1, r_2, \dots, r_n}$$

It gives the highest value and is best suited for new cities.

### 3. Incremental Increase Method or Method of Varying Increment:

➤ Here % decadal growth rate is not assumed to be constant.

$$P_n = P_0 + n.\bar{x} + \frac{n(n+1)}{2}.\bar{y}$$

Where,  $\bar{x}$  = average increase in population of known decades

$\bar{y}$  = Average of incremental increases of the known decades.

➤ The results obtained by this method is somewhere between the results given by arithmetic increase method and geometric increase method. Hence, it is considered to be giving quite satisfactory results and suitable for both old and new cities.

### 4. Decreasing rate of growth method:

➤ This method is applicable only in cases, where the rate of growth shows a downward trend.

➤ In this method, the average decrease in the percentage increase is calculated and then subtracted from the latest percentage increase for each successive decade.

**Steps:**

1-Calculate the increase in population ( $\Delta x$ ) between  $P_r$  and  $P_{r+1}$  ( $r = 0, 1, 2 \dots$ )

2-Calculate percentage increase in population i.e.  $\left( r_i = \frac{\Delta x}{P_r} \times 100\% \right)$

3-Calculate decrease in percentage increase i.e. ( $\Delta r = r_i - r_{i+1}$ ,  $i = 1, 2, 3, \dots$ )

4-Forecasted population,  $P_n$  is given as:

$$P_2 = P_1 + \left( \frac{r_0' - \bar{r}}{100} \right) P_1$$

Where,  $\bar{r}$  = mean of values of  $r_1, r_2, \dots, r_n$

$P_1$  = Population of at present (i.e. last know ncensus)

$P_2$  = Forecasted population in next decade

$r_0'$  = percentage Increase between present population and last decade population

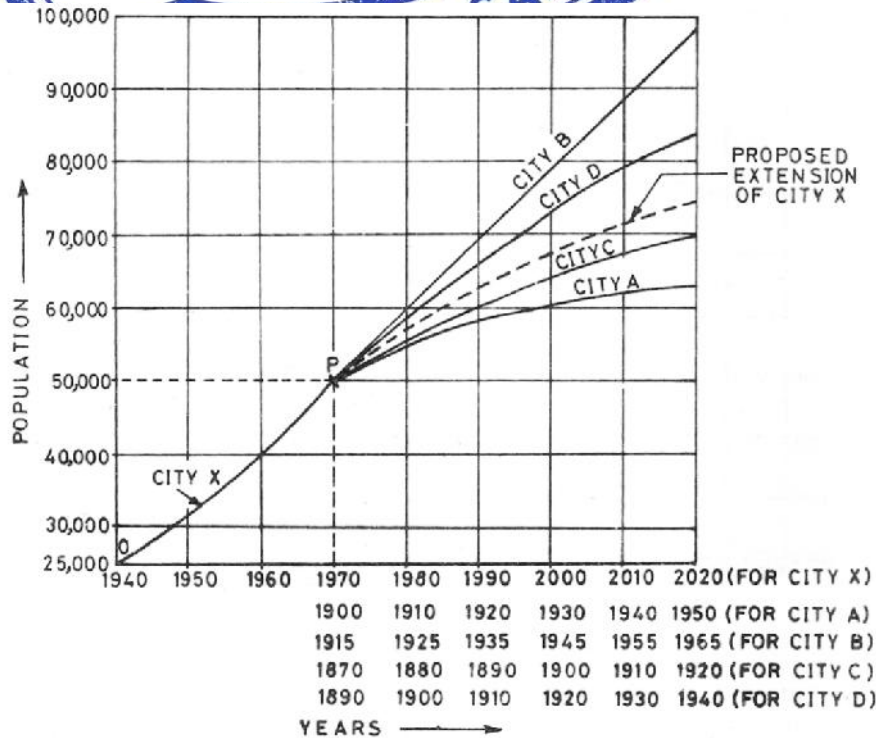
**5. Simple Graphical Method:**

➤ A graph is plotted from the available data, between time and population and the curve is smoothly extended up to the desired year to get the desired value.

➤ An approximate method.

**Comparative Graphical Method:**

➤ Cities of similar conditions and characteristics as that of city under consideration ( $x$ ) are selected and a graph is plotted for population growth for all this selected city to find future population of the city ( $X$ )



**6. Master plan method or zoning method:**

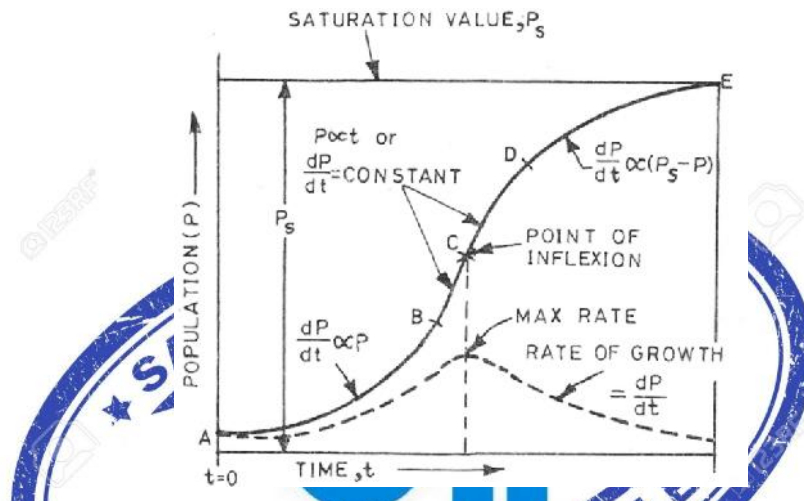
- Applicable for big and metropolitan cities.
- A master plan is prepared for a city to regulate the development schemes.

**7. The Ratio method or the approximate method:**

- In this method, the city’s census population record is expressed as percentage of the population of whole country.
- This method is suitable for those areas whose growth is parallel to the national growth.

**8. The Logistic Curve Method:**

- Under normal conditions, the population of a city will grow as per the logistic curve as shown in figure.



**Figure:** Ideal population growth curve, called logistic curve.

- P.F. Verhulst gave a mathematical solution to the logistic curve and defined the entire curve AD by an autocatalytic first order equation as given:

$$\log_e \left( \frac{P_s - P}{P} \right) - \log \left( \frac{P_s - P_0}{P_0} \right) = -k.P_s.t$$

Where  $P_0$  = Population at the starting point of curve A.

$P_s$  = Saturation population

$P$  = Population at any time ‘t’ from the origin A.

$K$  = Constant

On solving we get:

$$P = \frac{P_s}{1 + m.\log_e^{-1}(nt)}$$

Where,  $m = \frac{P_s - P_0}{P_0}$  (A constant)

$n = -K.P_s$  (A constant)

- As per, Mclean,  $P_s, m, n$  can be found by equation :

$$P_s = -\frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$m = \left( \frac{P_s - P_0}{P_0} \right)$$

$$n = \frac{2.303}{t_1} \log_{10} \left[ \frac{P_0(P_s - P_1)}{P_1(P_s - P_0)} \right]$$

[Where,  $P_0, P_1, P_2$  are values at  $t_0 = 0, t_1$  and  $t_2 = 2t_1$ . respectively.]

### Practice Question with Solution

1. Determine the Future Population of a satellite Town by the Geometric increase method for the year 2011, the following data are given as :

Year	1951	1961	1971	1981	.....	2011
Population thousand	93	111	132	161	.....	?

**Solution:**

Year (A)	Population Thousand (B)	Increase in population (thousand) (C)	% increase in population growth  rate = $\frac{(C)}{(D)} \times 100\%$
1951	93		
1961	111	18	19.35
1971	132	21	18.92
1981	161	29	21.97

Hence, for Geometric increase Method

$$\text{Growth Rate } r = \sqrt[3]{19.35 \times 18.92 \times 21.97} = 20.04\% \text{ per decade}$$

∴ From Formula

$$P_n = P_0 \left( 1 + \frac{r}{100} \right)^n$$

$$P_{2011} = P_{1981} \left( 1 + \frac{r}{100} \right)^3 \quad [n = 3]$$

$$= 161 \times 1000 \left( 1 + \frac{20.04}{100} \right)^3 = 278486$$

2. A Water supply scheme has to be designed for a city having a population of 1,50,000. Estimate the Major kinds of drafts which may be required to be recorded for an average water consumption of 250 *pcd*. Assume suitable figures and data where needed.

**Solution:**

Average Daily Draft: = 250 × 150000 *l* / day

$$(q_{avg.}) = 375 \times 10^5 \text{ l / day}$$

Maximum daily drafts: 1.8 ×  $q_{avg.}$

$$(q_{max.}) = 1.8 \times 375 \times 10^5 \text{ l / day} = 675 \times 10^5 \text{ l / day}$$

Maximum hourly drafts (  $q_{n-max.}$  ) = 2.7 ×  $q_{avg.}$

$$= 2.7 \times 375 \times 10^5 \text{ l / day}$$

$$= 1012.50 \times 10^5 \text{ l / day}$$

**Fire demand,**

$$= 4637 \sqrt{P} \left[ 1 - 0.01 \sqrt{P} \right] \text{ l / min.}$$

$$= 4637 \sqrt{150} \left[ 1 - 0.01 \sqrt{150} \right] \text{ l / min.}$$

$P \rightarrow$  population (in thousand)

$$= 49835.92 \text{ l / min} = 49835.92 \times 60 \times 24 \text{ l / day} = 718 \times 10^5 \text{ l / day}$$

$$\text{Coincident draft} = q_{max} + Q$$

Or } maximum of these 2 values

$$q_{n-max.}$$

$$= (675 + 718) \times 10^5 \text{ l / day}$$

Or } maximum of these 2 values

$$= 1012.50 \times 10^5 \text{ l / day}$$

$$= 1393 \times 10^5 \text{ l / day}$$

CHAPTER-2

**SOURCES OF WATER**

Sources of water are classified in two categories:

**1. Surface Sources**

- a) Ponds and Lakes
- b) Streams and Rivers
- c) Storage Reservoirs
- d) Oceans (*generally not used*)

**2. Sub-Surface Sources or Underground Sources**

- a) Springs
- b) Infiltration galleries
- c) Infiltration Wells
- d) Wells and tube-wells

**1. Surface sources**

**(a) Ponds and Lakes**

- A natural large sized depression formed within the surface of the earth, when filled up with water, is known as a *pond or a lake*.
- If the size of the depression is comparatively small, it is called a *pond* and if the size is large it is called a *lake*.
- The quality of water in a lake is generally good and does not need much purification.
- Self-purification of water due to sedimentation of suspended matter, bleaching of colors, removal of bacteria etc. makes the water purer and better.
- However, in still water of lakes and ponds, the algae, weed, and vegetable growth takes place freely, imparting bad smells, taste etc. to this water.

**(b) Streams and Rivers**

- Rivers are most important source of water.
- River water are not suitable for direct use for public supply, hence it should be properly treated before use.

**Storage Reservoirs**

- The pool or artificial lake formed on the upstream side of the dam to store the water is known as storage reservoir.
- Silt deposition is a major problem in the reservoir which leads to decrease in the capacity of reservoir.

➤ **Trap efficiency ( $\eta$ )**

Generally, Value of  $\eta$  ranges between

$$95-100\% = \frac{\text{Total sediment deposited in the reservoir}}{\text{Total sediment flowing in the river}}$$

## GATE, IES & PSUs ( 2015-16)

➤ Capacity-In flow ratio: The ratio of the reservoir capacity to the total inflow of water in it is known as *capacity-inflow ratio*.

Trap efficiency ( $\eta$ ) is a function of capacity-inflow ratio.

$$\eta = f\left(\frac{\text{capacity}}{\text{inflow}}\right)$$

**To Buy Postal Correspondence Package call  
at 0-9990657855**

