Hydrology & Water Resources Engineering

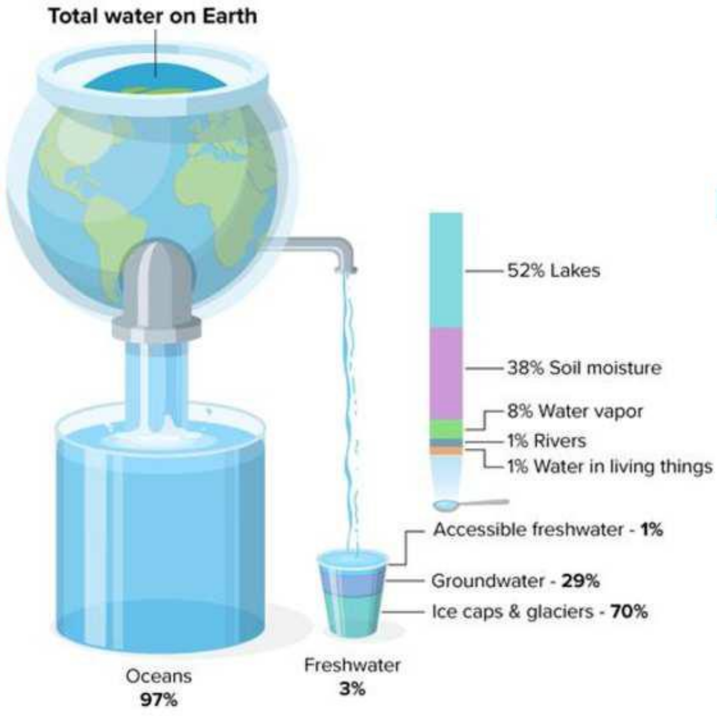
A. Hydrological Cycle

Meenu Priya

Hydrology

Sources of Water:

Oceans	97.25%
Ice Caps and Glaciers	2.05%
Groundwater	0.68%
Lakes	0.01%
Soil Moisture	0.005%
Atmosphere	0.001%
Streams and Rivers	0.0001%



Definition of Hydrology:

Hydrology is a multidisciplinary subject that deals with the occurrence, circulation and distribution of the waters of the Earth.

Application of Hydrology:

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1.Study the groundwater development

2.Determination of maximum intensity of the storm

3.Calculates rainfall, surface runoff, and precipitation.

4.It mitigates and predicts flood, landslide and drought risk

5.Enables real-time flood forecasting and flood warning.

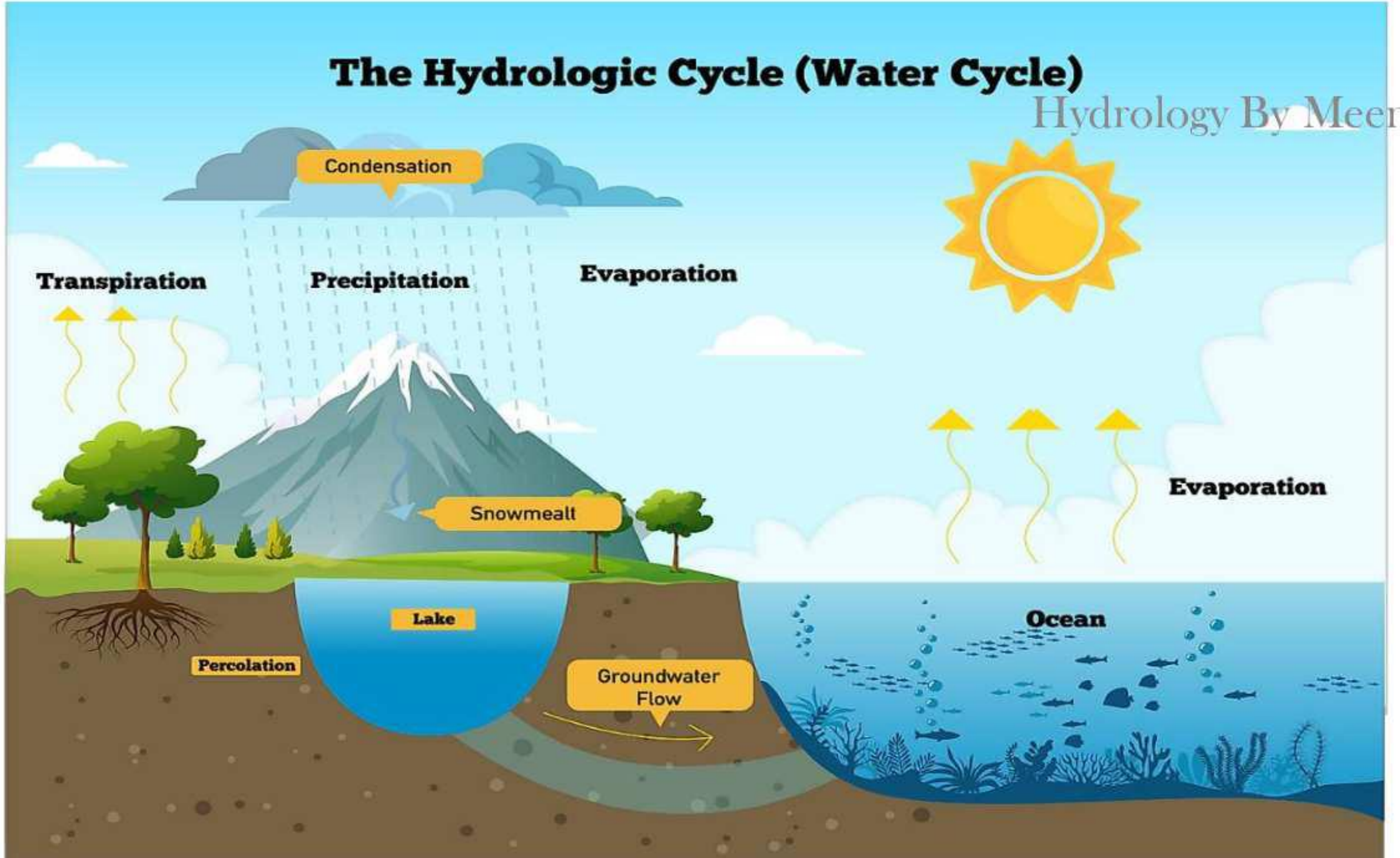
6.Reservoir capacity for irrigation and municipal water supply

7.It is used in the design and operation of hydraulic structures

8.It is used for hydropower generation.

9.Brings measures to control erosion and sediments.

Journey of water from the ocean to atmosphere and back to the earth and ultimately to the ocean through the processes of evaporation, precipitation, percolation, runoff and return to the ocean is called hydrologic cycle.



Hydrology Cycle Components

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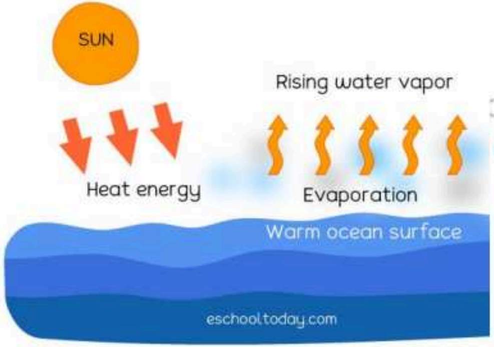
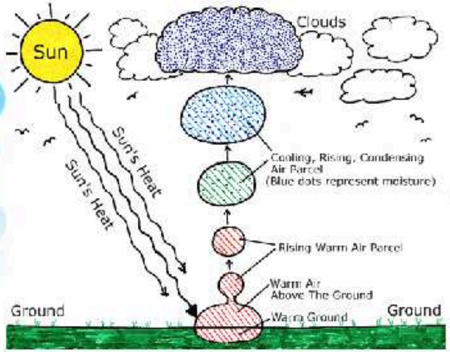




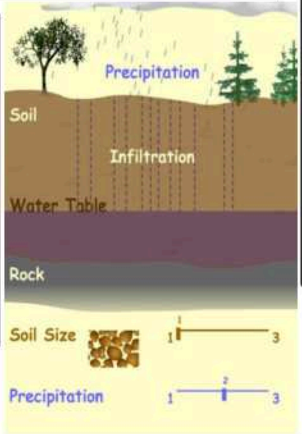
Evaporation Physical process by which water is vaporized into the atmosphere from free water surface and land areas.

Transpiration: Water from the soil is absorbed by plant roots and leaves

Condensation : it is the change of the state of matter from the gas phase into the form of clouds

Precipitation is any product of the condensation of atmospheric water vapor that falls from clouds due to gravitational pull.

Infiltration: Movement of water from the land surface to the upper layers of the soil.



Percolation: Movement of water through the subsurface down to the water table.

Surface runoff: Includes all overland flow as well as precipitation falling directly onto stream channels.

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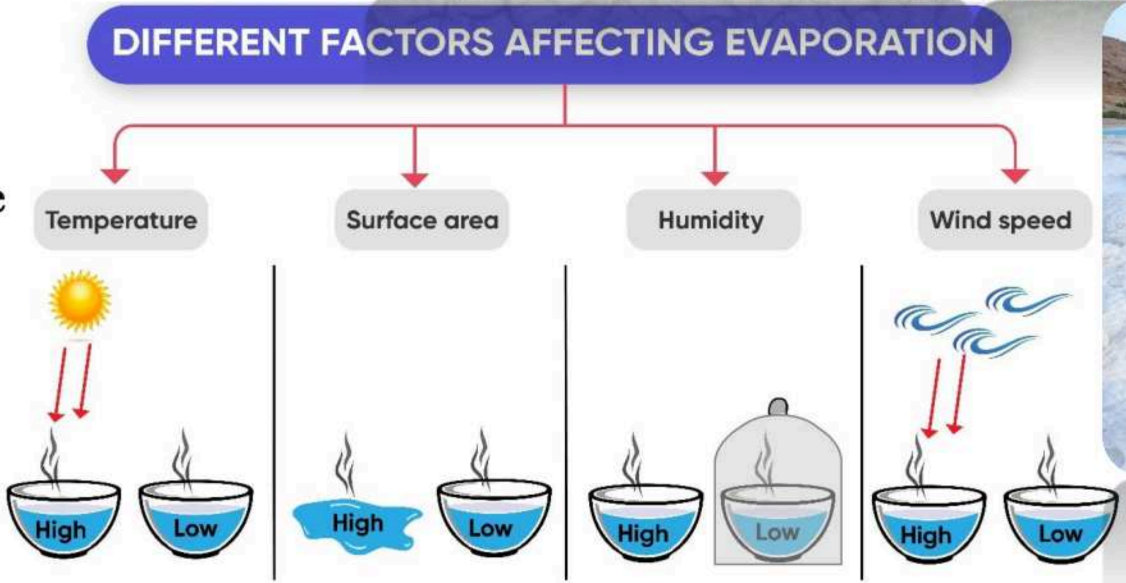
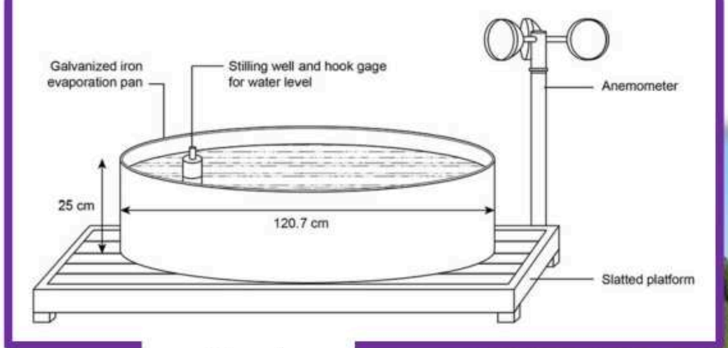
1. Evaporation (E)

Factors Affecting Evaporation

1. Nature of Evaporation Surface
2. Surface area
3. Temperature
4. Humidity
5. Wind speed
6. Quality of water

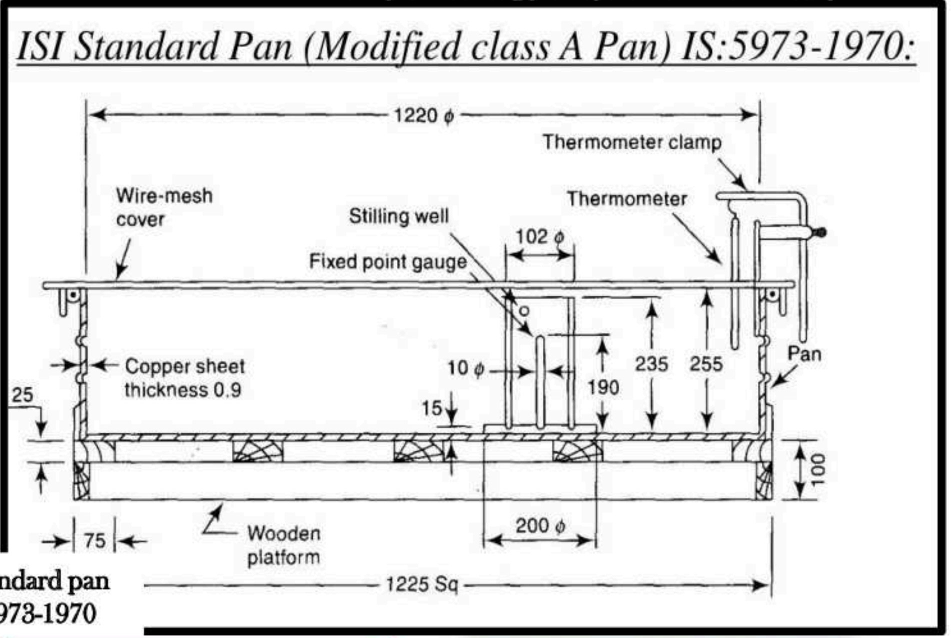


Measurement of Evaporation by using Pans

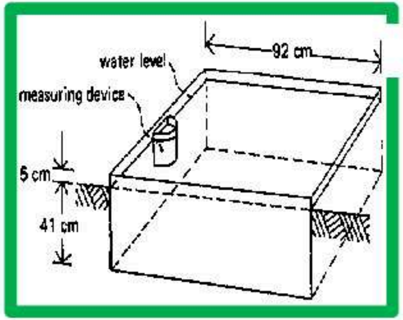


Class A Standard pan

ISI Standard pan IS : 5973-1970



US Geological survey Floating Pan



Colorado Sunken Pan

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Measurement of Evaporation by using Empirical Equations

1. **Dalton's law:** evaporation rate, E, controlled by two factors, the windspeed and the saturation deficit

e_a : current vapor pressure, e_s : saturation pressure at that temperature.

$$E_L = C\,(e_w - e_a)$$

E_L = rate of evaporation (mm / day)

C = constant

e_w and e_a are in mm of mercury

2. **Meyer's formula :** it is the empirical equation used to determine the lakes evaporation

$$E_L = K_M\,(e_w - e_a)\left[1 + \frac{u_9}{16}\right]$$

E_L = lake evaporation (mm / day)

e_w = saturation vapour pressure at the water surface temperature (mm of merucry)

e_a = actual vapour pressure of the overlying air at a specified height (mm of merucry)

u_9 = monthly mean wind velocity (kmph) at a height of 9m above the ground

K_M = coefficient accounting for other factors (0.36 for large deep waters and 0.50 for small shallow lakes)

3. **Rohwer's Equation :** Accounts for the effect of pressure in addition to the wind speed effect

$$E_L = 0.771(1.465 - 0.000732\,p_a)(0.44 + 0.0733\,u_0)(e_w - e_a)$$

p_a = mean barometric pressure (mm of mercury)

u_0 = mean wind velocity in kmph at ground level (taken as the wind velocity at 0.6m height above the ground)

E_L, e_w, and e_a are as mentioned earlier

Analytical Methods of Evaporation Estimation

1.Water Budget Method : If the unit of time is kept very large, estimates of evaporation will be more accurate.

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E_L + \Delta S + T_L$$

P = daily precipitation

V_{is} = daily surface inflow into the lake

V_{ig} = daily groundwater inflow

V_{os} = daily surface outlow from the lake

V_{og} = daily groundwater outflow

E_L = daily lake evaporation

ΔS = increase in lake storage in a day

T_L = daily transpiration loss

All quantities are expressed in units of volume or depth

2. Energy Budget Method : Energy available for evaporation is determined by considering the incoming energy, outgoing energy, and the energy stored in the water body over a known time interval

$$H_n = H_a + H_e + H_g + H_s + H_i$$

H_n = net heat energy received by the water surface = $H_c(1 - r) - H_b$

H_b = back (long wave) radiation from the water body

H_a = sensible heat transfer from the water surface to the air

H_g = heat flux into the ground

H_s = heat stored in the water body

H_e = heat energy used up in evaporation = $\rho L E_L$ (E_L = evaporation, L = latent heat of evaporation, ρ = mass density of the fluid)

H_i = net heat conducted out of the system by water flow (advected energy)

Example 4.15. *A reservoir with average surface spread of 4.8 km² in the first week of November has the water surface temperature of 30°C and relative humidity of 40%. Wind velocity measured at 3.0 m above the ground is 18 km/h. The mean barometer reading is 760 mm of Hg. Calculate the average evaporation loss from the reservoir in mm/day and the total depth and volume of evaporation loss in the first week of November. Use both Meyer's equation as well as Rohwer's equation. Take saturation vapour pressure at 30°C as 31.81 mm of Hg.*

Solution : (a) *Using Meyer's formula*

$$E = K_m (e_s - e_a)\left[1 + \frac{V_9}{16}\right]$$

Given : $e_s = 31.81$ mm Hg. Relative humidity $R_H = 40\% = 0.4$

∴ $e_a = e_s \cdot R_H = 31.81 \times 0.4 = 12.724$ mm Hg.

$$V_9 = V_2\left(\frac{9}{3}\right)^{1/7} = 18 \times 1.1699 = 21.06 \text{ km/h}$$

$K_m = 0.36$ for large, deep waters

∴ $$E = 0.36\,(31.81 - 12.724)\left[1 + \frac{21.06}{16}\right] = 15.91 \text{ mm /day}$$

∴ Total depth of evaporation in one weak $= 7 \times 15.91 = \mathbf{111.4\ mm}$

Total volume of water evaporated $= (111.4 \times 4.8 \times 10^6)\,10^{-3}$

$= 0.5347 \times 10^6$ m³ $=$ **53.47** hectare–m

(b) ***Using Rohwer's formula***

$$E = 0.771\,(1.465 - 0.000732\,P_a)\,(0.44 + 0.0733\,V_{0.6})\,(e_s - e_a)$$

where $e_s = 31.81$ mm Hg and $e_a = 12.724$ mm Hg, as earlier.

$P_a = 760$ mm Hg.

$$V_{0.6} = \left(\frac{0.6}{2}\right)^{1/7} \times 18 = 15.16 \text{ km/h}$$

∴ $E = 0.771\,(1.465 - 0.000732 \times 760)\,(0.44 + 0.0733 \times 15.16)\,(31.81 - 12.724)$

$= 20.74$ mm/day

∴ Total evaporation for one week $= 20.74 \times 7 \simeq \mathbf{145.2\ mm}$

∴ Total volume of water evaporated $= (145.2 \times 4.8 \times 10^6)\,10^{-3} = 0.697 \times 10^6$ m³

$=$ **69.7 hectare–m**

Thus, we find that Rohwer's formula gives about 30% higher results than Meyer's formula.

2. Precipitation

Forms of Precipitation:

Drizzle: a light steady rain in fine drops (0.5 mm) and intensity <1 mm/hr

Rain: the condensed water vapour of the atmosphere falling in drops (>0.5 mm, maximum size—6 mm) from the clouds.

Glaze: freezing of drizzle or rain when they come in contact with cold objects.

Sleet: frozen rain drops while falling through air at subfreezing temperature.

Snow: ice crystals resulting from sublimation (i.e., water vapour condenses to ice)

Hail: small lumps of ice (>5 mm in diameter) formed by alternate freezing and melting, when they are carried up and down in highly turbulent air currents.

Dew: moisture condensed from the atmosphere in small drops upon cool surfaces.

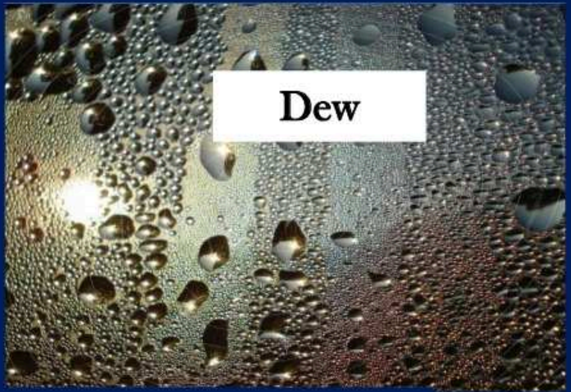
Frost: a feathery deposit of ice formed on the ground or on the surface of exposed objects by dew

Fog: a thin cloud of varying size formed at the surface of the earth by condensation of atmospheric vapour

Mist: a very thin fog


Hail


Sleet


Dew


Frost


Rain


Snow


Mist


Fog
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Glaze


Drizzle

Types of Precipitation

1. **Convectional Precipitation**

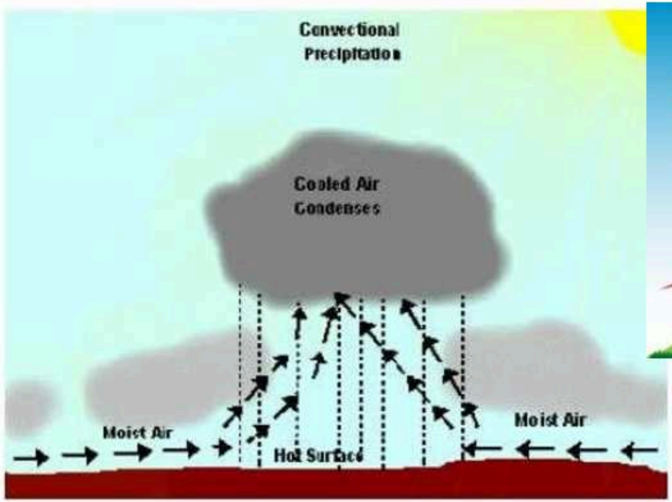
It results from the heating of the earth's surface. Due to this, the warm air rises rapidly into the atmosphere. As the air rises, it cools. Water vapour in the air condenses into clouds and precipitation.

2. **Orographic Precipitation:**

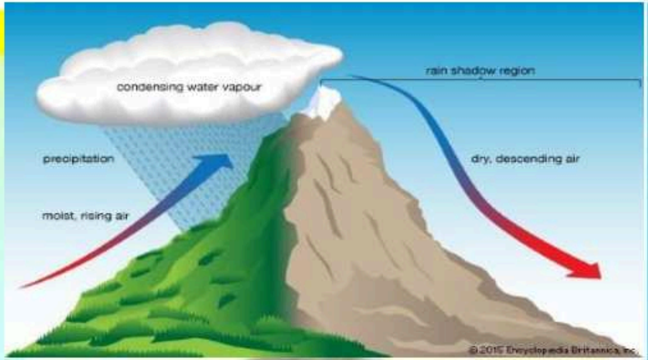
It results when warm moist air moving across the ocean is forced to rise by large mountains. As the air rises, it cools. As air cools, the water vapour in the air condenses and water droplets form. Precipitation occurs on the windward side of the mountain. The air is now dry and rises over top the mountain. As the air moves back down the mountain, it collects moisture from the ground via evaporation.

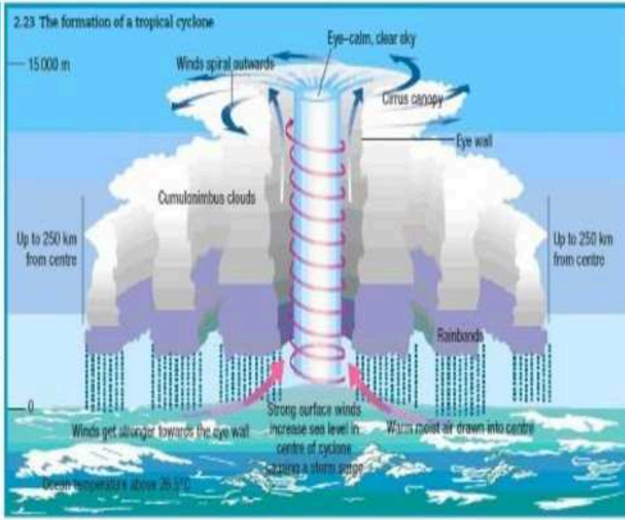
3. **Cyclonic**

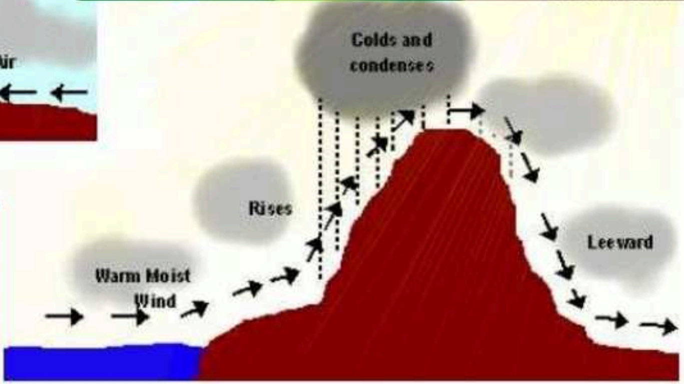
Cyclonic or Frontal precipitation results when the leading edge of a warm, moist air mass



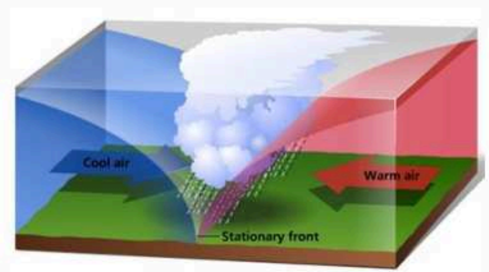
Convectional Precipitation

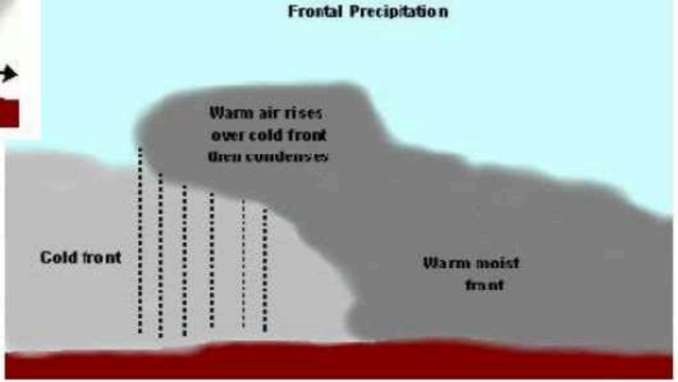






Orographic Precipitation





Frontal Precipitation

3. Infiltration

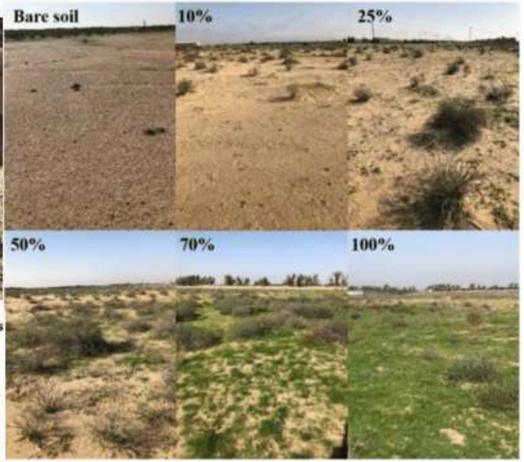
It is the process of water entry into a soil from rainfall, or irrigation.

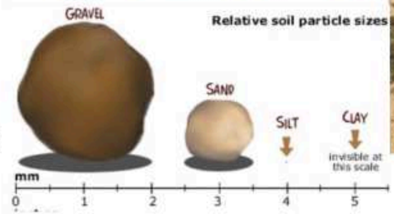
Infiltration rate is the rate at which the water actually infiltrates through the soil during a storm and it must be equal the infiltration capacities or the rainfall rate, whichever is lesser.

Infiltration capacity is the maximum rate at which a soil in any given condition is capable of absorbing water.

Factors affecting infiltration

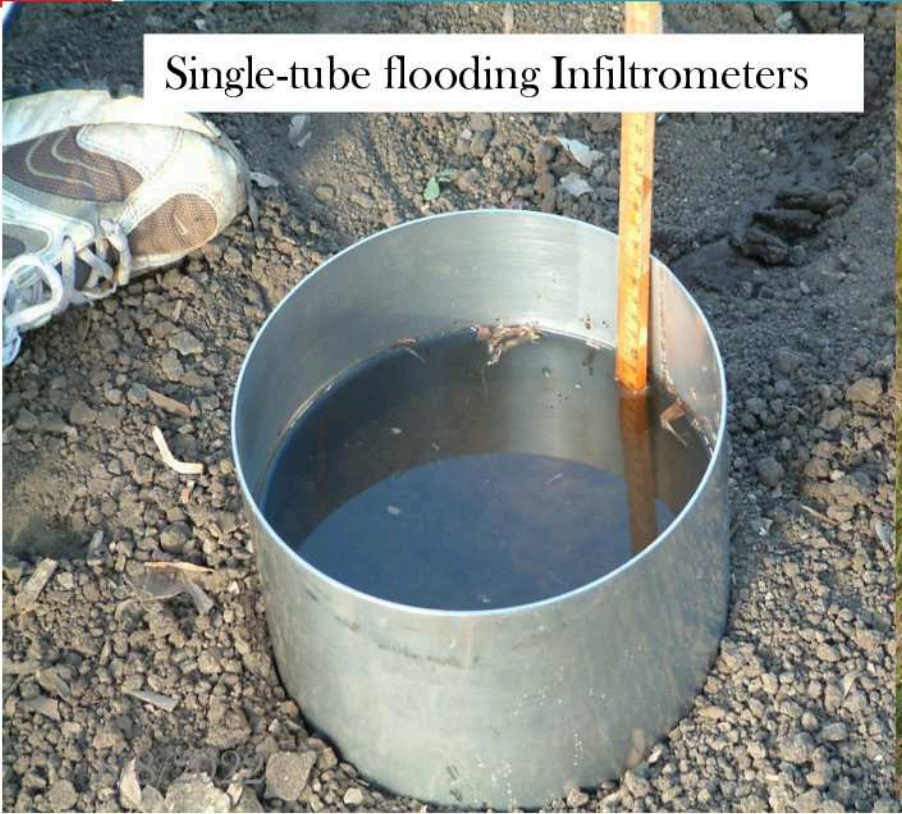
- Condition of the land surface (cracked, crusted, compacted
- Land vegetation cover
- Surface soil characteristics (grain size & gradation),
- Storm characteristics (intensity, duration & magnitude)
- Surface soil and water temperature, chemical properties of the water and soil





Measurement of Infiltration

The rate of infiltration is initially high. It goes on reducing with time and after some time it becomes steady. The rate of infiltration for a soil is measured in the field as well as in the laboratory. These are known as **Infiltrometers**



Single-tube flooding Infiltrometers

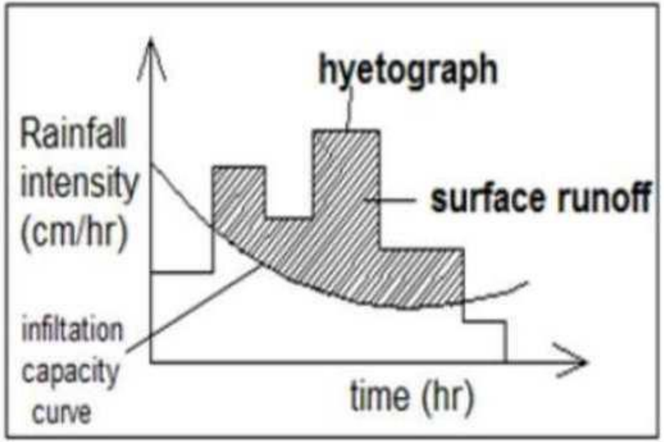
Double-Ring flooding Infiltrometers

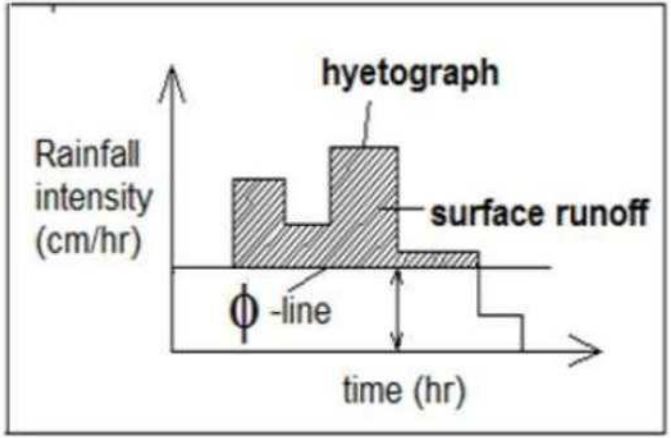
Infiltration indices

The average value of infiltration **is called Infiltration Index.**

Types:

- ϕ - Index
- W – Index





$$w\text{-index}=(P-R-I_a)/t_e$$

$$\phi\text{-index}=(P-R)/t_e$$

Where,

P = total storm precipitation (cm), R = total surface runoff (cm) , Ia = Initial losses (cm)

t_e = elapsed time period (in hours)

Example 4.18. *The rainfall rates for successive 30-minutes intervals upto 4 hours are given below. If the surface runoff is 3.6 cm, determine Φ and W indices.*

Time (minutes)	*0*	*30*	*60*	*90*	*120*	*150*	*180*	*210*	*240*
Rainfall intensity (cm/h)	*0*	*1.3*	*2.8*	*4.1*	*3.9*	*2.8*	*2.0*	*1.8*	*0.9*

Solution : (*a*) ***Computation of Φ-index***

Let $i =$ rate of rain in cm/h and Φ-index be expressed in cm/h.

Then total $R = \Sigma (i - \Phi_i) t$ where t is the time in hours.

Assuming Φ_i to be greater than 1.3 cm/h, but less that 1.8 cm/h we have

$$3.6 = [(2.8 - \Phi_i) + (4.1 - \Phi_i) + (3.9 - \Phi_i) + (2.8 - \Phi_i) + (2.0 - \Phi_i) + (1.8 - \Phi_i)] \frac{30}{60}$$

From which we get Φ_i **= 1.7 cm/h**

Since this is greater than 1.3 and less than 1.8 cm/h, the above computations are correct.

(*b*) ***Computation of W-index***

$$W_i = \frac{P - R - S_R}{t_r}$$

Here $P = 1.3 + 2.8 + 4.1 + 3.9 + 2.8 + 2.0 + 1.8 + 0.9) \frac{30}{60} = 9.8$ cm

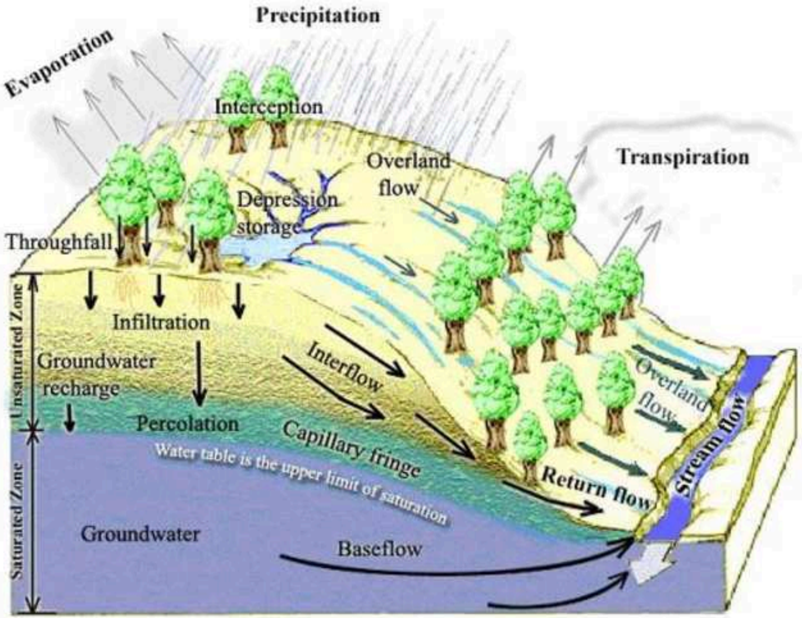
$R = 3.6$ cm; $S_R = 0$ and $t_r = 4$ hours

$\therefore \quad W_i = \frac{9.8 - 3.6 - 0}{4} =$ **1.55 cm/h**

Runoff: Runoff is defined as the portion of precipitation that makes its way towards rivers or oceans as surface or subsurface flow.

Factors affecting Runoff:

1. Climate factors
   a) Type of precipitation
   b) Intensity of rainfall
   c) Duration of rainfall
   d) Area distribution of rainfall
   e) Antecedent or Previous precipitation
   f) Other climatic factors that effect evaporation and transpiration



2. Physiographic factors
   a) Land use
   b) Type of Soil
   c) Area of the basin or catchment
   d) Shape of the basin
   e) Elevation
   f) Slope
   g) Orientation or Aspect
   h) Type of drainage network
   i) Indirect drainage
   j) Artificial drainage

Computation of Runoff:

1. Empirical Formulae (to find peak runoff)
    a) Dicken's formula
    b) Ryve's formula
    c) Igles's formula
    d) Khosla's formula
2. Infiltration Indices
3. Unit Hydrograph Method

This formula was developed in areas of old Bombay state. It states that

$$Qp = \frac{123\ A}{\sqrt{A + 10.4}}$$

Where,

Q_p = Peak discharge in Cumecs (m^3/s).

A = Area of the catchment in sq km (km^2).

In this method, the amount of mean annual runoff is calculated by following formula:

$R = P - (T / 3.74)$

Where:

R = mean annual runoff of watershed by cm,

P = mean annual precipitation by cm, and

T = mean annual temperature by ˚C.

Igles's Formula:

Khosla's Formula:

This formula was developed in the year 1865. It states that

$$Q_p = C_d A^{3/4}$$

Where,

Q_p = peak discharge rate (m^3/s)

C_d = a constant (Dickens'), ranging from 6 to 30

A = Drainage basin area (km^2).

For Indian conditions, suggested values for C_d are given as below:

Region	Topography	C_d
Northern states	Plains	6
	Hills	11-14
Central states	-	14.28
Coastal area	-	22.28.

Ryve's formula was reported in the year 1884. It states that

$$Q_p = C_r A^{2/3}$$

Where,

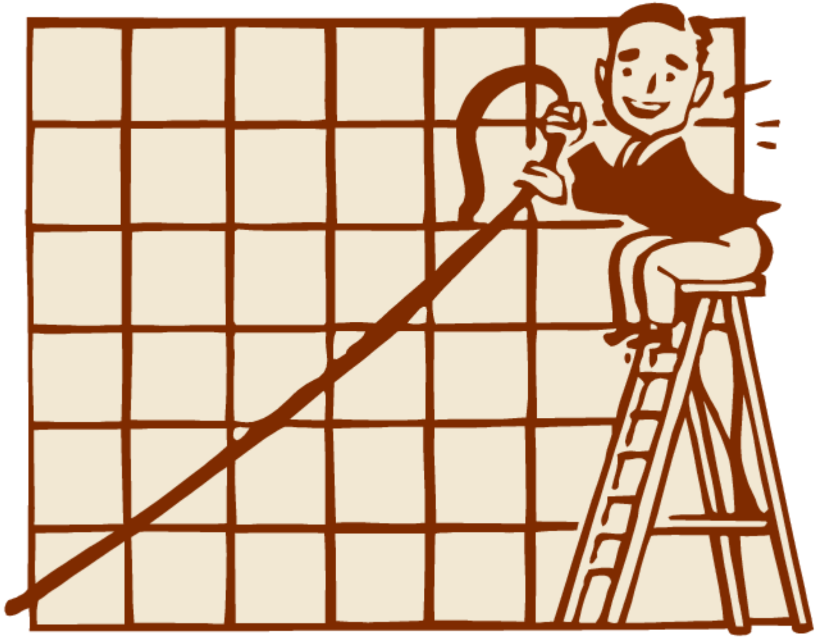
Q_p = Peak discharge rate (m^3/s).

A = Drainage basin area (km^2).

C_r = A constant (Ryves), as shown below:

Region	C_r
Within 80 km from east coast	6.8
80-160 km from east coast	8.5
Hills	10.2

B. Analysis of Hydrographs



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Hydrograph Record of River Discharge over a period of time

River Discharge = cross sectional area X rivers mean (average) velocity
(at a particular point in its course)

Why Construct & Analyse Hydrographs ?

- To find out discharge patterns of a particular drainage basin
- Help predict flooding events, therefore influence implementation of flood prevention measures

HYDROGRAPH

Hydrograph

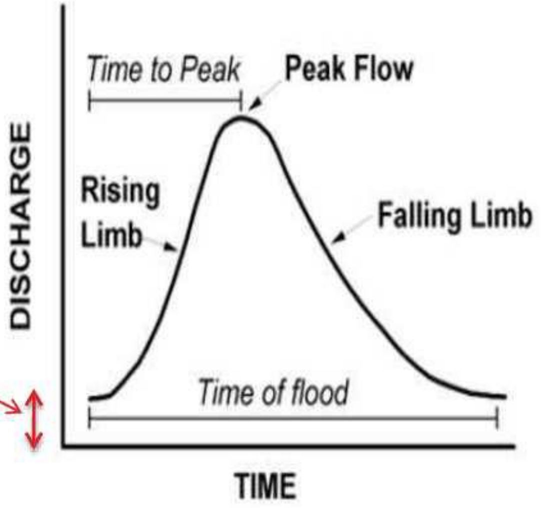
Hydrograph is the graphical representation of the instantaneous rate of discharge of a stream plotted with respect to time

Terminology:

Lag time: The time period between peak rainfall and peak discharge.

Base flow: The constant part of a river's discharge produced by groundwater and slow through flow seeping slowly into the river.

Surface Runoff: Combination of overland flow and rapid through flow.



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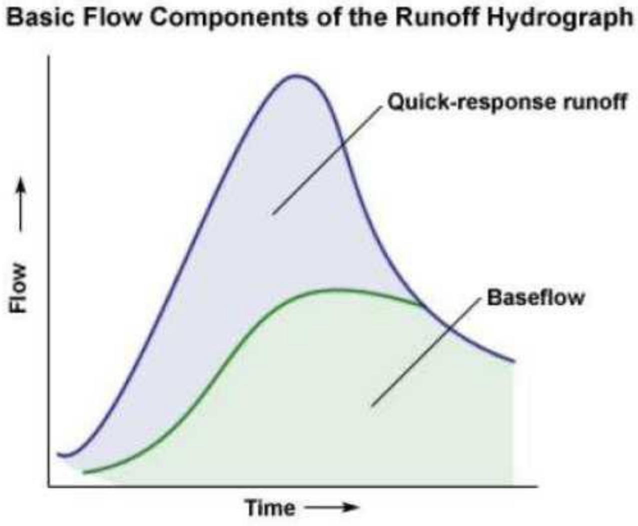

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Factors affecting the hydrograph shape

Climatic factors

- ✓ Precipitation (Intensity and duration of the storm), Evapotranspiration
- ✓ Soil characteristics
- ✓ Soil moisture (Antecedent /pre-existing conditions), Permeability of soil
- ✓ Drainage basin characteristics
- ✓ Drainage density, Size of drainage basin, Slopes , Rock type, Vegetation cover,
- ✓ Soil depth
- ✓ Human activity
- ✓ Forests (Deforestation / Reforestation), Urban development, Agricultural practices

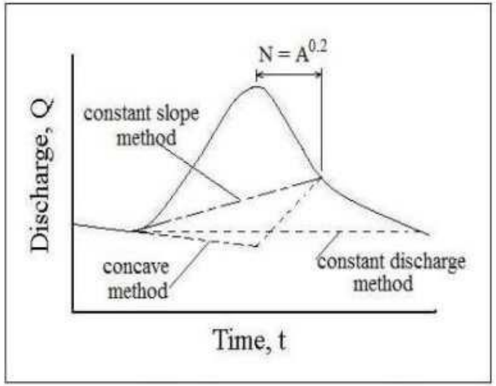
Hydrograph Separation

Baseflow separation is performed to determine the portion of the hydrograph attributable to Baseflow which is not associated with storm.

Methods of Baseflow Separation:

1.Constant Discharge Method - minimum value immediately prior to beginning of storm hydrograph

2.Constant Slope Method - Connect inflection point on Receding limb of storm hydrograph to beginning of storm hydrograph accurate model of hydrograph recessions is needed combine data from several recessions to make general



Baseflow Separation Methods

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1.Concave Method (most realistic) - Project hydrograph trend from minimum discharge value immediately prior to beginning of storm hydrograph to directly beneath hydrograph peak connect that point to inflection point on receding limb of storm hydrograph

2.Master depletion curve method

Hydrograph Analysis

Unit Hydrograph:

- Very often it is required to predict the flood hydrograph resulting from a known storm
- Unit Hydrograph Method is the most popular and widely used method for predicting flood hydrograph resulting from a known storm

The Unit Hydrograph of a catchment is defined as the hydrograph resulting from an effective rainfall of 1mm evenly distributed over the basin during the time.

Assumptions:

1.The duration of direct runoff is always the same regardless of the intensity

2.The ordinates of the UH are directly proportional to the storm intensity

3.The time distribution of the direct runoff is independent of concurrent runoff from antecedent storm events. This implies that direct runoff responses can be superposed
4.Hydrologic systems are usually nonlinear due to factor such as storm origin and patterns and stream channel hydraulic properties

Creating a Unit Hydrograph:

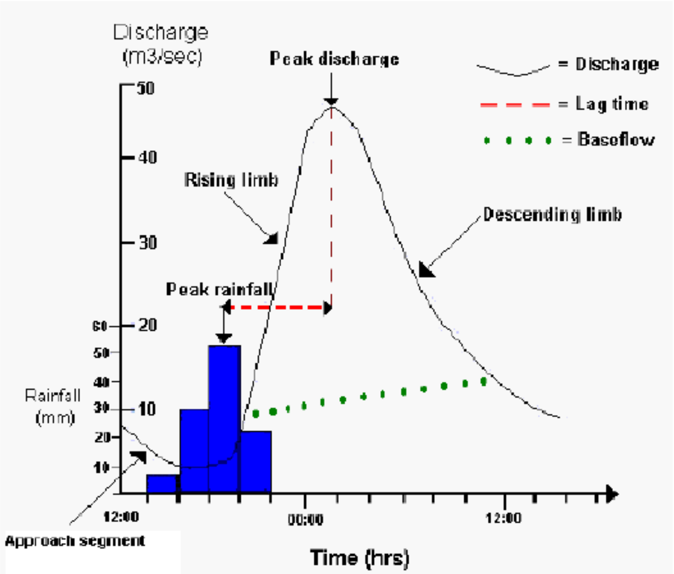
1.Select the appropriate storm (uniform rate and coverage).

2.Separate the base flow and plot the direct runoff hydrograph.

3.Measure the total volume of water that has passed the flow measuring point by finding the area under the DRH curve

4.Calculate the average uniform rainfall depth that produced the DRH by dividing the volume of flow by the catchment area.

5.Adjust the hydrograph to represent 1



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Application of Unit Hydrograph:

1.A unit hydrograph is used to estimate stream flow or discharge given a basin averaged rainfall.

2.The development of flood hydrographs for extreme rainfall magnitudes (for use in the design of hydraulic structures)

3.Extension of flood flow records based on rainfall records

4.Development of flood forecasting and warning systems based on rainfall

Limitations of application of Unit Hydrograph:

1.Unit hydrographs assume uniform distribution of rainfall over the catchment and uniform intensity during the duration of rainfall excess. In practice, these two conditions are never satisfied.

2.The size of the catchment imposes an upper limit on the applicability of the unit hydrograph theory

3.The upper limit for use of the unit hydrograph method is 5000 km^2

Problem 1:

Given below are observed flows from a storm of 6 hour duration on a stream with a catchment area of 500 km^2

Time(hr)	0	6	12	18	24	30	36	42	48	54	60	66	72
Flow(m^3/s)	20	120	270	220	170	120	90	70	55	45	35	25	20

Assuming a constant base flow of 20 m^3/s, derive the ordinates of a 6 hour unit hydrograph.

Solution

Time Hour	Observed flow cumecs	Base flow cumecs	Direct runoff cumecs	6 hour U.H cumecs	Hour after start
0	20	20	0	0	0
6	120	20	100	23.15	6
12	270	20	250	57.87	12
18	220	20	200	46.30	18
24	170	20	150	34.72	24
30	120	20	100	23.15	30
36	90	20	70	16.20	36
42	70	20	50	11.57	42
48	55	20	35	8.10	48
54	45	20	25	5.79	54
60	35	20	15	3.47	60
66	25	20	5	1.16	66
72	20	20	0	0	72
			1000	231.48	

$\sum$ D. R = 1000 cumecs , drainage area = 500km^2

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$$\text{D.R depth} = \frac{1000 \times 6 \times 60 \times 60}{500 \times 10^6} \times 100 = 4.32cm$$

Check $\sum$ U.H ordinates = 231.48 cumecs

$$\text{U.H depth} = \frac{231.48 \times 6 \times 60 \times 60}{500 \times 10^6} \times 100 = 0.999 \approx 1cm$$

Problem 2: The ordinates of 3 hour unit hydrograph of a basin at 6 hour interval are given below 0,3,5,9,11,7,5,4,2,1,0 cumecs. Derive the storm hydrograph due to a 3 hour storm with a total rainfall of 15 cm. Assume an initial loss of 0.5 cm and □- index of 1 cm/hr. Take base flow = 4 cumecs.

Solution: Effective rainfall depth R = 15 – 0.5 – 1 x 3 = 11.5 cm

Time (hours)	Unit hydrograph ordinates (cumecs)	Direct runoff ordinates (cumecs)	Base flow	Ordinate of storm hydrograph (cumecs)
0	0	0	4	4
6	3	34.5	4	38.5
12	5	57.5	4	61.5
18	9	103.5	4	107.5
24	11	115.0	4	119.0
30	7	80.5	4	84.5
36	5	57.5	4	61.5
42	4	46.0	4	50.0
48	2	23.0	4	27.0
54	1	11.5	4	15.5
60	0	0	4	4.0

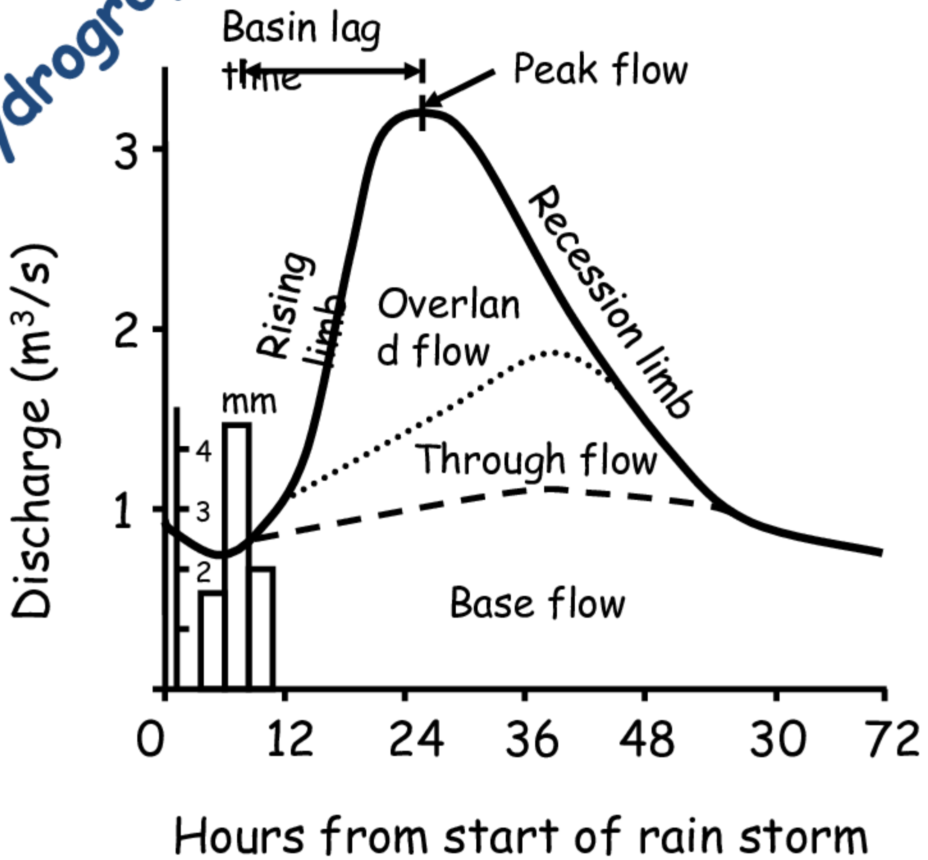
Table 6.7 Calculation of a 12-h Unit Hydrograph from a 4-H Unit Hydrograph—Example 6.9

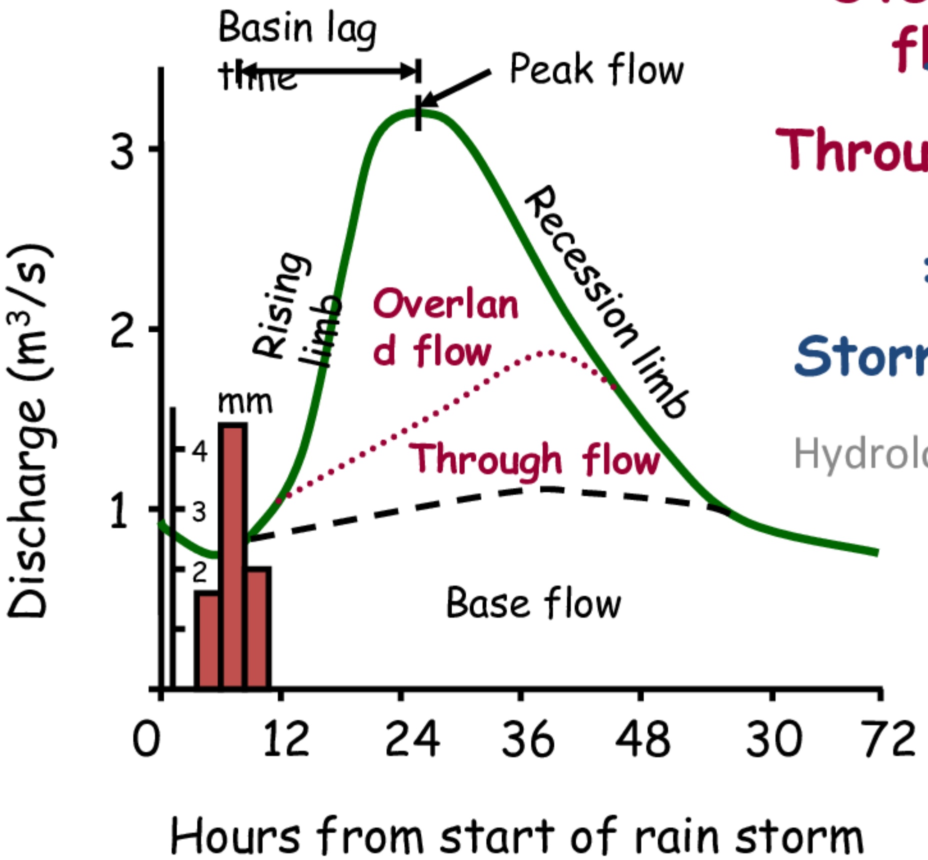
Time (h)	Ordinates of 4-h UH (m^3/s) A	B Lagged by 4-h	C Lagged by 8-h	DRH of 3 cm in 12-h (m^3/s) (Col. 2+3+4)	Ordinate of 12-h UH (m^3/s) (Col. 5)/3
1	2	3	4	5	6
0	0	—	—	0	0
4	20	0	—	20	6.7
8	80	20	0	100	33.3
12	130	80	20	230	76.7
16	150	130	80	360	120.0
20	130	150	130	410	136.7
24	90	130	150	370	123.3
28	52	90	130	272	90.7
32	27	52	90	169	56.3
36	15	27	52	94	31.3
40	5	15	27	47	15.7
44	0	5	15	20	6.7
48		0	5	5	1.7
52			0	0	0

Construction

Of
Storm (flood) Hydrographs

Flood Hydrograph





Overland flow

+

Through flow

=

Storm Flow

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Factors influencing Storm Hydrographs

- Area
- Shape
- Slope
- Rock Type
- Soil

- Land Use
- Drainage Density
- Precipitation / Temp
- Tidal Condition

S-Hydrograph

$$Q_0 = \frac{(A \times 100 \times 100)\, R_0}{100 \times 3600} = \frac{A\, R_0}{36} \text{ cumecs}$$

$$Q_0 = \frac{(A \times 1000 \times 1000)\, R_0}{100 \times 3600} = 2.778\ A\, R_0 \text{ (cumecs)}$$

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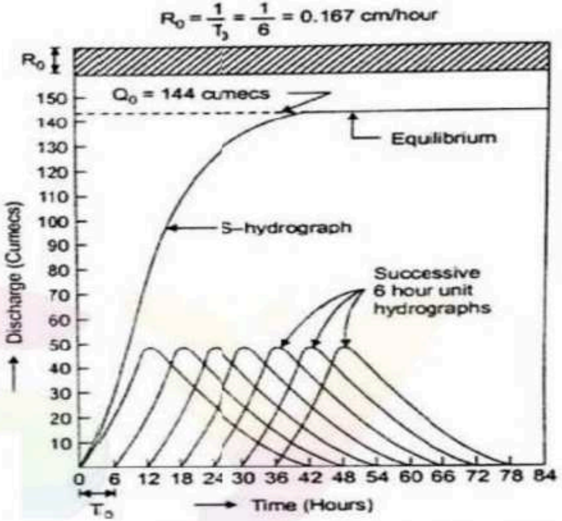


DERIVATION OF S-HYDROGRAPH FROM UNIT HYDROGRAPH

TABLE COMPUTATIONS FOR S-HYDROGRAPH

Time	*Ordinate of unit hydrograph*	*Ordinates of successive unit hydrographs*						*Ordinate of S-hydrograph*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
00	0	http://Easyengineering.net			–	–	–	0
03	9	–	–	–	–	–	–	9
06	20	0	–	–	–	–	–	20
09	35	9	–	–	–	–	–	44
12	49	20	0	–	–	–	–	69
15	43	35	9	–	–	–	–	87
18	35	49	20	0	–	–	–	104
21	28	43	35	9	–	–	–	115
24	22	35	49	20	0	–	–	126
27	17	28	43	35	9	–	–	132
30	12	22	35	49	20	0	–	138
33	9	17	28	43	35	9	–	141
36	6	12	22	35	49	20	0	144
39	3	9	17	28	43	35	9	144
42	0	6	12	22	35	49	20	144

Unit - III

By Meenu priya

A) Irrigation

Irrigation: The process of Artificially Supplying Water to Soil for Raising Crops.

Necessity & Importance of Irrigation:
- Inadequate Rainfall
- Non-Uniform Rainfall
- Growing a No. of Crops in a Year
- Growing perennial & Superior Crops
- Increasing Yield of Crops
- Insurance against droughts.

Advantages of Irrigation:
- Yield of Crops
- optimum benefits
- Elimination of Mixed Cropping
- prosperity of Farmers
- Sources of Revenue
- Hydro-Electric power Generation
- Water Supply
- General Communication Line in remote Village area
- Navigation Water way
- Aesthetic View
- Development of Fishery
- Tree plantation
- Protection from Famine
- Increase of Groundwater level
- Aid to Civilization
- Nutrition of people
- Recreation
- Social & Cultural Improvement
- Self - Sufficiency in Food

Ill-Effects of Irrigation: Raising Water-Table, Damp Climate, Breeding places of Mosquitoes, loss of Valuable land, Return of Revenue.

Methods of Application of Irrigation Water

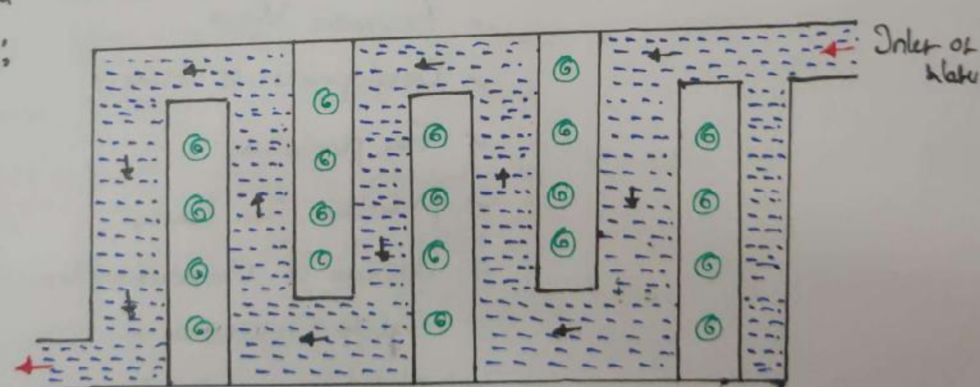
Types of Irrigation

- Surface Irrigation
  - Flooding Method
    - Wild Flooding
    - Controlled Flooding
      - Free Flooding
      - Contour laterals
      - Border Strips
      - Check Flooding
      - Basin Flooding
      - Zig-Zag Method
  - Furrow Method
  - Contour Farming
- Sub-Surface Irrigation
- Sprinkler Irrigation
- Drip Irrigation

1) Surface-Irrigation: It is the Irrigation Technique in which water is applied & distributed over soil surface by Gravity.

→ Ground Slope < 3%.
→ Infiltration Capacity of Soil – low to Moderate
→ Flow of water under Gravity
→ Maximum Wastage of Water

a) Furrow Method:



→ In this Method only 1/5th to 1/2 of land Surface is wetted by water
→ It avoids Flooding the entire Surface by Channeling Flow along

Primary direction of Field using Furrows, grooves, Lines

→ Furrows are Narrow Field ditches excavated B/n Rows of Plants & Carry irrigation Water through them.

→ Evaporation loss is less here

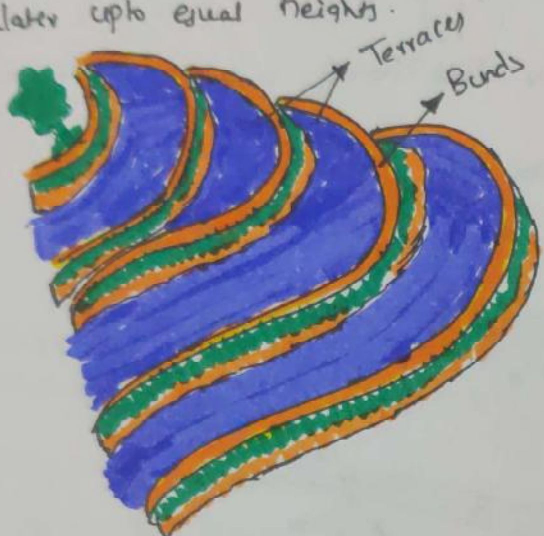
→ It's Suitable For Row Crops.

b) Contour Farming :

→ Its practiced in Hilly areas with Slopes & Falling Contour.

→ land divided into Series of horizontal Strips Called Terraces

→ Small bunds are Constructed at the end of each terrace to hold Water upto equal heights.



c) Flooding Method : It Consist of Opening a Water Channel in a plot or Field so that Water Can Flow Freely in all direction & Cover over Surface of land in a Continuous Sheet.

i) Uncontrolled / Wild Flooding : Water is Spread or Flooded on Smooth Flat land, without Control, Without preparation of land

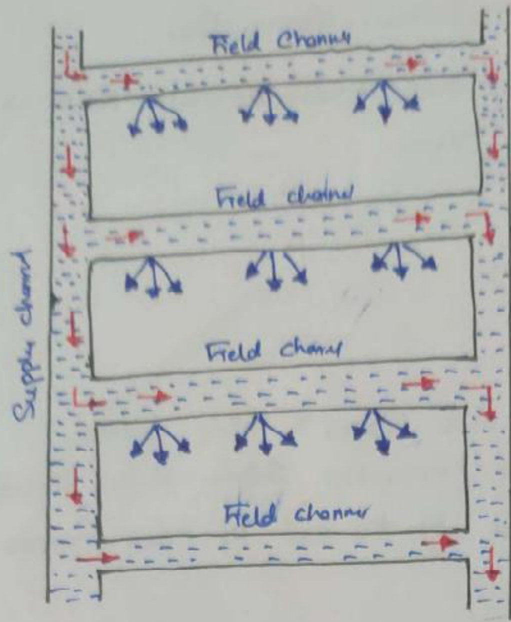
ii) Controlled Flooding : Water is applied by Spreading it over the land with proper Control on Flow Of Water.

@ Free Flooding : → dividing entire land to be into Small Strips Called as laterals of Field Channel.

→ these laterals may be either @ right angles to the Sides of Field

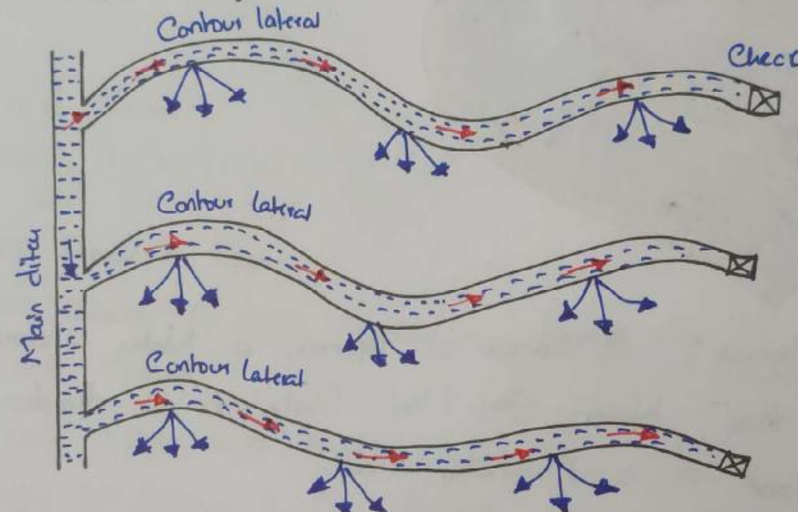
→ The Field Channels Recieve Water From Main Supply Channel

→ This Method is Used For both Flats & Steep Land



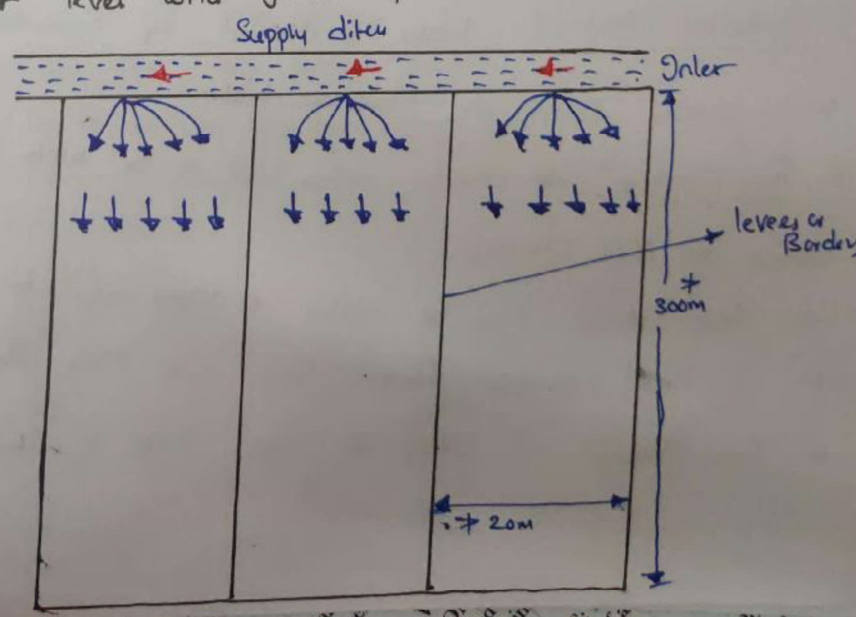
(b) Contour laterals: Incase of Free Flooding Field channel or laterals aligned along contour lines.

→ In this Method Irrigation possible only on Side of laterals.

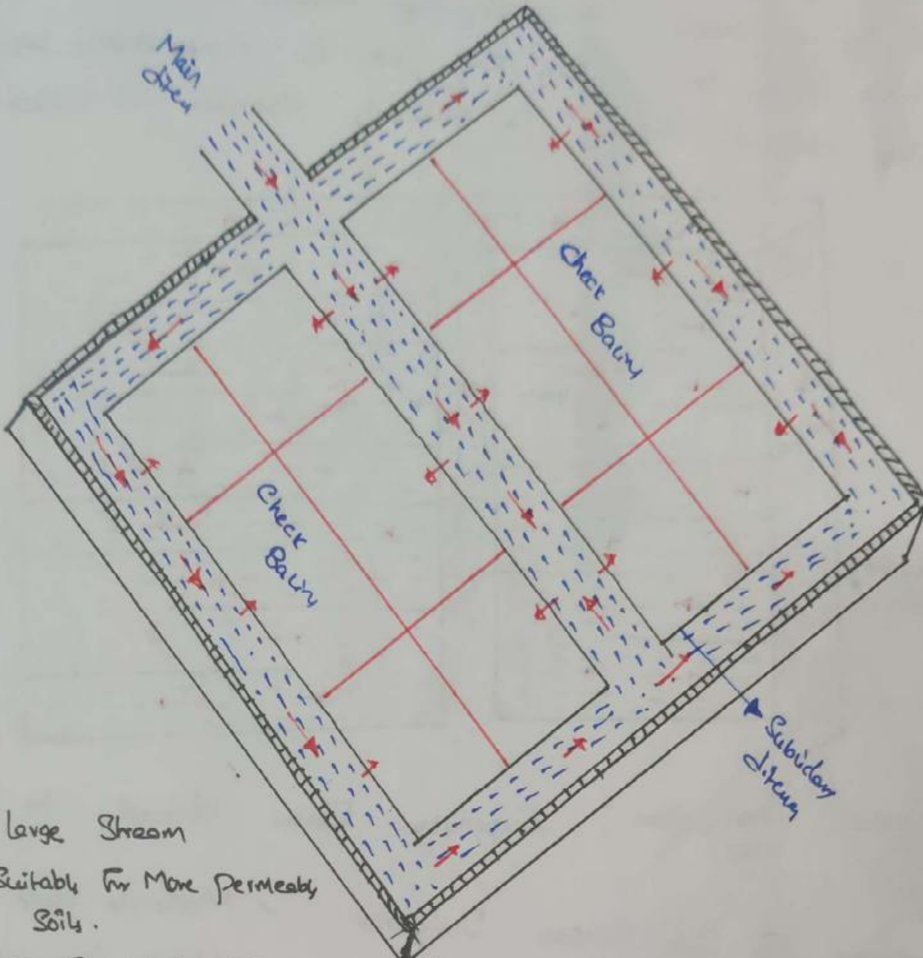


(c) Border Strip Method: land divided into Series of Strips 10 to 20m wide & 100 to 300 m long by levees (Small bunds)

→ It's Suitable at level with gentle Slope.



(d) Check Flooding : Area divided into Some Plots & Controlled by Small levees (5)



→ Because of large Stream discharge Suitable For More permeable Soils.

→ Ground Slope Should be Flat

→ Type of Soil Suitable For deep homogeneous loam or clay Soil with medium Infiltration rate Method.

→ Yielding Close growing crops paddy and Ceral Crops

→ less permeable Soil Suitable For these Irrigation

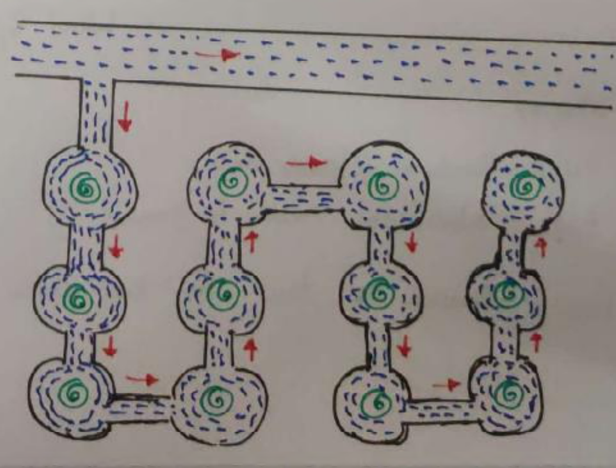
(e) Basin Flooding : One type of Check Flooding

→ Each plant is enclosed by Circular Channels Called as Basins

→ Basins are Connected to Small Field ditches

→ Field ditches are Fed From Main Supply Channel.

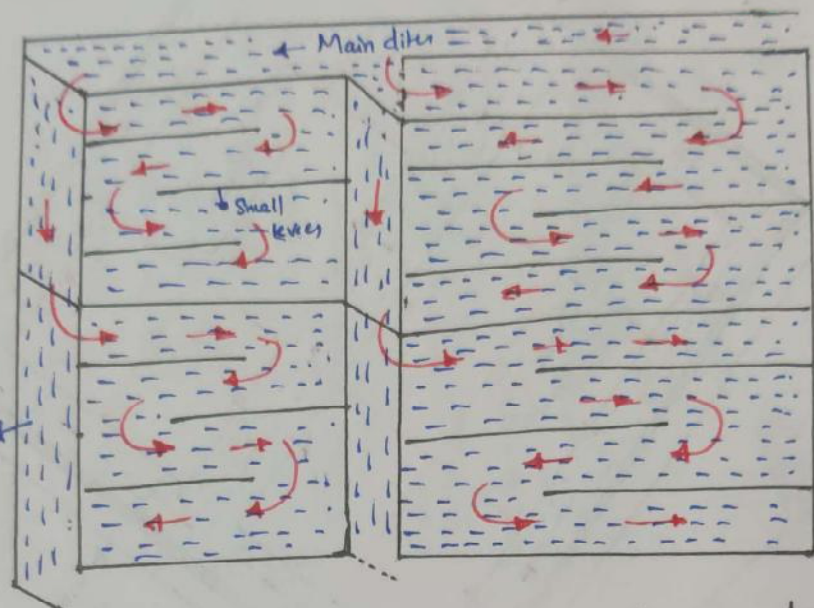
→ Ring Basin May be Formed For two or More Trees



(F) Zig-Zag Method : Agricultural area is Sub-divided into Small plots by low bunds in a Zig-Zag Manner.

→ Water Flows in a Zig-Zag way to Cover entire area.

→ When desired depth is attained, openings are closed.



2) Sub-Surface Irrigation : Supplying Water directly to the root Zone of the plants.

→ Conditions For Sub-Surface Irrigation
- Moderate Slope
- Uniform topographic Condition
- Good quality of Irrigation Water
- Impervious Sub-Soil at reasonable depth (2-3m)

3) Sprinkler Irrigation : Artificial application of Rain.

→ Consist of Network of pipes & Sprinkles Spaced @ Suitable places.

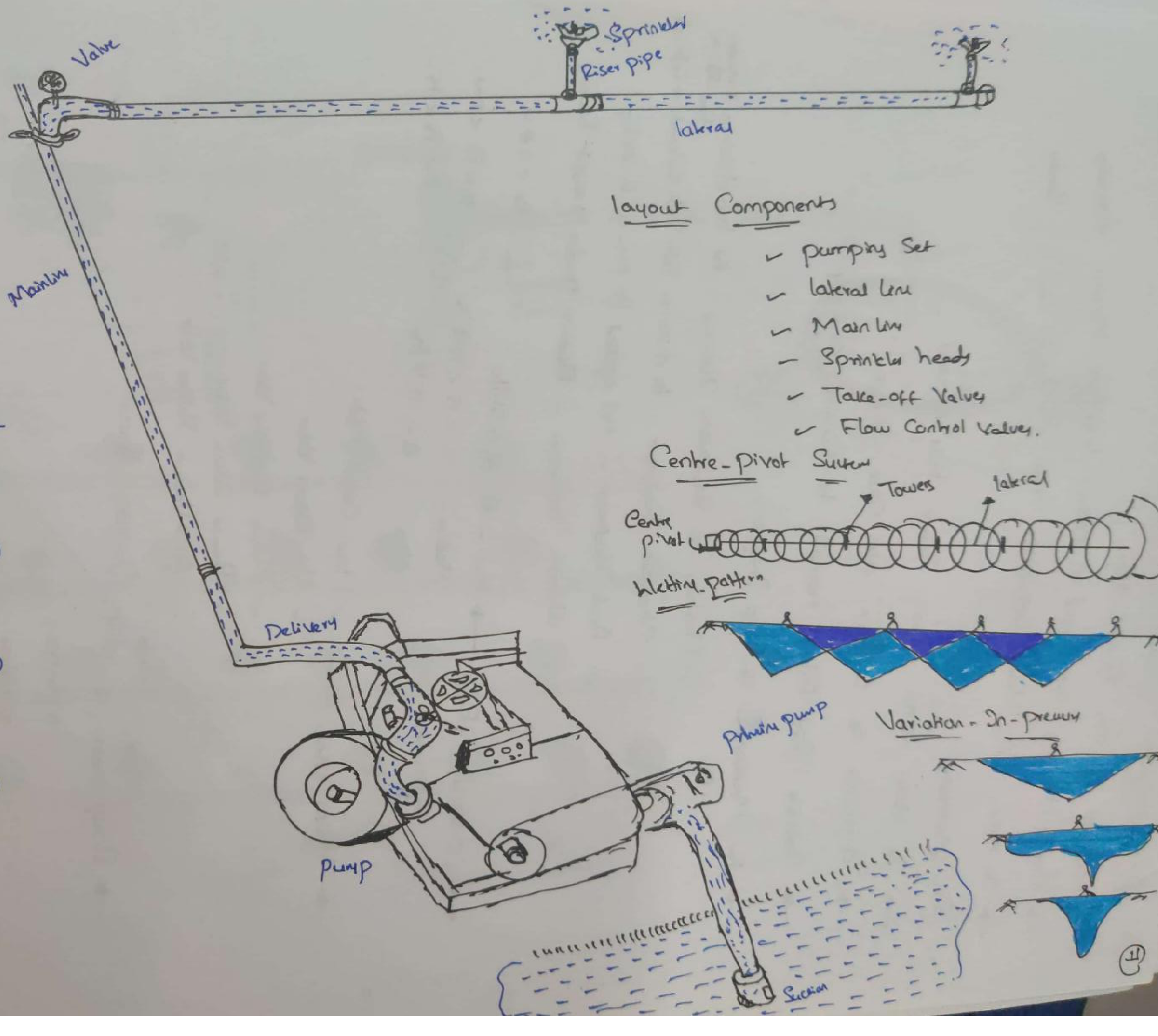
→ @ Nozzle "pressure head" Converted to "Velocity head".

→ Area of land Wetted depends on
- Velocity of Water Jet
- Angle of Flow
- Type of Sprinkler & it's design
- Wind Speed & direction.

→ Gradient is Steeper

→ Adaptable @ high Sandy or Clayey Soil
@ high Water table near to ground

→ Seasonable Water demand is low For that area.



layout Components

- ✓ pumping Set
- ✓ lateral line
- ✓ Main line
- – Sprinkler heads
- ✓ Take-off Valves
- ✓ Flow Control valves.

Centre-pivot System

Wetting pattern

Variation - In - pressure

Layout - Sprinkler Irrigation System

4) Drip Irrigation : Water is applied Frequently @ Slow rate < 14 lit/hr

→ Acceptable to any Farmable Slope

→ Crop & drippers are placed at Contour lines to Minimize discharge.

→ In clayey Soil, Water application rate Should be low, in Sandy Soil Moderate.

→ If Water is not Clean, System may chocked.

→ deposition of Fertilizer also Cause chocking

→ Suitable Sand Filters needed to Counter chocking.

→ For Maintenance of Drip Irrigation

- ✓ Flushing of Sub-Main & laterals - For low discharge & remove Sand Silt
- ✓ Chemical Treatment - to dissolve Salts & Bi-carbonate of Ca, Fe, Na
- ✓ Acid Treatment — HCl applied till pH-4 for 24 hrs
- ✓ Chlorine Treatment - Bleaching powder to avoid Bacteria

→ discharge Rates & pressures →

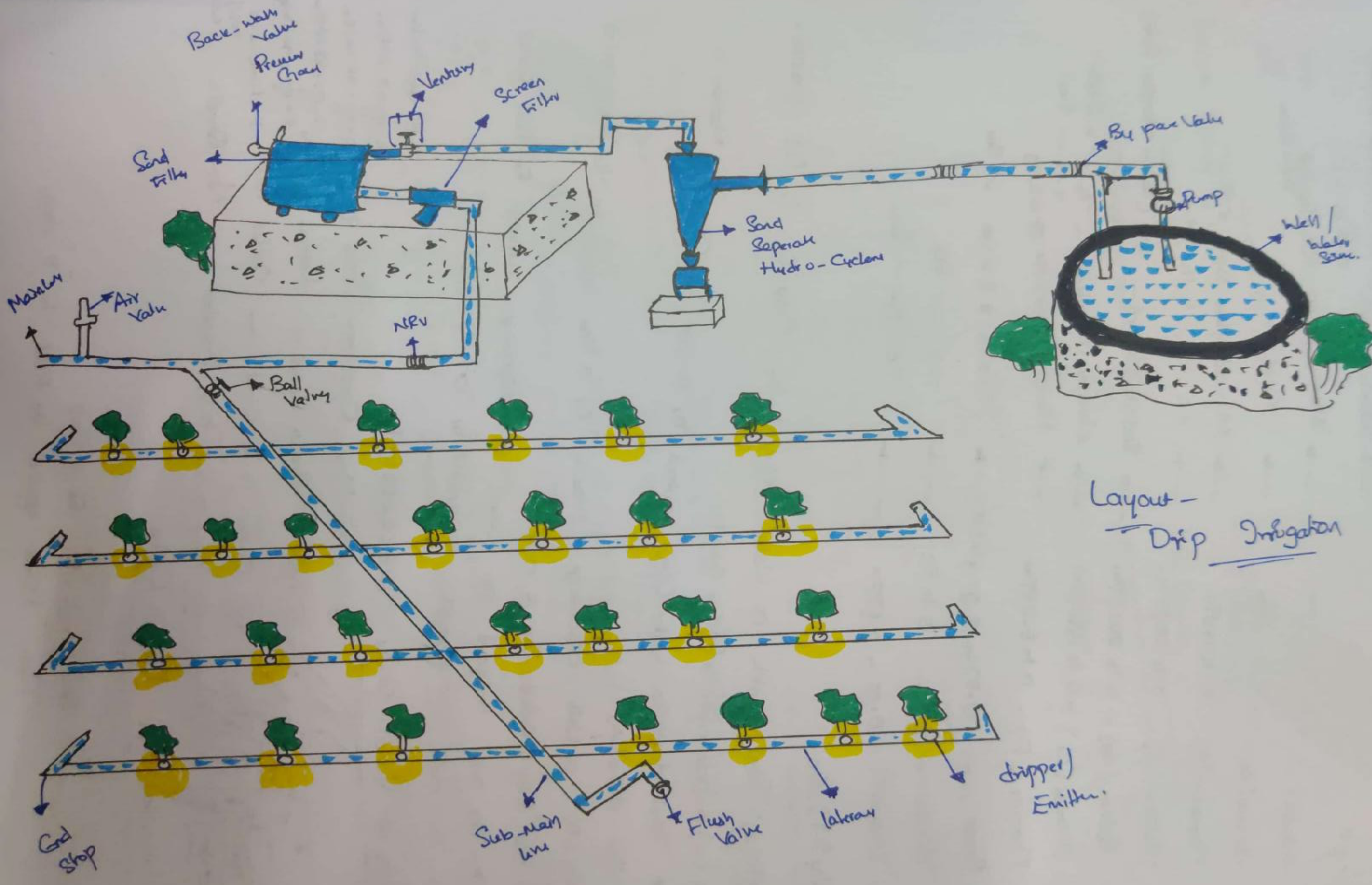
low	$Q < 4$ lit/hr	$P_r < 0.8$ M
Medium	$4 < Q < 10$ lit/hr	$2 < P_r < 8$ M
High	$Q < 15$ lit/hr.	$8 < P_r < 15$ m

→ Valves Used →

- ✓ Flow Control Valve
- ✓ Non-Return Valve
- ✓ Pressure Regulating Valve
- ✓ Pressure Relief Valve
- ✓ Air & Vaccum Release Valve.

→ Components of drip Irrigation System

1) drippers
2) Valves
3) Filters
4) Main line
5) Sub-Main line
6) lateral lines
7) Pump
8) Fertilizer tank, etc..



Layout -
Drip Irrigation

Quality of Irrigation Water : Mainly depends on Amount & type of Salts (10) present in Water

pH	2.7 to 11.3	→ Salinity hazard — EC (Electrical Conductivity) 0–0.25 ✓
Alkalinity	0 to 1120 PPM	→ Alkalinity hazard – RSC – Residual Sodium Carbon – <1.25 Safe.
		→ <1.25 ✓
Calcium (Ca)	0 to 500 PPM	→ Mg adsorption Ratio < 50 ✓
Magnesium (Mg)	0 to 190 PPM.	→ <4 ✓, 4-12 OK ✓
Sulphur (S)	0 to 750 PPM.	→ Sodicity hazard – SAR (Sodium adsorption Ratio) 0–10 ✓
Sodium (Na)	0 to 2500 PPM	→ chloride concentration – 4 ✓ * Excellent; 4-7 ✓ Good
Chloride (Cl)	0 to 1480 PPM	→ Flouride concentration ≯ 0.3 mg
Fluroide (F)	0 to 8.3 PPM	
Boron	0.33 to 3.25 mg/lt 3.25	→ B<0.33 & B < 1.00 ✓ Safe
		<5 ✓ Safe
Nitrate – (NO_3)	5 to 30	→ <0.1 ppm ✓ Safe
Litium	0.05 – 2.5 PPM	→

Duty & Delta

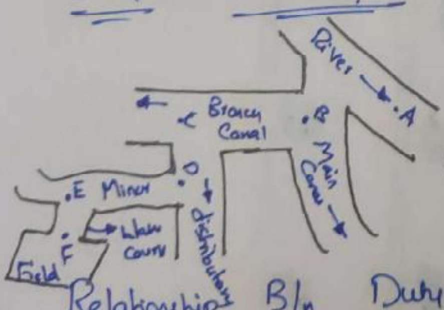
Delta (Δ): Total quantity of Water required by Crop for its full growth. (in cm) or (hectare-m) or (Million Cubic Ft) required by a Crop to come to Maturity is

→ Total depth of Water (cm) required by a Crop to come to Maturity is called delta (Δ).

Duty (D): a Unit discharge flowing for a time equal to the base period of the Crop, called Base of duty.

→ The area irrigated per cumec of discharge running for base period B. The duty is generally represented by "D". $D = A/Q$

Duty at Various places : A<B<C<D<E<F



@ head of Main Canal — Gross quantity
@ head of Branch Canal — Lateral quantity
@ Outlet of a Canal — Outlet Factor
@ head of land to be Irrigated — Net Quantity.

A – $\frac{100}{15}$ = 66.66 hect/cm.
B – $\frac{100}{14}$ = 71.42 he/cm
C – $\frac{100}{13}$ = 76.9 ha/cm
D – $\frac{100}{12}$ = 83.33 ha/cm
E – $\frac{100}{11}$ = 90.9 hect/cm
F – 1 Cumec → 100 hect/cm

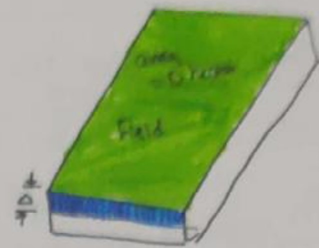
Relationship B/n Duty & Delta

let, Base period "B" for a Crop
Water "1 Cumec" applied on Field for "B" days.

Volume of Water applied to Crop in "B" days

$$V = 1\times(60\times60\times24\times B)\,m^3$$

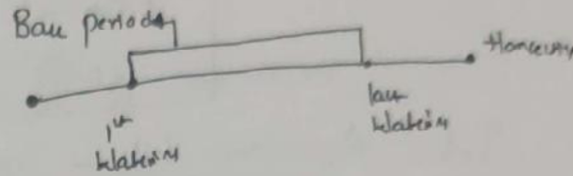
Volume $V = 86{,}400\,B\ m^3$



Quantity of Water (V)

Area ⇒ Matures "D" hectares of land $= 10^4 \times D = A$

1 hectare $= 10^4$ sq.m



Total depth of Water = Volume / Area

$$= \frac{V}{A}$$

$$= \frac{86{,}400\,B}{10^4 D}$$

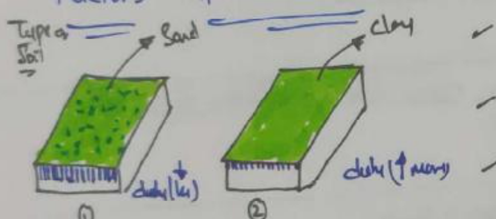
$$\boxed{\Delta = \frac{8.64B}{D}\ \text{meter}}$$

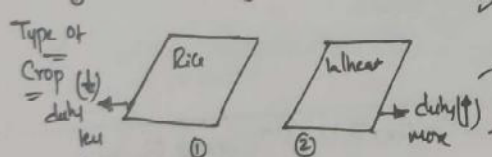
$$\boxed{\Delta = \frac{864B}{D}\ \text{cm}}$$

Where Δ → Delta in cm
D → Duty in hectare/cumec
B → Base period in day.

Factors Affecting Duty :

- Methods & Systems of Irrigation
- Mode of applying Water to Crops
- Types of Crop & Type of Soil
- Base period of Crop
- Climatic Conditions of the area - Temp ↑ duty ↓
- Quality of Water
- Characteristics of Soil in Canal & Subsoil in Field





Methods of Improving duty :

- → Suitable Method of applying Water Used
- → land Should be properly ploughed & leveled
- → land Should be Cultivated frequently
- → Canals Should be lined.
- → parallel Canals Should be Constructed.
- → Rotation of Crops Should be practiced.

B - Ground Water

— By Meenu Priya

Introduction: The Water present in Earth Mantle is Called as "Ground water"

→ Ground Water hydrology is a Science of Water below the Surface of earth

→ Saturated Formation of Ground Water based on extracting From Various earth Materials.

i) **Aquifer**: a geological Formation Contains permeable materials which permit storage & movement of Water through it.

Ex: Sand & Gravel

ii) **Aquiclude**: a geological Formation of impermeable material which permit storage, not transmitting Water.

Ex: [redacted] clay

iii) **Aquifuge**: a geological Formation Neither Contains nor transmits water

Ex: Solid rock

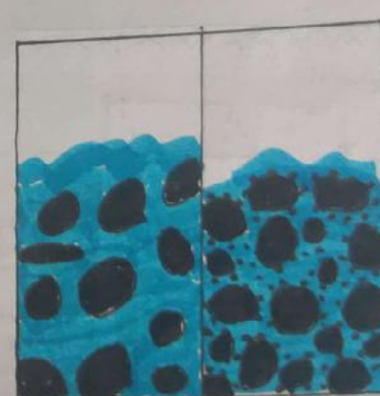
iv) **Aquitard**: a geological Formation Stores as well as yields water but less than aquifer

Ex: Sandy clay

Aquifer parameters

i) **porosity**: It is defined as the ratio of the Volume of Voids to the total Volume of Material.

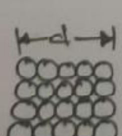
$$\text{porosity} = \frac{\text{Volume of Voids}}{\text{Total Volume of Material}}$$



Greater porosity   less porosity

$$n = \frac{V_v}{V} \times 100\%.$$

Ex:

a) 

→ Cubical $V_v = V - V_s$

$$V = d^3$$

$$V_s = \frac{\pi}{6} d^3$$

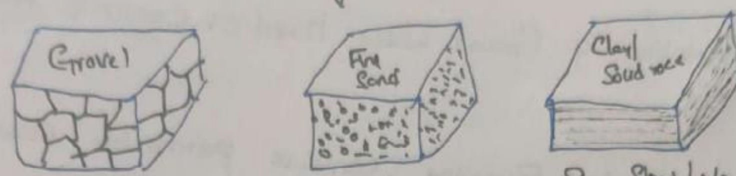
$$V_v = d^3 - \frac{\pi}{6} d^3 = d^3\left(1 - \frac{\pi}{6}\right)$$

$$n = \frac{V_v}{V} \times 100 = \frac{d^3\left(1 - \frac{\pi}{6}\right)}{d^3} \times 100 = 47.6\%.$$

ii) Specific yield : It is the ratio of Volume of water that after Saturation, Can be drained by gravity to its own Volume

$$\text{Specific yield} = \frac{\text{Volume of Water drained by gravity}}{\text{Total Volume}}$$

$$S_y = \frac{W_y}{V} \times 100 \%$$



S_y - Rapid drainage S_y - Moderate drainage S_y - Slow / No drainage

iii) Specific Retention : It is the ratio of Volume of water it will retain after Saturation against the force of gravity to its own Volume.

$$\text{Specific Retention } S_r = \frac{W_r}{V} \times 100$$

Where,

W_r = Volume of Water Retained

$$\text{porosity } n = \frac{V_v}{V} \times 100$$

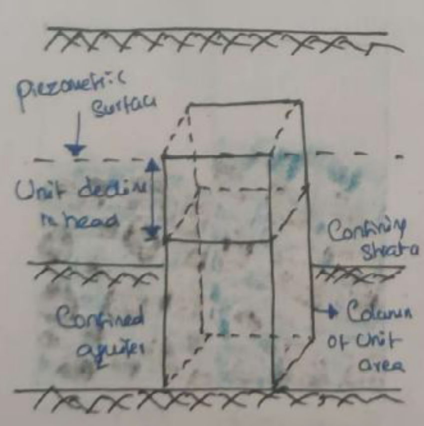
$$= \frac{W}{V} \times 100$$

$$W = \text{Volume of water} = W_y + W_r$$

$$n = S_y + S_r.$$

iv) Storage Coefficient : The Water Yielding Capacity of a Confined aquifer Can be expressed as Storage Coefficient.

→ Storage Coefficient is defined as the Volume of Water that an aquifer releases from or takes into Storage per unit Surface area of aquifer per unit change in the Component of head normal to that Surface.



Storage Coefficient.

v) Coefficient of Permeability : its also designated as "Hydraulic Conductivity" reflects the Combined effect of porus medium & Fluid properties.

→ From an analogy of laminar flow through a Conduit, 'k'

$$k = \frac{C d_m^2 w}{\mu}$$

Where,
w → Specific weight
d_m → Mean particle size
C → Constant
μ → Viscosity

$$k = \frac{C d_m^2 (\rho g)}{\mu} \qquad w = \rho g$$

$$k = \frac{C d_m^2 g}{\mu / \rho}$$

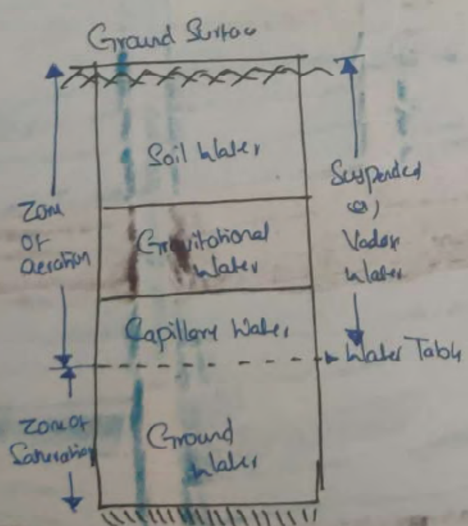
$$k = \frac{C d_m^2 g}{\nu}$$

ν → Kinematic viscosity.

vi) **Coefficient of Transmissibility (T):** Transmissibility (T) is considered as an aquifer of unit width & thickness B. The transmissibility through this aquifer is given by $T = k \times B$ m/s

Where, T = Transmissibility (m^3/day)
k = Coefficient of permeability (m/day)
B = Thickness of aquifer (m)

Division of Sub-Surface Water: 2 Zones



a) **Zone of Aeration:** It is consisting of
i) Soil Water Zone: Soil Water
ii) Intermediate Zone: Pellicular & Gravitational Water
iii) Capillary Zone: Capillary Water

b) **Zone of Saturation:** Ground water fills all the interstices in the Saturated Zone.

c) **Capillary Fringe:** a Transition Zone with higher Moisture Content.

Water Table: Upper Surface of Zone of Saturation

→ Vadose Zone: Subsurface Zone in Rock openings are Unsaturated & Filled with air & water partly

Type of Aquifer: 2 types

a) Unconfined Aquifer:

→ an Aquifer that is bounded from above by a phreatic Surface is Called a phreatic or Unconfined, aquifer, or a Water table aquifer

→ It has a Water table, only partly filled with water

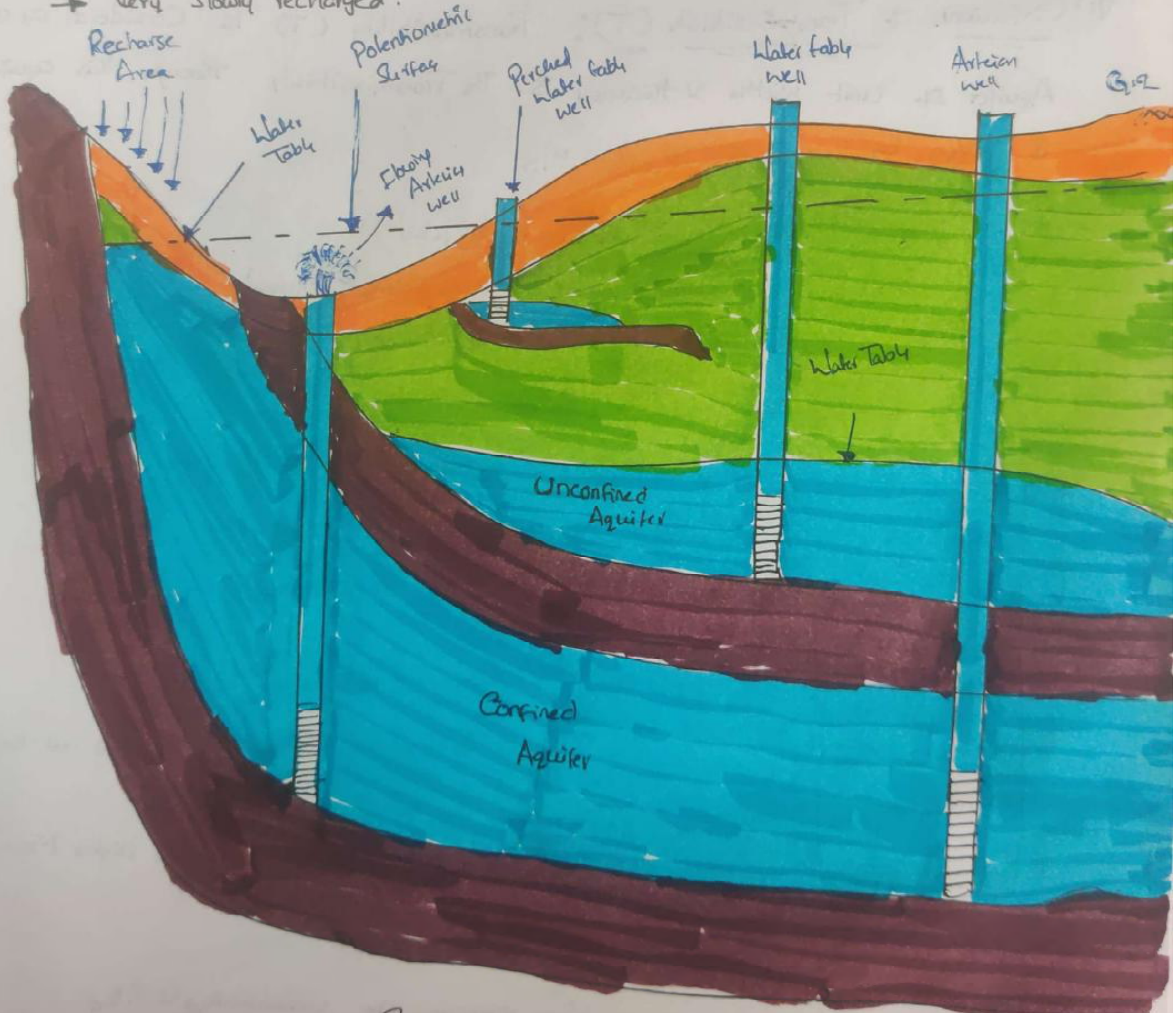
→ Rapidly recharged by precipitation Infiltrating down to the Saturated zone

b) Confined Aquifer:

→ Completely filled with water under pressure (hydrostatic head)

→ Seperated from Surface by impermeable Confining layer/aquitard

→ Very Slowly recharged.



Confined & Unconfined Aquifer

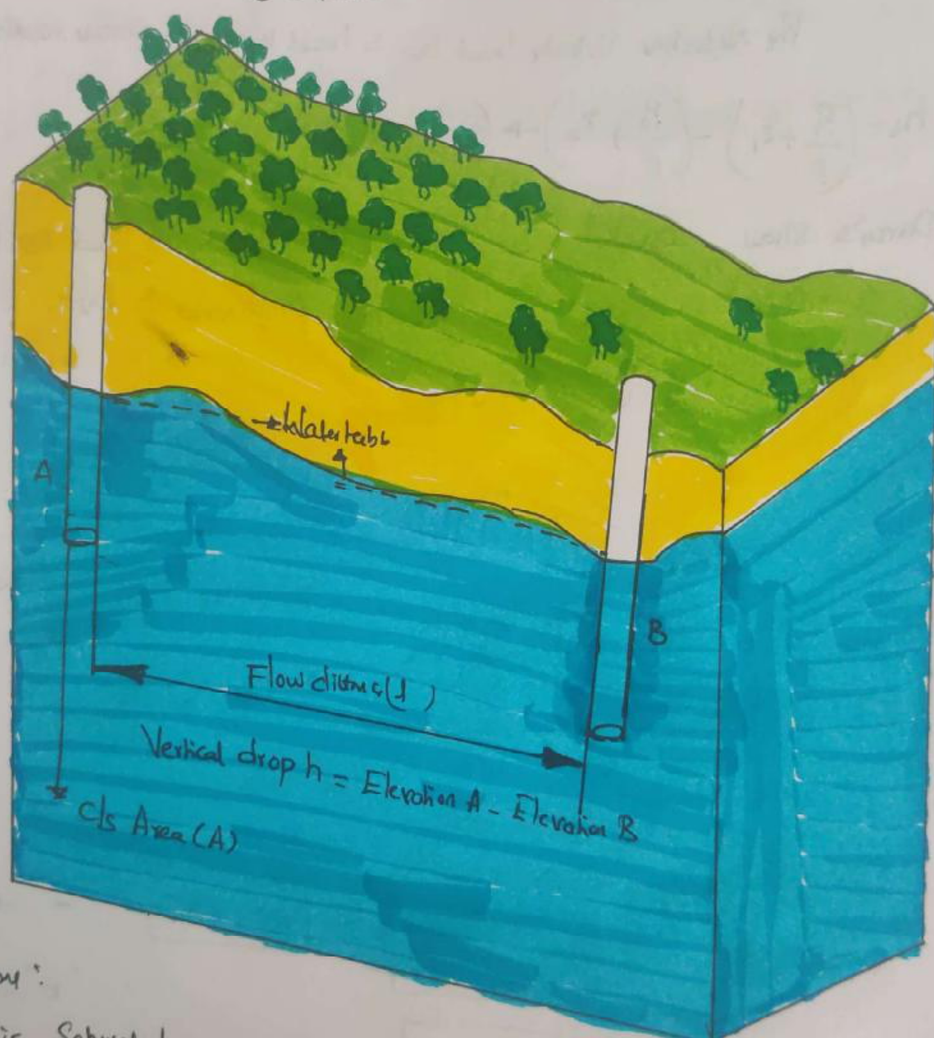
Well Hydraulics

Darcy's law - Henry Darcy (1803 - 1858)

Laminar flow through Saturated Soil mass, the discharge per unit time is proportional to the hydraulic gradient.

$$Q = A\left(k \times \frac{h}{l}\right)$$

where Q = Volume of Water
A = c/s Area of flow
k = Permeability or hydraulic Conductivity
h = Vertical drop
l = Flow distance



Assumption:

- Soil is Saturated
- Flow through Soil is laminar
- Flow is Continuous & Steady
- Temperature @ 27°C Atmospheric @ time of Testing
- Total c/s area of Soil mass is Considerd

$$Q = A \times V$$

$$Q = k \times i \times A \qquad V = k \times i$$

By Applying Bernoulli e'n

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + h_L \rightarrow (1)$$

where,
- P = Pressure
- ρ = Specific Weight of water
- V = Velocity of flow
- g = Acceleration due to gravity
- z = elevation
- h_L = head loss

By Neglecting Velocity head low & head loss in porous media

$$(1) \Rightarrow h_L = \left(\frac{P_1}{\rho} + z_1\right) - \left(\frac{P_2}{\rho} + z_2\right) \rightarrow (2)$$

Darcy's Show discharge is directly proportional to head loss h_L & Area A
Inversely proportional to length L

$$Q \propto \frac{A}{L} \times h_L$$

$$\frac{Q}{A} \propto \frac{h_L}{L}$$

$$V \propto \frac{h_L}{L}$$

Velocity $V = \frac{Q}{A} = \frac{\text{discharge}}{\text{Area}}$

$$\frac{h_L}{L} \approx \frac{dh}{dl}$$

$$V \propto \frac{dh}{dl}$$

$$V = -k\frac{dh}{dl}$$

$$\boxed{V = -k\frac{dh}{dl}} \approx \boxed{V = +k \times i}$$

"−" → Falling head direction

"k" → hydraulic Conductivity

$$\boxed{Q = k \times i \times A}$$

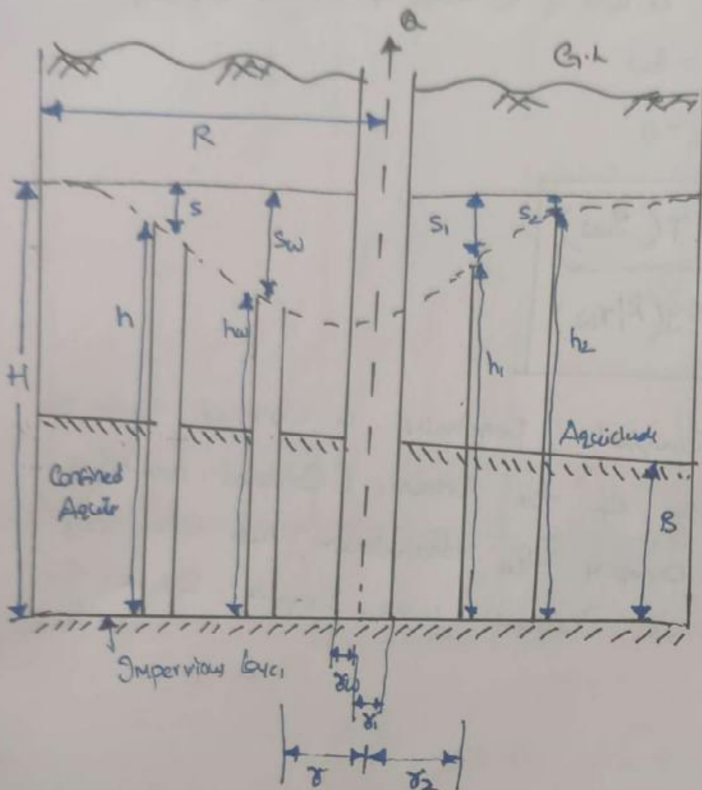
→ Reynold number '1' taken as a limit of darcy's low

$$R_e = 1 = \frac{\rho V d}{\mu} = \frac{V d_a}{\nu}$$

Where,
d_a → Mean particle Size (d_a → 10 Mean 10% of particles)
ν → Kinematic Viscosity

Steady radial Flow to a Well

Dupuit's theory - Confined Aquifer :



→ Consider a well which is penetrating through a Confined aquifer of thickness "B"

→ H - piezometric head @ Radius "R"

→ Sw - drawdown & piezometric head @ Radius "rw"

→ hw - depth of water in well

As per darcy's law

→ Velocity through porous Medium

$$V = k \times \frac{dh}{dr}$$

→ Area of Confined aquifer

$$A = (2\pi r) \times B$$

→ discharge Q = Area x Velocity = $A \times v$

$$Q = 2\pi r \times B \times k \times \frac{dh}{dr}$$

$$Q = (2\pi r \times T) \times \frac{dh}{dr} \qquad T = k \times B$$

$$\frac{Q}{2\pi r \times T} dr = dh$$

$$\frac{Q}{2\pi T}\left(\frac{1}{r}\right) dr = dh$$

Integrating above eqn with limits r_1 & r_2 and h_1 & h_2

$$\frac{Q}{2\pi T}\int_{r_1}^{r_2} \frac{1}{r} dr = \int_{h_1}^{h_2} dh$$

$$\frac{Q}{2\pi T}\left[\log r\right]_{r_1}^{r_2} = \left[h\right]_{h_1}^{h_2}$$

$$\frac{Q}{2\pi T}(\log r_2 - \log r_1) = (h_2 - h_1)$$

$$\frac{Q}{2\pi T} = \frac{h_2 - h_1}{\log(r_2/r_1)}$$

$$Q = \frac{2\pi T(h_2 - h_1)}{\log(r_2/r_1)}$$ → Theim's eqn

above eqn @ wall of a well & @ edge of Zone of Influence

$r_1 = r_w$, $h_1 = h_w$, $S_1 = S_w$

$r_2 = R$, $h_2 = H$, $S_2 = 0$

$$Q = \frac{2\pi T(S_w)}{\log(R/r_w)}$$

Problem

9) a 30 cm diameter well completely penetrates a confined aquifer of permeability 45 m/day. the length of the strainer (confined aquifer) is 20 m under steady state of pumping the drawdown at well was found to be 3 mts and Radius of Influence was 300 mts. Calculate the discharge through it?

Sol)

Given data

permeability $K = 45\,m/day = \frac{45}{24 \times 60 \times 60} = 5.20 \times 10^{-4}\,m/sec$

$B = 20\,m$

dradown $S_w = 3\,mts$

$R = 300\,mts$

$D_w = 30\,cm$ $R_w = \frac{30}{2} = 15\,cm = 0.15\,m$

→ $T = K \times B = 5.20 \times 10^{-4} \times 20$

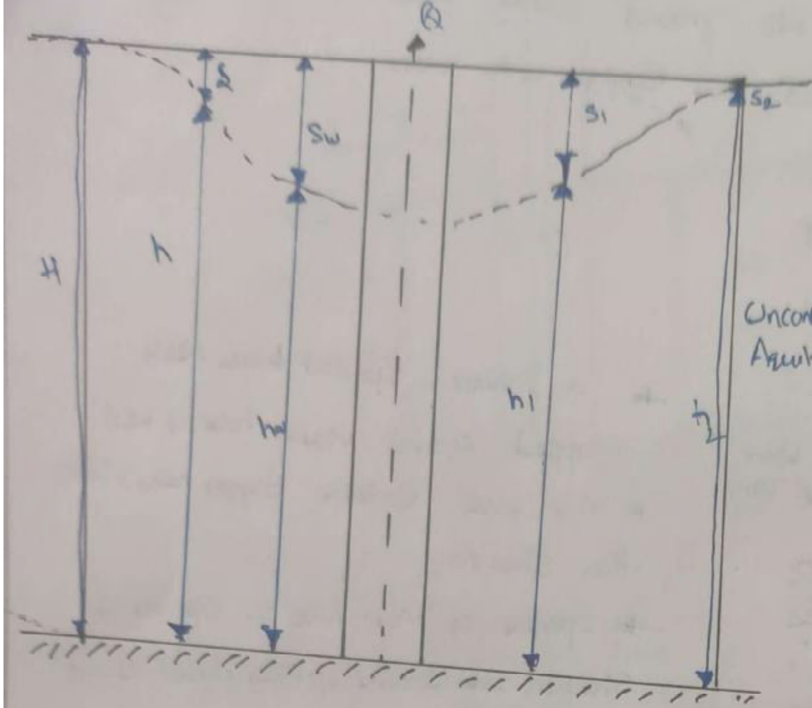
$= 10.416 \times 10^{-3}\,m^2/sec$

→ $Q = \frac{2\pi T(S_w)}{\log(R/R_w)}$

$= \frac{2 \times \pi \times 10.416 \times 10^{-3} \times 3}{\log\left(\frac{300}{0.15}\right)}$

$Q = 0.059\,m^3/sec$

Dupuit's theory – Unconfined Aquifer



→ All Stream lines in a Flow are "Horizontal line"

→ All "equipotential lines are Vertical line"

As per darci's law

Velocity $V = k \times \frac{dh}{dr}$

Area $A = 2\pi r \times h$

Discharge = Area × Velocity

$Q = A \times V$

$Q = 2\pi r h \times k \times \frac{dh}{dr}$

$$Q = 2\pi r h \times k \times \frac{dh}{dr}$$

$$\frac{Q\,dr}{2\pi r k} = h\,dh$$

Integrating above eqn B/n r_1 & r_2; h_1 & h_2

$$\frac{Q}{2\pi k}\int_{r_1}^{r_2} \frac{1}{r}\,dr = \int_{h_1}^{h_2} h\,dh$$

$$\frac{Q}{2\pi k}\left[\log \frac{r_2}{r_1}\right] = \left[\frac{h_2^2 - h_1^2}{2}\right]$$

$$\frac{Q}{2\pi k}\left(\log \frac{r_2}{r_1}\right) \times 2 = \left(h_2^2 - h_1^2\right)$$

$$Q = \frac{\pi \times k \times (h_2^2 - h_1^2)}{\log(r_2/r_1)}$$

Applying @ edge zone

$r_1 = r_w$, $h_1 = h_w$, $S_1 = S_w$

$r_2 = R$, $h_2 = H$, $S_2 = 0$

discharge

$$\boxed{Q = \frac{\pi \times k \times (H^2 - h_w^2)}{\log(R/r_w)}}$$


Water Requirement
of Crops
BY
Meenu Priya

SOIL CLASSIFICATION

Sr. No.	Name of the soil group	Grain size diameter in mm
1	Gravelly Soil	60 to 2
2	Sandy Soil	2 to 0.5
3	Silty Soil	0.5 to 0.002
4	Clayey Soil	<0.002

Types of Soils

Soils - Loose material and upper most layer of earth's crust

- Formed due to weathering of rocks
- Providing nutrients and water to plants

Major types according to Indian Council of Agricultural Research (ICAR)

1) **Alluvial soils** are fine-grained fertile soil deposited by water flowing over flood plains or in river beds.
2) **Black soils** created from igneous rocks
3) **Red soils** formed due to weathering of old crystalline rocks in the areas of low rainfall.
4) **Laterite soils** formed under high temperature and rainfall with wet and dry spell
5) **Desert soils**
6) **Mountain soils**
7) **Saline and Alkaline soils**
8) **Peaty and Marshy soils** occur in Humid region. Formed by accumulation of organic matter

Suitability of Crops:

1) **Alluvial soils -** Rice, Wheat, Sugarcane, Cotton, Jute
2) **Black soils -** Cotton, Sugarcane, Groundnut, Millets, Rice, Wheat, Oilseeds
3) **Red soils -** Ragi, Groundnut, Millet, Tobacco, Potato, Rice, Wheat, Sugarcane
4) **Laterite soils -** after taking soil conservation measures, the soil is suitable for Tea, Coffee, Cashew, Rubber and Coconut
5) **Desert soils -** Drought resistant crops like millets and barley
6) **Mountain soils -** Tea, Coffee, Spices, and Tropical Fruits
7) **Saline and Alkaline soils -** Infertile. Unfit for Cultivation
8) **Peaty and Marshy soils -** Highly acidic

ALLUVIAL SOIL

- It can be divided into two parts:-
- Bangar:- Soil containing old alluvium in the upper valley region of a river is called Bangar Soil. It is sticky and has dark color.
- Khadar:- The soil formed due to fresh alluvial deposit is known as Khadar Soil. This soil is formed due to the river floods, it is found mostly nearby the river. Generally such soil is sandy.

BLACK SOIL

- *Black soil is the gift of peninsular plateau.*
- *This soil is very sticky and fertile.*
- *It can contain humidity for a prolonged time.*
- *It is formed from the metamorphic rocks and is very useful for cotton cultivation.*
- *That is why it has become famous as black cotton soil.*
- *It is also known as regur soil.*

RED SOIL

- Such soil is found in regions of igneous and metamorphic rocks.
- Its red colour is due to its ferrous and other humus contents.
- The soil is porous and fertile.
- Such soil is seen in Goa, Tamil Nadu, Andhra Pradesh, Odisha and Jharkhand.
- Some crops grown in the red soil are:- Groundnut, Ragi, Tobacco, etc.




LATERITE SOIL

- *Laterite soil develops as a result of excessive erosion by rain.*
- *Due to heavy rain, the humus contents from the top soil descend into the lower strata which is called leaching.*
- *As the soil contains less humus,it is fertile.*
- *Such soil is found in mountainous region of Deccan, Karnataka, Kerala, Odisha, and some parts of North - East .*

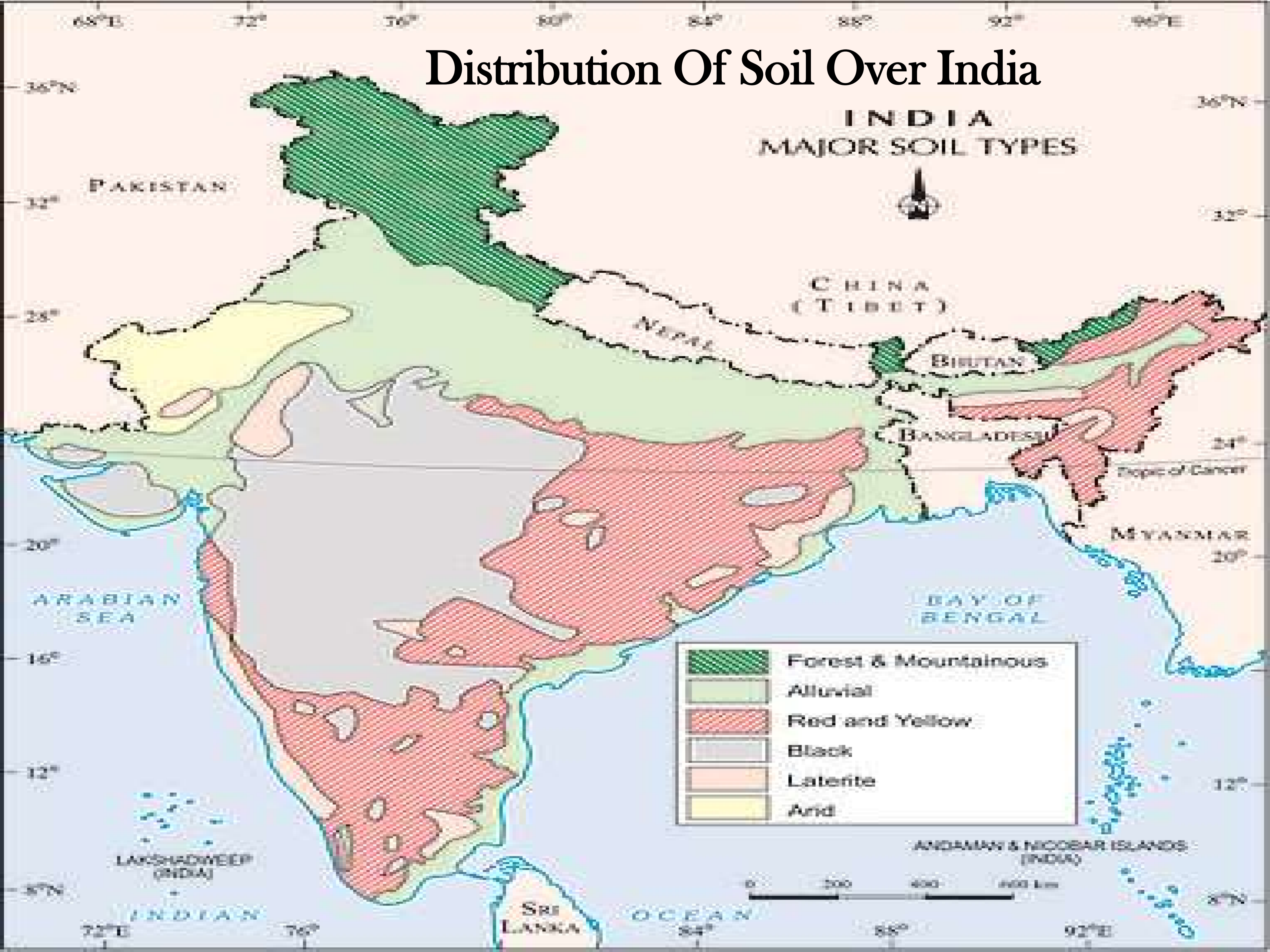
MOUNTAIN SOIL

- Humus content is more due to the forests, although it differs from place to place.
- Such soil on Shivalik Range is less fertile and less developed.
- The soil is sandy and porous and does not contain humus.
- Such soil is found in the mountainous region of the country, such as in Himachal Pradesh, Arunachal Pradesh, Jammu – Kashmir states.

DESERT SOIL

- Such soil is found in the arid and semi-arid regions of Gujarat, Rajasthan, Punjab, and Haryana.
- The soil here is more alkaline and has less humus contents.
- Agriculture has been made possible in such soil only through irrigation.
- Thus , a large diversity in soils of the nation is seen due to diversity in climate and relief features.

Distribution Of Soil Over India



Irrigation


Agri
Seri
Pisci
Viti
Horti
+
Culture

Agriculture

The science and art of cultivation on the soil, raising crops and rearing livestock . It is also called farming.

Sericulture

Comercial rearing of silk worms . It may supplement the income of the farmer

Pisciculture

reeding of fish in specially constructed tanks and ponds .

Viticulture

Cultivation of crops .

Horticulture

Growing vegetables ,flowers and fruits for commercial use .

Gross Commanded Area (GCA)

The total area lying between drainage boundaries which can be commanded or irrigated by a canal system or water course is known as gross commanded area.

Culturable Commanded Area (CCA)

Gross commanded area contains some unfertile barren land, local ponds, villages, graveyards etc which are actually unculturable areas.

The gross commanded area minus these unculturable area on which crops can be grown satisfactorily is known as Culturable Commanded Area.

$$CCA = GCA - \text{Unculturable Area}$$

Culturable Cultivated Area

The area on which crop is grown at a particular time or crop season.

Culturable Uncultivated Area

The area on which no crop is grown at a particular time or crop season

Kor depth and Kor period

- **The distribution of water during the base period is not uniform, since crops require maximum water during first watering after** the crops have grown a few centimeters.
- During the subsequent watering the quantity of water needed by crops gradually decreases and is least when crop gains maturity.
- The first watering is known as kor watering, and the depth applied is known as kor depth.
- The portion of the base period in which kor watering is needed is known as kor period.
- While designing the capacity of a channel, kor water must be **taken into account since discharge in the canal has to be maximum during this time.**

CROP SEASONS

MAJOR CROPS OF INDIA

Agricultural cropping season in India is July to June

1. Food grains: Rice, Wheat, Maize, Millets, Pulses
2. Cash Crops: Cotton, Jute, Sugarcane, Oilseeds
3. Plantation crops: Tea, Coffee, Rubber, Coconut
4. Horticulture crops: Fruits and Vegetables

CROPPING SEASONS IN INDIA

1. Kharif: July to October (Monsoon crops)
2. Rabi: October to March (Winter crops)
3. Zaid: March to June (Summer crops)

Apart from India, our neighbouring countries Bangladesh and Pakistan also use the Kharif and Rabi terminology.

CROP SEASONS

Crop Seasons in India

KHARIF	RABI	ZAID
Monsoon crop (High water requirement)	Winter crop	Summer crop
July - October	October - February	March - June
Rice, Maize, Jowar, Bajra, Soyabean, Cotton, Groundnut, Jute, Urad Dal, Moong Dal, Tur Dal	Wheat, Barley, Gram, Peas, Mustard	Watermelon, Muskmelon, Cucumber, Vegetables and Fodder crops
		

Q. The terms "Kharif" and "Rabi" are derived from which language?

Ans. Arabic (Kharif means Autumn and Rabi means Spring season)

Q. What percentage of population of India is rural and dependent on agriculture?

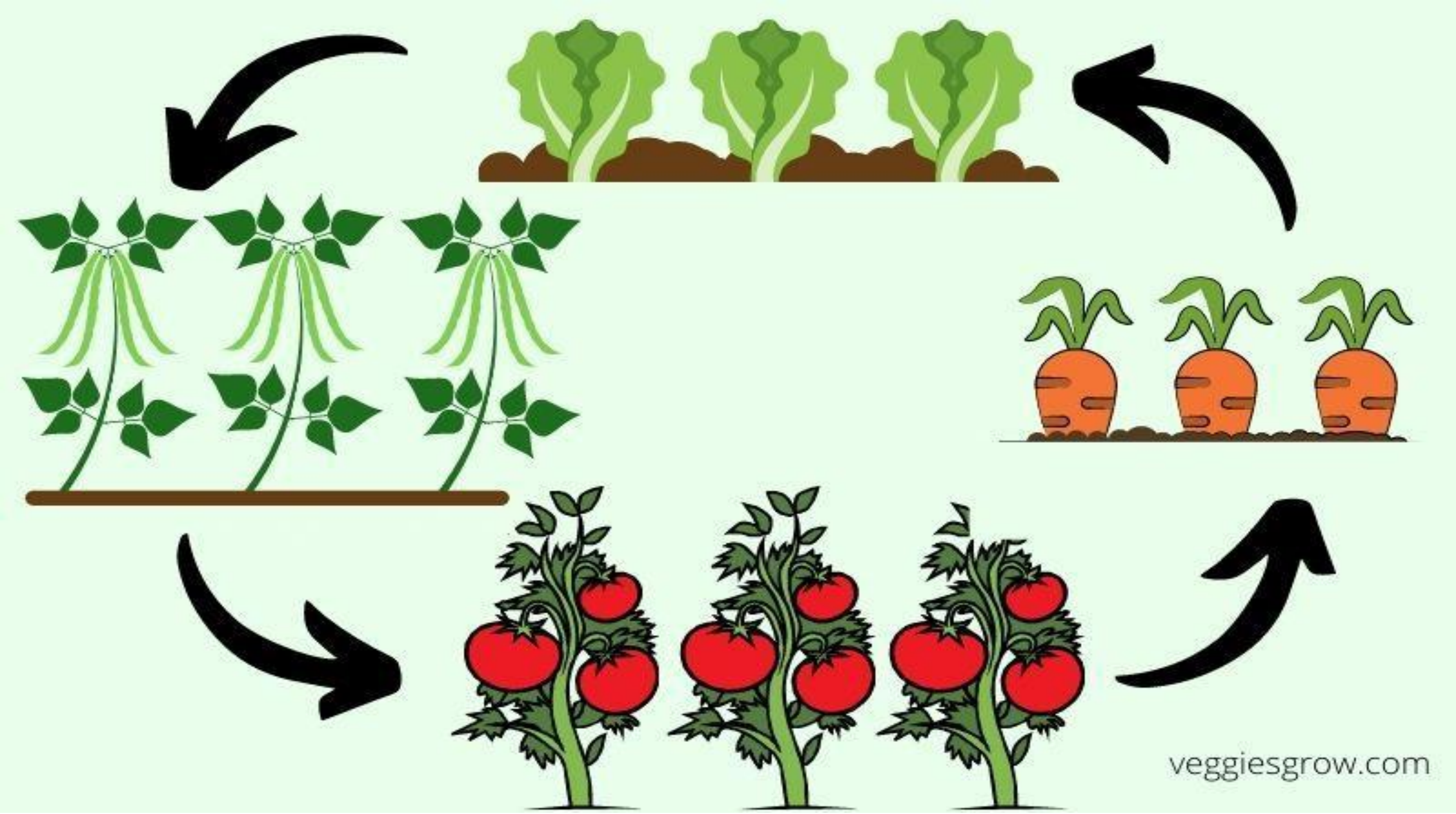
Ans. 61.5% (As per 2011 census)

Q. What is the contribution of agriculture to the GDP of India?

Ans. 14.4% as per Economic Survey 2018-19

Q. Which sector of India is the largest consumer of groundwater in India?

Ans. Agriculture (89%). Crops such as paddy and sugarcane consume more than 60% of irrigation water available in India. Atal Bhujal Yojana is launched recently.



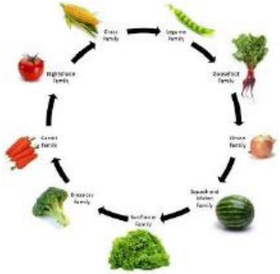
Crop rotation is an organic gardening practice that can increase productivity by increasing the health of the soil and plants.

Crops rotation:

The method of growing different crops in rotation one after the other in the same field is called crop rotation.

Necessity for rotation :

- Fertility of land gets reduced as the soil becomes deficient.
- More balanced fooding.
- Rotation will reduce the diseases and wastage due to insects.
- Increase nitrogen content of soil
- The soil will be better utilized
- Rotation of cash crops, fooder crops and soil renovating crops.



Advantages of Crop Rotation

- *There is an overall increase in the yield of crops due to maintenance of proper physical condition of the soil*
- *Rotation of crops helps in saving on nitrogenous fertilizers, because leguminous plants grown during the rotation of crops can fix atmospheric nitrogen in the soil with the help of nitrogen fixing bacteria.*
- *Rotation of crops help in weed control and pest control. This is because weeds and pests are very choosy about the host crop plant, which they attack. When the crop is changed the cycle is broken. Hence, pesticide cost is reduced.*
- *There is regular flow of income over the year.*
- *Proper choice of crops in rotation helps to prevent soil erosion.*

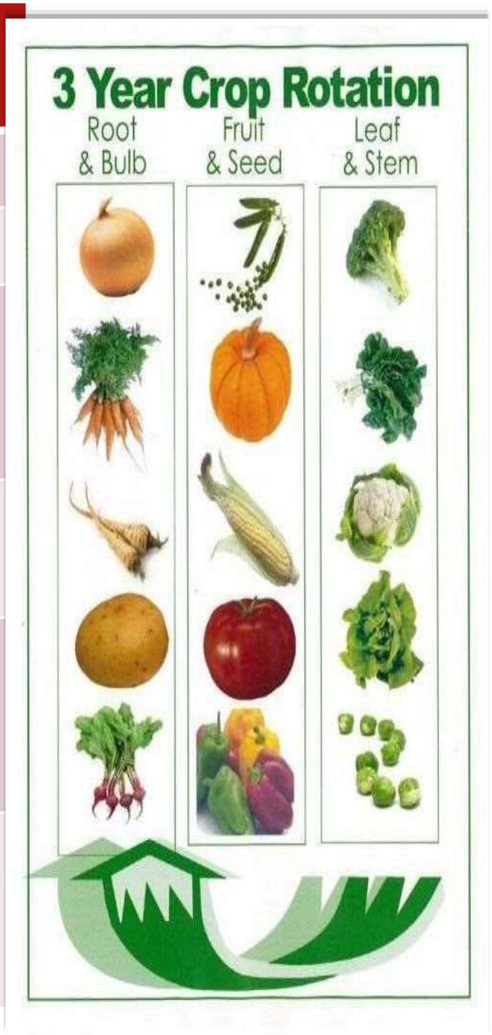
Different crop rotation:

1. Cotton – Groundnut
2. Rice – Gram/ Sunflower.
3. Hybrid Jowar – Wheat/ Jowar/ Gram.
4. Jowar – Sunflower – Groundnut.
5. Sunflower – Potato – Groundnut.
6. Groundnut – Wheat – Vegetables.

7.Sorghum – Wheat – Green gram – Cotton – Groundnut.

8. Sun hemp – Sugarcane – Groundnut

Type	Rotations
One-year rotation	1. Maize-mustard
	2. Rice-wheat
Two-year rotation	1. maize-mustard-sugarcane-fenugreek (methi)
	2. Maize-potato-sugarcane-peas
Three-year rotation	1. rice-wheat-mung-mustard-sugarcane-berseem
	2. Cotton-oat-sugarcane-peas-maize-wheat



Irrigation Efficiencies

Efficiency is the ratio of the water output to the water input, and is usually expressed as percentage. Input minus output is nothing but losses, and hence, if losses are more, output is less and, therefore, efficiency is less. Hence, efficiency is inversely proportional to the losses.

Water conveyance Efficiency (ηc)

It is the ratio of the water delivered into the fields from the outlet point of the channel, to the water pumped into the channel at the starting point. It takes the conveyance or transit losses into account.

$$\eta_c = \frac{\text{Water delivered to the farm}}{\text{Water diverted from the river or reservoir}} = \frac{W_f}{W_r}$$

Water application efficiency (η_a)

- Ratio of water stored in root zone of plants to the water applied to the land.

- Denoted by $\eta_a = (W_z/W_l) \times 100$

η_a = water application efficiency

W_z = amount of water stored in root zone

W_l = amount of water applied to land

Water use efficiency (η_u)

- Ratio of the amount of water used to the amount of water applied.
- Denoted by η_u .

$$\eta_u = (W_u/W_l) \times 100$$

η_u = water efficiency use.

W_u = water used

W_l = water applied

Consumptive use efficiency (η_{cu})

- Ratio of the consumptive use of water to the amount of water depleted from the root zone.

$$\eta_{cu} = (C_u / W_p) \times 100$$

η_{cu} = consumptive use efficiency

C_u = consumptive use of water

W_p = amount of water depleted from root zone

DETERMINATION OF IRRIGATION REQUIREMENTS OF CROP

In order to determine the irrigation requirements of a certain crop, during its base period, one should be acquainted with the following terms.

1.Effective Rainfall (Re): is part of the precipitation falling during the precipitation period of the crop, that is available to meet the evapotranspiration needs of the crop.

2.Consumptive Irrigation Requirements (CIR): is the amount of irrigation water that is required to meet the evapotranspiration needs of the crop (Cu) during its full growth. CIR = Cu - Re

3.Net Irrigation Requirement (NIR): is the amount of irrigation water required at the plot to meet the evapotranspiration needs of water as well as other needs such as leaching etc. Thus

NIR = Cu –Re + water lost in deep percolation for the purposes of leaching

4. **Field Irrigation Requirement (FIR):** is the amount of irrigation water required to meet the *net irrigation requirements* plus the water lost at the field (i.e in percolation in the field water courses, field channels and field application of water). If η_a is water application efficiency:

$$FIR = NIR / \eta_a$$

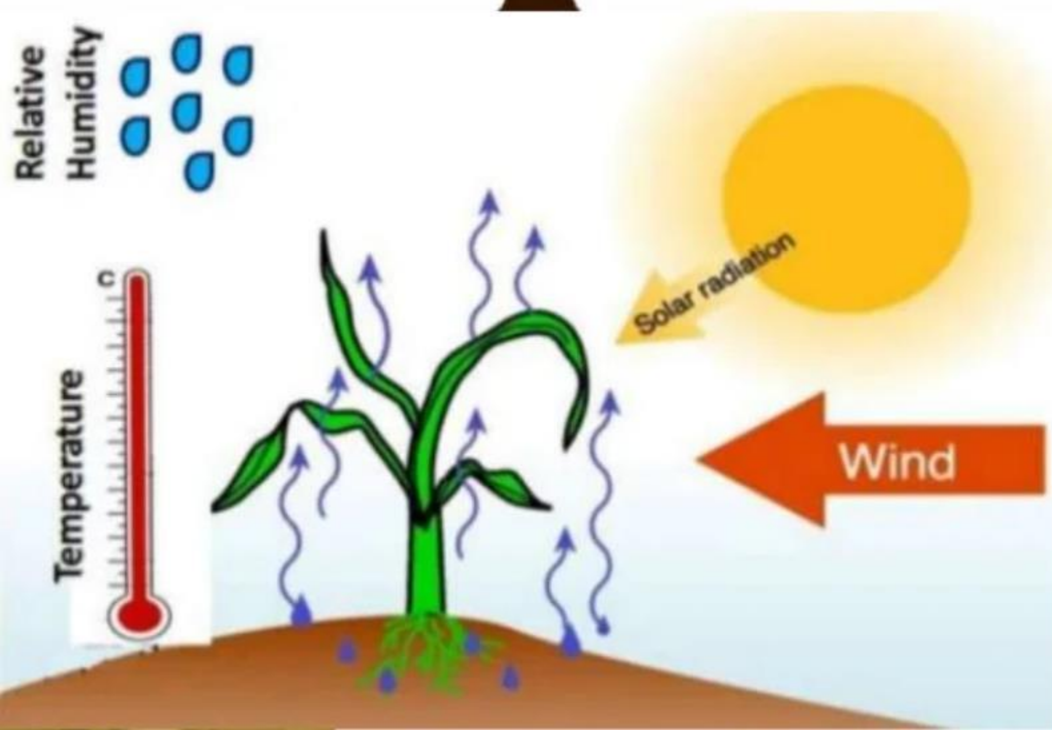
5. **Gross Irrigation Requirement (GIR):** is the sum of water required to satisfy the field irrigation requirement and the water lost as conveyance losses in distrbutaries up to the field. If η_c is the water conveyance efficiency, then

$$\text{GIR} = \text{FIR} / \eta_c$$

Consumptive Use of Water (CU)

- Water requirement of crop is the total quantity of water from the time the crop is sown to the time it is harvested. This water requirement may vary from crop to crop, from soil to soil and period to period. Water required to meet the demand of evapo-transpiration and metabolic activities of the crop to-geather is known as consumptive use (CU) of water

Factors Affecting the Consumptive Use of Water

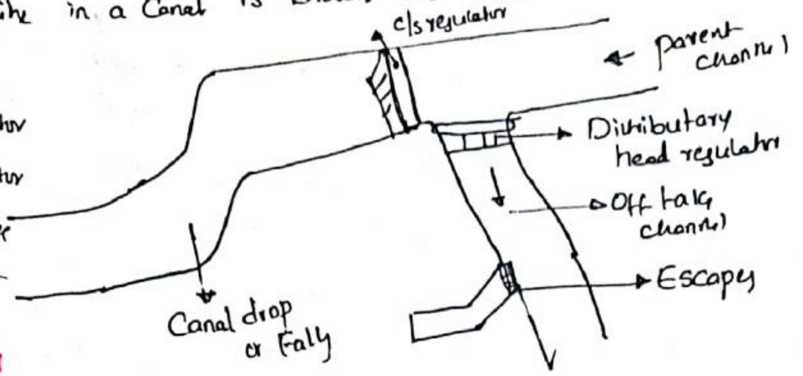


1. Evaporation which depends on humidity
2. Mean Monthly temperature
3. Growing season of crops and cropping pattern
4. Monthly precipitation in area
5. Wind velocity in locality
6. Soil and topography
7. Irrigation practices and method of irrigation
8. Sunlight hours

Canal Regulation Works

Introduction : Any structure constructed to regulate the discharge, Full Supply level or Velocity in a Canal is known as "Regulation Work."

1) Canal Falls
2) Head Regulator
3) Cross Regulator
4) Canal Escape
5) Canal Outlet



1) Canal Falls

Necessity : a fall is an irrigation structure constructed across a Canal to lower down its water level & destroy the surplus energy liberated from the Falling Water which may otherwise scour the bed & banks of the Canal.

Location of Fall :

→ For the Canal which does not irrigate the area directly, the fall should be located from the consideration of economy in cost of excavation of the channel with regard to balancing depth & the cost of falls itself.

→ For a Canal irrigating the area directly, a fall may be provided at a location where F.S.L outstrips the ground level, but before the bed of the Canal comes into filling. After the drop, the F.S.L of the Canal may be below the ground level for 1/2 to 1/4 km.

→ The location of the Fall — Regulator + Bridge + Masonry work Combining place.

→ Economy — large No. of Small Falls
Small No. of Large Falls.

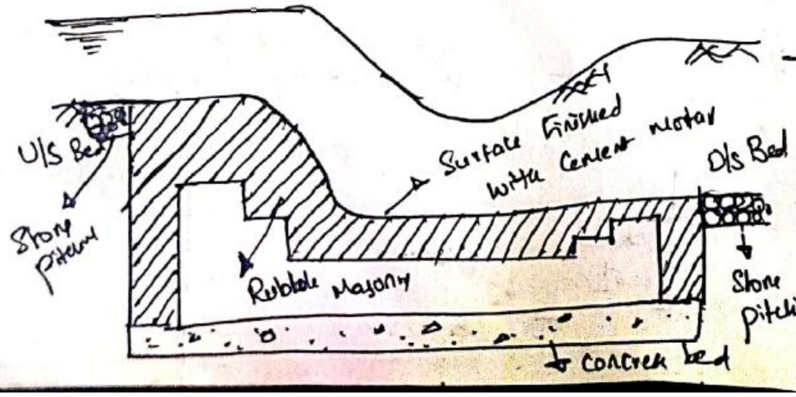
Development of Falls (or) Types of Falls

→ The ancient people always tried to avoid falls by aligning Canals along Zig-Zag route inorder to increase the length of the Canal & thus dissipate the excess energy head in Friction.

→ The Eastern Yamuna Canal Constructed by Mughal emperors had no falls, the Canal - followed a Sinous path.

→ The falls were 1st Constructed by the British in India in 19th Century.

1) Ogee Fall

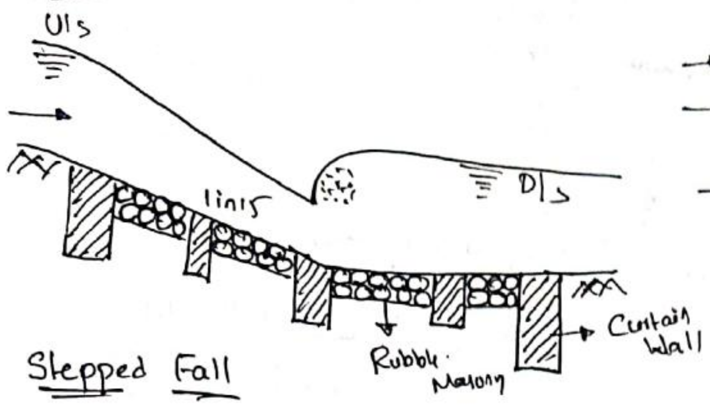


→ 1st Constructed by Sir proby Cautley on Ganga Canal.

→ it has gradual convex & Concave Cur-
* to provide Smooth transition
* to reduce disturbance & impact

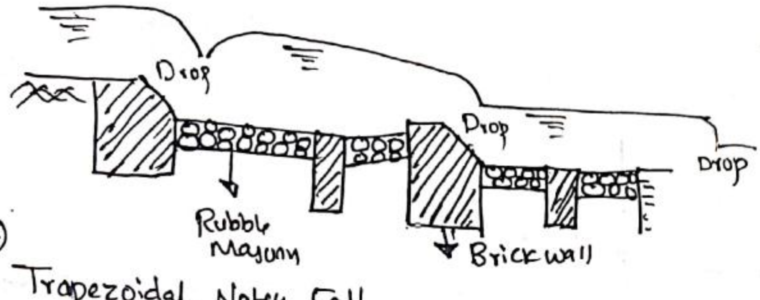
→ Defects
* draw down effect on U/s = Bed Gra-
* Smooth transition = K.E was preserved.

2) Rapid Fall



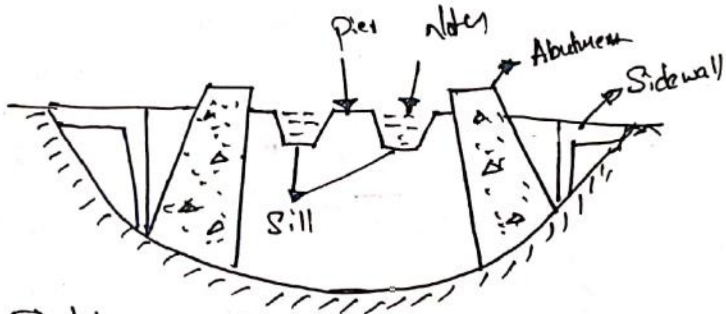
- it Consist of glacis Sloping 1:10 to 1:20
- high Cost of Construction
- when Slope of Natural ground Surface is even & long
- Curtain walls provided on U/s & D/s side of Sloping glacis

3) Stepped Fall



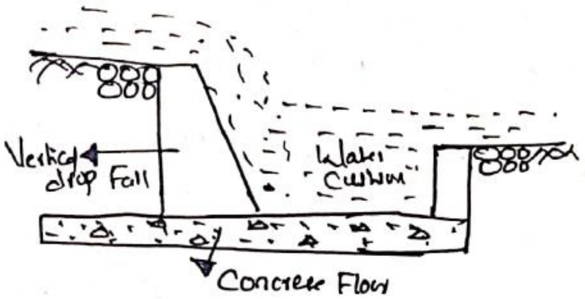
- it was provided at the tail of main escape of Sarda Canal
- cost is too high.
- Suitable for the Canal which has it U/s @ Very high level Compared to D/s.

4) Trapezoidal Notch Fall



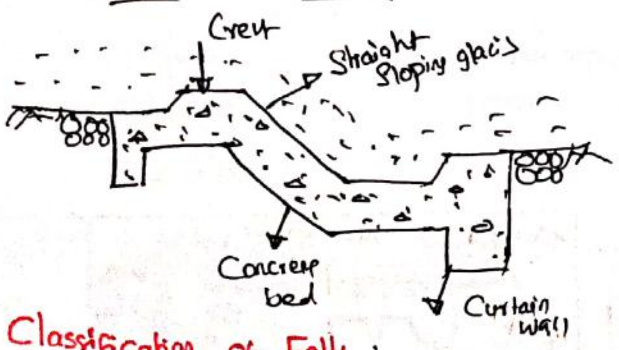
- Body Wall Constructed across Canal
- it Consist of Trapezoidal Notches B/n Side piers & Intermediate piers
- Notches are kept at U/s bed level of Canal.
- Body wall Constructed with masonry or Concrete.

5) Vertical drop Fall



- Consists of Vertical drop wall Constructed with masonry work.
- Water Flows over the Crest of wall.
- Concrete floor provided D/s to Control Scouring effect.
- Curtain wall provided on U/s & D/s side.
- This type falls provided at Sarda Canal. UP.

6) Straight Glacis Canal Fall



- Modern type of Construction, its a raised Crest Constructed across Canal & gentle Straight Inclined Surface is provided from raised Crest to downstream.
- The Water Coming from U/s crosses the raised Crest and falls on Inclined Surface with Sufficient energy dissipation.

Classification of Falls :

- Class-I depth-discharge Relation
  - Trapezoidal Notch
  - Low Crested Rectangular Notch
- Class-II Fixed-Supply level
  - Siphon
  - High Crested Weir
- Class-III Variation of Surface level
  - Sluice gates
  - Stoplogs
  - Vertical needles
- Mis Cellaneous
  - Cylinder, Chute & Pipe Falls

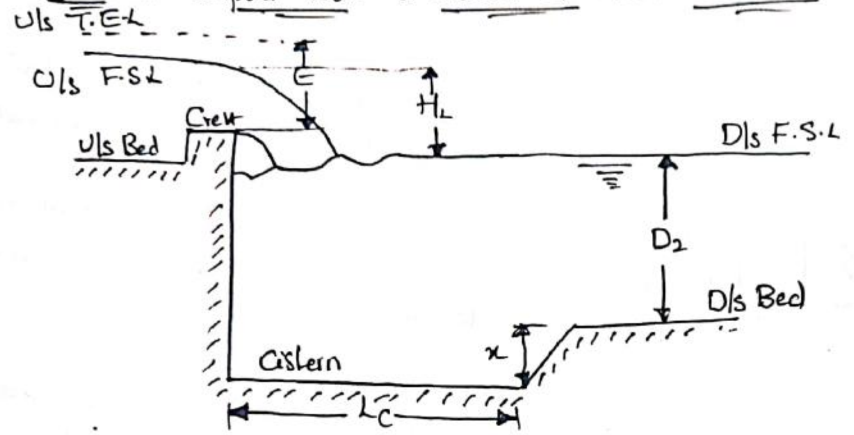
Scanned by CamScanner

Cistern Design : The cistern is that portion of fall down stream of the crest wall where the surplus energy of water leaving the crest is destroyed.

→ The complete cistern element consist of

i) Sloping glacis
ii) the cistern
iii) Roughening devices
iv) device for deflecting the high velocity jet.

Class I : Impact from a stream of water falling freely under gravity



U.P. Irrigation Research Institute

$$L_c = 5\sqrt{EH_L}$$

$$x = \frac{1}{4}(EH_L)^{2/3}$$

Montagu's Formulae

$$x = \frac{1}{2}E_{f2}$$

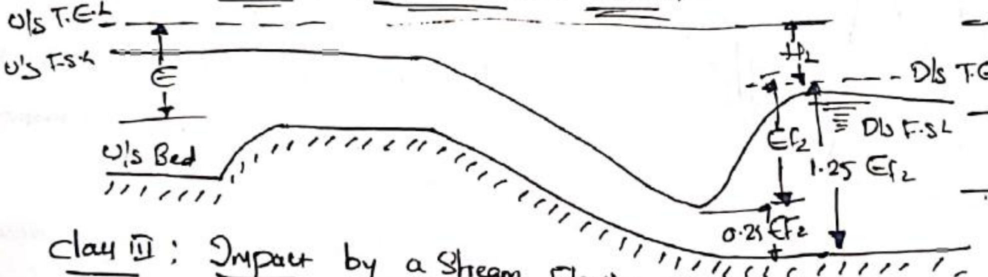
$$L_c = 4E_{f2}$$

E_{f2} = Energy of flow downstream

E = U/s Total Energy, above crest

L_c = length of cistern.

Class II : Impact by a horizontal stream



→ drop "H_L" in Energy line
→ discharge intensity "q"
→ depth of cistern increased by 25% of E_{f2}
→ R.L. of cistern = D/s T.E.L − $1.25E_{f2}$

Class III : Impact by a stream flowing on an inclined glacis

→ The falling jet of water has a vertical component on glacis, formation of hydraulic jump on glacis doesn't help in dissipating it.

→ Energy dissipation is not perfect, additional roughening devices have to be provided.

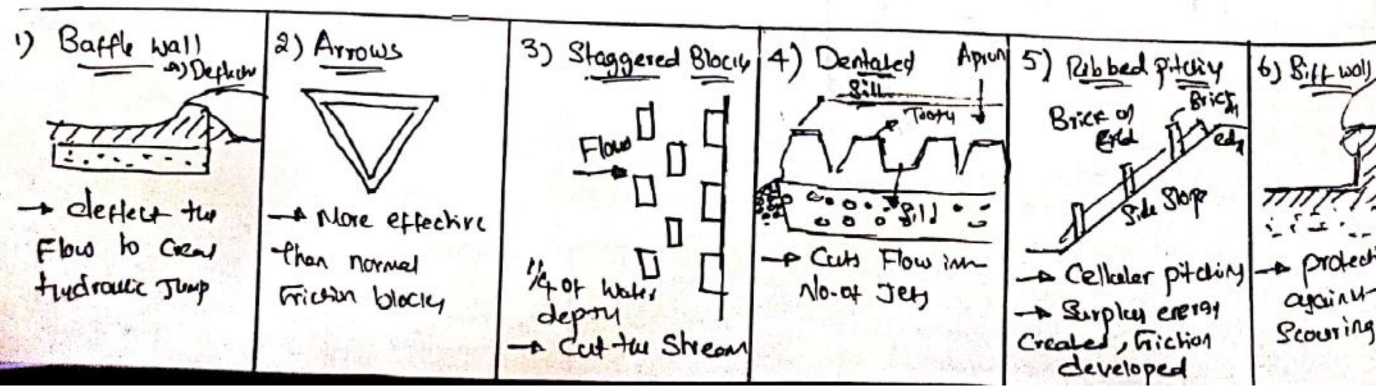
Class IV : Cistern without impact

→ The energy dissipation takes place by the provision of roughening devices.

Roughening Devices

→ depends on experience
→ No theoretical treatment

Types



Design of Sarda Type Fall

Step-by-Step procedure

Step 1: Calculation of H & d

$Q < 14$ Cumec – Rectangular Crest

$Q \geq 14$ Cumec – Trapezoidal Crest

$Q = 1.835 L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$ – Rect

$Q = 1.99 L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$ – Trapezoidal

Step 2: Design of Crest

a) Rectangular

$B = 0.55\sqrt{d}$

$B_1 = \frac{H+d}{\rho}$

$Q = 1.835 L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$

b) Trapezoidal

$B = 0.55\sqrt{H+d}$

U/s Batter = 1:3, D/s Batter = 1:8

$V_a = \frac{Q}{(L+D)D}$, $\frac{V_a^2}{2g}$

Step 3: Design of Cistern

a) depth $= x = \frac{1}{4}(E H_L)^{2/3}$

b) length $= L_c = 5(E H_L)^{1/2}$

c) R.L of bed cistern = R.L of D/s Bed – x

Step 4: Design of Impervious Floor

a) length of Impervious Floor $= C \times H_s$

b) Vertical length of Creep $= 2(d_1 + d_2)$

c) H. length = Total Creep – Vertical

d) Minimum Creep length $= L_d = 2(D + 1.2) + H_L$

Step 5: D/s protection

1) Bed pitching $= 6\sqrt{E H_L}$

2) Toe wall = — m depth
— m width

3) Side-pitching = — m thick on edge
— m width
— Angle of pitching.

Scanned by CamScanner

Design of Sarda type Fall

Problem 19: Design a Sarda type fall for the following data:

i) Full Supply discharge : $\frac{U/s}{D/s}$ = 40 Cumecs (Q)

ii) Full Supply level : $\frac{U/s}{D/s} = \frac{218.30\text{ M } (*)}{216.80\text{ M } (*)}$

iii) Full Supply depth : $\frac{U/s}{D/s} = \frac{1.8\text{ M}}{1.8\text{ M}}$ (D)

iv) Bed Width : $\frac{U/s}{D/s} = \frac{26\text{ M}}{26\text{ m}}$

v) Bed level : $\frac{U/s}{D/s} = \frac{216.50\text{ M } (*1)}{215.00\text{ M } (*)}$

vi) Drop : 1.5 M (H_L)

Design the Floor on Bligh's theory taking coefficient of Creep = 8. (Check the design by Khosla's theory & make changes if necessary). Safe exit gradient may be taken equal as 1/5.

Sol

Step 1: Calculation of H & d

Q > 14 Cumecs → Trapezoidal Crest (Q < 14 → Rectangular)

$$Q = 1.99\, L H^{3/2} \left(\frac{H}{B}\right)^{1/6} \rightarrow ①$$

L = Width of Canal = 26 M

Q = 40 Cumecs

$$B = 0.55\sqrt{H+d} \rightarrow ②$$

H + d = D + drop in the level (H_L)

H + d = 1.8 + 1.5 = 3.3 M

H + d Sub in ②

$$B = 0.55\sqrt{3.3\text{ M}}$$

$$B = 1.0\text{ m} \rightarrow ③$$

Sub B in ①

$$40 = \frac{1.99 \times 26 \times H^{(3/2 + \frac{1}{6})}}{(1.0)^{1/6}}$$

$$H^{\frac{5}{3}} = \frac{40 \times 1}{1.99 \times 26} = 0.774$$

$$H = (0.774)^{3/5}$$

$$H = 0.86\text{ m} \rightarrow ④$$

Sub ② H = 0.86 m

d = 3.3 − H

d = 3.3 − 0.86

d = 2.44 M

Step 2: Design of Crest

Trapezoidal Crest will be adopted

Height of Crest above bed $= D - H$

$= 1.8 - 0.86$

$= 0.94\,m$

Top width $B = 1\,m$

D/s Batter $= 1:3$

U/s Batter $= 1:8$

Assuming Canal Side Slope 1:1

Velocity of approach $V_a = \frac{Q}{A} = \frac{Q}{(L+D)D}$

$V_a = \frac{40}{(26+1.8)\,1.8} = 0.8\,m/sec$

Velocity head $= \frac{V_a^2}{2g}$

$= \frac{0.8^2}{2 \times 9.81} = 0.032\,m$

U/s, T.E.L = U/s F.S.L + Velocity head

$= 218.30 + 0.032$

U/s T.E.L $= 218.332\,m$

R.L of Crest = U/s F.S.L − H

$= 218.30 - 0.86 = 217.44\,m$

E = U/s T.E.L − R.L of Crest

$E = 218.332 - 217.44 = 0.892\,m$

Step 3: Design of Cistern

Depth of Cistern $= x = \frac{1}{4}(EH_L)^{2/3}$

$= \frac{1}{4}(0.892 \times 1.5)^{2/3}$

$x = \frac{1}{4}(0.892 \times 1.5)^{2/3} = 0.304\,m$

length of Cistern $= L_c = 5(EH_L)^{1/2}$

$= 5(0.892 \times 1.5)^{1/2}$

$L_c = 5.8\,m \simeq 6\,m$

R.L of bed of Cistern = R.L of D/s Bed − x

$= 215.00 - 0.304$

$= 214.696\,m.$

Final Value of $x = 215.00 - 214.696$

$= 0.31\,m.$

Step 4: Design of Impervious Floor

Seepage head $= H_s = d = 2.44\ M$

Bligh's Coefficient $= 8$

length of Impervious Floor (or) Creep length $= C \times H_s$

$= 8 \times 2.44$

$= 19.5\ M$

Provide U/s Cutoff $d_1 = 1M$

D/s Cutoff $d_2 = 1.6\ M$

Vertical length of Creep $= 2(d_1 + d_2)$

$= 2(1+1.6) = 5.2M$

length of horizontal Impervious Floor

$= 19.5 - 5.2 = 14.3M$

Provide 15 m length of Impervious Floor

Minimum length of Impervious Floor to d/s of toe of Crest wall)

$l_d = 2(D + 1.2) + H_L$

$= 2(1.8 + 1.2) + 1.5$

$L_d = 7.5M$ ✓

$L_d = 8M.$

Step 5: D/s protection

1) Bed pitching : length of bed pitching $H = 0.86M$

$L_b = (9 + 2 \times 1.5) = 12\ M$

$L_b = (9 + 2H_L)$ → provide @ horizontally

@ End of masonry Sloping 1 in 10

length of Slope pitching $= 6 \times \sqrt{E H_L}$

$= 6\sqrt{0.892 \times 1.5} \simeq 7\ M$

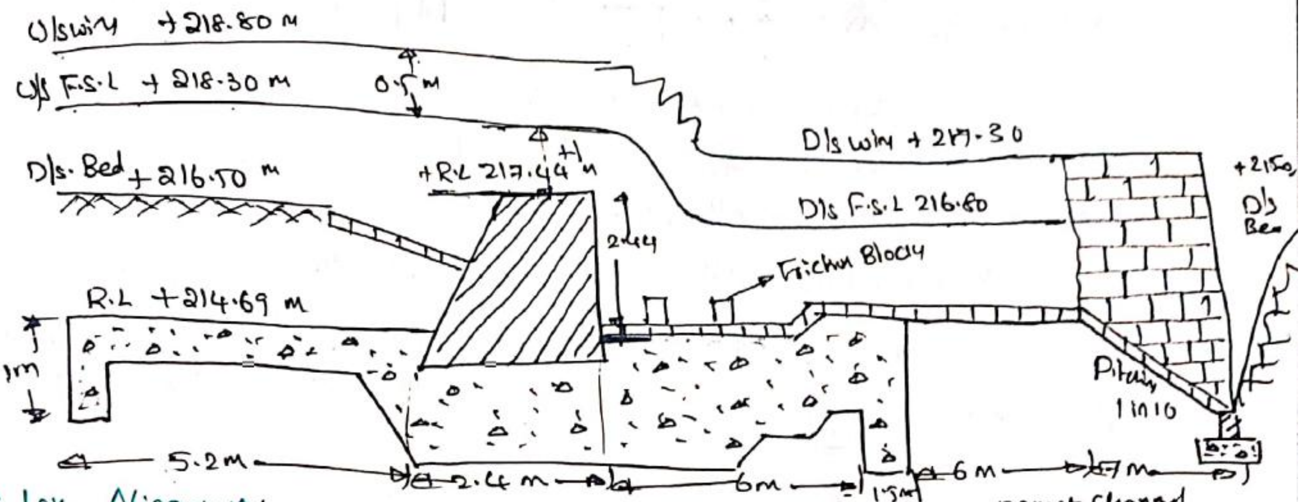
Horizontal pitch $L_b = \frac{12M}{2} = 6M$ each. → Both n

2) Toe-Wall : 1m depth - 0.4m width

3) Side-pitching : 0.2m thick on edge brick

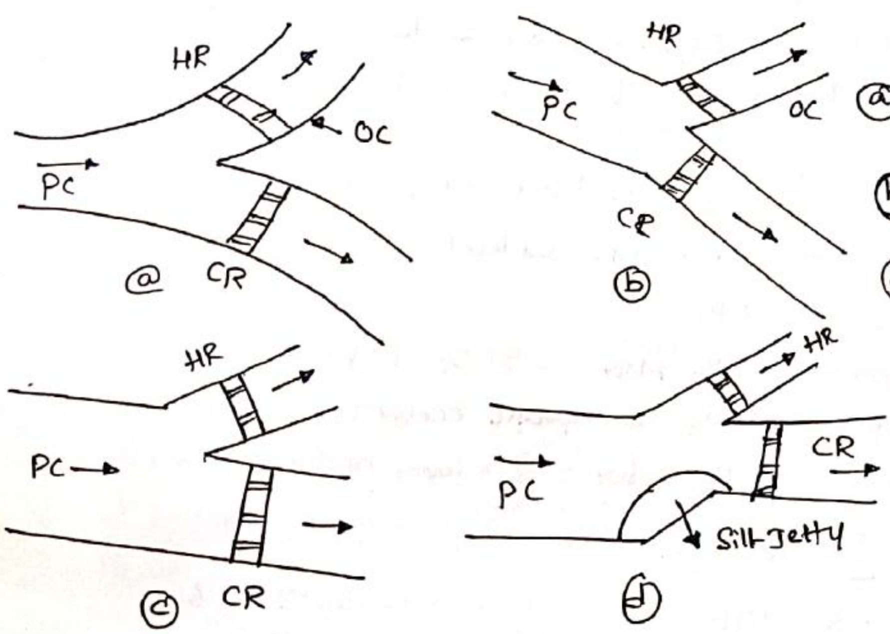
Side pitching only 45° 0.4m thick 1m deep

Sarda Fall Detailing – longitudinal Section



Off-take Alignment:

PC → parent Channel
CR → Cross Regulator
HR → Head Regulator



ⓐ * OC Zero angle with PC
* Transition Curve has to design

ⓑ OC & PC makes angle with alignment

ⓒ PC has to be Straight U/s & D/s OC – angle take off

ⓓ Unbalanced off-take results in the formation of Jetty.

Function of head & Cross Regulator:

Head Regulator

→ They regulate or Control the Supplies to the Off-taking Channel

→ They Serve as a meter for measuring the discharge entering into offtaking channel.

→ They Control the Silt entry in Off-taking Canal.

→ They help in shutting off the Supplies, OC can be closed for Repairs

Cross Regulator

→ The effective regulation of whole Canal System can be done with help of CR

→ When low discharge in P.C, CR raises water level of U/s & feeds off-taking channel in rotation

→ It helps in closing Supply to D/s of P.C for the purposes of repairs etc.

→ Bridges & other Communication works Can be Combined with it

Design of Cross & Distributory Head Regulator

Cross Regulator

Step - By - Step procedure

Step 1: Design of Crest & Water-way

i) Discharge $Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$

C_1, C_2 = Constant (0.557, 0.80)

ii) Difference in water level h = U/s F.S.L − d/s F.S.L

iii) depth of D/s water level d = d/s F.S.L − Crest level

iv) Crest level = U/s Bed level F.S.L of P.C − Depth of water in P.C

v) L = length of Water-way — Provide n bays & M = n × x (L_b); Provide m piers y & M = m × y (L_p)

Width of Regulator = $L_b + L_p$

Step 2: Design of D/s Floor

i) $q = \frac{Q}{L_b}$

ii) $H_L = h$ = U/s F.S.L − d/s F.S.L ≈ H_L

iii) D/s Floor level = D/s T.E.L − E_{f2}

≃ D/s F.S.L − E_{f2}

For H_L & q using Blench Curves E_{f2} = ?

D/s Floor level ≤ D/s Bed level

iv) $E_{f1} = E_{f2} + H_L$

v) Length of Cistern Floor = $5(D_2 - D_1)$ = Cistern length

depth D_1, & D_2 from Specific energy Curves

vi) length of D/s Floor = $\frac{2}{3}$ × length of Impervious Floor.

Step 3: Design of Impervious Floor

i) Depth of U/s cutoff = $d_1 = \frac{1}{3}$ U/s water depth + 0.6m

ii) Depth of D/s Cutoff = $d_2 = \frac{1}{2}$ D/s water depth + 0.6m

iii) Width of Cutoff = d_2 and d_1 less value.

iv) Maximum Static head = H_s = U/s F.S.L − D/s Floor level

v) $G_E = \frac{1}{\pi\sqrt{\lambda}} \frac{H_s}{d_2}$ $\qquad \frac{1}{\pi\sqrt{\lambda}}$

From exit gradient Curves,

$\frac{b}{d_2} = \alpha$

b = Impervious Floor length

vi) D/s Floor length = $\frac{2}{3} \times b$

Step 4: U/s & D/s protection

i) U/s protection

depth of U/s Cutoff = $\frac{1}{3}$ F.S.D + 0.6 = d_1

Cubic Content of Apron = $2.25 d_1$

ii) D/s protection

depth of D/s Cutoff = $\frac{1}{2}$ F.S.D + 0.6

Cubic Content of Apron = $2.25 d_2$

Head Regulator [D/s F.S.L & Q & D/s water depth protection]

Step 1: Design of Crest & Water-way

i) Discharge $Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$

C_1, C_2 = Constant (0.557, 0.80)

ii) difference in water level h = U/s F.S.L − d/s F.S.L

iii) depth of D/s water level d = D/s F.S.L − Crest level

iv) Crest level = U/s Bed level F.S.L + 0.5

v) length of water-way = L — provide n bays — m = L_b = Width of Regulator; Crest width.

Step 2: Design of D/s Floor

i) $q = \frac{Q}{L_b}$

ii) $H_L = h$ = U/s F.S.L − D/s F.S.L

iii) For q & H_L From Blench Curves $E_{f2} = ?$

R.L. of D/s Floor = D/s F.S.L − E_{f2}

iv) $E_{f1} = E_{f2} + H_L$

v) length of Cistern $= 5(D_2 - D_1)$

(Next step) vi) length of D/s Floor $= \frac{2}{3} \times$ Impervious Floor length

Step 3: Design of Impervious Floor

i) Depth of U/s Cutoff $= d_1 = \frac{1}{3} \times$ U/s water depth + 0.6

ii) Depth of D/s cutoff $= d_2 = \frac{1}{2} \times$ D/s water depth + 0.6

iii) Seepage head = U/s F.S.L − D/s Floor level

iv) $G_E = \frac{1}{\pi\sqrt{\lambda}} \frac{H_s}{d_2} \Rightarrow \frac{1}{\pi\sqrt{\lambda}}, \alpha$

From exit gradient Curves

Impervious Floor length $b = \alpha d_2$

v) D/s Floor length $= \frac{2}{3} \times b$

Step 4: U/s & D/s protection

1) U/s protection

U/s Scour depth $= \frac{1}{3} \times$ F.S.D + 0.6 $= d_1$

launching apron Volume $= 2.25 d_1$

2) D/s protection

D/s Scour depth $= d_2 = \frac{1}{2}$ d/s water depth + 0.6m

Launching apron Volume $= 2.25 d_2$

Problem 20: Design a Cross Regulator & head Regulator for a distributory channel taking off from the parent channel, for the following data: Permissible exit gradient = 1/5

Discharge of parent Channel = 100 Cumecs (Q_c)

Discharge of Distributory = 15 Cumecs (Q_d)

F.S.L of parent channel : U/s / DS = 218.10 / 217.90

F.S.L of distributory = 217.10 M

Bed width of P.C = U/s / D/S = 42 M / 38 M

Bed width of D.C = 15 M

Depth of water in P.C = U/S / D/S = 2.5 M / 2.5 M

Depth of water in D.C = 1.5 M

Soy

Cross Regulator (CR)	Distributary Head Regulator (D.C)

Cross Regulator (CR)

Step 1: Design of Crest & Water-Way

i) Discharge

$$Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$$

$Q = 100$ Cumecs, $C_1 = 0.557$, $C_2 = 0.80$

ii) h = U/s F.S.L − d/s F.S.L

$h = 218.10 - 217.90 = 0.20\,M$

iii) d = D/s F.S.L − Crest level

Crest level = U/s F.S.L − depth of water

$= 218.10 - 2.50$

Crest level $= 215.60\,M$

d = D/s F.S.L − Crest level

$= 217.90 - 215.60 = 2.30\,M$

iv) Length of Water Way

$$Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$$

$$100 = \frac{2}{3} \times 0.557 \times L \sqrt{2 \times 9.81}\,(0.20)^{3/2} + 0.80 \times L \times 2.30 \times \sqrt{2 \times 9.81 \times 0.20}$$

$L = 26.2\,m$ provide 4 bays 7m $= 4 \times 7 = 28\,M$

$L_b = 28\,M$

provide 3 piers 1.5m $= 3 \times 1.5 = 4.5\,M$

$L_p = 4.5\,M$

Total width of C/R $= 28 + 4.5 = 32.5\,M$

Step 2: Design of D/s Floor

i) $q = \frac{Q}{L_b} = \frac{100}{28} = 3.58$ Cumecs/m

ii) $h_L = h$ = U/s F.S.L − D/s F.S.L

$h_L = 218.10 - 217.90 = 0.20\,M$

iii) For $q = 3.58$, $h_L = 0.20$

Using Blench Curves

$E_{f_2} = 1.89\,M$

iv) D/s Floor level = D/s F.S.L − E_{f_2}

$= 217.90 - 1.89 = 216.01$

v) $E_{f_1} = E_{f_2} + H_L = 1.89 + 0.20 = 2.09\,M$

vi) length of Cistern $= 5(D_2 - D_1)$

$D_1 = 0.7\,m$, $D_2 = 1.65\,M$ From Energy Curve

$= 5(1.65 - 0.7)$

$= 4.75\,M$

Step 3: Design of Impervious Floor

i) $d_1 = \frac{1}{3}$ U/s water depth $+ 0.6\,m$

$= \frac{1}{3} \times 2.5 + 0.6$

$d_1 = 1.43\,M$

Distributary Head Regulator (D.C)

Step 1: Design of Crest & Water-Way

i) Discharge

$$Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$$

$Q = 15$ Cumecs, $C_1 = 0.577$, $C_2 = 0.80$

ii) h = U/s F.S.L − d/s F.S.L

$h = 218.10 - 217.10 = 1.0\,M$

iii) d = D/s F.S.L − Crest level

Crest level = U/s F.S.L + 0.5 − depth of water

$= (218.10 - 2.50) + 0.5$

Crest level $= 216.10\,M$

d = D/s F.S.L − Crest level

$d = 217.10 - 216.10 = 1.0\,M$

iv) length of Water Way

$$Q = \frac{2}{3} C_1 L \sqrt{2g}\, h^{3/2} + C_2 L d \sqrt{2gh}$$

$$15 = \frac{2}{3} \times 0.577 \times L \sqrt{2 \times 9.81} \times 1^{3/2} + 0.80 \times L \times 1 \sqrt{2 \times 9.81 \times 1}$$

$L = 2.87\,M$ provide 2 bays 3.5m each

$L_b = 2 \times 3.5 = 7\,m$

1m thick pier

Overall width of D/R $= 7 + 1 = 8\,M$

Step 2: Design of D/s Floor

i) $q = \frac{Q}{L_b} = \frac{15}{7.0} = 2.1$ Cumecs/M

ii) $h_L = h$ = U/s F.S.L − D/s F.S.L

$h_L = 218.10 - 217.10 = 1.0\,M$

iii) For $q = 2.1$, $h_L = 1.0$

Using Blench Curve

$E_{f_2} = 1.58\,M$

iv) D/s Floor level = D/s F.S.L − E_{f_2}

$= 217.10 - 1.58 = 215.52$

v) $E_{f_1} = E_{f_2} + H_L = 1.58 + 1.0 = 2.58\,M$

vi) length of Cistern $= 5(D_2 - D_1)$

$D_1 = 0.42\,M$, $D_2 = 2.55\,M$ From Energy Curve

$= 5(2.55 - 0.42)$

$= 10.5\,M$

Step 3: Design of Impervious Floor

i) $d_1 = \frac{1}{3}$ U/s water depth $+ 0.6$

$= \frac{1}{3} \times 2.5 + 0.6$

$d_1 = 1.5\,M$

ii) $d_2 = \frac{1}{2}$ d/s water depth $+ 0.6$ M

$= \frac{1}{2} \times 25 + 0.6 = 1.85$ m $\simeq 2$ m

iii) Maximum Static head $= H_s$

= U/s F.S.L − D/s Floor level

$= 218.10 - (217.90 - 2.5) = 2.7$ m

iv) $G_E = \frac{1}{\pi\sqrt{\lambda}} \frac{H_s}{d_2}$

$\frac{1}{5} = \frac{1}{\pi\sqrt{\lambda}} \times \frac{2.7}{2}$

$\frac{1}{\pi\sqrt{\lambda}} = \frac{2}{5 \times 2.7} = 0.148$

From Exit gradient Curves

$\alpha = 8$, $\frac{1}{\pi\sqrt{\lambda}} = 0.148$

$\frac{b}{d_2} = 8$

$b = 8d_2 = 8 \times 2 = \underline{16M}$

v) D/s Floor length $= \frac{2}{3} \times 16 = 10.6$ m

Step 4: U/s & D/s protection

i) U/s Scour depth $= \frac{1}{3} \times$ F.S.D $+ 0.6 = d_1$

$d_1 = \frac{1}{3} \times 2.5 + 0.6 = 1.43$ M

iii) Apron Volume $= 2.25 \times d_1 = 2.25 \times 1.43$

$= 3.21\ m^3/m$

ii) D/s Scour Cutoff $= \frac{1}{2} \times$ F.S.D $+ 0.6 = d_2$

$d_2 = \frac{1}{2} \times 2.5 + 0.6 = 1.85$ M

Volume $= 2.25 \times d_2 = 2.25 \times 1.85$

$= 4.16\ m^3/m$

ii) $d_2 = \frac{1}{2}$ d/s water depth $+ 0.6$ M

$= \frac{1}{2} \times 1.5 + 0.6 = 1.35$ M

iii) Seepage head $= H_s$

= U/s F.S. L − d/s Floor level

$= 218.10 - 215.50 = 2.60$ M

iv) $G_E = \frac{1}{\pi\sqrt{\lambda}} \frac{H_s}{d_2}$

$\frac{1}{5} = \frac{1}{\pi\sqrt{\lambda}} \times \frac{2.6}{2}$

$\frac{1}{\pi\sqrt{\lambda}} = \frac{2}{5 \times 2.6} = 0.154$

From Exit gradient Curves

$\alpha = 7$, $\frac{1}{\pi\sqrt{\lambda}} = 0.154$

$\frac{b}{d_2} = 7$

$b = 7d_2 = 7 \times 2 = 14$ M

v) D/s Floor length $= \frac{2}{3} \times 14 = 9.33$ m

Step 4: U/s & D/s protection

i) U/s Scour depth $= \frac{1}{3} \times 2.5 + 0.6 = 1.5$ M

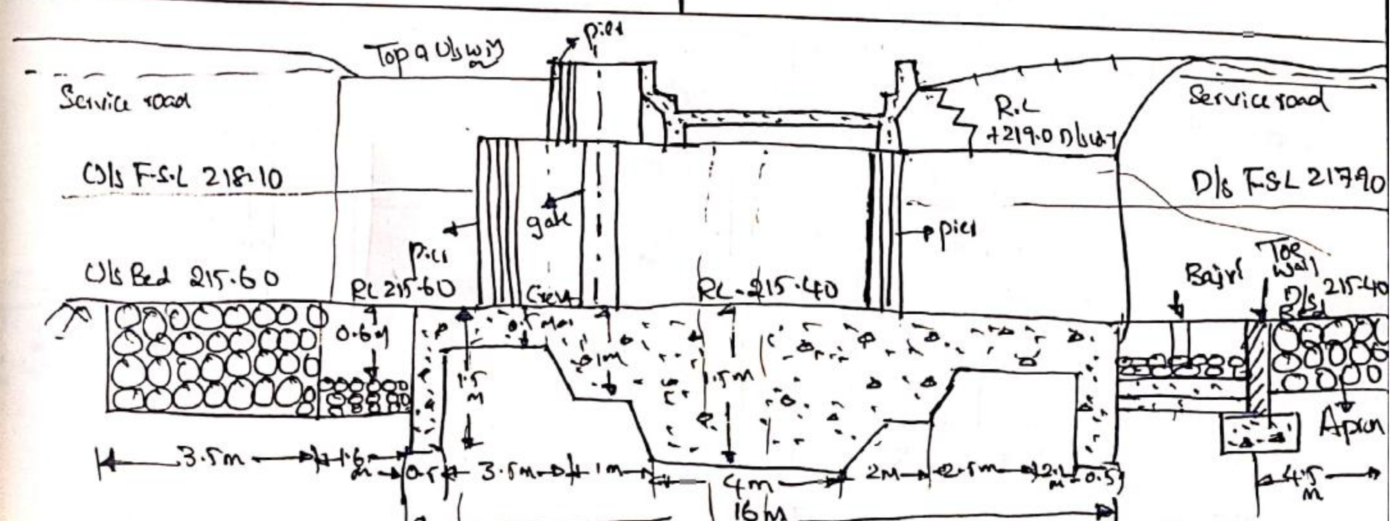
ii) D/s Scour depth $= \frac{1}{2} \times 1.5 + 0.6$

$= 1.35$ M

Volume of Apron $= 2.25\, d_2$

$= 2.25 \times 1.35$

$= 3.04\ m^3/m$



Longitudinal C/s of Regulator Cross

Ir H.R

Only check in piers & operating platform location

Cross Drainage Works

Meenu Sri Priya
Civil Engineering

Cross Drainage Works

- Cross drainage works is a structure constructed when there is a crossing of canal and natural drain, to prevent the drain water from mixing into canal water.
- This type of structure is costlier one and needs to be avoided as much as possible.
- Cross drainage works can be avoided in two ways:

- ❑ By changing the alignment of canal water way.
- ❑ By mixing two or three streams into one and only one cross drainage work to be constructed, making the structure economical.

TYEPS OF CDWs

(1) Type I (Irrigation canal passes over the drainage)

- (a) Aqueduct,
- (b) Siphon aqueduct.

(2) Type II (Drainage passes over the irrigation canal)

- (a) Super passage,
- (b) Siphon super passage.

(3) Type III (Drainage and canal intersection each other of the same level)

- (a) Level Crossing,
- (b) Inlet and outlet.

AQUEDUCT:

When the HFL of the drain is sufficiently below the bottom of the canal such that the drainage water flows freely under gravity, the structure is known as Aqueduct.

- In this, canal water is carried across the drainage in a trough supported on piers.
- Bridge carrying water
- Provided when sufficient level difference is available between the canal and natural and canal bed is sufficiently higher than HFL.

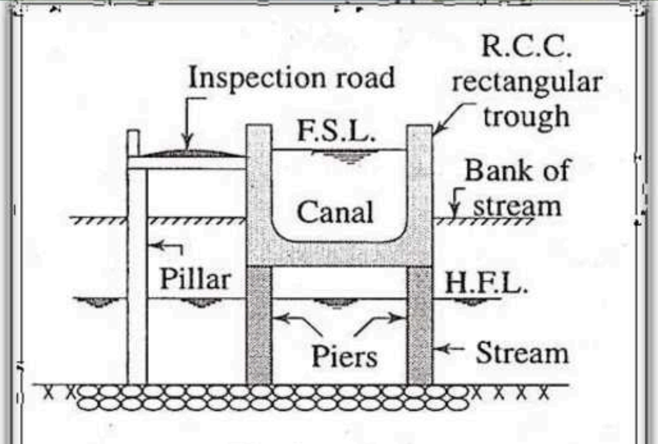
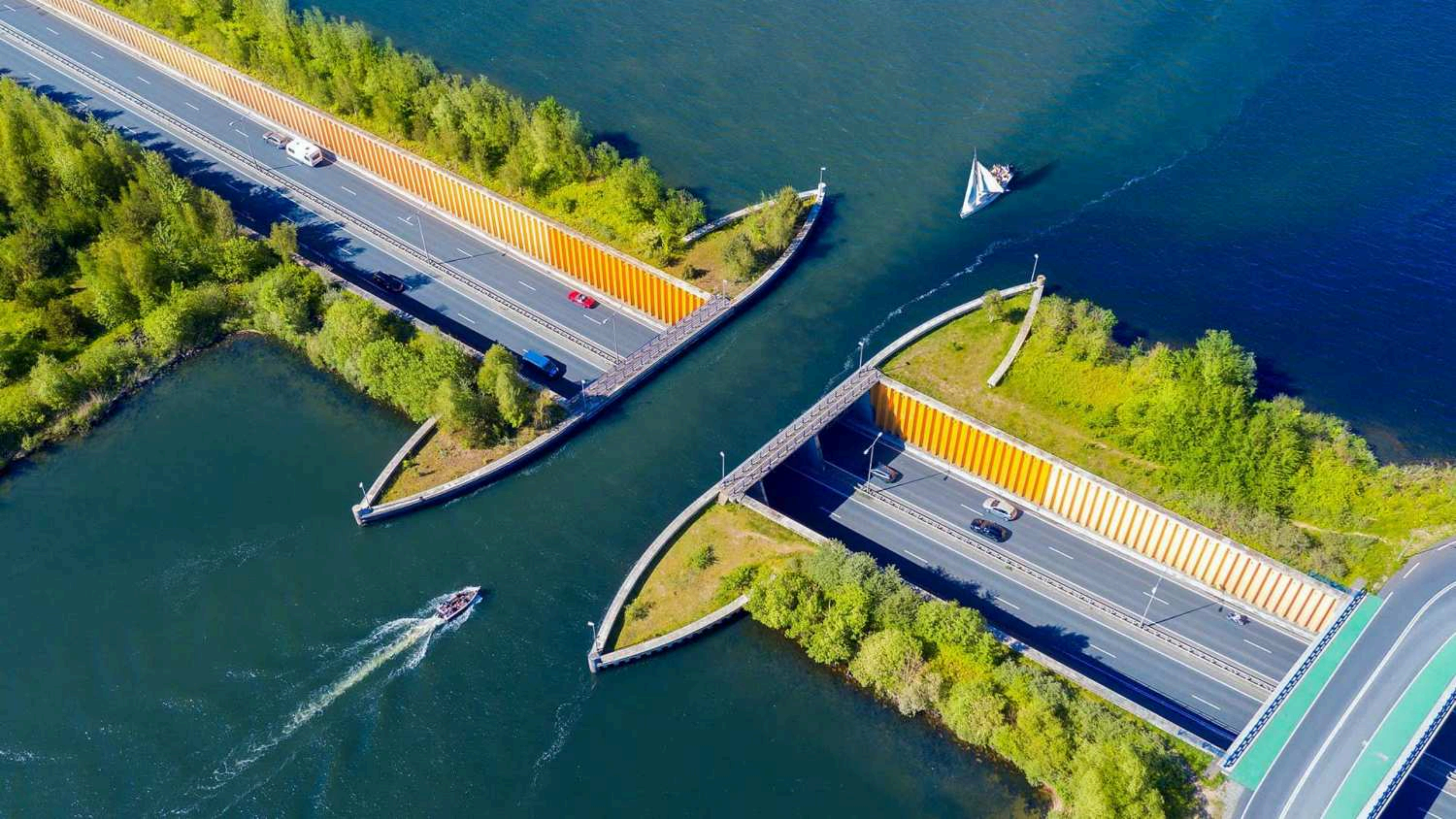


Fig: Aqueduct



SIPHON AQUEDUCT:

- In case of the siphon Aqueduct, the HFL of the drain is much higher above the canal bed, and water runs under siphonic action through the Aqueduct barrels.
- The drain bed is generally depressed and provided with permanent floors, on the upstream side, the drainage bed may be joined to the permanent floor either by a vertical drop or by glacis of 3:1.
- The downstream rising slope should not be steeper than 5:1.
- When the canal is passed over the drain, the canal remains open for inspection throughout and the damage caused by flood is rare.
- However during heavy floods, the foundations are susceptible to scour or the waterway of drain may get choked due to debris, tress etc.

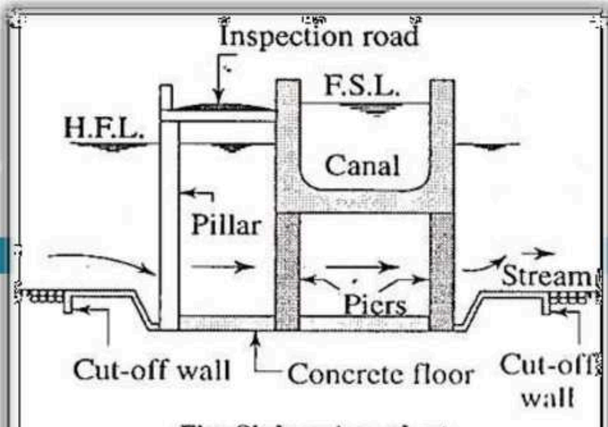
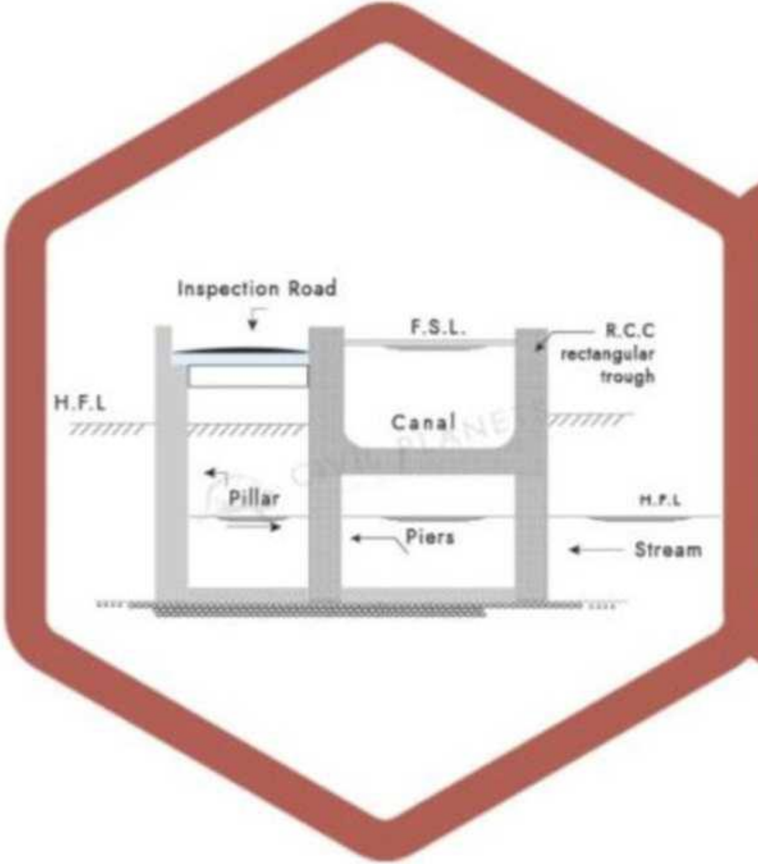


Fig: Siphon Aqueduct

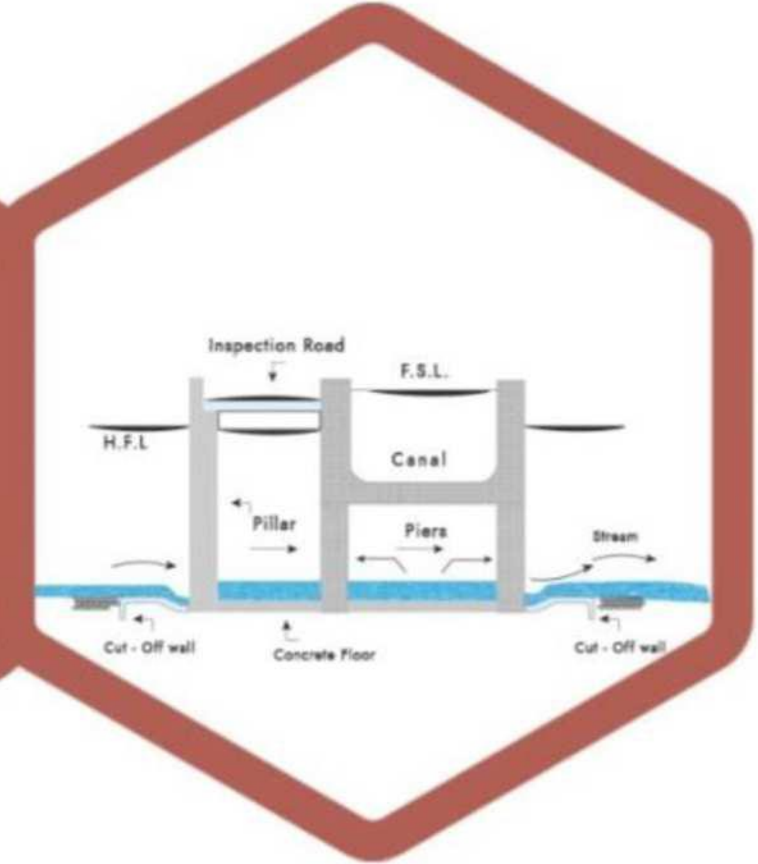
Crossing works: (aqueducts)


Concept of Canal Syphon
Water Flow

AQUEDUCT

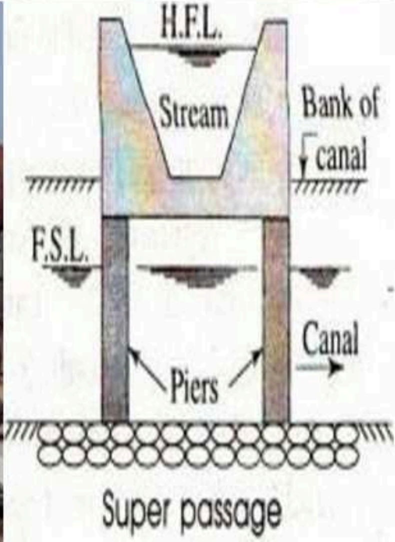


SIPHON AQUEDUCT



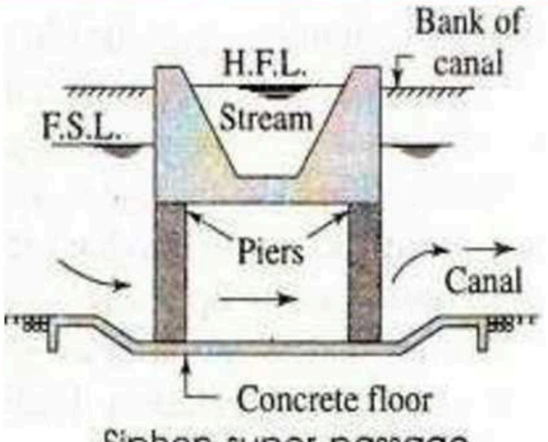
SUPER PASSAGE:

- The hydraulic structure in which the drainage is passing over the irrigation canal is known as super passage. This structure is suitable when the bed level of drainage is above the flood surface level of the canal. The water of the canal passes clearly below the drainage
- A super passage is similar to an aqueduct, except in this case the drain is over the canal.
- The FSL of the canal is lower than the underside of the trough carrying drainage water.
- Thus, the canal water runs under the gravity.
- Reverse of an aqueduct



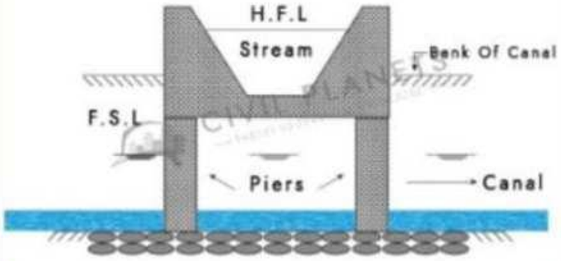
CANAL SYPHON SUPER PASSAGE:

- If two canals cross each other and one of the canals is siphoned under the other, then the hydraulic structure at crossing is called "canal siphon". For example, lower Jhelum canal is siphoned under the Rasul-Qadirabad (Punjab, Pakistan) link canal and the crossing structure is called "L.J.C siphon"
- In case of Siphon Super Passagesiphon the FSL of the canal is much above the bed level of the drainage trough, so that the canal runs under the siphonic action.
- The canal bed is lowered and a ramp is provided at the exit so that the trouble of silting is minimized.
- Reverse of an aqueduct siphon
- In the above two types, the inspection road cannot be provided along the canal and a separate bridge is required for roadway. For economy, the canal may be flumed but the drainage trough is never flumed.

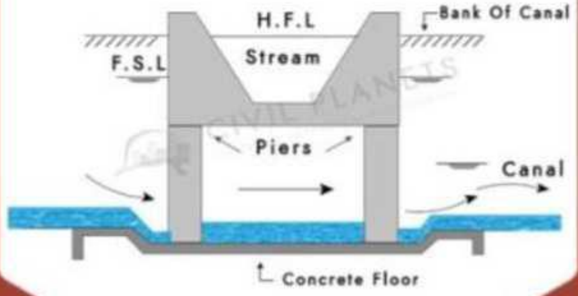


Siphon super passage

SUPER PASSAGE

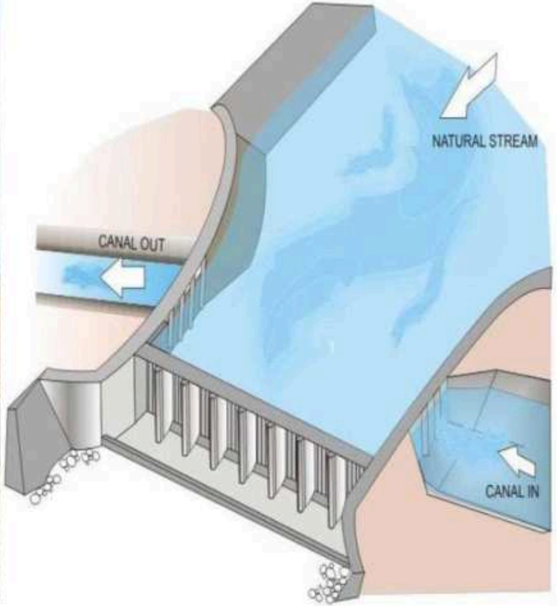


SIPHON SUPER PASSAGE



- ## Level Crossings

When the bed level of canal and the stream are approximately the same and quality of water in canal and stream is not much different, the cross drainage work constructed is called level crossing where water of canal and stream is allowed to mix. With the help of regulators both in canal and stream, water is disposed through canal and stream in required quantity. Level crossing consists of following components (i) crest wall (ii) Stream regulator (iii) Canalregulator.



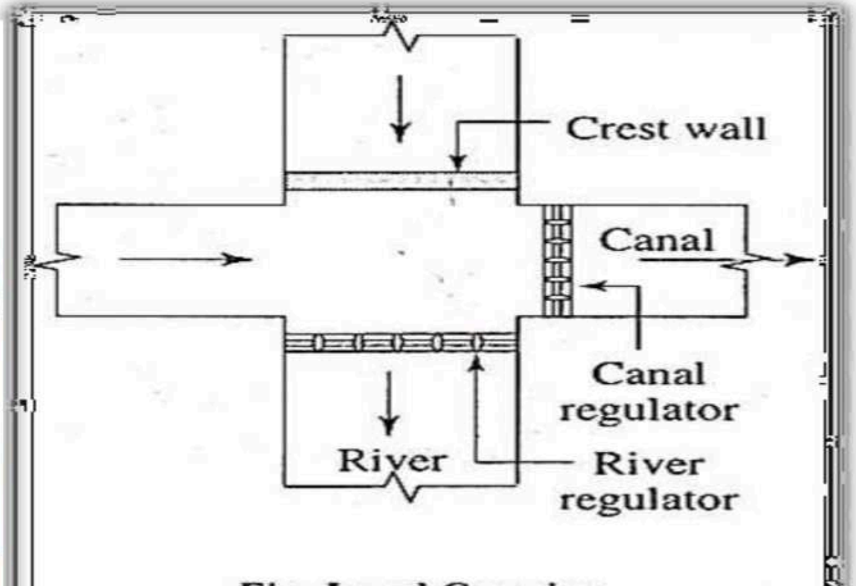


Fig: Level Crossing

- ## Inlet and Outlet

When irrigation canal meets a small stream or drain at same level, drain is allowed to enter the canal as in inlet. At some distance from this inlet point, a part of water is allowed to drain as outlet which eventually meets the original stream. **Stone pitching** is required at the inlet and outlet. The bed and banks between inlet and outlet are also protected by stone pitching. This type of CDW is called Inlet and Outlet.

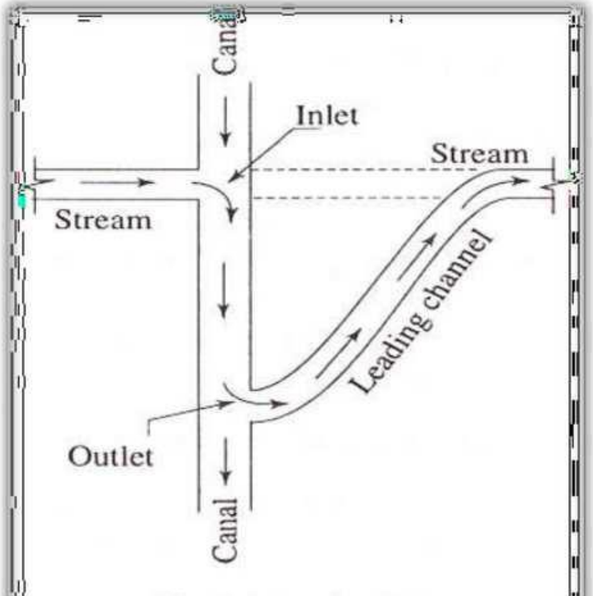
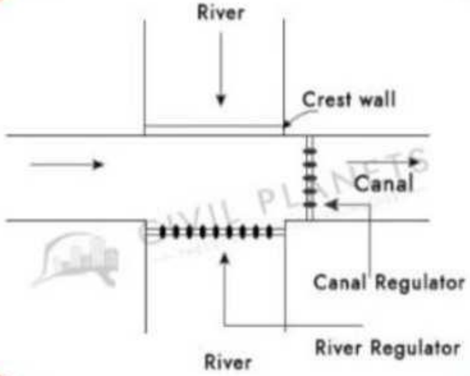
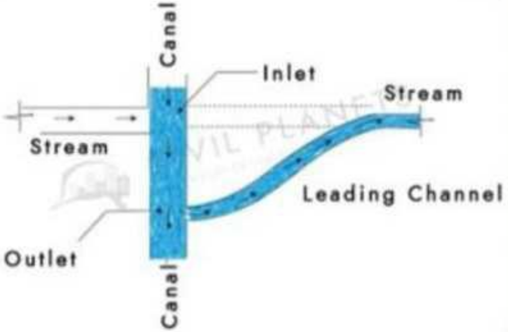


Fig: Inlet and outlet

LEVEL CROSSING



INLET & OUTLET



CLASSIFICATION OF AQUEDUCT AND SIPHON AQUEDUCT

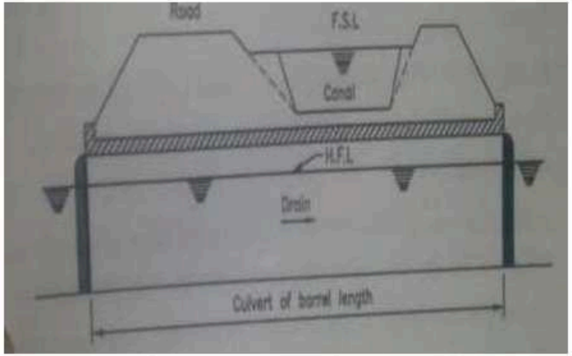
Depending upon the nature of the sides of the aqueduct or siphon aqueduct - classified

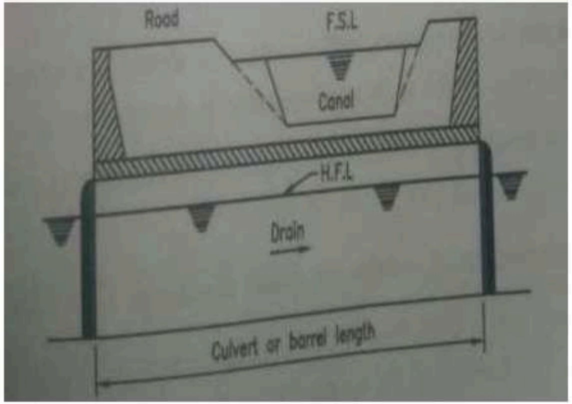
Type I:

- Sides of the aqueduct in **earthen banks** with complete earthen slopes. The length of culvert should be sufficient to accommodate both, water section of canal, as well as earthen banks of canal with aqueduct slope. Sides of the aqueduct in earthen banks, with other slopes **supported by masonry wall**. In this case, canal continues in its earthen section over the drainage but the outer slopes of the canal banks are replaced by retaining wall, reducing the length of drainage culvert.

Type II:

- Sides of the aqueduct made **of concrete or masonry**. Its earthen section of the canal is discontinued and **canal water is carried in masonry or concrete trough**, canal is generally flumed in this section.

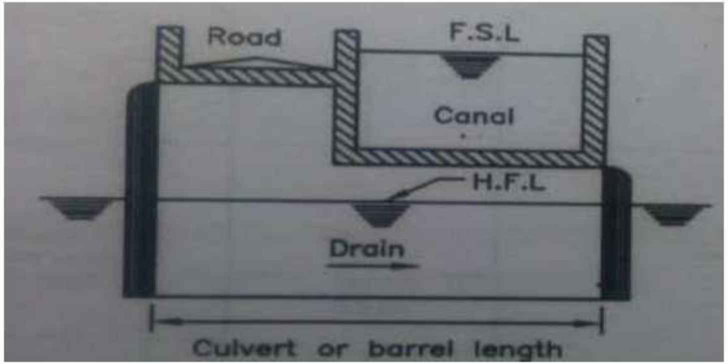




CLASSIFICATION OF AQUEDUCT AND SIPHON AQUEDUCT

Type III:

- Sides of the aqueduct made of **concrete or masonry**. Its earthen section of the canal is discontinued and canal water is carried in masonry or **concrete trough**, canal is generally flumed in this section.



Selection of a Suitable 'Site' for Cross Drainage Work

The following points should be considered while selecting the site of a cross-drainage work:

- At the site, the **drainage should cross the canal alignment at right angles**. Such a site provides good flow conditions and also the cost of the structure is usually a minimum.
- **The stream at the site should be stable** and should have stable banks.
- For **economical design and construction of foundations**, a firm and strong sub-stratum should exit below the bed of the drainage at a reasonable depth.
- **The length and height of the marginal banks and guide banks for the drainage should be small**.
- In the case of an aqueduct, sufficient headway should be available between the canal trough and the high flood level of the drainage.
- **The water table at the site should not be high,** because it will create De-watering problems for laying foundations.
- As far as possible, the **site should be selected d/s of the confluence of two streams**, thereby avoiding the necessity of construction of two cross-drainage works.
- The **possibility of diverting one stream into another stream upstream** of the canal crossing should also be considered and adopted, if found feasible and economical.
- A **cross-drainage work should be combined with a bridge**, if required. If necessary, the bridge site can be shifted to the cross-drainage work or vice versa.
- **The cost of the combined structure is usually less**. Moreover, the marginal banks and guide banks required for the river training can be used as the approaches for the village roads.

Selection of a Suitable 'Type' of Cross Drainage Work

1. Relative levels and discharges:

The relative levels and discharges of the canal and of the drainage mainly affect type of cross-drainage work required. The following are the broad outlines:

1.If the canal **bed level is sufficiently above the H.F.L. of the drainage, an aqueduct** is selected.

2.If the **F.S.L. of the canal is sufficiently below the bed level of the drainage, a super-passage** is provided.

3.If **the canal bed level is only slightly below the H.F.L. of the drainage, and the drainage is small, a siphon aqueduct is provided**.

4.If **the F.S.L. of the canal is slightly above the bed level of the drainage and the canal is of small size, a canal syphon is provided.**

5.If **the canal bed and the drainage bed are almost at the same level, a level crossing is provided**

2. Performance:

- the structure having an **open channel flow** should be preferred to the structure having a pipe flow,Therefore, an **aqueduct should be preferred** to a syphon aqueduct.
- The performance of inlet-outlet structures is not good and should be avoided.

3. Provision of road:

- **An aqueduct is better than a super-passage** because in the former, a road bridge can easily be provided along with the canal trough at a small extra cost, whereas in the latter, a separate road bridge is required.

4. Size of drainage:

- When the drainage is of small size, a syphon aqueduct will be
- if the drainage is of large size, an aqueduct is preferred.

5. Cost of earthwork:

The type of cross-drainage work which does not involve a large quantity of earthwork of the canal should be preferred

6. Foundation:

7. Material of construction:

8. Cost of construction:

The overall cost of the canal banks and the cross-drainage work, including maintenance cost, should be a minimum.

9. Permissible loss of head:

if the head loss cannot be permitted in a canal at the site of cross-drainage, a canal syphon is ruled out.

10. Subsoil water table:

If the subsoil water table is high, the types of cross-drainage which requires excessive excavation should be avoided, as it would involve De-watering problems.

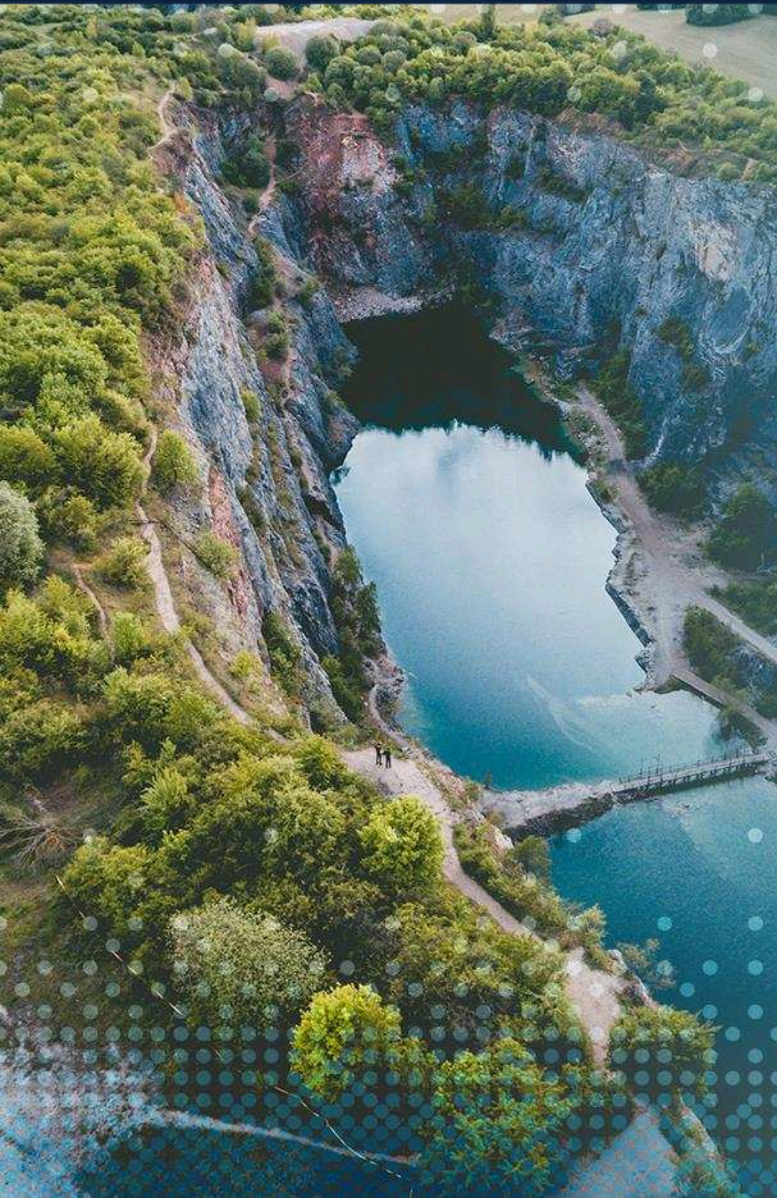
11. Canal alignment:

By changing the alignment, the type of cross-drainage can be altered. The canal alignment is generally finalized after fixing the sites of the major cross-drainage works.

Reservoir Planning

Meenu Sri Priya

CONTENTS



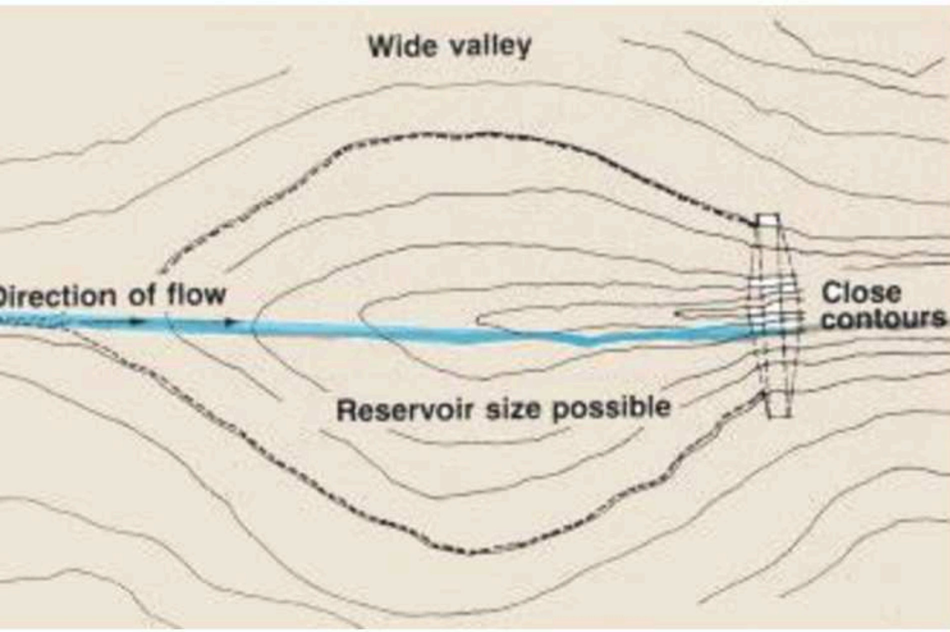
Investigations for reservoir planning

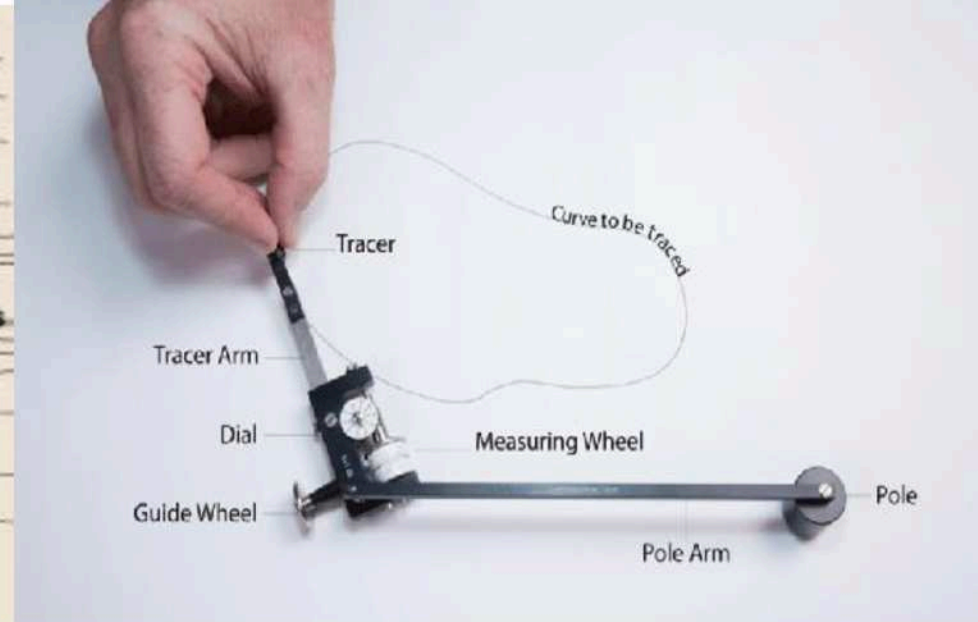
For any reservoir planning, various investigations, which are require to be carried out, are the following:

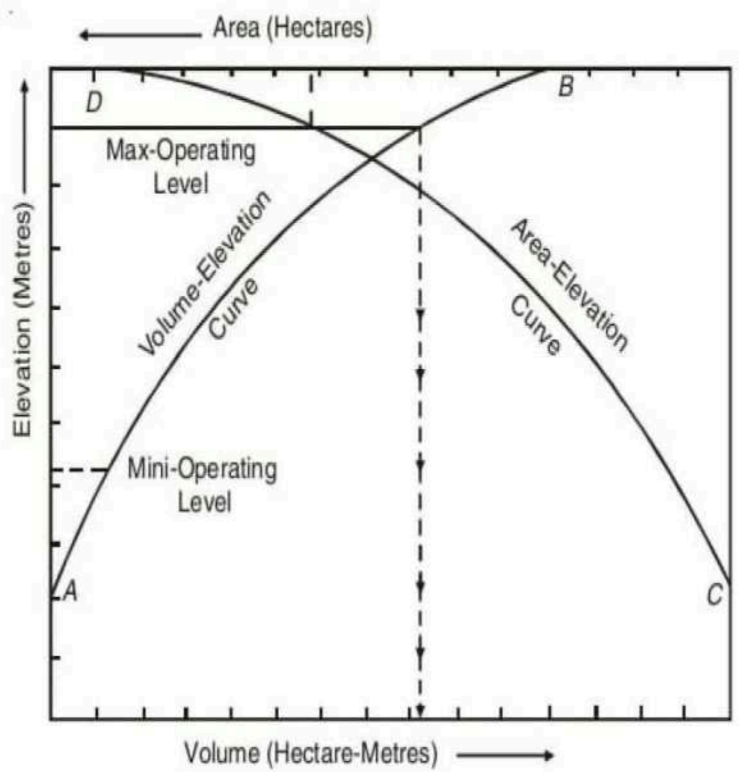
1. Engineering surveys
2. Hydrological investigations
3. Geological investigations.

1. Engineering Surveys.

- **The area of propose reservoir** is extensively surveyed and **contour plan** is prepared.
- **Contour plan is very useful for fixing the height of the dam, evaluating the area** that will be submerge an d fixing the positions of spill ways, sluice ways and other river training works, require for the developme nt of a reservoir.
- **Area-elevation curve and storage elevation curves can be draw from the contour plan** which help in fixin g the maximum **operating Area-elevation and Volume-elevation curves.**


Wide valley
Direction of flow
Close contours
Reservoir size possible


Tracer
Curve to be traced
Tracer Arm
Dial
Measuring Wheel
Guide Wheel
Pole
Pole Arm


Area (Hectares)
D
B
Max-Operating Level
Volume-Elevation Curve
Area-Elevation Curve
Elevation (Metres)
Mini-Operating Level
A
C
Volume (Hectare-Metres)

Area elevation curve

. A **contour plan of the proposed site of a reservoir is prepare.**

- Considering from the **bottom let A1, A2, A3……An be the areas of successive contours**.
- These **areas can be easily determine with the help of planimeter.**
- The **value of area A1 is minimum at the base of the basin.**
- As elevation of the contours increases the area under them also increases.
- A curve as CD between area elevation is shown in **Fig. Storage elevation curve.**
- The volume of storage corresponding to different contours can be calculate by using either **prismoidal formula or trapezoidal formula.**
- We have seen that **area of the contours goes on increasing as we proceed from bottom of the reser voir towards top.**
- Consequently **volume of storage also goes on increasing as we proceed from bottom of the reservo ir towards top.**
- **The volumes of storage for different contours may be calculated and curve between storage and el evation may be plot shown by curve AB**

2. Hydrological Investigations.

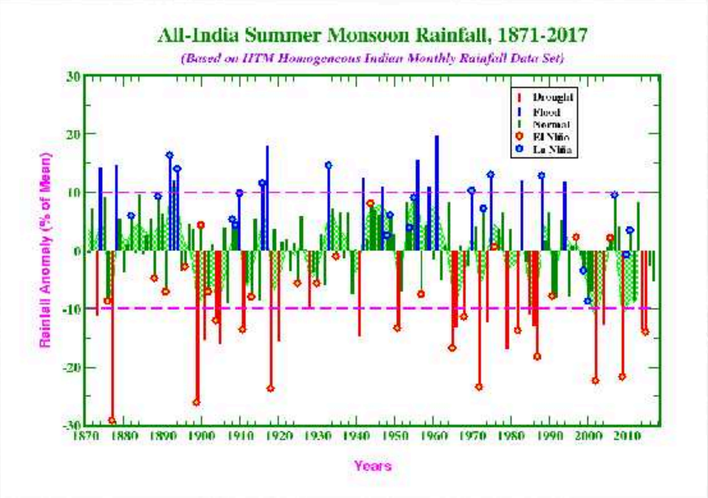
•It is very important aspect of reservoir planning.

•Capacity of reservoir, its **potential for irrigation, power generation** etc.

•all **depend upon the availability of water from the reservoir**.

• **Capacity of spillway, storage capacity, height of dam**, etc.

•Hence **rainfall records, catchment characteristics, spread of catchment, climatic characteristics etc.**



3. Geological Investigations.

•In all the **major Civil Engineering projects, geological advice is considered very essential.**

•It costs very little but relieves the Engineer from the **worry of possible presence of fissure rocks** or other geological faults which may cost too much when they come to notice later.

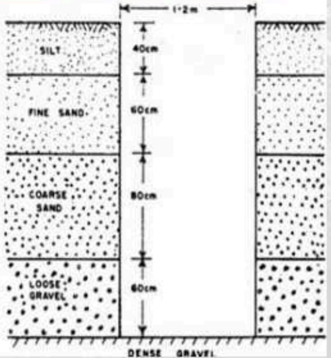
(i) **Reservoir basin should be water tight without having any embedded fissured formations**.

(ii) Position of ground water table.

(iii) **Type of soil and its suitability** in regard to foundation of the dam. **Type and depth of soil**

(v) **Position of quarry sites for materials** required for the construction of dam etc.

•**Trial pits may be bore in the catchment area** and geological conditions investigated.



SELECTION OF RESERVOIR SITE

Before finally selecting the reservoir site following factors should be seriously considered.

1.**Catchment area should have such geological conditions that percolation and absorption losses are minimum**.

2.**Available run-off should be maximum**.

3.**The site should be free from fissured rocks.**

4.This will **avoid possibilities of leakage** when reservoir is full to capacity. The reservoir site must have **adequate capacity**.

5.The **reservoir basin should have a deep narrow opening in the valley** so that the length of the dam may be kept minimum.

6.**Heavily silt laden tributaries** should not lead their discharge to the reservoir. Suitable site for dam should be available.

7.It is very important point as **cost of dam** is often a controlling factor in selection of the reservoirs site.

8.**Site should be such that deep reservoir** is formed. Deep reservoir would store more of water and expose minimum area at the surface for evaporation.

1.**If earthen dam is propose to be construct, then separate suitable site for spillway works** should be available.

2.Reservoir site should be well **connected by rail and road.**

3.**Materials for the construction of dam** should be available nearby.

4.**The soil formation at reservoir site should be free from harmful salts.**

5.If **reservoir water is to be use for irrigation, the dam site should be near the area propose to be irrigate.**

6.**This would reduce the length of the canal system and consequently the cost of the project.**

7.Reservoir should **not submerge habited area or areas of fertile lands or gardens.**

8.**River banks should be hard, strong and high** so that cost on river training works is minimum.

STORAGE ZONES OF A RESERVOIR

1. Dead Storage.

•The volume of water stored **below the minimum pool lev**el of the reservoir is know dead storage.

•This storage is **not of such use in the operation of the reservoirs**.

2. Useful Storage.

•The volume of water stored in a reservoir **between minimum pool level and normal pool level** is know useful storage.

•The useful storage may be further **classified into conservation storage and flood mitigation storage** in a multi-purpose reservoi r.

3. Surcharge Storage.

•The volume of water stored **between normal pool level and the maximum pool level** is know surcharge storage.This storage i s an **uncontrolled storage.**

•It **exists only till floods are in progress** and cannot be retained for later use.

4. Bank Storage.

•When reservoir is full of water some amount of water seeps in the permeable banks of the reservoir.This seeped water comes out as soon the reservoir level gets deplete.

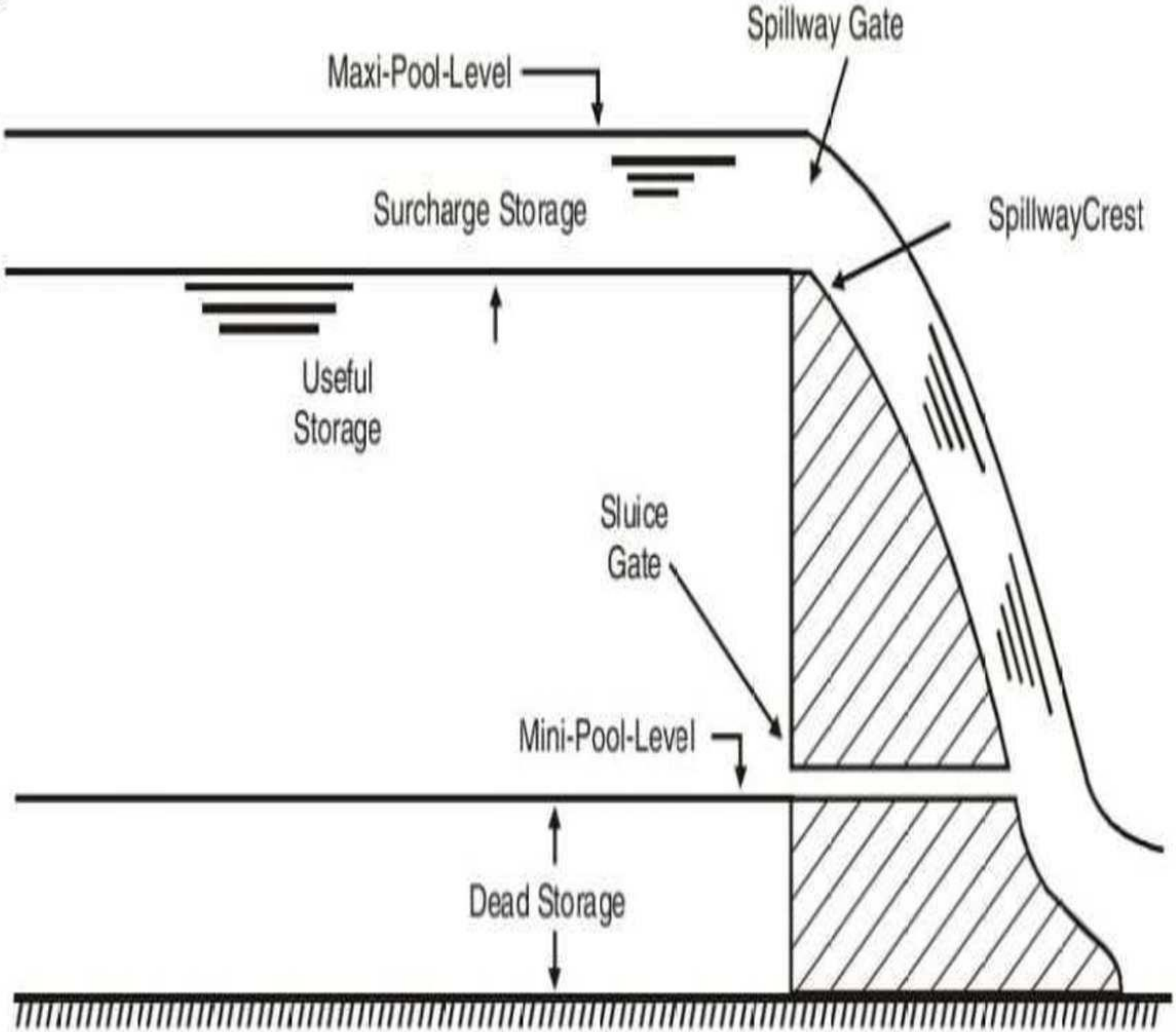
•This **amount of seeped water which becomes available after the reservoir is deplet** is know Bank storage.

•Amount of bank storage may amount to several per cent of the reservoir storage depending upon the geological formations of the banks. **This storage increases the capacity of the reservoir above that indicated by the elevation-volume curve**

5. Valley Storage.

•Some **amount of water is stored by the stream channel even before a dam is constructed.**This storage is know valley storage.

•Amount of valley storage is variable as it **depends upon the rate of flow in the reservoir.**



Spillway Gate
Maxi-Pool-Level
Surcharge Storage
SpillwayCrest
Useful
Storage
Sluice
Gate
Mini-Pool-Level
Dead Storage

Storage capacity &Yield

1. Yield of the Reservoir.

- It is the **amount of water that can be supplied by the reservoir in a specified interval of time.**
- The specified time interval may vary from a day **for a small distribution reservoir to a month or year for large conservation reservoirs.**
- If we say that three million cubic meters of water can be supplied from a reservoir in a year then its yield is **3000000 m3/year.**
- **The yield of the reservoir is dependent upon the inflow and thus varies from time to time.**

2. Safe Yield.

- It is also known as **firm yield.**
- It is the **maximum quantity of water that can be supplied from the reservoir** with full **guarantee during the worst dry period.**

3. Design Yield.

- The critical period for a reservoir is generally considered, when **natural flow in the reservoir is minimum.**
- There is **possibility that sometimes the minimum natural flow in the reservoir may even fall short of guaranteed yield.**
- Hence a lower value than the guaranteed yield or safe yield may be taken for design purpose.
- This yield whose value is smaller than the safe or firm yield is known as design yield.
- The value of design yield for a reservoir to be used for water supply is taken less than the safe yield.
- **In the case of reservoirs used for irrigation purpose the design yield may be taken slightly more than the safe yield as crops can tolerate some deficiency of water during exceptionally dry season.**

4. A Secondary Yield.

- **The quantity of water available in excess of safe yield is known as secondary yield.**
- This yield is available during period of high inflows.
- This secondary yield of the reservoir can be used either to **generate extra hydroelectric power or for irrigation of extra lands.**

5. Average Yield.

- **The arithmetic average of the safe yield and the secondary yield considered for a numb er of years is known as average yield.**
- The storage capacity of the reservoir and its yield are very much interdependent.
- The water is stored in the reservoir to fulfill the safe yield requirements.
- If capacity of the reservoir is more it can **certainly provide more water and hence yield i s more.**
- The reservoirs are designed to meet a specific demand of water.
- The capacity of the reservoir and the yield are governed by the following storage equati on:

Inflow – outflow = Increase in storage.

Mass Inflow Curve

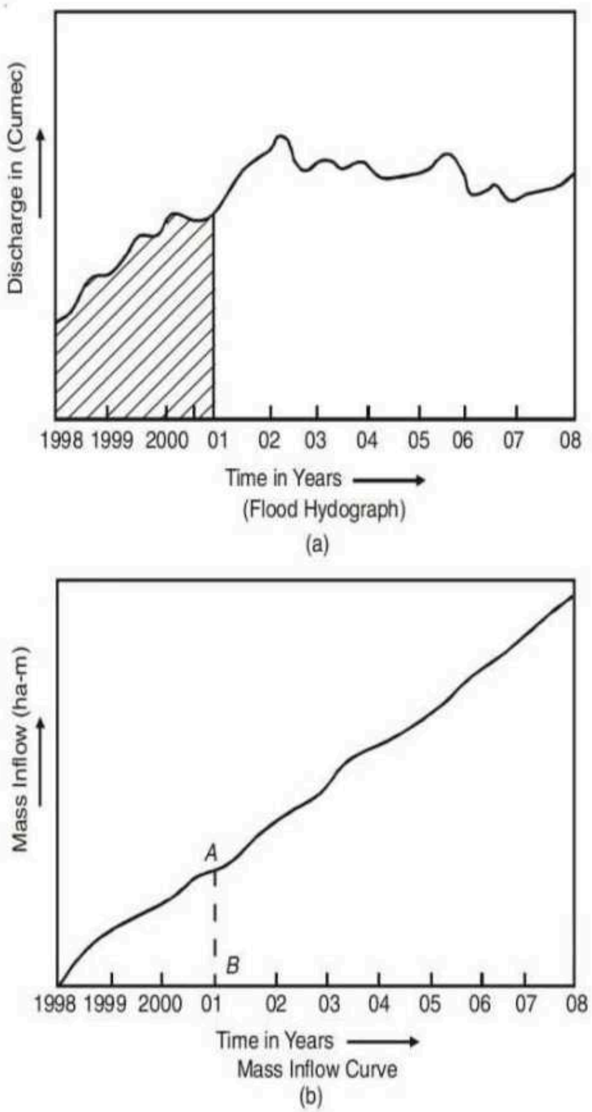


Fig. 9.4. *Flood hydrograph and mass inflow curve.*

- Mass inflow is a curve which represents the cumulative flow in a reservoir at any particular instance. It is a **plot between cumulative inflow in the reservoir with time.**
- It can be prepared with the help of a hydrograph of the river for the dam site **for a large number of years. hydrograph is a plot or curve between discharge versus time**
- Figure 9.4 (a) shows a **hydrograph of a river for the dam site for a number of years** and Fig. 9.4 (b) a **corresponding mass curve prepared from the hydrog raph** of Fig. 9.4 (a).
- **In mass curve, the corresponding ordinate at time t1 (ordinate AB) will repr esent the total volume of water indicated by the hatched area of hydrograph curve.**
- Similarly the **ordinates of the mass curve corresponding to other years can b e determined from the hydrograph curve and plotted.**
- When **all such points are joined free hand we get the mass curve correspond ing to the hydrograph.**
- It is evident that a **mass curve will continuously rise as it is the plot of accum ulated inflow versus time.**
- **Periods of no inflow would be indicated by horizontal lines on the mass curv e.**
- **The slope of the mass curve at any time gives the rate of inflow at that time.**
- Mass inflow curve is sometimes known as **Ripple diagram** also.

Demand Curve

- It is a plot between accumulated demand of water from reservoir with time.
- If demand of water is at constant rate then demand curve becomes a straight line.
- The slope of the demand curve represents the rate of demand.
- If demand is variable the demand curve does not remain a straight line but assumes curved s hape.

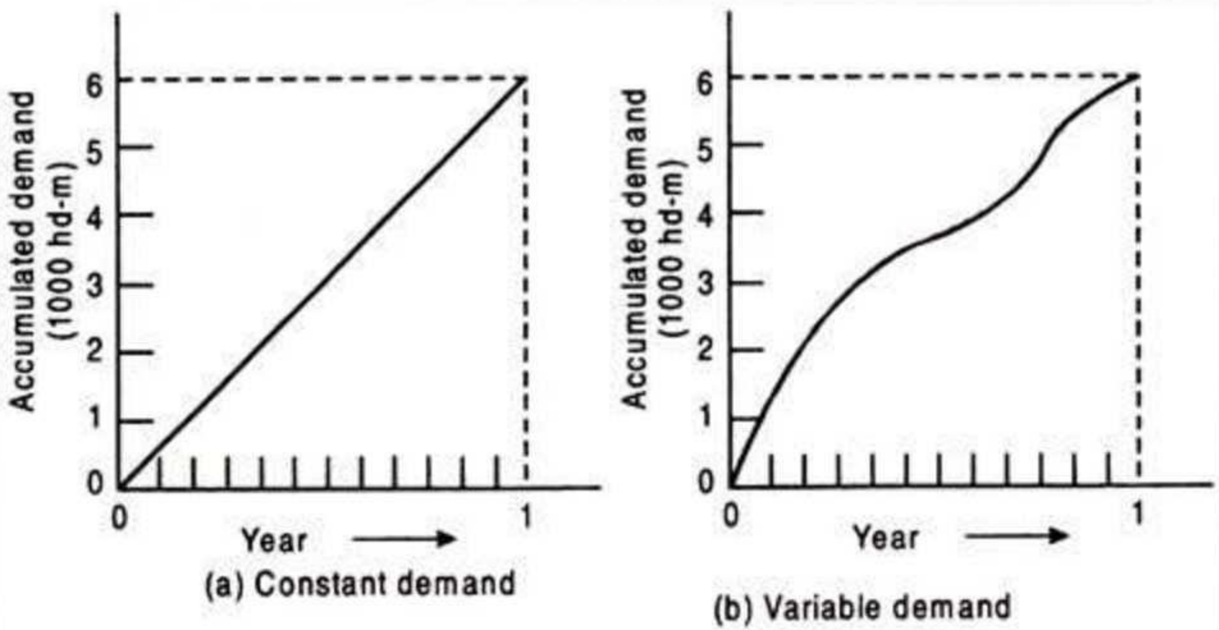


Fig. 3.14 *Demand curve*

Determination of Capacity of a Storage Reservoir required for a Specified Yield or Demand using Mass Curve

The capacity of a storage reservoir is determined on the basis of the inflow to the reservoir and the demand of the consumers (or the yield of the reservoir).

The capacity of a storage reservoir required for a specified yield or demand may be determined by using mass curve of inflow and mass curve of demand or demand curve as indicated below:

(1) A mass curve of inflow is prepared from the flow hydrograph for a number of consecutive years selected from the available stream flow record such that it includes the most critical or the driest period. Figure 3.15 shows a mass curve of inflow for a typical stream for a 6 year period.

(2) Corresponding to the given rate of demand, a demand curve is prepared. If the rate of demand is constant then the corresponding demand curve is a straight line as shown in Fig. 3.15.

(3) Lines such as GH, FJ, etc., are drawn parallel to the demand curve and tangential to the high points G, F, etc., of the mass curve of inflow (or the points at the beginning of the dry periods).

(4) The maximum vertical intercepts X_1, Y_1 X_2Y_2 etc., between the tangential lines drawn in step (3) and mass curve are measured. The vertical intercepts indicate the volume by which the total flow in the stream falls short of the demand and hence required to be provided from the reservoir storage. For example assuming the reservoir to be full at G, for a period corresponding to points G and Z_1, there is a total flow in the stream represented by Y_1Z_1 and there is a total demand represented by X_1Z_1 leaving a gap of volume represented by X_1Y_1 which must be met with from the reservoir storage.

(5) The largest of the maximum vertical intercepts X_1Y_1, X_2Y_2, etc., determined in step (4) represents the reservoir capacity required to satisfy the given demand. However, the requirement of storage so obtained would be the net storage which must be available for utilization and it must be increased by the amount of water lost by evaporation and percolation.

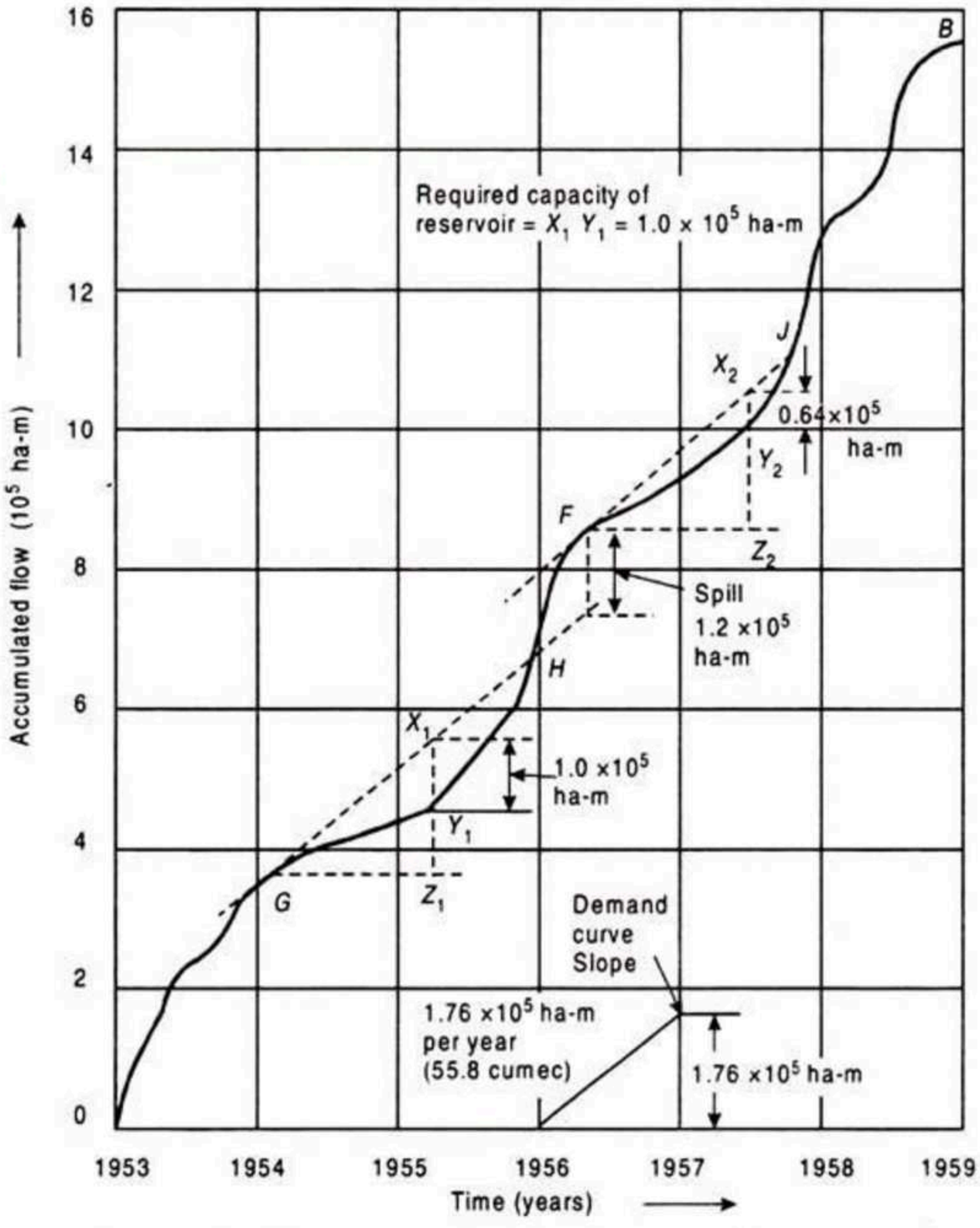
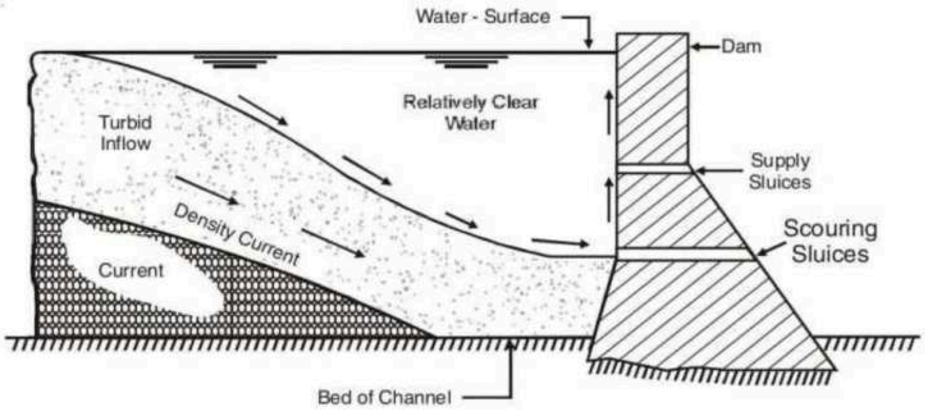


Fig. 3.15 *Use of mass curve to determine the capacity of a storage reservior required to produce a specified yield*

- The vertical distance between the succe ssive tangential lines such as GH and FJ represents the quantity of water which c ould spill over from the reservoir throu gh the spillway and go as a waste to the downstream side.
- This is so because between H and F the reservoir would remain full and all inflo w in excess of demand would flow thro ugh the spill-way to the downstream sid e.
- The tangential lines drawn parallel to th e demand curve when extended forwar d must intersect the mass curve, such as at H, J, etc., so that the reservoir which was full at G and F will be filled again at H and J.
- However, if the line does not intersect t he mass curve, the reservoir will not be filled again. Moreover, if the reservoir is very large the time interval between the points G and H, F and J, etc., may be s everal years.

LIFE OF RESERVOIR



•Any reservoir cannot last for ever.

•Ultimately all the reservoirs get silted up.

•Silting of the reservoir starts from the day it is created.

•When reservoirs are created some of its capacity is left unused.

•This is the capacity of the reservoir lying below the crest level of the bottom most under sluices.

•This storage capacity which remains unused is know dead storage.

•This dead storage capacity is used to accommodate deposited silt so that effective storage of the reservoir is n ot affected.

•So long as dead storage capacity of the reservoir is not silted completely, effective storage or useful storage ca pacity is not affected.

•The process of silting continues even after complete silting of dead storage.

•The further silting affects the effective storage of the reservoir and the reservoir does not have enough water t o fully fulfil its obligations.

•Generally useful life of the reservoir is considered terminated when its effective storage is reduced by 20% of the designed capacity of the reservoir.

Flood Routing and Its Methods

Flood routing is a process with the help of which characteristics of hydrograph of a flood, entering the reservoir are completely changed when it emerges out of the reservoir. The change in flood hydrograph characteristics takes place because certain volume of flood is stored in the reservoir temporarily and is let off as the floods recede.

Methods of Flood Routing:

There are several methods, but following methods, are in most common use:

1. Graphical Method:

The relation between inflow, outflow, and change in storage can be expressed mathematically as follows:

$$I = O + \Delta s \qquad (1)$$

where ,

I = Average inflow during given time interval

O = Average outflow during same time interval

Δs = Volume of water stored or change in storage during the same time interval.

Increase in storage should be taken as positive and decrease in storage as negative.

Let I_1 and I_2 be the inflow rates and

O_1 and O_2 be the outflow rates at the beginning and end of the time interval t.

Let S_1 be the storage in the beginning and S_2 at the end of the time interval t.

Steps of Graphical Method:

1. Determine total inflow for the first time interval t from the inflow hydrograph. Enter this value as AB
2. Through B draw a vertical line to meet the curve 2S/t + O at point C. The point C represents the value of o utflow at the end of the interval.

3. Through C draw a horizontal line A_1CB_1 cutting (2S/t – O) curve in point A_1.

4. Now calculate the total inflow during second subsequent time interval t again from inflow hydrograph. Measure the total inflow from A_1 on line A_1CB_1 and mark poin t B_1.

5. Again draw a vertical ordinate from B_1 to meet the curv e (2S/t + O) a point C_1 and repeat the procedure as sta ted in steps (3) and (4) until the entire flood is routed.

6. The outflow discharge at any time interval is given by th e total vertical ordinate. The largest of these ordinates will indicate the value of the peak outflow rate. The sp illways are designed based of the largest discharge.

7. After determining the outflow discharge at various interv als as described above, the reservoir water level for the se can be determined from graph II.

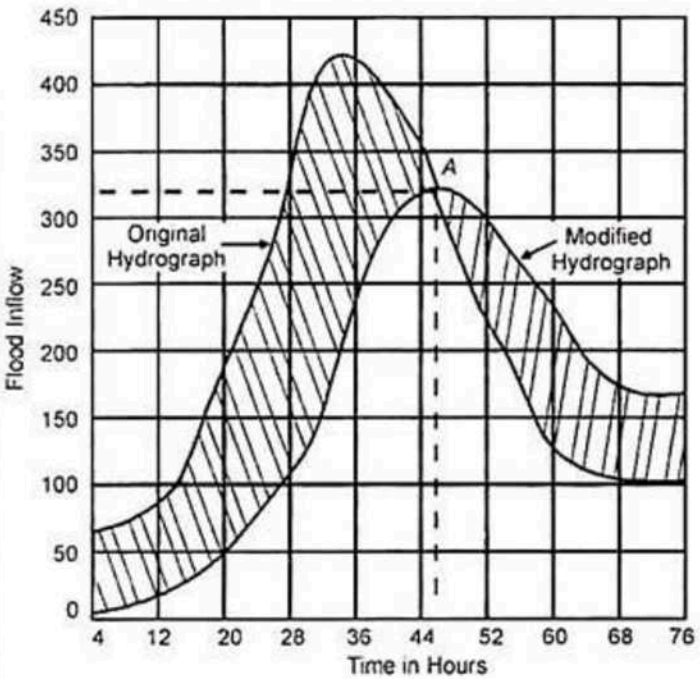
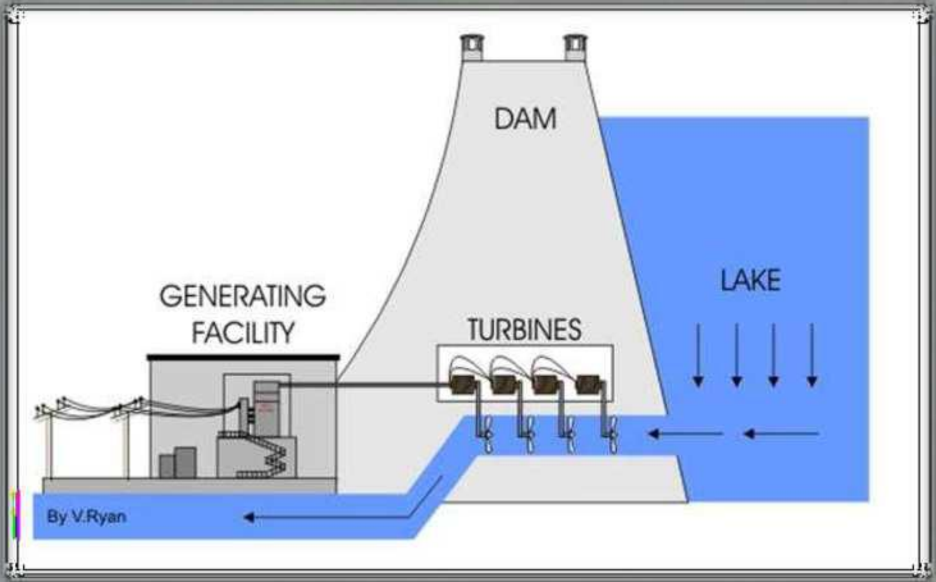


Fig. 9.15. *Modified hydrograph.*

DAMS



Meenu Sri Priya
Civil Engineering

Dams

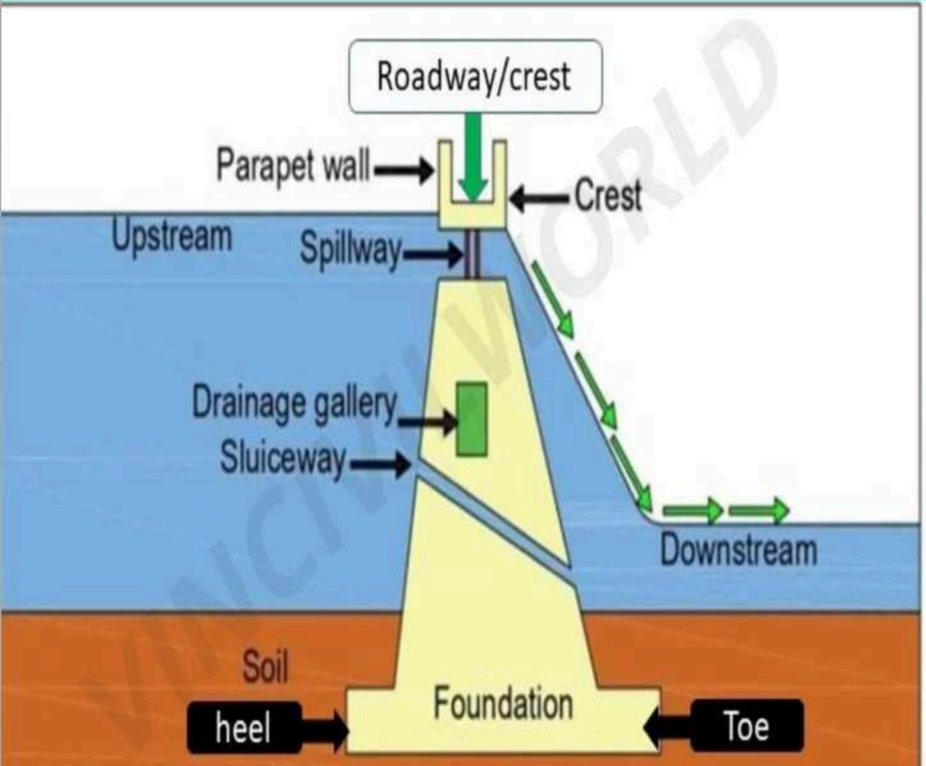
Dam is a solid barrier constructed at a suitable location across a river valley to store flowing water.

Storage of water is utilized for following objectives:

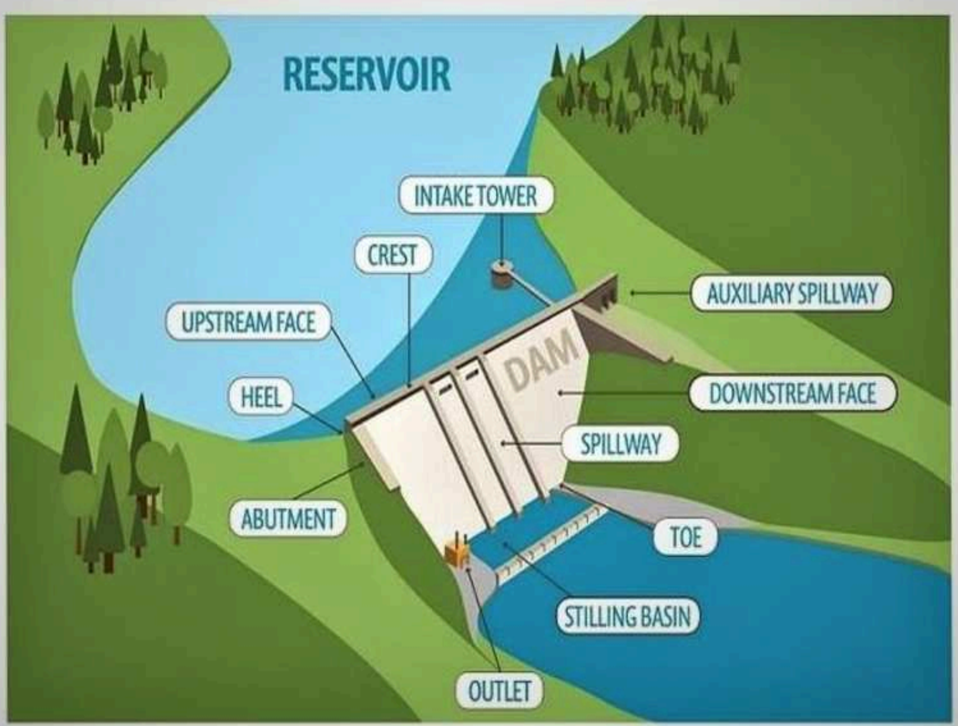
- Hydropower
- Irrigation
- Water for domestic consumption
- For drought and flood control
- Other additional utilization is to develop fisheries.

Structure of dam

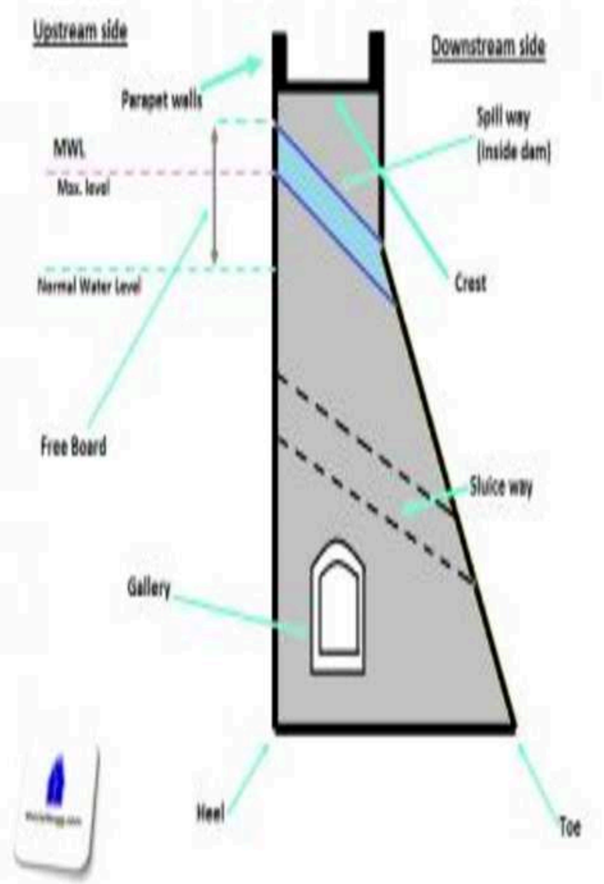
COMPONENTS OF DAM



ANATOMY OF A DAM



- **Crest:** The top of the Dam. These may in some cases be used for providing a roadway or walkway over the dam.
- **Parapet walls:** Low Protective walls on either side of the roadway or walkway on the crest.
- **Heel:** Portion of Dam in contact with ground or river-bed at upstream side.
- **Toe:** Portion of dam in contact with ground or river-bed at downstream side.
- **Spillway:** It is the arrangement made (kind of passage) near the top of dam for the passage of surplus/ excessive water from the reservoir.
- **Abutments:** The valley slopes on either side of the dam wall to which the left & right end of dam are fixed to.
- **Gallery:** Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
- **Sluice way:** Opening in the dam near the base, provided to clear the silt accumulation in the reservoir.
- **Free board:** The space between the highest level of water in the reservoir and the top of the dam.
- **Dead Storage level**: Level of permanent storage below which the water will not be withdrawn.
- **Diversion Tunnel:** Tunnel constructed to divert or change the direction of water to bypass the dam construction site. The dam is built while the river flows through the diversion tunnel.



Classification of Dams

Classification based on function

- Storage Dam
- Detention Dam
- Diversion Dam
- Coffer Dam
- Debris Dam

Classification based on hydraulic design

- Overflow Dam/Overfall Dam
- Non-Overflow Dam

Classification based on material of construction

- Rigid Dam
- Non Rigid Dam

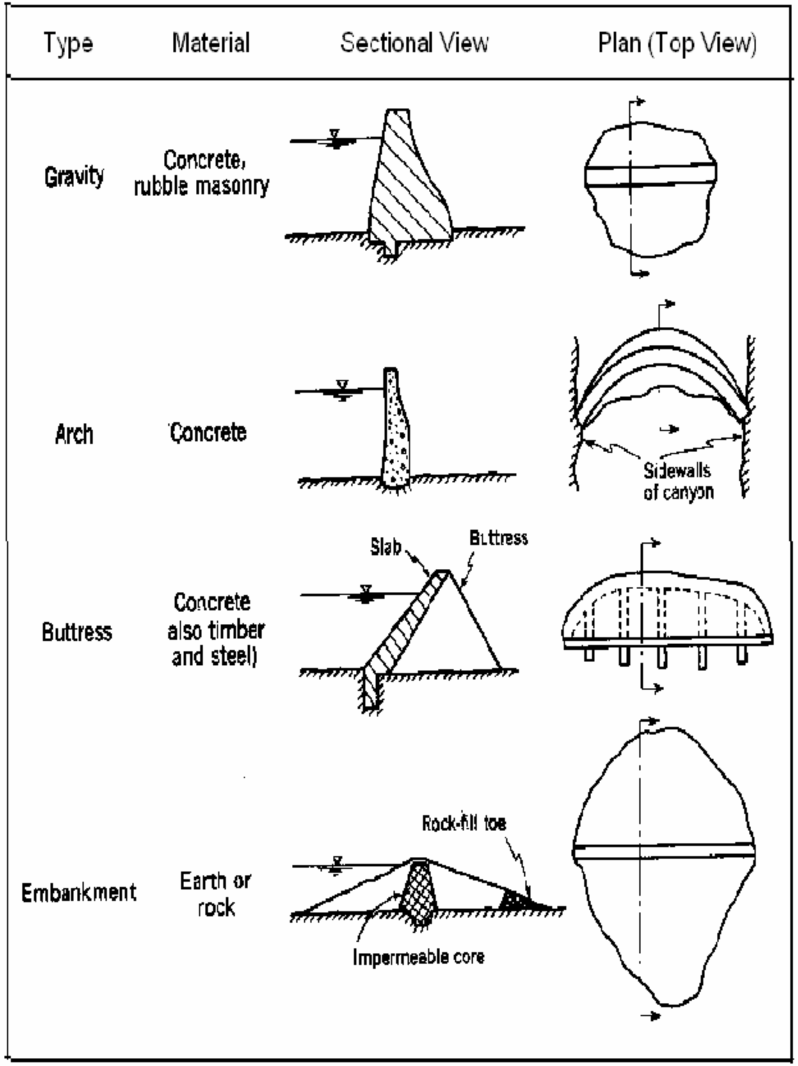
Classification based on structural behavior

- Gravity Dam
- Arch Dam
- Buttress Dam
- Embankment Dam
- Rock-fill dam

Based on structure and design, dams can be classified as follows

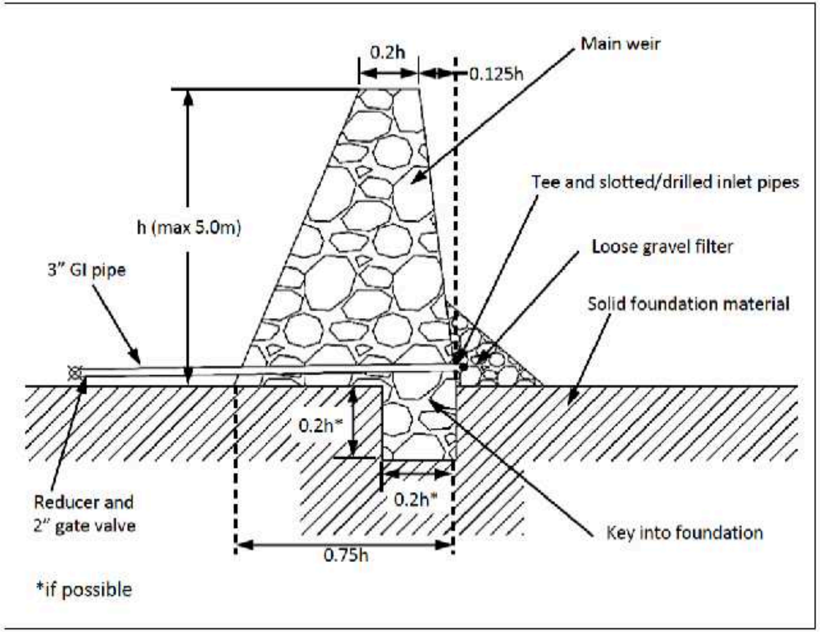
Gravity Dams: A gravity dam is a massive sized dam fabricated from concrete or stone masonry.

- They are designed to hold back large volumes of water. By using concrete, the weight of the dam is actually able to resist the horizontal thrust of water pushing against it. This is why it is called a gravity dam.
- Gravity essentially holds the dam down to the ground, stopping water from toppling it over.
- Gravity dams are well suited for blocking rivers in wide valleys or narrow gorge ways.
- Since gravity dams must rely on their own weight to hold back water, it is necessary that they are built on a solid foundation of bedrock.



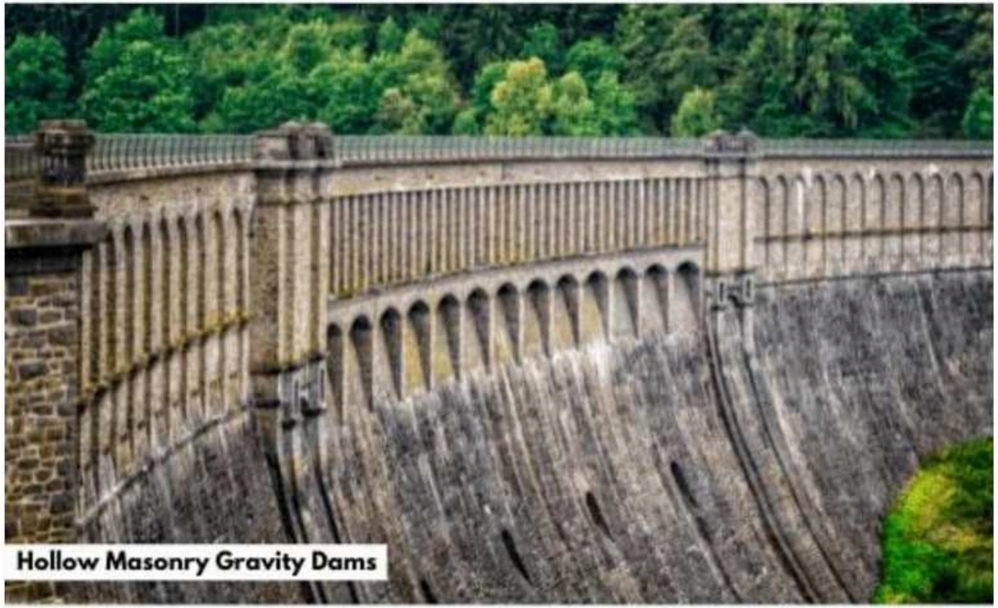
Solid Masonry Gravity dams

- These are big and expensive dams but are more durable and solid than earth and rock dams
- These are of great weight so that can be built at places where there is a natural strong foundation.

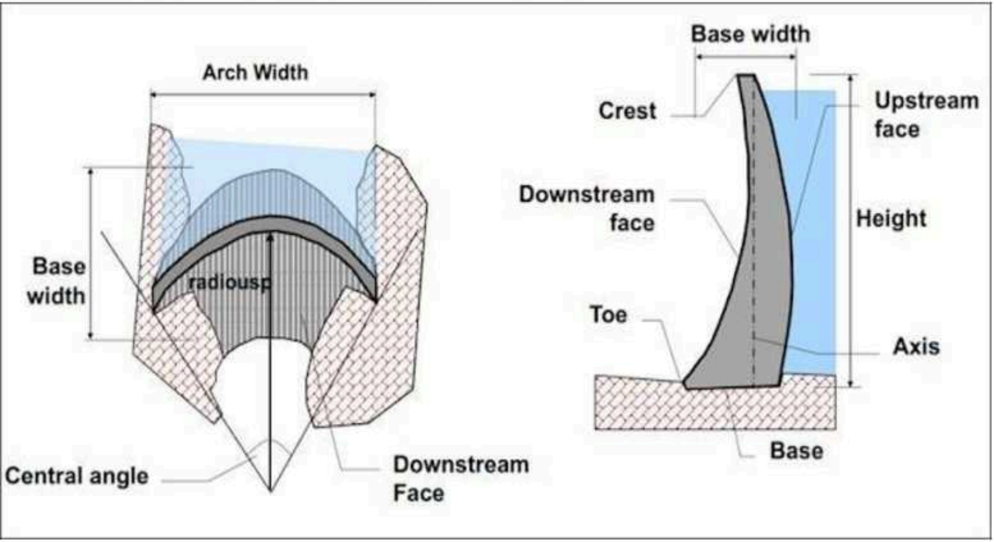


The hollow masonry gravity dams

- Build in the same way as solid masonry gravity dams but with less concrete or masonry
- A deck of RCC or arches carry the weight of water
- These are difficult to build and are only adopted if skilled labor is easily available.



Arch dams



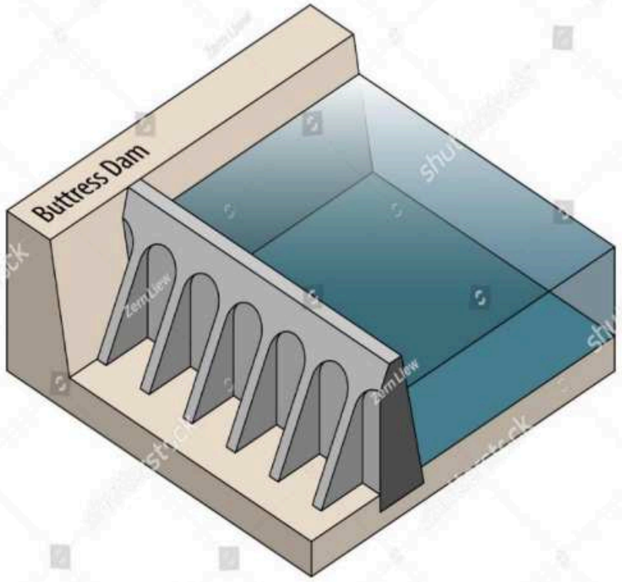
- An arch dam is curved in plan, with its convexity towards the upstream side.
- An arch dam transfers the water pressure and other forces mainly to the abutments by arch action.
- An arch dam is quite suitable for narrow canyons with strong flanks which are capable of resisting the thrust produced by the arch action.
- The section of an arch dam is approximately triangular like a gravity dam but the section is comparatively thinner.
- The arch dam may have a single curvature or double curvature in the vertical plane. Generally, the arch dams of double curvature are more economical and are used in practice.
- The horizontal arch action of the dam is used to hold back the water
- Best suited at sites where dams must be extremely high and narrow.

Buttress Dams:

Buttress dams are of three types :

(i) Deck type, (ii) Multiple-arch type, and (iii) Massive-head type.

- A deck type buttress dam consists of a sloping deck supported by buttresses.
- Buttresses are triangular concrete walls which transmit the water pressure from the deck slab to the foundation.
- Buttresses are compression members. Buttresses are typically spaced across the dam site every 6 to 30 metre, depending upon the size and design of the dam.
- Buttress dams are sometimes called hollow dams because the buttresses do not form a solid wall stretching across a river valley.The deck is usually a reinforced concrete slab supported between the buttresses, which are usually equally spaced.



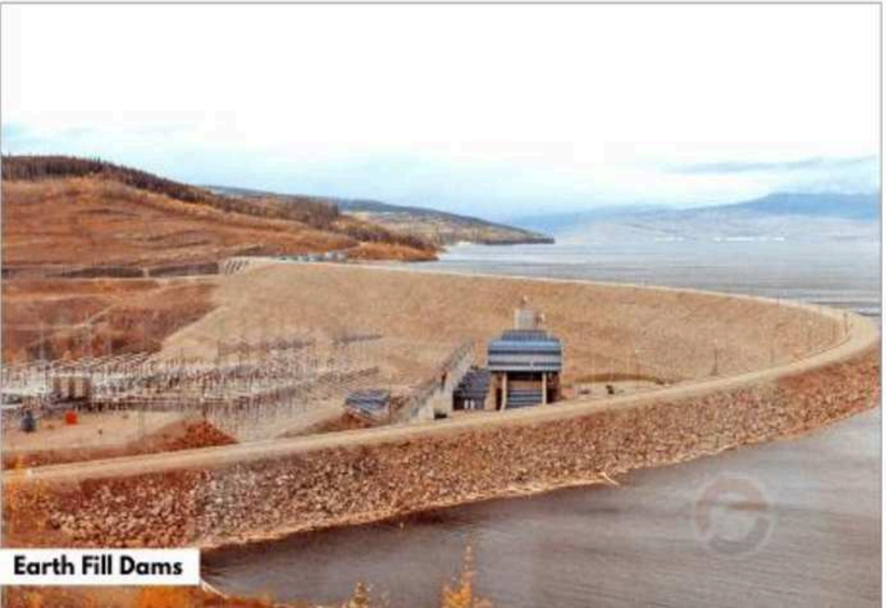
Embankment-Earth or Rockfill dams

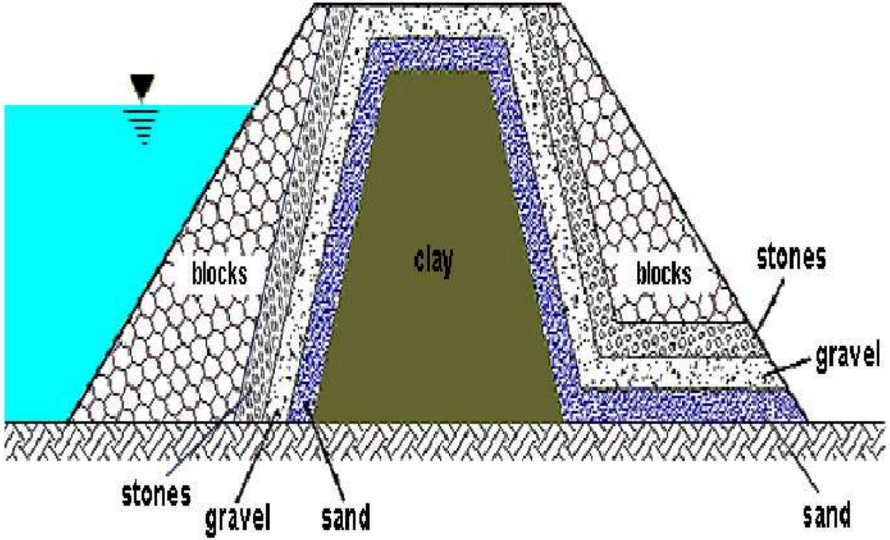
Earth fill dams

•Earth fill dams are made by solidifying the soil down slowly.

•These are constructed at places that are not strong enough to bear the weight of a concrete dam

•Mainly used in places where the earth is more easily available as a building material compared to others.

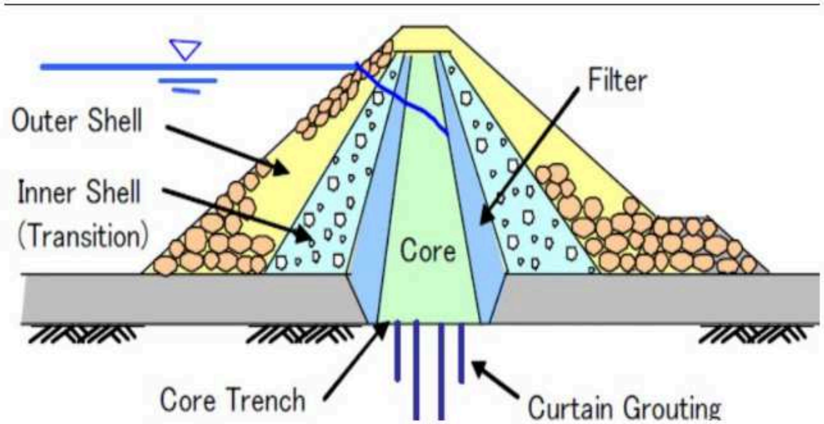




Rockfill dams

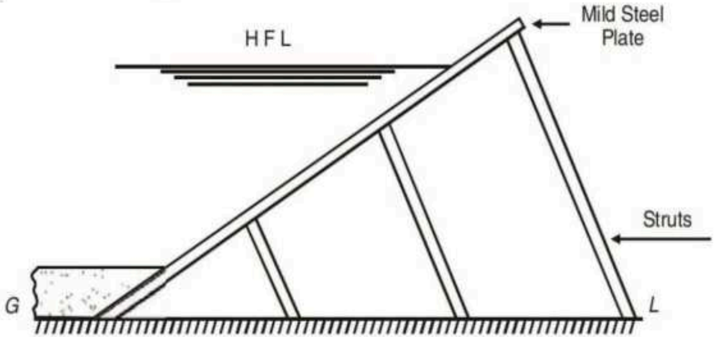
•These dams are constructed using loose rocks and boulders piled in the riverbed

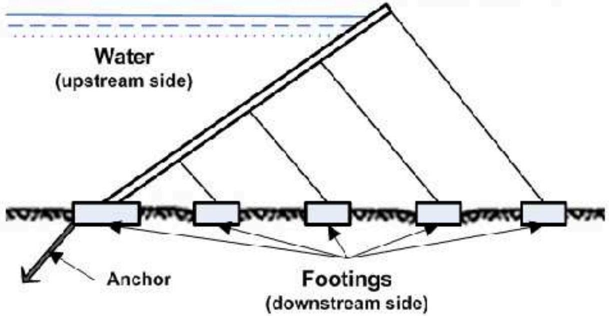
•On the upstream side of the dam, a slab of reinforced concrete is often laid across to make it watertight



Steel dams

- Not used for major works
- Used as temporary cofferdams needed for constructing permanent dams
- Timber is used for the reinforcement of steel cofferdams.





Timber dams

•Timber dams have short-lived around 30 to 40 years with proper maintenance

•Mostly used in agricultural areas to create a pool of water for cattle and to meet other low-level needs.

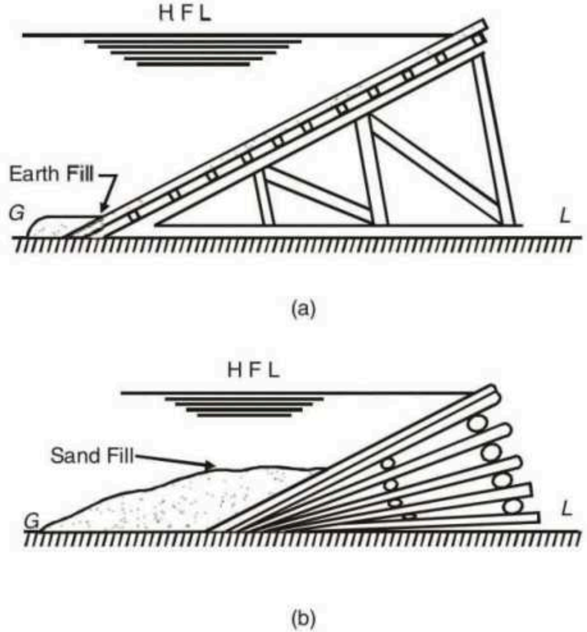


Fig. 11.12. *(a) Framed timber dam (b) Beaver timber dam.*

Classification Based on the Flow over its Top.

(i) Overflow dams

- These dams are designed in such a way to pass the surplus water over their crest
- Mostly called Spillways
- Must be constructed with materials that will not be eroded by such discharges.

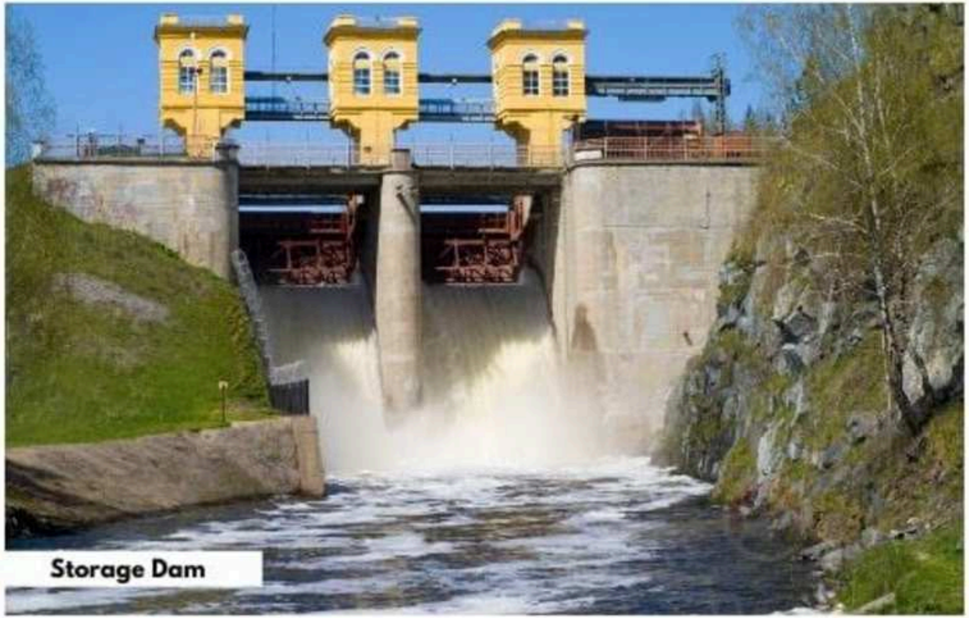
(ii) Non-overflow dams

- Designed not to be overtopped
- Gives a wider choice of materials including earth fill and rockfill
- In most cases, the overflow and non-overflow dams are combined to form a composite single structure.

Classification Based on the Use of the Dam.

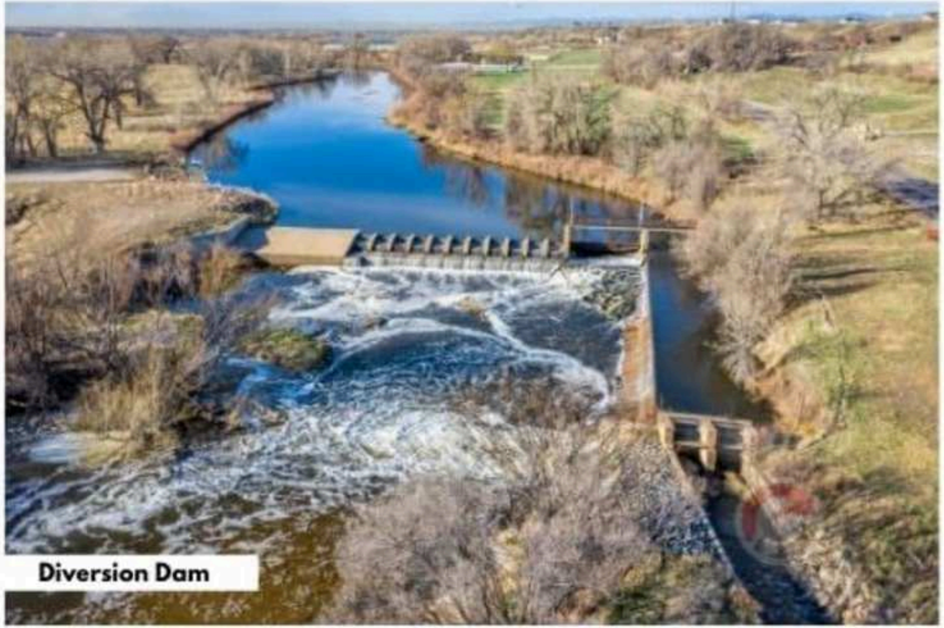
(i) Storage dam

- Constructed to store water during the time of surplus water and to be used later in the time of shortage
- They can be further classified according to the use of water like navigation, recreation, water suppl fish, electricity, etc.



(ii) Diversion dam

- Small dams are used to raise the water level to off-take canal or some other conveyance system
- Useful for irrigation development works
- Mostly called a weir or a barrage.



(iii) Detention dam

- These dams detain floodwaters temporarily to flood runoff
- To minimize bad effects caused due to flood
- Also constructed to trap sediments and often called Debris dams.

Advantages of Dams:

- Dams gather drinking water for people -> ***Water Supply***
- Dams help farmers bring water to their farms -> ***Irrigation***
- Dams help create power and electricity from water -> ***Hydroelectric***
- Dams keep areas from flooding -> ***Flood Control***
- Dams create lakes for people to swim in and sail on -> ***Recreation & Navigation***

Disadvantages of Dam

- Dams detract from natural settings, ruin nature's work
- Dams have inundated the spawning grounds of fish
- Dams have inhibited the seasonal migration of fish
- Dams have endangered some species of fish
- Dams may have inundated the potential for archaeological findings
- Reservoirs can foster diseases if not properly maintained
- Reservoir water can evaporate significantly
- Some researchers believe that reservoirs can cause earthquakes.

SELECTION OF SITE FOR A DAM

1. Suitable **foundation**(Hard bed) should be available at the dam site.

2. For **economy** its necessary that the length of the dam should be as **small** as possible and for a given **height** it should store large volume of water.

3. The **river valley** at the dam site should be as **narrow** as possible and it should open out u/s to create a reservoir with as far as possible **large storage capacity**.

4. As far as possible the dam should be **located on high ground** as compared to the river basin. This will reduce the cost and facilitate drainage of the dam section.

5. if the spillway is to be located separately from the dam - vicinity.

   Otherwise, integral part - dam

6. From the standpoint of economy the bulk of the materials required for the construction of dam should be available at or near the dam site.

SELECTION OF SITE FOR A DAM

7. Immediately on the u/s of the dam site there should be a watertight rim for the reservoir formed by the surrounding hills up to the proposed elevation of the dam.

8. The value of the property and land submerged in the reservoir created by the proposed dam should be as low as possible.

9. The dam site should be such that the reservoir would not silt up soon.

10. It is preferable to select a dam site which is already connected or can be conveniently connected to a nearby rail head by road or rail - easily accessible - facilitate transportation - men, material, machinery, and various other essential items to the dam site.

11. In the near vicinity of the dam site ample space with healthy environment must be available - colonies for labour and other staff members.

12. The dam site should be such that it involves minimum overall cost of construction as well as minimum cost of subsequent maintenance.

FACTORS AFFECTING to the DAM TYPE SELECTION

- Topography
- Geology
  - Bearing capacity of the underlying soil
  - Foundation settlements
  - Permeability of the foundation soil
- Material availability
- Spillway position
- Earthquakes
- Safety
- Height
- Aesthetic view
- Qualified labour
- Cost

Gravity Dam

Meenu Sri Priya

Civil Engineering

INTRODUCTION

- A gravity dam is a solid structure, made of concrete or masonry, constructed across a river to create a reservoir on its upstream.
- The section of the gravity dam is approximately triangular in shape, with its apex at its top and maximum width at bottom.
- The section is so proportioned that it resists the various forces acting on it by its own weight.
- Where good foundations are available, gravity dams can be built upto any height. It is the most permanent one, and requires little maintenance.
- The most ancient gravity dam on record was built in Egypt more than 400 years B.C. of uncemented masonry.

FORCES ACTING ON DAM

The gravity dam is subjected to the following main forces:

1. **WEIGHT OF THE DAM**
2. **WATER PRESSURE**
3. **UPLIFT PRESSURE**
4. **WAVE PRESSURE**
5. **SILT PRESSURE**
6. **ICE PRESSURE**
7. **WIND PRESSURE**
8. **EARTHQUAKE FORCES**

1. WEIGHT OF THE DAM

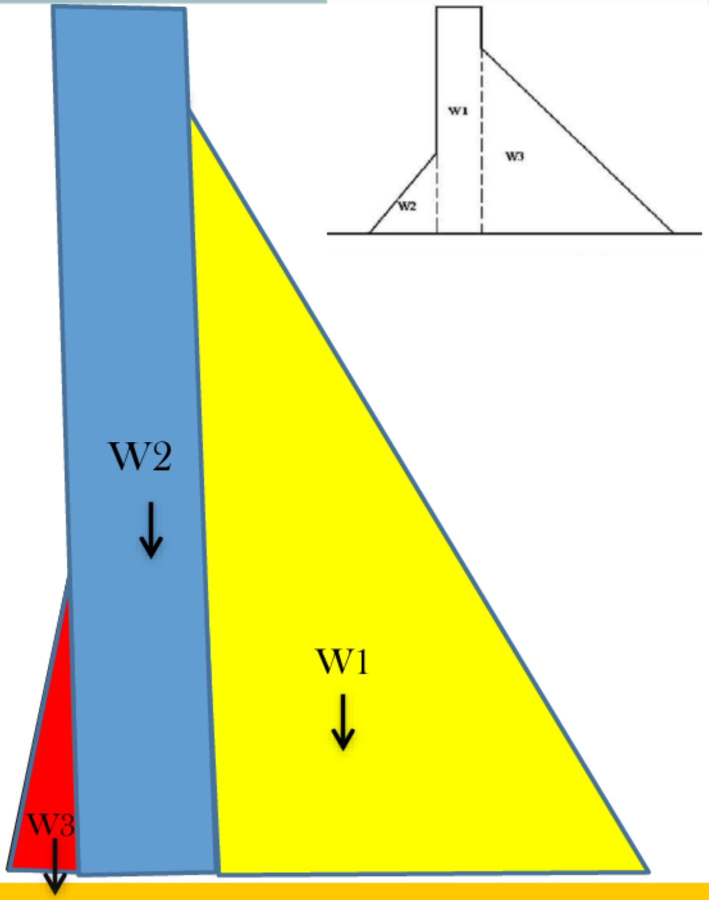
- The weight of the dam is the main stabilizing force in a gravity dam.

- The dead load = weight of the concrete + weight of such appurtenances (as piers, gates and bridges).

- The weight/unit length = area of cross-section * specific weight (or unit weight)of the material.

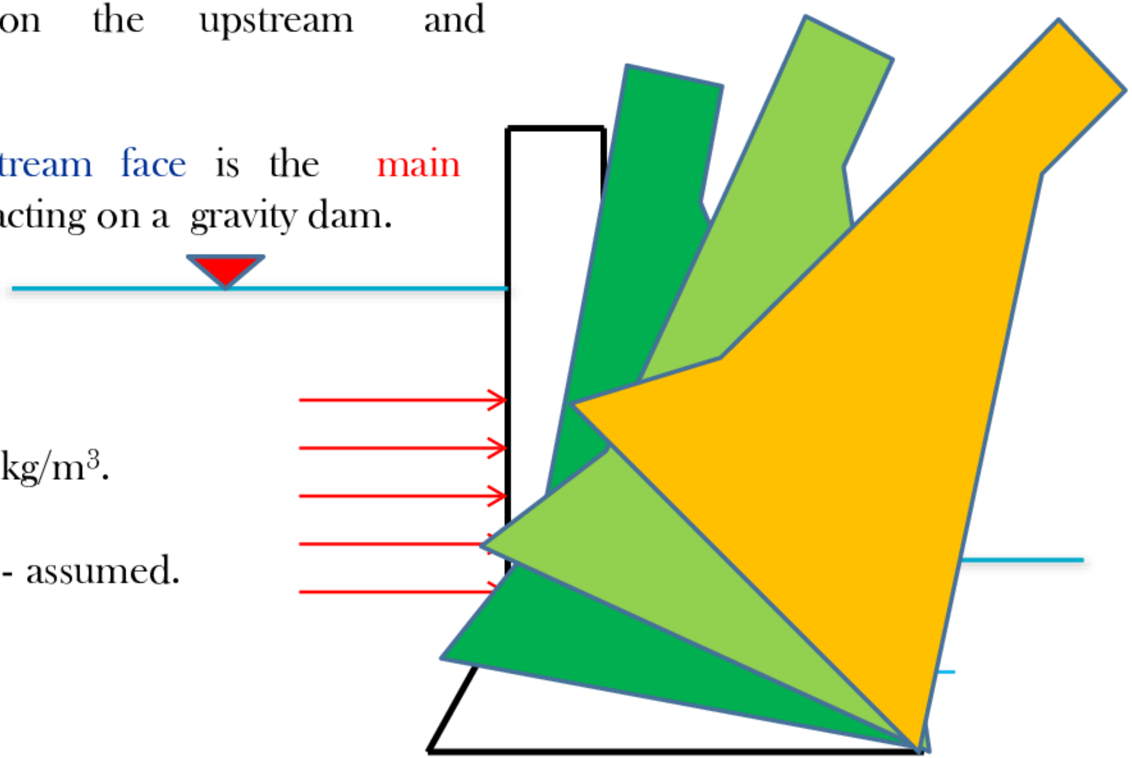
Concrete - 24 kN/m^3
masonry - 23 kN/m^3

- For convenience, the cross-section of the dam is divided into simple geometrical shapes, such as rectangles and triangles, for the computation of weights.
- The areas and centroids of these shapes can be easily determined.
- Thus the weight components W1, W2, W3etc. can be found along with their lines of action.
- The total weight W of the dam acts at the C.G. of its section.



2. WATER PRESSURE

- The water pressure acts on the upstream and downstream faces of the dam.
- The water pressure on the upstream face is the main destabilizing (or overturning) force acting on a gravity dam.
- The tail water pressure helps in the stability.
- The mass of water is taken as 1000 kg/m^3.
- Linear distribution - water pressure - assumed.



- The water pressure intensity ***p*** (kN/m²) - depth **y** (m) as :

$$p = \gamma_w y$$

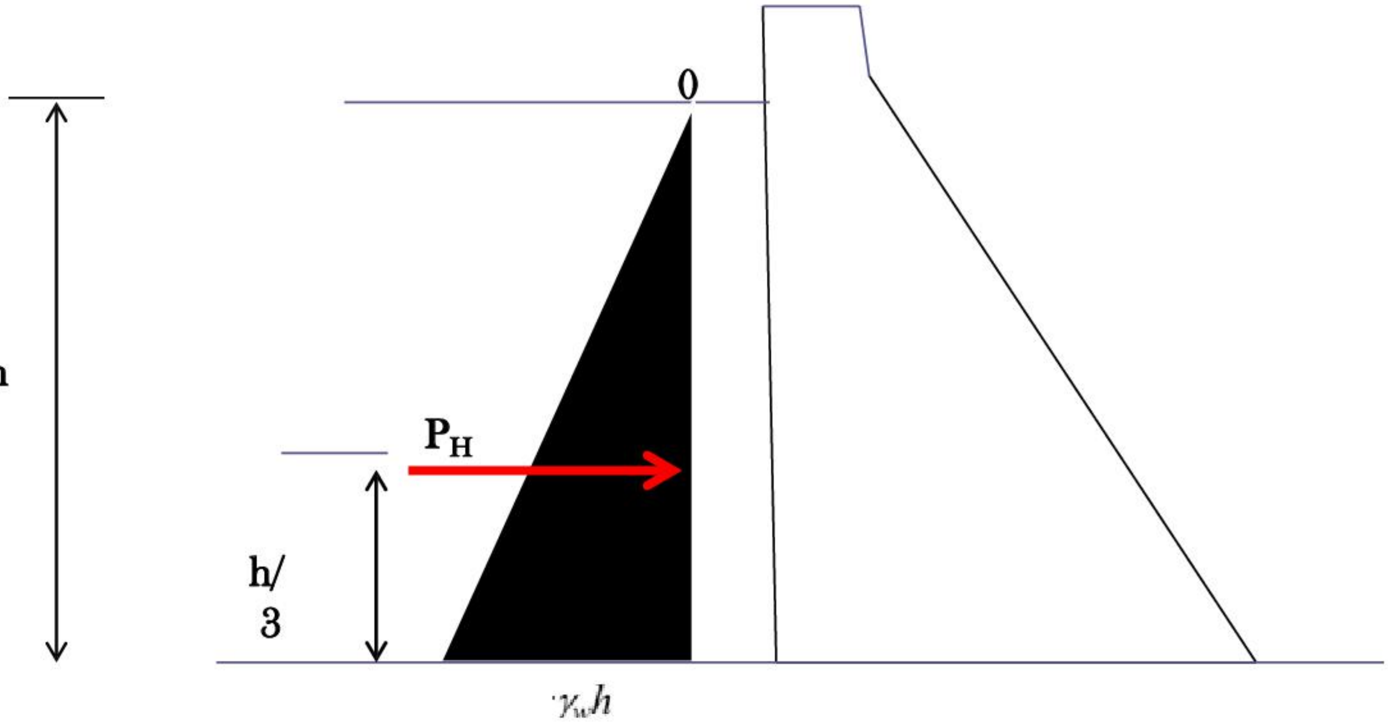
- The water pressure always acts normal to the surface.

(a) U/s face vertical:

- When the upstream face of the dam is vertical, the water pressure diagram is triangular in shape with a pressure intensity of **γ_w * h** at the base.
  - where **h** is the depth of water.
- The total water pressure per unit length is horizontal and is given by

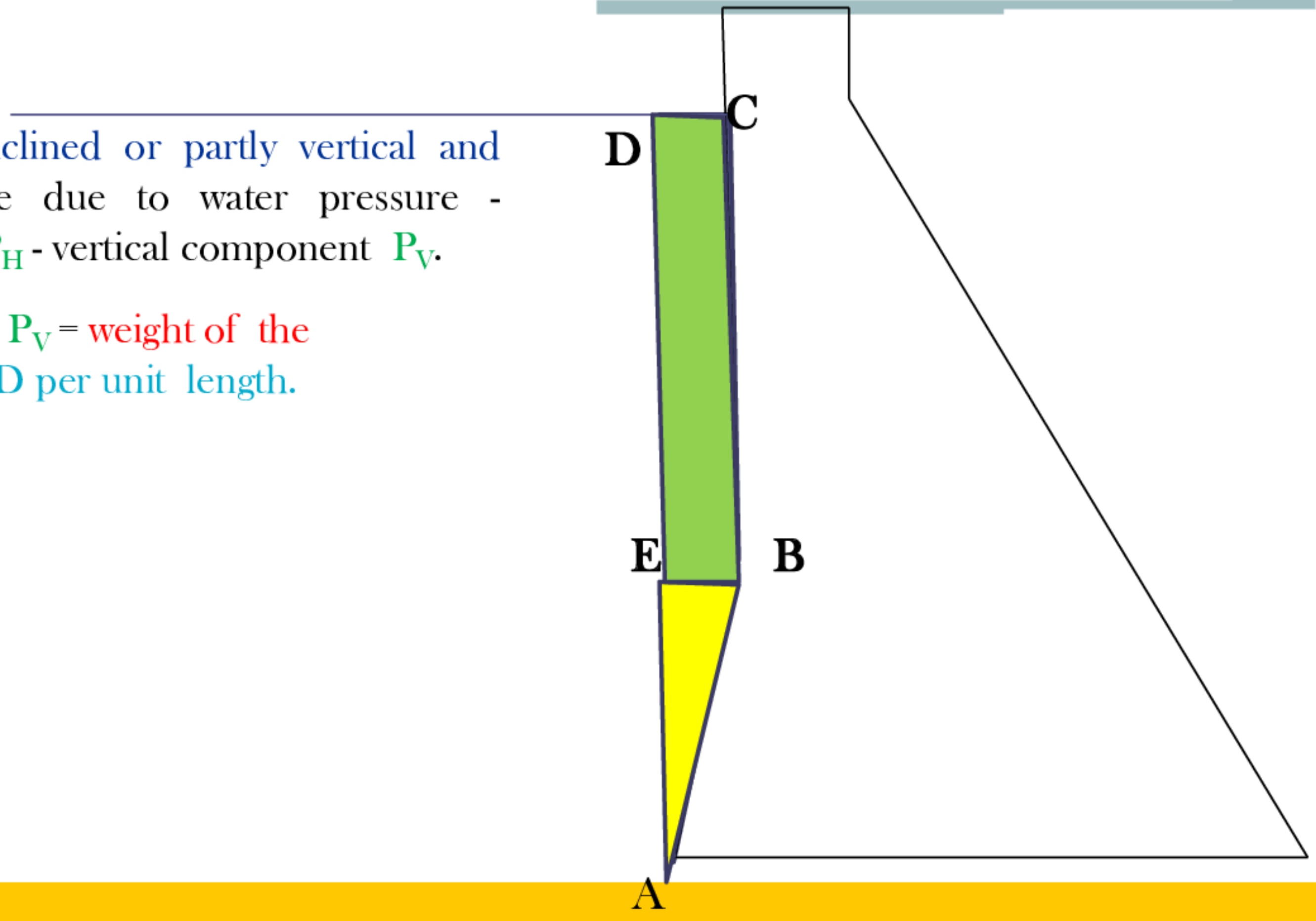
$$P_H = \frac{1}{2} \gamma_w h^2$$

- It acts horizontally at a height of h/3 above the base of the dam.

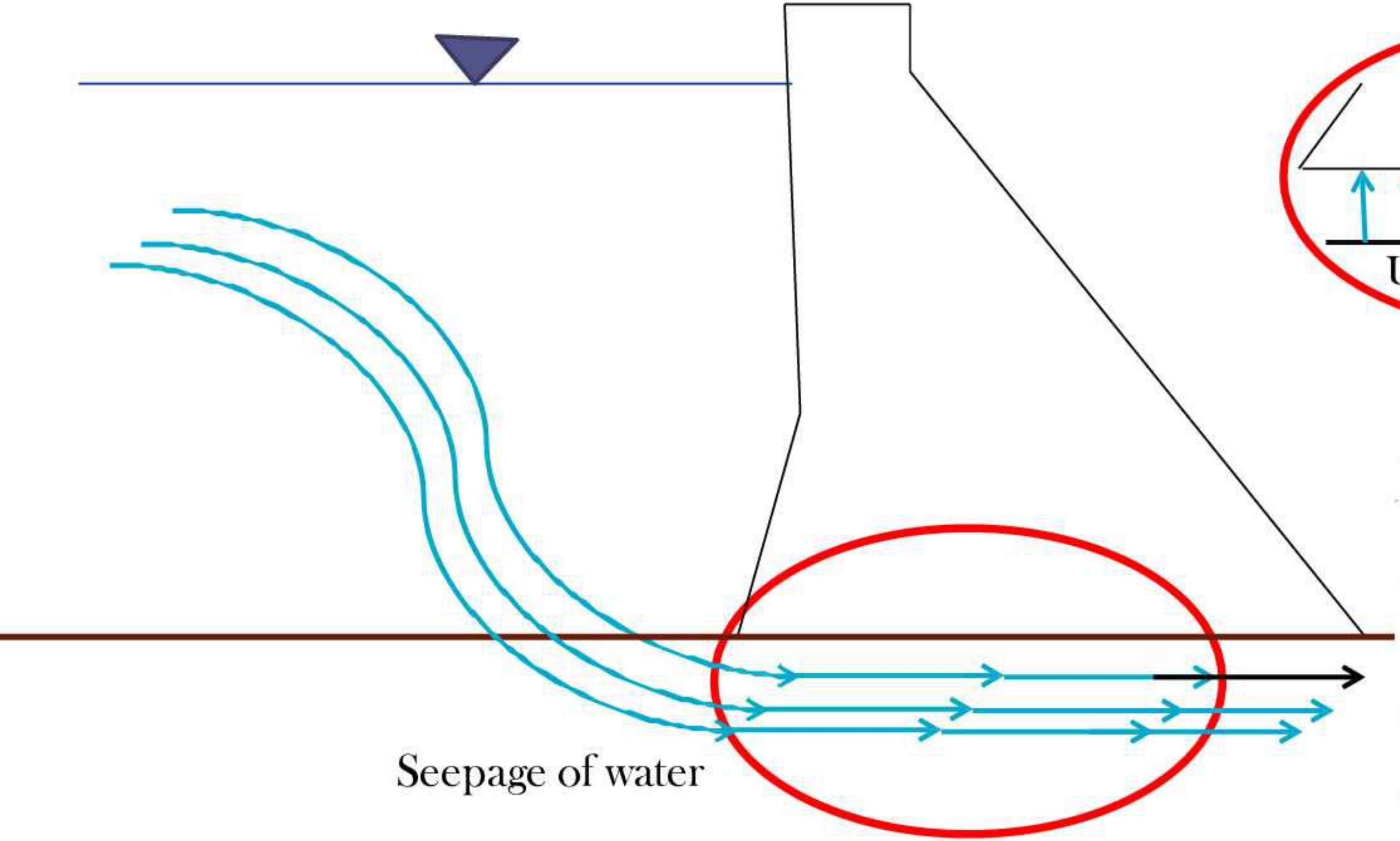


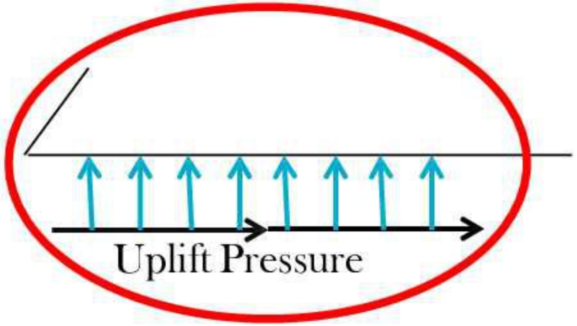
(b) U/s face inclined:

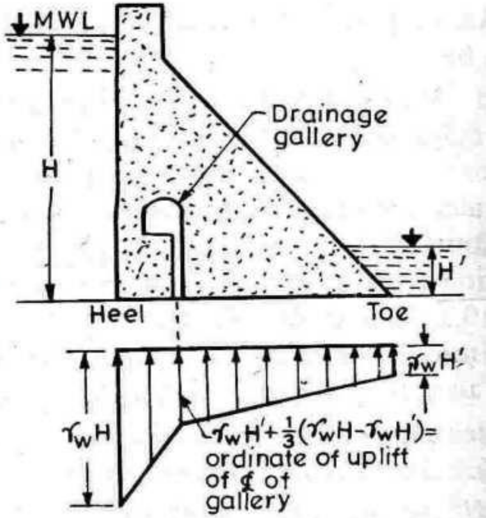
- Upstream – ABC - inclined or partly vertical and partly inclined - force due to water pressure - horizontal component P_H - vertical component P_V.
- The vertical component P_V = weight of the water in the prism ABCD per unit length.



3. Uplift pressure







- The computation of U.L. pressure is two folded,
  (i) the area on which the uplift pressure acts and,
  (ii) the intensity of the uplift pressure at various points.

- The % of area on which the uplift pressure acts is defined as the "**area factor**".

- The present practice followed in the design of dams is that the uplift pressure is assumed to act over 100% of the area within the body of the dam as well as foundation

- The intensity factor is defined as the ratio of the actual intensity of uplift pressure developed when cutoff wall is provided, to the intensity of the uplift pressure which would be developed without cutoff wall.

- In the most of the case in order to reduce the uplift pressure, both the drains as well as cutoff wall are provided.

4. EARTHQUAKE (or SEISMIC) FORCES:

- Earthquake acceleration imparted to the foundation is also transmitted to the dam.

- The earthquake acceleration is usually designated as a fraction of '**g**' the acceleration due to gravity.

$$\alpha^{*}g$$

where **α = seismic coefficient.**

- Seismic coeff. = f {intensity of the earthquake, zone of dam site, E of materials, foundation, etc}

As per IS: 1893-1984: the value of the seismic coeff. α may be determined by one of the following two methods.

(a) Seismic coeff. Method:

$$\alpha = \beta \, I \, \alpha_0$$

(b) Response spectrum method:

$$\alpha = \beta \, I \, F_0 \left(\frac{S_a}{g}\right)$$

Where, β = Soil – Foundation system factor, the value of which for dams is taken as 1.0 I = Importance factor, the value of which for dams is taken as 2.0.

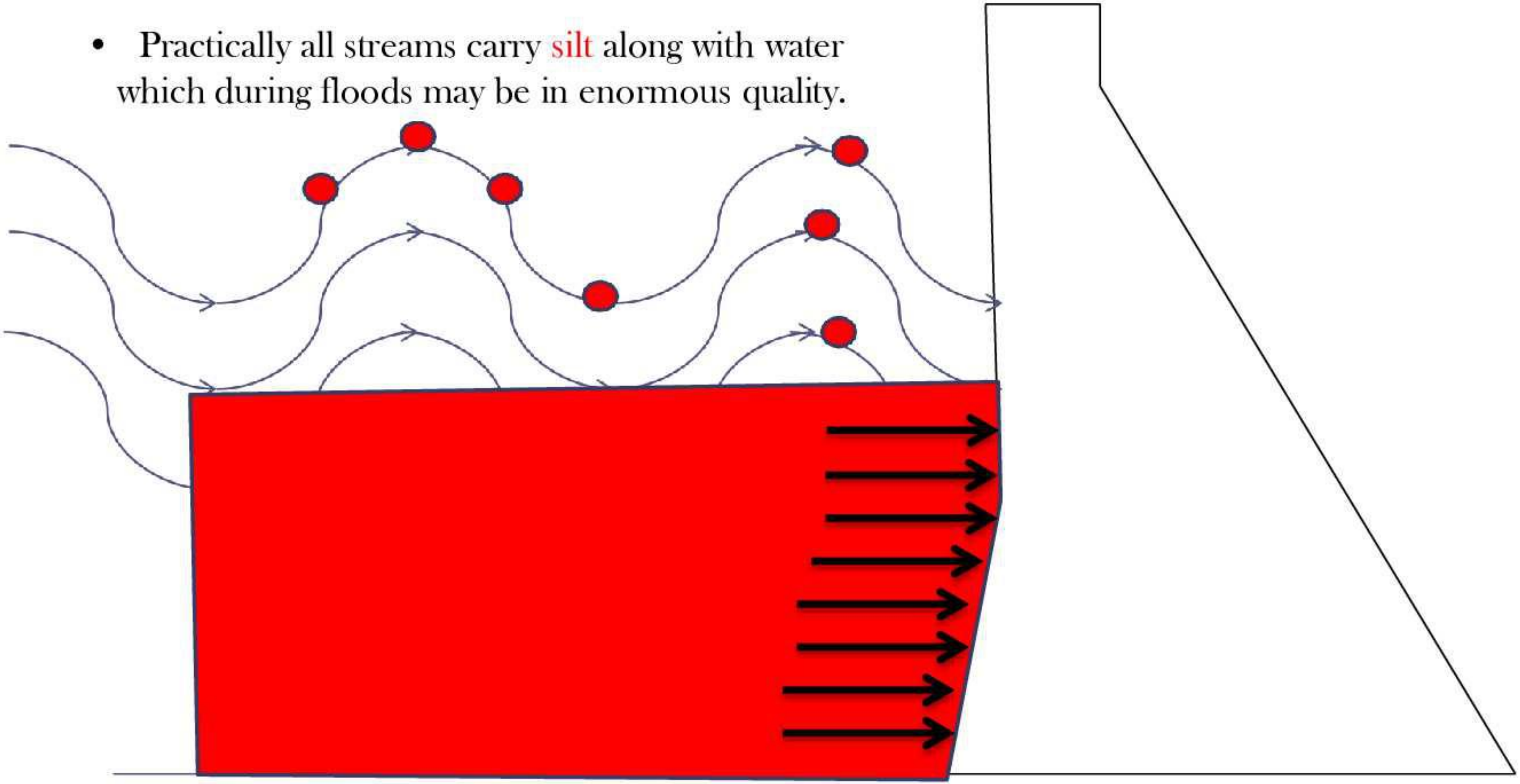
α_0 = basic seismic coeff., the value of which for each of the five seismic zones

F_0 = seismic zone factor for avrg. Acceleration spectra

(S_0/g) = Avrg. Acceleration coeff.

5. Earth and Silt Pressures

- Practically all streams carry silt along with water which during floods may be in enormous quality.



- Silt is treated as saturated cohesionless soil having full uplift and whose value of the angle of internal friction is not materially changed on account of submergence

- For determining silt pressure on the dam "Rankine's Formula" may be used according to which the total silt pressure Ps_h acting per unit length of the dam with U/S face vertical is given as follows:

$$Ps_h = \frac{1}{2} w_s h_1^2 \left(\frac{1-\sin\varphi}{1+\sin\varphi}\right)$$

where, w_s = submerged sp.wt. of silt in N/m3.

h_1 = the depth of silt deposited in m, and φ = angle of internal friction of silt.

- In absence of internal friction, submerged weight – Assumed – due to which correct value may not be obtained.

- As such conditions the method recommended – "*silt and water*".

- The horz. And vert. components of the presssure due to silt and water acting per unit length of the dam may be obtained as follows.

$$Ps_{h'} = \frac{1}{2} w_s' h_1^2$$

which is acting horizontally at a distance of $2h_1/3$ below the surface of the silt deposited.

- For computing the horz. and the Vert. components of the “Silt and Water Pressure” different sp.wt’s have been recommended as indicated below.

- (a) For horizontal component “Silt and water” assumed to have sp.wt. as 13.342 kN/m^3 [1360 $kg(f)/m^3$].

- (b) For vertical component “silt and water” is assumed to have sp. Wt. of 18.884 kN/m^3 [1925 $kg(f)/m^3$]

6. Wave Pressure

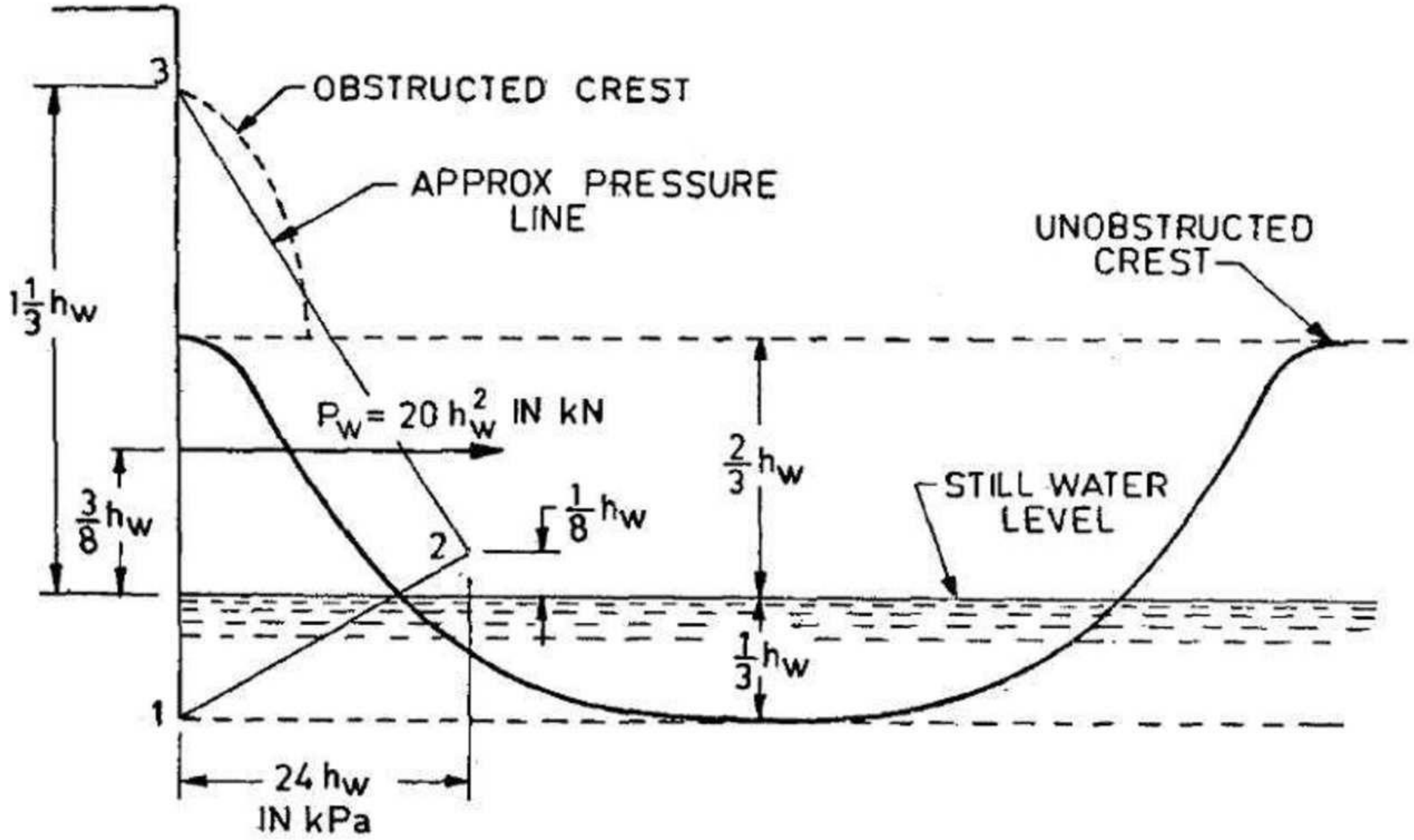
- The force and dimensions of waves depend mainly on the extent and configuration of the water surface, the velocity of wind and the depth of reservoir water.
- The height of wave is generally more important in the determination of the free board requirements of dams to prevent overtopping by wave splash.
- An empirical method based upon research studies on specific cases has been recommended by T. Saville for computation of wave height h_w(m).
- It takes into account the effect of the shape of reservoir and also wind velocity over water surface rather than on land by applying necessary correction.

- Wind velocity of 120 km/h over water in case of normal pool condition and of 80 km/h over water in case of maximum reservoir condition should generally be assumed for calculation of wave height if meteorological data is not available.

- The maximum unit pressure P_w in kPa occurs at 0.125 h_w, above the still water level and is given by the equation:

$$p_w = 24h_w$$

- The wave pressure diagrams can be approximately represented by the triangle l-2-3 as in Fig.



3
OBSTRUCTED CREST
APPROX PRESSURE LINE
UNOBSTRUCTED CREST
$1\frac{1}{3} h_w$
$P_w = 20 h_w^2$ IN kN
$\frac{2}{3} h_w$
STILL WATER LEVEL
$\frac{3}{8} h_w$
$\frac{1}{8} h_w$
2
$\frac{1}{3} h_w$
1
$24 h_w$ IN kPa

- The total wave force Pw, (in kN) is given by the area of the triangle,

$$P_w = 20h_w^2$$

- The centre of application is at a height of 0.375 hw, above the still water level.
- Sometimes the following Molitor's empirical formulae are used to estimate wave height

$$h_w = 0.032\sqrt{V_w F} + 0.763 - 0.271(F)^{1/4} \qquad \text{for } F < 32 \text{ km}$$

$$h_w = 0.032\sqrt{V_w F} \qquad \text{for } F > 32 \text{ km}$$

where V_w= wind velocity in km/hr and F= fetch length of reservoir in km.

7. Ice Pressure

- The problem of ice pressure in the design of dam is not encountered in India except, perhaps, in a few localities.

- Ice expands and contracts with changes in temperature.

- Ice pressure it may be provided for at the rate of **250 kPa** applied to the face of dam over the anticipated area of contact of ice with the face of dam.

8. Wind Pressure

- Wind pressure does exist but is seldom a significant factor in the design of a dam. Wind loads may, therefore, be ignored.

- However, the superstructure of dams carrying very large sluice gates may be subjected to an appreciable amount of wing pressure.

- As such in the design of a superstructure of a dam wind pressure may be considered as the rate of **1 to 1.5 kN/m^2** over the area exposed to the wind.

STABILITY ANALYSIS

1) OVERTURNING

- If the resultant of all the force acting on a dam at any of the section, passes outside the toe, the dam shall rotate and overturn about the toe.

$$F.O.S = \frac{Resisting\ moments}{overturning\ moments}$$

- Its value generally varies between 2 to 3.

2) SLIDING

- A dam may fail in sliding at its base.
- Sliding will occur when the net horizontal force exceeds the frictional resistance developed at that level.

$$F.O.S = \frac{\mu . \Sigma V}{\Sigma H} > 1$$

Where μ = coefficient of static earth pressure

= 0.65 to 0.75

STABILITY ANALYSIS

3) COMPRESSION OR CRUSHING
   - A dam may fail by the failure of its materials.
   - The compressive stress may exceed the allowable stress and the dam material may get crushed.

4) TENSION
   - Masonry and concrete gravity dam are usually designed in such a way that no tension is developed anywhere,

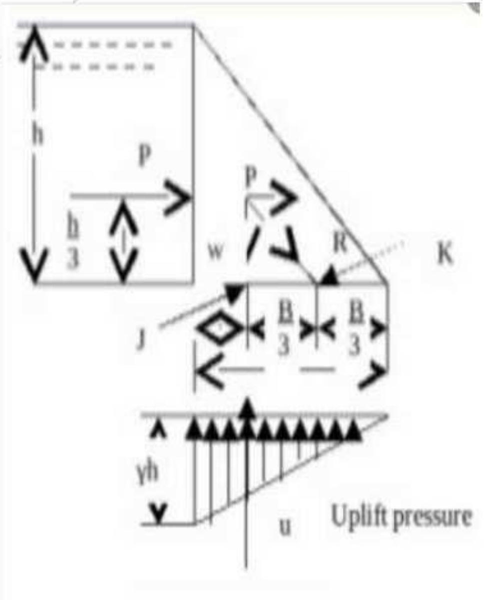
     because the materials can not withstand sustained tensile stresses.
   - If it subjected to such stresses, these materials may crack.

ELEMENTARY PROFILE

- When water is stored against any vertical face, then it exerts pressure perpendicular to the face which is zero at top & maximum at bottom.
- The required top thickness is thus zero & bottom thickness is maximum forming a right angled triangle with the apex at top, one face vertical & some base width.
- Two conditions should be satisfied to achieve stability –
  - When empty - The external force is zero & its self weight passes through C.G. of the triangle.
  - When Full - The resultant force should pass through the extreme right end of the middle-third.
- The limiting condition is –

$$h = \frac{\sigma_c}{\gamma (1 + S)}$$

where, σ_c=allowable compressive stress.



PRACTICAL PROFILE

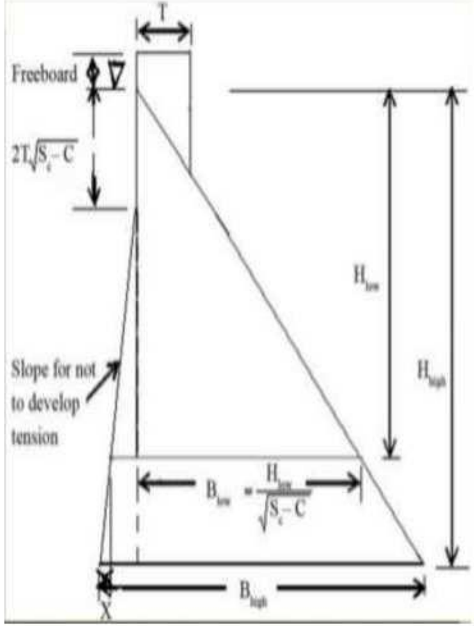
Various parameters in fixing the parameters of the dam section are –

- Free Board –IS 6512, 1972 specifies that the free board will be 1.5 times the wave height above normal pool level.
- Top Width – The top width of the dam is generally fixed according to requirements of the roadway to be provided. The most economical top width of the dam is 14% of its height.
- Base Width – The base width of the dam shall be safe against overturning, sliding & no tension in dam body. For elementary profile –
  - When uplift is considered,

$$B = \frac{h}{\sqrt{S}}$$

  - When uplift isn't considered,

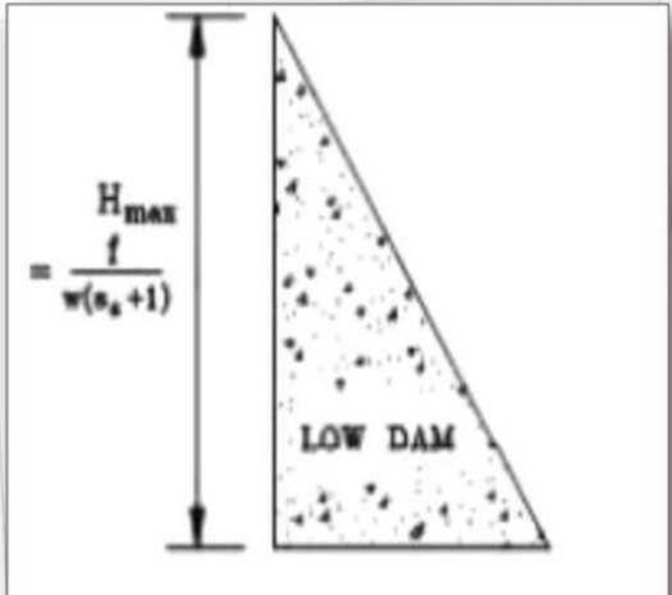
$$B = \frac{h}{\sqrt{S-1}}$$



ECONOMICAL HEIGHT

- The cost of construction of dam increases with the increase in its height.
- The height should be such that it gives more storage capacity at minimum cost. This height is considered to be economical height.
- To calculate the economical height, storage capacities for different heights of dams are calculated & the cost of the dams are worked out & plotted in graph with height of dam versus cost benefit ratio.
- The height of the dam is economical when the cost benefit ratio is maximum.

LOW GRAVITY DAM



Low gravity dam

- A low gravity dam is designed on the basis if of elementary profile, where the resultant force passes through the middle-third of its base. The principal stress is given by –

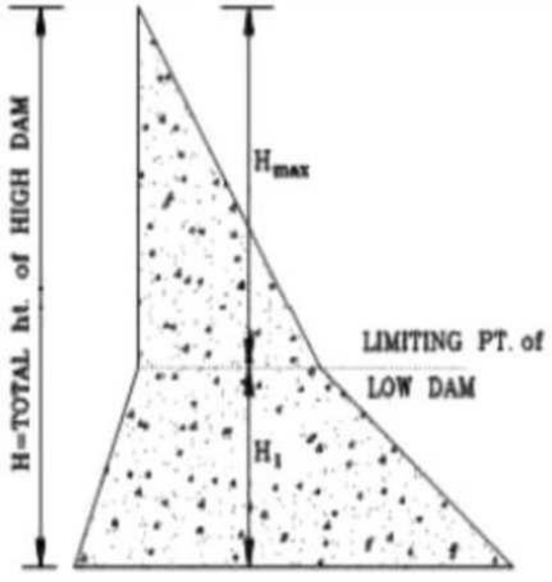
$$\sigma = \gamma H (S - C + 1)$$

Where, σ=principal stress, γ=unit weight, S=Specific Gravity and C=A constant.

- The principal stress varies with 'H' as all other terms are constant. To avoid failure of the dam the value of 'σ' shouldn't exceed allowable working stress(f).

$$F = \gamma H (S - C + 1)$$

HIGH GRAVITY DAM



High gravity dam

- The high gravity is a complicated structure, where the resultant force may pass through a point outside the middle-third of the base.

- The section of the dam is modified by providing extra slope on the upstream and downstream side.

- The condition for the high gravity dam are –

$$H > \frac{f}{w\,(S + 1)}$$

Where, f=allowable working stress.

FAILURE OF GRAVITY DAM

Failure of gravity dams are caused due to –

- Sliding – It may take place on a horizontal joint above formation, on the foundation. Sliding takes place when total horizontal forces are grater than the combined shearing resistance of the joint and the static friction induced by total vertical forces.

- Overturning – A dam fails in overturning when total horizontal forces acting on the dam section are quite great in comparison with total vertical forces. In such cases the resultant of two passes outside the limits of the dam.

- Dam may fail when tension is produced in the concrete.

- Dam may fail in crushing.

PRECAUTIONS AGAINST FAILURE

- To prevent overturning, the resultant of all forces acting on the dam should remain within the middle-third of the base width of the dam.
- In the dam, the sliding should be fully resisted when the condition for no sliding exists in the dam section.
- In the dam section, the compressive stresses of concrete or masonry should not exceed the permissible working stress to avoid failure due to crushing.
- There should be no tension in the dam section to avoid the formation of cracks.
- The factor of safety should be maintained between 4 to 5.

DESIGN OF GRAVITY DAMS

- The section of gravity dam should be chosen in such a way that it is the most economical section and satisfies all the conditions and requirements of stability. Hence, after the section of dam has been arrived at, the stability analysis for the dam must be carried out.
- TO DECIDE WHETHER THE DAM IS LOW OR HIGH- First of all, the height of the dam to be constructed, should be checked so as to ensure whether it is a low gravity dam or a high gravity dam.

- If the ht. of the dam is less than that given by $\dfrac{f}{\gamma_w(Sc+1)}$

  (where f is the permissible compressive stress of the dam material and Sc is the Sp. Gravity of the dam material) then the dam will be a low gravity dam otherwise vice versa.

Galleries in Gravity Dams

Galleries are openings or passageways left in the dam body. They may be provided parallel or normal to dam axis at various elevations The galleries are interconnected by steeply sloping passages or by vertical shafts fitted with lifts. The shape and size of the gallery depends on the size of the damned and the function served.

The functions for which the galleries are provided are:

1. Drainage: To cater for the drainage of dam section by intercepting seepage from the water face and carry it away from the downstream face.

2. Inspection: To provide access to the interior of the mass comprising the dam with a view to inspect the structure and study the structural behaviour of the dam in post-construction period.

3. Drilling: To provide access for carrying out drilling and grouting of foundations, etc.

4. Operation of gates and control equipment: To provide access to mechanical equipment for the operation of rates and control equipment.

5. Post-construction grouting: To provide space for header and return pipes for post-construction grouting of longitudinal joints of the dam. Also to provide access for grouting the construction joints which cannot be done from the face of the dam.

Galleries in Gravity Dams

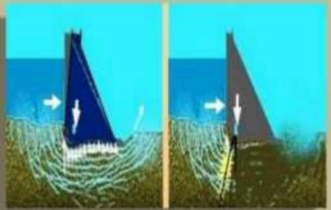
- **Galleries are the horizontal or sloping openings or passages left in the body of the dam.**
- They may run longitudinally (i.e. parallel to dam axis) or traversely (i.e. normal to the dam axis) and are provided at various elevations. **All the galleries are interconnected** by steeply sloping passages or by vertical shafts fitted **with stairs or mechanical lifts.**

Function and types of galleries in Dams

(i) Foundation Gallery

- **A gallery provided in a dam may serve one particular purpose or more than one purpose**. For example, a gallery provided near the rock foundation, serves **to drain off the water** which percolates through the foundations. This gallery is called a **foundation gallery or a drainage gallery.**

Foundation Gallery



Function and types of galleries in Dams

Inspection Galleries

- **The water which seeps through the body of the dam is collected by means of a system of galleries provided at various elevations** and interconnected by vertical shafts, etc. **All these galleries, besides draining off seepage water, serves inspection purpose.**
- They provide access to the interior of the dam and are, therefore, called **inspection purposes. They generally serve other purposes along with this purpose.**

Inspection Galleries

Function and types of galleries in Dams

The main functions are summarized below:

- They **intercept** and drain off the **water seeping through the dam body.**
- They **provide access to dam interior** for **observing and controlling the behavior of the dam.**
- They **provide enough space for carrying pipes**, etc. during **artificial cooling of concrete**