

Syllabus:

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Unit-1 Introduction:

[4 Hours]

- ✓1.1 Needs and objectives of Irrigation
- ✓1.2 Advantages and dis-advantages of Irrigation
- ✓1.3 Sources of Irrigation water and types of irrigation system.
- ✓1.4 History and future scope of irrigation in Nepal

Unit-2 Crop Water and Irrigation Water Requirements:

[8 Hours]

- ✓2.1 Types and season of crops
- ✓2.2 Base and Crop periods
- ✓2.3 Duty, delta and their relation
- ✓2.4 Commanded areas (gross, net and irrigable)
- ✓2.5 Soil moisture contents and irrigation interval
- ✓2.6 Water requirement of different crops.
- ✓2.7 Irrigation water requirement considering losses, land preparation and effective rainfall.

Unit-3 Water Availability for Irrigation:

[8 Hours]

- ✓3.1 Occurrence and distribution of rainfall in Nepal (surface and ground water)
- ✓3.2 Catchment area and runoff generation (factors affecting runoff).
- ✓3.3 Rain gauges and stream gauges (Gauge types and data presentation)
- ✓3.4 Stream flow measurement by velocity area method (Floats and Current meters)
- ✓3.5 Long term monthly flows at gauged and un-gauged locations.

Unit-4 Methods of Irrigation:

[6 Hours]

- 4.1 Surface irrigation [free flooding, Border strip, Check, Basin and Zigzag methods]
- 4.2 Sub-surface irrigation.
- 4.3 Sprinkler irrigation.
- 4.4 Drop or trickle irrigation.

Unit-5 Diversion Head Works:**[8 Hours]**

- 5.1 Layout, components and their functions
- 5.2 Weir and Barrage Systems.
- 5.3 Silt control by under sluices at head works (still pond regulation and continuous flushing).
- 5.4 Silt excluder and sediment ejector.
- 5.5 Head regulator.

Unit-6 Canal Irrigation:**[10 Hours]**

- 6.1 Components of canal system
- 6.2 Alignment of canals
- 6.3 Design of alluvial canals [Lacey's and Kennedy's theories]
- 6.4 Design of non-alluvial canals [Manning's and Chezy's Formulae].
- 6.5 Seepage of canals and lining
- 6.6 Canal standards.

Unit-7 Irrigation Structures:**[8 Hours]**

- 7.1 Cross-drainages
- 7.2 Drops or Falls
- 7.3 Head and cross regulators
- 7.4 Escapes
- 7.5 Outlets

Unit-8 Water Logging and Drainage:**[5 Hours]**

- 8.1 Causes, effects and preventive measures of water logging.
- 8.2 Need and importance of drainage
- 8.3 Surface and Sub-surface drainage systems

Unit-9 Irrigation Management:**[3 Hours]**

- 9.1 Operation and maintenance of irrigation works
- 9.2 Institutional development of irrigation systems

Definition:

- ↳ Irrigation may be defined as the artificial process of supplying water to soil for increasing crop production or yield.
- ↳ It is the science of planning and designing of an efficient, lowcost and economical irrigation system.
- ↳ It is also the engineering of controlling and regulating the various natural sources of water by construction of dam or reservoir, canal and headwork and finally distributing the water to agricultural field.

Necessity of Irrigation [Needs and Objectives of Irrigation]:

• Needs:

- ↳ The needs of irrigation system can be summerised in the following points:

① Less Rainfall:

- ↳ The rainfall is lesser than water requirements for the crops, artificial supply is necessary. In such a cases irrigation work may be constructed at a place where more water is available and then convey the water to the area where there is difficiency of water.

② Non-uniform Rainfall:

- ↳ The rainfall in the particular area may not be uniform over the crop period. Thus it is not possible to obtain good crops by rainfall alone.
- ↳ By collection of water during excess rainfall period, water may be supplied to crop during the period when there may be no rainfall.

③ Growing a number of crops during a year:

- ↳ The rainfall in the area may be sufficient to raise only one types of crops during the rainy season i.e. Kharif crops for which no irrigation may be required. However with the provision of irrigation facilities in that area crop can be raised in other season i.e. rabi crops.

④ Growing Perennials crops:

↳ Perennial crop such as sugarcane etc which need water throughout the year can be raised only throughout the provision of irrigation facilities in the area.

⑤ Commercial crop with additional water:

↳ The rainfall in the particular area may be sufficient to raise the usual crops but more water may be necessary for raising commercial or cash crops.

⑥ Controlled Water supply:

↳ By construction of proper distribution system the yield of crops may be increased because of controlled supply of water.

● Objectives [Purposes]:

↳ When the water is applied to the soil by the modern method of irrigation, it serves the following purposes:

- ① It adds water to the soil to supply the moisture essential for the plant growth.
- ② It saves the crops from drying during short duration of droughts.
- ③ It cools the soil and the atmosphere and thus makes more favourable environment for healthy plant growth.
- ④ It washes out or dilutes salt in the soil.
- ⑤ It reduces the hazards of soil piping.
- ⑥ It fulfills the crop requirements throughout the crop period.

Advantages and Dis-advantages of Irrigation:

⊗ Advantages:

↳ Following are the advantages of irrigation:

① Increase in Crop Production:

↳ Due to controlled and timely supply of water to the crops, the crop yield is increased.

② Protection from Famine:

↳ Proper irrigation facilities helps in the increase of food production, thus solving food problem of country.

③ Cultivation of Cash Crops:

↳ Irrigation makes it possible to growth cash crops such as sugercane, tobacco, cotton etc.

④ Elimination of mixed crops:

↳ Availability of irrigation facilities in the area gives the farmer protection against the vaganes of the weather, resulting in the elimination of mixed cropping system.

⑤ Addition to the wealth of country:

↳ All the irrigation project are so designed that they being some revenue to the state, as the water charge are collection from farmers.

⑥ Increase in Prosperity of People:

↳ The increased production of crops, makes the people of the reach and more prosperous and developed.

⊗ Generation of hydroelectric power:

↳ Major river valley projects are planned as multipurpose project. Hydro-electricity is generated in addition to irrigation.

⑧ Domestic and Industrial Watersupply:

↳ The canal makes also utilized domestic and industrial watersupply.

⑨ Inland Navigation:

↳ Large canal can also be used for inland navigation purpose or transportation system.

⑩ Improvement of Communication:

↳ Canals may be used as means of road communication for reaching the interior of the region.

⑪ Canal Plantation

⑫ Improvement in the ground water storage

⊗ Dis-advantages or Ill effect of Irrigation:

↳ Following are the dis-advantages of excess and unscientific irrigation:

① Breeding places of mosquitoes:

↳ Due to excess application of water and due to leakage of water, ponds and depression gets filled with water and creating breeding place of mosquitoes.

② Creation of Waterlogged area:

↳ If the water table is near the surface, over irrigation may rise the water table and the whole area becomes water logged. If water is also seepage from the canal the area where seepage is also water-logged.

③ Damp Climate:

↳ The area which are already damp and cold becomes damper and colder due to irrigation.

④ Crossing structure:

↳ Construction of canal affects the drainage of the area to overcome this problem, so costly cross drainage structures are constructed.

⑤ Danger to the cattle and people:

↳ lined canal having steep side slopes cause danger to cattle and people. In case they accidentally fall in the canal, they can not come out easily.

Sources of Irrigation water and Types of Irrigation system:

* Sources of Irrigation water:-

↳ The main sources of irrigation water are as follows:

① Surface Sources:

↳ Surface sources of water are those sources in which water flows over the surface of the earth and is directly available for water supply and irrigation as runoff from catchment area during rainfall and the precipitation. This is supplied to the field by weir (checkdam) by gravity. Checkdam/weir system is used only when the source of water from river, spring water that starts from upstream. The surface sources of irrigation water are:

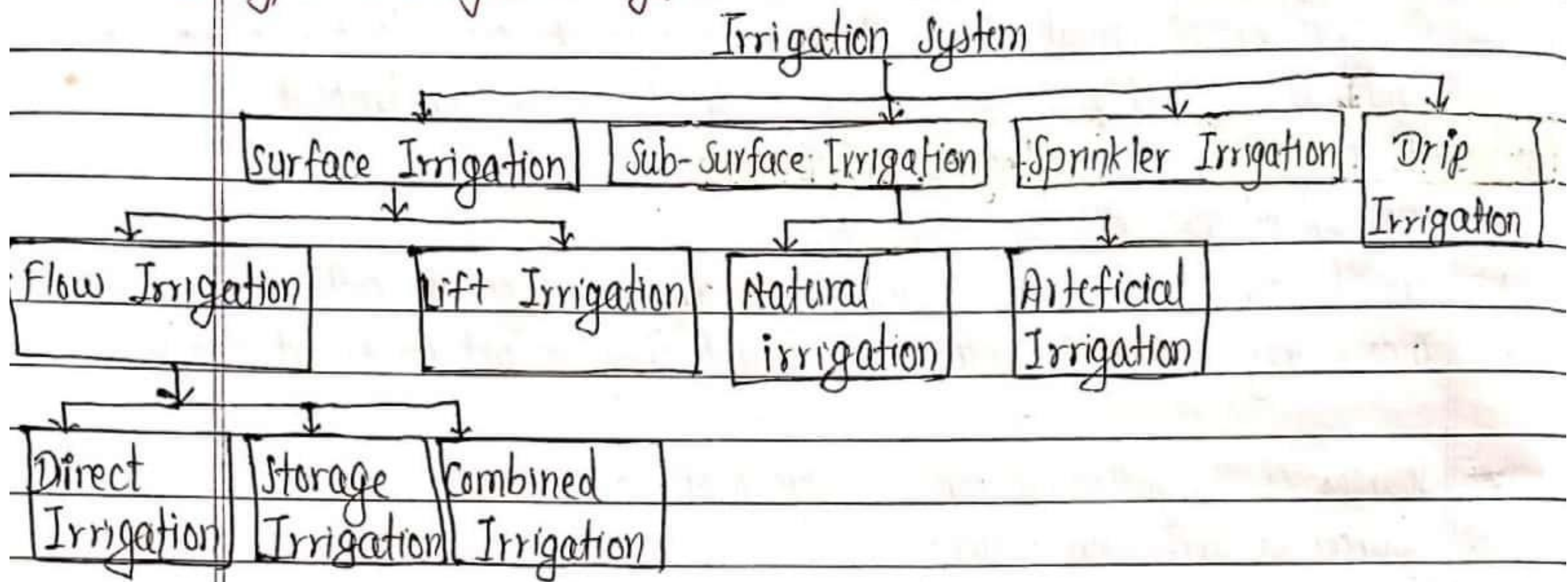
- River
- stream
- Pond
- Lake
- Impounded Reservoir.

② sub-surface sources [Ground Sources]:

↳ The water which gets in the ground water reservoir through infiltration is known as sub-surface water. This is supplied only by using pump. The sub-surface sources of irrigation water are;

- springs
- Wells
- Infiltration Galleries.

⑧ Types of Irrigation System:



① Surface Irrigation:

- ↳ Flow of water takes place over the surface of the earth, which is surface irrigation.
- ↳ The irrigation water which is flow above the ground surface, and application of water by flooding or gravity actions to the crops is known as surface irrigation system.

② Flow Irrigation:

- ↳ Flow irrigation is that type of irrigation in which the supply of irrigation water is conveyed into the land by gravity.
- ↳ It is also divided into two classes:

① Perennial Irrigation System:

- ↳ In this system the irrigation water is supply in accordance with crop requirements throughout the crop period. For storage headworks, dams and weir or barrage are constructed to store the excess water during floods and release it to the crops when it is required.

② Innudation Irrigation System:

- ↳ If the irrigation is carried out by utilize the flood, such type of irrigation is called innudation irrigation system.

① Lift Irrigation:

- ↳ It is provided when water is available in the lower level of the field. When water is lifted up from the sources and then is allowed to flow through channel, it is known as lift irrigation.

② Sub-surface Irrigation:

- ↳ Supplying of water directly to the root zone of the crops inside or below the surface of earth is called sub-surface irrigation system.
- ↳ Sub-surface irrigation water is applied to the plant by the capillary action.
- ↳ sub-surface irrigation system is of two types:
 - ① Natural sub-surface irrigation
 - ② Artificial sub-surface irrigation.

③ Sprinkler Irrigation:

- ↳ Water is applied to the soil in the form of spray through a network of pipe and pump at uniform rate less than the infiltration rate of soil. It is kind of artificial rain and gives good effect. It is used for all type of soil and different topographical slope.

⊕ Favourable Conditions / suitability :

- Excess slope
- Irregular topography
- Erosive soil
- Soil is excessively permeable or impermeable.
- Depth of soil is shallow over gravel or sand.

④ Drip (Trickle) Irrigation:

- ↳ In this method, water is applied in the form of drops directly nearly base of plants. Water is conveyed through a system of flexible pipelines; operating at low pressure and applied to the plants through drip nozzles.

History and Future Scope of Irrigation in Nepal:

• History / status of Irrigation in Nepal:

↳ Farmers are using their own sources, techniques, methods for constructing small and medium irrigation system for ancient time. From the government side, the development of irrigation has been started in 1979 B.S. The first canal namely Chandra Canal (Chandra Shamser 1846-1951) situated in Saptari District was constructed in 1985 B.S. Later on Juddha canal on Sarlahi and Jagdishpur Reservoir in Kapilbastu were constructed during 1932-1945 under the supervision of retired Indian Engineers.

↳ After the Democracy of 2007 B.S., development of irrigation was situated on institutional basis. In 2009 B.S., department of canal was established. It was finally named as Department of Irrigation in 2044 B.S.

↳ Out of total area 1,47,181 sq.km., Nepal has cultivated area of 26,41,000 ha. According to progress report of 2072/73 (Department of Irrigation) out of total cultivated area, irrigable land is 17,66,000 ha. By the end of 2072/73 a total of 13,92,107 ha. is irrigated by different schemes developed by different agencies.

↳ Out of total irrigated land by the end of 2072/73 the area covered by different methods are as follows:

- Surface Irrigation = 7,80,415 ha
- Sub-surface Irrigation = 4,09,463 ha.
- Farmers water course = 2,02,229 ha.

↳ Total Irrigated area = 13,92,107 ha.

• Scope of Irrigation in Nepal:

- ↳ The scope of irrigation is not limited to a application of water to the soil. It deals with all aspects and problem extending from watershed to the agricultural form. It deals with design and construction of works such as dam, weir, barrage, head regulator etc in connection with storage and diversion of water. The scope of irrigation can be divided into two heads:

① Engineering Aspects:

- Storage, diversion, lifting of water.
- Conveyance of water to agricultural field.
- Application of water by different methods to the agricultural field.
- Drainage and relieving waterlogging.
- Development of waterpower.

② Agricultural Aspects:

- ↳ Proper depth of water necessary
- ↳ Distribution of water uniformly and periodically.
- ↳ Capacity of different soil for irrigation water.
- ↳ Reclamation of water and alkali lands.

• Importance of Irrigation in Nepal:

① Uneven Distribution of Rainfall:

- ↳ Rainfall distribution of Nepal is non-uniform all over the country. There may be surplus water at one place and deficit at other. So, to manage this problem, irrigation is important.

② Increasing the Yield of Crops:

- ↳ Fertility characteristics alone are not sufficient for better yield of crops. There are such zone in Nepal, where no irrigation facility but fertile land is present. So to increase the yield of crop irrigation is required.

3- To grow Number of Crops:

↳ Seasonal variation within a year is better in Nepal. So with well managed irrigation system, number crops can be grown.

4- Inadequate Rainfall:

↳ There may be scarcity of water in the Terai belt due to inadequate rainfall. So, proper irrigation system can fulfill it.

5- Sound Economic Growth:

↳ With the help of well managed irrigation system, crop production is increased. It results the economic growth of the nation.

6- Growth of Agro-based Industry.

7- Utilization of natural water resources

8- Increases the employment

9- To conserve cultivable land.

Unit-2 Crop Water & Irrigation Water Requirements

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Crop Water:

- ↳ Water is the most important requirement for the crops because:
 - It supplies moisture which is essential for the plant leading to its growth.
 - It cools the soil and atmosphere and thus makes more favourable environment for healthy plant growth.

Types and seasons of Crops:

- ↳ The main crops are rice, wheat, sugarcane, maize, mustard, potato, pulses etc. From agricultural point of view, the year can be divided into two main cropping seasons:
 - 1- Rabi Season [Winter]: 1st oct to 31st mar. Eg: Wheat, potato, mustard etc.
 - 2- Kharif Season [Summer]: 1st Apr to 30th Sept. Eg: Rice, maize, pulses etc.

- ↳ Depending upon the season of crops, crops are classified as follows:

① Kharif Crops [Summer/ Monsoon Crops]:

- ↳ Kharif crops are sown by the beginning of the south-west monsoon and harvested in autumn (1st Apr to 30th Sept.). It is also known as summer crops or monsoon crops. Eg: Rice, maize (corn), Bajra, jowar, sorghum, pulses, groundnut (peanut) etc.

② Rabi Crops [Winter Crops]:

- ↳ Rabi crops are sown in autumn and are harvested in spring (1st oct to 31st march). It is also known as winter crops. Eg: Grams, wheat, barley, mustard, tobacco, potato etc.

③ Eight month crops:

- ↳ These crops such as cotton requires irrigation water for 8 months.

④ Perennial crops:

- ↳ These are crops that require water for irrigation throughout the year. Eg: sugarcane, fruits, vegetables etc.

Base and Crop Periods:

⊗ Base Period:

→ Base period of crops refers to the whole period of cultivation from the time when irrigation water is first issued for preparation of the ground for planting the crops to its last watering before harvesting.

- The time between first water of crops after sowing to its last watering before harvesting is called base period. Base period is slightly less than crop period, which is time between sowing and harvesting but for all practical purpose they are assumed same. It is represented by B .

⊗ Crop Period:

→ Crop period is the time that the crop takes from the instant of its sowing to that of its harvesting. The time period that elapses from the instant of its sowing to the instant of its harvesting is called crop period. It is slightly more than base period.

Duty, Delta and their Relation:

* Duty [D]:

→ The area of land irrigated by unit quantity of water ($1 \text{ m}^3/\text{sec}$ or 1 cumec) for the full growth period of crop is known as duty. It is denoted by ' D ' and its general unit is hectare/cumec.

→ It can be also defined as the ratio of cumec area of land to be irrigated discharge of water.

- Duty can also be expressed as:

$$\therefore \text{Duty } (D) = 8.64 \times \frac{B}{\Delta} \quad \therefore \text{Where, } B = \text{Base period} \\ \Delta = \text{delta.}$$

→ It varies with crop.

• Factors affecting Duty:

↳ The factors affecting to the duty are as follows:

- | | |
|---|--|
| (i) Soil characteristics | OR → (i) Methods and system of irrigation |
| (ii) Subsoil condition | (ii) Mode of applying water to the crops |
| (iii) Climate condition | (iii) Methods of cultivation |
| (iv) Base period | (iv) Time and frequency of tilling |
| (v) Crop-period | (v) Types of crops |
| (vi) Delta | (vi) Base and crop period of crop |
| (vii) Types of crops | (vii) Climate conditions of the area |
| (viii) Rainfall | (viii) Quality of water |
| (ix) Unevenness of field | (ix) Method of assessment |
| (x) Preparation of field | (x) Canal conditions |
| (xi) Longitudinal slope of field | (xi) Character of soil and sub-soil of the canal. |
| (xii) Field position in relation to canal | (xii) Character of soil and sub-soil of the irrigation fields. |
| (xiii) Use of irrigation water | |
| (xiv) skill of farmers | |
| (xv) Chemical composition of water | |
| (xvi) Method of Irrigation | |
| (xvii) Canal condition. | |

* Delta (Δ):

↳ It is defined as the total depth of water required by a crop during its entire base period of the crop. It is denoted by ' Δ '.

↳ Delta for any crop can be obtained by dividing the total water required in ha-m by the area in which the crop is grown.

$$\therefore \Delta (\Delta) = \frac{\text{Total quantity of water required (ha-m)}}{\text{area of the land having the crop (ha)}}$$

↳ Its unit is 'm' or 'cm'.

↳ Eg: If crop requires 10 watering of 10cm each the delta of the crop = $10 \times 10 = 100 \text{ cm} \approx 1 \text{ m}$.

Kor Period:

→ Kor period is the critical growth period of crops during which water demand is maximum. For most crops kor period varies between 2-4 weeks.

Kor Depth:

→ The kor depth is the depth of water during the kor period.

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Relationship between Duty & Delta with Base Period:

Let,

B = Base period of crops

D = Duty in hectare.

Δ = Delta

Assume, 1 cumec discharge of water is applied for base period for B days.

$$\text{Volume of water (V)} = 1 \times B \times 24 \times 60 \times 60 \\ = 86400 B \text{ m}^3$$

D = Area in hectare irrigated by 1 cumec water for B days.

$$\text{Total depth of water } (\Delta) = \frac{\text{Volume}}{\text{Area}}$$

$$\Delta = \frac{86400 B}{D \times 10000} \quad \because [1 \text{ ha} = 10^4 \text{ m}^2]$$

$$\therefore \left[\Delta = 8.64 \times \frac{B}{D} \right]$$

Where,

B = Base period in days

Δ = Delta in m.

D = Duty in hectare per cumec.

* Command Areas:

1. Gross Command Area [G.C.A]:

↳ It is the total area used for irrigating purpose considering without the limitation of water. It includes both culturable and non-culturable area.

↳ It contains unfertile barren land, local pond, villages, alkaline soil (generally pH value greater than 7 having low infiltration capacity) etc

$$\therefore \text{Gross Command Area} = \text{Culturable area} + \text{Non-culturable area.}$$

2. Net Command Area [N.C.A]

↳ It is the portion of culturable command area which is irrigated by using irrigation system (canal) easily. The area where irrigation facilities are provided is known as net command area. In this area ditches, ponds, forests, canal etc are deducted from G.C.A.

3. Irrigable Command Area [I.C.A]:

↳ The area of cultivation where irrigation water is provided regularly for crops according to its base period of time is known as irrigable command area.

4. Culturable Command Area [C.C.A]:

↳ It is that area on which crops can be grown. The area utilized for growing crops is known as culturable command area.

↳ It is divided into two categories:

(a) Cultivated Culturable Area:

↳ It is the area on which crop is grown at a crop season or present time.

(b) Non-cultivated Culturable Area:

↳ It is the area on which crop is not grown (sown) in crop season or present time due to some reason.

Definition of Important Terms:

• Commanded Area:

↳ The area which can be irrigated by a canal system is called the commanded area. It is also known as irrigable area.

• Intensity of Irrigation:

↳ Ratio of cultivated land for a particular crop to total culturable command area.

$$\therefore \text{Intensity of Irrigation (I.I.)} = \frac{\text{Land cultivated}}{\text{C.C.A.}}$$

• Crop Ratio:

↳ The ratio of area irrigated in Rabi season to that irrigated in Kharif season is known as crop ratio. The crop ratio is so selected that the discharge in the canal during both the seasons may be uniform.

Soil Moisture Contents and Irrigation Interval:

• Soil Moisture Content:

↳ Soil moisture content of soil is defined as the ratio of mass of water held in the soil to the dry soil. The mass of water is determined by the difference before and after drying the soil.

↳ It is the water retained in the pore space in the unsaturated zone of soil mass. It is also called natural moisture content. Soil moisture content present in the soil pores that have good aeration and drainage that follows for rapid exchange of air and water with plant roots.

↳ Knowing the soil moisture status enables highly efficient irrigation, providing water when required and eliminating the wasteful use of water when irrigation is not needed.

↳ Soil water dissolves salts and makes up the soil solution, which is important as medium for supply of nutrients for growing plants.

↳ Various Soil moisture Contents are described below:

① Saturation Capacity:

↳ This can also be called as maximum moisture holding capacity or total capacity and is the amount of water required to fill all the pores spaces between soil particles by replacing all air hold in the pore spaces.

② Field Capacity:

↳ The field capacity is the moisture content of soil when all the gravity water is removed from it after saturation.

③ Permanent Wilting Point:

↳ The moisture contents of soil, soil below which plant can not extract sufficient water for their growth is called permanent wilting point.

* Note * $SC > FC > PWP$

• Irrigation Interval:

↳ The time between start of successive water application on the same field in days is called irrigation interval. It is based on irrigation scheduling used by irrigation system managers to determine the correct frequency and duration of watering.

↳ The interval between irrigation and the amount of water to apply at each irrigation depends on how much water is held in the root zone and how fast it is used by the crops.

↳ It is determined by:

- Soil texture.
- Soil structure / water penetration.
- Depth of effective root zone of the soil.
- The crop grown.
- The stage of development of crop.

Water Requirements of Different Crops:

↳ Every crops required a certain quantity of water in certain fixed interval throughout its period of growth. If the natural rain is sufficient and timely so as to satisfy the both these requirements, no irrigation water is required for the raising of crops. Magnitude and frequency of rainfall varise throughout a country. Certain crops required irrigation in certain part of country and some may not require any irrigation in the same other part of country.

↳ The term water requirements of crops means the total quantity and the way in which a crop required water from the time it is sown to the time it is harvesting. The water requirement varise with the crops as well as the place.

↳ Following table shows the crop water requirements of major crops.

S.N.	Crop's Name	Water Requirement (mm)	S.N.	Name of Crops	Water Requirement (mm)
1.	Rice	900 - 2500	6.	Tomato	600 - 800
2.	wheat	450 - 650	7.	Potato	500 - 700
3.	Maize	500 - 800	8.	Onion	350 - 550
4.	Sugarcane	1500 - 2500	9.	chillies	500
5.	Tobacco	400 - 600	10.	Cotton	450 - 700

• Factors affecting the crop water requirements:

↳ Water requirements depends upon the following factors

1. Climate
2. Useful rainfall
3. Types of soil
4. Cultivation method
5. Type of crop
6. Base period of crop
7. Quality of water
8. Method of assessment
9. Canal condition etc.

* Irrigation water Requirement Considering losses, Land Preparation and Effective Rainfall:

- ↳ The term irrigation water requirement means that total quantity and the way in which the crop required water from the time it is sown to the time it is harvesting.
- ↳ Different types of losses in the field or in canal play vital role for considering the water requirement-in irrigation. They are evaporation loss, percolation loss, seepage loss and others. It is considered about 15% of discharge of irrigation.
- ↳ Land preparation plays the important role for water requirements. Effective land preparation minimize the losses in the field. Cross-section of canal and land & its slope play vital role for minimizing the losses in canal and land for preparation of land, its slope is designed by the special consideration or accurately then, water logging problem and seepage in the field is minimized.
- ↳ Effective rainfall play vital role for water requirements. for kharif crops more water required for irrigation than Rabi Crops. By effective rainfall in kharif season less canal irrigation scheme is effective.

Formulae:

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

Where,

Δ = Delta (m)

B = Base period (days)

D = duty (ha/cumec)

$$\bullet \Delta = \frac{\text{Volume (V) - m}^3}{\text{Area (A) - m}^2} \rightarrow \text{Delta becomes in 'm'}$$

$$\bullet D = 8.64 \times \frac{\text{kor period (days)}}{\text{kor depth (cm)}} \rightarrow \text{Duty becomes in 'ha/cumec'}$$

$$\bullet Q = \frac{\text{Area (A)}}{\text{Duty (D)}} \quad \text{Where, } \left[\begin{array}{l} A \text{ is in hectare} \\ D \text{ is in ha/cumec.} \end{array} \right]$$

$\therefore$ Discharge becomes in 'm³/sec'

Numericals

Q. No. 1 The CCA for distributing land is 600 hectares. The intensity of irrigation is 40% for rice and 30% for wheat. The kor period of rice and wheat are 20 days and 15 days respectively. Calculate the discharge of canal, kor depth for rice and wheat is 150 mm and 110 mm.

Solution: Given that,

Culturable command area (C.C.A) = 600 ha.

Cultivated area of rice (A_R) = 40% of C.C.A.

$$= \frac{40}{100} \times 600$$

$$= 240 \text{ ha.}$$

Cultivated area of wheat (A_W) = 30% of C.C.A.

$$= \frac{30}{100} \times 600$$

$$= 180 \text{ ha.}$$

Kor period of rice = 20 days

Kor period of wheat = 15 days.

Kor depth for rice = 150 mm = 0.15 m

Kor depth for wheat = 110 mm = 0.11 m.

Now,

$$\begin{aligned} \text{Duty for rice } (D_R) &= 8.64 \times \frac{\text{kor period}_R}{\text{kor depth}_R} \\ &= 8.64 \times \frac{20}{0.15} \end{aligned}$$

$$= 1152 \text{ ha/cumec.}$$

and,

$$\begin{aligned} \text{Duty for wheat } (D_W) &= 8.64 \times \frac{\text{kor period}_W}{\text{kor depth}_W} \\ &= 8.64 \times \frac{15}{0.11} \end{aligned}$$

$$= 1178.18 \text{ ha/cumec.}$$

Then,

$$\begin{aligned}\text{Discharge of canal for rice } (Q_R) &= \frac{\text{Area } (A_R)}{\text{Duty } (D_R)} \\ &= \frac{240}{1080} \\ &= 0.22 \text{ m}^3/\text{sec (cumec)}\end{aligned}$$

and,

$$\begin{aligned}\text{Discharge of canal for wheat } (Q_W) &= \frac{\text{Area } (A_W)}{\text{Duty } (D_W)} \\ &= \frac{180}{1178.18} \\ &= 0.15 \text{ m}^3/\text{sec (cumec)}.\end{aligned}$$

Hence,

Taking maximum value for discharge at outlet of canal.
 $\therefore$ Discharge of canal $(Q) = 0.22 \text{ m}^3/\text{sec}.$
 #.

Q.No.2 A field channel has a C.C.A. of 4000 hectares. The intensity of irrigation for gram is 30% and wheat is 50%. Gram has a kor period of 18 days whereas wheat has 15 days. kor depth of gram and wheat is 12 cm and 15 cm respectively. Calculate the discharge of field canal.

Solⁿ Given that,
 Cultivation command area $(A) = 4000 \text{ ha}.$
 Cultivation area for gram $(A_g) = 30\% = \frac{30}{100} \times 4000 = 1200 \text{ ha}.$
 Cultivation area for wheat $(A_w) = 50\% = \frac{50}{100} \times 4000 = 2000 \text{ ha}.$

kor period of gram = 18 days

kor period of wheat = 15 days

kor depth of gram = 12 cm = 0.12 m

kor depth of wheat = 15 cm = 0.15 m.

$$\text{Duty for gram} = 8.64 \times \frac{\text{kor period (for gram)}}{\text{kor depth (for gram)}}$$

$$= 8.64 \times \frac{18}{0.12}$$

$$= 1296 \text{ ha/cumec.}$$

and,

$$\text{Duty for wheat} = 8.64 \times \frac{\text{kor period (for wheat)}}{\text{kor depth (for wheat)}}$$

$$= 8.64 \times \frac{15}{0.15}$$

$$= 864 \text{ ha/cumec.}$$

Then,

$$\text{Discharge of field canal for gram } (Q_g) = \frac{\text{Area}}{\text{Duty}}$$

$$= \frac{1200}{1296}$$

$$= 0.92 \text{ m}^3/\text{sec (cumec)}$$

and,

$$\text{Discharge of field canal for wheat } (Q_w) = \frac{\text{Area}}{\text{Duty}}$$

$$= \frac{2000}{864}$$

$$= 2.31 \text{ m}^3/\text{sec (cumec).}$$

Since,

gram and wheat are crops of same season.

Hence,

$$\text{Total discharge of field canal } (Q) = 0.92 + 2.31$$

$$= 3.23 \text{ m}^3/\text{sec}$$

✱.

Q.No.3 An irrigation canal has GCA 80,000 hectares out of which 85% is cultivable (Irrigable) area. The intensity of irrigation of kharif season is 30% and for Rabi season is 60%. Find the discharge required at the head of canal if the duty at its head is 800 ha/cumec for kharif season and 1700 ha/cumec for Rabi season.

Solⁿ: Given that,
 Gross Command Area (G.C.A) = 80000 ha.
 Cultivable (Irrigable) Area (C.A) = 85% of G.C.A

$$= 0.85 \times 80000$$

$$= 68000 \text{ ha.}$$

Cultivable area for kharif season = 30% of C.A

$$= 0.3 \times 68000$$

$$= 20400 \text{ ha.}$$

Cultivable area for Rabi season = 60% of C.A

$$= 0.6 \times 68000$$

$$= 40800 \text{ ha.}$$

Duty for kharif season (D_k) = 800 ha/cumec.

Duty for Rabi season (D_R) = 1700 ha/cumec.

Then,

$$\text{Discharge required for kharif season} = \frac{\text{Area}}{\text{Duty}} = \frac{20400}{800}$$

$$= 25.50 \text{ Cumec.}$$

and,

$$\text{Discharge required for Rabi season} = \frac{\text{Area}}{\text{Duty}} = \frac{40800}{1700}$$

$$= 24 \text{ cumec.}$$

So,

Taking maximum value for discharge at head of canal.

$$\therefore \text{Discharge of canal (Q)} = 25.50 \text{ cumec. (m}^3/\text{sec)} \quad \#.$$

Q.No.4 Gross Command Area of reservoir is 50000 hectares. The C.C.A is 80 % of G.C.A. Find the capacity of reservoir which is able to irrigate areas as given below:

Crop	Base Period (days)	Duty (ha/cumec.)	Intensity of Irrigation (%)
Wheat	120	2000	25.00
Rice	140	900	18.75
Cotton	180	1600	12.50

Solution: Here, we have

$$\text{Gross Command Area (G.C.A)} = 50000 \text{ ha.}$$

$$\begin{aligned} \text{Culturable Command Area (C.C.A)} &= 80\% \text{ of G.C.A} \\ &= 50000 \times \frac{80}{100} \end{aligned}$$

$$= 40,000 \text{ ha.}$$

$$\begin{aligned} \text{Area of wheat} &= 25\% \text{ of C.C.A} \\ &= 0.25 \times 40000 \\ &= 10,000 \text{ ha.} \end{aligned}$$

$$\begin{aligned} \text{Area of rice} &= 18.75\% \text{ of C.C.A} \\ &= 0.1875 \times 40000 \\ &= 7500 \text{ ha.} \end{aligned}$$

$$\begin{aligned} \text{Area of Cotton} &= 12.5\% \text{ of C.C.A} \\ &= 0.125 \times 40000 \\ &= 5000 \text{ ha.} \end{aligned}$$

Now,

$$\Delta_1 \text{ for wheat} = \frac{8.64 \times B}{D} = \frac{8.64 \times 120}{2000} = 0.518 \text{ m}$$

$$\Delta_2 \text{ for rice} = \frac{8.64 \times B}{D} = \frac{8.64 \times 140}{900} = 1.342 \text{ m.}$$

$$\Delta_3 \text{ for cotton} = \frac{8.64 \times B}{D} = \frac{8.64 \times 180}{1600} = 0.972 \text{ m.}$$

Then,

$$\begin{aligned}\text{Quantity of water required for wheat (V}_1\text{)} &= \text{Area} \times \text{Delta} \\ &= 10000 \times 0.518 \\ &= 5180 \text{ ha-m}\end{aligned}$$

$$\begin{aligned}\text{Quantity of water required for rice (V}_2\text{)} &= \text{Area} \times \text{Delta} \\ &= 7500 \times 1.342 \\ &= 10065 \text{ ha-m}\end{aligned}$$

and,

$$\begin{aligned}\text{Quantity of water required for cotton (V}_3\text{)} &= \text{Area} \times \text{Delta} \\ &= 5000 \times 0.972 \\ &= 4860 \text{ ha-m}\end{aligned}$$

$$\begin{aligned}\therefore \text{Total quantity of water} &= 5180 + 10065 + 4860 \\ &= 20105 \text{ ha-m}\end{aligned}$$

Assume, 10 % for losses.

$$\therefore \text{Grand total quantity} = 20105 + 20105 \times \frac{10}{100} = 22115.50 \text{ ha-m}$$

$$\text{Hence, } = 22115.50 \times 10000 = 221155000 \text{ m}^3$$

$$[\text{Capacity of Reservoir} = 221155000 \text{ m}^3]$$

#.

[2015]

Q. NO. 5

The water course has culturable command area of 3000 hectares. Intensities of irrigation for perennial sugarcane and rice crops are 25% and 50% respectively. The duties of these crops at the head of water course are 800 hectares/cumec. and 1750 ha/cumec. respectively. Find the discharge required at the head of water course if the peak demand is 120% of the average requirement.

Solution:

Given that,

$$\text{Culturable Command area (CCA)} = 3000 \text{ ha.}$$

$$\text{Area required for sugarcane (A}_1\text{)} = 25\% \text{ of C.C.A.}$$

$$= 0.25 \times 3000$$

$$= 750 \text{ ha.}$$

$$\text{Area required for rice (A}_2\text{)} = 50\% \text{ of C.C.A.}$$

$$= 0.50 \times 3000$$

$$= 1500 \text{ ha.}$$

$$\text{Duty for sugarcane (D}_1\text{)} = 800 \text{ ha/cumec.}$$

$$\text{Duty for rice (D}_2\text{)} = 1750 \text{ ha/cumec.}$$

Now,

$$\text{Discharge of water for sugarcane} = \frac{\text{Area}}{\text{Duty}} = \frac{750}{800} = 0.94 \text{ m}^3/\text{s.}$$

And,

$$\text{Discharge of water for rice} = \frac{\text{Area}}{\text{Duty}} = \frac{1500}{1750} = 0.86 \text{ m}^3/\text{s.}$$

Then, -

$$\begin{aligned} \text{The total discharge of water} &= 0.94 + 0.86 \\ &= 1.80 \text{ m}^3/\text{sec.} \end{aligned}$$

But,

$$\text{Peak demand of water} = 120\% \text{ of average demand.}$$

$$= 1.80 \times 1.2$$

$$= 2.16 \text{ m}^3/\text{s.}$$

Hence,

$$[\text{The discharge required at head of water course is } 2.16 \text{ cumec}]$$

#

[2069]
Q. No. 6

Determine the discharge required at the head of distributory for the gross commanded area of 6400 hectare, 75% of which is culturable irrigation. The intensity of irrigation for Rabi season is 50% and that for kharif season is 25%. If the average duty at the head of the distributory is 2000 hectare/cumec for Rabi season and 900 hectare/cumec for kharif season, find out the discharge required at the head of the distributory from average demand consideration.

Solution: We have,

$$\text{Gross Command Area (G.C.A)} = 6400 \text{ ha.}$$

$$\begin{aligned}\text{Culturable Area (C.A.)} &= 75\% \text{ of G.C.A} \\ &= 0.75 \times 6400 \\ &= 4800 \text{ ha.}\end{aligned}$$

$$\begin{aligned}\text{Culturable area for Rabi season} &= 50\% \text{ of C.A} \\ &= 0.5 \times 4800 \\ &= 2400 \text{ ha.}\end{aligned}$$

$$\begin{aligned}\text{and, Culturable area for kharif season} &= 25\% \text{ of C.A} \\ &= 0.25 \times 4800 \\ &= 1200 \text{ ha.}\end{aligned}$$

$$\text{Duty for Rabi season} = 2000 \text{ ha/cumec.}$$

$$\text{Duty for kharif season} = 900 \text{ ha/cumec.}$$

Then,

$$\text{Discharge of water for Rabi season} = \frac{\text{Area}}{\text{Duty}} = \frac{2400}{2000} = 1.20 \text{ cumec.}$$

and,

$$\text{Discharge of water for kharif season} = \frac{\text{Area}}{\text{Duty}} = \frac{1200}{900} = 1.33 \text{ cumec.}$$

Hence,

from average demand consideration;

$$\text{Discharge required at head of distributory (Q)} = 1.33 \text{ cu.mec.}$$

[2070]

Q.No. 7

Intensity of irrigation, duties and base periods of various crop under a canal system are given in table below. If reservoir losses are 10% and conveyance loss in canal system 20%, find out the reservoir capacity.

Crop	Base Period	Duty at field m. (hectares/cumec)	Area under each crop in (hectares)
Wheat	120	1800	5400
Sugarcane	330	800	6000
Cotton	200	1200	3000
Rice	130	800	4000
Vegetable	100	700	2000

Solution: Here,

$$\hookrightarrow \text{Delta for wheat } (\Delta_1) = 8.64 \times \frac{B}{D} = 8.64 \times \frac{120}{1800} = 0.58 \text{ m.}$$

$$\hookrightarrow \text{Delta for sugarcane } (\Delta_2) = 8.64 \times \frac{B}{D} = 8.64 \times \frac{330}{800} = 3.56 \text{ m}$$

$$\hookrightarrow \text{Delta for cotton } (\Delta_3) = 8.64 \times \frac{B}{D} = 8.64 \times \frac{200}{1200} = 1.44 \text{ m.}$$

$$\hookrightarrow \text{Delta for Rice } (\Delta_4) = 8.64 \times \frac{B}{D} = 8.64 \times \frac{130}{800} = 1.40 \text{ m.}$$

and,

$$\hookrightarrow \text{Delta for Vegetable } (\Delta_5) = 8.64 \times \frac{B}{D} = 8.64 \times \frac{100}{700} = 1.23 \text{ m.}$$

Area of wheat (A_1) = 5400 ha.

Area for sugarcane (A_2) = 6000 ha.

Area for cotton (A_3) = 3000 ha.

Area for Rice (A_4) = 4000 ha.

Area for vegetable (A_5) = 2000 ha.

then,

Volume of water required, $V = \text{Area} \times \text{Duty}$.

$$\begin{aligned} \hookrightarrow \text{For wheat, } (V_1) &= \text{Area} \times \text{Duty} \\ &= 5400 \times 0.58 \\ &= 3132 \text{ ha-m.} \end{aligned}$$

$$\begin{aligned} \hookrightarrow \text{For Sugarcane, } (V_2) &= 6000 \times 3.56 \\ &= 21360 \text{ ha-m.} \end{aligned}$$

$$\begin{aligned} \hookrightarrow \text{For cotton } (V_3) &= 3000 \times 1.44 \\ &= 4320 \text{ ha-m.} \end{aligned}$$

$$\begin{aligned} \hookrightarrow \text{For rice } (V_4) &= 4000 \times 1.40 \\ &= 5600 \text{ ha-m.} \end{aligned}$$

$$\begin{aligned} \hookrightarrow \text{For Vegetable } (V_5) &= 2000 \times 1.23 \\ &= 2460 \text{ ha-m.} \end{aligned}$$

Now,

$$\begin{aligned} \text{Total capacity of Reservoir} &= 3132 + 21360 + 4320 + \\ &\quad 5600 + 2460 \\ &= 36872 \text{ ha-m.} \end{aligned}$$

adding,

convey loss in canal system as 20%.

$$\therefore \text{Net total capacity} = 36872 + \frac{36872 \times 20}{100}$$

$$V_0 = 44246.4 \text{ ha-m.}$$

and, Reservoir losses as 10%.

$$\therefore \text{Grand total capacity} = 44246.4 + \frac{44246.4 \times 10}{100}$$

$$V = 48671.04 \text{ ha-m.}$$

Since, $1 \text{ ha} = 10000 \text{ m}^2$, So,

$$V = 48671.04 \times 10000 = 486710400 \text{ m}^3.$$

Hence, The grand total capacity of reservoir is 486710400 m^3 .

#.

[2073]

Q.No.8

From the following data, find the field capacity of soil:

Depth of root zone = 1.5m

present water content = 5%

Dry density of soil = 1.6 gm/cm^3 water applied to the soil = 7000 m^3

water loss due to evaporation = 10%

Area of plot = 1 hectare = 10^4 m^2

Solution:

Given that,

depth of root zone (d_r) = 1.5m.Present water content (w) = 5% (omc) = 0.05Dry density of the soil (γ_s) = 1.6 gm/cm^3 water applied to the soil (V) = 7000 m^3

Water loss due to evaporation = 10%

Area of the plot (A) = 10000 m^2

Now,

actually applied water = water applied - losses

$$= 7000 - 7000 \times \frac{10}{100} \text{ (evaporation)}$$

$$= 6300 \text{ m}^3$$

$$\text{and, Depth of water (} d_w \text{)} = \frac{\text{Volume of water}}{\text{Area of Plot}} = \frac{6300}{10000} = 0.63 \text{ m.}$$

Then, By a formula,

$$d_w = \frac{\gamma_s}{\gamma_w} \times d_r (F.C. - omc.) \quad \because [F.C. = \text{Field Capacity}]$$

$$0.63 = \frac{1.6}{1} \times 1.5 (F.C. - 0.05) \quad \because [\gamma_w = 1 \text{ gm/cc}]$$

$$\therefore F.C. = 0.3125 = 31.25 \%$$

Hence,

$$\text{Field Capacity} = 31.25 \%$$

Q.No.9 From the following data, find the field capacity of soil:

Depth of root zone = 2m.

Present water content = 5%.

Dry density of the soil = 15 kN/m^3

Water applied to the soil = 500 m^3

Water loss due to evaporation = 10%.

Area of plot = 1000 m^2 .

Solution:

Given that,

Depth of root zone (d_r) = 2m.

Present water content (w) = 5% = 0.05

Dry density of the soil (γ_s) = 15 kN/m^3

water applied to the soil (V) = 500 m^3

Water loss due to evaporation = 10%.

Area of plot (A) = 1000 m^2 .

Now,

$$\text{actual applied water } (V_a) = 500 - 500 \times \frac{10}{100} = 450 \text{ m}^3$$

$$\text{So, depth of water } (d_w) = \frac{V_a}{A} = \frac{450}{1000} = 0.45 \text{ m.}$$

Then,

By formula of depth of water,

$$d_w = \frac{\gamma_s}{\gamma_w} \times d_r (F.C. - OMC.)$$

$$\therefore \left[\gamma_w = 1000 \text{ kg/m}^3 = \frac{1000 \times 10 \text{ kN/m}^3}{1000} = 10 \text{ kN/m}^3 \right]$$

$$\text{or, } 0.45 = \frac{15}{10} \times 2 (F.C. - 0.05)$$

$$\therefore F.C. = 0.2 = 20\%$$

Hence

$$[\text{Field capacity of soil} = 20\%]$$

Unit-3 Water Availability for Irrigation

PAGE NO. :

DATE : / /

Occurance and Distribution of Rainfall in Nepal:

→ Nepal is a mountainous country with various topography. Larger amount of rainfall occurring in the country due to monsoon rain in the summer season.

The monsoon originates in the bay of bengal and enters into Nepal through the East to the West. So, Eastern region receives considerably more rain as compared to West.

During winter season, Nepal receives low rainfall which is the impact of western -lies originating in Eastern Europe. Westerlies enters Nepal through the west. So, west Nepal receives the more rain as compared to East Nepal during winter season.

Hydrological Cycle:

→ The total water of earth is in constant circulation from earth to atmosphere and back to earth. A complete hydrological cycle is shown in figure.

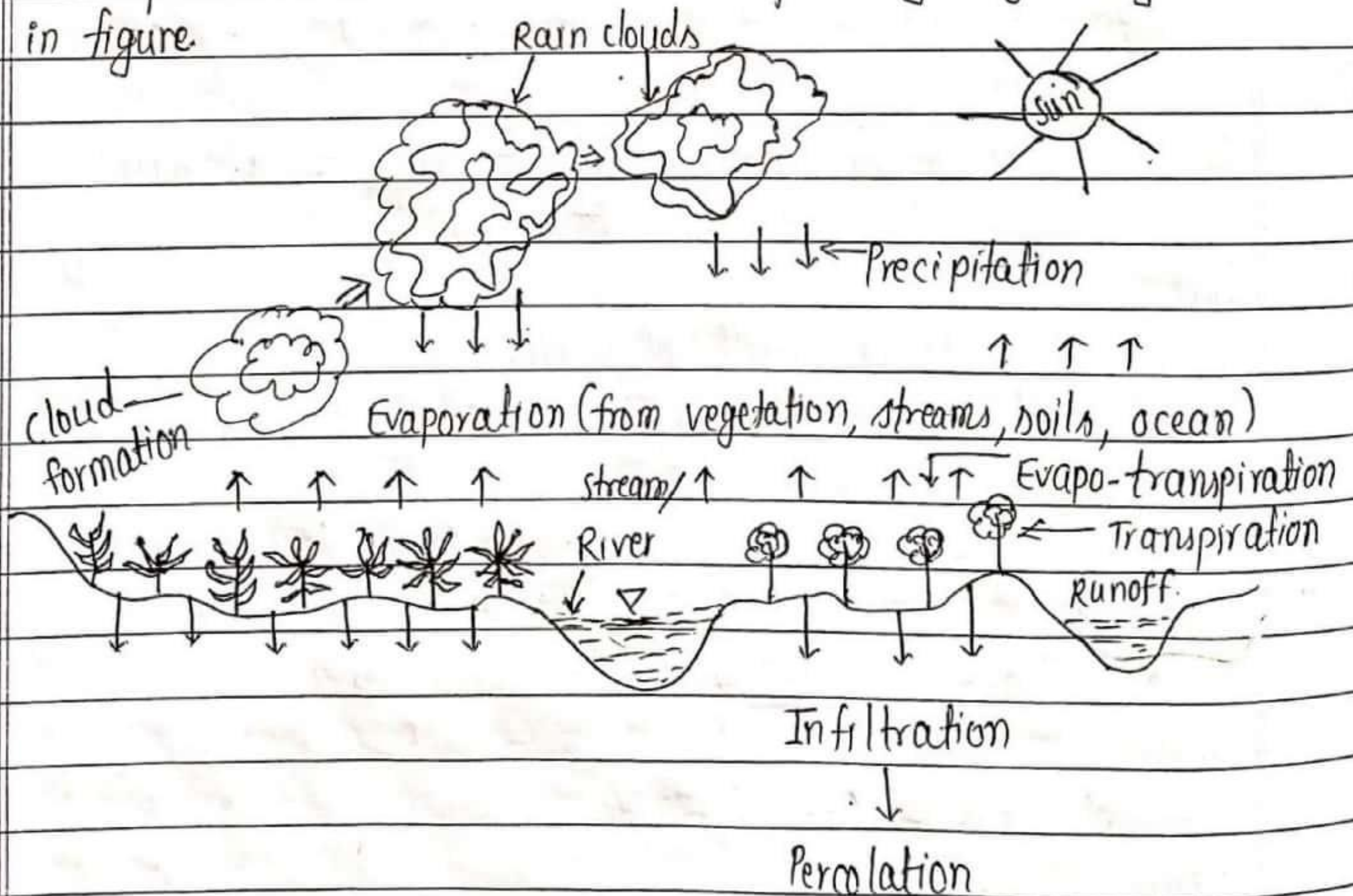


fig: Hydrological Cycle.

↳ Total quantity of water is always same in the atmosphere but earth's water is always in movement. i.e. water goes through different phases: liquid, solid (ice), gas (vapour). The circulation and conservation of earth's water circulates from the land to the sky and back again is called hydrological cycle or water cycle.

↳ The various phenomenon of hydrological cycle can be explained as follows:

- **Evaporation:**

↳ It is the process by which liquid water is converted into gaseous state as it moves from the ground or bodies of water into the overlying atmosphere due to solar radiation.

- **Condensation:**

↳ It is the change in state of water from vapor to liquid in the air, creating cloud and fogs.

- **Precipitation:**

↳ It is the process that occurs when any and all forms of water particle falls from atmosphere and reach the ground surface. Most of the precipitation occurs rain but it also includes snow, hail, fog etc.

- Drizzle — $< 0.15 \text{ mm}$ drop rain.

- Rain — 0.5 mm to 1 mm

- Sleet — ice grain (1 to 5 mm)

- Hail — ice grain (5 to 10 mm)

- Snow — fine crystal.

- Frost or dew — night at ground surface (occurs).

- **Interception:**

↳ When the precipitation reaches the earth, first it is obstructed by trees, building etc; this process is called interception.

- **Infiltration:**

↳ Absorption and downward movement of water into the soil layer is called infiltration. Infiltration makes the soil moisture.

Continue-----

• Runoff:

↳ Topographic flow of water from the area on which it precipitates towards stream channels located at lower elevation. This includes both surface runoff and channel runoff.

• Evapo-transpiration:

↳ Release of water vapor from plants into atmosphere.

Sources of Water:

↳ Water sources are mainly divided into two types:

① Surface sources (Surface waters)

② Ground sources (Ground waters).

① Surface Sources of Water:

↳ Surface sources of water are those sources in which water is flows over the surface of the earth and is directly available for water supply as well as irrigation as runoff from catchment area during rainfall and precipitation. These sources are:

- River
- Stream
- Lake
- Pond
- Impounded reservoir (Storage reservoirs)

② Ground Sources of Water:

↳ The water which gets stored in the ground water reservoir through infiltration is known as ground water. This water is generally pure because it undergoes natural filtration during the percolation through the soil pores. These sources are:

- Springs
- Wells → Open wells (Deep wells, shallow wells)
↳ Tube wells
- Infiltration galleries

* Catchment Area and Runoff Generation:

- ↳ The area drained by a river or any other water bodies is called catchment area or basin. It is the area of land bounded by watershed line or ridge line.
- ↳ Catchment area for a stream at a given point is the area from which all the drainage enters the stream above that point. It is also called drainage area or drainage basin or basin.

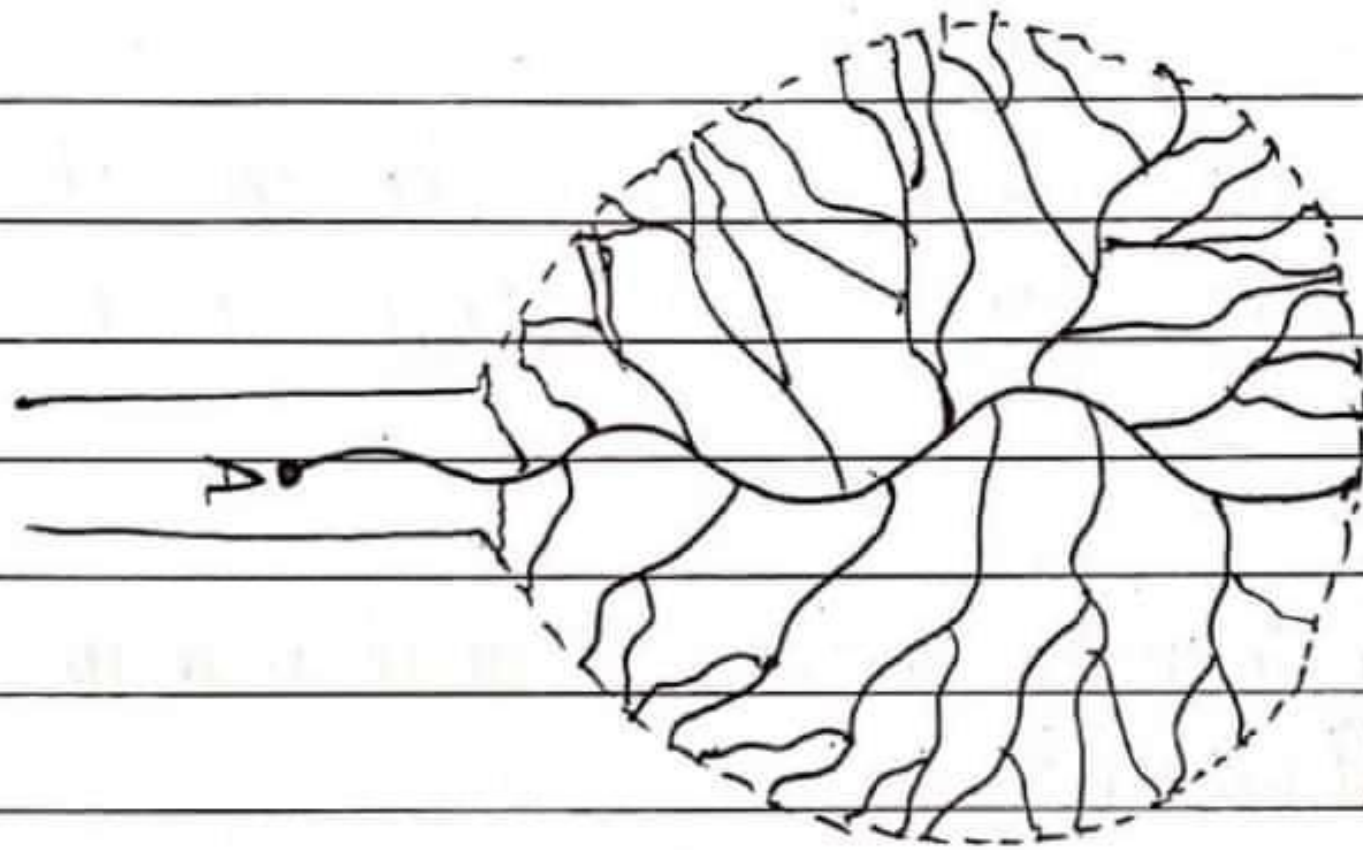


fig: Drainage area for point A.

• Runoff:

- ↳ Runoff is that portion of precipitation that is not evaporated. i.e. When the rain falls to the earth surface as precipitates, a part of it fill the depression, a part of it percolate into the ground, a part of it evaporated in atmosphere and remaining precipitation is available as runoff which ultimately runs to the ocean through surface or subsurface streams.
- ↳ Runoff may be classified as:
 - ① Surface Runoff:
 - ↳ Water flows over the land and reaches stream, river and finally discharge the water in the sea.
 - ② Sub-surface Runoff:
 - ↳ The runoff infiltrates into surface soil and depending on the geology of the basins runs as sub-surface runoff and reaches streams, rivers.

Factors Affecting Runoff:

The factors affecting the runoff are generally categorized into the following parts:

① Characteristics of Precipitation

② Characteristics of drainage basin / catchment area

① Characteristics of Precipitation:

↳ Due to characteristics of precipitation, the runoff is affected by following factors:

① Type of Precipitation:

↳ Precipitation may occur either in the form of rainfall or snowfall or other. If precipitation occurs in heavy rain it will produce more runoff and vice versa.

② Rainfall Intensity:

↳ If rainfall intensity increases, runoff also increases and vice-versa.

③ Rainfall Duration:

↳ Infiltration capacity goes reducing with longer duration of rainfall till it becomes constant. If infiltration less, the surface runoff will be more. So longer duration rainfall may produce considerable runoff.

④ Rainfall Distribution:

↳ The rainfall distribution may occur either on the whole basin (catchment area / drainage) or on the part of it. The rainfall distribution is generally expressed in distribution coefficient. It is obtained by dividing the max. rainfall at any point to the mean rainfall at the basin. Hence, the greater distribution coefficient more will be the runoff.

⑤ Soil Moisture Deficiency:

↳ If the rainfall occurs after the long dry spell, soil is dry and it can absorb large amount of moisture thus increase rain may not produce sufficient run-off. But if rain occurs in rainy season the soil is already wet, when there is less infiltration. So, small intensity of rain may cause peak flow.

Continue ----

(vi) Direction of storm:

↳ If the direction of storm and direction of movement of water is in the same direction, runoff will be higher and vice-versa.

(vii) Other Climatic Condition:

↳ Temperature, wind etc affect the losses from drainage basin and thus runoff is affected. More losses, less will be the available runoff and vice-versa.

(B) Characteristics of Drainage Basin / Catchment Area:

↳ Due to characteristics of drainage basin, the runoff is affected by following factors:

(i) Size of Basin:

↳ If basin is larger, total flood will take more time to pass the outlet, so peak flow reduces. Actual combination of flow from different direction of basin gives more runoff.

(ii) Shape of Basin:

↳ Discharge in fan-shaped basin is always less than that of fern-shaped basin.

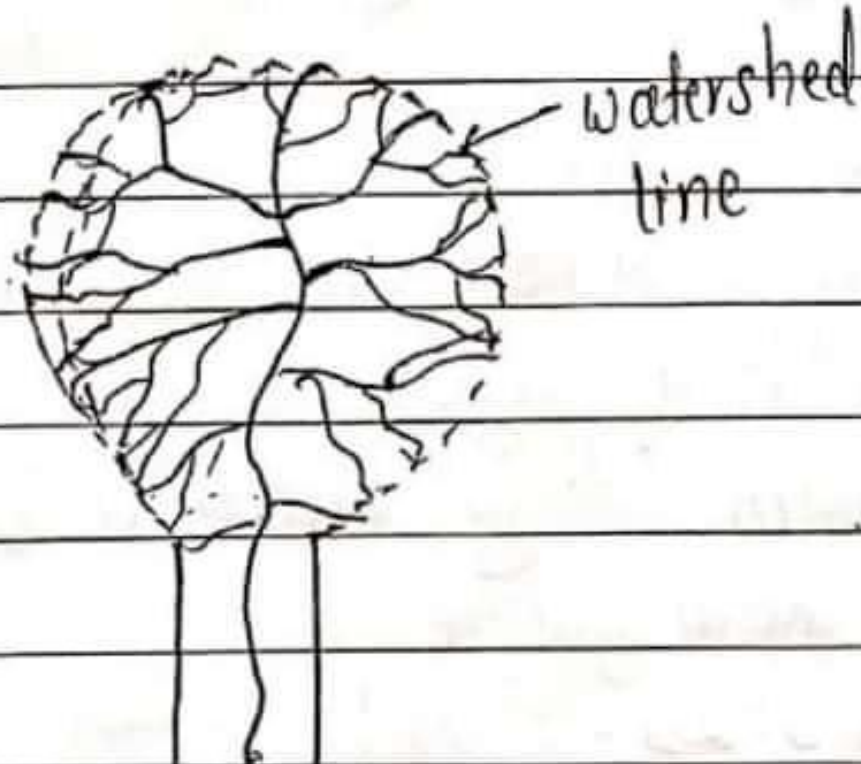


fig: Fan-shaped

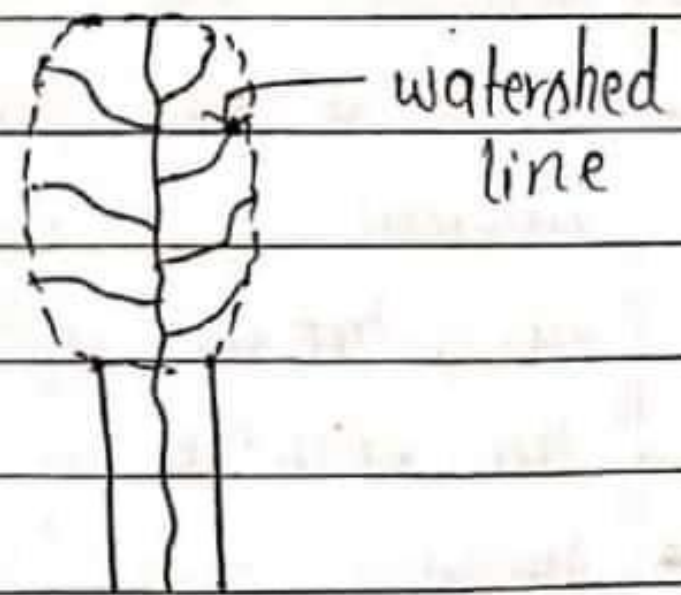


fig: Fern-shaped

(iii) Slope of Catchment:

↳ If the catchment area has more slope, discharge available for runoff is more.

(iv) Nature of Surface of basin:

↳ If the surface of catchment basin is permeable, runoff is less.

(v) Topography of basin:

↳ The catchment having more slopy and smooth surface and less vegetation this gives more run-off and vice-versa.

OR • Factors Affecting Runoff :

→ Factors that affect the runoff discharge are as follows:

- (i) Precipitation characteristics.
- (ii) shape and size of the catchment.
- (iii) Topography
- (iv) Geological characteristics
- (v) Meteorological characteristics
- (vi) character of the catchment surface.
- (vii) storage characteristics.

Rain Gauges and Stream Gauges [Gauge types and Data Presentation] :

[2074] # Rainfall measurement by Rain-gauge:

→ There are mainly two types of rain-gauge:

- (a) Non-automatic Type Rain-gauge [Non-Recording Type]
- (b) Automatic Type Rain-gauge [Recording Type]

(a) Non-Automatic (Non-Recording) type Rain Gauge:

→ It is a rain gauge which does not provide the distribution of amount of precipitation in a day. It simply gives the amount of precipitation after 24 hours (daily precipitation).

→ Its example is Simon's Rain gauge.

[2068] • Simon's Rain-Gauge [IS 5225-1969]

→ It is most common type of non-recording type rain gauge and is used by Meteorological Department Government of India.

- Simon's Rain gauge consists of a cylindrical vessel with 127mm (5") diameter and a base enlarged to 210mm (8") diameter.
- The top section is a funnel provided with circular brass rim exactly 127mm (5") internal diameter.
- The funnel shank is inserted in the neck of receiving bottle which is 75 to 100mm (3" to 4") diameter.

- Capacity of bottle is 75 to 100mm of rainfall. or 10cm to 12cm also.
- The rain gauge is placed in concrete block of 60cm * 60cm * 60cm (2' * 2' * 2').
- The rim should be 305mm (1') above the ground surface.
- The bottle is fixed slightly below the ground level. The rain water enters the bottle through the conical funnel and get collected to bottle. It collect about 10-12 cm of rain. Rainfall is recorded daily at 8:30 Am. by deputed man for this purpose. If rainfall is too much and exceed than the capacity of bottle, then two or more immediate reading are taken and their sum is recorded as the total rainfall during past 24 hours. The rain gauge is located at free levelled open ground and away from attached object for rainfall.
- Water contained in the bottle is measured by suitably graduated measuring glass, with an accuracy upto 0.1mm.

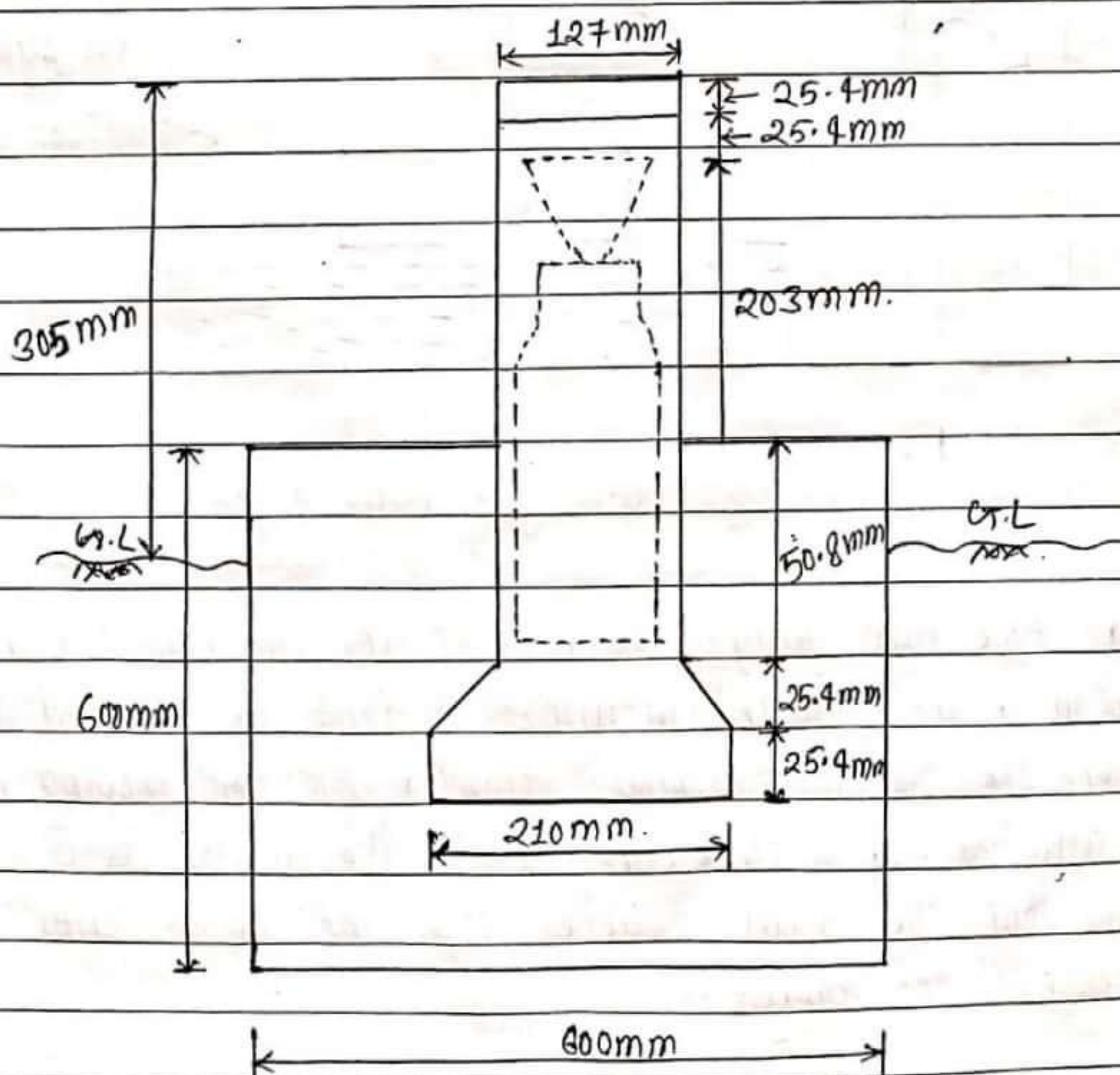


Fig: Simon's Rain gauge

(b) Automatic (Recording) Type Rain Gauge:

↳ An instrument that automatically records the amount of precipitation collect as a function of time is called automatic type rain gauge.

↳ It is sub-divided into following types:

- ① Float type rain gauge
- ② Weighing bucket rain gauge
- ③ Tipping bucket rain gauge.

① Float Type Rain-gauge:

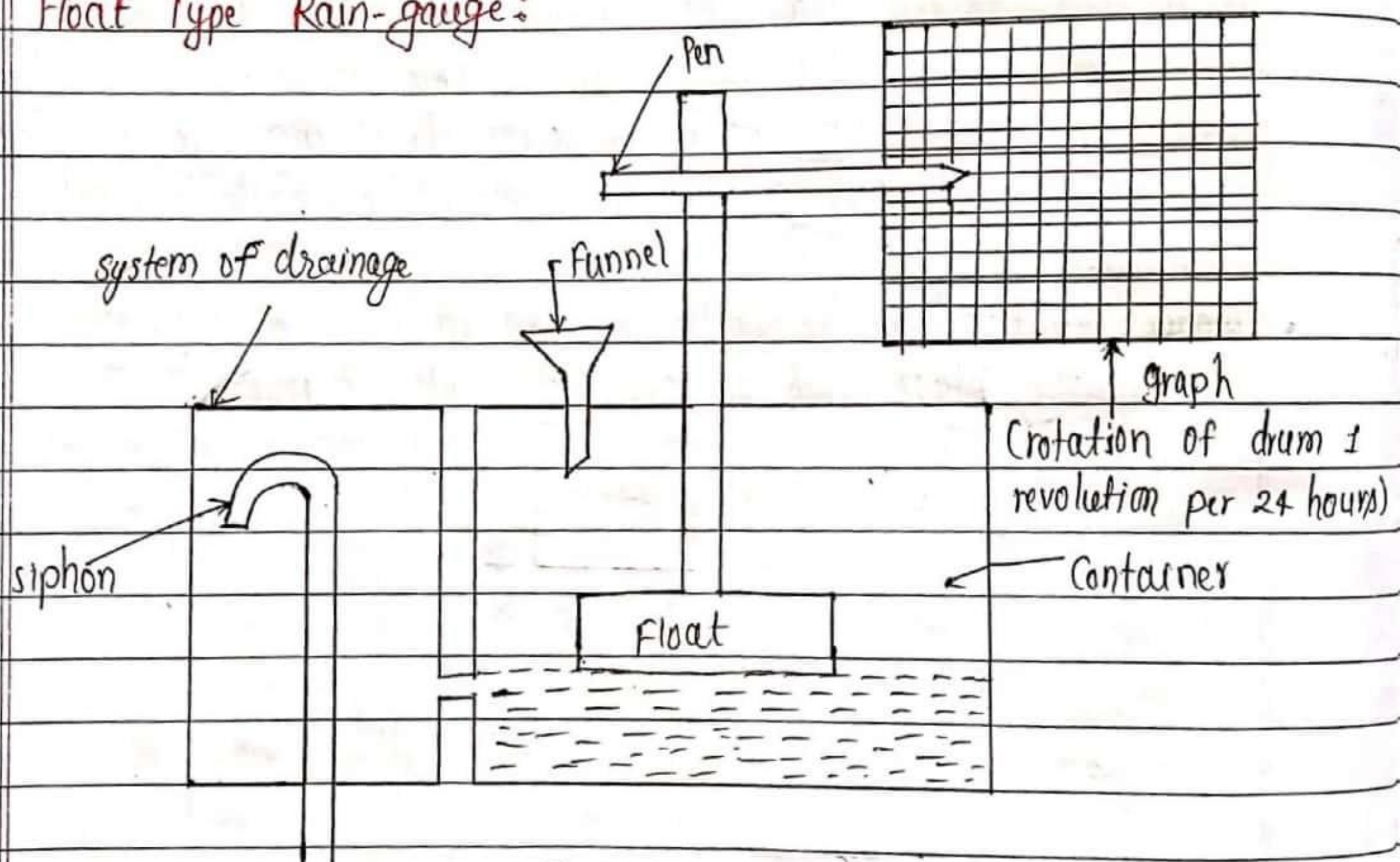


Fig: Float type rain gauge

↳ In float type rain gauge, funnel receives the rain water which is collected in a rectangular container. A float is provided at bottom of container. Its movement being recorded by pen moving on a recording drum attached by a clockwork, when the water level in container rises, so that the float touches top. The Siphon comes into operation and releases the water.

Ⓜ Weighing Bucket Rain-gauge :

→ The weighing bucket rain-gauge essentially consist of a receive bucket which receives rain, is supported by a spring or level balls or any other weighing mechanism. The movement of bucket due to its increase in weight is transmitted to the pen which traces the record on a clockwise driven chart.

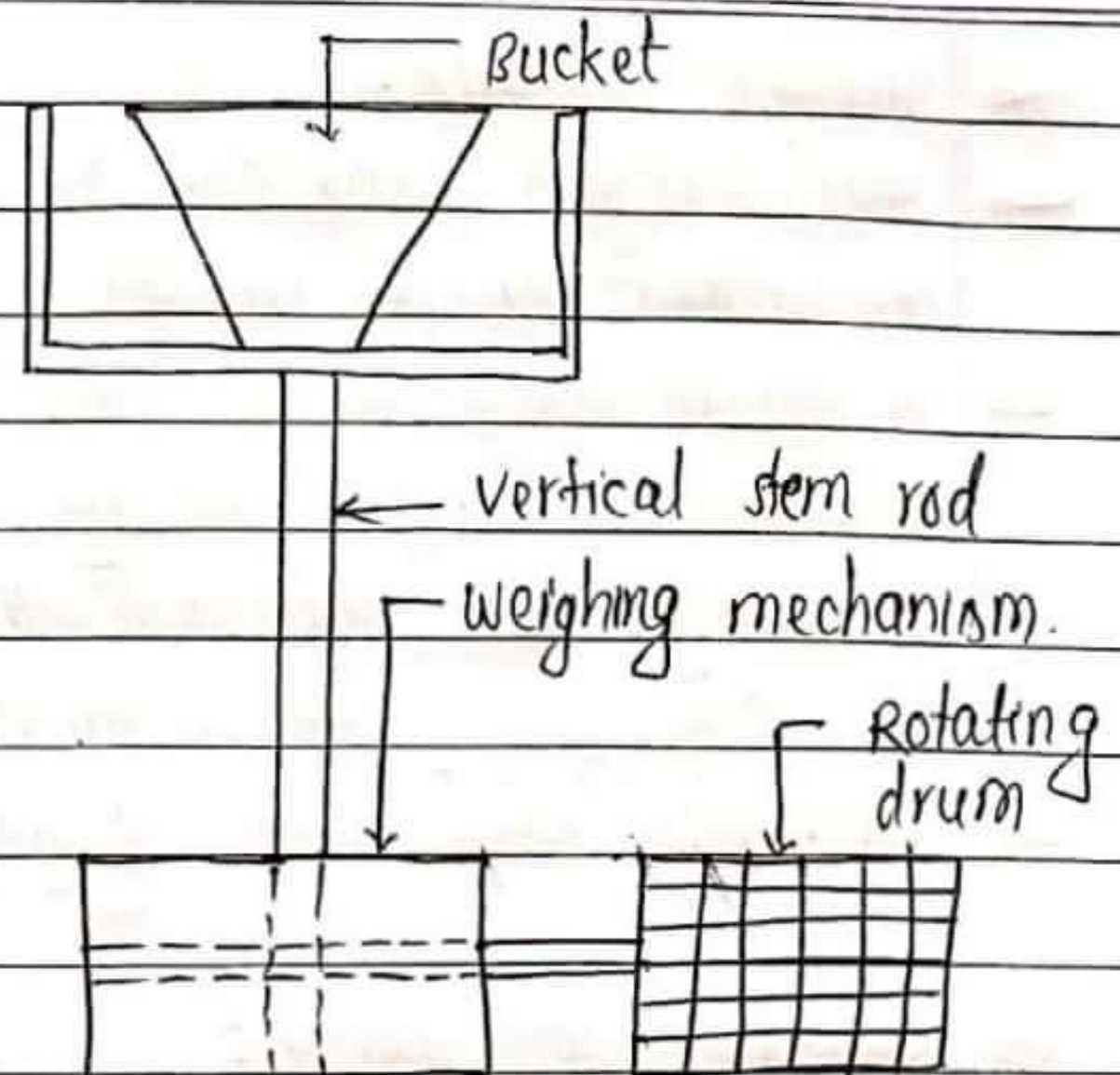


Fig: Weighing bucket rain guage

(2068)

Ⓜ Tipping bucket-type Rain-gauge :

→ The tipping bucket type rain gauge consist of 30cm diameter sharp edge receiver. At the end of receiver funnel is provided. A pair of bucket are provided under funnel in such a way that when one bucket receives 0.25mm of precipitation it tips discharging it connect to the reservoir bringing the other bucket under the funnel. Tipping of bucket completes the electric circuit causing the movement of pen to mark on clock driven revolving drum which carries a record sheet.

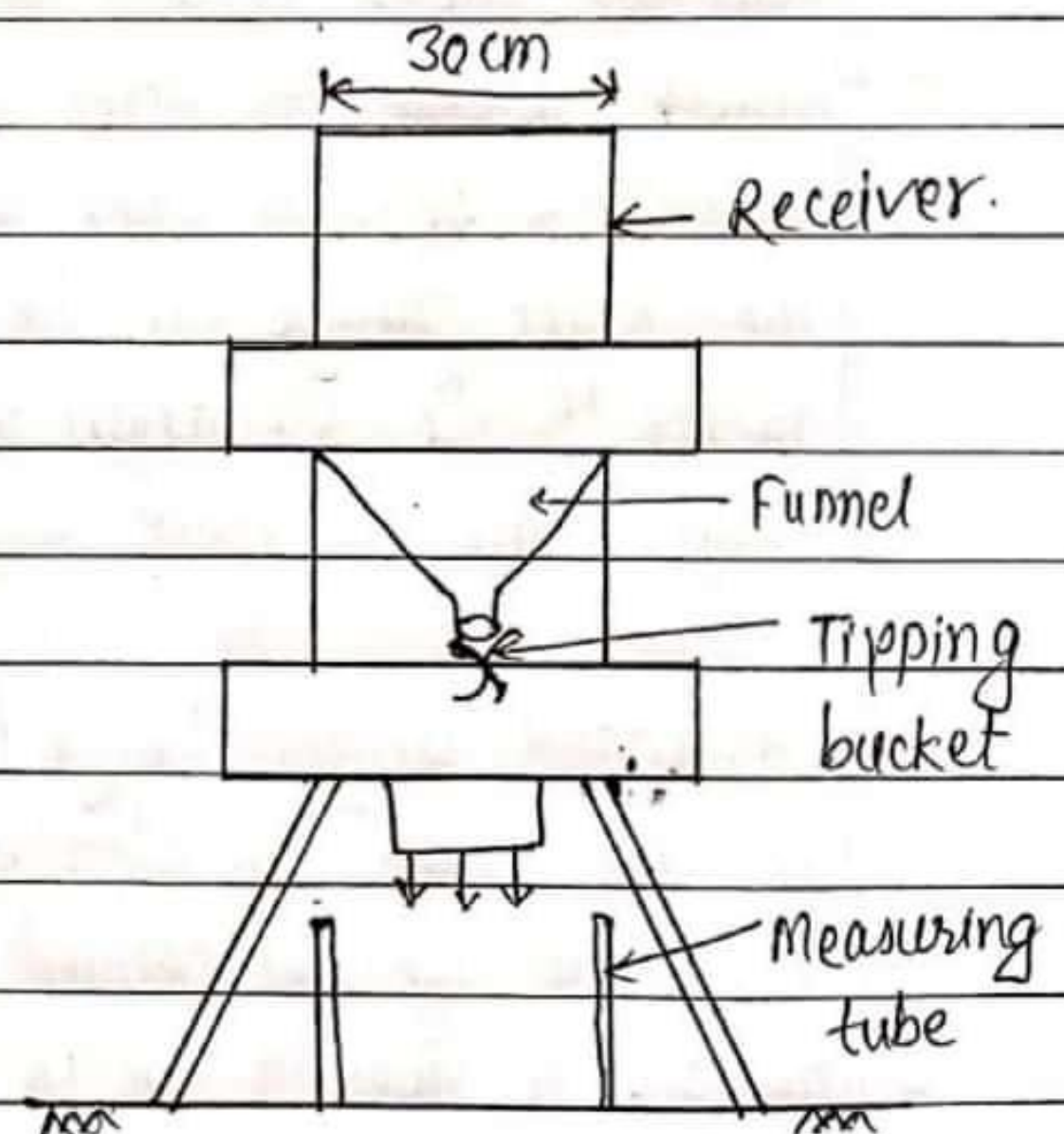


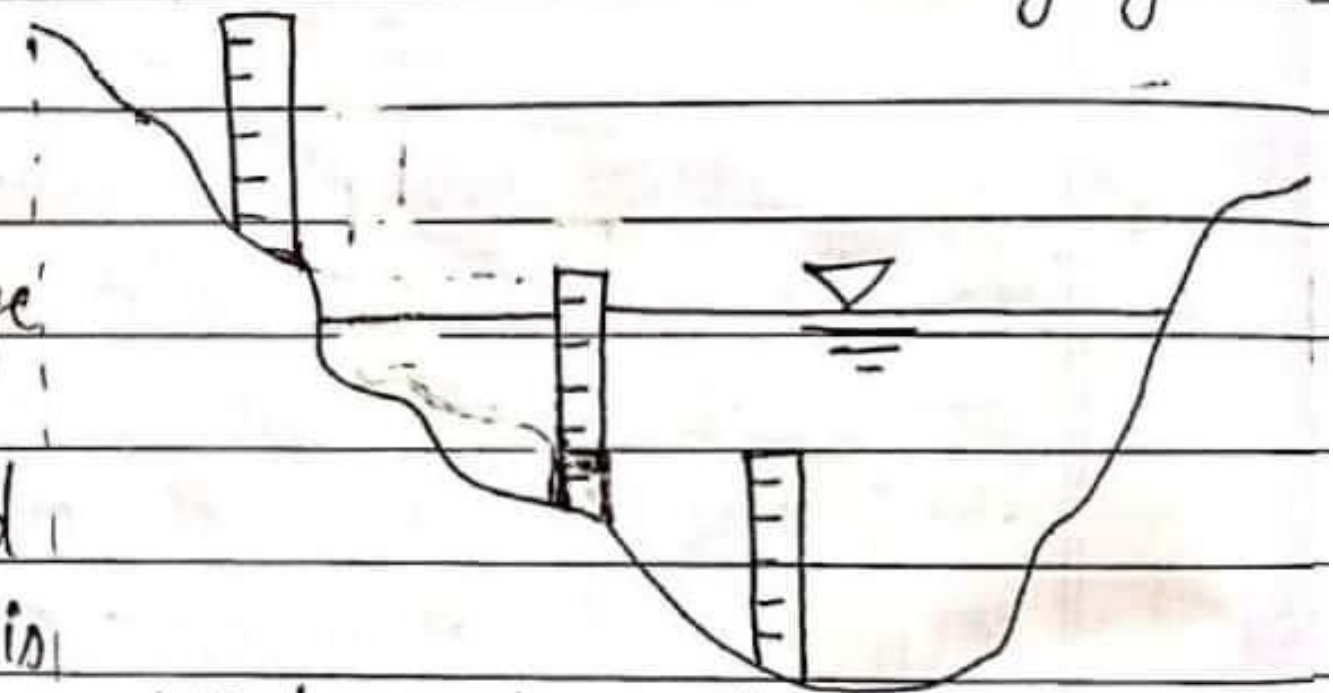
Fig: Tipping bucket type rain guage

Stream Gauging:

- ↳ When runoff joins the stream it becomes stream flow. The process of measuring a depth of stream is called stream gauging.
- ↳ A stream gauge consists instruments that measure and record the amount of water flowing in the river or stream, or its discharge. Generally, these measurements occur automatically every 15 minutes or more frequently in times of flooding.
- ↳ Generally used stream gauging are explained below:

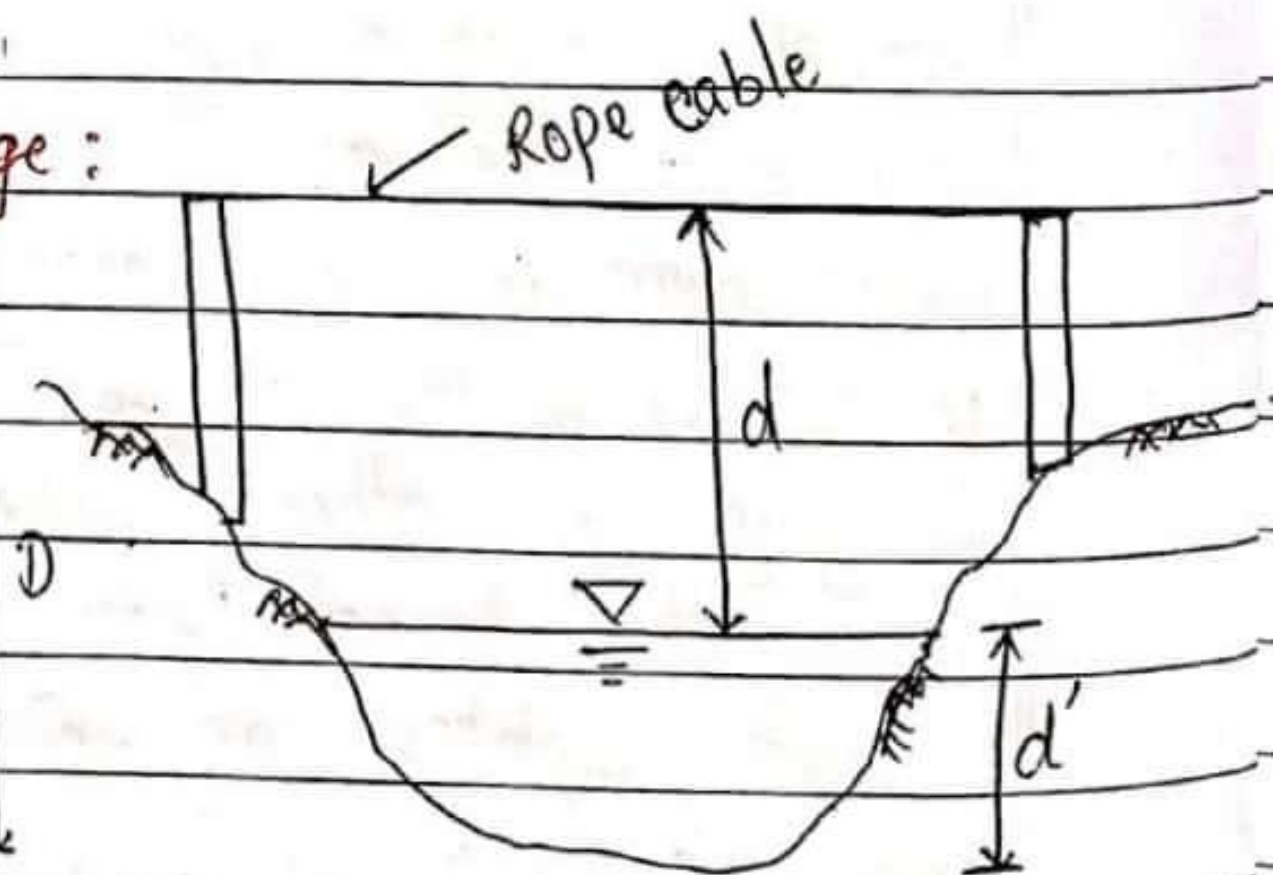
(a) Vertical Staff Gauge:

- ↳ The river stage is usually measured with a vertical staff gauge installed at river banks such that its lower portion is always under water. If there is a bridge aboutment or any other structure, the staff gauge can be attached to it. If the variation of stage is large, two or more gauging are installed at different levels.



(b) Suspended weight Gauge / Rope-gauge:

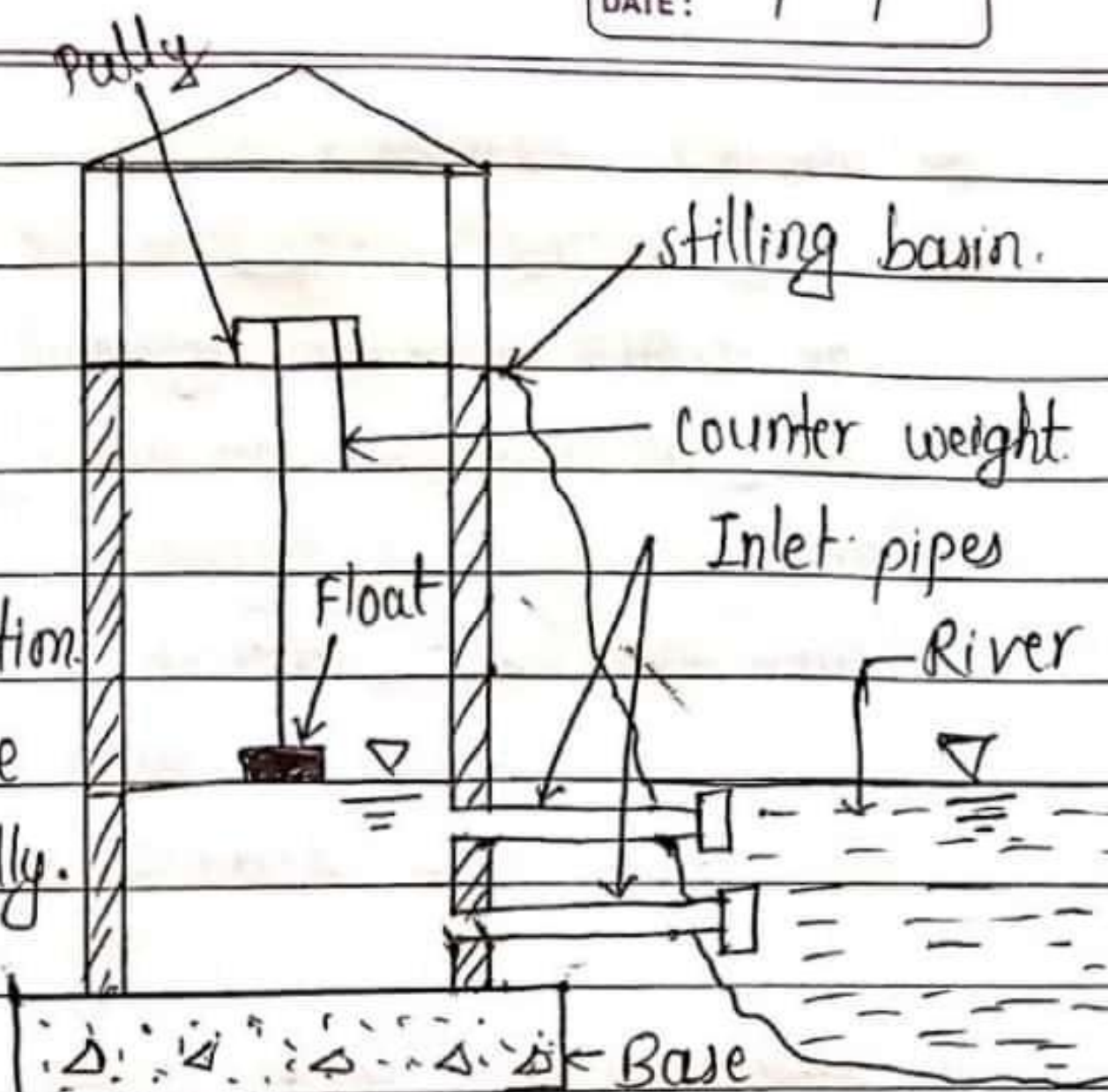
- ↳ The river stage can also be measured by suspended weight gauge. A weight is attached to a rope and it is lowered from a cable or bridge or any other fly over structures till the weight touch the water surface. The stage is obtained by subtracting the length of rope. This type of gauge can be used upto water depth of 25m.



$$\therefore [d' = D - d]$$

① Recording Type Gauge :

↳ Recording type gauge is more useful than manual gauges, as they provide continuous record of the river-stage. Figure shows a recording type rain gauge installation. It consists of a float attached to one end of the cable running over a pulley. A counter weight is attached to the other end of the cable. The gauge is installed in a stilling well



constructed for this purposes. There are two or three intake pipes at different levels to connect the river with stilling well. As the river level rise and the pulley rotates the movement of pulley attached a pen which moves on a chart traced around a clock driven drum attached with graph.

✱ Stream / River Flow (Discharge) measurement By Velocity Area Method :

↳ In area velocity method for the discharge measurement in an open channel like river, stream, the cross sectional area of the stream at a place is determined by obtaining area of flow and flow velocity. The discharge at a place can be calculated as:

$$\text{Discharge (Q)} = \text{Area (A)} \times \text{Velocity (V)}$$

● Area of flow Measurement :

↳ Area of flow is the cross-sectional area of the stream / river at a place. Commonly methods of using to calculate the area are:

① Segment Method

② Simpson's Rule or Method

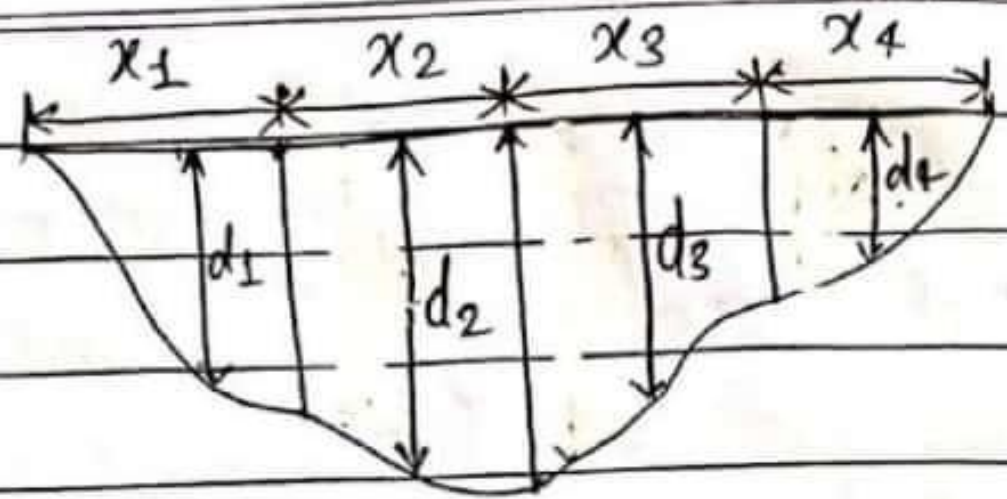
↳ One of the above method of area of flow calculation is adopted for area calculation and is taken for discharge measurement.

① Segment Method :

Let, $x_1, x_2, x_3, \dots, x_n$ are the length of each segment and $d_1, d_2, d_3, \dots, d_n$ are the average depth of segment. Then,

Area of flow = area of 1st segment + area of 2nd segment + $\dots$ + area of n^{th} segment.

$$\therefore [A = x_1 d_1 + x_2 d_2 + x_3 d_3 + \dots + x_n d_n]$$



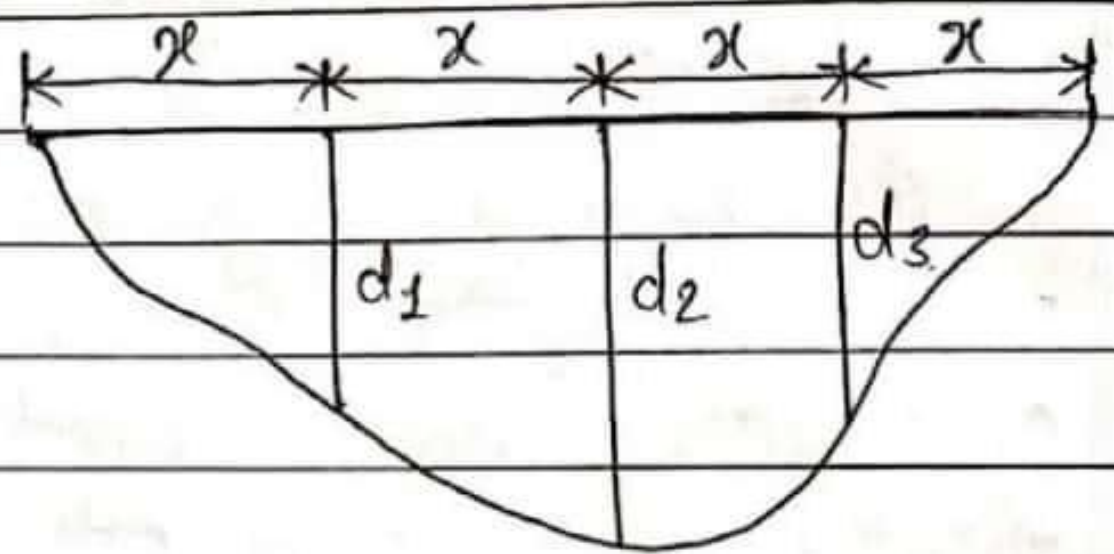
② Simpson's Method :

In this method, the entire width of river or stream is divided into even number of equal segment as shown in figure and depth are measured at the section. Let, x = length of each segment.

$d_1, d_2, \dots, d_n$ = depth at the end of each segment.

By, Simpson's Rule ;

$$\therefore \text{Area of flow (A)} = \frac{\text{length of segment}}{3} \left[(\text{1st depth} + \text{last depth}) + 2(\text{sum of odd depth}) + 4(\text{sum of even depth}) \right]$$



● Velocity of Flow Measurement :

Velocity of flow can be measured by :

① Floats

② Currentmeter

③ Pitot tube

① Floats :

Floats are simple instrument used for measuring the velocity of flow. Floats are of following types :

① Surface floats

② Velocity Rod floats

③ Double floats

① Surface floats:

↳ Surface float consist of a objects that can be floated on water surface such as half filled bottle, wooden floats, orange etc. The float is allowed to travel on a water surface for known distance and time taken to travel the distance is noted. The total distance is divided by time, which gives velocity of flow. Since, surface velocity is greater than mean velocity, so it is multiplied by a factor - 0.85 to obtain mean velocity.

② Double floats:

↳ The double float consist of two floats connected by string or wire. Both the floats are spherical in shape, one of the floats remain at the surface of water and other floats remain at the 0.6 depth. The double float gives the direct value of mean velocity. These floats are suitable for large stream and rivers.

③ Velocity Rods Float:

↳ These are wooden rods of 25mm to 50mm in diameter. The certain weight is attached at bottom to keep them nearly vertical in water. The weighted bottom is adjusted such that bottom of the rod reaches to

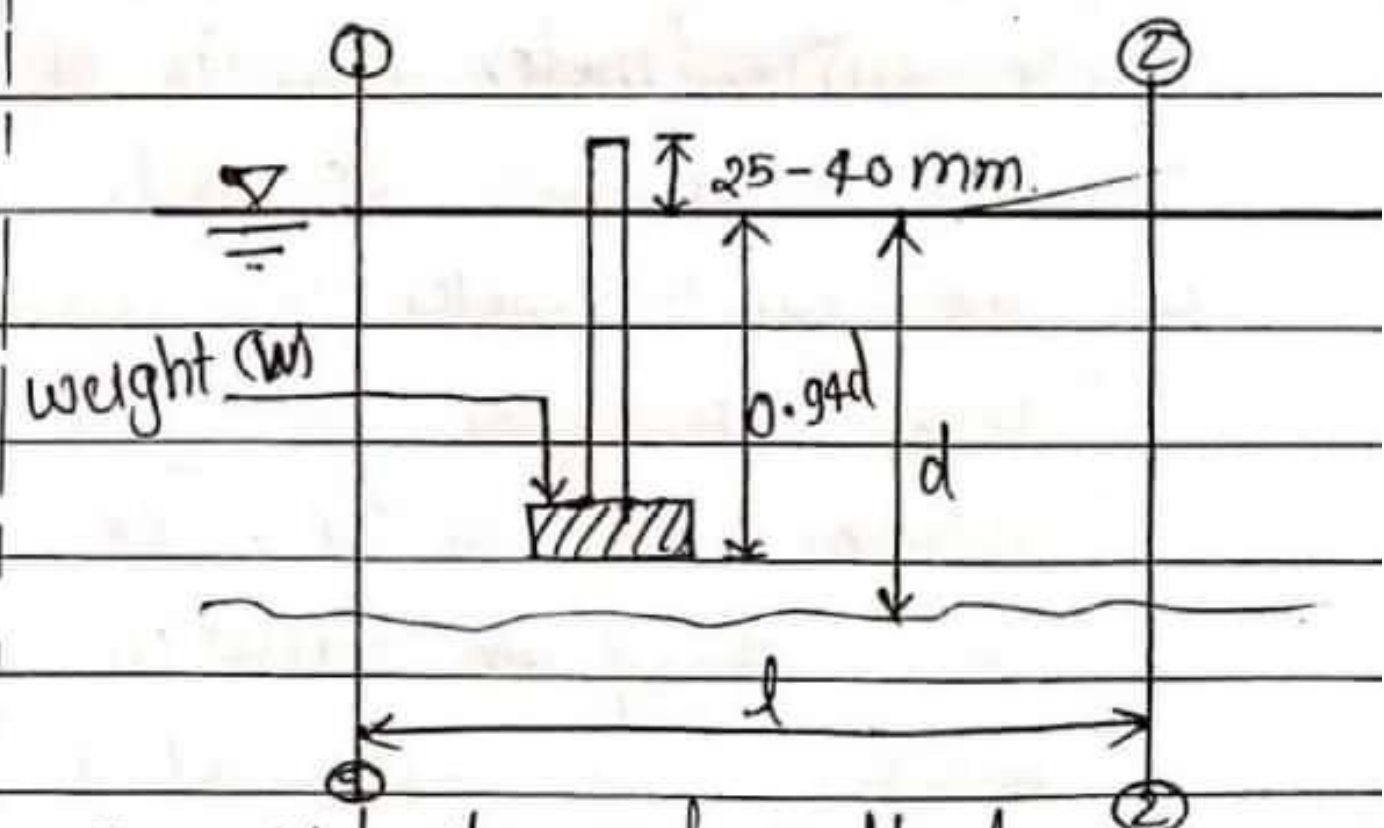


Fig: Velocity-rod method

a level of $0.94d$ from surface (where 'd' total depth of flow of water in river). As, in case of floats a rod is allowed to travel in known distance and time taken to travel the known distance is noted. The distance divided by time taken gives the velocity. Advantage of velocity rod over surface floats is these rod directly gives the mean velocity of flow.

① Currentmeter Method :

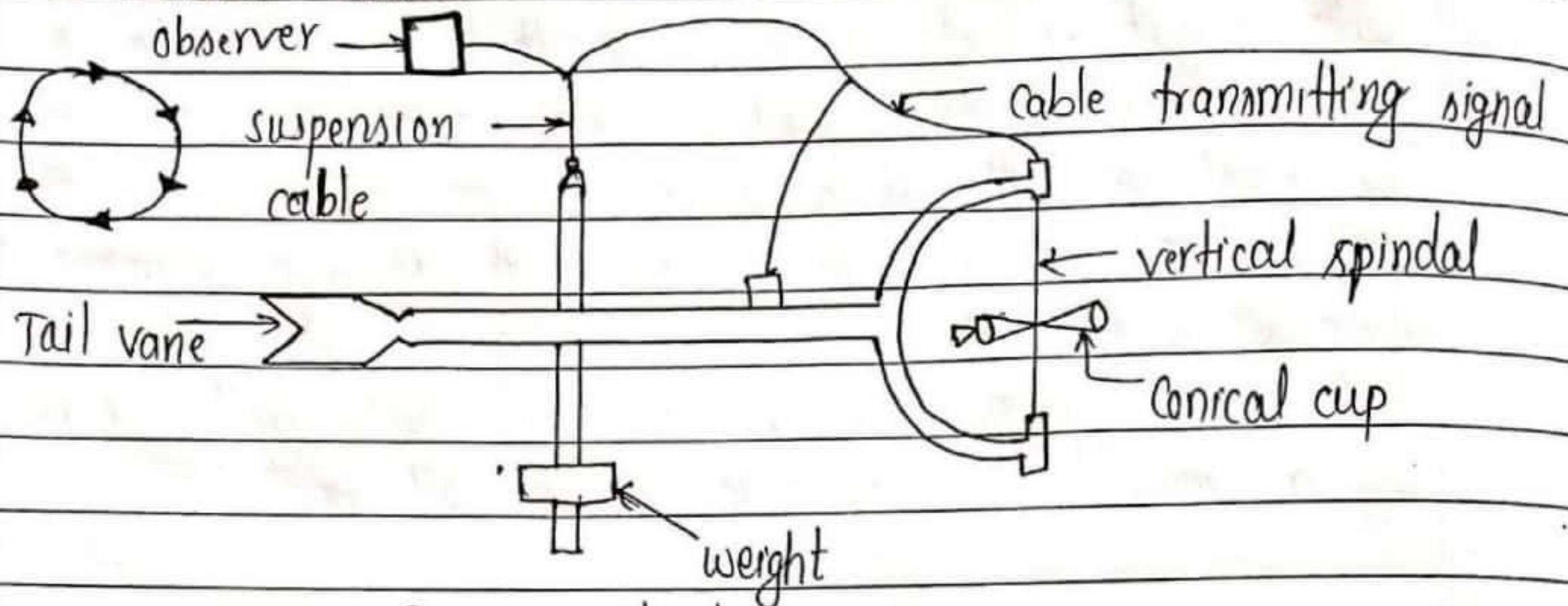


Fig: Currentmeter

→ A current-meter essentially consist of a rotating element which can be placed in flowing water at a point where velocity is required. The element rotate at a speed which depends on the velocity of flow of stream. By counting the number of revolution of rotating element in a given time, the velocity is obtained. This type of currentmeter consists of six conical cup which are mounted over a vertical spindal.

→ The current-meter is suspended by a cable at a required depth. In order to keep the cable in tension, a weight is attached at bottom. The tail vane helps to align the current-meter along the direction of flow. The currentmeter is held in water at a depth where velocity is required. The flowing water strikes the cup and the cups starts to rotating. The revolution of cup are transmitted to the observer. By mounting the number of revolution of cup in unit time, the velocity of the flow can be obtained by the following equation.

$$V = a + b \cdot N$$

Where ,

V = velocity of flow.

N = number of revolution

a, b = constants.

Computation of average rainfall over a Catchment Area (Basin):

↳ In order to compute the average rainfall over a basin or catchment area, the rainfall is measured at a no. of rain gauge stations suitably located in the area

↳ If a basin or catchment area contains more than one rain gauge station, the computation of average precipitation or rainfall may be done by the following methods:

1. Arithmetic average method
2. Thiessen polygon method
3. Isohyetal method

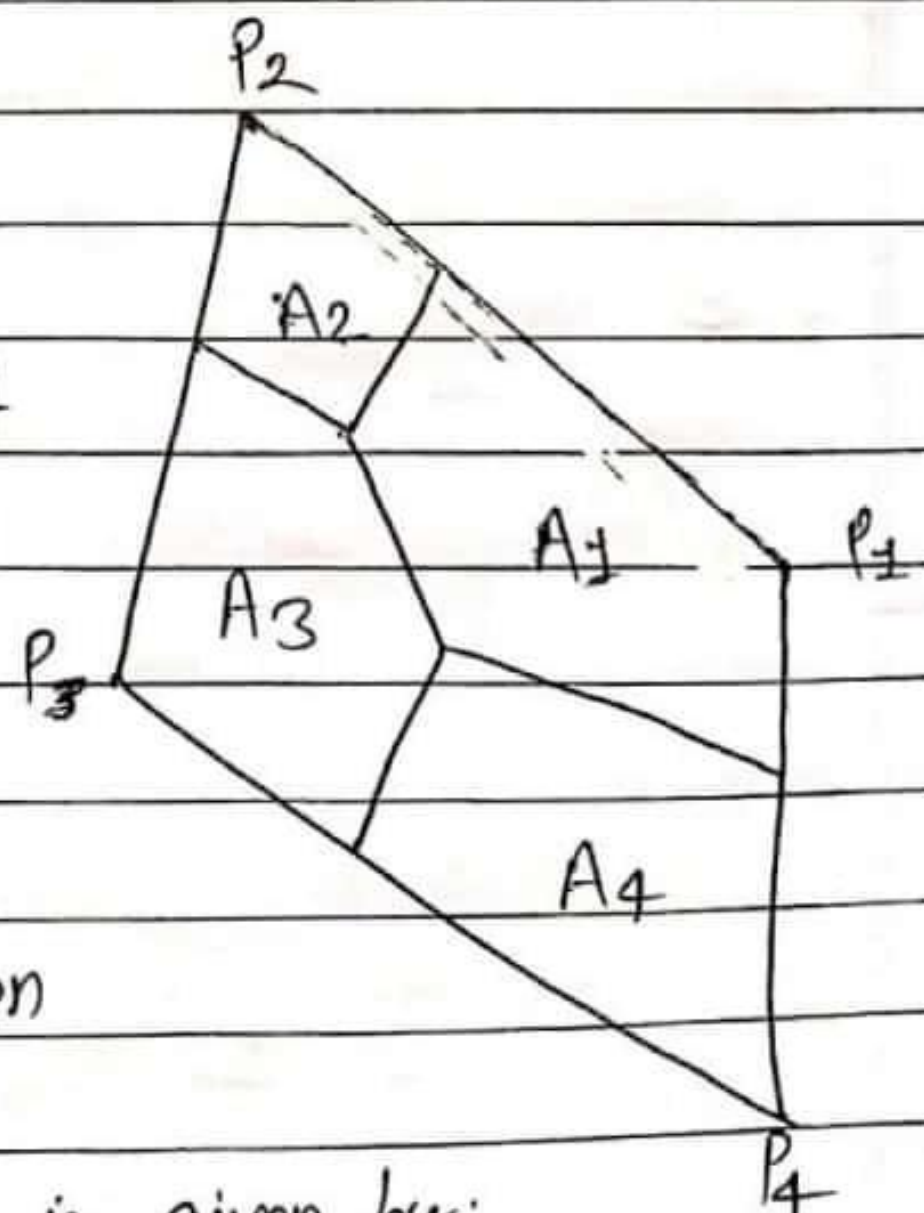
1. Arithmetic Average Method:

↳ It is used when rainfall measured at various stations in a catchment shows little variation. If, $P_1, P_2, P_3, \dots, P_n$ are the rainfall values in a given period in the N stations within a catchment, then value of mean precipitation P_{av} is given by:

$$P_{av} = \frac{(P_1 + P_2 + \dots + P_n)}{N}$$

2. Thiessen Polygon Method:

↳ In this method rainfall recorded at each station is given a weight age on the basis of its area closest to the station. If $P_1, P_2, \dots, P_n$ are the rainfall magnitude recorded by the stations 1, 2, ..., n respectively and, $A_1, A_2, \dots, A_n$ are the respective areas of the Thiessen polygon. Then,



Average Rainfall over the catchment is given by;

$$P = \frac{P_1 A_1 + P_2 A_2 + \dots + P_n A_n}{A_1 + A_2 + \dots + A_n} = \sum_{i=1}^n \frac{P_i A_i}{A}$$

where, $\frac{A_i}{A}$ is called weight age factor for each station.

3. Isohyetal Method:

→ Isohyets are the contours of equal rainfall. In the isohyetal method the catchment area is drawn to scale and the rain gauge stations are marked. If $P_1, P_2, P_3, \dots, P_n$ are the values of isohyets and $A_1, A_2, A_3, \dots, A_n$ are the inter isohyets areas respectively. Then, mean PPT over catchment area A is given by:

$$P = \frac{A_1 (P_1 + P_2)}{2} + \frac{A_2 (P_2 + P_3)}{2} + \dots + \frac{A_n (P_{n-1} + P_n)}{2}$$

A

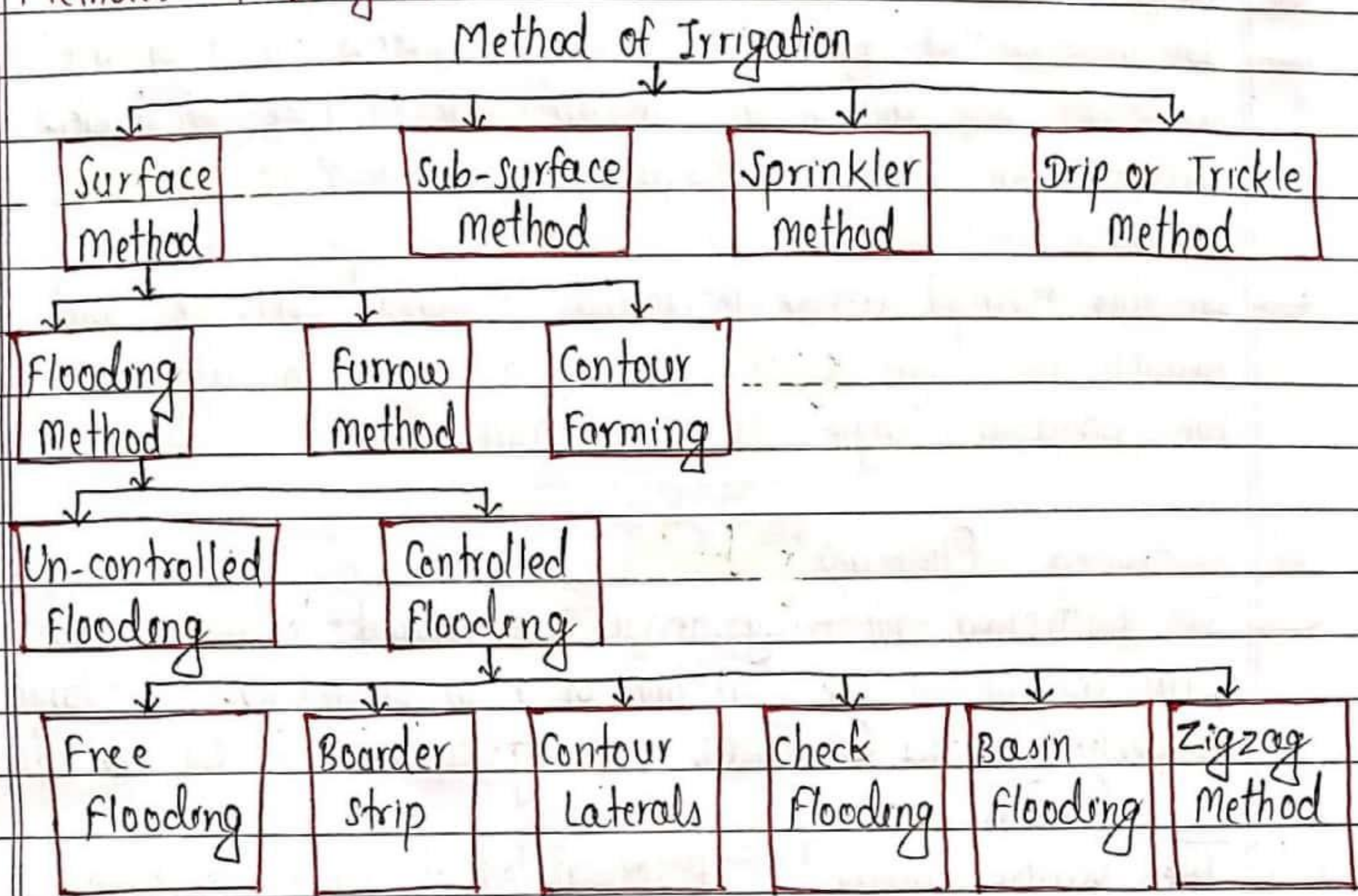
→ This isohyetal method is the most elaborate and accurate than other methods.

Unit-4 Methods of Irrigation

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Methods of Irrigation:



Surface Irrigation:

↳ The irrigation water which is flow above the ground surface and application of water by flooding or gravity action to the crop is known as surface irrigation method.

↳ It is the most common method of irrigation throughout the world.

① Flooding Method:

↳ It consists of opening water channel in a plot or field so that water can flow freely in all directions and cover the surface of land in a continuous sheet.

↳ It is further sub-divided into two types:

⑥ Uncontrolled (wild) Flooding

⑦ Controlled Flooding

④ Uncontrolled Flooding:

- ↳ In uncontrolled flooding, water is applied to unprepared field without any control in the direction of flow of water. It is useful when there is maximum amount of water and inexpensive water.
- ↳ In this method water is forced to spread over the land during season of high stream flow. The water is allowed to flow the natural slope of the land.

⑤ Controlled Flooding:

- ↳ In controlled flooding, water is applied to the prepared land with control in the direction of flow of water. The land is properly graded (leveled) and agricultural fields are divided into small units by levees.
- ↳ The various methods of controlled flooding are explained below:

① Free Flooding:

- ↳ Free flooding is the little bit improved method of uncontrolled flooding. In this method fields are divided into large plots and the water is allowed to spread on whole of the field, so as to give time to time to the soil absorb sufficient amount of water.
- ↳ This is suitable method for an area where cheap and abundant supply of water is available.
- ↳ This is a common method of irrigation where water may be applied as a continuously.

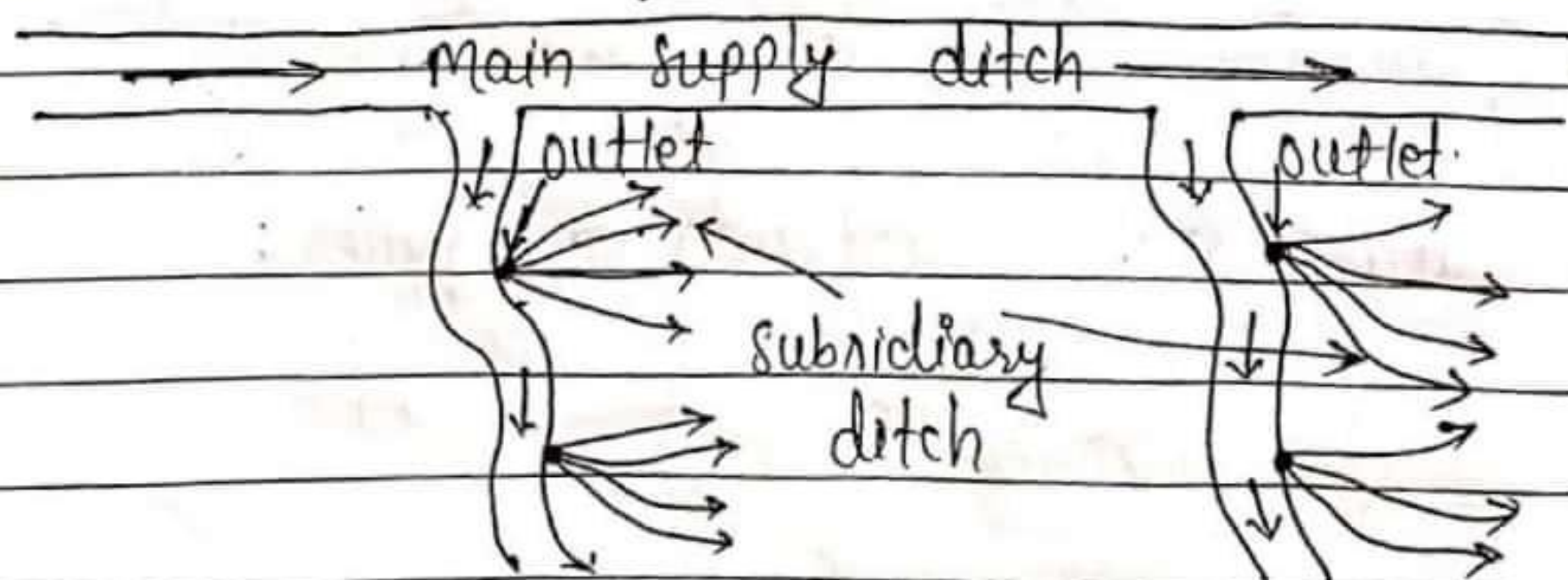


Fig: Free flooding.

Boarder Strip Method :

- The field is divided into a series of strips '10-20 m' wider and '100 m' to '300 m' length. These strips are divided by low levees called boarder.
- To irrigate, water is supplied on supply ditches and it enters each strips through a controlled gate.

Advantages :

- ① It is the best method to irrigate close growing crops.
- ② Less labor requirement to irrigate the field.
- ③ Operation of this system is easy and simple.
- ④ Uniform and high water application efficiencies if the system is properly designed.

Dis-advantages :

- ① Large irrigation streams are required.
- ② More labor is required for the levelling of field.
- ③ Wastage of land due to too many ridges.

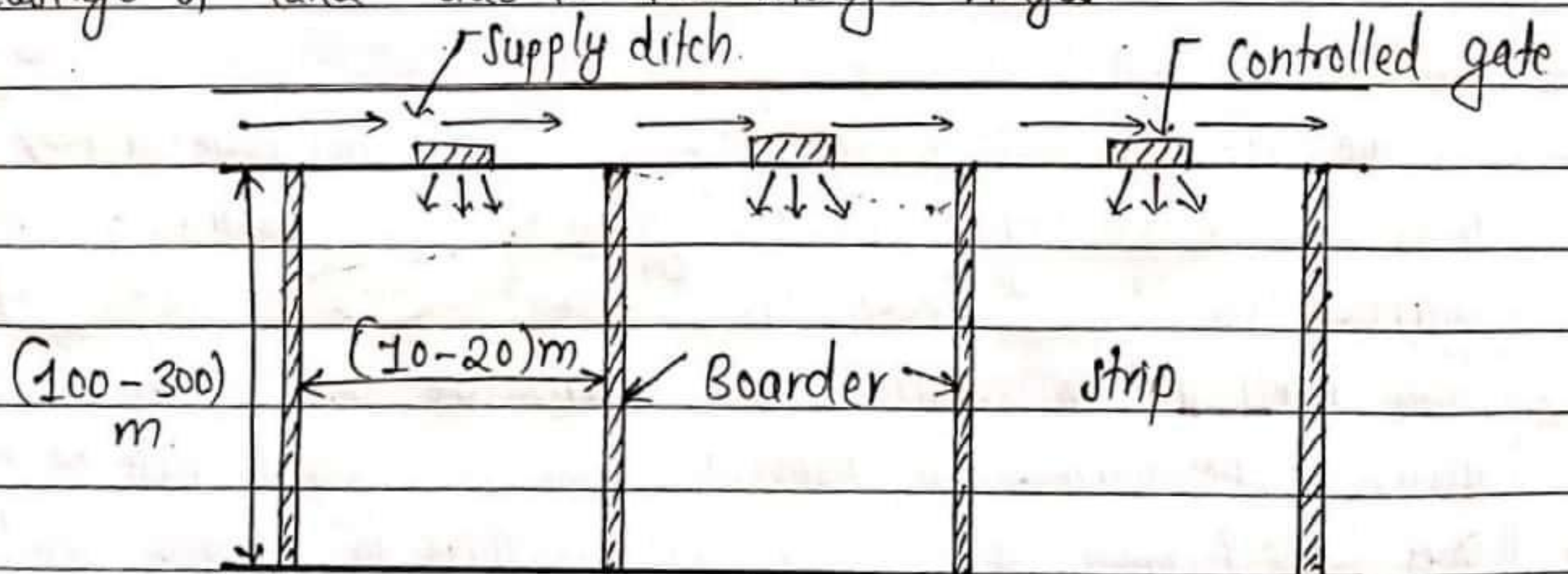


Fig: Boarder-strip method

- This method is suitable when the area is at level with the gentle slope.

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(iii) Contour Lateral Method:

- ↳ It is used for irrigation steeper terrain. In this method a number of small contour laterals (drains) are constructed. The spacing of these drains depend upon the gradient of field between adjacent ditches spacing is less for steep and more for flat slope.
- ↳ This is a special case of free flooding in which the field channels or laterals are aligned approximately along the contour lines.

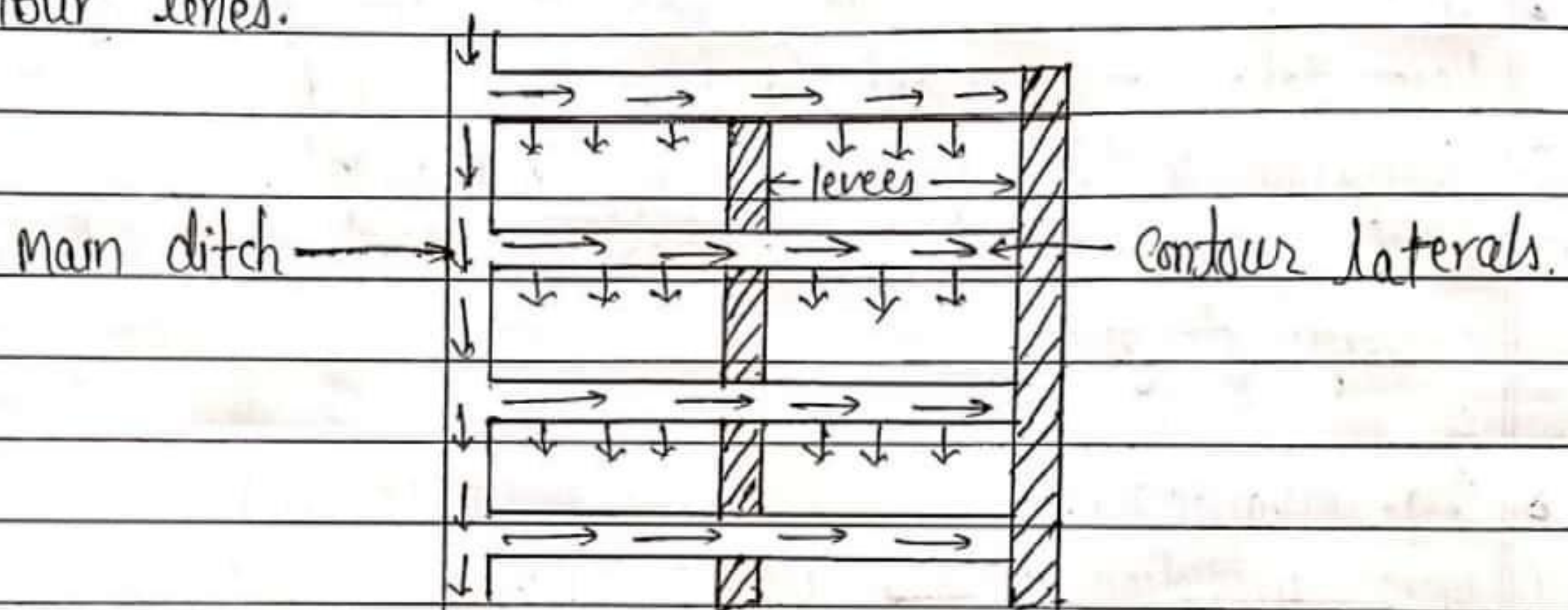


Fig: Contour Laterals

(iv) Check Flooding:

- ↳ In the check flooding, a large stream discharge water supply into a relatively levelled ground. This ground or plot is surrounded by checks or levees.
- ↳ This method is suitable for permeable soil which must be quickly percolates. To prevent from maximum rate of percolation and deficiency of water, this method is mostly used.

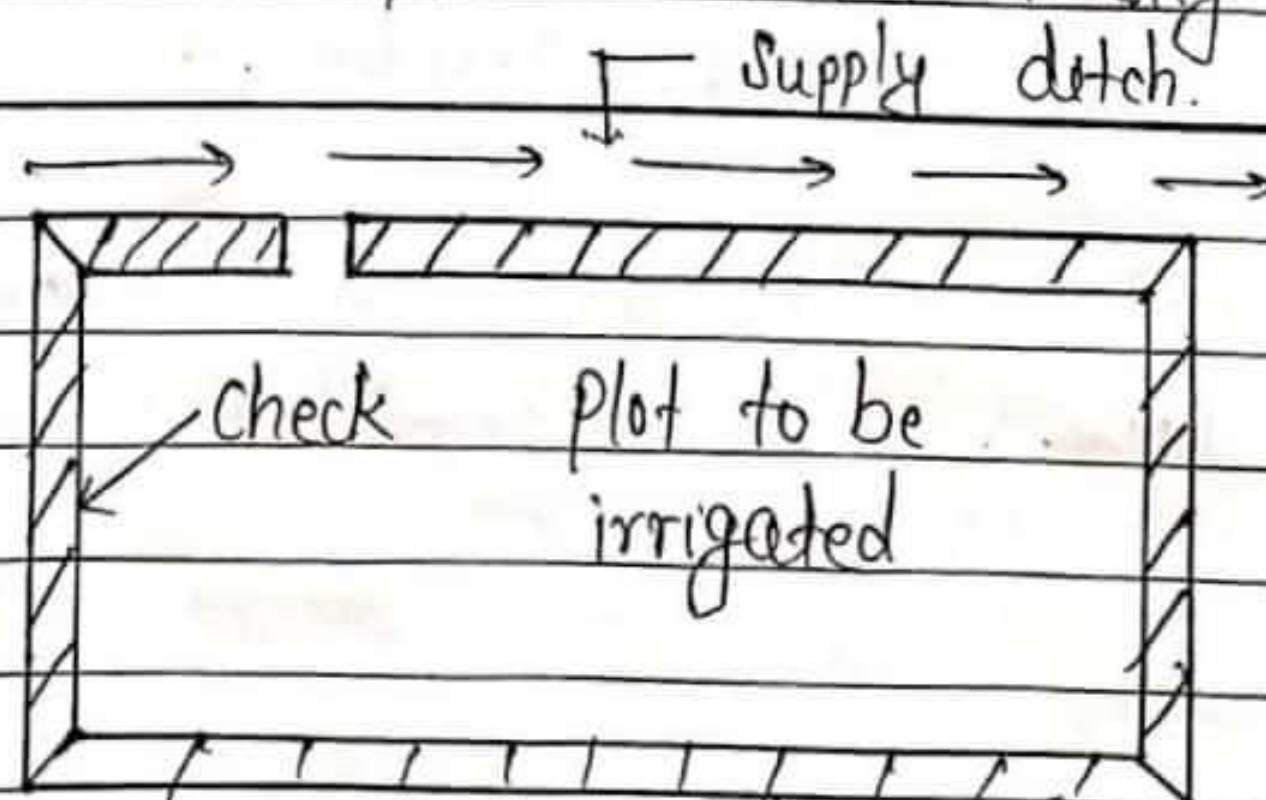


Fig: Check flooding

⑥ Basin Flooding :

- ↳ It is special form of checked flooding adopted to orchards.
- ↳ The basins are formed for each tree.
- ↳ Water is supplied to the basin through supply ditch.

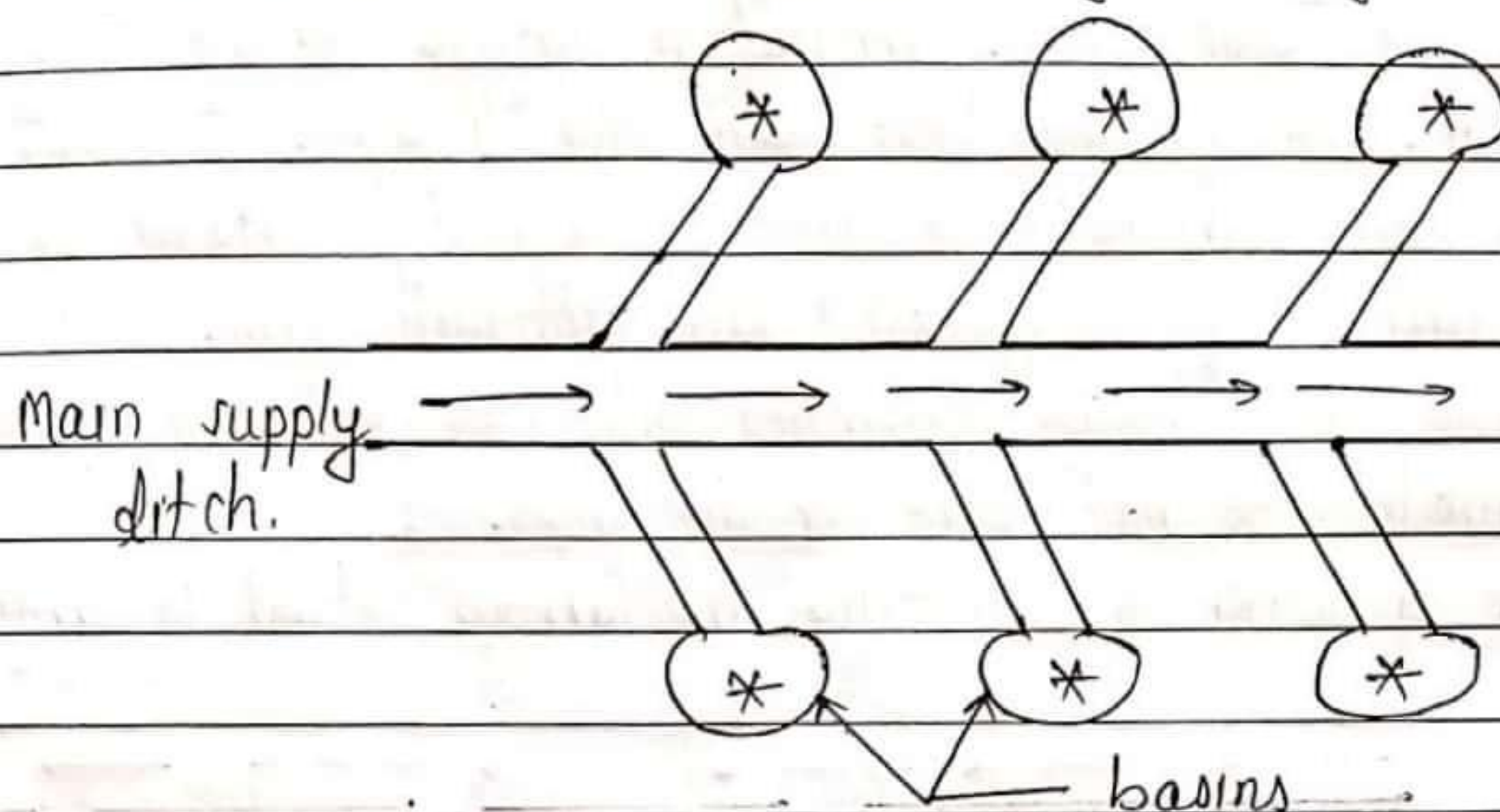


Fig: Basin Flooding (Plan).

⑦ Zigzag Method :

- ↳ In this method, the agricultural area is sub-divided into small plots by low bunds in a zigzag manner.
- ↳ It is the special type of flooding where water takes circulation of zig-zag route.
- ↳ The water is supplied to the plots from the field channel through the openings. It is suitable for plane ground.

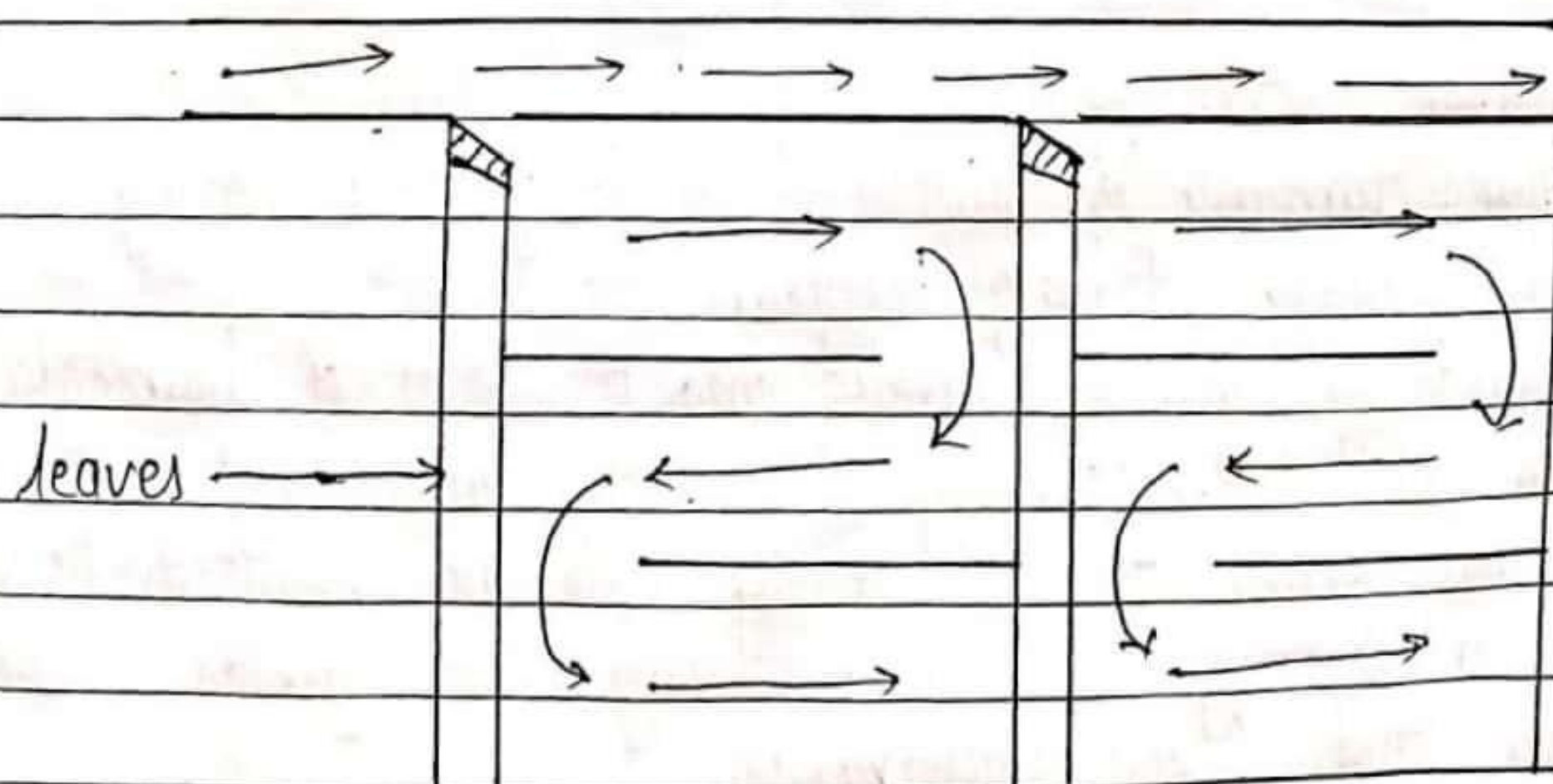


Fig: Zig-zag method

② Furrow Method:

- ↳ The furrow method of irrigation is very much used for row crops like maize, sugarcane, cotton, potatoes, tobacco etc. Furrow spacing for the row crops is determined by the proper spacing of plant row. Irrigation furrow being provided for each row. The spacing kept generally 1-2 m.
- ↳ Furrows are narrow field ditches, excavated between rows of plants and carry irrigation water through them.
- ↳ Water from the furrows infiltrates into the soil and spreads laterally to saturate the root zone of the crops.
- ↳ Wastage of water is minimum in furrow method of irrigation.

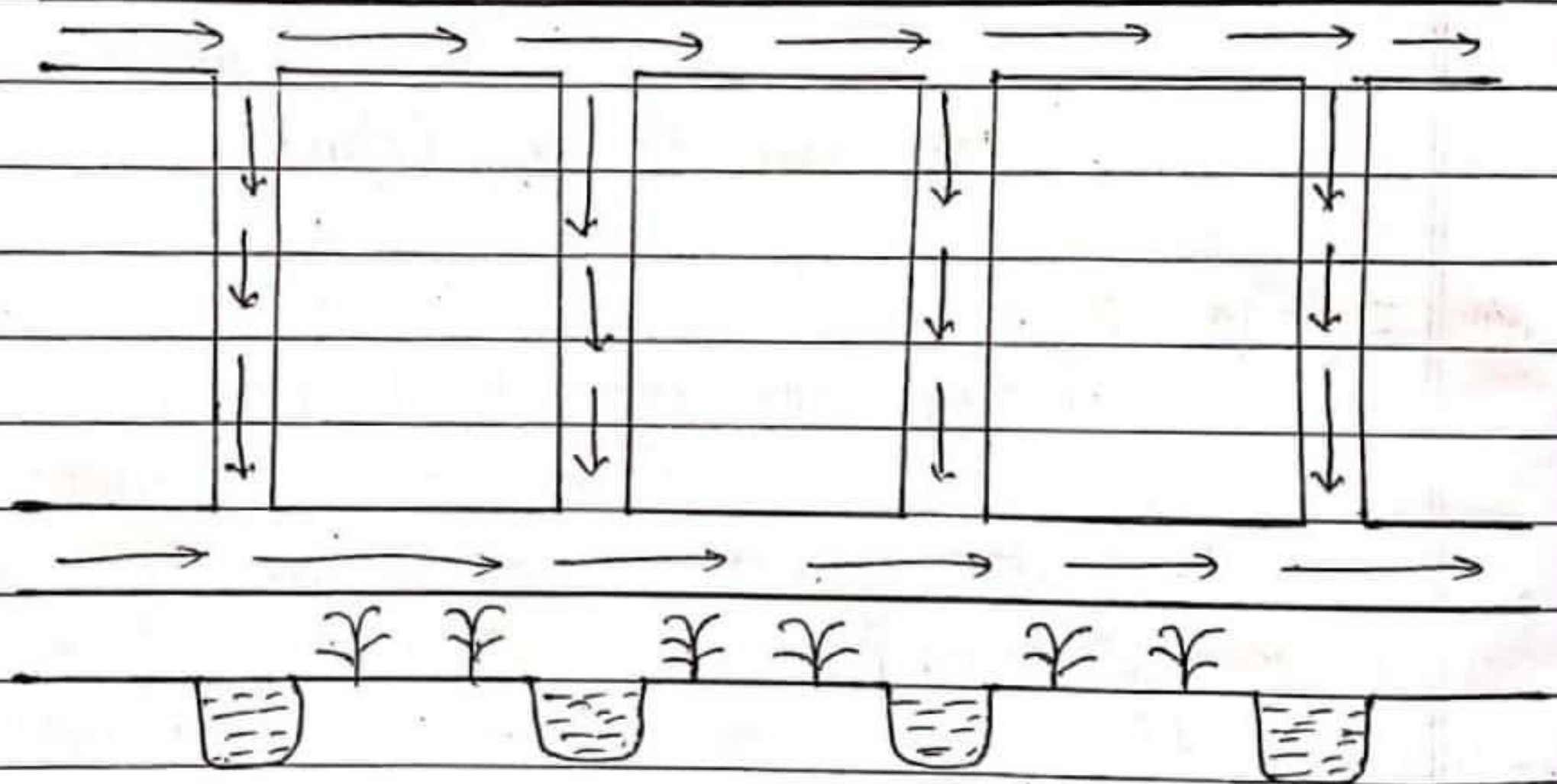


Fig: Furrow Method.

③ Contour Farming:

- ↳ Contour farming is practiced in hilly area having steeper slopes which quickly falling contour.
- ↳ The plot or area is divided into a series of horizontal curved strips called terraces. Small bunds are constructed at the end of each terrace to hold water upto the required height.
- ↳ Contour farming, besides producing crop yields, helps in mitigating flood and soil conservation.
- ↳ The irrigation water is stored in some depression.

- ↳ Before starting contour farming on land which is not banded, contour guide lines are established first.

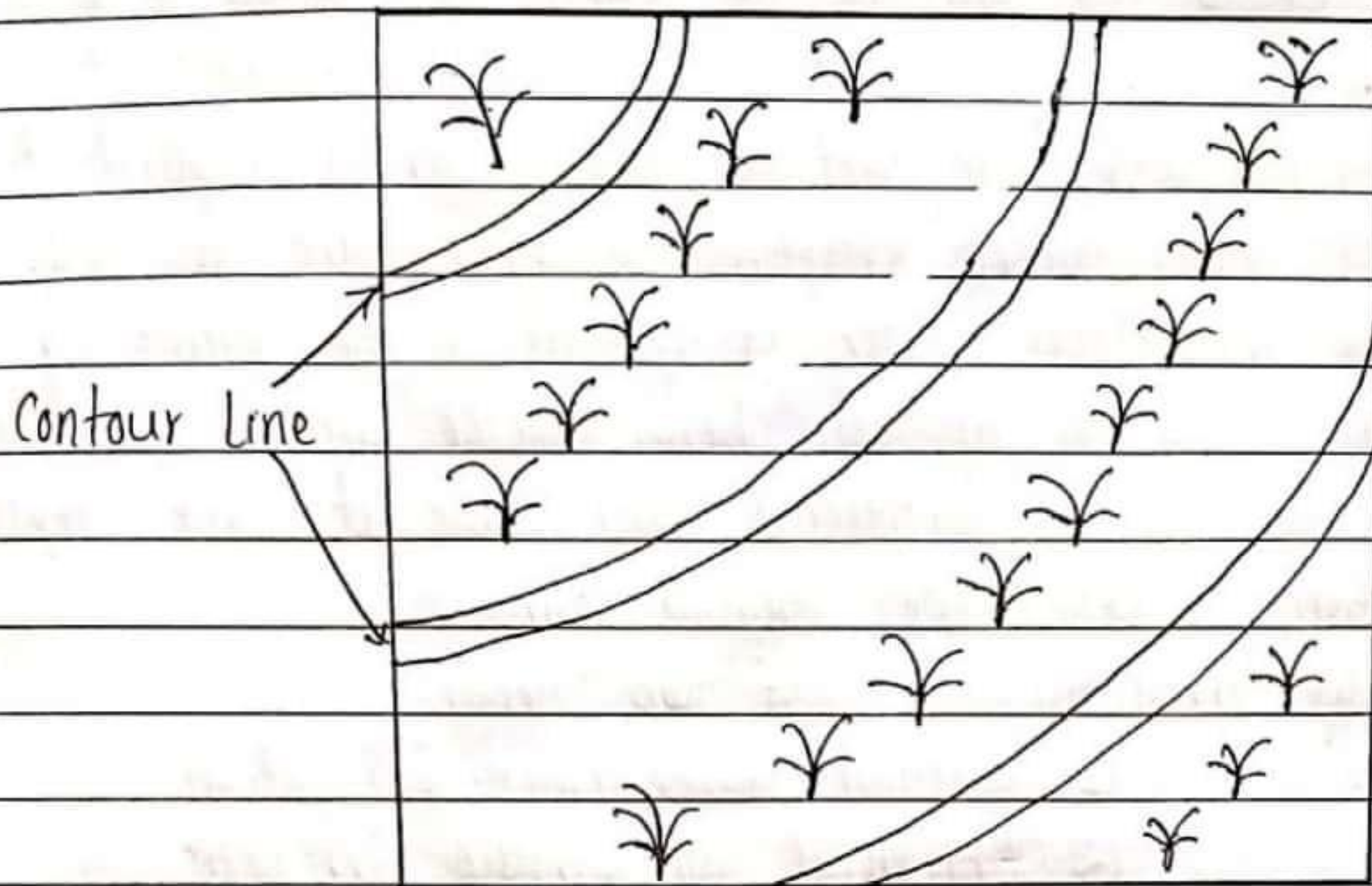


fig: Contour Farming

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Imp Lift Irrigation:

- ↳ Lift irrigation is the process of lifting water normally from underground sources and sometimes from surface sources by pump i.e. mechanical power or man power and then directly this lifted water is supplied to the agricultural field. In remote villages, if electricity is not available, water is lifted by hand pump.

● Merits of Lift Irrigation:

- ↳ Farmers can supply water to the crop field according to their needs, hence there is no possibility of over irrigation.
- ↳ Water table is lowered considerably in lift irrigation, so there is no possibility of water logging as in surface irrigation.
- ↳ As the loss of water is low, duty of water is very high.
- ↳ Maintenance cost of lift irrigation is lower than that of flow irrigation.

Sub-Surface Irrigation:

- ↳ The supplying of water directly to the root zone of the crops inside or below the surface of earth is called sub-surface irrigation.
- ↳ Water does not wet soil surface and water is applied directly to the root zones, hence evaporation losses are avoided.
- ↳ Sub-surface irrigation water is applied to the plant by capillary action. The water is applied beneath the ground by creating and maintaining an artificial water table at some depth, usually 30 to 75cm, below the ground surface.
- ↳ Sub-surface irrigation is of two types:
 - ① Natural Sub-surface Irrigation
 - ② Artificial Sub-surface Irrigation.

① Natural Sub-Surface Irrigation :

- ↳ It is suitable for the place where water table is high and within the capillary reach of root zone of crops. The water table is changed by seepage from irrigation canals.
- ↳ Leakage water from canal, reservoir goes underground by gravity flow with flow line inside soil and during passage through sub-soil, it can be irrigate crops on surface by capillary action.
- ↳ When under ground irrigation is achieved by natural process, it is called natural sub-surface irrigation.

② Artificial Sub-surface Irrigation :

- ↳ In this system, open jointed or perforated conduit is artificially laid below the soil to supply water to the crops by the capillary action.
- ↳ In this method, holes are made in the pipe which are laid down below the surface of the earth to supply water in the root zone of the crops.
- ↳ This type of irrigation is very costlier.

Sprinkler Irrigation:

↳ In this method, water is applied in the field similar to the natural rainfall. In this method water is applied to the field in the form of spray. It consists of pumping unit, pipe network and sprinklers.

↳ Pump lift water from water source and supplies it to lateral pipelines through a main pipeline. It is kind of artificial rain and gives good effect. It is used for all type of soil and different topographical slope.

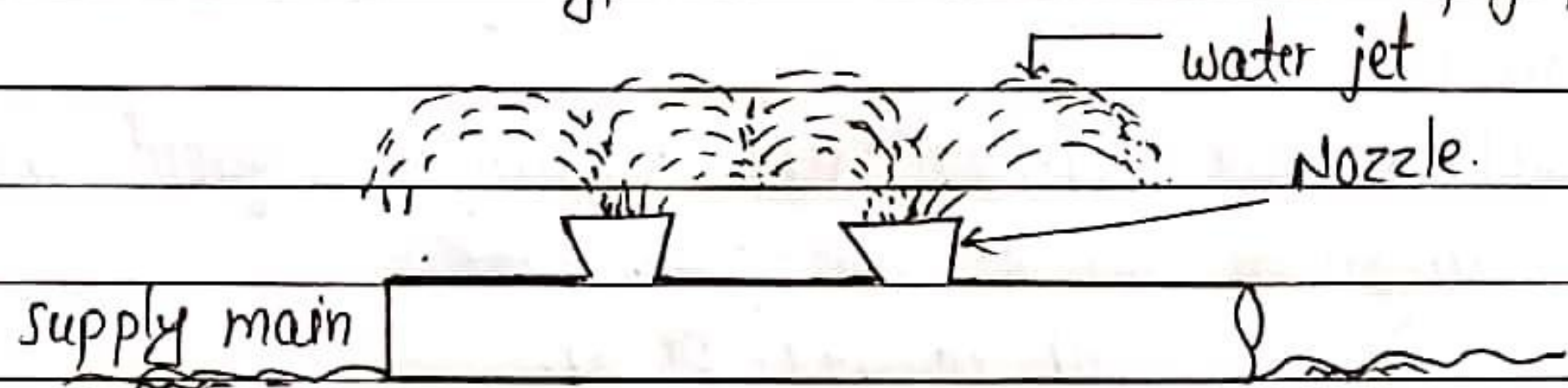


Fig: Sprinkler Irrigation.

• Favourable Conditions for Sprinkler Irrigation:

↳ The conditions favourable for the adoption of sprinkler method are as follows:

- Excess slope
- Irregular topography
- Erosive soil
- Soil is excessively permeable or impermeable.
- Depth of soil is shallow over gravel or sand.

• Advantages of Sprinkler Irrigation:

↳ The advantages of sprinkler irrigation are as follows:

- Erosion can be controlled.
- Uniform application of water is possible.
- Controlled irrigation process.
- No land preparation is required.
- Crop damage from frost action can be reduced.
- Time and amount of fertilizer can be controlled.
- Small streams of irrigation water can be used efficiently.

• Dis-advantages of Sprinkler Irrigation:

↳ The dis-advantages of sprinkler irrigation are as follows:

- Wind effect.
- For constant supply of water, nozzle is required.
- Clean water needed
- In the areas of high temperature and high wind velocity, the considerable evaporation losses of water may take place.
- Initial cost of system is very high, and system requires high technical skills.
- Not suitable for the crops requiring frequent and larger depths of irrigation such as jute, rice.
- It requires larger electrical power.
- Heavy soil with poor intake can not be irrigated efficiently.

✱ Drip Irrigation [Trickle Irrigation] Method:

↳ Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize the evaporation.

↳ This system involves laying of system of heads, mains, sub-mains, laterals and drop nozzles. Water oozes out of these small drip nozzles uniformly and at very small rate, directly into the plants roots area.

• Suitability of Drip Irrigation:

- ↳ It is suitable where shortage / deficiency of water is maximum.
- ↳ In the region of high temperature, high wind velocity and low humidity, drip irrigation is most suitable.

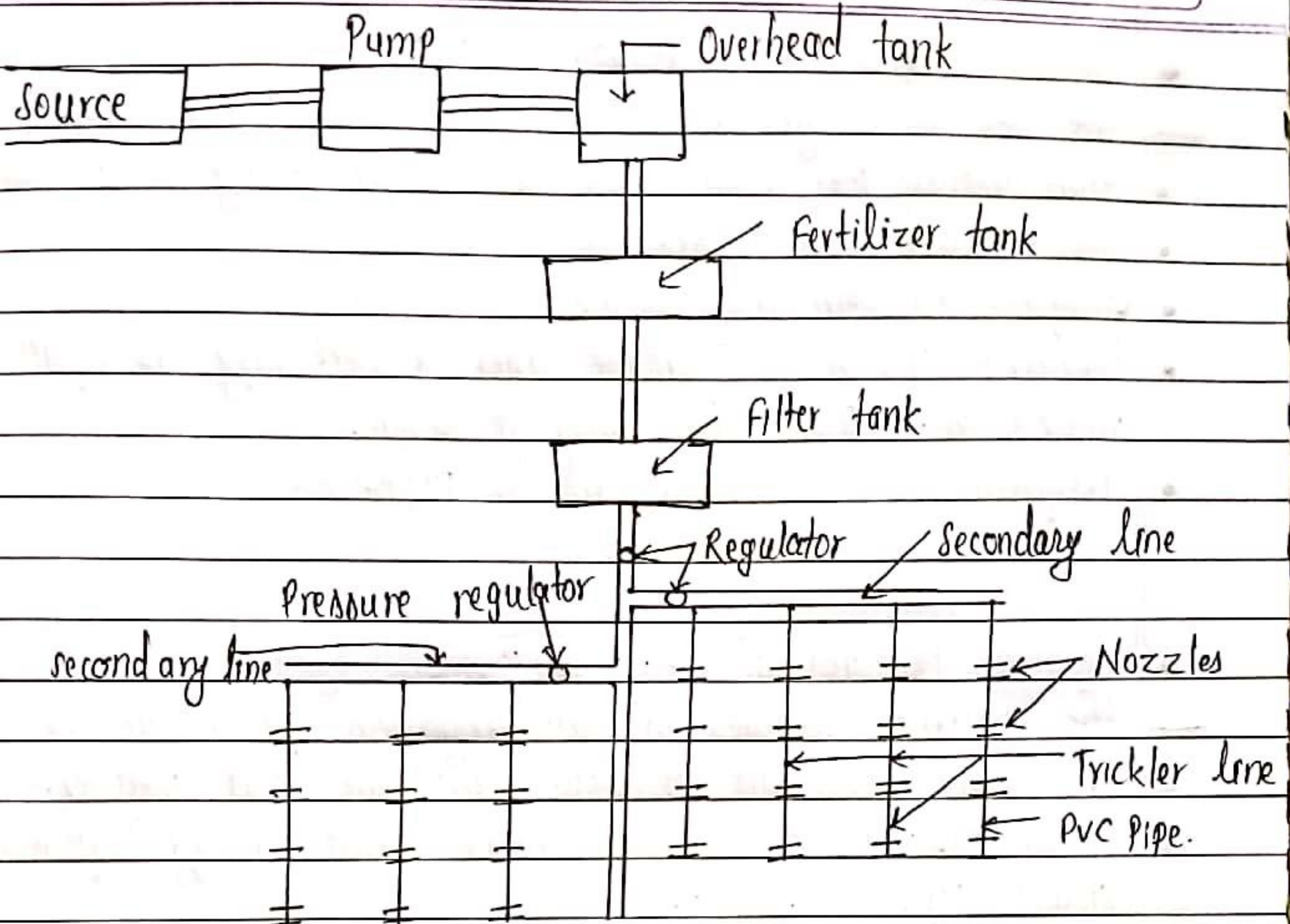


Fig: Drip / Trickle Irrigation.

• Advantages of Drip Irrigation:-

↳ The advantages of drip irrigations are as follows:

- It requires less amount of water.
- Excellent control of water is possible.
- There is no chances of water logging.
- High yield can be obtained.
- Evaporation from soil is reduced to minimum.
- Reduces labor cost.
- Nutrients can be applied directly to plant roots by adding liquid fertilizer to the water.
- It can be used for uneven topography also.
- Erosion of soil does not take place.
- No water is available for weeds and hence weeds are grown in less number.

• Dis-advantages of Drip Irrigation:

↳ The dis-advantages of drip irrigation are as follows:

- High initial i.e. setup cost because of costly setup materials.
- High maintenance cost.
- Clogging problem may arise.
- Frequent change of trickle lines is necessary as spacing of nozzle is different for types of crops.
- Frequent replacement of plastic pipe.

• Salient Features of Drip Irrigation System:

↳ The salient features of drip irrigation system are as follows:

- (i) The pipes used are of low pressure and cheaper.
- (ii) It operates on low pressure hence least energy requirement and small capacity pump.
- (iii) It has highest water application efficiency (90%).
- (iv) It requires low initial cost and operation costs.
- (v) It does not required land levelling before irrigation.
- (vi) It is adoptable to all climatic variations.
- (vii) It is not affected by windy conditions.
- (viii) The system is free from any movable components.

Unit-5 Diversion Head Works

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Definition:

→ All the works, which are constructed at the head of the canal, in order to divert the river water to the canal, so as to ensure a regulated continuous supply of silt free water with a certain minimum head into the canal are known as diversion head works.

→ The function of diversion headworks are:

- It raise the water level on upstream side.
- It regulates the supply of water into canal.
- It controls the entry of silt into canals.
- It provides some pondage creating small pond.
- It controls the fluctuations in river.

V.IMP # Layout, Components and their functions:

• Layout:

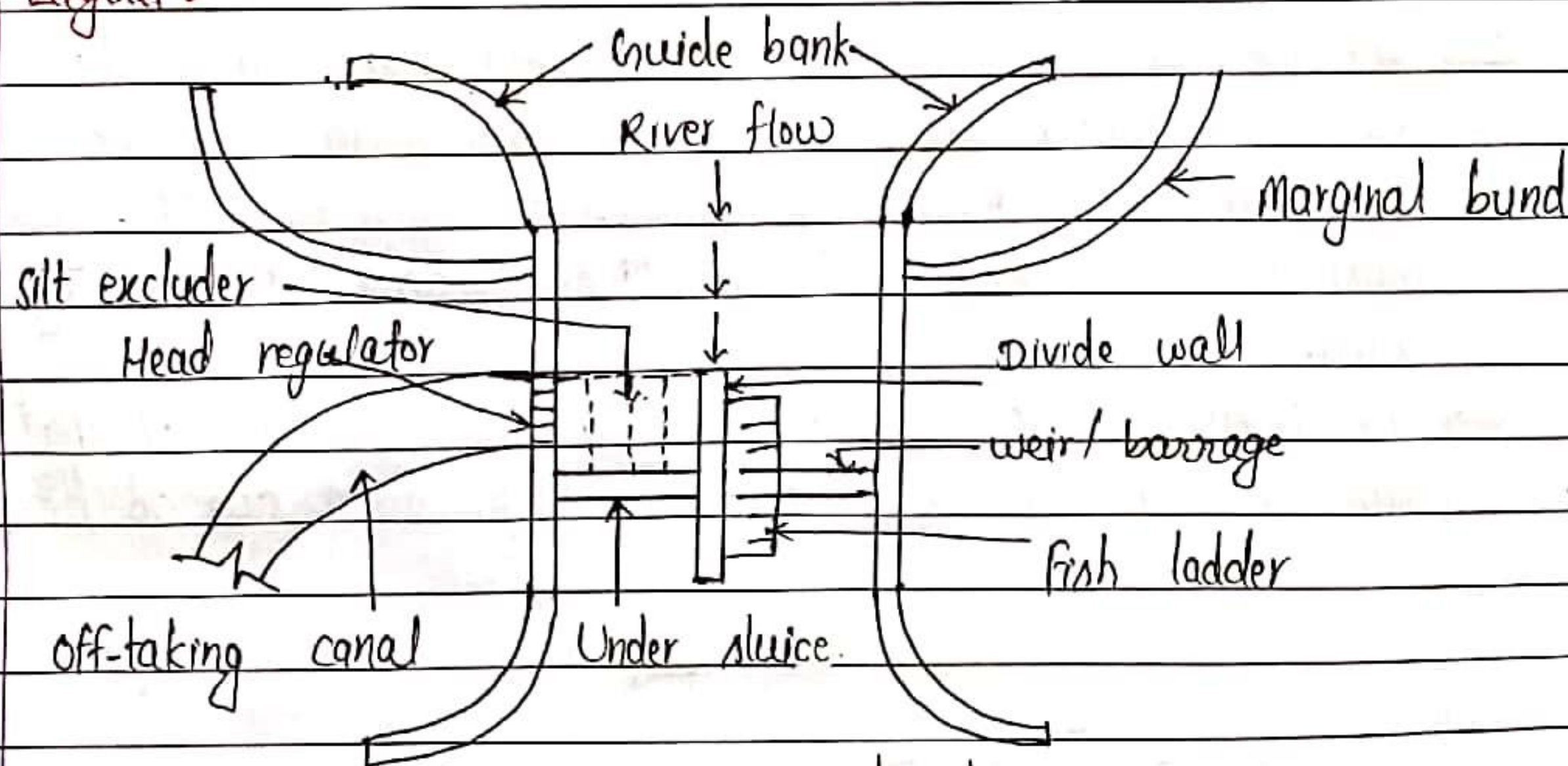


Fig: Diversion Headworks

→ A diversion head works is a structure constructed across a river for the purpose of raising water level in the river, so that it can be diverted water into off-taking canals. Diversion headworks are generally constructed on the perennial rivers which have adequate flow throughout the river and therefore there is no necessity of creating a storage reservoir.

● Components:

↳ A diversion headworks consist of following components :

- (i) Weir/ Barrage.
- (ii) Under sluice
- (iii) Divide wall
- (iv) Fish ladder
- (v) Canal head regulator
- (vi) Silt excluder
- (vii) Silt ejector
- (viii) Guide bank
- (ix) Marginal bunds etc.

✗ Weir ✗ Barrage Systems:

● Weir :

↳ The weir is a solid obstruction constructed across the river to raise its water level and divert the water into the canal. It is made up of masonry or cement concrete. In the case of weir most of the raising of water (i.e. ponding) is done by solid wall.

↳ Its main function is to raise the water level so that water can be diverted by canal to crop field due to head difference.

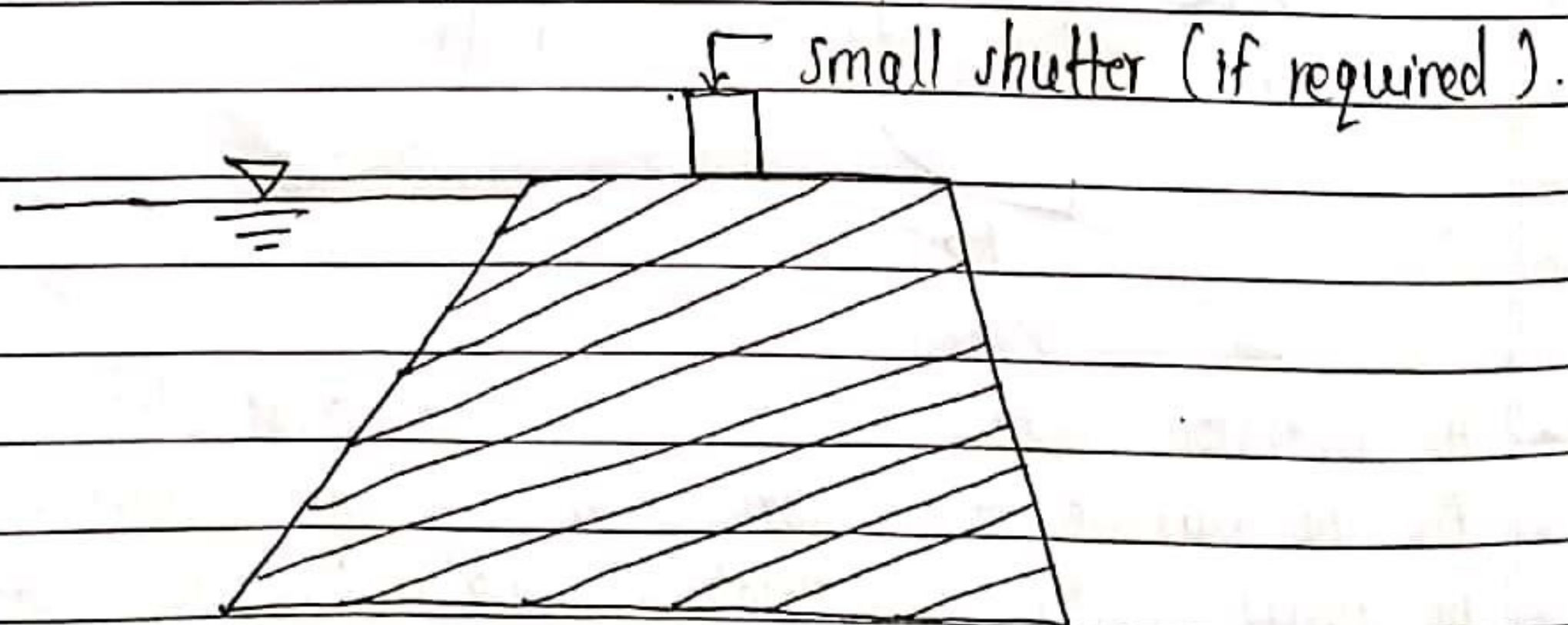


Fig: weir.

* Types of Weir:

↳ Based on floor design criteria, weirs are of two types:

- ① Gravity Weir
 - ↳ Vertical drop weir
 - ↳ sloping weir
 - ↳ Masonry or concrete slope weir
 - ↳ Dry stone slope weir
 - ↳ Parabolic weir

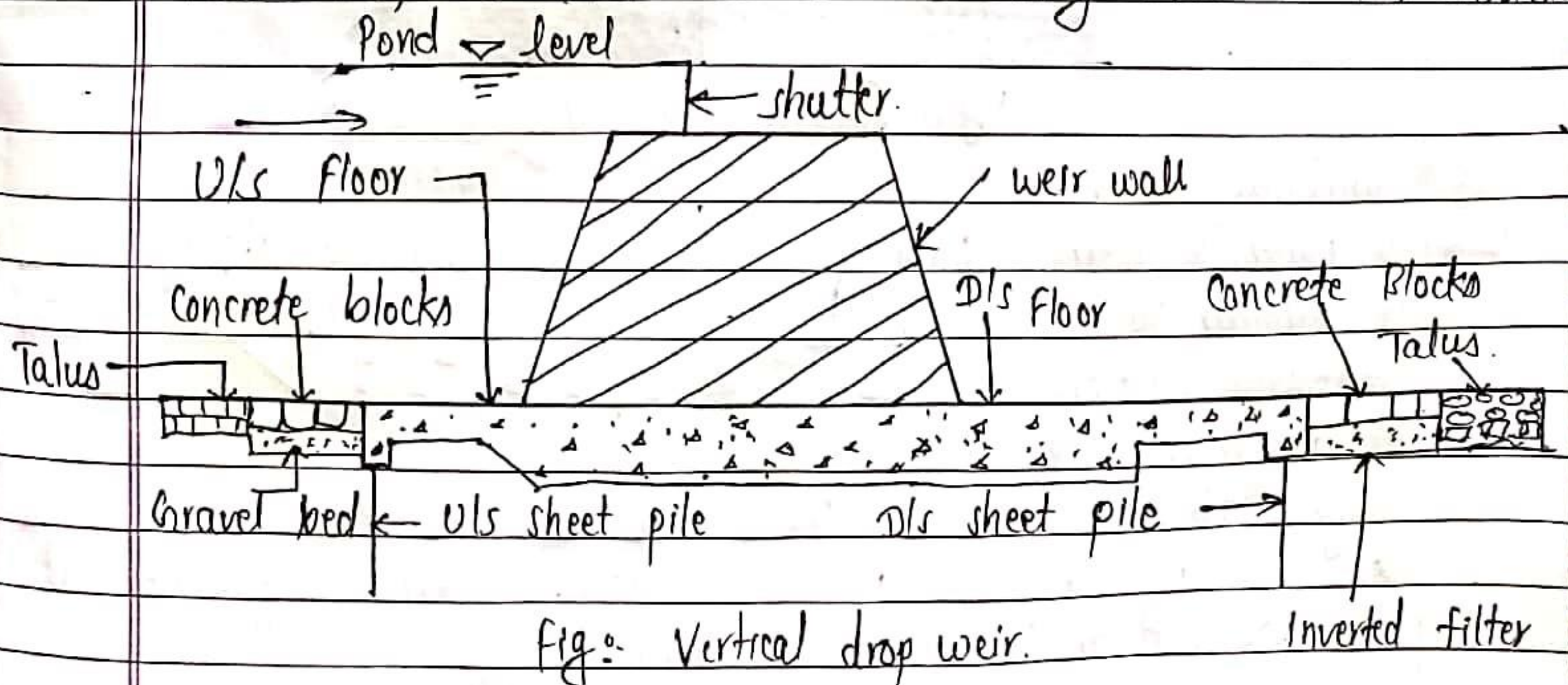
② Non-Gravity Weir

③ Gravity Weir:

↳ Gravity weir is one in which the uplift pressure due to the seepage of water below the floor is resisted entirely by the weight of floor. The gravity weir is of following types:

④ Vertical Drop Weir:

- ↳ A vertical drop weir consists of vertical drop wall or crest wall with or without crest gates. Vertical drop weir is suitable for any types of foundation.
- ↳ Water is ponded upto the top of the shutters during the rest of the period.
- ↳ Vertical drop weirs were quite common in early diversion headworks, but these are now becoming more or less obsolete.



⑥ **Sloping Weir :** It is of following types:

① **Masonry or concrete slope Weir :**

↳ They are suitable for soft sandy foundation and generally used where the difference in weir crest and downstream river bed is limited to 3m when water pressure over such a weir, hydraulic jump is formed on sloping glacis.

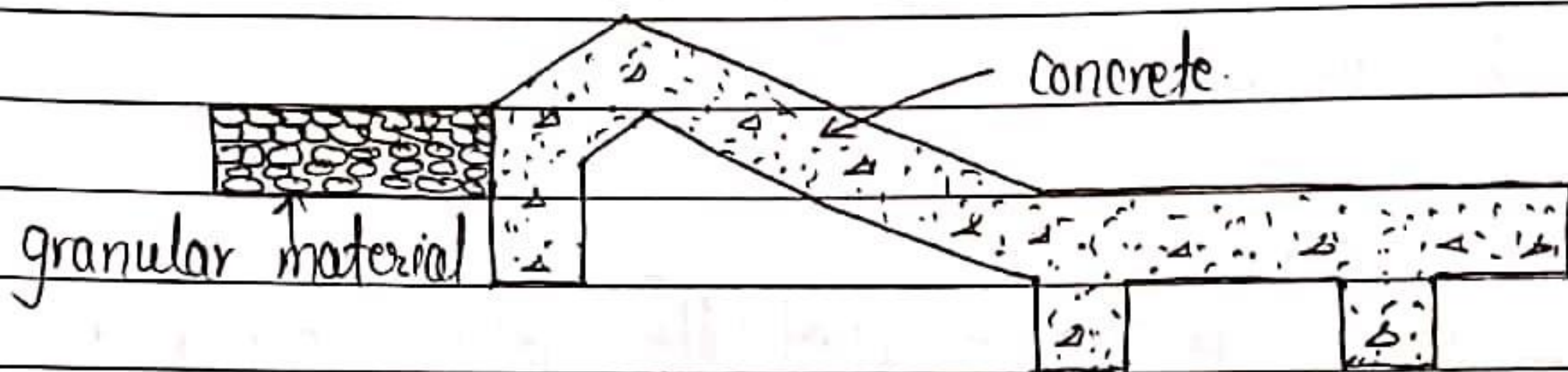


Fig: Sloping weir of concrete.

② **Dry stone slope Weir :**

↳ A dry stone weir or rockfill weir consist of a body of wall and upstream and downstream rock fills laid in the form of glacis with few intervening core wall.

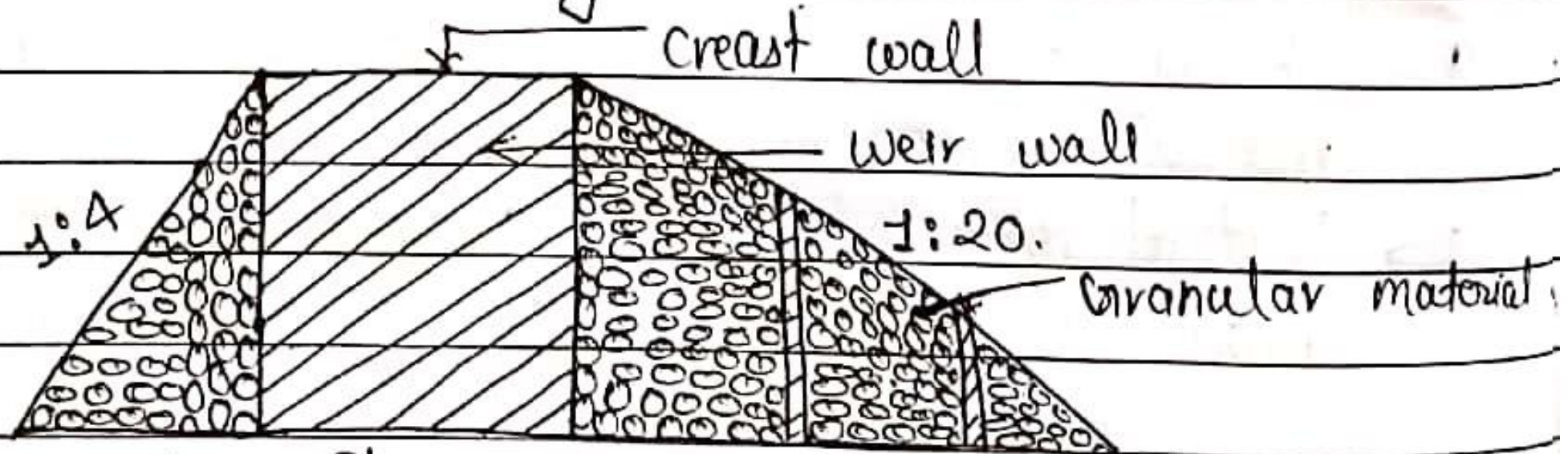


Fig: Sloping weir of dry stone.

③ **Parabolic Weir :**

↳ A parabolic weir is similar to the spill-way section of a dam. The body wall of such

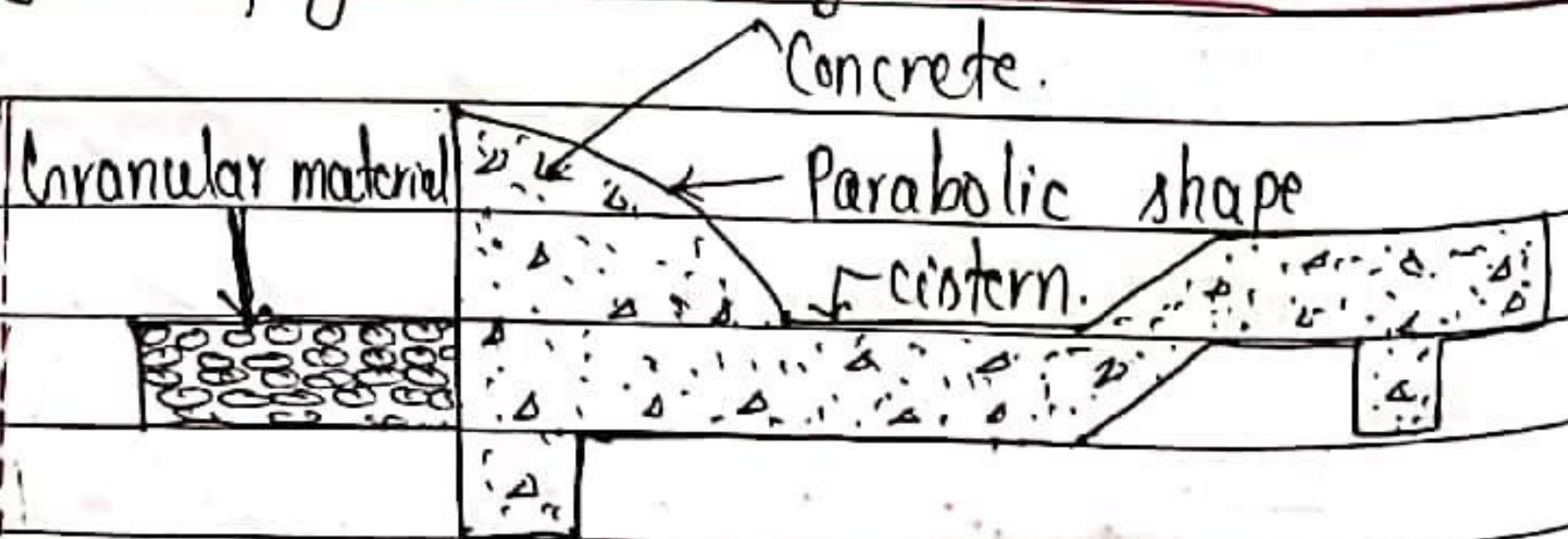


Fig: Parabolic Weir.

weir is designed as flow-dam. Cistern is provided at the downstream side to dissipate energy.

• Barrage:

↳ A barrage is a solid obstruction constructed across a river with higher gates. The river bed is low, most of ponding is done by gates. During the floods, gates are opened and therefore afflux is very small.

↳ Hence, barrage provides better control over the flux by suitable manipulation of gate. The current trend is to construct a barrage and not a weir as far as possible. However, barrage is more costlier than weir.

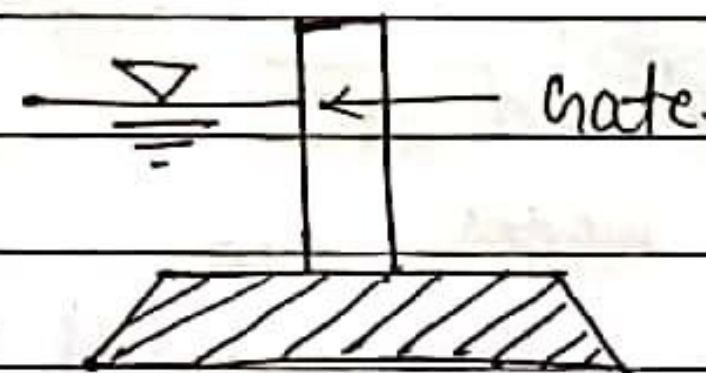


Fig: Barrage

* Difference Between Weir & Barrage:

↳ The differences between weir and barrage are as follows:

S.N.	Weir	Barrage
1.	High set crest	Low set crest.
2.	Ponding is done against the raised crest.	Ponding is done by means of gate.
3.	Shutters in part length	Gated over entire length.
4.	No control of river in low floods.	Perfect control on river flow.
5.	Excessive afflux in high floods	High floods can be passed with minimum afflux.
6.	Raised crest causes silting upstream.	Less silting upstream due to low set crest.
7.	No means for silt disposal	Silt removal is done through under sluices.
8.	Relatively cheaper than barrage and shorter construction period.	Costly structure with longer construction period.

Under Sluice [Scouring sluice]:

↳ The under sluice maintain deep channel in front of the head regulator and dispose heavy silt and a part of flood discharge on the downstream side of barrage.

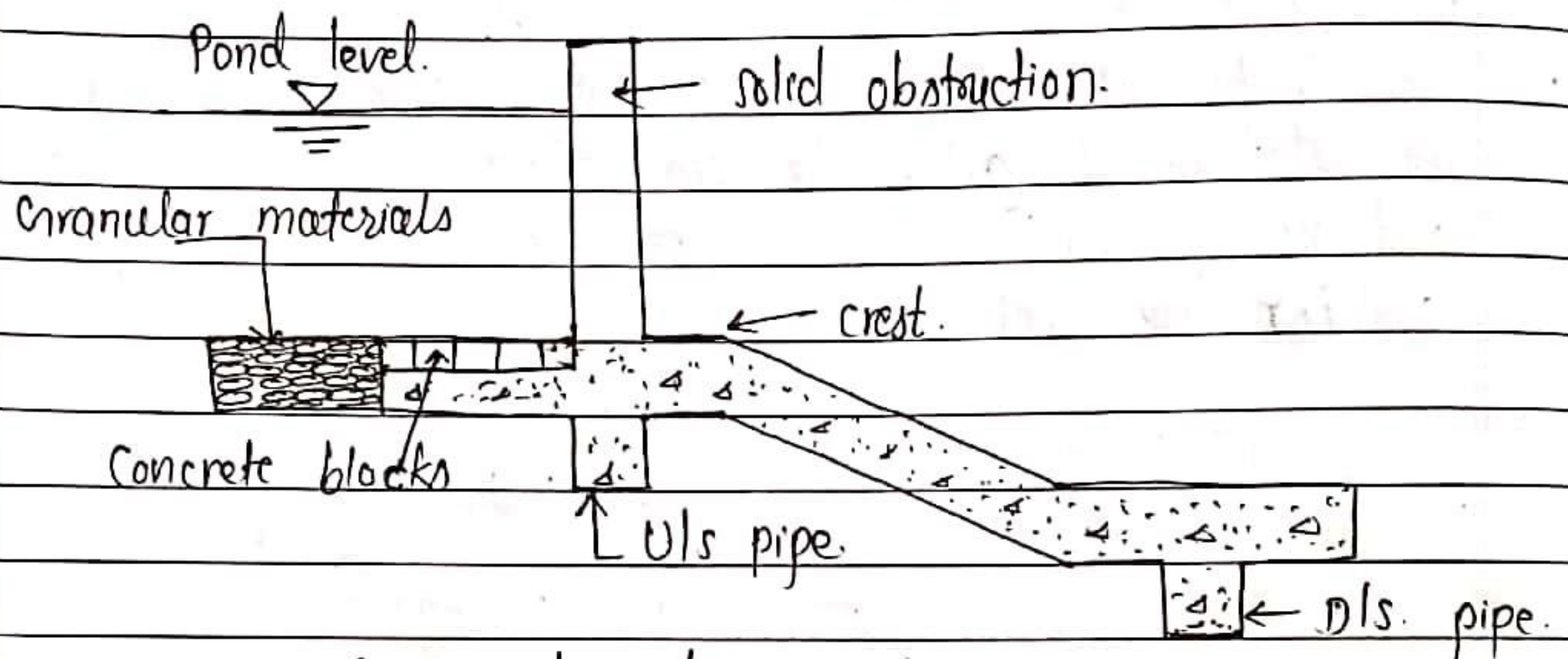


Fig: Under-sluice.

• Functions of Under Sluice:

↳ Following are the main functions of under sluice:

- They control the silt entry into the off-taking canal.
- They pass the flow flood without dropping the shutter of main weir.
- They help in impounding fair amount of flood to secure full storage.
- They provide greater water-way for floods thus lowering the floods levels.
- During high floods, they should be capable of passing 10-20% of flood discharge.

Divide Wall :

↳ It is masonry or concrete wall constructed perpendicular to the axis of weir, which separates the weir or barrage portion from under sluice portion.

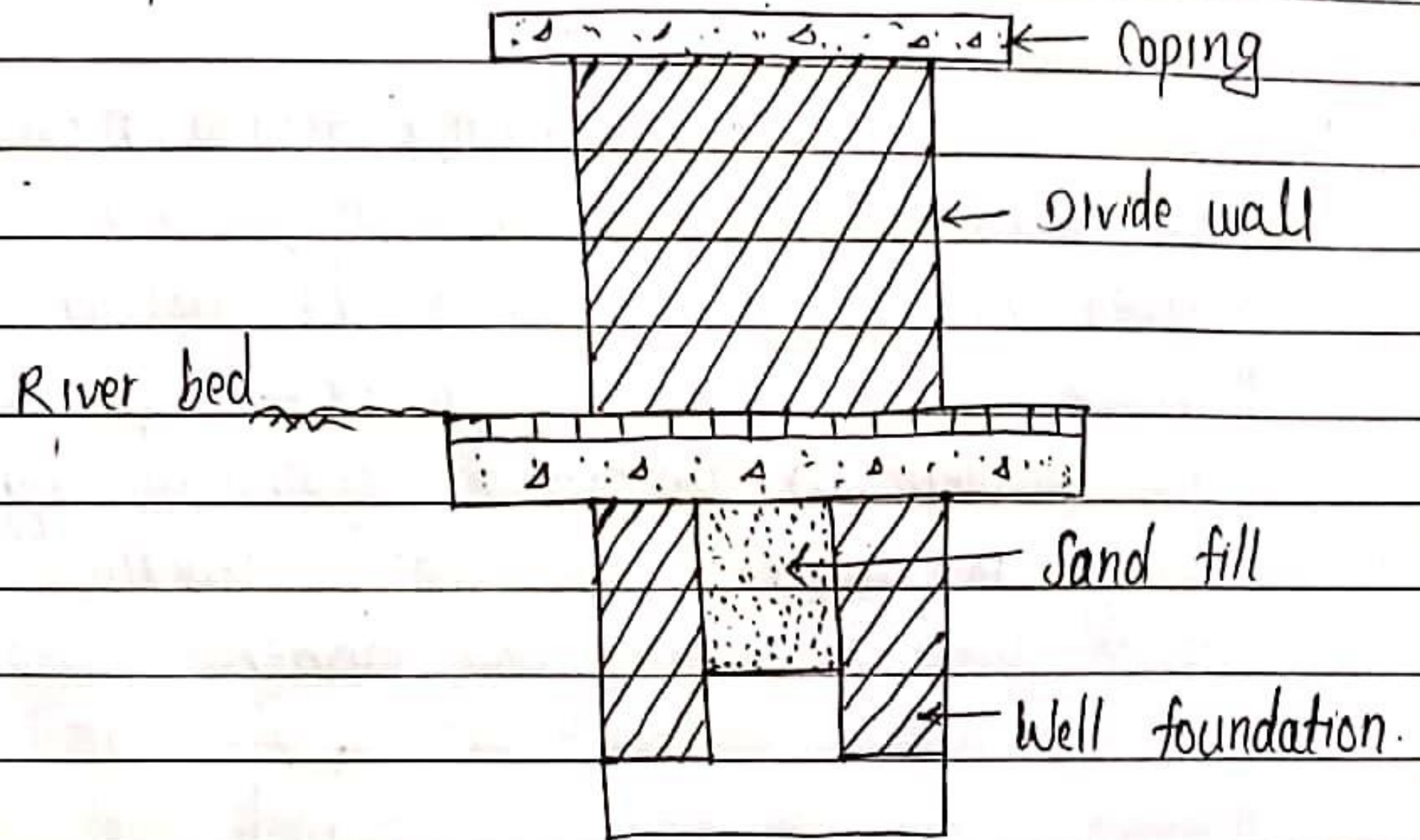


Fig: Divide wall.

• Functions of Divide Wall :

↳ Following are the functions of divide wall.

- The floor of under sluice is generally lower than the floor of main weir / barrage. Hence, a level to prevent the turbulent flow.
- The divide wall increases the effectiveness of undersluices.
- The divide wall provides a comparatively still pocket in front of canal head regulator which helps in the more silt deposit in the pocket and entry of clear water in the canal.
- Divide wall incidently serves as one of the side wall of fish-ladder.

Fish Ladder:

↳ The structure constructed on or around artificial and natural barriers (such as dams) to facilitate the movement of fishes in the water is known as fish ladder. It is also known as fish way, fish pass, fish steps.

↳ In big rivers, the migrating fishes move from D/S to U/S in search of clear water during monsoon. These migrating fishes can not pass across the barrier to U/S, if weir or barrage is high and velocity exceeds 3 m/sec . In order to solve this problem, a device is constructed by which the flow energy is reduced and velocity remains below 3 m/s , the device used is called fish ladder.

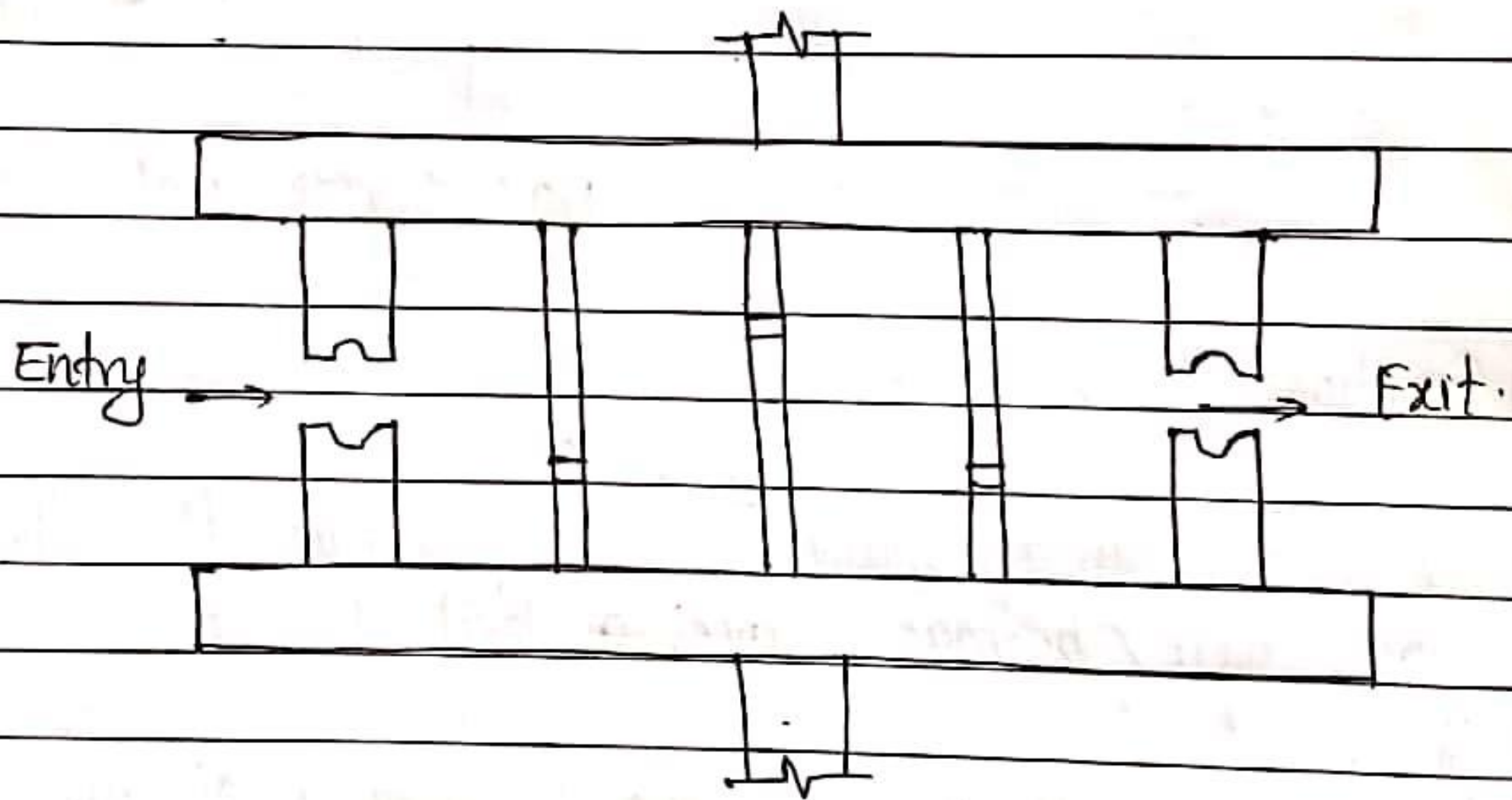


Fig: Fish Ladder.

• Functions of Fish Ladder:

↳ The main function of fish ladder is to provide safety on the movement from downstream to upstream during monsoon and in case of velocity more than 3 m/sec .

Silt Excluder and Sediment Ejector:

• Silt Excluder:

- ↳ The silt excluder is a device by which silt is excluded from water entering the canal. It is constructed in the bed of river, in front of the head regulator.
- ↳ The alignment of silt excluder is parallel to the axis of head regulator (i.e. at right angle to the axis of flow of canal). The silt excluder prevents entry of silt into canal. The bottom layer of water which are highly charged with silt pass down the silt excluder and escape through under-sluice.
- ↳ A silt excluder consists of a number of small tunnels with their roof slab at the same level as the crest of head regulator as shown in figure. The length of tunnel adjacent to the head of regulator. There are 4-6 tunnels in a silt excluder.

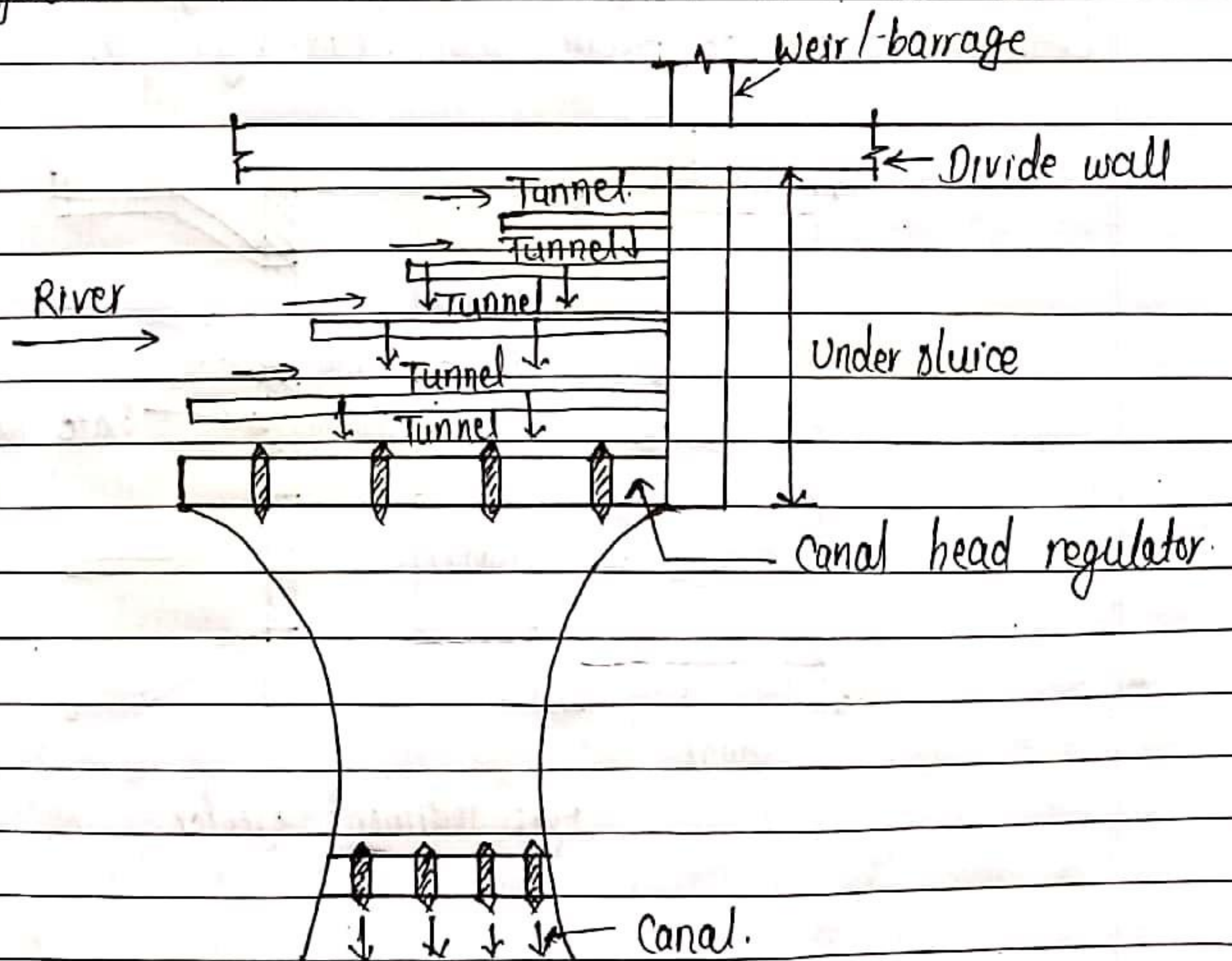


Fig: Silt excluder

● Silt Ejector / Silt Extractor (Sediment Ejector):

→ A sediment ejector is the structure constructed on the main canal D/s of the head regulator for removing silt which has entered the canal. It is constructed at the canal at some distance away from the head regulator. Sediment ejector consists of a number of tunnel with span equal to the entire width of canal. There is a horizontal diaphragm slab over the top of the tunnel at the level slightly greater than canal bed level.

→ The canal depressed under diaphragm so that the tunnel of height 0.5 to 0.6m can be provided below the diaphragm. The bottom layer of canal water containing silt are discharged by the silt ejector into the escape of channel. Silt ejector is located into the escape of channel. Silt ejector is located usually between 150m to 500m from head-regulator.

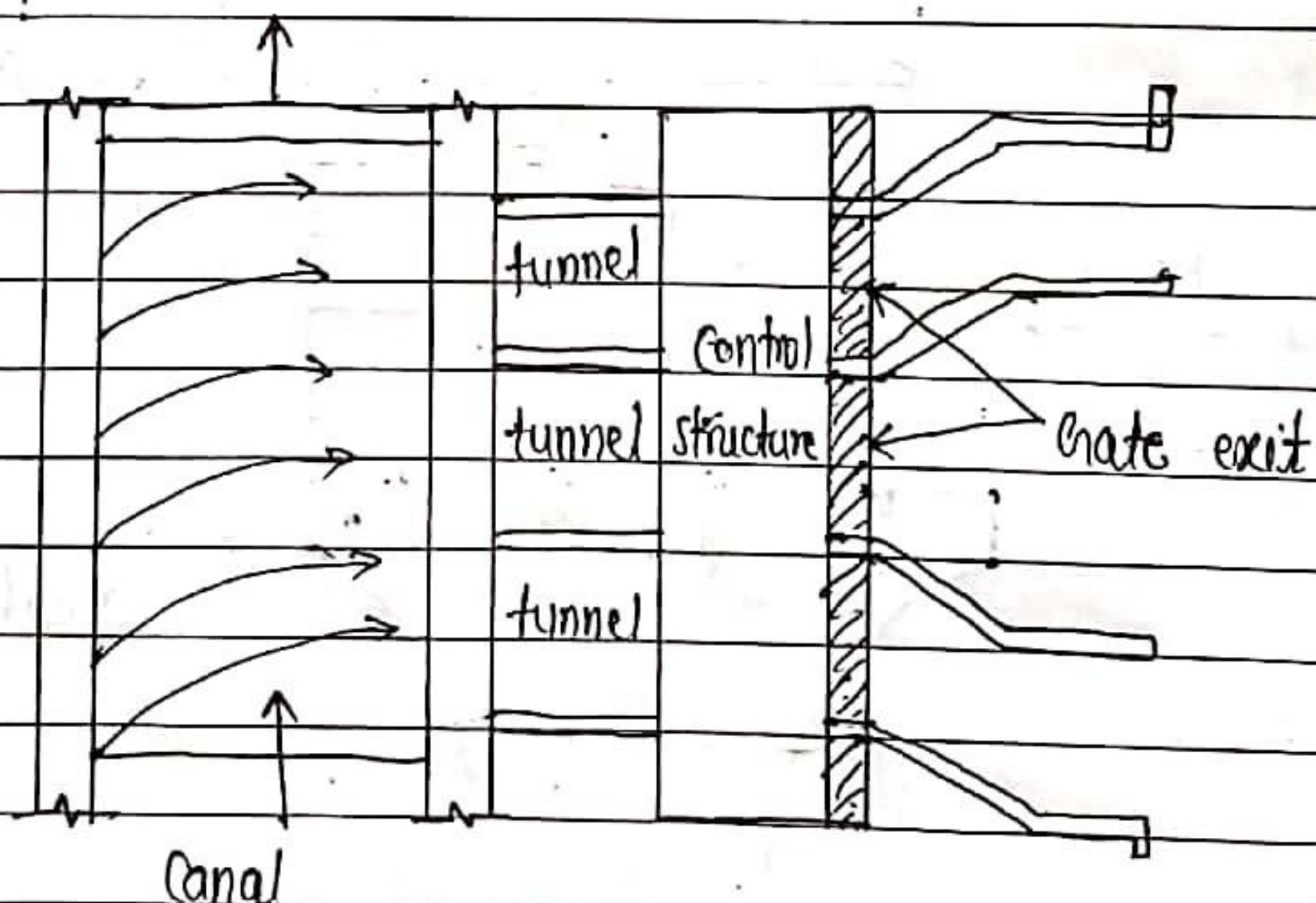


Fig: Sediment ejector.

Difference between Silt excluder and silt ejector :

↳ Following are the differences between silt excluder & silt ejector :

S.N.	Silt excluder	Silt ejector
1.	It is located in the under sluice section of the river.	It is located on the canal at some distance away from canal head regulator.
2.	The structure is heavy as it is subjected to large force.	The structure is relatively light.
3.	Silt exclusion can be done by once before the water enters the canal.	Silt exclusion is done after the sediment charge enters into the canal.
4.	Good approach conditions are difficult to achieve.	Good approach conditions are easily achieved.
5.	Over-all cost is low as compared to silt ejector.	Overall cost is low if the extraction is not very far from the head regulator.
6.	It is located in the bed of river.	It is located in the bed of canal.

Head Regulator :

↳ The regulators constructed at the off taking point are called head regulators. A head regulator is a structure constructed at the head of canal taking off from under sluice portion. When it is constructed at the head of main canal it is known as canal head regulator.

↳ A head regulator may consists of number of spans separated by piers and operated by gates similar to that provided in a barrage.

↳ Regulators are normally aligned at 90° to the weir.

↳ The head regulator is usually aligned at an angle of 90° to 110° to the barrage axis.

● Functions of Head Regulator:

↳ The functions of head regulator are as follows:

- (i) To admit water into the off-taking canal.
- (ii) To regulate the supplies into the canal.
- (iii) To indicate the discharge passed into the canal.
- (iv) To check silt entry to canal.
- (v) To shut-out river floods.

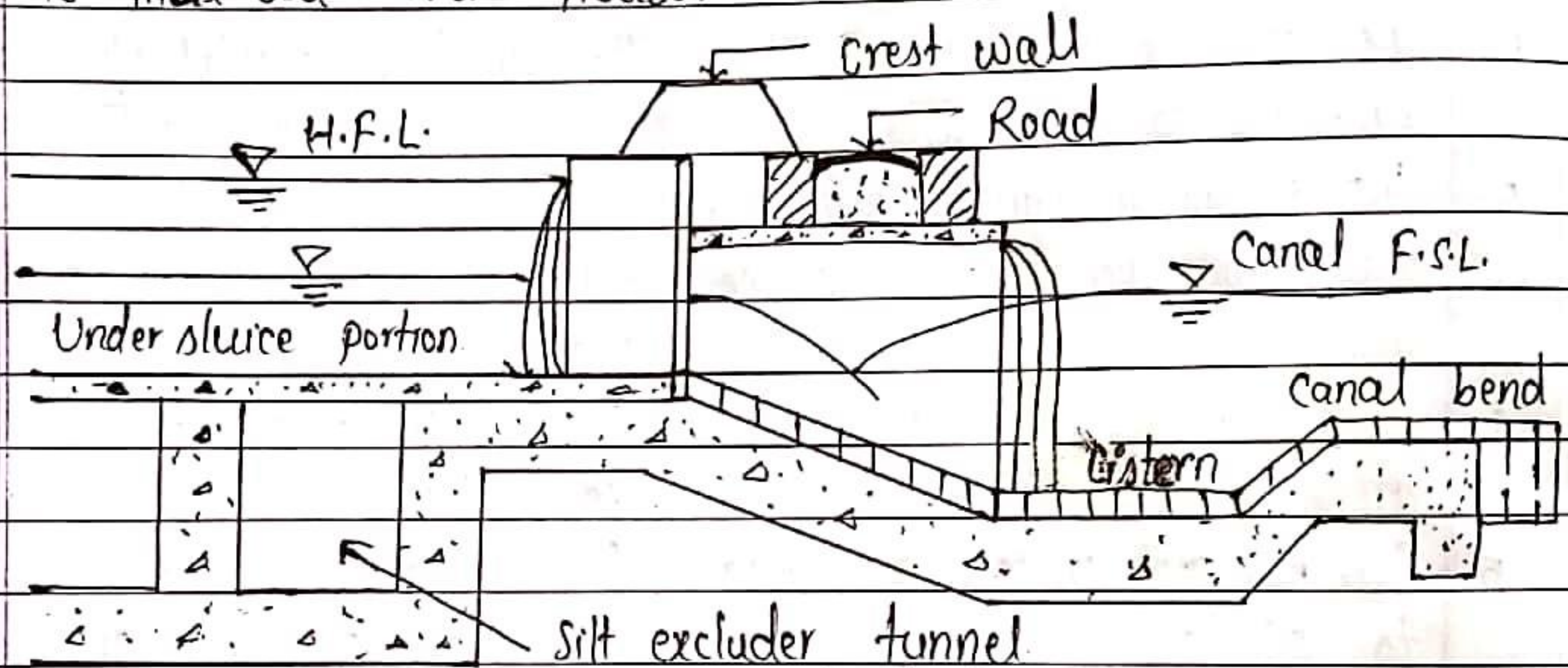


Fig: Canal head regulator

Cross Regulator:

↳ A regulator constructed in the main canal or parent canal downstream of an off taking canal is called cross-regulator.

↳ It is generally constructed at a distance of 9 to 12 km along the main canal and 6 to 10 km along branch canal.

● Functions of Cross-Regulator:

↳ The functions of cross-regulator are as follows:

- (i) To control the flow of water in canal system.
- (ii) To feed the off taking canals.
- (iii) To enable closing of the canal branches on the D/s.
- (iv) To provide roadway for vehicular traffic.

River Training Works:

- ↳ River training means to stabilize the river channel along a well defined alignment with a certain cross-section. The protection works are structures to protect the hydraulic structures from damage during floods.
- ↳ River training work is the process adopted on river to direct and guide the river flow, to train and regulate the bed or to increase the low water depth.
- ↳ River training work is generally required when river is meandering type. It is of three types
 - ① High water training: for discharge
 - ② Low water training: for depth
 - ③ Mean water training: for sediment control.

• Purposes/Objectives of River Training Works:

- ↳ Following are the main objectives of river training works:
 - ① To prevent the river from changing its course and to avoid out-flanking of structures like bridges, weirs and aqueducts.
 - ② To prevent flooding of the surrounding countries by providing a safe passage for flood water without overtopping the banks.
 - ③ To protect the river banks by deflecting the river away from the attacked banks.
 - ④ To provide minimum water depth required for navigation.
 - ⑤ To fix the direction of flow through certain well defined alignment.
 - ⑥ To provide a safe passage to flood flow without overflowing of banks to protect the inhabited areas, standing crops etc.

• Methods for River Training Works / Types of River Training Work:

↳ Following are generally adopted methods for river training works;

- (i) Guide banks
- (ii) Marginal bunds
- (iii) Spurs / Groyones.
- (iv) Artificial cutoffs
- (v) Pitching of banks
- (vi) Pitching island
- (vii) Revetments and rock riprap.
- (viii) Closure bunds

(i) Guide Banks / Bell's Bunds:

↳ Guide banks are symmetrical and parallel structures provided in pairs along the river channel to ensure a permanent reasonable width of water-way for river flow.

(ii) Marginal bunds / Marginal Embankments or levees:

↳ Marginal bunds are generally earthen embankments, running parallel to the river at some suitable distance from it. These embankments retain the flood water and thus prevent it from spreading into the nearby lands and towns.

(iii) Spurs / Groyones:

↳ These are the embankment type structures, constructed transverse to the river flow extending from the banks into the river. They protect the bank by deflecting the water current away from the bank.

Unit-6

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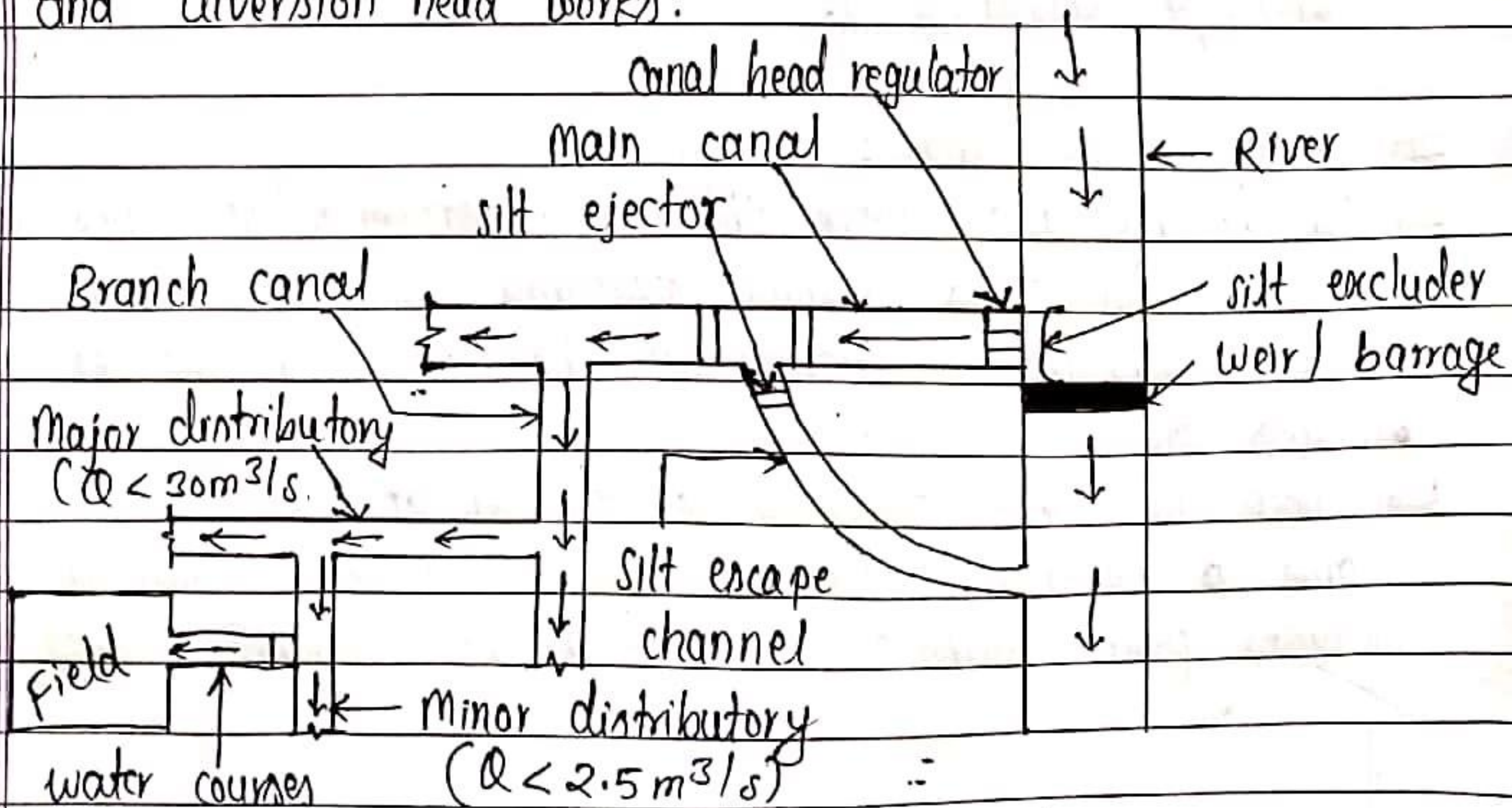


Fig : Canal System

↳ The network of canal may consists of main canal, branch canal, major distributary, minor distributary, water courses etc.

- **Main Canal:**

↳ It is the channel taking off directly from the headwork. No direct irrigation is carried out from main canal.

- **Branch Canal:**

↳ It receives discharge from main canal and supply to the distributaries. In general, branch canal also do not carry out any direct irrigation. They usually carry a discharge over 5 cumec.

- **Major distributaries:**

↳ These are small channels, taking off from the branch canals.

- **Minor distributaries:**

↳ These channels supply water to water courses.

- **Water Course:**

↳ It is small channel connecting outlet to the fields. Farmers are normally construct it.

Structures in Canal:

↳ For the regulation work, the main components / structures in canal consists of cross-drainage structures, canal fall, canal escapes, cross-regulators, distributary, head regulator, out let etc.

- **Cross-drainage structures:**

↳ These are the structures constructed at the crossing of canals, and a natural drainage. So, as dispose of drainage water takes place without obstructing the continuous canal supply.

- **Canal fall:**

↳ Whenever the available natural ground slope is steeper than designed bed slope, the difference is adjusted by constructing fall structures called Canal fall.

- **Cross-Regulator:**

↳ It is a structure provided on the parent channel just D/s of the off take point of offtaking canal to raise water level in parent channel so that the full supply can be taken into offtaking channel even when the parent channel is running full.

- **Distributories:**

↳ A distributory head regulator provided at the head of each distributory channel.

- **Outlet:**

↳ An outlet is usually a pipe embedded in the bank of a channel.

Classification of Canals:

↳ Classification of canals based on various forms are as follows:

① **Classification based upon the type of soil:**

(a) Alluvial canals

(b) Non-alluvial canals

② **Classification based upon the nature of water supply:**

(a) Perennial canals

(b) Non-perennial canals

③ **Classification based upon the funds available:**

(a) Protective canals

(b) Productive canals

(A) Classification based upon the size of canal:

- (a) Main canal
- (b) Branch Canal
- (c) Major distributary
- (d) Minor distributary
- (e) Water Course.

(a) Main Canal:

↳ The main canal is the largest canal in the system takes off directly from canal headwork. No direct irrigation is normally done from a main canal.

(b) Branch Canal:

↳ It takes off from a main canal or another branch canal. The discharge capacity of it is usually more than 5 cumecs. Generally no direct irrigation is done from a branch canal.

(c) Major Distributary:

↳ A major distributary takes off from a main canal, a branch or another distributary and supplies water to minor distributaries and water courses. The discharge capacity is usually between 0.25 to 5.0 cumecs. The major distributaries are generally used for direct irrigation.

(d) Minor Distributary:

↳ It takes off from a main canal, a branch canal, a major distributary or another minor distributary and supplies water to water courses. Its discharge capacity is usually less than 0.25 cumecs. The minor distributaries are also used for direct irrigation.

(e) Water Courses:

↳ Water courses are small channels which take water from a branch canal, a major distributary or a minor distributary and supply it to the agricultural fields.

⑤ Classification Based upon the canal alignment:

(a) Contour canals

(b) Watershed or ridge canals.

(c) side slope canals.

(a) Contour Canal:

↳ The canal which is aligned parallel to the contours of a country is called contour canal. It can irrigate only on one side of the canal, i.e. low value contour sides.

(b) Watershed or Ridge Canal:

↳ The canal which is aligned along ridge line is known as watershed or ridge canal. The advantage of this type of canal is that it can irrigate the areas on both sides. The irrigation canals are generally aligned along water-shed.

(c) Side Slope Canal:

↳ The canal which is aligned at right-angles to the contours of a country (i.e. along the side slope) is known as side slope canal. This canal runs approximately parallel to the natural drainage of a country.

==# Alignment of Canals:

↳ A canal is aligned in such a way, it covers the entire area proposed to be irrigated with shortest possible length and at the same time, its cost including the cost of cross drainage structure is minimum. The canal alignment is selected on the basis of following considerations:

① The alignment should have minimum number of cross-drainage structures.

② The alignment selected should irrigate high command area as far as possible.

- (iii) The alignment is economical of distributing water in land.
- (iv) The alignment along watershed is preferred, which is most economical.
- (v) The length of main canal should be minimum between two points.
- (vi) The alignment should avoid the residential area including houses, temples, roads etc.
- (vii) The alignment should not contain more number of curves.
- (viii) The alignment of canal should not be made in rocky or on hard strata etc.
- (ix) The alignment should be passed from balance depth of cutting.
- (x) Ideal length of canal should be minimum and branches should be economically planned.

• Factor affecting canal alignment :

↳ Following are the factors that affecting the alignment of canal:

- (i) Topography
- (ii) Canal structures
- (iii) Soil type
- (iv) Location
- (v) Geological condition
- (vi) Permanent structures.

• Factors to be Considered while Designing the canal in Hill Area :

↳ The design criteria of hill irrigation canal are as follows:

- (i) Canal alignment should be along contour.
- (ii) Canal should be avoided in filling part.
- (iii) Large cross section should be avoided.
- (iv) Lining of canal will give good result in long run.
- (v) Covered canal must be provided in landslide area. (i.e. by providing hume pipe).
- (vi) Using Manning's and Chezy's equation for design.

* Seepage of Canals and Lining :

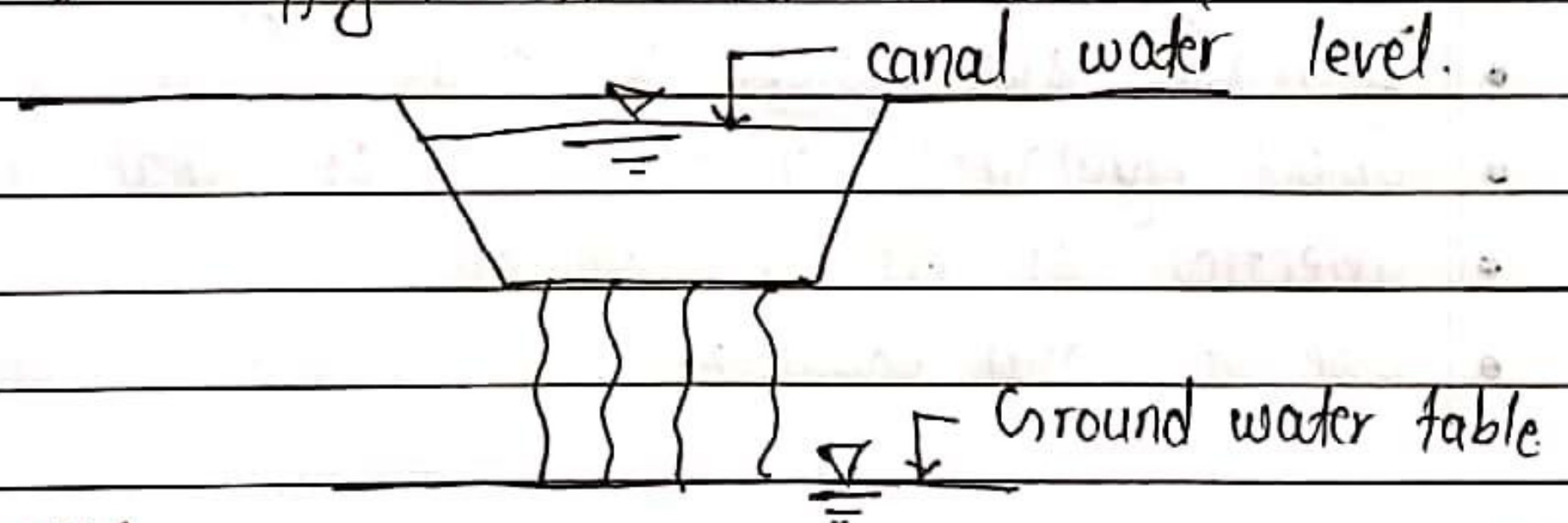
Seepage of Canal :

↳ Seepage of canal is caused due to the percolation of water or absorption of water below the ground. The seepage loss depends upon porosity of soil, temperature of water, underground water table position, turbidity of water, velocity of water flow, amount of silt carried in suspension etc.

↳ It can be further sub-divided into two types:

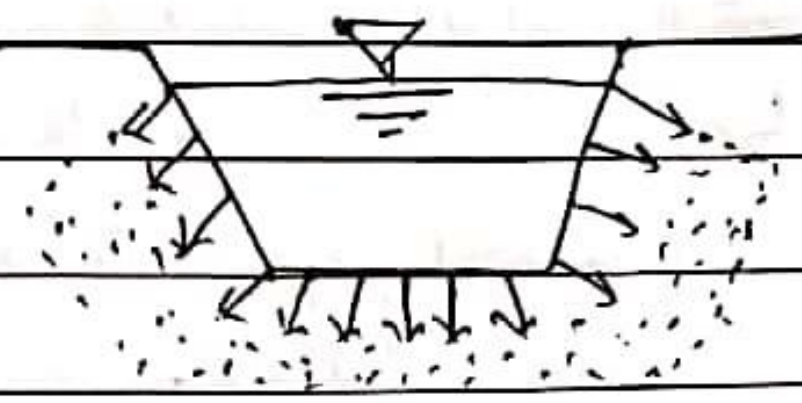
(a) Percolation Loss :

↳ When the water table is close to ground level, the seepage water may establish a direct and continuous flow in between the canal section and water table. Thus, the space between the water table and canal bed enclosed by two flow lines, marked remain completely saturated with water when in direct flow is established, the seepage loss depends upon the head difference between the full supply level of canal and water table.



(b) Absorption Loss :

↳ When the water table is considerably below ground level, the water seeping through pores is unable to join the water table and wets to the sub-soil



locally forming a saturated zone. The zone in between saturated zone and zone of capillary moisture remains unsaturated. Seepage loss depends upon following:

- Soil permeability
- Condition of canal (age of canal)
- Amount of silt carried by water
- Velocity of canal water.

* Canal Losses:

↳ During the passage of water from main canal to outlet at the head of the water course, water may be lost either by evaporation from a surface or by seepage through the peripheries of the canal. This is known as canal losses.

↳ The canal losses are occurs due to following reasons:

- (i) Losses due to evaporation
- (ii) Losses due to transpiration
- (iii) Loss due to seepage:
 - Percolation loss
 - Absorption loss.

Control of Canal Losses:

↳ Canal losses can be controlled by following ways:

- Lining of canal
- Avoiding canal alignment of filling
- Increase side slope of canal
- Good hydraulic cross-section of canal
- Selection of efficient section.
- Use of closed conduits.

Canal Lining:

↳ Canal lining is the process of reducing seepage loss of irrigation water by adding an impermeable layer to the edges of the trench.

↳ It is the process of applying stable surface like concrete, tiles, asphalt etc on the earthen surface of canal which is direct contact with water. The seepage loss can be reduced by 2-5% of their original values by lining the canal.

↳ Canal linings are also used to prevent weed growth, which can spread throughout an irrigation system and reduce water flow. It also prevent water logging problem around low-lying areas.

● Objectives / Needs / Purposes of Canal Lining :

↳ Following are the objectives of canal lining:

- (i) To minimize the seepage loss in canal.
- (ii) To increase discharge by increasing velocity.
- (iii) To prevent the erosion of bed and side due to velocity.
- (iv) To prevent the maintenance cost of canal.
- (v) To prevent from weed and grass growth.

● Advantages of Canal Lining :

↳ The advantages of canal lining are :

- (i) Seepage control.
- (ii) Prevention of water logging.
- (iii) Increase in canal capacity or velocity.
- (iv) Reduction in evaporation amount.
- (v) Smoothness of canal surface.
- (vi) Less chances of silting.
- (vii) Hygienic environment.
- (viii) Increase in available head.
- (ix) Reduction in weed growth.
- (x) Make canal section more stable and durable.

● Dis-advantages of Canal Lining :

↳ The dis-advantages of canal lining are:

- (i) High initial investment [3 to 4 times costlier than unlined one].
- (ii) Longer construction period.
- (iii) Lining being permanent, it is difficult to shift outlet often.
- (iv) Difficult to repair and maintenance the damage lining.
- (v) Maintenance cost goes to high.
- (vi) Safety is decreased as compared to unlined canal.

• Types of Canal Lining:

↳ The various types of canal lining can be grouped into following three categories:

(a) Exposed and hard surface linings:

- (i) Cement concrete lining
- (ii) Precast concrete lining
- (iii) shotcrete lining
- (iv) Cement mortar lining
- (v) Hydraulic lining
- (vi) Brick tile or burnt clay tile lining
- (vii) Stone blocks or undress stone lining
- (viii) Asphaltic concrete lining

(b) Buried membrane linings:

- (i) Sprayed-in-place asphalt membrane lining
- (ii) Prefabricated asphaltic membrane lining
- (iii) Polyethylene film and synthetic rubber membrane lining.
- (iv) Bentonite and clay membrane lining.
- (v) Road oil lining.

(c) Earth Lining:

- (i) Thin compacted earth lining
- (ii) Thick compacted earth lining
- (iii) Loosely placed earth lining
- (iv) Stabilized soil lining
- (v) Bentonite soil lining
- (vi) Soil-cement lining.

- Canal lining may be of following types depending upon their properties:

(i) Cement Concrete Lining:

↳ Cement concrete lining is widely accepted as the best impervious lining. It can resist the effect of scouring and erosion very efficiently.

(ii) Lime Concrete Lining:

↳ This lining is preferred where hydraulic lime, surkhi and brick, ballast are available in plenty along the course of the canal. It is less durable as compared to cement concrete lining.

(iii) Precast Concrete Lining:

↳ It consists of precast concrete slabs of size $60\text{cm} \times 60\text{cm} \times 5\text{cm}$ which are set along the canal bank and bed with cement mortar. It is adopted for the canal in full banking.

(iv) Cement-Mortar Lining:

↳ The lining is not durable unless protected suitably. A thickness of 2.5cm of cement lining can reduce seepage losses by 90% .

(v) Brick Lining:

↳ The first class bricks are recommended for the work. The brick lining is preferred because of its low cost and can be done quickly.

(vi) Shotcrete Lining:

↳ Shotcrete is a mixture of cement and sand in the ratio of $1:4$. The lining is preferred for repairing of old but sound concrete lining. The thickness of shotcrete lining varies from 2.5cm to 5cm .

(vii) Sodium Carbonate Lining:

↳ This lining consists of 10% clay and 6% sodium carbonate. The lining is not durable.

(viii) Asphalt Lining:

↳ The lining is prepared by spraying asphalt at a high temp. (about 1500°C) on the sub-grade to a thickness varying from 3mm to 6mm . The lining is very cheap and can control the seepage of water very effectively, but it can't control the growth of weeds.

Design of Alluvial Canals:

Alluvial Canals:

↳ The soil which is formed by transportation and deposition of silt through the agency of water over a course of time is called alluvial soil. The canals excavated through soils are called alluvial canals.

↳ For the design of alluvial soil canal, the hypothetical theories given by Kennedy and Lacey are used. For designing the properly functioning canals, we must think to design a canal in which neither scouring nor silting takes. Such canals are known as stable or regime canals.

Regime Canal:

↳ A canal is said to be regime if the flow in the canal does not cause silting and scouring. Such state is possible in an ideal canal. The basis for designing an ideal canal, non-silting, non-scouring canal is that whatever silt has entered in the canal at its head is kept in suspension. So that it does not settle-down and deposit at any point in the canal. Moreover the velocity of water should be such that it does not produce local silt by erosion of canal bed and its slope.

• In an alluvial canal, both scouring and silting may occur if the channel is not properly designed. Therefore the alluvial canal should be designed in such a way that neither scouring nor silting occurs. The velocity of which is called critical velocity.

↳ The following two theories are normally used for design of canal in alluvial soil:

Kennedy's Silt Theory:

↳ R.G. Kennedy in 1895 carried out extensive investigation on some of the canal in the Upper Bari Doab Canal System (Punjab). From the experiment and observation, he gives the following conclusions:

- The silt supporting power is proportional to the bed width of stream and not to its wetted perimeter.
- The silt supporting power in a canal cross-section was mainly dependent upon the generation of eddies (twists and turns).
- These eddies are generated due to friction of flowing water with canal surface.

↳ He defined the critical velocity and gave a relation between critical velocity to the depth of flowing water which is valid for Upper Bari Doab Canal (UBDC):

- In general,

$$V_0 = 0.55 D^{0.64}$$

$$\therefore [V_0 = 0.55 m D^{0.64}]$$

Where, V_0 = critical velocity of canal (m/s)

D = water depth in canal (m)

m = critical velocity ratio (CVR)

$\therefore m=1$, for UBDC system

$m>1$, for sediments coarser than for UBDC.

$m<1$, for sediments finer than for UBDC.

↳ The equation used by Kennedy for design alluvial canals are

- Continuity equation $\rightarrow Q = A \cdot V$ — (*)

- Flow equation such as Kutter's equation:

$$V = \left[\frac{1}{N + \left(23 + \frac{0.00155}{S} \right)} \right] \times \sqrt{RS} \text{ — (*)}$$

- Kennedy's Critical Velocity equation $\rightarrow [V_0 = 0.55 m D^{0.64}]$ — (*)

• Design Procedure [When Q, m, N, S are given]:

↳ Given, Q, m, N & S .

• Steps:

① Assume, trial value of depth ' D '

② Critical velocity, $V_0 = 0.55 m D^{0.64}$

③ Area, $A = \frac{Q}{V_0} \quad \because Q = A \cdot V$

④ $A = BD + zD^2$

If, $z = 0.5:1$, $A = BD + 0.5D^2$

⑤ Equating, Area in step ③ & ④, and find B .

⑥ Wetted Perimeter:

$P = B + D\sqrt{5}$ (If, side slope $z = 0.5:1$)

$P = B + 2D\sqrt{z^2 + 1}$ (If, side slope is given).

⑦ Compute, actual velocity ' V ' from Kutter's formula.

$$V = \left(\frac{1}{N} + \left(23 + \frac{0.00155}{S} \right) \right) \div \left(1 + \left(23 + \frac{0.00155}{S} \right) \times \frac{N}{\sqrt{R}} \right) \times \sqrt{RS}$$

⑧ After that,

If, $V \approx V_0$, then the assumed depth is ok.

Otherwise, change the value of depth and repeat the procedure till the V and V_0 comes tend to equal i.e. $V \approx V_0$.

Where,

↳ V_0 = Critical Velocity (m/s) ↳ $R = \text{H.P.D.} = \frac{A}{P}$

↳ Q = Discharge of canal (m³/s)

↳ m = Critical velocity ratio. ↳ N = Rugosity constant

↳ S = Bed slope of canal

↳ A = Cross-sectional area of canal.

↳ D = Depth of water in canal.

↳ B = width of canal

↳ z = side slope of canal

↳ P = wetted perimeter

[2073]

Q. NO. 1 Design a channel for 30 cumec discharge by Kennedy's theory. Other given data are as follows:

$$N = 0.0225, m = 1, S = 20 \text{ cm/km}.$$

Solution: Given that,

$$\text{Design Discharge (Q)} = 30 \text{ cumec.}$$

$$\text{Kutter's Rugosity coefficient (N)} = 0.0225$$

$$\text{Critical Velocity Ratio (m)} = 1$$

$$\text{Bed slope of canal (S)} = 20 \text{ cm/km}$$

$$= \frac{20}{1 \times 1000 \times 100} = \frac{1}{5000}$$

$$= 1 \text{ in } 5000.$$

Assuming side slope, $z:1 = 0.5:1$.

Now,

Trial-1- Assuming depth of canal (D) = 2 m.

$$\begin{aligned} \bullet \text{ Then, Critical velocity (V}_0\text{)} &= 0.55 m D^{0.64} \\ &= 0.55 \times 1 \times 2^{0.64} \\ &= 0.86 \text{ m/s.} \end{aligned}$$

$$\begin{aligned} \bullet \text{ Cross-sectional area (A)} &= \frac{Q}{V_0} \quad \because [Q = A \times V] \\ &= \frac{30}{0.86} = 34.88 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \bullet \text{ Again, Assuming the cross-section of canal is trapezoidal.} \\ \therefore A &= BD + zD^2 \\ 34.88 &= B \times 2 + 0.5 \times 2^2 \\ \therefore B &= 16.44 \text{ m.} \end{aligned}$$

$$\begin{aligned} \bullet \text{ Wetted Perimeter (P)} &= B + D\sqrt{5} \quad \because [z = 0.5:1] \\ &= 16.44 + 2\sqrt{5} \\ &= 20.91 \text{ m.} \end{aligned}$$

$$\bullet \text{ Hydraulic mean depth (R)} = \frac{A}{P} = \frac{34.88}{20.91} = 1.67 \text{ m}$$

• Therefore,

$$\text{Actual velocity (V)} = \frac{\frac{1}{N} + \left(23 + \frac{0.00155}{S}\right)}{1 + \left(23 + \frac{0.00155}{S}\right) \times \frac{N}{\sqrt{R}}} \times \sqrt{RS}$$

$$= \frac{\frac{1}{0.0225} + 23 + \frac{0.00155}{1/5000}}{1 + \left(23 + \frac{0.00155}{1/5000}\right) \times \frac{0.0225}{\sqrt{1.67}}} \times \sqrt{1.67 \times \frac{1}{5000}}$$

$$= 0.90 \text{ m/s.}$$

• Comparing, $V > V_0$

Trial-II. Assuming, depth of canal (D) = 2.3m.

$$V_0 = 0.55 \times m D^{0.64} = 0.55 \times 1 \times 2.3^{0.64} = 0.94 \text{ m/s.}$$

$$A = Q/V = 30/0.94 = 31.91 \text{ m}^2.$$

$$\text{Again, } A = BD + zD^2$$

$$\therefore 31.91 = B \times 2.3 + 0.5 \times 2.3^2 \quad \therefore B = 12.72 \text{ m.}$$

$$P = 12.72 + 2.3\sqrt{5} = 17.86 \text{ m.}$$

$$R = \frac{31.91}{17.86} = 1.79 \text{ m.}$$

$$V = \frac{\frac{1}{0.0225} + \left(23 + \frac{0.00155}{1/5000}\right)}{1 + \left(23 + \frac{0.00155}{1/5000}\right) \times \frac{0.0225}{\sqrt{1.79}}} \times \sqrt{1.79 \times \frac{1}{5000}}$$

$$V = 0.94 \text{ m/s.}$$

• Comparing, $V \approx V_0$. Hence, Correct.

Design Summary:

Depth of canal (D) = 2.3m

Width of canal (B) = 12.72 m.

Design Velocity (V) = 0.94 m/s.

[2069]

Q. NO. 2 Design an irrigation canal to carry a discharge of **50** cumecs. Assume bed slope, 1:4000, side slope 0.5:1 (H:V) and Manning's Constant = 0.023. The critical velocity ratio for the soil is 1.1.

Solutions Given that,

Design discharge (Q) = 50 cumecs

Longitudinal bed slope (S) = 1:4000

Side slope (Z) = 0.5:1 (H:V)

Manning's Constant = 0.023

Critical velocity Ratio (m) = 1.1

Now,

Trial-I Assuming, depth of canal (D) = 2.5 m

• Then, Critical velocity (V_c) = $0.55 \text{ m D}^{0.64} = 0.55 \times 1.1 \times 2.5^{0.64}$
 $= 1.09 \text{ m/s}$

• Cross sectional area (A) = $\frac{Q}{V} = \frac{50}{1.09} = 45.87 \text{ m}^2$

• Again, assuming the cross-section of canal is trapezoidal.

i.e. $A = BD + ZD^2$

$45.87 = B \times 2.5 + 0.5 \times 2.5^2$

$\therefore B = 17.10 \text{ m}$

• Wetted Perimeter (P) = $B + D\sqrt{5} \quad \because [Z = 0.5:1]$
 $= 17.10 + 2.5\sqrt{5}$
 $= 22.69 \text{ m}$

• H.M.D. (R) = $\frac{A}{P} = \frac{45.87}{22.69} = 2.02 \text{ m}$

• Actual velocity (V) by Kutter's formula is given by,

$$V = \left[\frac{1}{N} + \left(23 + \frac{0.00155}{S} \right) \right] \times \sqrt{RS}$$

$$\left[1 + \left(23 + \frac{0.00155}{S} \right) \times \frac{N}{\sqrt{R}} \right]$$

$$= \left[\frac{1}{0.023} + \left(23 + \frac{0.00155}{1/4000} \right) \right] \times \sqrt{\frac{2.02 \times 1}{4000}}$$

$$\left[\frac{1 + \left(23 + \frac{0.00155}{1/4000} \right) \times 0.023}{1/4000} \right] \times \sqrt{2.02}$$

$\therefore V = 1.11 \text{ m/s} > V_0$. So, trial again.

Trial-II Assuming, depth of canal (D) = 2.6 m

- Critical velocity (V_0) = $0.55 \times 1.3 \times 2.6^{0.64} = 1.12 \text{ m/s}$.
- Cross-sectional area (A) = $\frac{50}{1.12} = 44.64 \text{ m}^2$

- Assuming, the cross-section is trapezoidal. Then,

$$A = BD + zD^2$$

$$44.64 = B \times 2.6 + 0.5 \times 2.6^2$$

$$\therefore B = 15.87 \text{ m}$$

- Wetted Perimeter (P) = $15.87 + 2.6\sqrt{5} = 21.68 \text{ m}$.

- H.M.D (R) = $\frac{A}{P} = \frac{44.64}{21.68} = 2.06 \text{ m}$.

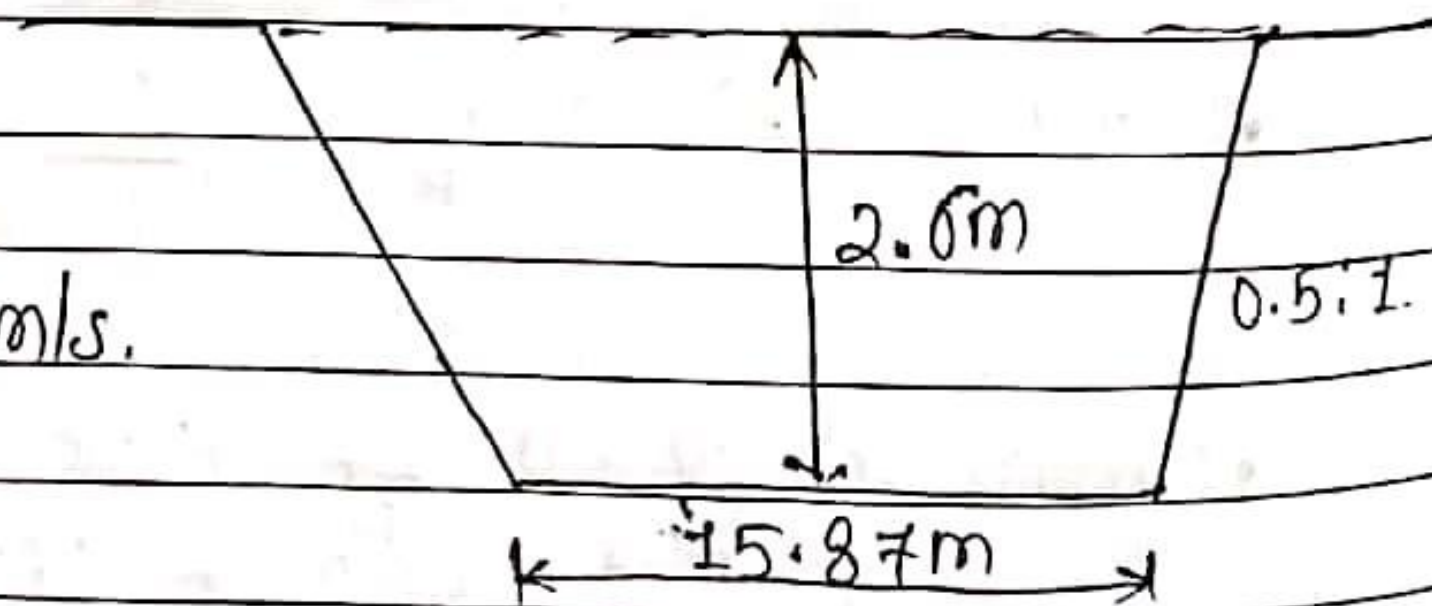
$$V = \left[\frac{1}{0.023} + \left(23 + \frac{0.00155}{1/4000} \right) \right] \times \sqrt{\frac{2.06 \times 1}{4000}}$$

$$\left[\frac{1 + \left(23 + \frac{0.00155}{1/4000} \right) \times 0.023}{1/4000} \right] \times \sqrt{2.06}$$

$\therefore V = 1.12 \text{ m/s} = V_0$. Hence, correct.

Design Summary:

- (i) Bed width (B) = 15.87 m
- (ii) Depth (D) = 2.6 m.
- (iii) Design velocity (V) = 1.12 m/s.
- (iv) Bed slope 1 in 4000
- (v) Side slope 0.5H:1V.



#.

• Design Procedure [When Q, m, N & B/D are given]:

↳ Given that, Q, m, N & B/D Ratio.

• steps:

① Cross-sectional area, $A = BD + zD^2 \because [B/D = x, B = xD]$.

If $z = 0.5:1, [A = BD + 0.5D^2]$.

② Critical velocity, $V_0 = 0.55 m D^{0.64}$.

③ Continuity equation, $Q = A \cdot V_0$, and findout D and then B from B/D ratio.

④ Wetted perimeter, $P = B + 2D\sqrt{z^2 + 1}$

If, $z = 0.5:1, P = B + D\sqrt{5}$

⑤ Hydraulic mean depth $R, = \frac{A}{P}$

⑥ Findout, V_0 , which is V (actual velocity).

⑦ Determine, the slope (bed slope) of canal from Kutter's formula:
i.e.

$$V = \left(\frac{1}{N} + \left(23 + \frac{0.00155}{S} \right) \right) \times \sqrt{RS} \div \left(1 + \left(23 + \frac{0.00155}{S} \right) \times \frac{N}{\sqrt{R}} \right)$$

[2070][2070]

Q.No.1 Design an Irrigation canal to carry a discharge of 10 cumec.
Assume, $N = 0.0225$, $m = 1.0$, and $B/D = 3.5$

Solution: Given that,

Design discharge (Q) = 10 cumec.

Rugosity Coefficient (N) = 0.0225

Critical Velocity Ratio (m) = 1.0.

B/D ratio = 3.5 i.e. $B = 3.5D$

Now,

$$\bullet \text{ Critical velocity } (V_0) = 0.55 m D^{0.64} = 0.55 D^{0.64} \quad \text{--- (I)}$$

→ and, assuming the side slope of canal 0.5:1.

• Then, cross-sectional area of trapezoidal area is,

$$A = BD + zD^2 = 3.5D^2 + 0.5D^2 = 4D^2 \quad \text{--- (II)}$$

Now, By Continuity equation

$$Q = A \times V$$

$$10 = 4D^2 \times 0.55 D^{0.64}$$

$$\therefore D = 1.77 \text{ m.}$$

$$\therefore B = 3.5D = 3.5 \times 1.77 = 6.20 \text{ m.}$$

$$\bullet \text{ Wetted Perimeter } (P) = B + D\sqrt{5} = 6.20 + 1.77\sqrt{5} = 10.15 \text{ m}$$

$$\bullet \text{ Cross-sectional area } (A) = 4D^2 = 4 \times 1.77^2 = 12.53 \text{ m}^2$$

$$\bullet \text{ Hydraulic mean depth } (R) = \frac{A}{P} = \frac{12.53}{10.15} = 1.23 \text{ m.}$$

$$\bullet \text{ From eqn (I), } V_0 = 0.55 D^{0.64} = 0.55 \times 1.77^{0.64} = 0.79 \text{ m/s.}$$

• So, From Kutter's formula

$$V = \left(\frac{1}{N} + \left(23 + \frac{0.00155}{S} \right) \right) \times \sqrt{RS}$$

$$\text{or, } 0.79 = \left[\frac{1}{0.0225} + \left(23 + \frac{0.00155}{S} \right) \right] \times \sqrt{1.23 \times S}$$

$$\text{or, } S = 2.38 \times 10^{-4} = 1 \text{ in } 4189.52 \approx 1 \text{ in } 4190$$

Design Summary:

$$B = 6.20 \text{ m, } D = 1.77 \text{ m, } V = 0.79, S = 1 \text{ in } 4190.$$

[2068]

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Q.No. 2

Design an irrigation canal to carry a discharge of 40 cumecs with B/D ratio of 2.5. The critical velocity ratio is 1.0 and rugosity coefficient is 0.023.

Solution:

Given that,

Design discharge (Q) = 40 cumec.

B/D ratio = 2.5 i.e. $B = 2.5D$.

C.V.R (m) = 1.0

Rugosity Coefficient (N) = 0.023

$$\bullet \text{ Critical velocity } (V_0) = 0.55 m D^{0.64} = 0.55 \times 1 \times D^{0.64} \text{ ——— (I)}$$

• Cross sectional area of trapezoidal section is, [assume, $z = 0.5:1$]

$$A = BD + zD^2 = 2.5D \times D + 0.5D^2 = 3D^2 \text{ ——— (II)}$$

• By continuity equation,

$$Q = A \times V \Rightarrow$$

$$\text{or, } 40 = 3D^2 \times 0.55 D^{0.64}$$

$$\therefore D = 3.36 \text{ m.}$$

$$\text{and, } B = 2.5D = 2.5 \times 3.36 = 8.40 \text{ m.}$$

$$\bullet \text{ Wetted Perimeter (P)} = B + D\sqrt{5} = 8.4 + 3.36\sqrt{5} = 15.91 \text{ m.}$$

$$\bullet \text{ Cross sectional area (A)} = 3D^2 = 3 \times 3.36^2 = 33.87 \text{ m}^2.$$

$$\bullet \text{ H.M.D (R)} = \frac{A}{P} = \frac{33.87}{15.91} = 2.13 \text{ m.}$$

$$\bullet \text{ Then, } V_0 = 0.55 \times 3.36^{0.64} = 1.19 \text{ m/s}$$

Now, By Kutter's formula;

$$V = \left[\frac{1}{\frac{1}{N} + \left(23 + \frac{0.00155}{S} \right)} \right] \times \sqrt{RS.}$$

$$\text{or, } 1.19 = \left[\frac{1}{0.023 + \left(23 + \frac{0.00155}{S} \right)} \right] \times \sqrt{2.13 \times S.}$$

$$\left[\frac{1}{1 + \left(23 + \frac{0.00155}{S} \right) \times \frac{0.023}{\sqrt{2.13}}} \right]$$

$$\therefore S = 2.69 \times 10^{-4} = 1 \text{ in } 3716.62 \approx 1 \text{ in } 3720.$$

• Design Summary:

Width (B) = 8.40 m, Design velocity (V) = 1.19 m/s.

Depth (D) = 3.36 m, Bed slope = 1 in 3720

Side slope (z) = 0.5:1.

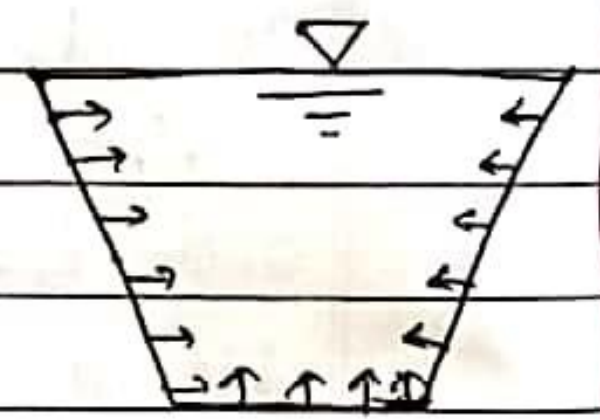
* Lacey's Silt Theory :

↳ According to Lacey's, the bed width, depth and slope of stable channel in alluvial soil carrying given discharge and silt load are fixed by nature in channel constructed in alluvium to carry a certain discharge, there will be scouring and silting the width, depth and bed slope will undergo modifications, till an equilibrium is reached by channel.

• Regime channel:

↳ It is a stable channel having width, depth and bed slope modification by silting and scouring an equilibrium condition has been attained the regime condition. Hence, an artificially constructed channel having a certain fixed section and certain fixed slope can behave in regime only if following conditions are satisfied.

- Discharge is constant.
- Flow is uniform
- Silt charge and silt grade is constant.
- Channel is flowing through a material which can be scoured as easily as it can be deposited and is of the same grade as it is transported.



Canal according to Lacey's theory

↳ Silt is kept in suspension by the vertical component of eddies. According to Lacey, the eddies are generated off the side and bed of channel and support silt. Lacey introduces the factor is called silt factor 'f'.

$$\therefore f = 1.76 \sqrt{M_r}$$

Where, M_r = average particle size or diameter in mm.

↳ Some equations used by Lacey are as follows:

$$V = \sqrt{\frac{2}{5} \cdot f \cdot R} \quad \text{--- (I)}$$

$$A f^2 = 140 \cdot V^5 \quad \text{--- (II)}$$

$$V = 10.8 R^{2/3} S^{1/2} \quad \text{--- (iii)}$$

In equation (ii),

$$Af^2 = 140 \cdot V^5$$

$$\text{or, } V \cdot Af^2 = 140 \cdot V^6 \quad [\text{multiply both sides by } V]$$

$$\text{or, } Qf^2 = 140 V^6 \quad \because [A \cdot V = Q]$$

$$\therefore V = \left(\frac{Qf^2}{140} \right)^{1/6} \quad \text{--- (iv)}$$

Similarly, eqn (i) becomes [While double squaring on both sides]

$$\therefore V^4 = \frac{4}{25} f^2 R^2 \quad \text{--- (v)}$$

In equation (iv),

$$V = \left(\frac{Qf^2}{140} \right)^{1/6}$$

$$\text{or, } V^6 = \frac{A \cdot V \cdot f^2}{140}$$

$$\therefore f^2 = \frac{140 V^5}{A} \quad \text{--- (vi)}$$

Equation (v) becomes,

$$V^4 = \frac{4}{25} \times \frac{140 V^5}{A} \times R^2$$

$$\text{or, } V^4 = \frac{4}{25} \times \frac{140 \cdot V^5}{A} \times \frac{A^2}{P^2} \quad \because \left[R = \frac{A}{P} \right]$$

$$\text{or, } 25 P^2 = 4 \times 140 \times A \cdot V$$

$$\text{or, } 25 P^2 = 560 Q$$

$$\text{or, } P = \sqrt{\frac{560 \cdot Q}{25}}$$

$$\text{or, } P = 4.733 \sqrt{Q}$$

$$\therefore [P = 4.75 \sqrt{Q}] \quad \text{--- (x)}$$

slope equation:

$$\left[S = \frac{f^{5/3}}{3340 Q^{1/6}} \right] \quad \text{--- (x)}$$

• Design Procedure:

- ① Calculate velocity; Where, $Q = \text{discharge in m}^3/\text{s}$

$$V = \left(\frac{Q f^2}{140} \right)^{1/6}$$
 $f = \text{Silt factor} = 1.76 \sqrt{d} \text{ or } 1.76 \sqrt{m_r}$
 $\therefore m_r = (\text{diameter of particle in mm} / \text{average particle size in mm})$

② Calculate Hydraulic Mean Depth;

$$R = \frac{5}{2} \times \frac{V^2}{f} \quad \therefore V = \sqrt{\frac{2}{5} f R}$$

③ Wetted Perimeter.

$$P = 4.75 \sqrt{Q}$$

④ Calculate Area of channel section:

$$A = Q/V$$

⑤ Determine 'B' and 'D'

$$A = BD + zD^2 \quad \text{or} \quad [A = BD + 0.5D^2 \text{ if assume } z = 0.5:1]$$

⑥ Perimeter,

$$P = B + 2D\sqrt{z^2 + 1} \quad \text{or} \quad [P = B + D\sqrt{5} \text{ if } z = 0.5:1]$$

⑦ Bed slope:

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

⑧ Compute, $R = \frac{A}{P}$

- Compare, value of R obtained with value of R in step ②
 i.e. from equation, $R = \frac{5}{2} \times \frac{V^2}{f}$

$\therefore$ Both values of R should be approximately equal.

Q.No.1 Design the irrigation canal from the following data:

$Q = 20 \text{ cumec}$, Silt factor $= 1$.

Solution: Given that,

Discharge (Q) = 20 cumec.

Silt factor (f) = 1.

$$\bullet \text{ Velocity } (V) = \left(\frac{Qf^2}{140} \right)^{1/6} = \left(\frac{20 \times 1^2}{140} \right)^{1/6} = 0.72 \text{ m/s.}$$

$$\bullet \text{ Hydraulic mean depth } (R) = \frac{5}{4} \times \frac{V^2}{f} = 1.31 \text{ m.}$$

$$\bullet \text{ Area } (A) = Q/V = 20/0.72 = 27.78 \text{ m}^2.$$

$$\bullet \text{ Wetted Perimeter } (P) = 4.75 \sqrt{Q} = 4.75 \sqrt{20} = 21.24 \text{ m.}$$

$$\bullet \text{ Cross-sectional area } (A) = BD + zD^2$$

$$\therefore A = BD + 0.5D^2 \quad [\text{assuming } z = 0.5:1]$$

$$27.78 = BD + 0.5D^2 \quad \text{--- (i)}$$

$$\bullet \text{ Perimeter, } P = B + D\sqrt{5}$$

$$\therefore B = 21.24 - D\sqrt{5} \quad \text{--- (ii)}$$

Putting the value of B in equation (i), we get.

$$27.78 = (21.24 - D\sqrt{5}) \times D + 0.5D^2$$

$$\therefore D = 1.49 \text{ m.}$$

$$\text{and, } B = 21.24 - 1.49\sqrt{5} = 17.91 \text{ m.}$$

$$\bullet \text{ Bed slope } (S) = \frac{f^{5/3}}{3340 \times Q^{1/6}} = \frac{1^{5/3}}{3340 \times 20^{1/6}} = 0.00018$$

$$\therefore S = 1 \text{ in } 5502.81 \approx 1 \text{ in } 5500$$

$$\bullet \text{ Hydraulic mean depth } (R) = \frac{A}{P} = \frac{27.78}{21.24} = 1.31 \text{ m.}$$

Hence, ok.

Design summary:

$$B = 17.91 \text{ m}$$

$$D = 1.49 \text{ m}$$

$$V = 0.72 \text{ m/s.}$$

$$S = 1 \text{ in } 5500$$

$$Z = 0.5:1 \text{ (H:V) \#.}$$

Q. NO. 2 The bed slope of regime canal is 1 in 5800. Determine the channel section and discharge. The average particle size is 0.323 mm.

Solution: Given that,

average particle size (M_r) = 0.323 mm

$$\therefore \text{silt factor } (f) = 1.76 \sqrt{M_r} = 1.76 \sqrt{0.323} = 1.00$$

Bed slope (S) = 1 in 5800.

$$\bullet \text{ We know, } S = \frac{f^{5/3}}{3340 Q^{1/6}} \Rightarrow \frac{1}{5800} = \frac{1^{5/3}}{3340 \times Q^{1/6}}$$

$$\therefore Q = 27.42 \text{ m}^3/\text{s}$$

$$\bullet \text{ Velocity } (v) = \left(\frac{Q f^2}{140} \right)^{1/6} = \left(\frac{27.42 \times 1^2}{140} \right)^{1/6} = 0.76 \text{ m/s}$$

$$\bullet \text{ Cross-sectional area } (A) = \frac{Q}{v} = \frac{27.42}{0.76} = 36.08 \text{ m}^2$$

$$\bullet \text{ Wetted perimeter } (P) = 4.75 \sqrt{Q} = 4.75 \sqrt{27.42} = 24.87 \text{ m}$$

$$\bullet \text{ H.M.D } (R) = \frac{A}{P} = \frac{36.08}{24.87} = 1.45 \text{ m}$$

$$\bullet \text{ Cross-sectional area } (A) = BD + zD^2 \quad [\text{assume } z = 0.5:1]$$

$$\therefore 36.08 = BD + 0.5D^2 \quad \text{--- (I)}$$

$$\bullet \text{ Perimeter } (P) = B + D\sqrt{5}$$

$$B = 24.87 - D\sqrt{5} \quad \text{--- (II)}$$

Putting the value of B in eqⁿ (I), we get.

$$36.08 = (24.87 - D\sqrt{5}) \times D + 0.5D^2$$

$$\therefore D = 1.64 \text{ m}$$

$$\text{and, } B = 24.87 - 1.64\sqrt{5} = 21.20 \text{ m}$$

$\bullet$ Check for H.M.D:

$$R = \frac{5v^2}{2f} = \frac{5 \times 0.76^2}{2 \times 1} = 1.45 = R. \text{ Hence ok. \#}$$

Design Summary:

$$Q = 27.42 \text{ m}^3/\text{s}$$

$$B = 21.20 \text{ m}$$

$$D = 1.64 \text{ m}$$

$$v = 0.76 \text{ m/s}$$

Difference between Kennedy's and Lacey's Theory :

↳ The differences between Kennedy's and Lacey's theory are as follows:

S.N.	Kennedy's Theory	Lacey's Theory
1.	It states that silt carried by the flowing water is kept in suspension by the vertical component of eddies which are generated from the bed of the channel.	It states that the silt carried by the flowing water is kept in suspension by the vertical component of eddies which are generated from the entire wetted perimeter of canal.
2.	Kennedy did not give any flow equation but recommended the use of Kutter's equation.	Lacey gave his own flow equation.
3.	Kennedy introduced the critical velocity ratio (m) for silt grade.	Lacey introduced the silt factor, gives an equation for its determination for average particle size.
4.	Kennedy did not give any formula for bed slope.	Lacey gives his own formula for bed slope.
5.	Kutter's equation is used for finding the mean velocity.	This theory gives an equation for finding the mean velocity.
6.	In this theory, the design is based on trial and error method.	This theory does not involve trial and error method.
7.	In this theory, there is the relation between ' V ' & ' D '.	In this theory, there is the relation between ' V ' & ' R '.
8.	Kennedy's theory is not unique.	Lacey's theory is unique.

* Design of Non-alluvial Canals:

Non-alluvial Canal:

- ↳ In non-alluvial channel, the water is clear and therefore no silting problem occurs. Non-alluvial soils are clay, hard loam or soils, formed as a result of disintegration of rocks.
- ↳ Non-alluvial channels are considered stable if there is no silt problem in such channels. These channels are usually designed based on the maximum permissible velocity which the channel boundary surface can resist without scouring. Mean flow velocity for the design discharge under uniform flow conditions should be less than permissible flow velocity.
- ↳ The design of non-alluvial channels is usually done by using Manning's formula or Chezy's Equation.

Manning's Formula:

- ↳ Velocity of flow in the channel;

$$V = \frac{1}{N} R^{2/3} S^{1/2} \quad \text{becomes in m/sec.}$$

Where, N = Manning's Rugosity constant

R = Hydraulic mean depth / Hydraulic radius. (m)

S = Longitudinal bed slope of channel.

Chezy's Equation:

- ↳ Mean Velocity of flow;

$$V = C \sqrt{RS} \quad \text{becomes in m/sec.}$$

Where,

C = Chezy's Constant.

R = Hydraulic mean depth (m)

S = Bed slope of canal.

$$C = \frac{87}{1 + \frac{K}{\sqrt{R}}}$$

$\therefore K$ = Bazin's Constant.

$$\text{OR, } C = \frac{1}{\frac{1}{N} + \left(\frac{23 + 0.00155}{S} \right)}$$

$$= \frac{1}{\frac{1}{N} + \left(\frac{23 + 0.00155}{S} \right) \times \frac{N}{\sqrt{R}}}$$

● Design Procedure:

↳ Given;

- Discharge (Q)
- Maximum permissible velocity (V)
- Manning's Constant (N) / Chezy's Constant (C).
- Side slope (Z)
- Bed slope (S)

① Calculate cross sectional area.

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

② H.M.D (R)

$$V = \frac{1}{N} R^{2/3} S^{1/2} \quad / \quad V = C \sqrt{RS}$$

③ Wetted Perimeter (P)

$$P = \frac{A}{R} \quad \because \left[R = \frac{A}{P} \right]$$

④ Depth and Bed width [$D \times B$]:

$$A = BD + ZD^2 \quad \text{--- (x)}$$

$$P = B + 2D\sqrt{Z^2 + 1} \quad \text{--- (x)}$$

Q.No.1 Design an Irrigation Channel in non-alluvial material to carry a discharge of 15 cumec when the maximum permissible velocity is 0.8 m/sec. Assume bed slope 1 in 4000 and side slope as 1:1 and Manning's coefficient is 0.025.

Solution

Given that,

Design Discharge (Q) = 15 cumec.

maximum permissible velocity (V) = 0.8 m/sec.

Bed slope (S) = 1 in 4000

Side slope (Z) = 1:1

Manning's coefficient (N) = 0.025

Now,

- Area (A) = $Q/V = 15/0.8 = 18.75 \text{ m}^2$

- H.M.D. (R) :

$$V = \frac{1}{N} R^{2/3} S^{1/2} \Rightarrow 0.8 = \frac{1}{0.025} R^{2/3} \left(\frac{1}{4000} \right)^{1/2}$$

$$\therefore R = 1.42 \text{ m.}$$

- Wetted Perimeter, $P = A/R = 18.75/1.42 = 13.20 \text{ m.}$

Assuming, the section of canal is trapezoidal.

$$A = BD + ZD^2$$

$$18.75 = B \times D + 1 \cdot D^2 \quad \text{--- (i)}$$

and, $P = B + 2D\sqrt{Z^2 + 1}$

$$B = 13.20 - 2D\sqrt{1^2 + 1} = 13.20 - 2.83D \quad \text{--- (ii)}$$

Putting the value of B in eqn (i), we get.

$$18.75 = (13.20 - 2.83D) \times D + D^2$$

$$\therefore D = 1.94 \text{ m.}$$

$$\therefore B = 13.20 - 2.83 \times 1.94 = 7.71 \text{ m}$$

Design Summary:

$$B = 7.71 \text{ m}$$

$$D = 1.94 \text{ m}$$

$$S = 1 \text{ in } 4000$$

$$Z = 1:1.$$

#.

Q.No.2 Design an irrigation canal with following data:

Discharge of canal $= 24 \text{ m}^3/\text{s}$, Permissible mean velocity $= 0.8 \text{ m/sec}$, Bed slope, $S = 1 \text{ in } 5000$, Side slope $= 1:1$
Chezy's Constant, $C = 44$.

Solution: Given that,

Discharge of canal (Q) $= 24 \text{ m}^3/\text{s}$.

Permissible mean velocity (V) $= 0.8 \text{ m/sec}$

Bed slope (S) $= 1 \text{ in } 5000$

Side slope (z) $= 1:1$

Chezy's Constant (C) $= 44$.

Now,

- Cross sectional area (A) $= \frac{Q}{V} = \frac{24}{0.8} = 30 \text{ m}^2$

We know, that, By Chezy's equation.

- $V = C\sqrt{RS}$

or, $0.8 = 44\sqrt{R \times (1 \div 5000)}$

$\therefore \text{H.M.D. (R)} = 1.65 \text{ m}$.

then,

- Wetted Perimeter (P) $= \frac{A}{R} = \frac{30}{1.65} = 18.18 \text{ m}$.

↳ Assuming the, cross sectional area is trapezoidal. Then

$$A = BD + zD^2$$

or, $30 = RD + D^2$ ——— ① $\because [z = 1:1]$

and,

$$P = B + 2D\sqrt{z^2 + 1}$$

or, $B = P - 2D\sqrt{1^2 + 1}$

$\therefore B = 18.18 - 2.83D$ ——— ②

Then, putting the value of B in eqⁿ ①, we get

$$30 = (18.18 - 2.83D) \times D + D^2$$

$\therefore D = 2.09 \text{ m}$

and, $B = 18.18 - 2.83 \times 2.09 = 12.27 \text{ m}$

Cross-Drainages:

↳ In an irrigation project, when the network of main canal, branch canal, distributaries etc are provided, then those canals may have to cross the natural drainages like rivers, streams etc at different points within the commanded area of the project. The crossing of the canals with such obstacles can not be avoided. So, suitable structures must be provided at the crossing point for easy flow of water of the canal and drainage in the respective direction.

These structures are known as cross-drainage works or structures.

↳ A cross-drainage work is generally a very costly item, and should be avoided as far as possible by:

- ① Direct the one stream into the other stream before reaching the canal.
- ② Change the alignment in such a way that crosses the stream below the junction of two streams.

Types of Cross-Drainage Works:

↳ Depending upon the relative water levels, cross drainage works are classified into following types:

1. Type-I: Irrigation canal passes over Drainage:

- ① Aqueduct
- ② Syphon Aqueduct

2. Type-II: Drainage passes over the Irrigation canal:

- ① Super Passage
- ② Canal Syphon.

3. Type-III: Drainage and Canal intersect each other of the same level.

- ① Level Crossing
- ② Canal Inlet and Outlet.

Type-I Irrigation Canal passes over the drainage :

(a) **Aqueduct :**

↳ The aqueduct is just like a bridge where canal is taken over the deck supported by piers instead of road or railway. Generally, the canal is in the shape of rectangular trough which is constructed with reinforced cement concrete. Sometimes, the trough may be of trapezoidal section. It is shown in figure below :

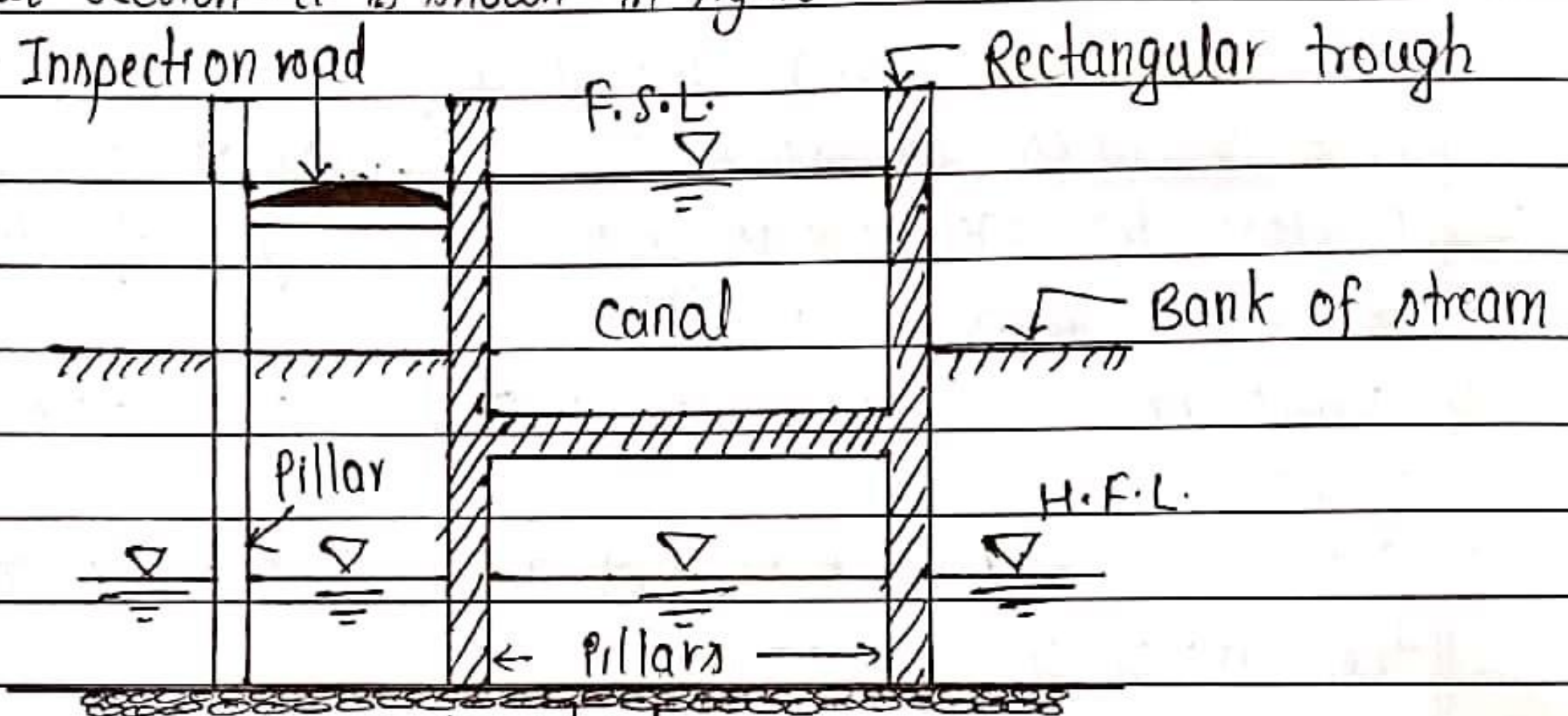


Fig: Aqueduct

- An inspection road is provided along the side of the trough.
- The bed and banks of the drainage below the trough is protected by pitching with cement grouting.
- The selection of the trough is designed according to the full supply of the canal.
- A free board of about 0.50m 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.

⑥ Syphon Aqueduct:

↳ The syphon aqueduct, the bed of drainage is depressed below the bottom level of the canal trough by providing sloping apron on both sides of crossing. It is shown in figure below

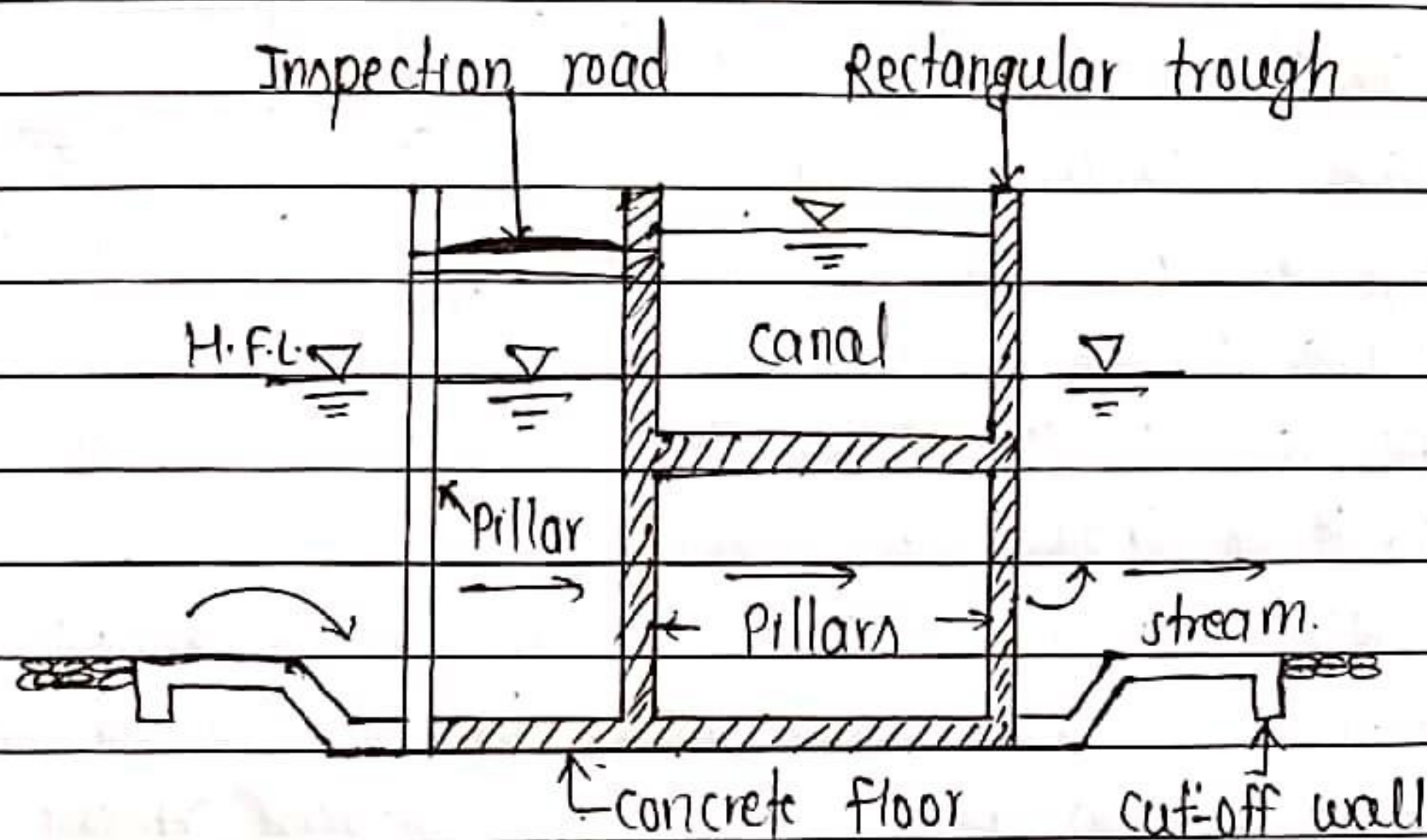


Fig: syphon Aqueduct

- The sloping apron may be constructed by stone pitching or cement concrete.
- The section of drainage below the canal trough is constructed with cement concrete in the form of tunnel. This tunnel acts as a syphon.
- 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 component like canal-trough, piers, inspection road etc should be designed according to the methods adopted in case of aqueduct.

Type-II Drainage passes over the irrigation canal:

(a) Super Passage:

↳ The super passage is just opposite of the aqueduct. In this case, the bed level of drainage is above the full supply level of the canal. The drainage is taken through a rectangular or trapezoidal trough of channel which is constructed on the deck supported by the piers. It is shown in figure:

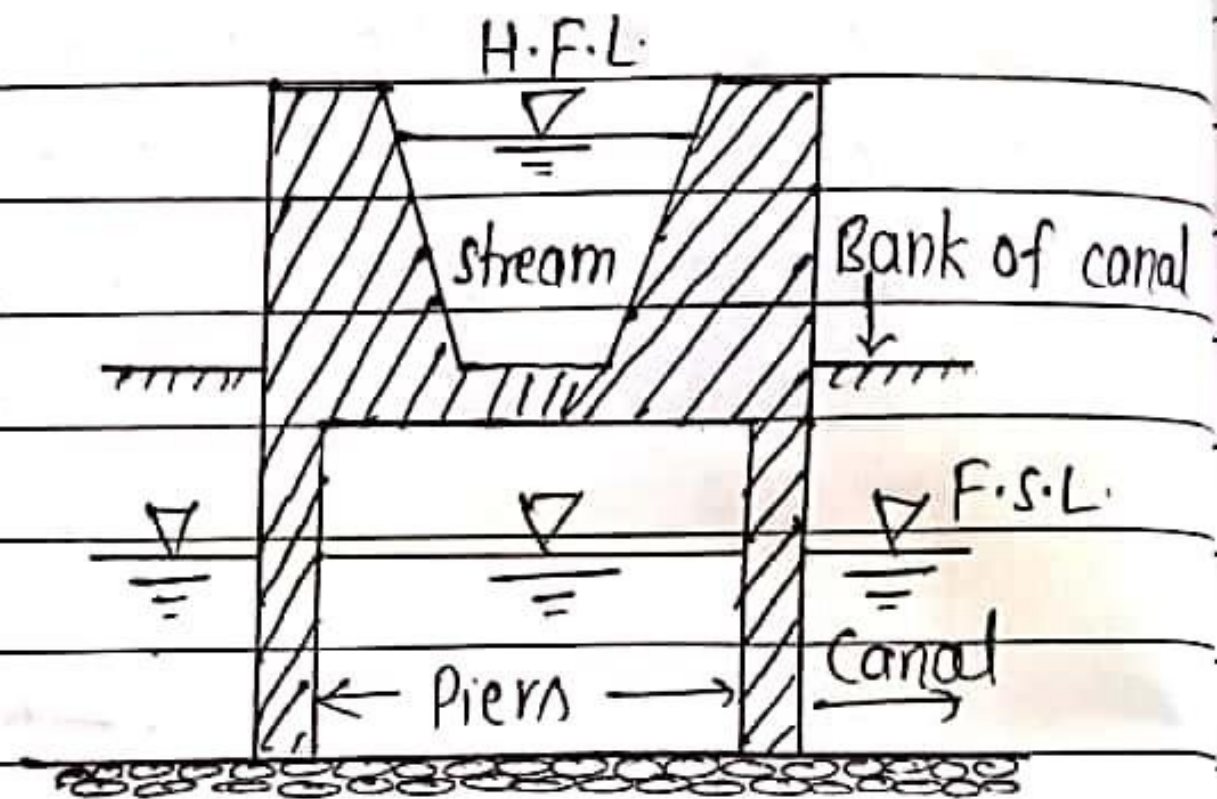


Fig: Super Passage

- The section of the drainage trough depends on the high flood discharge.
- A free board of about 1.5m should be provided for safety.
- The trough should be constructed of reinforced cement concrete.
- The foundation of the piers will be same as in the case of aqueduct.

(b) Canal Syphon / Syphon super passage:

↳ It is just opposite to syphon aqueduct.

In this case, the canal passes below the drainage trough. The section of the trough is designed according to high flood discharge. The bed of the canal is depressed below the bottom level of drainage trough by providing sloping apron on both sides of the crossing.

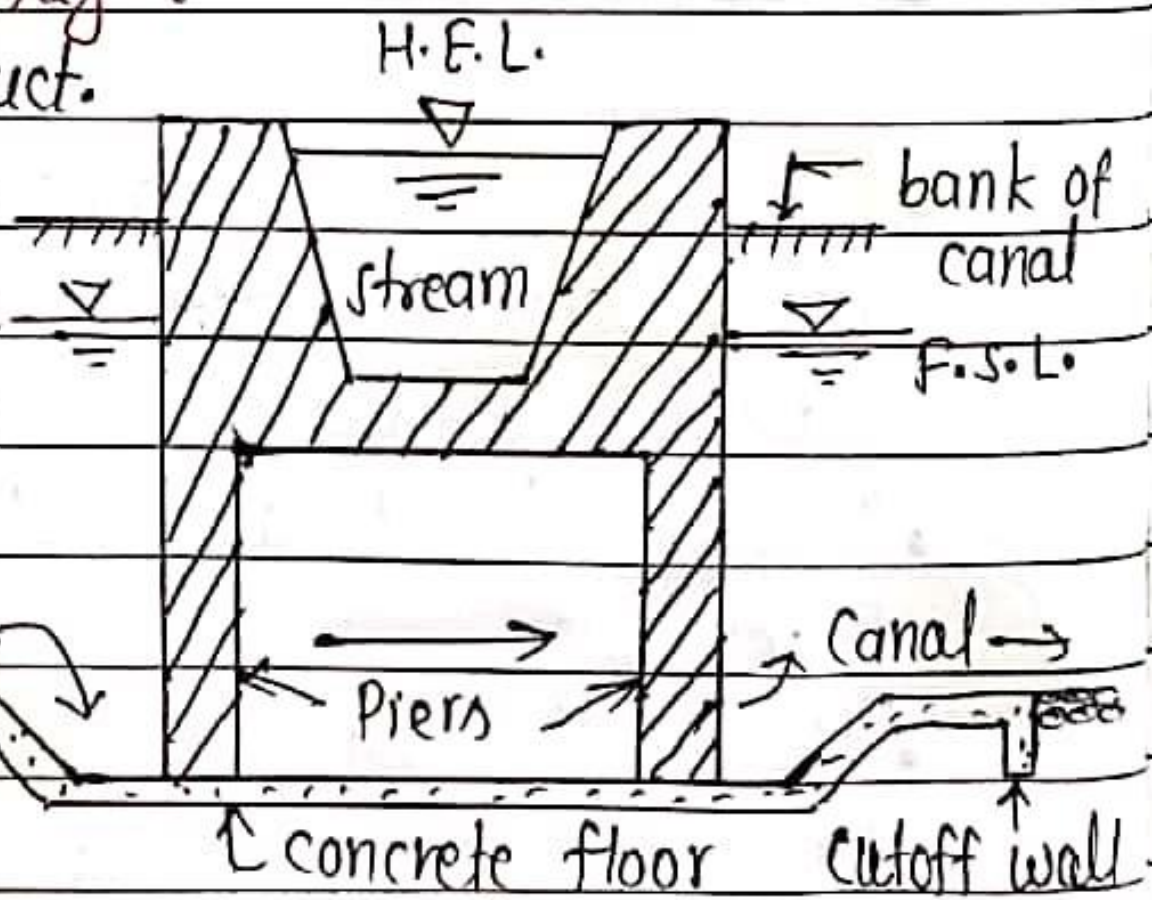


Fig: Canal syphon

- Cutoff walls are provided on U/s & D/s side of sloping apron.
- The section of canal below the trough is constructed with cement concrete in the form of tunnel which acts as syphon.
- If the canal water flow under gravity i.e. freely, then it is called super passage and if the canal water flow under syphonic action then this is called canal syphon.
- Other components are same as in the syphon aqueduct.

Type-III Drainage and Canal Intersect each other of the same level:

① Level Crossing:

↳ The level crossing is an arrangement provided to regulate the flow of water through the drainage and canal when they cross each other approximately at the same bed level. It is shown in figure below:

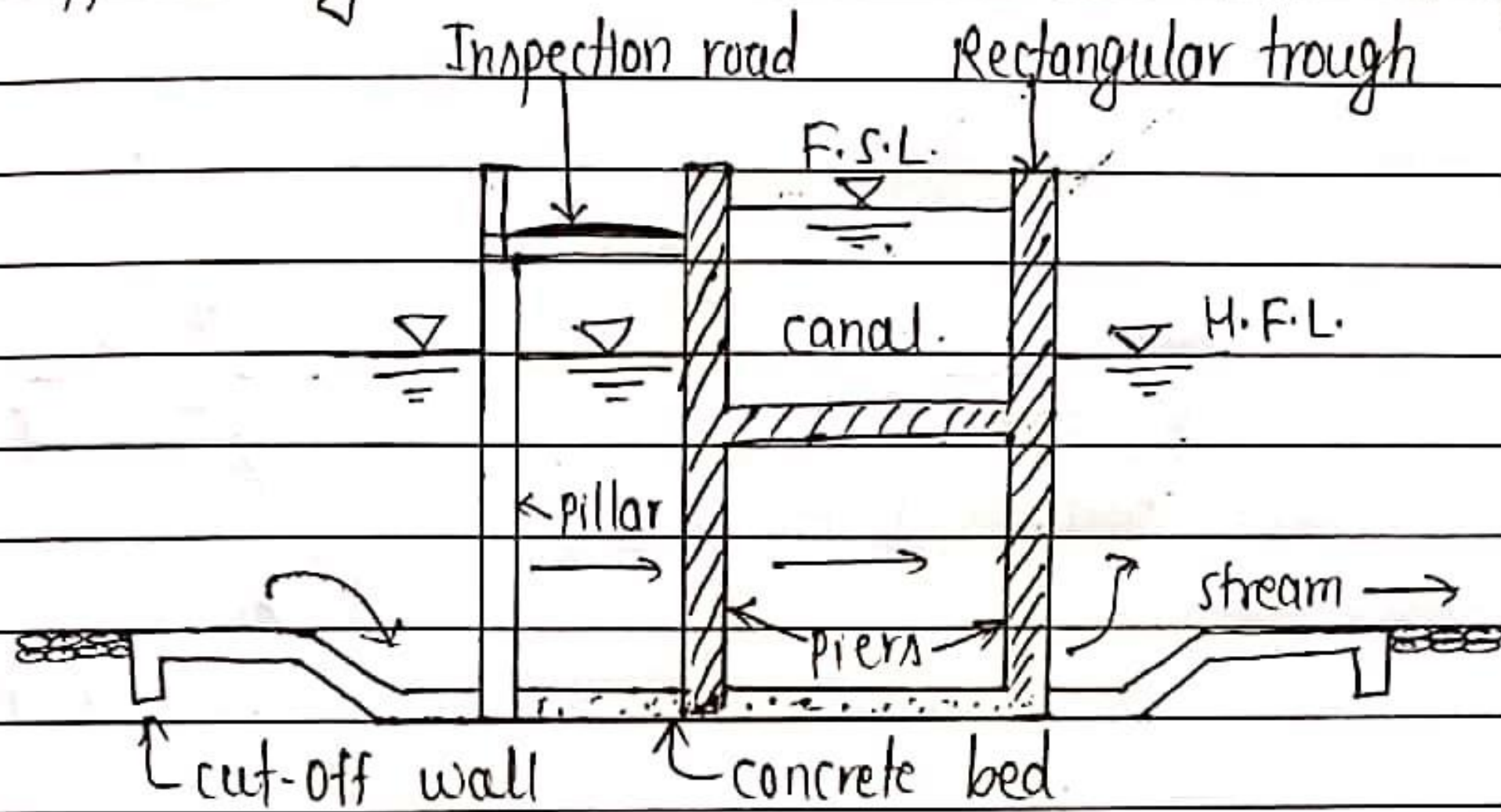


Fig: Level-Crossing

↳ The level crossing consists of following components:

① Crest wall:

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

② Drainage Regulator:

↳ It is provided across the drainage just the down-stream side of crossing point. The regulator consists of adjustable shutter at different tiers.

③ Canal Regulator:

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

⑥ 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. The arrangement is known as canal inlet and outlet. It is shown in figure below:

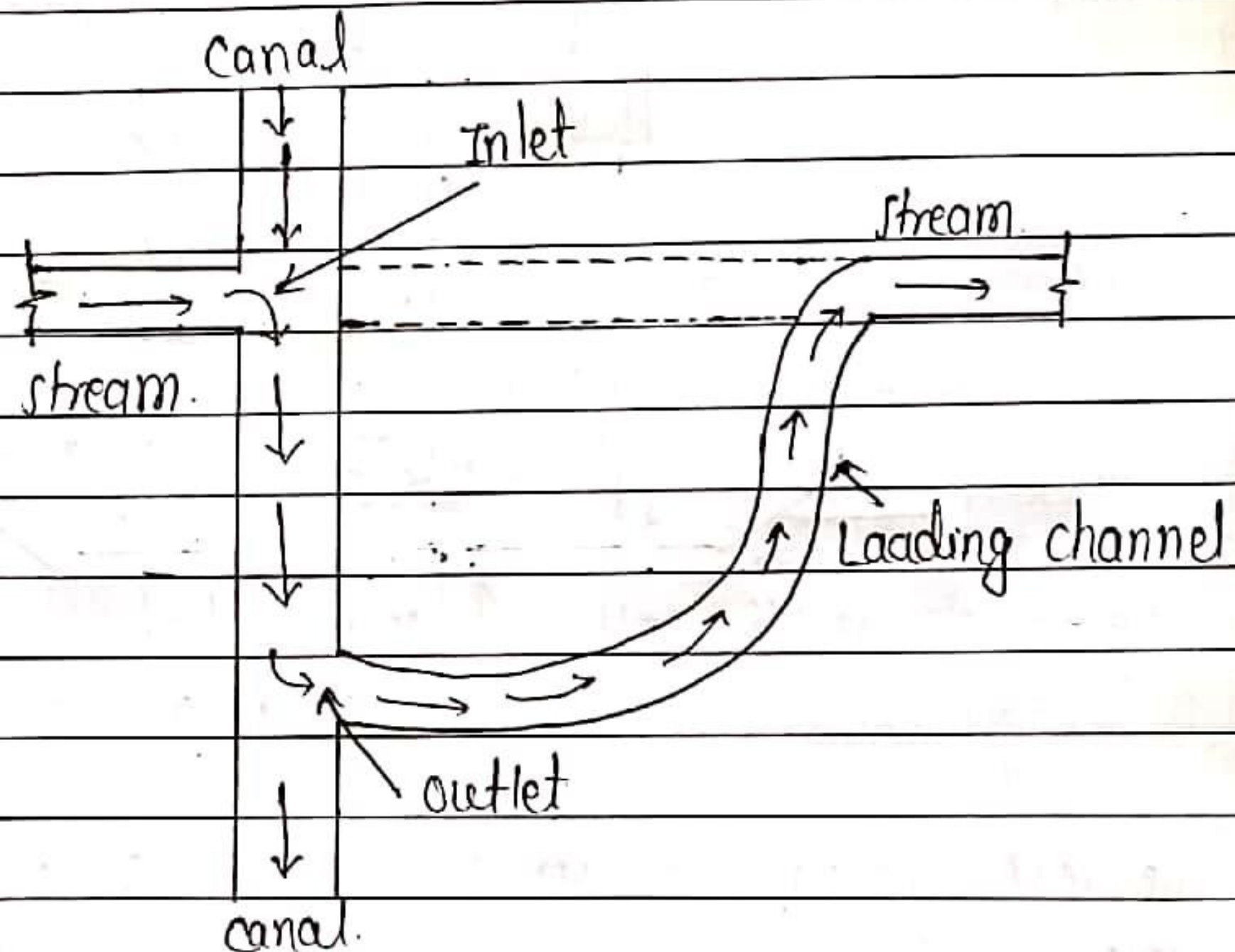


Fig: Canal inlet and outlet.

- In this system an inlet is provided in the channel bank simply by open cut and the drainage water is allowed to join the channel.
- A canal inlet is constructed when cross drainage flow is small and its water may be observed into the canal.
- A canal outlet is constructed to pass out the additional discharge which has entered the canal.
- The number of inlet may or may not be equal to the number of outlet.

Canal Outlets:

↳ A canal is a small structure which admits water from the distributing channel to the water course of field channel. Thus, an outlet is a sort of head regulator for the field channel delivering water to the irrigation fields.

↳ A canal outlet is constructed to pass out the additional discharge which has entered into the canal.

• Requirements of good outlet:

↳ The good outlet should have following requirements.

- ① It should be strong and cheap enough.
- ② It should provide sufficient quantity and constant discharge.
- ③ Its design should be simple, so that local technician can maintain it.
- ④ It should work efficiently and draw silt fairly.

• Types of Canal Outlets:

1. Non-modular outlet:

↳ A non-modular outlet is one in which the discharge depends upon the difference in level between the water levels in the distributing channel and the water course. Eg: masonry sluice, submerged pipe outlet, orifices etc.

2. Semi-Module or Flexible Outlet:

↳ A flexible or semi-module is the one in which discharge is affected by the fluctuation of water levels in the distributing channel while the fluctuation in the water levels of field channel do not have any effect on discharge. Eg: Kennedy's gage outlet, crump's open flume outlet, pipe-cum-open-flume outlet.

3. Rigid module:

↳ A rigid module is the one which maintains constant discharge within limits irrespective in the water level in the distributing channel and/or Khanna's rigid module, foot module.

V. imp #

Canal Fall/Canal Drop/Drop/fall:

↳ A canal drop or fall is the structure constructed on a channel to lower down the water level and bed level of channel because of the drop of water level of the fall; the potential energy of channel is converted into kinetic energy which may damage the D/S portion of canal by scouring action. It is designed to dissipate surplus energy possessed by the water falling over the structure. Thus, canal fall consists of combination of water lowering structure and energy dissipating device.

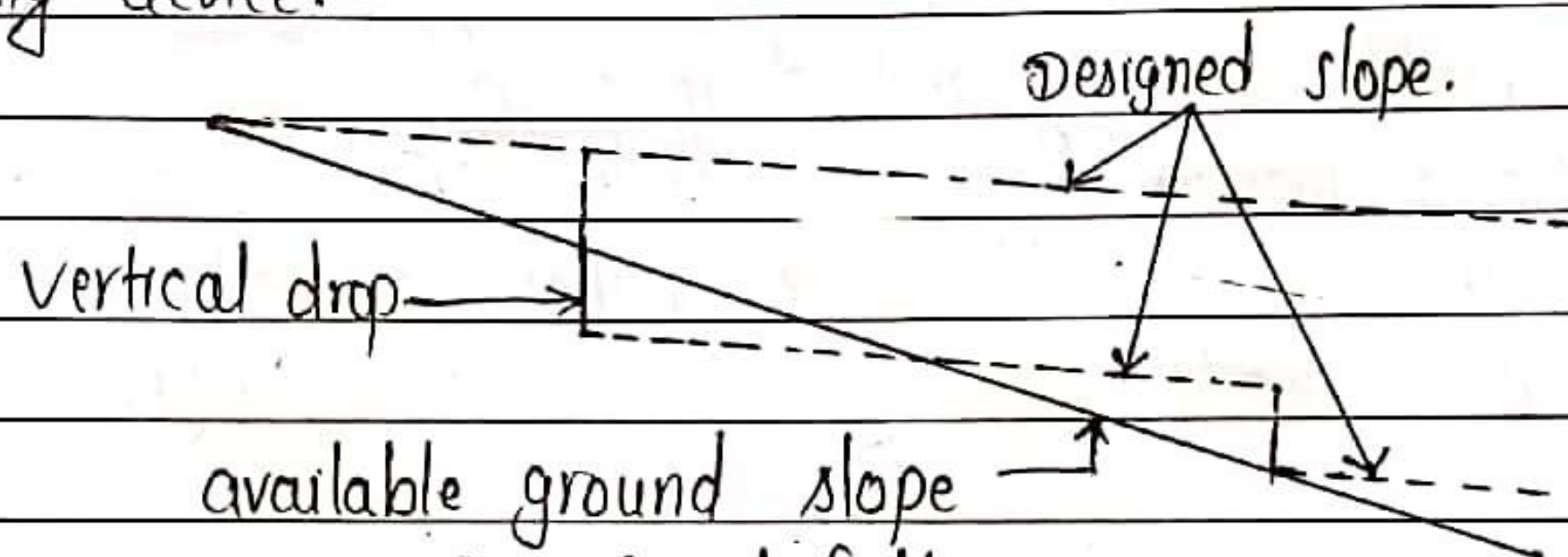


fig: Canal fall.

- ↳ The canal fall are required when the natural slope of ground along the canal alignment is steeper than bed slope of canal.
- ↳ Normally, the ground slope is about 1 in 200 to 1 in 50 and that for canal is 1 in 4000 to 1 in 8000. This difference is adjusted by providing vertical fall in the bed of canal at suitable interval. At the fall, masonry structures are constructed to prevent scouring.

• Types of Drops or Falls:

↳ Following are the various types of drops or falls:

1. Ogee fall
2. Rapid fall
3. Stepped fall
4. Notch fall
5. Vertical drop fall
6. Enlacin type fall
7. Montague type fall
8. Inglis type fall

(2074)
(2071)

⑤ Drops or falls:

A canal fall or fall structure constructed on a channel to lower down the water level and the bed level of channel because of the drop of water level of the fall, the potential energy of channel is converted into the kinetic energy which may damage the downstream portion of canal by scouring action. It is designed to dissipate surplus energy possessed by the water falling over the structure. Thus canal fall consist of combination of water lowering structure and an energy dissipating device.

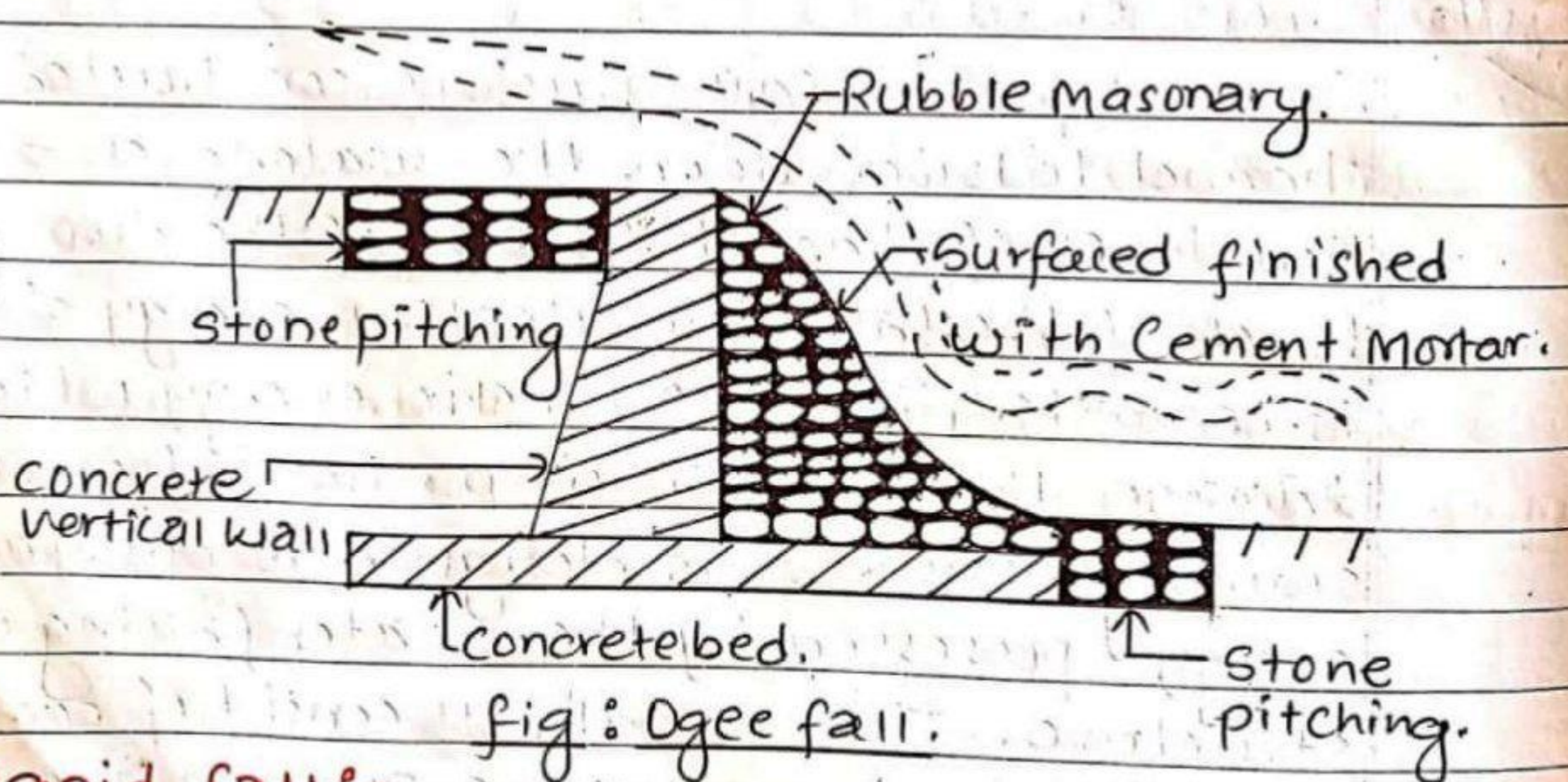
There are various types of canal fall they are as follows:

①. 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. It is shown in figure below:

- ↳ The fall consists of a concrete vertical wall and concrete bed.
- ↳ Over the concrete bed the rubble masonry is provided in the shape of ogee curve.
- ↳ The surface of masonry is finished with rich cement mortar (1:3).
- ↳ The upstream and downstream side of fall is protected by stone pitching with cement grouting.
- ↳ The design consideration of ogee fall depends on the site condition.



②. 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. It is shown in figure below:

- ↳ Curtain walls are provided on the upstream and downstream side of sloping glacis.

- The sloping bed is provided with rubble masonry.
- The upstream and downstream side of the fall is also protected by rubble masonry.
- The masonry surface is finished with rich cement mortar (1:3).
- The long glacies assured the formation of hydraulic jump.

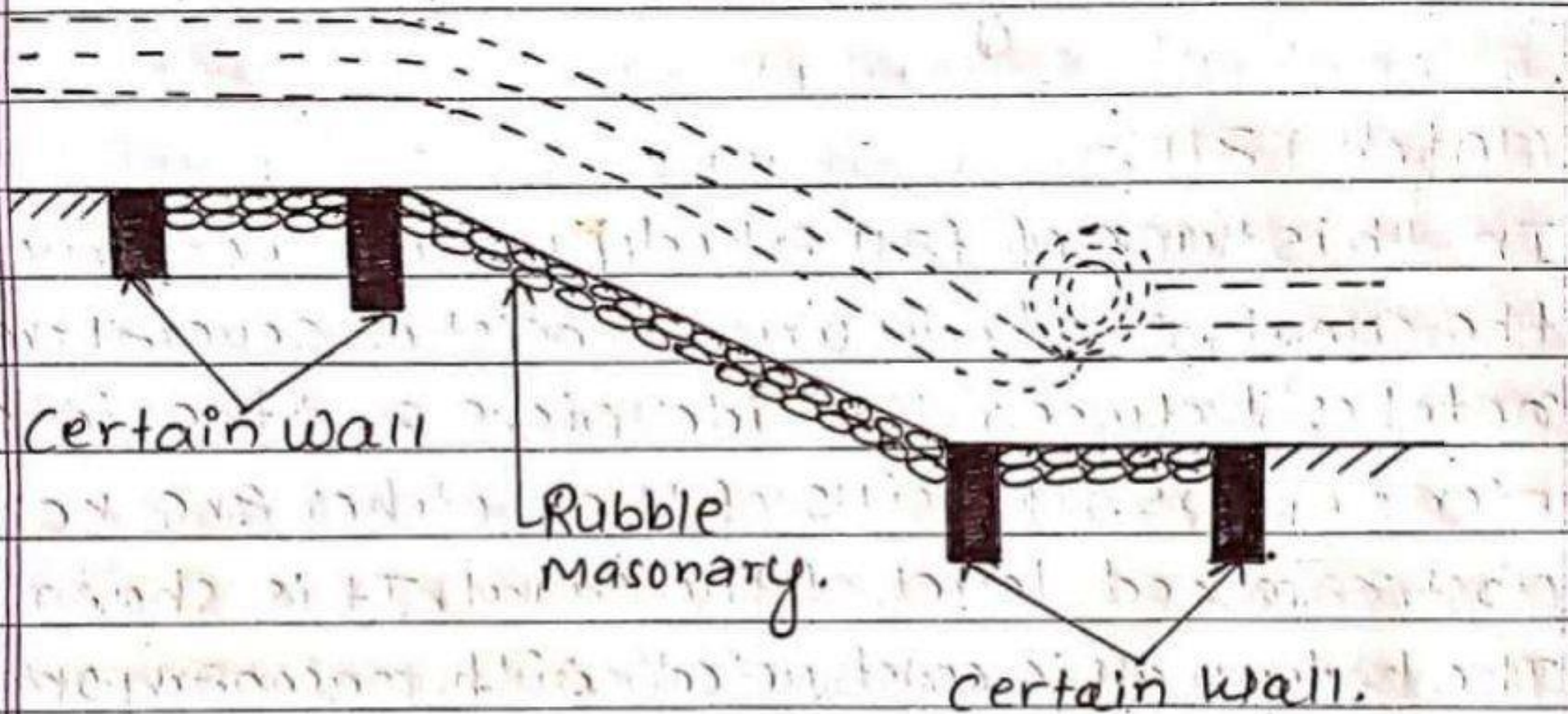


fig: Rapid fall.

③ Stepped fall :-

Stepped fall was a next development of rapid fall which consist of a series of vertical drops in the form of steps. This fall is suitable in the places where the sloping ground is very long and requires long glacies to connect the higher bed level with lower bed level. It is shown in figure below.

- The fall is practically a modification of rapid fall.
- The sloping glacies is divided into a number of drops so that the flowing water may not cause any damage to the canal bed. Brick walls are provided at each end of drops.
- The bed of canal within the fall is protected by rubble masonry with surface finishing by rich cement mortar (1:3)

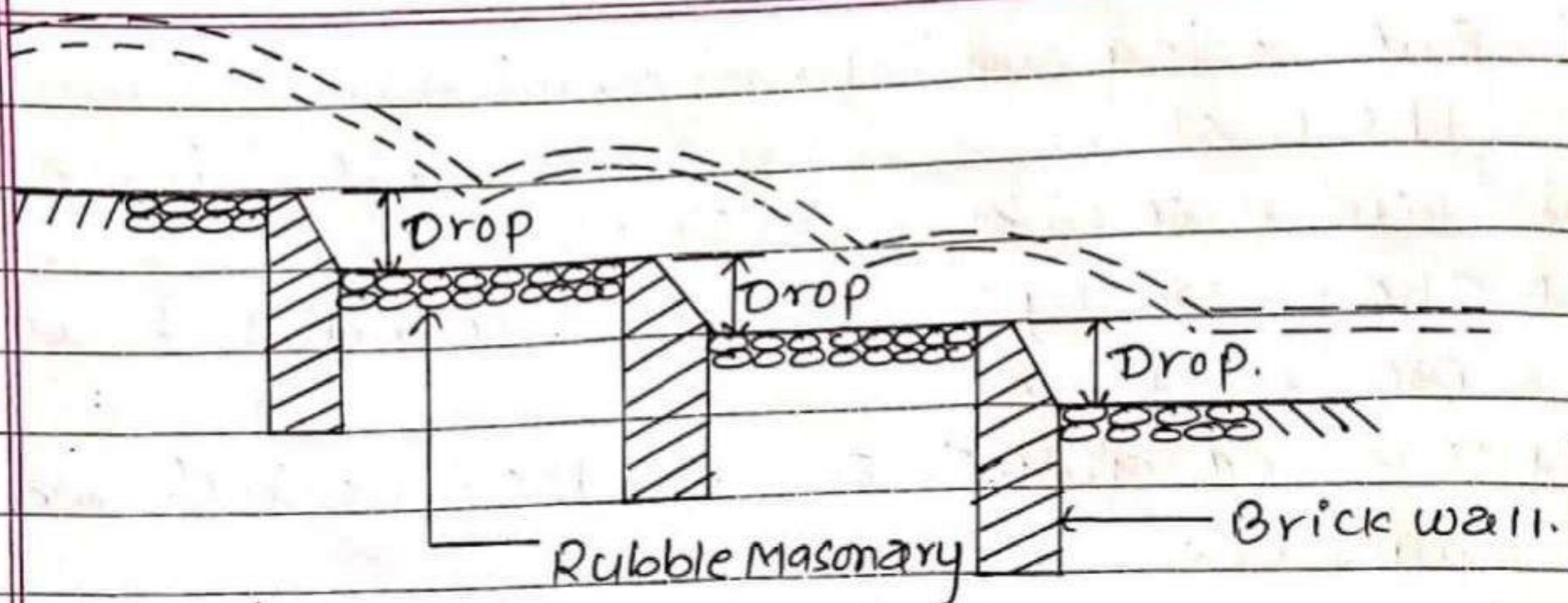


Fig:- Stepped Fall.

④ 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.) The sills of the notches are kept at the upstream bed level of the canal. It is shown in fig below.

- ↳ The body wall is constructed with masonry or concrete.
- ↳ An intermediate floor is provided to resist the scouring effect of the falling water.
- ↳ The upstream and downstream side of the fall is protected by stone pitching finished by cement grouting.
- ↳ The size and number of notches depends upon the full supply discharge of the canal.

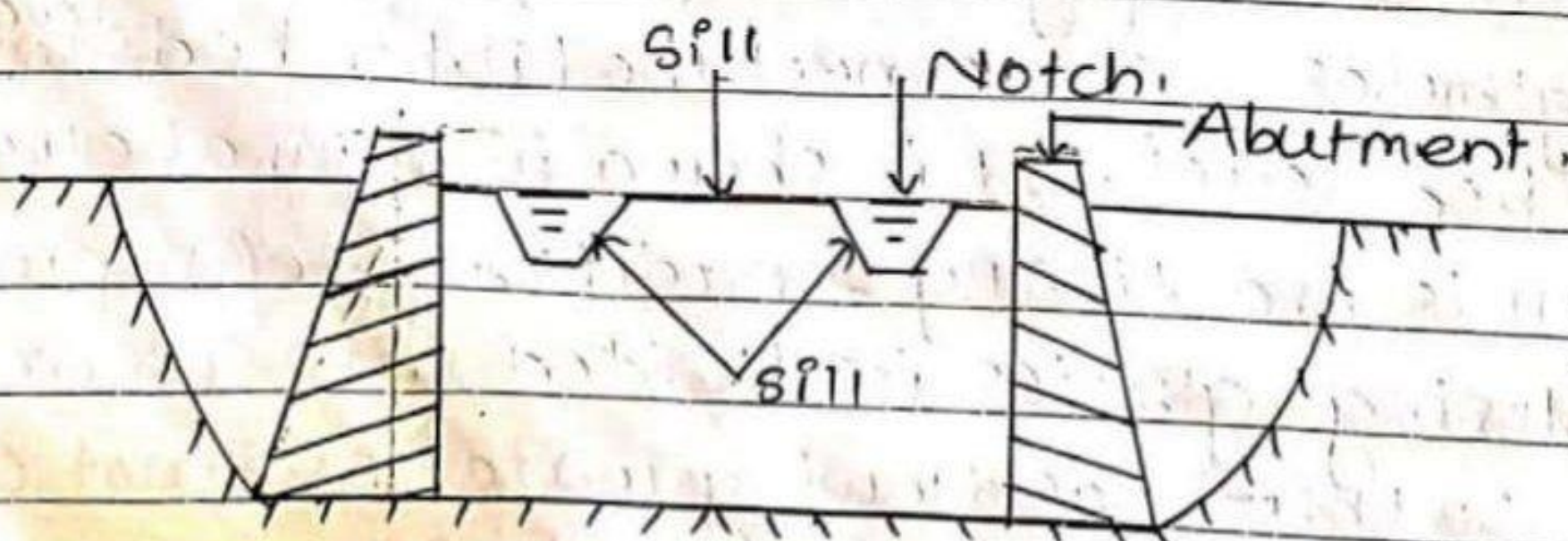
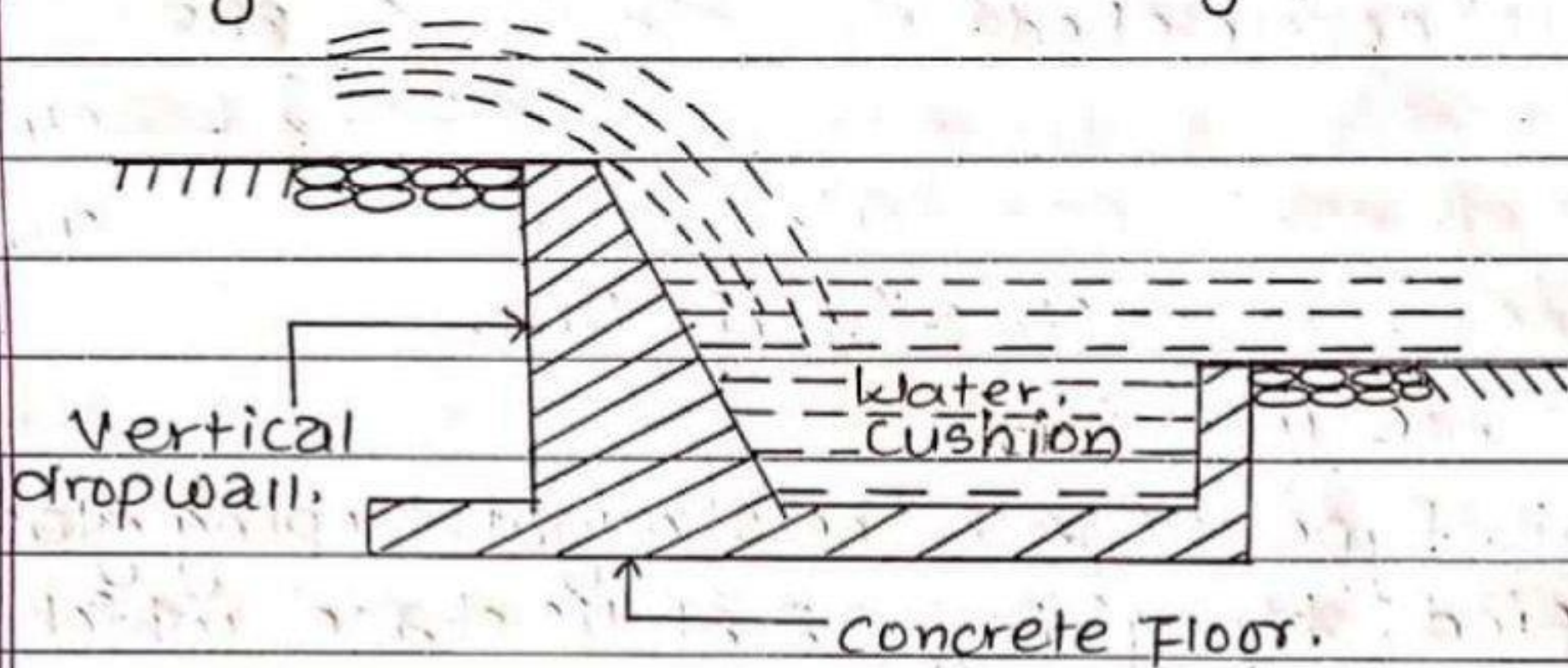


Fig:- Notch fall.

⑤. Vertical drop fall :-

In the vertical drop fall nappe impinges clear into the water cushions below. It consists of a vertical drop wall which is constructed with masonry work. The water flows over the crest of the wall. A water cushion is provided on the downstream side which acts as a water cushion to dissipate the energy of falling water. It is shown in figure below:



- ↳ A concrete floor is provided on the downstream side to control the scouring effect of flowing water.
- ↳ Curtain walls are provided on the upstream and downstream side.
- ↳ Stone pitching with cement grouting is provided on the upstream and downstream side of fall to protect scouring.

⑥. Glacis type fall :-

Efficiency of the fall increases a hydraulic jump. It consists of straight sloping glacis provided with a crest. A water cushion is provided on the downstream side to dissipate the energy of flowing water. It is shown in figure below:

- ↳ The sloping glacis is constructed with cement concrete.
- ↳ Curtain wall and toe wall are provided on the upstream and downstream side.

- ↳ The space between the toe walls and curtain walls is protected by stone pitching.
- ↳ This type of fall is suitable for drops upto 1.5 m.

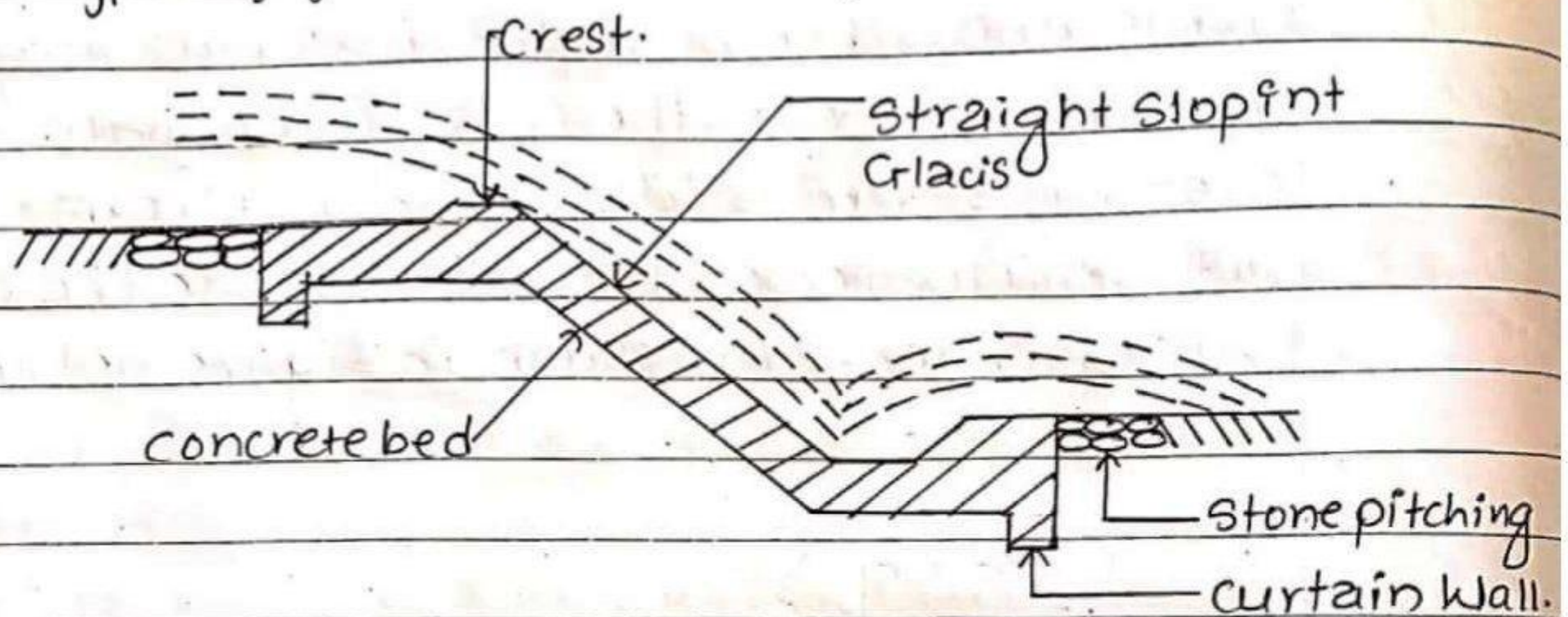


fig:- Glacis fall.

⑦. Montague Type fall:-

In this type of fall, the straight sloping glacis is modified by giving parabolic shape which is known as Montague. It is shown in figure below: Taking 'O' as origin, the montague profile is given by the equation:-

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

where, x = distance of point p from ox axis.

y = distance of point p from oy axis.

v = velocity of water at crest.

g = Acceleration due to gravity.

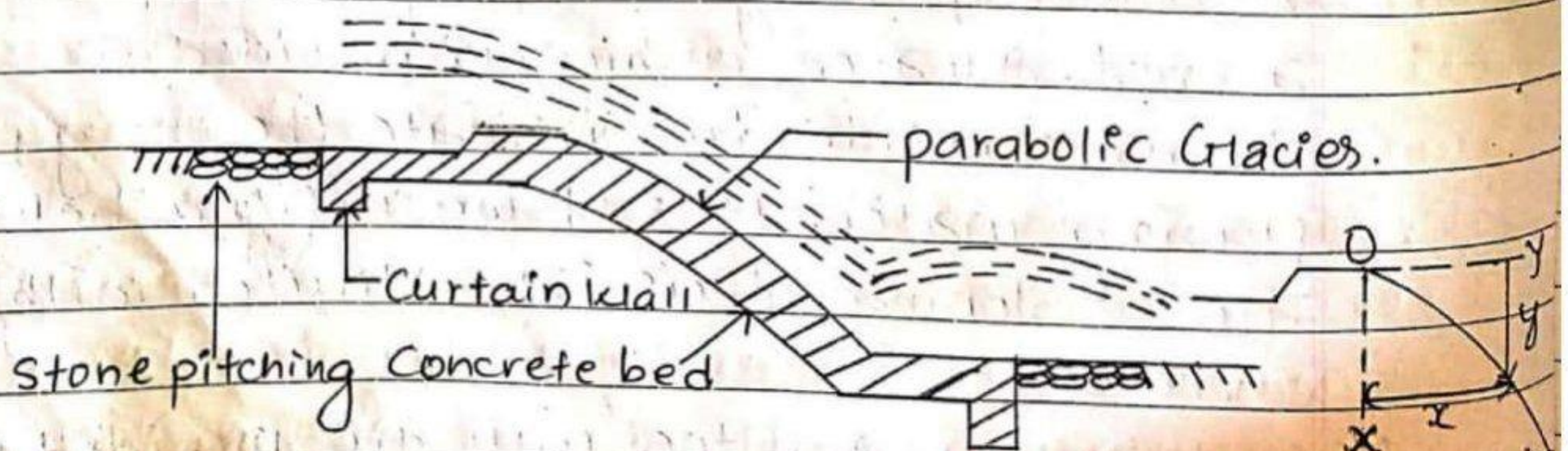


fig:- Montague Type fall.

⑧. Inglis type fall:-

In this type of fall, the glacis is straight and sloping, baffle wall are provided on the downstream floor to dissipate the energy of flowing water. It is shown in figure below.

- ↳ The height of baffle depends on the head of water on upstream side.
- ↳ The main body of fall is constructed with cement concrete.
- ↳ The toe walls and curtain walls are same straight glacis.
- ↳ The protection ^{works} with stone pitching are also same. Sometimes this fall is known as baffle fall.

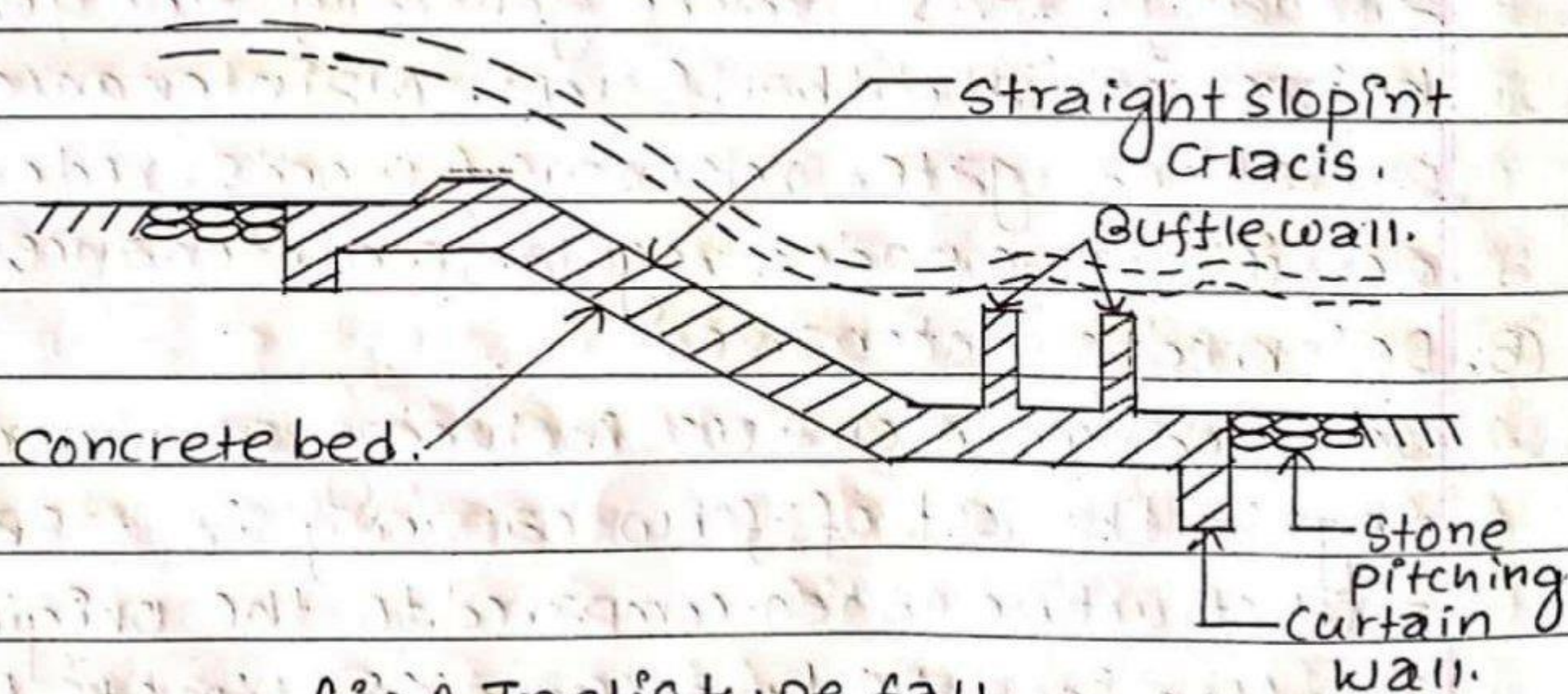


fig: Inglis type fall.

Head and Cross Regulators:

* Head Regulator:

- ↳ A head regulator is provided at the head of off-taking canal, which controls the flow of water entering the new channel.
- ↳ A head regulator may consist of number of span separated by piers and operated by gates similar to that provided in a barrage.

• Functions of head regulator:

- (i) To admit water into the off-taking canal.
- (ii) To regulate the supplies into the canal.
- (iii) To check silt entry to canal.
- (iv) To indicate the discharge passed into the canal.

Cross Regulator:

- ↳ A Cross regulator is required in the main canal at down-stream and is operated when water is required on its up-stream side. Thus, it is required to ensure the supply of water even during the periods of low flow in the main channel.

- (i) To control the flow of water in canal system.
- (ii) To feed the off-taking canals.
- (iii) To enable closing of the canal branches on the down-stream.
- (iv) To provide roadway for vehicular traffic.

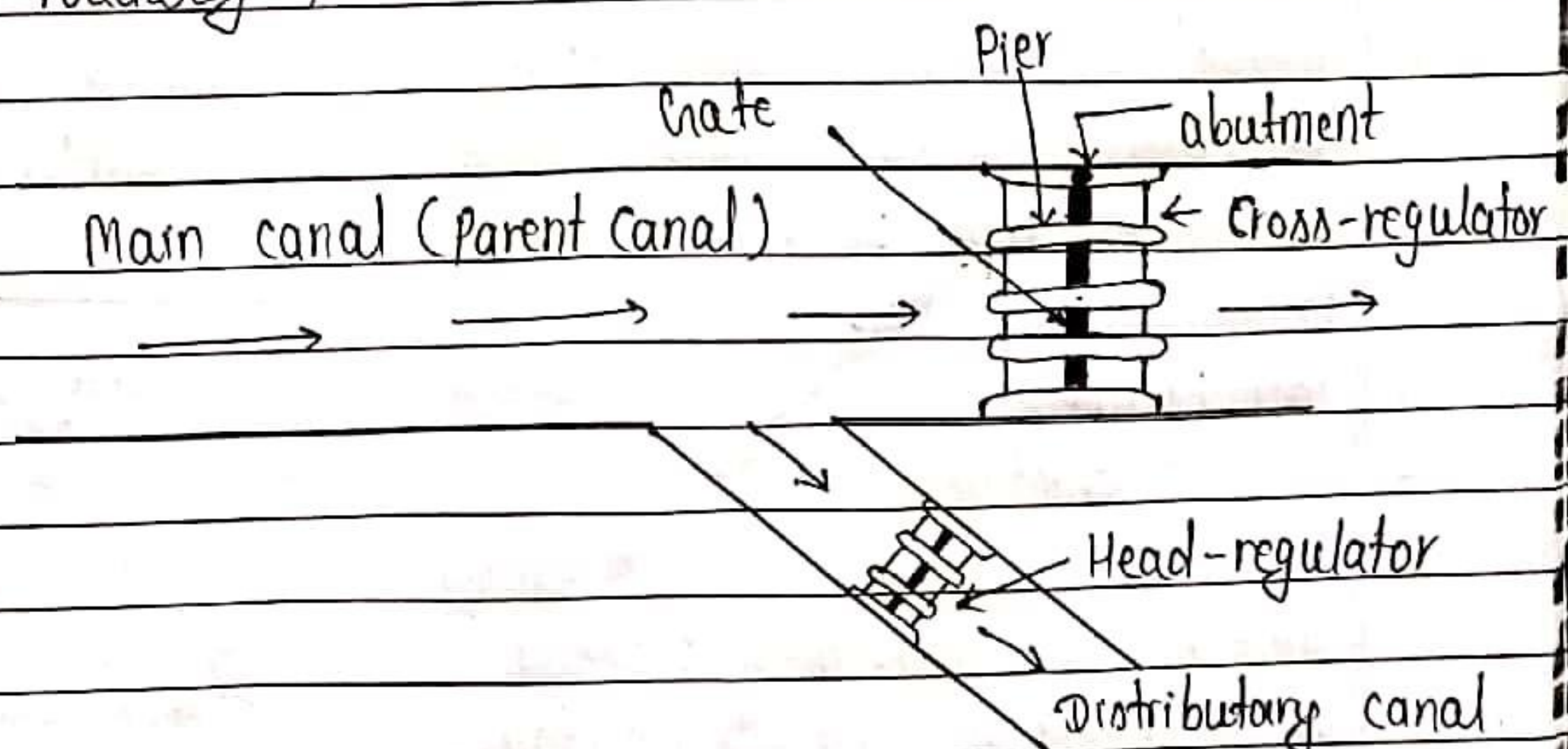


Fig: Head and Cross regulators.

Canal Escapes [Escapes]:

↳ It is the structure or side channel required to dispose (remove) of surplus or excess water from an irrigation canal (main canal, branch canal, or distributaries etc) into a natural drain. Thus, a canal escape serves as safety valve for canal system. It provides protection to the canal from possible damage due to excess supply which may be due to;

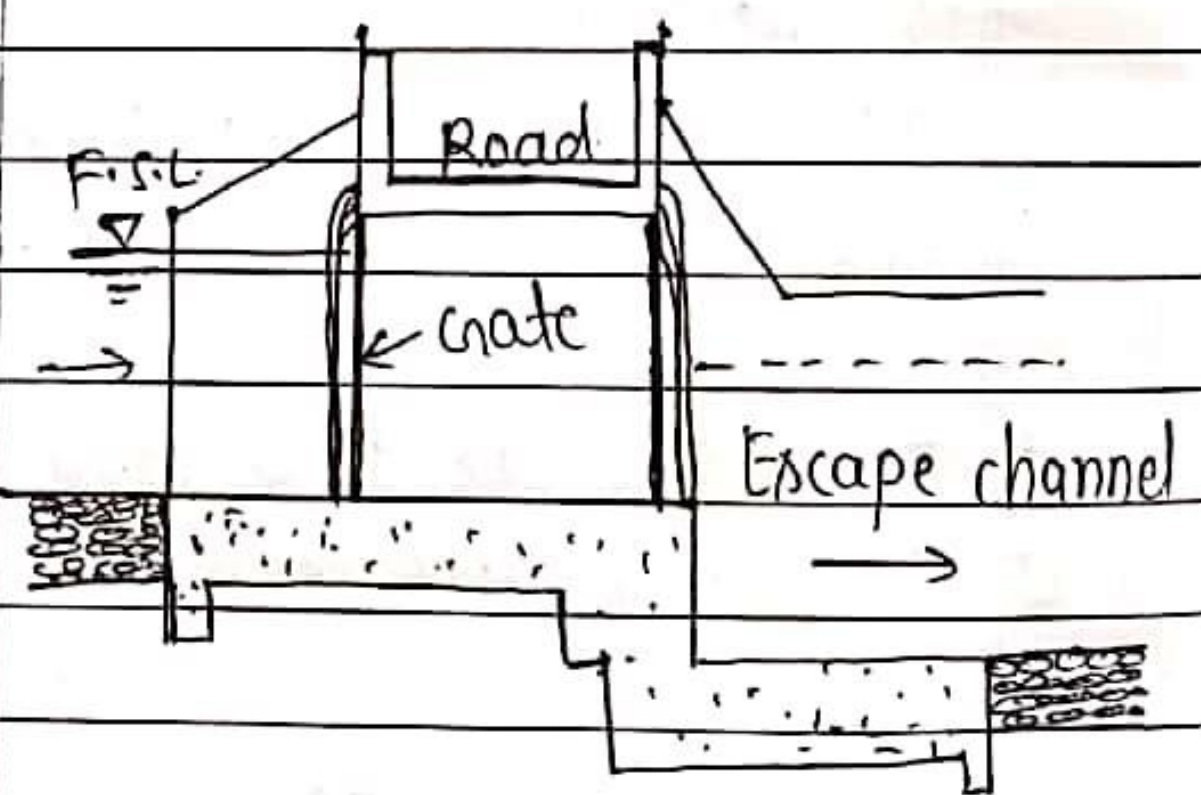
- Mistakes.
- Difficulty in regulation at the head.
- Excess rainfall in the upper reaches.
- Outlets being closed by cultivators as they find the demand of water is over.

• Types of Canal Escapes:

↳ Depending upon the purpose, canal escape may be of three types:

1. Canal Scouring Escape:

↳ For the purpose of scouring of excess silt from time to time, the escape constructed is known as canal scouring escape.



2. Surplus Escape:

↳ To remove surplus water from canal escape are provided at a certain interval are known as surplus escape. The capacity of escape channel should not be less than 50% of capacity of parent channel.

Fig: Scouring Escape or surplus water escape.

3. Tail Escape:

↳ It is a structure constructed on an irrigation canal for purpose of wasting some of the water. It is provided at tail end of canal to maintain the full supply level at the tail end.

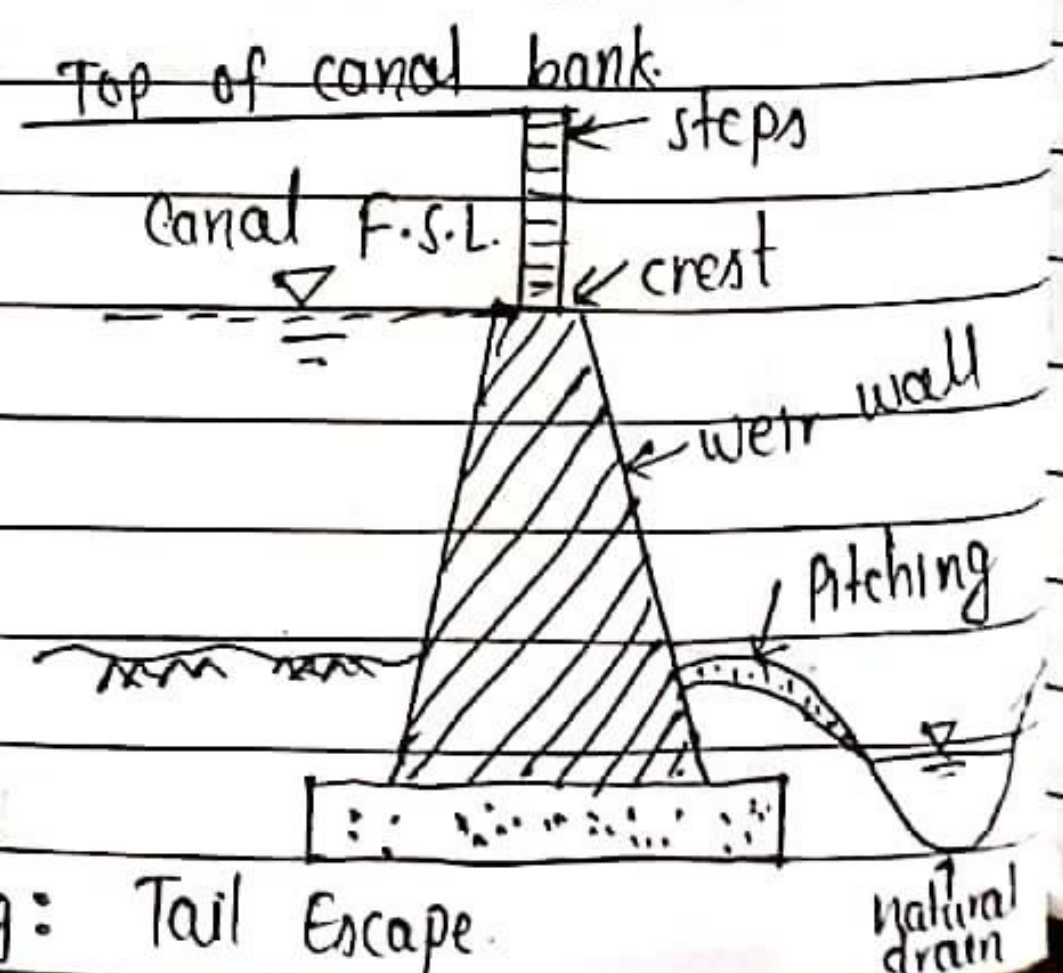


Fig: Tail Escape.

Water Logging:

- ↳ In the artificial field, the soil pores within the root zone of the crops get saturated and the normal circulation of air is cut-off, the problem is called water logging.
- ↳ Water logging is the form of natural flooding and over irrigation that brings water at underground level to surface level.

Causes of Water Logging:

- ↳ The causes of water logging may be summarised as follows:

① Over Irrigation:

- ↳ The main causes of water logging is due to over irrigation in the land. The excess water applied to the land percolates deep into the ground and join the water table and it comes close to the ground surface, water logging occurs.

② Inadequate Surface Drainage:

- ↳ Heavy precipitation combined with inadequate surface drainage causes flooding of land. The prolonged flooding results in heavy percolation of water in the ground. Which causes rise the water table and water logging occurs.

③ Obstruction of Natural Drainage:

- ↳ If natural surface drainage (stream) over the irrigated land is obstructed by constructing an embankment for a road, a canal, a railway etc, the flooding of that area leading to water logging.

④ Obliteration of Natural Drainage:

- ↳ If an existing natural drainage is obliterated or destroyed, it results in stopping of natural flow and consequent flooding from which water logging occurs.

(v) Obstruction of Natural Sub-Surface Drainage:

↳ If there is impermeable stream below the land surface at a relatively low depth, it prevents the natural downward movement of water into sub-soil. It may result in water table rising, which may cause water logging.

(vi) Impervious Top Layer:

↳ If the top layer land is impervious such as black cotton soil, it obstruct the flow of water in the downward direction. Due to which the over irrigation and flooding takes place and cause water logging.

(vii) Seepage from Canal:

↳ Canal seepage from the bed and sides of an unlined canal. It adds to the ground water table, reservoir and there is rise in water table, which may lead water logging.

(viii) Construction of reservoir

(ix) Defective method of cultivation

(x) Defective irrigation practice etc.

Ill Effects of Water Logging:

↳ Water logging of land causes many numbers of ill-effects. Some of them are explained below:

(i) Reduction of growth of plants:

↳ Because of water logging, there is absence of aeration in the roots of plants, due to which the plant growth decrease.

(ii) Deficiency in Cultivation:

↳ As the land becomes water logged, the soil becomes slushy and puddled, due to which cultivation becomes difficult.

(v) Increase in Salinity:

- ↳ Water logging generally causes an increase in salinity of the soil. Salts of soil move upward along with water from the land surface there is accumulation of salts and the fertility of the soil is decreased.

(vi) Growth of Weeds:

- ↳ Due to availability of excess water at the land surface, there is growth of water weeds. This results in decrease of crop yields.

(vii) Increase of Plant Diseases:

- ↳ Due to water logging, various diseases occur in the plants which decreases their growth.

(viii) Fall in Soil Temperature:

- ↳ There is fall in soil temperature when the soil becomes waterlogged. Due to lower temperature, there may be decrease in action of soil bacteria and growth of plant may decreased.

(ix) Increase the Incidence of Malaria:

- ↳ The water logged land becomes breeding place of mosquitoes, which may cause malaria. Moreover, the climate becomes damp which may cause the ill effect in the health of community.

Preventive Measures of Water Logging:

↳ The following measures are usually adopted for prevention of water logging or relieving the area which are water logged:

(i) Controlling the Intensity of Irrigation:

↳ In the regions where there is possibility of water logging, the annual intensity of irrigation should be kept low. In general, the average annual intensity of irrigation should not be more than 40 to 60 % of culturable command area.

(ii) Providing the drainage system:

↳ Water logging can be prevented by providing a properly designed drainage system.

(iii) Lining of canal:

↳ The seepage from canals can be considerably reduced by lining of canals. Consequently, the water table can not rise and the water logging is prevented.

(iv) Lowering the FSL of canal:

↳ The seepage of water from an unlined canal can be reduced to some extent by lowering the FSL (full supply level) of canal. The canal should be designed such that FSL is as low as possible.

(v) Improving the natural drainage of the area:

↳ If there is water logging problem due to disturbance in natural drainage system by man-made structure or other, improving the natural drainage system to prevent water logging.

(vi) Adopting crop rotation

(vii) By providing intercepting drains

(viii) Introducing lift irrigation etc.

Need and Importance of Drainage:

- ↳ While designing a canal irrigation network, it is desirable to provide a suitable drainage system for the removing of excess irrigation water formed in the field due to over irrigation. Drainage system is also required for draining out the storm water and thus to prevent its percolation and to ensure easy disposal.
- ↳ A properly designed drainage system is quite effective for the prevention of water logging.

↳ The needs and importances of drainage are as follows:

- (i) To improve fertilizing capacity of land for increasing crop yield.
- (ii) Adequate drainage improves soil structure and increase productivity of soil
- (iii) Water logged saline and alkaline lands can be reclaimed.
- (iv) Adequate drainage leads to early ploughing and planting.
- (v) Drainage of the area lengthens crop growing seasons.
- (vi) Drainage decreases soil erosion and gullyng by increasing water infiltration into soils.
- (vii) Excess salt from soil can be leached out.
- (viii) Drainage reduce water table of the area and there by:
 - Provides more available plant foods by increasing depths of root zone.
 - Increase soil ventilation.
 - Favours growth of soil bacteria.
 - Assures high soil temperature.

Surface and Sub-Surface Drainage System:

Surface Drainage System:

↳ Surface drainage is the removal of excess rain water falling on the fields or the excess irrigation water applied to the fields, by constructing open ditches, field drains, and other related structures.

↳ Surface drainage system consists of surface drains, storm sewers, culverts etc which are constructed to disposal of the surface water after the rainfall or precipitation.

↳ Surface drains are of three types:

(i) Storm water Drains:

↳ To drain-off excess rain water

↳ To carry the flood flow from the catchments under their commands.

(ii) Seepage Drains:

↳ Provided in the track which get irrigation water from the canal.

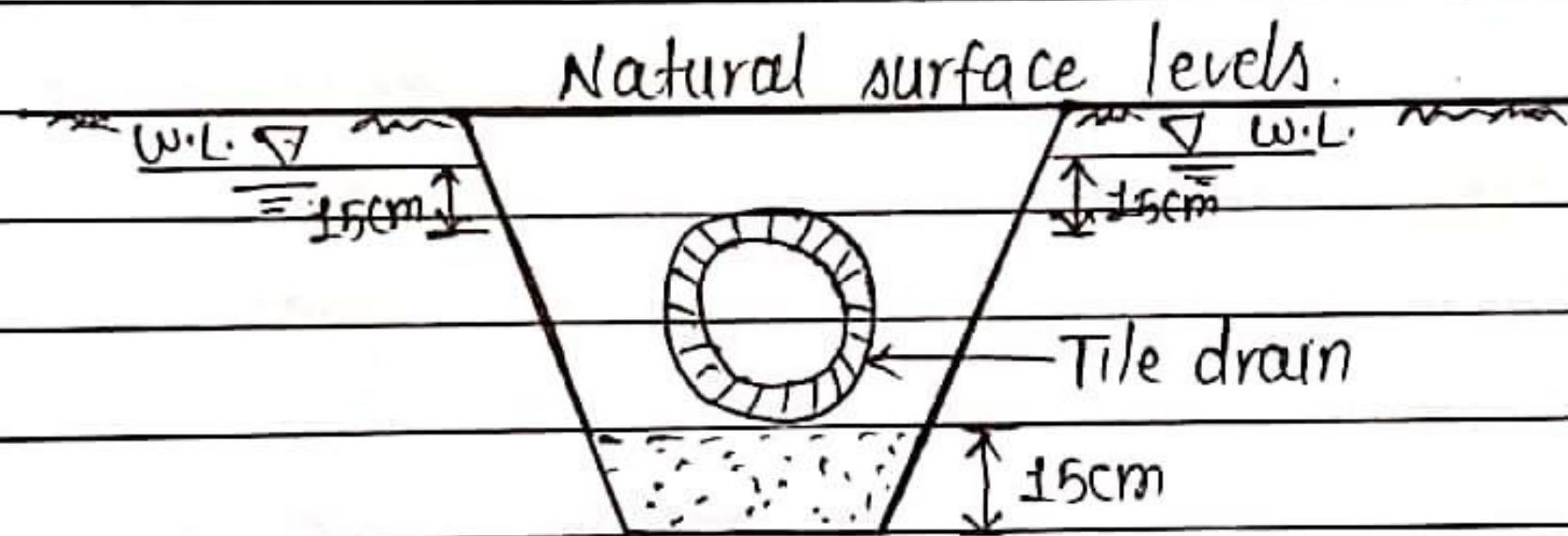
↳ As the result, water table rises and the crop root zone is filled with excess water, this contribution to the underground reservoir, these drains are constructed.

(iii) Storm-cum-seepage Drains:

↳ It perform the both of the above function, rainy season they carry rainy storm water.

Sub-surface Drainage System :

- ↳ Sub-surface drains are required for soils with poor internal drainage and high water table. Sub-surface drains are tile and pipe drains laid in the permeable stratum below the ground water table.
- ↳ Such drains are laid about 0.6m below a level upto which water table is to be lowered.
- ↳ The aim of sub-surface drainage scheme is to lower the underground water table sufficiently below the natural ground level.
- ↳ The trenches are excavated in the ground upto the required depth and a tile line is laid on the 15cm above sand bed.



- ↳ Sub-surface drains are further classified into several types according to their function:
- (i) **Relief Drains :**
 - ↳ Relief saturated soil of its excess water content.
- (ii) **Carrier Drains :**
 - ↳ Collect water from relief drains and carry that water towards an outlet.
- (iii) **Intercepting Drains :**
 - ↳ It is used to intercept the seepage water before it joins the under-ground water table.

↳ For design of drainage system, following points should be considered:

- As far as possible, drain should follow contour in a valley or natural drainage line.
- Alignment should be straight to reduce the length and cost.
- Alignment should not pass through ponds and marshes land.
- It should be designed for maximum anticipated flooding.

Unit-9 Irrigation Management

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Introduction:

- ↳ Irrigation management aims at increasing food production, contributing to economic development and reducing poverty through improvements in performance, productivity and sustainability of irrigated agriculture and irrigation systems.

Operation and Maintenance of Irrigation Works:

Operation of Irrigation Works:

- ↳ Operation is defined as the process of storing, diverting, regulating, measuring, delivery, conveying and applying the right amount of water at right time at right place for a certain required duration and destroying the escape water with a view to meet the pre-determined objective.
- ↳ The objectives of operation are as follows:
 - To distribute the available water to the crop at right time and right place.
 - To distribute the available water to the crop for a desired duration at adequate quantity.
 - To distribute the available water to the crop effectively and worth least cost.

Maintenance of Irrigation Works:

- ↳ Maintenance of the schemes that supply rich water to communities is of vital importance if they are to be effective in improving production. The success of efforts depends on the effectiveness of the maintenance program and their organization.
- ↳ Irrigation system that serves the agriculture areas where operated and maintained by the Department of Irrigation (DoI) as well as other local and international agencies.

• Types of Maintenance :

↳ The types of maintenance in irrigation works are as follows:

- ① Routine or Regular or Normal Maintenance
- ② Deferred Maintenance
- ③ Special Maintenance
- ④ Periodic Maintenance

① Routine Maintenance :

↳ It includes all work necessary to keep the irrigation system functioning satisfactory and is normally done annually. It is done generally two times per annum before Rabi and Kharif crop. Maintenance of intake, operational gate, removals of weeds, rodents and debris come under regular maintenance.

② Deferred Maintenance :

↳ Differed maintenance including any work necessary to regain the lost of flow capacity in canals, reservoirs, and structure when compared to original design. It often includes large modifications to the canal system and structures arising from importance changes (cropping patterns, drainage problems etc) that have occurred in an irrigation scheme.

③ Special Maintenance :

↳ Special maintenance includes repairs of damage caused by major disasters, such as floods, earthquake and typhoons. The unforeseeable nature of such natural phenomena make it very difficult to take specific preventive action, although general safe guards can be installed in particularly prone areas. It is also known as emergency maintenance.

④ Periodic Maintenance :

↳ Periodic maintenance is done quarterly, half yearly or yearly basis to get the proper service from the canal. Reshaping of canal, lining of canal, maintenance of structures, necessary structure construction, removal of excessive vegetation, removal of sediment deposits etc are comes under periodic maintenance.

Operation and Maintenance of Irrigation Canal :

- ↳ When irrigation canal is put into operation after construction, it is essential for its maintenance for proper and efficient functioning.
- ↳ Canals are required to maintain due to the following causes :

(a) silting in Canal :

- ↳ In unlined canal, silting causes a regular problem as the velocity of water is not enough to carry the silt along with water to the crop field. Although both silt excluder and silt ejector are provided to arrest the silt from entering the canal yet a part of silt enters the canal, removal of which is necessary. The methods adopted for silt removal are :

- (i) By iron rakes
- (ii) Flushing
- (iii) Water jets
- (iv) Manual labour

(b) Weed Growth :

- ↳ The weeds are unwanted water loving plants. This decrease the area of flow and offer resistance to flow. The deposition of silt and light encourages the growth of weeds. If velocity of flow is increased, silt comes into suspension, water becomes turbid and light can not penetrate to help the growth of weed.
- ↳ Weed control may be done by manual labour and burning them when dry.

(c) Overflowing of canal banks :

- ↳ If canal overflows during heavy rain, bank height is required to increase.

(d) Breaching of canal banks :

- ↳ To reduce the failure of bank, it has to be strengthened. For these external and internal berms by silting and extra earth works can be provided.

(e) Canal Regulation

- ↳ Control and regulate the discharge, depth and velocities in canals.

Institutional Development of Irrigation Systems:

- ↳ Water as one of the essential resources in agricultural production, has several unique characteristics, especially in hill environments. Individual farmers acting alone, can seldom acquire water for irrigation.
- ↳ Farmers generally can not transport water economically over great distances, and the locations to which it can be conveyed are limited by the topography. One implication of these characteristics is that institutions are needed for the development and operation of the irrigation systems. The form and function of these institutions vary depending on the physical, social and economic environment.
- ↳ Two institutions that have evolved to enable the collective management of water for agricultural production.
 - ① Farmer Organization.
 - ② Convention of property rights in water
- ↳ Both institutions are essential for the effective operation of the irrigation systems. Irrigation institutions are designed to enable the accomplishment of:
 - Certain activities related to water
 - Activities related to physical structures for control of water
 - The organization of farmers which manage the irrigation system.
- ↳ Institutions of both kinds contribute to production and development processes in several ways. They facilitate the aggregation of resources beyond an individual's capacity and the application of resources to the solution of problems for the benefit of many. They reduce uncertainty by the predictability of behavior that they encourage and enforce in various spheres including the distribution of benefits from collective investments.