RRB JE

RAILWAY RECRUITMENT BOARD

CIVIL

ENGINEERING

IRRIGATION ENGINEERING

SELF STUDY MATERIAL

CIVIL ENGINEERING FOR ALL

IRRIGATION ENGINEERING

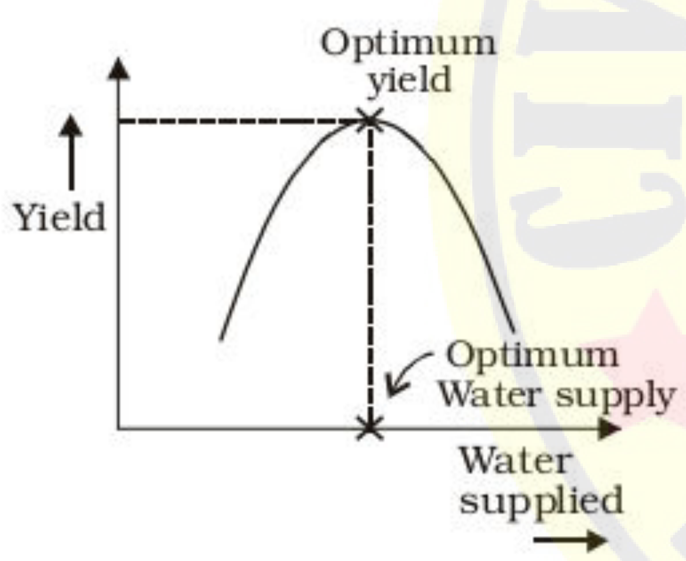
DEFINITION :

Irrigation may be defined as the science of artificial watering of the land in accordance with the crop required throughout the crop period, for full nourishment of the crop.

Different crops will have different water requirements and the same crop may have different water requirements at different places of the same country, depending upon the variations in climate, type of soil, method of cultivation and useful annual rainfall etc.

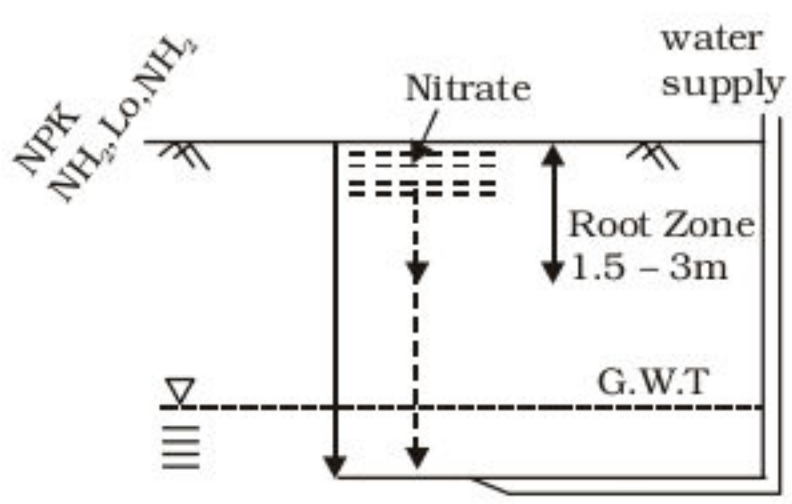
ADVANTAGES OF IRRIGATION :

1. Increase in food production.
2. Ensuring optimum growth and yield.
3. Elimination of mixed cropping.
4. Generation of hydroelectric power.
5. Improving domestic water supply.
6. Inland navigation.
7. Aforestation.



DISADVANTAGES :

1. Over Irrigation may cause, water logging which reduces crop yield.
2. Irrigation may lead to creation of environmental conditions, which are favourable for outbreak of disease like-Malaria and Dengue.
3. Irrigation may lead to seepage of nitrate into the ground water table causing a fall in soil fertility.



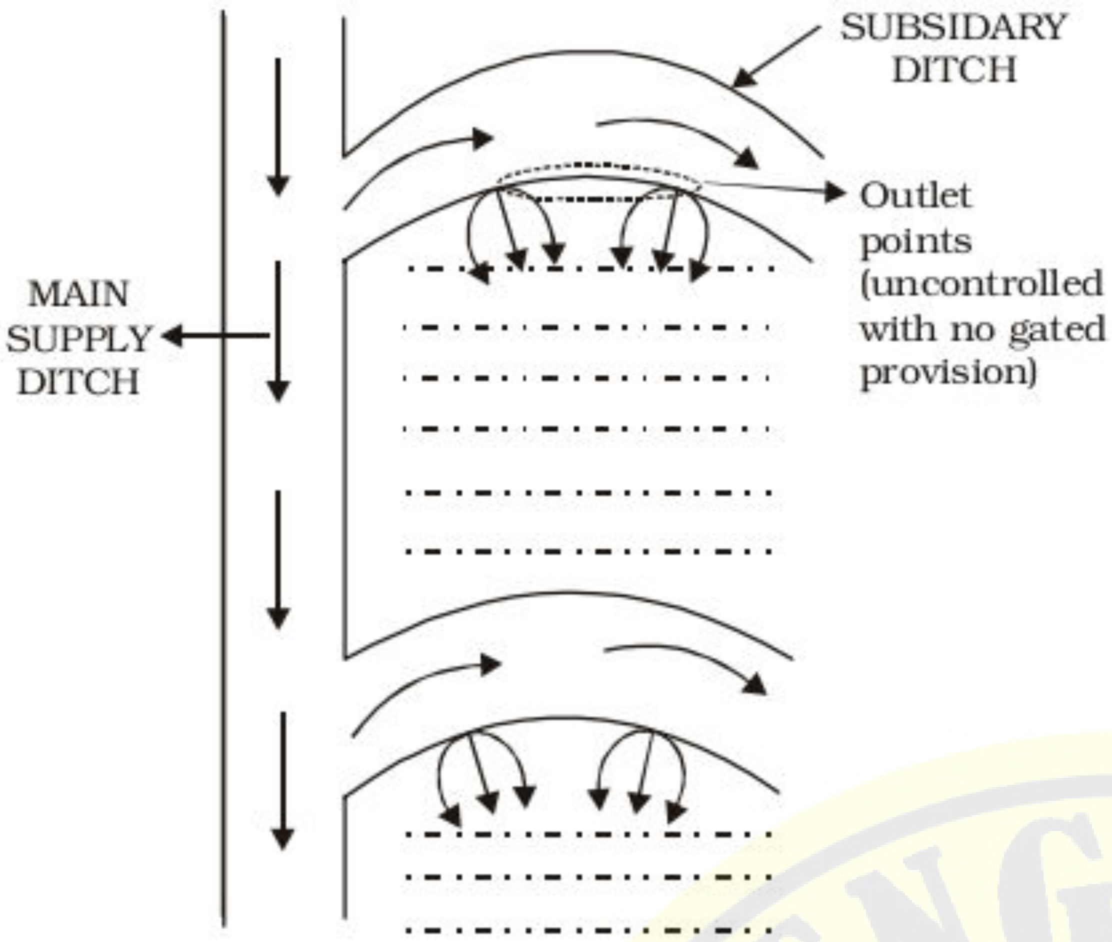
Types of Irrigation

- Surface
  - Flow (Channel irrigation)
    - Perennial (throughout the year) [Indus Canal of Punjab]
    - Flood (INNUDATION/UNCONTROLLED) [Deccan Indian canal]
  - Lift (Tube well irrigation)
- Sub-surface
  - Natural
  - Artificial

1. **FLOW IRRIGATION :** When the water is available at a higher level and it is supplied to lower level under the effect of gravity, it is called flow irrigation.
2. **LIFT IRRIGATION :** If the water is lifted up by some mechanical or manuals means, such as by pumps, etc and then supplied for irrigation, it is called lift irrigation.
3. **PERENNIAL IRRIGATION :** In this system of irrigation, there is constant and continuous water supplies to the crops in accordance with the requirements of the crop throughout the crop period.
4. **FLOOD IRRIGATION :** In this method of irrigation, soil is kept submerged and flooded with water, so as to cause thorough saturation of the field.
5. **NATURAL SUB-SURFACE IRRIGATION :** Leekage water from channels etc, goes underground and during passage through the sub-soil, it may irrigate crops by capillarity. This water is called capillary water.
6. **ARTIFICIAL SUB-SURFACE IRRIGATION :** When a system of open-joined drains is artificially layed below the soil, so as to supply, water through the crops by capillarity, then it is known as artificial surface irrigation.

TECHNIQUES OF WATER DISTRIBUTION IN THE FIELD

1. **FREE FLOODING :** This is also called ordinary flooding or wild flooding, because the flow of water is not controlled.
   - This method is suitable for, close growing Crops.
   - The water application efficiency of this method is low.
   - This method is suitable for irregular topography.
   - This method may be used on rolling land (topography irregular) where border, checks basins and furrows are not feasible.



Field view with crops.

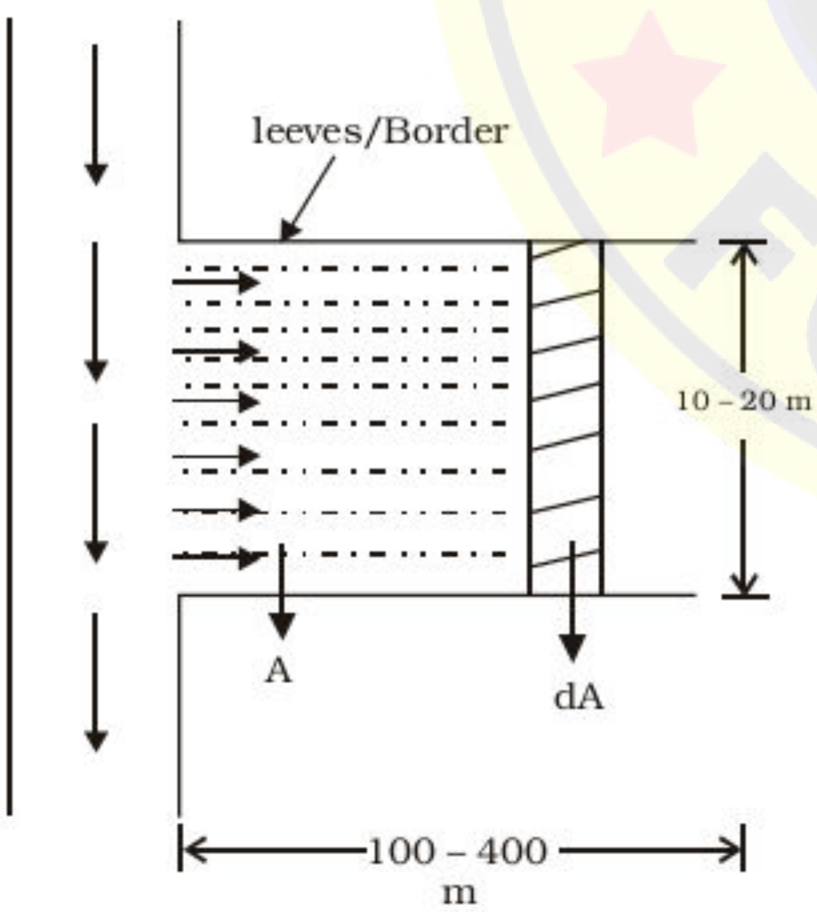
2. BORDER FLOODING : In this method, the field is divided into a number of strips, separated by low leeves called borders.

- The land area is confined between, 10-20 m width and having a length of 100-400 m.

f : Infilteration Capacity of soil (depth/unit time).

y : Depth of water flowing through strip.

Q : Supply of water in main ditch.



∴ In time 'dt' water supplied to the field = Q.dt

∴ Q.dt = f.A.dt + y.dA.

∴ Q – f.A) dt = y.dA.

$$t = 2.303\ \frac{y}{f}\ \log\frac{Q}{Q - fA}$$

If $t \to \infty$ then for

$$Q - fA = 0$$

$$A_{max} = \frac{Q}{f}$$

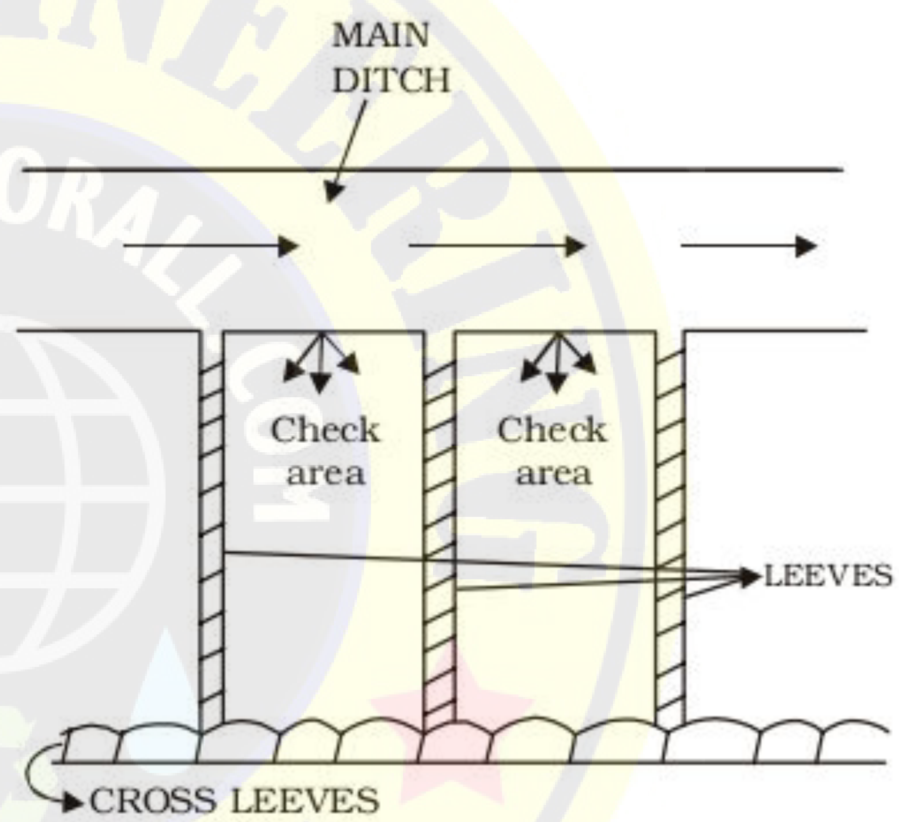
Note : This method of irrigation is very common in India. Shorters and narrower strips are found to be more efficient.

To prevent water from concentration on either side of the border, the land should be levelled perpendicular to the water flow.

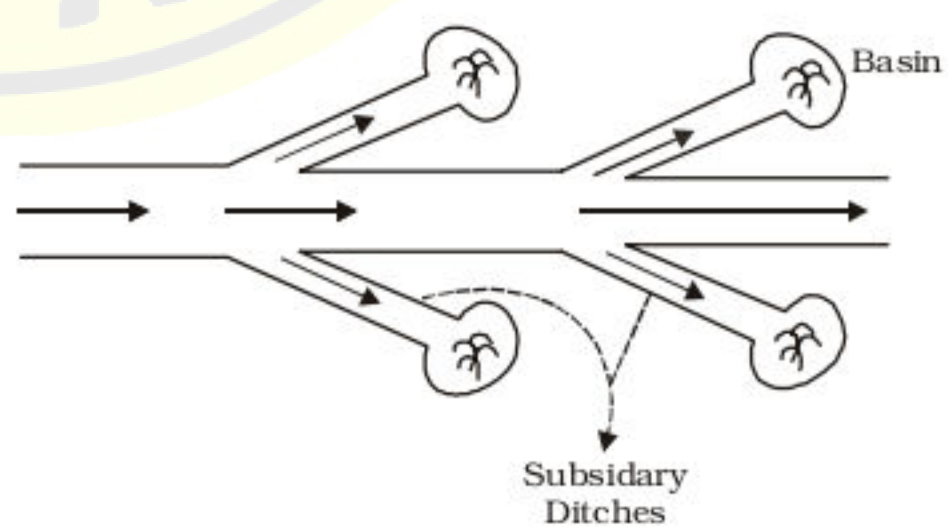
3. CHECK FLOODING :

- This is the modified form of ordinary flooding, in which water is controlled by sorrounding the check area with low and flat leeves. These leeves are connected with cross leeves at convenient place as shown in fig.

Note : This method is suitable for low permeable as well as high permeable soils.



4. BASIN FLOODING : This method is a special type of check flooding and is specifically adopted for clard trees, or orchard tree.

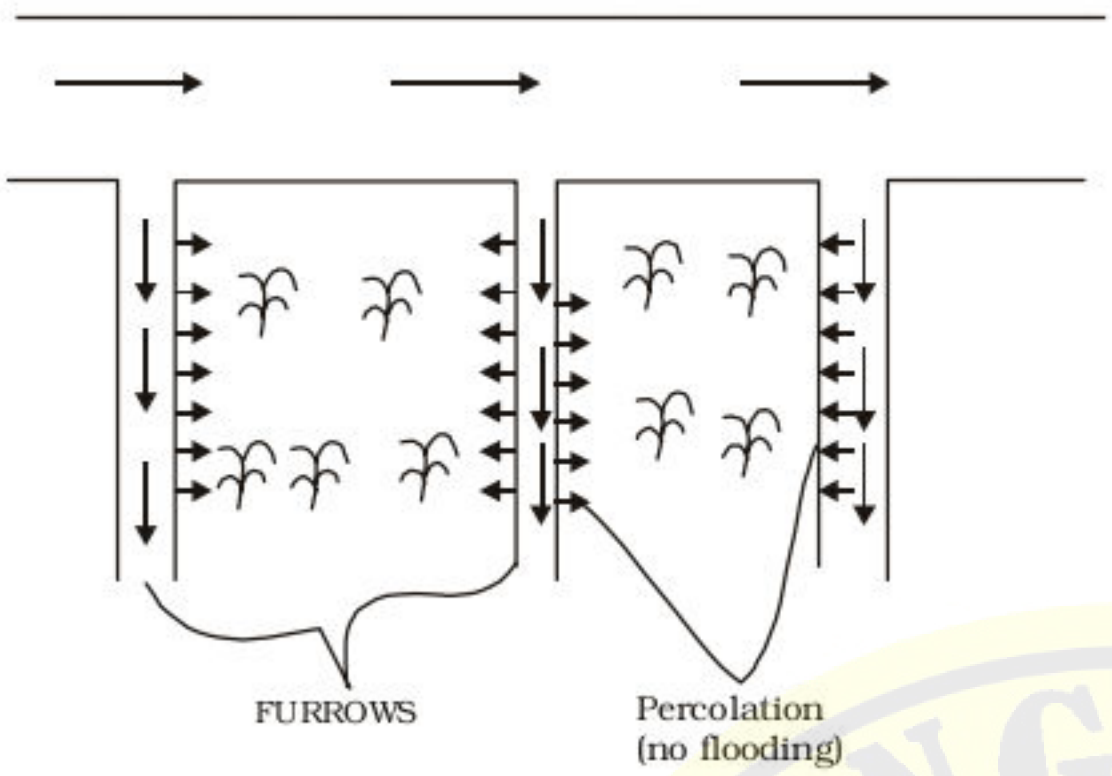


5. FURROW IRRIGATION :

Furrows are narrow drains which are excavated between rows of plants and carrying irrigation water through them.

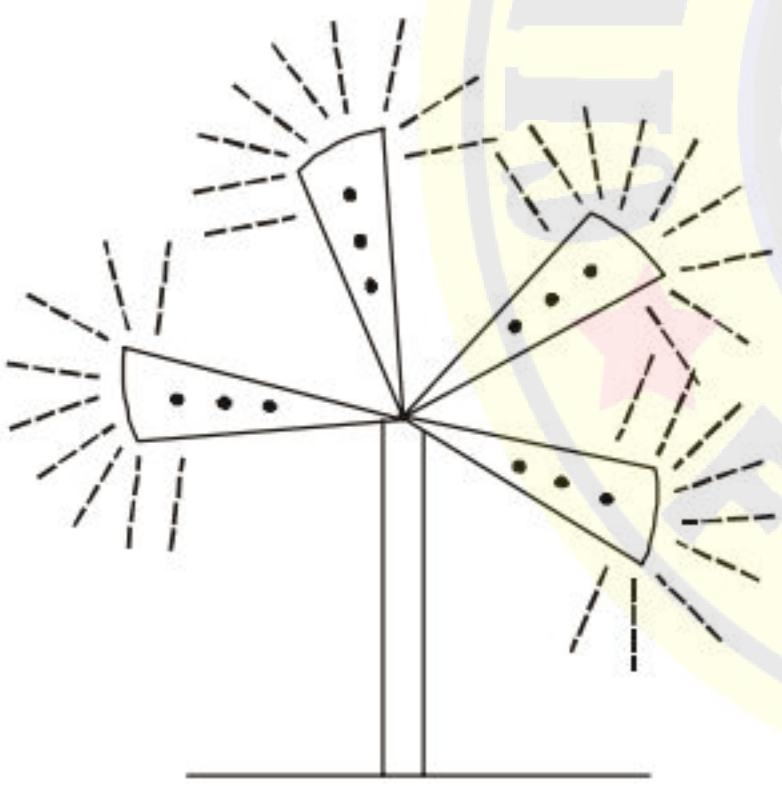
- In this method of irrigation, only 20-50% of the field area is wetted and hence evaporation loses are considerably reduced.

- Furrows vary in depth from 8 to 30 cm, and may be as much as 400 metres long.



6. SPRINKLER IRRIGATION :

- In this method of irrigation, water is applied through a network of pipes and pumps. In this method, water is made available in the form of spray.



ADVANTAGES OF SPRINKLER IRRIGATION;

(i) It can be used in following cases :

(a) When topography is irregular.

(b) When water table is high.

(c) When soil is less permeable.

(d) When water is not easily available.

(e) Where seepage loss is more.

(f) When number of labours have to be reduced.

(g) When fertilizers and insecticides have to be mixed with water.

(h) Contributes to water conserration as water loss because of evaporation is reduced.

DISADVANTAGES OF SPRINKLER IRRIGATION

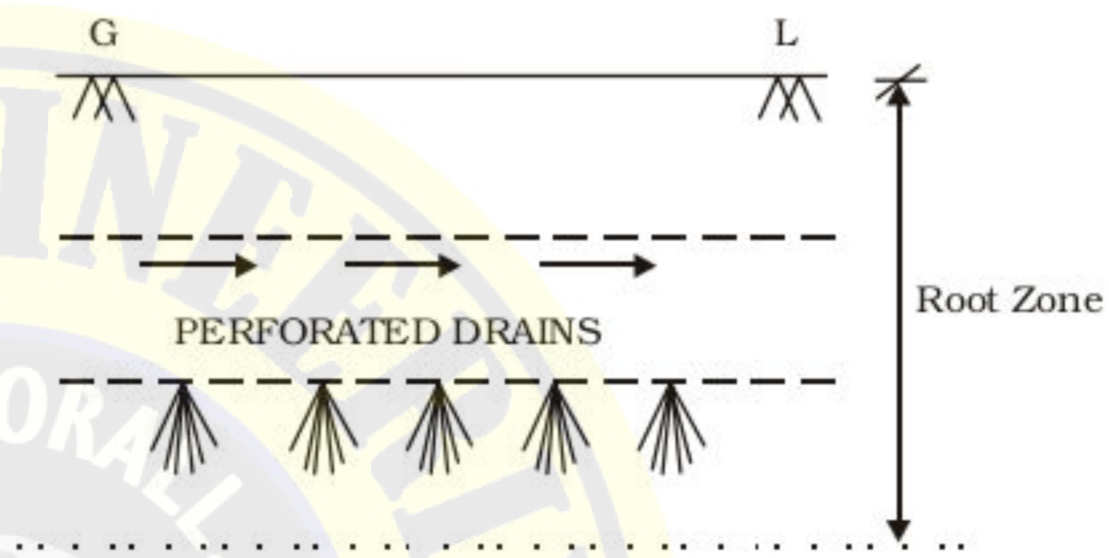
(a) Initial installation cost is high.

(b) Technical man power is required.

(c) It is not suitable for heavy irrigation for e.g. Rice.

7. DRIP IRRIGATION : (Trickling Irrigation)

- This is also called trickle irrigation.
- In this method, water is directly applied to the root zone of the plant using drip nozzels.
- Evaporation and percolation loses are considerably reduced in this method of irrigation.
- This method cannot be used, when heavy irrigation is required.

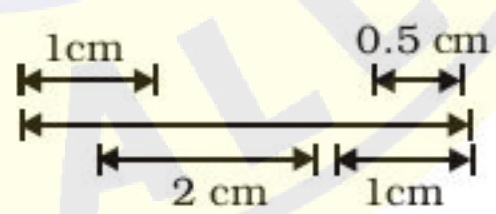


3. Delta of a Crop : (Δ) :

The summation of the total water depth, supplied during, base period of a crop for its full growth, represents the total quantity of water required by the crop for its full nourishment.

Definition

This total water depth (in cm) required by a crop to come to maturity is called its **(delta).**



Delta (Δ) for Certain Important Crops

CROPS	Δ(cm)
1. Sugarcane	120
2. Rice	120
3. Cotton	50
4. Wheat	40
5. Maize	22.5
6. Fodder	20

4. Duty of water (D) :

- It is defined as the number of hectares of field irrigated for full growth of a given crop by supply of 1 m^3/s of water continuously during the entire base period of that crop.

Eg : If duty of crop is 5 hectare, then it means that by supplying $1m^3$/sec of water for a base period, we can grow 5 hectare of that crop.

Base Period Changes → hectare changes/m^3/sec (remains constant)

- **RELATIONSHIP BETWEEN DELTA, BASE PERIOD AND DUTY :**

- Let there be a crop of Base period B (days) and Let 1 cumec of water is supplied to this crop for B days.

  Then, VT = (B) × (1) × (24 × 60 × 60) days m^3/sec

  = 86400 Bm^3

- If duty of the crop be 'D' ha then total depth of water supplied for 'B' days = $\frac{86400\ B}{D \quad 10^4}$ m

$\Delta = \frac{864\ B}{D}$ (cm) ; B in days and D in hectares

UNITS :

1 hectare = $10^4 m^2$

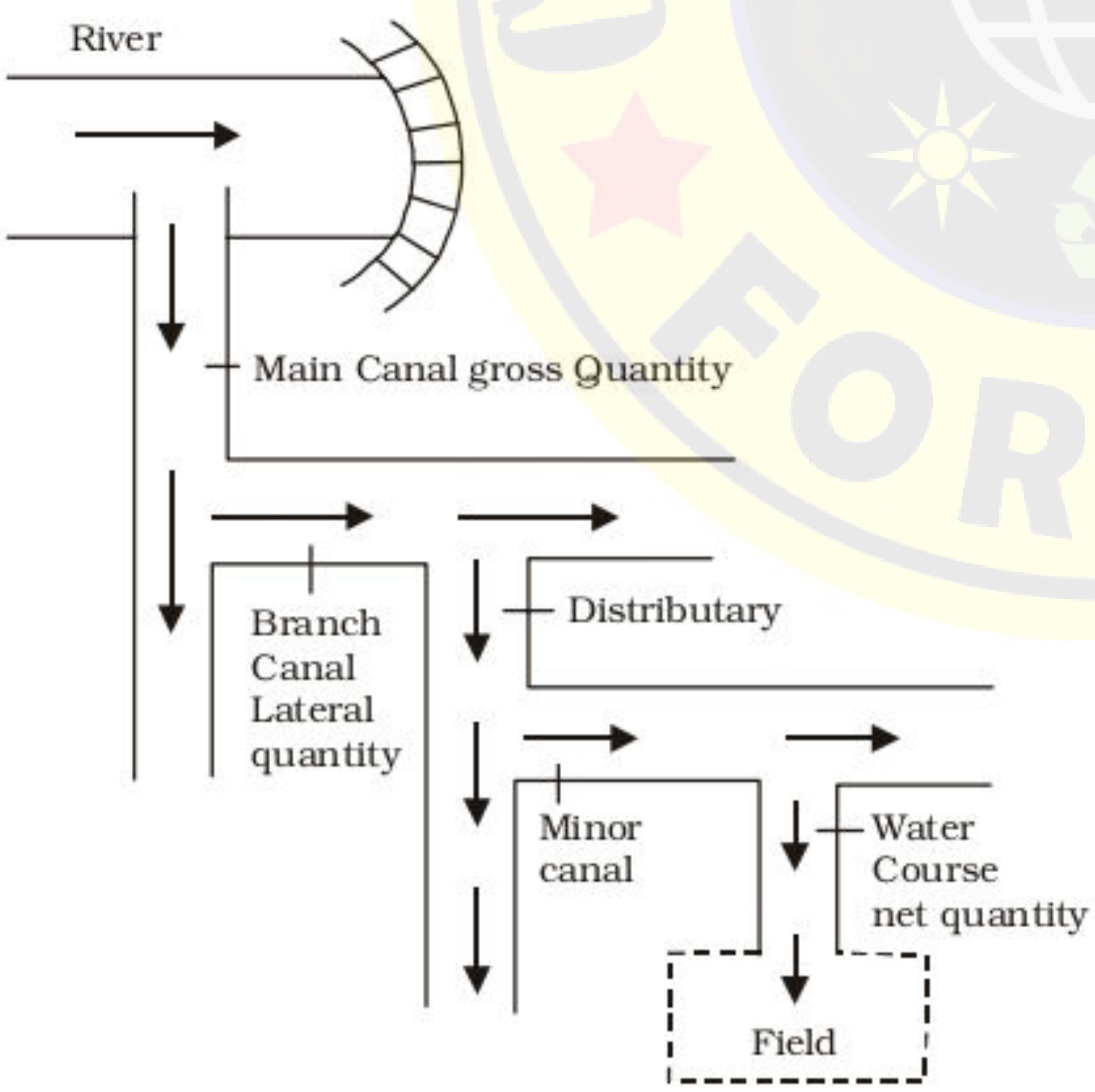
1 Acre = 0.4047 hectare

1 Cumec = 0.0283 cumec

1 Acre/cumec = 14.3 hectare/cumec

1 cumec day = 8.64 hectare-metre.

- **DUTY AT DIFFERENT PLACES :**



- During the passage of water from these irrigation channels water is lost due to evaporation and percolation. These looses are called transmission losses or conveyance losses in channels.

  Since duty of water for a crop is the number of hectares of field which the unit flow of water for B(days) can irrigate, i.e. the duty of water will be seen as having lesser magnitude at the head of water course than the duty of water on the field and subsequently it can be compared for other channels.

Note :

1. The duty at the head of water course is called outlet factor.
2. The duty at the head of field is called net quantity.
3. The duty at the head of branch canal is called lateral quantity.
4. The duty at the head of main canal is called gross quantity.

- **FACTORS AFFECTING DUTY :**

  1. Type of Crops : Water required by crop is more then D
  2. Climate and season → Rain↑ ; D↑
  3. Usefull Rainfall → Rain↑ ; D↑
  4. Type of soil seepage↑ D↓
  5. Efficiency of cultivation method.

- **IRRIGATION EFFICIENCIES;**

- Water is lost in irrigation due to varied process and Therefore there are different kinds of irrigation efficiencies as given below;

  1. **Efficiency of water Conveyance or (Water Conveyance Efficiencies) η_c :**

     It is the ratio of water delivered into the field, to the water entering into the channel at its starting point.

     $$\eta_c = \frac{w_f}{w_r} \quad 100$$

     It takes the conveyance or transmission losses into consideration.

  2. **Efficiency of water application : η_a**

     It is the ratio of quantity of water stored in the root zone of the crops to the quantity of water actually delivered in the field.

     $$\eta_a = \frac{w_s}{w_f} \quad 100$$

     It takes into consideration, the water lost in the farm or field.

  3. **Efficiency of water storage : η_s**

     It is the ratio of the water stored in the root zone during irrigation to the water needed in the root zone, prior to the irrigation.

     $$\eta_s = \frac{w_s}{w_n} \quad 100$$

  4. **Efficiency of water used : η_u**

     It is the ratio of water beneficially used to the quantity of water delivered including leaching water.

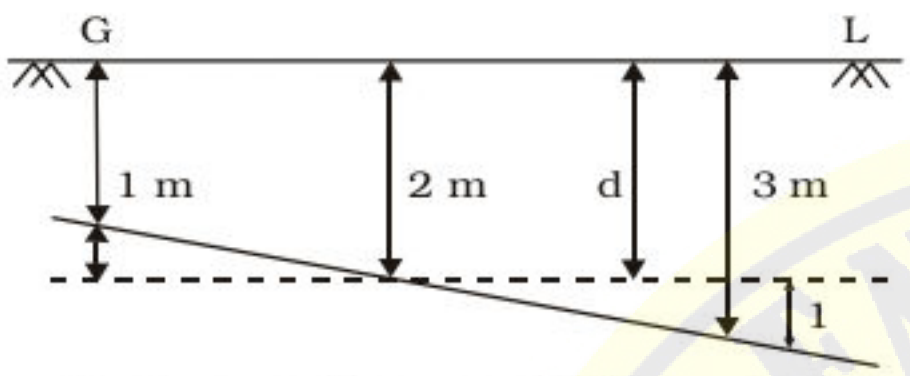
     $$\eta_u = \frac{w_u}{w_d} \quad 100$$

w_u = water used beneficially or consumptively
w_d = water delivered.

5. **Water distribution efficiency : (η_d)**
It represents to the extent to which the water has penetrated or percolated to the uniform depth throughout the field. It is given by

$$\eta_d = 1 - \frac{d}{D}$$

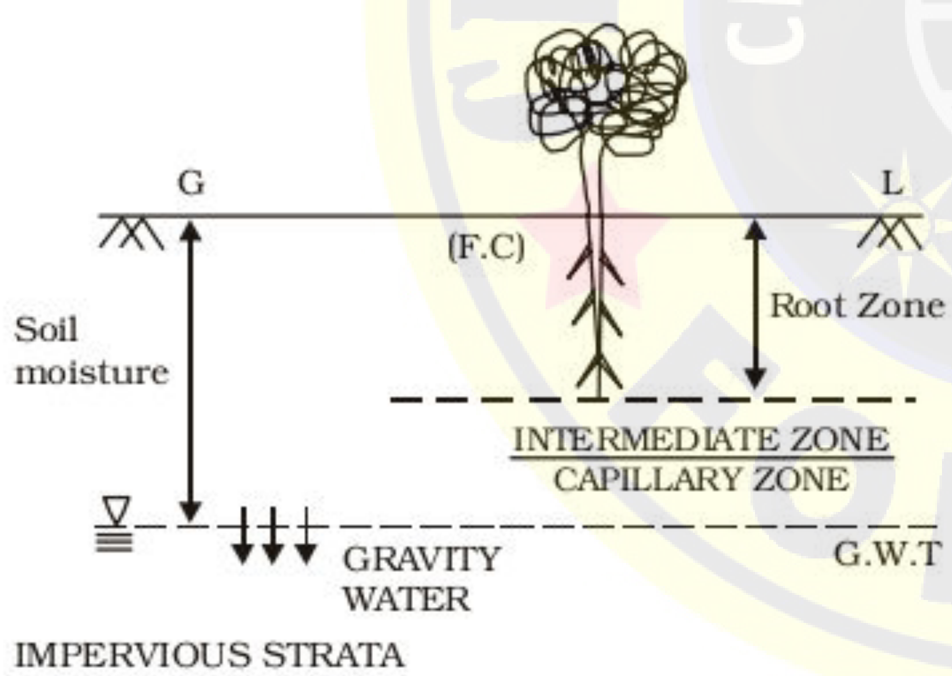
Where, d = average of the absolute values of deviation from the mean value.
D = mean depth of water stored during irrigation

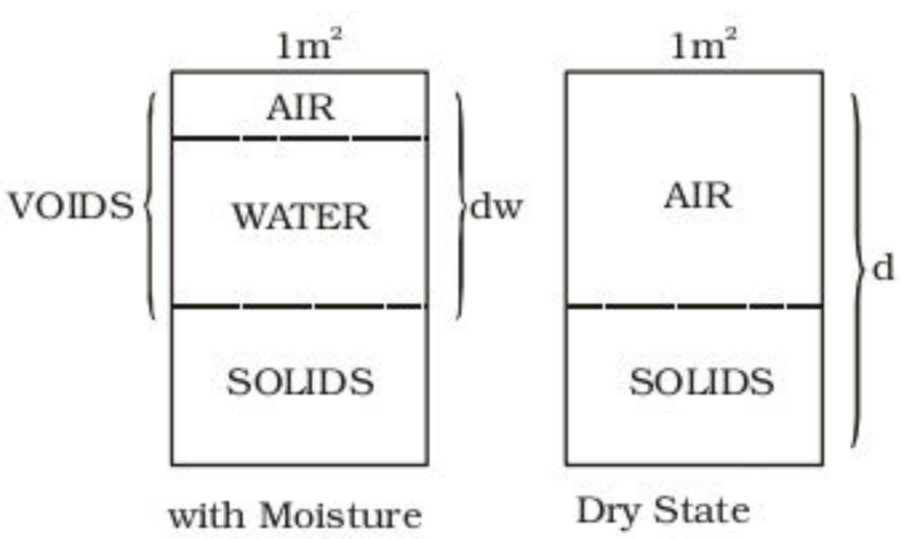


6. **Consumptive use efficiency (η_{cu}) :**

It is given by $\eta_{cu} = \frac{w_{cu}}{w_d} \times 100$ where, w_{cu} = normal consumptive use of water, w_d = net amount of water depleted from root zone soil.

- **SOIL - MOISTURE - IRRIGATION RELATIONSHIP**



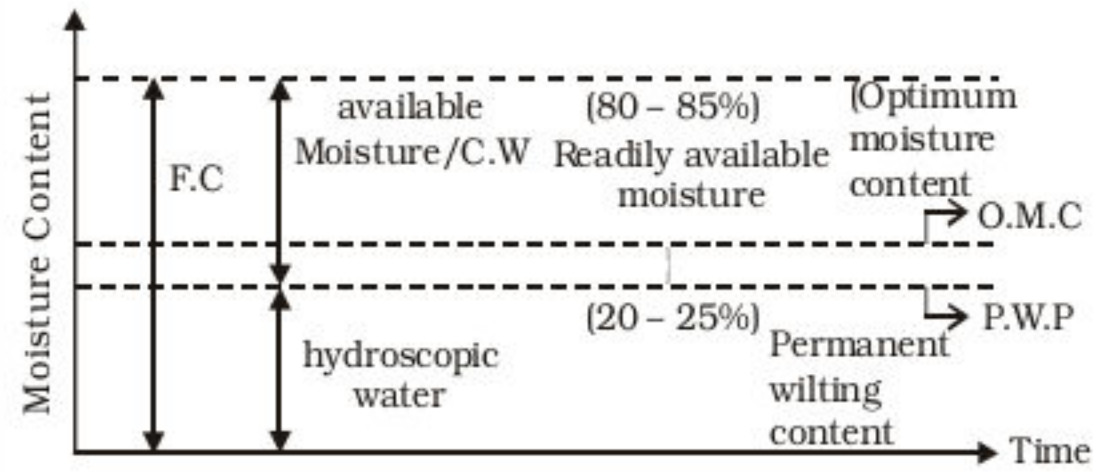


Field Capacity (FC)

$$F.C = \frac{\text{weight of water in certain volume of soil}}{\text{weight of dry soil of same volume}}$$

$$\therefore \quad F.C = \frac{\chi_w(dw.1)}{\chi_d(d.1)}$$

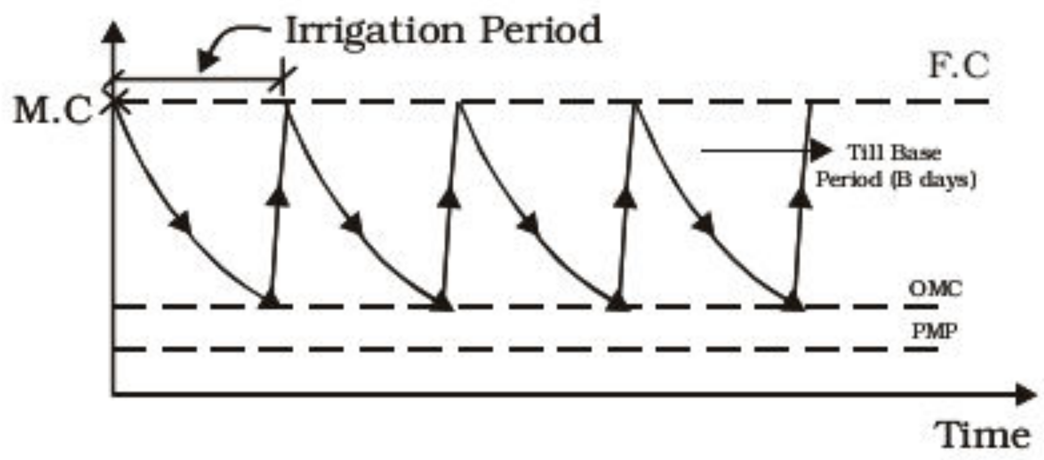
$$\therefore \quad dw = \frac{F.\chi_d.d}{\chi_w}$$



1. **Root zone:** It is the most important component from irrigation point of view, because it is the zone from which the plants take their water supply.
2. **Gravity water :** When water falls over the ground, a part of it gets absorbed as form of soil moisture and the rest flows downward under the action of gravity and is called gravity water.
3. **Field Capacity.**
   - Immediately after a rain or irrigation, when all the gravity water has drained down to the water table, a certain amount of water is retained in root zone.
   - This water cannot be easily drained under the action of gravity and is called the field capacity.
   - The field of capacity water (i.e the quantity of water which any soil can retain permanently against gravity) is expressed as the ratio of weight of water retained in a certain volume of soil to the net same volume of **dry soil**
   - The field capacity of water further consists of two parts (a) **Capillary water/available moisture**. It is that part of field capacity. That is available to the plants growth. It is equal to the difference of F.C and P.W.P.

(b) **Hygroscopic water**
   - The water left in the soil after the permanent wilting point is reached and not available to the plant growth is known as unavailable moisture or hygroscopic water.

4. Permanent wilting point is that water content, beyond which plant can no longer extract sufficient water for its growth and undergoes wilting.
5. Optimum moisture content is that portion of the available moisture which is most easily extracted by the plants and is approximately 75-80% of the available moisture.



✶ This may vary from plant to plant type.

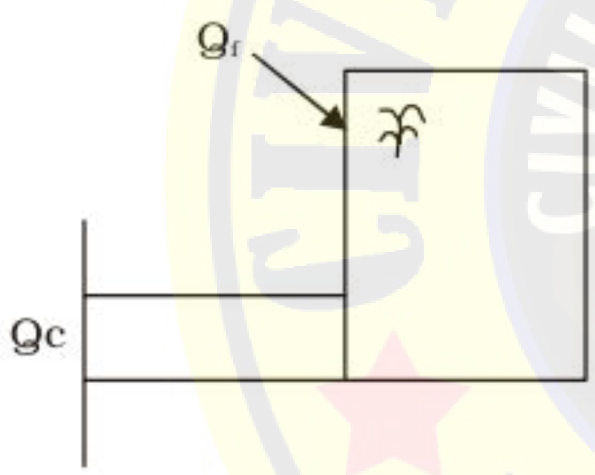
✶ Above is taken are standard assumptions.

Note : The irrigation water should be supplied as soon as the moisture falls to OMC and its quantity should be just sufficient to bring the moisture content upto its F.C also making allowance for application losses.

THEORY OF CONSUMPTIVE USE :

Introduction

(1) Consumptive use for a particular crop may be defined as the total amount of water used by the plants in transpiration (building of plant tissues,etc.) and evaporation from adjacent soil in any specified time.



(2) The value of consumptive use (cu) may be different for different crops and may be different for the same crop at different times and places.

Transpiration : It is defined as the process by which the water leaves a living plant during photosynthesis to enter the atmosphere as water vapour. It occurs when the plants manufactures, carbohydrates for its growth by the process of photosynthesis,

● **Certain Important Definition :**

(1) Effective Rainfall : It is the part of the precipitation which falls during the growing period of the crop and that is available, to meet the (Cu) i.e. evapo-transpiration.

(2) Consumptive Irrigation Requirement [CIR] :

P_{eff} = Effective Rainfall over the field

$\therefore$ CIR = Cu – P_{eff}

(3) Net Irrigation Requirement : [NIR] is the amount of Irrigation water required in order to meet the evapo-transpiration need of the crop as well as water lost through seepage.

NIR = CIR + (Water lost) Seepage or precipitation

(4) Field Irrigation Requirement, takes into account the losses occuring in the field

$$F.I.R = \frac{N.I.R}{a}$$

(5) Gross Irrigation Requirement takes into consideration, the water losses in the canals

$$G.I.R = \frac{F.I.R}{c}$$

FACTORS AFFECTING CONSUMPTIVE USE :

(1) Humidity and climatic condition : ↑ (cu↓)

(2) Mean monthly temperation : ↑ (cu↓)

(3) Crop period : ↑ (cu↓)

(4) Rainfall during the crop period : (cannot be said directly depends on other factor separately)

(5) Irrigation depth and supply of water :
→ Cu ↑ or ↓ (depending on transpiration and depth and supply of water in root zone)

(6) Wind velocity and irrigation technique :

(7) Soil and its properties :
Soil (↑ permeable), (↑ seepage loss) and so, Cu↓

● **CANAL IRRIGATION SYSTEM :**

(1) Primary Distribution system (Main canal + Branched canal).

(2) Secondary Distribution system (Major and Minor Distributaries).

(3) Tertiary Distribution system (field channels water courses).

Note : (1) The entire water conveyance system is divided into 3 categeries as above.

(2) Above canal arrangement is an integral management system for conveying and distributing irrigation system from the source (river or reservoirs) to the agricultural field so as to ensure adequate supplies.

● **Certain Important Definitions :**

(1) **Gross command area (GCA) :** It is the total area bounded within the irrigation boundary of a project which can be economically irrigated without considering the limitation of the quantity of available water.

It includes the cultivable as well as uncultivable area. Eg. Residential area, Roads, Reserved forests etc.

(2) **Cultivable Command Area [CCA]**: It is the cultivable part of the gross command area and it includes all the land of GCA on which cultivation is possible.

It will therefore, include barren lands on which cultivation cannot be made feasible It does-not include areas such as reserved forests, roads, residential area etc.

(3) Intensity of Irrigation [IOI]

The entire cultivated portion of CCA is not composed to be irrigated at one time (in one season). To avoid intensive irrigation of a particular area, which may cause harmfull effects like water logging, salivity and diseares such as dunque etc.

The percentage of CCA proposed to be irrigated in a given season is called, the intensity of irrigation of that season. The fields therefore, supplied water in rotation over different crop seasons, thereby, irrigation is possible for only about 40-60% of the fields of various sub areas over a season.

(4) Area to be irrigated land is obtained by multiplying CCA by the seasonal or annum Intensity of Irrigation as the case may be depending on data available.

(5) Time factor : It is the ratios of the actual operating period of the canal to the crop period. To check the dangers of over irrigation leading to water logging and no distributary is allowed to operate on all the days during a crop season.

- **CROPS AND CROPPING SEASONS :**

(1) KHARIF : (June - September) = Summer crops. Eg. Rice, Maize, Bajra, Jowar, Cotton.

(2) RABI : (Nov-March) = Winter crop Eg. Wheat, Pulses, Potato, Sugarcane.

(3) ZAID : (April - June) (less consumption of water Eg. Vegetables.

(4) Perennial Crop : (B > 300 days) ; Eg. sugarcane.

- **DESIGN CAPACITY OF IRRIGATION CANAL :**

(1) The capacity of the cannal should be sufficient to fulfill the maximum of the peak demand of all the crops that are required to be irrigated at any one time amongst all the seasons.

(2) Hence, the cannal should be designed for a capacity equal to the greater of the water requirement of rabi and sugarcane of kharif.

- **LOSSES OF WATER IN CANALS SYSTEM :**

Evaporation   Seepage

Absorption   Percolation

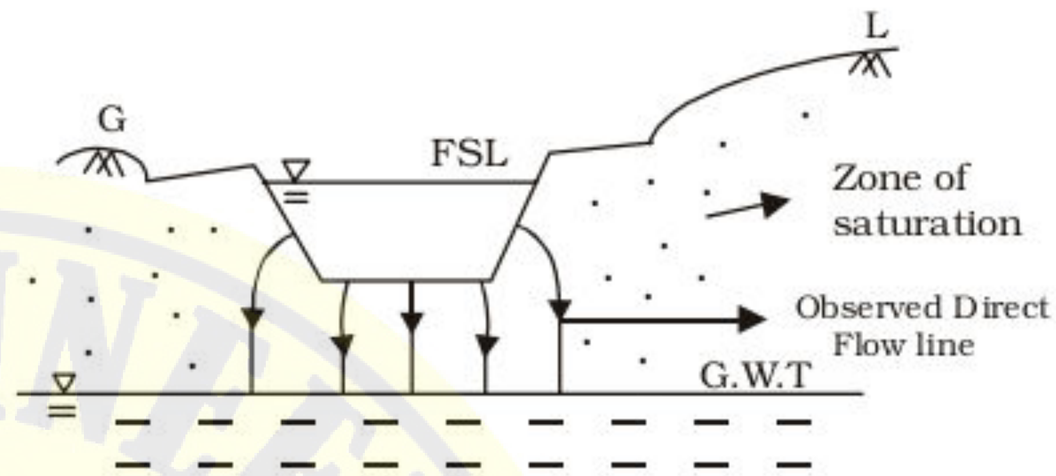
(i) Evaporation :

- The water lost by evaporation is generally very small as compared to the water lost by the seepage in certain channel.
- It depends upon factors such as temperature, wind velocity, humidity, etc.

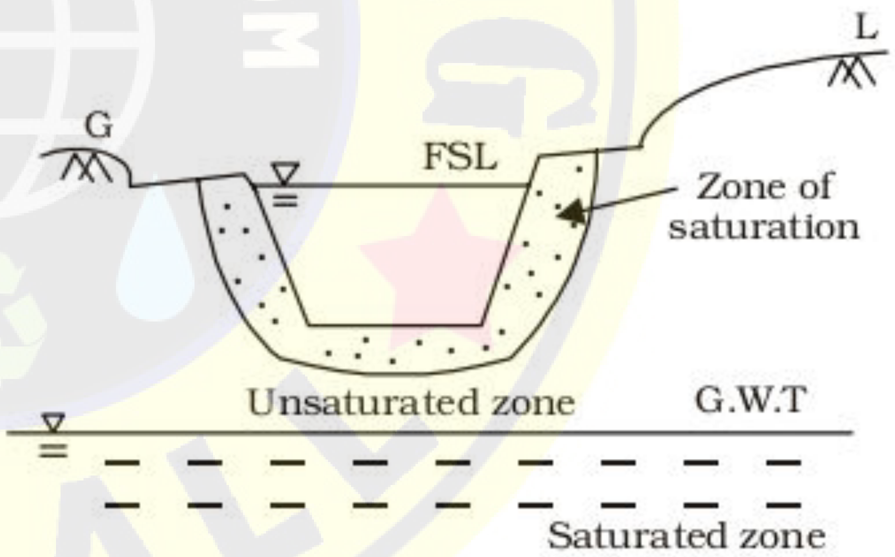
(ii) Seepage :

- There can be two different conditions of seepage :

(a) PERCOLATION : In percolation, there exists a zone of continuous saturation from the canal to the water table such that as observed a direct flow is established. Almost all the water lost from the canal joins the ground water.



(b) ABSORPTION : In absorption a small saturate zone exist around the canal C/S. So, there exist an unsaturated zone lying between the two saturated zones as shown in fig.



FACTORS AFFECTING SEEPAGE LOSS :

(1) Type of seepage, that is whether percolation or increased absorption.

(2) Soil permeability; Increase losses

(3) The condition of the canal - The seepage through a silted canal is less than that from a new canal.

(4) "Amount of silt carried by the canal"

~ More the silt (settling tendency increase ; Less are the Losses)

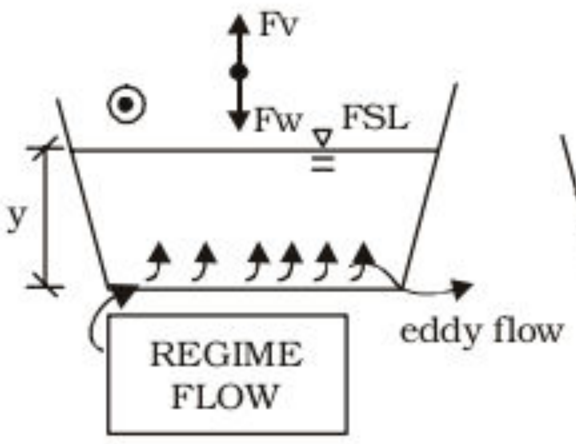
(5) Velocity of canal water ; Increasing of water flow in canal reducesiting of canal.

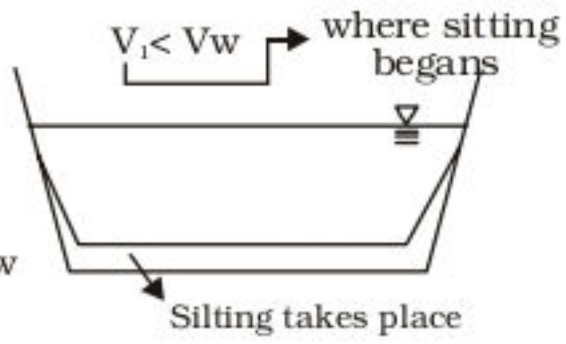
DESIGN OF CANALS :

Introduction :

(1) All the north-Indian Rivers flow through such soils that they carry a certain amount of sediment.

(2) Artificial canals carry their water supply from such rivers and therefore carry sediments



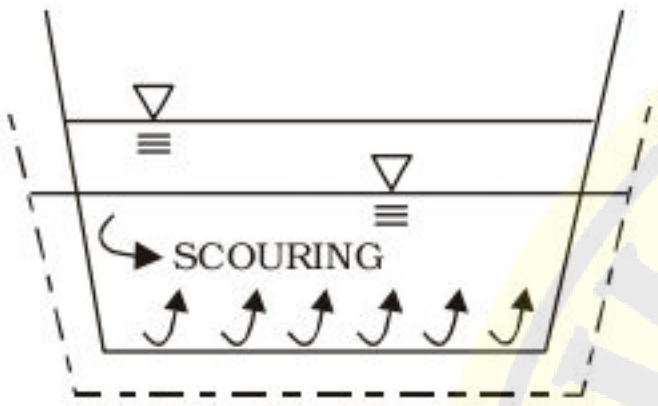


$V_2 > V_N \rightarrow$ Where scouring beging

on observation :

$\therefore \mathbf{V_1 < V_N < V_2}$

V_o = (Critical value)



$V_o = C_1yc^2 \Rightarrow V_0 = C_1 \cdot m \cdot y\, C_2$

Where,

m (Correction factor) = CVR [Critical value Ratios]

(3) The direct mathematical solution to the design of canals in alluvial soil is complicated. Therefore, in India, alluvial canals are designed on the basis of hypothetical theory given by Kennedy and Lacey.

(4) The water moving with a given velocity and a certain depth can carry on suspension only a certain amount of silt of a certain nature.

If water of a given velocity and the depth is not fully charged with silt (that it can carry in suspension), it will scour the bed and the sides of the canal, till it is fully charged with silt.

Therefore, if the velocity flow in the channel is more, the bed and the sides are likely to be eroded and similarly if the velocity is less, the silt which was formerly carried in suspension is likely to be settled.

Note : Therefore, when designing a proper functioning canal, it should be designed in such a way that neither silting nor scouring takes place. Such channels/canals are known as stable channels or Regime channel.

(5) It had been observed that scouring lowers the FSL and also causes failure of foundations of irrigation structures and loss of command area whereas due to silting channel section gets reduced, therefore reducing the discharge capacity of the channel.

- **KENNEDY'S THEORY :**

Kennedy was an executive Engineering in Punjab PWD. He studied existing canal of Punjab in upper bari doab plains canal system.

Which had not faced any problems of Silting and scouring.

(3) From the observation, he concluded that the silt supporting power in a channel C/S was mainly dependent upon the generation of the eddies. These eddies are generated due to the friction of flowing water with the channel surface and the vertical component of these eddies try to move the sediments upward, whereas the weight of the sediment tries to bring it down thereby keeping the sediment in suspension form.

(4) Based upon the above concepts, he defined critical velocity ($_0$) in a channel as the mean velocity (across the c/s) which will keep the channel free from silting or scouring and related it to the depth of flow by following equation :-

$_0 = C_1 \cdot yC_2$

Where,

$C_1 = 0.55$ } in M.K.S or S.I

$C_2 = 0.64$ } unit respectively

(5) He later introduced a factor (m) to account for the type of soil through which the canal is to pass. This factor is dependent upon the silt grade and was named as critical velocity Ratios therefore, the modified form of Kennedy's Equation given is ;

$_0 = 0.55\, m\, y^{0.64}$

Values of m :

(1) m = 1 ; for particles of river in NW. India in region of Sind and Punjab.

(2) m = 1 – 1.2 ; for particles of river in southern India (coarse particles)

(3) m = 0.7 – 1; for fine particles derived from lower valleys of Ganges and Indus.

- **LIMITATIONS OF KENNEDY'S THEORY :**

(1) According to Kennedy, eddies are generated from the base/bed of channel, however in real practice, it has been observed that eddies are created from the sides of the channel also.

(2) He had not given, his own formula, for calculation of the actual mean velocity but had used Chezy's or Manning's equation and therefore, all the limitation of those equations becames the limitation of Kennedy's theory

(3) The value of (m) has been randomly related to silt grade, without giving any proper relationship

(4) He had not given his own equation for calculation of the channels bed slope.

(5) He had not taken into the consideration the factor of silt concentration.

(6) He had not given any importance to width by depth ratios.

- **LACEY'S THEORY : OR Lacey's Silt Theory**

It was stated by Kennedy that a channel is said to be in a state of regime if there is neither silting nor scouring in the channel.But Lacey came up with the statement that even a channel showing no silting or scouring may actually not be in Regime. He (Lacey) therefore, differentiated between 3 regime conditions.

Ist : Initial Regime : Lacey theory is not valid

- If only the bed slope of the channel varies and its wetted perimeter remains unaffected then a condition of non-silting and non-scouring may exist, which is called initial Regime.
- During the subsequent flow, due to change in site condition, the regime condition may change and under such a condition, Lacey's silt theory is not valid.

2nd : True Regime :

- There can be only one channel section and one bed slope at which channel having a given discharge and a particular quantum of silt would be regime.
- Such channels are artificial which have fixed slope discharge at uniform rate and carries a fix amount of silt with the same rate.
- Such condition are ideal in nature and do not exist in practice or in reality. Lacey's silt theory is valid for such a regime conditions.

3rd : Final Regime :

- If all the variables such as perimeter, depth, flow etc are free to vary and can adjust according to the discharge and grade of silt such that there occurs no silting and no scouring. then such channels are said to have achieved permanent stability and are called final Regime condition.
- Lacey's silt theory is valid for final Regime conditions.

Note : Since, Kennedy did not take effectively the effect of silt grade in his theory while calculating ('m'), Lacey in his theory introduced a term called as silt factor and connected it to the average particle size.

Step - 2 : Find the hydraulic radius given by ;

$$R = \frac{5}{2}\frac{V^2}{f}$$

$V \rightarrow m/s$
$R \rightarrow m$

Step - 3 : Calculate the dimensions of the C/S

$$A = \frac{Q}{V} = (B + ny)y$$

Step - 4 : Wetted Perimeter

$P = 4.75\sqrt{Q}$ $\quad Q \rightarrow m^3/S$, $P \rightarrow m$

Step - 5 : Calculation of bed slope :

$$S = \frac{f^{5/3}}{3340\, Q^{1/6}}$$

- **COMPARISON OF LACEY'S AND KENNEDY'S THEORY :**

Kennedy's theory	Lacey's theory
(i) He neglected the eddies which are generated from sides of the channel	(i) It was accounted by Lacey
(ii) He stated that all channel are in regime condition if they donot silt or scour	(ii) Lacey differentiated between 3 regime conditions that were, initial, true and final regime condition.
(iii) He has not given any effective relation between silt factor and grain size	(iii) Silt factor was given by lacey through an empirical formula ; $f = 1.76\sqrt{(d)_{mm}}$
(iv) Bed slope was to be assumed in kennedy's true for suitable channel	(iv) Lacey has given his own equation for calculation of channel bed slope $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$
(v) No such equation was given; instead, Cherzy's or manning equation was assumed for calculation.	(v) Lacey provided his own equation for calculation of Actual mean velocity of Reginte

- **LINING OF CANALS :**
  - The term lining of canal means that the earthen surface is lined with a stable lining surface (Inerodible), such as concrete, tiles etc.
  - Since, seepage causes in unlined canals were found to be as high as 10-25% in general. So, to avoid seepage lining of canal was seen as a sustainable solution.

- **ADVANTAGES OF LINING :**

1. Seepage control : Upto 30% of water loss in seepage can be saved by lining.
2. Prevention of water logging;

3. Increase in channels capacity by permitting greater velocity
4. Reduction in maintenance cost (approximately : 40-50)
5. Elimination of flood danger.
6. Increase in command area : Since, higher velocities are permissible, therefore, steeper gradients can be provided. Thus, increasing the command area.

✶ By providing steeper gradient, the velocity can be more for the canal so,

$Q = AV$; Volume = $Q \times$ time period

$V\uparrow \rightarrow Q\uparrow \rightarrow$ for constant time period volume supplied$\uparrow$

● **DISADVANTAGE OF LINING CANAL.**

1. Large initial investment
2. Greater condition period

● **ECONOMIC JUSTIFICATION OF LINING :**

Statement :

"If average annual benefit is greater than average annual investment, then lining is desirable".

● **Average Annual Benefit**

◆ Monetary benefit is achieved by following two factors :

(i) By reducing seepage; Let 'm' cumec of water is saved every year by preventing seepage and it is sold to farmers at the rate of rupees R_1 per cumec then average annual saving will be ;

Sa_1 = Rs. mR_1/cumec

(ii) Reduction in maintainance cost, let Rupees R_2 per annum is the maintenance cost per annum of unlined canal and due to lining percentage of maintenance cost is saved, then annual saving in this case will be equal to

Sa = Rs. pR_2

● **Average annual Investment :**

◆ Following are two investments :

(i) Annual Expenses :

Let 'C' be the total capital investment required for lining a canal and '*y*' - years be the service life of a canal, then average annual investment of the lining will be :

Ia_1 = ₹ C/Y

(ii) **Loss due to interest :**

Loss of interest at the rate 'r' also takes place

(a) In the begining, loss is on Rs. C

(b) Whereas, at the end capital reduces to zero

Fig

$$\therefore \; Ia_2 = \frac{C.r}{2 \times 100} ₹$$

Benefits — Sa_1, Sa_2 $>$ Investment — Ia_1, Ia_2

It's when only lining is done.

● **SEDIMENT TRANSPORT MECHANISM :**

◆ **Shield's theory**

Introduction :

◆ Whenever water flows in a channel, (natural or artificial), it tries to scours its surface. Silt or gravel are removed from the bed or sides of the channel. These eroded particles are carried done stream by the flowing water. This phenomenon is known as sediment transport.

Importance of sediment transport :

(a) This phenomenon causes large scale scouring and siltation of irrigation channel thereby increasing their maintenance.

(b) The design of flood control is generated by pick discharge and which is dependent upon scouring and silting of the sediment.

(c) The storage capacity of reservoir by silting navigational capacity of channel will be reduced. Thus, sediment transport poses numerous problems related to water Resources Engineering and Structures.

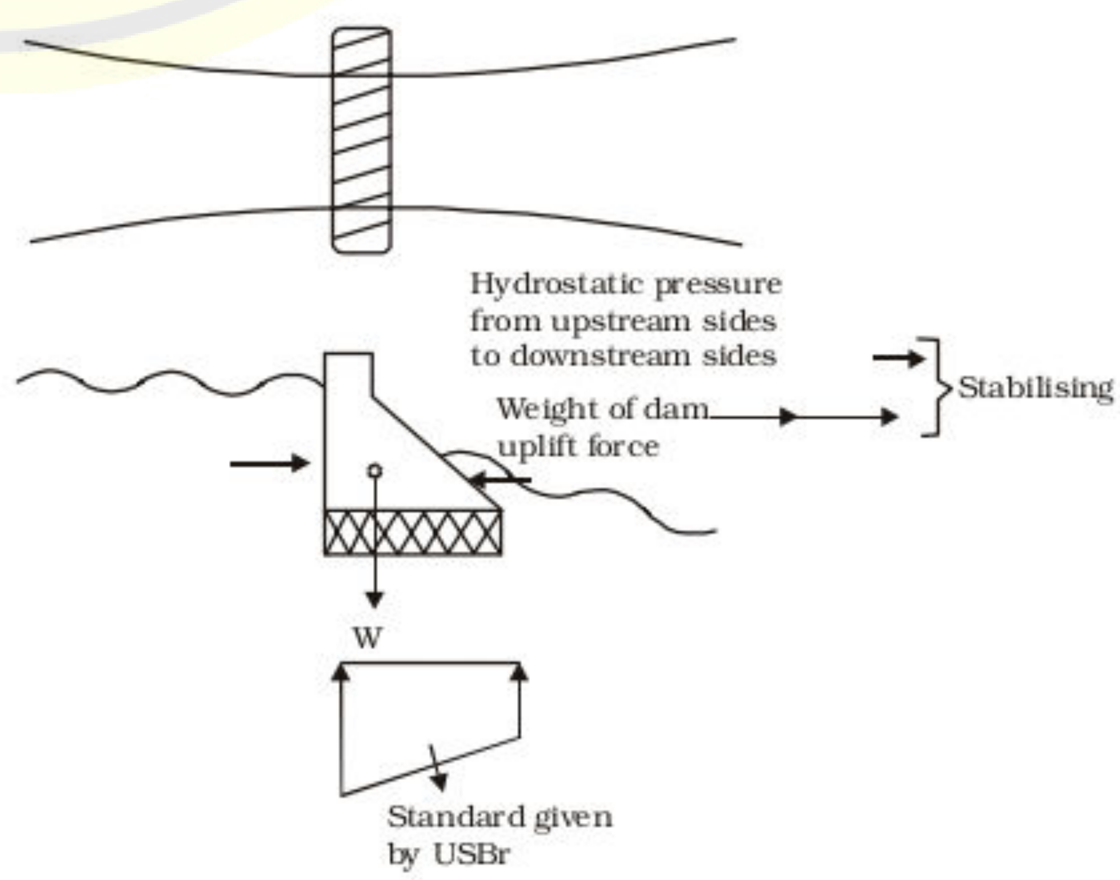
● **ANALYSIS OF GRAVITY DAMS :**

1. Types of Dams
2. Forces on Dam
3. Stability Analysis of Dams
4. Elementary profile of G.D

Definition :

◆ A Dam is a physical obstruction constructed across a river or stream so as to store or divert the water from its upstream side.

◆ The pool of water formed on the upstream is called the reservoir of the dam



- **TYPES OF DAMS :**

(i) **Earthern Dam (Major) :**

◆ These are made up of soil, i.e. filled down perfectly.

They are built in areas where the foundation is not strong enough to bear the weight of a concrete dam and where local soil is easily available as a building material compared to concrete, stone or rock. eg : Hirakund Dam

(ii) **Rock - Fill Dam (Major) :**

◆ These are formed of loose rocks and boulders arranged in the river bed.

◆ A slab of R.C.C is often laid across the upstream face of a rock filled dam to make it water tight. Eg : Tehri Dam

(iii) **Solid–Masonry Gravity Dam (Major) :**

◆ They are built with solid blocks of concrete which holds back the flow of water by its weight.

◆ They can be constructed where there is a natural foundation strong enough to bear the greater weight of the dam.

Eg : Bhakra Dam

(iv) **Steel Dams :**

◆ They are used as temporary dams needed for the construction of permanent dams.

◆ They are usually reinforced with timber or earth fill.

(v) **Timber Dam :**

◆ These are short spaned dams since in few years, degradation of timber takes place.

Their life is not more than 30-40 years and they must have regular maintenance during that time.

(vi) **Arch Dam :**

◆ These are very complex and complicated.

◆ They make use of horizontal arch section in place of weight to hold back the water.

◆ They are best suited where the dam is extremely high and narrow.

Eg : 100u KI dam in Kerala

- **FACTORS AFFECTING SELECTION OF A DAM SITE :**

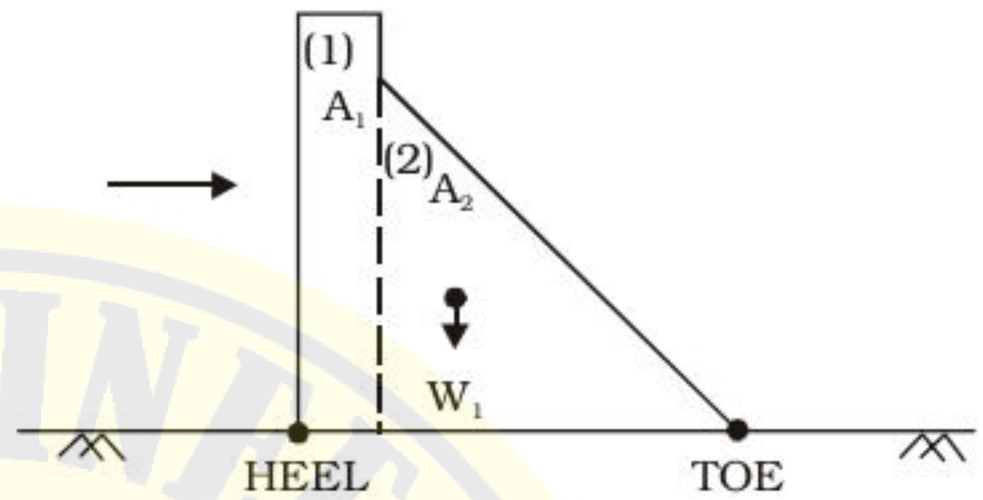
1. Topography of the region should be such that it has deep valleys of low submergence of area E/A department for approval.
2. Base of the Dam site, where the foundation is to be laid should be impermeable.
3. The region should be free from earthquake prone area of seismic activity.
4. River should be perrenial in nature i.e. flowing throughout the year
5. Easy availability of construction material and cheap labour.

Note : In India, there are 3 main regions having hydro-electric potential.

(i) Himalayan Region.
(ii) Central India (Satpura and Vindhyan Ranges)
(iii) Western Ghats

- **FORCES ACTING ON GRAVITY DAM :**

1. Weight of the Dam of Gravity force



γ_C = unit weight of concrete

$W_1 = \gamma_C \cdot A_1 \cdot 1$ for 1m length of Dam Body

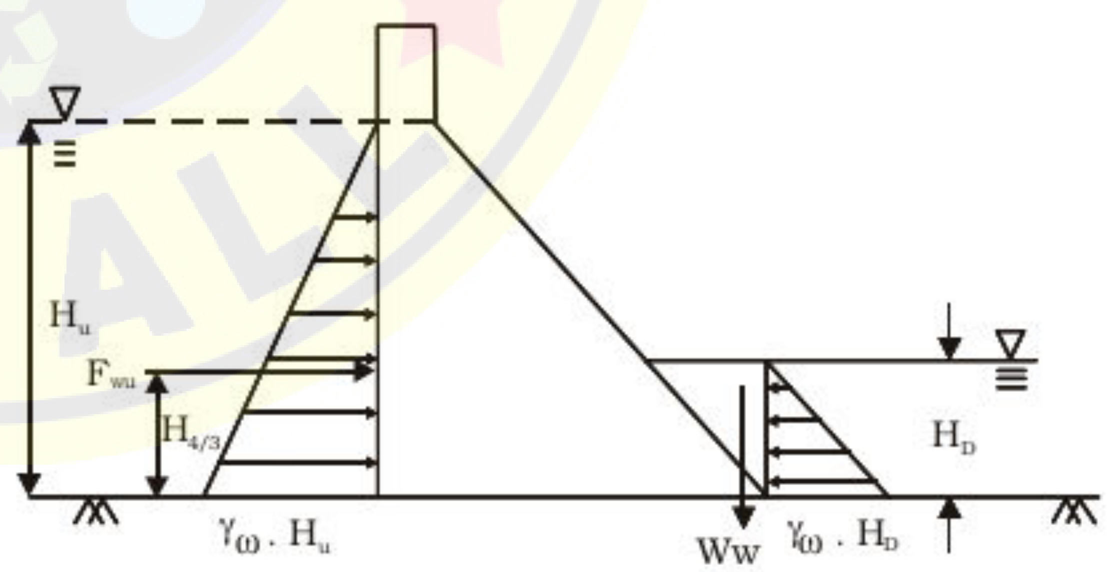
$W_2 = \gamma_C \cdot A_2 \cdot 1$

$W = W_1 + W_2$

$W_1 = \gamma_C \cdot 1\ \Sigma\ Ai \rightarrow$ in general for i no of section

This is a stablising force and is calculated as above.

2. Water pressure :



(added to Dam's weight)

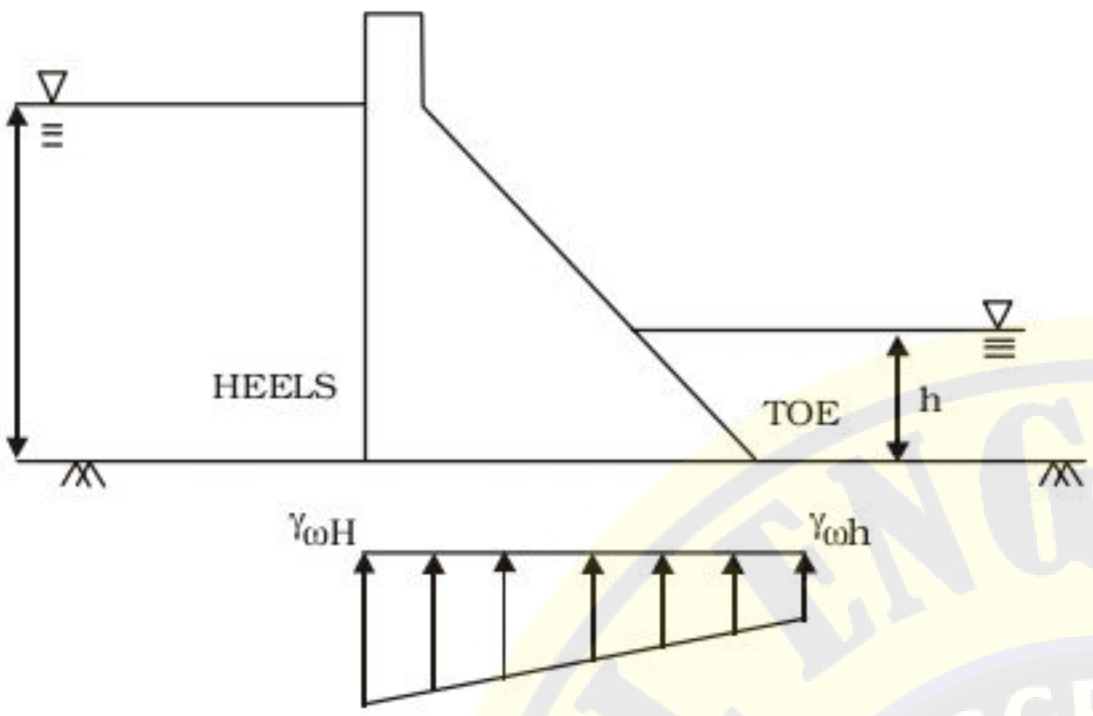
$\therefore$ for 1m length of Dam

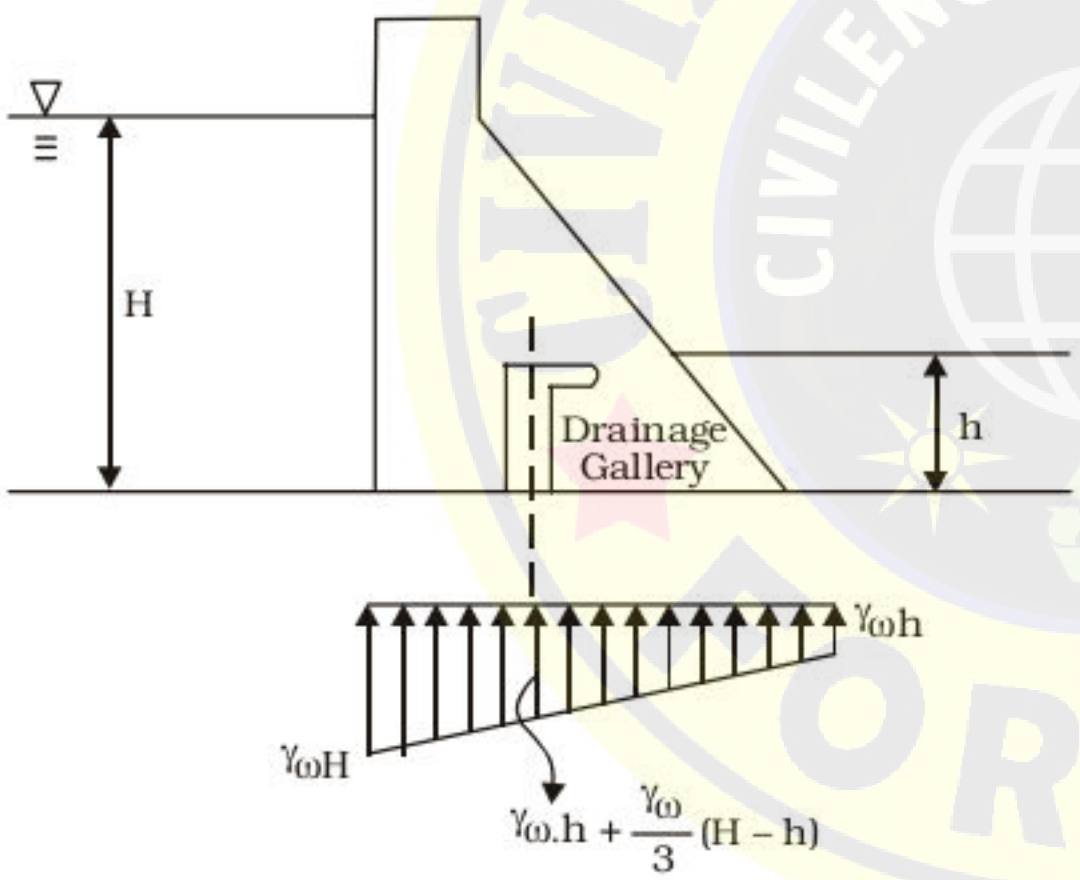
$$FW_u = \frac{1}{2}(\gamma_w \cdot H_u) \cdot H_u \cdot 1 = \frac{\gamma_w \cdot H^2u}{2}$$

$$FW_D = \frac{1}{2}(\gamma_w \cdot H_D) \cdot H_D \cdot 1 = \frac{\gamma_w \cdot H^2_D}{2}$$

(a) $\frac{H_D}{3}$ from base

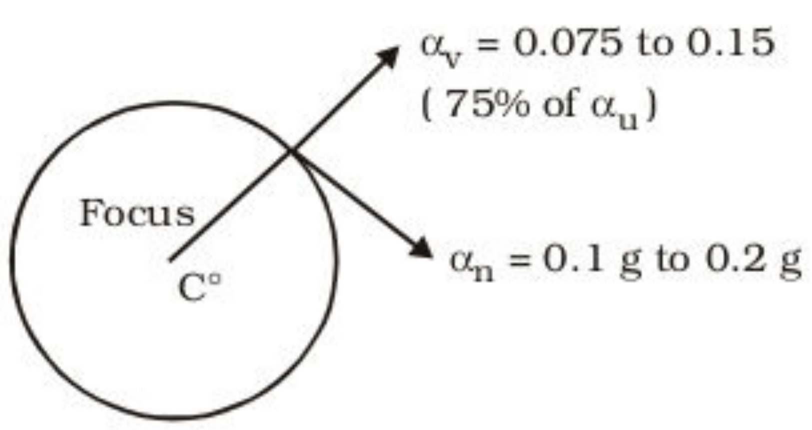
3. Uplift Pressure [Studies as per USBR] :
Water seeping through the pores, Cracks of foundation material and dam's body, get beneath the ground level and exerted an uplift pressure on the base of the dams. Such an uplift pressure in vertically upward direction reduces the downward weight of the body of the dam and acts against the dam stability.





- According to USBR, the pressure intensity at the location of drainage gallery, is independent of location of drainage gallery.
- According to USBR convention, the uplift force is independent of earthquake force.

4. Earthquake force :



Note :

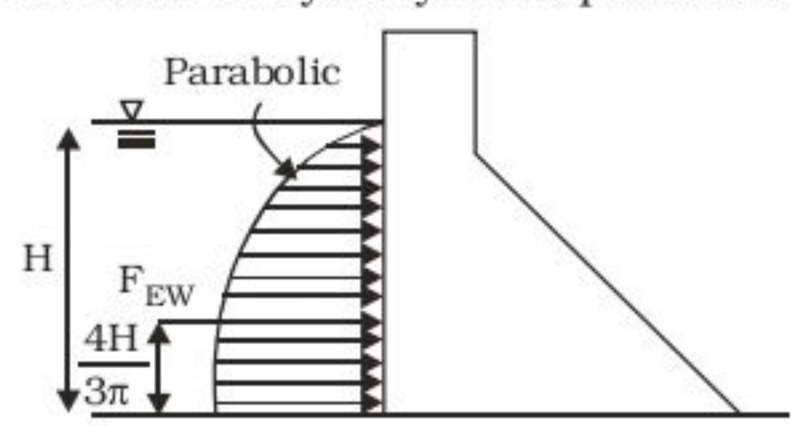
(i) The earthquake effect on the surface of the earth is broadly seen in form of a horizontal and a vertical acceleration as shown above.

(ii) In general form, αn is given as
$\alpha n = kg$
Where, K = $\beta I\ \alpha\theta$ and $\alpha\theta$ is given by :-
By β/s

Zone	Value of α
I	0.01
II	0.02
III	0.04
IV	0.05
V	0.08

β = Soil foundation factor
β = 1 ; For gravity Dams
I = Importance factor.
I = 2, For gravity Dam
∴ $K = \beta I_{ao}$ ≡ Sesimic co-efficient

- **Effects of horizontal Acceleration :**
- The horizontal acceleration produces an inertia force into the body of the dam.
- This force is generated in order to keep the body and the foundation of the dam.
  Together as 1 set the direction of the produced force will be opposite to the acceleration imparted by the earthquake.
  $FI = M.\alpha n$
  $= M.kg$
  $= \frac{w}{g} . kg \Rightarrow FI = k.W$
  Hence, we will design for worse FI case scenario, i.e. destabilising case.
- Hydrodynamic pressure, horizontal acceleration acting towards the reservoir causes a moment increase in the water pressure and as the foundation and dam, acceleration towards the reservoir due to which the water resists its movement due to its inertia.
- This extra pressure exerted by the above process is known as hydrodynamic pressure :



$\boxed{F_{EW} = 0.55\ \gamma_w.K_c.H_2}$ ≡ Hydro-dynamic Forces

Von-Korman Equation

$K_e = \alpha_h = 0.1$ g to 0.2 g

- Effects of Vertical Acceleration :-
- It increases or decreases the apparent weight or self weight component.

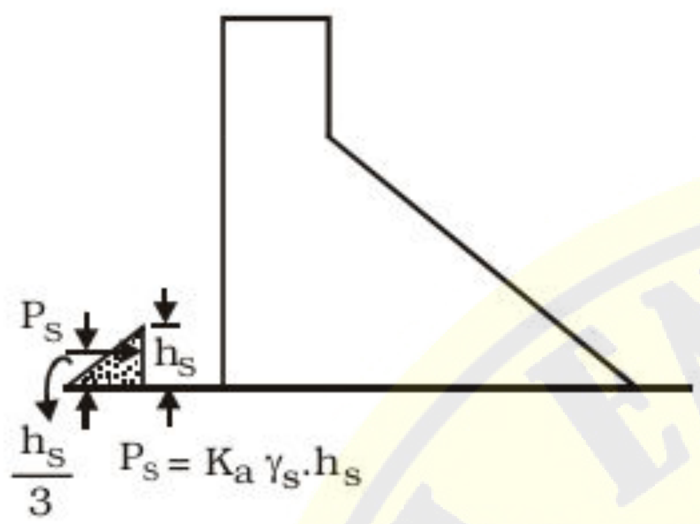
$$WAD = \frac{w}{g}(g \pm \alpha v)$$

$\alpha v \uparrow (-)$

$\alpha v \downarrow (+)$

Note : When the vertical acceleration is acting upwards, it will be stabilized and the design has to be prepared for this case.

5. Silt Pressure :



$\therefore P_s = \frac{1}{2} \times p_s \times h_s \times 1$

$\therefore P_s = \frac{1}{2} \times K_a \times \gamma_s . h_s^2$

$\gamma_s = \gamma_{sat} - \gamma_w$

h_s = height of Silt load

Where, K_a = Active earth pressure coefficient and

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi} = \tan^2(45 - \phi/2)$$

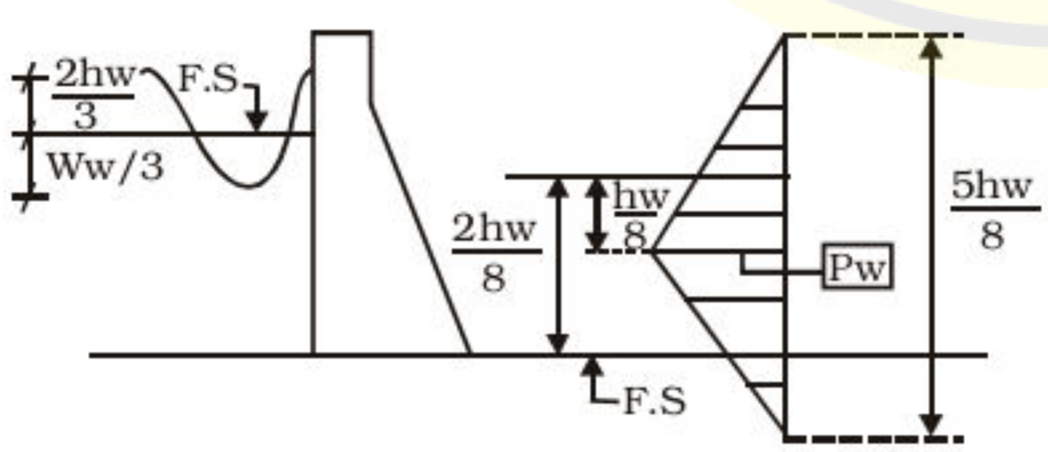
and $\phi = \angle$ of internal friction for silt.

and γ_s = Submerge unit weight of silt

Note : If upstream face is inclined then weight of silt block acts downwards and have to be accounted as a vertical load.

6. WAVE PRESSURE :

Pressure diagnosis due to wave Action



P_w = Maximum wave pressure Intensity

$= 2.4 \times \gamma_w h_w$; h_w = height of wave

$\therefore$ Maximum wave force ;

$$P_w = \frac{1}{2} \times \frac{5}{3} \times h_w \times 2.4 . \gamma_w . h_w \text{ acting at } \frac{3h_w}{8}$$

from free surface (F.S)

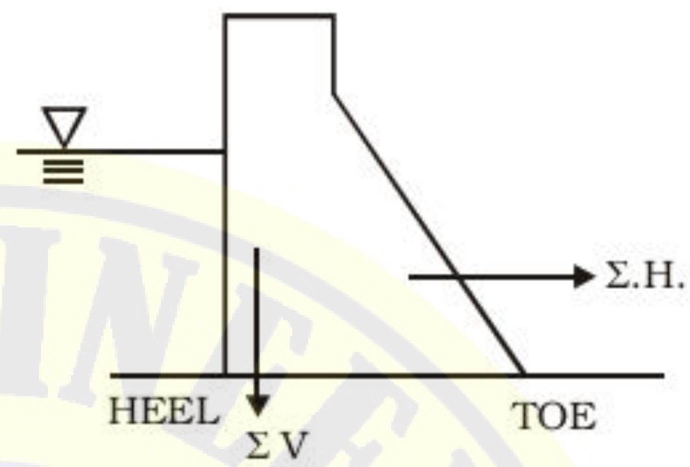
7. Ice Pressure : Its value is generally taken as 50 tonne per metre however the exact value depends upon the temperature.

8. Wind Pressure : It may be taken as 1 to 1.5 kN/m^2 of exposed area.

- **MODES OF FAILURE OF DAM :**

1. Overturning
2. Cushing/compression
3. Sliding/shear
4. Cracks due to tension

1. OVER TURNING ;



ΣMO = Over turning moment {From individual force}

ΣMR = Re-storing moment {From individual force}

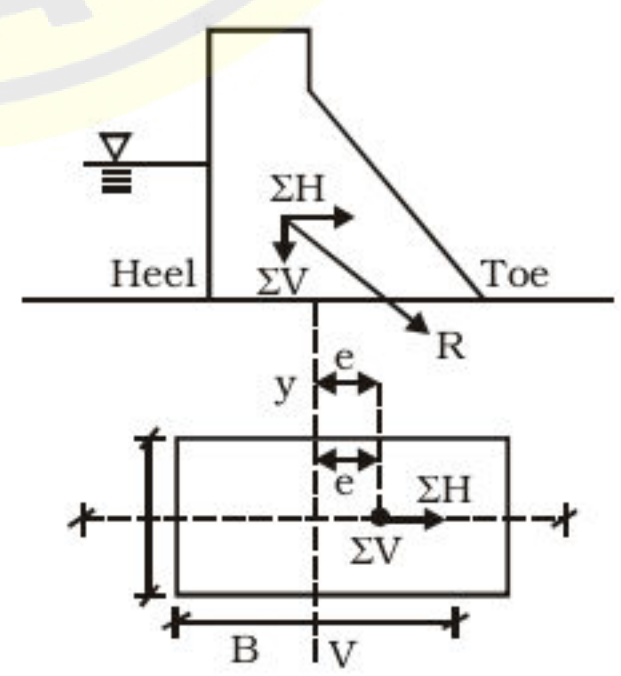
Finally for safety;

$\Sigma M_R > M_O$ } about toe

$$F.S = \frac{\Sigma M_R}{\Sigma M_o} \geq 1.5$$

2. CRUSHING/COMPRESSION :

- In full reservior condition, the resultant force passes through the base of the dam at an incentricity 'e' from the centre of the base width
- Hence, resultant compressive stress, (due to compression and bending) caused by vertical force may be calculated for the following three case;



$$\sigma_R = \sigma_d \pm \sigma_b$$

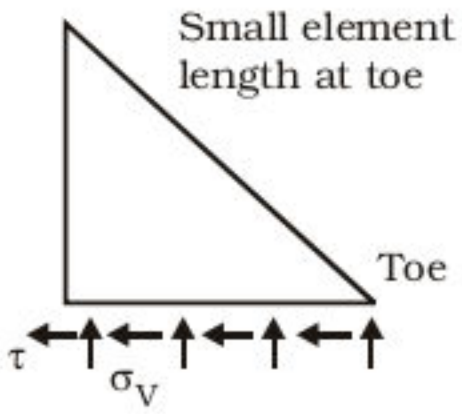
$$\sigma_R = \frac{\Sigma V}{B.1} \pm \frac{\Sigma Ve . x}{Iy}$$

$$\sigma_R = \frac{\Sigma V}{B} \pm \frac{\Sigma Ve\,.\,x}{1.B^3/12}$$

$$\sigma_{R.Max/Min} = \frac{\Sigma V}{B} \pm \Sigma\frac{V.e\,.\,B/2}{B^3/12}$$

$$\therefore \quad \sigma_{R.Max/Min} = \frac{\Sigma V}{B} + \frac{6\Sigma.v.e}{B^2} \quad \text{(a) Toe} = \sigma_{Vmax}$$

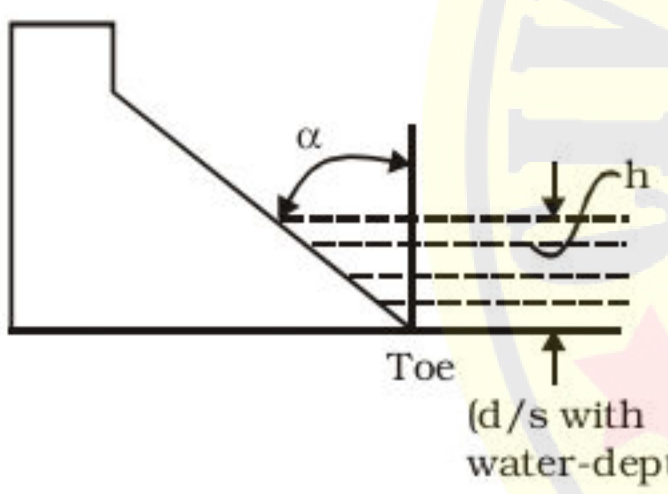
$$\sigma_{R.Min} = \frac{\Sigma V}{B} - \frac{6\Sigma.v.e}{B^2} \quad \text{(a) Heel} = \sigma_{Vmin}$$

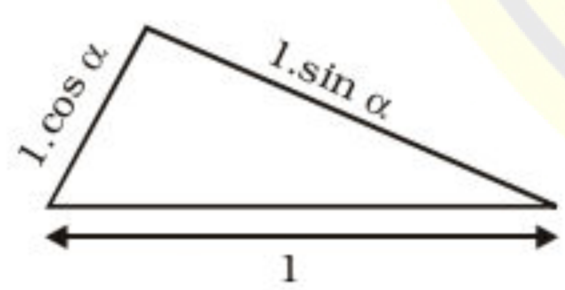


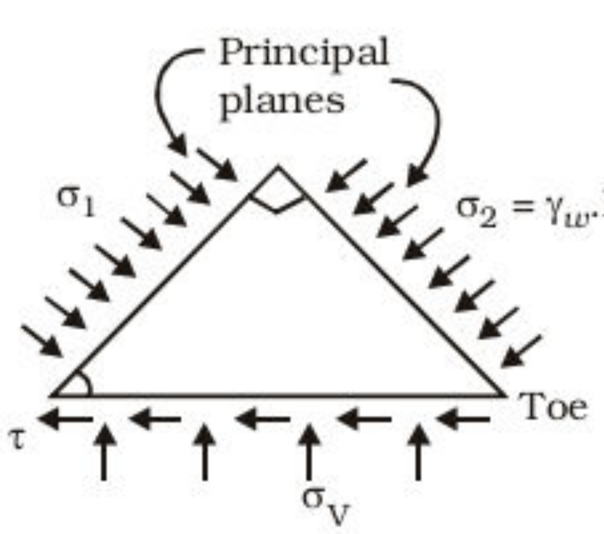
Here, σ_v max → maximum for only cause of vertical force

It is NOT the maximum stress in dam as τ on the plan is not zero

(d/s with water - depth)







$\sigma_2 = \gamma_w.h$ Principal stress (minor) as no shear acts due to stagnant water & σ_1 will act as the reaction of σ_2.

$\Sigma Fv = 0$

$\Rightarrow \sigma v\,(1.1) = \sigma^2.\,(1\sin\alpha.1)\sin\alpha + \sigma_1(1.\cos\alpha.1)\cos\alpha$

$\sigma_1 = \sigma v \sec^2\alpha - \sigma_2\tan^2\alpha$

If h = 0 σ_1 = maximum

$\sigma_1 = \sigma_V \sec^2\alpha$ and $(\sec^2\alpha)$ max = 1

when $\alpha = 0$

But $\alpha \neq 0$ never

$\Sigma FM = 0 \qquad \sigma_1 > \sigma_V$

$\Rightarrow \tau\,(1\times 1) = \sigma_1(1\,.\,\cos\alpha)\times 1)\sin\alpha - \sigma_2(1.\sin\alpha\,.\,1)\cos\sigma$

$$\Rightarrow \tau = \frac{(\sigma_1 - \sigma_2)\sin2\alpha}{2}$$

$$= \frac{(\sigma_v\sec^2\alpha - \sigma_2\tan^2\alpha - \sigma_2)\sin2\alpha}{2}$$

$$\tau = (\sigma_V - \sigma_2)\frac{\sec^2\alpha\,.\,\sin^2\alpha}{2}$$

$\Rightarrow \tau = (\sigma_V - \sigma_2)\tan\alpha$

- If earthquake force are also taken into consideration then σ_2 will be $(\sigma_2 - p_e)$

So, $\sigma_2 \to \sigma_2 - p_e$

pe = earthquake stress coming in the direction of σ_2.

$\because$ for τ_{max} ; σ_2 should be minimum.

3. TENSION FAILURE :

- As concrete is weak in tension, i.e it is desirable to avoid any tension in any part of the dam's body

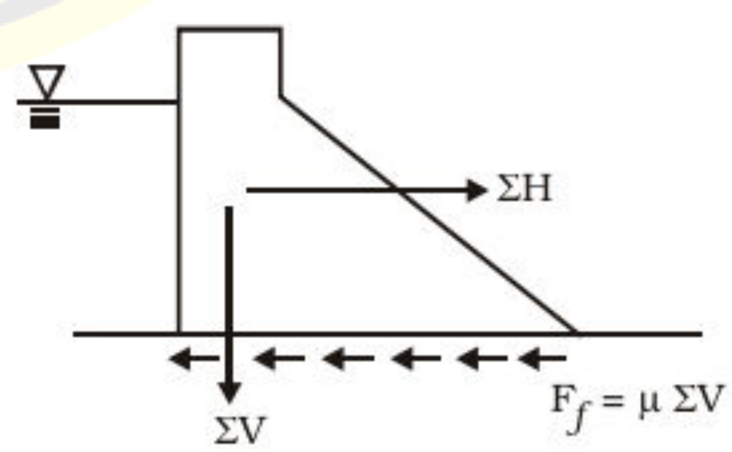
$$\sigma_V \min = \frac{\Sigma.V}{B} - \frac{6\Sigma.v.e}{B^2} \quad \text{(a) Heel}$$

$\because$ for no tension; (σ_V) min ≥ 0

$\therefore e \leq B/6$

Note : This means that for no tension failure ; resultant must always pass to middle 3rd strip of the base (Middle 3rd Rule)

4. SLIDING/SHEAR FAILURE :



$\therefore$ For stability

$\mu\Sigma V > \Sigma H$

$$\therefore \frac{V}{H} > 1$$

$$\therefore \text{FOS} = \frac{V}{H} \Rightarrow \text{No bond strength considered}$$

F.O.S = $\frac{V \quad q(B.I)}{H}$ ⇒ ; Bond strength of concrete is considered.

q = Bond strength of concrete

Note let F.O.S = 1

$\therefore \Sigma V = \frac{H}{\quad}$ → ΣV (corresponding to weight of dam is more

$\Sigma V = \frac{H - qB}{\quad}$

◆ If Bond strength of concrete/shear strength of concrete design is also considered in addition to friction, then the design will result in economy of the structure.

● **WATER LAGGING AND DRAINAGE DESIGN**

◆ A soil is said to be water logged, if productivity of the land gets reduced due to high water table. This happens because, the soil becomes ill aerated.

● **CAUSES OF WATER LOGGING :**

1. Over and intensitive Irrigation
2. Seepage from canal and higher land
3. Inadequate natural drainage system
4. Excessive rainfall
5. Submergence due to flood
6. Irregular topography

● **CONTROL MEASURES :**

1. Lining of cannals
2. Reduction in intensity of irrigation
3. Improved Under Ground Drainage system
4. Crop rotation → done with leguminous crops
5. Introduction of lift irrigation

● **EFFECTS OF WATER LOGGING :**

1. Reduction in Productivity
2. Creation of wet climatic condition, which may cause, public health problems
3. Increase in salinity and alkalinity of the soil

HYDROLOGY

◆ It is the science of water which deals with the occurence, circulation and distribution of water on earth surface and its atmosphere.

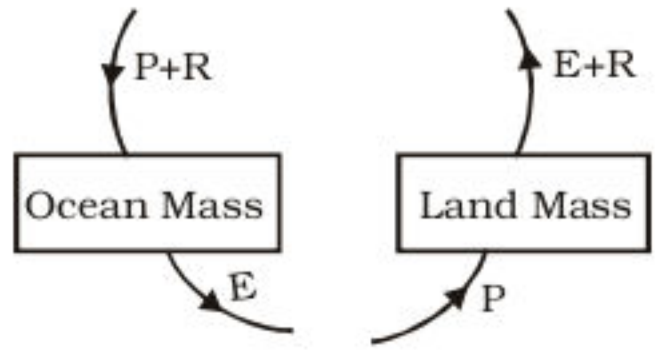
● **Hydrological cycle :**

It is a cycle in which water moves from one phase to another having different residence time in each phase.

● **Residence time :** (Ocean is larger than Global Ground water) Residence time is the time taken by a water particle in crossing a particular phase to another of a hydrological cycle $\left(t_r \quad \frac{vol}{Q}\right) \frac{m^3}{m^3/s} \quad s$

◆ Sun is the source of energy that drives the hydrologic cycle.

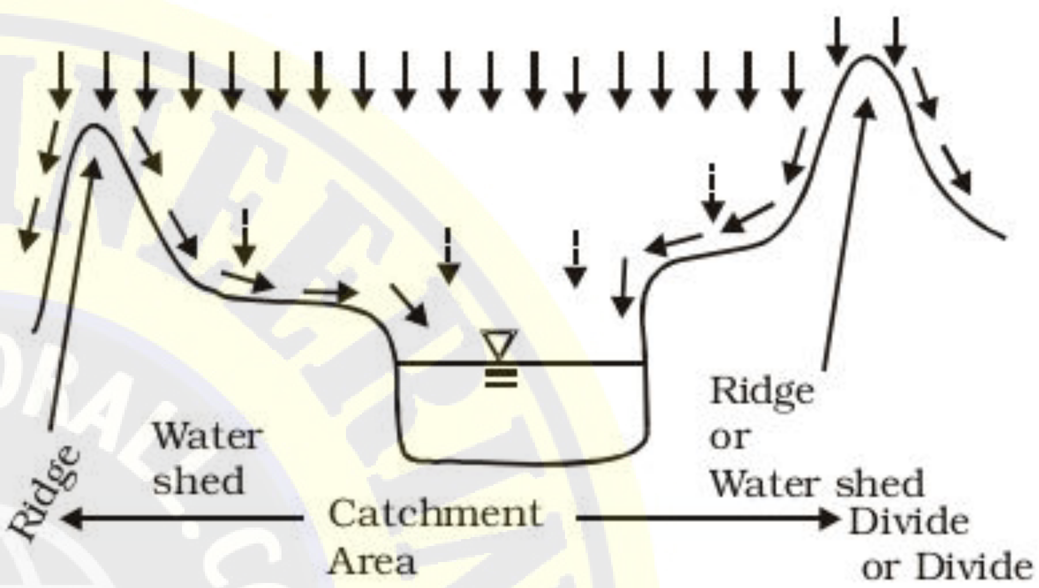
◆ Over the ocean surface evaporation exceeds precipitation (approximate 9%) whereas on the land mass, precipitation is more than evaporation.



P + R = E　　　　P = E + R

P < E　　　　$\therefore$ P > E

3. Catchment Area :

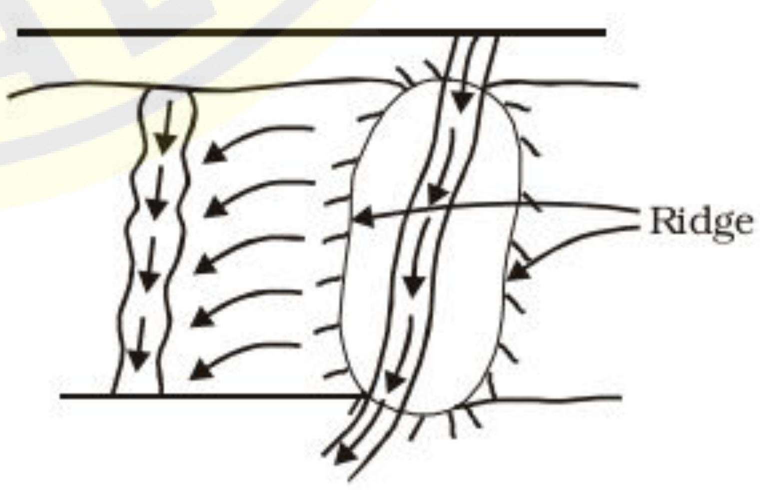


◆ The area draining into a river or stream is called the catchment area of that stream at a given location.

In U.S, catchment area is also called as watershed.

4. Ridge : It is the line which demarkets one catchment area from its neighbouring catchment area. This is also called as water divide, or divide.

In U.K. this is also called as water shed.



● **Water Budget Equation :**

This equation is based on law of conservation of mass. It states that, mass inflow and mass outflow is equal to change in storage.

Precipitation

◆ It denotes all forms of water, that reaches the earth surface from the atmosphere.

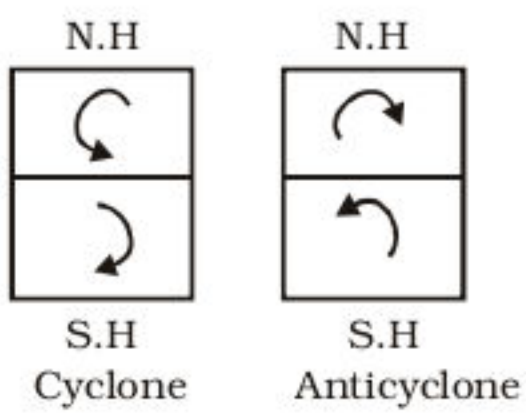
◆ Following are the different types of precipitate :

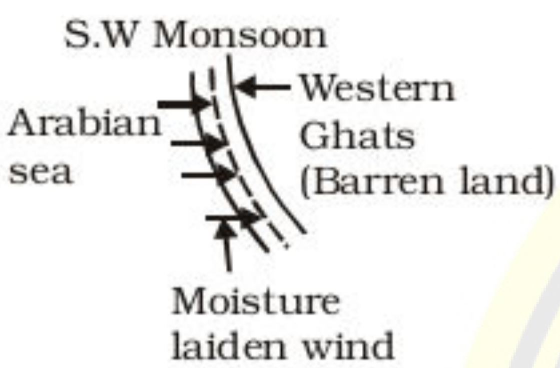
(i) Rain: This is the principle mode of precipitation in India. It denotes water droplets with diameter ranging 0.5 mm to 6 mm. On the basis of intensity, rainfall is classified as follow ;

(a) 0-2.5 mm/hour → Light

(b) 2.5 – 7.5 mm/hour → Moderate/Medium

(c) > 7.5 mm/hour → heavy





Heavy rainfall in India, earlier Cherapunji but now its Mawnsynram

- In India rainfall data is collected everyday at 8:30 am and if the rainfall is more than 2.5 mm then that day is called as a rainy day

- Average rainfall per year in India Book → (120 cm)
  According to present data → 150 to 105 cm
  Therefore, volume of rainfall in India = 120 cm × Area of India 3.3 mkm or 330 Mha.

(ii) Snow : These are ice crystals having a density of 0.1 gm/cc.

(iii) Drizzle : These are fine droplets of water whose size is less than 0.5 mm and intensity is less than 1 mm per hour.

(iv) Glaze : When droplets of water comes in contact with, cold ground surface [approximate at 0°C] then the water droplet is converted into ice which is called as Glaze.

(v) Sleet : These are frozen rain drops of transparent nature.

(vi) Hail : These are lumps of ice whose size is greater than 8mm.

As per international convection, the lump whose size is more than 5 mm is called hail whereas the lumps with size less than 5 mm is called Gravel.

Headquater of WMO : Geneva

Headquater of IME : New Delhi.

Note :

- Unit of cloud Measurement : Okta (1/8th)
  If sky is fully covered then it's 8 Okta
  If sky is fully 1/2 covered then it's 4 Okta
- In India, the dominant form of Rainfall is Orographic.

● **Average annual Rainfall**

- The amount of rain, collected by a rain gauge in last 24 hrs is called daily rainfall and the amount collected in one year is called annual rainfall.
  Average annual Rainfall is the average value of annual rainfall for the last 35 years.

● **Index of wettness**

- This index is used to find the rainfall variation or deviation for a given year. it is given as;

$$\text{Index of wettness} = \frac{\text{Rainfall in year}}{\text{Average Annual Rainfall}} \times 100$$

- Suppose in a particular year, India receives 90 cm rainfall. Then Index of wettness $= \frac{90}{120} \times 100 =$ 75%
  This Indicates that, rainfall deficiency is 25%
  if Rainfall deficiency is between :
  35 – 45 % : large deficiency
  45 – 60 % : Serious deficiency
  > 60% : disasterous deficiency
- If Index of wettness is 100% then it indicates that rainfall is normal monsoon.
- If Index of wettness >100%; it indicates a good year
- If Index of wettness <100%. It indicates a bad year

● Occurence of flood or drought are regional specific phenomena, and cannot be directly co-related with the Index of wettness of a country.

● **Drought**

- It is a climatic situation which is characterised by less availability of moisture.
- It can be further classified as follow;
  (a) Metrological Drought; denotes deficiency in precipitation. If the decrease in precipitation is greater than 25%, it is called as drought.

If deficiency	type of drought
25 – 50%	Moderate drought
> 50%	Server drought

- A particular year is called a drought year if area affected by drought is more than 20% of the total area of the country.
- If drought occurs in an area with a probability of 0.2 to 0.4, then that area is called drought prone area P€ (0.2 to 0.04).

If this P€ (> 0.4) then that area is called Chronically drought prone area.

About 33% of area of India comes under the category of drought prone area.

i.e approx ; 109 to 110 Mha

(b) Hydrologic drought; It denotes below average value of stream flow, water content in lakes, underground water, reservoir etc.

(c) Agricultural drought; it is characterised by less availability of water for the plants growth. It is expressed by a factor called as;

Aridity Index $0 < A.I < 100$

$$\text{Aridity Index} = \frac{PET - AET}{PET} \times 100\%$$

CW = PET → Potential Evapo-transpiration. It is the amount of water consumed by plants for its full growth if sufficient moisture is available. It is also called as consumptive use (cu).

AET → Actual Evapo-transpiration. It is the actual water consumed by plant, under the vailing conditions.

- If aridity Index is between;

  0 - 25 % : Mild Arid Region

  25-50 % : Moderate Arid Region

  > 50% : Severe Arid Region
- Apart from the above Index, certain other Indicies can also be used for finding the agricultural drought such as ;

  – Palmer Index

  – Moisture Availability Index

● Average Rainfall and Design of Rain gauge station;

- In order to find, average rainfall over a catchment, rainfall is measured at a number of rain gauge station which are suitably located.
- The network density of raingauge depends on :

(i) Magnitude of rainfall.

(ii) Topography of the region.

(iii) Desired level of accuracy.

● **MEASUREMENT OF RAINFALL :**

- Rainfall is expressed in terms of depth to which water would stand on the area if all the rain water is to be collected on it.
- Rainfall is measured by an instrument called as rain gauge, which is also called as;

  – Pluniometer.

  – Ombro meter.

  – Hyeto meter.

  – Vdometer.
- A Rain Gauge essentially consists of a cylindrical vessel assembly which is kept in the open to collect rain water.
- Following are the requirements which are to be satisfied for installing a rain gauge

(i) The rain gauge must be surrounded by an open force area. with size of atleast (5.5 × 5.5)m

(ii) It must be kept at a distance of atleast 30 m or 2 times the height of building or obstruction.

(iii) It must be installed on level ground surface which is free from undulations.

- Rain gauges can be broadly classified under 2 heads.

(a) NON - RECORDING RAIN GAUGE :

- **It measures but do not records.**

  This basically consists of the cylindrical vessel whose area is known and which is having graduations.

  In India the most commonly used non-recording R.G is the Symon's R.G which has a collecting diameter of 127 mm or 5 inch.

  Recently, IMD has switched over to the used of fibre glass reinforced polyster type R.G which comes in two variants having collecting area of 100 cm^2 and 200 cm^2

(b) RECORDING RAIN GAUGE :

This type of rain gauage produces a continuous rainfall variation against time. Using this data. the total accumulated rainfall v/s time curve and the rainfall intensity v/s time curve can also be plotted.

● Typical examples, of this type of Raingauge includes.

– Tipping Bucket (does not produce a mass curve of precipitate)– weighing Bucket

– Float type

In India, the most commonly used recording type raingauage is the (float type R.G) [Natural syphon type].

The latest improvements in raingauge technology is as follows :

Telemetering Raingauage: This is basically a recording type Raingauage which contains an electronic unit. So as to transfer rainfall data to the base states.

Thus, this type of Rain gauge, can be used for remote and inaccessible locations.

Radar technology : This is used to find the aerial extent locations and movement of rainstorms. Rainfall over a large area can be measured with good accuracy.

Meterological Radars, operate at a wavelength range of 3 to 10 cm. For heavy rainfall, 10 cm of the wavelength is to be used, whereas for light rainfall and snow, 3 cm wavelength is to be used.

Raingauge Network :

- For analysing rainstorm, finding peak flood discharge, forcasting flood and drought, a proper distribution of Raingauge station is necessary at most suitable places.
- Following are the recommendations of WMO regarding the density of Raingauge.

(i) For flat regions of Temperate, tropical and mediterranean : 1 station/600-900 km^2 zones.

(ii) For mountain region of temperate, tropical and mediterrcan zones : 1 Station/100-250 km^2.

(iii) For arid and polar region : 1 station/ 1500 - 10,000 km^2.

- **IS - Recommendations :**

(i) for Plain Regions : 1 Station/ 520 km^2

(ii) for Regions having average elevation : 1 Station/ 260-390 km^2 of 1000m

(iii) for hilly Region with heavy rainfall : 1 station/ 130 km^2.

As per actual data available, India is having a raingauge density of 1 station/600 km^2.

Israel is the country having maximum density of rain gauge stations. 37 station/1000 km^2

Out of the total number of raingauges, approximately 10% is maintained by /MD where as the others are maintained by independent agencies such as Railway, Airport Authority of India, NHAI and other state government departments.

Note : As per recommendation of WMO atleast 10% of the rain gauges should be of recording types.

Optimum Number of Raingauges;

This can be calculated on the basis of allowable percentage error and the variation or deviation in the available Rainfall Data, If N is the optimum number of Raingauge.

Then ;
$$N = \left(\frac{Cv}{\epsilon}\right)^2$$

$$\overline{X} = \frac{xi}{n}$$

$$\sigma = \sqrt{\frac{\Sigma(x-\overline{x})^2}{n-1}}$$

Where, CV = Co-efficient of variation

$$= \frac{}{\overline{X}} \times 100$$

ϵ = allowable percent error

The value of CV usually lies between 15-70 and in most of the cases, this value is close to 30.

The above method of finding the number of gauge is purely statistical.

- **ESTIMATION OF MISSING RAINFALL DATA :**

- If on a particular day, month or year, the data at station x, could not be recorded and it is required to find an approximate value of this missing data, then the following method is to be adopted.

Method :

- Few stations close to the problematic station x are selected and the rainfall values at these station are recorded as P_1, P_2, P_3, ... P_m

P_x is the missing value of rainfall data at the station x which has to be approximately calculated.

- Let N_1, N_2, N_3 .... N_m and so on be the normal annual rainfall values for the station 1 to m and X.

Normal precipitate or Rainfall is the average value of precipitate for a particular day, month or year (or any other time Interval on the basis of recorded deta of the last 30 years).

P_x can be calculated by one of the following methods

Case 1 ;

When N_1, N_2, N_3, ... N_m differs from N_x by less than 10% then

$$P_x = \frac{P_1 \quad P_2 \quad P_3 \; \ldots\ldots \; P_m}{m}$$

Case 2 ;

When one or more of N_1, N_2, N_3 .... Nm differs from Nx by > 10% then

$$P_x = \frac{N_x}{m}\left[\frac{P_1}{N_1} \quad \frac{P_2}{N_2} \quad \ldots\ldots \quad \frac{P_m}{N_m}\right]$$

Method 2 : Inverse Distance Method;

This method is also known as U.S service method . It is considered to be the most appropriate method for scientific analysis.

$$P_x = \frac{P_i w_i}{w_i}$$

W_i = weightage of station

$$= \frac{1}{d_1^2} = \frac{1}{\left(\sqrt{x_1^2 \quad y_1^2}\right)} = \frac{1}{\sqrt{(x_1-x)^2 \quad (y_1-y)^2}}$$

SNOWFALL

- It is inform of ice crystal, having a density of 0.1 gm/cc i.e., they are light than water.

Analy sis of show full talks about:

1. **Snow stakes :** This is a permanent graduated post which is used for measuring the depth of snow.
2. **Snow Boards :** This is a side square board, which is used to collect snow sample.

   Note : The water equivalent of snow is taken as approx. 10%.
3. **Water equivalent of snow :** It can be obtained in the following ways :

   Snow gauge : This is a large cylindrical receiver, having a diameter of 203 mm used for collecting the snow.

   Snow Tubes : This is a set of telescopic metal tube with side ranging from 40 mm to 90 mm.

- Evaporation loss can be reduced to a minimum if a film pressure commonly known as of 0.04 N/m is maintained.

- Through experiments, it has been observed that evaporation can be controlled upto 60% by using ethyl alcohol. In field condition it is 20 to 50% in evaporation Rate.
  The maximum reduction can be achieved in small size lake whose area is ≤ 1000 Hectare.

- **Method of determining Evaporation :**

(i) Class A Evaporation Pan :
It is the pan, that has been developed by U.S weather Bureau. It has
diameter → 1210 mm and depth → 255 mm
In case of persistent corrossion, Monel metal is used

(ii) ISI Standard Pan :
This is a modified form of Class A evaporation Pan in which the diameter is 1220 mm and depth is 255 mm
This pan is made of copper sheet having a thickness of 0.9 mm. Top of the Pan is fully covered with a hexagonal wire netting in order to prevent the water from any disturbance and to ensure that uniform temperature is maintained during day and night time.

3. Colorado sunken pan :
- The main advantage of this pan is to create actual radiation and aerodynamic condition.
- In order to convert, Pan evaporation values into lake evaporation, a pan co-efficient is used as
  Lake Evaporation = C_p × Pan Evaporation

Note :
1. Apart from the above mentioned pan, another type of Pan can also be used to find the evaporation which is U.S Geological survey floating Pan.
2. That is made to float in water so as to create actual field condition. The value of C_p = 0.8 for this Pan is however not used very frequently as its installation cost is very high

Note :
At Present India has about 220 Pan evaporation station maintained by IMD.

4. Empirical Method :
This method is based on Dalton's law and the equation so developed is called Meyer's equation.

$$E = k_m(e_w - e_a)\left(1 \quad \frac{V_q}{16}\right)$$

Where,
E = Rate of Evaporation Per day
e_w = Saturated Vapour (mm of Hg) Pressure measured in N/m^2
e_a = actual vapour pressure or vapour Pressure of air
V_q = month mean wind velocity in km/hr at a height of about 9m from the ground.
km = Constant which depends on the size of water body

km	type of water body
0.36	deep
0.5	Shallow

Note : If wind velocity follows the $\left(\frac{1}{7}\right)^{th}$ Power law then velocity is given as :
at a height (h) $V_n = C_n^{1/7}$
Acetyle alcohol is found to be the most suitable chemical for use as an evaporation inhibitor.

- Apart from the above methods, certain other methods can also be used for finding the evaporation such as (i) Water Budget Equation
  (ii) Energy balance approach
  (iii) Mass transfer

Transpiration : It's a process that refers to loss of water from plant suface in form of vapour.
Transpiration takes place along with evaporation of water from the soil and other water bodies. and hence, these two terms are considered advantageously in the form of 1 single factor which is called as Evapo-transpiration.
Evapo-transpiration is a direct measure of the water required by plant during its growth period and hence it is also called as consumptive use. (Cu).
Following methods may be used in order to find the evapo-transpiration.
→ Lysimeter → field plot → Penman's equation
↓

Blaney Giddel equation This is an empirical equation used extensively by irrigation Energy	This method makes use of Energy balance and mass transfer approach.

Note : Imaginary lines joining all the points, having same value of evapo-transpiration are called canal lines.

- In India, the highest PET is recorded for Rajkot (Gujrat) : 214.5 cm
- Evaporation is an on going process which continues all through day and night (although the rates are different) whereas transpiration is essentially confined to day light hours.

Stream Flow Measurement

- In the science and practise of water measurement stream flow measurement is called hydroneetry. Among the different phases of hydrological cycle, stream flow is the only part that can be measured accurately.
  Stage : This is defined as the water surface elevation measured above datum. This datum could be mean sea level or any other fixed value.
  (Mean Sea level → earlier (Karachi)
  Now (Mumbai)
  The Process of measurement of scales is called ganging.

The mean sea level of Bay of Bengal is slightly higher than mean sea level of Arabian sea.

◆ Following ganges may be used in order to find the stage.

To calculate the discharge of the river or water body, we need to draw stage-discharge curve (G - Q curve) or Rating Curve before we measure.

(i) **Staff Gange :** This is the graduated staff which is rigidly fixed to the pier or abutment of a bridge.

(ii) **Wire Gange:**

This is used for measurement of water surface elevation from above the surface of water such as from a bridge or any other suitable location.

◆ The above two gange of stage measurements are mannual gange

(iii) **Float Gange :**

This is the most commonly used automatic stage recorder. In this type of Gauge stilling well is provided in order to prevent enteries of debris and the neglecting of the curve effect.

4. Bubble Gange : Here assumption is taken as the bubble p(know) (moves)

◆ **Q (Discharge Measurement) :**

In order to find the dischage of a steam velocity is required which can be measured using the following method :

◆ **Float :** This is a floating device which is passed along the water surface.

This method gives the approximate velocity of water on River Surface.

◆ The movement of this float is affected by external factor such as wind etc. and hence, certain Improvements have been suggested in the convention float such as.

(a) Canister float;

(b) Road float.

◆ The average velocity in the river or stream can be calculated by the following methods.

(i) $V_{average} = V_0.6y \rightarrow$ for shallow

(ii) $V_{average} = \dfrac{V_{0.2y} \quad V_{0.6y}}{2} \rightarrow$ for deep

◆ for flashy rivers and in flood like situation

$V_{average} = K.Vs$

$K = 0.85$ to 0.95

$$V_{average} = \frac{Q_{avg}}{A} = \frac{\int V.dA}{\int dA}$$

● **Current Meter :**

It consists of a rotating element that rotates as per reaction due to stream. The no of rotations made by the current meter is used to find the value of RPS $\rightarrow$ Rotation Per second

$V = aNs + b$

The above is characteristic equation in current meter where a and b characteristic are constants.

There are basically two types of current meter :

(i) Vertical Axis current Meter :

This has vertical axis on which a rotating disc is mounted.

Its major disadvantage is that it can be used in that situations where there is an appreciable inclined flow.

Typical examples of this type of current meter – Price C.m and - Gurley C.M

(ii) Horizontal Axis current meter :

These type of current meters are fairly rugged and are not affected by inclined flow upto 15°

Typical example of this type of current meter includes - Ott c,m – Neytitec c.m and watt C.m

Note :

Calibration of a current meter is done by using a flowing tank

This is a standard weight which is attached to the current meter in order to keep the current meter at a fixed location. In order to reduce the drag force, these are stream line in shape.

∴ Constants a and b are calculated using V_1 and NS_1 and V_2 and NS_2.

Runoff : It is the fraction of precipitation which flows through the surface and subsurface and finally joins the still water bodies.

Runoff has following constituents :

1. Overland flow or surface runoff
2. Subsurface flow or seepage flow or interflow or thorough flow or quick return flow.

The inter flow is some times classified in to prompt (inter flow with the least time lag) and delayed interflow.

Type of Record : Based on time lag of runoff, it can be :

1. Direct runoff
2. Base flow

Direct runoff = Total runoff – Base flow

1. Direct runoff : This part of runoff enters the stream immediately after the precipitation. It includes surface runoff, prompt interflow and precipitation on the channel surface.

2. Base flow : The delayed flow that reaches a stream essential as ground water flow is called base flow.

HYDROGRAPH

It is a graphical representation of discharge with time at a given point on the stream. Some important points associated with hydrograph are as follow :

Portion AB : It is called Rising limb and its shape depends on catchment as well as storm characteristic. It is also known as concentration curve.

Portion CD is called Falling limb and its shape depends on catchment characteristic only.

- T_A is the duration of the Rainfall
- T_C is called as the lag time
- It is the time interval between the Centre of mass of Rainfall and the Centre of mass of hydrograph.
- T_B is the Base time
- The point C corresponds to the point of maximum storage.
- Shape of falling limb is given by the equation

$Q_t = Q_o.e^{-at}$

∴ (Its a falling Exponential curve)

- The different factors affecting the shape of a hydrograph are as follows :

(i) Shape of the Catchment :

It influences the time taken by a water particle in reaching the outlet from the farthest point of the catchment and hence it influences the time after which Peak discharge is attained.

- Some other factors based on shape are as follows :

(a) FORM FACTOR : It is defined as the rates of average width of the basin to the axial length.

$$\therefore \text{ Form factor} = \frac{B_{average}}{L_{axial}}$$

∴ If form factor is more, then peak discharge value will be more.

Keep (L_{axial} = const.) if B is more then area is more and so peak is more.

(b) COMPACTNESS COEFFICIENT :

This is defined as the ratios of perimeter of the basin to the perimeter of a circle whose area is same as that of the basin.

$$\therefore \text{ Compactness Co-efficient} = \sqrt[2]{A}$$

(ii) Stream Density :

This is defined as the, no of streams per unit area of the catchment.

$$\text{Stream Density} = \frac{N_s}{A} \text{ [Keeping Area const.]}$$

(iii) Drainage Density :

This is defined as the total length of the stream per unit area of the catchment.

(iv) Size of catchment :

Peak discharge varies with catchment according to following relation :

$Q_p \propto A^n$

Where, n is an exponent whose value is generally less than 1

Few other Factors :

- ✶ Slope of Catchment
- ✶ Direction of strom
- ✶ Rainfall Intensity
- ✶ Soil moisture condition
- ✶ Land use Pattern.

- Area under hydrograph gives volume of the Rainfall.

  If Rainfall is constant and Peak discharge is increasing then Base time will decrease.

  K(Co-efficient of Runoff) will be more in Urban Area than rural area.

● **Determination of Runoff :**

Following methods may be used :

(i) Rational equation method
(ii) Emperical equation
(iii) use of unit hydrograph
(iv) use of Infilteration curve
(iv) use of co-efficient of Runoff
(v) Rainfall Relation Runoff

(iv) Rainfall Relation Runoff :

This is a statistical method in which a co-relation equation is established between Runoff and Precipitation.

$R = ab + b$

$\Sigma(\text{distance})^2$ minimum (method of least square)

$$\therefore a = \frac{n\Sigma PR - \Sigma P \Sigma R}{n\Sigma p_2 - (\Sigma p)^2}$$

$$b = \frac{\Sigma R - a\Sigma P}{n}$$

$\Sigma R = a\Sigma p + \Sigma b$ ....(1)

$\Sigma RP = a\Sigma p^2 + \Sigma P$ ....(2)

(Solve equation (1) and (2) gives b and a value)

Unit Hydrograph :

It is a DRH that gives a runoff depth of 1 cm. This 1 cm could be some other unit value also, for exmaple : (1 mm), (1 Inches) etc. for a rainfall of same unit duration.

Unit Duration :

It means the duration Rainfall which produces a unit Hydrograph.

Example : AD hr UH indicates a DRH resulting in a Runoff depth of 1 cm. from a storm or Rainfall which lasts for unit duration This Dhr is called as the unit duration of the Unit hydrograph.

● **Theory of Unit Hydrograph :**

- This theory was proposed by SHERMAN in 1932. It has the following basic assumptions;

(i) Time Invariance :

According to this assumption, the DRH for a given effective rainfall is always the same in the catchment, irrespective of the time, when rainfall or storm takes place.

(ii) Linear Response :

This is the single most important assumption in the theory of UH. Accorting to this assumption, any change in the input value is proportionately reflected in the output value.

- Peak of 2hrs will be more than 4 hr. [As area under curve is same and time is on increases so].

From above two basic assumptions, there are certain implicit assumption the theory of Unit HYDROGRAPH,has:

(1) The Rainfall is uniformaly distributed over the whole catchment.

(2) The intensity of excess rainfall is assumed to be constant for the duration of rainfall.

∴ In Dhr. UH

Then, rainfall intensity = $\left(\frac{1}{D}\right)$ cm/hr

or, if R.I = x

then $x \times D = 1$ cm

(2) Runoff is only from rainfall and not from snowfall.

Note : Both DRH and ERH (Excess Rainfall Hydrograph) represent the same quantity but in different units.

- **LIMITATIONS OF THEORY OF HYDROGRAPH :**

(1) It is only applicable for a moderate size catchment whose area is less than 5000 km^2 (500000 hectares).

(2) It cannot be applied to those catchment whose area is less than 2 km^2/200 hectares.

- **APPLICATION OF U.H :**

(i) CONSTRUCTION OF FLOOD HYDROGRAPH;

- Suppose a flood hydrograph gives a runoff depth of n cm from a rainfall of the same 4 hr duration.
- For this the ordinates of 4 hr UH. are multiplied by 'n' in order to obtain a DRH of 4 hr. Rainfall giving a runoff depth of n cm.

To this add the Baseflow in order to obtain the required flood hydrograph.

(ii) CONSTRUCTION OF OTHER UNITHYDROGRAPH FROM A GIVEN UH.

Case 1 : When $t_o = nT_o$

T_o = Given duration of UH

t_o = duration required

n = (+ve) integer

- The given UH of T_o duration is lagged and superimposed in such a way so as obtain a DRH of (t_o) duration. This DRH is then divided by the Runoff depth in order to obtain the UH of (T_o).

WELLS:-

A water well is a hole usually vertical, excavated in the earth for bringing ground water to the surface. The well may be classified into two types:-

(i) open well; and

(ii) Tube well:

(i) **Open well or Dug wells** :

Open wells are generally open masonry wells, having comparatively bigger diameters and are suitable for low discharges of the order of 1-5 litres per second. The depth of open wells are generally less then 20m.

The yield of open well is limited because such wells can be excavated only to a limited depth where the ground water storage is also limited.

Moreover in such a well, the water can be withdrawn only at the critical velocity depending on type of soil. Higher velocitites cannot be permitted as that may lead to disturbance of soil grains and consequent subsidence of the well lining in the hollow so formed.

Yield of an open well:- The yield of an open well can be determined in the field by performing either of the following two types of pumping tests (i) Equilibrium pumping test, (ii) recuperating test

Equilibrium pumping test:-

A pump is first installed so as to draw sufficient supplies of water from open well and to cause heavy drawdown down fall in its water level. The rate of pumping is then charged and so adjusted that the water level in the well become constant. In this condition of equilibrium, the rate of pumping will be equal to the rate of yield of the well at a particular drawdown. knowing this yield say Q_1at a certain known drawdown, say S_1, the yield (Q) at any given drawdown (S) can be evaluated as follows:-

By Darcy's law, $Q = K.I.A = K.\frac{S}{L}\ A = \frac{K}{L}.S.A$

or Q = C.A.S, where 'S' is the depression head or drawdown in the well.

If Q_1 is the known discharge at a certain known drawdown S_1, We have

Q_1= C.A. S_1

Q_1 and S_1 are known and 'A' is the area of cross-section of the well. In case a cavity is formed, the area 'A' is taken as 4/3 times the actual cross-sectional area of the bottom of the well. knowing Q_1, A and S_1in equation above, the value of 'C' can be calculated. Hence, the discharge Q at any other value of depression head (s) can be easily worked out.

Velocity increases with the depression head (s). The Value of 'S' for which the velocity becomes equal to the critical value is called the critical depression head. Generally the depression head is kept equal to 1/3 times the critical depression head and such a head is known as the working head.

Hence, the maximum yield or critical yield corresponds to the critical depression head, and the maximum safe yield corresponds to working head.

Recuperating test :

Athough the pumping test gives accurate value of the safe yield, it sometime become very difficult to adjust the rate of pumping, so as to keep the well water level constant. In such circumstances, recuperating test is adopted.

In this method, water is first of all drained out from the well at a fast rate so as to cause sufficient drawdown. The pumping is then stopped.The water level in the well will start rising.

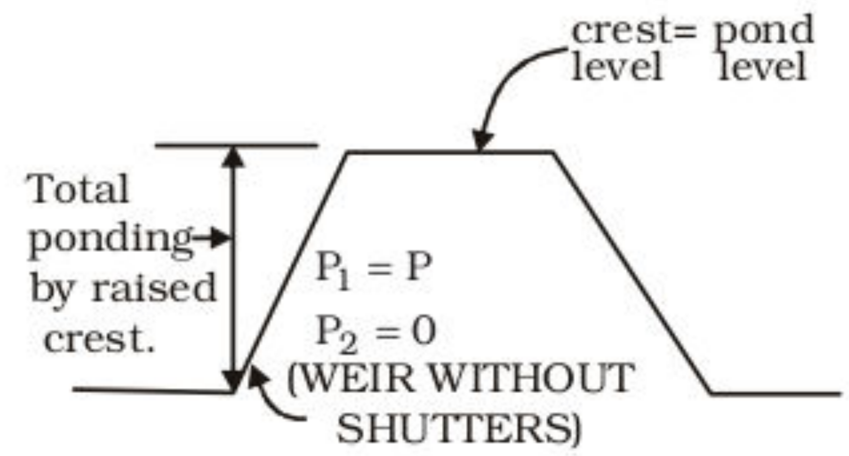
Discharge can be worked out by the formula:-

$$Q = \left(\frac{C^1}{A}\right)A.S \quad \text{or} \quad Q = \left(\frac{2.3}{T}\log_{10}\frac{S_1}{S_2}\right)A.S.$$

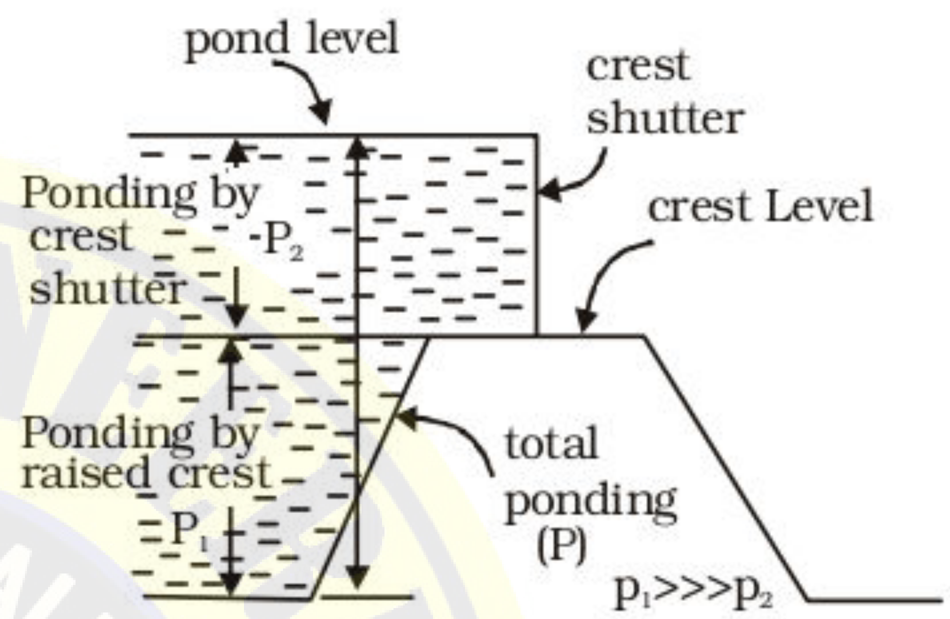
WEIR AND BARRAGE:

The main permanent canal, forming the primary part of a direct irrigation scheme takes off from a diversion weir or barrage. In fact these permanent canals take off from rivers and the arrangements are so well made at their heads that a constant and a continuous water supply is ensured into the canal, even during the periods of low flow. The works, which are constructed at the heads of the canal in order to divert the river water towards the canal, so as to ensure a regulated continuous supply of silt-free water with a certain minimum heads into the canal are known as Diversion Head works.

In general above purpose can be accomplished by constructing a barrier across a river, so as to raise the water level on the upstream side of the obstruction and thus to feed the main canals taking off from its upstream side at one or both of its flanks. The ponding of water can be acheived either only by a permanent pucca raised crest across the river or by a raised crest supplemented by falling counter -balanced gates or shutters working over the crest. If the major part or the entire ponding of water is achieved by a raised crest or nil part of it is achieved by the shutters,then this barrier is known as a weir [fig$_1$(a)] & [fig$_1$(b)].On the other hand, if most of ponding is done by gates and a smaller or nil part of it is done by the raised crest then the barrier is known as a Barrage or a River Regulator. [fig2(a) & 2(b)].

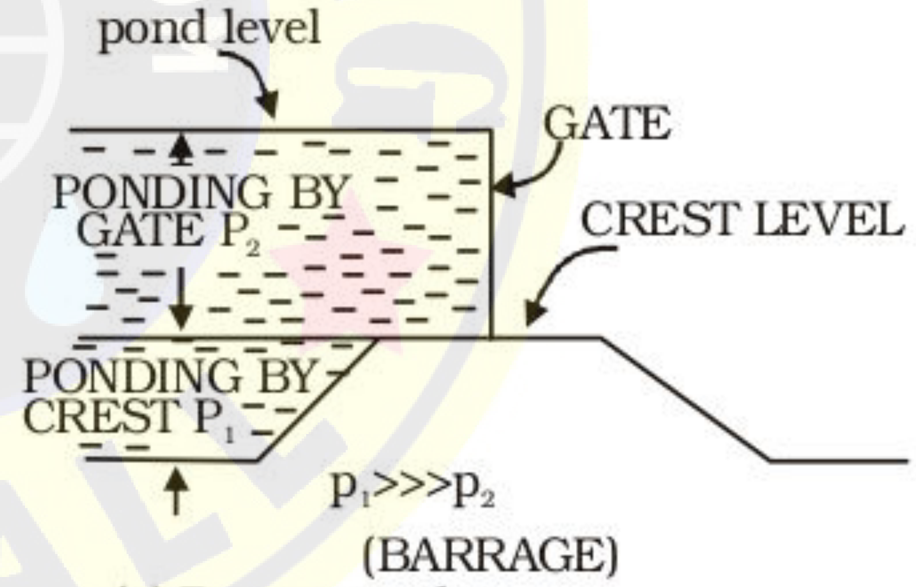


(a) Weir without shutters.

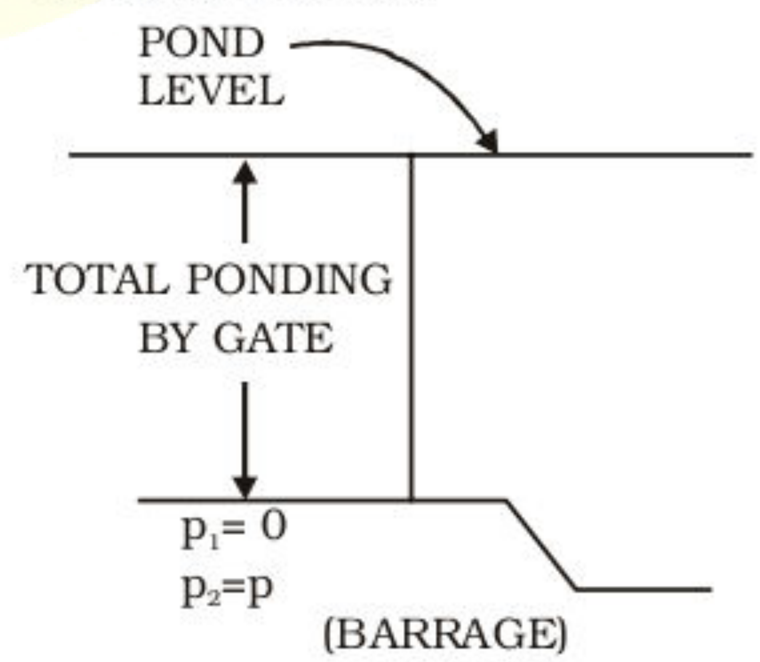


(b) Weir with shutter.

Fig 1



(a) Barrage with a small raised crest.



(b)Barrage without any raised crest.

Fig2

FAILURE OF WEIRS AND PERMEABLE FOUNDATION :

Hydraulic structures such as dams, weirs, barrages, head regulators, cross drainage works etc, may either be founded on an impervious solid rock foundation or on a pervious foundation. Whenever such a structure is founded on a pervious foundation, it is subjected to seepage of water beneath the structure in addition to all other forces to which it will be subjected to when founded on an impervious rock foundation. The water seeping below the body of the hydraulic structure, endangers the stability of the structure and may cause its failure either by:-

(i) piping,or by (ii) Direct uplift

(i) **Failure by piping or underminding** :

When the seepage water retains sufficient residual force at the emerging downstream end of work, it may lift up the soil particles. This leads to increased porosity of soil by progressive removal of soil from beneath the foundation. The structure may ultimately subside into the hollow so formed resulting in failure of structure.

(ii) **Failure by Direct uplift**:-The water seeping below the structure exerts an uplift pressure on the floor of the structure. If the pressure is not counter-balanced by the weight of the concrete or masonry floor, the structure may fail by a rupture of a part of the floor.

SILT AND SCOUR :

Most of the silt tries to settle down in water, thus confining itself mostly in the bottom layer of water silt. It is kept in suspension by the force of the vertical eddies generated by the friction is of the flowing water against the bed. The entry of silt into a canal, which takes off from a Head-works, can be reduced by constructing certain special works called silt control works.

These works may be classified into the following two types:-

(a) **Silt Excluders** :- These are constructed on the bed of the river, upstream of the head regulator.

(b) **Silt Ejectors**:- Silt ejectors,also called silt extractors, are devices used to extract the silt from the canal-water after the silted water has travelled a certain distance in the off-take canal.

Scour is the removal by hydrodynamic forces of granular bed material in the vicinity of coastal structures.

FLOOD:- A flood is an unusually high stage in a river, normally the level at which the river overflows its banks and inundates the adjoining area. The hydrograph of extreme floods and stages corresponding to flood peaks provide valuable data for purpose of hydrologic design.

Causes and effects of flood:-

Floods are caused by many things. One of these is when water exceeds the capacity of the area it is in, thus causing it to overflow outside the water's boundary. One more way of flooding is when dam break. Massive dams that hold water back prevent flooding. When the gate breaks, the water flows out of it and creates a flood.

The effects of floods are devasting.Many times flood can destroy everything. Floods adversely affect environmental and economical situations. When flood occur, there is a large amount of water that runs over the ground.

FLOOD CONTROL:- The term flood control is commonly used to denote all the measure adopted to reduce damage to life and property by floods.The flood control method that are in use can be classified as:-

(1) **Structural measures**:-

(a) Storage and detention reservoirs

(b) Levees (flood embankments)

(c) Flood ways (new channel)

(d) Watershed management.

(2) Non-Structural methods:-

(a) Flood plain zoning

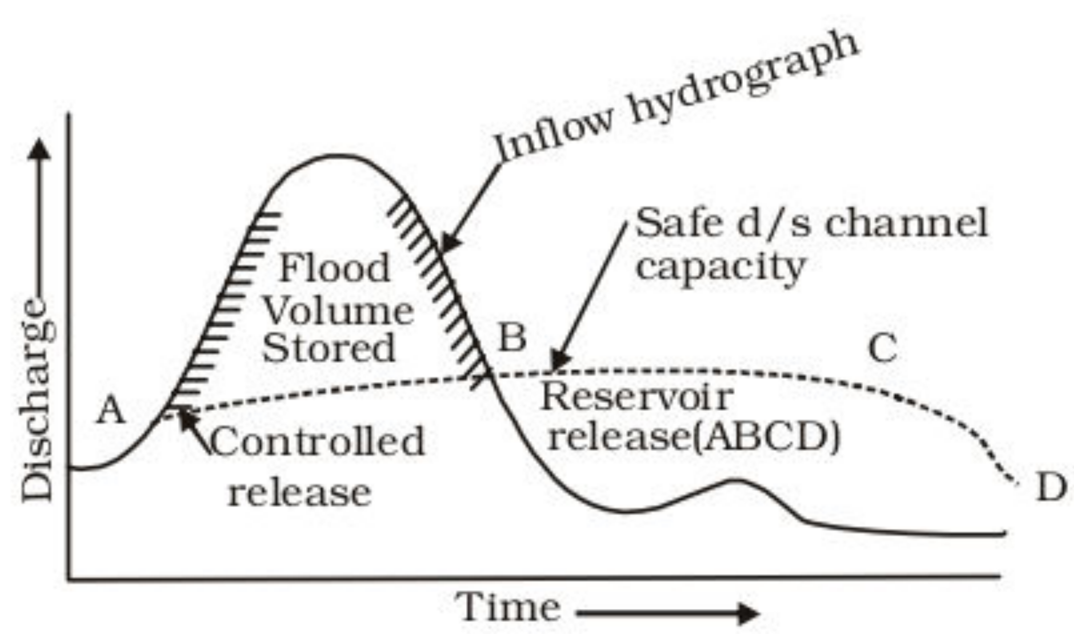
(b) Flood forecast/warning

(c) Evacuation and relocation

(d) Flood insurance.

(1) **STRUCTURAL, METHOD:-**

STORAGE RESERVOIRS:- If offers one of the most reliable and effective methods of flood control. Ideally in this method, a part of the storage in the reservoir is kept apart to absorb the in coming flood. Further, the stored water is released in a controlled way over an extended time so that downstream channel donot get flooded. Fig. shows an ideal operating plan of a flood control reservoir.



DETENTION RESERVOIR:- This reservoir consists of an obstruction to a river with an uncontrolled outlet. These are essentially small structures and operates to reduce the flood peak by providing temporary storage and by restriction of the outflow rate. These structure are not common in India.

LEVEES:- Levees also known as dikes or flood embankments are earthen banks constructed parallel to the course of the river to confine it to a fixed course and limited cross-sectional width. The height of levees will be higher than the design flood level with sufficient free board. The confinement of the river to a fixed path frees large tracts of land from inundation and consequent damage.

Levees are one of the oldest and most common method of flood-protection works adopted in the world. Also, they are probably the cheapest of structural flood-control measures.

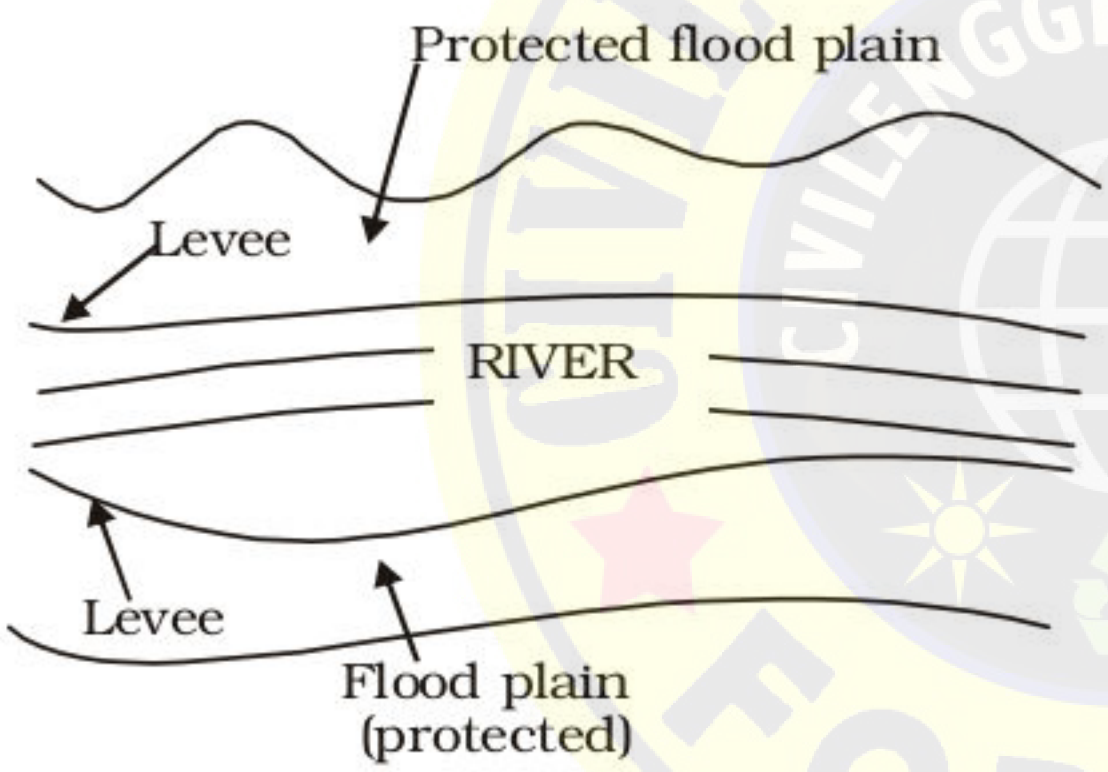


Fig:- A typical levee : Plan (Schematic).

FLOODWAYS:-Floodways are natural channels into which a part of the flood will be diverted druing high stages. A flood way can be a natural or man-made channel and its location is controlled essentially by the topography. Generally wherever they are feasible, floodways offer an economical alternative to other structural flood-control measures. To reduce the level to the river Jhelum at Srinagar, a supplementary channel has been costructed to act as a floodway with a capacity of $300 m^3/s$.

CHANNEL IMPROVEMENT:-The works under this category involves:-

(i) Widening or deepening of the channel to increase the cross-sectional area.

(ii) Reduction of the channel roughness, by clearing of vegetation from the channel perimeter.

(iii) Short circuiting of meander loops by cut off channels.

WATERSHED MANAGEMENT:- Watershed management and land treatment in the catchment aims at cutting down and detlaying the runoff before it gets into the river. Watershed management measures include developing the vegetative and soil cover in conjuction with land treatment works like Nala,bunds,check dams, contour bunding, zing terraces etc.

(2) **NON-STRUCTURAL METHODS**:- The flood managment strategy has to include the philosophy of liviing with the floods. The following non-structural measures encompass this aspect.

FLOOD PLAIN ZONING:- When the river discharges are very high, it is to be expected that the river will overflow its banks and spill into flood plains. Flood plain management identifies the flood prone areas of a river and regulates the land use to restrict the damage due to floods.

FLOOD INSURANCE:- Flood insurance provides a mechanism for spreading the loss over large numbers of individuals and thus modifies the impact of loss burden.Further it helps, though indirectly, flood plain zoning,flood forecasting and disaster preparedness activities help reduce the possible loss.

FLOOD CONTROL IN INDIA:-

In India the Himalayan rivers account for nearly 60% of the flood damage in the country. Floods in these rivers occur during monsoon months and usually in the months of August or September. On an average about 7.5 Mha land is affected by flood annually. Out of this, about 3.5 Mha are lands under crops.

Flood forecasting is handled by CWC in close collaboration with the IMD which lends meterological data support.

WATER LOGGING :

An agricultural land is said to be water-logged when its productivity gets affected by the high watertable. The productivity of land infact, gets affected when the root zone of the plants gets flooded with water, and thus become ill -aerated.Ill aeration affects roof growth, hence, reduces crop yield.

Causes of water-logging:-

(i) **Over and intensive Irrigation:-** When a policy of intensive irrigation is adopted, the maximum irrigable area of small region is irrigated. This leads to, too much of irrgation in that region, resulting in heavy percolation and subsequent rise of watertable.

(ii) Seepage of water from the adjoining high lands.

(iii) Seepage of water through canals.

(iv) **Impervious obstruction:-** Water seeping below the soil moves horizontally (i.e,laterally) but may find an impervious obstruction, causing the rise of watertable on the upstream side of the obstruction. Similarly, an impervious stratum may occur below the top layers of pervious soil. In such cases, water seeping through the pervious soils will not be able to go deep, and hence quickly resulting in high watertable.

(v) Inadequate Natural Drainage

(vi) Inadequate Surface Drainage.

(vii) Excessive Rains

(viii) Submergence due to floods

(ix) Irregular or Flat Topography.

Water-logging control:-

It is evident that water-logging can be controlled only if the quantity of water into the soil below is checked and reduced. To achieve this, the inflow of water into the underground reservoir should be reduced and the outflow from this reservoir should be incerased as to keep the highest position of water table at least about 3m below the ground surface. The various measures adopted for controlling water-logging are enumerated below:-

(i) Lining of canals and water courses.

(ii) Reducing the intensity of irrigation.

(iii) By introducing crop-rotation.

(iv) By optimum use of water

(v) By providing intercepting drains.

(vi) By provision of an efficient drainage system.

(vii) By Improving the natural drainage of the a area.

(viii) By adopting consumptive use of surface and subsurface water.

LAND RECLAMATION:-

Land reclamation is a process by which an un cultivable land is made fit for cultivation. Saline and water logged lands gives very less crop yields and are, therefore almost unfit for cultivation, unless they are reclaimed.

Every agricultural soil contains certain mineral salt in it. Some of these salts are beneficial while certain others prove injurious to plant growth. These injurious salts are called alkali salts and their common examples are Na_2CO_3, Na_2SO_4 and Nacl.

Na_2CO_3 or black alkali is the most harmful and NaCl is the least harmful.These salts are soluble in water.

If the water table rises up, or if the plants roots happen to come within the capillary fringe, water from the watertable start flowing upward. The soluble alkali salts also move up with water and get deposited in the soil within the plant roots as well as on the surface of the land. This phenomena of salt coming up in solution and forming a thin (5 to 7.5 cm) crust on the surface,after the evaporation of water is called effeorescence. Land affected by effeorescence is called saline soil. The salty water surrounding the roots of the plants reduces the osmotic activity of the plants.

Reclamation of salt affected lands:- Effeorescence can be avoided if the watertable is maintained sufficiently (about 3m) below the roots so that the capillary water is not able to reach the root zone of the plant. Hence, all these measures which were suggested for preventing water logging hold good for preventing salinity of land also.

An efficent drainage system consisting of surface drains as well as sub-surface drains must be provided in order to control and lower the watertable in saline lands. After the high watertable has been lowered by suitable drainage, the soil is freed from the existing salts by process,called leaching.

MAJOR IRRIGATION PROJECTS IN INDIA:-

The methods of irrgation used in india can be broadly classified into major,medium and minor irrigation scheme. Irrigation projects having culturable command area(CCA) of more than 10,000 hectares each are classified as major projects.

Those having a CCA between 2,000 hectares and 10,000 hectares fall under the category of medium irrigation projects. And the projects which have a CCA of less than 2,000 hectares are classified as minor irrigation projects.

□□□