ENVIRONMENTAL ENGINEERING (PART-1)

Water is extremely useful to man, providing him luxuries and conterts, in addition to fulfilling his basic necessities of life. It has been estimated that two third of human body is constituted of water. Suitable systems should be designed for collecting, transporting, and treating water.

Essential elements of a public water supply scheme:

(*i*) **Intake and reservoir:** To collect water.

(*ii*) **Water treatment plant:** Screening, sedimentations, filteration, disinfection units etc.

(*iii*) **Elevated tanks and stand pipes:** It provide storage to meet peak demands occuring for limited periods.

(*iv*) **Valves:** It control the flow of water in the pipe system.

(*v*) **Hydrants:** It provide a connection with the water in the main for fighting fires, flushing streets etc.

(*vi*) **Distribution system:** Mains, submains, and branch lines which carry the water to the streets.

(*vii*) **Servies:** It carry the water to the individual house etc.

WATER DEMAND

In fact the first requirement is to consider the demand, and the second requirement is to find sources to fulfil that demand.

Various Types of Water Demands:

- Domestic water demand – 55 to 60% of total water consumption.
- Industrial water demand – 50 mp
- Institutional and commercial water demand – 20 lpcd
- Demand for public uses – 10 lpcd
- Fire demand; –1 lpcd and
- Water required to compensate losses in wastes and thefts – 55 lpcd
- As per is 1172-1983 as well as National building code, the domestic consumption under normal conditions in an Indian city is expected to be around 135 letre/head/day.

  The break up of 135 lpcd, may be shown below.

Use	***Consumption in litres per capita per day***
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of utensils	10
Washing and cleaning of houses and residences	10
Flushing of latrines, etc.	30
Total	**135**

- The ordinary per capital consumption for industrial needs of a city is generally taken as 50 litres/capita/day.
- On an average, per capita demand of 20 l/h/d is usually considered to be enough to meet such commercial and institutional water requirements, although this demand may be as high as 50 l/h/d for highly commercialised cities.
- Demand for public uses is generally taken as 10 l/h/day.

FIRE DEMAND :

- Fire hydrants are usually fitted in the water mains at about 100 to 150 metres apart.
- The per capita fire demand is thus generally ignored while computing the total per capita water requirement of a city.
- Kilo litre of water required = $100\sqrt{P}$ when population exceeding 50,000 where, P = Population in thousand.
- Rate of fire demand is worked out on the basis of certain empirical formula.

  Kuichling's Formula $Q = 3182\sqrt{P}$

  where, P = Population in thousand.

  Freeman's Formula

  Amount of water required in litres/min,

  $$Q = 1136\left[\frac{1}{10} + 10\right]$$

  For a central congested high value city

  $$Q = 4637\sqrt{P}\,[1 - 0.01\sqrt{P}]$$

- Wastes and thefts, etc. – 55 l/h/d.

PER CAPITA DEMAND.

q = Total yearly water requirement of the city in litres/ 365 × Design population

- For an Indian city, as per recommendation of IS code, per capita demand, q = 270 1/h/d.

Factors Affecting Per Capita Demand

(*i*) Size of the city
(*ii*) Climate conditions
(*iii*) Types of gentry and habits of people
(*iv*) Industrial and commercial activities
(*v*) Quality of water supplies
(*vi*) Pressure in the distribution system
(*vii*) Development of sewerage facilities
(*viii*) System of supply
(*ix*) Cost of water
(*x*) Policy of metering and Method of charging.

Variation in the Demand

1. Maximum daily consumptions

$= 180\%$ of the annual average daily demand

$= 1.8 \times$ Average daily demand

$= 1.8q$

2. Maximum hourly consumption

$= 150\ \%$ of the average hourly demand of the month day.

$$= \frac{150}{100} \times \frac{\text{Maximum daily demand}}{24}$$

$$= \frac{150}{100} \times \frac{108q}{24} = \frac{1.8 \times 1.5}{24} q$$

$$= 2.7\left(\frac{q}{24}\right)$$

$= 2.7 \times$ Annual average hourly demand

3. Maximum hourly demand of maximum day = $2.7\ q$

4. **Goodrich's formula** $\quad P = 180 + t^{-0.10}$

where, P = % of the annual average draft for the time t in days.

$$t = \text{time in days from } \frac{1}{24} \text{ to } 365$$

When, t = 1 day (for daily variations), then

$$P = 180 \times (1)^{-0.10} = 180$$

$$\therefore \quad \frac{\text{Maximum daily demand}}{\text{Average daily demand}} = 180\%$$

When, t = 7 days (for weekly variations), then

$$P = 180 \times (7)^{-0.10} = 148\%$$

$$\therefore \quad \frac{\text{Maximum weekly demand}}{\text{Average weekly demand}} = 148\%$$

$$\text{Similarly,} \quad \frac{\text{Maximum monthly demand}}{\text{Average monthly demand}} = 128\%$$

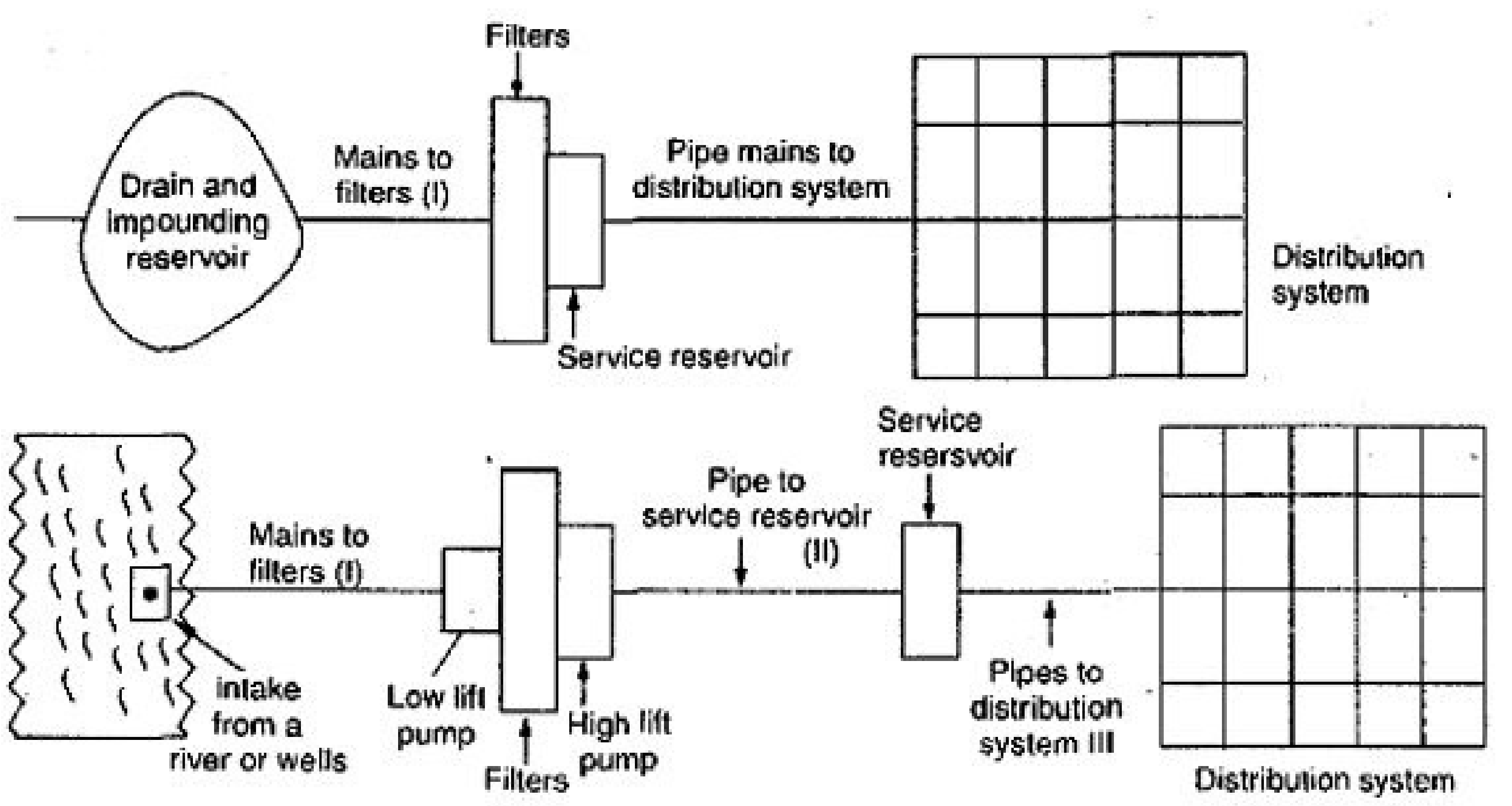
5. The pipe mains carrying water from the source to the reservoir is designed for the maximum daily demand.

6. Distribution system is designed for maximum hourly demand 5.5.

7. The filters and other units of the treatment plant are designed for a 2 times the average daily demand.

8. **Coincident demand :** The maximum daily demand when added to fire demands for working out total demand is known as *coincident demand.*

WATER SUPPLY SCHEME



- In case of dams and reservoirs - Generally no needs of pumps.
- In case a river is used as a source, is required dumping equipment is required

DESIGN PERIODS & POPULATION FORECASTS

- The future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as **design period**.
- Water supply projects, under normal circumstances, may be designed for a design period of 30 years. This 30 years is to be counted after the completion of the project.

Factor affecting population growth:

1. Birth,
2. Deaths, and
3. Migrations, besides these some other factors like wars, nature havoc and disasters may also bring about sharp reduction in the populations.

Population Forecasting methods:

1. Arithmetical increase method,
2. Geometrical increase method,
3. Incremental increase method,
4. Decreasing rate method,
5. Simple graphical method,
6. Comparative graphical method,
7. Master plan method,
8. The apportionment method or Ratio method
9. The logistic curve method.

Methods 1 to 5 are based on the assumption that factors and conditions which were responsible for population increase in the past and continue even in the future also, with the intensity.

This is a vague assumption.

Methods 6 to 9 are advanced and time consuing methods which gives fair results.

- None of these methods is exact, and they are all based on the laws of probability, and thus, only approximate estimation for possible future population can be made.

1. Arithmetical increase method:

$$P_n = [P_0 + n\bar{x}]$$

where, P_n = Forecasted population after n decades from the present.

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

n = Number of decades between present and future.

$\bar{x}$ = Average population increase in the known decades.

2. Geometrical increase method or Uniform increase method:

In arithmetic method, no compounding is done but, in geometric method compounding is done every decade.

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

where, P_o = Initial population

P_n = Future population after n decades

r = Assumed growth rate (%)

Computation of assumed growth rate (r) from the past known population data.

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

where, P_1 = Initial known population

P_2 = Final known population

t = Number of decades between P_1 and P_2

Note: Arithmetic mean, $r = \dfrac{r_1 + r_2 + r_3 + \dots\dots r_t}{t}$

Geometric mean, $r = \sqrt[t]{r_1 + r_2 + r_3 \dots\dots\dots r_t}$

where, $r_1, r_2, r_3 \dots\dots\dots r_t$ are % growth rates of the several known decades of past.

Arithmetic mean is slightly higher than geometric mean

Also r can be calculated as

$$r = \frac{\text{increase in population}}{\text{original population}} \times 100$$

Note: In geometric method computing is done every decade

3. Incremental increase method or Method of varying increment:

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

where, P_n = Population after n decades from present

P_o = Present population

$\bar{x}$ = Average increase of population of known decades.

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

- Population obtained by
  Arithmetic increase method < Incremental increase method < Geometrical increment method.
- Incremental method gives quite satisfactory results.
- For new younger cities expanding at faster rates → Geometrical increment method is applied.
- For old cities → Arithmetic method is better.
- Incremental method is applied for any type of city.

4. Decreasing rate method:

- This method is applicable only in cases where the rate of growth shows a downward manner.
- In this method, the average decreases in the percentage increases is worked out, and is then substracted from the latest percentage increase for each successive decade.

Example:

Year	Population	Increase in population	% increase in population	Decrease in % increase
1990	80,000	40,000	50%	10%
1950	1,20,000	98,000	40%	4%
1960	1,60,000	98,000	36%	
1970	2,28,500	60,500		
			Total	**14%**

Average per decade = $\frac{14}{2} = 7\%$

$$\therefore \quad P_{1980} = 2,28,580 + \left(\frac{36-7}{100}\right) \times 2,28,580$$

$$= 2,28,580 + \frac{29}{100} \times 2,28,580 = \mathbf{2,94,870}$$

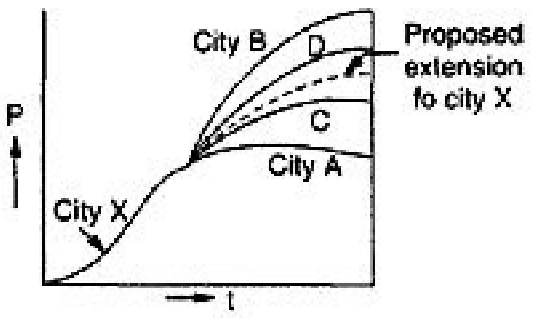
$$P_{1990} = 294870 + \left(\frac{29-7}{100}\right) \times 294870$$

$$= 294870 + \frac{22}{100} \times 294870 = \mathbf{3,59,740}$$

5. Simple graphical method:

In this method, a graph is plotted from the available data, between time and population. The curve is then smoothly extended upto the desired year.

6. Comparative graphical method:



7. Master plan method:

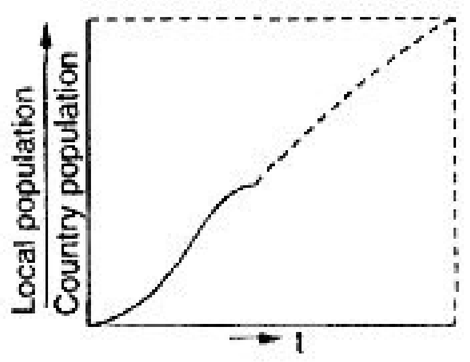
It is very easy to access precisely the design population, because the master plan will give us as to when and where the given number of houses, industries and commercial establishment would be developed.

8. Apportionment method or Ratio Method : The local population and the country population for the last four or five decades is obtained from the census method.

9. The logistic curve method:

Equation of the logistic curve

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



where, P = Population at any time t from the origin A

P_s = Saturated population

$m = \frac{P_s P_0}{P_0}$ (a constant)

$n = kp_s$ (another constant)

P_0 = Population at the start point of the curve.

k = constant

- If only three pairs of characteristic values P_0, P_1, P_2 at time $t = t_0 = 0$, t_1 and $t_2 = 2t_1$ extending over the useful range of the census population are chosen, then

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

$$m = \frac{P_s - P_0}{P_0}$$

$$n = \frac{1}{t_1}\log_e\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

SOURCES OF WATER

After calculating the demand of water, the main job is to search the source of water.

Various sources of water available on the earth can be classified into the following two categories:

A. Surface sources:

(*i*) Ponds and lakes;

(*ii*) Streams and rivers;

(*iii*) Storage reservoirs; impounding reservoir, and

(*iv*) Ocean, generally not used for water supplies; at present.

B. Sub-surface sources or Underground sources:

(*i*) Spring

(*ii*) Infiltration galleries

(*iii*) Infiltration wells

(*iv*) Wells and tube-wells.

- The yield which correspond to the worst or most critical year on record is called **firm yield** or **safe yield**.

Hydrologic Principles

- The precipitation and evaporation continues forever, and thereby a balance is maintained between the two. This process is known as **hydrological cycle**.
- The evaporated water comes back to the surface of the earth is in its various forms like rain, show, hail, mist, sleet etc. is known as **precipitation**.
- A major part of the precipitation occurs in the form of rain, and a minor part occurs in the form of snow.

PRECIPITATIONS

Types of Precipitations :

(*i*) Cyclonic precipitation;

(*ii*) Convective precipitation; and

(*iii*) Orographic precipitation.

- The usual mechanism by which the air is cooled to cause precipitation is the lifting of the air mass.

(*i*) **Cyclonic precipitation:** It is caused by the lifting of the air mass due to the pressure difference. If low pressure occurs in an area, air will flow horizontal from the surrounding area, causing the air in the low pressure area to lift. The precipitation that results, is called *non-frontal cyclonic precipitation*. If one air mass lifts over another air mass, then the precipitation is called **frontal or cyclonic precipitation**.

- The boundry between these two air masses of different temperatures and densities is known as a **front** or a **frontal surface**.
- The large whirling mass of air, at the centre of which the barometric pressure is low, is known as a **cyclone**.

(*ii*) **Convective precipitation:** Convective precipitation is due to the upward movement of air that is warmer than its surroundings. Precipitation occurs of high intensity and short duration.

(*iii*) **Orographic precipitation:** Orographic precipitation is the most important precipitate which is responsible for most of the heavy rains in India. Orographic precipitation caused by air masses which strike some natural topographic barriers like mountain and cannot move forward, and hence rise up, causing condensation and precipitation.

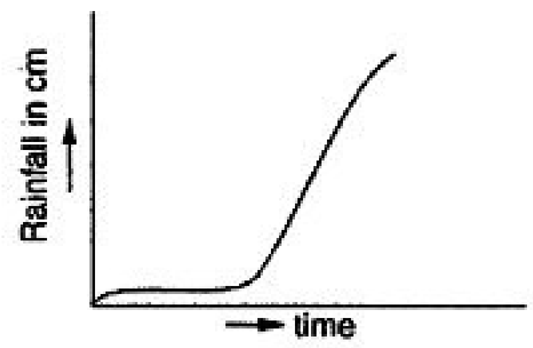
RAINFALL AND IT'S DISTRIBUTION

- **Rainfall interception (P_i) :** The rain interrupted by buildings and trees.
- **Ground rainfall (P_g) :** Total rainfall = $P - P_i$
- **Infiltration (F) :** The ground rainfall infiltrated by the soil.
- The maximum rate at which the soil in a given condition can absorb water is known as **infiltration capacity (*f*)**.
- **Depression storage (S_d) :** None of it appear as surface runoff.
- **Rainfall excess (P_e):** (P_e) = Rainfall rate (P) - Infiltration capacity (*f*)

Measurement of Rainfall :

Two types of raingauge :

1. **Non-recording type** (only collect the rain) → Symen's type (Obsolete); → Standard gauges adopted by Indian Metrological department (MID.).
2. **Recording type rain gauge:** It gets recorded automatically on a graph paper. This gauge thus produces a record of cumulative rain Vs. time in the form of graph, which is known as the **mass curve of rainfall**.



- It is also known as integrating raingauges or continuous rain-gauges.
- Various type of Recording Raingauges :
  (*i*) Tipping bucket type-operated through telecommunication system.
  (*ii*) Weighing type
  (*iii*) Floating type, etc, (most widely used in India).

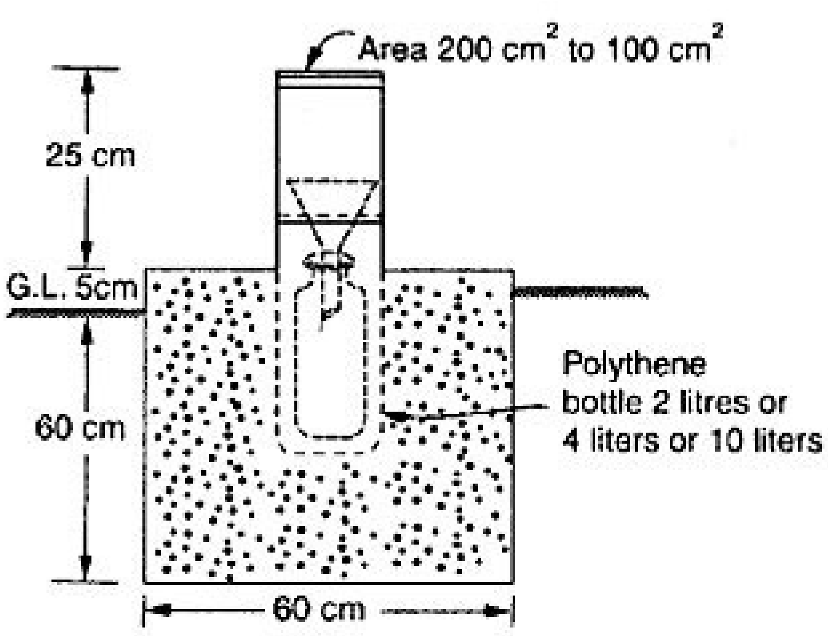


Fig. Standard non-recording raingauge.

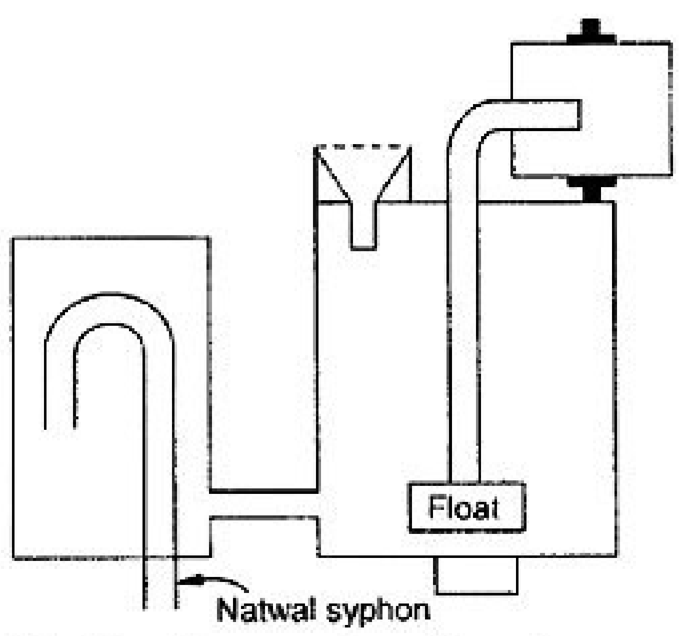


Fig. Float type automatic raingauge.

- The rotating drum completes one revolution in 24 hours or sometimes in 7 days.

Average annual rainfall

$$= \frac{\text{Annual rainfall at a given station should be recorded over a number of years (35 years)}}{\text{Number of years}}$$

Index of Wetness.

Index of wetness

$$= \frac{\text{Actual rainfall in a given year at a given place}}{\text{Normal rainfall of that place (i.e. Average)}}$$

- Index of wetness, gives us an idea of the wetness of the year.
- 60% index of wetness means a rain deficiency of 40%.
- A deficiency of about 30 to 45% is known as **large deficiency**.
- A deficiency of about 45 to 60% is known as **serious deficiency**.
- A deficiency more than 60% is known as **disastrous deficiency**.

The year in which the rainfall is less than the average annual, is called a **bad year** or a **sub normal year;** and the year in which the rainfall is more than the average, is called a **good year**. If the rainfall in a particular year is a approximately equal to the annual average value, then it is known as a **normal year**.

The average annual rainfall of a given place is very useful for planning water supply schemes at that place, because it direct gives us an idea of the probable amount of water that may be available at that place.

ESTIMATING RUN-OFF AND YIELD OF A BASIN.

1. English Formula:

$$\left.\begin{array}{ll} Q_y = 0.85\,P_y - 304 & \text{for hilly catchment} \\ Q_y = P_y\left[\dfrac{P_y - 17.8}{254}\right] & \text{for plane catchment} \end{array}\right\}\text{Used in South India.}$$

where, Q_y = yearly runoff in cm depth over the basin

P_y = yearly precipitation or annual rainfall in cm.

2. Khosla's Formula:

$Q_y = P_y - 0.4813\ T_m\ (T_m > 4.5°C)$

3. $Q_y = KP_y$

where, K = Impervious factor.

This runoff is helpful in evaluating the amount of water available in the river over long periods. They are, therefore, useful for estimating the storage capacity of the reservoir, and this fixed the height of the dam required to be constructed for that storage. These determinations are hence useful when storage reservoir is to be used as a source of water. However, when a river or a stream is to be directly used as a source of water, we must determine the day to day quantities of flow in that river or stream.

SURFACE SOURCES OF WATER SUPPLIES

Ponds and Lakes as Surface Sources of Supplies:

- If the size of the depression is comparatively small, it may be termed as a **pond**, and when the size of depression is larger, it may be termed as a **lake**.
- Bleaching of colour.
- Due to the smaller quantity of water available from them, lakes are not considered as principal source of water supplies.

Streams and Rivers as Surface Sources of Supplies:

- Small stream channels feed their waters to the lakes or rivers.
- Rivers are the most important sources of water supply schemes.

  (*a*) Perennial river - water is available throughout the year.

  (*b*) Non-perennial rivers.
- The quality of water obtained from rivers is not reliable.

Storage Reservoirs as Surface Sources of Supplies:

A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers demands during extremely low flows. To avoid such problem we construct a dam across a river for storage of water. The artificial lake is formed on the up stream side is known as **storage reservoir**.

- The subject of design and planning of dams and reservoirs is a big topic in itself, and is generally dealt under the subject of irrigation.
- Surface waters are, however, generally soft and less corrosive than ground waters. On the whole it can be stated that the surface supplies are generally contaminated and cannot be used without treatment.

SUBSURFACE OR UNDERGROUND WATER SOURCES

- Sometimes, the ground water is brought to the surface by some natural processes like **springs**, and sometimes the water is tapped by artificial means by constructing wells, tubewells, infiltration galleries etc.
- Since the ground water is largely tapped in our country for water supplies and there is a scope for its development in future also.

Factors Governing the selection of a particular source of water:

(*i*) Quantity of available water.
(*ii*) Quality of available water.
(*iii*) Distance of the source of supply.
(*iv*) General topography of the interveing area.
(*v*) Elevation of the source of supply.

- The dead storage zone in a reservoir is provided for storage of sand and slit.
- Trap efficiency

$$= \frac{\text{Total sediment deposited in the reservoir}}{\text{Total sediment flowing in the river}}$$

- With the reduction in the reservoir capacity, the quantum of sediment trapped by it decreases.

DEVELOPMENT OF GROUND WATER

Geological factors governing the occurrance of ground water

The possibility of occurrance the underground water mainly depends upon two properties of the underground soil, i.e.

(*i*) Porosity of the soil; and
(*ii*) Permeability of the soil.

- $\eta = \frac{V_V}{V} \times 100(\%)$
- Uniform and well sorted grains give rise to higher porosity; whereas heterogeneous grains with irregular arrangement reduces the porosity.

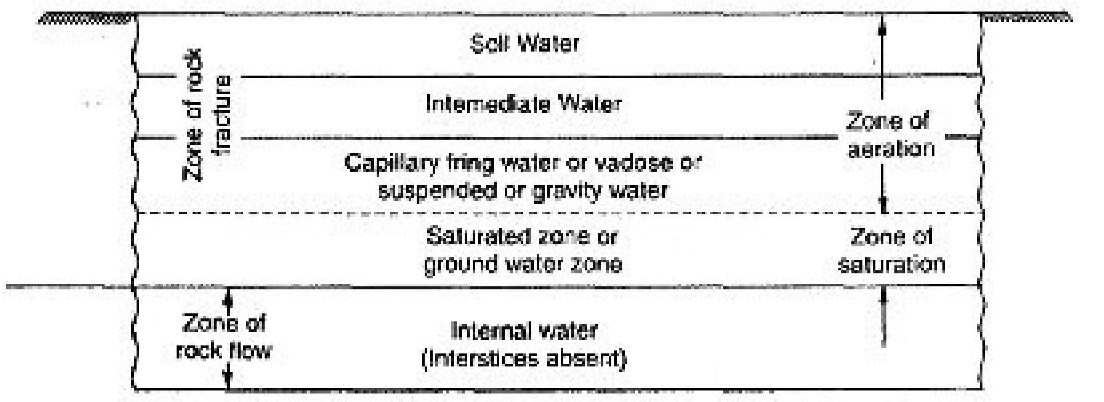
Porosity values of a few Rock Formations:

Granite, Quartzite	–	1.5%
Slate, Shale	–	4 %
Limestone	–	5 to 10 %
Sandstone	–	10 to 15 %
Sand and Gravel	–	20 to 30 %
Only gravel	–	25%
Only sand	–	35%
Clay and Soil	–	45%

Permeability and Transmissibility

- The porosity of the rock, thus, defined the maximum amount of water that can be stored in the rock. This porosity, however, in itself, does not ensure the storage of underground water, because the water can enter into a rock only if the rock permits the flow of water through it.
- A rock which is porous, may or may not be permeable.
- The capability of the entire soil of full width and depth is represented by **Permeability**; while that of the soil of unit width and full depth is known as **Transmissibility**.
- The permeability is measured in terms of coefficient of permeability.

Zones of Underground Water



- In the zone of saturation, water exists within the interstices and is known as *ground water*. This is the most important zone for a ground water hydrolic engineering because it has to tap out this water. Water in this zone is under hydrostatic pressure.

$$Q = kiA$$
$$V = ki$$

where, V is the discharge velocity not the actual velocity (V_a) through the soil medium.

- $$A_v V_a = A \times V$$

where, A_v = cross-sectional area of void

$$V = \frac{A_v}{A} V_a$$
$$V = \eta V_a$$
$$V_a = \frac{V}{n} = \frac{ki}{n}$$

- 1 Darcy = 9.87×10^{-9}
- Intrinsic permeability or specific permeability

$$k_o = \frac{kv}{g} = k\left(\frac{\mu}{\gamma w}\right)$$

- Relation between coefficient of permonability (k) and coefficient of transmissibility (T).

$$T = kd$$

where, d = mean particle size of porous medium.

- Drainage of ground water mean extracting the water from below the water lable through well, infiltration galleries, springs, etc.

Porosity

= Specific yield + Specific retention

$$= \frac{\text{Volume of water obtained by gravity drainage}}{\text{total weight of the material drained}}$$

$$+ \frac{\text{Volume of water held against gravity drainage}}{\text{total weight of the material drained}}$$

- Large particles of soils like coarse gravels, the specific retention would be small and it would result in large specific yields.
- Water bearing formation of coars gravel would supply large quantities of water to wells, whereas clay formations, although saturated and of high porosity, would be of little value in this respect.

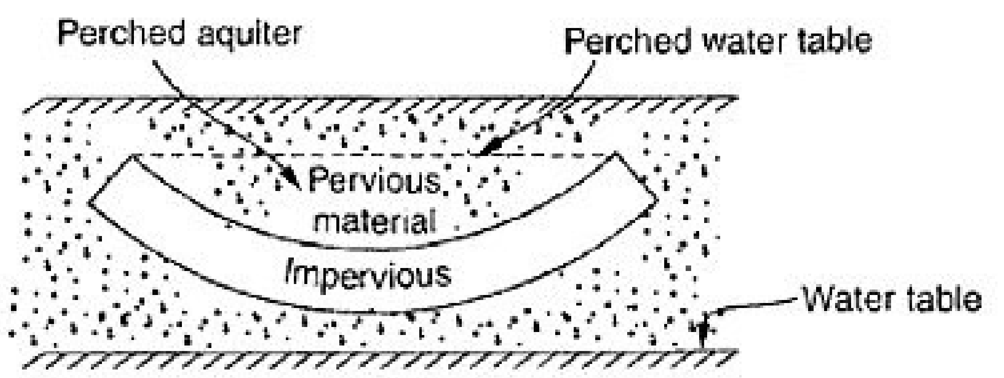
AQUIFERS

Types of Aquifers:

1. Unconfined or **Non-artesian** aquifers; and
2. Confined or Artesian aquifer.

- The top most water bearing stratum having no confined imperemable overburden (i.e. aquiclude) lying over it, is known as unconfined aquifer or non-artesian aquifer.
- When an aquifer is confined on its upper an under surface, by impervious rock formation (i.e. aquiclude), and is also broadly inclined so as to expose the aquifer for somewhere to the catchment area at higher level for the creation of sufficient hydraulic head, it is called a **confined aquifer** or **an artesion aquifer**.

Perched aquifer:



- **Aquifuse :** It is that geological formation which is, neither porous nor permeable. Granite rock is an example of aquifuse.
- **Aquitard :** It is that geological formation, which does not yield water problems to wells due to its lesser permeability. The yield from such a formation is, thus insignificant. e.g., sandy clay.
- **Aquiclude :** It is highly porous, containing large quantities of water, but essentially impervious. e.g. clay layer.

Storage co-efficient (A)

It is defined as the volume of water that an aquifer release or storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The storage coefficient (A) for an artesian aquifer is equal to the volume of the water released from the aquifer of full height and unit area when the piezometric surface declines by unity.

GROUND WATER SPECIFIC YIELD

It is the ratio of volume of water obtained by gravity-drainage to the total volume of the subsoil *i.e.*

$$\text{Specific yield} = \frac{\text{Volume of water obtained by gravity drainage}}{\text{Total volume of the sub-soil}} \times 100$$

$$\text{Specific retention} = \frac{\text{Volume of water held against gravity drainage}}{\text{Total volume of the material}} \times 100$$

Porosity = Specific yield + specific retention

GROUND WATER VELOCITY

(a) Slichter's formula: $v = \dfrac{k' SD^2}{\mu}$

where, v = velocity of ground water in m/day
k' = constant (approx. 400)
s = slope of hydraulic gradient line
D = effective size of the particle in aquifer (in mm)
μ = dynamic viscosity

(b) Hazen's formula: $v = \dfrac{k'' SD^2}{60}(1.8T + 42)$

where, K″ = constant (approx. 1000)
T = Temperature (in °C)

Specific yield of well in recuperating test can be determined from the following formula:

$$\frac{C'}{A} = \frac{2.3}{T}\log_{10}\frac{S_1}{S_2}$$

Where, S_1 = depression head in the well immediately after the pumping was stopped.
S_2 = depression head in well at time 'T' after the pumping was stopped.
T = time after which S_2 was measured
$\frac{C'}{A}$ = specific yield.

Discharge, $Q = \left(\frac{C'}{A}\right).AS$

where, A = cross-sectional area of well

- Yield of a well,

$$Q = \frac{\pi \rho k (H^2 - h^2)}{2.3 \log_{10} R/r} m^3/\text{day}$$

$$= \frac{\pi \rho k \times 1000}{2.3 \times 24 \times 60} \frac{H^2 - h^2}{\log_{10} R/r} \text{ litres/minute}$$

$$= \frac{k_m H^2 - h^2}{\log_{10} (R/r)} lpm$$

where, $k_m = \frac{\pi \rho k \times 1000}{2.3 \times 24 \times 60}$ is known as transmission constant of the aquifer.

- The above formula is known as **Thiem's formula.**

Yield of tubewell when equilibrium conditions have not reached can be determined using following formula:

$$s = \frac{Q}{4\pi\mu}\left[\log e\left(\frac{4T\mu}{r^2 A}\right) - 0.5772\right]$$

where, s = draw down in observation well after time T.

r = radial distance of the observation well from the main well.

Q = yield or constant discharge pumped out from the well.

A = coefficient of storage of measured drawdown.

μ = coefficient of transmissibility.

$$s_1 - s_2 = \frac{2.3Q}{4\pi\mu} \log_{10}\left(\frac{T_2}{T_1}\right)$$

Various forms of underground sources and their exploitation

The underground water is generally available in the following forms :

1. Infiltration galleries
2. Infiltration wells
3. Springs
4. Wells including tubewells.

INTAKE FOR COLLECTING SURFACE WATER

The basic function of the intake structure is to help in safely withdrawing water from the source over a predetermined range of pool levels and then to discharge this water into the withdrawal condict, through which it flows upto the water treatment plant.

Site Selection of Intake depends on

(*i*) Availability of water is all seasons.

(*ii*) Quality and quantity of water.

(*iii*) Away from the pollution.

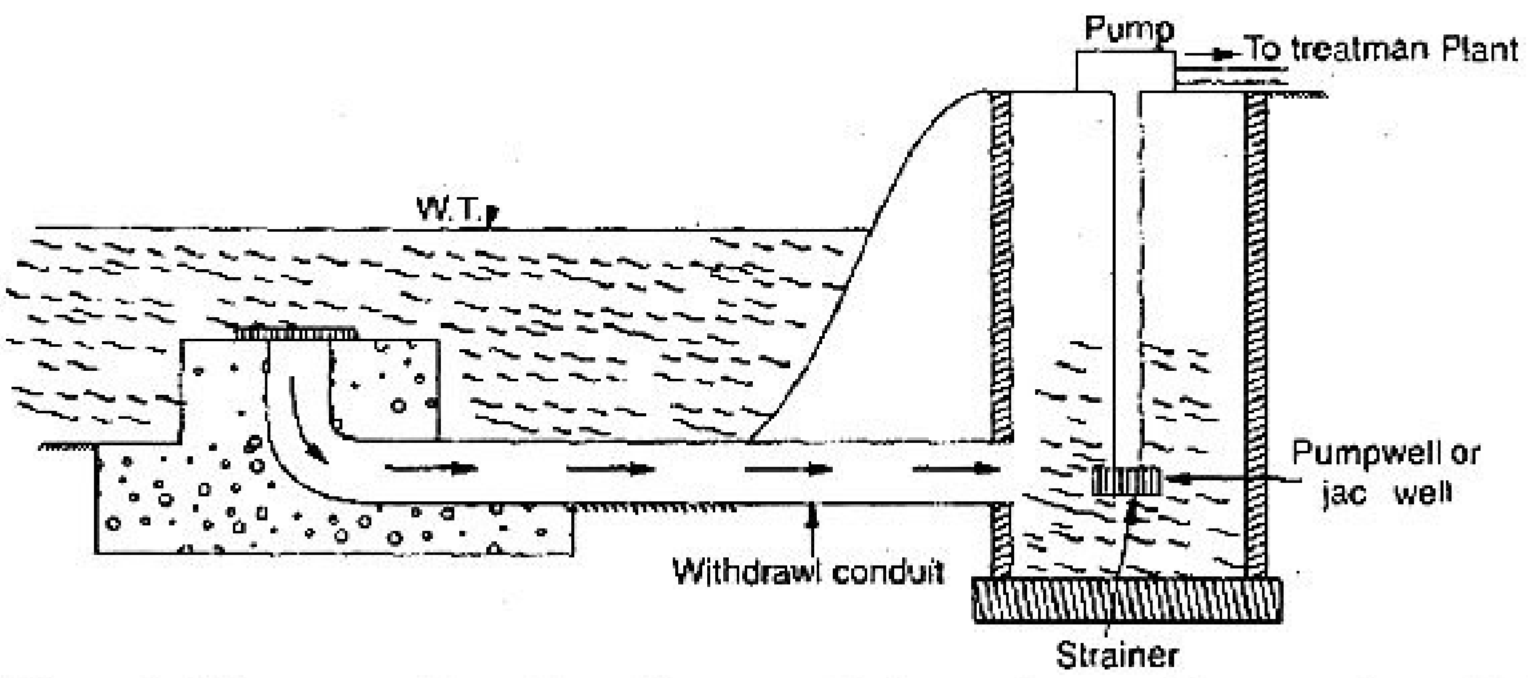
(*iv*) Nearer to the city.

(*v*) Upstream side of the river.

(*vi*) Costs and reliability.

Types of Intakes:

1. Simple Submerged Intakes:



These intakes are not used on bigger projects on river and reservoir, as their main disadvantage is the fact that they are not easily accessible for cleaning, repairing, etc.

2. Intake Tower :

(*i*) Wet intake towers; and
(*ii*) Dry intake towers
} Standing in the river or reservoir

- The essential difference between a dry intake tower and a wet intake tower is that, in a wet intake tower, the water enters from the entry ports into the tower and then it enters into the conduit pipe through separate gate controlled opening; but in a dry intake tower, the water is directly drawn into the withdrawal conduit through the gated entry ports.

3. Medium sized intake wells (River intake) :

(*i*) **Medium sized river intake:** The water from the intake chamber is taken through a withdrawal conduit (called intake conduit) to a sump well, from where it is lifted and taken to the treatment plant.

(*ii*) Canal intake well

Design criteria

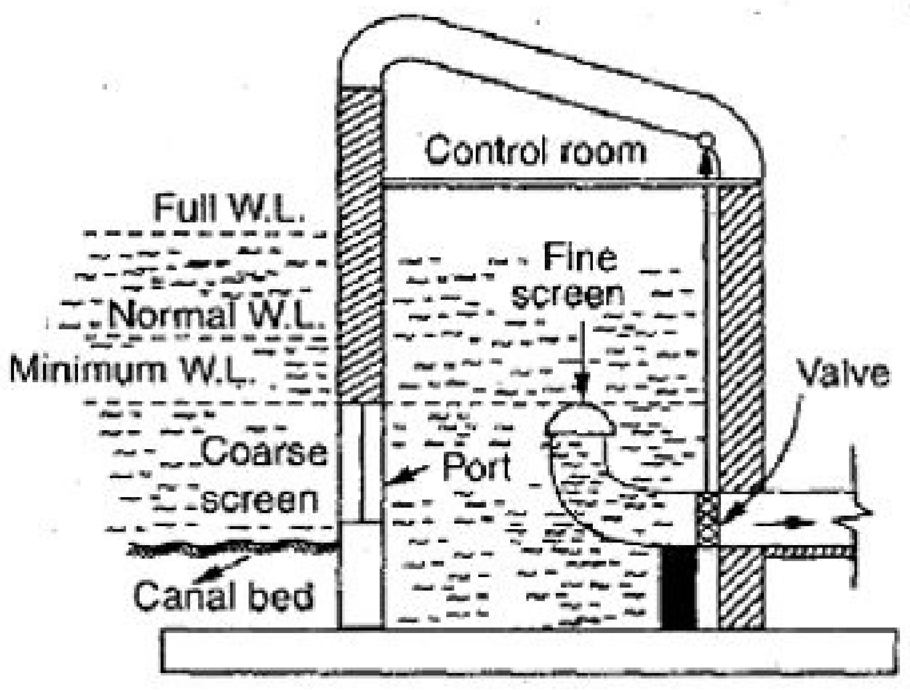


Fig. Canal intake well

- The entry of water in the intake well takes through a coarse screen, the top of which is generally provided at minimum water level in the canal, and bottom is about 0.45 m above the canal bed to avoid entry of bed load.
- An additions fine screen is provided at the inlet end of the withdrawal conduit. This inlet end of bell mouth shape with perforation of fine screen on its surface.
- An outlet value, operating from the top, is provided to controlled entry of water into the outlet pipe.
- The flow velocity through the outlet conduit is generally kept as about 1.5 m/sec and this helps in determining the area and diameter of the withdrawal conduit.
- The area of coarse screen is designed by limiting the flow velocity to as low as 0.15 m/sec or so. The flow velocity through the bell mouth inlet is limited to about 0.3 m/sec or so.
- The head loss in the intake conduit upto treatment works, can be determined by using Darcy Weisback formula

$$H_L = \frac{f'LV^2}{2gd}$$

or by using Hazen William's formula.

$$V = 0.85\, C_H + R^{0.63}\, S^{0.54}$$

where, $S = \frac{H_L}{L}$ = slope of the energy line

$$C_H = 130 \text{ for C.I. pipe.}$$

4. Intake for Sluiceways of dam:

In case a reservoir developed by constructing a dam, it is a common practice to fetch water through the sluiceways from inside the dam.

- In case of earthen dams, the intake for withdrawing water into the sluiceway of the dam, is generally located near the upstream toe of the dam. Whereas for masonry dam the intake well for withdrawing water is generally located inside the body of the dam.
- The arrangement is similar to that of a dry intake tower, only different that it was surrounded by water on all sides and was standing in the river, whereas this valve tower is fed through conduits and is standing in the dam or very near the dam.

Design and Sketch of River Intake:

1. Population = 50,000; demanding water @ 135 Ipcd

RL.D. bed of river – 50.00 m.

RL of L.W.L. – 52.5 m.

RL of H.W.L. – 55.5 m.

Assume other data necessary for design.

$$Q = 50000 \times 135$$
$$= 6750000\ l/d = 0.07\ m^3/sec$$

Taking detention time in the intake well = 20 minute (IS code: 10—30 minutes)

Volume of the intake well = Q × D.T. = 0.078 × 20 × 60 = 94 m^3

For minimum assured water, h = 2.5 metre.

$$\therefore \qquad 94 = \frac{4}{9} D^2 \times h = \frac{4}{9} D^2 \times 2.5 = 94$$

Hence, Diameter of intake well, D = 7m.

Provide 2 well one working and other stand by;

Flow velocity through coarse screen = 0.15 m./sec.

Flow velocity through fine screen = 0.30 m./sec.

Velocity through pipe = 1 m./sec.

Provide height of coarse screen (20 mm diameter bars @ 40 mm/cm.) = 2 m.

$$\text{Net area required} = \frac{Q}{V} = \frac{0.078}{0.15} = 0.52\ m^2$$

$$\therefore \quad \text{Gross area of screen} = 2 \times 0.52 = 1.04\ m^2$$

$$\therefore \quad \text{Length of screen} = \frac{1.04}{2} = 0.52$$

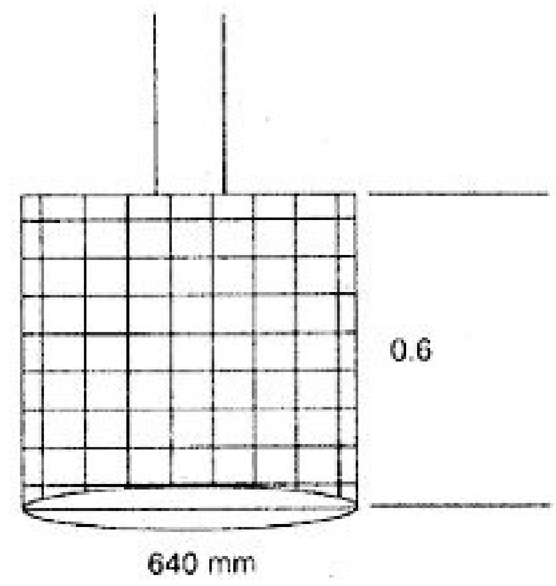
- **Pumping design:**

Pumping design for $1\frac{1}{2}$ times average flow of pumping is running for 16 hours. Then

Design flow, $Q = Q_{av} \times 1.5 \times \frac{24}{16}$

$= 0.078 \times 1.5 \times \frac{3}{2}$

$= 0.176 \text{ m}^3/\text{sec.}$



Net area for strainer $= \frac{Q}{V} = \frac{0.176}{0.3} = 0.6 \text{ m}^2$

$\therefore$ Gross area $= 2 \times 0.6 = 1.2 \text{ m}^2$

Provide length of strainer = 0.6 m.

$\therefore$ Perimeterial distance $= \frac{1.2}{0.6} = 2$ m

i.e. $\pi d = 2$

or $d = 0.64$ m. = 640 mm.

Diameter of the Suction Pipe:

$$0.176 = \frac{\pi}{4} d^2 \times v = \frac{\pi}{4} d^2 \times 1$$

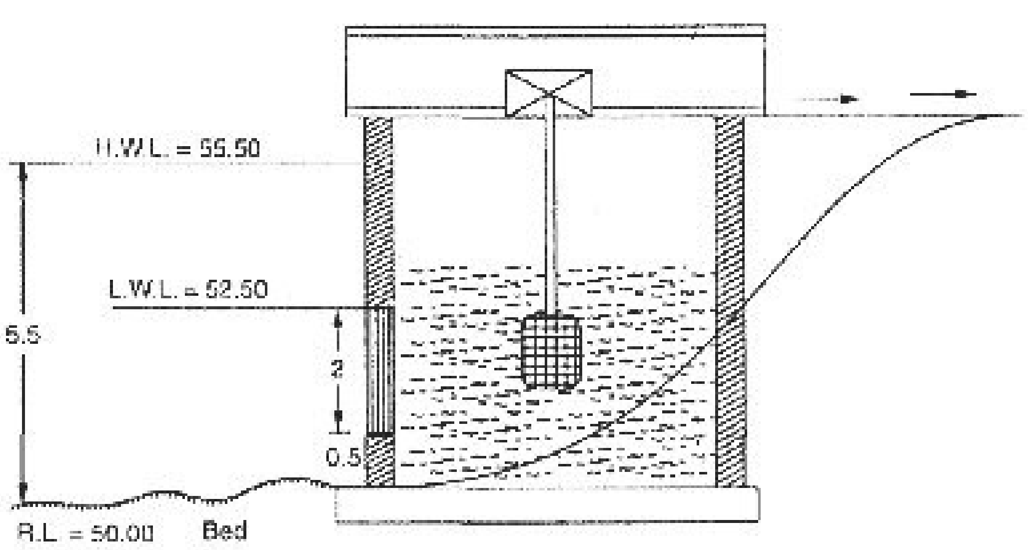
$$\Rightarrow \quad d = \sqrt{\frac{0.176 \times 4}{\pi}} = 0.4731 = 0.5 \text{m.}$$

$\therefore$ Power required

= WQH

$= 9810 \times 0.176 \times$ H (watt)

$= \frac{9810 \times 0.176 \times H}{746}$ (H.P.) (if efficiency is 100%)



Design of canal intake:

1. Q and then assume D.T. and get volume of intake.
2. Design of coarse screen.
3. Design of bell mouth entry.
4. Design of intake conduit.
5. Head loss.

CONDUITS FOR TRANSPORTING WATER

Types of conduits:

1. Gravity conduits; and

2. Pressure conduits (Pressure above the atmospheric pressure)

1. Gravity conduits;
   (*i*) Canal (often used for irrigation)
   (*ii*) Flumes
   (*iii*) Aqueduits (are closed, rectangular, circular or horse shoe sections). They are generally designed as $\frac{1}{2}$ to $\frac{3}{4}$th full.

- In gravity conduit, the hydraulic gradient line will coincide with the water surface and will be parallel to the bed of the conduit.
- These conduits cannot, therefore, go up and down hills and valleys as desired by existing topography of the area.
- From hydraulic point of view, a circular section provides the maximum hydraulic mean depth or maximum area per unit of wetted perimeter $\left(i.e.\ R = \frac{A}{P}\right)$ and is, therefore, the most efficient. Moreover, since the perimeter per unit of cross section is less than the construction cost or material required is also the least. But circular sections cannot be easily supported on ground and, therefore seldom used.
- A rectangular shape is hydraulically inefficient and requires more material for construction, but is more stable to support on the ground, and therefore widely used.
- Horse shoe shape may be used with great advantage.
- The bed or the invert of the conduit in pressure flows is thus independent of the grade of the hydraulic gradient line which really governs the flow velocities.
- The pressure pipes can, therefore, follow the natural, available ground surface and can freely go up and down hills or can dip beneath valleys or mountains, sometimes even rising above the H.G. Lines and thus requiring lesser length of conduit.