SAMPLE STUDY MATERIAL

Postal Correspondence Course

GATE, IES & PSUs

Civil Engineering

HYDROLOGY

&

IRRIGATION

ENGINEERS INSTITUTE OF INDIA
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CONTENT

CHAPTER-1

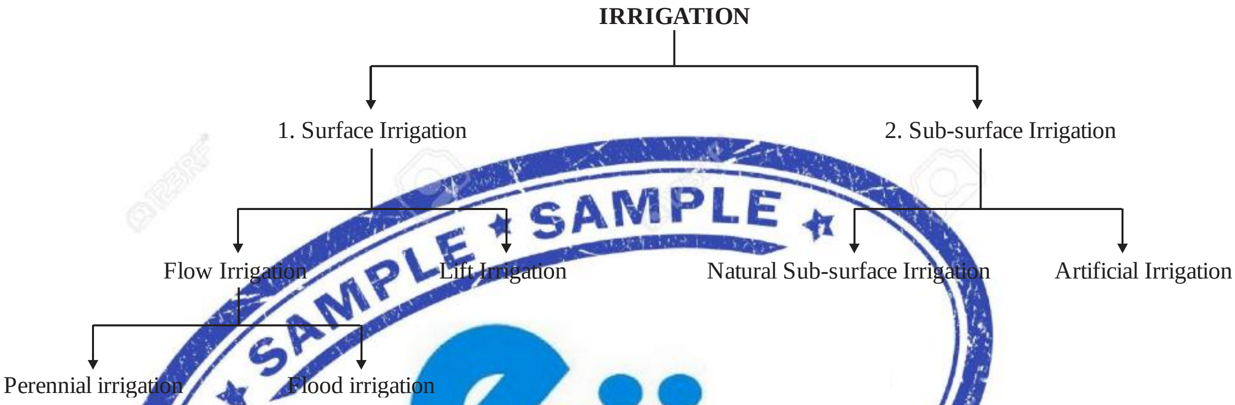
IRRIGATION TECHNIQUES AND WATER REQUIREMENT OF CROPS

IRRIGATION

IRRIGATION DEFINITION:

Irrigation is the science of artificial application of water to the land, in accordance with the “crop requirement” throughout the “crop period” for the complete nourishment of the crops.

TYPES OF IRRIGATION:



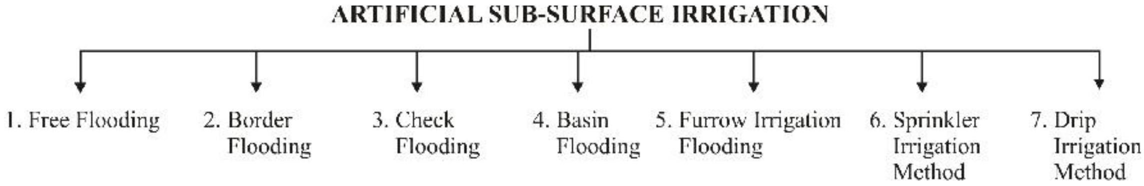
1. **Surface Irrigation:** Water application method in which water is distributed over the surface of soil by gravity or pumping.
   - **(a) Flow Irrigation:** Supply of water by the action of gravity. (i.e., from higher level to lower level)

     It can be sub-divided into:
     - (i) **Perennial Irrigation:** Constant and continuous water supply to the crops

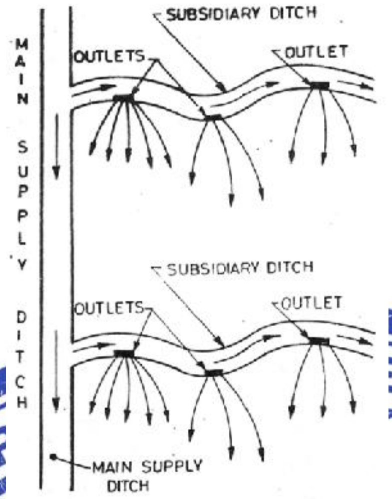
       e.g. Direct irrigation (Direct runoff of river), storage irrigation (water storage in dam).
     - (ii) **Flood Irrigation:** Soil is kept submerged and thoroughly flooded with water, so as to keep the land saturated.
   - **(b) Lift Irrigation:** Supply of water by lifting up water by mechanical means [i.e. by the help of pumps] or manually etc. e.g. use of wells, tube well etc.
2. **Sub-Surface Irrigation:** Water application method in which underground water (either through natural on artificial way) Nourises the plant root by capillary action.
   - **(a) Natural sub-surface Irrigation:**

     Due to leakage of water from channels etc, crops sown on lower land may be irrigated by capillary action. This type of irrigation simply by natural processes is called as natural sub-surface irrigation.
   - **(b) Artificial sub-surface Irrigation:**
     - ➢ A System of open jointed drains is artificially laid below the soil, so as to supply water to the crops by capillarity.

- This type of irrigation is called as artificial sub-surface irrigation.
- It is classified as follows :



1. Free Flooding:

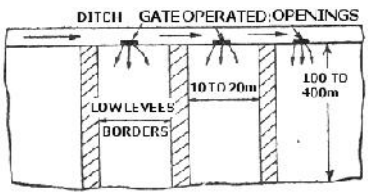


Free flooding (plan view)

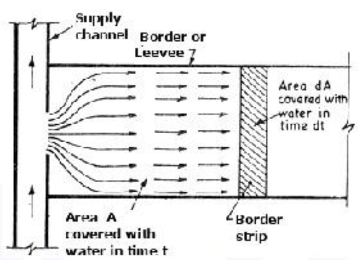
- It is an ordinary method of flooding
- Ditches are excavated in the field either on the contour or up and down the slope. Water flow from these ditches across the field.
- Since the movement of water is not restricted, it is also known as wild flooding.
- Initial cost of land preparation and water application efficiency is also low.
- It is suitable for close growing crops, pastures etc, particularly where the land is steep.
- Contour ditches are generally spaced at 20-50metres.

2. Border Flooding:

Plan view



Plan view



- In this method, the land is divided into a number of strips, separated by low leaves called borders.
- Approximate Dimension of each strip: Width = 10-20 m ; Length = 100-400m.
- Overtopping of water over borders during irrigation should be prevented.
- Land is prepared perpendicular to the direction of flow in ditch.
- Supply ditch (irrigation stream) may be in the form of earthen channel, lined channel etc.

Equation to obtain the approximate time required to irrigate a given area with a supply ditch.

Let,

Discharge through supply ditch = Q

Average depth of water flowing over the strip = h

Rate of infiltration = f

Area of land irrigated = A

Hence, Time required to cover the given area with water (t) is given as:

$$t = 2.303.\frac{h}{f}.\log_{10}\left(\frac{Q}{Q-fA}\right)$$

Question-1:

Determine the time required to irrigate a strip of land of 0.204 hectares by a stream discharge of 0.043 cumec. The infiltration capacity of the soil may be taken as 5cm/hr and the average depth of flow on the field as 6.35cm.

Solution

Given

Area of the strip, A= 0.204 ha= $0.204 \times 10^4 m^2$

Discharge, Q = 0.043cumecs = $0.043\ m^3/s$

$= 0.043 \times 60 \times 60 = 154.8\ m^3/hr$

In filtration capacity of soil, f = 5cm/hr = 0.05m/hr

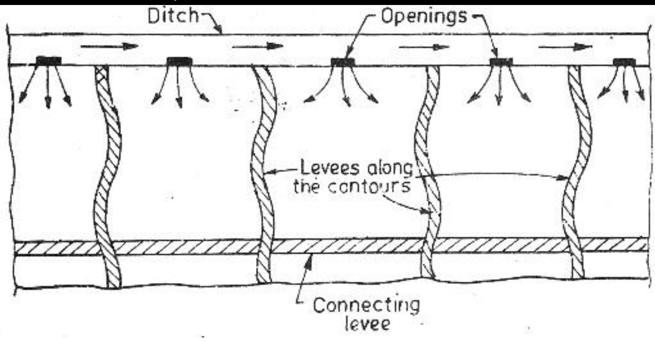
Average depth of flow in the field, h = 6.35cm

Time required to irrigate an area of 0.204 hectares

$$T = 2.303\ \frac{h}{f}\log_{10}\left(\frac{Q}{Q-fA}\right) = 2.303 \times \frac{6.35}{5}\log_{10}\frac{154.8}{154.8-0.05\times0.204\times10^4}$$

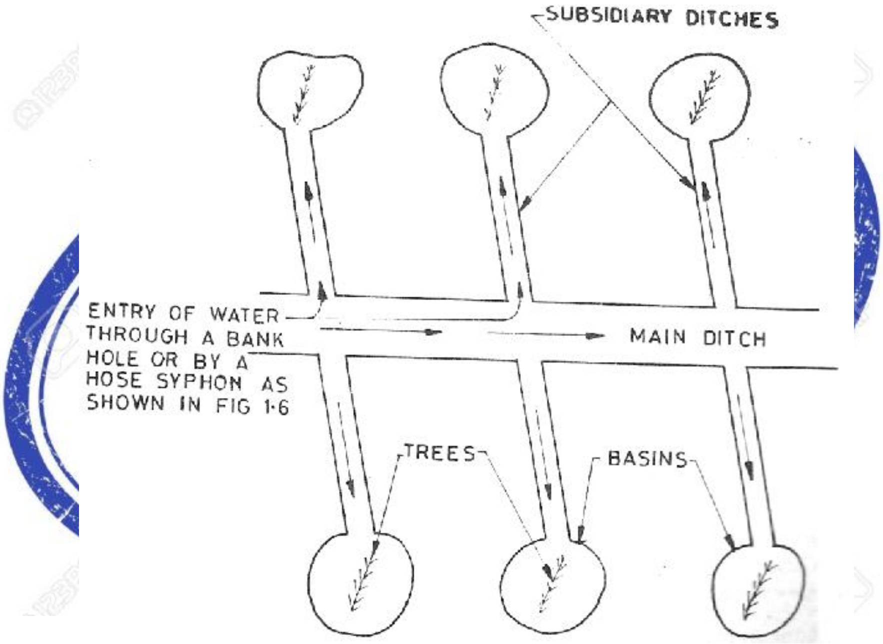
$$=2.303\times\frac{6.35}{5}\log_{10}\frac{154.8}{154.8\text{-}102} = 1.367 \text{ hours}$$

3. Check Flooding:



- This is similar to ordinary flooding except that the water is controlled by surrounding the check area with low and flat levees.
- This method is suitable for both more and less permeable soil.
- This is commonly seen in large mechanized farms.
- This method suits close growing crops like Jowar or Paddy.

4. Basin Flooding:

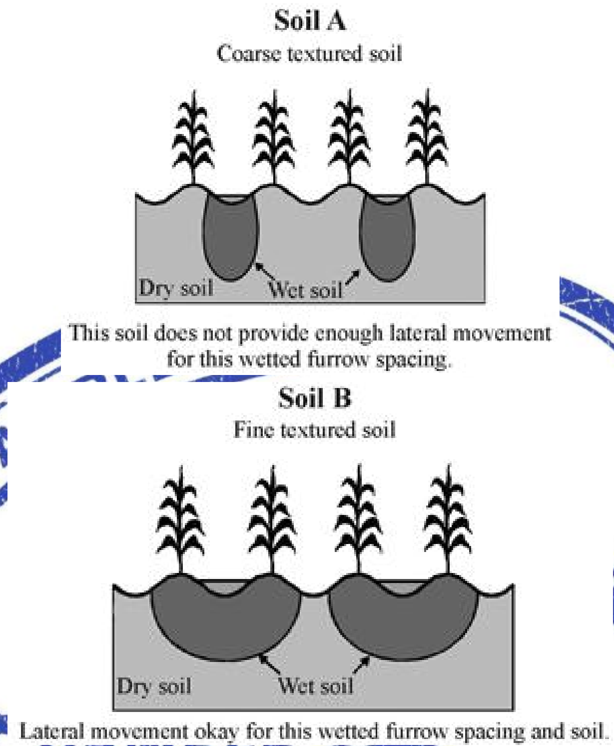


- This is a type of check flooding and is used for orchard trees.
- A suitable method mainly for crops which are unaffected by standing water over long periods of time.
- The basin shape can be either regular or irregular.
- Coarse sand is highly unsuitable for this type (reason is high water losses due to percolation).

5. Furrow Irrigation Method:

- In this method, water is applied to the land to be irrigated by a series of furrows.
- In this method, only $\frac{1}{5} to \frac{1}{2}$ of land surface is wetted by water. Thus, it results into less evaporation, less pudding of soil and permits cultivation sooner after irrigation.

- Furrows are narrow field ditches, excavated between rows of plants and carrying water through them.
- Crops are grown on the ridges between the furrows.
- Spacing of furrows depends on proper spacing of plant. Furrows are 8-30 cm. deep and up to 400m. long.
- This method is suitable for various types of soil especially for row crops.
- This method is recommended for coarse sands in order to spread the water laterally and serve the required purpose.
- In this method, there is no wastage of land as compared to the few after methods.



6. Sprinkler Irrigation Method:

- In this method, water is applied to the soil in the form of spray through a network of pipes and pumps.
- It is a costly method.
- Suited for very light soils (like sandy & silty soil) as the losses due to deep percolation are avoided.
- It is also called overhead irrigation.
- **Conditions favorable for adopting this method:**

  (i) When gradient is steeper

  (ii) When topography is irregular

  (iii) When water table is high

  (iv) When soil is highly impermeable

  (v) When water availability is low

- **There are three types of sprinkler system:**

  (a) Permanent system

  (b) Semi-permanent system

  (c) Portable system

- **Advantages of this method are:**

  (i) Uniform application of water (as it is controlled process).

  (ii) Efficiency is high up to 80 %.

  (iii) Fertilizers and insecticides can be mixed with water.

  (iv) Prevention from salinity and water logging.

  (v) Seepage losses are minimized.

  (vi) Levelling of land is not required.

  (vii) Less labour oriented method.

- **Disadvantages of this method are:**

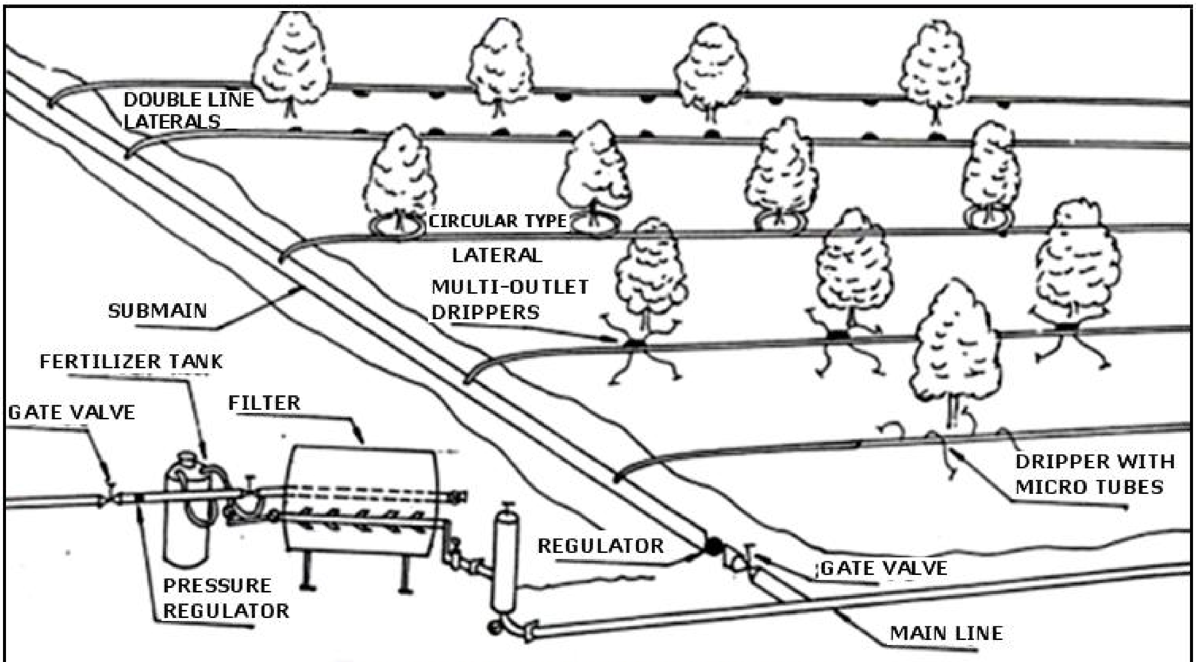
  (i) Evaporation losses are high.

  (ii) Initial cost and operating cost are high.

(iii) Not suitable for crops requiring frequent and larger depth of irrigation e.g. paddy.

(iv) Water to be used should be sand and silt free as it may damage pump impellers.

7. Drip Irrigation Method:



Layout of mains, laterals and drip nozzles

- In this method, water and festilizers are slowly and directly applied to the root zone of the plants, so as to minimize the evaporation and percolation losses.
- This method is used at places where water availability is scarce and water has salinity problem.
- This system involves laying a system of head, mains, sub-mains, laterals and drop-nozzles.
- This method is also called trickle irrigation.
- This method is best suited for row crops and orchards
- **Advantages of this method are**

  (i) Losses due evaporation & wind is almost negligible.

  (ii) Less requirement of water compared to other methods.

  (iii) Crops yield is very high.

  (iv) Soil surface is less wetted.

  (v) Less labour requirements.

  (vi) No soil erosion.
- **Disadvantages of this method are:**

  (i) Main, sub mains of plastic material can be attacked by small animals

  (ii) Expertise required in the design, installation, operation and maintenance of the drip – nozzle set up.

QUALITY OF IRRIGATION WATER:

Major constituents affecting the quality of water are

1. **Sediment Concentration:**
   - The effect of sediment present in the irrigation water depends on the type of irrigated land. When fine sediment from water is deposited on sandy soil, it improves fertility and if the sediment has been derived from the eroded areas, it may reduce the fertility.
   - Sedimentation also increases the siltation in canal etc.
2. **Total concentration of soluble salts in water:**
   - Salts of Ca, Mg, Na, K etc. present in the irrigation water is harmful for plants. Their excessive concentration may decrease the osmotic activities of plants and may prevent adequate aeration causing injuries to plant growth.
   - As time passes, the salt concentration may increase to a harmful level, since soil solution gets concentrated by evaporation.
   - The salinity concentration of soil solution (C_S) after the consumptive water (C_u) has been extracted from the soil, is given by:

$$\underset{(ppm)}{C_s} = \frac{C.Q.}{\left[Q-(C_u - P_{eff})\right]}$$

Where Q = Quantity of water applied ; C_u = Consumptive use of water

P_{eff} = Effective rainfall ; C = Concentration of salt in irrigation water

   - Salt concentration in excess of 700 ppm (mg/l) are harmful to some plants, and more than 2000 ppm are injurious to all crops.
   - Salt concentration (C_s) is generally measured by determining the electrical conductivity (E.C.) of water. It is expressed in **micro mhos/cm.**
   - Also, $C_s \propto E.C.$

S.No.	Type of water	Use in irrigation
1.	Low salinity water (C1). Conductivity between 100 to 250 micro mhos/cm at 25ºC	Can be used for irrigation for almost all crops and for almost all kinds of soils. Very little salinity may develop, which may require slight leaching; but it is permissible under normal irrigation practices except in soils of extremely low permeabilities.
2.	Medium salinity water (C2). Conductivity between 250 to 750 micro mhos/cm at 25°C.	Can be used, if a moderate amount of leaching occurs. Normal salt-tolerant plants can be grown without much salinity control.
3.	High salinity water (C3). Conductivity between 750 to 2250 micro mhos/cm at 25°C.	Cannot be used on soils with restricted drainage-Special precautions and measures are undertaken for salinity control and only high-salt tolerant plants can be grown.
4.	Very high salinity water (C4). Conductivity more than 2250 micro mhos/cm at 25°C.	Generally not suitable for irrigation.

Note: Leaching is a method of applying small amount of excess irrigation water to water having high salinity for salinity control.

3. Proportion of Na^+ ions to other Cations:

- The % of Na^+ is generally less than 5% of total exchangeable cations.
- If % of Na^+ ions $\geq$ 10%, the aggregation of soil grains break down. The soil becomes less permeable and of poorer tilth. It starts crusting when dry and its pH increases
- The proportion of Na^+ ions present in the soil is measured by a factor called as **Sodium-Absorption Ratio (SAR)**. It represents the sodium hazards of water.

i.e. $$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Where, concentration of ions is expressed as **equivalent per million (epm).**

$$epm = \frac{\text{concentration of salt } (mg/l)}{\text{Combining weight}} \quad \& \quad \text{Combining weight} = \frac{\text{Atomic weight}}{\text{Valency}}$$

- SAR value can be reduced by adding Gypsum to the water or to the soil.

S.No.	Type of water	Use in irrigation
1	Low sodium water (S1). SAR value lying between 0 to 10.	Can be used for irrigation on almost all soils and for almost all crops except those which are highly sensitive to sodium, such as stone-fruit trees and adocados, etc.
2.	Medium sodium water (S2). SAR value lying between 10 to 18.	Appreciably hazardous in fine textured soils, which may require gypsum, etc.; but may be used on course-textured or organic soils with good permeability.
3.	High sodium water (S3). SAR value lying between 18 to 26.	May prove harmful on almost all the soils, and do require good drainage, high leaching, gypsum addition etc. for proper irrigation.
4.	Very high sodium water(S4). SAR value above 26.	Generally, not suitable for irrigation.

Classification of Saline and Alkaline Soils

. No.	Classification	lectrical Conductivity (EC) in micro-mho/cm	xchangeable Sodium Percentage (ESP)	pH value
1.	**Saline soil** or white alkali	> 4000	< 15	< 8.5
2.	**Alkaline soil** or Non-saline alkali	< 4000	> 15	8.5 to 10.0

	or Sodic soil or Black alkali			
3.	Saline-alkali soil	> 4000	> 15	< 8.5

4. Bicarbonate Concentration:

- Precipitation of Ca- and Mg-bicarbonates from the soil solution increases the relative proportion of Na+ ions. This leads to sodium hazards.

5. Concentration of potentially toxic elements:

- Boron, selenium etc. may be toxic to plants.
- Concentration of Boron above 0.3 ppm is harmful to certain plants like nuts, citrus fruits, deciduous fruits etc.
- Even very low concentration of selenium is toxic for plants.

6. Bacterial Contamination:

- Bacterial contamination of irrigation water is actually not a serious problem, but the intake of vegetables, crops etc. irrigated with highly contaminated water may be dangerous.

Question-2:

If the concentration of Na^+, Ca^{++}, Mg^{++} in a water sample are 345, 60 and 18mg/l respectively. Find the Sodium Absorption Ratio (SAR) of the water sample.

Solution:

$$SAR=\frac{Na^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$$

Where Na^+, Ca^{++} and Mg^{++} are the concentration of ions in equivalent per million

$$Na^+=\frac{345mg/l}{23g}=15\ meq/l$$

$$Ca^{++}=\frac{60mg/l}{20g}=3\ meq/l$$

$$Mg^{++} = \frac{18mg/l}{12g} = 1.5\ meq/l$$

$$SAR = \frac{15}{\sqrt{\frac{3+1.5}{2}}} = \frac{15}{1.5} = 10$$

Question-3: An irrigation water has following characteristics: concentration of Na, Ca and Mg are 22.5 and 1.5 mili-equivalents per litre respectively. Calculate its sodium absorption ratio (SAR) value

Solution:

Sodium absorption ratio (SAR) = $\frac{Na^{+}}{\sqrt{\frac{Ca^{++}+mg^{++}}{2}}} = \frac{22.5}{\sqrt{\frac{3.5+1.5}{2}}} = 14.23$

Value of SAR is between 10 to 18 , it is classified as medium sodium water and represented as S2 **Ans.**

WATER REQUIREMENT OF CROPS

Crop period or Base period:

- The time period between the instant of sowing crop to the instant of its harvesting is called as **crop period.**
- The time period between the first watering of a crop at the time of its sowing to its last watering before harvesting is called as **base period.**
- **Crop period** is greater than **base period,** but for all practical purposes, **crop period** and **base period** are taken as **equal.**
- Base period is of important concern for irrigation engineer as it is used in determining the total water requirement of a crop.

Delta (a):

- The total depth of water required by a crop during its base period to come to maturity is called as **delta.**
- It is expressed as **hectare-meter** or as **depth of water on the irrigated area.**

Question-4:

If rice requires about **10cm.** depth of water at an average interval of about **12days** and the crop period for rice is 120 days, find out the delta for rice?

Solution: No. of watering required $= \frac{120}{12} = 10$

∴ Total depth of water required, $\Delta = 10 \times 10cm = 120\ cm.$

Duty (D):

- It is defined as the number of **hectares** of land irrigated for full growth of a given crop by supply of 1m^3/s of water continuously during the base period (B) of the crop.

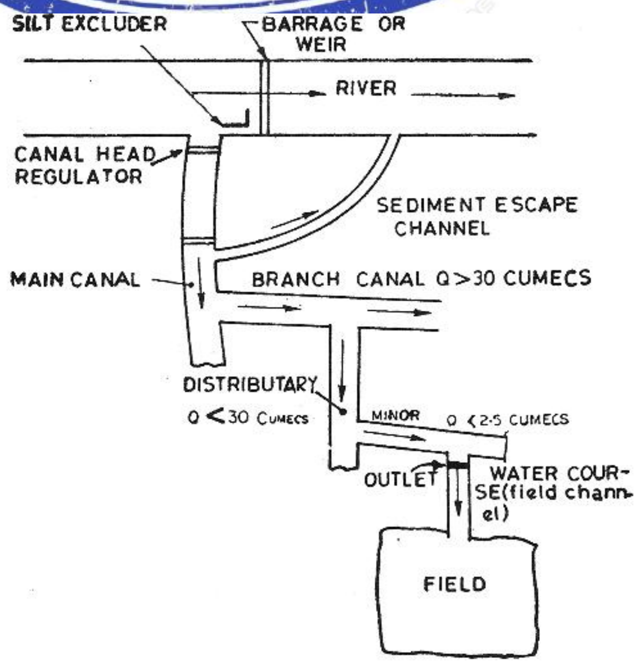
Relation between duty and delta:

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

Where, Δ = Delta (cm) ; B = Base period (days) ; D = Duty (hectares/cumec)

Duty at various places in a canal Irrigation System:

- As water moves from the source towards the field channel or water courses, duty increases.
- Duty at head of
  Main canal < Branch Canal < Distributary < Minor < water course
- The duty at the head of water-course is called the **outlet discharge factor.**
- Loss of water due to evaporation and percolation known as transit losses or transmission losses in channel, takes place during the passage of water through irrigation channel.
- In **direct Irrigation,** duty is expressed as **hectares / cumec.** It is then called as **flow duty or duty.**
- In **storage Irrigation,** duty is expressed as **hectares/million cumec** of water available in the reservoir. It is then called as **Quantity duty or storage duty.**
- In general, the duty of water is expressed to include only the water applied through irrigation.



Layout of a canal System.

Factors affecting Duty:

- Climatic condition of area

  Temperature ↑, Duty↓

  Wind velocity ↑, Duty↓

  Humidity ↑, Duty↑

- Base period of crop

  Base period ↑, Duty↓

- Type of crop

  Crop requiring large quantity of water lowers duty, crops requiring less quantity of water enhances duty.
- Type of soil

  Sandy soil → reduces duty

  Clayey soil → enhances duty
- Efficiency of cultivation method

  Proper cultivation methods leads to higher duty of water.
- Method and system of Irrigation

  Furrow method is the most, suitable flooding methods to enhance the duty of water.

Important Definitions and terms:

- From agricultural point of view, the year can be divided into mainly two cropping seasons: