Water Supply Engineering

Chapter 3

Quantity of Water

Lecture 4 (Week 4)

Variation in demand of water, Peak factor, Factors affecting demand of water, Population forecasting - necessity and methods, Numerical on population forecasting and water demands

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Learning Objectives

By the end of this lesson, students will be able to:

- ➢ Understand variations in water demand and identify daily, seasonal, and hourly fluctuations.
- ➢ Define and interpret peak factor and its significance in water supply design.
- ➢ Identify key factors affecting water demand, including climate, population, lifestyle etc.
- ➢ Explain the need for population forecasting in planning water supply systems.
- ➢ Apply different methods of population forecasting:
- ➢ Solve numerical problems related to population forecasting and water demand estimation.

3.4 Variation in Demand of Water

The average consumption or demand of water per head per day is the rate of demand of water.

- The rate of demand of water, however, does not remain constant but it varies with the seasons or month of the year, with the days of the week, and with the hours of the day.

These variations in the rate of demand of water are termed as: Variation in Demand Of water.

Variation May be:

Seasonal or Monthly Variations

- The rate of demand of water varies from season to season. During summer, more quantity of water is required for drinking, bathing, washing of clothes. It is due to the hotter climatic condition during summer. During winter, due to cool weather the consumption of water is less. In Nepalese context, the seasonal variation is low and can be neglected.

- The rate of demand of water varies considerably from season to season (or month to month).
- In summer season the average rate of demand of water is usually 30 to 40 per cent above the annual average rate of demand of water.
- On the other hand, in winter season the average rate of demand is about 20 per cent lower than the annual average rate of demand of water.
- Similarly, during rainy season, the rate of demand of water will be much less.
- Maximum Seasonal Demand = Seasonal Peak Factor * Annual average demand
- In Nepal, the seasonal peak factor is taken as 1, generally. (Kansakar, 2015)

ii) Daily Variations

- The rate of demand of water also varies from day to day. The consumption of water during special occasion and function is more than in any other normal day.

- Water is consumed more during Dashain, Tihar, wedding ceremony and other festivals. In Nepalese context, water is consumed more on Saturday
- The rate of demand of water also varies from day to day.
- This is due to change in the day-to-day climatic conditions, or due to the day being a holiday or some festival day.

The maximum daily demand is obtained as:

- Maximum Daily Demand = Daily Peak Factor * Annual average demand
- The daily peak factor is 1 in Nepal. Where, as in India it is 1.8

iii.) Hourly Variations:

The rate of demand of water also varies from hour to hour. The demand of water is high in the morning from 5 AM to 7 AM as more amount of water is consumed for cleaning and sanitary purposes. The demand is also high during the period of cooking.

The water demand remains less during day time and increases from 5 PM to 7 PM. From midnight to 5 AM in the morning, the demand remains almost zero.

- **Maximum Hourly Demand = Hourly Peak Factor * Annual average demand**
- The hourly peak factor is 3 in Nepal.

3.5 Peak Factor

- Peak factor is the ratio of the maximum or peak demand of water to that of average annual demand of water.
- Maximum demand or peak demand of year is given by multiplying average water demand and peak factor i.e.

  Max. demand=peak factor * annual average demand …………. (1)

  Peak factor= Seasonal peak factor*daily peak factor * hourly factor ………..(2)

- Peak factor in Nepal is 2 to 4 and peak factor adopted for intermittent system of water is 4 to 6.

3.6 Factors Affecting Demand of Water

Water demand is the total quantity of water required by a community for domestic, commercial, industrial, and public use.

Understanding the factors that affect water demand is essential for designing an efficient water supply system.

key Factors Affecting Water Demand

1. Population Size and Density

- Rate of demand depends upon the size of city and no. of population.
- Generally higher the population, higher is the demand and lower the population lower the demand.
- Thus, urban area has larger per capita consumption than rural areas.

2. Climatic Conditions

- Rate of demand in place is significantly higher in hot climate and generally lower in cool climate.

- In India seasonal water demand increases by 140% of the annual average demand, while it is neglected in case of our country.
- As per the International Journal of Geospatial and Environmental Research water demand changes by 48% from winter to summer season.
- Hot and dry climates increase water demand for:
  - Bathing, drinking, washing
  - Gardening, air cooling
- Example: Higher demand in **Terai** (e.g., Nepalgunj) than **Hilly regions** (e.g., Dhulikhel).

3. Standard of Living

- Demand of water or per capita consumption also depends upon the standard of living of people.
- Higher the standards of living higher the demand of the water because of luxury life and services they use.

- Average water consumption for people in Kathmandu is 70lpd while of London people is 164lpd.
- Higher living standards lead to:
  - Use of showers, flush toilets, washing machines
  - Personal vehicles and lawn irrigation
- Urban areas in Nepal like **Kathmandu** and **Pokhara** show increasing demand due to improved lifestyle.

4. Water Quality

- Quality of water also affect the consumption.
- While in case of low-quality water it needs to be treated and consumption rate decreases.
- Poor-quality water (bad taste, color, contamination) reduces use.
- Example: **Arsenic contamination** in Terai groundwater limits its usage for drinking.

5. Pressure in the distribution system

- Consumption of water depends on water pressure.
- Higher pressure in the supply system causes larger losses and wastage so increases water demand.

6. System of Supply

There are mainly two types of supply system, continuous and intermittent supply.

- The continuous system provides the water continuously and intermittent provides water for limited period in a day.
- Thus, demand is less in the intermittent system because consumers are forced to use the limited amount of water.
- But the hourly peak factor is very high in intermittent supply while comparatively low in continuous system.

7. Economic Activities

- Industrial and commercial zones have higher demand:
  - Manufacturing, cooling, cleaning processes
  - Hotels, offices, markets, schools
- Example: **Bhairahawa** has increased water demand due to industrial corridor.

8. Cost of Water

- The cost of water also a major aspect that affect the water demand.
- If the cost of water provided is more that it will gradually decrease the water demand rate.
- Besides metering followed by cost of water strictly controls the water demand of a community.

9. Metering and Tariff System

- Metered supply encourages efficient water use. And flat-rate billing leads to overconsumption and the water system may be metered or unmetered.
- Records the quantity of water consumed by consumers, and charged as per the meter reading.
- Hence installation of meters reduces the rate of demand of water.

10.Cultural and Social Practices

- Festivals and rituals increase temporary water demand.
- Rural communities may also use water for livestock and communal washing.

11. System Losses

- Water lost due to: Pipeline leakage, Illegal connections, Overflowing storage
- In Nepal, system losses can reach **30–50%** in some areas.

Factor	**Effect on Demand**
Climate	↑ in hot, dry regions
Lifestyle	↑ with modern living
Population	↑ with size
Economy	↑ in industrial/commercial zones
Supply Availability	↑ with 24/7 supply
Metering	↓ with efficient billing
Culture	↑ during festivals
System Losses	↓ usable water
Quality	↓ if poor

3.7 Population Forecasting: Necessity and Methods

- Prediction of future population based on the study and analysis of the available records and data is Population Forecasting.
- The information about the population of a town or a village or a city at any time can be obtained from the census records.
- Government of Nepal usually conducts census in a interval of 10 years, which is termed as decennial census.
- Population in the emerging town or city may increase due to increase in births, decrease in deaths and more importantly the migration.
- Thus, population to be used in calculating water demand is the design year population because a water supply project is planned to meet the present requirements as well as the requirements for a reasonable future time period.

Methods of Population Forecasting.

- Arithmetical increase method.
- Geometrical increase method.
- Incremental increase method.
- Decreased rate of growth method.
- Simple graphical method.
- Logistic curve method
- Apportionment method / Zoning method
- Graphical comparison method. (Dr. B.C Punmia, 2013)

3.7.1 Arithmetical Increase Method.

- Based on assumption that the rate of change of population with respect to time is constant.
- Suitable for large and old cities with considerable development. If used for emerging cities, it gives lower population estimate.
- In this method, the average increase in population per decade is calculated from past census reports. This increase is added to the present population to find out the population of the next decade.
- Therefore, future population P_n after n decades is given by:

$P_n = P + nI$, where P_n = future population at the end of n decades.

P = present population

I = average increase in population for a decade.

3.7.2 Geometrical Increase Method

- Based on assumption that the percentage increase in population per decade remains constant for each future decade.
- The value of this constant percentage increase in population per decade is determined from the known populations of a number of past successive decades.
- Suitable for emerging towns at the beginning of development as it gives higher estimation.

Expression for the future population P_n after n decades is:

$$P_n = P(1 + \frac{r}{100})^n$$

where P_n = future population at the end of n decades.

Where, P = present population

r = average percentage increase in population for a decade

3.7.3 Incremental Increase Method

- Combination of arithmetic and geometric increase method
- First, the actual increase in each decade is found.
- Then the increment in increase for each decade is found. The incremental increase may be positive or negative depending on the increase in the population during a successive decade is more than or less than the increase in the population during the preceding decade.
- Then average increment of the increases is calculated.
- The population in next decade is found by adding present population, average increase(arithmetical increase) and the average incremental increase per decade and so on. i.e.

  $$P_n = P + nI + \frac{n(n+1)}{2}x$$

where P_n = future population at n^{th} decade

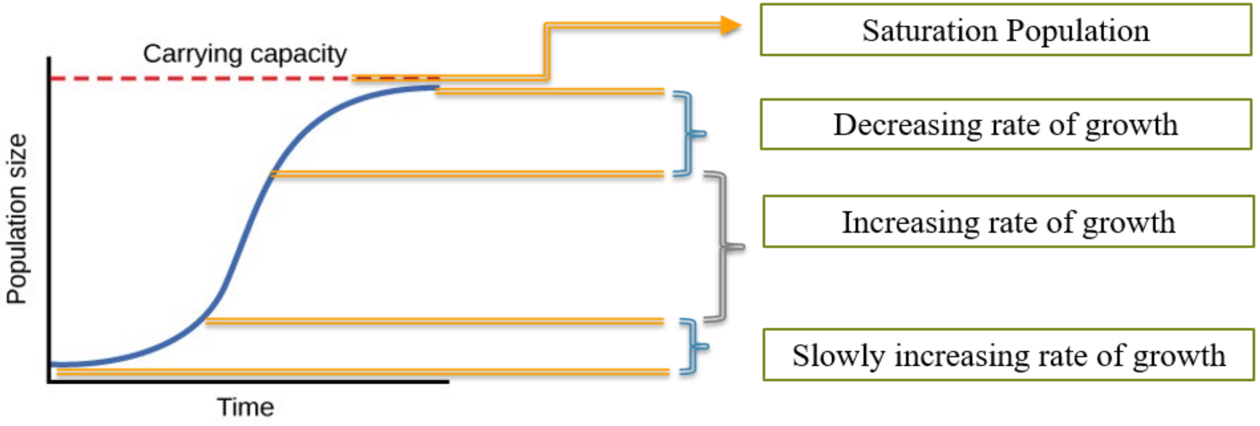
P = present population

I = average increase in population for a decade.

x = average incremental increase in population for a decade.

3.7.4 Decreased rate of growth method.

- Suitable for decreasing rate of growth.
- Generally, the population vs time graph for a developing city is found in the form of logistic curve(S-curve).



3.7.4 GRAPHICAL METHOD

- In this method, the populations of last few decades are correctly plotted to a suitable scale on graph.
- The population curve is smoothly extended for getting future population.
- This extension should be done carefully and it requires proper experience and judgment
- The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition

Graph between the population and the corresponding year is plotted based on the available census data. The obtained curve is extended in the same manner to get the population of required year.it is the approximate method as the accuracy is dependent on the skill and experience of the person dragging the curve.

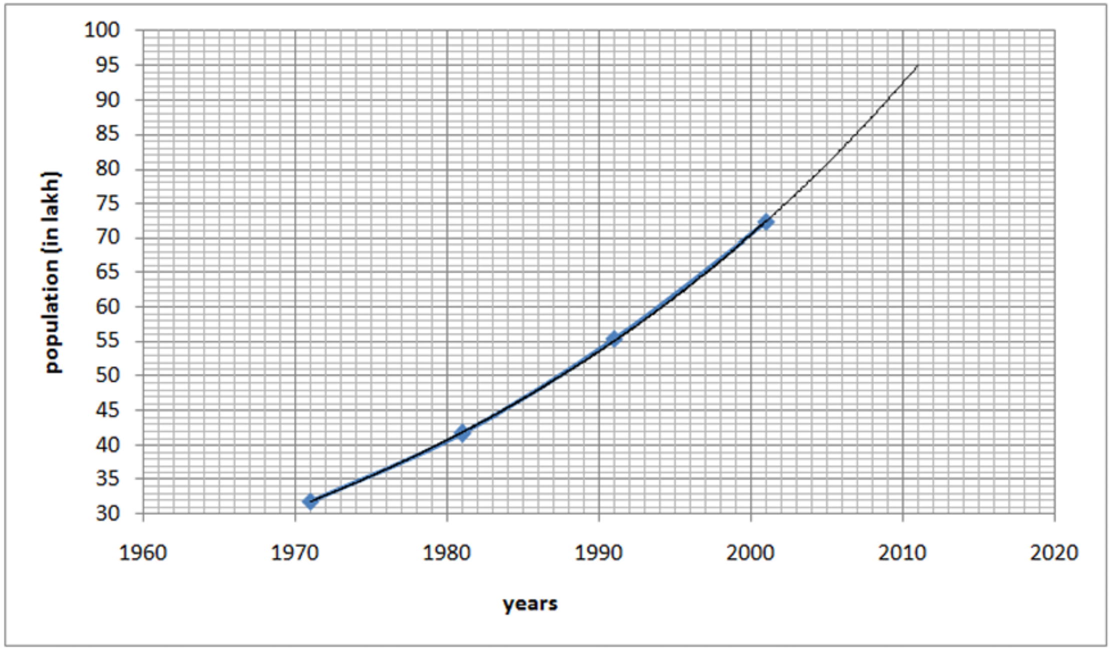


Figure 1:Graphical Method for Population Forecasting   Source: (Dinesh W. Gawatre, 2016)

3.7.5 logistic curve method

- The growth is assumed to be a function of the time and follows some logical mathematical relationship the population tends to according to the logistic curve staring at low rate followed by high rate and then at lower rate towards the saturation limit.

- This method is used when the growth rate of population due to births, deaths and migrations takes place under normal situation and it is not subjected to any extraordinary changes like epidemic, war, earth quake or any natural disaster etc. then this method is used
- The curve so obtained under normal condition is look like S-shaped curve and is known as logistic curve.

3.7.6 Apportionment Method

The **Apportionment Method** or **Zoning Method** is used when a larger administrative area (like a district or region) has an established population growth trend, and we want to **estimate the future population of a smaller area (like a town or ward)** within it.

It **"apportions"** or **"shares"** the projected population of the large area proportionally among smaller zones.

How It Works:

1. **Obtain past population data** of both the **region** and the **zone**.
2. **Determine the proportion** of the zone's population with respect to the region over the years.
3. Use these proportions to estimate the zone's share of **future population** of the region.

Formula (Simple Approach):

If:

- Pt = projected population of the **region** at time t
- r = average **proportion** of the zone in the total region in previous years

Then,

$P_{zone} = r \times P_t$

Where,

r = average **proportion** of the zone in the total region in previous years

r= Population of zone / Population of region

(based on historical trend)

Steps in Detail:

1. **Collect data** of the region and the zone (past 2-3 decades is ideal).
2. **Calculate ratio** of zone's population to the region's population for each census year.
3. **Find the average** ratio over time.
4. Forecast the **future population of the region** (using arithmetic/geometric/etc.).
5. **Multiply the forecasted regional population by the average ratio** to estimate the zone's future population.

Example:

Let's say we want to forecast the population of **Pokhara Lekhnath Metropolitan Ward 5**, and we know:

Year	**Region (Pokhara)**	**Ward 5**
2001	200,000	20,000
2011	300,000	30,000

So the proportion of Ward 5 to Pokhara:

- In 2001: 20,000 / 200,000 = 0.10
- In2011:30,000/300,000=0.10

  So the ratio is stable = 0.10

Now, suppose Pokhara's projected population in 2031 is 500,000 (from another method like geometric increase), then:

Ward 5 population in 2031=0.10×500,000=50,000

Where This Method is Useful:

- When you don't have detailed census data for small areas.
- When the **growth rate is driven by the overall region** (e.g., migration into a city, not just one ward).
- When zoning or municipal boundaries have recently changed.

Limitations:

- Assumes **constant ratio**, which may not be true (some areas may urbanize faster).
- Doesn’t account for **local developments** (like a new industry, housing, or road).
- Depends on **accurate regional forecasting**, so errors carry forward.

Advantages:

- Simple and practical.

- Useful for **planning within a larger city**.
  - Requires less data than other forecasting methods.

Q. Determine the population of the town in the year 2021 and 2026 by:

1.Arithmetical method

2.Geometrical increase method

3.Decreased rate of growth method

4.Incremental increase method

Year	1961	1971	1981	1991	2001	2011
Population	18000	27000	38000	51000	66000	83000

(Kansakar, 2015)

Year	Population	Increase in Population	Percentage Increase in Population	Decrease in Percentage Increase in Population
1961	18000	-	-	-
1971	27000	9000	50	-
1981	38000	11000	40.74	9.26
1991	51000	13000	34.21	6.53
2001	66000	15000	29.41	4.8
2011	83000	17000	25.76	3.65
Total		65000	180.12	24.24
Average		13000	36.02	6.06

From table:

P = 83000   I = 13000   r = 36.02%   r' = 6.06   X = 2000

1.Arithmetical method

$P_n = P + n*I$

P_{2021} = 83000 + 1*13000 = 96000

P_{2026} = 83000 + 1.5*13000 = 102500

2.Geometrical increase method

$P_n = P\{1+\frac{r}{100}\}^{n}$

$P_{2021} = 83000\ \{1+\frac{36.02}{100}\}^{1}$ =112897

$P_{2026} = 83000\{1+\frac{36.02}{100}\}^{1.5}$ =131669

3. Decreased rate of growth method

$\mathbf{P_n = P\{1+\frac{rn-r'}{100}\}\{1+\frac{rn-2*r'}{100}\}.......}$

$P_{2021} = 83000\{1+\frac{25.76-6.06}{100}\}$ = 99351 (1 decade power 1…2-decade power 1 and another 1)

$P_{2026} = 83000\{1+\frac{25.76-6.06}{100}\}^{1}\ \{1+\frac{25.76-2*6.06}{100}\}^{0.5}$ = 105910 (for 1.5-decade power 1 and 0.5)

4. Incremental increase method

$P_n = P + n\times I + n(n+1)\frac{X}{2}$

$P_{2021} = 83000 + 1*13000 + 1(1+1)\frac{2000}{2}$ = 98000

$P_{2026} = 83000 + 1.5*13000 + 1.5(1.5+1)\frac{2000}{2}$ = 106250

Q. Determine the total water demand of a small town in Nepal with a projected population of 50,000 for the design year.

Assume the following per capita demands:

- Domestic demand: 135 liters/capita/day (lpcd)
- Industrial demand: 50 lpcd
- Commercial demand: 20 lpcd

- Institutional and public use: 25 lpcd
- Firefighting demand: Use National Fire Demand formula
- Include 15% for losses and wastage.

Calculate the total water demand in million liters per day (MLD).

Step 1: Calculate population-based demands

Population=50,000

Domestic=135×50,000=6,750,000liters/day

Industrial=50×50,000=2,500,000liters/day

Commercial=20×50,000=1,000,000liters/day

Institutional/Public=25×50,000=1,250,000liters/day

Subtotal = 6,750,000 + 2,500,000 + 1,000,000 + 1,250,000 = 11,500,000 liters/day

Step 2: Calculate fire demand

Use National Board of Fire Underwriters formula:

$Q = 4637 \times \sqrt{P} \times (1 - 0.01 \times \sqrt{P})$, Where P = 50

$Q = 4637 \times \sqrt{50} \times (1 - 0.01 \times \sqrt{50})$

$\approx 4637 \times 7.07 \times (1 - 0.0707) \approx 30{,}460$ liters/min

Convert to liters/day:

$30{,}460 \times 60 \times 24 \approx 43{,}862{,}400$ liters/day But practically, fire demand is taken as 1% of total demand: Fire demand = $0.01 \times 11{,}500{,}000 = 115{,}000$ liters/day

Step 3: Add 15% for losses and wastage

Total without losses = 11,615,000 liters/day

Losses = $0.15 \times 11{,}615{,}000 = 1{,}742{,}250$ liters/day

Step 4: Total water demand

Total demand = $11{,}615{,}000 + 1{,}742{,}250 = 13{,}357{,}250$ liters/day

Convert to MLD:, Total Demand = 13,357,250 / 1,000,000 = 13.36 MLD

The total water demand for the town is approximately 13.36 million liters per day (MLD).

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Thank You!!!