

Wollo university

Kombolcha Institute of Technology

Department of WRIE

Water supply Engineering

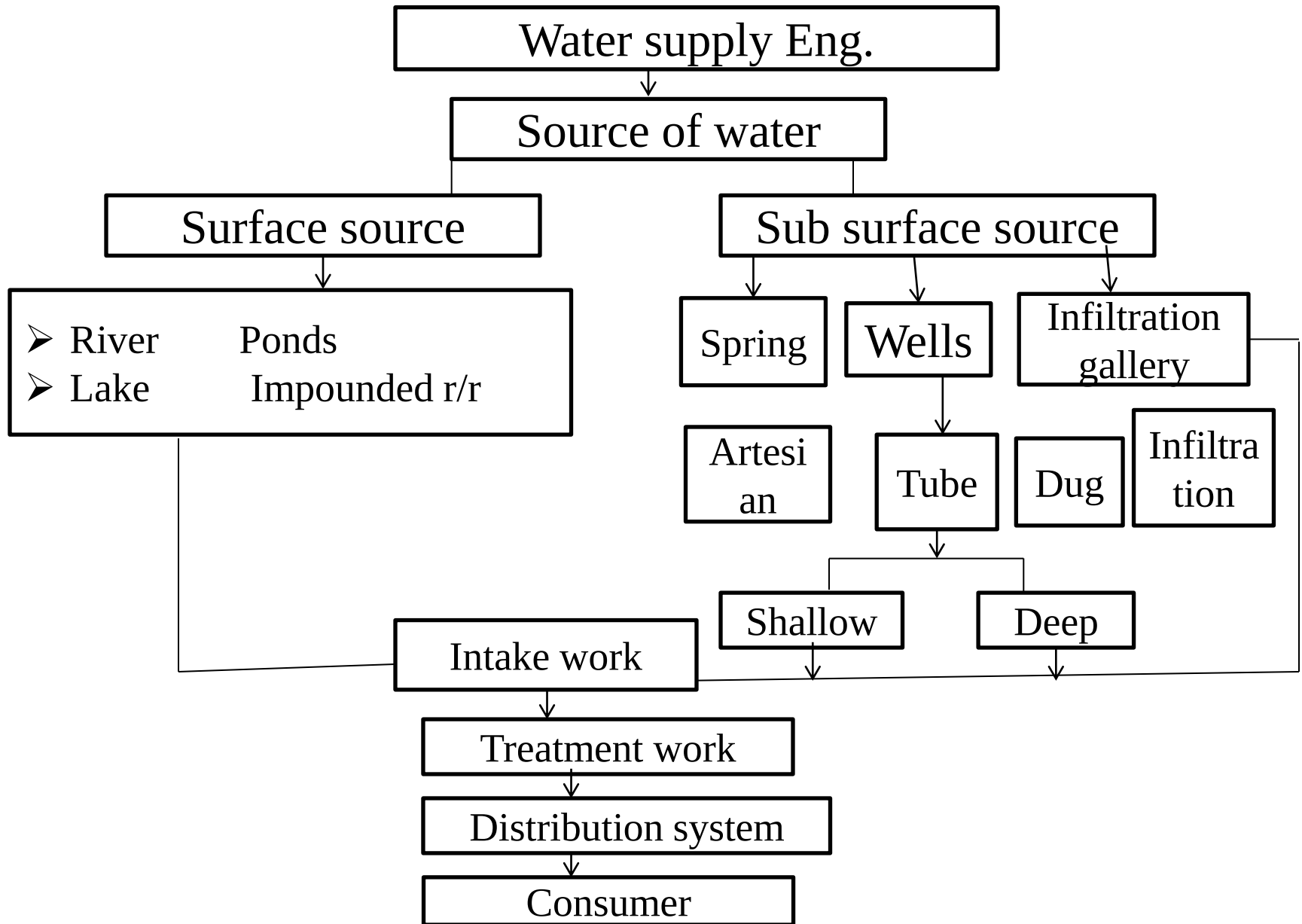
Lecture note,2020

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Out lines

- Introduction
- Out lines of water supply scheme
- Need to protected water supply

outlines of water supply scheme



INTRODUCTION

Water supply schemes

- ❖ Next to the air, the other important requirement for human life to exists is water.
- ❖ Water is available in various forms such as rivers, lake, streams etc.
- ❖ The earliest civilizations organized on the banks of major river systems & required water for drinking, bathing, cooking etc.
- ❖ The use of water by man, plants & animals is universal.
- ❖ It is the principal raw materials for food production & for many other uses outside home & on the farm.

Cont.....

- ❖ In addition to that, indirect consumption water effects our daily life like
 - ✓ Manufacturing of essential commodities
 - ✓ Generation of electrical power.
 - ✓ Transportation, Recreation
 - ✓ Industrial activities
- ❖ Thus water can be considered as the most important raw material of civilization b/c of the fact that with out water, the man can not live & industry can not operate.

Need to protected water supply

- **Protected water supply** means the supply of water that is treated to remove the impurities and made safe to public health.
- Water when exposed to the atmosphere contain many impurities which are harmful to any living organisms. If untreated H_2O is consumed by living organisms, it is likely to cause serious harm to their health (water born diseases).
- Hence, in order to make H_2O potable & free from various impurities, the purification methods should be adopted.

Objective of community Water Supply

- To provide whole some water to the consumers for drinking purpose.
- To supply adequate quantity to meet at least the minimum needs of the individuals.
- To make adequate provisions for emergencies like fire fighting, festivals, meeting etc.
- To make provision for future demands due to increase in population, increase into prevent pollution of water at source, storage and conveyance.
- To maintain the treatment units and distribution system in good condition with adequate staff and materials.
- To design and maintain the system that is economical and reliable standard of living, storage and conveyance.

WHOLE SOME WATER

- Absolutely pure water is never found in nature and w/c contains only 2 parts of H & one part of O by volume. But the water found in nature contains no of impurities in varying amounts.
- **Wholesome water** is defined as the water w/c containing the minerals in small quantities at required levels & free from harmful impurities.
- **potable water** is The water that is fit for drinking safe and agreeable is called.
- Requirements of wholesome water.
 - ✓ It should be free from bacteria
 - ✓ It should be colorless and sparkling(bright)
 - ✓ It should be tasty, odour free and cool
 - ✓ It should be free from objectionable matter
 - ✓ It should not corrode pipes.
 - ✓ It should have dissolved oxygen and free from carbonic acid so that it may remain fresh.

QUESTIONS

1. What are the uses of water?
2. Explain the need for protected water supply?
3. What is meant by wholesome water? What are the requirements of wholesome water?

2.Demand for water

Various types of Water Consumption (Demands)

- While designing the water supply scheme for a town or city, it is necessary to determine the total quantity of a water required for various purposes by the city.
- As a matter of fact the first duty of the engineer is to determine the water demand of the town and then to find suitable water sources from where the demand can be met.
- **Following are the various types of water demands of a city or town.**
 - i. Domestic water demand
 - ii. Industrial demand
 - iii. Institution and commercial demand
 - iv. Demand for public use
 - v. Fire demand
 - vi. Loses and wastes

Domestic water demands

- It includes the quantity of water required in the houses for drinking, bathing, cooking, washing etc.
- The quantity of water required for domestic use mainly depends on the habits, social status, climatic condition and custom of the people.

Estimation of per capita demand for piped water in l/c/d (1997) for population of greater than 30,000(urban and rural)

No.	Activity	House Connection	Yard Connection	Public fountains (Stand pipes)	Rural Schemes
1	Drinking	2.5	2.5	2.5	2.5
2	Cooking	7.5	5.5	4.5	3.5
3	Ablutions	17	12	7	5
4	Washing dishes	5	4	4	3
5	Laundry	15	8	7	4
6	House cleaning	7	3	2	2
7	Bath and shower	20	4	3	
8	Toilets	6	1		
	Total	80	40	30	20

Estimate of per capita demand for piped water in l/c/d (1997) for population of less than 30,000(for urban between 2500 and 30000)

No.	Activity	House Connection	Yard Connection	Public fountains (Stand pipes)	Rural Schemes
1	Drinking	1.5	1.5	1.5	1.5
2	Cooking	5.5	3.5	3.5	3.5
3	Ablutions	15	10	6	5
4	Washing dishes	5	2	2	2
5	Laundry	15	8	7	3
6	House cleaning				
7	Bath and shower	4	1		
8	Toilets	20	4		
	<i>Total</i>	70	30	20	15

Estimate of per capita demand for rural schemes in l/c/d (1997)

No.	Activity	Minimum	Average	Maximum
1	Drinking	1.5	1.5	3.5
2	Cooking	2.5	3.5	4.5
3	Ablutions	4	5	5
4	Washing dishes	2	2	4
5	Laundry		3	3
6	House cleaning			
7	Bath and shower			
8	Toilets			
	Total	10	15	20

Industrial water demand

- The water required in the industries mainly depends on the type of industries, which are existing in the city.
- The water required by factories, paper mills, Cloth mills, Cotton mills, Breweries, Sugar refineries etc.
- The quantity of water demand for industrial purpose is around 20 to 25% of the total demand of the city

Institutional and commercial demand

- Universities, Institution, commercial buildings and commercial centers including office buildings, warehouses, stores, hotels, shopping centers, health centers, schools, temple, cinema houses, railway and bus stations etc comes under this category.

Commercial and institutional demand

Categories	Typical rate of water use per day
Day school	5lit/pupil
Boarding school	100lit/pupil
Hospitals	100lit/bed
Church/Mosque	5lit/visitor
Cinema houses	5lit/visitor
Public paths	100lit/visitor
Abattoir	300lit/cow
Hotels	100lit/bed
Restaurant-bar	15lit/seat
Offices	5lit/person
Bus terminals	10lit/visitor
Prison	30lit/person

As per IS: 1172-1963, water supply requirements for the public buildings other than residences as follows. **Source water supply engineering book First Edition : 2005**

SL.No.	Type of Building	Construction per capita per day (litres)
1.	a) Factories where bathrooms are required to be provided.	45
	b) Factories where no bathrooms are required to be provided	30
2.	Hospitals per bed	
	a) No. of beds not exceeding 100 No.	340
	b) No. of beds exceeding 100 No.	450
3.	Nurses homes and medical quarters.	135
4.	Hostels	135
5.	Offices	45
6.	Restaurants (per seat)	70
7.	Hotel (per bed)	180
8.	Cinema concert halls and theatres (per seat)	15
9.	Schools	
	a) Day schools	45
	b) Boarding schools	135
10.	Garden, sports grounds	35 per sq.m
11.	Animal/vehicles	45

Demands for public use

- Quantity of water required for public utility purposes such as for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc comes under public demand.
- To meet the water demand for public use, provision of 5% of the total consumption is made designing the water works for a city.

The requirements of water for public utility shall be taken as given in the next Table

Purpose	Water Requirements
Public parks	1.4 litres/m ² /day
Street washing	1.0-1.5 litres/m ² /day

Fire demand

- Fire may take place due to faulty electric wires by short circuiting, fire catching materials, explosions, bad intension of criminal people or any other unforeseen miss happenings.
- If fires are not properly controlled and extinguished in minimum possible time, they lead to serious damage and may burn cities.
- In cities fire hydrants should be provided on the mains at a distance of 100 to 150m apart.

The quantity of water required for fire fighting is generally calculated by using different empirical formulae. These are:-

National board of fire underwriter formulas.

$$Q = 64 \sqrt{P (1 - 0.01\sqrt{P})}$$

Where Q = rate of flow of water in l/sec

P = Population in thousand

Freeman formula.

$$Q = 1135.5 ((P/10) + 10)$$

Where

Q is Quantity of water in lit/min

P is population in thousands

He also states that

$$F = 2.8 * \sqrt{p}, \text{Where}$$

F = period of occurrence of fire in years.

P = population in thousands

Knuckling's formula

$$Q = 3182 * \sqrt{p}$$

Where

Q = Quantity of water required in 1/min.

P = population in thousands

Cont.....

Although the actual amount of water in a year for firefighting is smaller than the rate of use, the Insurance Service Office (USA) uses the formula

$$Q = 18 * C * A^{0.5}$$

Where Q = the required fire flow in gpm (lit/min/3.78)

C = a coefficient related to the type of construction which ranges from a max of 1.5 *for wood frame* to a minimum of 0.60 *for fire resistive construction*.

A = total floor area $ft^2(m^2 \times 10.76)$ excluding the basement of the building

Example In order to determine the max water demand during a fire, the fire flow must be added to the maximum daily consumption. It is assumed that a community with a population of 22,000 has an average consumption of 600 lit/capita/day and flow directed by a building of ordinary construction (C = 1) with a floor area of $1000m^2$ and a height of 6 stories, the calculation is as follows:

Solution

Average domestic demand = $22,000 * 600 = 18.2 * 10^6$ lit/day

Maximum daily demand = $1.8 * 13.2 * 10^6 = 23.76 * 10^6$ lit/day

$F = 18(1) (1000 * 10.76 * 6)^{0.5} = 17,288$ lit/min = $24.89 * 10^6$ lit/day

Maximum rate = $23.76 * 10^6 + 24.89 * 10^6$
= $48.65 * 10^6$ lit/day

Unaccounted for Water

- These include the quantity of water due to wastage, losses, thefts, etc, i.e.
 - Losses due to defective pipe joints, cracked and broken pipes, faulty valves and fittings.
 - Losses due to, consumers keep open their taps of public taps even when they are not using the water and allow the continuous wastage of water.
 - Losses due to unauthorized and illegal connections
- While estimating the total quantity of water of a town; allowance of 15-20 % of total quantity of water is made to compensate for losses, thefts and wastage of water.

PER CAPITA DEMAND

- In community, water is used for various purposes as described above. For the purpose of estimation of total requirement of water, the demand is calculated on the average basis, which is expressed in per capital demand (lit / clay)
- Per capita demand = $\frac{Q}{P \times 365}$, Where
 - Q: – is the total quantity of water required by various purposes by a town per year in liter.
 - P: - The population of the town

factors affecting per capita demand of the town

- **Climatic conditions** :- In hotter & dry place ➡ quantity of H₂O more, In cold places, ➡ water required less.
- **Size of community** :- Water demand is more with increase of size of town because more water is required in street washing, running of sewers, maintenance of parks and gardens.
- **Living standard of the people** :- The per capita demand of the town increases with the standard of living of the people because of the use of air conditioners, room coolers, maintenance of lawns, use of flush, latrines and automatic home appliances etc.
- **Industrial & commercial activities** :- The presence of industries & commercial activity in a town will increase the per capita demand of the town.

- **Quality of water:** If the Quality of water is good, & more water will be consumed.
- **Cost of water:-** The cost of water directly affects its demand. If the cost of water is more, less quantity of water will be used by the people as compared when the cost is low.
- **System of sanitation:** The presence of water carriage system in a town will increase the per capital demand of the town.
- **Pressure in the distribution system :-**
If the pressure  - more water loss due to leakage, wastage
- **System of supply**

VARIATIONS IN DEMAND

- The per capita demand of town is the average consumption of water for a year. In practice it has been seen that this demand does not remain uniform throughout the year but it varies from season to season, even hour to hour.

SEASONAL VARIATIONS

- The water demand varies from season to season. In summer the water demand is maximum, because the people will use more water in bathing, cooling, lawn watering and street sprinkling.
- This demand will become minimum in winter because less water will be used in bathing and there will be no lawn watering.

DAILY VARIATIONS

- This variation depends on the general habits of people, climatic conditions and character of city as industrial, commercial or residential.
- More water demand will be on Sundays and holidays due to more comfortable bathing, washing etc as compared to other working days.

HOURLY VARIATIONS

Design period

- **Design Period:** - is the no of years for which the designs of the water works have been done. It should neither be too short or too long, mostly water works are designed for design period of 22 – 30 years.
- **Factor, which should be kept in view while fixing the design period:**
 - ✓ Fund
 - ✓ The life of the material used in project (pipes, structural materials)
 - ✓ Anticipated expansion of the town
 - ✓ The rate of interest on the loan taken

Population Forecasting

- The design of the water supply project is done on the basis of projected population at the end of the design period. Otherwise a present scheme will be inadequate in near future.
- The following are the common methods by which the forecasting of population is done.
 1. Arithmetic increases method
 2. Geometric increase method
 3. Incremental increase method
 4. Decrease rate method
 5. Simple graphical method
 6. Master plan curve method
 7. Logistic curve method
 8. Ration & correlation

Arithmetic increase method

- This method is based on the assumption that the population is increasing at a constant rate i.e. the rate of change of population with time is constant.
- i.e. $\frac{dp}{dt} = k$
 $dp = k dt$ when we integrate the limit $P_o - P_n$ & $o - n$
 $P_n - p_o = k (n - o) = kn$
- **$p_n = p_o + kn$**
Where p_o = initial population (present popn)
 P_n = future population at n decade or year
 k = arithmetic increase
 n = Decade or year
- This method is generally applicable to a large and old city.

Example 1

- The following data have been noted from the census department.

Year	1940	1950	1960	1970
Population	8,000	12,000	17,000	22,500

- Calculate the probable population in the year 1980, 1990 and 2000

Solution

Year : 1940 1950 1960 1970
Population: 8000 12,000 17,000 22,500
Increase in
Population: 4,000 5,000 5,500
Average $\frac{4000 + 5,000 + 5,500}{3} = \frac{14,500}{3} = 4,833$
Increase:

Probable popn in various decades shall be as flows

Year	Population
1980	$22,500 + 1 * 4833 = 27,333$
1990	$22,500 + 2 * 4833 = 32,166$
2000	$22,500 + 3 * 4833 = 36,999$

Geometrical increase method.

- This method is based on the assumption the percentage increase in population from decade to decade remains constant.
- If the present population is p and average percentage growth is k , the population at the end of n decade will be:

$$P_1 = P_0 + Kp_0 = p_0 (1 + k)$$

$$P_2 = p_1 + kp_1 = p_1 (1 + k) = p_0 (1 + k) (1 + k) = P_0(1 + k)^2$$

$$P_3 = p_2 + kp_2 = p_2 (1 + k) = p_0 (1 + k) (1 + k) (1 + k) \\ = P_0(1 + k)^3$$

- **$P_n = P_0(1 + k)^n$**

where p_0 = initial population, P_n = popn at n

decades or year, n = Decade or year & k = Percentage

(geometric) increase

- This method is mostly applicable for growing towns and cities having vast scope of expansion.

- Example 2: Forecast the population of example 1 by means of geometrical increase method.

Solution

Year	Population	Increase in popn	Percentage increase in popn
1940	8,000	-----	-----
1950	12,000	4,000	$(4000/8000)*100=50\%$
1960	17,000	5,000	$(500/12000)*100=41.7\%$
1970	22,500	5,500	$(5,500/17,000)*100=32.4\%$
Total:		14,500	124.1%

Average per Decade : $4,833 = 14,500/3$ $41.37\% = 124.1\%/3$

The popn at the end of various decades shall be as follows:

Year Expected popn

$$1980 \quad 22,500 + (41.37/100) 22,500 = 22,500 (1+41.37/100) \\ = 31,808$$

$$1990 \quad 22,500 (1 + 41.37/100)^2 = 44,967$$

$$2000 \quad 22,500 (1 + 41.37/100)^3 = 63,570$$

Incremental Increase method

- This method is improvement over the above two methods. The average increase in the population is determined by the arithmetical method and to this is added the average of the net incremental increase once for each future decade.
- **Example 3:** Forecast the population of example 1 by mean of incremental increase method.

Solution

Year	Population	Increase in population	Incremental increase
1940	8,000	-----	-----
1950	12,000	4000	-----
1960	17,000	5000	+ 1000
1970	22,500	<u>5500</u>	<u>+500</u>
Total		14500	1500
Average		$14500/3=4833$	$1500/2=750$

The Population at the end of various decades shall be as follow:

<u>Year</u>	<u>Expected Population</u>
1980	$22,500 + 1* (4,833 + 750) = 28,083$
1990	$22,500 + 2* (4,833 + 750) = 33,666$
2000	$22,500 + 3* (4,833 + 750) = 39,249$

Decreasing rate method

- In this method, the average decrease in the percentage increase is worked out and is then subtracted from the latest percentage increase for each successive decades.
- This method is applicable to average size cities growing under normal condition. Example 4: Solve example 1, by using decrease rate of growth method.

Solution

Year	Population	Increase in population	% age increase in population	Decrease in % age increase
1940	8000	-----	-----	-----
1950	12000	4000	$4000/8000*100=$ 50	-----
1960	17000	5000	$5000/12000*100$ =41.7	+8.3
1970	22500	<u>5500</u>	$5500/17000*100$ =32.4	+9.3
Total		14,500		17.6
Avg		$14,500/3=4833$		$17.6/2=8.8$

Cont...

- Now the popn at the end of various decades shall be as follows:

Net Percentage increase

Year	In population	Population
1980	$32.4 - 8.8 = 23.6$	$22,500 + 23.6/100 * 22,500 = 27,810$
1990	$23.6 - 8.8 = 14.8$	$27,810 + 14.8/100 * 27,810 = 31,926$
2000	$14.8 - 8.8 = 6.0$	$31,926 + 6/100 * 31,926 = 33,842$

Simple graphical method

- In this method the population of last few years is correctly plotted to a suitable scale on the graph with respect to years.
- Then, the curve is smoothly extended to forecast the future population.

Master plan method

- In the method, the master plan of the city or town is used to determine the future expected population.
- The population densities for various zones (residential, commercial, industrial and other zones) of the town are fixed and hence the future population of the city when fully developed can easily be worked out.

Logistic curve method

- When the population of a town is plotted with respect to time, the curve so obtained under normal condition shall be S shaped logistic curve.

According to P.F. Verhulst, the logistic curve can be represented by the equation

$$P = \frac{P_s}{1 + m \log e^{-1} n.t}$$

- Where P_s = Saturation population
 P_o = Population at starting point
 P = Population at any time t from the starting point

$$P_s = \frac{2 P_1 * P_2 * P_3 - P_2^2 (P_1 + P_2)}{P_1 P_3 - P_2^2}$$

$$m = \text{Constant} = \frac{P_s - P_o}{P_o}$$

$$n = \text{Constant} = \frac{2.3 \log_{10} \left(\frac{P_o (P_s - P_1)}{P_1 (P_s - P_o)} \right)}{t}$$

P_0 = Popn of the town at t_0

P_1 = >> >> >> >> >> t_1

P_2 = >> >> >> >> >> t_2

➤ **Ration and correlation method**

In this method, the rate of population growth of a town is related to the rate of population growth of state or nation.

- Hence it is possible to estimate the population of a town under consideration by considering the rate of population growth of state or nation.

Questions

1. Explain the various factors affecting the per capita demand ?
2. Name the different types of seasonal variation?
3. Explain the various types of water demands?
4. Population of a town as obtained from the census report is as follows.

Year	1941	1951	1961	1971
Population in thousands	242	485	770	1090

Estimate the population of the town in the year 1981, 1991 & 2001 by

- ✓ Arithmetic increase method
- ✓ Geometrical increase method
- ✓ Incremental increase method
- ✓ Decrease rate method

3. Water supply sources

All the sources of water can be broadly divided into:

- ✓ Surfaces sources and
- ✓ Sub surface sources

Surfaces Sources

The following are the different surface sources of water:

- ✓ River or stream
- ✓ Ponds or lakes
- ✓ Storage reservoir

River or stream

- ✓ It is formed by the runoff in the mountain & hill areas.
- ✓ Some rivers are perennial (water available through out the year) and some are non perennial (water available in raining season only).
- ✓ Perennial River should always be selected for the scheme. In case of non perennial rivers, the weir or low dam may be constructed to form a storage reservoir.
- ✓ The streams are suitable for small water supply scheme.

Pond or lake

- It is natural or artificial depressions where surface runoff is collected in rainy season.

Impounding Reservoirs

- In some rivers the flow becomes very small and cannot meet the requirements of hot weather. In such cases, the water can be stored by constructing weir or a dam across the river at such places where minimum area of land is submerged in the water and maximum quantity of water to be stored.
- This sources is always preferred for large water supply projects

Ground Water Sources

- ✓ **Springs**
- ✓ **Well**
- ✓ **Infiltration galleries**

Spring

- ✓ When the under ground water reappears at the ground surface by under ground pressure, then it is known as spring.

Types of springs:

- ✓ **Gravity Springs:** When the surface of the earth drops sharply the water bearing stratum is exposed to atmosphere.
- ✓ **Surface Spring:** This is formed when an impervious stratum which is supporting the ground water reservoir becomes out crops
- ✓ **Artesian Spring:** When the ground water rises through a fissure in the upper impervious stratum. When the water-bearing stratum has too much hydraulic gradient and is closed between two imperious stratum,

Well

- A well is defined as an artificial hole or pit made in the ground for the purpose of tapping water.

The three factors which form the basis of theory of wells are

1. Geological conditions of the earth's surface
2. Porosity of various layers
3. Quantity of water, which is absorbed and stored in different layers

Shallow Wells

- Shallow wells are constructed in the uppermost layer of the earth's surface. The diameter of well varies from 2 to 6m and a maximum depth of 7m.
- The quantity of water obtained from shallow wells is better than the river water but requires purification.
- The shallow wells should be constructed away from septic tanks, soak pits etc because of the contamination of effluent.
- The shallow wells are used as the source of water supply for small villages, undeveloped municipal towns, isolated buildings etc because of limited supply.

Deep well

- The theory of deep well is based on the travel of water from the outcrop to the site of deep well.
- The outcrop is the place where aquifer is exposed to the atmosphere. The rain water entered at outcrop and gets thoroughly purified when it reaches to the site of deep well.
- The depth of deep well should be decided in such a way that the location of outcrop is not very near to the site of well. The water available at a pressure greater atmospheric pressure, therefore deep wells are also referred to as a pressure wells.

Water Sources Selection Criteria

The choice of water supply to a town or city depends on the following:

- ✓ **Location:** The sources of water should be as near as to the town as possible.
- ✓ **Quantity of water:** the source of water should have sufficient quantity of water to meet up all the water demand through out the design period. Source of water should be able to meet the maximum demand in dry season also.
- ✓ **Quality of water:** The quality of water should be good which can be easily and cheaply treated.
- ✓ **Cost:** The cost of the units of the water supply schemes should be minimum.

Questions

1. Explain the sources of water?
2. Explain the classification of wells?
3. What are points should be kept in mind while selecting source of water supply?

4.COLLECTION AND DISTRIBUTION OF WATER

Intakes for Collecting Surface Water

- The main function of the intakes works is to collect water from the surface source and then discharge water so collected, by means of pumps or directly to the treatment water.
- The following points should be kept in mind while selecting a site for intake works.
 - ✓ Where the best quality of water available so that water is purified economically in less time.
 - ✓ At site there should not be heavy current of water, which may damage the intake structure.
 - ✓ The intake can draw sufficient quantity of water even in the worst condition, when the discharge of the source is minimum.
 - ✓ The site of the work should be easily approachable without any obstruction
 - ✓ The site should not be located in navigation channels
 - ✓ As per as possible the intake should be near the treatment plant so that conveyance cost is reduced from source to the water work
 - ✓ As per as possible the intake should not be located in the vicinity of the point of sewage disposal for avoiding the pollution of water.
 - ✓ At the site sufficient quantity should be available for the future expansion of the waterworks.

Types of Intake structures

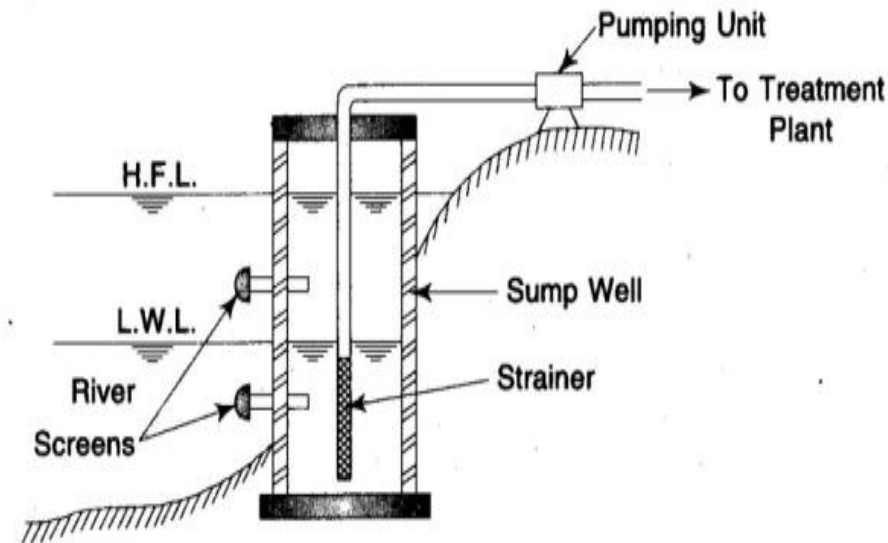
Depending upon the source of water the intake works are classified as following

River intake

- A circular or rectangular sump well is constructed with masonry work in the bank of river in such a way that the water can enter the well in both conditions (H.F.L & L.W.L) through pipes installed at different level.
- Screens are provided at the end of the pipe to eliminate suspended matters.
- The main suction pipe having strainer at the bottom is inserted into the

sump well and connected to the pumping unit which delivers water to the treatment plant.

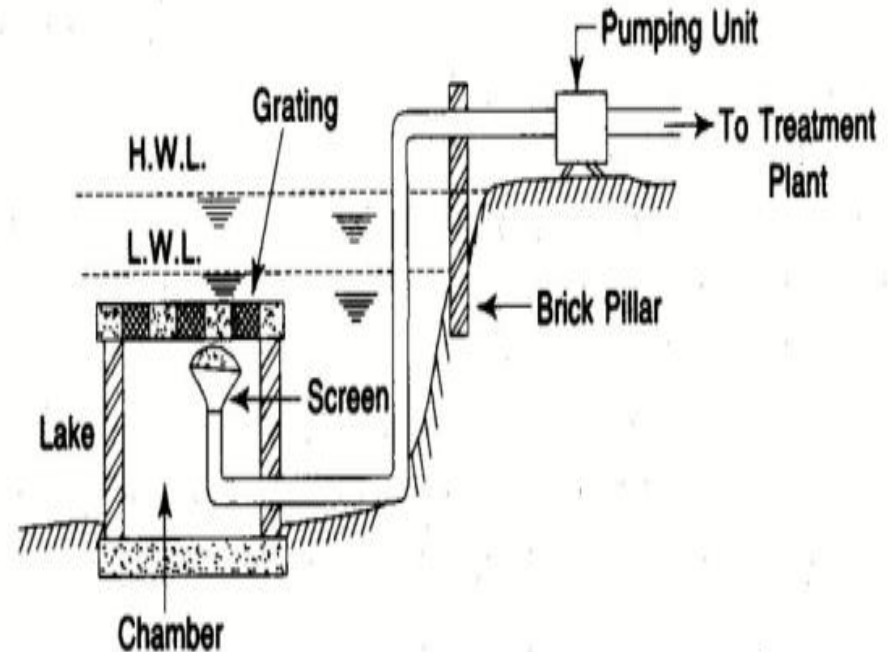
- Sometimes intake works may be constructed in the middle of the river. In the case, all precautions should be taken to protect the structure from silting and heavy current of river



Lake Intake

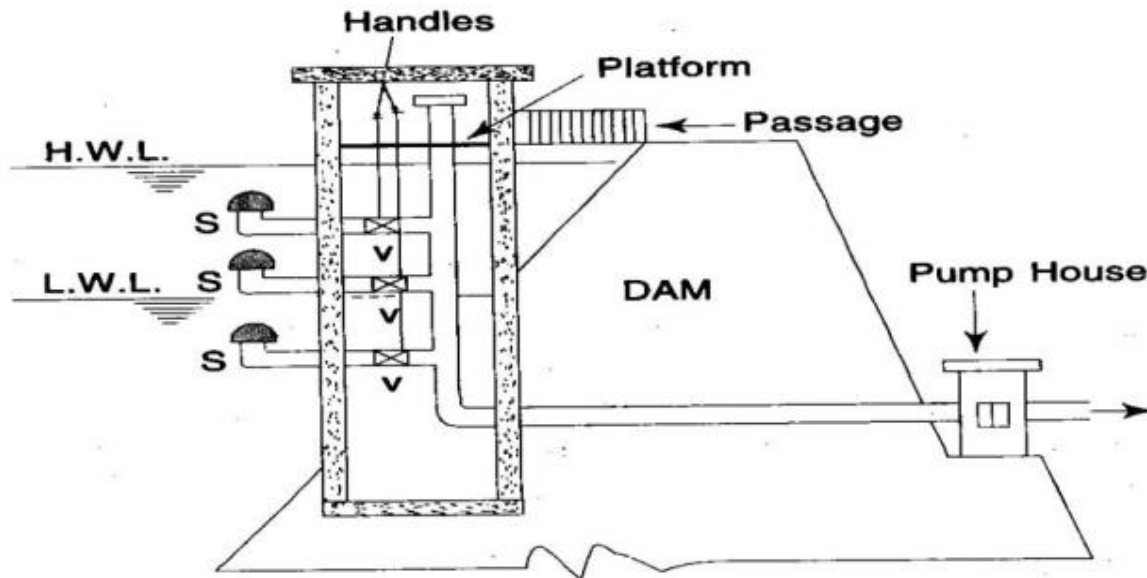
- A submersible rectangular chamber is constructed at the bed of the lake below the low water level. So as to draw water in dry season also.
- The top cover of the chamber consists of several holes having gratings on it to prevent the entry of debris, aquatic life, weeds etc to the chamber.
- A bell mouthed pipe is provided in the chamber which contain screen at the top. It is connected to pumping unit through suction pipe to draws water from the chamber and delivers to the

treatment plant.



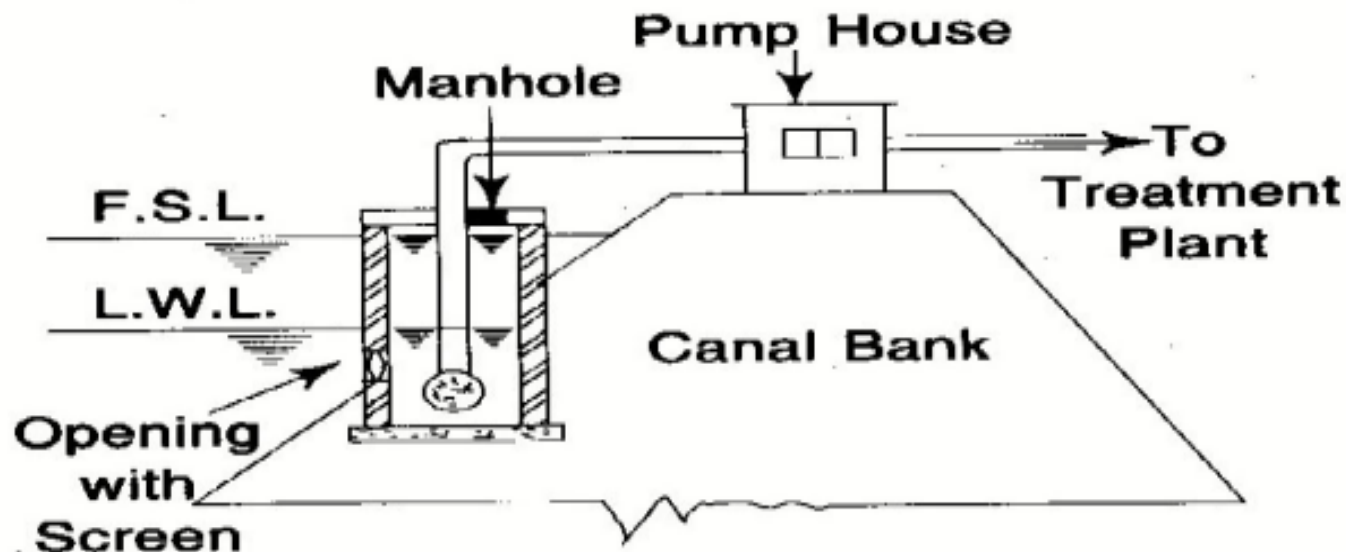
Reservoir Intake

- If a non perennial becomes the only source of water for a town, then the weir or dam may be constructed across the river to form reservoir. However, an intake well is constructed on the body of the weir or dam in such way that the water can be tapped throughout the year.
- The intake pipes which have screen at the ends are fitted at different level to a vertical pipe which provided inside the well. This vertical pipe again connected to the treatment plants.



Canal intake

- It is a very simple structure constructed on the bank of the canal. The well may be circular or rectangular and it is constructed with masonry work. It has an opening on its side provided with screen.
- An inlet pipe is inserted in to the well extending up to the L.W.L of the canal for drawing water and it carries a hemispherical screen at the end.
- A manhole is provided on the well cap for inspection work. The intake pipe is connected to the pumping unit for sending water to treatment unit.



DISTRIBUTION OF WATER

Requirement of Distribution System

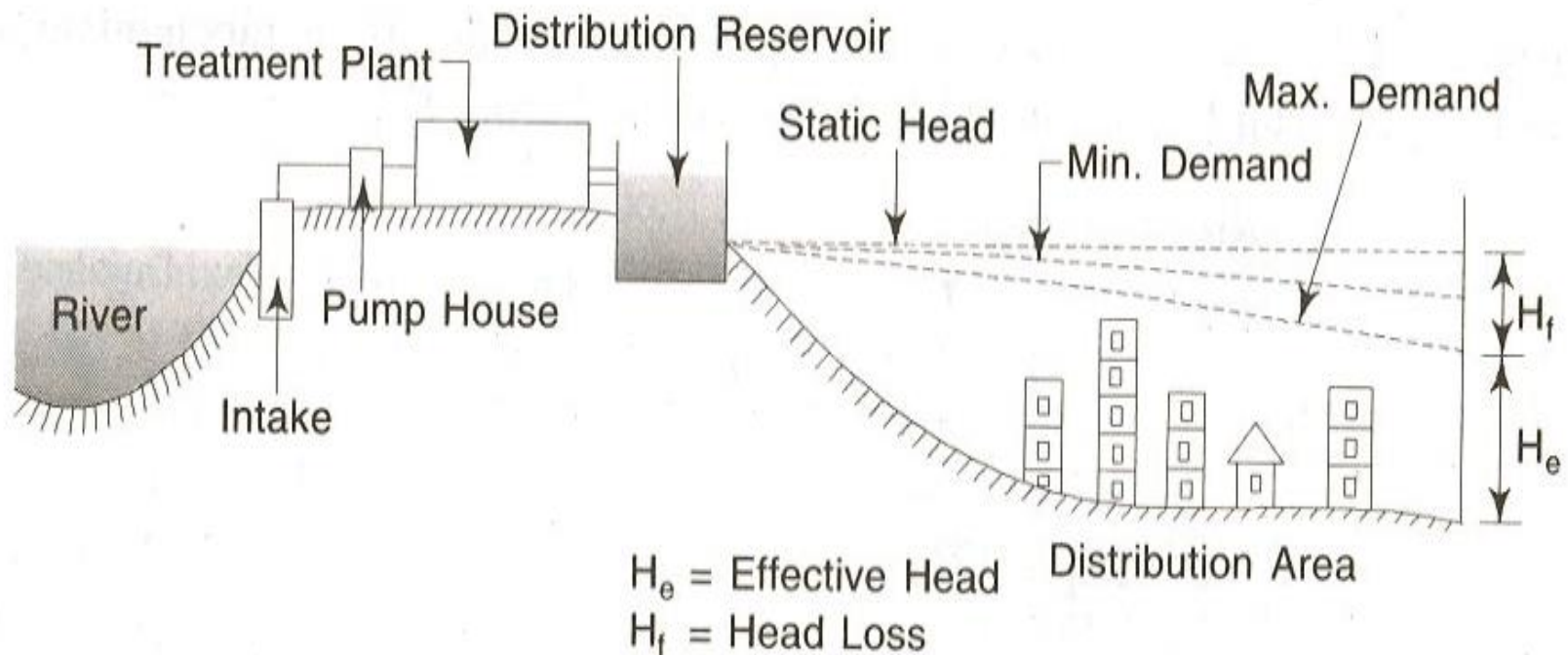
- ✓ The should convey the treated water up to consumers with the same degree of purity
- ✓ The system should be economical and easy to maintain and operate
- ✓ The diameter of pipes should be designed to meet the fire demand
- ✓ It should safe against any future pollution. As per as possible should not be laid below sewer lines.
- ✓ Water should be supplied without interruption even when repairs are undertaken
- ✓ The system should be so designed that the supply should meet maximum hourly demand.

System of Distribution

- For efficient distribution it is required that the water should reach to every consumer with required rate of flow. Therefore, some pressure in pipeline is necessary, which should force the water to reach at every place.
- Depending upon the methods of distribution, the distribution system is classified as the follows:
 - ✓ Gravity system
 - ✓ Pumping system
 - ✓ Dual system or combined gravity and pumping system

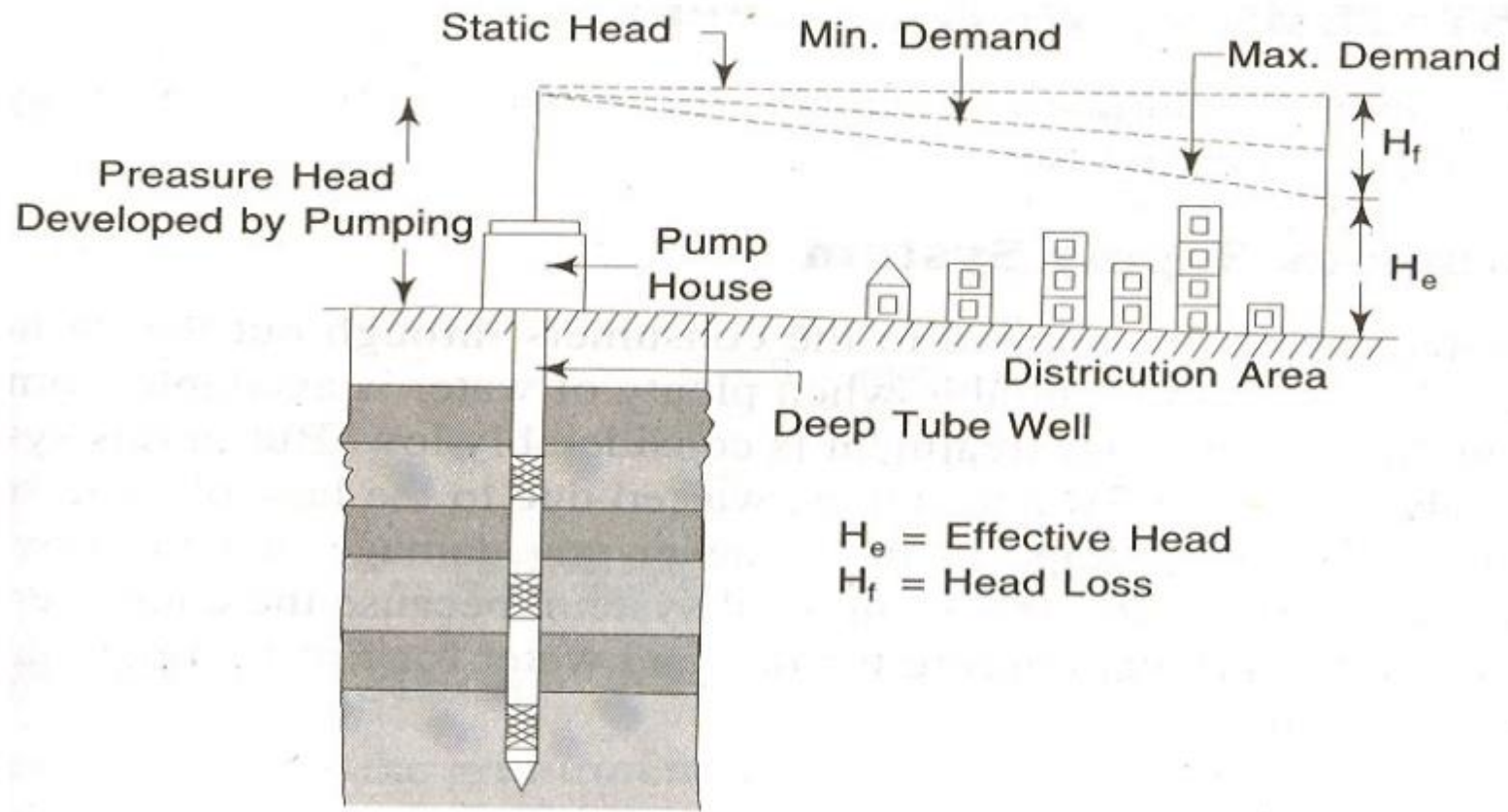
Gravity System

- In this system, the water flows under the force of gravity from the distribution reservoir to the distribution area.
- This system is suitable when the source of water treatment plant and the distribution reservoir are situated at a high level than the distribution area.



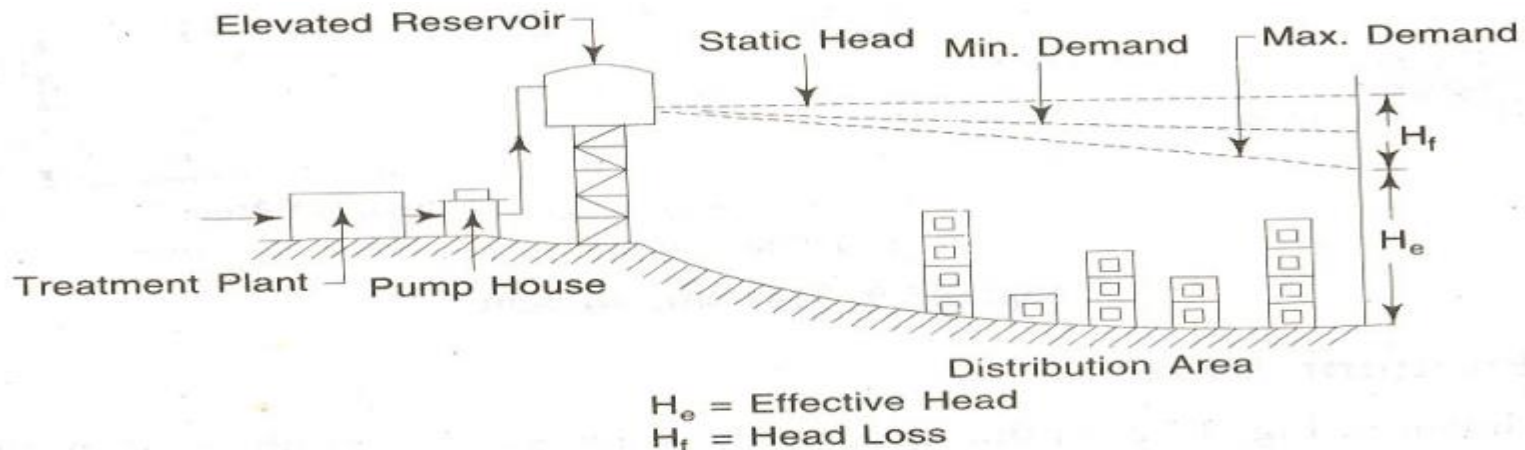
Pumping System

- In this system, the water is directly pumped in the main. Since the pumps have to work at different rates in a day, the maintenance cost will increase.



Dual System

- In this system, the pumping and gravity both systems are utilized simultaneously when required.
- Normally, the pumps are operated at a constant speed to meet the average demand of water. So, during the period of low demand, the excess water is stored in an elevated reservoir. During the period of peak demand, the water is supplied by pumping and from the elevated reservoir simultaneously.
- This system is fairly reliable b/c in the case of failure of pumping the water supply can be continued for some period from the reservoir.



Methods of Supply of Water

- The water may be supplied to the consumers by either of the two systems

Continuous System

- This is the best system and water is supplied for all 24 hours. This system is possible when there is adequate quantity of water for supply.
- In this system less diameter of pipes are required and rusting of pipes will be less. Losses will be more if there are leakages in the system.

Intermittent System

If plenty of water is not available, the supply of water is divided into zones and each zone is supplied with water for fixed hours in a day or on alternate days.

Cont...

The system has following disadvantages:

- ✓ Consumers have to store water for non-supply hours.
- ✓ Bigger sized pipes are to be laid, because full day's supply is to be provided within few hours of supply.
- ✓ Pipelines are likely to rust faster due to alternate wetting and drying. This increases the maintenance cost.
- ✓ There is also pollution of water by ingress of polluted water through leaks during non-flow periods.
- ✓ More wastage of water due to the tendency of the people to store more water than required quantity and to waste the excess to collect fresh water each time.

Layouts of Distribution System

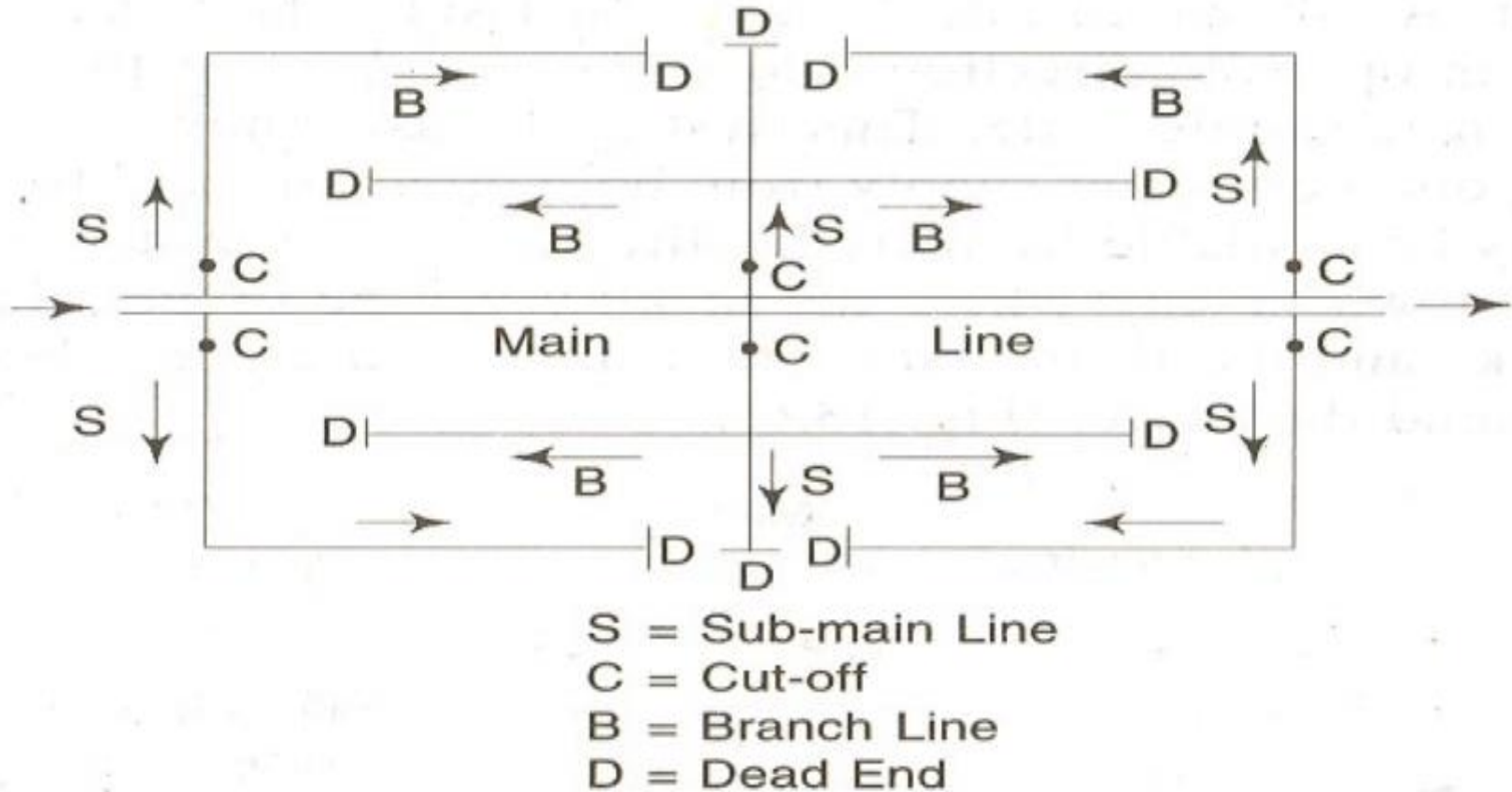
Generally in practice there are four different systems of distribution which are used. They are:

- ✓ Dead End or Tree system
- ✓ Grid Iron system
- ✓ Circular or Ring system
- ✓ Radial system

Dead end or Tree System

- ✓ In this system, a main line is taken from the reservoir along the main road. The sub-mains are taken suitably from the main line. Cut-off valves are provided at the entry of sub-mains.
- ✓ From the sub mains, the branch lines are taken from which service connections are give to consumer through the ferrule. The end of the sub-mains and branch lines are stopped by scour valves which are known as dead – ends.
- ✓ In this system water flows in one direction only into sub-mains and branches.

- Due to the dead – ends, there is no free circulation of water and the water remains stagnant within the pipe line.
- This system is suitable for regular developing town or city.



Advantages

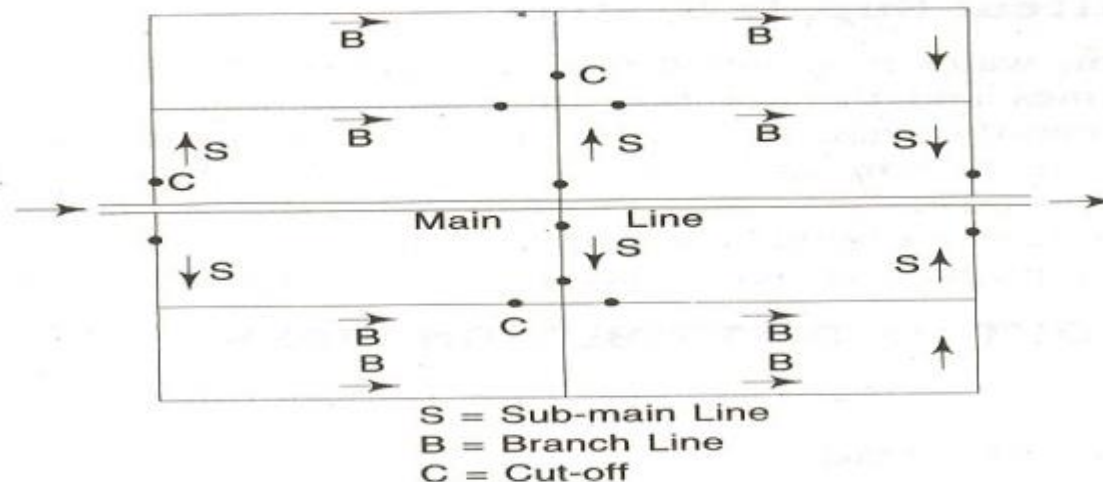
- ✓ Discharge and pressure at any point in the distribution system is calculated easily.
- ✓ The valves required in this system of layout are comparatively less in number.
- ✓ The diameter of pipes used are smaller and hence the system is cheap and economical.
- ✓ The laying of water pipes is used are simple.

Disadvantages

- ✓ There is stagnant water at dead ends of pipes causing contamination.
- ✓ During repairs of pipes or valves at any point the entire downstream end are deprived of supply.
- ✓ The water available for firefighting will be limited in quantity.

Grid Iron System

- From the mains water enters the branches at all junctions in either direction into sub-mains of equal diameters.
- In this system, the main line, the sub-main lines, and the branch lines are interconnected. So, there is free circulation of water through the pipe lines. Cutt-off valves are provided at each junction point so that the repair works may be conducted at a particular area without disturbing the whole area.
- In this system the length of the pipe is too long, and hence it is very costly. It is suitable for town or city having rectangular layout of roads.



Advantages

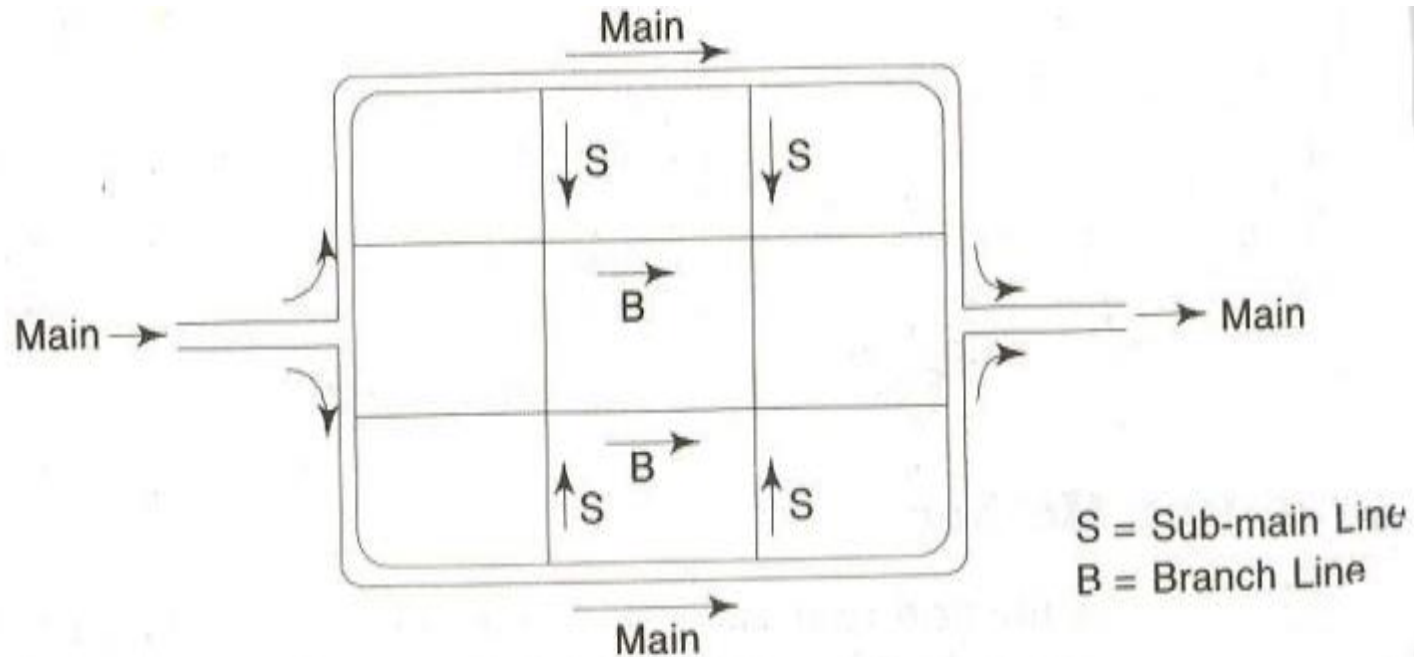
- ✓ As water is supplied from both the sides at any point, very small distribution area will be affected during repair.
- ✓ Every point receives supply from two directions and with higher pressure
- ✓ In case of fire, more quantity of water can be diverted towards the affected area, by closing the valves of nearby localities.
- ✓ There is free circulation of water and hence it is not liable for pollution due to stagnation.

Disadvantages:

- ✓ More length of pipes and number of valves are needed and hence there is increased cost of construction
- ✓ Calculation of sizes of pipes and working out pressures at various points in the distribution system is laborious, complicated and difficult.

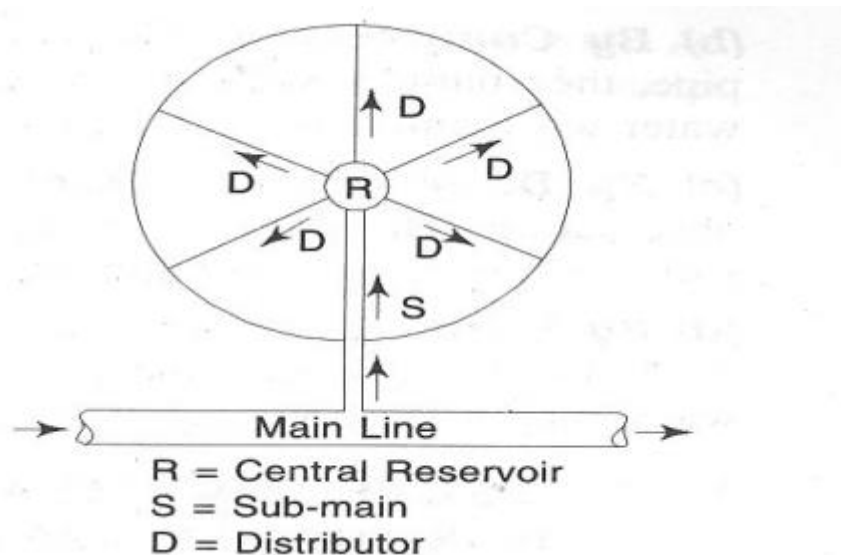
Circular or Ring System

- Supply to the inner pipes is from the mains around the boundary. It has the same advantages as the grid-Iron system. Smaller diameter pipes are needed.
- The advantages and disadvantages are same as that of grid-Iron system.



Radial System

- In this system, the town or city is divided into various circular or square zones and distribution reservoirs are placed at the centre of each zone. The distributor lines are laid radially from reservoir towards the periphery of each zone.
- In this system the water from the main reservoir is allowed to flow through the main pipe and sub main pipe and collected at distribution reservoir of each zone. The water is supplied to consumer through distributor pipe lines.



Service Reservoir

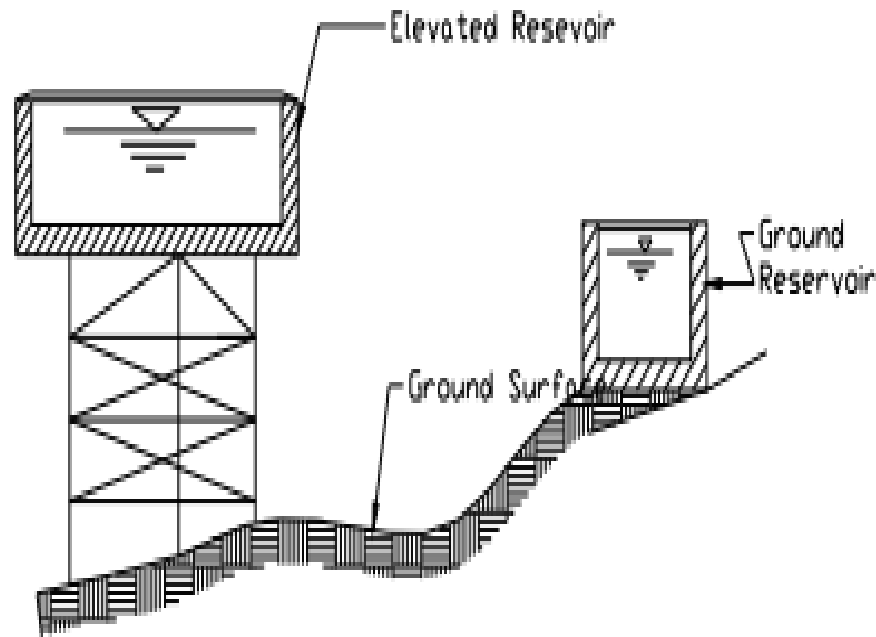
The Service Reservoir is also known as distribution reservoirs. It's has four main function.

- ✓ To balance or equalize (allow a uniform rate) the supply and demand over a long period of high consumption.
- ✓ Provide a supply during a failure or shutdown of treatment plant, pumps or trunk main.
- ✓ To give a suitable pressure for the distribution system and reduces pressure fluctuations there in.
- ✓ To provide a reserve of water to meet fire and other emergency demand.

Types of Service Reservoirs

Generally, there are two types of service reservoirs:

1. Surface reservoir (Ground Reservoir or Non-elevated)
2. Elevated reservoir (Over head Tank)

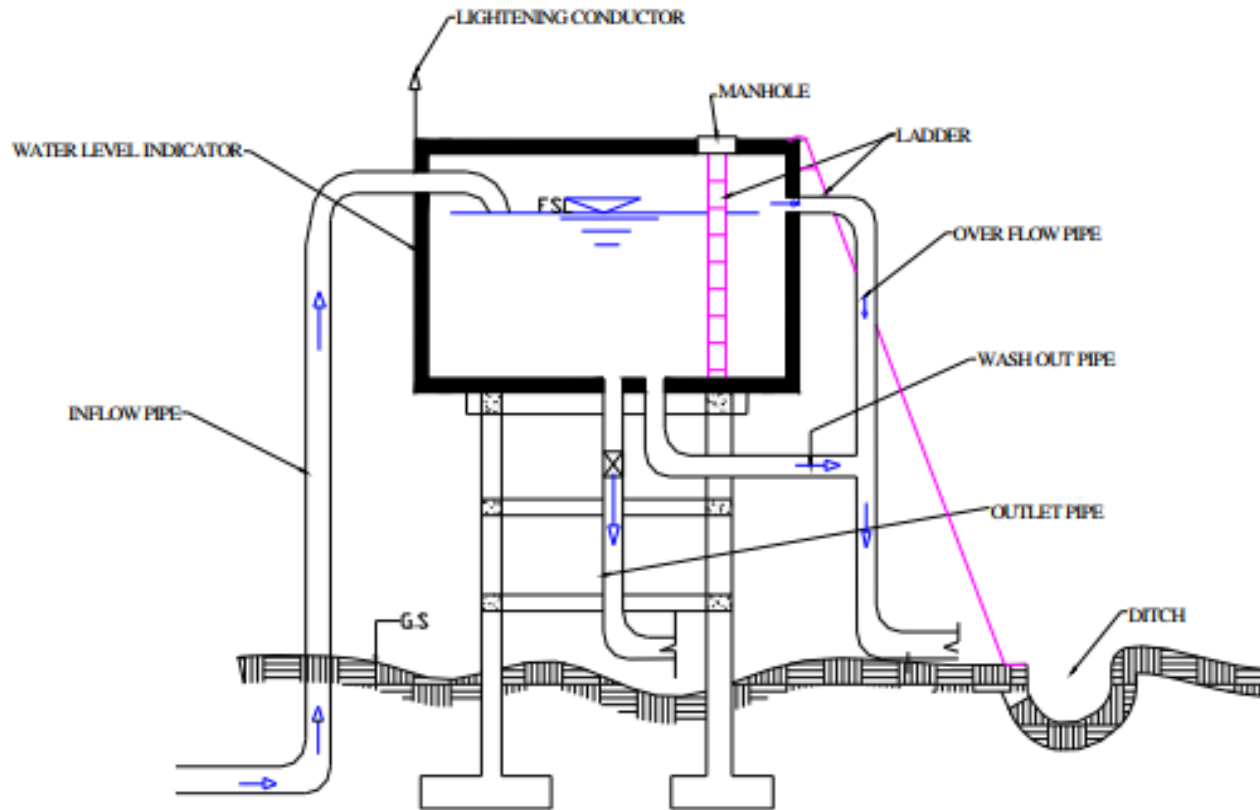


Accessories of Service Reservoirs

The service reservoirs are to be provided with the following accessories:

- ✓ **Inlet Pipe** : For the entry of water
- ✓ **Ladder** : To reach the top of the reservoir and then to the bottom of the reservoir, for inspection and cleaning
- ✓ **Lightening Conductor** : In case of elevated reservoirs for the passage of lightening
- ✓ **Manholes** : For providing entry to the inside of reservoir for inspection and cleaning
- ✓ **Outlet pipe**: For the exit of water
- ✓ **Outflow Pipe** : For the exit of water above full supply level

- ✓ **Vent pipes** : For free circulation of air
- ✓ **Washout pipe** : For removing water after cleaning of the reservoir
- ✓ **Water level indicator**: To know the level of water inside the tank from outside



Determination of Storage Capacity of Reservoir

The total capacity of the service reservoir is determined by adding the quantity of water required for various purposes. These are for balancing reserve, for Breakdown reserve and for fire reserves.

- ✓ **For Balancing Reserve:** - This requires equalizing b/n the fluctuations of demand rate with the constant rate of pumping.
Balancing Storage: - Max. Surplus + Max. Deficient
- ✓ **For Break down Reserve:-** This is the amount of storage during the break down of pumps.
From 2 – 3 hrs pumping capacity is provided against this storage.
- ✓ **For Fire reserve:** - This is storage required for fighting a fire out break.
A provision of 5 to 10% of the total storage is sufficient to meet the requirement.
- ✓ The total reservoir storage can finally be worked out by adding all the three storages.

Example 1:

A small town with a design population of 1600 is to be supplied water at 150liters per capita per day. The demand of water during different periods is given in the following table:

Time (hr)	0-3	3-6	6-9	9 -12	12 - 15	15 18	18 -21	21 24
Demand (1000liters)	20	25	30	50	35	30	25	25

Determine the capacity of a balancing reserve if pumping is done 24 hours at a constant rate.

Solution:

Per capita water consumption = 150l/c/d

Total water demand = demand * population = $150 \times 1600 = 240,000$ liters

Rate of pumping = $240,000/24 = 10,000$ lit/hr = 30,000lit/3hr

a) **Analytical method**

Time	Pumping	Demand	Cum. Supply	Cum. Demand s	Surplus	Deficit
0 - 3	30,000	20,000	30,000	20,000	10,000	
3 - 6	30,000	25,000	60,000	45,000	15,000	
6 - 9	30,000	30,000	90,000	75,000	15,000	
9 - 12	30,000	50,000	120,000	125,000	0	5,000
12 - 15	30,000	35,000	150,000	160,000		10,000
15 - 18	30,000	30,000	180,000	190,000		10,000
18 - 21	30,000	25,000	210,000	215,000		5,000
21 - 24	30,000	25,000	240,000	240,000		0

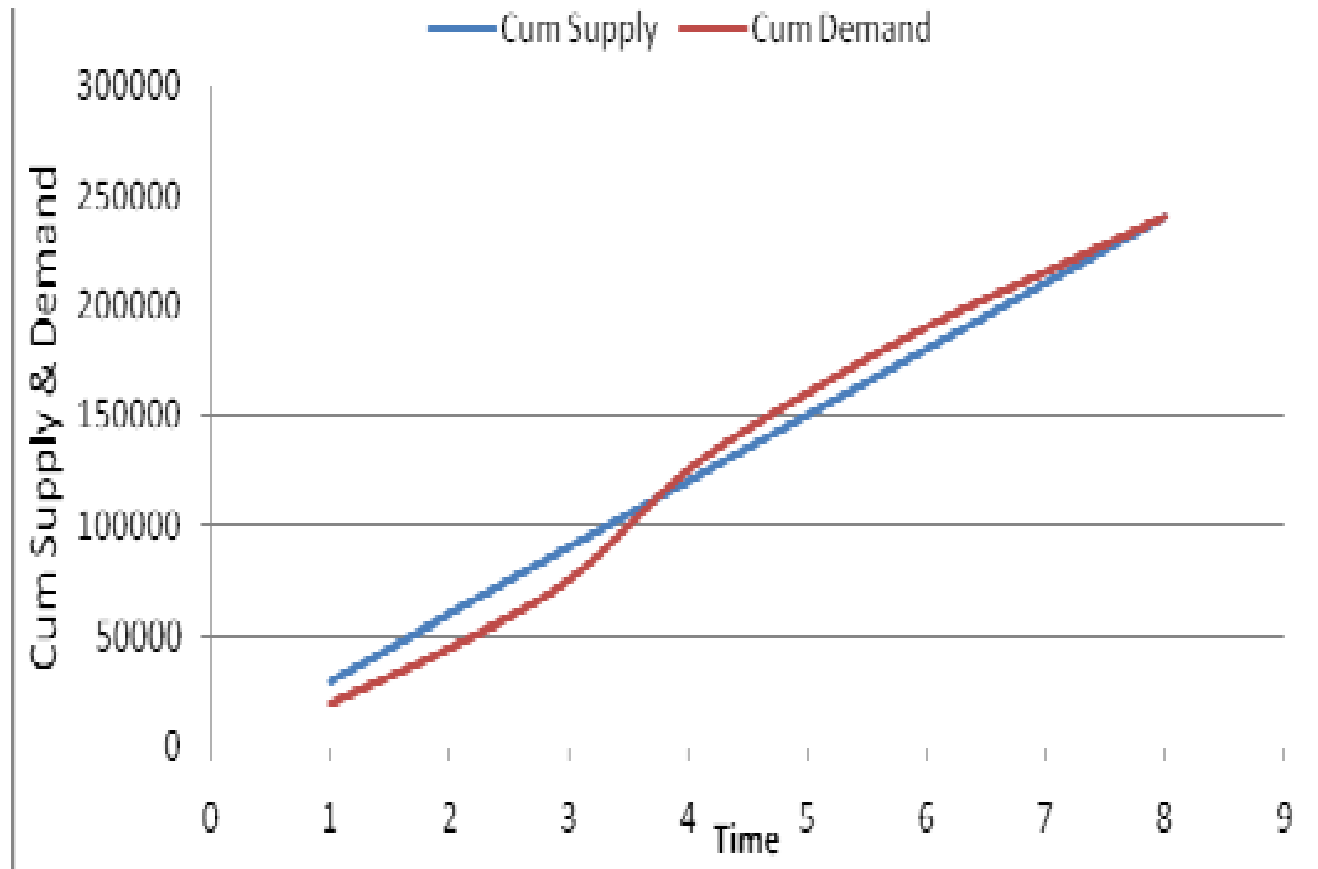
Maximum cumulative surplus = 15,000 liters

Maximum cumulative deficit = 10,000 liters

Balancing storage = 15000 + 10000 = 25,000lit = $25m^3$

If the reservoir is circular with depth, $h = 3.0$ m, $d = \sqrt{25 * \frac{4}{3\pi}} = 4.3$ m

Mass curve method



Example 2: Consider example 1, if the pumping is done for:

- a) Eight hours from 8 hrs to 16 hrs
 - b) Eight hrs from 4 hrs to 8 hrs and again 16 hours to 20 hrs.
- Calculate the capacity of the balancing reserve.

Solution:

Total water demand = 240,000lit/hr

Rate of pumping = $240,000/8 = 30,000\text{l/h} = 90,000\text{lit/3hrs}$

a) Eight hours from 8 hrs to 16 hrs

A) Analytical Method

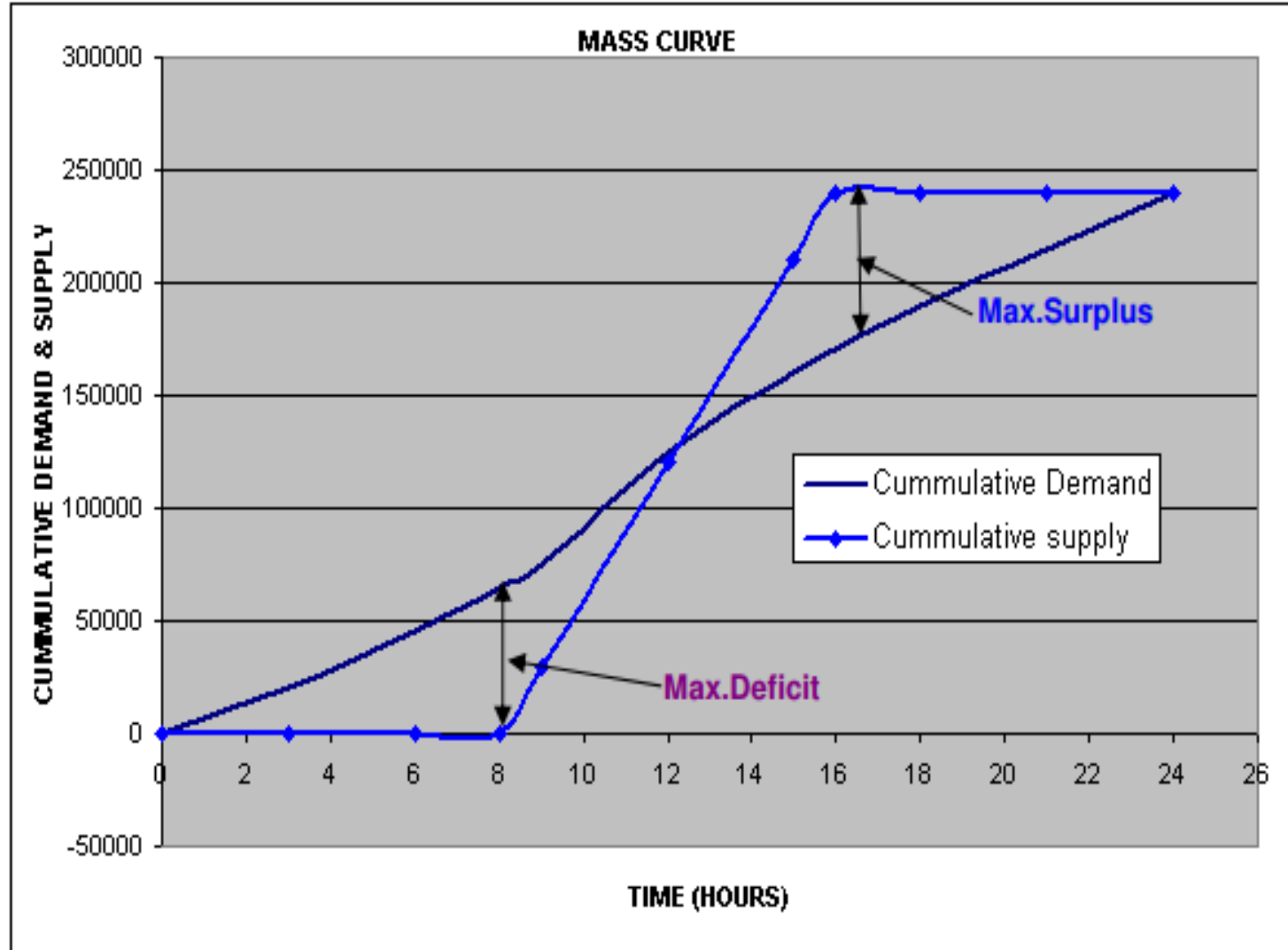
Time	Pumping	Demand	Cum. Supply	Cum. Demand	Surplus	Deficit
0 - 3	0	20000	0	20000		20000
3 - 6	0	25000	0	45000		45000
6 - 8	0	20000	0	65000		65000
8 - 9	30000	10000	30000	75000		45000
9 - 12	90000	50000	120000	125000		5000
12 - 15	90000	35000	210000	160000	50000	
15 - 16	30000	10000	240000	170000	70000	
16 - 18	0	20000	240000	190000	50000	
18 - 21	0	25000	240000	215000	25000	
21 - 24	0	25000	240000	240000	0	0

Maximum cumulative surplus = 70,000

Maximum cumulative deficit = 65,000

Balancing storage, S = 135,000lit = 135m³

B) Graphical Method



b) Eight hrs from 4 hrs to 8 hrs and again 16 hours to 20 hrs.

A) Analytical Method

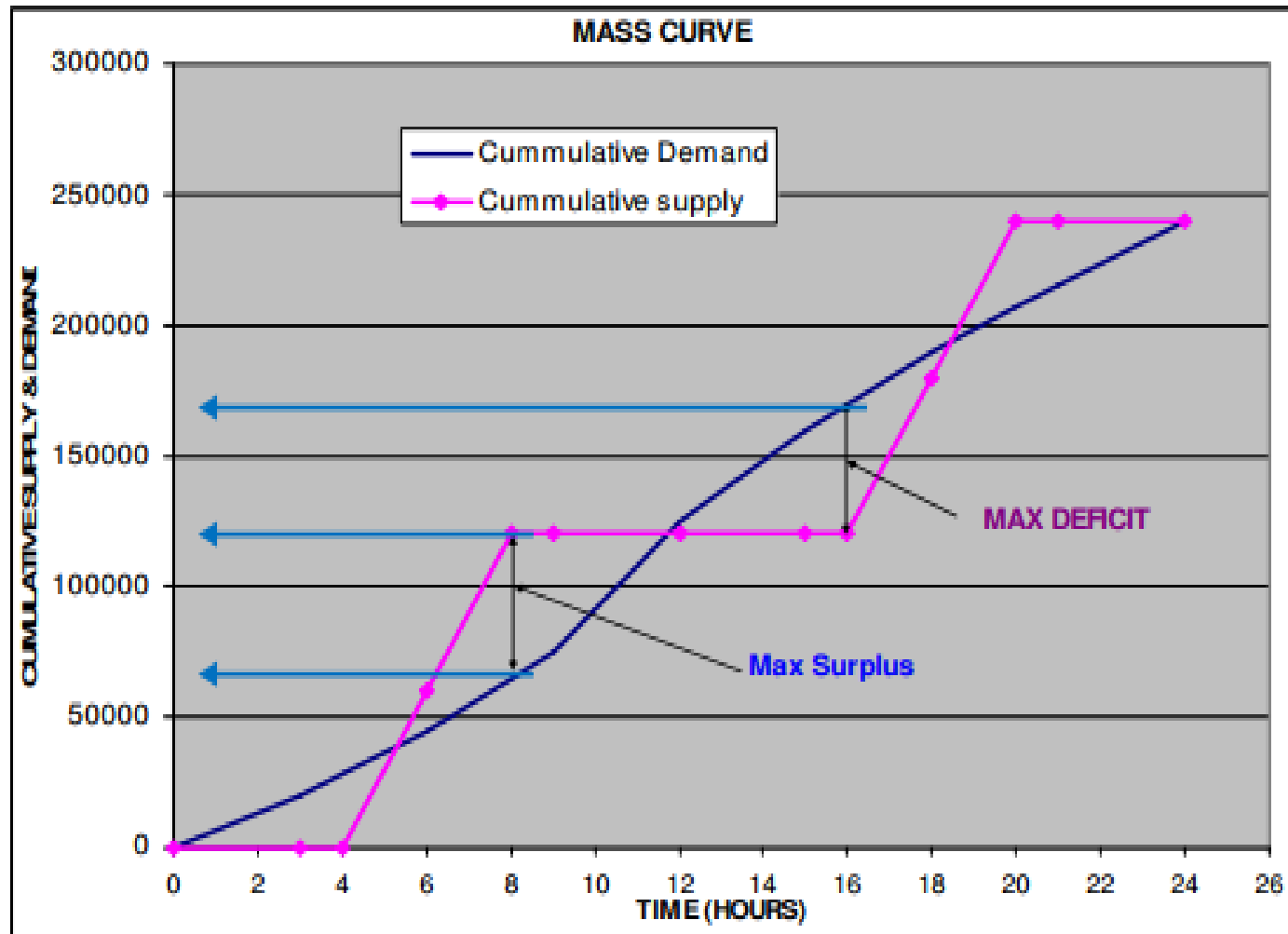
Time	Pumping	Demand	Cum. Supply	Cum. Demand	Surplus	Deficit
0 - 3	0	20000	0	20000		20000
3 - 4	0	8333	0	28333		28333
4 - 6	60000	16667	60000	45000	15000	
6 - 8	60000	20000	120000	65000	55000	
8 - 9	0	10000	120000	75000	45000	
9 - 12	0	50000	120000	125000		5000
12 - 15	0	35000	120000	160000		40000
15 - 16	0	10000	120000	170000		50000
16 - 18	60000	20000	180000	190000		10000
18 - 20	60000	16667	240000	206667	33333	
20 - 21	0	8333	240000	215000	25000	
21 - 24	0	25000	240000	240000	0	0

Maximum cumulative surplus = 55,000

Maximum cumulative deficit = 50,000

Balancing storage, $S = 105,000\text{lit} = 105\text{m}^3$

B) Graphical Method



(Graph paper is required)

Depth Service Reservoirs

➤ Depths usually used are as follows

Size (m ³)	Depth of water (m)
Up to 3500	2.5 to 3.5
3500 to 15,000	3.5 to 5.0
Over 15,000	5.0 to 7.0

These figures don't apply to water towers or pre-stressed concrete reservoirs.

Factors

influencing depth for a given storage are:

1. Depth at which suitable foundation conditions are encountered
2. Depth at which the out let main must be laid
3. Slope of ground, nature and type of back fill
4. The need to make the quantity of excavated material approximately equal to the amount required for backing, so as to reduce unnecessary carting of surplus material to tip.
5. The shape and size of land available

Shape of service reservoir

- Circular reservoir is geometrically the most economical shape, giving the least amount of walling for a given volume and depth
- However, this shape is seldom adopted .It is unsuitable for division in to two compartments, which would allow one half to be drained for maintenance without taking the whole reservoir out of service.
- rectangular reservoir usually proves most economical when division walls are incorporated .

Pipes used in the water distribution system

Pipe materials used in transmission and distribution systems must have the following characteristics:

- ✓ Adequate tensile strength and bending strength to withstand external loads.
- ✓ High bursting strength to withstand internal water pressure.
- ✓ Ability to resist impact loads to water flow suitable for handling and joining facilities.
- ✓ Resistance to both internal and external corrosion.

A pipe material is selected based on various conditions:

- ✓ Cost
- ✓ Type of water to be conveyed
- ✓ Carrying capacity of the pipe
- ✓ Maintenance cost
- ✓ Durability, etc.

The types of pipes used for distributing water include:

- ✓ Cast iron pipe
- ✓ Steel pipe
- ✓ Concrete pipe
- ✓ Plastic pipe
- ✓ Asbestos cement pipe
- ✓ Copper pipe
- ✓ Lead pipe

Cast iron pipes

Advantages:

- ✓ The cost is moderate
- ✓ The pipes are easily joined
- ✓ The pipes aren't subjected to corrosion
- ✓ The pipes are strong and durable
- ✓ Service connections can be made easily

Disadvantage:

- ✓ The breakage of this pipe is large
- ✓ Carrying capacity decreases with increase in life

Galvanized Iron Pipes

Advantages:

- ✓ The pipes are cheap
- ✓ Light in weight and easy to handle and transport
- ✓ Easy to join

Disadvantage:

- ✓ These pipes are liable to incrustation (due to deposition of some materials inside part of pipe)
- ✓ Can be easily affected by acidic or alkaline water
- ✓ Short useful life

Plastic Pipes

Advantages:

- ✓ The pipes are cheap
- ✓ The pipes are flexible and possess low hydraulic resistance (less friction)
- ✓ They are free from corrosion
- ✓ The pipes are light in weight and it is easy to bend, join and install them
- ✓ The pipes up to certain sizes are available in coils and therefore it becomes easy to transport

Disadvantage:

- ✓ The coefficient of expansion for plastics is high, the pipes are less resistant to heat
- ✓ Some types of plastics may impart taste to the water

Determination of Pipe Sizes

- ✓ Permissible velocities for best results for different pipe sized pipes are within the range of 0.3 to 2 m/s.
- ✓ For small size pipes flowing with high velocity of flow, loss of head due to friction is more. Once the velocity of flow is established loss of head due to friction, bends and other reasons can be computed.

The size of the pipe used in the water distribution system or the velocity of flow through the pipe can be determined by one of the following formulas:

Darcy –Weisbach formula:

$$h_f = \frac{fLv^2}{2gd}$$

Where, h_f = head loss (m)

f = friction factor (which is related to the relative roughness of the pipe material & the fluid flow characteristics)

L = length of pipe (m)

V = velocity of flow (m/s)

D = diameter of pipe (m)

g = Acceleration due to gravity

- ✓ The major energy loss (head loss) in pipes can be found by Darcy –Weisbach formula.

Hazen-Williams formula

$$Q = 0.278 C D^{2.63} S^{0.54} \quad S = \frac{h_f}{L}$$

Where,

C = Coefficient that depends on the material and age of the pipe

S = Hydraulic gradient (m/m)

Table - Values of C for the Hazen-Williams formula

Pipe Material	C
Asbestos Cement	140
Cast Iron	
▪ Cement lined	130 – 150
▪ New, unlined	130
▪ 5years-old, unlined	120
▪ 20 years old, unlined	100
Concrete	130
Copper	130 - 140
Plastic	140 - 150
New welded Steel	120
New riveted Steel	100

Nomographs shown in fig – solve the equation for $C = 100$. Given any two of the parameters(Q , D , h_f or V) the remaining can be determined from the intersections along a straight line drawn across the nomograph

Exercise

For $Q = 30\text{l/s}$, $D = 200\text{mm}$, $C = 100$, $L = 1500$, Find h_f . By using Hazen-Williams formula and nomograph ?

Manning's Formula:

$$Q = \frac{AR^{2/3}S^{1/2}}{n} \quad R = \frac{D}{4} \quad S = \frac{h_f}{L}$$

Where, n = Coefficient of roughness depending on pipe material, usually

$n = 0.013 \rightarrow$ GI pipes

$n = 0.009 \rightarrow$ Plastic pipes

$n = 0.015 \rightarrow$ Clay concrete pipes

- ✓ The most common pipe flow formula used in design and evaluation of a water distribution system is the Hazen-Williams' formula.

Water supply pipes sizes commercially available are given in the following table:

Metric sizes (mm)	10	20	25	30	40	50	60	80	100	150	200	250	300
English (In)	1/2	3/4	1	1 1/4	1 1/4	2	2 1/2	3	4	6	8	10	12

Metric sizes (mm)	350	375	400	450	500	525	600	675	750	900	950	1050
English (In)	14	15	16	18	20	21	24	27	30	36	38	42

Example 1:

Given

Total population of a town = 80,000

Average daily consumption of water = 150liters/capita/day

If the flow velocity of an outlet pipe from intake = 1.5 m/s, determine the diameter of the outlet pipe.

Solution

$$\begin{aligned}\text{Total flow, } Q &= \text{Demand} * \text{Population} = 150 * 80,000 = 12 \times 10^6 \text{ lit/day} \\ &= \frac{12 \times 10^6}{24 \times 60 \times 60 \times 10^3} = 0.1389 \text{ m}^3/\text{s}\end{aligned}$$

$$\text{Required pipe area, } A = \frac{Q}{V} \Rightarrow \frac{\pi D^2}{4} = \frac{Q}{V} \Rightarrow D = \sqrt{\frac{4Q}{4V}} = \sqrt{\frac{0.1389 * 4}{1.5 * \pi}} \approx 343 \text{ mm}$$

But the pipe size available on the market is 300mm & 350mm, then take $D = 350 \text{ mm}$

Example 2:

A town has a population of 100,000 persons. It is to be supplied with water from a reservoir situated at a distance of 6.44km. It is stipulated that one-half of the daily supply of 140lit/capita should be delivered in 6 hours. If the loss of head is estimated to be 15m, calculate the size of pipe. Assume $f = 0.04$.

Solution

$$\text{Total daily supply} = \frac{140 \times 100,000}{10^3} = 14,000 m^3$$

Since half of this quantity is required in 6 hours

$$\text{Maximum flow} = \frac{14,000}{2 \times 6 \times 60 \times 60} = 0.324 m^3/s$$

According to the Darcy-Weisbach formula:

$$h_f = \frac{f l Q^2}{12.1 d^5} \quad \text{Where, } h_f = 15m, f = 0.04, L = 6440m$$

$$15 = \frac{0.04 \times 6440 \times (0.324)^2}{12.1 \times d^5} \Rightarrow d = \sqrt[5]{\frac{0.04 \times 6440 \times (0.324)^2}{15 \times 12.1}} \approx 0.683m = 683mm$$

But available pipe sizes 675mm & 750mm, take 750mm diameter pipe

Procedure of Analyzing Pipe Size and Pressure

Hardy Cross Method

- Hardy cross method is commonly employed method for the analysis of pressures and pipe diameters
- Analysis of a pipe network is essential to understand or evaluate a pipe network system. In a branched pipe network, the pipe discharges are unique and can be obtained simply by applying discharge continuity equations at all the nodes .
- The method is based on the following basic equations of continuity of flow and head loss that should be satisfied:
- The sum of inflow and outflow at a node should be equal:
 $\sum Q_i = q_j$ for all nodes $j = 1, 2, 3, \dots, \dots$
where Q_i is the discharge in pipe i meeting at node (junction) j ,
and q_j is nodal withdrawal at node j

The algebraic sum of the head loss in a loop must be equal to zero:
 $\sum_{loop\ k} K_i Q_i = 0$ for all loops $k = 1, 2, 3, \dots, k_L$,

Where,

$$K_i = \frac{8f_i L_i}{\pi^2 g D_i^5},$$

Where i = pipe link number to be summed up in the loop k

$$\Delta Q_k = - \frac{\sum_{loop\ k} K_i Q_i |Q_i|}{2 \sum_{loop\ k} K_i |Q_i|}.$$

Knowing ΔQ_k , the corrections are applied as

$$Q_{i\ new} = Q_{i\ old} + \Delta Q_k \quad \text{for all } k.$$

5.APPURTENANCES IN THE DISTRIBUTION SYSTEM

Appurtenances :-are various devices fixed along the water distribution system.

The necessity of the various appurtenances in distribution system are as follows:-

- ✓ To control the rate of flow of water
- ✓ To release or admit air into pipeline according to the situation
- ✓ To prevent or detect leakages
- ✓ To meet the demand during emergency and
- ✓ Ultimately to improve the efficiency of the distribution

The following are the some of the fixtures used in the distribution system.

- ✓ Valves
- ✓ Fire hydrants and
- ✓ Water meter

TYPES OF VALVES

The following are the various types of valves named to suit their function.

SLUICE VALVES

- ✓ These are also known as gate-valves or stop valves. These valve control the flow of water through pipes .

CHECK VALVE or REFLUX VALVE

- ✓ These valves are also known as non-return valves. A reflux valve is an automatic device which allows water to go in one direction only
- ✓ When the flow of water in this direction ceases, the water tries to flow in a backward direction. But this valve prevents passage of water in the reverse direction.

AIR VALVES

AIR INLET VALVES

These valves open automatically and allow air to enter into the pipeline so that the development of negative pressure can be avoided in the pipelines.

AIR RELIEF VALVES

- ✓ Some times air is accumulated at the summit of pipelines and blocks the flow of water due to air lock.
- ✓ In such cases the accumulated air has to be removed from the pipe lines. This is done automatically by means of air relief valves.

DRAIN VALVES

- ✓ These are also called wash out valves they are provided at all dead ends and depression of pipelines to drain out the waste water. These are ordinary valves operated by hand.

SCOUR VALVES

- ✓ These are similar to blow off valves. They are ordinary valves operated by hand.
- ✓ They are located at the depressions and dead ends to remove the accumulated silt and sand. After the complete removal of silt; the value is to be closed

WATER METER

- ✓ These are the devices which are installed on the pipes to measure the quantity of water flowing at a particular point along the pipe.
- ✓ The readings obtained from the meters help in working out the quantity of water supplied and thus the consumers can be charged accordingly.

FIRE HYDRANTS

A hydrant is an outlet provided in water pipe for tapping water mainly in case of fire. They are located at 100 to 150 m apart along the roads and also at junction roads.

A good fire hydrant

- ✓ Should be cheap
- ✓ Easy to connect with hose
- ✓ Easily detachable and reliable
- ✓ Should draw large quantity of water