BHUBANANANDA ODISHA SCHOOL OF ENGINEERING, CUTTACK

DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTE ON: WATER SUPPLY AND WASTE WATER ENGINEERING, (TH-4), 5th SEMESTER

PREPARED BY: IPSITA THAKUR

LECTURER IN CIVIL ENGINEERING DEPT.

BOSE, CUTTACK

Chapter 1: Introduction to Water Supply, Quantity and Quality of water

Topics to be covered:
1.1 Necessity of treated water supply
1.2 Per capita demand, variation in demand and factors affecting demand
1.3 Methods of forecasting population, Numerical problems using different methods
1.4 Impurities in water – organic and inorganic, Harmful effects of impurities
1.5 Analysis of water –physical, chemical and bacteriological
1.6 Water quality standards for different uses

1.1 Necessity of treated water supply

- To provide the community with good quality potable water with sufficient quantity to meet their requirements
- To prevent the population from deadly water Bourne diseases such as cholera, dysentery etc by providing them with treated good quality water

1.2. Per capita demand, variation in demand and factors affecting demand

Per capita water demand (liters/capita/day)

$$= \frac{Total\ annual\ average\ water\ consulption\ of\ community}{population \times 365}$$

Water demand of a community (IS 1172:1993)

- Domestic water demand
- Industrial water demand
- Institutional or commercial water demand
- Demand for public use
- Fire demand
- Demand to compensate losses and theft

Domestic/residential water demand

- It includes water requirements for drinking, cooking, bathing, washing of clothes, utensils etc.
- Provision is sometimes made to domestic animal.
- IS 1172-1171 recommends per capita water consumption of 135 L/day?

Average domestic water consumption in an Indian city:

Use	Consumption in L/day /person
Drinking	5
Cooking	5
Bathing	55

Washing clothes	20
Washing utensils	10
Washing and cleaning of houses	10
Flushing toilet	30
Total	135

Industrial water demand

- The presence of industries near the cities has a great impact on the water demand.
- The quantity of water demand depends upon type of industries.
- For a city with moderate factors a provision of 40liters / day /capita for each purpose.

Institutional water demand

- It includes the water used in hospitals, schools, hostels, colleges, hotels, railway & bus stations, cinema halls etc.
- According to IS 1172-1171 recommendation a per capita water consumption is 45lit/day is required under this head.

Demand for public or civil use

- Water requirement for public or civil uses are :-
- Road washing
- Sanitation
- Public parks
- Fire fighting
- For road washing in the municipality area a provision of 5 liters/day /head is made.
- Similarly for sanitary purposes such as clinic public sanitary blocks, flushing, sewer system etc. A provision of 3-10 liters /day/head is made.
- Water required for maintaining public parks may be 2-3 liters/day /sq.m

Fire demand

- Water required for firefighting is known as fire demand.
- Fire may takes place due to faulty electric wires by short-circuiting, fire catching materials, explosions, bad intension of criminal people.
- Fire demand can be calculated from the following formula:
  - Kuichling's formula: $Q = 3182\sqrt{P}$
  - Boston's formula: $Q = 5663\sqrt{P}$
  - Freeman formula: $Q = 1136(p/10 + 10)$
  - National board of fire under writers formula: $Q = 4640\sqrt{p}(1-0.01\sqrt{p})$

Where Q = Quantity of water in liters /day
p= population of thousand

The unit of fire demand will be in **liters/min** for all the above formulas.

Q. Compute the fire demand for a city having population of 140,000 using various formulas.

Demand to compensate losses and theft

- Leakage & over flow from service reservoirs
- Leakage of main service pipe connections
- Leakage & losses of consumers' premises.
- Large leakage & wastage from public taps
- Losses in the supply line are many due to defective, pipe joints, crack pipes, loose, valves & fittings.
- In India a per capita water consumption of 55litres /day is required under this head.

Per capita water demand

- For the purpose of estimation of total requirement of water the demand is calculated on an average basis & is expressed in liters/day /capita
- It is obtained by dividing the quantity of water supply during the year by no. of days in the year & the no. of persons served

Per capita water demand (liters/capita/day)

$$= \frac{Total\ annual\ average\ water\ consulption\ of\ community}{population \times 365}$$

For an average, Indian town, the requirements of water in various uses are:

- Domestic use-135lpcd
- Industrial use-40 lpcd
- Public use-25 lpcd
- Institutional and commercial use-15 lpcd
- Losses & thefts-55 lpcd

  Total (per capita water demand) = 270 lpcd

Q. What will be the average quantity of water required by a city of population 50,000?

Variation in water demand:

- Seasonal variation
- Daily or hourly variation

Seasonal variation:

- The water demand varies from season to season. In summer the demand will be maximum whereas will be minimum in winter season

- People will tend to use more water in bathing, cooling, watering lawn etc. in summer season than the winter season.

Daily or hourly variation:

- In most of the Indian city the peak demand occurs in the morning & evening. During the night hour the consumption is below the average.
- This variation depends on the general habits of the people, climatic condition, and character of the city such as residential, industrial or commercial.

The variations are as follows:

Average daily water demand (Q) = Population × per capita water demand
Maximum daily water demand = $Q_{\max(daily)} = 1.8Q$
Maximum hourly water demand = $Q_{\max(hourly)} = 1.5Q_{\max(daily)} = 2.7Q$

Factors affecting water demand:

The variation in per capita water demand in Indian cities depends on following factors:

- Size & type of community
- Standard of living
- Climatic condition
- Quality of water
- Cost of water
- Water pressure
- Method of supply

Size & type of community

- The fluctuation in demand depends upon the size of the city.
- In a large city the fluctuation may be less with higher demand.
- In a small city per capita consumption is expected to be less, because there are only limited uses of water.
- The presence of industries in a small city increases its demand.

Standard of living

- The higher the standard of living, the higher the demand.
- Such as the per capita water demand of the town increase with the standard of living of the people .The people will start use of air conditioners, room coolers, maintenance of lawns, use of flush latrines, use of automatic dish washer etc. with the rise in their standard of living.

Climatic condition

- In the community located in a hot climate the water used will be increased by bathing, lawn sprinkling etc.
- Similarly in extreme cold climates the water may be wastage due to freezing in pipes resulting increase consumption.
- Hence extremes at hot & cold cause variation in demand.

- Quality of water - Poor quality of water results in a reduction in use
- Pressure in the supply - High pressure results in increase use while low pressure results in decrease use
- Method of supply - The water supply may be intermediate. Generally intermediate supply will reduce the rate of demand.
- Cost of water - If cost of water is more people will reduce the usage of water hence demand will be less and vice versa.

1.3. Methods of forecasting population, Numerical problems using different methods

Population: Population indicates total no. of human beings living in a certain area at any particular time.

Population density: It indicates the no. of persons per unit area.

Population fore casting: It is the method of forecast the population in the coming decades.

Methods of population forecasting:

- Arithmetic increase method
- Geometric increase method
- Incremental increase method
- Decrease rate of growth method

Arithmetical increase method

- It is the simplest method of population forecasting.
- In this method per decade increase in population is assumed to be constant.

Mathematically, dp/dt = k

Where dp/dt is the rate of change of population

k is the constant

Let P_0 be the latest known last decade population data

$\bar{x}$ be the arithmetic average of per decade increase in population

Population after 1 decade, $P_1 = P_0 + \bar{x}$

Population after 2decade, $P_2 = P_1 + \bar{x} = P_0 + 2\bar{x}$

Population after n decades, $P_n = P_0 + n\bar{x}$

Problem: The following is the population data of a city available from past census records. Determine the population of the city in 2011 by arithmetic increase method.

year	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**
population	**12000**	**16,500**	**26,800**	**41,l500**	**52,500**	**68,000**	**74,100**

Solution:

Year	Population	Increment per decade
1931	12,000	----
1941	16,500	4,500
1951	26,800	10,300
1961	41,500	14,700
1971	52,500	11,000
1981	68,000	15,500
1991	74,100	6,100
Total increment		62100
Average increment per decade ($\bar{x}$)		62100/6 = 10350

Latest known population (P_0) = 74,100
Number of decades (n) = (2011-1991)/10 = 2
Population after n decades, $P_n = P_0 + n\bar{x}$
= 74,100+2×10,350 = 94,800

Geometric increase method

In this method it is assumed that the % increase in population from decade to decade is constant.

Let $\bar{r}$ (or k) be the geometric average of per decade percentage increase in population (assumed to be constant)

To find future population, $\bar{r}$ is compounded with the existing population.

Population after 1 decade, $P_1 = P_0 + \frac{\bar{r}}{100} P_0 = P_0 \left(1 + \frac{\bar{r}}{100}\right)$

Population after 2 decades,

$$P_2 = P_1 + \frac{\bar{r}}{100}P_1 = P_1\left(1 + \frac{\bar{r}}{100}\right) = P_0\left(1 + \frac{\bar{r}}{100}\right)^2$$

$$Population\ after\ n\ decades, P_n = P_0\left(1 + \frac{\bar{r}}{100}\right)^n$$

$\bar{r}$ can be found out as $\bar{r} = (r_1 + r_2 + \cdots + r_n)^{\frac{1}{n}}$

Problem: The following is the population of a city available from past census records. Determine the population of the city in 2011 by Geometric increase method.

year	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**
population	**12000**	**16,500**	**26,800**	**41,l500**	**52,500**	**68,000**	**74,100**

Solution:

Year	**Population**	**Increment / decade**	**% increase / decade**
1931	12,000	________	______
1941	16,500	4,500	37.5
1951	26,800	10,300	62.42
1961	41,500	14,700	54.85
1971	52,500	11,000	26.50
1981	68,000	15,500	29.52
1991	74,100	6,100	8.97
Average % age increment per decade ($\bar{r}$)			31.07

Latest known population (P_0) = 74,100
Number of decades (n) = (2011-1991)/10 = 2

$$Population\ after\ n\ decades, P_n = P_0\left(1 + \frac{\bar{r}}{100}\right)^n$$

$$= 74100\left(1 + \frac{31.07}{100}\right)^2$$

Exercise:
The following is the population of a city available from past census records. Determine the population of the city in 2010, 2030 and 2050 by arithmetic and Geometric increase method.

Year	Population
1970	40000
1980	46000
1990	53000
2000	58000

1.4 Impurities in water – organic and inorganic, Harmful effects of impurities

Raw water → Treatment → Wholesome water

Quality of water (testing of water)
- To know the extent of impurities present in the water, based on which degree of treatment is decided.
- To ensure the quality of water before supply

Impurities in water

Based on size of impurities:
- Suspended impurities (macro) [10^{-1} mm to 10^{-3} mm]
- Colloidal impurities (micro) [10^{-3} mm to 10^{-6} mm]
- Dissolved impurities (micro) [10^{-6} mm to 10^{-8} mm]

Suspended impurities
- The suspended particles which have the same specific gravity as that of water are mixed in the water.
- E.g. clay, organic and inorganic matters etc.
- These impurities are macroscopic and the size of these impurities ranges from 10^{-1} mm to 10^{-3} mm.

Colloidal impurities
- It is very finely divided dispersion of particles in water. All the colloidal impurities are electrically charged (due to presence of ions) and remain in continuous motion.
- E.g. acid materials like silica, glass, acquire negative charge where as basic materials such as metallic oxide, aluminum oxide, ferrous oxide are positively charged.

- Due to the electric charge action all the colloidal particles remain in motion and don't settle which makes its removal very difficult.
- Most of the time colloidal impurities impact color to the water. The size of colloidal particles ranges between 10^{-3} mm to 10^{-6} mm.

Dissolved impurities

- Some impurities are dissolved in water when it moves over the rocks soil etc. These dissolve impurities may contain organic compounds, inorganic salts and gases etc.
- The size of the dissolved particles varies from 10^{-6} mm to 10^{-8} mm.

<u>Based on nature of impurities:</u>

- Organic impurities: Presence of organic impurities promotes growth of micro-organisms in the water which is objectionable.
- Inorganic impurities: Inorganic impurities of natural origin are harmless but human generated are hazardous in nature. E.g. cadmium, chromium, nickel, lead, zinc, mercury, etc. are toxic in nature.

<u>Based on state of matter:</u>

- Physical impurities
- Chemical impurities
- Biological impurities

Harmful effects of impurities

- Bacteria- cause disease
- Protozoa-cause odour
- Clay, silt- cause turbidity
- Carbonate- cause hardness
- Sulphate- cause hardness
- Bicarbonate- cause alkalinity and hardness
- Fluorides- cause mottled enamel of teeth
- Chloride- taste and salinity
- Manganese- cause black or brown color
- Iron oxide- cause taste corrosiveness, hardness and color
- Metal lead- cause lead poisoning

1.5 Analysis of water –physical, chemical and bacteriological

The analysis of water is done to identify the impurities present in the water based on which treatment procedures should be adopted in the treatment plants before supplying the water to the public.

The quality of treated water is also checked before supply to confirm it fulfills the requirement of the standards laid down by the public health department.

The following tests which are done during water analysis

- Physical tests
- Chemical tests
- Bacteriological tests

Physical water quality

It accesses the extent of physical impurities present in the water. Physical water quality parameters are those which respond to human senses.

1) Temperature
2) Color
3) Turbidity
4) Taste and odour

Temperature

- The temperature of water is measured by means of ordinary thermometers.
- Warm temperature is ideal for microbial growth
- Solubility of gases depends on temperature. Higher the temperature lower will be solubility.
- Chemical reactions are temperature controlled.
- Density, viscosity, vapor pressure and surface tension of water depends on temperature.
- The desirable range of temperature is 10 to 20°C

Color

- Apparent color → Suspended solids
- True color → Dissolved solids

  Before testing the color of the water, the suspended mater should be removed.
- Color in water is measured on Burgess Scale (platinum scale) and expressed in terms of True Colour Unit (TCU).
- The device used to measure the colour is known as tintometer.
- 1 TCU = 1mg of platinum as a chloroplatinate ion mixed in 1litre of distilled water, then the colour produced is taken as 1 standard TCU
- The permissible limit for domestic water is 5 to 20TCU

Turbidity

- The opaqueness in water is known as turbidity. It is the resistance to passage of lights through the water by the suspended and colloidal particles.

- Turbidity is measured in silica scale and expressed in terms of turbidity units (TU).
- 1TU=1mg of finely divided silica mixed in 1 litre of distilled water, then the turbidity produced is taken as 1 standard turbidity unit.
- Turbidity is measured by turbidimeters (Jackson turbidity unit: JTU) and nepthlometers (nepthlometric turbidity unit: NTU).

Taste and Odour

- Test and odours in water may be due to the presence of dead or alive micro organism, dissolved gases, mineral substances etc.
- The water having bad smell or odour is objectionable and should not supply to the public.
- Odour in water is measured by a device called Osmoscope (200ml capacity) and is expressed in terms of Threshold Odour Number (TON)
- TON is a dilution ratio at which odour is just detectable.
- Drinking water standard for odour = <3TON
- There is no test for taste. Generally a sample having bad colour is expected to taste bad. Taste is expressed as Flavored Threshold Number (FTN).

Chemical water quality

- The following are the different chemical water quality parameters

1. **Solids**

The residue left on evaporation is called solids.

- Total solids (TS)
- Suspended solids
- Total dissolved solids (TDS)

The presence of solid in water is measured by gravimetry method (weight measurement) and expressed in terms of mg/L or ppm (parts per million).

Total solids: Measured as the ratio of weight of residue after oven drying of raw water to the total volume of water taken

Suspended solids: Suspended solids are measured by filtration method. Filter paper of pore size smaller than the smallest suspended particles is used for filtration. The weight of solid retained on filter paper is measured and expressed in mg/L.

Total dissolved solids (TDS): It includes both colloidal and dissolved particles. TDS of a water sample is measured as the weight retained after oven drying of a filtered sample per the volume of filtered sample.

Drinking water standards for TDS = <500mg/L

2. **pH**

pH is the measure of potential of hydrogen ion concentration in water.
Water treatment is pH sensitive as extreme pH causes damage in property such as pipes etc. and hence increases the cost of treatment.
Measurement of pH:

- pH paper: approximate method
- Titrometry: not being used now a days
- pH meter: (potentio meter) It is a digital electronic device measures pH very accurately

Drinking water standard for pH: 6.5 to 8

3. **Acidity**

- The measure of ability of water to neutralize base
- Acidity in water is generally caused by excess minerals or presence of CO_2
- Acidity in water causes corrosion problem and tuberculation (micro-projection)
- It is measured by titrometry and expressed in terms of mg/L as $CaCO_3$
  Titrant: NaOH
  Indicator: Methyl orange/ phenolphthalein

4. **Alkalinity**

- The measure of ability of water to neutralize acids
- It is caused by hydroxyl ions (OH) carbonates and bicarbonates
- Alkalinity causes scaling (growth of thin layer inside pipes), incurstanation, and bitter taste to the water.
- It is measured by titromtry method.
  Titrant: H2SO4
  Indicator: Methyl orange/ phenolphthalein

5. **Hardness**

- It is the property of water which prevents the lathering of the soap. It is caused due to the presence of carbonate & sulphate of calcium and magnesium in the water.
- Hardness in water causes: corrosion, scaling, bitter taste, increased soap consumption
- Hardness is measured by versenate method (EDTA method) which is a titrometry method.
  Titrant: EDTA
  Indicator: Erichrome black T
  Change in color: wine red to blue

Hardness in mg/L as CaCo3	Type of water
<75	soft
75-150	Moderately hard
150-300	Hard
>300	Very hard

6. Chlorides

- Sodium chloride is the main substance in chloride water. The natural water near the mines and sea has dissolve sodium chloride.
- Excess of chlorides is dangerous and unfit for use. The chloride can be reduced by diluting water. Chloride above 250ppm is not permissible for drinking water.
- The chloride can be determined by titrating the water with silver nitrate and potassium chromate. In this titration process yellow color will change into brick red color in the presence of chlorides.

7. Chlorine test

- Dissolved free chlorine is never found in natural waters.
- Residue chlorine is determined by the stratch-lodide test. In this test, potassium iodide and starch solution are added to the sample of water due to which blue color is formed. This blue color is then removed by titrating with N/100 sodium thiosulphate solution and the quantity of chlorine is calculated.
- The residue chlorine should remain between 0.5 p.p.m in the water so that it remains safe against bacteria.

8. Iron and manganese

- These are generally found in ground water. If it present in water then the water is not suitable for domestic, bleaching, dyeing and laundering purposes.
- The presence of iron & manganese in water makes brownish red color in it, leads to the growth of micro- organism & corrodes the water pipes.
- The quantity of iron & manganese is determined by colorimetric methods. In this method some coloring agents are added in the water and colors so formed are compared with standard color solution.
- It is generally in 0.3 p.p.m
-

9. Dissolved gases test

Oxygen: Surface waters contain large amount of dissolved oxygen, because they absorb it from the atmosphere. The presence of oxygen in water is necessary to keep it fresh & sparkling, but more quantity of oxygen causes corrosion to the pipe materials.

Carbon di-oxide:

- The water absorbs carbon-di-oxide from the atmosphere. It causes hardness in water.
- The presence of carbon-di-oxide can be easily determined by mixing of the lime solution in the water. If it gives milky white color then carbon-di-oxide is present in the water.

Nitrogen:

- The presence of nitrogen in the water indicates the presence of organic matters in the water.
- The presence of nitrates is not so harmful, but in no case its quantity should increase 45 p.p.m, because excess presence of nitrate will cause disease to the children.
- It is determined by color matching methods. In this method the color is obtained if phenol-di-sulphonic acid & potassium hydroxide are added. The colors so developed are compared with standard colors.

Biological water quality

In biological/bacteriological analysis of water the following two tests are done.

- Total count of bacteria
- E-coli test

Total count of bacteria

- In this method total number of bacteria present in a milliliter of water is counted. The sample of water is diluted; 1 ml of sample water is diluted in 99 ml of sterilized water. Then 1 ml of diluted water is mixed with 10 milliliter of agar of gelatin.
- This mixture is then kept in incubator at 37 degree centigrade for 24 hours or at 20 ^{o}C for 48 hours. After the sample will be taken out from the incubator & colonies of bacteria are counted by means of microscope.

Escherichia coli (E-coli) test

- Now a day a new technique of finding out the E-coli is developed which is called “membrance filter technique”.
- In this method the sample of water is filtered through a sterilized membrane of special design due to which all the bacteria are retained on the membrance.
- The member is then put in contact of culture medium – M – Endos medium in the incubator for 24 hours at 37 ^{o}C. The membrance after incubating is taken out and the colonies of bacteria are counted by means of microscope.
- For drinking water it is necessary that it must be free from pathogenic bacteria.

1.6 Water quality standards for different uses

Water quality parameters	**Acceptable limits**
Temperature	10-15.6°C
Odour	0-4
Colour	10-20 ppm
Turbidity	5-10 ppm
Taste	no objectionable taste
Total solids	< 500 ppm
Hardness	75-115 ppm
Chlorides	< 250 ppm
Iron and manganese	< 0.3 ppm
PH value	6.5 to 8
Lead	< 0.1ppm
Arsenic	< 0.05 ppm
Sulphate	< 250 ppm
Carbonate alkalinity	< 120 ppm
Dissolve oxygen	5-6 ppm
MPN	<=1nos per 100ml
E-coli index	nil

CHAPTER 2: SOURCES AND CONVEYANCE OF WATER

2.1 Surface sources – Lake, stream, river and impounded reservoir
2.2 Underground sources – aquifer type & occurrence – Infiltration gallery, infiltration well, springs, well
2.3 Yield from well- method s of determination, Numerical problems using yield formulae (deduction excluded)
2.4 Intakes – types, description of river intake, reservoir intake, canal intake
2.5 Pumps for conveyance & distribution – types, selection, installation.
2.6 Pipe materials – necessity, suitability, merits & demerits of each type
2.7 Pipe joints – necessity, types of joints, suitability, methods of jointing Laying of pipes – method

There are 2 sources of water.

1) Surface sources:-
   Ex :- streams , ponds , lakes , rivers ,reservoirs etc
1) Underground sources:-
   Ex:- springs ,wells, tube wells ,infiltration gallery etc

2.1. SURFACE SOURCES OF WATER

STREAMS:-

In mountainous region streams are formed by the run off. The discharge in stream is much in rainy season than other season

PONDS:-

These are depressions in plains like lake of mountains, in which water is collected during rainy season.

lakes:-In mountains at some places natural basins are formed with impervious bed. Water from springs & streams generally flows towards these basins and lakes are formed.

RIVERS:-

Rivers are born in the hills, when the discharge of large number of springs & streams combine together. In mountains the quantity of water in rivers remains small, so it is known as Small River.

IMPONDED RESERVOIRS

In summer season ,the discharge of some river is insufficient to meet the water requirement. In such cases it becomes essential to store the water for summer season. The water can be stored in the river by constructing a weir or dam across the river is known as imponded reservoir.

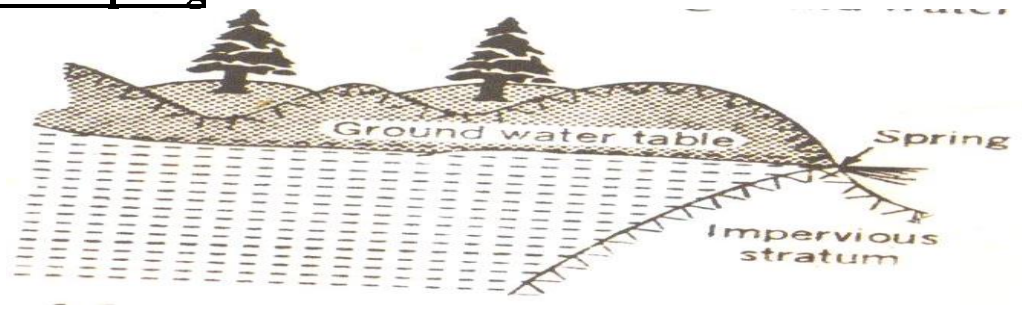
2.2. UNDERGROUND SOURCES

SPRINGS:-

Sometimes ground water reappears at the ground surface in the form of springs.

Generally springs can supply small quantity of water.
Hence these can not be used as source of water to big towns.

Figure of spring



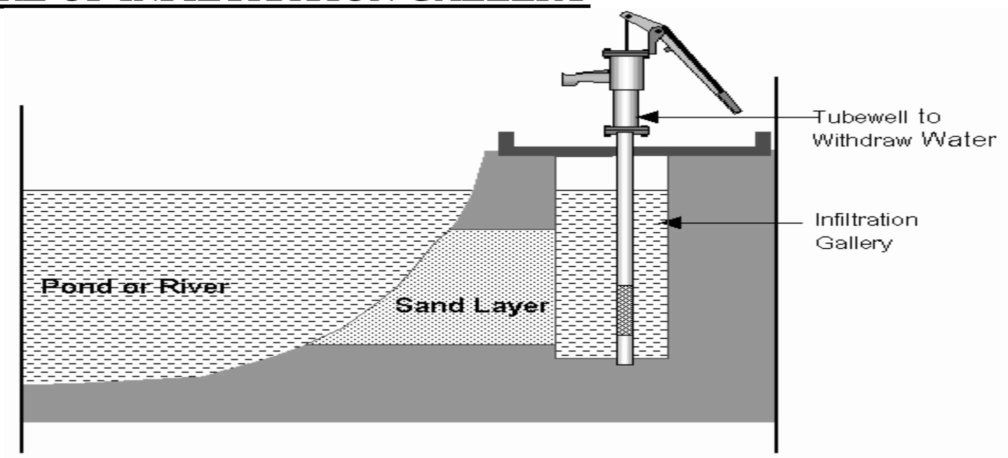
INFILTRATION GALLERY

- We have seen that ground water travels towards lakes, rivers or streams.
- This water which is travelling can be intercepted by digging a trench or by constructing a tunnel with holes on sides at right angle to the direction of flow of underground water.
- These underground tunnel used for tapping underground water near rivers, lakes or streams are known as infiltration gallery.

INFILTRATION WELL:-

- The shallow wells constructed under the beds or rivers and nallas is known as infiltration well.
- These wells are very suitable for Indian conditions where there are deposits of sand & porous material at least 3m deep in river bed.
- In order to obtain large quantity of water infiltration wells are sunk in seriess in the bank of river.

FIGURE OF INFILTRATION GALLERY



AQUIFER
Definition:-

- A permeable stratum which is capable of yielding appreciable quantities of ground water under gravity is known as aquifer.

TYPES OF AQUIFIER

There are 3 types of aquifer.

1) Unconfined aquifer:-

The top most water bearing stratum, is known as unconfined aquifer.

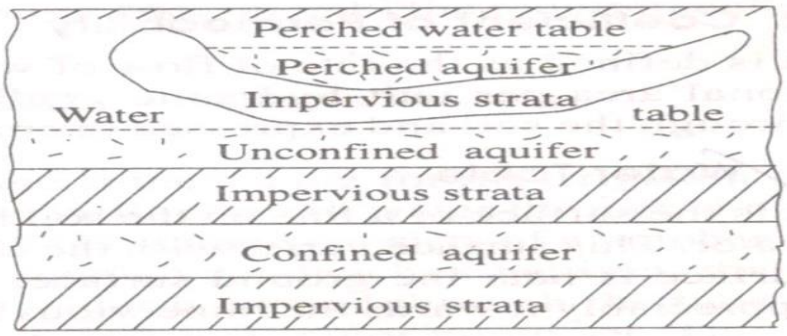
2) Confined aquifer:-

The aquifer which is sandwiched between two impervious layer is known as confined aquifer.

3) Perched aquifer:-

The aquifer which contain water but can't pass water is known as perched aquifer.

FIGURE OF AQUIFER



TYPES OF WELL

There are 2 types of well.

1) Open well
2) Tube well

OPEN WELL

The well which is constructed by digging earth , whose diameter varies from 1m to 2m & depth varies from 10m to 20m is known as open well.

There are 2 types of open well.

A) Shallow open well:-

The well which is constructed in the top permeable strata is known as shallow open well.

- This well is likely to get dried up in summer.

B) Deep open well:-

The well which is constructed in the deeper permeable strata is known as deep open well.

- This well are not dried up in summer.

TUBE WELL

- The well which is constructed by using G.I pipes of diameter varying from 3.75 cm to 15 cm & length varying from 7m to 8m is known as tube well.
- There are 2 types of tube well.

- The well which is constructed by using a G.I pipe of diameter varying from 3.75 cm to 15 cm & length varying from 7m to 8m is known as tube well.
- There are 2 types of tube well.
- i) **shallow tube well:-**
- The tube well in which the diameter varies from 3.7cm to 5cm and depth varies from 30m to 40m is known as shallow tube well
- It draws water from the top most aquifer; hence the water of the well may be dried up in summer.
- ii) **Deep tube well :**
- The tube well in which the diameter varies from 10cm to 15cm and depth varies from 200m to 300m is known as shallow tube well
- It draws water from the deeper most aquifer; hence the water is available through out the year.

2.3. YIELD OF WELL

Definition:-

- The rate of pumping of water from the well with out causing the failure of the well is known as yield of well.

METHODS OF DETERMINATION OF YIELD OF WELL

The yield of open well can be determine by the following test

1. constant level test
2. recuperation test.

CONSTANT LEVEL TEST

- It is also known as pumping test. In this test, the water from the open is pumped for some period so that the water level is depressed by a head "H" which is known as depression head.
- the rate of pumping is adjusted in such a way that the water level remains Constance in the well.
- At this time the rate of pumping is equal to the rate yield from the well.
- From Darcy's law Q= KAi

$$\Rightarrow Q=KA \times \left(\frac{H}{L}\right) \qquad \text{(where } i=H/L\text{)}$$

$$\Rightarrow Q= CAH \qquad \text{(where } C=K/L\text{)}$$

Where Q=discharge,

K= coefficent of permeability

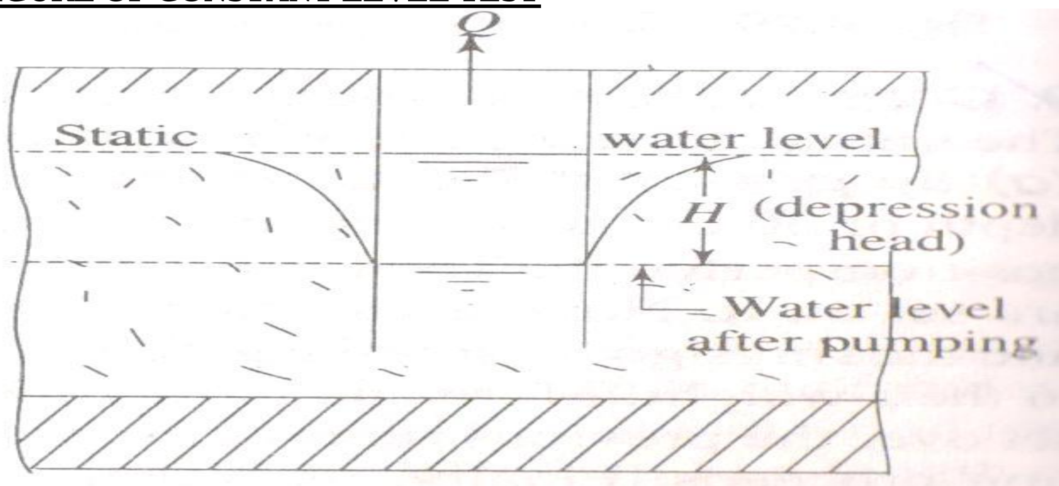
A=cross sectional area of permeable layer

H=depression head

L=length of flow path

C=percolation intensity coefficient

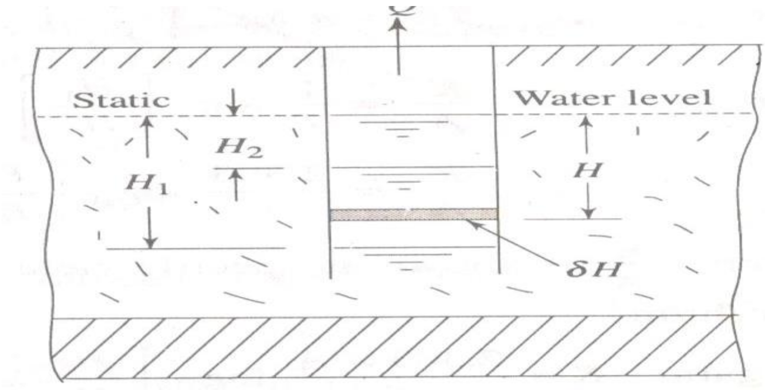
<u>FIGURE OF CONSTANT LEVEL TEST</u>



RECUPERATION TEST

- As it is very difficult to adjust the rate of pumping to maintain the constant level in the well, the recuperation test is carried out to determine the yield of open well.
- In this test , the water from the well is pumped to a depression head $'H_1'$ and the pumping is stopped.
- The water level rises due to ground water flow.
- $\frac{K}{A} = \frac{2.303}{T} \log_{10}(\frac{H_1}{H_2})$
- Where K/A = specific yield of well per unit area
- $H_{1=}$ depression head when pumping was stopped
- $H_{2=}\ depression\ head\ after\ certain\ period$
- T= time taken by the water level to rise from H_1 to H_2
  K= specific capacity of well in m^3/hr /unit head
- The discharge of the well Q =KH
- where H= depression head

FIGURE OF RECUPERATION TEST



PROBLEM-1 calculate the specific capacity of an open well from the following data : initial depression head=5 final depression head=2m time of recuperation=2hrs diameter of well=3m calculate the specific yield and yield of the well under head of 3m.

2.4. INTAKES

- An intake is a structure which is constructed across the surface of water so as to permit the withdrawal of water from the source.
- The structure may be of stone masonry, brick masonry, R.C.C. or concrete block.

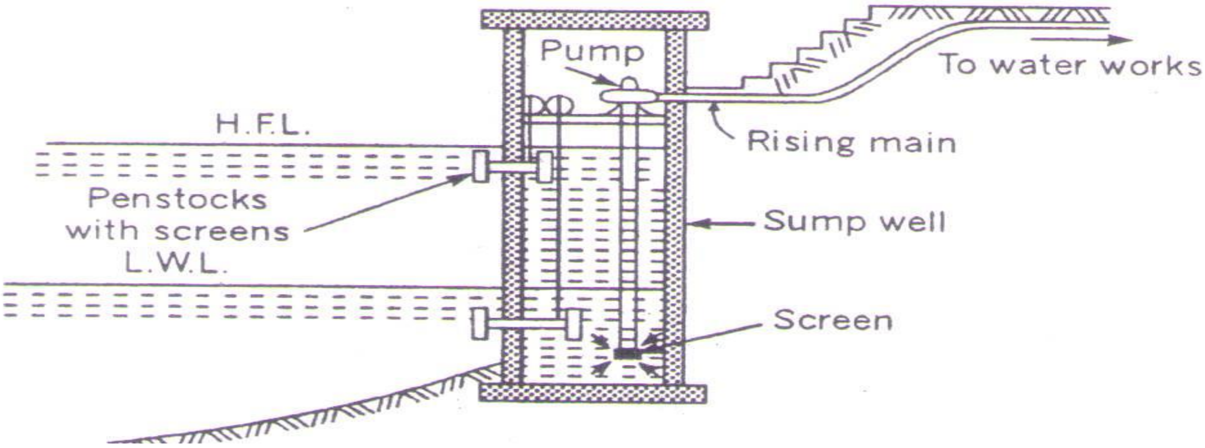
Types of intake:

- River intake
- Reservoir intake
- Canal intake

River intake:

- It is circular masonry tower of 4 to 7 meters in diameter constructed along the bank of the river at the place from where required quantity of water can be obtained even in the dry period.
- The water enters in the lower portion of the intake known as sump-well from penstocks.
- The penstocks are fitted with screens to check the entry of the suspended solids may only enter sump well. The penstocks with screens are providing with strainer at its lower end.
- The water from jack well is pumped and sent to the treatment plant.
- To prevent the back flow of water due to gravity, a valve should also be providing on the rising main leading to the treatment plant.
- To reach up to the bottom of intake from the floor of pump room, the ladder or steps in zigzag manner should be provide.

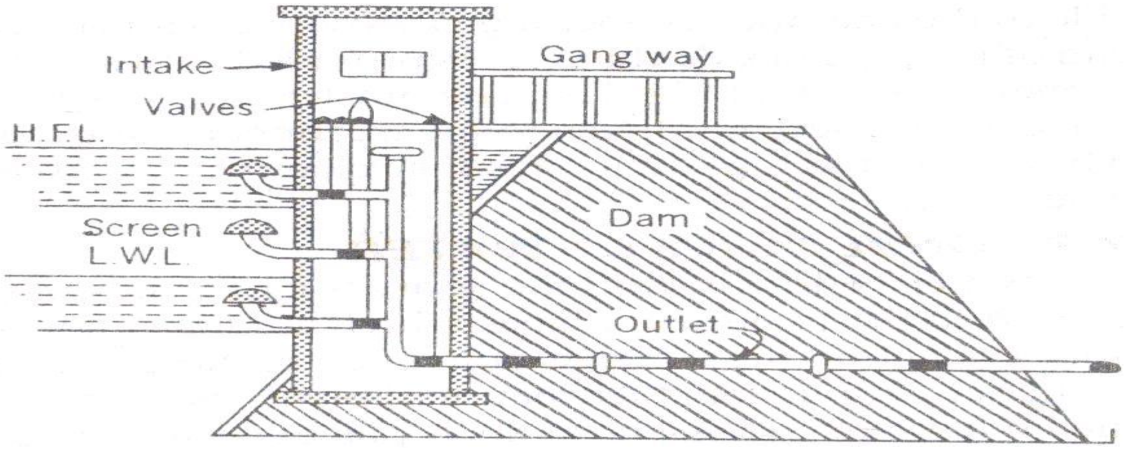
Figure of river intake:



Reservoir intake:

- Reservoir intakes which is mostly used to draw the water from earthen dam reservoir.
- It essentially consists of an intake tower constructed on the slop of the dam at such from where intake can draw sufficient quantity of water even in the driest period.
- Intake pipes are located levels with a common vertical pipe. The valves of intake pipes are operated from the top and they are installed in a valve room.
- Screens are provided at the mouth of all intake pipes to prevent the floating and suspended matter in them.
- The water which enters the vertical pipe is taken to the other side of the dam by means of an outlet pipe.
- At the top of the sluice valves are provided to control the flow of water.
- The valve tower is connected to the top of the dam.

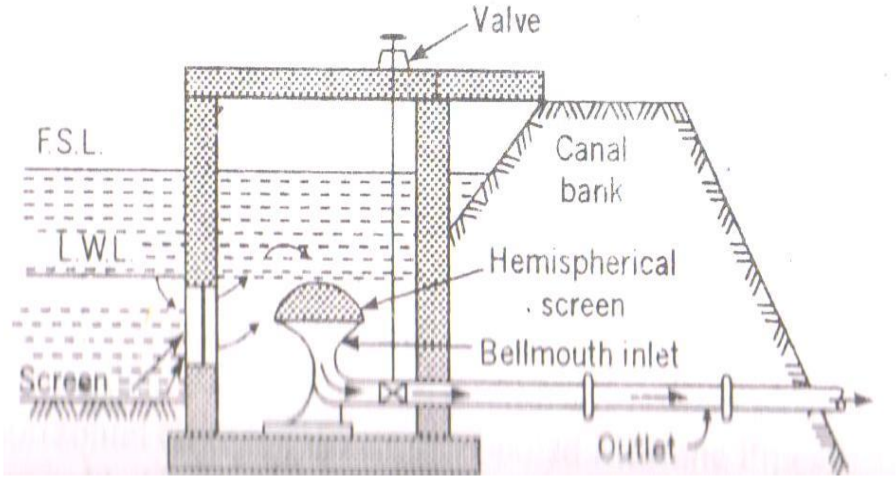
Figure of reservoir intake:



Canal intake:

- An intake chamber is constructed in the canal section. This results in the reduction of waterway which increases the velocity of flow.
- The entry of water in the intake chamber takes through the course screen and the top of outlet pipe is providing with fine screen.
- The inlet to outlet pipe is of bell-mouth shape with fine screen on its surface.
- The outlet valve is operated from the top and it controls the entry of water into the outlet pipe from where it is taken to the treatment plant.
- As the water level in the canal section partially remains constant, it is not necessary to provide intake pipes at various levels.

Figure of canal intake:



2.5. PUMP

- The mechanism by which the water is lifted from the under ground sources to some height or some place is known as pump.

Types of pump

1) Reciprocating pump
2) Centrifugal pump

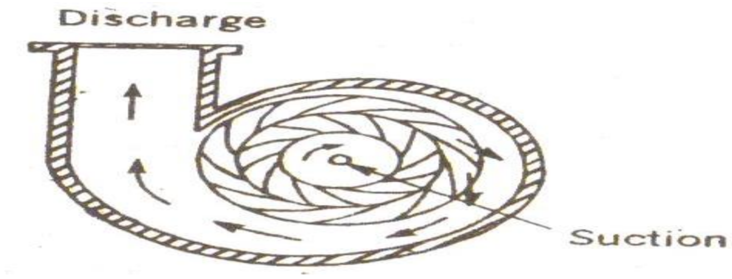
RECEPROCATING PUMP

- This consist of a close cylinder in which a piston moves to and fro by connecting rod.
- The connecting rod is again hinged with a wheel which is rotated by a motor.
- During the suction stroke the suction valve is opened and delivery valve remains closed and water entered the cylinder.
- During the delivery stoke ,the delivery valve is open and the suction valve remain closed and water is forced through the delivery pipe.

CENTRIFUGAL PUMP

- The centrifugal pump involve the principle of centrifugal force.
- When the water in the casing of a pump is rotated by the impellers about the central point , the centrifugal force develop which forces the water towards the periphery of the casing.
- Thus the velocity head is converted to pressure head and this head forces the water through the delivery pipe.

FIGURE OF CENTRIFUGAL PUMP



2.6. PIPE MATERIALS

Requirement:

- Carrying capacity of the pipe.
- Durability and life of the pipe
- Types of water to be convoyed and its corrosive effect on the pipe material.
- Availability of funds.
- Easy maintenance and repair.

Types of pipe:

- Cast iron pipes
- Wrought iron pipes
- Steel pipes
- Concrete pipes
- Cement lined pipes
- Asbestos cement pipes
- Copper and lead pipes
- Wooden pipes
- Vitrified clay pipes

Cast iron pipe:

- **Merits:**

i. The cost is moderate.
ii. The pipes are strong and durable.

- **Demerits:**

i. The breakages of these pipes are large.
ii. The pipes are heavier and uneconomical.

Wrought iron pipe:

- **Merits**:

i. These pipes are light in weight.
ii. They can be easily cut, threaded and worked.

- **Demerits**
    i. They are found to be costly.
    ii. The pipes are less durable as compare to the cast iron.

Steel pipe:

- **Merits**:
    i. The pipes are available in long lengths and hence, the number of joints becomes less.
    ii. The pipes are light in weight.
- **Demerits:**

i. The maintenance cost is high.
ii. The pipes are requiring more time for repairs.

Concrete pipe:

- **Merits:**
    - The maintenance cost is low.
    - These are not corroded by the water.
- **Demerits:**
- They are heavy and difficult to handle and transport.
- They can not withstand high pressure.

Cement lined cast iron pipe:

- Merits:

i. Their life is more about 75 years.
ii. They can be easily constructed in the factories'.

- Demerits:

i. They are affected by acids, salty waters.

ii. Their repairs are very difficult.

Wooden pipes:

- **Merit**:

i. The pipes are light in weight.

- **Demerit**:

i. They can not bear high presser.

Plastic pipes:

- **Merits**:

i. The pipes are cheap.
ii. The pipes are free from corrosion.

- **Demerits**:

i. The pipes are less resistance to heat.
ii. The coefficient of expansion for plastic is high.

2.7. PIPE JOINTS

- For the facilities in handling, transporting and placing in position, pipes are manufactured in small lengths of 2 to 6 meters.
- These small pieces of pipes are then joined together after placing in position, to make one continuous line.

Types of joint:

1. Spigot and socket joint
2. Expansion joint
3. Flanged joint
4. Mechanical joint
5. Flexible joint
6. Screwed joint
7. Collar joint
8. A.C pipe joint

Suitability:

- For cast iron/ wrought iron pipes: Spigot and socket joint
- For steel pipes: Welded or riveted joint
- For RCC pipes: Collar joint
- For temporary work: flanged and threaded joint
- For temperature change: Expansion joint
- For places where settlement is suspected: Flexible joint

CHAPTER-10

Sanitary engineering

Introduction:

- Aims and objectives of sanitary engineering
- Definition of terms related to sanitary engineering
- Systems of collection of wasted-conservancy and water carries system-features, comparison, suitability
- Aims and objectives of sanitary engineering:

Sanitary engineering is the application of engineering methods to improve sanitation of human communities, primarily by providing the removal and disposal of human waste and in addition to the supply of safe portable water.

In every town or city wastes of different types such as spent water from bathroom, kitchen, house &street washings from various industrial process, semi-liquid wastes of human excreta, dry refuse of house & street sweepings, broken furniture are produce daily. If proper arrangements for the collection treatment & disposal of all the wastes produce from the town or city are not made, then it will occur so many problems such as the disease bacteria will bread up in the water & health of the public will be in danger. All the drinkable water will be polluted.

DEFINATION OF SOME COMMON TERMS, USED IN SANITARY ENGINEERING:

- **Anti-siphonage pipe:** A pipe which installed in the house drainage to pressure the water seal of traps is known as anti-siphonage. It maintains proper ventilation & does not allow the siphonic to take place.
- **Siphoage**: Water seal of trap may be break up to siphonic action. This is known as siphonage& it occur when water is suddenly discharged from a fixture on the upper flow.
- **Siphonic action**: A tube running from the liquid in a vessel to a lower level outside the vessel so that atmospheric pressure forces the liquid through the tube.
- **Soil pipe**: The term soil pipe is used to indicate the pipe which carries discharge from soil fittings such as urinals, water closet etc.

- **Vent pipe**: The pipe installed for the purpose of ventilation.
- **Waste pipe**: this term is used to indicate the pipe which carries discharges from sanitary fitting such as bathrooms.
- **Invert**: The lowermost level or surface of a sewer is known as invert.
- Refuse: it indicates what is rejected material.

  It is divided in to 5 types:

  - **Garbage**: The term garbage is used to indicate dry refuse such as decayed fruits, grass, leaves, paper pieces, sweeping, vegetables, etc.
  - **Sewage:** The term sewage is used toindicate the liquid waste such as sullage, discharge from latrine, urinals, etc., industrial waste and storm water.
  - **Combine sewage**: This indicates a combination of sanitary sewage and storm water with or without industrial waste.
  - **Crude or raw sewage**: This indicates the sewage that is not treated.
  - **Domestic or sanitary sewage**: This indicates sewage mainly derived from residential, institution, etc.
  - **Fresh sewage**: This term is used to indicate the sewage which has been recently originated or produce.
  - **Septic sewage**: This indicates sewage which is undergoing the treatment process.
- **Storm water**: The term storm water is used to indicate the rain water of the locality.
- **Subsoil water**: This indicates the ground water which finds its entry into sewers through leaks.
- **Sullage**: The term sullage is used to indicate the waste water from bath rooms, kitchens, etc.
- **Sewer**: The underground conduits or drain through which sewage is conveyed are known as sewers.

  Following terms are used in practice in connection with different types of sewers:

  a) **Branch or sub main sewer**: The sewer which obtained its discharge from a few laterals and delivers it to the main sewer is known as branch sewer.

b) **Combined sewer**: The sewer which carries domestic sewage and storm water is known as combined sewer.
c) **Common sewer**: The sewer which all the inhabitants have equal legal rights is known as common sewer.
d) **Depressed sewer**: When an obstruction or obstacle is met with, the sewer is constructed lower than the adjacent section to overcome the obstruction or obstacle. Such a portion or section of sewer is known as depressed sewer.
e) **Intercepting sewer**: This term is used to indicate the sewer which intercepts the discharge from a number of main or outfall sewers, and it carries the flow to e point of treatment and disposal.
f) **Lateral sewers**: The sewer obtaining its discharge directly from building is known lateral sewers.
g) **Main sewer**: The sewer obtains its discharge from a few branch or sub main sewers, is known as main sewer.
h) **Outfall sewer**: The length of main or trunk sewer between the connection of lowest branch and final point of disposal is known as outfall sewer.
i) **Relief or overflow sewer**: the sewer which is meant to carry the excess discharge from sewer is known as relief sewer.
j) **Trunk sewer**: The sewer which obtains its discharge from two or more main sewer is known as trunk sewer.

- **Sewerage**: The entire science of collecting & carrying sewage by water carriage system through sewers is known as sewerage.
- **Rubbish**: All sundry solid wastes as paper, broken furniture, waste building materials, etc. are known as rubbish.

SYSTEM OF COLLECTION OF WASTED:

The sanitation of a town or city is done by two methods, which are:

a) Conservancy system
b) Water-carriage system

Conservancy system:

Sometimes this system is also called system. This system is in practice from very ancient times. Actually this is out of date system. Various types of refuse and storm water are collected, conveyed and disposed of separately by different methods in this system, therefore ,it is called conservancy system.

Garbage or dry refuse of a town is collected in dustbins placed along the roads &streets, from where it is conveyed by trucks or covered carts once or twice in a day to the point of disposal. All the non-combustible portions of the garbage such as sand, dust, clay, ashes etc are used for the lower level are as to lost land for the further development of the town. The other portions of garbage such as dry leaves, waste paper, broken furniture etc are burnt. The decaying fruits, vegetables, grass &other such things are first dried and then disposed of by burning or in the manufacture of manure.

Human excreta are collected separately in an outside toilet or conservancy latrines. The liquid and semi-liquid wastes are collected in separate drains of the same latrine, from where they are removed through human agency. After removed night soil is taken outside the town.

Merit of conservancy system:

- It is cheaper in initial cost because storm water can pass in open drains and conservancy latrines are much economical.
- The quantity of sewage reaching at the treatment plant before disposal is low.
- As the storm water goes in open drains, the sewer section will be small.
- In floods if the water level of river rises at the out-fall, it will not be costly to pump the sewage for disposal.

Demerits of conservancy system:

- It is possible that storm water may go in sewers causing heavy load on treatment plants, therefore it is to watched.
- In crowded lanes it is very difficult.
- For burying human excreta more space of land is required.
- Building can not be deigned as one compact unit, be provided away from the living rooms due to foul smell.
- This system completely depends on the merry of sweepers at every time.

Water-carriage system:

With the development of the cities, urgent need was felt to replace conservancy system with some more improved type of system in which human agency should not be used for the collection .After large number experiments, it was found that the water is the only cheapest substance which can be easily used for the collection &conveyance of sewage. As in this system water is main substance, therefore it is called water-carriage system. In this system the excremental matters are mixed up in large quantity of water and are taken out from the city through properly designed sewerage systems, where they are disposed off after necessary treatment in a satisfactory manner.

MERITS:

- It is hygienic method.
- The risk of epidemic is reduced.
- As only one sewer is laid.
- Building can be deigned compact as one unit.

DEMERITS:

- This system is very costly in initial cost.
- The maintenance of this system is also costly.

COMPARISON OF CONSERVANCY AND WATER-CARRIAGE SYSTEM:

Conservancy system	Water-carriage system
1. Very cheap in initial cost.	1. It involves high initial cost.
2. Due to foul smell from the latrines they are to be constructed away from the living room, so building cannot be constructed as compact units.	2. As there is no foul smell, latrines remain clean & neat hence are constructed with rooms.
3. The aesthetic appearance of the city can not be increased.	3. Good aesthetic appearance of the city can be obtained.
4. For burying of excremental matter, large area is required.	4. Loss area is required as compared with the conservancy system.

5. This system is fully dependent on the human agency.	5. As no human agency is involved in this system.
6. Excrete is not removed immediately.	6. Excrete is immediately removed.
7. As sewage is disposed of without any treatment, it may pollute the natural water courses.	7. Sewage is treated up to required degree of sanitation.

CHAPTER-11

Quantity of sewage

Contents:

- Quantity of sanitary sewage- Domestic & industrial sewage, variation in sewage flow, numerical problem on computation quantity of sanitary sewage, storm water of flow-rational method of computation of flow
- Computation of size of sewer, application of chazy's formula, limiting velocities of flow-self cleaning and scouring.

Sanitary sewage includes waste water from residences and industries. Sanitary sewage is also called as Dry Weather flow (D.W.F) and it flows only in one system. Before designing the sewerage system, it is necessary to know the quantity of sewage which will flow in it after the completion the project.

Domestic & Industrial sewage:

i. Water supplied to the public for domestic purpose by local authority.
ii. Water supplied to the various industries for various industrial processes by the local authority.
iii. Water drawn from wells by individual houses for their purpose.
iv. Water supplied by the local authority to various public places such as schools, cinemas, hotels, railway-station etc.
v. Water drawn from wells, lakes, canals etc by industries for their purpose.
vi. Infiltration of ground water into sewers through leaky joints.
vii. Unauthorized entrance of rain water is sewers lines.

Variation in sewage flow:

Seasonal and Daily Variation:The consumption of water in summer is more than in winter or rainy season, and this change in consumption of water directly affects the quantity of sewage. Practically, it has been that the ratio of maximum to average flow of sewage is between 1.5 to 1.0 &the ratio of minimum to average flow of sewage is between 1.2 to 1.0.These are also change in the sewage quantity if the city has seasonal industries such as sugarcane crushing, fruit canning etc.On the closing days of market, offices, industries, the quantity of sewage shall be more due to both washing, house washing etc.

Peak Rates of Flow:

If long-term records of sewage flow of developed cities are prepared, they will be much useful regarding the relation of maximum or peak sewage- flow rates to the yearly average daily rates.

Two formulas are:

1. Babbit's formula:

$M=5/p^{1/5}$

2. Harmon's formula:

$M=1+14/4+P^{1/5}$

Where M- The ratio of peak rate of average rate
P- Population in thousand

Minimum flow:

The flow in the sewers is minimum during nights. The effect of this flow is maximum in the lateral connected direct to the houses and minimum to the main trunk sewer.

Quantity of Strom-water:
Generally there are two methods by which the quantity of storm-water is calculated

i. Rational Method
ii. Empirical formulae method

Rational Method:

This method is mostly used in determining the quantity of storm water.

The storm water quantity is determined by the rational formula.

$$Q= \frac{C.I.A}{360}$$

Q=Quantity of storm - water in m3\sec
C=Co-efficient of run-off
$=A_{1.}C_1 + A_{2.}C_2 +\ldots.+A_{n.}C_n/A_1+A_2+\ldots..A_n$
I=Intensity of rainfall in mm/hr
A=Drainage area in hectares

Velocity of flow:

Sewage of all the towns carries large amounts of organic and inorganic solid matters which remain floating or suspended due to the flow of the sewage. If the velocity of flow is small the floating or suspended will get deposited on the bottom of the sewer,thereby will reduce the of sectional area of the sewer. I will cause obstruction in the flow of sewage. The minimum velocity at which no solids get deposited in the invert of the sewer is called **self-cleaning velocity**.

Application of chazy's formula:

Following formula are generally adopted for the determination of the slopes, and the designed velocity of flow during the design of sewers.

Chezy's formula

$$V=C\sqrt{m.i}$$

Where m=hydraulic mean depth in meter

V= Velocity of flow in meter per second

I= slope of the sewer

$$=\frac{fall of sewer}{length}$$

C= a constant

The value of C can be determined by kutter's formula as

$$C=\frac{23+\frac{155\times10^{-5}}{i}+\frac{1}{n}}{1+(23+\frac{155\times10^{-5}}{i})\frac{n}{\sqrt{m}}}$$

Where n=coefficient of roughness of the sewer surface