
UNIT-1
Crop Water
Requirement
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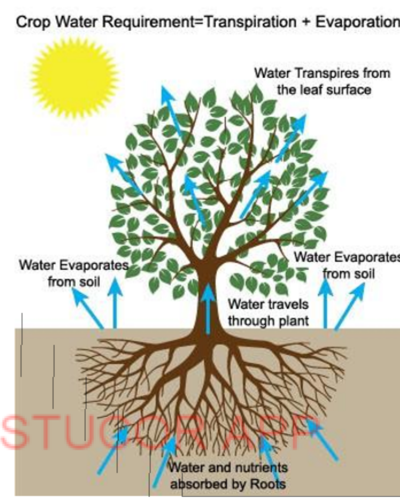
CE8603- Irrigation Engineering

UNIT-1

CROP WATER REQUIREMENT

Need and classification of irrigation- historical development and merits and demerits of irrigation- types of crops-crop season-duty, delta and base period- consumptive use of crops- estimation of Evapotranspiration using experimental and theoretical methods.



Irrigation- Definition

- Irrigation is an artificial application of water to the soil.
- It is usually used to assist the growing of crops in dry areas and during periods of inadequate rainfall.

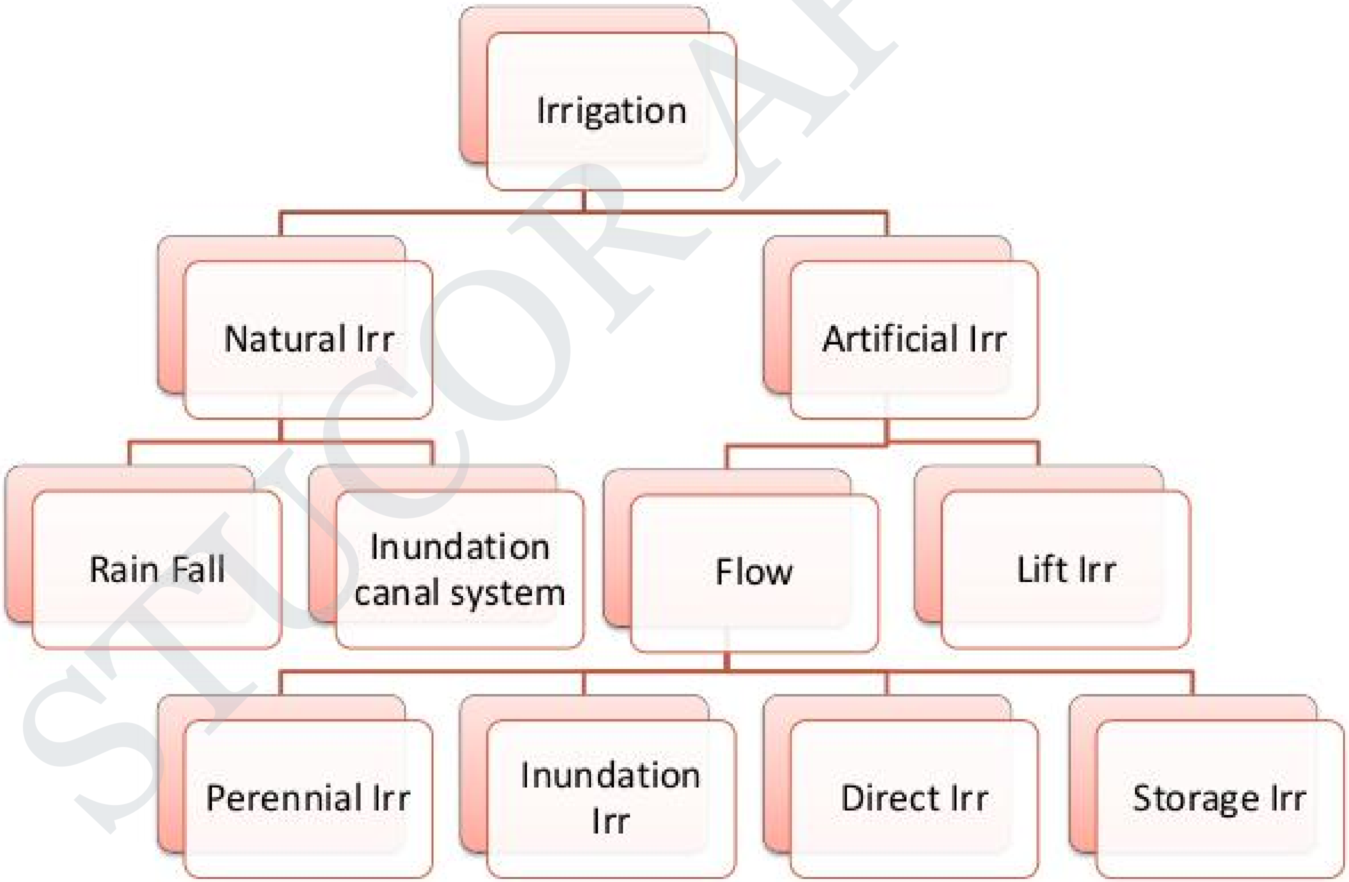
Need of the Irrigation

- Less rainfall
- Non uniform rainfall
- Commercial crops with additional water
- Controlled water supply

Benefits of Irrigation

- Increase in food production
- Protection from famine
- Cultivation of cash crop (Sugarcane, Tobacco)
- Addition to the wealth of the country
- Increase the prosperity of people
- Generation of hydro-electric power
- Domestic & industrial water supply
- Inland navigation
- Improvement of communication
- Canal plantations
- Improvement in the ground water storage

Types of Irrigation OR Classification of Irrigation



Natural Irrigation

No engineering structure is constructed.

1)Rainfall Irrigation

Rainfall is only used for raising crops.

2) Inundation canal system

Flood water is utilized for Irrigation purpose by properly direction flow of water.

Artificial Irrigation

Properly designed engineering structure are constructed.

1) Flow irrigation

- Water flows to the irrigated land by gravity.
- Water sources is to be higher level than the

a) Perennial irrigation :

Water is supplied according to the requirements throughout the crop period through storage canal head works & Canal distribution system.

b) Inundation irrigation:

- Lands are submerged & throughly flooded when floods occur in the river.
- Lands are allowed to drain off & the crop are sown.
- Now the soil retains sufficient moisture for the crops to grow.

c) Direct irrigation :

- Water is directly diverted to the canal from the river is called Direct irrigation.
- Discharge in the river shall be higher than the water requirement during the crop period.
- A low diversion weir or a barrage is constructed across the river to rise the water level and divert the same to the canal.
- Direct irrigation can be adopted only where there is enough flow in the river to provide sufficient quantity of water required for irrigation

d) Storage Irrigation:

- River flow is not perennial or insufficient during crop period, Storage Irrigation is adopted.
- A dam is construction across the river to store water in the reservoir.
- In some area rain water that run off from a catchment area is stored in tanks and is used for irrigation during the crop period.

2) Lift or well Irrigation:

- Water is lifted up by mechanical such as pump etc or manual to supply for irrigation .
- Lift irrigation is adopted when the water source is lower than the level of lands to be irrigated.

Historical development of Irrigation

- Indus Civilization flourished on the banks of rivers and the water was harnessed for sustenance of life.
- Irrigation technologies during the Indus Valley Civilization were in the form of small and minor works like digging wells.

Irrigation during Medieval India

- Rapid advances took place in the construction of canals.
- Water was blocked by constructing bunds across steams
- Ghiyasuddin Tughluq is credited to be the first ruler who encouraged digging canals. Fruz Tughlug is considered to be the greatest canal builder.
- Irrigation is said to be one of the major reasons for the growth and expansion of the Vijayanagar

cen tury.

- Babur, in his memoirs called 'Baburnamah' gave a vivid description of prevalent modes of irrigation practices in India at that time.
- The Gabar Bunds, presently in Sindh, Pakistan, captured and stored annual runoff from surrounding mountains and river Sindhu (Indus) to be made available to tracts under cultivation.

Irrigation in British India

- Renovation, improvement extension of existing works and
- New projects, like the Upper Ganga Canal, the Upper Bari Doab Canal and Krishna and Godavari Delta Systems.
- Major canal works like the Sirhind, the Lower Ganga, the Agra and the Mutha Canals, and the Periyar Dam and canals.

PERIYAR CANAL SYSTEM

UPPER GANGA CANAL

PERIYAR DAM

GODAVARI DELTA SYSTEM

BETWA CANAL

GOKAK FALL

RUSHIKULYA RIVER

Irrigation development after Independence

- To achieve set targets of economic development, the responsibility of irrigation development was given to the **Union Ministry of Water Resources**

- It took initiatives from time to time on water resources development and for technical assistance to the states on irrigation, multipurpose projects, ground water exploration and exploitation, drainage, flood control, water logging, sea erosion problems, dam safety and hydraulic structures for

Irrigation development programs undertaken

Command Area Development & Water Management (CADWM):

- To provide central assistance for development of infrastructure to facilitate use of sprinkler / drip irrigation systems as an alternative to construction of field channels.
- The assistance is limited to construction of stilling tank, pump house and laying of conveyance pipes up to farmer's fields.

Accelerated Irrigation Benefits Program (AIBP):

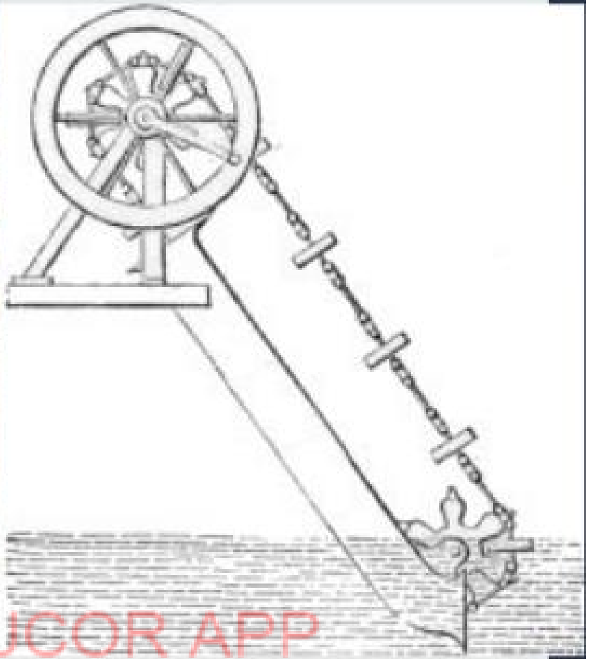
- The AIBP was conceived in the year 1996 by the Government of India in order to provide financial assistance to States to complete various ongoing projects in the country so that envisaged irrigation potential of the project could be created and thereby extend irrigation to more areas

Some older methods of irrigation

PERSIAN WHEEL

PULLEY SYSTEM

BULLOCK DRAWN WELL IRRIGATION



CHAIN PUMP

Some modern methods of irrigation

BUNDS

RAIN GUN

DRIP IRRIGATION

SPRINKLER IRRIGATION

BORE WELL/ OPEN WELL PUMP IRRIGATION

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Advantages of irrigation

I.Direct Benefits

- Multiple cropping for cultivation
- Productivity is high
- Quality of the crop is improved
- Higher economic return and employment opportunities.
- Development of pisciculture and afforestation
- Prevention of damage through flood

Indirect Benefits

1. Increase in gross domestic product of the country, revenue, employment, land value, higher wages to farm labour, agro-based industries and groundwater storage.

2. General development of other sectors and development of the country

3. Increase of food production.

4. Modify soil or climate environment – leaching.

5. Lessen risk of catastrophic damage caused by

Indirect Benefits

1)Increase standard of living.

2)Increase value of land.

3)National security thus self sufficiency.

4)Improve communication and navigation facilities.

5)Domestic and industrial water supply.

6)Improve ground water storage.

7)Generation of hydro-electric power.

Disadvantages of Irrigation

- Water logging.
- Salinity and alkalinity of land.
- Ill aeration of soil.
- Pollution of underground water.
- Results in colder and damper climate causing outbreak of diseases like malaria.

Types of Crops:

1) **Wet crops-** which lands are irrigated and than crop are cultivation

2) **Dry crops-**which do not need irrigation.

3) **Garden crops-** which need irrigation throughout the year

4) **Summer crop (Kharif)**-which are sown during the south west monsoon & harvested in autumn.

5) **Winter crops(rabi)**-which are sown in autumn & harvested in spring.

ash **crop** – which has to be encased in the market. As

S.No	Crop	Sown	Harvested
1	Summer season (Kharif crop)		
	Rice	June -July	Oct-Nov
	Maize	June -July	Sep-Oct
	Bajra	June -Aug	Sep-Oct
	Jowar	June -July	Oct-Nov
	Pulses	June -July	Nov-Dec
2	Winter season (Rabi Crops)		
	Wheat, Barley, peas	Oct-Nov	March - April
	Gram	Sep- Oct	March - April
	Tobacco	Feb-Mar	June
	Potato	Oct	Feb
3	Eight Months Crop cotton	May-June	Dec-Jan
4	Annual crop sugercane	Feb-March	Dec-march

Crop Seasons:

- In north India the crop season is divided as Rabi & Kharif.
- Rabi crops are called as winter crops and kharif crops are called as summer crops.
- Kharif crops required more water than rabi crops.
- Rabi starts from 1 st oct and ends on 31 march
- In TamilNadu crops are classified as wet and dry crops.

Crops rotation:

Rotation of crops implies the nature of the crop sown in a particular field is changed year after year.

Necessity for rotation :

- Fertility of land gets reduced as the soil becomes deficient
- More balanced fooding
- Rotation will check the diseases
- increase nitrogen content of soil
- The soil will be better utilized
- rotation of cash crops, fooder and soil renovating crops.

General rotation of crops can be summarized as:

1. Wheat – great millet – gram.
2. Rice – gram
3. Cotton – wheat – gram.
4. Cotton – wheat – sugarcane
5. Cotton – great millet – gram.

Crop Period or Base Period:

- The time period that elapses from the instant of its sowing to the instant of its harvesting is called the crop period.
- The time between the first watering of a crop at the time of its sowing to its last watering before harvesting is called the base period.

Consumptive Use of Water

- Considerable part of water applied for irrigation is lost by evaporation & transpiration.
- This two processes being difficult to separate are taken as one and called Vapor- transpiration or Consumptive use of water.

Duty:

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

Simply we can say that, the area (in hectares) of

io , B (in

Delta of a Crop :

The total quantity of water required by the crop for its full growth may be expressed in hectare-meter.

or

Simply as depth to which water would stand on the irrigated area if the total quantity supplied were to stand above the surface without percolation or evaporation.

This total depth of water is called delta (Δ).

Problem –1: If rice requires about 10 cm depth of water at an average interval of about 10 days, and the crop period for rice is 120 days, find out the delta for rice.

***Solution*:**

No. of watering required = 120/10 = 12

Total depth of water required in 120 days = 10 × 12 = 120 cm

Δ for rice = 120 cm

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Problem –2: If wheat requires about 7.5 cm of water after every 28 days, and the base period for wheat is 140 days, find out the value of delta for wheat.

***Solution*:**

No. of watering required = 140/28 = 5

Total depth of water required in 140 days = 7.5 × 5 = 37.5 cm

Δ for wheat = 37.5 cm

Relation between duty and delta

$$\Delta = \frac{8.64B}{D}$$

Where,

Δ=Delta in meter

D = Duty in Ha/cumec

B = Base period in days

Also

$$\Delta = \frac{2B}{D}$$

Where,

Δ=Delta in meter

B = Base period in days

D = Duty in acre/cures

Factors on which duty depends:

- Type of crop
- Climate and season
- Useful rainfall
- Type of soil
- Efficiency of cultivation method

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Importance of Duty

- It helps us in designing an efficient canal irrigation system.
- Knowing the total available water at the head of a main canal, and the overall duty for all the crops required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out.
- *Inversely, if we know the crops area required to be irrigated and their duties, we can work out the discharge required for designing the channel.*

Measures for improving duty of water:

(1) Proper Ploughing

(2) Methods of supplying water

- Furrow method For crops sown ion rows
- Contour method For hilly areas
- Basin For orchards
- Flooding For plain lands

(3) Canal Lining

(4) Minimum idle length of irrigation Canals:

(5) Quality of water:

Irrigation Requirements of crops

(1) Consumptive Irrigation Requirement (CIR)

$$CIR = Cu - P_{eff}$$

Where, Cu= total consumptive use requirement

P_{eff}= Effective rainfall.

(2) Net Irrigation Requirement (NIR)

$$NIR = CIR + \text{Leaching requirement}$$

(3) Field irrigation requirement (FIR)

$$FIR = \frac{NIR}{\eta_a}$$

(4) Gross irrigation requirement, (GIR)

$$GIR = \frac{FIR}{\eta_c}$$

Consumptive use of crops

Definition:

- It is the quantity of water used by the vegetation growth of a given area.
- It is the amount of water required by a crop for its vegetated growth to evapotranspiration and building of plant tissues plus evaporation from soils and intercepted precipitation.
- It is expressed in terms of depth of water. Consumptive use varies with temperature, humidity, wind speed, topography, sunlight hours, method of irrigation, moisture availability.

  Mathematically,

Consumptive Use = Evapotranspiration =

It is expressed in terms of depth of water.

Factors Affecting the Consumptive Use of Water

- Evaporation which depends on humidity
- Mean Monthly temperature
- Growing season of crops and cropping pattern
- Monthly precipitation in area
- Wind velocity in locality
- Soil and topography
- Irrigation practices and method of irrigation
- Sunlight hours

Types of Consumptive Water Use

1. Optimum Consumptive Use
2. Potential Consumptive Use
3. Seasonal Consumptive Use

1. Optimum Consumptive Use:

It is the consumptive use which produces a maximum crop yield.

2. Potential Consumptive Use:

If sufficient moisture is always available to completely meet the needs of vegetation fully covering the entire area then resulting evapotranspiration is known as Potential Consumptive Use.

3. Seasonal Consumptive Use:

The total amount of water used in the evapo-transpiration by a cropped area during the entire growing season.

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Methods of Determination of Evapotranspiration

1)Direct Methods/Field Methods

2)Empirical Methods

3)Pan evaporation method

1. Direct Methods:

In this method field observations are made and physical model is used for this purpose. This includes,

1.Vapour Transfer Method / Soil Moisture Studies

2.Field Plot Method

1.Vapour Transfer Method:

- In this method of estimation of water consumptive use, soil moisture measurements are taken before and after each irrigation.
- The quantity of water extracted per day from soil is computed for each period.
- A curve is drawn by plotting the rate of use against time and from this curve, the seasonal use can be estimated.
- This method is suitable in those areas where soil is fairly uniform and ground water is deep enough.
- It is expressed in terms of volume i.e. **Acre-feet or**

ii. Field Plot Method:

- We select a representative plot of area and the accuracy depends upon the representativeness of plot (cropping intensity, exposure etc).
- It replicates the conditions of an actual sample field (field plot). Less seepage should be there.

Inflow + Rain + Outflow = Evapotranspiration

- The drawback in this method is that lateral movement of water takes place although more representative to field condition.
- Also some correction has to be applied for deep

iii. Tanks and Lysimeter:

- In this method of measurement of consumptive use of water, a watertight tank of cylindrical shape having diameter 2m and depth about 3m is placed vertically on the ground.
- The tank is filled with sample of soil. The bottom of the tank consists of a sand layer and a pan for collecting the surplus water.
- The plants grown in the Lysimeter should be the same as in the surrounding field.

- The consumptive use of water is estimated by measuring the amount of water required for the satisfactory growth of the plants within the tanks. Consumptive use of water is given by,

Cu = Wa – Wd

Where, Cu = Consuptive use of water

Wa = Water Applied

Wd = Water drained off

- Lysimeter studies are time consuming and expensive. Methods 1 and 2 are the more reliable methods as compare to this method.

iv. Integration Method:

- In this method, it is necessary to know the division of total area, i.e. under irrigated crops, natural native vegetation area, water surface area and bare land area.
- In this method, annual consumptive use for the whole area is found in terms of volume.
- It is expressed in Acre feet or Hectare meter.

***Mathematically*,**

tiv

use

Total Area Annual Consumptive Use

= Total Evapotranspiration

= A+B+C+D

Where,

A = Unit consumptive use for each crop x its area

B = Unit consumptive use of native vegetation x its area

C = Water surface evaporation x its area

D = Bare land evaporation x its area

v. Irrigation Method:

- In this method, unit consumption is multiplied by some factor.
- The multiplication values depend upon the type of crops in certain area.
- This method requires an Engineer judgment as these factors are to be investigated by the Engineers of certain area.

vi. Inflow Outflow Method:

In this method annual consumptive use is found for large areas. If U is the valley consumptive use its value is given by,

$$U = (I+P) + (Gs - Ge) - R$$

Where,

U = Valley consumptive use (in acre feet or hectare meter)

I = Total inflow during a year

P = Yearly precipitation on valley floor

Gs = Ground Storage at the beginning of the

2. Empirical Methods:

Empirical equations are given for the estimation of water requirement. These are,

1)Blaney-Criddle method

2)Lowry Johnson Method

3)Penman Equation

4)Hargreave's Method

a. Blaney-Criddle method:

- Blaney and Criddle (1950) observed that the amount of water consumptively used by crops during their growing seasons was closely correlated with mean monthly temperatures and daylight hours and the length of the growing seasons.
- The correlation coefficients are then applied to determine the ET for other areas where only climate data are available.
- Blaney-Criddle formula is one of the best known procedures for estimating Potential Evapotranspiration

If CU is monthly consumptive use, its value is given by

Cu= K.f (inches)

Where,

k = crop factor to be determined for each crop; its value depends upon Certain environmental conditions

F = monthly consumptive use factor

= $t \times (p/100)$

t = mean temperature in ^{o}F.

p = percentage of day time hours of the year, occurring during the period.

If Expressed in metric units, the above formula becomes:

$$C_u = k.\frac{p}{40}\left[1.8t + 32\right] = k.f$$

Where,

t = temperature in °C

Cu= monthly consumptive use in cm

b. Lowry Johnson Method:

The equation for this method is,

U = 0.0015 H + 0.9 (Over specified)

U = Consumptive Use

H = Accumulated degree days during the growing season computed from maximum temperature above 32 °F

c. Penman Equation:

Penman(1948) proposed an equation for evaporation from open water surface, based on a combination of energy balance and sink strength which is given below with changes in certain symbols in view of the recent trends.

According to this method,

$$U = ET = AH + 0.27\ EaA - 0.27$$

ET = Evapotranspiration or consumptive use in mm Ea = Evaporation (mm/day)

H = Daily head budget at surface (mm/day)

A = Slope of saturated vapour pressure curve of air at

d. Hargreave's Method:

- It is a very simple method.
- The pan is circular with a diameter of 1.21 m and depth of 255 mm which gives it a volume of about 0.3 m3.
- The basin is put on a 150 mm high wooden frame due to air circulation around the basin. The water level is kept about 50 mm below the rim, due to allowance of percolation and the need of water.
- The water level is measured every day, either you measure the difference between the present and the origin

n he water

According to this method,

$$Cu = K\,Ep$$

Where,

- Cu = Consumptive Use coefficient (varies from crop to crop)

  Ep = Evapotranspiration

- K = Coefficient

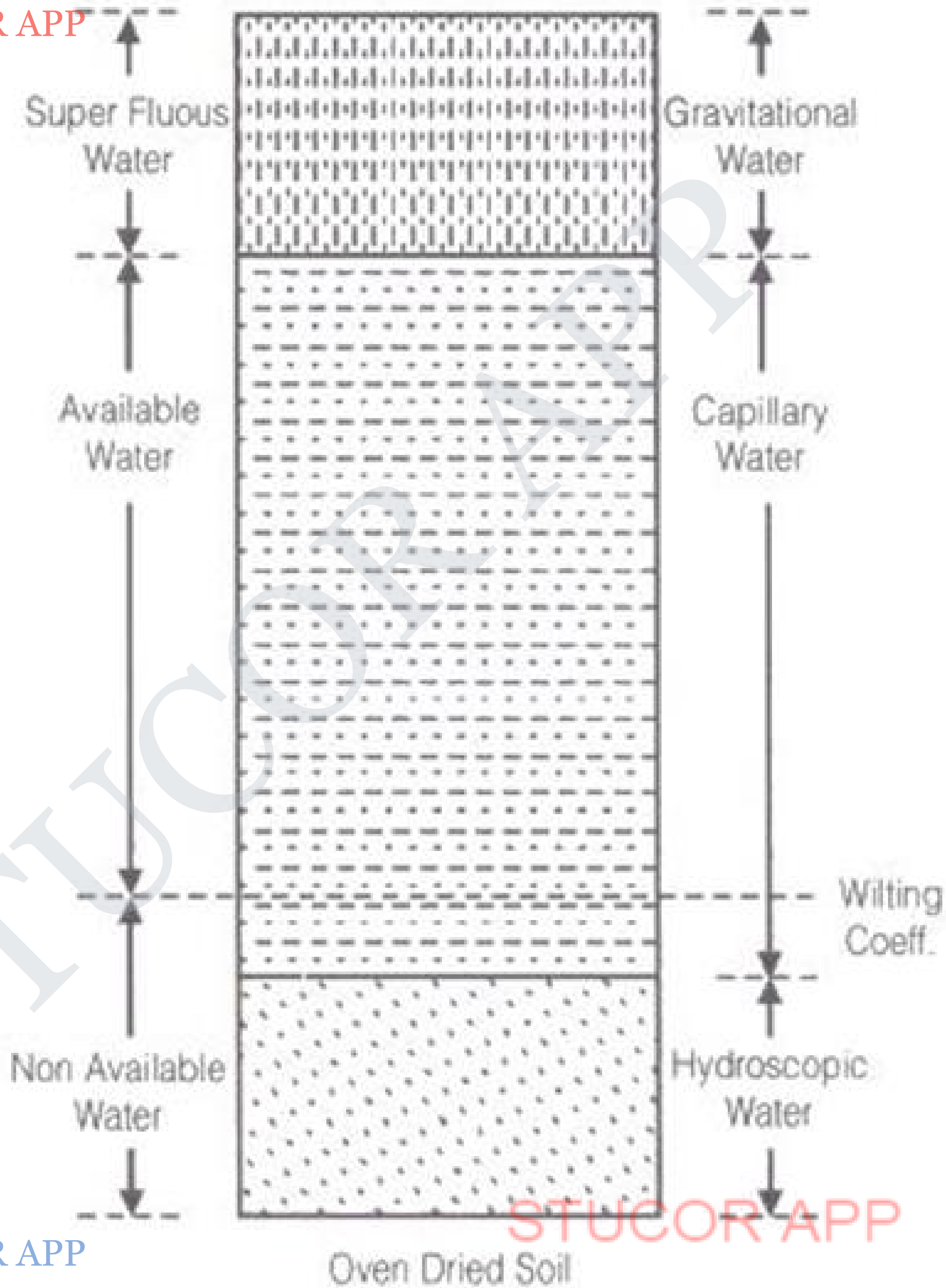
Crop Water Requirements

Soil moisture

Classes and availability of soil water

Water present in the soil may be to classified under three heads

1. Hygroscopic water
2. Capillary water
3. Gravitational water


Super Fluous Water
Gravitational Water
Available Water
Capillary Water
Wilting Coeff.
Non Available Water
Hydroscopic Water
Oven Dried Soil

Hygroscopic water

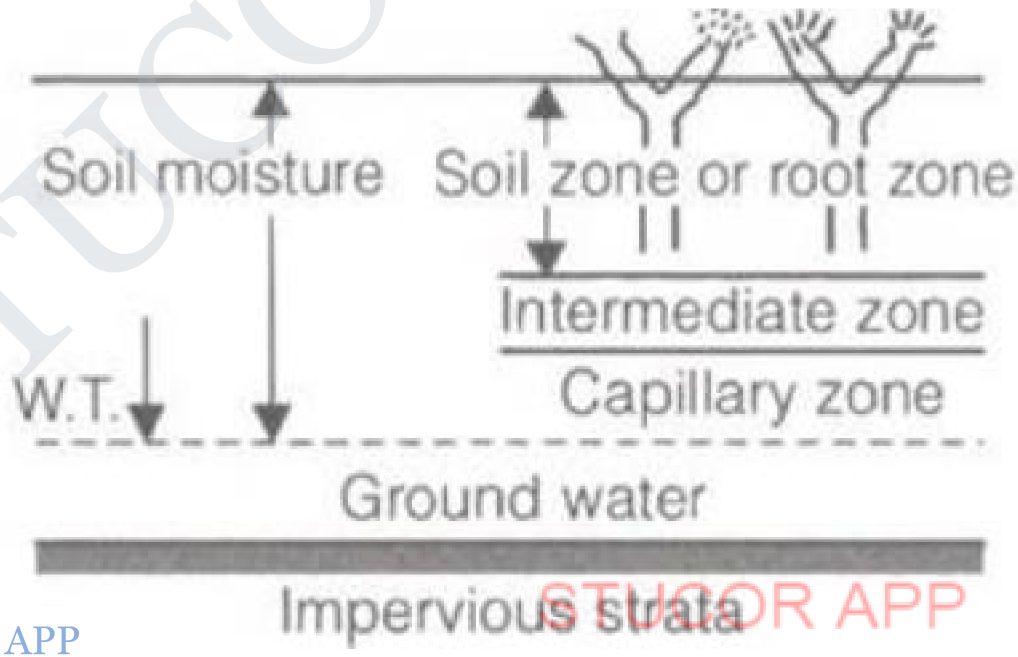
- Water attached to soil particles through **loose chemical bonds** is termed hygroscopic water.
- This water can be removed by **heat** only. But the plant roots can use a very small fraction of this soil moisture under drought conditions.

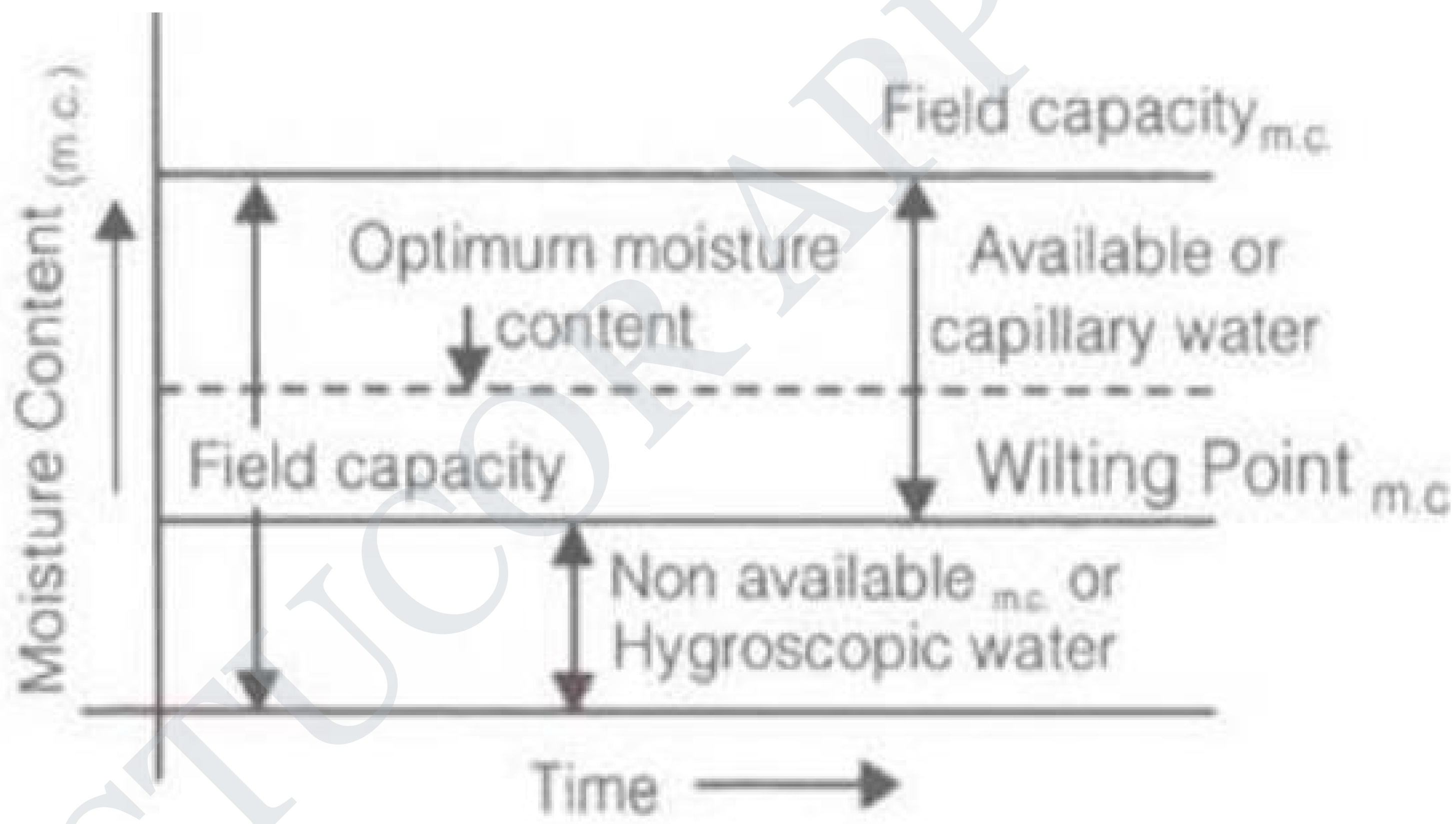
Capillary water

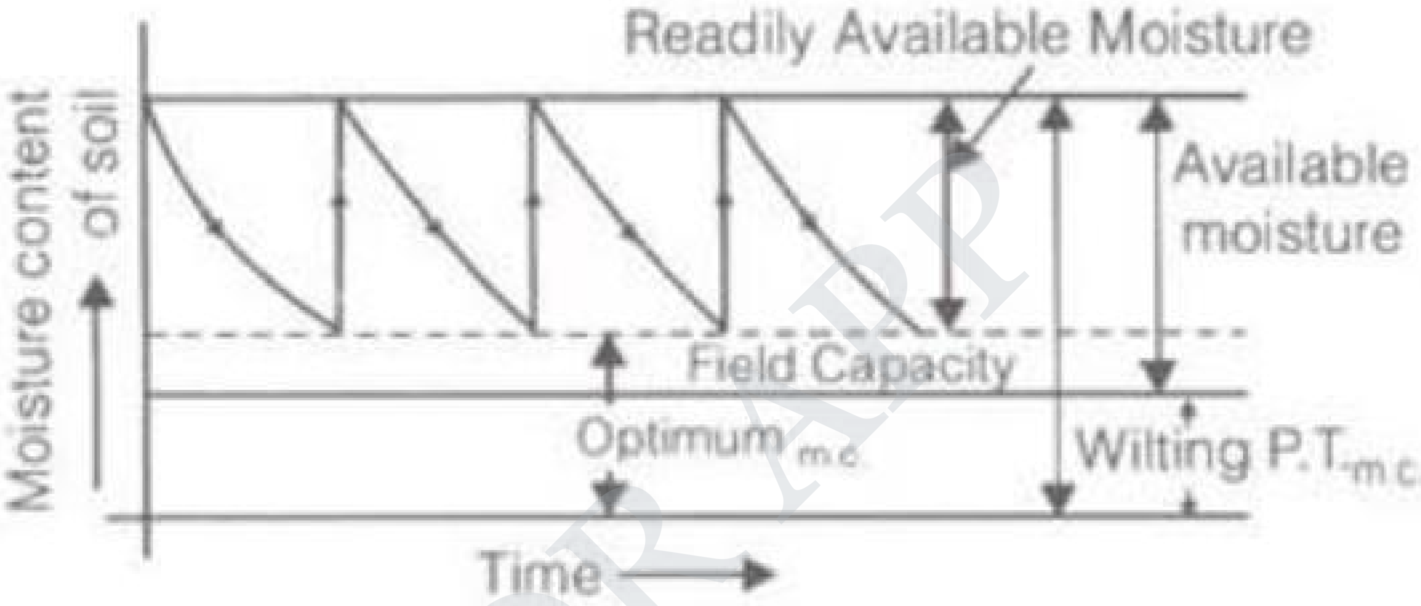
- The capillary water is held within soil pores due to the **surface tension forces** (against gravity) which act at the liquid-vapour (or water-air) interface.

Gravitational water

- Gravity water is that water which drains away under the **influence of gravity**.
- Soon after irrigation (or rainfall), this water remains in the soil and saturates the soil, thus, **preventing circulation of air** in the void spaces.




Field capacity m.c
Optimum moisture content
Available or capillary water
Field capacity
Wilting Point m.c
Non available m.c or Hygroscopic water
Moisture Content (m.c.)
Time



(1) Available moisture for the plant $= F_C - \phi$

(2) Readily available moisture for the plant = FC - Mo

Here FC= field capacity

φ = wilting point or wilting coefficient below

(3) Frequency of Irrigation $= \dfrac{\text{weight / readily available moisture depth}}{\text{consumptive use rate}}$

4) $F_C = \dfrac{\text{weight of water stored in soil of unit area}}{\text{weight of same soil of unit area}}$

where, weight of water stored in soil of unit area $= \gamma_w \cdot d_w \cdot 1 \cdot$

Weight of same soil of unit area $= \gamma \cdot d \cdot l$

dw= depth of water stored in root zone.

5) $d_w = \dfrac{\gamma \cdot d}{\gamma_w} \cdot F_C$ $\gamma \rightarrow$ dry unit wt. of soil

6) Available moisture depth to plant

$$d_w' = \frac{\gamma . d}{\gamma_w}\left(F_C - \phi\right)$$

(7) Readily available moisture depth to plant

$$d_w' = \frac{\gamma . d}{\gamma_w}\left(F_C - m_o\right)$$

(8) $F_C = n / G$

where, G = specific gravity and n = porosity

Wilting Point

The permanant wilting point is that water content at which plant can **no longer extract sufficient water** for its growth, and wilts up.

Available Water :

Available water or available moisture is defined as the difference in water content of the soil between **field capacity and permanant wilting point**.

Readily available water :

It is that portion of the available moisture which is most **easily extracted** by the plants and is

m

isture.

Soil – Moisture deficiency :

The water required to bring the soil moisture content of a given soil to its **field capacity** is called the field moisture deficiency or soil moisture deficiency.

Equivalant Moisture :

Equivalant moisture is the water retained by a saturated soil after being centrifuged for 30 minutes by a centrifugal force of **1000 times that of gravity.**

Discussions ?

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UNIT-2

IRRIGATION METHODS

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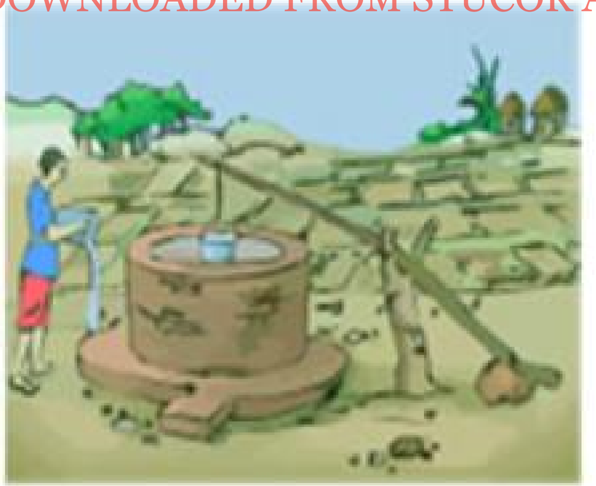
Syllabus

IRRIGATION METHODS

Tank irrigation – Well irrigation – Irrigation methods: Surface and Sub-Surface and Micro Irrigation – design of drip and sprinkler irrigation – ridge and furrow irrigation-Irrigation scheduling – Water distribution system- Irrigation efficiencies.



Tank irrigation

- A tank is a **reservoir** for irrigation, **a small lake or pool** made by damming the valley of a stream to retain the monsoon rain for later use.
- It accounts for approximately **3% of the net irrigated area** in India. Tank Irrigation is popular in the peninsular plateau area where Andhra Pradesh and Tamil Nadu are the leading states.
- Andhra Pradesh has the largest area (29%) of tank irrigation in India followed by Tamil nadu (23%).

s • f Tamil Nadu

Irrigation Tank

Kinds of Tanks

1)System Tanks and

2)Non-System Tanks.

System Tanks

- The **canal fed tanks** are known as System Tanks, which were exclusively under the management of the Public Works Department.
- The System Tanks are fed with **water from rivers** and run off through diversion weirs, feeder channels and surface flow.
- System Tanks are the minority of tanks that are supplied from major

iv rs.

System Tanks

Non System Tanks

- The **rain fed tanks** are known as Non-System Tanks.
- NonSystem Tanks which command **area below 40 hectares** are coming under the control of Panchayat Unions.
- These Non-System Tanks have a **small storage capacity.**

Non System Tanks

Merits

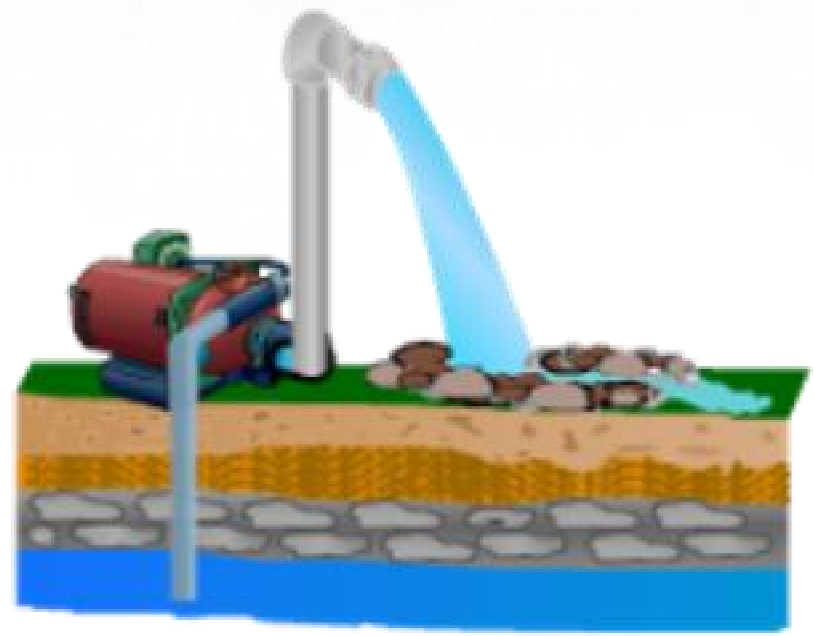
- Most of the tanks are natural
- Do not involve cost for their construction
- Independent source for an individual farmer
- longer life span
- can be used for fishing also

- **Demerits**
  - Depends on rain
  - These tanks may dry up during the dry season
  - Silting of their beds
  - Require large areas
  - Evaporation losses
  - Need to lift the water to take it to the field

Wells (and Tube Wells)

- A well is a **hole dug in the ground** to obtain the subsoil water.
- An ordinary well is about 3-5 metres deep but deeper wells up to 15 metres are also dug.
- This method of irrigation has been used in India from time immemorial.
- Various methods are used to lift the ground water from

Dug well



Tube well

Well Irrigation

- Well irrigation is gradually giving way to **energized tube wells**.
- But there are many wells still in use where **electricity is not available** or the farmers are too poor to afford diesel oil.
- This method of irrigation is popular in those areas where **sufficient sweet ground water is available**.
- It is particularly suitable in areas with **permeable rock structure** which allows accumulation of ground water through percolation.

Well Irrigation

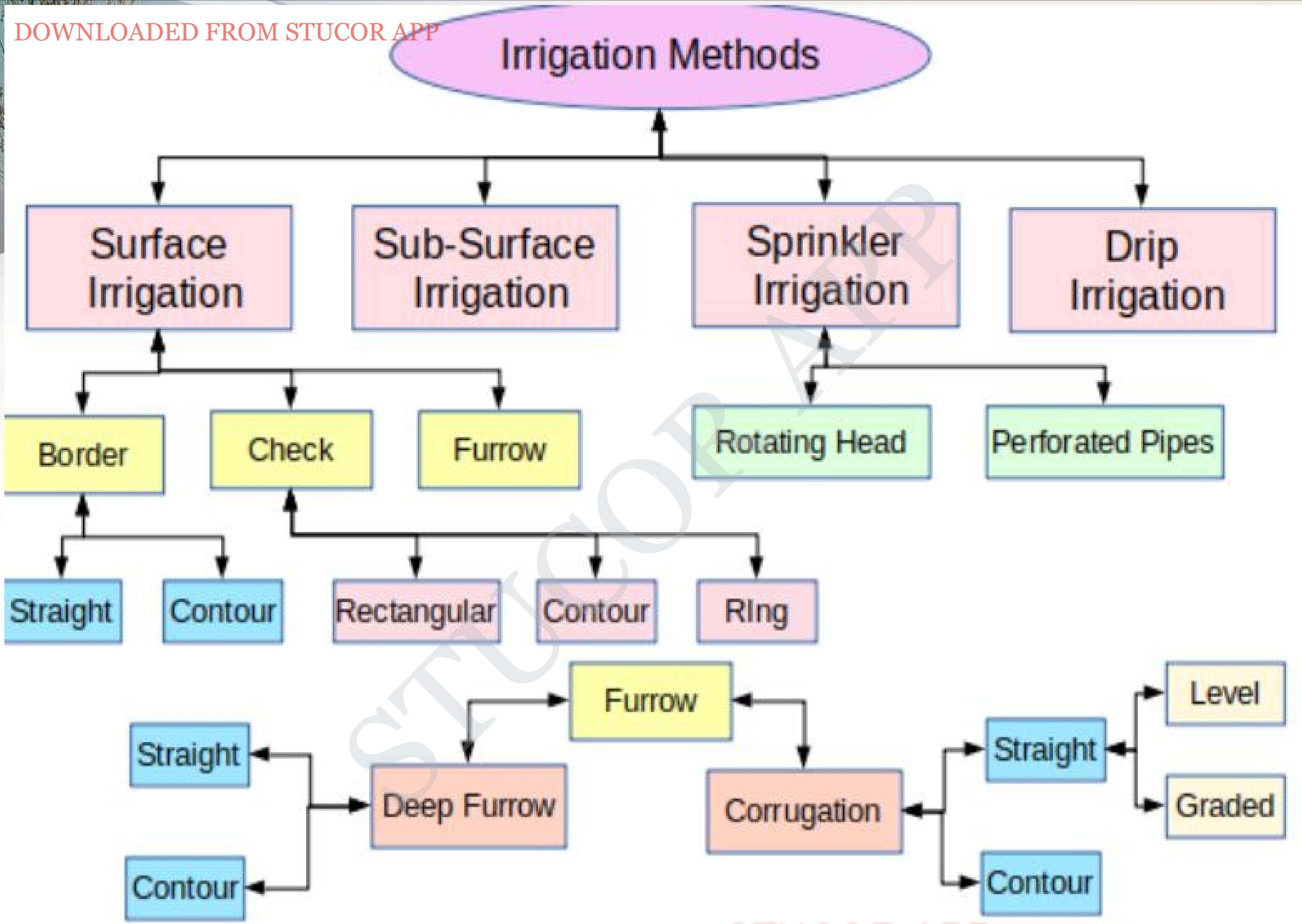
Merits

- Simplest
- Cheapest
- Well is an independent source of irrigation and can be used as and when the necessity arises.
- Canal irrigation, on the other hand, is controlled by other agencies and cannot be used at will.
- Some ground water salts are useful for crops
- Does not lead to salinization and flooding problems

yo d the tail end

Demerits

- Only limited area can be irrigated.
- Normally, a well can irrigate 1 to 8 hectares of land.
- Not suitable for dry regions
- Overuse may lead to lowering of water table


Irrigation Methods
Surface Irrigation
Sub-Surface Irrigation
Sprinkler Irrigation
Drip Irrigation
Border
Check
Furrow
Rotating Head
Perforated Pipes
Straight
Contour
Rectangular
Contour
Ring
Furrow
Level
Straight
Straight
Deep Furrow
Corrugation
Graded
Contour
Contour

SURFACE IRRIGATION:

- Surface irrigation is defined as the group of application techniques where water is applied and distributed **over the soil surface** by gravity.
- It is by far the **most common form of irrigation** throughout the world and has been practiced in many areas virtually unchanged for thousands of years.

SURFACE IRRIGATION

Flood irrigation

Basin irrigation

Furrow irrigation

SUB SURFACE IRRIGATION

Surface irrigation

There are four variations under this method viz.

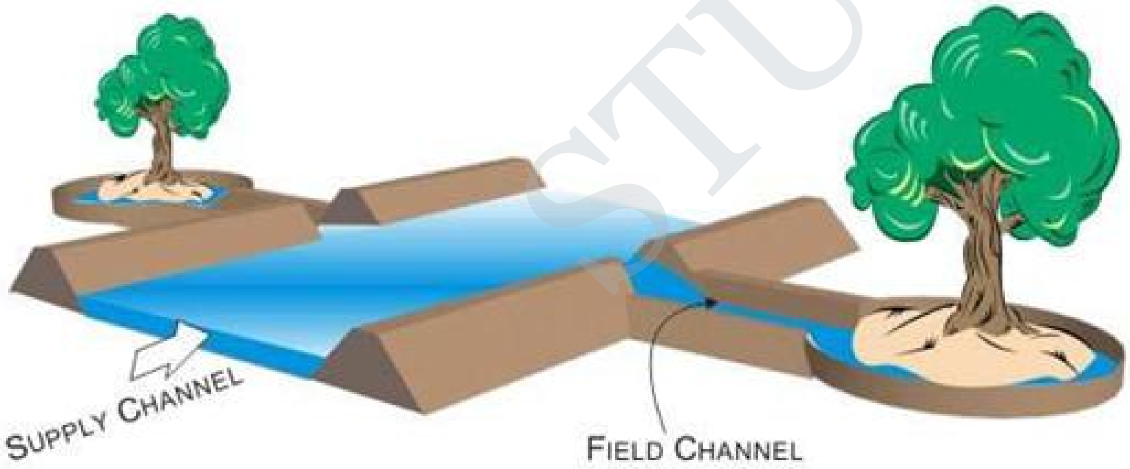
1.Flooding,

2.Bed or border method (Saras and flat beds)

3.Basin method (ring and basin) and

4.Furrow method (rides and furrows, broad ridges or raised beds)

- Flooding



- B e d o r

- F u r r o w

Flooding

- It consist of opening a water channel in a plot or field so that water can **flow freely in all directions** and cover the surface of the land in a continuous sheet.
- It is the most **inefficient method** of irrigation as only about 20 percent of the water is actually used by plants.
- The rest being lost as a **runoff, seepage and evaporation**.
- Water distribution is very **uneven and crop growth is not uniform.**

- It is suitable for **uneven land** where the cost of leveling is high and where a cheap and **abundant supply of water is available.**

- It is unsuitable for crops that are **sensitive to water logging** the method suitable where broadcast crops, particularly pastures, alfalfa, peas and small grains are produced.

Adaptations:

1)An abundant supply of water

2)Close growing crops

3)Soils that do not erode easily

4)Soils that is permeable

5)Irregular topography

6)Areas where water is cheap.

Advantages:

1)Can be used on shallow soils

2)Can be employed where expense of leveling is great

3)Installation and operation costs are low

4)System is not damaged by livestock and does not interfere with use of farm implements.

Disadvantages:

- Excessive loss of water by run of and deep percolation
- Excessive soil erosion on step land.
- Fertilizer and

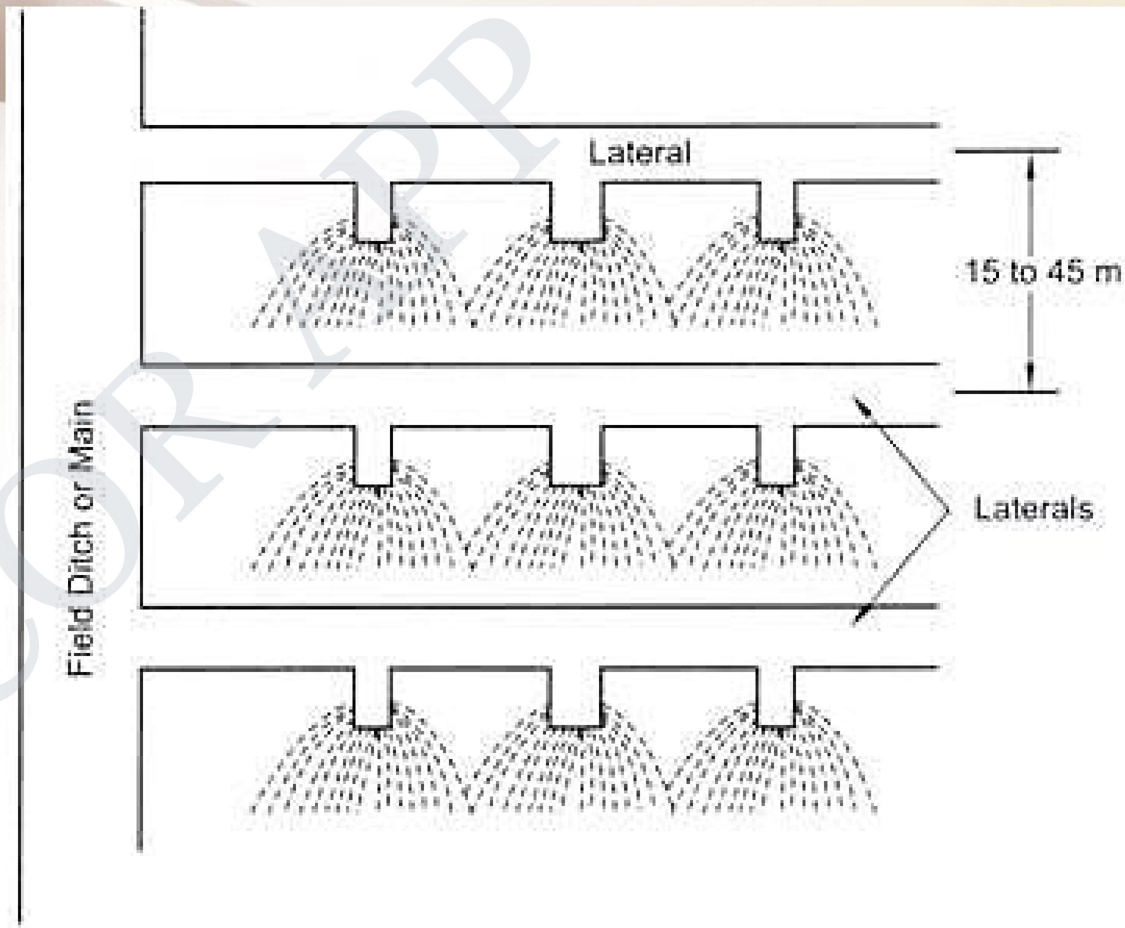


Fig. 6.1. (a) Free-flooding method for erodable soils

Bed or border method (Sara and Flat beds or check basin):

- In this method the field is leveled and divided into small beds surrounded by bunds of 15 to 30 cm high.
- Small irrigation channels are provided between two adjacent rows of beds.
- The length of the bed varies from 30 meters for loamy soils to 90 meters for clayey soils.
- The width is so adjusted as to permit the water to flow evenly and wet the land uniformly.
- For high value crops, the beds may be still smaller especially where water is costly and not very abundant.

- It requires leveled land.It is more efficient in the use of water and ensures its uniform application.
- It is suitable for crops plant in lines or sown by broadcast.
- Through the initial cost is high requires less labour and low maintenance cost.

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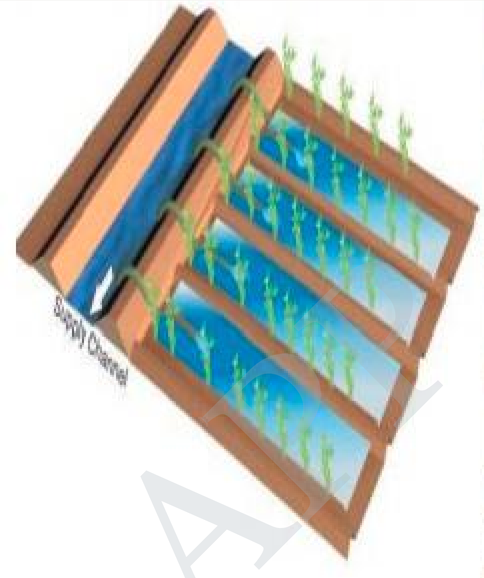
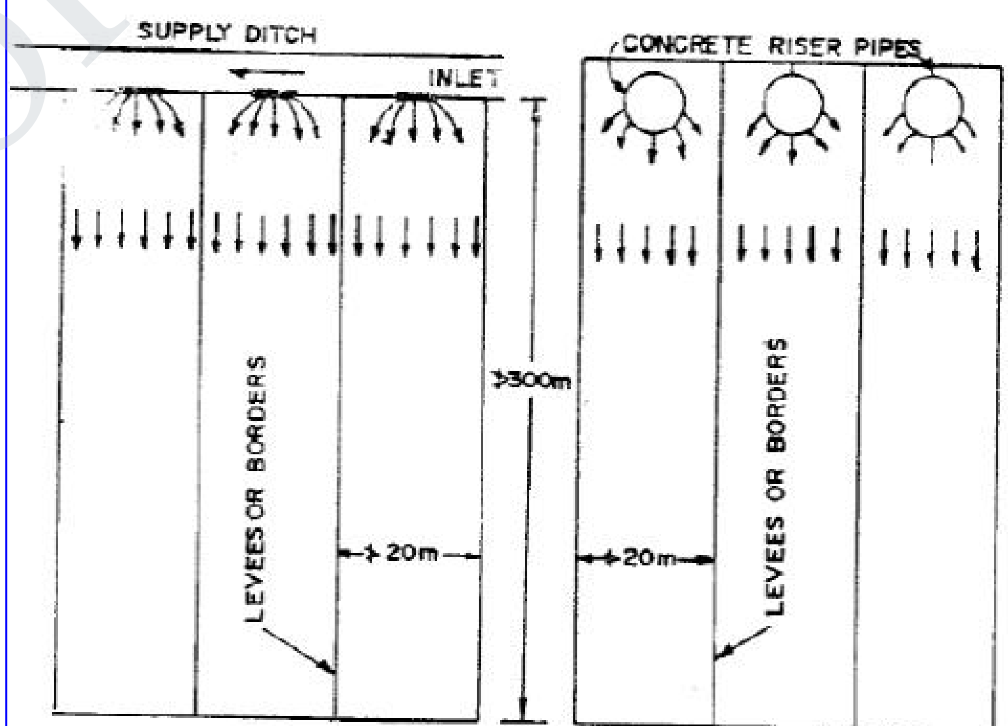




Types of Border Irrigation

1)Straight Border

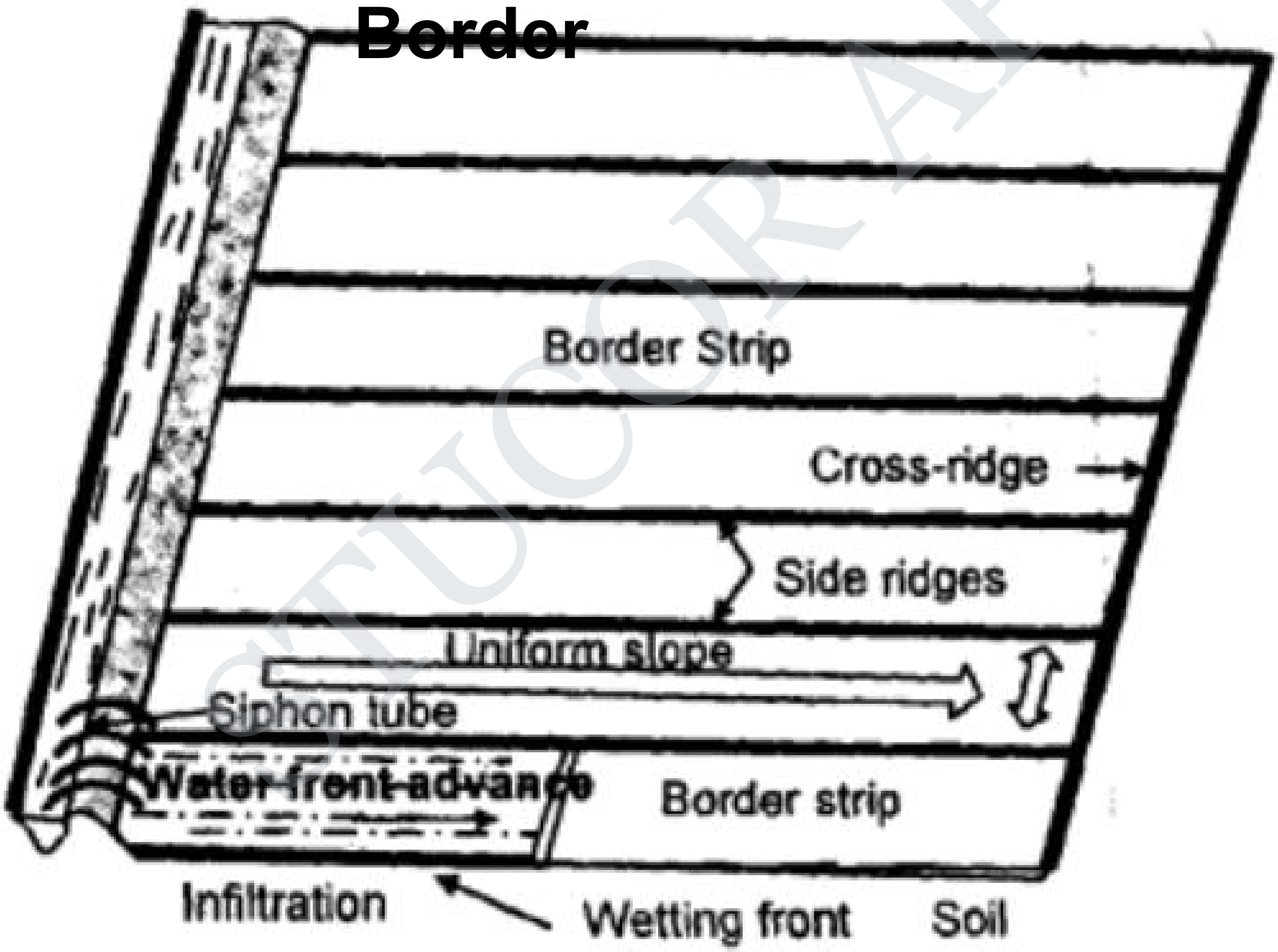
2)Contour Border

Straight Border

- These are formed across the **general slope of the field** and are preferred when land slope exceeds the safe limits.
- As fields are undulating and require a lot of earth work

si **le**. Design

Straight Border



Contour Border

- These are formed across the general slope of the field and are preferred when **land slope exceeds the safe limits.**
- As fields are undulating and require a **lot of earth work** to level, economical levelling is not possible.
- Design criteria for both are not different.

Adaptations:

1)A large supply of water

2)Most soil textures including sandy Loam, loams and clays

3) Soil at least 90 cm deep

4)Suitable for close growing crops.

1)**Advantages:**

2)Fairly large supply of water is needed.

3)Land must be leveled

4)Suited only to soils that do not readily disperse.

5)Drainage must be provided

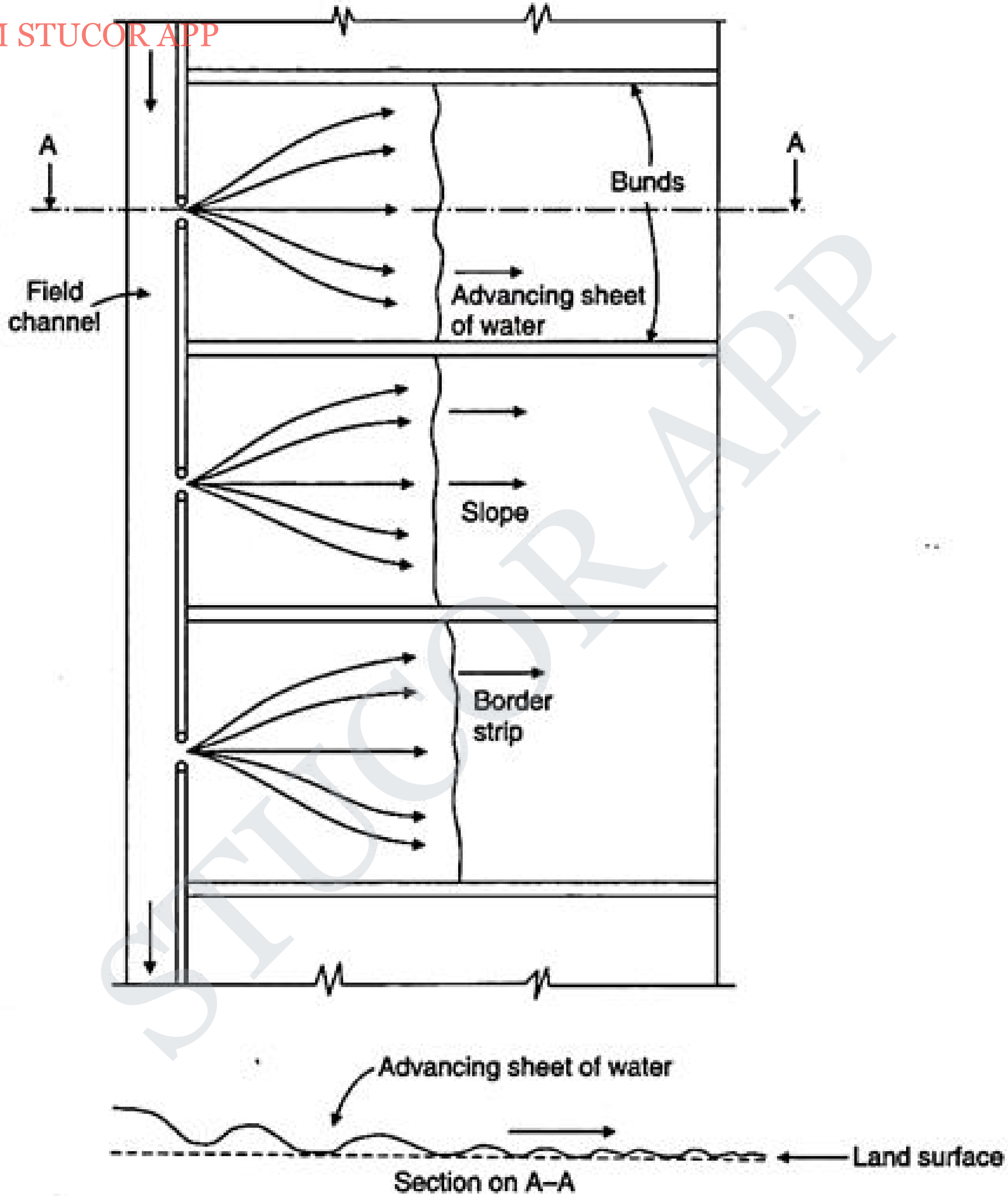


 Fig. 17.1 Border strip method of irrigation

Basin irrigation

- This method is suitable for **orchids and other high value crops** where the size of the plot to be irrigated is very small.
- The basin may be **square, rectangular or circular** shape. A variation in this method viz. ring and basin is commonly used for irrigating **fruit trees**.
- A small bund of **15 to 22 cm high** is formed around the stump of the tree at a distance of about 30 to 60 cm to

- The height of the outer bund varies depending upon the **depth of water proposed** to retain.
- Basin irrigation also requires **leveled land** and not suitable for all types of soil.
- It is also efficient in the use of water but its **initial cost is high.**
- There are many variations in its use, but all involve dividing the field into **smaller unit areas** so that each has a nearly level surface.

Types of Check Basins

Rectangular

- The basins are rectangular in shape when the land can be graded economically into **nearly level fields**.

Contour

- The **ridges follow the contours** of the land surface and the contour ridges are connected by cross ridges at intervals when there is **rolling topography**.

Adaptations:

1)Most soil texture

2)High value crops

3)Smooth topography.

4)High water value/ha

Advantages:

- Varying supply of water
- No water loss by run off
- Rapid irrigation possible

of fertilizers and organic manures

Disadvantages:

1) If land is not leveled **initial cost may be high**

2) Suitable mainly for orchids, rice, jute, etc.

3) Except rice, not suitable for soils that **disperse easily and readily** from a crust.

Furrow Method

- In this method, irrigation water is useful for **row crops**. Narrow channels are dug at regular intervals.
- Water from the main supply is allowed to enter these **small channels or furrows.**
- Water from the furrows infiltrates into soil and spread laterally to **saturate the root zone of the crops**.
- It is suitable for row crops like **potatoes, sugarcane, tobacco, maize, groundnut, cotton, jowar**, etc.

Furrow Method

- It is suitable for **sloppy lands** where the furrows are made along contours.
- The length of furrow is determined mostly by soil permeability and it varies from **3 to 6 meters.**
- In sandy and clay loams, the length is shorter than in **clay and clay loams**. Water does not come in contact with the plant stems.

Types of Furrows

(a) straight furrows, and

(b) contour furrows.

Straight Furrows

- They are best suited to sites where the land **slope does not exceed 0.75 per cent.**
- In areas of intense rainfall, however, the furrow grade should not exceed **0.5 per cent** so as to minimise the erosion hazard.
- The range in furrow slopes for efficient irrigation in different soil

or

Contour Furrows

- Contour furrows carry water across a slopping field rather than the slope. Contour furrows are **curved to fitthe topography** of the land.
- Contour furrow method can be successfully used in nearly **all irrigable soils.**
- The limitations of straight furrow are overcome by contouring to include **slopping lands**.
- Light soils can be irrigated successfully across **slopes up to 5**

Adaptations:

Medium and fine textured soils.

Variable water supply

Farms with only small amount of equipment.

Advantages:

High water efficiency

Can be used in any row crop

Relatively easy in stall

Furrow Method

Fig. 6.5 Furrow Irrigation

Contour farming

- Contour farming involves **ploughing, planting and weeding along the contour**, i.e, across the slope rather than up and down.
- Contour lines are lines that run across a (hill) slope such that the line stays **at the same height and does not run uphill or downhill.**
- As contour lines travel across a hillside, they will be **close together on the steeper parts of the hill** and

Benefits

1)Contouring can **reduce soil erosion by as much as 50%** from up and down hill farming.

2)By reducing sediment and run off and **increasing water infiltration.**

3)Contouring promotes **better water quality.**

4)It gives **10-15% additional yield**.

Criteria for Surface Irrigation Method Selection

- The deciding factors for the suitability of any surface irrigation method are **natural conditions** (slope, soil type), **type of crop**, **required depth of application**, **level of technology**, **previous experiences with irrigation**, **required labour input**.
- Moreover the irrigation system for a field must be **compatible with the existing farming operations**, such as **land preparation, cultivation, and harvesting practices.**

Physical Factors

- **Crops and cultural practices** are of prime importance while selecting an irrigation system.
- Hence, **proper knowledge of agronomic practices** and irrigation intervals is necessary for proper use of irrigation water and to **increase water use efficiency**.

Crop Parameters

- Tolerance of the **crop to soil salinity** during development and maturation.
- **Magnitude and temporal distribution** of water necessary for maximum production.
- **Economic value of crop**.

Soils Parameters

- **Texture and structure**;infiltration rate and erosion potential;salinity and internal drainage, bearing strength.
- Sandy soils have a **low water storage capacity** and a high infiltration rate.
- High intake characteristicrequire **higher flow rate** to achieve the same uniformity and efficiency.
- **Crusting of soil** and its effects on infiltration
- **Reclamation and salt leaching**- basin irrigation

Field Topography

- **Uniform, mild slopes** facilitate surface irrigation.
- **Location and relative elevation** of water source – water diversion, pumping
- **Acreage** in each field
- Location of **roads, natural gas lines, electricity lines, water lines and other obstructions.**
- Shape of field – **non rectangular shapes are more difficult** to

Fi eld slope – steepness & regularity

Climate and Weather Conditions

- Under **very windy conditions**, drip or surface irrigation methods are preferred.
- Scalding (the **disruption of oxygen-carbon dioxide exchange between the atmosphere and the root**) & the effect of water temperature on the crop at different stages of growth -risk in basin irrigation.
- Irrigation with **cold water** early in the spring can **delay growth**, whereas in the hot periods of the summer, it can cool the

l o

Water Supply

- Source and delivery schedule
- Water quantity available and its reliability
- Water quality
- Water table in case of ground water source.
- Availability and Reliability of Electricity
- Availability and reliability of energy for pumping of water is

Economic Considerations

1) Capital investment required and recurring cost.

2) Credit availability and interest rate.

3) Life of irrigation system, efficiency and cost economics.

Social Considerations

1. The **education and skill** of common farmers and labours available for handling the irrigation system

2. **Social understanding** of handling of cooperative activities and sharing of water resources

co ... peration and

Suitability and Limitations of Surface Irrigation Methods

- Some form of surface irrigation is adaptable to **almost any vegetable crop**.
- **Basin and border strip irrigation** have been successfully used on a **wide variety of crops**.
- **Furrow irrigation** is **less well adapted** to field crops if cultural practices require **travel across the furrows**. However, it is widely used in vegetables like **potato**.
- Basin and border strip irrigations flood the soil surface, and will

m y inhibit the

Surface irrigation systems perform better when **soils are uniform, since the soil controls** the intake of water.

For basin irrigation, **basin size should be appropriate for soil texture** and infiltration rate.

Basin lengths should be limited to **100 m** on very coarse textured soils, but may **reach 400 m on other soils.**

Furrow irrigation is possible with all types of soils, but extremely **high or low intake rate** soils require excessive labor or capital

c

MICRO IRRIGATION METHOD

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MICRO IRRIGATION METHOD

- Micro irrigation methods are **precision irrigation methods** of irrigation with **very high irrigation water efficiency.**
- In many parts of the country there is **decline of irrigation water** and conventional methods are having **low water use efficiency.**
- To surmount the problem, micro irrigation methods has **recently been introduced** in Indian agriculture.

- These methods **save a substantial amount of water** and helps **increasing crop productivity** particularly valuable cash crops like vegetables.
- The research results have confirmed a **substantial saving of water ranging between 40 to 80%** and there are reports of **two times yield increase** for different crops by using micro irrigation.

Advantages of Micro Irrigation

(a) Water saving, possibility of using saline water.

(b) Efficient and economic use of fertilizers.

(c) Easy installation, flexibility in operation.

(d) Suitable to all types of land terrain also suitable to waste lands.

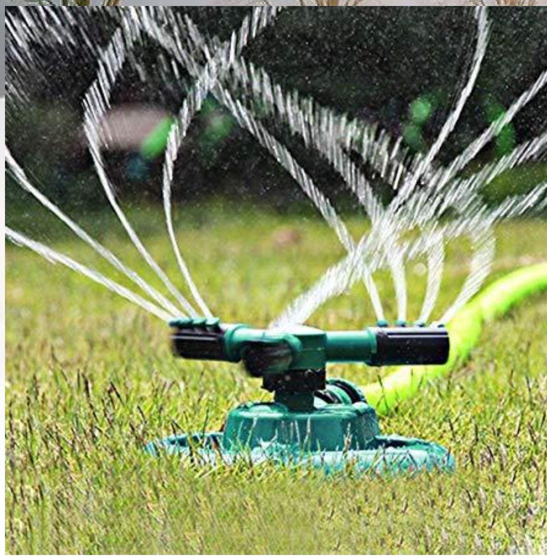
(e) Enhanced plant growth and yield and uniform and better quality of produce.

(f) Less weed growth.

(g) Labour saving.

(h) No soil erosion, saves land as no bunds, etc. are required.

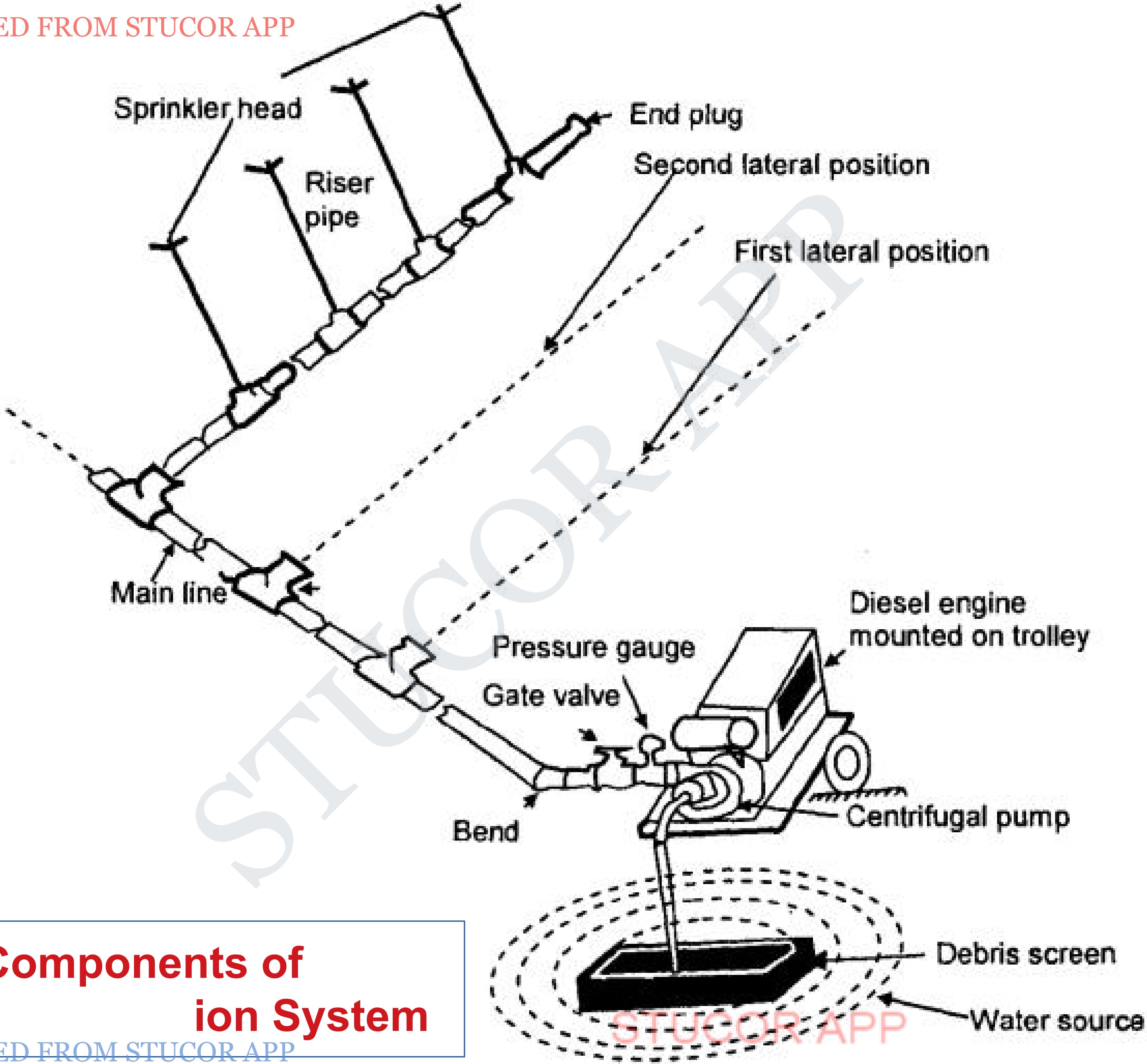
SPRINKLER IRRIGATION





SPRINKLER IRRIGATION

- In sprinkler irrigation, water is delivered through a **pressurized pipe network to sprinklers nozzles or jets** which spray the water into the air.
- To fall to the soil in an **artificial "rain"**. The basic components of any sprinkler systems are : **a water source. a pump to pressurize the water.**
- A pipe network to distribute the water **throughout the field. sprinklers to spray the water over the ground**, and valves to control the flow of water.
- The sprinklers when properly spaced give a relatively **uniform**



Components of
gat ion System

General Classification of Sprinkler Systems

(a) Rotating head or revolving sprinkler system.

(b) Perforated pipe system.

Components of Sprinkler Irrigation System

(a) A pump unit

(b) Tubings-main/sub-mains and laterals

(c) Couplers

(d) Sprinker head

(e) Other accessories such as valves, bends, plugs and risers.

Suitability and Limitations

- With regards to crops, soils, and topography nearly **all crops can be irrigated with some type of sprinkler system** though the characteristics of the crop especially **the height, must be considered in system selection.**
- Sprinklers are sometimes used to **germinate seed and establish ground cover for crops** like lettuce alfalfa and sod.
- The **light frequent applications** that are desirable for this purpose are easily achieved with some sprinkler systems.
- Sprinklers are applicable to soils that are t**oo shallow to permit**

ce rrigation.

Suitability and Limitations

- In general, sprinklers can be used on **any topography that can be formed.**
- Land **leveling is not normally required**.
- With regards to labour and energy considerations, it has been observed that **labour requirements vary depending on the degree of automation and mechanization** of the equipment used.
- **Hand-move systems require the least degree of skill**, but the greatest amount of labor.

Advantages of Sprinkler Irrigation

(a) Elimination of the channels for conveyance, therefore **no conveyance loss.**

(b) **Suitable to all types of soil except heavy clay**, suitable for irrigating crops where the plant population per unit area is very high. **It is most suitable for oil seeds** and other cereal and vegetable crops.

(c) **Water saving, closer control of water application** convenient for giving light and frequent irrigation and **higher water application efficiency.**

(d) **Increase in yield.**

Advantages of Sprinkler Irrigation

(e) Mobility of system.

(f) May also be used for undulating area, **saves land as no bunds** etc. are required, areas located at a higher elevation than the source can be irrigated.

(g) Influences greater conducive micro-climate.

(h) Possibility of using soluble fertilizers and chemicals.

(i) Less problem of clogging of sprinkler nozzles due to sediment laden water

Capacity of Sprinkler System

$$Q = 2780 \times \frac{A \times d}{F \times H \times E}$$

Where,

Q = Discharge capacity of the pump, liter/second,

A = Area to be irrigated, hectares,

d = Net depth of water application, cm,

F = Number of days allowed for the completion of one irrigation,

H = Number of actual operation hours per day, and

E = Water Application Efficiency in %

DRIP IRRIGATION

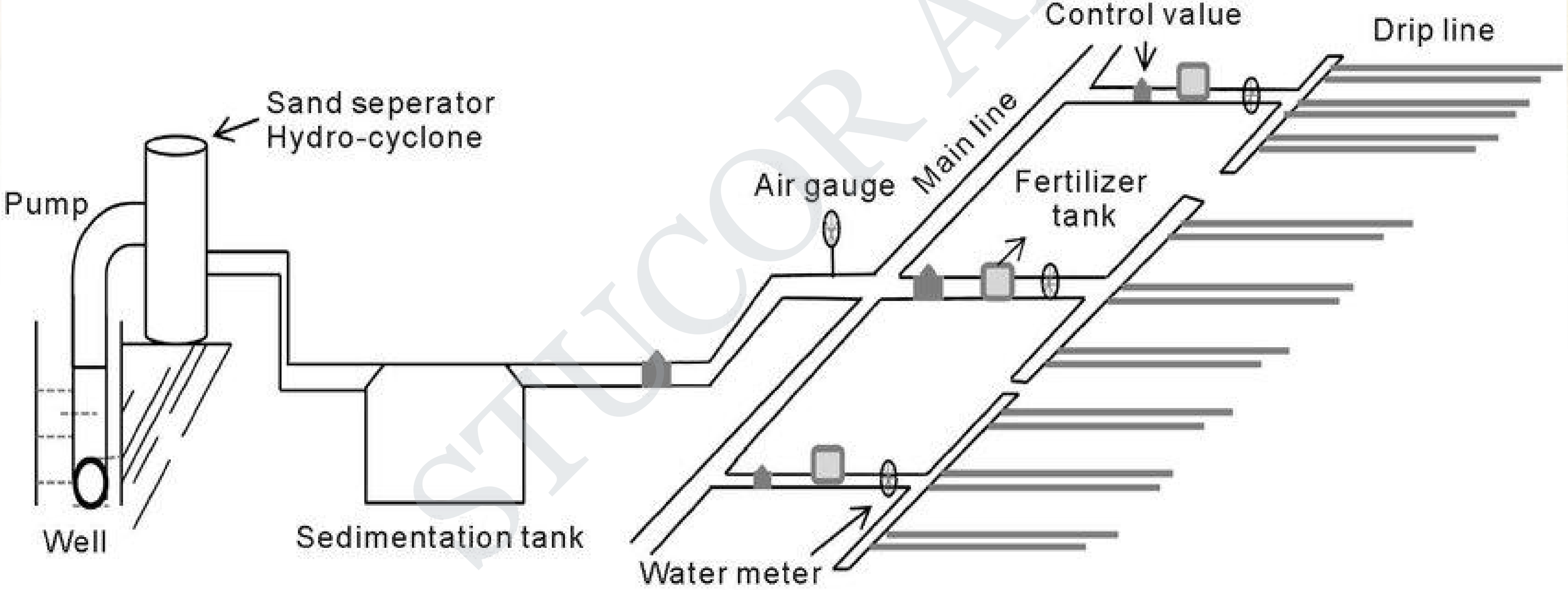
DRIP IRFUGATION

- Drip irrigation, also known as **trickle irrigation** or **microirrigation** is an irrigation method which **minimizes the use of water and fertilizer** by **allowing water to drip slowly to the roots of plants**, either onto the soil surface or directly onto the root zone, through a **network of valves, pipes, tubing, and emitters.**
- It is becoming popular for **row crop irrigation**.
- This system is used in place of water scarcity as it **minimizes conventional losses such as deep percolation, evaporation and run-off** or recycled water is used for irrigation.

- **Small diameter plastic pipes fitted with emitters or drippers** at selected spacing to deliver the required quantity of water are used.
- Drip irrigation may also use devices called **micro-spray heads, which spray water in a small area**, instead of dripping emitters.
- Subsurface drip irrigation (SDI) uses **permanently or temporarily buried drip per line or drip tape** located at or below the plant roots.
- **Pump and valves** may be manually or automatically operated by a controller Drip irrigation is the slow, **frequent application of water to the soil though emitters** placed along a water delivery line.

- The term drip irrigation is general, and includes s**everal more specific methods.**
- Drip irrigation applies the water through small emitters to the soil surface, usually **at or near the plant to be irrigated**.
- **Subsurface irrigation** is the application of water **below the soil surface.**
- Emitter discharge rates for drip and subsurface irrigation are generally **less than 12 liters per hour**.

DRIP IRFUGATION



Components of Drip Irrigation System (Listed in Order from Water Source)

(a) Pump or pressurised water source.

(b) Water Filter(s) - Filtration Systems : Sand Separator, Cyclone, Screen Filter, Media Filters.

(c) Fertigation Systems (Venturi injector).

(d) Backwash Controller.

(e) Main Line (larger diameter Pipe and Pipe Fittings).

(f) Hand-operated, electronic, or hydraulic Contvl Valves and Safety Valves.

(g) Smaller diameter polytube (often referred to as "laterals").

(h) Poly fittings and Accessories (to make connections).

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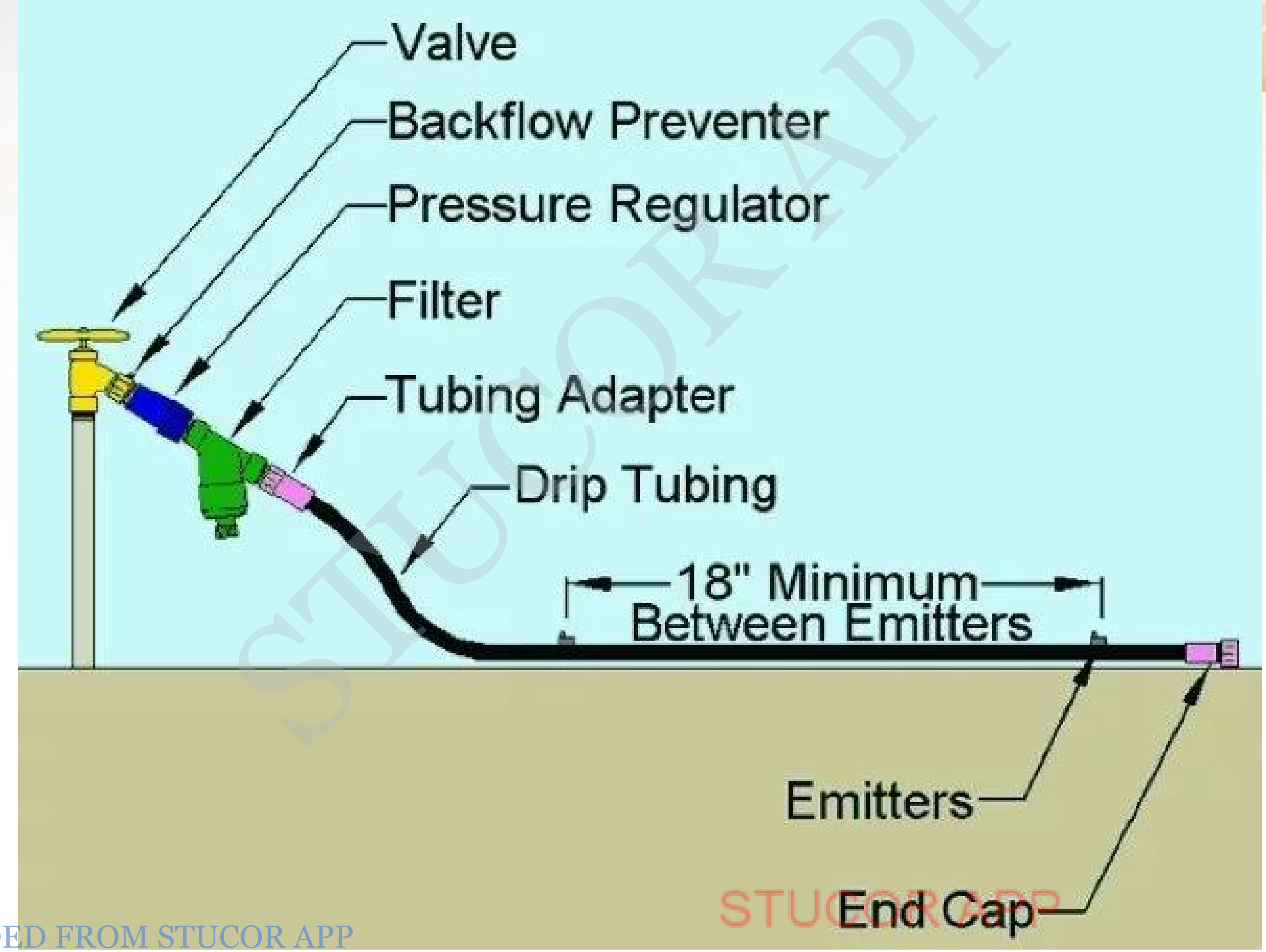
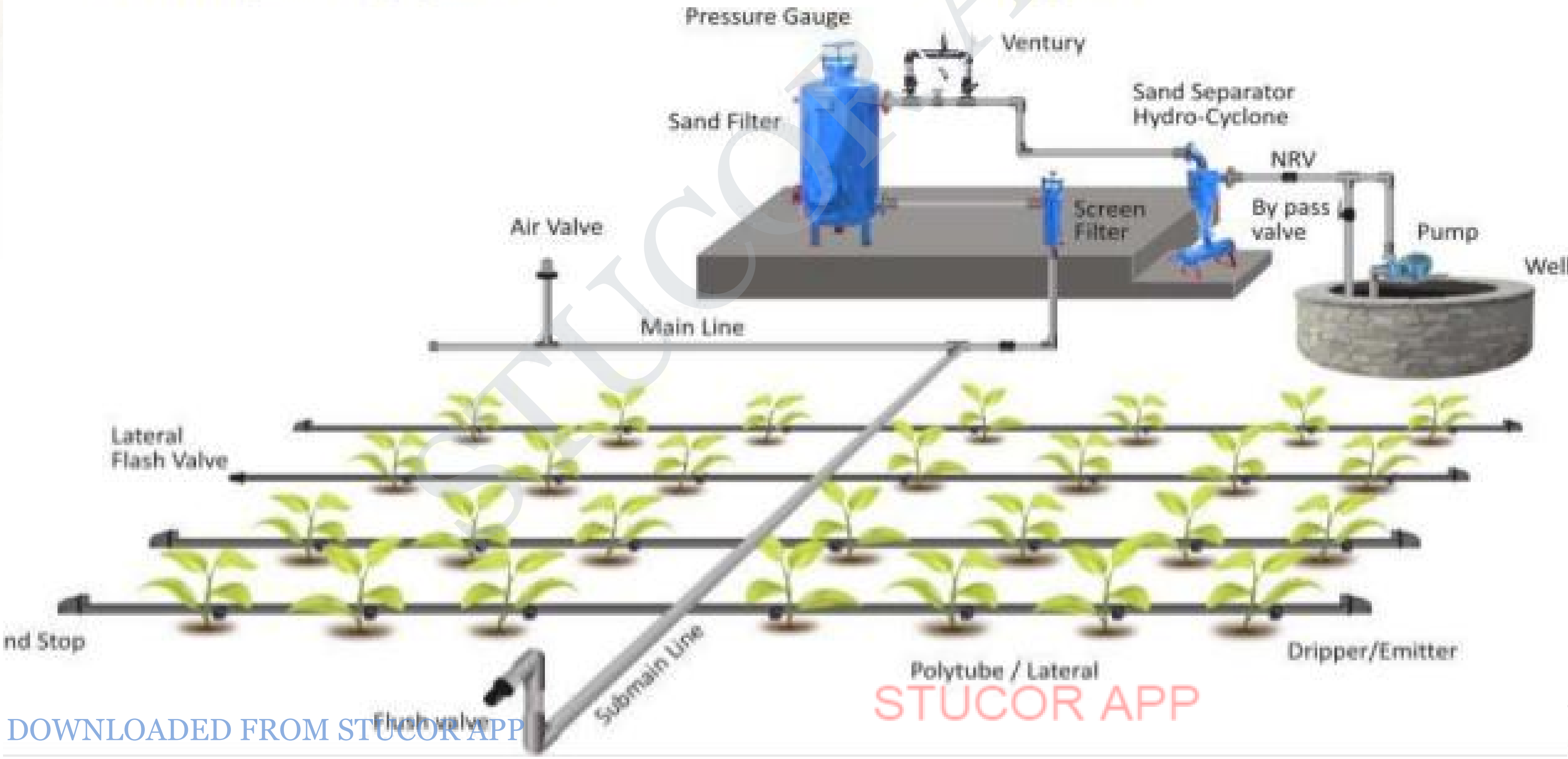
Components of Drip Irrigation System



COMPONENTS OF DRIP IRRIGATION

1. Water source
2. Pumping unit
3. Filters(Hydro cyclone, sand, screen filters)
4. Fertigation equipment
5. Main line
6. Sub main line
7. Valves
8. Laterals/Poly tubes
9. Drippers



Suitability and Limitation

(a) From **stand point of crops**, soil, and topography, drip irrigation is best suited for **tree, vine, and row crops**.

(b) With respect to water quantity and quality, drip irrigation uses a **slower rate of water application over a longer period of time** than other irrigation methods.

(c) Though a form of pressurized irrigation, **drip is a low pressure**, low flow rate method.

(d) High efficiencies are USP of drip irrigation system. Properly

pa ... ble of high

(e) **Labour and energy considerations** are very important consideration in drip irrigation system.

(f) Drip irrigation systems generally use **less energy than other forms** of pressurized irrigation systems.

(g) Economic factors need special attention in case drip irrigation system as **initial cost and operational cost is reasonably high**.

(h) Drip systems **costs can vary greatly**. Depending on crop (plant. and therefore emitter and hose spacings) and type of hose employed (permanent or "disposable" thin-walled tubing).

Advantages

1. **Minimised fertilizer nutrient loss** due to localized application and reduced leaching, allows safe use of recycled water.
2. **High water distribution efficiency.** Moisture within the root zone can be maintained at field capacity.
3. **Leveling of the field not necessary**. Soil type plays less important role in frequency of irrigation, minimised soil erosion.
4. Highly **uniform distribution of water,** i.e. controlled by output of each nozzle.
5. **Lower labour cost.**
6. **Early maturity** and good harvest.

Performance Indicator	Conventional Irrigation Methods	Drip Irrigation
Water saving	Waste lot of water. Losses occur due to percolation, runoff and evaporation	40-70% of water can be saved over conventional irrigation methods. Runoff and deep percolation losses are nil or negligible.
Water use efficiency	30-50%, because losses are very high	80-95%

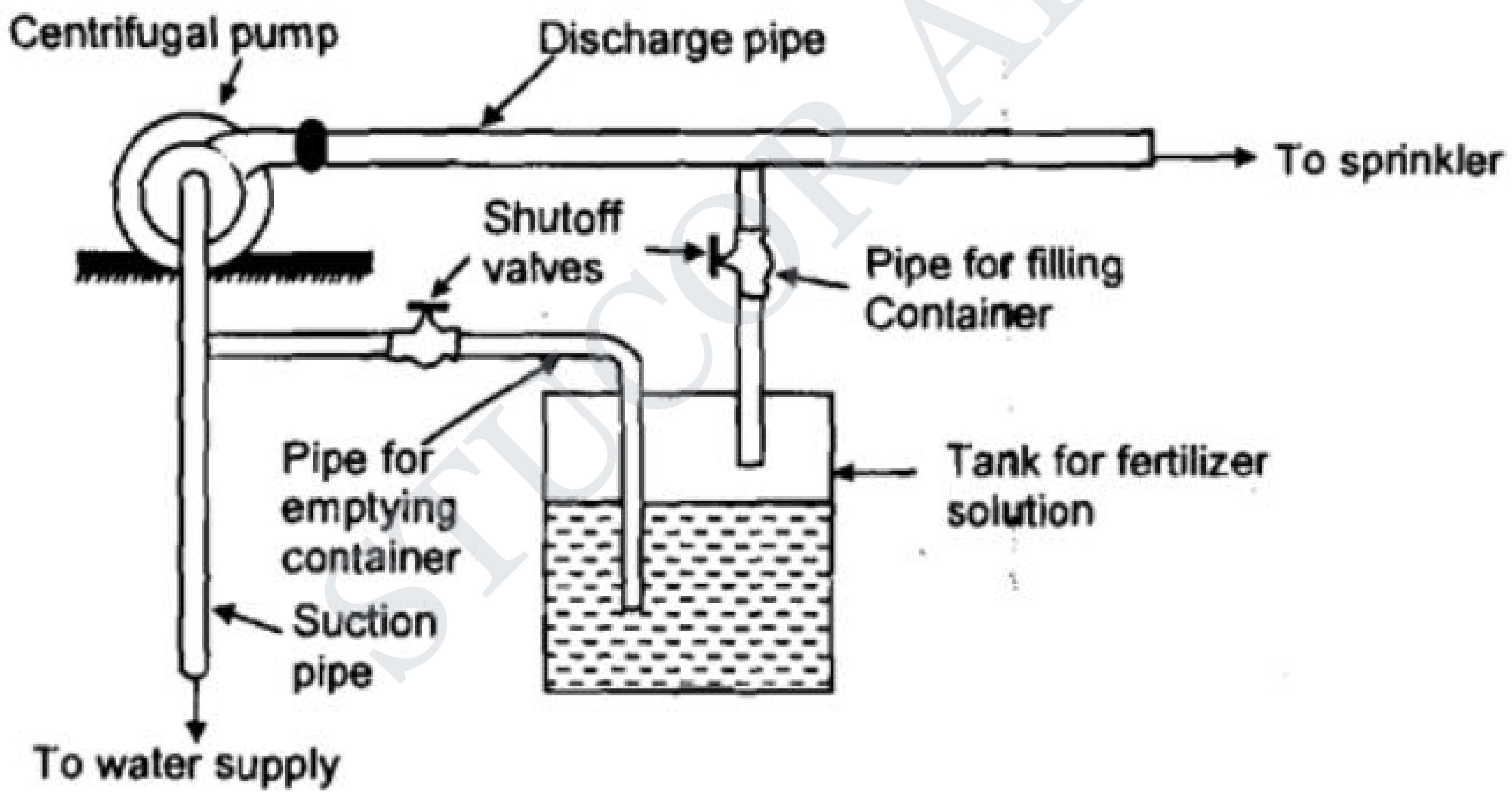
Saving in labour	Labour engaged per irrigation is higher than drip	Labour required only for operation and periodic maintenance of the system
Weed infestation	Weed infestation is very high	Less wetting of soil, weed infestation is very less or almost nil.
Use of saline water	Concentration of salts increases and adversely affects the plant growth. Saline water cannot be used for irrigation	Frequent irrigation keeps the salt concentration within root zone below harmful level
Diseases and pest problems	High	Relatively less because of less atmospheric humidity

Suitability in different soil Type	Deep percolation is more in light soil and with limited soil depths. Runoff loss is more in heavy soils	Suitable for all soil types as flow rate can be controlled
Water control	Inadequate	Very precise and easy
Efficiency of fertilizer use	Efficiency is low because of heavy losses due to leaching and runoff	Very high due to reduced loss of nutrients through leaching and runoff water
Soil erosion	Soil erosion is high because of large stream sizes used for irrigation.	Partial wetting of soil surface and slow application rates eliminate any possibility of soil erosion
Increase in crop yield	Non-uniformity in available moisture reducing the crop yield	Frequent watering eliminates moisture stress and yield can be increased up to 15- 150% as compared to conventional methods of irrigation.

FERTIGATION

- Fertigation is the process of **application of water soluble solid fertilizer** or liquid fertilizers through drip irrigation system.
- Through fertigation **nutrients are applied directly into the wetted volume of soil immediately below the emitter** where root activity is concentrated.
- **Fertigation is practiced only in drip irrigation system.** However, fertilizer solution can be added with sprinkler irrigation system also.

FERTIGATION



Components of Fertigation

The main component of a fertigation is drip irrigation system. The main components are :

(a) Venturi pump (injector)

(b) Fertilizer tank with flow bypass

(c) Pressure bypass tank

(d) Injection pump.

Advantages of Fertigation

1) The **fertilizer solution is distributed evenly in the irrigation network** with the same uniformity as the irrigation water.

2) The availability of nutrients including **micro-nutrients is high,** therefore the **efficiency is very good.**

3) The fertilizer system can also be used for other activities such as **incorporating acid to flush the drip system**.

4) It **eliminates the work of spreading fertilizer**. Manual spreading of fertilizer causes soil compaction and may damage the growing crop.

1) **Fertilizer placement is exactly to the root zone of plant** and can be uniformly applied through drip irrigation system.

2) All types of **nutrients can be given simultaneously.**

3) **Lower doses of fertilizer could be applied daily or weekly** (i.e. a large number of split application) to avoid leaching and fixation in soil.

4) Some liquid fertilizers are free of sodium and chloride salts, so **these are not harmful to soil.**

1) **Spraying with liquid fertilizer** is possible.

2) **Liquid fertilizers are immediately available** to plants.

3) Fertilizer use **efficiency can be increased by 25 to 30%** over the tradition method of fertilizer application.

4) It **decreases labour and energy cost.**

5) The **quality and quantity of crop production can be improved**

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Limitations

- The main one is the **danger of poisoning people** who drink the irrigation water particularly laborers those work on the farm.
- It is therefore necessary to warn the people in the field about drinking water separately and put up **warning signs.**
- **Toxicity and Contamination**
- **Fertilizer Suitability**
- **Corrosion**

Irrigation scheduling

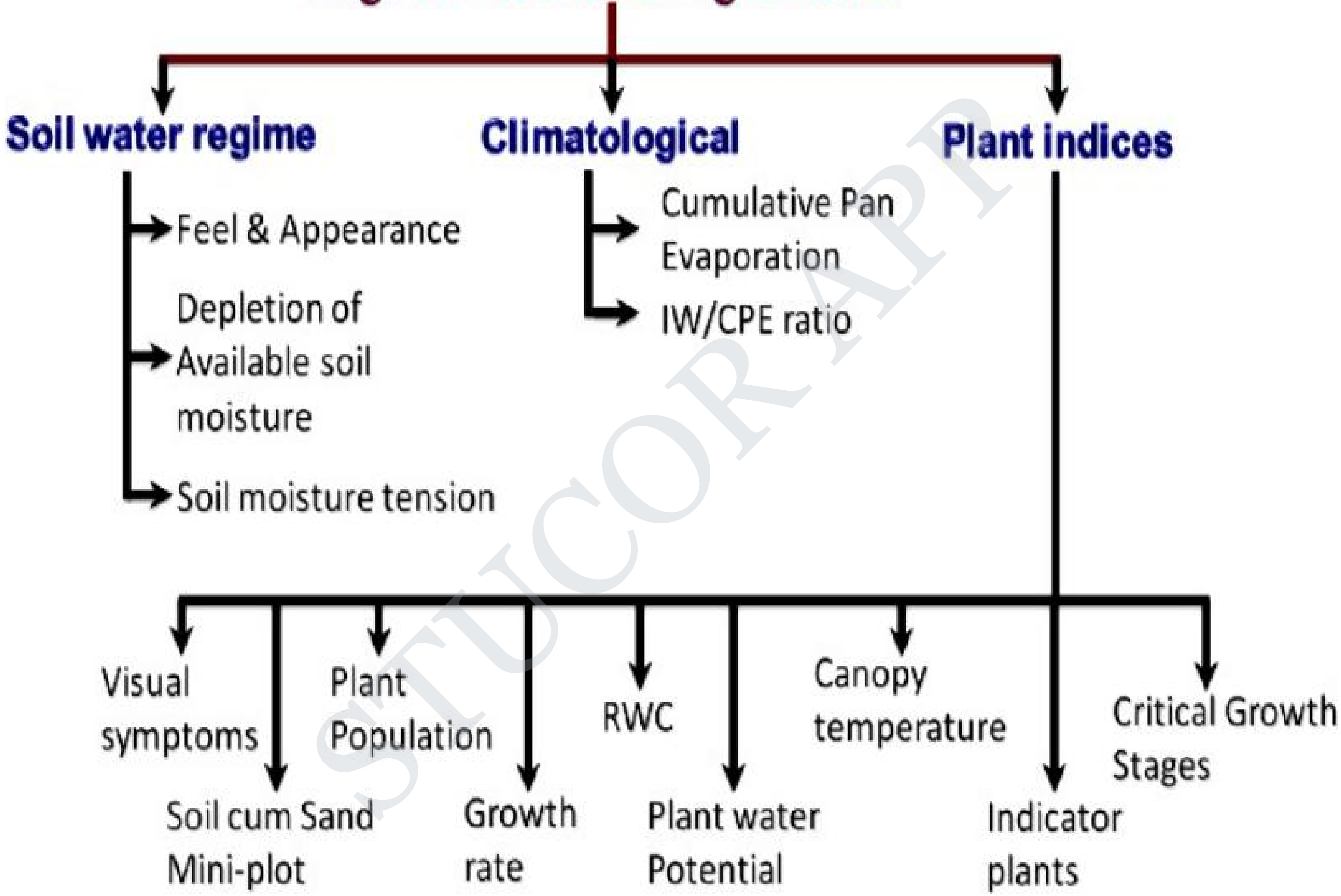
Irrigation scheduling is the process used by irrigation system managers to determine the **correct frequency and duration of watering.**

Advantages of Irrigation Scheduling

- It enables the farmer to **schedule water rotation** among the various fields to minimize crop water stress and maximize yields.
- It reduces the farmer's **cost of water and labour**
- It **lowers fertilizer costs** by holding surface runoff
- It **increases net returns** by **increasing crop yields** and crop quality.
- It **minimizes water-logging problems**
- It assists in **controlling root zone salinity problems**

w **ter to irrigate**

Irrigation Scheduling Criteria

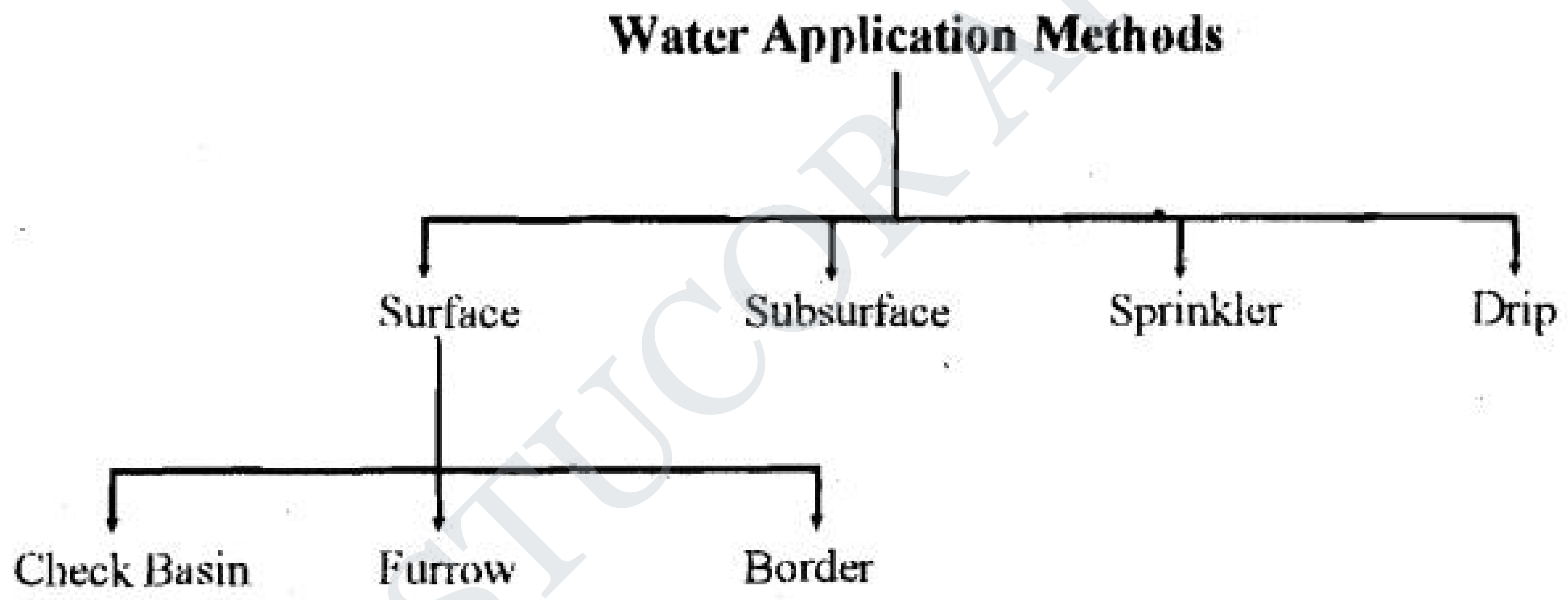


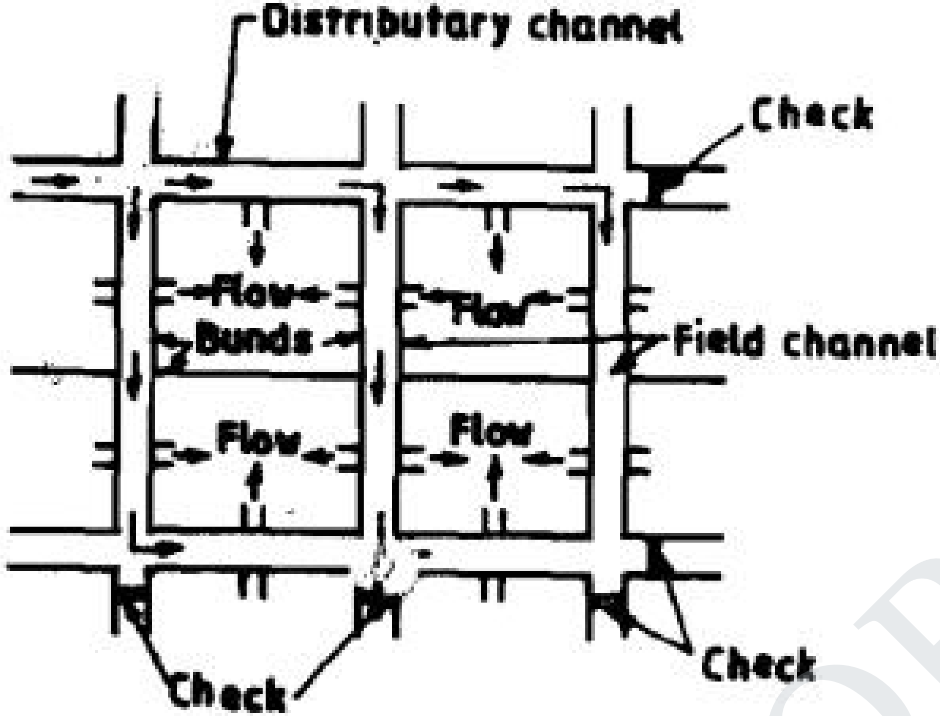
Water distribution system

Irrigation water inay be applied to crops either by **flooding the field by applying water beneath the soil surface, by spraying it under pressure or by applying it in drops.**

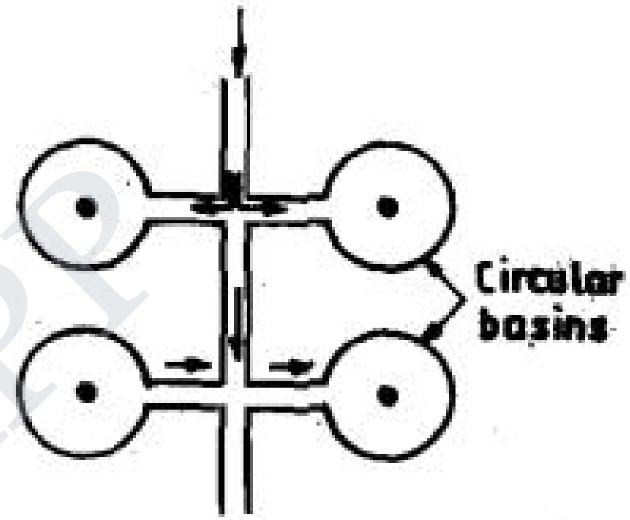
Selection of the suitable method, from among these methods, depends on **topography, soil condition, land preparation, type of crop and its value, available water supply** and other factors

Water distribution system

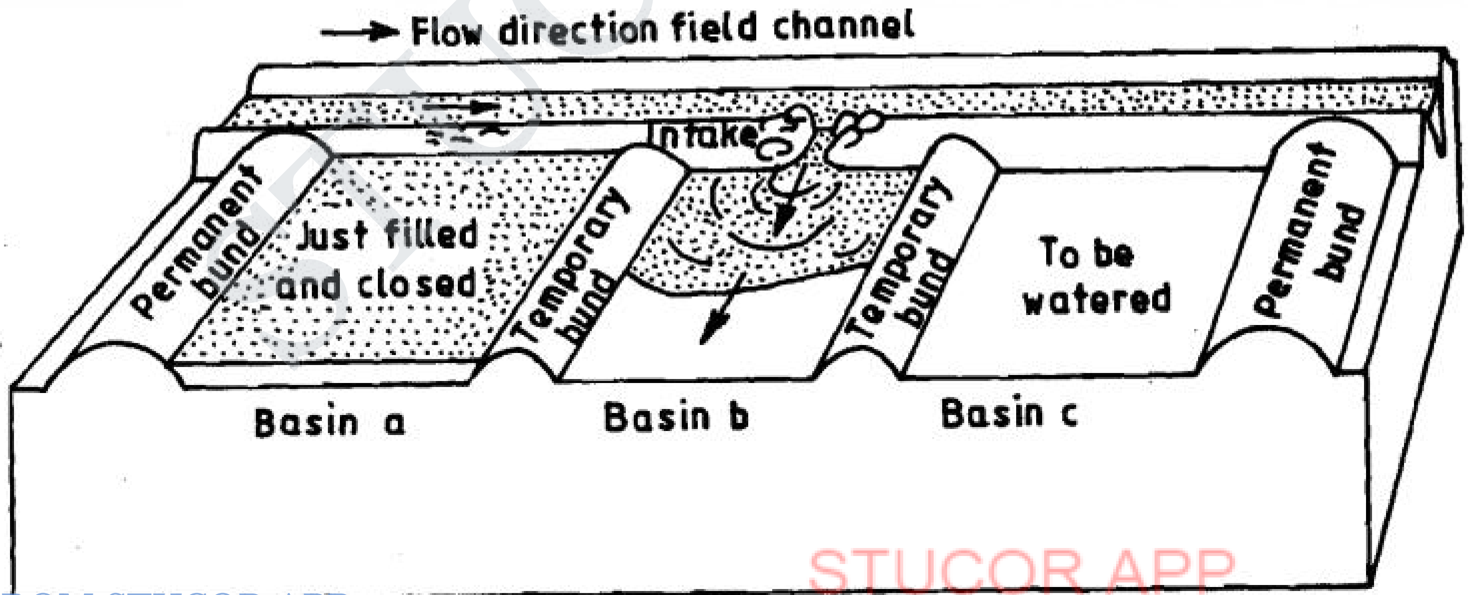


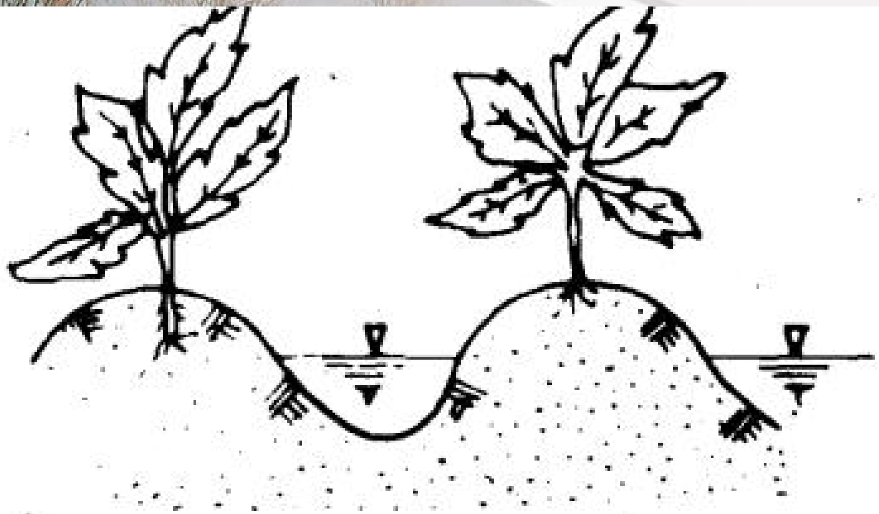


(a) Check basins

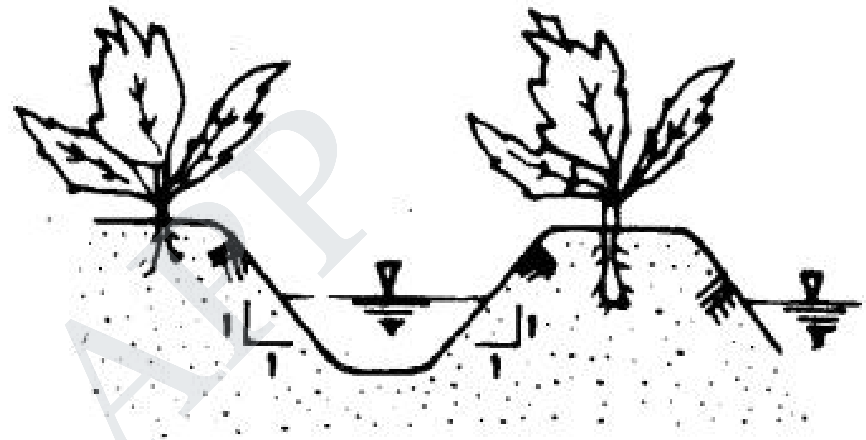


(b) Ring or circular basins

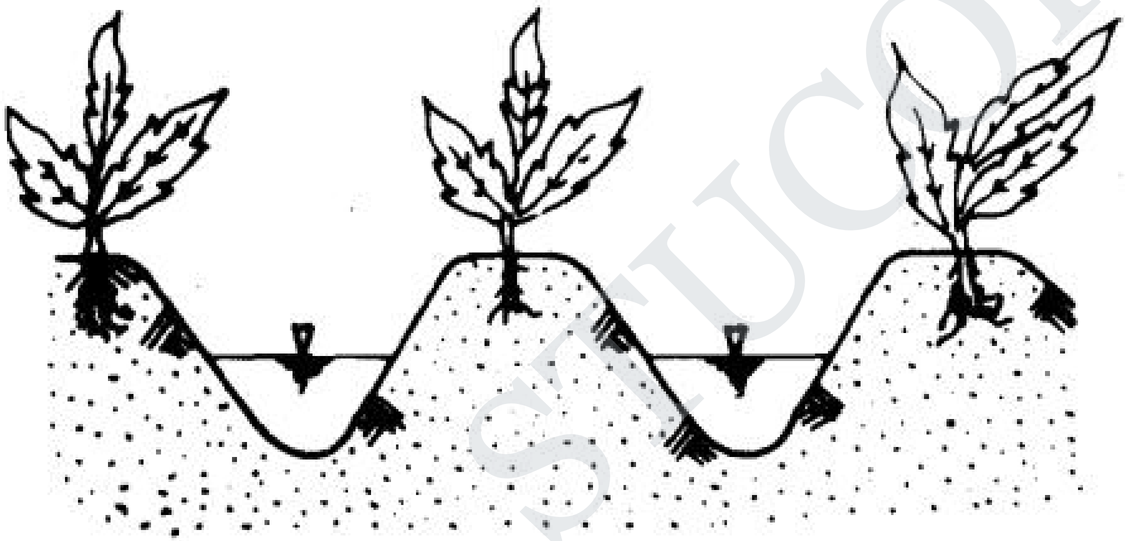




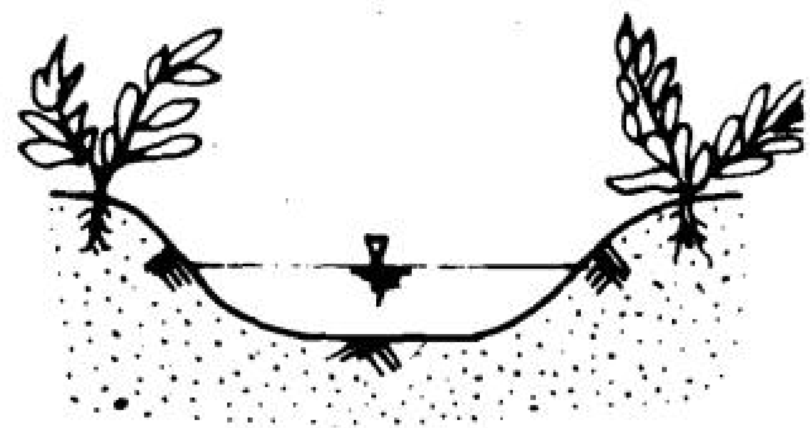
(a) Round shaped furrows



(b) 'V'- Shaped furrows

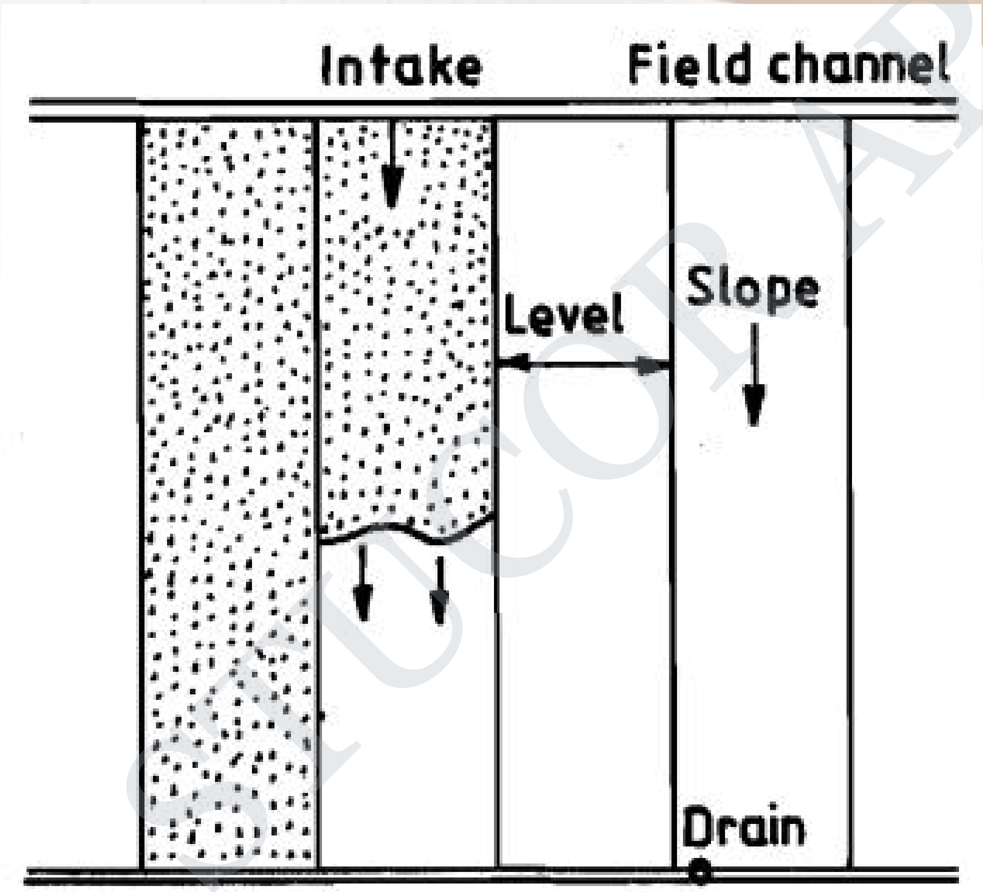


(c) Parabolic furrows



(d) Broad based furrows

BORDER IRRIGATION



CHOICE OF METHOD OF IRRIGATION

- Natural conditions (slope & soil type).
- Type of crop,
- Level of technology that is available,
- Previous experience with the practice of irrigation and
- Required labour inputs.

Irrigation Efficiencies

- Efficiency is the **ratio of the water output to the water input**, and is usually expressed as percentage.
- Input minus output is nothing but losses, and hence, if Losses are more, output is less and, therefore, efficiency is less. Hence, **efficiency is inversely proportional to the losses**.
- **Water is lost in irrigation during various processes** and, therefore, there are different kinds of irrigation efficiencies

Kinds of irrigation efficiencies

1)Efficiency of Water-conveyance

2)Efficiency of Water Application

3)Efficiency of Water Use

4)Efficiency of water storage

5)Water Distribution Efficiency

Efficiency of Water-conveyance (η_c)

It is the ratio of the **water delivered into the fields from the outlet point of the channel, to the water entering into the channel at its starting point**. It may be represented by η_c. It takes the conveyance or transit losses into consideration.

$$\eta_c = (W_f/W_r) \times 100$$

Where

η_c= Water conveyance efficiency,

r delivered to the irrigated plot at field supply Channel,

Efficiency of Water Application (η_a)

It is ratio of **water stored into the root zone of the crop to the quantity of water delivered at the field (Farm).**

$$\eta_a = W_s/W_f \times 100$$

Where,

η_a = Water application efficiency,

W_s = Water stored at the root zone during the irrigation

W_f = Water delivered to the farm.

Efficiency of Water Use (η_u)

It is the ratio of the **water beneficially used including leaching water, to the Quantity of water delivered.** It may be represented by η_u

$$\eta_u = (Wu/Wd) \times 100$$

Where,

η_u = Water use efficiency,

Wu = Beneficial use of water or consumptive.

Efficiency of water storage: (η_s)

The concept of water storage efficiency gives an insight to **how completely the required water has been stored in the root zone during irrigation.**

$$\eta_s = (Ws/Wn) X 100$$

Where,

η_s= Water storage efficiency,

Ws = water stored in the root zone during irrigation.

tio .

Water Distribution Efficiency (η_d)

Water distribution efficiency evaluates **the degree to which water is uniformly distributed throughout the root zone**.The more uniformly the water is distributed , the better will be crop response.

$$\eta_d = 100\,(1 - y/d)$$

Where,

η_d= Water distribution efficiency,

y= avg numerical deviation in depth of water stored from avg depth

Consumptive use Efficiency (η_{cu})

It is the ratio of **consumptive use of water to the water depleted from the root zone**.

$$\eta_{cu} = (W_{cu}/W_d) X 100$$

Where,

η_{cu}= Consumptive use efficiency,

W_{cu}= Nominal consumptive use of water

W_d = Net amount of water depleted from the root zone soil.

Discussions ?


THANK
YOU

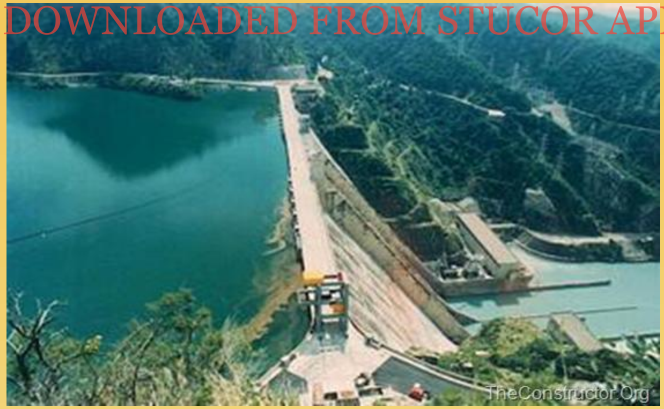
UNIT-3

DIVERSION AND IMPOUNDING STRUCTURES

P.Muthuraman

DIVERSION AND IMPOUNDING STRUCTURES

Types of Impounding structures - Gravity dam – Forces on a dam -Design of Gravity dams; Earth dams, Arch dams- Diversion Head works - Weirs and Barrages.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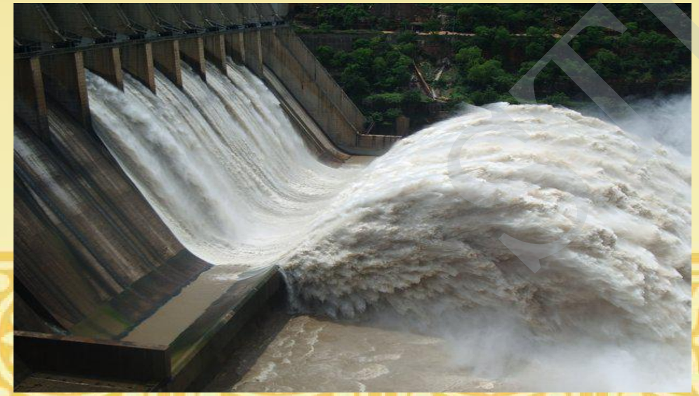


Impounding structure

Impounding structure or dam means a **man-made device structure**, whether **a dam across a watercourse or other structure outside a watercourse**, used or to be used **to retain or store waters or other materials.**

The term includes:

(i) all dams that are **25 feet or greater in height** and that create an impoundment capacity of **15 acre-feet**

Diversion headwork.

- Any **hydraulic structure**, which **supplies water to the off-taking canal**, is called a headwork.
- A diversion headwork serves **to divert the required supply in to the canal** from the river.

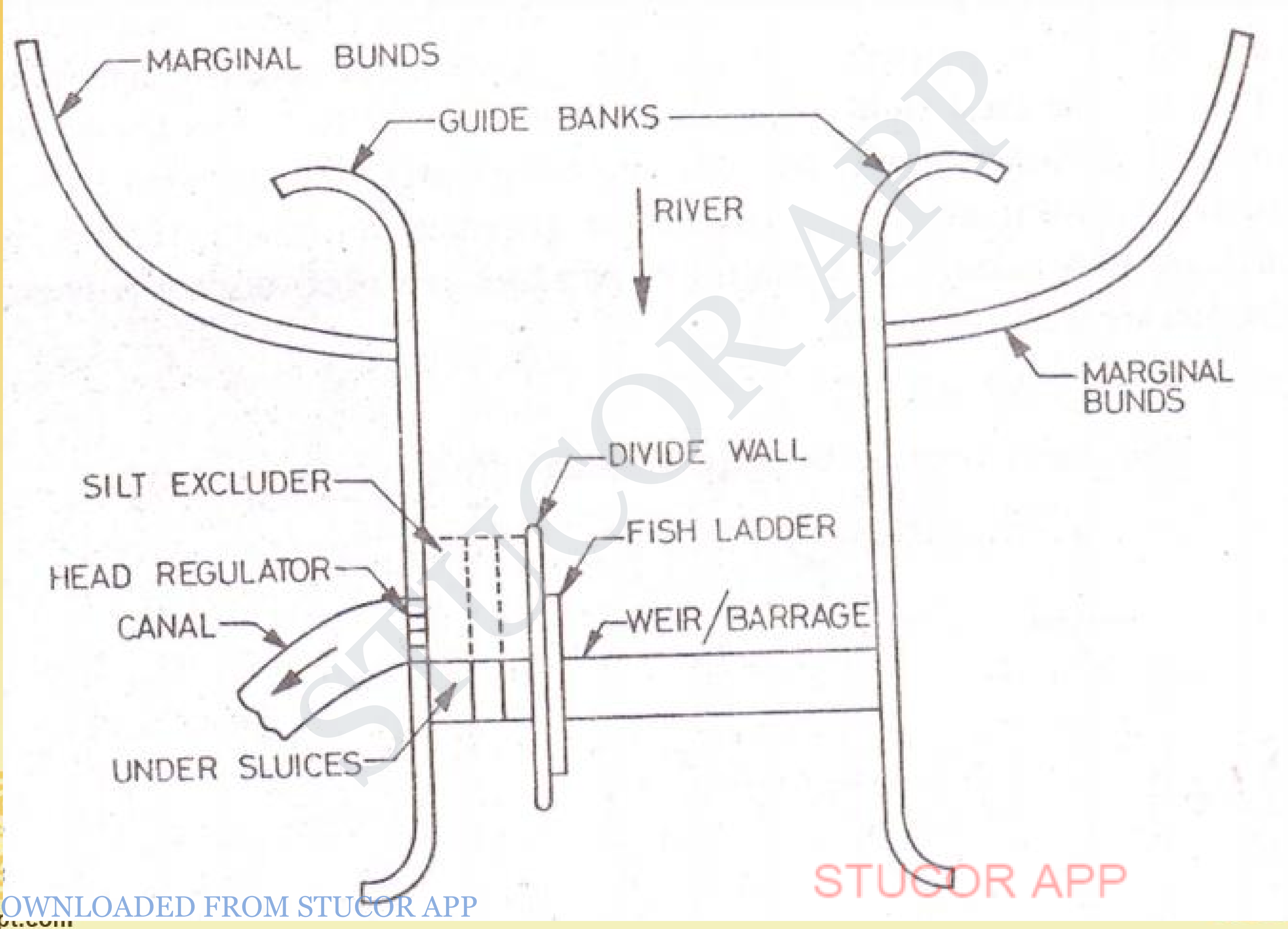
The purposes of diversion headwork.

- It **raises the water level in the river** so that the commanded area can be increased.
- It **regulates the intake of water** in to the canal.
- It **controls the silt entry** in to the canal.
- It **reduces fluctuations in the level of supply** in the river.
- It **stores water for tiding** over small periods of short supplies.

The component parts of diversion headwork

- Weir or barrage
- Divide wall or divide groyne
- Fish ladder
- Head sluice or canal head regulator
- Canal off-takes
- Flood banks
- River training works.

Component parts of Diversion headwork.



Dam

A dam is a **hydraulic structure constructed across a river to store the suppliy for a longer duration** and release it through designed outlets.

Types of Dams

Based on Materials of Construction

- Rigid.
- Non-Rigid.

Based on Structural Behaviour

- Gravity Dam.
- Arch Dam.
- Buttress Dam.

Based on Functions

- Storage Dam.
- Detention Dam.
- Diversion Dam.
- Coffer dam.

Based on Hydraulic Behaviour

- Over Flow Dam.
- Non Over Flow Dam.

General Types

- Solid gravity dam (masonry, concrete, steel and timber)
- Arch dams
- Buttress dams
- Earth dams
- Rockfill dams
- Combination of rockfill and earth dams

Gravity dam

Gravity dam

- A gravity dam is a structure so proportioned that **its own weight resists the forces exerted upon it**.
- It requires **little maintenance** and it is **most commonly used.**
- A Gravity dam has been defined as a **"structure which is designed in such a way that its own weight resist the external forces".**
- This type of a structure is **most durable and solid** and less maintenance.

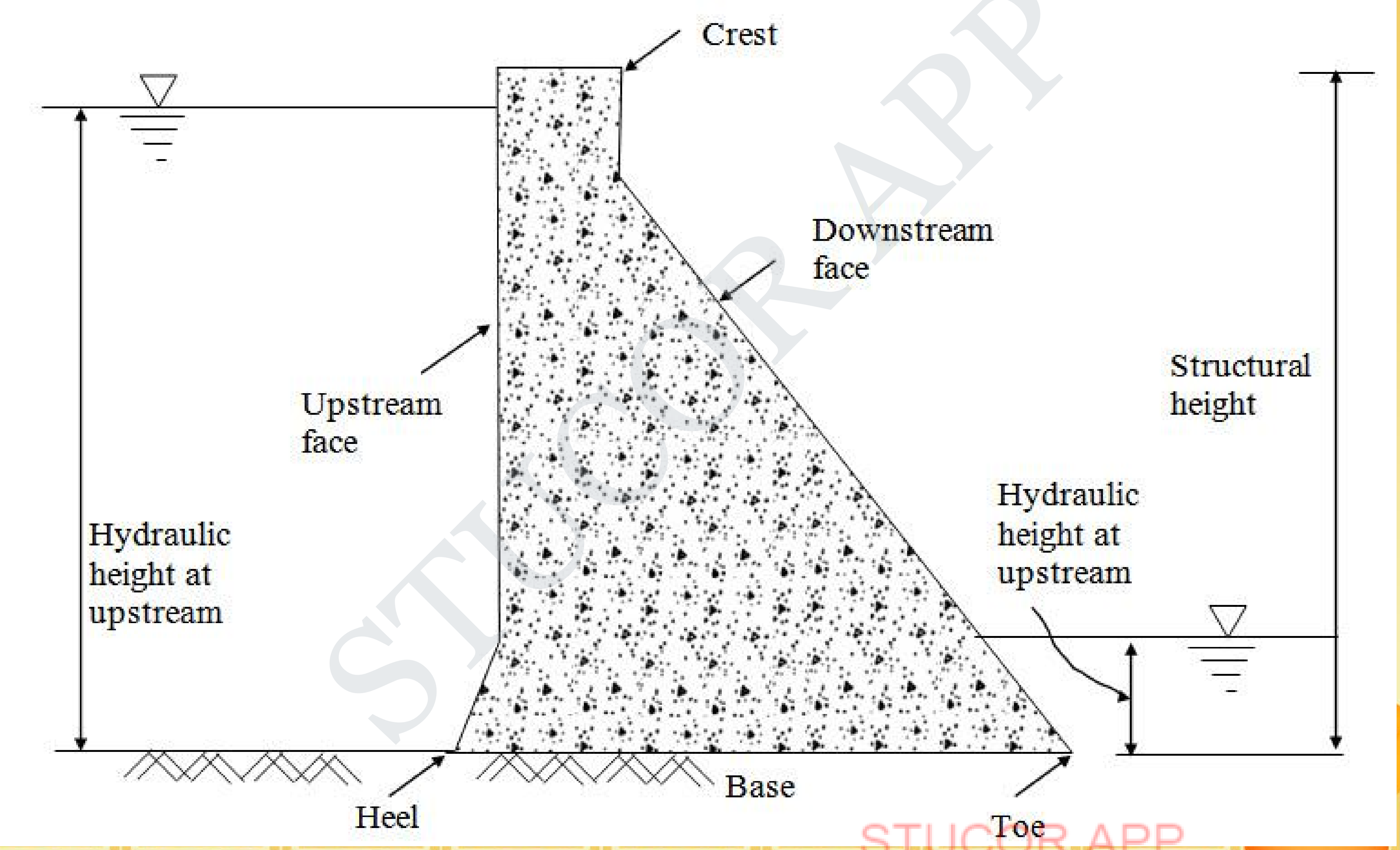
ry

- Such dams are constructed of **masonry or Concrete.**
- However, **concrete gravity dams are preferred** these days and mostly constructed.
- The line of the upstream face or the line of the crown of the dam if the upstream face is sloping, is taken as the reference line for layout purpose etc. and is known as the **Base line of the dam or the "Axis of The Dam"** When suitable conditions are available such dams can be constructed up to great heights.

Components of a solid gravity dam

- Crest.
- Free Board.
- Heel.
- Toe.
- Sluice Way.
- Drainage Gallery.

Typical cross section of gravity Dam:



Heel: contact with the ground on the upstream side

Toe: contact on the downstream side

Abutment: Sides of the valley on which the structure of the dam rest

Galleries: small rooms like structure left within the dam for checking operations.

Diversion tunnel: Tunnels are constructed for diverting water before the construction of dam. This helps in keeping the river bed dry.

Spillways:

It is the arrangement near the top to **release the excess water** of the reservoir to downstream side

Sluice way:

An opening in the dam near the ground level, which is used to **clear the silt accumulation** in the reservoir side.

Forces Acting on Gravity Dam

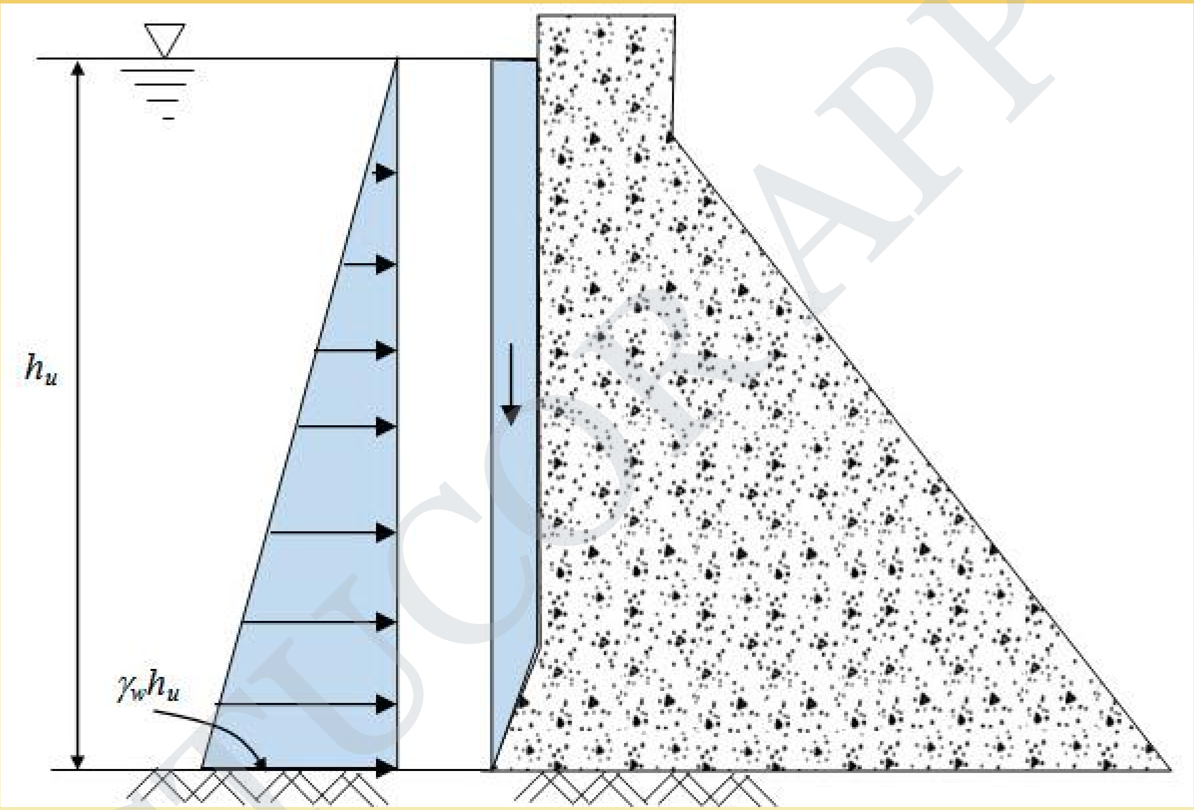
- Water Pressure
- Uplift Pressure
- Pressure due to Earthquake forces
- Silt Pressure
- Wave Pressure
- Ice Pressure
- The stabilizing force is the weight of the dam itself

Self weight of the Dam

- Self weight of a gravity dam is **main stabilizing force** which counter balances all the external forces acting on it.
- For construction of gravity dams the specific weight of concrete & stone masonry **shouldn't be less than 2400 kg/m^3 & 2300 kg/m^3** respectively.
- Its calculated by the following formula –
- Where γ_m is the specific weight of the dam's material.

Water pressure

- **On upstream face** pressure exerted by water is stored upto the **full reservoir level.**
- **On downstream face** the pressure is exerted by **tail water.**
- The downstream face is always inclined. It is calculated by the following formula –
- Where γw is the unit weight of water & h is the height of water.



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Uplift water pressure

- The uplift pressure is the **upward pressure of water** at the base of the dam.
- The water stored on the upstream side of the dam has a tendency to **seep through the soil below foundation**.
- While seeping, the water exerts a **uplift force on the base** of the dam **depending upon the head of water**.
- This **uplift pressure reduces the self weight of the dam**.
- It is calculated by the following formula–

SEISMIC FORCES :

- Dams are subjected to **vibration** during earthquakes.
- Vibration affects both the **body of the dam** as well as the **water in the reservoir** behind the dam.
- The most danger effect occurs when the **vibration is perpendicular to the face of the dam**.

Body Forces: Body force acts horizontally at the center of gravity and is calculated as:

Water Force: Water vibration produces a force on the dam acting horizontally & calculated by:

Two conditions should be satisfied to achieve stability

When empty - The external force is zero & its self weight passes through C.G. of the triangle.

When Full - The resultant force should pass through the extreme right end of the middlethird.

The limiting condition is –

where, σc=allowable compressive stress

Low Gravity Dam

- A low gravity dam is designed on the basis if of elementary profile, where the **resultant force passes through the middle-third of its base.**
- **The principal stress** is given by **$\sigma = \gamma H (S - C + 1)$** Where, σ=principal stress, γ=unit weight, S=Specific Gravity and C=A constant.
- The principal stress **varies with 'H'** as all other terms are constant. **To avoid failure of the dam the value of 'σ' shouldn't exceed allowable working stress**(F). Where **$F = \gamma H (S - C + 1)$**

High Gravity Dam

- The high gravity is a complicated structure, where the **resultant force may pass through a point outside the middle-third of the base.**
- The section of the dam is modified **by providing extra slope on the upstream and downstream side.**
- The condition for the high gravity dam are
- – Where, f=allowable working stress.

Precautions against Failure

- To prevent overturning, the **resultant of all forces acting on the dam should remain within the middle-third of the base width** of the dam.
- In the dam, the **sliding should be fully resisted** when the condition for **no sliding exists** in the dam section.
- In the dam section, the **compressive stresses** of concrete or masonry **should not exceed the permissible working stress to avoid failure** due to crushing.
- There should be **no tension in the dam section to avoid the formation of cracks.**
- The factor of safety should be maintained between **4 to 5**

Temperature Control

During **setting of concrete heat of hydration** is evolved producing **internal temperature stresses** resulting in development of **internal cracks can get formed.**

To control the temperature the following steps may be taken

1) **Low heat cement** may be used in concrete.
2) The water & coarse aggregates should be **cooled down to 5°C** by suitable means before mixing.
3) During laying the **height of concrete blocks should not be more than 1.5 m**.
4) cooled by **crushed ice before using** it for the

Advantages

- Gravity dams are more suitable in narrow valleys.
- Maintenance cost is lower
- Failure of these dams is not very sudden.
- Gravity dams may be built to any height.
- Loss of water by seepage in gravity dams is less

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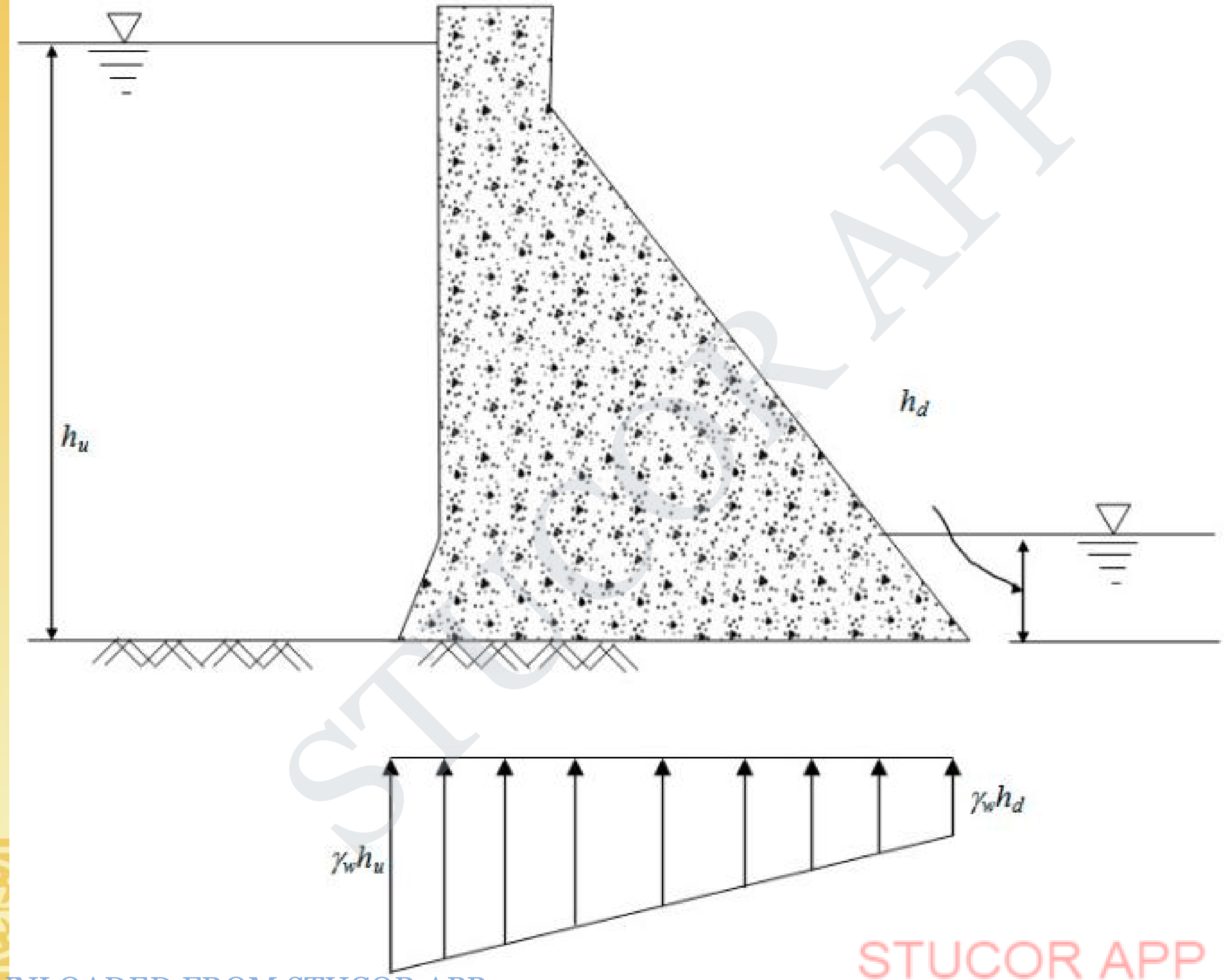
Disadvantages

- Initial cost for construction of gravity dams is very higher.
- Gravity dams of greater height can only be constructed on sound rock foundations.
- Require skill labour for construction.
- Design of gravity dams is very complicated.

Pressure Distribution



General Requirement for Stability

A gravity dam may fail in the following modes,

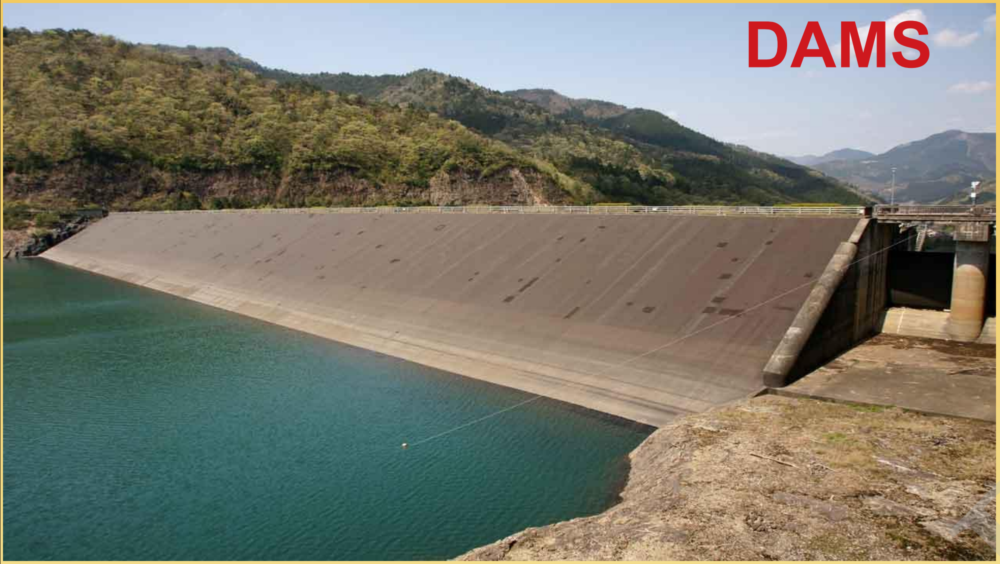
- Overturning
- Sliding
- Compression
- Tension

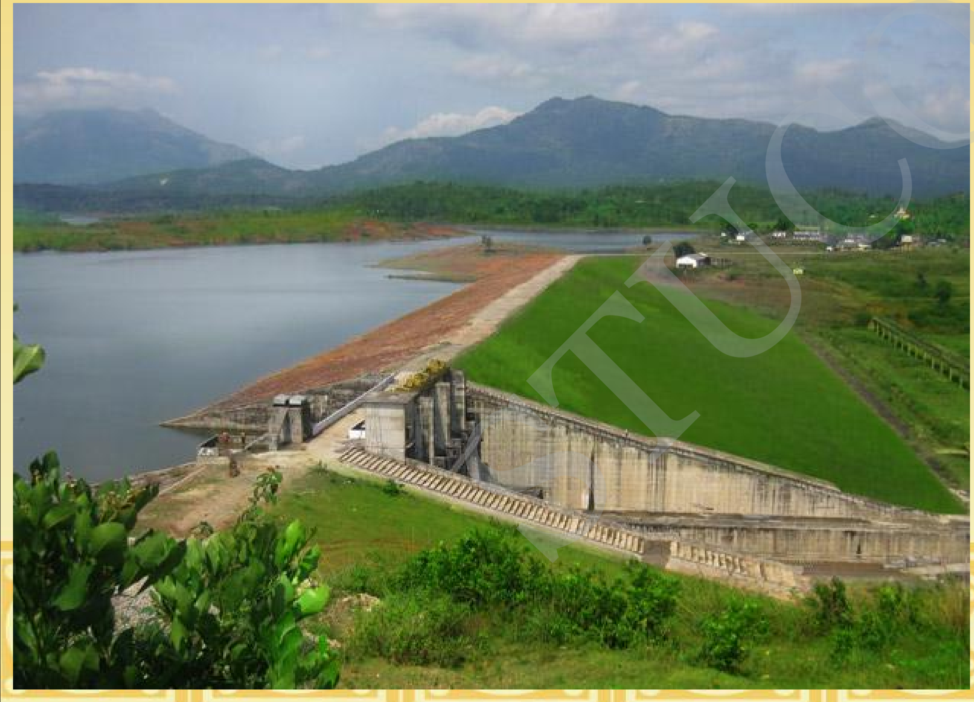
Therefore, the requirements for stability are,

1) The dam should be **safe against overturning.**
2) The dam should be **safe against sliding**.
3) The **induced stresses** (either tension or compression) in the

er

EARTHEN DAMS





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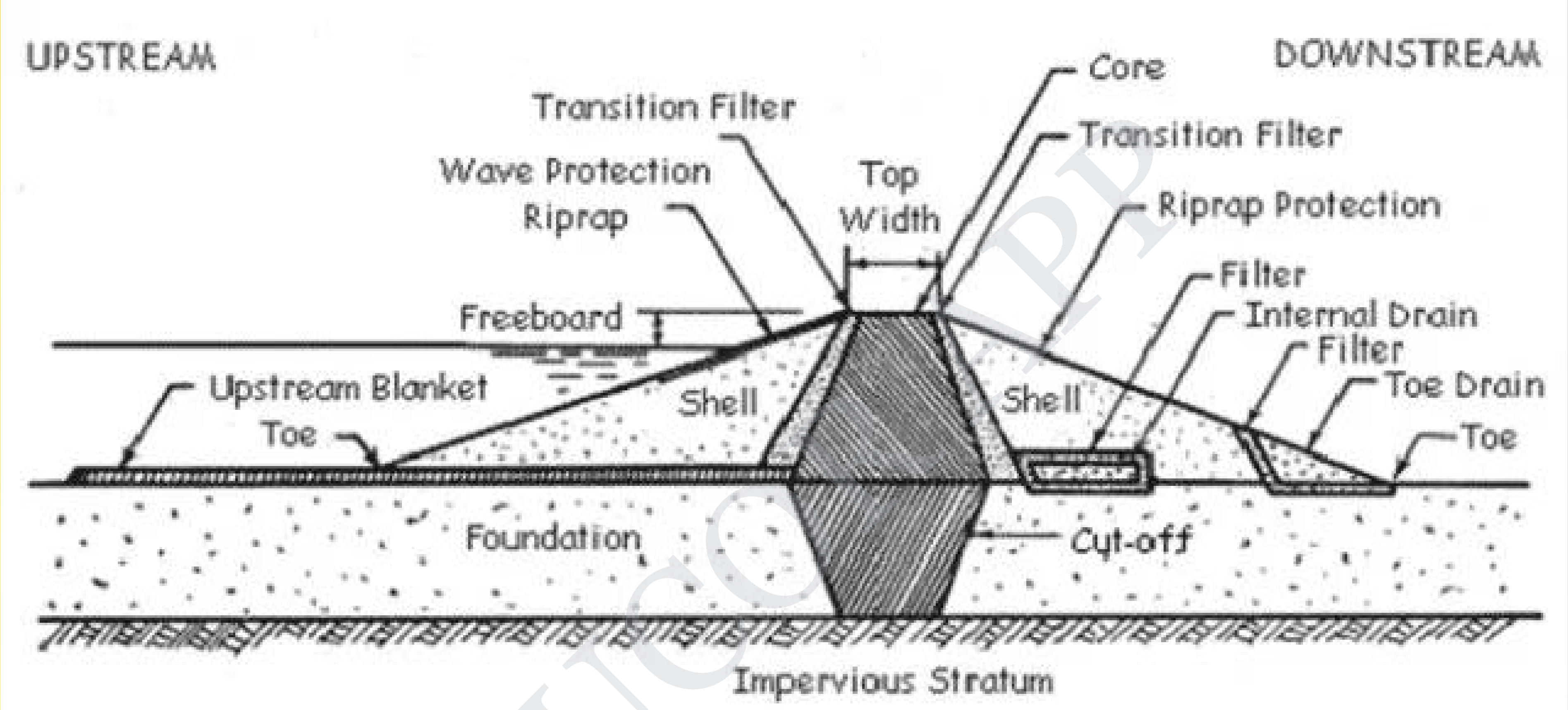
EARTHEN DAMS

- An earthen embankment is a **raised confining structure made from compacted soil.**
- The purpose of an earthen embankment is to **confine and divert the storm water runoff.**
- It can also be used for **increasing infiltration, detention and retention facilities.**
- Earthen embankments are generally **trapezoidal in shape** and **most simple** and **economic** in nature.

EARTHEN DAMS

- They are mainly built with **clay, sand and gravel**, hence they are also known as **earth fill dams or earthen dams.**
- They are constructed where the **foundation or the underlying material or rocks are weak to support the masonry dam** or where the suitable competent rocks are at greater depth.
- They are relatively **smaller in height** and **broader at the base.**


UPSTREAM
DOWNSTREAM
Core
Transition Filter
Transition Filter
Wave Protection
Riprap
Top
Width
Riprap Protection
Filter
Internal Drain
Filter
Toe Drain
Toe
Freeboard
Upstream Blanket
Toe
Shell
Shell
Foundation
Cut-off
Impervious Stratum

EARTHEN DAM

Components of an Earthen Dam

1. Shell, Upstream Fill, Downstream Fill or Shoulder:

- These components of the earthen dam are constructed with **pervious or semi-pervious materials** upstream or downstream of the core.
- The upstream fill is called the **upstream shell** and the downstream portion is the **downstream shell.**

2. Upstream Blanket:

- It is a **layer of impervious material laid on the upstream side** of an earthen dam where the substratum is pervious, **to reduce seepage and increase the path of flow.**
- The blanket **decreases both the seepage flow and excess pressure** on the downstream side of the dam.
- A natural blanket is a **cover of naturally occurring soil material of low permeability.**

3.Drainage Filter:

- It is a **blanket of pervious material constructed at the foundation** to the downstream side of an earthen dam, to **permit the discharge of seepage and minimize the possibility of piping failure.**

4.Cutoff Wall or Cutoff:

- It is a **wall, collar** or other structure intended **to reduce percolation of water** through porous strata.
- It is provided in or on the foundations.

5.Riprap:

- **Broken stones or rock pieces** are placed on the **slopes of embankment** particularly the upstream side for **protecting the slope against the action of water**, mainly wave action and erosion.

6.Core Wall, Membrane or Core:

- It is a centrally provided **fairly impervious wall** in the dam.
- It **checks the flow of water** through the dam section.
- It may be of **compacted puddled clay, masonry, or concrete** built inside the dam.

7.Toe Drain:

- It is a **drain** constructed at the downstream slope of an earthen dam **to collect and drain away the seepage water** collected by the drain filters.

8.Transition Filter:

- It is a component of an earthen dam section which is provided with core and consists of an **intermediate grade of material placed between the core and the shells** to serve as a **filter and prevent lateral movement of fine material** from the core.

Advantages

1) Design procedures are straightforward and easy.
2) Local natural materials are used.
3) Comparatively small establishment and equipment are required.
4) Earth fill dams resist settlement and movement better than more rigid structures and can be more suitable for areas where earth movements are common.

Disadvantages

1) An earthen embankment is **easily damaged or destroyed by water flowing on, over or against it.**
2) Designing and constructing adequate **spillways** is usually the **most technically difficult** part of any dam building work.
3) If it is **not adequately compacted** during construction, the dam will have **weak structure prone to seepage**.
4) Earthen dams require **continual maintenance** to prevent erosion, tree growth, subsidence, animal and insect damage and seepage.

Types of Earthen Dam

1. Based on the method of construction:

(a) Rolled Fill Earthen Dams:

- In this type of dams, successive layers of **moistened or damp soils are placed** one above the other.
- Each layer not exceeding **20 cm in thickness** is properly consolidated at **optimum moisture content maintained** by sprinkling water.
- It is **compacted by a mechanical roller** and only then the next layer is laid.

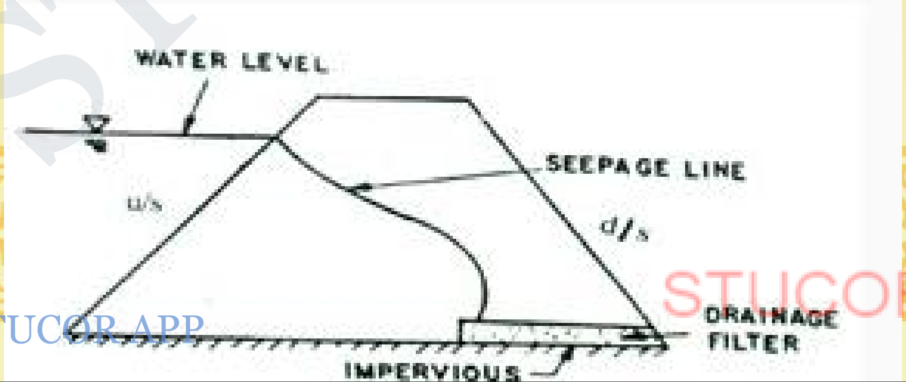
(b) Hydraulic Fill Earthen Dam:

- In this type of dams, **the construction, excavation and transportation of the earth are done by hydraulic methods.**
- **Outer edges** of the embankments are kept slightly **higher than the middle portion** of each layer.
- During construction, a mixture of excavated materials in **slurry condition is pumped** and discharged at the edges.
- This slurry of excavated materials and water consists of **coarse and fine materials.**

2. Based on the mechanical characteristics of earth materials used in making the section of dam:

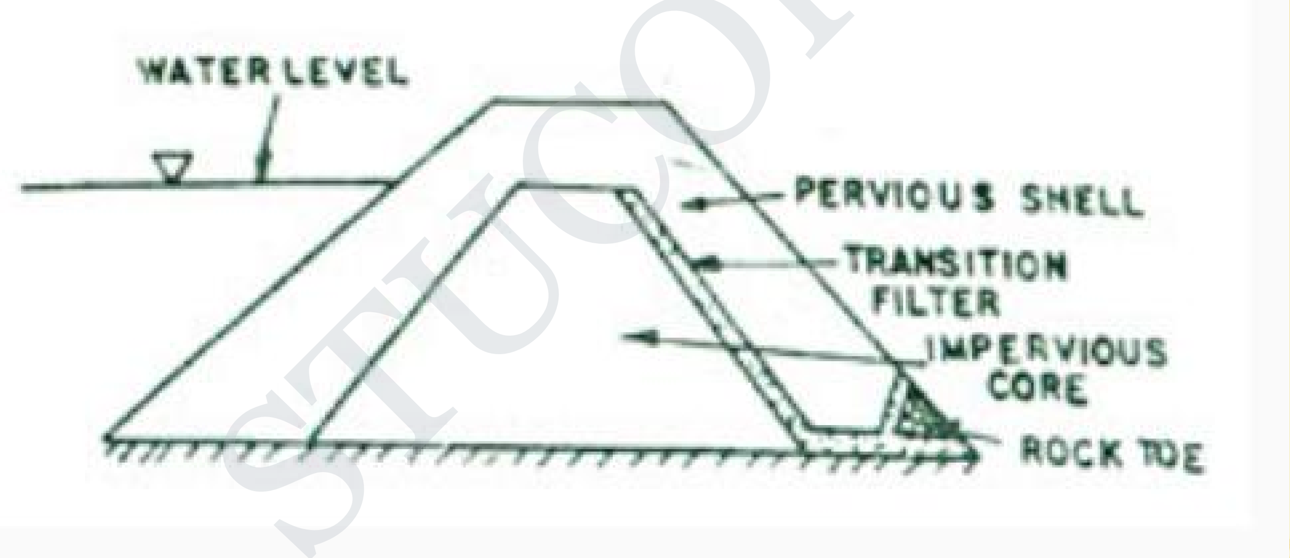
(a) Homogeneous Earthen Dams:

- It is composed of one kind of material (excluding slope protection).
- The material used must be **sufficiently impervious to provide an adequate water barrier**, and the slopes must be moderately flat for stability and **ease of maintenance**



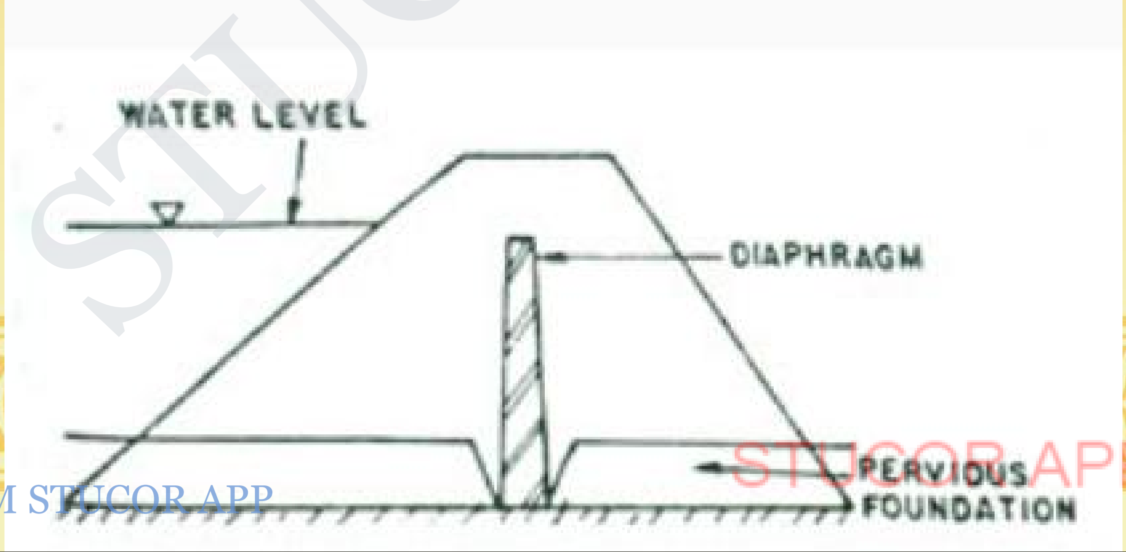
(b) Zoned Earthen Dams:

- It contains a **central impervious core**, surrounded by **zones of more pervious material, called shells.**
- These pervious zones or shells **support and protect** the impervious core.



(c) Diaphragm Earthen Dam:

- It is a **modified form of homogenous dam** which is constructed with pervious materials, with a thin impervious diaphragm in the central part **to prevent seepage of water.**
- The thin impervious diaphragm may be made of **impervious clayey soil, cement concrete** or masonry or any impervious material.



Design Criteria

1. **To prevent hydraulic failures** the dam must be so designed that erosion of the embankment is prevented.

- **Spillway capacity is sufficient** to pass the peak flow.
- **Overtopping by wave action** at maximum water level is prevented.
- The original height of structure is sufficient to maintain the **minimum safe freeboard** after settlement has occurred.
- **Erosion of the embankment** due to wave action and surface runoff does not occur.
- The crest should be wide enough to withstand **wave action and earthquake shock.**

2.To prevent the failures due to seepage:

- **Quantity of seepage water** through the dam section and foundation **should be limited.**
- The **seepage line** should be well **within the downstream face** of the dam to prevent sloughing.
- **Seepage water** through the dam or foundation **should not remove any particle** or in other words cause piping.
- **There should not be any leakage** of water from the upstream to the downstream face.

3. To prevent structural failures:

- The upstream and downstream **slopes of the embankment should be stable** under all loading conditions to which they may be subjected including **earthquake**.
- The foundation **shear stresses should be within the permissible limits** of shear strength of the material.

Design of Earthen Dam

- Top Width
- Free Board
- Settlement Allowance
- Casing or Outer Shell
- Cut-off Trench
- Downstream Drainage System

1. Top Width:

- Minimum top width (W) should be such that it can **enhance the practicability and protect it against the wave action** and earth wave shocks.
- Sometimes it is al **rposes.**
- It depends upon **am** and can be calculated as follo

$$W = \frac{H}{5} + 3 \quad \text{(for very low dam)}$$

$$W = 0.55\sqrt{H} + 0.2H \quad (H \leq 30)$$

$$W = 1.65\sqrt[3]{H + 1.5} \quad (H \geq 30)$$

2. Free board:

- It is the **vertical distance between the top of the dam and the full supply level** of the reservoir or the added height.
- It acts as a **safety measure for the dam** against high flow condition that is waves and runoff from storms greater than the design frequency from overtopping the embankment.

Recommended Values of Free Board given by U.S.B.R.

Nature of spillway	Height of dam	Free board
Free	Any	Minimum 2 m and maximum 3 m over the maximum flood level
Controlled	< 60 m	2.5 m above the top of the gate
Controlled	> 60 m	3 m above the top of the gate

2. Settlement Allowance:

- It is the result of the **settlement of the fill** and foundation material resulting in the **decrease of dam storage**.
- It depends upon the **type of fill material and the method and speed of construction.**
- It varies from **10% of design height for hand compacted to 5% for machine compacted** earthfill.

3. Casing or Outer Shell:

- Its main function is **to provide stability and protection** to the core.
- Depending upon the **upstream and downstream slopes**, a recommendation for the casing and outer shell slopes for different types of soils given by Terzaghi is presented in Table

Sl. No.	Types of material	u/s slope	d/s slope
1.	Homogenous well graded material	$2\frac{1}{2}:1$	$2:1$
2.	Homogenous coarse silt	$3:1$	$2\frac{1}{2}:1$
3.	Homogenous silty clay or clay a) Height less than 15 m b) Height more than 15 m	$2\frac{1}{2}:1$ $3:1$	$2:1$ $2\frac{1}{2}:1$
4.	Sand or sand and gravel with clay core	$3:1$	$2\frac{1}{2}:1$
5.	Sand or sand and gravel with R.C. core wall	$2\frac{1}{2}:1$	$2:1$

Cutoff Trench:

- It is provided **to reduce the seepage** through the foundation and also to reduce the piping in the dam.
- It should be aligned in a way that **its central line should be within the upstream face of the impervious core.**
- Its **depth should be more than 1 m**. Bottom width of cutoff trench (B) is calculated as:
- where h = reservoir head above the ground surface (m); and d = depth of cutoff trench below the ground surface (m).

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Causes of Failure

1.Hydraulic Failures - **40%**

2. Seepage Failures - **30%**

3. Structural Failures - **30%**

   a) Piping

   b) Sloughing

   a) Overtopping

   b) Wave Erosion

   c) Toe Erosion

   d) Gullying

Causes of Failure

a) Upstream slope failure due to sudden drawdown

b) Failure by excessive pore pressure

c) Downstream slope failure by sliding

d) Failure due to settlement of foundation

e) Failure by sliding of foundation

f) Failure by spreading

i. Overtopping:

The dam is overtopped when the **volume of incoming flow into the reservoir is more than the actual storage capacity** of the reservoir, or the capacity of spillway is not sufficient.

ii. Wave Erosion:

Wave action **removes the soil particles** from the unprotected part of upstream face of the clam, continuously.

iv. Gullying:

Development of gully in earthen dam is the result of **heavy down pour**. Such type of failures can be eliminated by providing a **proper size of berm, turf or good drainage system** towards d

2. Seepage Type Failures:

i. Piping; and

ii. Sloughing.

i. Piping:

The **continuous flow of seepage water through the body** as well as foundation of the dam is the main reason of piping. It causes catastrophic failures in the earth fill dams.

ii. Sloughing:

Failure of earthen dam due to sloughing is closely related to the **water level in the reservoir.**

th dam

Structural Failures:

- Upstream and downstream slope failures due to formation of excessive pore pressure.
- Upstream failure due to sudden drawdown in the reservoir water level.
- Downstream failure at the time of full reservoir.
- Foundation slide.
- Failure of dam due to earthquake.
- Failure of dam due to unprotected side slope.
- Failure due to damage caused by burrowing animals.

ate. ials.

i. Upstream and Downstream Slope Failure due to Pore Pressure:

- Development of pore pressure in the body of earthen dam, is mainly due to **poor compressibility of the soil**.
- A pore pressure equal to **140% of total weight of soil** develops a very crucial situation regarding dam stability.

ii. Failure of Upstream Slope due to Sudden Draw down in the Reservoir Water level:

- In this failure the upstream side slope did not get complete failure, because when slide takes place due to sudden draw down in reservoir water level, the pore pressure acting along

iii. Downstream Slope Slide during Full Reservoir Condition:

- When the reservoir is in full condition, then there happens **maximum percolation/seepage loss through the dam** section.
- This results into reduction of stability of the dam, which causes the downstream slope gets collapse.

iv. Failure due to Foundation Slide:

- This type of failure of earthen dam generally takes place, when foundation is constructed, using **fine silt or soft soil materials.**

v. Failure of Dam due to Earthquake:

- Earthquake develops **cracks** in the body of dam; and thus leading to **flow of water**, which ultimately causes to **failure the dam.**
- It **compresses the foundation** and embankment, both, thereby the **total free board provided to the dam gets reduce** and thus, increasing the chances of overtopping problem.

vi. Failure of Earthen Dam due to Slope Protection:

- Generally, slopes are protected by **rip-rap or revetment** using a layer of gravel or filter blanket.
- When a heavy storm occurs, then **water wave beats the dam slope repeatedly** above the reservoir level.

vii. Failure due to Damage Caused by Burrowing:

- Burrowing develops **piping type failure** in earthen dam.
- Generally, the **animals like muskats burrow the embankment** section, either to make shelter for their living or to make a direct passage for running from one end to

viii. Failure due to Water Soluble Materials:

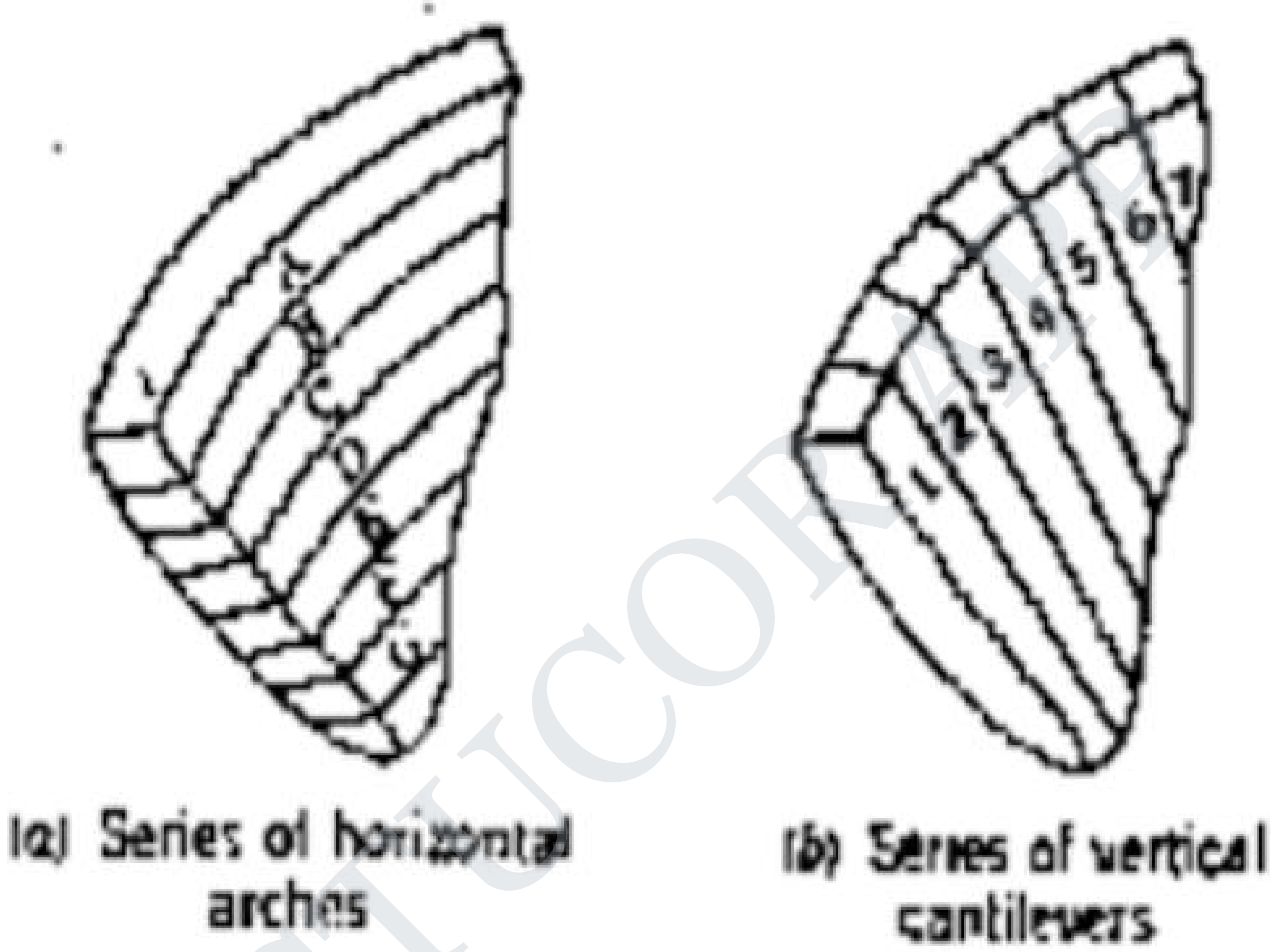
- Based on several observations on this aspect of failure of earthen dams, it has been found that the **leaching of natural water soluble materials such as zypsum** etc. from the dam tends to **create water leakage problem** through the dam section.
- In this condition, the **foundation also gets settle down**, and thus creates the **problem of overtopping** and ultimately the dam reaches to the point of its failure.

DESIGN OF ARCH DAM

DESIGN OF ARCH DAM

- Arch dam, as the name implies, is a **curved obstruction from the upstream side** singly spanned that mainly carries the load of the impounded water through **arch action as well as cantilever action.**
- Arch dams through **arch action transfers portion of the load of the water thrust horizontally** to the side abutments and the **other portion of that load is transferred to the dam foundation vertically by cantilever action.**

- In the arch action, **hydrostatic pressure / force** of water press against the face of the arch which in return **compresses and strengthens the matrix of the arch dam structure.**
- Arch Dams throughout the world are mostly made of **concrete** (either conventional concrete or roller compacted concrete); however, in the past some are also made with rubble and stone masonry.



Series of horizontal arches and vertical cantilevers

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Situations When Arch Dam is a must to use

- Arch dam is proved most economical and efficient when the **width of the canyon or valley to be spanned on the river is least.**
- As a major share of the impounding water thrust is taken by **abutment walls resting on the sides of the canyon**, thus these must be stable, strong and firm.
- Arch dam can be used most economically on a terrain where **width of the valley is less than 6 times of its height or in other words B/h ratio is less than 6.**

- If the area is remote such that the **naturally available material are not enough to provide sufficient supply of concrete** or earth-fill arch dam should be used as it needs minimum amount of construction concrete.
- The slope of the adjoining hills for the abutment should be steep i.e. **more than 45 degrees.**
- During the design of the arch dam it is considered that the **stresses generated are upto that of allowable stresses of the concrete.**

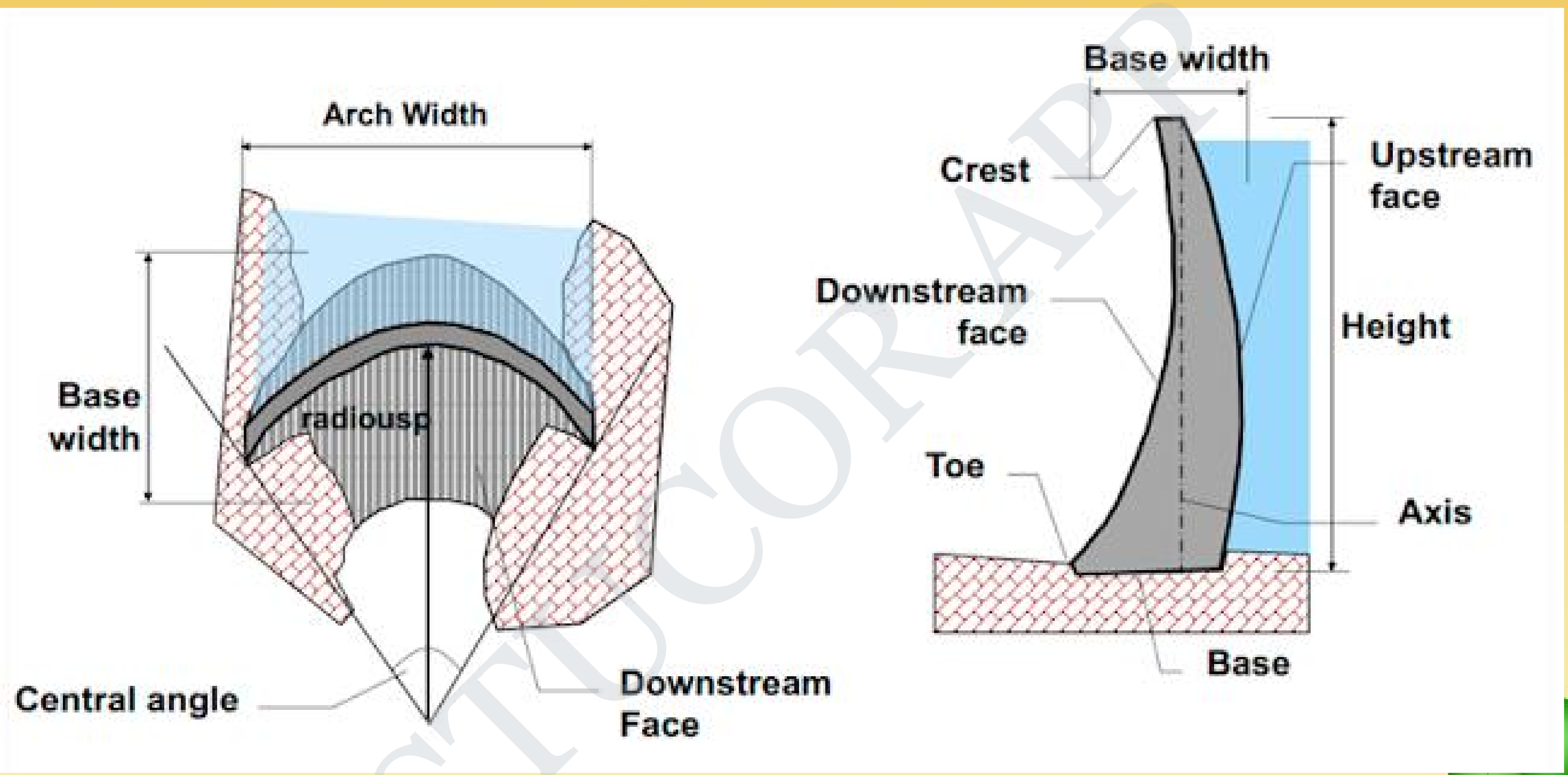
Advantages of Arch Dam

1) The major advantage derived from Arch dam is **minimal amount of concrete / filling material** required.
2) These dams are **best suited for a narrow canyon passage** and can store water as well as generate electricity.
3) Arch dams are particularly adapted to t**he gorges where the length is small in proportion to the height.**
4) For a **given height, the section of an arch dam is much lesser** than a corresponding gravity dam.
5) Hence, an arch dam requires **less material** and is, therefore, **cheaper.**

Disadvantages of Arch Dam.

- It requires **skilled labor and sophisticated form work.**
- The **design of an arch** dams are also quite **specialized**.
- The **speed of construction is normally slow.**
- It **requires very strong abutments of solid rock** capable of resisting arch thrust.
- Hence, it is **not suitable in the locations where strong abutments are not available**.Unfortunately, only few sites are suitable for this type of dam.

Components of a Typical Arch dam



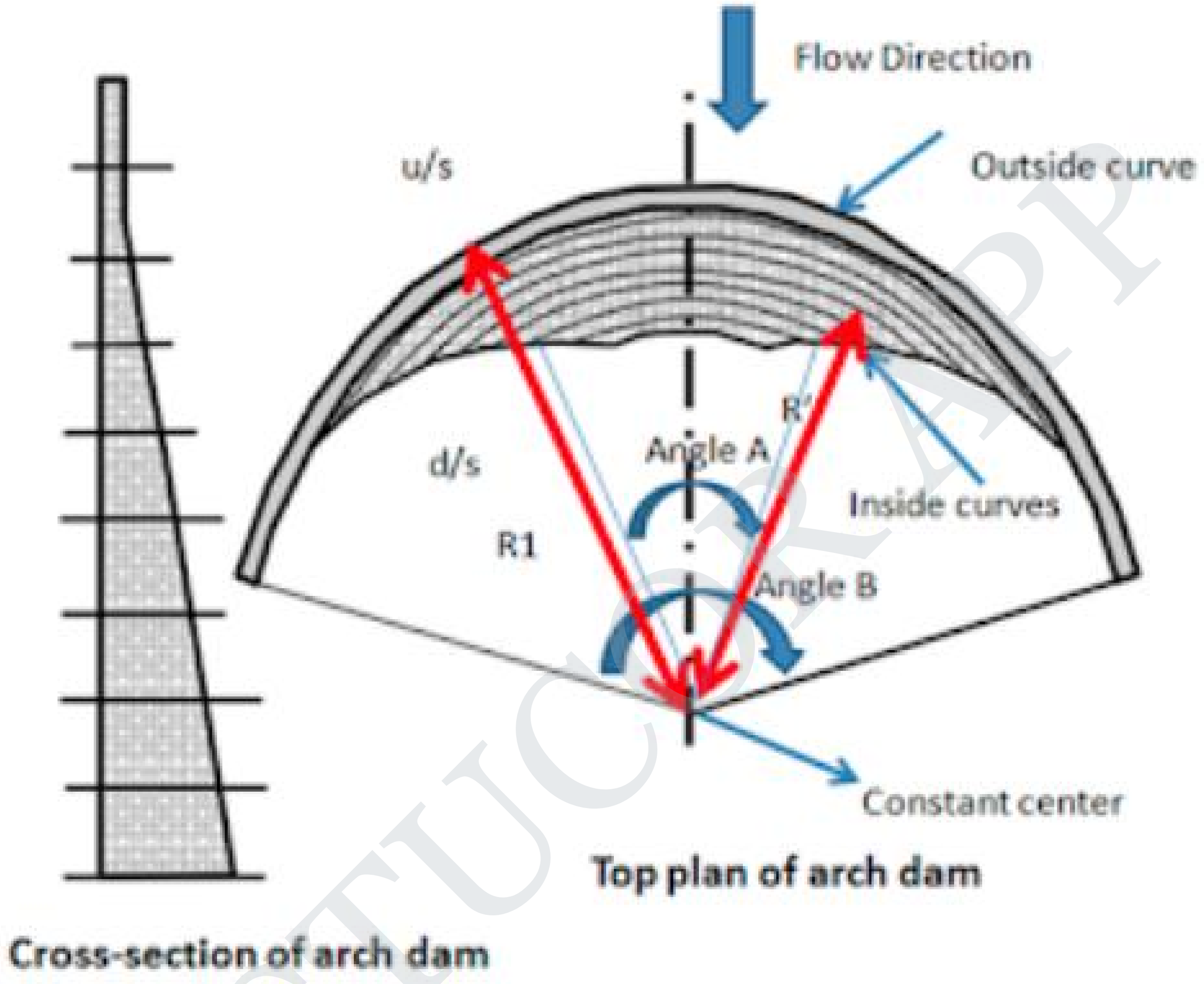
Types of Arch Dams

- Constant Radii Arch Dam
- Variable radii arch dam
- Constant angle arch dam

Constant Radii Arch Dam

In Constant Radius Arch Dam, the radius of the outside **Circular Curve is constant throughout the height / elevation** of the dam creating a linear upstream face of the dam.

However, the **inner curves of the arch are of variable radii** i.e. from top to bottom elevation of the arch dam the radius of the curves reduces creating a triangular cross-section of the arch d



Constant Radii Arch Dam Best suited for U-Shaped Valley

Variable Radii Arch Dam

- Variable radii arch dam is the one in which **the radius of the introdoes as well that of extrodos vary along the height.**
- Making it **maximum at the top and minimum at the bottom elevations**.
- The centers of the **various arch rings at different elevations,** do not lie on the same vertical line; it is also known as **variable center arch dam**. Such dams are preferred for **V-shaped valleys.**

Constant Angle Arch Dams

- The constant angle arch dam is a **special type of variable radius arch dam**, in which the **centeral angles of the horizontal arch rings are of the same magnitude at all elevations.**
- The design of such a dam can, thus be made by adopting **best central angle of 133 degrees and 34 minutes**; and hence such a dam proves to be the **most economical, out of the three types of ordinary arch dams.**

Design of Arch Dams

- The arch dam is a **complex structure which is a bit difficult to design and construct.**
- The design procedure adopted is a **hit and trial type**, a hydraulic dam design is proposed which is carried out through lengthy calculations.

  1) **Water Pressure**

  2) **Earthquake pressure**

  3) **Wave pressure**

  4) **Ice pressure**

Arch dams are designed and engineered by three famous methods :-

Thin cylinder theory

Theory of elastic arches

The trial load method

Diversion headwork

- Any hydraulic structure, which **supplies water to the off-taking canal**, is called a headwork.
- A diversion headwork **serves to divert the required supply in to the canal from the river.**

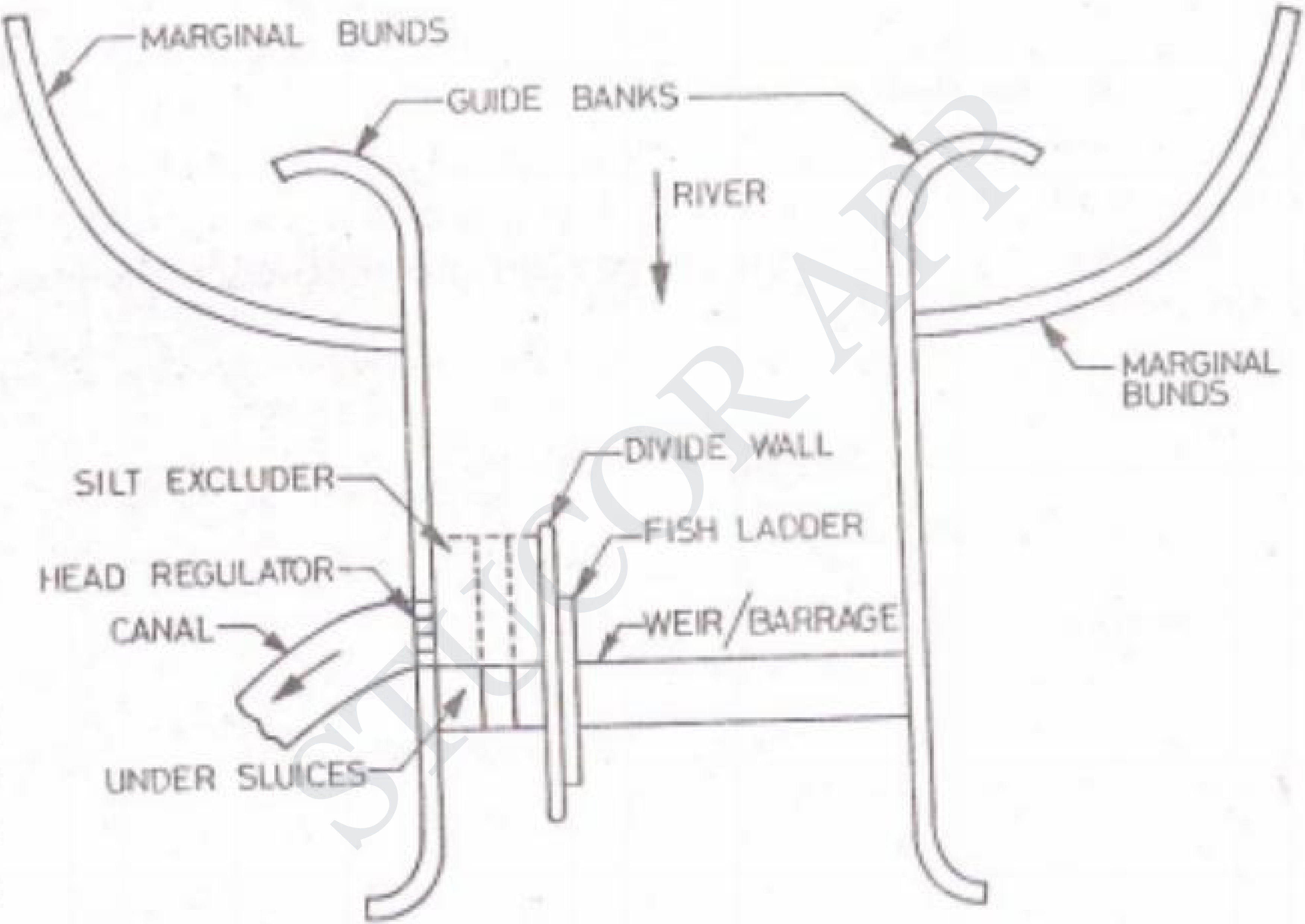
The purposes of diversion headwork.

- It **raises the water level in the river** so that the commanded area can be increased.
- It **regulates the intake of water** in to the canal.
- It **controls the silt entry** in to the canal.

ri er.

COMPONENT PARTS OF A DIVERRSION HEADWORK

1. Weir or barrage
2. Undersluices
3. Divide wall
4. Fish ladder
5. Canal head regulator
6. pocket or approach channel
7. Silt excluders/ Silt prevention devices
8. River training works (Marginal bunds and guide banks)

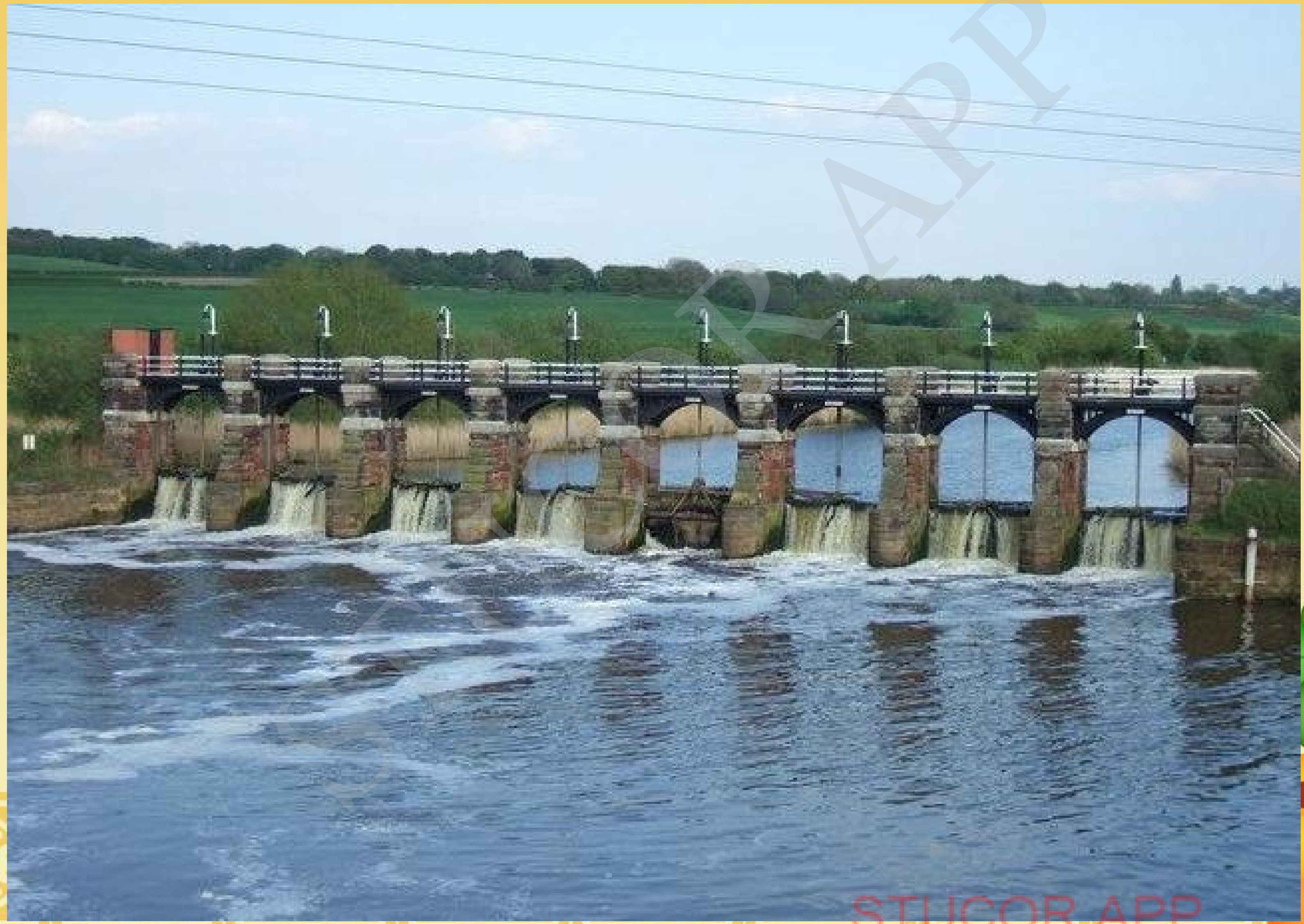


MARGINAL BUNDS
GUIDE BANKS
RIVER
MARGINAL BUNDS
DIVIDE WALL
SILT EXCLUDER
FISH LADDER
HEAD REGULATOR
WEIR/BARRAGE
CANAL
UNDER SLUICES

Undersluices

- Undersluice sections are provided **adjacent to the canal head regulators.**
- The undersluices should be **able to pass fair weather flow** for which the crest shutters on the weir proper need not be dropped.
- The **crest level** of the undersluices is generally **kept at the average bed level of the river.**

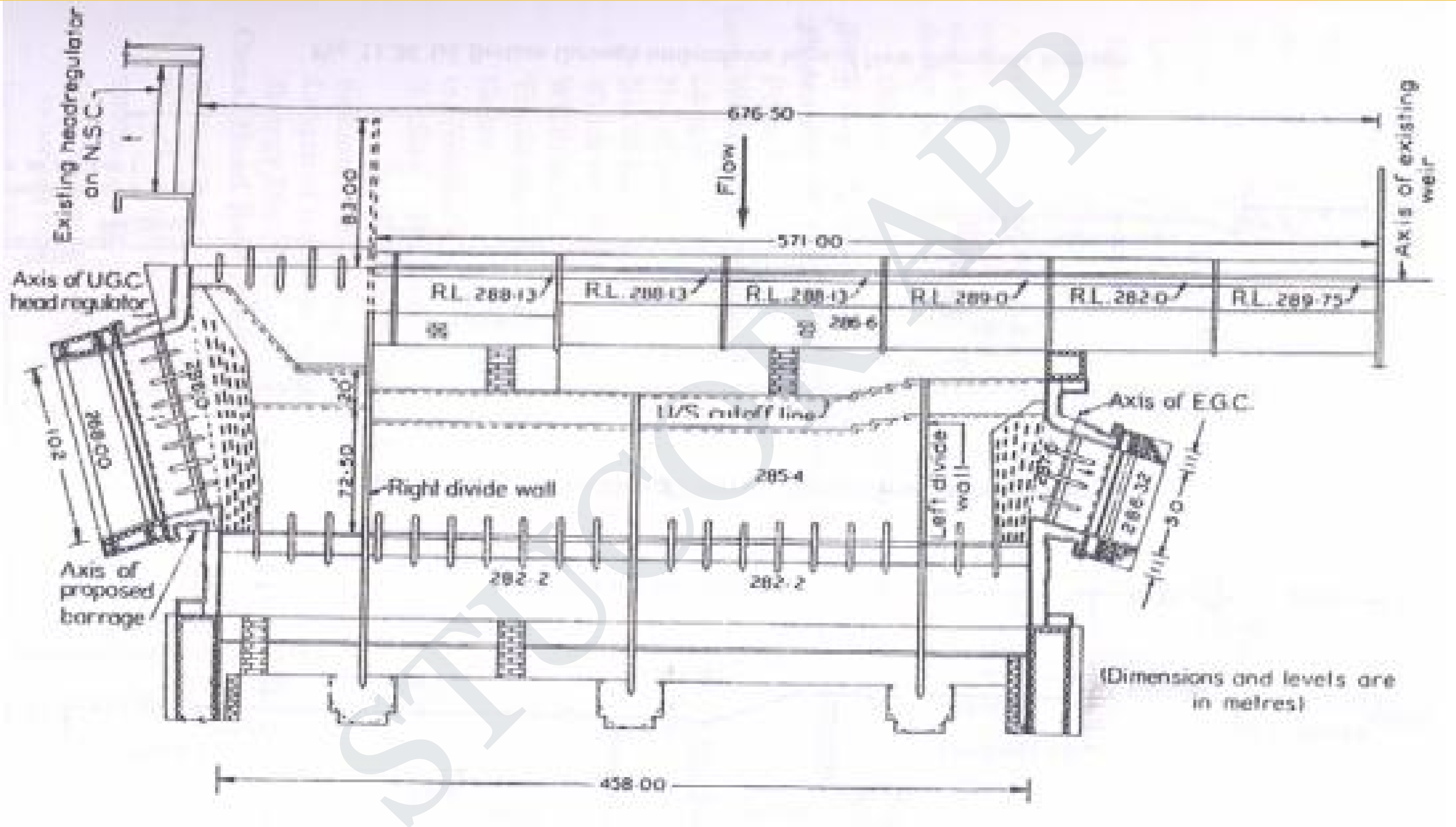
Undersluices



Divide Wall

- A divide wall is a wall constructed **parallel to the direction of flow of river** to separate the weir section and the undersluices section to avoid cross flows.
- If there are undersluices at both the sides, there are **two divide walls.**

Divide Wall


Existing headregulator on N.S.C.
676·50
Flow
Axis of existing weir
83·00
571·00
Axis of U.G.C. head regulator
R.L. 288·13
R.L. 288·13
R.L. 288·13
R.L. 289·0
R.L. 282·0
R.L. 289·75
286·6
U/S cutoff line
Axis of E.G.C.
102
72·50
Right divide wall
285·4
Left divide wall
282·2
282·2
Axis of proposed barrage
(Dimensions and levels are in metres)
458·00
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Divide Wall

Fish Ladder

- A fish ladder is a **passage provided adjacent to the divide wall** on the weir side for the **fish to travel from the upstream to the downstream** and vice versa.
- In a fish ladder the **head is gradually dissipated** so as to provide smooth flow at sufficiently low velocity.
- Suitable **baffles are provided** in the fish passage **to reduce the flow velocity.**

Fish Ladder

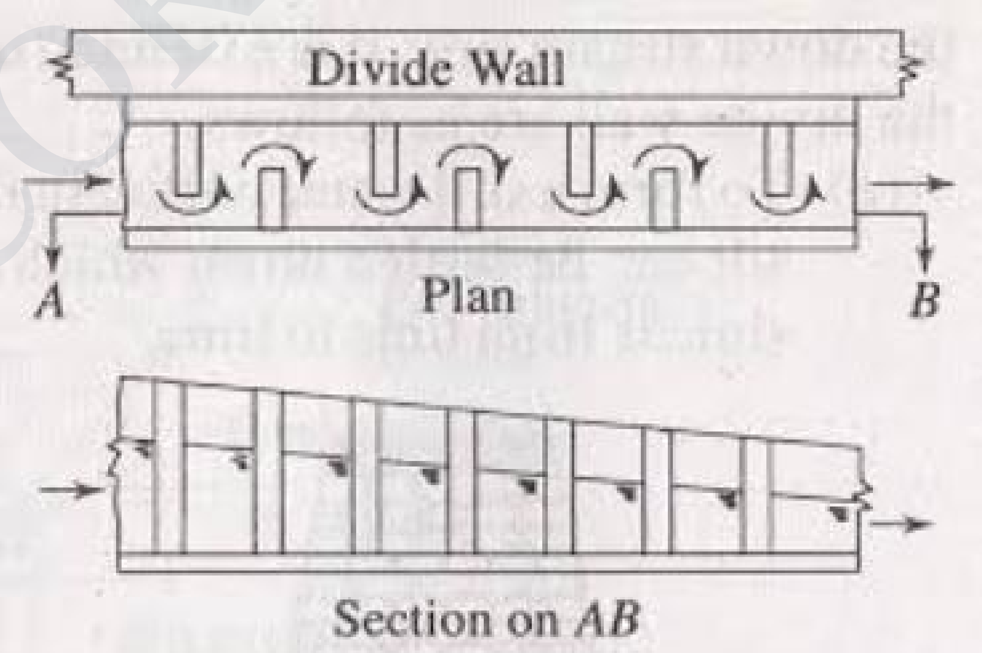
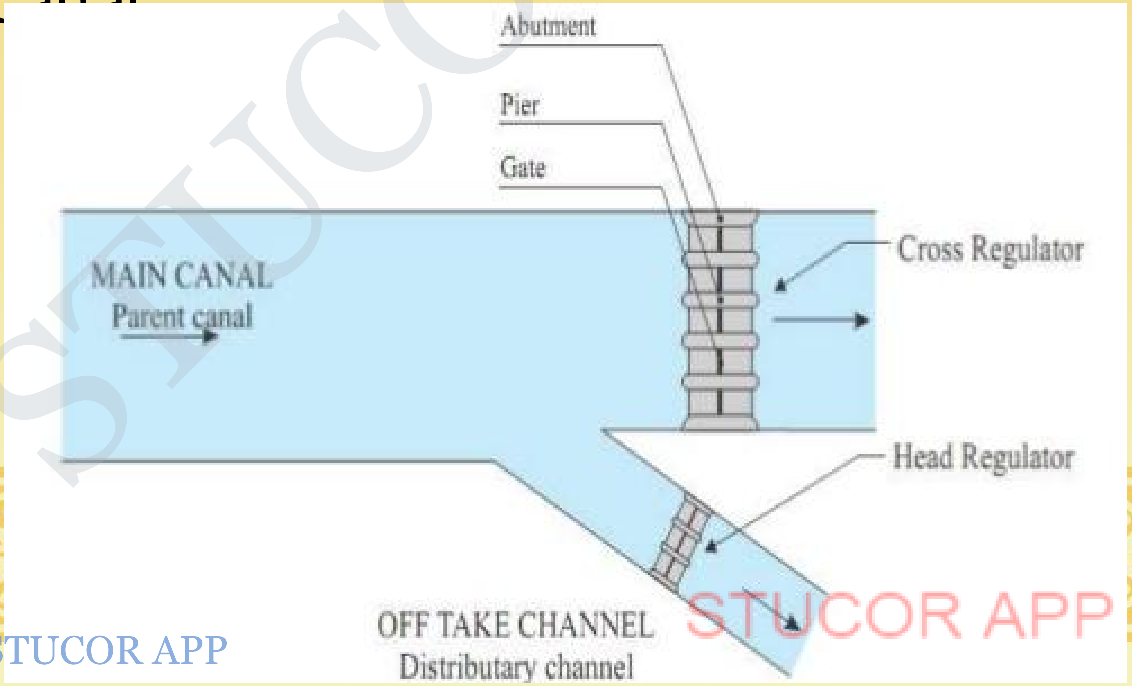


Fig: Fish Ladder

Canal Head Regulator

- A canal head regulator is provided at **the head of the canal offtaking from the diversion headworks.**
- It **regulates the supply of wate**r into the canal, controls the entry silt into the canal, and **prevents the entry of river floods** into canal.



Silt Excluder

- A silt excluder is a structure in the undersluices pocket **to pass the silt laden water to the downstream** so that only clear water enters into the canal through head regulator.
- The bottom layer of water which are **highly charged with silt pass down the silt excluder** an escape through the undersluices.

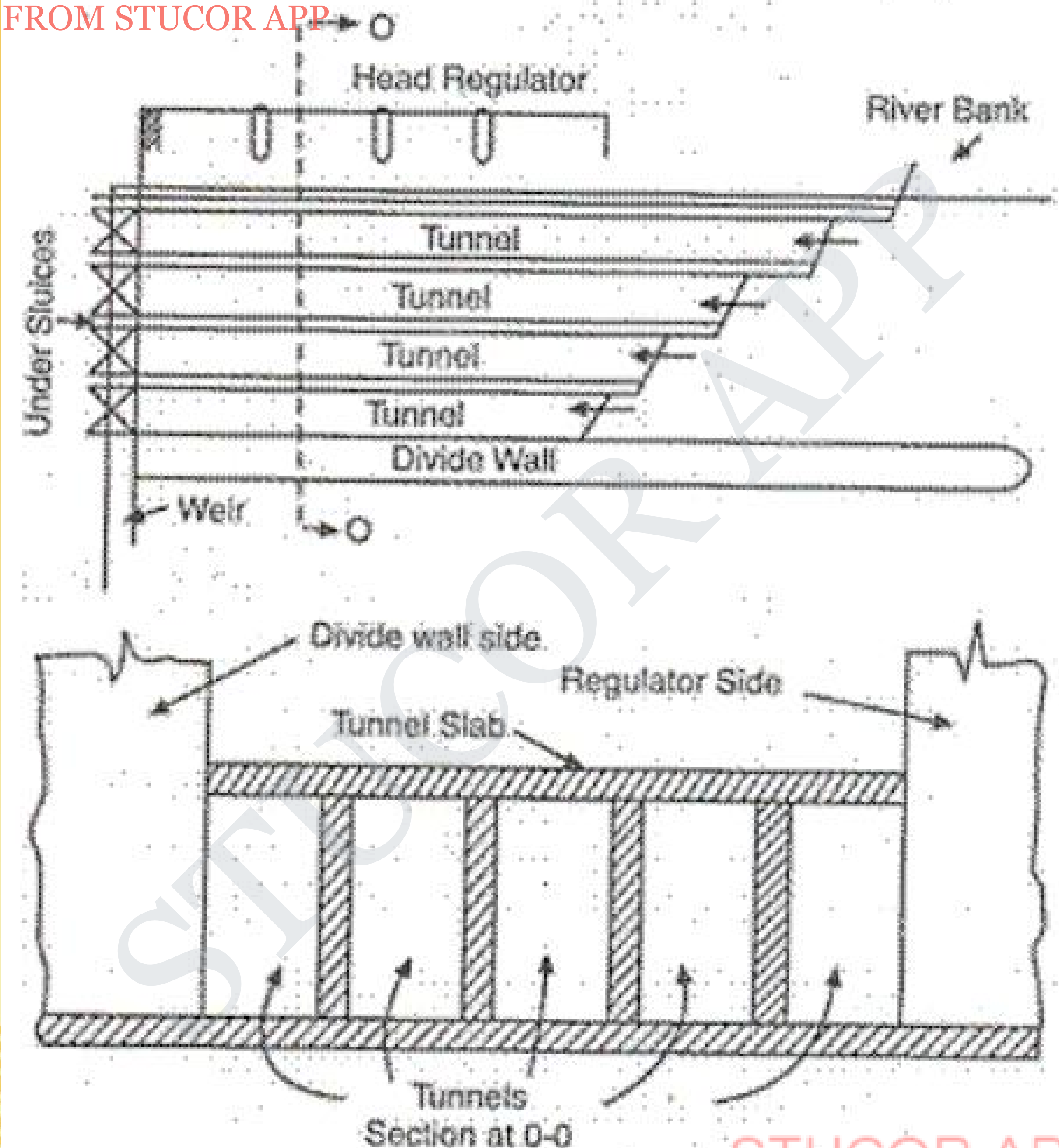
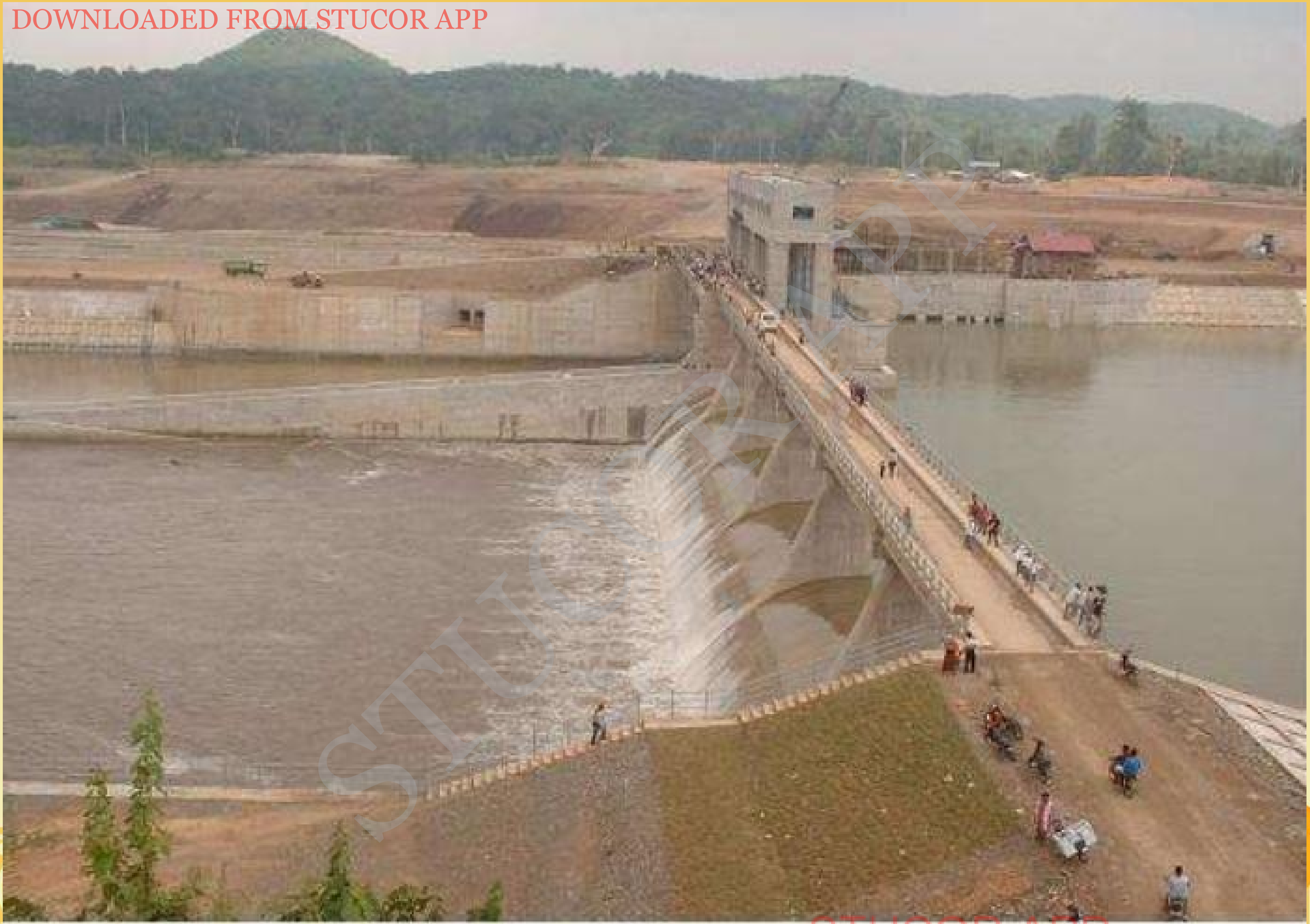


Fig. 12.10. Silt Excluder

Guide Banks and Marginal Bunds

- Guide banks are provided on **either side of the diversion headworks** for a smooth approach and **to prevent the river from outflanking.**
- Marginal bunds are provided on either side of the river upstream of diversion headworks **to protect the land and property** which is likely to be submerged during ponding of water in floods.

Marginal Bunds



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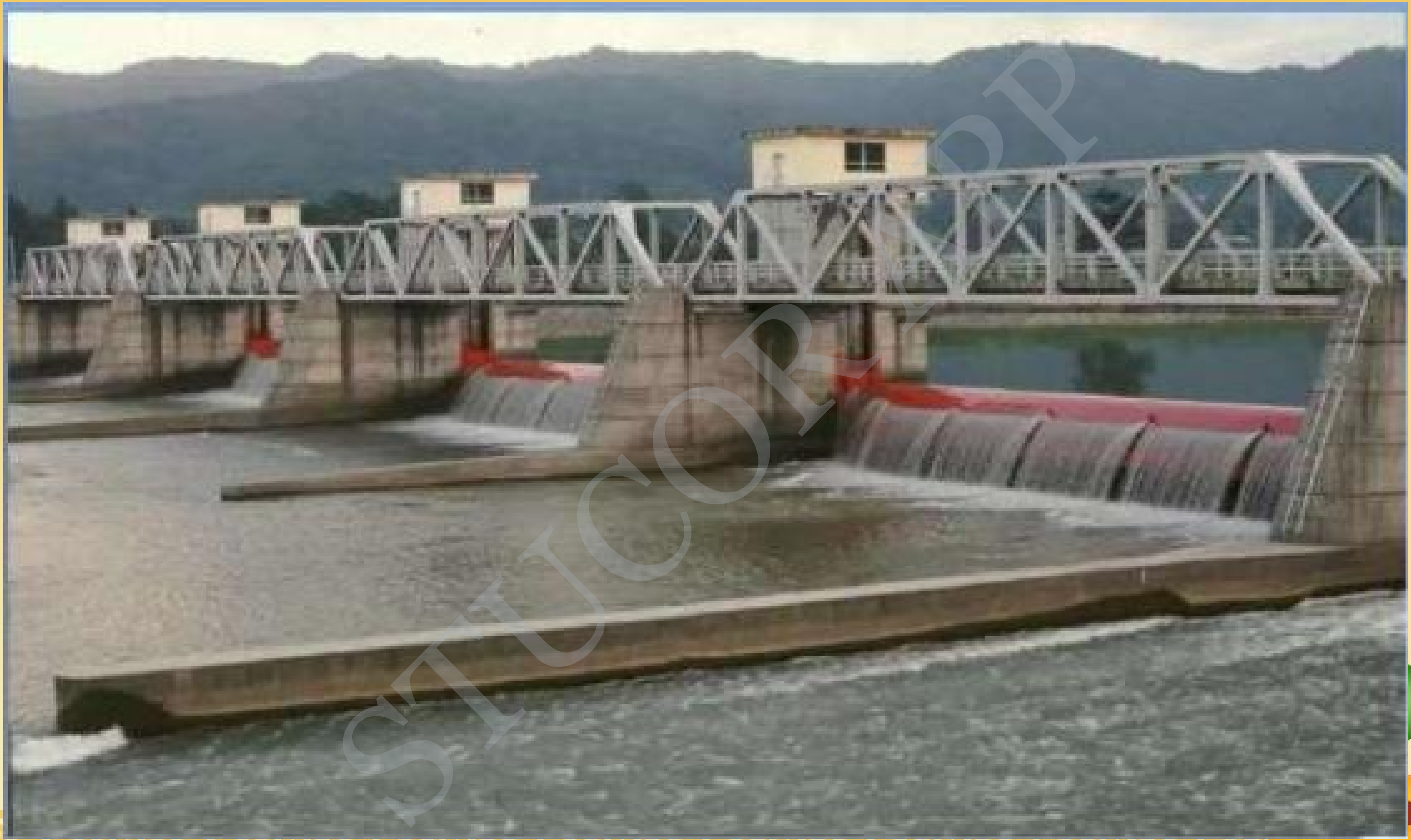
Weir

- The weir is a **solid obstruction put across the river to raise its water level and divert the water** in to the canal.
- If a weir also **stores water for tiding over small periods** of short supplies, it is called **a storage weir.**

Advantages:

- The initial cost of weirs is usually low.

Weir



Disadvantages:

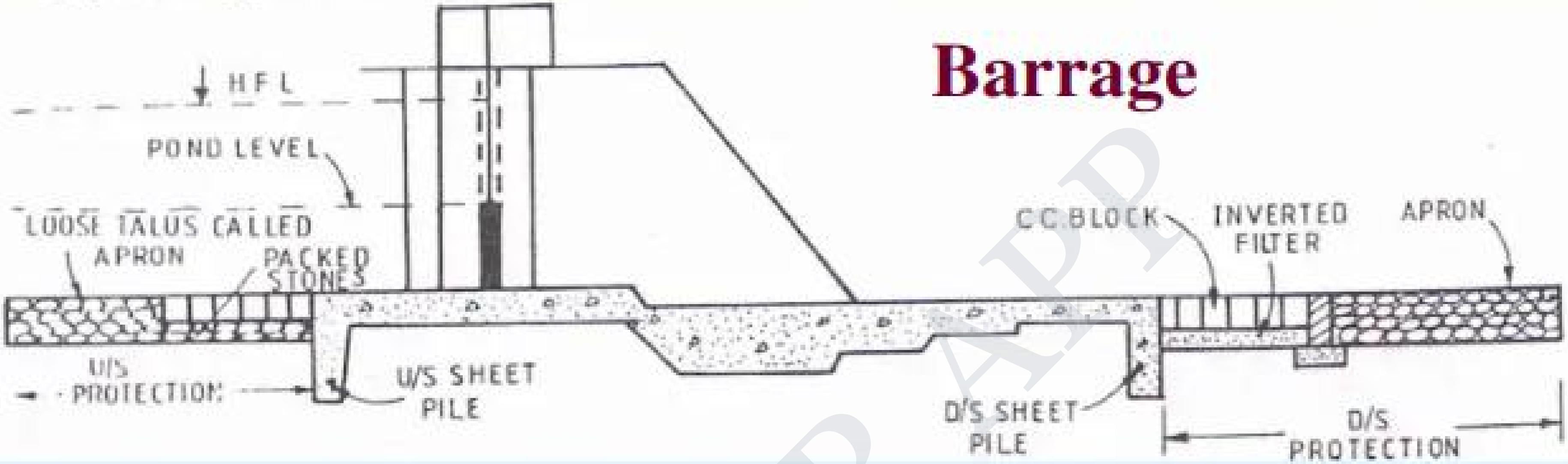
1) There is a **large afflux** during floods which causes **large submergence.**

2) Because the **crest is at high level**, there is **great silting problem**

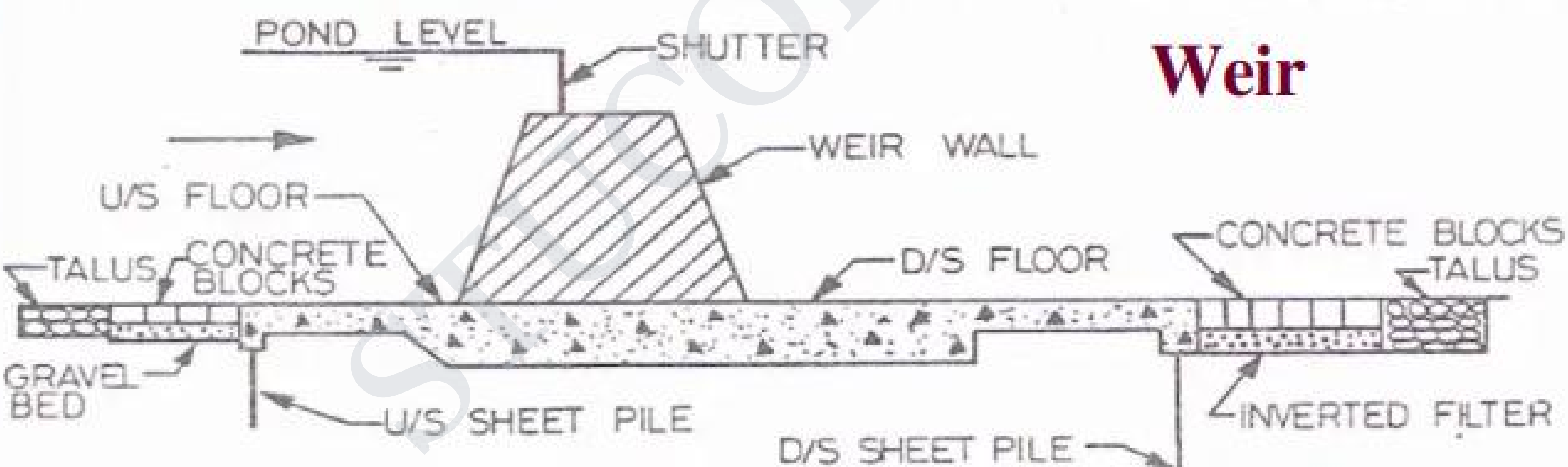
3) The raising and **lowering of shutters on the crest is not convenient.** Moreover, it requires considerable time and labour.

4) The weir **lacks an effective control on the river during floods.**

Barrage



Weir



Barrage

- A barrage has a **low crest wall with high gates**. As the height of the crest above the river bed is low most of the ponding is done by gates.
- During the floods the gates are opened so **afflux is very small.**

Advantages

1) The barrage has a **good control on the river** during floods. The outflow can be easily regulated by gates.
2) The **afflux during floods is small** and, therefore, the

- There is a **good control over flow conditions**, crosscurrents on the upstream of the barrage.
- There are **better facilities for inspection and repair** of various structures.
- A **roadway can be conveniently provided** over the structure at a little additional cost.

Disadvantage:

1) The **initial cost of the barrage is quite high**.

Barrag
e

TYPES OF WEIRS

1) **Vertical drop weirs.**

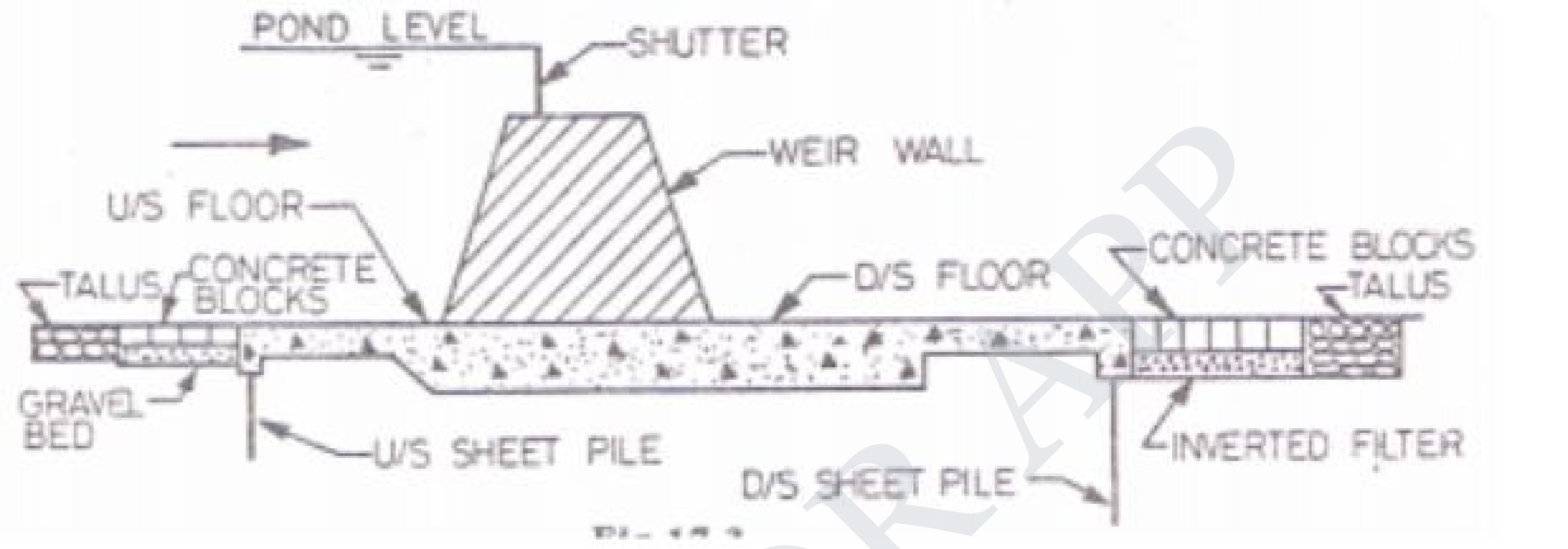
2) **Rockfill weirs.**

3) **Concrete glacis or sloping weirs**.

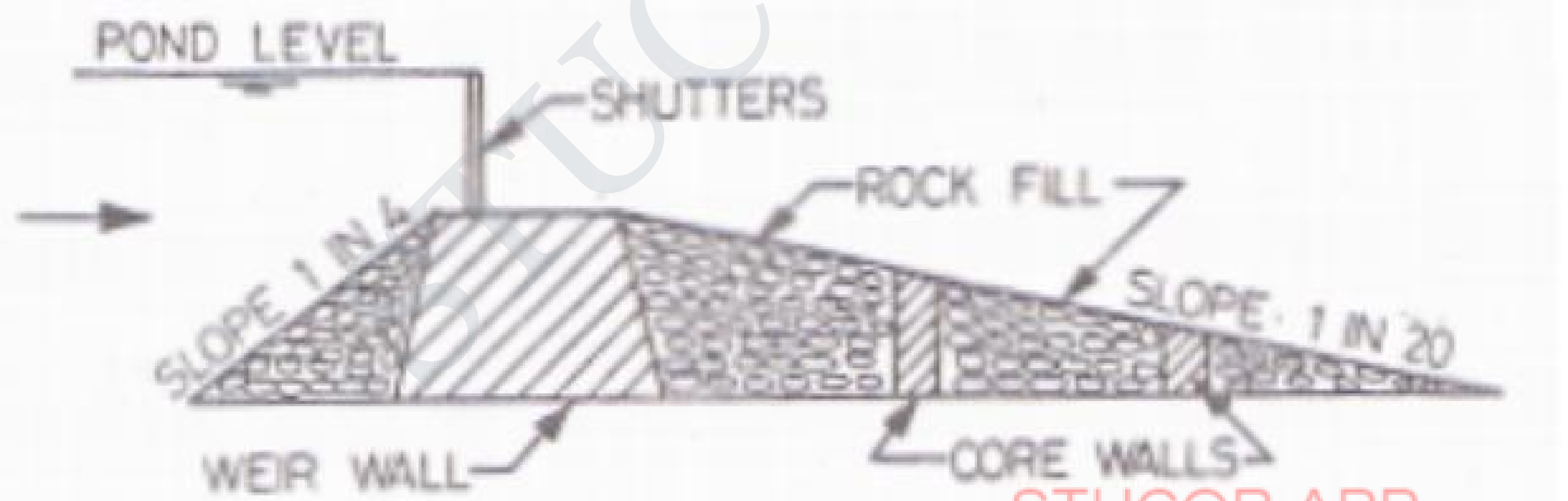
1. Vertical drop weirs

- A vertical drop weir consists of a **masonry wall with a vertical (or nearly vertical) downstream face** and a horizontal concrete floor.
- The **shutters are provided** at the crest, which are dropped

Vertical drop weirs



Rockfill weirs.

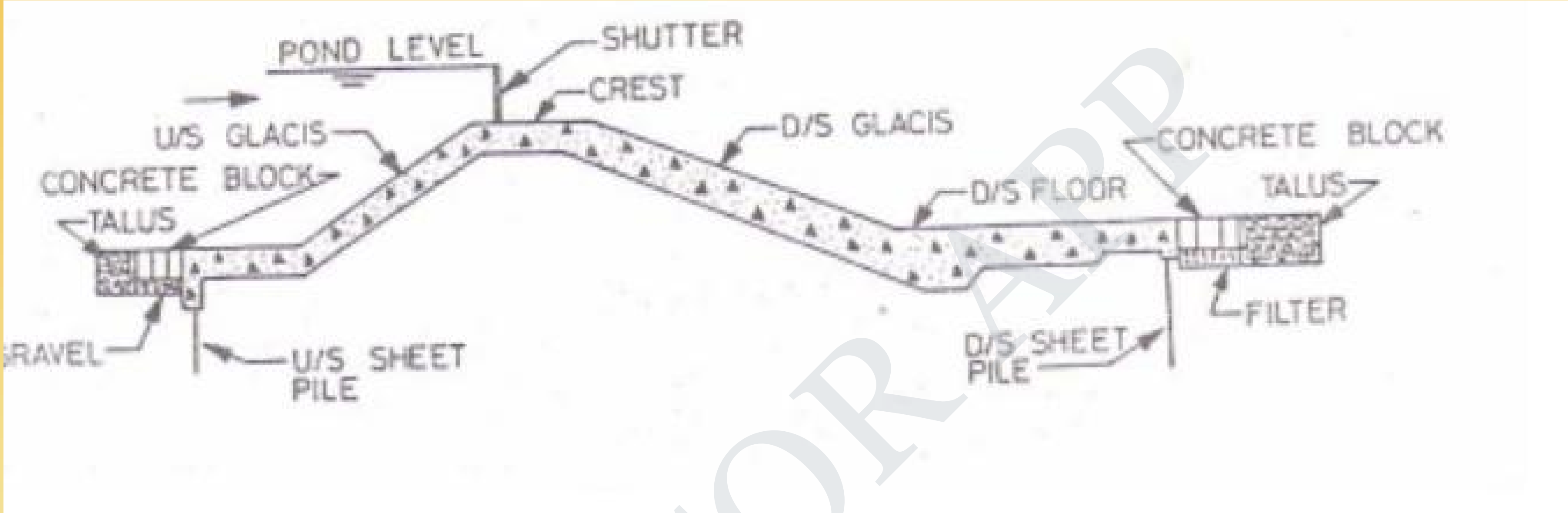


2. Rockfill weirs:

- In a rockfill type weir, there are a **number of core walls.**
- The space between the core walls is filled with the **fragments of rock (called rockfill).**

3. Concrete sloping weir :

- There are **sheet piles (or cut off walls)** driven upto the **maximum scour depth at the upstream and downstream ends** of the concrete floor.
- Sometimes an **intermediate pile** is also driven at the beginning of the upstream glacis or at the end of downstream



Concrete sloping weir

Discussions ?


THANK
YOU

UNIT – 4

CANAL IRRIGATION

P.Muthuraman, VVCOE

CANAL IRRIGATION

Syllabus

Canal regulations – direct sluice - Canal drop – Cross drainage works-Canal outlets – Design of prismatic canal-canal alignments-Canal lining - Kennedy's and Lacey's Regime theory-Design of unlined canal

CANAL:-

- A canal is an **artificial channel** generally **trapezoidal in shape** constructed on the ground **to carry water to the field** either from the river of from a reservoir.

Canal regulations

- **Any structure** constructed **to regulate the discharge, full supply level or velocity** in a canal is known as Regulation Work.

Canal regulations

Types & Location:

1. Head Regulator or Head Sluice **- at Barrage/Weir, Dam**

2. Cross Regulator **- on Parent Canal**

3. Distributory Head Regulator **- on Off-take Canal**

4. Canal Fall **- along Parent Canal or Off-take Canal**

5. Canal Escape **- on any type of canal**

6. Canal Outlet **- on Distributing Canal**

Types & Purpose:

1. Head Regulator or Head Sluice - **to divert water to parent channel from a barrage or weir**

2. Cross Regulator - **to head up water in the parent channel to divert some of it through an off take channel** or distributory canal

3. Distributory Head Regulator - **to control the amount of water flowing in to off take channel**

4. Canal Fall - **to lower the water level of the canal**

5. Canal Escape - **to allow release of excess water from the**

Canal Regulator

- A **head regulator provided at the head of the off-taking channel**, **controls the flow of water** entering the new channel.

- While **a cross regulator** may be required in the **main channel downstream of the off-taking channel, to ensure the required supply in the off-taking channel** even during the periods of low flow in the main channel.

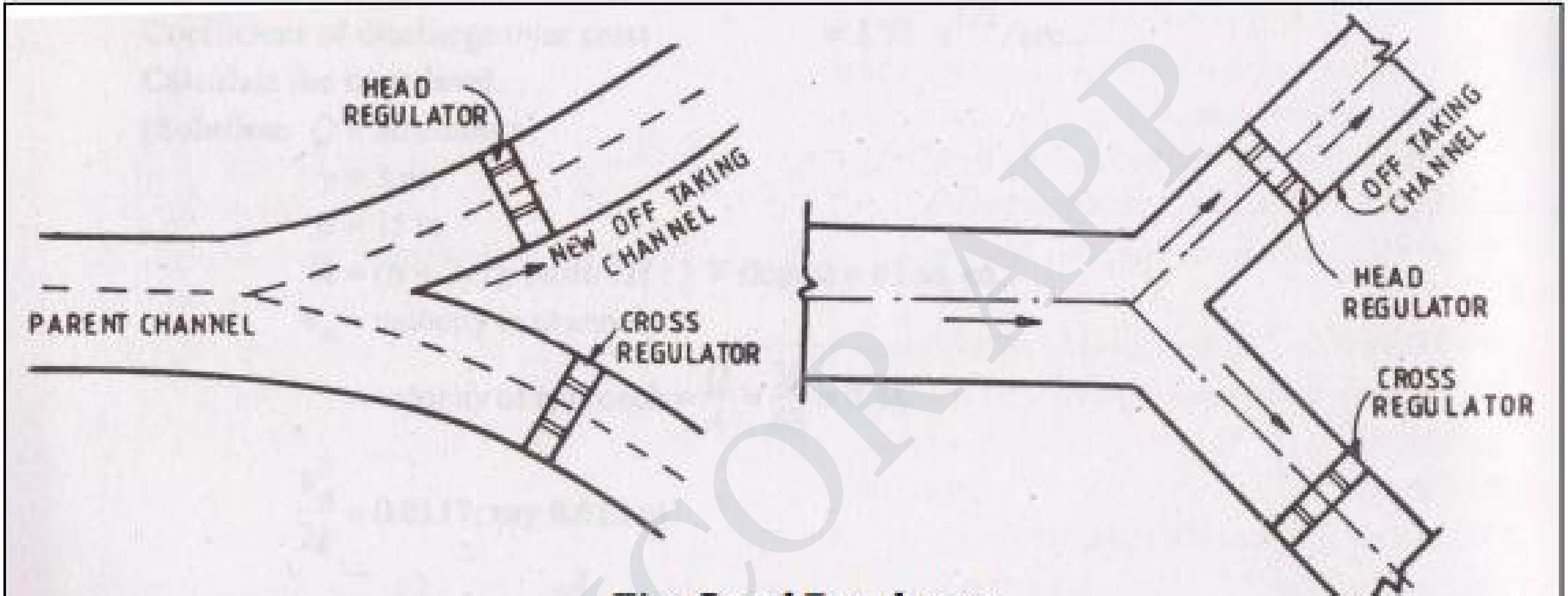
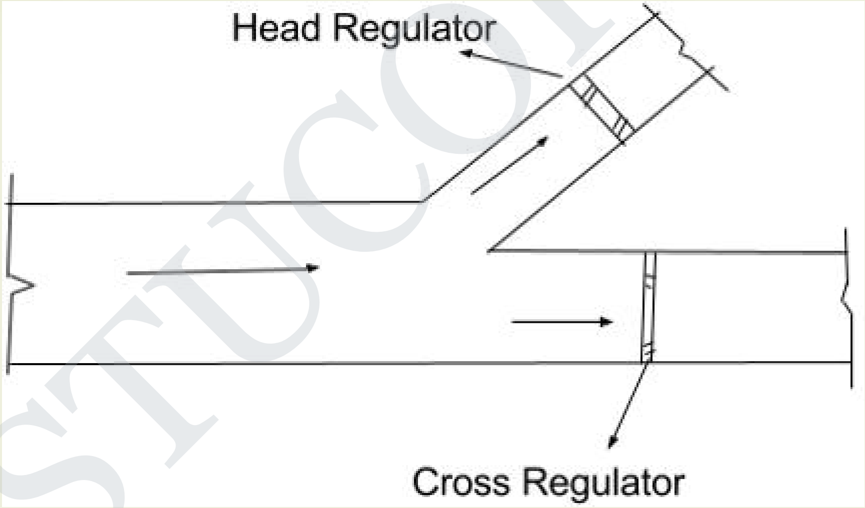


Fig: Canal Regulators

Canal Regulator

Main functions of a head regulator:

- To **regulate or control the supplies** entering the off-taking canal
- To **control the entry of silt** into the off-taking canal
- To **serve as a meter for measuring discharge**.



- It consists of a **raised crest with abutments on both sides.**
- The crest may be subdivided in **various bays by providing piers** on the crest.
- The **piers support roadway and a platform** for operating gates.
- The **gates control the flow** over the crest.
- They are **housed and operated in grooves** made in the abutments and piers.

Main functions of a cross regulator:

- To **control the entire Canal Irrigation** System.
- To **help in heading up water on the upstream side** and to fed the off-taking canals to their full demand.
- To **help in absorbing fluctuations** in various sections of the canal system, and in preventing the possibilities of breaches in the tail reaches.
- Cross regulator is often combined with bridges and falls, if required.

Canal Escapes:

•It is a side channel constructed **to remove surplus water from an irrigation channel** (main canal, branch canal, or distributary etc.) into a natural drain.

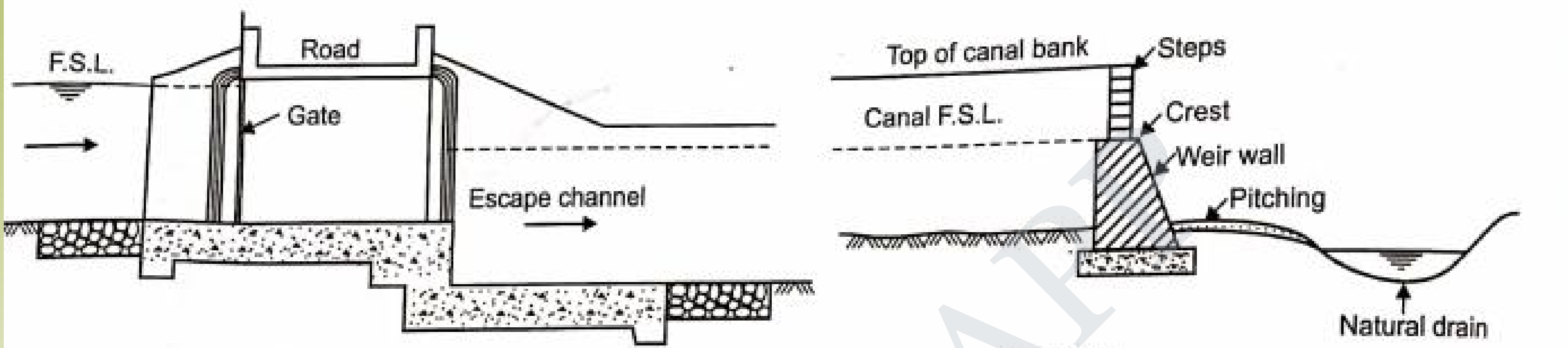
•The water in the irrigation channel may become **surplus due to**

1)Mistake

2)Difficulty in regulation at the head

3)Excessive rainfall in the upper reaches

4)Outlets being closed by cultivators as they find the demand of water is over



(a) Scouring Escape or Surplus Water Escape

(b) Tail Escape

Fig. 6.18 : Canal Escape

Canal E

Distributary Head Regulator:

•It is a **hydraulic structure** constructed at the head of a distributary. This regulator performs the same **functions as that of a head regulator.**

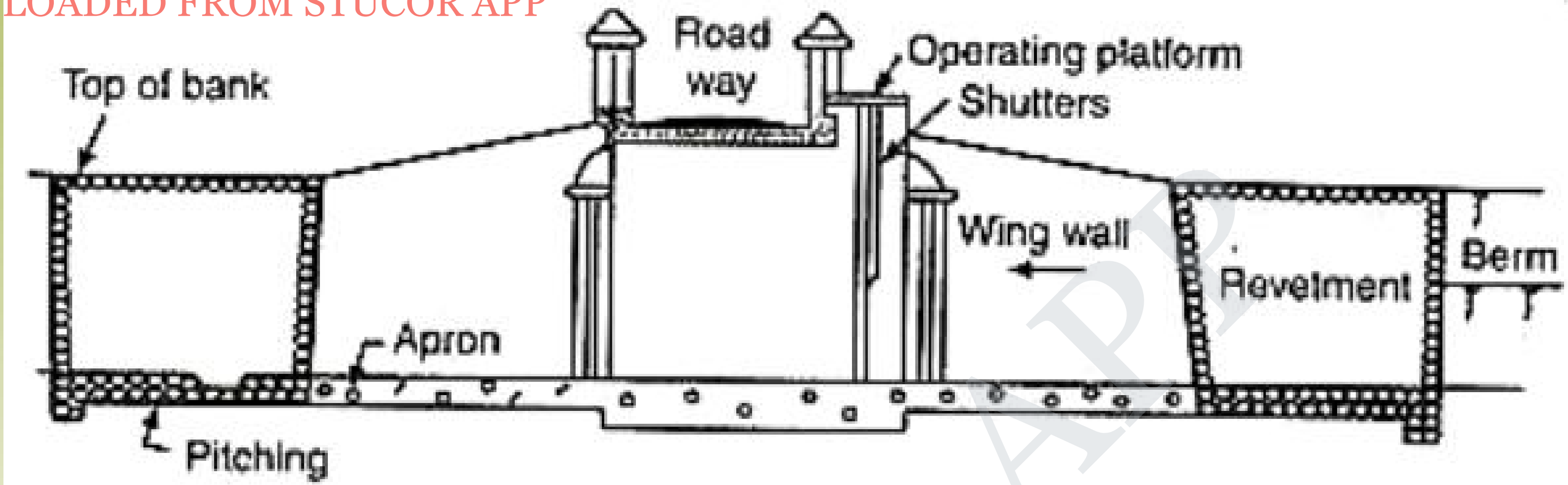
Functions of Distributary Head Regulator:

•It **regulates the supply** of the distributary.

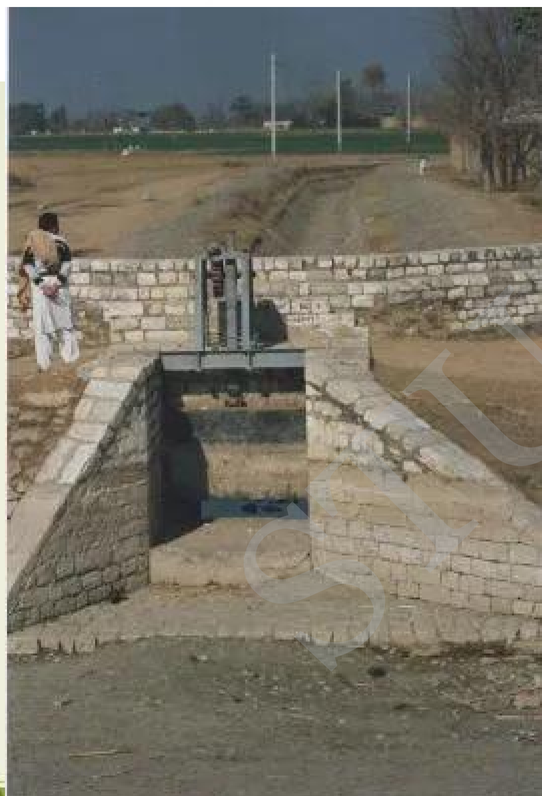
•It can be used **many times as a meter**.

•It is also a **silt selective structure**.

•Distributary head regulator **controls the flow** in the



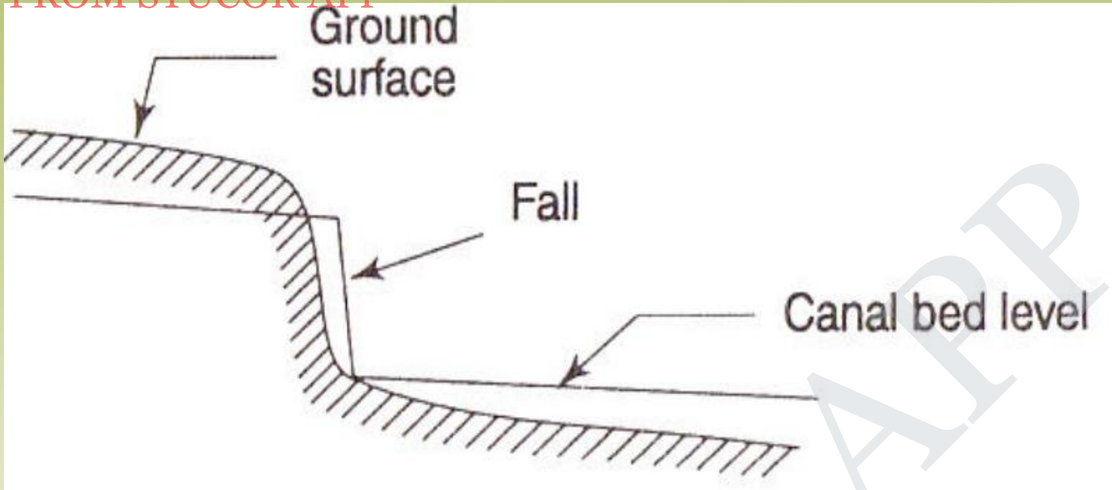
. Distributary head regulator



Canal drop or Fall

•A canal fall or drop is an **irrigation structure** constructed across a canal to **lower down its bed level to maintain the designed slope** when there is a **change of ground level to maintain the designed slope** when there is change of ground level.

•This falling water at the fall has some **surplus energy**. The fall is constructed in such a way that it can **destroy this surplus energy**



Canal drop or Fall

Types of Canal Fall:

1. Ogee Fall - to provide smooth transition and to reduce disturbance and impact

2. Rapid Fall - consists of a glacis sloping at 1: 0 to 1:20. Very high cost of construction

3. Stepped Fall - next development of rapid fall. Cost of construction is high

4. Notch Fall - the fall is consists of one or more trapezoidal notches

5. Vertical Drop Fall - high velocity jet enters the deep pool of water in the cistern and dissipation of energy is affected by turbulent diffusion

6. Glacis Type Fall - utilizes standing wave phenomenon for dissipation of energy.

Ogee Fall

•In this type of fall, **an ogee curve** (a **combination of convex curve and concave curve**) is provided for carrying the canal water from higher level to lower level.

•This fall is recommended when the natural ground surface **suddenly changes to a steeper slope** along the alignment of the canal.

Ogee Fall

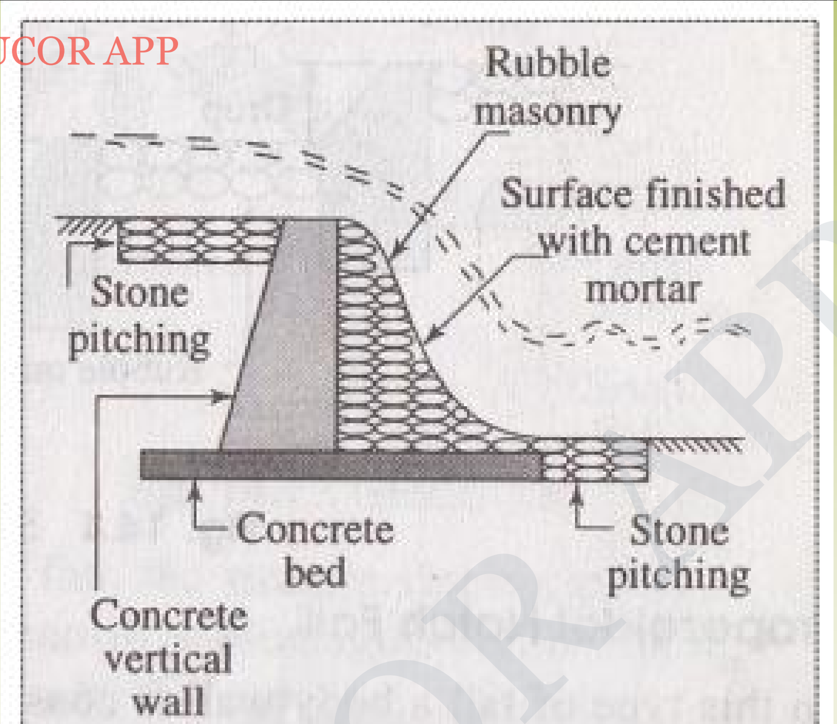


Fig: Ogee Fall

Rapid Fall

- The rapid fall is suitable when the **slope of the natural ground surface is even and long.**
- It consists of a long sloping glacis with longitudinal slope which varies from **1 in 10 to 1 in 20.**

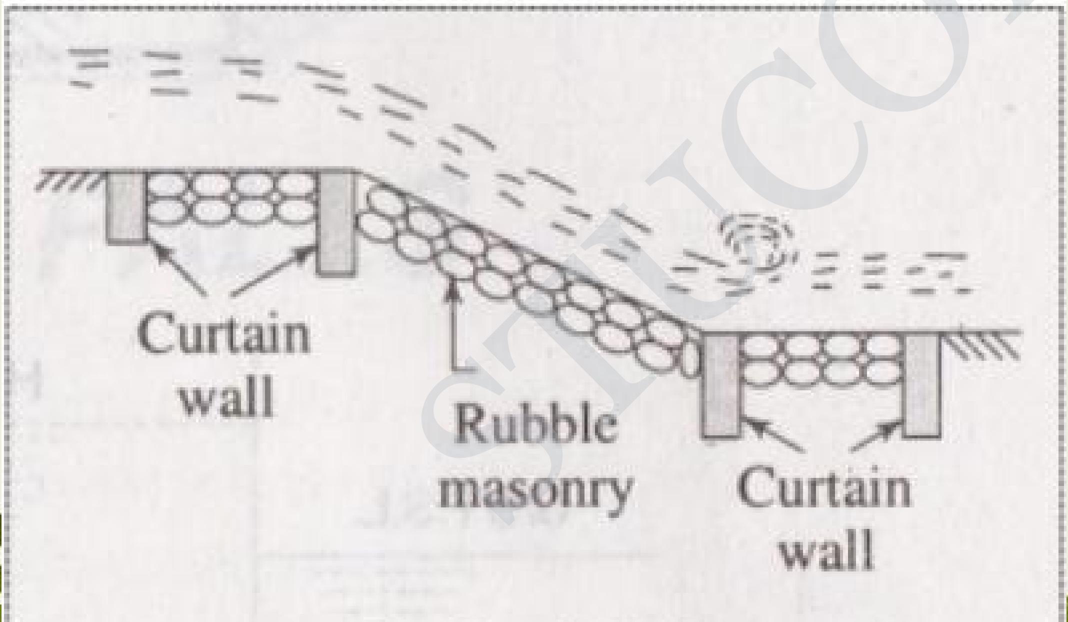


Fig: Rapid Fall

Stepped Fall

•Stepped fall consists of a **series of vertical drops in the form of steps.**

•This fall is suitable in places where the **sloping ground is very long and requires long glacis** to connect the higher bed level with lower bed level.

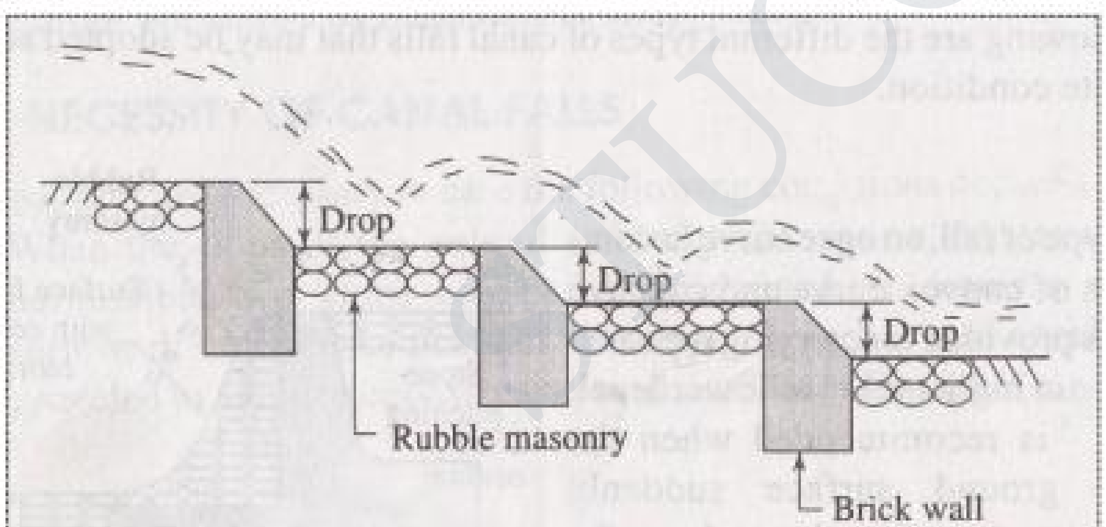


Fig: Stepped Fall

Trapezoidal Notch Fall

- In this type of fall a body wall is constructed **across the canal.**
- The body wall consists of **several trapezoidal notches between the side piers** and the intermediate pier or piers.

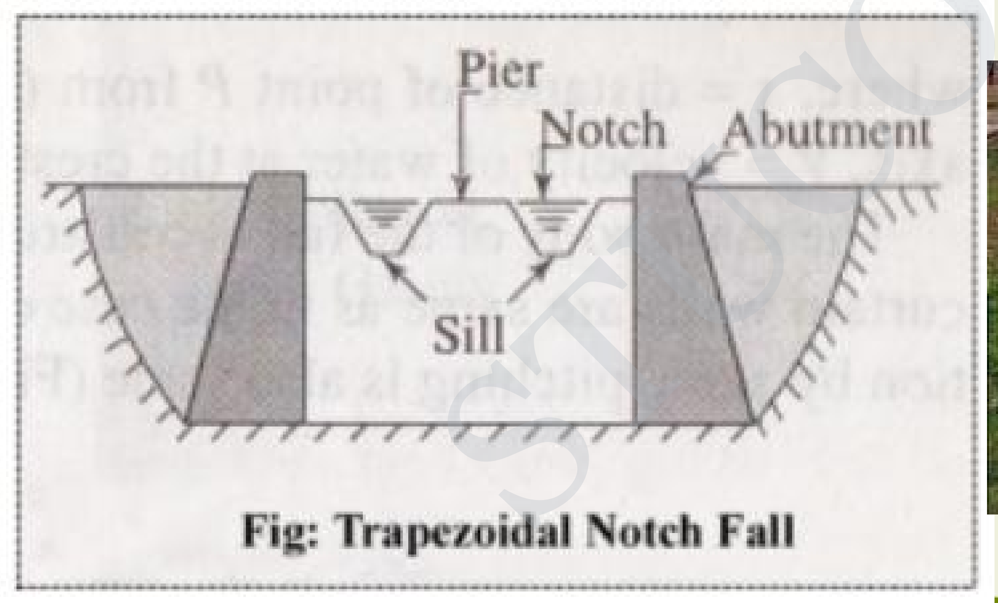


Fig: Trapezoidal Notch Fall

Vertical Drop Fall

- It consists of a **vertical drop walls which is constructed with masonry work**.
- The water flows **over the crest** of the wall.

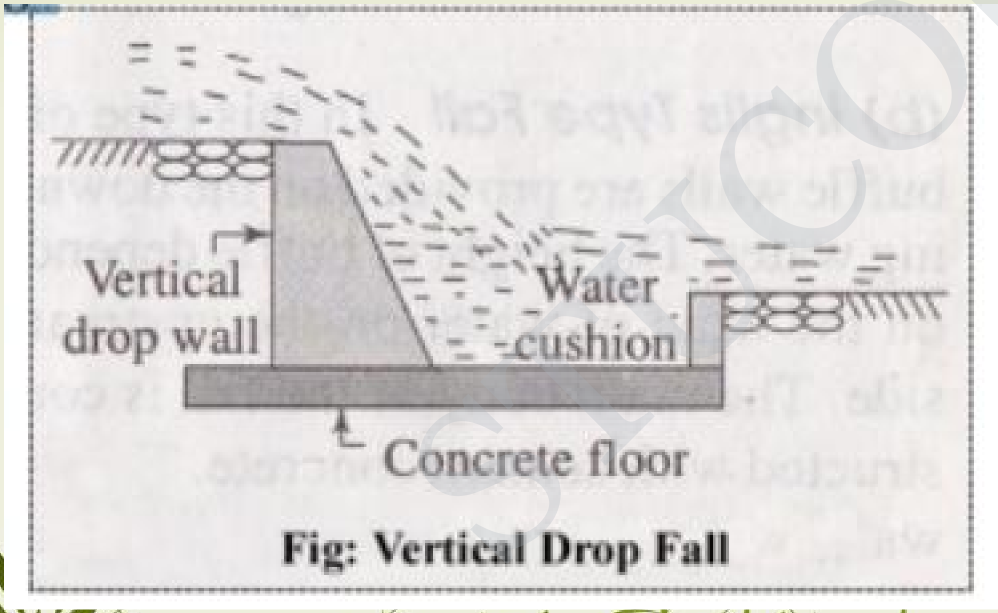
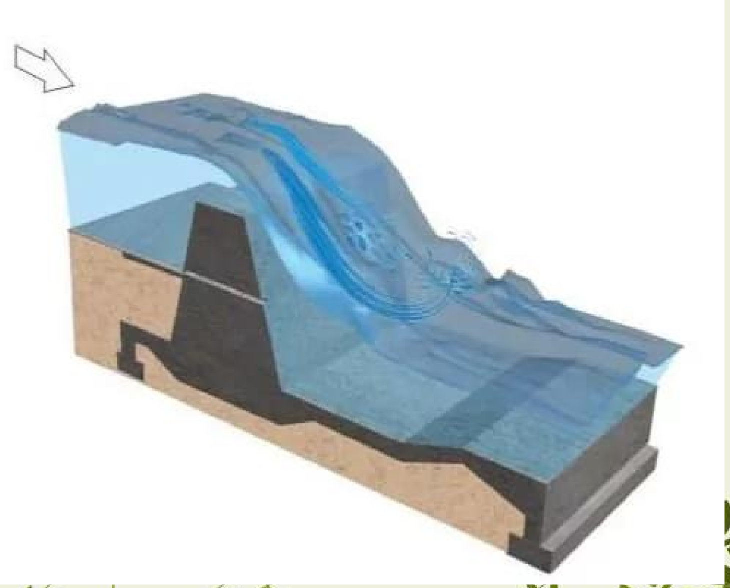


Fig: Vertical Drop Fall



Glacis Fall

- It consists of a **straight sloping glacis** provided with a crest.
- A **water cushion** is provided on the downstream side to **dissipate the energy** of flowing water.

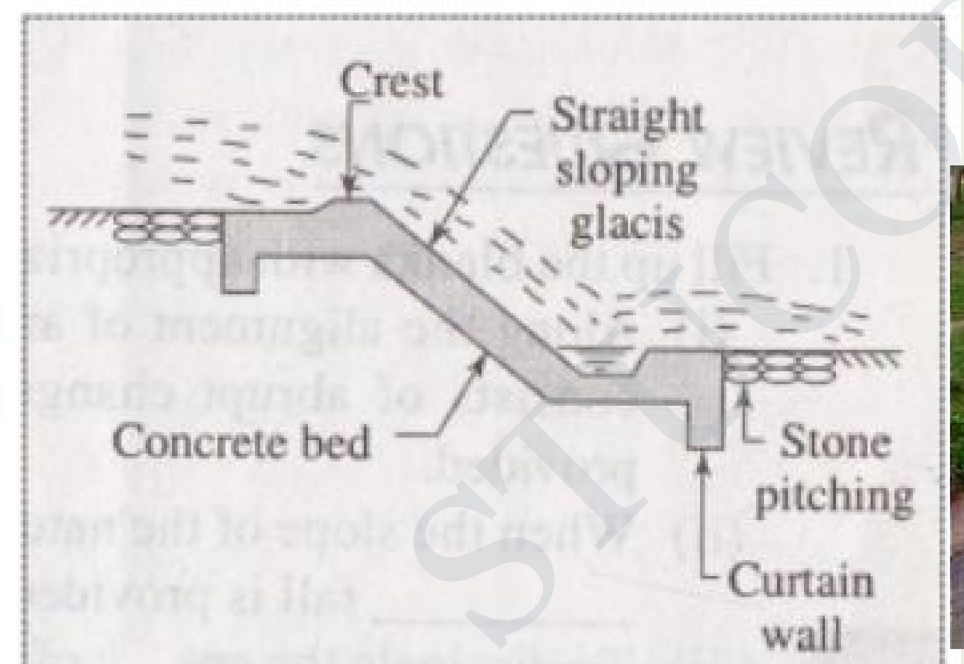


Fig: Glacis Fall

(a) Montague Type Fall

In this type of fall, **the straight sloping glacis** is modified by giving **parabolic shape** which is known as Montague profile. Taking “0” as the origin, the Montague profile is given by the equation,

$$X = v\sqrt{4\frac{y}{g} + Y}$$

Where, x = distance of point P from OX axis,

Y = distance of point P from OY axis,

u = velocity of water at the crest,

g = acceleration due to gravity

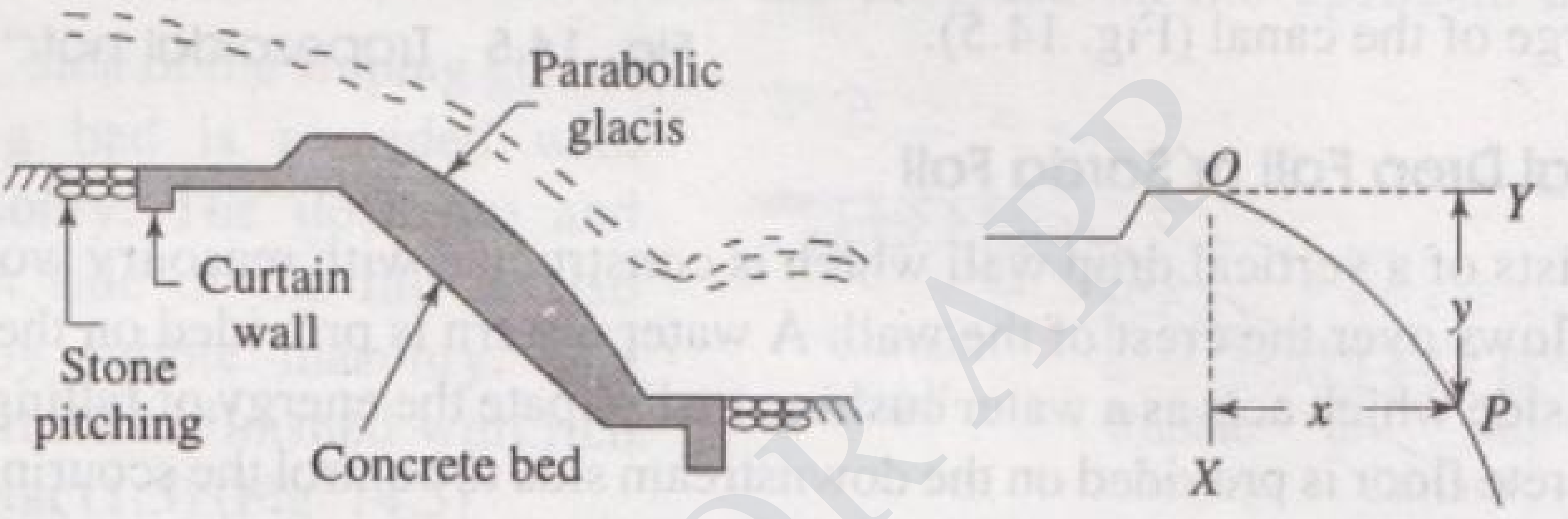


Fig: Montague Type Fall

(b) Inglis Type Fall

- In this type of fall, **the glacis is straight** and sloping, but buffle walls are provided on the downstream floor **to dissipate the energy of flowing water.**

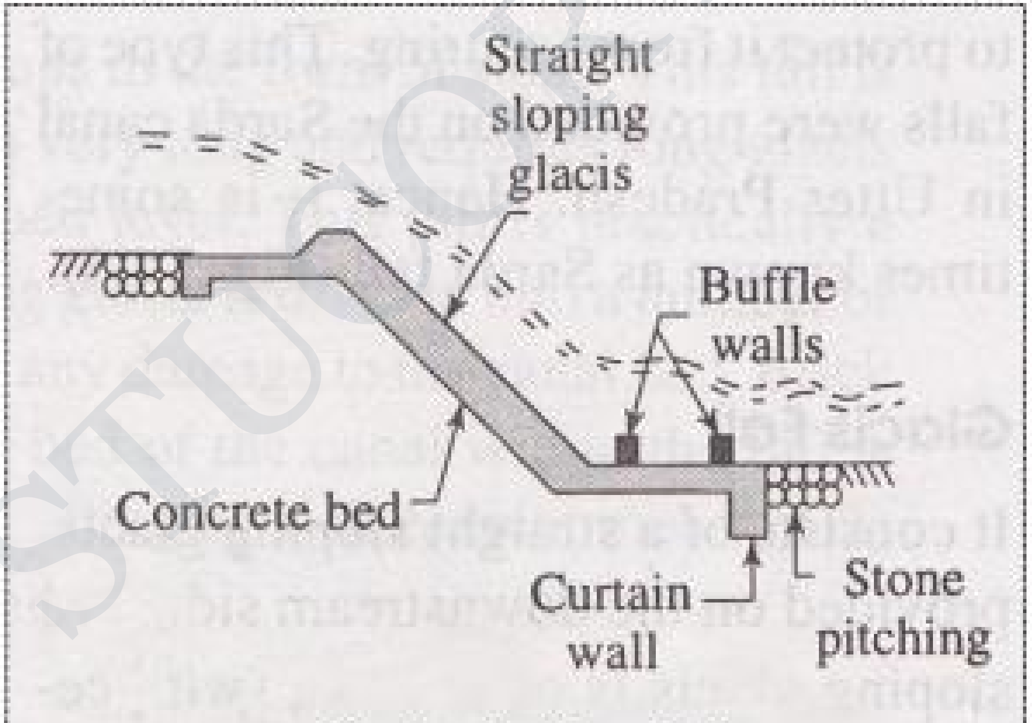


Fig: Inglis Type Fall

CROSS DRAINAGE WORKS

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Cross drainage works

- In an irrigation project, when the network of **main canals, may have to cross the natural drainages like rivers**, streams.
- The **crossing of the canals with such obstacle cannot be avoided.**
- So, **suitable structures must be constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions**.
- These structures are known as cross-drainage works.

Necessity of Cross-drainage works:

- In actual orientation of the canal network, the **obstacles like natural drainages may be present** across the canal.
- At the crossing point, the **water of the canal and the drainage get intermixed**.
- The site condition of the crossing point may be such that without any suitable structure, t**he water of the canal and drainage can not be diverted** to their natural directions.

Types of Cross-Drainage Works:

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

- Aqueduct
- Siphon aqueduct

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

- Super passage
- Siphon super passage

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

- Level Crossing
- Inlet and outlet

Selection of type of cross-drainage works

Relative bed levels

Availability of suitable foundation

Economical consideration

Discharge of the drainage

Construction problems

Aqueduct

- When the **HFL of the drain is sufficiently below the bottom of the canal**, so that the **drainage water flows freely under gravity**, the structure is known as an **Aqueduct.**
- The aqueduct is just like a **bridge where a canal is taken over the deck supported by piers** instead of a road or railway.
- An **inspection road** is provided along the **side of the trough**.
- The **bed and banks** of the drainage below the trough is **protected by boulder pitching** with cement grouting.
- The section of the **trough** is designed according to the **full supply discharge of the canal.**

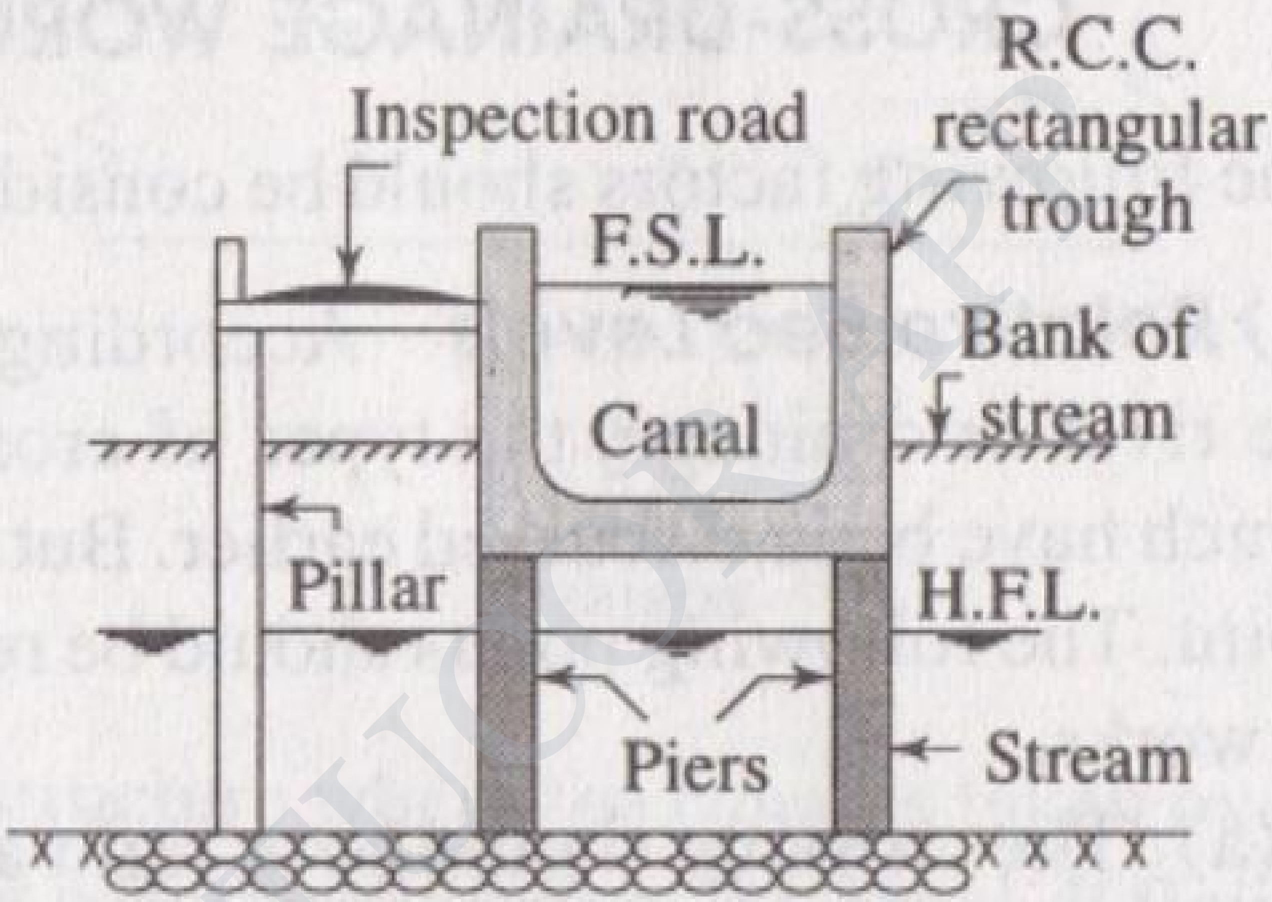
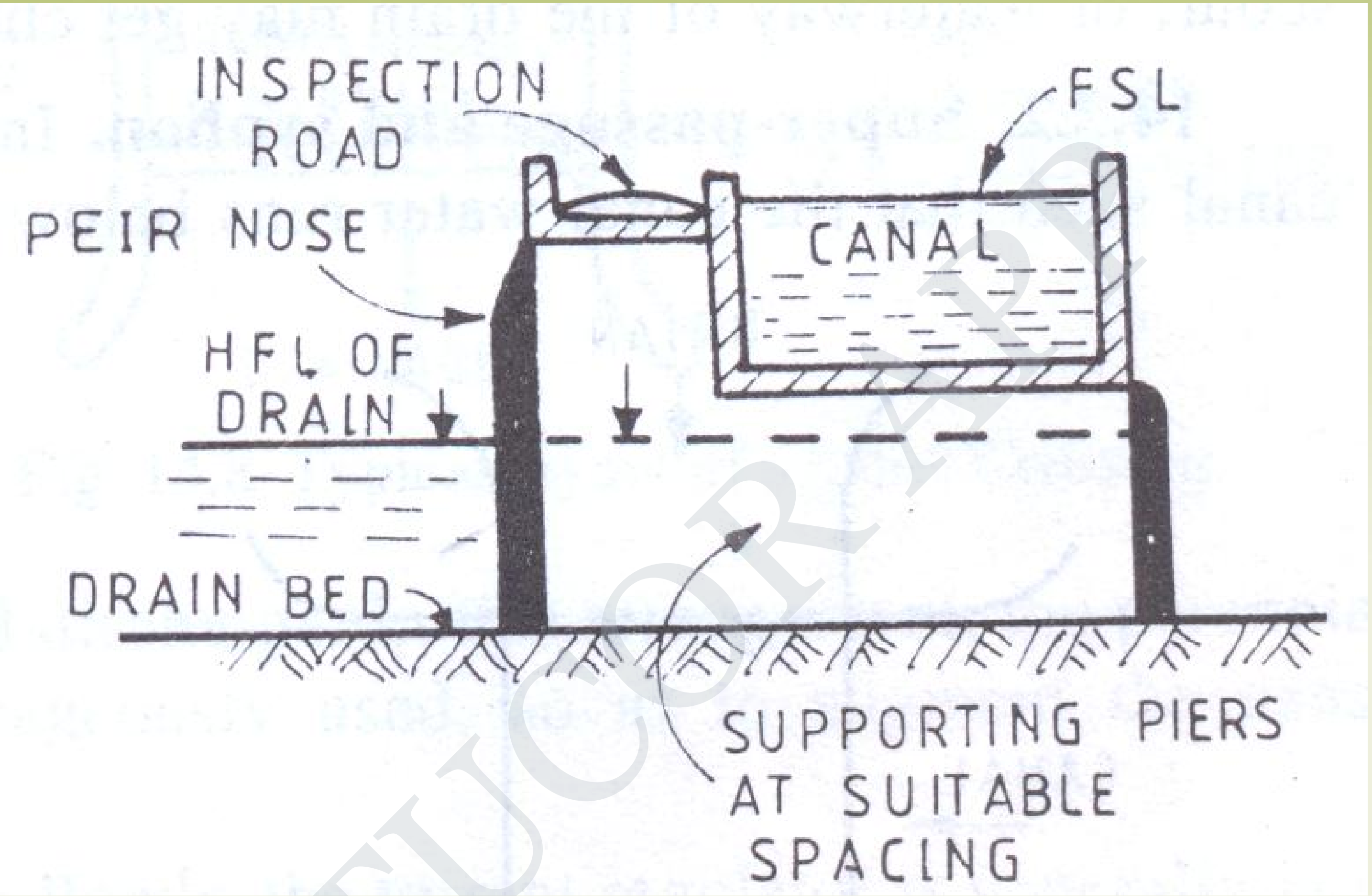


Fig: Aqueduct


INSPECTION
ROAD
FSL
PEIR NOSE
CANAL
HFL OF
DRAIN
DRAIN BED
SUPPORTING PIERS
AT SUITABLE
SPACING

Aqueduct

Aqueduct

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- A **free board** of about **0.50 m** should be provided.
- The **height and section of piers** are designed according to the **highest flood level and velocity** of flow of the drainage.
- The **piers** may be of **brick** masonry, **stone** masonry or **reinforced cement concrete.**
- **Deep foundation** (like well foundation) is **not necessary** for the piers.
- The **concrete foundation** may be done by providing the depth of foundation according to the **availability of hard soil**.

Siphon Aqueduct

- However, if the **HFL of the drain is higher than canal bed and the water passes through the aqueduct barrels under syphonic action**, structure is known as Syphon Aqueduct.
- The siphon aqueduct, **the bed of the drainage is depressed below the bottom level of the canal** trough by providing sloping apron on both sides of the crossing.
- The **sloping apron may be constructed** by stone pitching or cement concrete.
- The **section of the drainage** below the canal trough is constructed with cement concrete in the form of tunnel. **This atsiphon.**

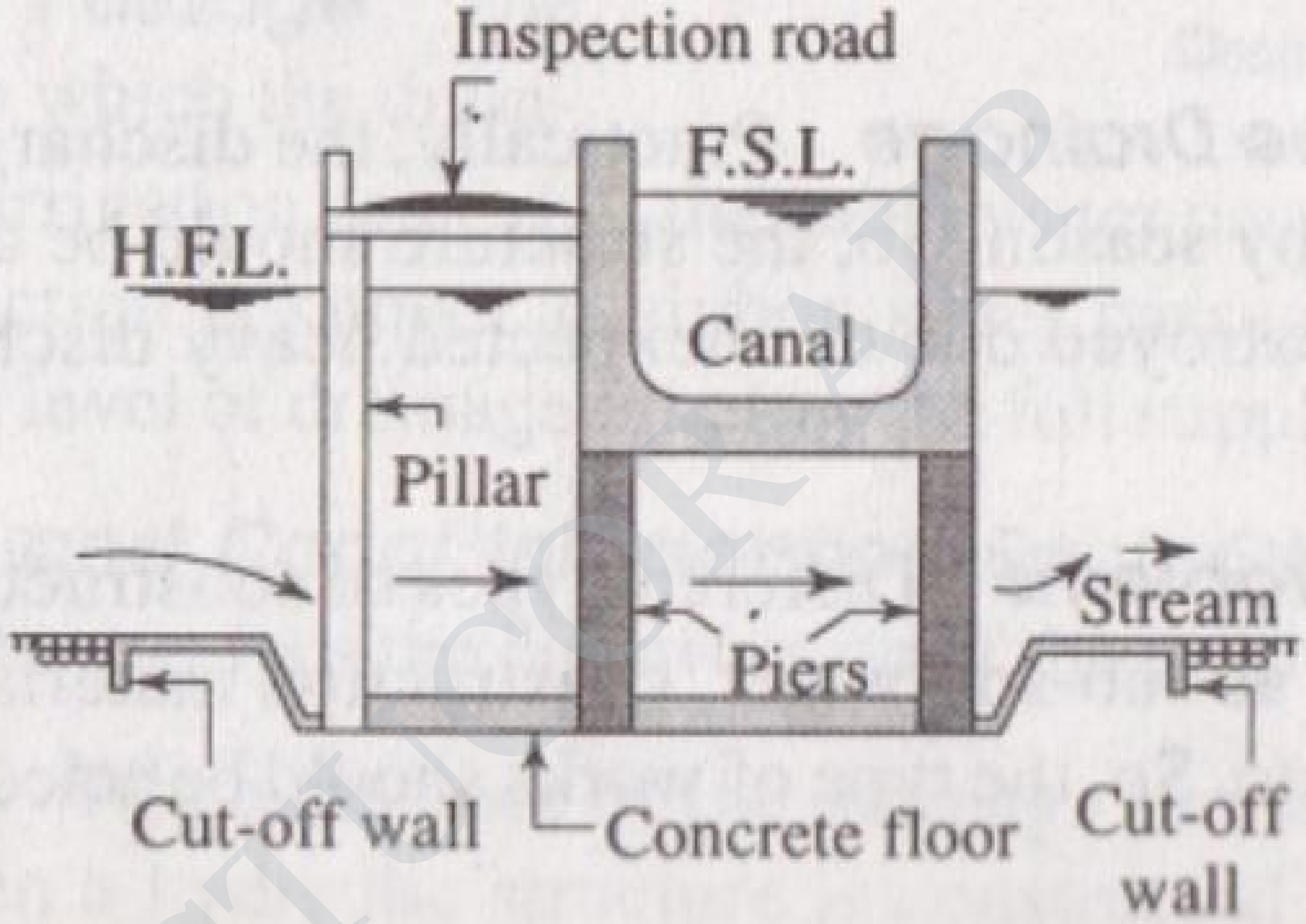
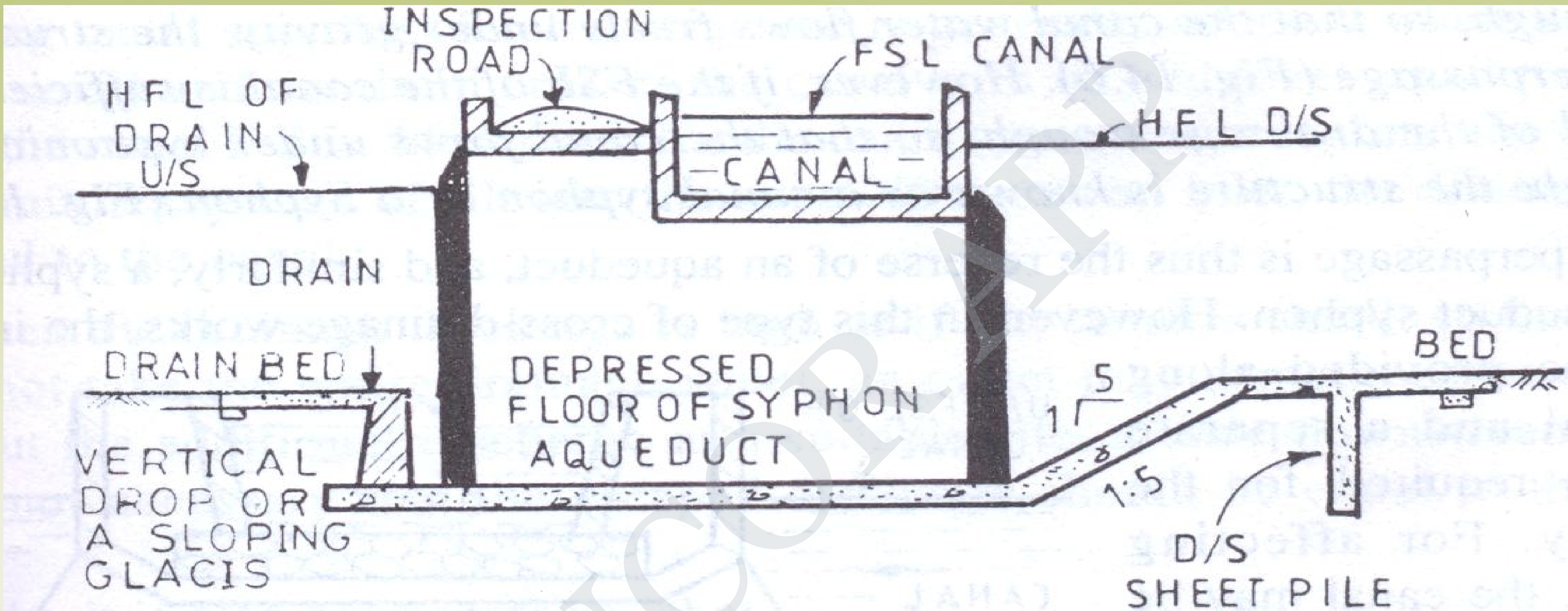


Fig: Siphon Aqueduct

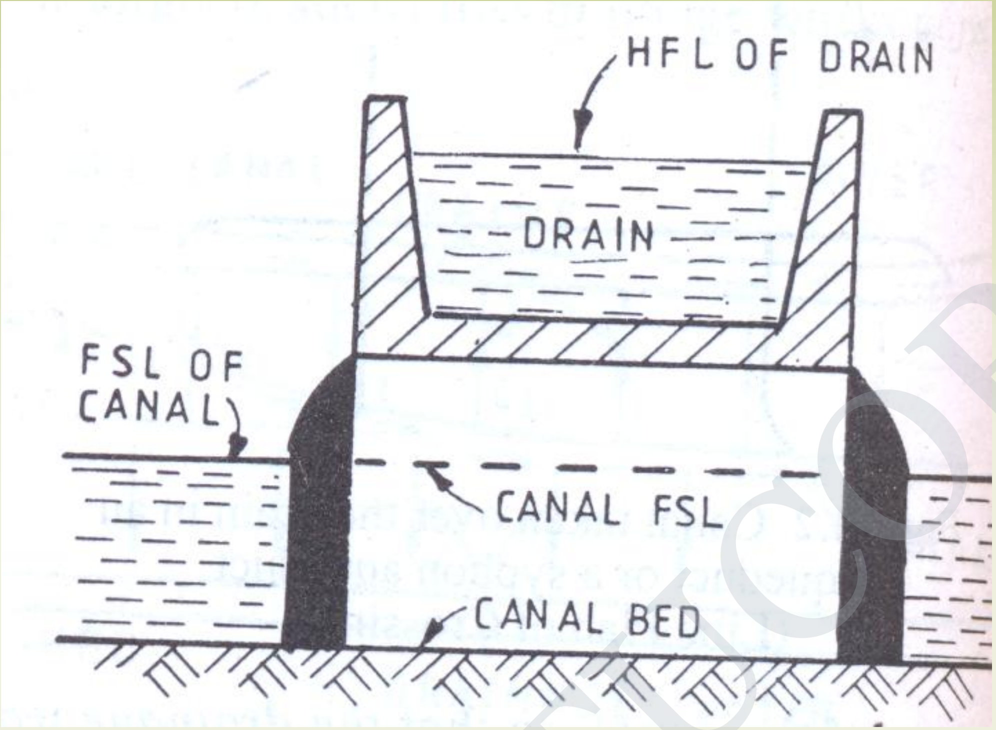


Siphon Aqueduct

- **Cut off walls** are provided on **both sides of the apron** to **prevent scouring**.
- **Boulder pitching** should be **provided on the upstream and downstream of the cut-off walls**.
- The other components like canal trough, piers, inspection road, etc. should be designed according to the methods adopted in case of aqueduct.

Super Passage

- The super passage is just **opposite of the aqueduct**. In this case, the bed level of the drainage is above the fully supply level of the canal.
- When the **FSL of the canal is sufficiently below the bed level of the drain trough, so that the canal water flows freely under gravity, the structure is known as a Super passage**
- The drainage is taken through a rectangular or trapezoidal trough of channel which is constructed on the deck supported by piers.



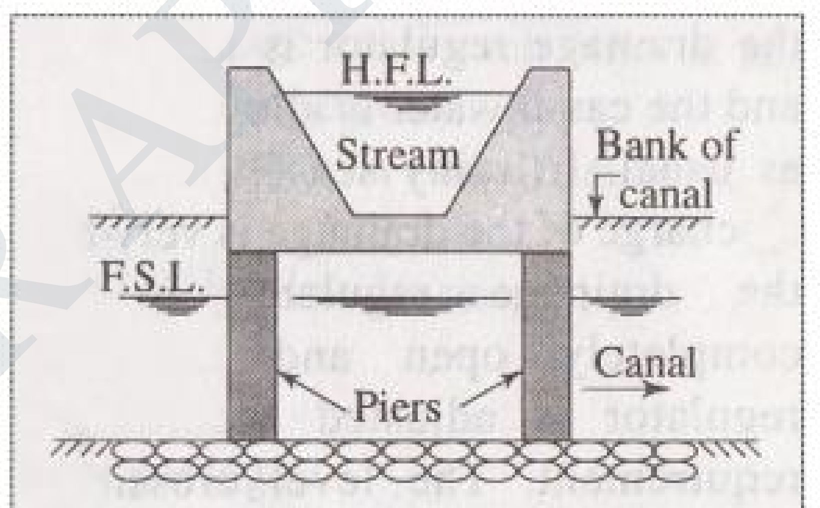


Fig: Super Passage

Super Passage

- The section of the **drainage trough depends on the high flood** discharge.
- **A free board of about 1.5 m** should be provided for safety.
- The **trough** should be constructed of **reinforced cement concrete.**
- The **bed and banks of the canal** below the drainage trough should be protected by boulder pitching or lining with **concrete slabs.**

Siphon Super Passage

- It is just **opposite siphon aqueduct**. In this case, the **canal passes below the drainage trough.**
- If the **FSL of the canal is sufficiently above the bed level of the drainage trough, so that the canal flows under syphonic action under the trough, the structure is known as a canal syphon** or a Syphon
- The bed of the canal is depressed below the bottom level of the drainage trough by providing sloping apron on both sides of the crossing.

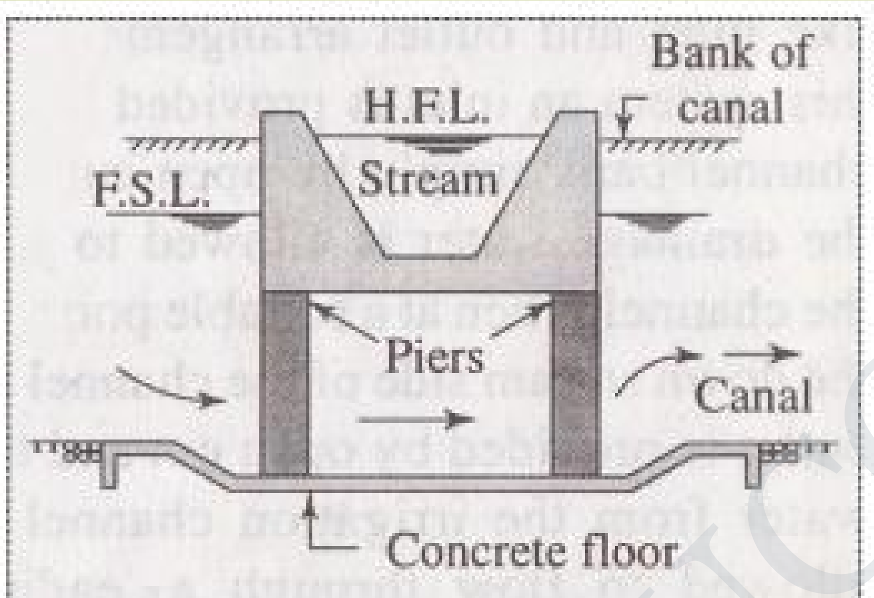
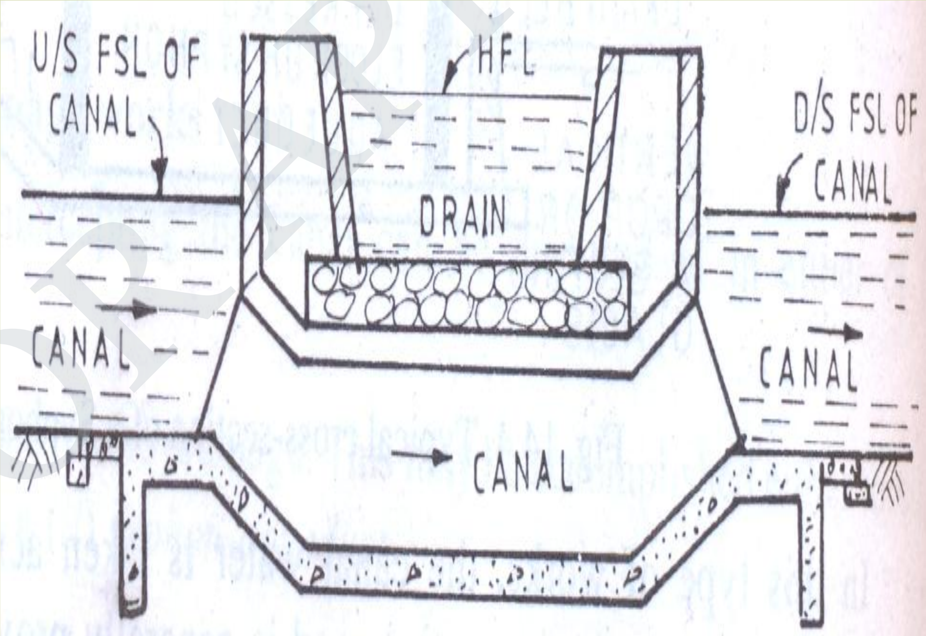


Fig: Siphon Super Passage



Siphon Super Passage

Level Crossing

- The level crossing is an arrangement provided to **regulate the flow of water through the drainage and the canal when they cross each other approximately at the same bed level**.

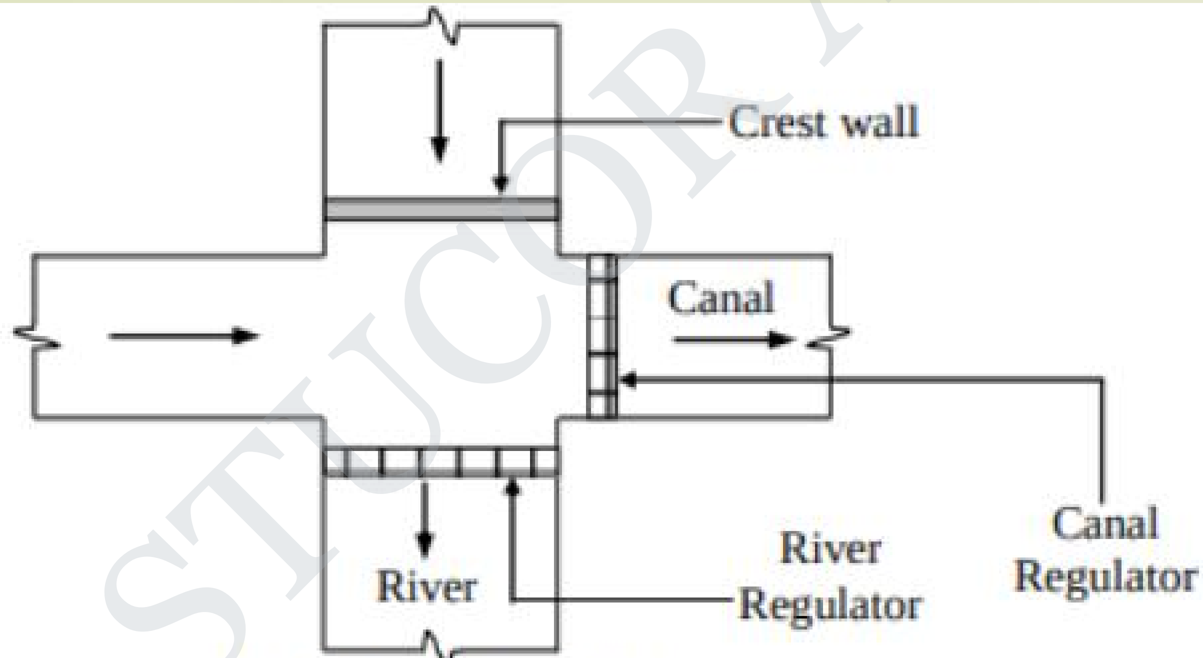


Fig: Level Crossing

Crest Wall:

- It is provided **across the drainage just at the upstream side** of the crossing point.
- The top level of the crest wall is kept at the full supply level of the canal.

Drainage Regulator:

- It is provided **across the drainage just at the downstream side** of the crossing point.
- The regulator consists of adjustable shutters at different tiers.

Canal Regulator:

- It is provided **across the canal just at the downstream side** of the crossing point. This regulator also consists of adjustable shutters at different tiers.

Inlet and outlet

- In the crossing of **small drainage with small channel** no hydraulic structure is constructed.
- **Simple openings** are provided for the flow of water in their respective directions. This arrangement is known as **inlet and outlet.**

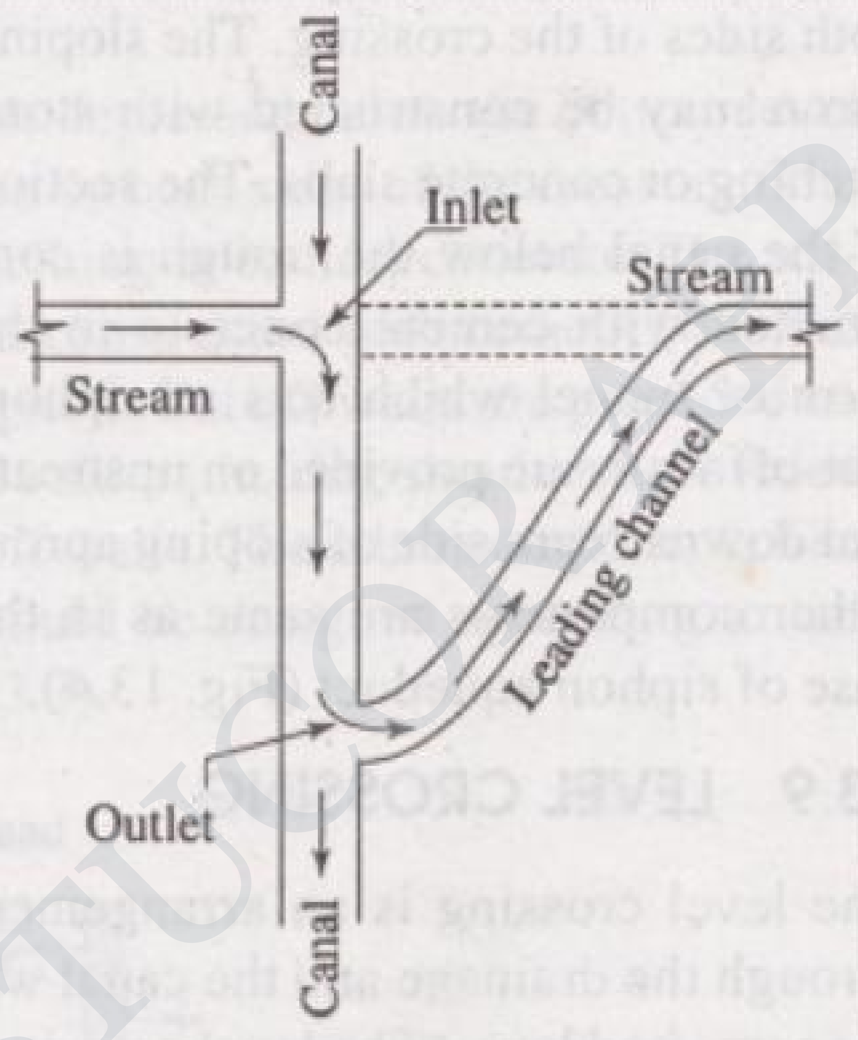


Fig: Inlet and outlet

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Canal Outlets/Modules:

- A canal outlet or a module is a **small structure built at the head of the water course** so as **to connect it with a minor or a distributary channel.**
- It acts as a connecting **link between the system manager and the farmers.**

Requirements of a good module:

It should **fit well** to the decided principles of water distribution.

It should be **simple** to construct.

It should **work efficiently** with a small working head.

- It should be **cheaper.**
- It should be **sufficiently strong** with no moving parts, thus **avoiding periodic maintenance**.
- It should e such as to **avoid interference by cultivators.**
- It should **draw its fair share of silt.**

Types of Outlet/modules:

1)Non-modular modules

2)Semi-modules or Flexible modules

3)Rigid modules or Modular Outlets

(a) Non-modular modules:

Non-modular modules are those through **which the discharge depends upon the head difference between the distributary and the water course.**

Common examples are:

(i) Open sluice

(ii) Drowned pipe outlet

(b) Semi-modules or Flexible modules:

- Due to construction, **a super-critical velocity is** ensured in the **throat** and thereby allowing the **formation of a jump** in the expanding flume.
- The formation of hydraulic jump makes the outlet discharge **independent of the water level in water course**, thus making it a semi module.
- Examples are **pipe outlet, open flume** type etc.

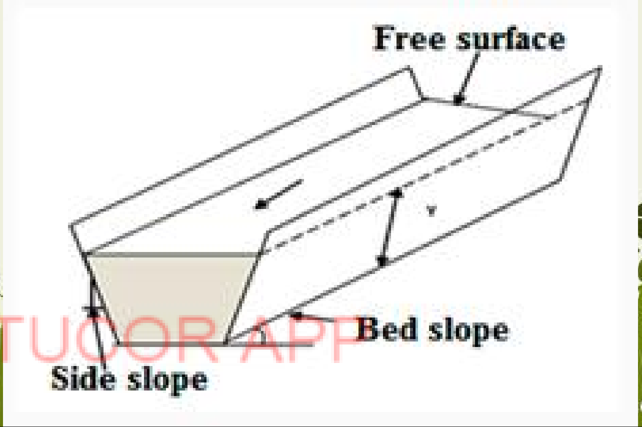
c) Rigid modules or Modular Outlets:

- Rigid modules or modular outlets are those through which **discharge is constant and fixed within limits**, irrespective of the fluctuations of the water levels of either the distributary or of the water course or both.
- An example is **Gibb's module**

Design of prismatic canal

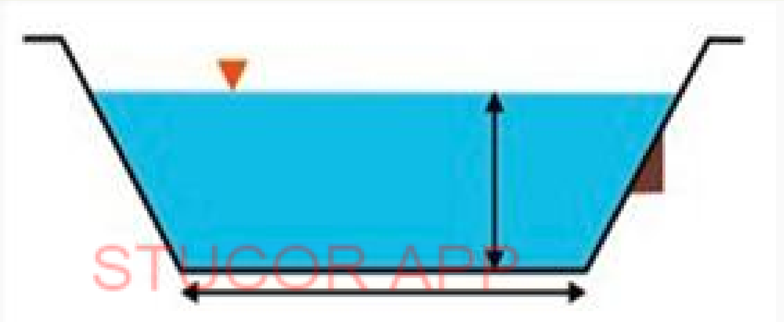
Open Channels

- Irrigation water is conveyed in either **open channel or closed conduits.**
- Open channels **receive water from natural streams or underground** water and **convey water to the farm** for irrigation.
- Open channels have **free surface**. The free surface is subjected to **atmospheric pressure**.



Prismatic and Non-Prismatic Channels

- A channel in which the **cross sectional shape, size and the bottom slope are constant over long stretches** is termed as prismatic channel.
- Most of the **man-made or artificial channels are prismatic** channels.
- The **rectangular, trapezoidal, triangular and half-circular** are commonly used shapes in manmade channels.
- All **natural channels** generally have varying cross section and consequently are **nonprismatic.**



Design of Open Channel

- Open Channel is a **passage through which water flows** and has **upper surface exposed to atmosphere**.
- Open channel design involves **determining cross-section** dimensions of the channel for the **amount of water** the channel must carry (i.e., capacity) at a given flow velocity, **slope** and, **shape** or alternatively determining the d**ischarge capacity** for the given cross-section dimensions.

i) Area of Cross Section (a):

Area of cross section of for a **rectangular cross section**, of wetted section. For a rectangular cross section, if b = width of channel and y = depth of water, the area of wetted section of channel **(a) = b.y.**

ii) Wetted Perimeter (p):

It is the sum of the lengths of that part of the channel sides and bottom which are in contact with water. The wetted perimeter **(p) = b+2y.**

iii) Hydraulic Radius (R):

It is the ration of area of wetted cross section to wetted perimeter. The hydraulic radius

$$(R) = \frac{a}{p} = \frac{by}{b+2y}$$

iv) Hydraulic Slope (S):

It is the ratio of vertical drop in longitudinal channel section (h) to the channel length (l). Hydraulic slope $(S) = \frac{h}{l}$

v) Freeboard:

- It is the **vertical distance between the highest water level** anticipated in channel flow **and the top of the retaining banks**.
- This is provided t**o prevent over topping** of channel embankments or damage due to trampling.
- This is provided between **15.25% of normal depth of flow.**

Discharge Capacity of Channel

Channel capacity can be estimated by equation given as:

$$Q = \frac{(16667)(DDIR)(A)}{(HPD)(Ei)}$$

where,

Q = channel capacity (L/min)

DDIR = design daily irrigation requirement (mm/day)

A = irrigated area supplied by canal or ditch (ha)

HPD = hours per day that water is delivered

Ei= irrigation efficiency including conveyance efficiency of canal or ditch (percent).

Velocity of flow

- The velocity of flow in a canal or ditch **should be non erosive and non silting** that **prevent the deposition of suspended substances.**
- Normally flow velocity in **excess of 0.6 m/s is non silting** (Schwab et al., 1993).
- The **maximum velocity** that **does not cause excessive erosion** depends on the erodibility of the soil or lining material.

Economical Section of a Channel

- A channel section is said to be **economical when the cost of construction of the channel is minimum.**
- The cost of construction of a channel depends on **depth of excavation and construction for lining**.
- The cost of construction of channel is **minimum when it passes maximum discharge** for its given cross sectional area.
- It is evident from the continuity equation and uniform flow formulae that for a given value of slope and surface roughness, the **velocity of flow is maximum when hydraulic radius is maximum.**

The conditions for the most economical section of channel

- A **rectangular channel** section is the most economical when either the **depth of flow is equal to half the bottom width or hydraulic radius is equal to half the depth of flow**.
- A **trapezoidal section** is the most economical if **half the top width is equal to one of the sloping sides of the channel or the hydraulic radius is equal to half the depth of flow**.
- A **triangular** channel section is the most economical when **each of its sloping side makes an angle of 45owith vertical or is half square described on a diagonal and having equal sloping sides.**

The discharge from a channel is given by

$$Q = AV = AC\sqrt{RS_0} = AC\sqrt{\frac{A}{P}S_o} = K * \frac{1}{\sqrt{P}}$$

where Q = discharge (m^3/s), A = area of cross section (m2), C = Chezys constant,

R= Hydraulic radius (m), P = wetted perimeter (m), = bed slope (fraction or m/m), K = constant for given cross sectional area and bed slope and = $A^{3/2}C\ S_o^{1/2}$ and the discharge Q will be maximum when the wetted perimeter P is minimum.

(i) Channel Shape:

- Among the various shapes of open channel the **semi-circle shape is the best hydraulic efficient cross sectional shape.**
- However the **construction of semicircle cross section is difficult** for earthen unlined channel.
- **Trapezoidal** section is commonly **used cross section.**

(ii) Channel Dimensions:

The channel dimensions can be obtained using uniform flow formula, which is given by

$$Q = A V$$

Where,

V = flow velocity (m/s)

A = cross-sectional area of canal perpendicular to flow (m2)

Q = capacity of the channel (m3/s)

Velocity is computed by **Manning's formula or Chezy formula**.

Manning's Equation is given by

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Chezy's equation is given by

$$V = C\, R^{1/2} S^{1/2}$$

Where,

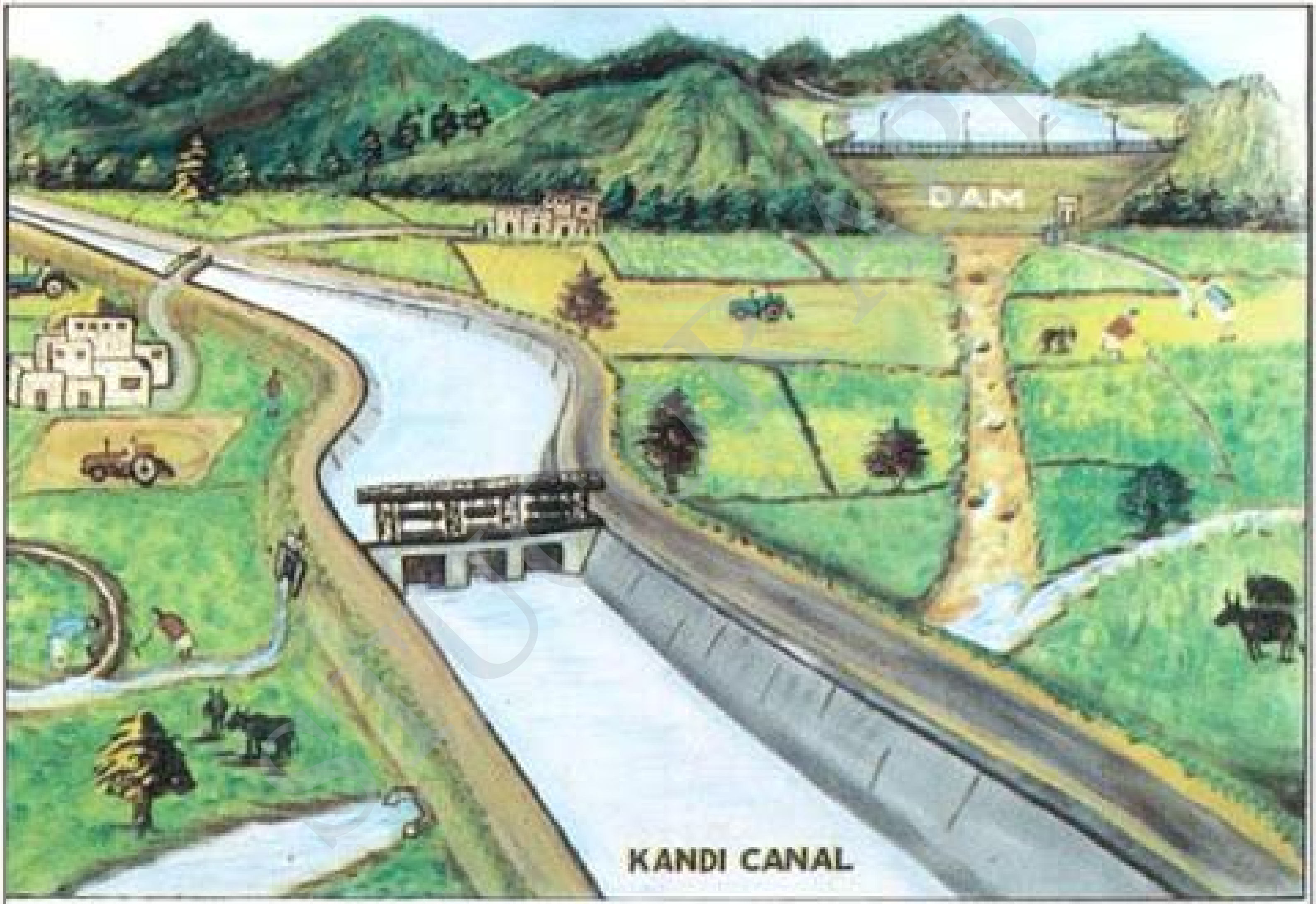
n = Manning's roughness coefficient

C = Chezy's roughness coefficient

R = hydraulic radius (m)

S = bed slope (m/m)

Canal alignments



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Canal alignments

- It is clear that **irrigation water**, in flow type, **should reach the fields by gravity.**
- To accomplish this requirement **irrigation canal** is always **aligned** in such a way that **the water gets proper command over the whole irrigable area**.
- The **watershed or the ridge** is a **dividing line between two drainage areas.**
- Thus a **canal** which runs over the ridge gets **command of area on both sides of the ridge.**

Irrigation canals can be aligned in any of the three ways

1. **As watershed canal**

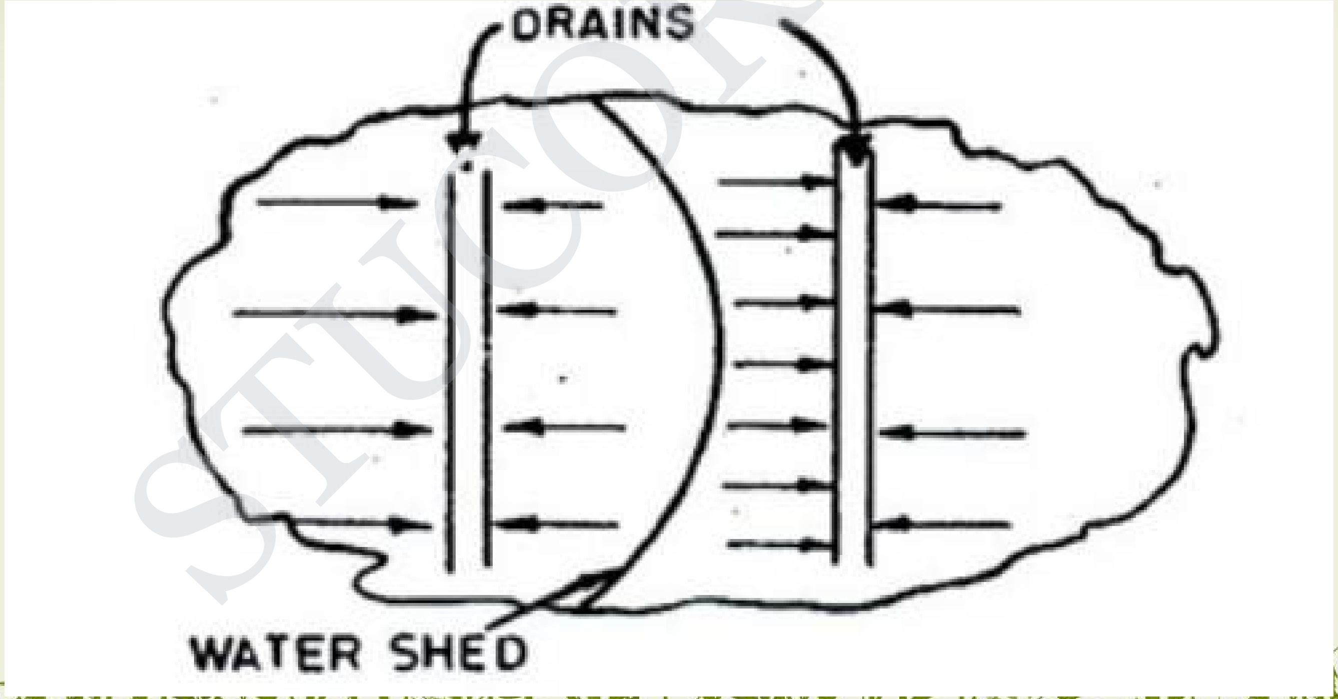
2. **As contour canal; and**

3. **As side slope canal**

Watershed Canal

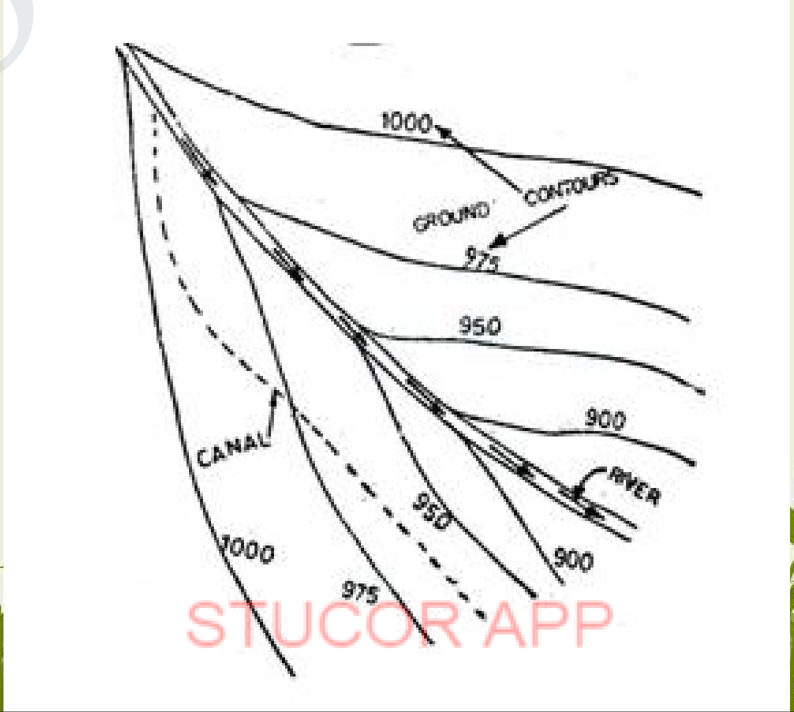
- The **dividing line between the catchment area of two drains** (streams) is called the watershed.
- Thus, between two major stream, there is the main watershed which **divides the drainage areas of the two.**

- Similarly, **between any tributary and the main stream**, and also between any two tributaries there, are subsidiary watersheds, dividing the drainage **between the two streams on either side.**



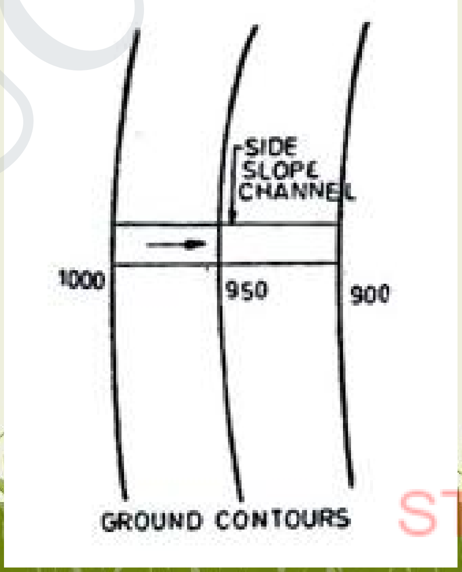
(ii) Contour Canal:

- The above arrangement of providing the canals along the watershed is **not possible in hill areas.**
- In the hills, the river flows in the valley, while the watershed or the **ridge line may be hundred of metres above it.**
- The channel, in such cases, is **generate sufficient flow velocities**, are given to it.



iii) Side Slope Canal:

- A side slope channel is that which is **aligned at right angles to the contours,i.e. along the side slopes**, as shown in figure.
- Such a channel is **parallel to the natural drainage** flow and hence, **does not intercept cross drainage**, and hence no cross drainage works are required.



Precautions in Canal Alignment:

i. The canal should be **aligned on the ridge** or in such a way as **to obtain maximum command**.

ii. So far as possible the canal alignment **should be kept in the centre of the commanded area.**

iii. The canal should be aligned in such a way that **the length is minimum possible.**

iv. The alignment should **avoid inhabited places, roads, railways, properties, places of worship** etc.

Canal Linings

Canal Linings

- Canal Linings are provided in canals **to resist the flow of water through its bed and sides**.
- These can be constructed using different materials such as **compacted earth, cement, concrete, plastics, boulders, bricks etc.**
- The main advantage of canal lining is **to protect the water from seepage loss.**

- Canal Lining is an **impermeable layer** provided for the bed and sides of canal **to improve the life and discharge capacity of canal.**
- **60 to 80% of water lost** through seepage in an unlined canal **can be saved** by construction canal lining.

Types of Canal Linings

1) **Earthen type lining**

2) **Hard surface lining**

1. Earthen Type lining

i. **Compacted Earth Lining**

ii. **Soil Cement Lining**

Compacted Earth Lining

- Compacted earth linings are preferred for the canals when the **earth is available near the site** of construction or In-situ.
- Compaction **reduces soil pore sizes** by displacing air and water.
- **Reduction in void size increases the density**, compressive strength and shear strength of the soil and **reduces permeability.**

Compacted Earth Lining

Soil Cement Lining

Soil-cement linings are constructed with **mixtures of sandy soil, cement and water**, which harden to a concrete-like material.

The **cement content should be minimum 2-8% of the soil** by volume. However, larger cement contents are also used.

In general, for the construction of soil-cement linings following **two methods** are used.

1) **Dry-mix method**

2) **Plastic mix method**

Soil Cement Lining

2. Hard Surface Canal Linings

It is sub divided into 4 types and they are

1)**Cement Concrete Lining**

2)**Brick Lining**

3)**Plastic Lining**

4)**Boulder Lining**

Cement Concrete Lining

- Cement Concrete linings are **widely used**, with benefits justifying their **relatively high cost**.
- They are **tough, durable, relatively impermeable** and **hydraulically efficient.**

There are several procedures of lining using cement concrete

- **Cast in situ lining**
- **Shortcrete lining**
- **Precast concrete lining**

Cement Concrete Lining

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Brick Lining

In case of brick lining, **bricks are laid using cement mortar on the sides and bed of the canal.**

After laying bricks, **smooth finish is provided on the surface** using cement mortar.

Plastic Lining

Plastic lining of canal is **newly developed technique** and holds good promise.

1. **Low density poly ethylene**

lar **high density polythene**

Brick Lining

- The advantages of providing plastic lining to the canal are many as **plastic is negligible in weight, easy for handling, spreading and transport, immune to chemical action** and **speedy construction**.
- The **plastic film is spread on the prepared sub-grade** of the canal.
- To **anchor the membrane** on the banks **'V trenches are provided**. The film is then covered with protective soil cover.

Plastic Lining

Boulder Lining

- This type of lining is constructed with **dressed stone blocks laid in mortar.**
- Properly dressed stones are not available in nature. Irregular **stone blocks are dressed and chipped off** as per requirement.
- When **roughly dressed stones** are used for lining, the **surface is rendered rough** which may put lot of **resistance to flow.**

Boulder Lining

Advantages of Canal Lining

- Seepage Reduction
- Prevention of Water Logging
- Increase in Commanded Area
- Increase in Channel Capacity
- Less Maintenance
- Safety Against Floods

Kennedy's Silt Theory

- **RG Kennedy** investigated canals systems for **twenty years** and come up with a **Kennedy's silt theory**.
- The theory says that, t**he silt carried by flowing water in a channel is kept in suspension by the eddy current rising to the surface**.

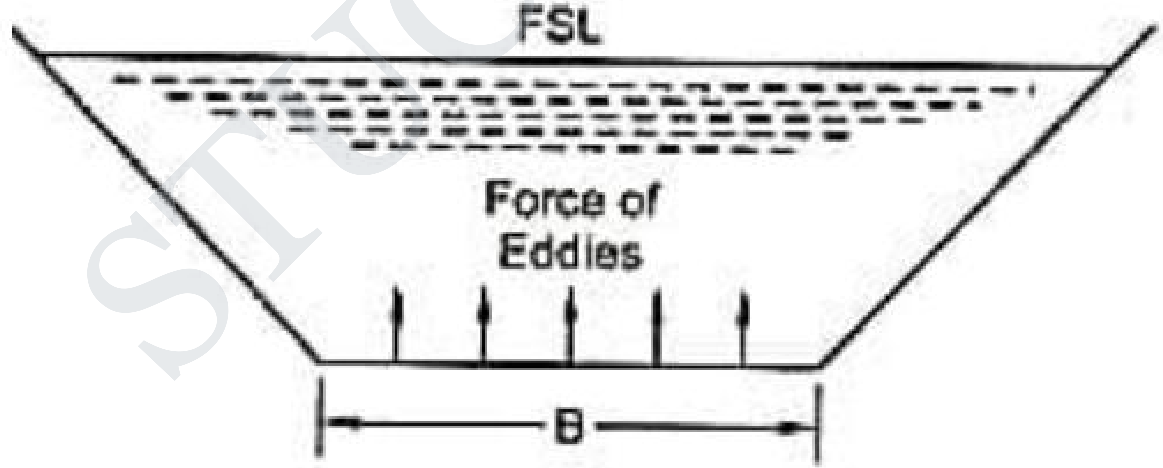

Fig.1: Eddies force according to Kennedy's silt theory

- The vertical component of the **eddy current tries to move sediment up** whereas **sediment weight tries to bring it down.**
- Therefore, if **adequate velocity** available to create eddies so as **to keep the sediment just in suspension silting will be prevented.**

Assumptions regarding Kennedy's Silt Theory

- The **eddy current** is generated because of **friction between flowing water and the roughness of the canal bed.**
- The **quality of the suspended silt is proportional to bed width.**
- The theory is applicable to those channels which are **flowing through the bed consisting of sandy silt or same grade** of silt.

Critical velocity based on Kennedy's Silt Theory

- Critical velocity is the mean velocity which will **just make the channel free from silting and scouring.**
- The velocity is based on the **depth of the water** in the channel.

The general form of critical velocity is as follow:Where

$V_o = C D^n$ ----------------(1)

V_o = Critical velocity

D = full supply depth

C & n: Constants which found to be 0.546 and 0.64, respectively.

$V_o = 0.546\ D^{0.64}$ ---------------(2)

Moreover, Equation 2 further improved upon realization that silt grade influences critical velocity. So, a factor termed as **critical velocity ratio** introduced and the equation became as follows:

$V_o = 0.546\ m\ D^{0.64}$ ---------------(2)

Where

m: critical velocity ratio which equal to **actual velocity (V) divided by critical velocity (Vo)**, value of m provided in Table

Channel lining	N values
Earth	0.0225
Masonry	0.02
Concrete	0.013 to 0.018

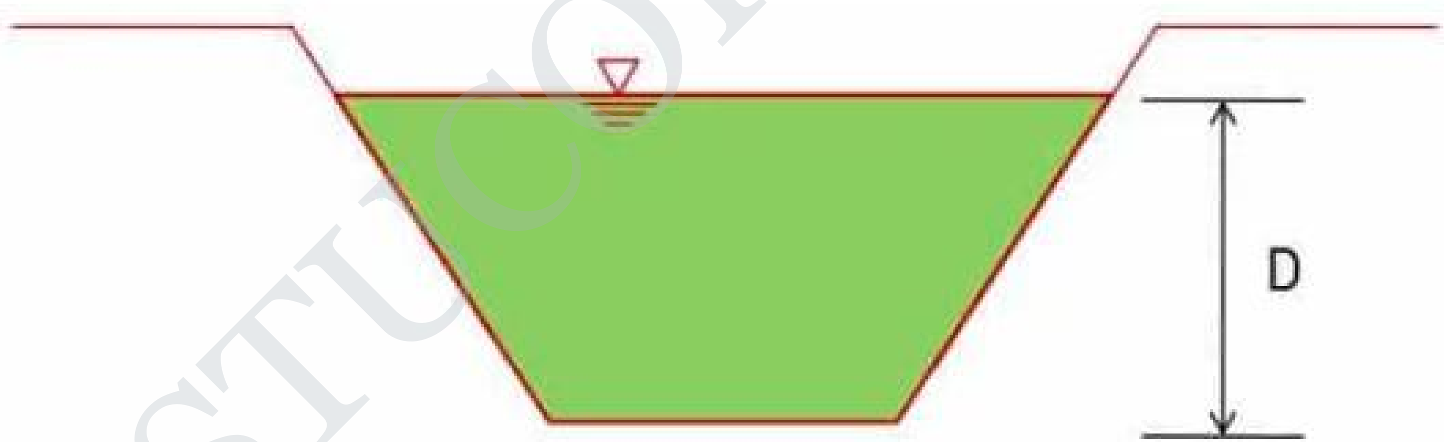

Fig.2: Depth of water in canal

Limitations of Kennedy's Silt Theory

- **Trial and error method** used for the canal design using Kennedy's Silt Theory.
- There is **no equation for bed slope assessment**, so the equation developed by Kutter used to compute bed slope.
- The **ratio of channel width (B) to its depth (D) has no significance** in Kennedy's Silt Theory.
- There is **not perfect definition for salt grade and salt charge.**
- Complex phenomenon of **silt transportation is not fully**

on

Procedure of Canal design using Kennedy's Silt Theory

Case 1

The following data shall be available before hand: discharge (Q), rugosity coefficient (N), Critical velocity ratio (m) and bed slope of the channel (s).

1. Assume suitable full supply depth (D).
2. Then, find the mean velocity by using Kennedy's equation (Equation 3).
3. After that, find the area of cross section by using continuity equation: Where: Q=A V

velocity

4.Assume the shape of channel section with side slopes (0.5V:1H)

5. Find out the value of base width of channel (B).

6. Then, find the perimeter of the channel (P). Which helps to find out the hydraulic mean depth of channel (R).

$$R = A/P \qquad \textit{Equation 5}$$

Where:

R: hydraulic mean depth

A: canal cross section area

7. Finally, calculate the mean velocity (V) using kutter's formula:

$$V = \left(\frac{1/N(23+0.00155/s)}{1+(23+0.00155/s)(N/\sqrt{R})}\right)\sqrt{Rs} \quad Equation\ 6$$

Where:

N: rugosity coefficient based on type of canal lining material. Table 2 provide N values for different lining condition.

S: bed slope as 1 in 'n'.

Both the values of V computed using equation 3 and V computed employing equation 6 must be the same. Otherwise repeat the above procedure by assuming another value of D.

Case 2

When discharge (Q), rugosity coefficient (N), Critical velocity ration (m) and B/D ratio are given.

1. Assume B/D = X
2. By using the Kennedy's equation find "V" in terms of D.
3. Find the area of cross section of the channel in terms of D2.
4. By using continuity Equation 4, find the value of D. and then Find the base width (B).

5. Find hydraulic mean depth (R) with Equation 5.

6. Finally, find the value of “V” using Equation 3.

7. Substitute the value of V in step 6 in Equation 6 will gives the longitudinal slope of the channel (S). This case will done by trial and error method.

Lacey's Silt Theory of Canals

- Lacey investigated the **stability conditions of different alluvial channels** and came up with Lacey's silt theory which explains about the **different regime conditions of a channel such as true regime, initial regime, and final regime** and the design procedure of canal.
- Lacey stated that a channel may not be in regime condition even if it is flowing with non-scouring and non-silting velocity

1) **True regime**
2) **Initial Regime**
3) **Final Regime**

1. True regime

- A channel is said to be in regime condition if **it is transporting water and sediment in equilibrium** such that there is neither silting nor scouring of the channel.

1)Canal discharge should be constant.

2)The channel should flow through incoherent alluvium soil

3)Silt grade should be constant.

4)Silt charge, which is the minimum transported load should be constant.

2. Initial Regime

- A channel is said to be in initial regime condition when **only the bed slope of channel gets affected by silting and scouring** and other parameters are independent even in non-silting and non-scouring velocity condition.
- It may be due to the **absence of incoherent alluvium**.
- According to Lacey's, regime theory is **not applicable to initial regime condition.**

3. Final Regime

- If the channel parameters such as **sides, bed slope, depth etc. are changing according to the flow rate and silt grade** then it is said to be in final regime condition.
- The **channel shape** may **vary according to silt grade.**

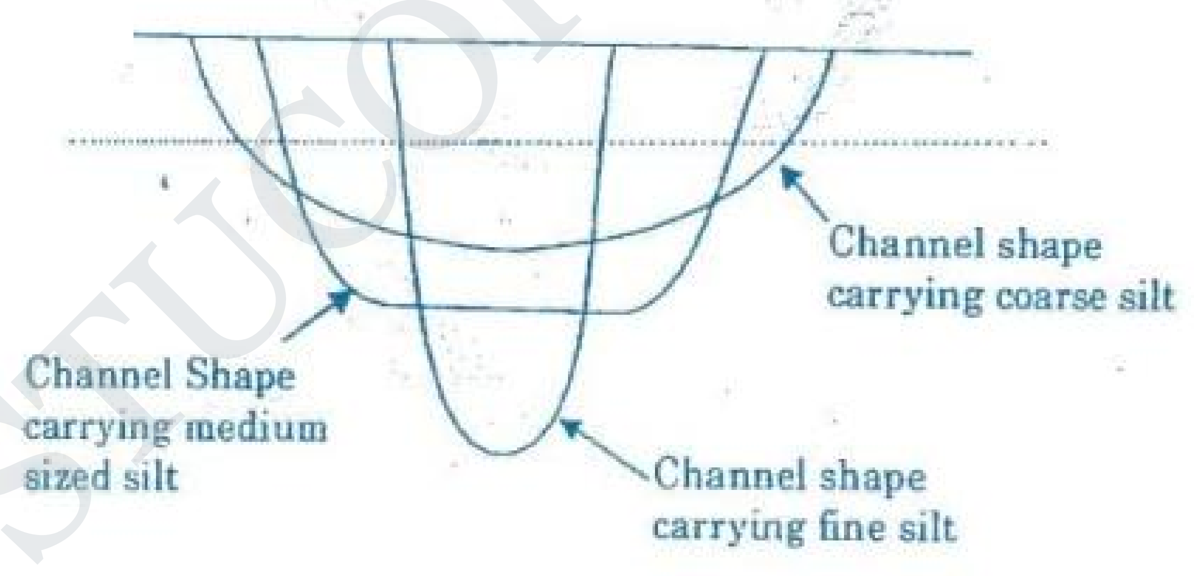

Fig 2: Channel Shape vs Silt Grade

Canal design using Lacey's Silt Theory

Canal discharge (Q) and mean particle size (dm) should be known.

From the **mean size or diameter of the particle (dm)**, silt factor is first calculated using the below expression

$$Silt\ factor, f = 1.76\sqrt{d_m}$$

S.No	Soil Type	Silt Factor, f
1	Fine silt	0.5 – 0.7
2	Medium silt	0.85
3	Standard silt	1
4	Medium sand	1.25
5	Coarse sand	1.5

Using discharge and silt factor, **velocity (V)** can be calculated by the expression as follows :

$$Velocity\ of\ flow, V = [\frac{Qf^2}{140}]^{1/6}$$

After attaining the velocity of canal flow, **find the area** of the canal by dividing discharge with velocity. Also, **find the mean hydraulic depth (R)** of the canal and **wetted perimeter (P)** of the canal.

$$Area = \frac{Q}{V}$$

$$Hydraulic\ Mean\ Depth, R = \frac{5V^2}{2f}$$

$$Wetted\ Perimeter, P = 4.75\sqrt{Q}$$

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

Drawbacks of Lacey's Silt Theory

- Lacey **did not explain the properties that govern the alluvial channel.**
- In general, flow is different at bed and sides of the channel which requires two different silt factors but **Lacey derived only one silt factor.**
- The **semi-elliptical shape** proposed by Lacey as the ideal shape of the **channel is not convincing.**
- Lacey **did not consider the silt concentration** in his equations.
- **Attrition of silt particles is ignored** by Lacey.
- Lacey **did not give proper definitions for the silt grade** and silt charge.

Discussions ?

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UNIT-5

WATER MANAGEMENT IN IRRIGATION

• P.Muthuraman, VVCOE

Syllabus

Modernization techniques- Rehabilitation – Optimization of water use-Minimizing water losses- On form development works-Participatory irrigation management- Water resources associations- Changing paradigms in water management- Performance evaluation-Economic aspects of irrigation.

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Modernization techniques

- Improving irrigation water management, in order to **increase productivity and minimize adverse effects** such as salinization, is one of the main contemporary issues in the agricultural sector.
- A considerable effort is being made to **improve irrigation operations and to reduce costs.**
- Society in general and water user associations, particularly where they have to bear the cost of irrigation, are demanding that **irrigation become more cost-effective.**

Rehabilitation, which consists of **re-engineering a deficient infrastructure** to return it to the original design. Although rehabilitation usually **applies to the physical infrastructure**, it can also concern institutional arrangements.

Process improvement, which consists of **intervening in the process without changing the rules** of the water management. For instance, the **introduction of modern techniques** is a process improvement.

Defining modernization

Irrigation modernization is a **process of technical and managerial upgrading** (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, with the objective **to improve resource utilization** (labour, water, economic, environmental) and **water delivery service** to farms.

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The need for a consistent framework for modernization

1)Increasing water productivity

2)Increasing the cost-effectiveness

3)Increasing the reliability in irrigation deliveries.

4)Increasing the flexibility of deliveries.

5)Consideration of other uses of water

6)Increasing knowledge and human resources development

Obstacles in the way of modernization

- **Technical gaps** between the **requirements needed to implement the improved method** (availability of expertise, technical maintenance of equipment) and available local resources.
- **Financial constraints** resulting from the gap between the **cost of equipment for the improved method and the gain in water savings** and improved services, as water is generally not priced or charges are low.

Social constraints.

- **Human resources are relatively less expensive** in developing economies than alternative technological solutions.
- An irrigation agency, often a large employer in the area, has some **obligation to maintain local staff**.

Institutional constraints.

- Bureaucratic **centralized irrigation administrations** are not well suited to service-oriented activities.

Model for the modern irrigation enterprise

- Hence **modernization** can be seen as a means to **create and favour modern irrigation enterprises** by introducing methodologies which have proved successful in other sectors.
- We advocate that **modern enterprises in irrigation require a reengineering of their processes** in order to cope with the new challenges faced by irrigation.

Reengineering irrigation system operations

- The reengineering of the irrigation operation should consist of **designing the most cost-effective answer to the redefined water service** within the scheme.
- The **spatial distribution of the effective demand** for the water service.
- The **spatial distribution of the physical infrastructure** characteristics

Flexibility in modernization

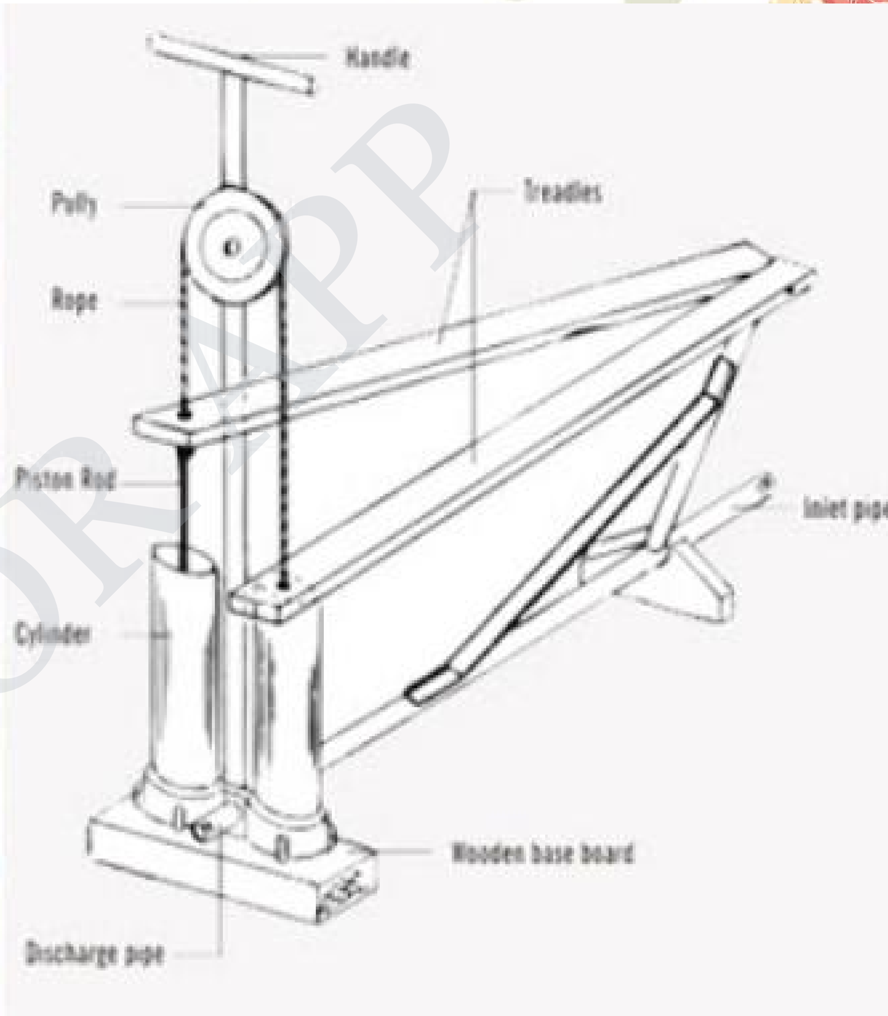
- Flexible deliveries can be proposed to **users in different forms (on request, free access, etc)** at a cost compared to a strict rotational distribution.
- This concept of flexibility leads to **abandoning the homogeneous approach of irrigation systems** that has so far prevailed.
- Instead, a **heterogeneous approach of the demand and of the efforts (inputs) to operate irrigation systems** is sought for a closer match of water availability

Low-cost technologies

The introduction of low-cost technologies, which could be part of the **modernization of small-scale irrigation projects**, provides another example of the site-specificity of success.

Inexpensive treadle pumps have been successful in some South Asian countries in extracting irrigation water from shallow aquifers.

These pumps have allowed **poor farmers to make good use of the available labour** in their households and so



Inexpensive treadle pump

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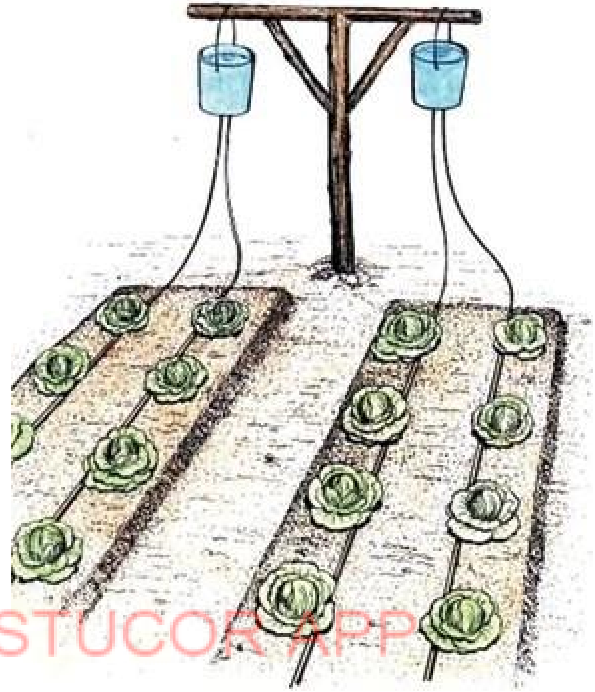
Bucket drip-irrigation kits

- Positive experience has been reported with the **introduction of bucket drip-irrigation kits**.
- These kits are suitable for the irrigation of **small plots of vegetables and fruit trees in peri-urban areas (close to markets)**



Rehabilitation

- The **renovation of a scheme** to meet its original design criteria
- **Inadequate operational practices** may **limit improvements to water supply** expected from improved infrastructure.
- **Trained and motivated operational staff** are needed.
- Farmers must be **willing and able to exploit a better supply.**

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Maintenance activities in a reservoir itself comprise:

- **Controlling aquatic weeds**,
- **Removing large debris** (e.g. tree trunks) floating in the water that may damage hydraulic works,
- **Monitoring the water quality**: not only from the salt content point of view but also from a biological standpoint in order to detect possible sources of pollution
- **Surveying the solid deposition** in the bottom of a reservoir.

Controlling aquatic weeds

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Surveying the solid deposition

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The retention in good working order of open drains includes the following operations:

- Light deforestation
- Weed control in the canal section
- Seeding grass in the canal section
- Maintenance of flow gauges and other measuring devices
- Removal of silt
- Maintenance of pumping stations where water cannot be evacuated by gravity.

Optimization of water use

Water efficiency of irrigation can be improved by making the right decisions regarding:

- Crop selection
- Irrigation scheduling
- Irrigation methods
- Source of water.

Improving Irrigation practices can:

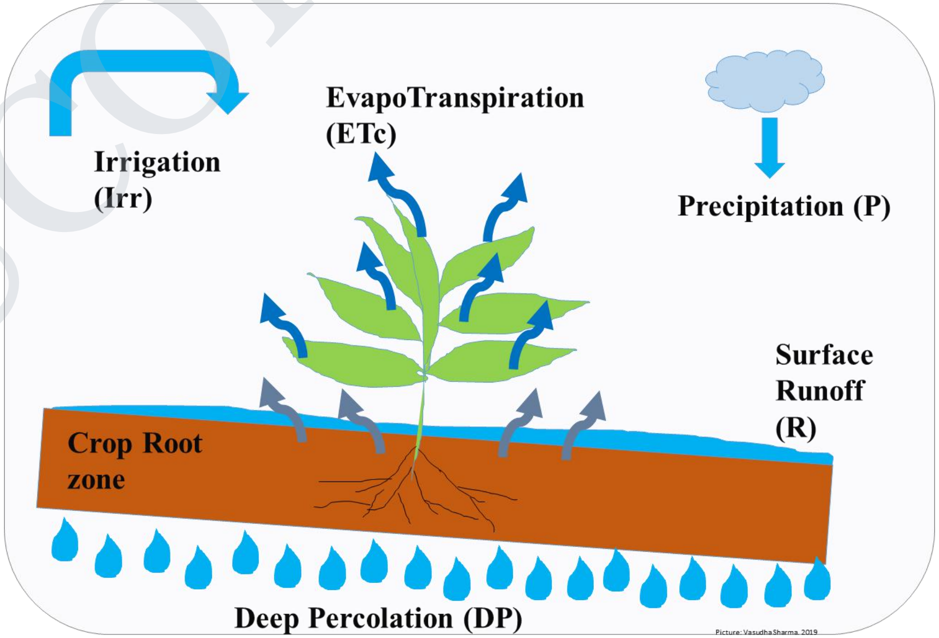
- Reduce water and pumping costs
- Reduce costs for fertilizers and other agricultural chemicals
- Maintain a higher soil quality
- Increase crop yields – by as much as 100%

Irrigation scheduling

- Irrigation scheduling helps **eliminate or reduce instances where too little or too much water is applied to crops**.
- However, proper irrigation scheduling involves **fine-tuning the time and amount of water applied** to crops based on the water content in the crop root zone, the amount of water consumed by the crop since it was last irrigated, and crop development stage.
- **Direct measurement of soil moisture content** is among

Good irrigation scheduling requires knowledge of:

- Crop water demand at different growth cycles
- Moisture content of the soil and soil water capacity
- Weather conditions



Soil capacity

- Soil capacity, which is the **ability of the soil to hold water between irrigation or precipitation** events, is another important factor.
- Determinants of soil capacity include **soil depth, ratios of different soil particles making up the soil, soil porosity, and soil water tension.**

Climatic conditions

The prevailing climatic conditions, such as **average ambient temperature, intensity of solar radiation, humidity, and windspeed** also affect both the moisture retained in the soil and the speed by which plants lose water through transpiration.

Accurate monitoring

- Accurate monitoring of water used in irrigation is an essential part of irrigation scheduling and **helps reach optimal performance, saving water while enhancing yields.**
- Measurement of **energy** used by irrigation pumps
- **End-pressure** measurements in sprinkler irrigation
- **Elevation differences** in irrigation reservoirs or tanks
- Measurement of **irrigation time and size of irrigation system.**

IRRIGATION METHODS

Once the quantitative and temporal characteristics of optimal water demand have been determined, a method that can make such **water available in the most effective way** should be selected. There are three main irrigation methods, namely:

1) **Surface (or gravity) irrigation**

2) **Sprinkler irrigation**

3) **Drip irrigation.**

Water losses be control

1. Measure to Reduce Evaporation Loss

a) The reservoir should be constructed of **less surface area and more depth.**

b) **Tall trees should be grown on the windward side** of the reservoir

c) The reservoir basin should be **surrounded by plantation or forest area** so that cooler environment exists within the reservoir area.

d) Certain chemical like **cetyl alcohol is spread over the reservoir surface.** It forms a thin film on water surface

2. Measure to Reduce Absorption Loss

a) The **weeds and plants at the periphery of the reservoir should be removed completely**.

b) The **weeds from the surface of the reservoir should be removed.**

3. Measure to Reduce Percolation Loss

a) Geological investigations should be carried out to **locate the zones of pervious formations, cracks and fissures** in the bed and periphery of the reservoir basin.

b) Suitable treatments should be adopted to stop the leakage of water through these zones.

c) Soil stabilization methods should be adopted if the basin is composed of permeable bed soil.

Water logging

Water logging

Water logging

- In agricultural land, when the **soil pores within the root zone of the crops get saturated with the subsoil water,** the **air circulation within the soil pores gets totally stopped.**
- This phenomenon is termed as water logging.
- The water logging makes the **soil alkaline in character and the fertility of the land is totally destroyed** and the yield of crop is reduced.

Effects of water logging

- Stabilization of soil
- Lack of aeration
- Fall of soil temperature
- Growth of weeds and aquatic plants
- Diseases of crops
- Difficulty in cultivation
- Restriction of root growth

Methods used for controlling water logging

- Prevention of percolation from canals
- Prevention of percolation from reservoirs
- Control of intensity of irrigation
- Economical use of water
- Fixing of crop pattern
- Providing drainage system
- Improvement of natural drainage
- Pumping of ground water
- Construction of sump well

ON FORM DEVELOPMENT WORKS (OFD)

- The efficient management of irrigation water for **maximizing productivity** requires both, **the efficient on farm water management and the optimization of the use of water and land**, through appropriate methods of water application.
- The **items of works pertaining to on farm water management** are termed as “On farm development works”.

The on farm development works comprise of following,

a) Field channels for conveyance of water

b) Control structures

c) Crossings

d) Surface drainage system

e) Farm roads

f) Field channel protection works and

g) Land forming (Smoothening / grading / leveling).

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Systems approach:

- The conveyance system **from the dam to the farm gate is one live system** and it is necessary that the designs of the different components are matched properly.
- The water management proposed to be adopted on the canal system should **always be kept in view as a reference frame.**

Sequence of design and execution:

- (a) The ideal sequence of finalization of design would be obviously **from the tail to the head**.
- First, according to the topography and soil conditions, **the land forming of each farm would be decided**, so as to ensure efficient irrigation.
- Next, the **chak water delivery system and surface drains would be designed** so as to ensure adequate water deliveries to the different farms and proper drainage.

(b) The execution of OFD works shall be done only in places where **canal water has actually reached**. The OFD works get disturbed and deteriorated if these are not put to use immediately.

(c) After construction of OFD works, **preparation of work-done drawings of OFD works (record drawings)** form the basic record for planning irrigation management.

Functional utility:

- The purpose of the OFD works is to **provide timely and adequate supplies of water** to each holding and preserve environmental balance as well, by **avoiding seepages, leakages and stagnations of water** which trigger problems like water logging, causing adverse impact on environment.
- To achieve this functional utility, the **planning and design of OFD works has to be hydraulically better and socially acceptable.**

Aspects of functional utility of OFD works

- Hydraulic design
- Economy for construction and maintenance
- Social acceptance i.e. User friendliness to community of farmers who will be actually using OFD works and
- Levels of accuracies and quality of construction.

Farmers Participation:

- Success of canal irrigation depends on the **response of the farmer, both as an individual and as a member of the group** benefited by the outlet.
- The irrigation facilities should be designed with a view **to meet his requirements, particularly in respect of land forming.**
- **Active participation of the farmer at the stage of design** should therefore be encouraged.
- This will also help in **building up of an atmosphere of common purpose** and thereby in the unification of the

Organizational Coordination:

- The works **from the canal head down to the distributory and from the distributory head to the outlet** are carried out by the Construction Organization (C.O.) of the Irrigation Department.
- The outlet of a capacity of about **30 litre/second is the last Government structure** on the canal system.
- Below outlet, OFD works are the community works.
- Design and construction proceed on the **basis of the location of the outlet and its sill level.**

Procedure for taking up OFD works:

The OFD works are part of CAD works. The cost estimates for OFD works are generally formulated in two parts.

a) **Part I works** : Cost estimates for **chak water delilvery system, field channel protection works and surface drainage** works in a chak.

b) **Part II :** Cost estimate for l**and forming works for each holding.**

Participatory irrigation management

- The term participatory irrigation management (PIM) refers to the **participation of irrigation users, i.e., farmers, in the management of irrigation systems** not merely at the tertiary level of management but spanning the entire system.
- Participation should not be construed as consultation alone. The concept of **PIM refers to management by irrigation users at all levels of the system and in all aspects of management**. This is the simplicity and flexibility of PIM.

- "Participation in irrigation management involves a **larger role for farmers, water groups, and other stakeholders.**
- There have been increasing efforts to use participation in various forms to **improve the quality, effectiveness, and sustainability of irrigation systems.**
- The phad system of **Nasik and Dhule** districts and the Malgujari tanks of **Chandrapur and Bhandara districts** in Maharashtra, the Ahar-Pyne system of **Bihar**, the Kuhl system of **H.P.** and the **Kudimaramath of Tamilnadu** are important examples of PIM under traditional

Water resources associations

International Water Resources Association (IWRA)

- IWRA is a non-profit, non-governmental, educational organisation established in 1971.
- It provides a global, knowledge based forum for **bridging disciplines and geographies by connecting professionals, students, individuals, corporations and institutions** who are concerned with the sustainable use of the world's water resources.

INDIAN WATER RESOURCES SOCIETY

- Department of Water Resources Development and Management, IIT Roorkee

American Water Resources Association (AWRA)

- Established in 1964, the American Water Resources Association (AWRA) is the preeminent multidisciplinary association for information exchange, professional development and education about water resources and related issues.

The European Water Resources Association (EWRA)

- The European Water Resources Association (EWRA) was initially established as ECOWARM (European Committee for Water Resources Management) and on September 14, 1992, its name was changed to European Water Resources Association.

The Canadian Water Resources Association (CWRA)

- The Canadian Water Resources Association (CWRA) is a national registered charity comprised of members from the public, private and academic sectors who are committed to promoting responsible, innovative and

The Tamil Nadu Water Resources Department (TNWRD)

- The Tamil Nadu Water Resources Department under **Public Works Department** is entrusted with the responsibility of **development of water resources of the State for catering to irrigation purposes** and also for maintenance of physical infrastructure.
- The WRD is also responsible to **upkeep the drainage system clean to adequately drain the rain water** and excess irrigation from the crop fields.

Changing paradigms in water management

- **World water demand** by the turn of the century is likely to reach almost half of the total global runoff water annually available.
- By then, **21 ten million plus metropolises** the world over will have t**o draw fresh water from sources further away or by pumping deeper with adverse environmental effects**. Yet, the efficiency of water use remains abysmally low.

- An estimated **60 per cent of irrigation water is lost even before it ever reaches a plant**.
- In cities, **more than onethirds of the treated water never reaches the customer** because of wastage and leakage.
- This situation cannot continue if development and the environment are to sustain.
- **Demand management** through **economic, technical and educational means** could greatly improve the efficiency of water use and reduce consumption.

7 good ways to reduce water consumption in cities

1) Introduce water metering and a tariff policy which is fair and which encourages conservation
2) Promote the use of water and sanitary fittings which reduce water usage'
3) Initiate a leak detection and repair programme within the city
4) Encourage water recycling in industries to reduce pressure on freshwater
5) Explore the possibility of reusing treated wastewater for crop production and fish farming
6) Engage the public through appropriate "save water" campaigns through local leaders

va r

Performance evaluation

Irrigation Performance can be;

Operational performance- the degree of fulfilment of either a specific quantified output target , typified by such things as yield , water use efficiency and cropping intensity, or a specific input target such as discharge , water level, or timing of irrigation deliveries.

Strategic performance – looks at the process by which available resources are utilised in order to fulfil the eventual outputs of the system, and involves assessment of the

n both

- Performance assessment can be done at **various system levels such as water delivery system, individual irrigation system, the irrigated agriculture system** and up to the national level.
- Each level has a set of **goals that may or may not co inside , and each requires a different set** of performance parameters.
- **Ideal level of performance** can only be achieved **when targets are achieved** , objectives are fulfilled , and there is efficient use of available resources.

Engineer/ designer- to be able to compare the actual performance to the intended design.

Irrigator – to assess if the system is performing well enough to enable adequate irrigation

Maintenance crew- as a diagnostic tool to identify what is wrong with the system or to prevent the system from malfunctioning or breaking down.

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Introduction to monitoring and evaluation

Monitoring and Evaluation (M&E) of a programme or a project or, in our case, an irrigation scheme is important in order **to provide information about how it is performing**.

There are four distinct reasons for carrying out M&E:

- To **keep track of the progress of development** activities during implementation.
- To **determine the relevance, efficiency and effectiveness** of development activities
- To **learn lessons for future development** planning

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Monitoring

- Is the **collection of information and the use of that information to enable management** to assess the progress of implementation and take timely decisions to ensure that progress is maintained according to schedule.
- **Assesses whether inputs are being delivered, are being used** as intended and are having the initial effects as planned.
- Is an **internal project or scheme activity, an essential part of good management practice** and therefore an integral part of day to-day management.

- The purpose of monitoring is **to achieve efficient and effective project or scheme performance** by providing feedback to the management at all levels.
- This enables management **to improve operational plans and to take timely corrective action** in case of problems.
- Monitoring is a **continuous or regular activity**.

Evaluation

- Evaluation is a **process of determining systematically and objectively the relevance, efficiency, effectiveness and impact of activities** in the light of their objectives.
- It is an organizational process for **improving activities still in progress and for aiding management** in future planning, programming and decision-making.
- While monitoring is a **continuous or regular activity,** evaluation is a **management task** that takes place at critical times of the life of a project or programme.

Indicators

- Indicators are a **way of measuring progress towards the achievement of the goal**, i.e. the targets or standards to be met at each stage.
- They provide an objective basis for **monitoring progress and evaluation of final achievements.**
- A good indicator should **define the level of achievement**, specifically: how much? (quantity), how well? (quality), by when? (time).
- One set of indicators needs to be formulated to monitor

The following six areas of M&E are important for irrigation schemes:

- Technical performance
- Agronomic performance
- Financial performance
- Socio-economic performance
- Environmental and health performance
- Managerial performance

Technical performance indicators

- Technical M&E should be carried out periodically in order **to ensure a technically sound and efficient irrigation scheme**.
- The M&E indicators to be measured depend on the **irrigation system (surface, sprinkler or localized).**
- The objective concerning the technical aspects of irrigation is **to fulfil the crop's need of water without causing harmful side effects**.

Guides for the development of indicators for the technical M&E are:

- Quantity and quality of constructed infrastructure
- Energy consumption rate of equipment
- Pump discharge rate
- Distribution of uniformity of irrigation water
- Condition of equipment, canals, reservoirs and other structures
- Condition of land grading
- Frequency of breakdown and repairs of equipment

Agronomic performance indicators

Guides for the development of indicators for the **agronomic M&E** are:

- Type of crops grown and area per crop grown
- Crop quality
- Cropping intensity
- Type, quality and quantity of agricultural inputs used
- Cultural practices used
- Yield levels
- Pests and diseases encountered and control

Guides for the development of indicators for the financial M&E

- Cost of energy
- Cost of water
- Other costs, for example hiring security guard
- Cost of repairs and servicing of equipment, canals and structures (operation & maintenance cost)
- Cost of inputs, for example seed, fertilizer, chemicals, transport
- Prices of produce

Socio-economic performance indicators

Asset ownership

Nutritional status of the family

Change in living conditions

Ability to pay school fees

Employment creation

Advancement of women

Backward and forward linkages

Food security status of the area

Improvement in service provision

Appropriateness of technology

Environmental and health performance indicators

- Environmental and health factors have an **impact on the short- to long-term performance** at field level.
- Equally important are **environmental impacts from irrigation schemes on the external environment and the impact from external factors** on the irrigation scheme.

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Guides for the development of indicators for the environmental and health M&E

- Changes in water quantity and quality
- Changes in soil salinity, alkalinity, sodicity, acidity and fertility
- Erosion occurrence (soil loss/accumulation)
- Water pollution, for example nitrates in streams
- Presence of water-related diseases, such as malaria and bilharzia, and degree of human infestation, in relation to the status before the introduction of irrigation

Managerial performance indicators

- Management and **entrepreneurial skills** are critical for success.
- A common problem is the **lack of long-term thinking**.
- When assessing the overall managerial performance, questions can be asked such as: **Are they able to supervise the scheme activities effectively? Have they established the necessary linkages with governmental agencies and private organizations? Are they task-oriented? Are the human and material resources**

Guides for the development of indicators for the managerial M&E are:

- Management structures, roles, responsibilities and skills
- Knowledge management and training at all levels
- Conflict resolution
- Farmer organization and management ability (self management)

Economic aspects of irrigation

- The economics of **crop production with different irrigation sources was worked out** to compare the **economic feasibility of irrigation investment** with existing and improved technologies.
- Different irrigation technologies, input and output prices and **break-even yields** could be important to justify the **future of irrigation technology transfer** and uptake.
- Worldwide, irrigation water consumes the bulk of **renewable fresh water resources.**

- As **water demand increases with rising living standards and population growth**, and as prospects for water diversion (extraction) are limited in some regions and nonexistent in others, the course of water policy left open is to increase efficiency of water use.
- This requires taking account of the **full cost of water and the way to achieve this goal** inevitably leads to some form of water pricing.
- Yet, **water policy makers and economists are far from agreeing on what constitutes the "right" price of water** in any given circumstance and how this price is to

Impacts of Irrigation

1)Environmental

2)Social

3)Economic

Environmental Impacts of Irrigation

1.Soil Erosion

- –e.g. Due poor designed or operated Furrow irrigation.
- Mitigation- proper design and O&M, sound drainage, land levelling, practicing soil and water conservation,

2.Water logging

Mitigation- Correct application rate, proper design and O&M, sound drainage, lining of canals, land levelling,

3.Salinisation of Salts

Mitigation- Flash irrigation water to leach the salts out of the root zone, Grow salt tolerant crops depending on severity of problems, Install drains so that during flashing or heavy rains , the salts will be washed away,

4.Leaching of nutrients →Eutrophication.

- Results: e.g. in algal blooms and weed proliferation
- Mitigation– Minimise washing way of nutrients from fields into water sources-Correct water and fertiliser application.

5. Deterioration of water Quality Downstream

- Mitigation - Apply correct amounts of chemicals , fertilizers and irrigation water, Impose water quality standards on return flow.

6. Reduction of Downstream flows

Mitigation - Damming, regulating abstraction, compensatory measures e.g. Supplement with borehole water downstream

7. Over pumping of ground water.

Mitigation - Artificial recharge of ground water , ensuring safe abstraction levels.

8. Alteration/ destruction of wildlife habitats

Mitigation– relocate affected species if possible, relocate project.

Social Impacts of Irrigation

1. Impediment of movement of livestock and humans

Mitigation - Create movement corridors, stretches of forests etc,

2. Threat to historical and cultural sites/ aesthetics

Mitigation - relocate project, salvage or protect sites e.g. relocate graves etc.

3. Dislocation of populations and communities

Mitigation - Resettlement programmes, relocate project,

4. Introduction/ Increase in water related diseases.

Mitigation - Avoid stagnant water in irrigation schemes, Undertake rigorous disease prevention , control and treatment e.g. Establish clinics in irrigation areas,

5. Water supply related conflicts

Mitigation - ensure equitable distribution of water.

Economic Impacts of Irrigation

- Increased agricultural production and productivity,
- Employment creation,
- Boosted rural development
- Improved standards of living,
- Increased food security at household and national levels,
- Increased food self sufficiency at household and national levels,
- Increased forex earnings,
- Increased GDP

Discussions ?


THANK
YOU