Irrigation and Flood Engineering

CE-4121

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Never give up hope of Allah's Mercy (Quran: 12:87)

Special THANKS to-

My friend

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INDEX

CLICK ON THE TOPIC TO GO TO THAT PAGE

Introduction

2018 , 2016

Irrigation:

Irrigation may be defined as the process of supplying water to soil for raising crops. It is a science of planning and designing and an efficient, low-cost, economic irrigation system tailored to fit natural conditions. It is the engineering of controlling and harnessing the various natural sources of water, the construction of dams, reservoirs, canals and head works and finally distributing the water to the agricultural fields.

2013

Necessity of Irrigation:

The necessity of irrigation can be summarised in the following points:

1. Less rainfall: When the total rainfall is less than needed for the crop, artificial supply is necessary. In such a case, irrigation works may be constructed at a place where more water is avaiable and then to convey the water to the area where there is deficiency of water.

2. Non-Uniform rainfall: The rainfall in a particular area may not be uniform over the crop. By the collection of water during the excess rainfall period, water may be supplied to the crop during the period when there may be no rainfall.

3. Growing number of crops during a year: The rainfall in an area may be sufficient to raise only one type of crops during the rainy season (i.e Kharip crops), for which no irrigation may be required. However, with the provision of irrigation facilities in that area, crops can be raised in other season also (i.e. rabi crops)

4. Growing perennial crops: perennial crops such as sugar-cane etc, which need water through out the year, can be raised only through the provision of irrigation facilities in the area.

5. Commertial crops with Additional water: The rainfall in a particular area may be sufficient to raise the usual crops, but more water may be necessary for raising commercial and cash crops.

6. Controlled water supply: By the construction of proper distribution system, the yield of the crop may be increased because of controlled water supply.

2018, 2017, 2016

What are the purposes served by the application of water?

Application of water to the soil by modern methods of irrigation 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 droughts.

3. It cools the soil and the atmosphere and thus makes more favourable environment for healthy plant growth.

4. It washes out or dillutes salts in the soil.

5. It reduces the hazard of soil piping.

6. It softens the tillage pans.

2017, 2014, 2012, 2008

Scope of Irrigation Science:

The scope of Irrigation can be divided into two heads:

(a) Engineering Aspect.

(b) Agricultural Aspect.

(a) Engineering aspect:

1. Storage, Diversion or Lifting of water.
2. Conveyance of water to the agricultural fields.
3. Application of water to the agricultural fields
4. Drainage and Relieving water logging.
5. Development of Water power.

(b) Agricultural aspect:

1. Proper depths of water necessary in single application of water for various crops.

2. Distribution of water uniformly and periodically.

3. capacities of different soils for irrigation water and the flow of water in soils.

4. Reclamation of waste and alkaline lands.

Benefits of Irrigation: 2016, 2015

There are many advantages of irrigation, as summarised below:

1. increase in food production.
2. protection from famine.
3. cultivation of cash crops.
4. Elimination of mixed cropping.
5. Addition to the wealth of the country.
6. Increase in prosperity of people.
7. Generation of Hydro-electric power.
8. Domestic and industrial water supply.
9. Inland navigation.
10. canal plantations.
11. Aid in civilisation.
12. Improvement in Ground water storage.
13. General development of the country.

2015

Ill-effects of Irrigation:

Excess irrigation and unscientific use of irrigation water may give rise to the following ill-effects.

1. **Breeding places for Mosquitoes:** Due to excess application of water and due to leakage of water, ponds and depressions get filled up with water and creat breeding places for mosquitoes.

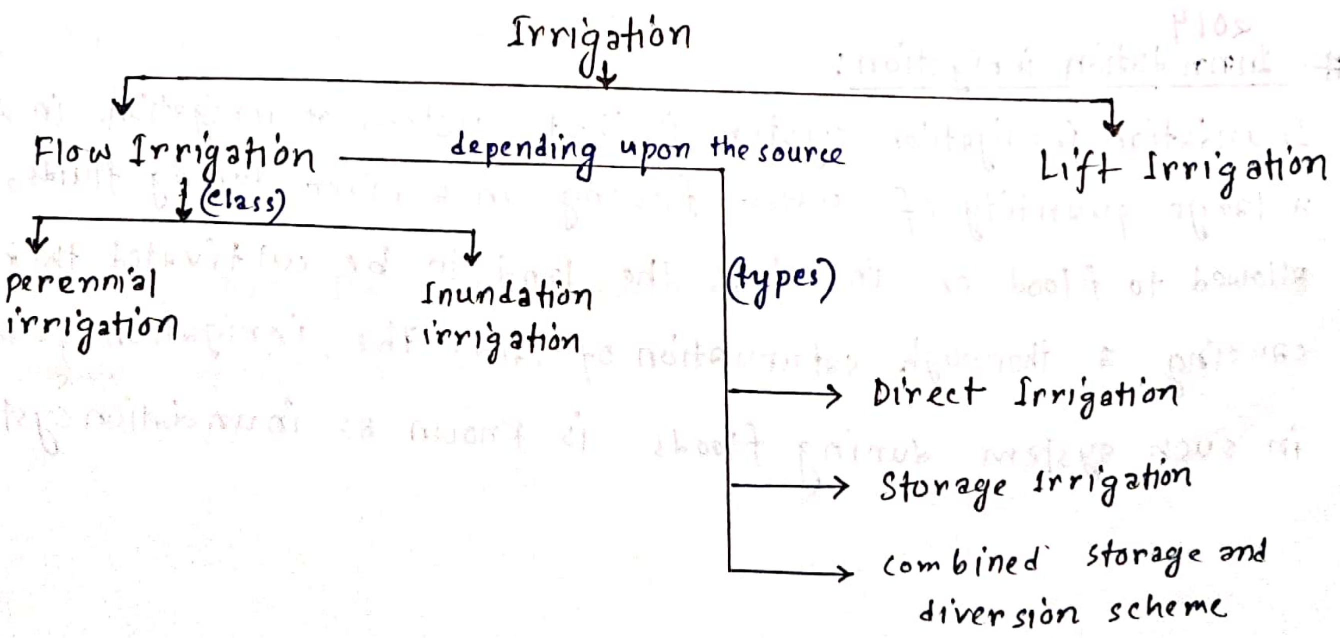
2. **Water logging:** If the water table is near the ground surface, over irrigation may raise the water table. This saturates the crop root-zone completely, causes effloreseene and the whole are become water logged.

3. **Damp Climate:** The areas which are already damp and cold, become damper and colder due to irrigation.

Types of Irrigation:

Irrigation has the following main types or classes:

(a) Flow Irrigation. (b) Lift Irrigation.



Flow Irrigation:

Flow irrigation is that type of irrigation in which the supply of water avaiable is at such a level that it is conveyed on to the land by the gravity flow.

Lift irrigation:

Lift irrigation system of irrigation in which the irrigation water is avaiable at a level lower than that of the land to be irrigated and hence the water is lifted up by pumps or other mechanical devices for lifting water and then conveyed to the land by gravity flow.

2014

Perennial Irrigation:

Perennial Irrigation system is that system of irrigation in which water is supplied as per the crop requirement at regular intervals, throughout the period sowing to harvesting of the crop. The irrigation practised in such system is known as perennial Irrigation.

2014

Inundation irrigation:

Inundation irrigation system is that system of irrigation in which a large quantity of water flowing in a river during floods, is allowed to flood or inundate the land to be cultivated, thereby causing a thorough saturuation of land. The irrigation practiced in such system during floods is known as inundation system.

2018, 2015

Direct Irrigation:

In this direct irrigation system, water is directly diverted to the canal without attempting to store the water. For such a system, a low diversion weir or diversion barrage is constructed across the river. This raises the water level in the river and thus diverts the water to the canal.

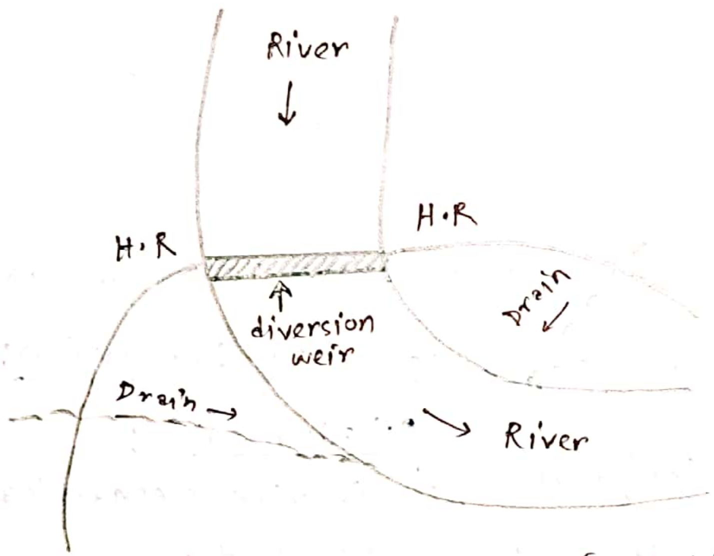


Figure: Direct Irrigation Scheme

2018, 2015

Storage Irrigation:

In the storage irrigation system, a solid barrier, such as a dam or a storage weir is constructed across the river and water is stored in the reservoir or lake so formed.

Depending upon the water requirements of crop, the volume of storage required is decided.

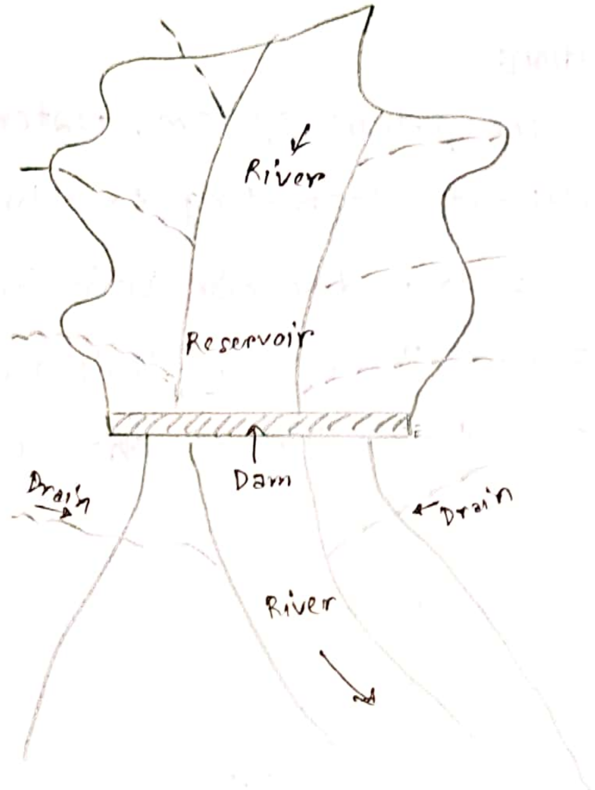


Figure: Storage Irrigation scheme.

2015

Advantages and Disadvantages of Lift Irrigation:

Advantages:

(i) Anti water logging Irrigation
(ii) Reduces the wastage of water
(iii) Not depend on the level of water sources.

Disadvantages:

(i) Require mechanical device to lift water.
(ii) It is costly.

2015

Advantages and disadvantages of Gravity or Flow Irrigation:

Advantages:

(i) Economical system of Irrigation
(ii) No need of mehanical device.

Disadvantages:

(i) causes water-logged to a large area.
(ii) wastage of water is high.

Soil-Water-Plant Relationship

Introduction:

The aim of irrigation practice is to ensure that the plants have an adequate supply of water in their root zone for achieving optimum yield of crops without damaging the quality of the soil. This necessitates a clear understanding of the interaction among the soil, water and plants in the root zone of the plants. The root zone of the plants of the most of the crops extends upto one to two meters below the land surface.

The nutrients required by the plants are normally present in the soil in the form of salts. The salts present in the soil are dissolved in the water retained by the soil. It is therefore essential that sufficient water is retained by the soil to make the salt solution dilute enough.

In addition to water, Air must also be present in the root zone for the respiration of the micro-organisms to occur and to provide a favourable environment for root development and the absorption of nutrients. As such the excess water must be drained out from the soil to enable free circulation of air in the root zone.

For proper growth of the plants requisite quantities of water, air and nutrients must be avaiable in the soil.

Root zone:

Root zone is the area of oxygen and soil sorrounding the roots of a plant. It is the maximum depth in the soil strata in which the crops spreads its root system and derives water from the soil.

2011

Soil Texture:

Soil texture refers to the composition of the soil and it is reflected by the particle size, shape and gradation. Generally the soils occuring in nature are a combination of sand, silt and clay. The relative proportions of sand, silt and clay in a soil mass determines the soil texture.

According to textural gradations the soils may be broadly classified. as:

(i) 'open' or 'light' textured soils,

(ii) 'medium' textured soils, and

(iii) 'tight' or 'heavy' textured soils.

The 'open' or 'light' texture soils contain very low content of silt and clay, and hence these soils are coarse or sandy.

The medium textured soils contain sand, silt and clay in sizable proportions. Thus, Loam soils are 'medium' textured soil.

The 'tight' or 'heavy' textured soils contain high content of clay. Thus clayey soils are 'tight' or 'heavy' textured soils.

2011

Soil structure:

In almost all the soils, groups of individual soil particles can adhere to form aggregates. The arragement of individual soil particles and the aggregates with respect to each other into a pattern is called soil structure.

The studies of soil texture have shown that soil is a porous medium, the interstices of which consists of irregularly shaped pores of various sizes.

Soil structure may be classified as: (i) Simple structure (ii) Compound Structure.

Simple structure is the one in which natural cleavage planes are absent or indistinct. Simple structure may be a single grained structure or massive structure.

Single grained structure occurs only in sands and silts with low organic matter content. Massive structure is a conherent structure and its example is Kaolinite clays.

Compound structure is the one in which natural cleavage planes are distinct. Montmorillonite clays are the examples of compound structure.

⇒ Both Texture and structure of a soil have pronounced effect on the properties of soil influencing Irrigation.

2018, 2017, 2013, 2011

Water holding capacity of soil:

Water holding capacity of soil is one of the dominant factors influencing irrigation. The water holding capacity of a soil mainly depends on its porosity.

The porosity of a soil is defined as the ratio of the volume of pores in the soil mass to its total volume and it is expressed as percentage. Thus,

$$P = \frac{V_v}{V} \times 100$$

In general, there are two types of soil pores:

(i) capillary or small pores (ii) Non capillary or large pores.

The capillary pores hold tightly by capillarity a large amount of water held by the soil at saturation and prevent it from being drained off under gravity.

On the otherhand, The non-capillary pores do not hold water tightly and hence a large amount of water held by the soil at saturation is drained off under gravity.

Thus, capillary pores induce greater water holding capacity while non-capillary pores induce drainage and aeration.

2012, 2014, 2008

Effect of soil texture and soil structure on the soil moisture content:

The relative magnitudes of capillary pores or non-capillary pores in a soil depend on its texture and structure.

Thus a sandy soil has more non-capillary pores which result in better drainage and aeration but low water holding capacity.

On the other hand, A clayey soil has more capillary pores which result in better water holding capacity but poor drainage and aeration.

2018, 2014

'Loam is an ideal soil'- Explain

The extraction of water from the soil by the roots of the plants is resisted by some forces, but the resisting forces are more in clayey soils than in sandy soils. Thus water can not be easily extracted by the roots of plants in clayey soils although large amount of water is held by these soils. On the other hand, Relatively less amount of water is held by sandy soils, but water can be easily extracted from these soils by the roots of the plants.

Thus an ideal soil for irrigation is that which has its pore spaces almost equally divided between capillary and non-capillary pores. Such a soil has enough small pores to provide adequate water holding capacity and also enough large pores to permit adequate drainage and aeration, and easy extraction of water by the roots of the plants.

The loams are therefore ideal soils as they possess good water holding capacity, have good drainage and aeration, and allow extraction of water by the roots of the plants without much resistance.

2018, 2017, 2015, 2014, 2007

Classification of soil water:

The water added to a soil mass during irrigation or otherwise is held in the pores of soil which is termed as 'soil water' or 'soil moisture'.

The soil water may exist in the soil in various forms, on the basis of which it may be classified in the following three categories:

(i) Gravitational Water (ii) Capillary Water (iii) Hygroscopic Water.

(i) Gravitational Water: It is that water which is not held by the soil but drains out freely under the influence of gravity.

(ii) Capillary water: The water content retained in the soil after the gravitational water has drained off from soil is known as capillary water, which is held in the soil by surface tension as a continuous film around the soil particles and in the capillary pores between the soil particles.

(iii) Hygroscopic Water: The hygroscopic water is that water which is absorbed by the particles of dry soil from the atmosphere and is held as a very thin film on the surface of the soil particles due to adhesion or attraction between suface particles and water molecules.

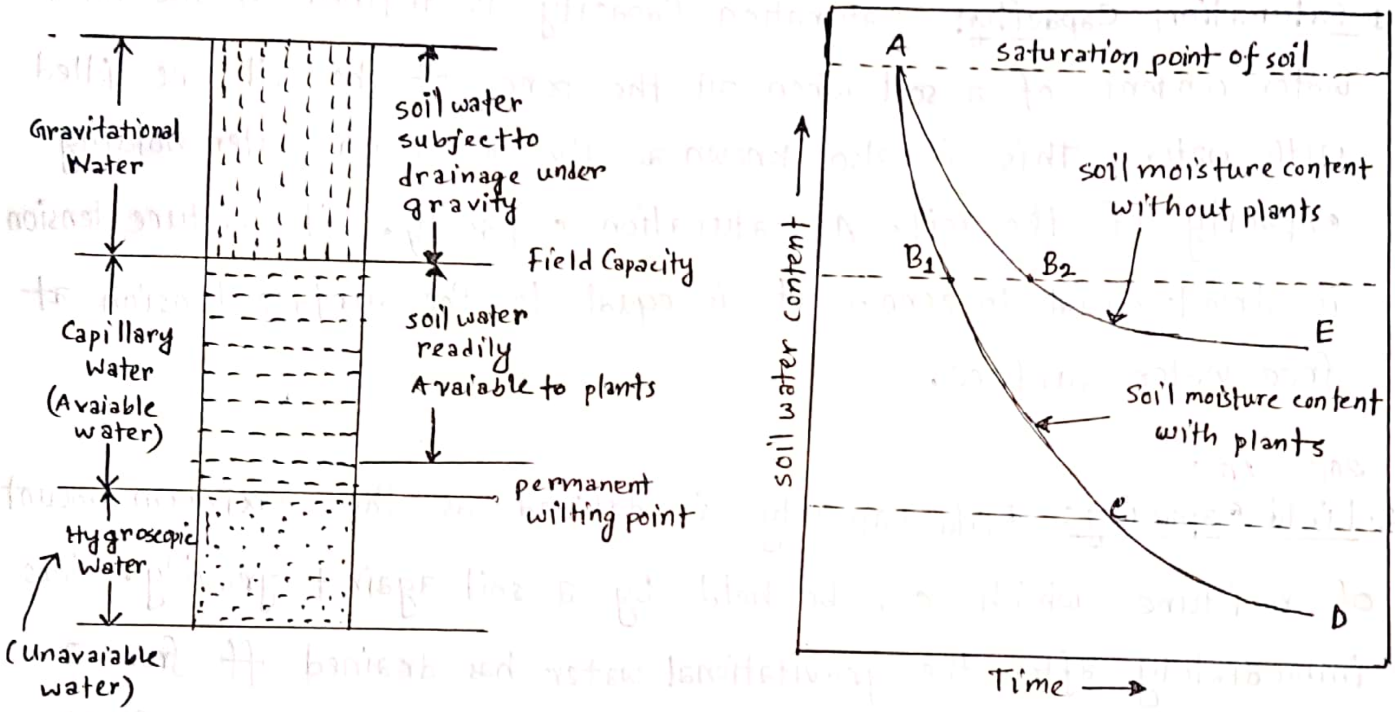


Figure. classification of soil

In Figure,
The water content of the soil corresponding to point B_1 or B_2 is termed as 'field capacity' which constitute the lower limit of the gravitational water.

The water content in the soil corresponding to point c is termed as 'permanent wilting capacity' which constitutes the lower limit of the capillary water.
Below the permanent wilting point, the soil con'ains only hygroscopic water.

Soil Moisture Constants:

Certain soil moisture contents are of particular significance in relationship between soil moisture and plants. These soil moisture contents are often called soil moisture constants.

Some are described below:

1. **Saturation Capacity:** Saturation Capacity is defined as the total water content of a soil when all the pores of the soil are filled with water. This is also known as the maximum water holding capacity of the soil. At saturation capacity, soil moisture tension is almost equal to zero as it is equal to the surface tension at free water surface.

2013, 2011

2. **Field capacity:** Field capacity is defined as the maximum amount of moisture which can be held by a soil against gravity. Thus immediately after the gravitational water has drained off from a saturated soil, the moisture content held by the soil is the field capacity.

The field capacity is usually expressed as the weight of the maximum amount of moisture held by the soil against gravity per unit weight of the dry soil and is given as percentage.

$$\text{Field capacity} = \frac{\text{weight of maximum moisture content in the soil sample}}{\text{Weight of the dried soil sample}} \times 100$$

The soil moisture tension at field capacity varies from soil to soil, but it is normally between $\frac{1}{10}$ to $\frac{1}{3}$ atmospheres.

* **How the field capacity can be determined:**

The field capacity of a soil may be determined as indicated below:

1. The soil in situ is wetted to saturation capacity.
2. It is allowed to drain freely under the action of gravity for two or three days.
3. A sample of the drained moist soil is taken and weighed.
4. The sample of the soil is then dried in an oven at 105° C.
5. The oven dried sample is then weighed.
6. The difference in the weight of the moist and the dried sample of the soil is determined which gives the weight of the maximum moisture content held by the soil sample

3. **Moisture Equivalent:** Moisture equivalent is defined as the percentage of moisture retained in an initially saturated sample of soil 10 mm thick after being subjected to a centrifugal force of 1000 times gravity for a period of 30 minutes. It may vary from about 5% for coarse sandy soils to more than 50% for heavy fine textured soils.

The moisture equivalent of a soil can be quickly determined and it is used as an approximate measure of field capacity.

For sandy soils the field capacity exceeds the moisture equivalent.

For very clayey soils the field capacity is generally lower than the moisture equivalent.

2009, 2008, 2007

4. **Permanent Wilting:** The permanent wilting point is defined as the amount of moisture content present in a soil when the plants become permanently wilted. A plant is considered to be permanently wilted when it does not regain turgidity even after being placed in a saturated atmosphere, but it may however regain turgidity if water is added to the soil.

Permanent wilting points differ widely for different soils. The value of permanent wilting may be as low as 2% for light sandy soils and it may be as high as 30% for heavy clay soils.

5. **Ultimate Wilting:** When ultimate wilting occurs the plants are completely wilted, that is the plant die away and they can not recover from wilting even after the addition of water. When ultimate wilting is expressed as percentage, it is termed as hygroscopic co-efficient. The hygroscopic co-efficient is about 67% of permanent wilting percentage.

At ultimate wilting point, the soil moisture tension may be as high as 60 atmospheres.

6. **Avaiable Moisture:** The difference in moisture content of the soil between the field capacity and the permanent wilting point is termed as the avaiable moisture. It is stored in the soil in the form of capillary water for being used subsequently by the plants.

2009, 2008, 2007

7. Readily Avaiable Moisture: It is the portion of the avaiable moisture which is most easily extracted by plant roots. Only about 75% of the avaiable moisture is readily avaiable, because the soil moisture content near the permanent wilting point can not be easily extracted by the plant roots and hence it is not readily avaiable for the plant use.

Extraction pattern of soil Moisture in Root zone by plant Roots:

The moisture extraction pattern shows the relative amount of moisture extracted by plant roots from different depths in the root zone.

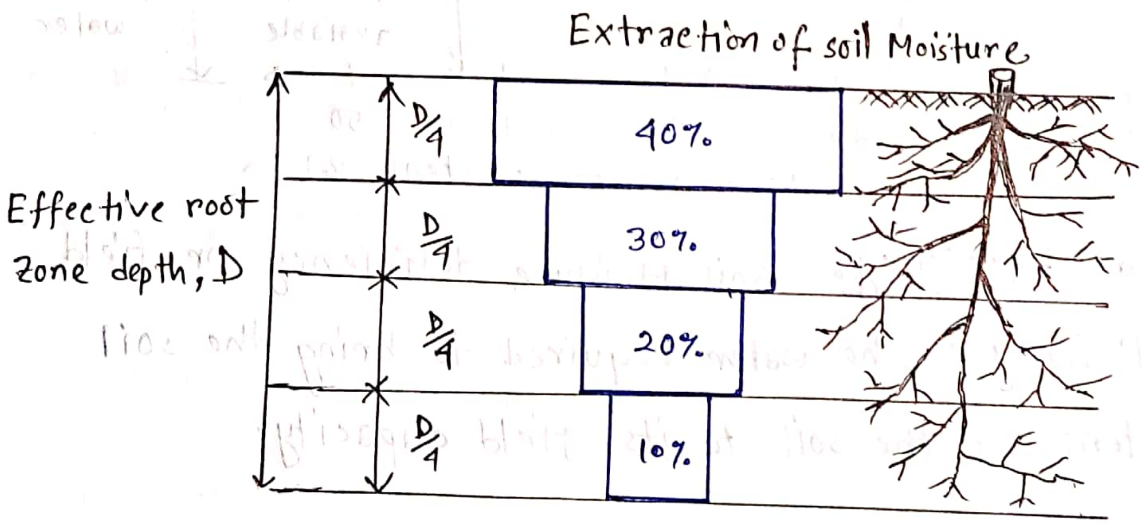


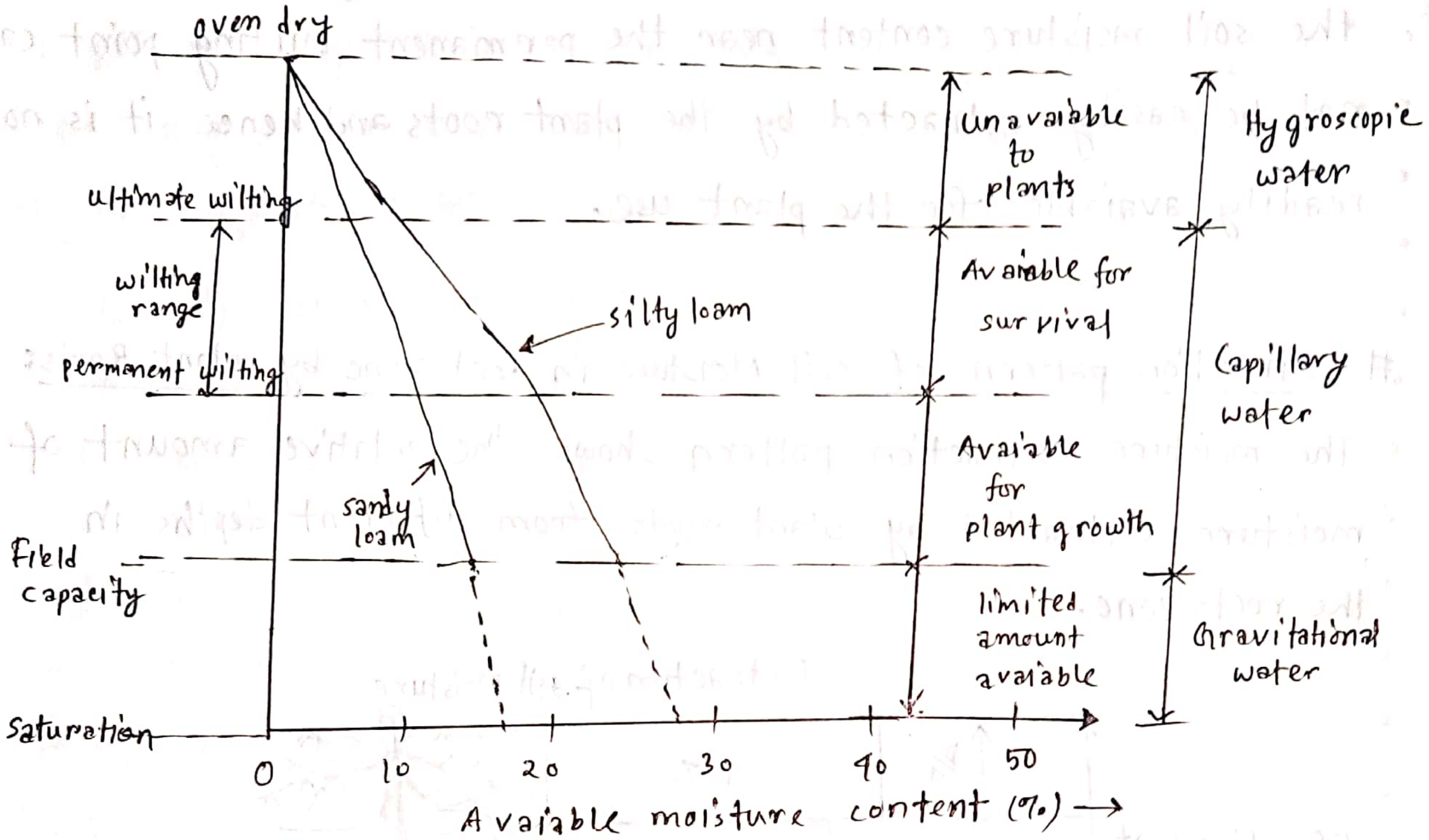
Fig. Extraction pattern of moisture from soil by plant roots.

This figure shows the moisture extraction pattern of most of the crop plants growing in deep uniform soils with adequate supply of soil moisture.

The larger extraction of moisture from the upper layers is due to the fact that in a uniform soil generally greater root developement takes place in the upper layers of the soil than else where.

2018, 2015, 2014

Difference in available moisture content between a sandy loam and a silty loam soil with neat sketch:



8. soil moisture deficiency: Soil Moisture deficiency or field moisture deficiency is the water required to bring the soil moisture content of the soil to its field capacity.

Depth of water stored in Root zone and Available to plants:

Let, d = depth of root zone

γ_d = dry unit weight of soil

γ_w = unit weight of water

consider unit area of soil, the weight of soil of unit area is equal to $(\gamma_d \times 1 \times d)$

Then, Field Capacity,

$$F_c = \frac{\text{wt. of water retained in unit area}}{\text{wt. of soil of unit area}}$$

$$= \frac{\text{wt. of water retained in unit area}}{(\gamma_d \times 1 \times d)}$$

$\therefore$ wt. of water retained in unit area $= F_c \cdot \gamma_d \cdot d$

$\Rightarrow \gamma_w \times 1 \times$ depth of water stored (in depth d) $= F_c \cdot \gamma_d \cdot d$

$\therefore$ depth of water stored (in depth d) $= \dfrac{F_c \cdot \gamma_d \cdot d}{\gamma_w}$

Depth of water held by soil at Field Capacity $= \dfrac{\gamma_d}{\gamma_w} \times d \times F_c$

Similarly,

Depth of water held by soil at permanent wilting point $= \dfrac{\gamma_d}{\gamma_w} \times d \times P.W.$

Depth of avaiable water $(d_w) = \dfrac{\gamma_d}{\gamma_s} \times d \times [F_c - P.W]$

Quality of Irrigation Water

Various Types of impurities, which make the water unfit for Irrigation:

These impurities are classified as:

(i) Sediment concentration in water.

(ii) Total concentration of soluble salts in water.

(iii) Proportion of sodium ions to other cations.

(iv) concentration of potentially toxic elements in water.

(v) Bicarbonate concentration as related to the concentration of calcium plus magnesium.

(vi) Bacterial contamination.

Effect of these impurities:

(1) Sediment Concentration: The effect of sediment present in the irrigation water depends upon the type of irrigated land. When fine sediment from water is deposited on sandy soils, the fertility is improved. On the other hand, if the sediment has been derived from the eroded areas, it may reduce the fertility or decrease the soil permeability.

2016

(2) Total concentration of soluble salts: Salts of calcium, magnesium, sodium and potassium, present in the irrigation water may prove injurious to plants. When present in excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration, causing injurious to plant growth. The injurious effects of salts on the plant growth depend upon the concentration of salts left in the soil.

At the beginning of irrigation with undesirable water, no harm may be evident, but with the passage of time, the salt concentration in the soil may increase to a harmful level, as the soil solution gets concentration by evaporation.

The salinity concentration of the soil solution (C_s) after consumptive water (C_u) has been extracted from the soil, is given by,

$$C_s = \frac{CQ}{[Q - (C_u - P_{eff})]}$$

where,

Q = The quantity of water applied.

P_{eff} = useful rainfall

$C_u - P_{eff}$ = used up irrigation water.

C = concentration of salt in irrigation water.

CQ = Total salt applied to the soil with Q amount of irrigation water.

The salt concentration is generally expressed by ppm (parts per million) or by mg/l.

$C_s > 700$ ppm – harmful for some plants

$C_s > 2000$ ppm – injurious to all crops.

The salt concentration is generally measured by determining the electrical conductivity of water. They are directly proportional to each other. Electrical conductivity is expressed as in micro mhos per centimeter.

* Classification of Irrigation Water based on Electrical conductivity

Type of Water	Conductivity at 25°C	Use in Irrigation
Low salinity water (C_1)	100–250 micro-mhos/cm	Can be used for irrigation for almost all crops and for almost all kinds of soils. Very light salinity may develop, which may require slight leaching.
Medium salinity water (C_2)	250–750 micro-mhos/cm	Can be used, if a moderate amount of leaching occurs. Normal salt tolerant plants can be grown without much salinity control.
High salinity water (C_3)	750 to 2250 micro-mhos/cm	Can not be used on soils with restricted drainage. Special precautions and measures are undertaken for salinity control and high salt tolerant plants can be grown.
Very high salinity Water (C_4)	More than 2250 micro-mhos/cm	Generally not suitable for irrigation

(3) Proportion of sodium ions to other cations: Most of the soils contain Calcium and magnesium ions and small quantities of Sodium ions. The percentage of the sodium ions is generally less than 5% of the total exchangeable cations. If this percentage increases to about 10% or more, the aggregation

of soils gains breaks down. The soil becomes less permeable and of poorer tilth.

2018, 2016

The proportion of sodium ions present in the soils, is generally measured by a factor called Sodium-Absorption Ratio (SAR) and represents the sodium hazards of water.

SAR is defined as:

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

where, the concentration of the ions is expressed in equivalent per million (epm).

$$epm = \frac{\text{the concentration of salt in ppm or mg/L}}{\text{its combining weight}}$$

$$\left(\text{i.e} = \frac{\text{Atomic weight}}{\text{Valence}}\right)$$

2018

* Classification of Irrigation water based on SAR

Type of Water	SAR Value	Use in Irrigation
Low Sodium water (S_1)	0–10	Can be used for irrigation on almost all soils and for almost all crops except those which are highly sensitive to sodium.
Medium Sodium water (S_2)	10–18	Appreciably hazardous in fine textured soils, which may require gypsum; but may be used on coarse-textured or organic coils with good permeability.
High sodium water (S_3)	18–26	May prove harmful on almost all the soils and do require good drainage, high leaching, gypsum addition etc. for proper irrigation.
Very high sodium water (S_4)	above 26	Generally not suitable for irrigation.

(4) <u>concentration of potentially toxic elements:</u> A large number of elements such as boron, selenium etc. may be toxic to plants. Traces of are essential to plant growth, but its concentrations above 0.3 ppm may prove toxic to certain plants. The concentration above 0.5 is dangerous to nuts, citrus fruits and delicious fruits. Cottons, cereals and certain truck crops are moderately tolerant to boron, while Dates, Beets, Asparagus etc. are quite tolerant. Even for most tolerant crops, the boron concentration should not exceed 4 ppm. Boron is generally present in various soaps. The waste water containing soap etc. should, therefore, be used with great care in Irrigation. Selinium, even in low concentration is toxic and must be avoided.

(5) <u>Bicarbonate concentration as related to concentration of calcium plus magnesium:</u> High concentration of Bi-carbonate ions may result in precipitation of calcium and magnesium bicarbonates from the soil-solution, increasing the relative proportion of sodium ions and causing sodium hazards.

(6) <u>Bacterial Concentration:</u> Bacterial contamination of irrigation water is not a serious problem, unless the crops irrigated with highly contaminated water are directly eaten, without being cooked. Cash crops like cotton, nursery stock etc. which are processed after harvesting, can, therfore, use contaminated waste water, without any trouble.

Standard for Irrigation water: class Test

On the basis of suitability of water for irrigation, it may be classified in Three categories as class I, Class II, class III. The standard for each of the three classes of irrigation water are given in the following Table:

Class of Water	Electrical Conductivity in micro-mhos/cm	Total Dissolved percentage (TDP) in ppm	Exchangeable sodium percentage (ESP)	Chlorides in ppm	Sulphates in ppm	Boron in ppm	Remarks
I	0-1000	0-700	0-60	0-142	0-192	0-0.5	Excellent to good for Irrigation
II	1000-3000	700-2000	60-75	142-355	192-480	0.5-2.0	Good to injurious. Suitable only with permeable soils and moderate leaching. Harmful to more sensitive crops.
III	over 3000	over 2000	over 75	over 355	over 480	over 2.0	Unfit for Irrigation.

Typical Analysis of Irrigation water:

(1) Electrical Conductivity should be known.

(2) Concentration of ions in ppm and tones per acre-feet should be evaluated.

(3) The constituents of cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and Anaions (SO_4^{--}, Cl^{-}, HCO_3^{-}, NO_3^{-}) are existed.

(4) Percentage of sodium should be known.

(5) Concentration of Boron should be known.

Then, the irrigation water can be classified.

classification of soils based on soluble salt concentration and exchangeably sodium content:

Soils may be classified as follows on the basis of their soluble salt concentration and exchangeably content:

(i) Saline soil or white Alkali

(ii) Alkali soil (Non-saline soil) or Black Alkali

(iii) Saline - Alkali soil.

2018, 2017, 2015, 2014, 2011

Saline Soils: saline-soils are the soils which contain soluble salts in such quantities that they interfere with the growth of most of the plants. The electrical conductivity of the saturation extract of saline soils is greater than 4 milli-mhos per centimeter (at 25°c) and the exchangeable sodium percentage is less than 15. The pH of the saturated-soil paste of a saline soil is usually less than 8.5.

These soils are also termed as white alkali. The saline soils can be reclaimed by leaching.

Saline-Alkali soils: These are the soils for which the electrical conductivity of saturation extract is greater than 4 millimhos per centimeter (at 25°c) and the exchangeable sodium percentage is greater than 15. The pH of the saturated soil paste of saline-alkali soil is generally about 8.5.

These soils can also be reclaimed by leaching.

2018, 2017, 2015, 2014, 2011

Alkali Soils: These are the soils for which the electrical conductivity of saturation extract is less than 4 millimhos per centimeter (at 25°C) and the exchangeable sodium percentage is greater than 15. The pH of the saturated soil paste of an alkali soil is generally between 8.5 and 10.

These soils are also termed as 'black alkali' soils. The alkali soil can be reclaimed by reducing the exchangeable sodium percentage and removing sodium salts.

2016

Leaching Requirement:

It is the amount of water which must be leached through the root zone of the plant to keep favourable salt in balance condition. It has been formulated by the staff of U.S. Lab.

Leaching Requirement is defined as the fraction of irrigation water that must be leached through the root zone to keep the salinity of soil below the specific limit or to control soil salinity at any specific limit. It is given by -

$$LR = \frac{D_d}{D_i} = \frac{E_{ci}}{E_{ed}} \quad \text{where, } E_{ed} = 2E_{ce} \text{ and } D_d = D_i - C_u$$

Here, D_d = Depth of Drainage water

D_i = Depth of Irrigation water

E_{ci} = Electrical conductivity of Irrigation water

E_{cd} = Electrical Conductivity of drainage water.

E_{ce} = Electrical conductivity of saturation extract of soil

C_u = consumptive use

Quality of Irrigation Water:

Just as every water is not suitable for human beings, in the same way every water is not suitable for plant life.

Water containing impurities, which are injurious to plant growth is not satisfactory for irrigation and is called the unsatisfactory water.

The quality of suitable irrigation water is very much influenced by the constituents of the soil which is to be irrigated. A particular water may be harmful for irrigation on a particular soil, but the same water may be tolerable or even useful for irrigation on some other soil.

Class Test

Water Requirements of Crops

Functions of Irrigation Water:

The function of soil moisture in plant growth are very important. Following are the main functions of irrigation water:

1. Triggers activity in a shield, setting a chain of bio chemical reactions.

2. Dissolves mineral nutrients for their rise from the soil to the plant.

3. Promotes chemical action with in the plant for its growth.

4. Promotes and supports the life of beneficial bacteria for the plant growth

5. Required for temperature control of soil.

6. Minimizes the effect of frost.

7. At end of the life cycle of plant, water is also a constituent of product which may be seed; stem, leaf, flower or fruit.

8. It reduces the hazard of soil piping.

9. It softens the tillage pans.

Crop Period:

Crop period is defined as the total time that elapses between the sowing of the crop and its harvesting. Thus crop period represents the total time during which the crop remains in the field.

Base period:

Base period is defined as the total time between the first watering done for the preparation of the land for sowing of a crop and the last watering done before its harvesting.

2017, 2015, 2014, 2013

Duty of Water:

Duty of water is the relation between the area of land irrigated and the quantity of water required to be supplied for growing a crop.

It is usually defined as the area of land in hactares which can be irrigated for growing any crop if one cumec ($1 m^3/sec$) of water is supplied continuously to the land for the entire base period of the crop. Since each crop has different water requirement, the duty of water varies with crop. Further duty of water is said to be high or low according to the area of the land irrigated per cumec of water is large or small.

Delta:

The duty of water may be expressed in terms of the depth of water which is termed as delta and is defined below:

Delta is defined as the total depth of water over the irrigated land required by a crop grown on it during the entire base period of the crop. It is denoted by a symbol 'Δ'.

In other words delta may be defined as the total water required by a crop for its growth in hectare-meter per hectare area of land over which the crop is growing.

How can the duty of water be expressed based on rainfall:

In general the duty of water is expressed to include only the water applied through irrigation. However, if during the base period of a crop, there is rainfall then the quantity of water required to be supplied through irrigation is correspondingly reduced. Thus in this case the duty of water may be expressed either of two ways:

(i) duty of water inclusive of rain.
(ii) duty of water exclusive of rain.

The effective or useful rainfall refers to that quantity of water which is actually available for the use of crop.

2010

Relation between duty of water (in hectares per cumec) and Delta:

Let, D = The duty of water (in hectare/cumec)

Δ = Delta or total depth of water supplied (in meters)

B = Base period of the crop (in days)

(i) If we take a field of area D hectares, water supplied to the field corresponding to the water depth Δ meters will be

$= \Delta \times D$ hectare-meters

$= \Delta \times D \times 10^4$ cubic-meters. ...... (1)

(ii) Again for the same field of D hectars, one cumec of water is required to flow during the entire base period. Hence, water supplied to this field $= (1) \times (B \times 24 \times 60 \times 60)\ m^3$ ...... (2)

Equating equations (1) and (2), we get

$$D \times \Delta \times 10^4 = B \times 24 \times 60 \times 60$$

$$\Rightarrow \Delta = \frac{B \times 24 \times 60 \times 60}{D \times 10^4} = 8.64 \frac{B}{D} \text{ meters.}$$

Note: 1 hectare = 10^4 sq. meter

1 cumec-day = 8.64 hectare-meters

In FPS system, $\Delta = 1.985 \frac{B}{D}$ acres/cusec
↓
(ft^3/sec.)

2015

Factors affecting Duty of Water:

The duty of water mainly depends on the following factors:

(1) Method of irrigation.

(2) Method of cultivation.

(3) Method of assessment of irrigation water rate.

(4) Climatic condition of the area.

(5) Canal conditions.

(6) Quality of Irrigation water.

(7) System of Irrigation.

(8) Time of Irrigation and Frequency of cultivation.

(9) Skill of cultivator.

(10) Base period of crop.

(11) Type of crop.

(12) Type of soil and sub soil of the irrigated field.

(13) Type of soil and subsoil of the area through which canal passes.

(14) Topography of land.

2017, 2014, 2013

Methods of Improving Duty of water:

The duty of water may be improved by counteracting all the factors which tend to lower the duty of water. Following measures should be taken to improve the duty of water:

(1) The land should be properly ploughed to the required depth and levelled before sowing the crop.

(2) The land should be cultivated frequently.

(3) Suitable methods of irrigation should be used.

(4) The canals should be lined.

(5) The canal should be close to the land to be irrigated by it

(6) Volumetric assesment of irrigation water should be made.

(7) Good quality of water should be used for irrigation.

(8) The rotation of crops must be practised.

(9) The alignment of the canal either in sandy soil or in fissured rock should be avoided.

(10) The canals should be maintained properly so that loss of water is minimised.

(11) The cultivator must be trained to use irrigation water efficiently and economically.

(12) The land should be redistributed to the farmers so that they get only as much as they are capable of managing it

(13) The canal administrative staff should be efficient, responsible and honest.

(14) Measures should be taken to increase water holding capacity of the soil.

Commanded Areas:

The commanded area is defined as the area which can be irrigated (or commanded) by a canal system. The command areas may be classified as follows:

1. Gross Commanded Area (G.C.A): The gross commanded area is defined as the total area which can be irrigated by a canal system on the presumption that ultimated quantity of water is avaiable.

2. Culturable Commanded Area (C.C.A): The culturable commanded area is that portion of the gross commanded area which is culturable or cultivable. Thus, culturable commanded area may be obtained by–

$$C.C.A = G.C.A - \text{unculturable area.}$$

The culturable commanded area may be subdivided in to two categories:

(i) Culturable cultivated area: It is that portion of the culturable commanded area which is actually cultivated during a crop season.

(ii) Culturable uncultivated area: It is that portion of the culturable commanded area which is not cultivated during a crop season.

Intensity of Irrigation:

The intensity of Irrigation is defined as the percentage of the culturable commanded area proposed to be irrigate annually. Usually the area irrigated during each crop season is expressed as a percentage of the culturable commanded area which represents the intensity of irigation for the crop season.

Rabi Season : October – March

Kharif season : April – October

Other Terms related to water requirements of crops:

2010, 2008
Paleo Irrigation: It is defined as the watering done prior to the sowing of a crop.

Kor watering: The first watering after the plants have grown a few centimeters high is known as Kor watering.

2010, 2008
Kor Depth: The depth of water applied during Kor watering is known as kor depth

Kor period: The Kor watering must be done in a limited period which is known as Kor period.

Capacity factor: The ratio of the mean-supply discharge of a canal for a certain duration to its maximum discharge capacity is defined as capacity factor.

Time factor: The ratio of number of days the canal has actually run during a watering period to the total number of days of the watering period is known as Time factor.

Outlet factor: The duty at the outlet is defined as Outlet factor.

Cumec day: The total quantity of water flowing for one day at the rate of 1 cumec is known as cumec-day

**
Consumptive Use of Water Evaporation: (Evapo-Transpiration)

consumptive use of water evaporation is defined as the total quantity of water used by the vegetative growth of a given area in transpiration and building of plant tissue, and that evaporated from the adjacent soil in the area in any specified time.

It, therefore, includes the water removed from the soil by transpiration and evaporation. Transpiration is the process in which the water that enters the plant roots and is used in building plant tissue, finally passes in to the atmophere in the vaporous form through the leaves of the plants. Evaporation is the process in which water from the adjacent soil passes into the atmosphere in the vaporous form.

Consumptive use is expressed in hectare-meter per hectare or, depth of water in meters for specified periods such as days, months or crop growing season.

2006
Factors affecting consumptive use of water:

There are several factors as indicated below which influence the consumptive use of water:

(1) Evaporation from the soil

(2) Temperature.

(3) Wind velocity.

(4) Relative humidity.

(5) Precipitation.

(6) Day time hours.

(7) Intensity of sunlight.

(8) Soil type and topography.

(9) Type of crop.

(10) Cropping pattern.

(11) Length of growing season.

(12) Stage of the growth of the plant.

(13) Amount of foliage of plants.

(14) Nature of leaves of plants.

(15) Method of Irrigation.

(16) Quality of Irrigation water supplied.

(17) Quantity of readily avaiable soil moisture.

2018, 2017, 2016

Potential Evapotranspiration: (PET)

If sufficient moisture is always avaiable to completely meet the needs of the plants the resulting evapotranspiration is called Potential evapotranspiration. (PET)

It is the amount of water transpired by a green crop of about the same color as green grass which completely covers the ground and which has an adequate water.

2017

Consumptive irrigation requirement: (CIR)

It is the amount of Irrigation water in order to meet the evaporation needs of the crop during its full growth period. It is, therefore, nothing but the consumptive use itself, but exclusive of effective precipitation, stored soil moisture, or ground water. If stored soil moisture and ground water are ignored, then we can write,

$$C.I.R = C_u - R_e$$

where, R_e = effective rainfall

2017, 2016

Net Irrigation Requirement: (NIR)

It is the amount of irrigation water in order to meet the evapotranspiration need of the crop as well as other needs such as leaching. Therefore,

$N.I.R = C_u - R_e$ + water lost as percolation in satifying other needs such as leaching.

2016

Methods of determining the consumptive use of water:

The various methods adopted for determining the consumptive use of water may be broadly classified under the following two categories:

(a) Direct measurement.

(b) Use of empirical formulae.

~~method~~

(a) Direct measurement of consumptive use of water:

1. Soil moisture studies on plot.
2. Tank or Lysimeter method.

3. Field experimental plots. 2016

4. Integration method.

5. In flow and out flow studies for large areas. (or water-balance method)

(b) use of empirical formulae :

1. Modified penman method.

2. Jensen – Haise method.

3. Hargreaves method.

4. Thornthwaite method.

5. Blaney – Criddle method.

6. Hargreaves class A pan evaporation method.

2018

Tank or Lysimeter Method :

Tanks are containers set flush with the ground level having an area of 10 m^2 and 2 m deep. Larger the size of tank, greater is the resemblance to root development. The tank is filled with soil of the field and crop is grown in it. consumptive use is determined by measuring the quantity of water required to maintain constant moisture with in the tank for satisfactory proper growth of the crop. In Lysimeters, the bottom is pervious. consumptive use is the difference of water applied and that draining through pervious and collected in a pan

2016

Field Experimental plots:

This method is more dependable than the tank or Lysimeter method. In this method, irrigation water is supplied to selected field experimental plots in such a way that there is neither runoff nor deep percolation. Yield obtained from different fields are plotted against total water used, as basis for arriving at the consumptive use, those yields are selected which appear to be profitable.

It is seen from observations that for every type of crop, the yield increases rapidly with an increase of water used to a certain point, and then decreases with further increase of water. At the break in the curve, the amount of water used is considered as the consumptive use.

Blaney-cridle method:

Blaney and cridle (1962) proposed an empirical relation which is largely used by irrigation engineers. Blaney Criddle equation expresses potential evapo transpiration (Cu) in terms of temperature and day time hours. It is given by—

$$C_u = kf$$

where, C_u = monthly consumptive use (cm)

k = monthly crop efficient

$f = \frac{p}{40}(1.8t + 32)$

Here, p = monthly percentage of hours of bright sunshine in the year

t = temperature (°C)

if C_u is the sessional consumptive use, then

$$C_u = K\Sigma f$$

if crop-efficient also varies from month to month,

$C_u = \Sigma Kf$

2018

Limitations of Blaney-criddle method:

The inaccuracy of the equation is exacerbated (बिगड़ जाना) by extreme variants of weather. This formulae is not suitable for following conditions-

(i) small island when air temperature is affected by the sorrounding sea temperature.

(ii) High Altitude where day time radiation is practically impossible.

(iii) Climates with a high variability in sunshine hour during transition month.

Water Balance Method: Class Test

In this method, the consumptive use of water is determined by measuring the inflow to and outflow from a selected area. If U is the consumptive use of water for a certain area, then its value is given by -

$$U = (I+P) + (G_s - G_e) - O$$

in which, I = Total inflow into the area during a year

P = Yearly precipitation

G_s = Ground water storage of the area at the beginning of the year

G_e = " " " at the end of the year.

O = Yearly out flow from the area.

All the above noted quantities of water are measured in hectare-meters

Crop efficient K_c and its determination: class Test, 2018

The evapo transpiration or consumptive use of water for specific crop may be estimated by the use of a co-efficient. This co-efficient is called crop-co-efficient.

$E_{tc} = K_c \, E_{tp}$ where,

E_{tc} = Cu of water for the crop

K_c = crop-coefficient

E_{tp} = potential evaporation.

The values of K_c for the different stages may be determined as indicated below:

1. Establish planting or sowing date of the crop from local information in similar climatic zones.

2. Determine total growing season of the crop and duration of each of four stages from local information.

3. Initial stage: Irrigation frequency of 7 days is assumed. plot the value of K_c so obtained as a horizontal straight line for the entire duration of initial stage.

4. Mid-season Stage: For given climatic condition, select K_c value for the mid-season stage of the crop. and plot the same as horizontal straight line for the entire duration of mid season stage.

5. Late-season stage: For time of full maturity, select K_c value for late season stage of crop for given climate condition. and plot K_c at the end of growing season. Assume straight line

between Kc values at the end of mid-season period and at the end of growing season.

6. <u>Development stage</u>: Assume straight line between Kc values at the end of the initial stage and the beginning of the mid-season stage.

A crop co-efficient graph is thus prepared for the entire growing season of crop, from which the Kc values can be obtained for different period of the growing season.

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Assessment of Irrigation water

2013

Assessment of Irrigation Water:

The water which has been supplied for irrigation to the farmers is at Goverment expenses. Some nominal charges must, therefore, be levied (ধার্য করা) on the farmers for using this water. The fixation of such charges is known as assessment of irrigation water.

2013

Methods of Assessment of Irrigation:

(i) Assessment on area basis or crop rate basis. → used in Bangladesh and India.

(ii) Volumetric assessment.

(iii) Assessment on sessional basis.

(iv) Composite rate basis.

(v) Permanent basis.

(i) Assessment on area basis or Crop rate Basis:

Under this system of assessment of irrigation, area sowing crops is recorded by 'patrol' both at the time of sowing and maturity. At the end of crop period a 'demand statement' for each irrigator is prepared. The measurements are checked by various officials.

Disadvantages:

1. The cultivators near the head reaches of the canal use more water.
2. Cultivators make a wasteful use of water.

(ii) Volumetric Assessments:

This method involves levying charges on actual volume of water supplied. This will be an ideal system under which the irrigator has an incentive for economic use of water and short falls in supplies can be distinctly located.

Short comings:

(i) A whole time staff is needed to keep records of the meters.

(ii) The meters may not work on small heads at the outlet.

(iii) Silt and debris obstruct the flow through the metered outlet.

Irrigation Efficiency

2010

Irrigation Efficiency:

The ratio of water avaiable for use to the water applied is defined as Irrigation Efficiency. It is given by-

$$E_i = \frac{W_c}{W_r}$$ where, W_c = consumptive use by crop, W_r = water delivered from canal

Various Types of Irrigation Efficiencies:

(1) Water Conveyance Efficiency (η_c): It is defined as the ratio of the quantity of water delivered to the fields or the irrigated land to the quantity of water diverted into the canal system from the river or reservoir. It is given by-

$$\eta_c = \frac{W_f}{W_r}$$ where, W_f = water delivered to farm. W_r = Water supplied from the river

(2) Water Application Efficiency (η_a): It is defined as the ratio of the quantity of water stored in the root zone of the plants to the quantity of water delivered to the field. Thus,

$$\eta_a = \frac{W_s}{W_f} \times 100$$

$$= \frac{W_f - (R_f + D_f)}{W_f} \times 100$$

where, R_f = surface runoff, W_f = water delivered to farm

D_f = Deep percolation, W_s = water stored in the root zone during irrigation

(3) Water Use Efficieny(η_u): It is defined as the quantity of water used beneficially including the water required for leaching to the quantity of water delivered. Thus,

$$\eta_u = \frac{W_u}{W_f} \times 100$$

where, W_u = water used benficially.

W_f = Water delivered to the field

(4) Water Storage Co-efficient(η_s): It is defined as the ratio of the quantity of water stored in the root zone during irrigation to the quantity of water needed to bring the moisture content of soil to the field capacity. Thus,

$$\eta_s = \frac{W_s}{W_n} \times 100$$

where, W_s = water stored in the root zone during irrigation

W_n = water needed in the root zone prior to irrigation
= (Field capacity − Avaiable moisture)

(5) Water Distribution Efficiency(η_d): It is determined from the following expression –

$$\eta_d = \left[1 - \frac{y}{d}\right] \times 100$$

where, y = Average numerical deviation in the depth of water stored from average depth stored during irrigation.

d = Average depth of water stored during irrigation.

(6) Consumptive Use Efficiency (η_{cu}): It is defined as the ratio of the normal consumptive use of water to the net amount of water depleted from the root zone. Thus,

$$\eta_{cu} = \frac{W_{cu}}{W_d} \times 100$$

where, W_{cu} = consumptive use of water or Evapotranspiration

W_d = Net amount of water depleted from root zone.

Methods of Irrigation

Classification of Irrigation Methods:

Irrigation methods are commonly designated according to the manner in which water is applied to the land (or field) to be irrigated. The water may be applied to the land to be irrigated either by spreading it on the land surface, or by spraying it over the land surface, or by appling it beneath the land surface. As such various methods of irrigation may be classified in the following three categories:

(i) Surface Irrigation methods
(ii) sprinkler irrigation methods
(iii) sub-irrigation methods or sub-surface irrigation methods.

All these methods of irrigation are in general used for the perennial system.

2010, 2002
Factors affecting the choice of the method of irrigation:

A proper selection of method of irrigation is very essential and is based on the following factors:

(i) soil characterestics of the land to be irrigated.
(ii) Topography of the country.
(iii) size of the stream supplying irrigation water to the land.
(iv) Avaiable water supplies and the rate of advance of irrigation water.
(v) Length of run and time required for wetting the total area of the land.

(vi) the water requirements of the crops grown and growth habits of the plant.

(vii) Rate of infiltration of the soil.

(viii) Depth of the root zone of the plants.

(ix) Depth of water table.

(x) possible erosion hazard.

(xi) Amount of water to be applied during each irrigation.

2016, 2006

Objectives that should be fulfilled for selection of the method of irrigation:

The method of irrigation should be so selected that the following objectives are fulfilled while providing water to the land to be irrigated:

(i) Adequate amount of water is stored in the root zone of the plants.

(ii) Uniform application of water is made possible.

(iii) As far as possible minimum soil erosion takes place.

(iv) There is minimum wastage of water.

(v) Reuse of water is made possible.

(vi) Minimum land is utilized for field channels, borders,

(vii) The method properly fits to the boundaries of the land to be irrigated.

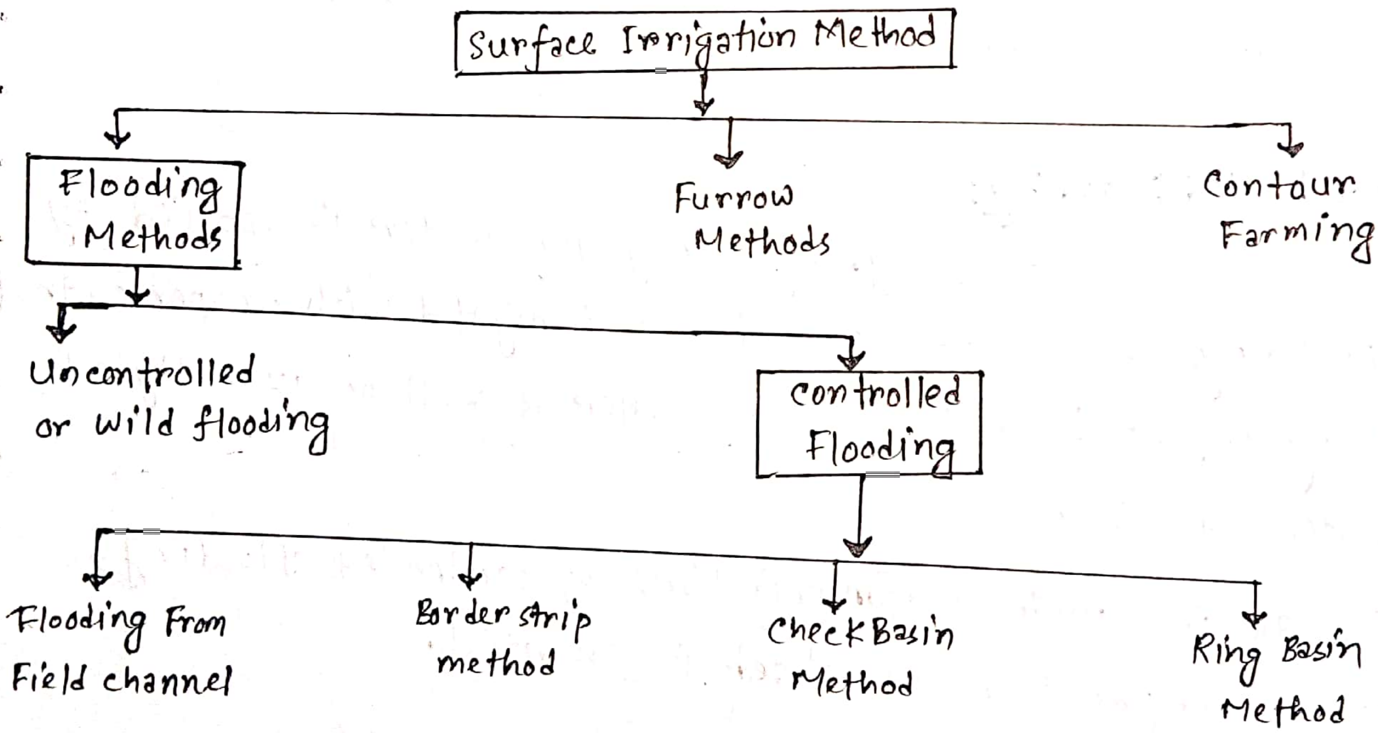
(viii) Minimum labour requirement for the irrigation arrangement.

(ix) Adopt a system for soil and topographic change.

(x) Facilitate use of machinery for land preparation, cultivation and for harvesting.

Classification of surface Irrigation methods:

In the surface irrigation methods the irrigation water is applied by spreading it in sheet or small streams on the land to be irrigated. The various methods of surface irrigation are classified as indicated below:



All the above noted methods of surface irrigation are adopted for the perenial irrigation system.

Uncontrolled or Wild Flooding:

In this method of irrigation, water is applied by spreading it over the land to be irrigated without any prior preparation of the land and without enforcing any control in the form of levees etc; to guide the flow of water or otherwise restrict the movement on the land.

This method of irrigation is suitable for smooth and flat land for which no prior preparation of land would normally be required and also better water application efficiency is achieved. This method involves a wasteful use of water and hence it is practised only where water is avaiable for irrigation in abundance and it is expensive.

2013

Controlled Flooding:

In controlled flooding, the irrigation water is applied by spreading it over the land to be irrigated with proper control being enforced on the flow of water as well as quantity of water applied.

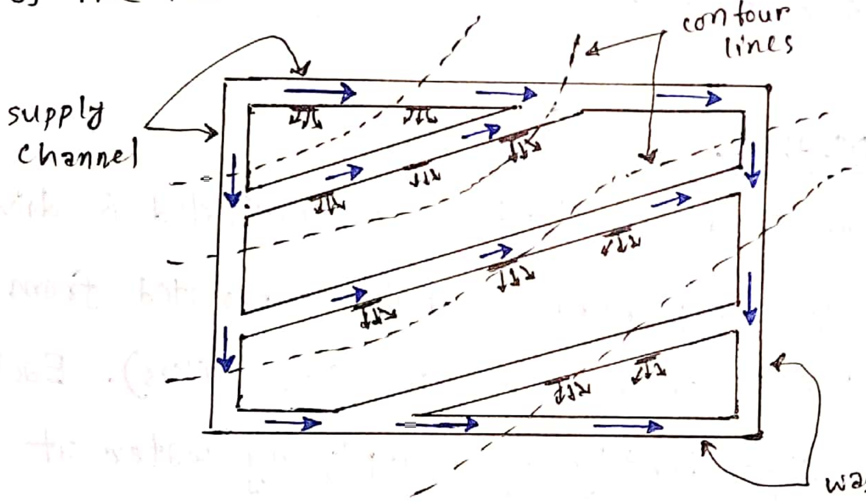
For all the methods of irrigations by controlled flooding, prior preparation of land is essential.

Scanned by CamScanner

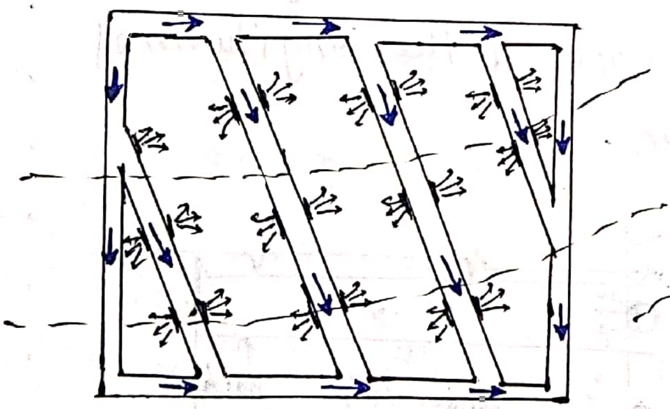
Flooding from the field Channel:

In this method, the land to be irrigated is divided into small strips by a series of field channels (or laterals) which are supplied water from the supply channels. The supply channels are located at the higher edges of the field and are aligned along the general slope of the land.

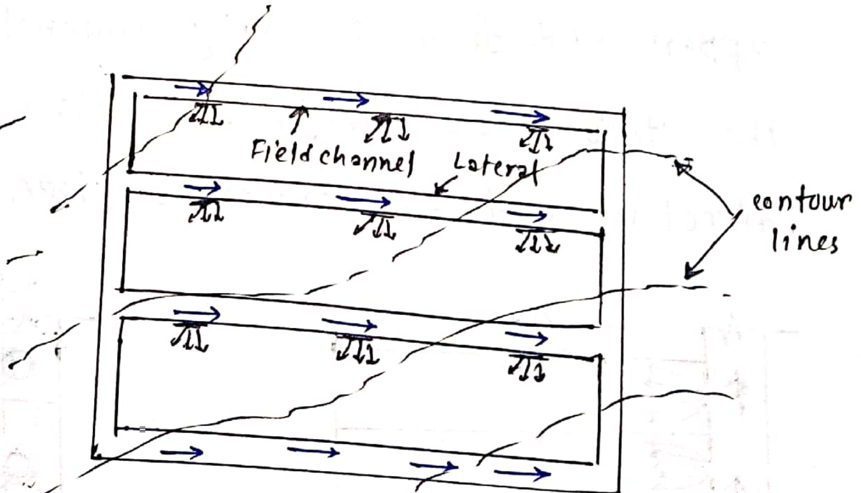
The laterals may be aligned either along the contour lines; or at right angles to the contour lines; or at right angles to the sides of the land.



(a) Field channels along contour lines



(b) Field channels at right angles to the contour lines



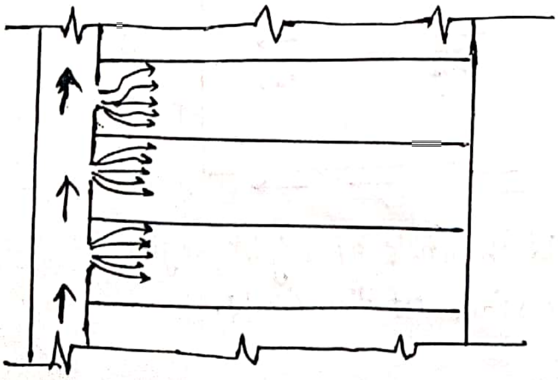
(c) Field channels at right angles to the sides of the field.

when the laterals are aligned at right angle to the contour lines then the land on both the sides of the channels can be irrigated, but in other two cases irrigation would be possible only on one side of the channel in the direction of the general slope of the land.

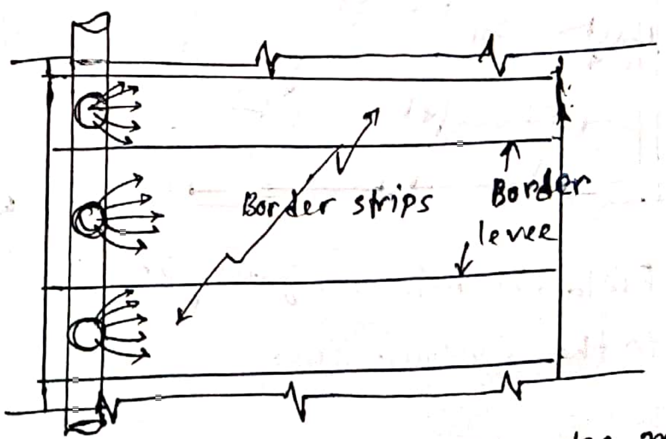
This method of irrigation can be used on relatively steep slopes as well as on flat lands. Further no major land preparations are required in this case, but careful location and proper spacing of the laterals is essential.

Border Strip Method:

In this strip method the land to be irrigated is divided into a series of long narrow strips seperated from each other by low levees or borders (low flat dikes). Each strip is irrigated independently by supplying water at its upper end from a supply channel or an underground pipe. The strips have uniform gentle slope in the longitudinal direction but have no cross slope.



(a) Border strips with supply channel.



(b) Border strips with supply pipe and Risers.

Design of Border Strip Irrigation:

Size of irrigation stream applied to unit area of land is varied according to the rate of infiltration of water into the soil. The relation between size of stream and time of water application over a given area of land can be most easily stated by means of a rational aquation derived below:

Consider a border strip as shown in figure which is irrigated by flooding a thin sheet of water over it.

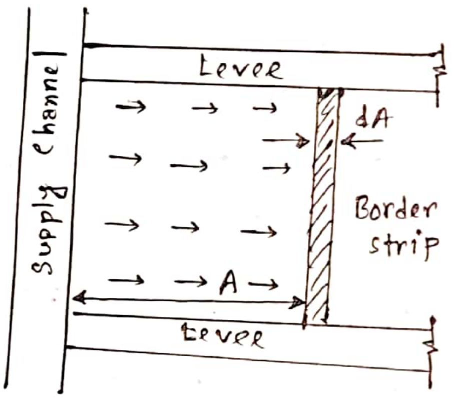


Fig. Design of border strip irrigation.

Let, A = Area of land covered at any time t,

I = Rate of infiltration im m/hr

Q = Discharge for the strip in cumec or ha m/hour

t = Time required to cover area A

y = Average depth of sheet of flowing water.

Total quantity of water flowing is small time interval dt,

$$Q\,dt = y\,dA + IA\,dt$$

$$\Rightarrow dt = \frac{y\,dA}{Q - IA} \quad \ldots\ldots (1)$$

considering I and y as constants and integrating, we get

$$t = \frac{y}{I} \log_e \frac{Q}{Q-IA}$$

$$\Rightarrow t = 2.303 \frac{y}{I} \log_{10} \frac{Q}{Q-IA} \quad \ldots\ldots (2)$$

The constant of integration being zero since $A=0$ when $t=0$.

In the above equation I has been considered constant, but actually I decreases as the soil gets saturated. Hence

Equation (2) can be rewritten as,

$$\log_{10} \frac{Q}{Q-IA} = \frac{It}{2.303y} = x \text{ (say)}$$

$$\Rightarrow 10^x = \frac{Q}{Q-IA}$$

From which,

$$A = \frac{(10^x - 1)Q}{10^x I} \simeq \frac{Q}{I} \quad \ldots\ldots (3)$$

if 'B' is the width of strip and 'L' is the length of strip, we have, $A = BL$. Similarly, $q = \frac{Q}{B}$.

From eqn (2) we obtain,

$$t = \frac{y}{I} \log_e \frac{Q}{Q-IBL}$$

$$= \frac{y}{I} \log_e \frac{q}{q-IL}$$

$$\text{Hence, } L = \frac{q}{I}\left[1 - e^{-\frac{It}{y}}\right] \quad \ldots\ldots (4)$$

If t is the time required for infiltration of water to the desired depth 'd' of irrigation to the root zone, we obtain, $d = I \cdot t$

substituting the value of d in Eqn (4), we obtain

$$L = \frac{q}{I}\left[1 - e^{-t/y}\right] \quad \ldots\ldots (5)$$

Equation (5) can be used for determining the length of border.

Average depth y of surface flow:

The average depth of surface flow, y is related to the normal uniform depth y_o by the lation,

$$y = 0.665\, y_o$$

Also, the normal or uniform depth y_o is given by Mannig's equation,

$$y_o = \left(\frac{nq}{\sqrt{S}}\right)^{0.6}$$

where,
S = slope of the border strip
n = roughness co-efficient
$= 0.55725 - 0.00013869 q'$

where, q' = inflow per unit width of border strip, in $cm^3/min/cm$

Time of application of water to the strip:

If the infiltration rate (I) and desired depth (d) of infiltration are known, the time of application is given by,

$$t = \frac{d}{I}$$

2015

Check Basin Method:

check Basin method is the most common method of irrigation used in many countries of the world. This method is also Known as irrigation by plots. In this method the land to be irrigated is divided into small plots or check basin so rounded by levees as shown in figure:

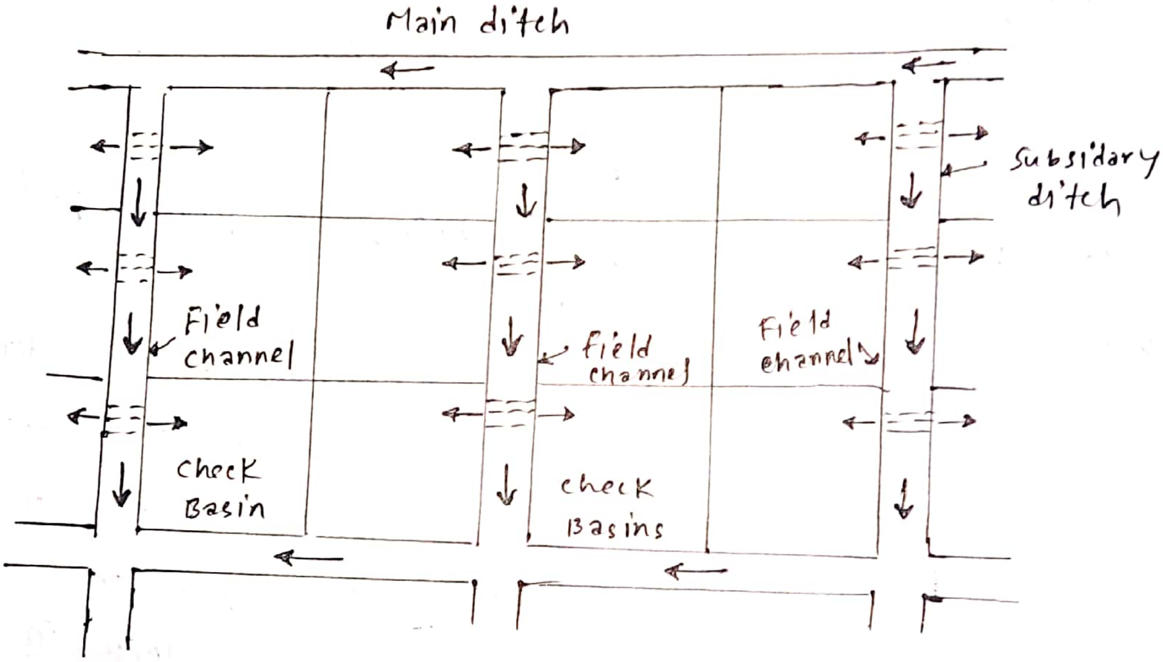


Fig. Check Basin Method

In this method, each basin or plot is practically level. The size of the levee depends upon the depth of water to be applied as well as the stability of the soil when it is wet. water is conveyed to the land by a system of supply channel (Known as main ditch). Usually There is one field channel for every two rows. Water is admitted to these plots at higher end and the supply is cut off as soon as the lower part of the plot has recieved the sufficient depth of water. The levees may be constructed semipermanantly for repeated used as in case of Paddy fields.

2018

Ring Basin Method:

The ring basin method of irrigation is a special form of check basin method of irrigation. It is used for the irrigation of orchards. In this method, generally for each tree, seperate basin is made which is usually circular in shape, and hence it is known as Ring Basin as shown in figure:

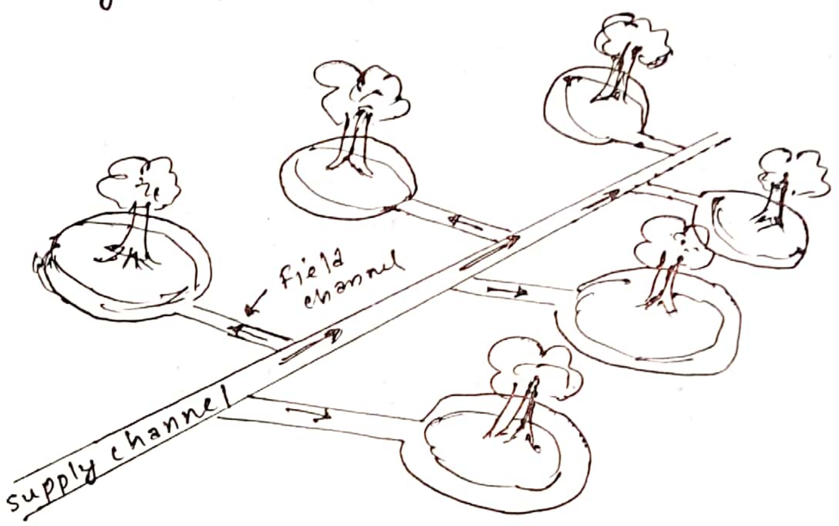


Fig. Ring Basin Method

water is supplied to the basin from a supply channel through small field channels connecting the basins with the supply channel. In most cases each basin is provided with a seperate field channel, so that water is supplied to each basin directly from the supply channel.

2015, 2014

Furrow Method:

The furrow method of irrigation is very much used for row crops like maize, jowar, sugar cane, cotton, tobacco, ground nut, potatoes etc.

In the method of irrigation water is applied to the land to be irrigated by a series of long, narrow field channels called furrows, which are dug in the land at regular interval as shown in figure:

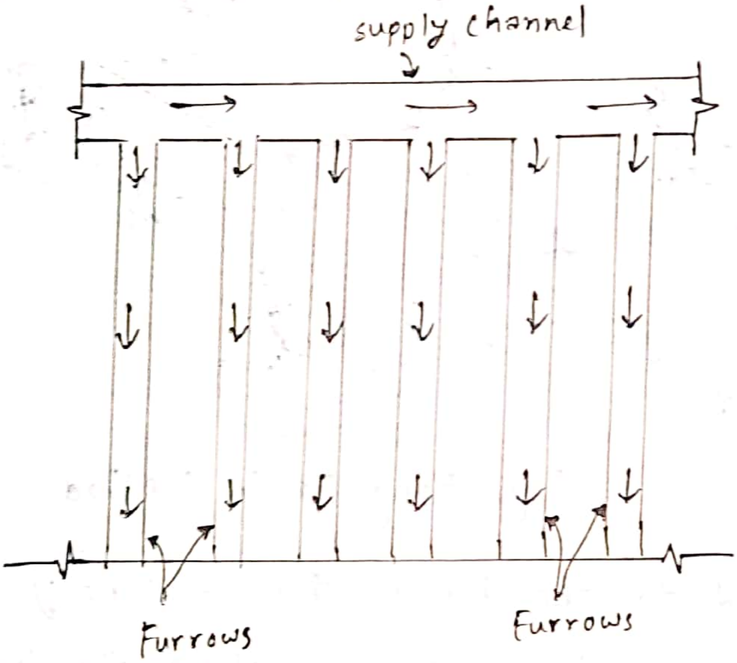


Fig. Furrow Method

The water flowing in the furrows infiltrates in to soil and spreads laterally to irrigate the land between the furrows. In this method only one half to one fifth of the surface is wetted and thus evaporation losses are very much reduced. The length of furrows varies from 3.0 m or less for gardens to as much as 500 m for field crops, the common length being 100 m to 200 m.

2014, 2015

Advantages of Furrow method:

1. In this method of irrigation, only a part of the land varying one-half to one-fifth is wetted, which results in reducing evaporation losses, lessening the puddling of heavy soils and making it possible to cultivate the soil soon after irrigation.

2. It is suitable for row crops such as maize, cotton, potatoes sugar cane, sugar beet, groundnut, tobacco etc.

3. It is espicially suitable for crops such as maize which are subjected to injury if allowed to come in contact with water ponded on the land in any of the methods of irrigation by flooding.

4. In this method the requirements of labour for land preperation and irrigation are very much reduced as compared to the various methods of irrigation by flooding.

5. In the furrow method, there is no wastage of land in field channels as compared to the checks or levees method of irrigation.

Corrugation Method:

corrugation method is generally similar to furrows but the main difference between the two being that whereas the furrows are the channels of relatively larger section, the corrugations are the channels of smaller section. corrugations may be laid along the slope of the land even for lands with steeper slopes. As such corrugation may also be known as small furrows used for irrigating the lands with steeper slopes.

Corrugation have either V or U-shapped cross-sections. They are made about 60 to 100 mm deep and slightly wider than their depth. The spacings of corrugations may be 400 to 900 mm. This method is commonly used for close-growing crops such as small grains and for pasture growing on lands having steep slopes.

2018

Contour Farming:

Contour farming is practised in hilly regions where the lands to be irrigated have steep slopes. It also controls erosion due to rainfall.

In this method, the land to be irrigated is divided into a series of strips usually known as terraces or brenches which are aligned to approximately follow the different contours at a vertical interval of 300 to 600 mm. Each of these strips forms an independent portion of the land to be irrigated.

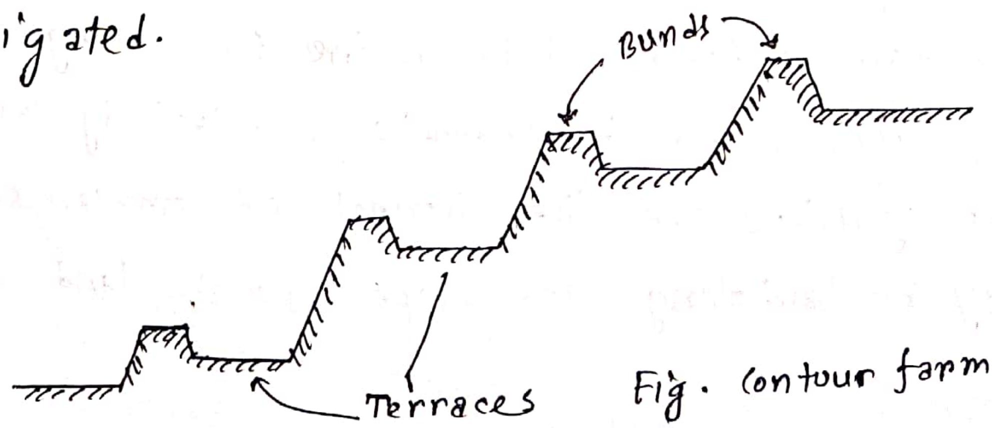


Fig. Contour farming.

The height of the bund should be sufficient to safely contain both irrigation water and the rainfall run off. On average hill sides, the first contour should ordinarily be laid about 1.2 to 1.5 m vertically below the top of the hill. Additional contour lines are located with the same spacing as the first.

Classification of subsurface Irrigation:

The sub-surface irrigation method consists of supplying water directly to the root zone of the crop. Subsurface irrigation may be of three classes:

(i) Natural sub-Irrigation,

(ii) Artificial sub-irrigation.

(iii) Drip or Trickle irrigation.

Favourable conditions for sub-surface irrigation practice:

1. Impervious sub-soil at reasonal depth (2 to 3 m) or existence of high water table.

2. Permeable soil such as loam or sandy loam in the root zone of the soil.

3. Uniform topographic conditions.

4. Moderate slopes.

5. Good quality irrigation water.

6. Abundant water supply.

if all these favourable conditions are fulfilled and if proper precautions are taken to prevent excess water-logging, the method results in economical use of water, high crop yield and low, labour cost in preparing the irrigation plots.

(i) Natural sub surface irrigation:

When underground irrigation is achieved simply by natural processes, without any additional extra efforts, it is called natural sub-irrigation.

Water flows at a slow rate and seeps into the ground to maintain the water table at a height such that water from the capillary fringe is avaiable to the crops.

(ii) Artificial sub-irrigation:

When a system of open jointed pipes/ drains is artificially laid below the soil, so as to supply water to the crops by capillarity, then it is known as artificial sub-irrigation.

Water is made to pass under pressure, through these underground perforated pipes.

This method is suitable only for those soils formations which have high horizontal permeability to permit free lateral movement through the root zones of crops.

(iii) Drip Irrigation:

In drip irrigation, also known as trickle irrigation, water is applied in the form of drops directly near the base of the plant. Water is conveyed through a system of flexible pipe lines, operating at low pressure and is applied to the plants through drip nozzles. This technique is also known as 'feeding bottle' technique. Drip irrigation limits the water supplied for consumptive use of the plant. The system permits the fine control on the application of moisture and nutrients at stated techniques. It is one of the latest methods of irrigation which is becoming popular increasingly in salt problems areas.

Limitations/shortcomings of Artificial sub-irrigation:

1. This method is highly expensive
2. In most of the cases the actual water distribution will be poor.
3. Water must be free from silt, sand and debris.
4. It is not suitable for Alkali condition.
5. There is no method of leaching. So water must be free from salinity.

Advantages of Drip Irrigation:

1. Excellent control of water application.
2. Efficiency is high as 90% or more can be achieved.
3. The evaporation losses from the land surface are minimal
4. The deep percolation of water can be almost entirely avoided.
5. It is applicable for saline water.
6. The labour cost is reduced.

Disadvantages of Drip Irrigation:

1. cost of drip irrigation equipment is considerably high
2. It has the problem of blockage of the outlet exists.
3. Prolems in moisture distribution.
4. Initial cost is high.

Sprinkler Irrigation Method:

In the sprinkler irrigation method, the irrigation water is applied to the land in the form of spray, somewhat as in ordinary rain. As such the sprinkler irrigation is also sometimes known as over head irrigation.

The sprinkler irrigation can be used for all the crops except rice and jute and for almost all the soils except very heavy soils with very low infiltration rates.

This method is best suited for very light soils as deep percolation losses are avoided. Further the method is flexible to suit undulating topography and hence land levelling is not necessary.
The pumping unit lifts water from the source and supplies it through the pipes to the sprinklers which develop the required spray of water.

Types of sprinklers:

Three types of sprinklers as indicate below are generally used:

(i) Fixed nozzle pipe.

(ii) Perforated pipe.

(iii) Rotating sprinkler.

(i) Fixed nozzle pipe: This type of sprinkler consists of the lateral pipes having a line of small holes drilled at the top at some regular interval along their lengths and on each of these holes small nozzles are fitted. A series of such pipe are installed parallel to each other at a distance of about 15 meter apart and supported on rows of posts.

(ii) Perforated pipe: This type of sprinkler consists of the lateral pipes having perforations or small holes drilled along their top and sides in a specially designed pattern to distribute water fairly uniformly. A series of such pipes are laid parallel to each other on the ground surface. These sprinklers are suitable for soil having high infiltration rates.

(iii) <u>Rotating sprinkler:</u> This type of sprinkler consists of one or two nozzles mounted on a body which is rotated slowly about vertical axis by the action of a deflecting vane connected to it. The rotating sprinklers are used very extensively for irrigating almost all the types of crops. The advantages of rotating sprinkler is that even with relatively large nozzle openings, water is applied at a slower rate.

Advantages of sprinkler Irrigation:

1. Erosion can be controlled
2. Uniform application of water is possible.
3. Irrigation is better controlled.
4. Land preparation is not required.
5. Labour cost is reduced.
6. Surface run-off is eliminated.
7. More land is avaiable for cropping.
8. Small streams of irrigation can be used efficiently.
9. Time and amount of fertilizers can be controlled for application.
10. crop damage from frost can be reduced.
11. It is a stand-by drainage pumping unit.

Limitations of sprinkler irrigation:

1. Wind may distort sprinkling pattern.
2. The first investment involved in the sprinkler irrigation is high.
3. A constant water supply is needed for commercial use of equipment.
4. Water must be clean and free from sand.
5. The power requirement is high.
6. Heavy soil with poor intake can not be irrigated efficiently.

Comparison of Furrow, Sprinkler and Drip Irrigation Methods.

Furrow Irrigation	Sprinkler Irrigation	Drip Irrigation
1. High water requirement	1. Low water requirement	1. Least water requirement
2. Less water lost by evaporation.	2. Higher evaporation loss.	2. Eveporation loss almost neglible.
3. Suitable for all soils except very light soil having high permeability.	3. Suitable for all types of soil especially for shallow coarse textured with highly permeable soils.	3. suitable for all types of soil, especially for coarse textured soils with scarce water resource.
4. Wets 20-25% of irrigated soil surface.	4. Entire surface area is wetted.	4. Least wetting of soil surface.
5. Comperatively low rate of vegetable Growth.	5. Better and quicker germination of seeds.	5. Highest rate of vegetable growth.
6. Non-uniform distribution of water.	6. The uniformity of irrigation may be 50%	6. The uniformity of irrigation may be 90% or above.
7. Percolation losses are high.	7. percolation of water is less.	7. Minimum percolation.

Furrow	Sprinkler	Drip
8. Moisture distribution is normal.	8. Moisture distribution is two dimensional	8. Moisture distribution is two dimension for soils of low permeability
9. The crop yield is less.	9. Higher crop yield though less than Drip irrigation system	9. Higher crop yield.
10. Lower intial investment but high operation labour charges.	10. High initial cost and operation charges.	10. Low initial cost and operation charges.

Design consideration of sprinkler irrigation:

1. Sprinkler section and spacing,

$$q = \frac{S_l \times S_m \times I}{360}$$

where, q = required discharge of individual sprinkler (l/sec)
S_l = Spacing of sprinkler along the lateral (m)
S_m = Spacing of sprinkler along the main (m)
I = Optimum application rate (cm/hr)

2. Capacity of the sprinkler system,

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

where, A = Area to be irrigated (ha)
Q = discharge capacity of pump (l/sec)
d = Net depth of water application (cm)
F = No. of days allowed for the completetion of one irrigation.
H = No. of actual operating (hrs/day)
E = Water application efficiency (%)

3. Uniformity co-effiecient for sprinkler,

$$C_u = 100\left(1 - \frac{\Sigma x}{mn}\right)$$

where, m = Average value of all observation.
n = Total no. of observation point.
Σx = Numerical deviation individual observation from average (mm)

4. The discharge of sprinkler nozzle,

$$q = ca\sqrt{2gh}$$

where, a = cross section area of nozzle.
c = co-effiecient (0.95 – 0.96)
g = Acceleration due to gravity = 9.81 m/s.
h = pressure head at the nozzle (m)

Water Logging

2017, 2016, 2015, 2014, 2010

Water logging:

An agricultural land is said to be water-logged, when its productivity gets affected by the high water table.

2017

Effect of Water Logging:

The productivity of land, in fact, gets affected when the root zone of the plants gets flooded with water. The effects of water logging is described below:

(i) Absence of aeration of soils in the root zone of the plant.

(ii) Difficulty in cultivation operations.

(iii) Growth of water loving plants such as grasses, weeds etc.

(iv) Rise in salt in surface layer.

(v) Restrict the growth of root.

(vi) Lower soil temperature.

(vii) plant deseases.

2015, 2014, 2010

Causes of water logging:

Water-logging is the rise of water table, which may occur due to the following factor:

1. over and Intensive Irrigation.
2. seepage of water through canals.
3. Impervious obstruction.
4. Inadequate natural drainage.

5. Inadequate surface drainage

6. Excessive Rains.

7. Submergence due to flood.

8. Irregular or Flat Topography.

2016, 2014, 2010

Water-logging control: (or measures to control water logging)

1. Lining of canals and water courses.
2. Reducing the intensity of Irrigation.
3. By introducing crop rotation.
4. By optimum use of water.
5. By providing Intercepting Drains.
6. By provision of an effluent Drainage system.
7. By improving the natural drainage of the area.
8. By adopting consumptive use of surface and sub surface water.

2018, 2017, 2014, 2011

Reclamation of salt affected Land:

Land reclamation is a process by which an unculturable land is made fit for cultivation. Saline and water logged lands give very less crop yields and are, therefore unfit for cultivation, unless they are reclaimed. Land reclamation can be done as follows:

1. Adequate artificial drainage is provided to lower the ground water table below the level of capillary action.

2. The excess salt are leached from top 0.9 m to 1.2 m of the root zone.

3. When the amount of salt has been reduced to such a safe limit that they can be tolerated by s salt resistant crops.

4. When Na_2CO_3 is present in a salt affected soil, Zypsum powder is used at a rate of about 2.5 tons/ha. mixed intimately in the presence of water, where Na_2SO_4 is produced and leached out.

5. To reduce evaporation from the surface of land, Mulching process (means using garbaze, vegetation, rass etc) is used.

How do you prevent salt affection of a land?

1. Using sufficient amount of water for irrigation.

2. Provision for surface drainage.

3. Allowing lower intensity of irrigation on the land.

4. Methods of irrigation of cultivation is selected such way to relating surface evaporation.

5. Not use alkaline water for irrigation.

Water Balance parameter:

The parameter which are used to balanced the water for the irrigation in the field or water requirements of crops are known as water balance parameter.

Followings are the water balance parameter:

(i) Losses through evaporation.

(ii) Losses through transpiration.

(iii) losses through plant metabolism.

(iv) losses through special needs.

(v) Application losses:

$$WR = Cu + Al + Sn$$

$$WR = IR + ER + Cu + S$$ where, S = carry over soil moisture.

Quality of Irrigation Water

S.K. Garg

2010, class test

Example 1.1: What is the classification of irrigation water having the following characterestics: concentration of Na, Ca, and Mg are 22, 3 and 1.5 milli-equiavalents per litre respectively, and the electrical conductivity is 200 micro mhos per cm at 25°C? (b) What problem might arise in using this water on fine textured soils? (c) What remedies do you suggest to over-come this trouble?

Solution:

(a)
$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = \frac{22}{\sqrt{\frac{3+1.5}{2}}} = \frac{22}{\sqrt{2.25}} = 14.67$$

if SAR is between 10 to 18, then it is classified as medium Sodium water and is represented by S_2

If the value of electrical conductivity is between 100 to 250 micro-mhos per cm at 25°C, the water is called of low conductivity (C_1 water)

Hence the given water is classified as C1-S2 water

(b) In fine textured soils, the medium sodium (S2) water may creat the following problems:

(i) soil becomes less permeable.

(ii) It starts crusting when dry.

(iii) It becomes plastic and sticky when wet.

(iv) Its pH increases towards that of alkaline soil.

(c) Gypsum addition, either to soil or to water is suggested to overcome sodium hazard posed by the given water.

Soil-Water Deficiency

B.C. Punmia

* P.N. Modi – Example - 3.2

Example - 3.2: The root of an irrigation soil has dry weight of 15 KN/m3 and a field capacity of 30%. The root zone depth of a certain crop having permanent wilting percentage of 8% is 0.8 m. Determine (a) depth of moisture in the root zone at field capacity (b) depth of moisture in the root zone at permanent wilting point, and (c) depth of water avaiable.

Solution:

(a) Depth of moisture in the root zone at field capacity

$$= \frac{\gamma_d}{\gamma_w} \times F_c = \frac{15}{9.81} \times 0.3 = 0.459 \text{ m/m}$$

$$= 459 \text{ mm/m}$$

(b) Depth of water in the root zone at permanant wilting point,

$$= \frac{\gamma_d}{\gamma_w} \times \text{permanent wilting point}$$

$$= \frac{15}{9.81} \times 0.08 = 0.122 \text{ m/m} = 122 \text{ mm/m}$$

(c). Depth of water avaiable in root zone,

$$= \frac{\gamma_d}{\gamma_w} \times d \times [F_c - \text{permanent wilting point}]$$

$$= \frac{15}{9.81} \times 0.8 \times [0.3 - 0.08]$$

$$= 0.269 \text{ m} = 269 \text{ mm}$$

(Ans.)

2017, 2014, 2008

Example – 3.5: Find the field capacity of a soil for the following data:

Root zone depth = 2 m

Existing water content = 5% * P.N. Modi – Example – 3.3

Dry density of soil = 15 KN/m^3 * (1500 Kg/m^3) // (1.5 g/cm^3) ← এই এককে ও থাকতে পারে।

Water applied to the soil = 500 m^3

Water loss due to evaporation and deep percolation = 10%

Area of plot = 1000 sq. meter

Solution: Total water applied = 500 m^3

Loss of water = 10 %

∴ Volume of water used in the soil $= \left(500 \times \frac{90}{100}\right) m^3$

$= 450\ m^3$

Weight of water used $= (450 \times 9.81) = 4414.5$ KN

* $(450 \times 9810) = 4414500$ N

Total dry weight of the soil $= (15 \times \underset{A}{1000} \times \underset{d}{2}) = 30000$ KN

* $(1500 \times 1000 \times 2 \times 9.81) = 29430000$ N

∴ % of water added $= \frac{4414.5}{30000} \times 100 = 14.72\%$

* $\frac{4414500}{29430000} \times 100 = 15\%$

Existing water content = 5%

Thus, New water content $= (14.72 + 5) = 19.72\%$

* $(15 + 5) = 20\%$

∴ Field Capacity = 19.72%

(Ans.)

2016 *P.N. Modi — Example-3.4

Example-3.6: A loam soil has field capacity of 22% and wilting co-efficient 10%. The dry unit weight of soil is 15 KN/m³. If the root zone depth is 70 cm, Determine the storage capacity of the soil. Irrigation water is applied when moisture content falls to 14%. If the water application efficiency is 75%, determine the water depth required to be applied in the field.

Solution: Given, $\gamma_d = 15\ KN/m^3$, $\gamma_w = 9.81\ KN/m^3$

Maximum storage capacity = Avaiable moisture

$$= \frac{\gamma_d}{\gamma_w} \times d \times [F_c - W_c]$$

$$= \frac{15}{9.81} \times 0.70 \times [0.22 - 0.10]$$

$$= 0.128\ m = 12.8\ cm.$$

Depth of Irrigation $= \frac{\gamma_d}{\gamma_w} \times d \times [F_c - w]$

$$= \frac{15}{9.81} \times 0.70 \times [0.22 - 0.14]$$

$$= 0.086\ m = 86\ mm$$

Water application efficiency = 75%.

∴ Field irrigation requirement $= \frac{86}{0.75} = 115\ mm$

(Ans)

* P. N. Modi — Example – 3.9

Example - 3.7: After how many days will you supply water to soil (clay loam) in order to ensure efficient irrigation of the given crop, if

(i) Field capacity of soil = 27%.

(ii) Permanent wilting point = 14%.

(iii) Dry density of soil = 15 KN/m³

(iv) Effective depth of root = 75 cm

(v) Daily consumptive use of water for the given crop = 11 mm

Same type — Example – 3.26

Solution: Avaiable moisture = Field capacity − Permanent wilting point

= (27 − 14) = 13%

Let, the readity avaiable moisture = 80% of Avaiable moisture

∴ Readily avaiable moisture = (0.8 × 13) = 10.4 %

Optimum moisture content, m_o = (27 − 10.4) = 16.6 %

Hence, when irrigation water is applied, moisture is raised from 16.6% to 27%.

Depth of water stored in root zone, during each watering,

$$= \frac{\gamma_d}{\gamma_w} \times d \times [F_c - m_o]$$

$$= \frac{15 \times 0.75}{9.81} \times [0.27 - 0.166]$$

$$= 0.119 \text{ m} = 11.9 \text{ cm}$$

Thus, depth of water avaiable for evaporation = 11.9 cm

Daily consumptive use = 1.1 cm   ∴ watering frequency = $\frac{11.9}{1.1}$ = 10.82 days ≃ 10 days. (Ans.)

S.K. Garg

Exercise– 8(b) 2011, 2006, 2005

compute the depth and frequency of irrigation required for a certain crop with data given below:

Root zone depth = 100 cm

Field capacity = 22%

wilting point = 12%

Apparent sp. gr. = 1.50

consumptive use = 25 mm/day

Effeciency of Irrigation = 50%

Assume 50% depletion on avaiable moisture before application of irrigation water at field capacity.

Solution:

Avaiable moisture = Field capacity – wilting point

$= (22-12) = 10\%$

∴ Readily avaiable moisture = 50% of Avaiable moisture

$= (0.5 \times 10) = 5\%$

∴ optimum moisture content, $m_o = (22-5) = 17\%$

∴ Depth of water stored $= \frac{\gamma_d}{\gamma_w} \times d \times [F_c - m_o]$

$= 1.5 \times \frac{100}{100} \times (.22 - .17)$

$= 0.075$ m

$= 75$ mm

For 50% efficieny of Irrigation, depth of water required $= \frac{75}{0.5} = 150$ mm

∴ Irrigation frequency $= \frac{150}{25} = 6$ days

(Ans.)

Duty and Delta

B.C Punmia

Example - 3.11 An irrigation canal has gross command area of 80000 hectares out of which 85% is culturable irrigable. The intensity of irrigation for Kharif season is 30% and for Rabi season 60%. Find the discharge required at the head of the canal if the duty at its head is 800 hectares/cumec for Kharif season and 1700 hectares/cumec for rabi season.

Solution:

Culturable irrigable area = $(0.85 \times 80000) = 68000$ hectares

Area under Kharif season = $(0.30 \times 68000) = 20400$ hectares

Area under Rabi season = $(0.60 \times 68000) = 40800$ hectares

water required at the head of the canal to irrigate land:

(i) under Kharif season $= \frac{20400}{800} = 25.5$ cumec.

(ii) under Rabi season $= \frac{40800}{1700} = 24$ cumec.

∴ Required discharge at the head of distributory = 25.5 cumec

(Ans.)

same type (Example - 3.22) → Class lecture

Example-3.12: A water course has culturable command area of 2600 hectares, out of which the intensities of irrigation for perinial sugar can and rice crops are 20% and 40% respectively. The duty for these crops at the head of water course are 750 hectares/cumec and 1800 hectares/cumec respectively. Find the discharge required at the head of water course if the peak demand is 120% of the average requirement.

Solution:

Area under sugar-cane $= (0.2 \times 2600) = 520$ hectares.

Area under rice $= (0.4 \times 2600) = 1040$ hectares.

water required for sugar cane $= \frac{520}{750} = 0.694$ cumec.

water required for rice $= \frac{1040}{1800} = 0.578$ cumec.

Since, sugar cane is perennial crop, it will require throughout the year.

Hence, the water course must carry a total discharge of

$(0.694 + 0.574) = 1.272$ cumecs.

$\therefore$ The design discharge to meet the peak demand

$= (1.2 \times 1.272) = 1.53$ cumecs.

(Ans.)

Example-3.13: The left branch canal carrying a discharge of 20 cumecs has culturable command area of 20000 hectares. The intensity of Rabi crop is 80 percent, and the base period is 120 days. The right branch canal carrying discharge of 8 cumecs has culturable command area of 12000 hectares, intensity of irrigation of Rabi crop is 50 percent, and the base period is 120 days. Compare the efficiency of the two canal systems.

Solution:

(a) For the left canal:

Area under Rabi crop $= (0.8 \times 20000) = 16000$ hectares

Discharge = 20 cumecs.

$$\therefore \text{Duty} = \frac{16000}{20} = 800 \text{ hectares/cumec}$$

(b). For the right canal:

Area under Rabi crop $= (0.5 \times 12000) = 6000$ hectares

Discharge = 8 cumecs

$$\therefore \text{Duty} = \frac{6000}{8} = 750 \text{ hectares/cumec.}$$

Since, the left canal system has higher duty, it is more efficient.

(Ans.)

2011, 2002

Example-3.14: A water course has a culturable command area of 1200 hectares. The intensity of irrigation for crop A is 40% and for B is 35%, both the crops being Rabi crops. Crop A has a Kor period of 20 days and crop B has kor period of 15 days. calculate the discharge of the water course if the Kor depth for crop A is 10 cm and for B it is 16 cm.

Solution:

(a) For crop A:

Area under irrigation = $(0.40 \times 1200) = 480$ hectares

Kor period, $b = 20$ days

Kor depth, $\delta = 10$ cm $= 0.1$ m

$\therefore$ Duty $= 8.64 \times \frac{b}{\delta} = \left(8.64 \times \frac{20}{0.1}\right) = 1728$ hectares/cumec.

Hence, Discharge required $= \frac{480}{1728} = 0.278$ cumec.

(b) For crop B:

Area under irrigation $= (0.35 \times 1200) = 420$ hectares

Kor depth, $\delta = 16$ cm $= 0.16$ m.

Kor period, $b = 15$ days.

$\therefore$ Duty $= 8.64 \times \frac{b}{\delta} = \left(8.64 \times \frac{15}{0.16}\right) = 810$ hectares/cumec.

Hence, discharge required $= \frac{420}{810} = 0.519$ cumec.

$\therefore$ The design discharge of water course

$= (0.278 + 0.519) = 0.79 \simeq 0.8$ cumec.

(Ans.)

Example - 3.15: A water course commands an irrigated area of 600 hectares. The intensity of irrigation of rice in this area is 60%. The transplantation of rice crop takes 12 days, and total depth of water required by the crop is 50 cm on the field during the transplantation period. During the transplantation period, the useful rain falling on the field is 10 cm. Find the duty of irrigation for the crop on the field during transplantation, at the head of the field and also the head of the distributory, assuming losses of water to be 20% in the water course. Also, calculate the discharge in the water course.

Solution: we know,

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

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

Here, $B = 12$ days

$\Delta = (50 - 10) = 40\text{ cm} = 0.4\text{ m}$

$$\Rightarrow D = 8.64 \times \frac{12}{0.4}$$

$\therefore D = 259.2$ hectares/cumec.

Since the losses in the canal = 20%.

Hence, the duty of water at the head of the water course

$= (0.8 \times 259.2) = 207.36$ hectares/cumec.

Area under rice plantation $= (0.6 \times 600) = 360$ hectares.

$\therefore$ Discharge at the head of water course $= \frac{360}{207.36}$ cumec.

$\simeq 1.74$ cumecs. (Ans.)

[Same type] Example - 3.27

Example - 3.16: Table below gives the necessary data about the crop, their duty, and the area under each crop, command by a canal taking off from a storage tank. Taking a time factor for the canal to be $\frac{13}{20}$. Calculate the discharge required at the head to the canal. If the capacity factor is 0.8. Determine the design discharge.

Crop	Base Period (days)	Area (hectares)	Duty at the head to the canal (ha/cumec)
Sugar cane	320	850	580
overlap for sugar cane in hot weather	90	120	580
Wheat (Rabi)	120	600	1600
Bajri (Monsoon)	120	500	2000
Vegetable (Hot weather)	120	360	600

Solution:

Discharge for sugar cane $= \frac{850}{580} = 1.466$ cumec.

for overlap sugar cane $= \frac{120}{580} = 0.207$ cumec.

for wheat $= \frac{600}{1600} = 0.375$ cumec.

for Bajri $= \frac{500}{2000} = 0.25$ cumec.

for vegetable $= \frac{360}{600} = 0.60$ cumec.

Since sugar cane has a base period of 320 days, it will require water in Rabi, Monsoon and Hot weather.

$\therefore$ Discharge in Rabi $= (1.466 + 0.375) = 1.841$ cumec.

Discharge in Monsoon $= (1.466 + 0.25) = 1.716$ cumec.

Discharge in Hot weather $= (1.466 + 0.207 + 0.60) = 2.273$ cumec.

Thus the maximum demand of 2.273 cumec in Hot weather.

Time factor = 13/20

∴ Full supply discharge at the head to the canal

$$= \left(2.273 \times \frac{13}{20}\right) = 3.497 \text{ cumec.}$$

Given, capacity factor = 0.8

$$\therefore \text{Design discharge} = \frac{3.497}{0.8} = 4.372 \text{ cumec.}$$

(Ans.)

Example – 3.17: The base period, intensity of irrigation and duty of various crops under a canal system are given in the Table below. Find the reservoir capacity if the canal losses are 20% and reservoir losses are 12%.

Crop	Base Period (days)	Duty at the head (hectar/cumec)	Area under the crop (hectares)
Wheat	120	1800	4800
Sugar-Cane	360	800	5600
Cotton	200	1400	2400
Rice	120	900	3200
Vegetable	120	700	1400

Solution:

Crop (1)	Base Period (days) (B) (2)	Duty (D) (hectar/cumec) (3)	$\Delta = \frac{8.64B}{D}$ (m) (4)	Area, (A) hectares (5)	Volume = $\Delta \times A$ hectare-meter (6) = (4) × (5)
Wheat	120	1800	0.576	4800	2764.8
Sugar Cane	360	800	3.888	5600	21772.8
Cotton	200	1400	1.234	2400	2962.3
Rice	120	900	1.152	3200	3686.4
vegetable	120	700	1.481	1400	2073.6

Σ = 33259.9 ha-m

Say, volume = 33260 ha-m

$$\therefore \text{Capacity of reservoir} = \frac{33260}{0.8 \times 0.88} = 47245 \text{ ha-m.}$$

(Ans.)

Do yourself

* Example-3.21 same type

2018, 2015, 2013, 2009

Example – 3.28: The base period, intensity of irrigation and duty of water for various crops under the canal system are given. Determine the reservoir capacity if the culturable command area is 40000 hectares, canal losses are 25% and reservoir losses are 15%.

Crop	Base period (days)	Duty (ha/cumec)	Intensity of Irrigation
Wheat	120	1800	20%
Sugar Cane	360	1700	20%
cotton	180	1400	10%
Rice	120	800	15%
vegetable	120	700	15%

Solution: In the table, Quantity of water = Q (cumec) × B (days) = $8.64 \times 10^4 QB$ (m^3)

Crop	Base period (days)	Intensity of Irrigation	Area (ha)	Duty (ha/cumec)	Discharge (cumec)	Quantity of water (m^3)
(1)	(2)	(3)	(4) = (3)×40000	(5)	(6) = (4)/(5)	(7) = 8.64×10^4 (6) × (2)
wheat	120	20%	8000	1800	4.444	46.08×10^6
sugar-cane	360	20%	8000	1700	4.706	146.38×10^6
cotton	180	10%	4000	1400	2.857	44.43×10^6
Rice	120	15%	6000	800	7.5	77.76×10^6
Vegetable	120	15%	6000	700	8.571	88.87×10^6

$\Sigma = 403.52 \times 10^6 \ m^3$

volume required at head of canal $= \dfrac{403.52\times10^6}{0.75} = 538.03\times10^6 \ m^3$

$\therefore$ storage capacity $= \dfrac{538.03\times10^6}{0.85} = 633\times10^6 \ m^3$

(Ans.)

Class Lecture 2017, 2014, 2008

The gross area of an irrigation project is 50000 hectares. Out of this about 5000 hectares have been utilized for construction of dwellings, roads, bridges etc. The area to be cultivated during Rabi (in winter season) is 25000 hectares and during Kharif crops (in summer season) is 24000 hectares. The duty of canal water for Rabi crops is 5000 hectare per cumec and for Kharif crop is 3000 hectare per cumec. Find the discharge for the canal after giving 10% allowance for peak discharge and loss of water in transit. What would be the annual intensity of irrigation.

Solution: Given, Gross command area = 50000 hectares

cultivable command area = (50000 − 5000) hectares

= 45000 hectares.

For Rabi crops:

Area under rabi crops = 25000 hectares

$\therefore$ intensity of irrigation $= \frac{25000}{45000} \times 100 = 55.56\%$

and, Discharge for rabi crops $= \frac{25000}{5000} = 5$ cumec

For Kharif crops:

Area under Kharif crop = 24000 hectares

$\therefore$ intensity of irrigation $= \frac{24000}{45000} \times 100 = 53.33\%$

and, Discharge for Kharif crops $= \frac{24000}{3000} = 8$ cumec

∴ Required discharge at the head of distributory

$= 8$ cumec. [* rabi & Kharif season থাকলে যেটা বড় হবে, ওইটাই required]

For 10% allowance for peak discharge, See - Example - 3.11

The design discharge $= (8 + 0.1 \times 8) = 8.8$ cumec.

And, Annual intensity of irrigation $= 55.56\%$ [বড়টা হবে]

(* intensity of irrigation $\leq 100\%$) (Ans.)

2018, 2017, 2015, 2012, 2004

To measure 5000 ha. of Rabi crops, an irrigation canal was run as follows: Calculate overall duty and depth of water used.

Month	Oct.	Nov.	Dec.	Jan.	Feb.
No. of Running days	14	28	21	21	14
Discharge in (m^3/s)	2.00	2.50	2.25	2.25	2.00

<u>Solution</u>: Given, $A = 5000$ hectares.

Month	No. of Running days	Q (m^3/s)	Duty, $D = \frac{A}{Q}$ (ha/cumec)
Oct.	14	2.0	2500
Nov.	28	2.5	2000
Dec.	21	2.25	2222.22
Jan.	21	2.25	2222.22
Feb.	14	2.0	2500
	$\Sigma B = 98$ days		$\Sigma D = 11444.44$ ha/cumec

overall duty $= \frac{\Sigma D}{n} = \frac{11444.44}{5} = 2288.89$ ha/cumec.

We know, $\Delta = 8.64 \times \frac{B}{D}$

$= 8.64 \times \frac{98}{2288.89} = 0.37$ m $= 370$ mm.

(Ans.)

2013

If wheat requires about 9.5 cm of water after every 30 days, and the base period of wheat is 150 days. Find the value of duty and delta of the wheat.

Solution:

Required depth = 9.5 cm, per every 30 days

No of interval = $\frac{150}{30} = 5$

∴ Delta of the wheat = $(9.5 \times 5) = 47.5$ cm = 0.475 m

(Ans.)

Duty of the wheat, $D = 8.64 \times \frac{B}{\Delta}$

$= 8.64 \times \frac{150}{0.475}$

$= 2728.42$ hectares/cumec

(Ans.)

Consumptive Use of Water

P.N. Modi

Example - 4.10: 2016

Determine the consumptive use requirement for a certain crop with the climate and other data given in the table below. Also calculate the field irrigation requirement if the water application efficiency is 75%. Use Blaney-Cridle formula.

Month	Mean Monthly temp °C	Monthly % of day time hr. of the yr.	Monthly Consumptive use co-efficient	Mean monthly eff. rainfall.
April	25	8.6	0.60	–
May	27	9.29	0.65	–
June	28	9.18	0.70	52.30
July	29	9.39	0.75	79.60
August	29	9.04	0.75	62.80
september	27	8.31	0.65	31.20
october	29	8.10	0.60	25.30

solution:

Month	t °C	p	K	$u = Kp(0.46t + 8.13)$ (mm)	Re (mm)
April	25	8.60	0.60	101.29	—
May	27	9.29	0.65	124.09	—
June	28	9.18	0.70	135.01	52.3
July	29	9.39	0.75	151.20	79.60
August	29	9.04	0.75	145.57	62.80
September	27	8.31	0.65	111.60	31.20
October	29	8.10	0.60	93.17	25.30
				$\Sigma u = 861.33$	$\Sigma Re = 246.2$

Total consumptive use requirement,

$$U = \Sigma u = 861.33 \text{ mm}$$

consumptive irrigation requirement,

$$CIR = U - \Sigma R_e$$

$$= (861.33 - 246.2)$$

$$= 615.13 \text{ mm}$$

Field irrigation requirement,

$$FIR = \frac{NIR}{\eta_a} = \frac{CIR}{\eta_a} = \frac{615.13}{0.75} = 820.17 \text{ mm}$$

(Ans.)

* যদি cm. এ data দেওয়া থাকে,

Use, $C_u(cm) = K \times \frac{P}{40}(1.8t + 32)$

See Example- 2.9 - S.K. Garg

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Irrigation Requirements of Crop

Modi - Exercise - 4.12

2012, 2003

Following data refer to an agricultural land growing rice:

(i) period of growth: 16th July to 31st July.

(ii) USBR Class A type Pan evaporation = 6 mm/day

(iii) Crop co-efficient, K = 1.2

(iv) Percolation loss = 5 mm/day

(v) Effective rainfall during the period = 60 mm

Calculate values of NIR, FIR and GIR. Assume 20% loss of water application and 25% in conveyance.

Solution:

Total period = 16 days (16th July - 31st July)

$\therefore$ Pan evaporation, $E_p = (6 \times 16)$ mm

$= 96$ mm

consumptive use of water, $C_u = K E_p = (1.2 \times 96)$ mm

$= 115.2$ mm

consumptive Irrigation Requirement, $C.I.R = C_u - R_e$

$= (115.2 - 60)$ mm

$= 55.2$ mm

Net Irrigation requirement, $N.I.R = (C_u - R_e) + E_L$

$= 55.2 + (5 \times 16)$

$= 135.2$ mm

water application efficiency, $\eta_a = (100-20) = 80\% = 0.8$

$\therefore$ Field Irrigation requirement, $FIR = \frac{NIR}{\eta_a}$

$= \frac{135.2}{0.8}$

$= 169$ mm

water conveyance efficiency, $\eta_c = (100-25)$
$= 75\% = 0.75$

$\therefore$ Gross Irrigation Requirement, $GIR = \frac{FIR}{\eta_c} = \frac{169}{0.75} = 225.33$ mm

(Ans.)

where I is in cm/h, T_r is in years and t is in minutes.
Estimates the peak rate of runoff for a 25 year frequency.

Solution: Given,
length of water course = 1.8 Km = 1800 m

Fall in the elevation = 22 m

$$\therefore S = \frac{22}{1800} = 0.0122$$

$$t_c = 0.0195\ L^{0.77}\ S^{-0.385}$$

$$= 0.0195 \times (1800)^{0.77} \times (0.0122)^{-0.385}$$

$$= 34.12 \text{ minutes.}$$

Given,

$$I = \frac{80\ T_r^{0.2}}{(t+13)^{0.46}} = \frac{80 \times (25)^{0.2}}{(34.12+13)^{0.46}} = 25.9 \text{ cm/hr}$$

$A_1 = 1.5\ Km^2$ $\quad$ $C_1 = 0.20$

$A_2 = 2.5\ Km^2$ $\quad$ $C_2 = 0.10$

$A_3 = 1.0\ Km^2$ $\quad$ $C_3 = 0.35$

$$\therefore Q = 2.778 I \Sigma C_i A_i$$

$$= 2.778 \times 25.9 \times (1.5 \times 0.20 + 2.5 \times 0.10 + 1.0 \times 0.35)$$

$$= 64.76 \text{ m}^3/\text{s}$$

(Ans:) $\quad$ * same Type Exercise - 14.18

Example - 14.3:
A culvert is proposed across a stream draining an area of 185 hectares. The catchment has a slope of 0.004 and the length of travel for water is 1150 m. Estimate the 25 year flood if the rainfall is given by -

$$I = \frac{1000\ T_r^{0.2}}{(t+20)^{0.7}}$$

Leaching Requirement

Micheal

Example- 9.6: 2014, 2013, 2005, 2007, 2009

Estimate the leaching requirement when the EC of the staturation extract of the soil is 11 mmhos/cm at 25 percent reduction in the yield of cotton. The EC of irrigation water is 1.5 mm-mhos/cm.

Solution:

we know, $LR = \frac{EC_i}{EC_d} = \frac{EC_i}{2 \times EC_e} = \frac{1.5}{2 \times 11} = 0.0682$

$\therefore LR = 6.82\%$

Thus, it is necessary to apply approximately 7% more water than consumptive use requirement.

(Ans.)

S.K. Garg

Example-6.1

Estimate the leaching requirement when EC value of a saturation extract of soil is 10 m.mhos/cm at 25% reduction in the yield of a crop. The EC of irrigation water is 1.2 m-mhos/cm. What will be the required depth of water to be applied to the field if the consumptive use requirement of the crop is 80 mm? EC value of the leaching water may be suitable assumed.

Solution: We know,

Leaching requirement, $LR = \frac{EC_i}{EC_d} = \frac{EC_i}{2 \times EC_e}$

Given, EC_i = 1.2 m.mhos/cm. and EC_e = 10 m.mhos/cm

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Hence, $LR = \frac{1.2}{2 \times 10} = 0.06 = 6\%$

$\therefore$ The leaching requirement, $LR = 6\%$.

Now, Again.

$$LR = \frac{D_d}{D_i} = \frac{D_i - C_u}{D_i}$$

Given, $C_u = 80$ mm.

Hence, $$0.06 = \frac{D_i - 80}{D_i}$$

$$\Rightarrow 0.06 D_i = D_i - 80$$

$$\Rightarrow 0.94 D_i = 80$$

$$\therefore D_i = 85.11 \text{ mm}$$

Hence, The required water depth for irrigation = 85.11 mm

(Ans.)

Irrigation Efficiency

P.N. Modi

2015

*S.K Garg – Example-2.7

Example - 4.22: A stream of 150 (125 litres) litres per second was delivered from a canal and 110 (70 litres) liters per second were delivered to the field. An area of 2.2 (1.6 hectares) hectares was irrigated in eight hours. The effective depth of root zone was 1.5 (1.7 m) m. The runoff loss in the field was 445 (420 m³) m^3, the depth of water penetration varied linearly from 1.5 m (1.7 m) at the head end of the field 1.1 m (1.3 m) at the tail end. Avaiable moisture holding capacity of the soil is 200 mm per meter (20 cm/m) depth of soil. Determine the water conveyance efficiency, water application efficiency, water storage efficiency, and water distribution efficiency. Irrigation was started at a moisture extraction level of % 50.

Solution:

water conveyance efficiency, $\eta_c = \frac{W_f}{W_r} \times 100$

$= \frac{110}{150} \times 100$

$= 73.33\%$

water application efficiency, $\eta_a = \frac{W_s}{W_f} \times 100$

∴ Water delivered to the plot $= \frac{110 \times (60 \times 60 \times 8)}{1000} m^3$ (hr to sec.) (litre to m^3)

$= 3168 \ m^3$

Run-off loss $= 445 \ m^3$

∴ water stored in the root zone, $W_s = (3168 - 445) \ m^3$

$= 2723 \ m^3$

$\therefore \eta_a = \frac{2723}{3168} \times 100 = 86\%$

water storage efficiency, $\eta_s = \frac{W_s}{W_n} \times 100$

water holding capacity of the soil $= (200 \times 1.5) = 300$ mm

Moisture required in the root zone → 50% extraction

$= (300 - (0.5) \times 300) = 150$ mm

$= \frac{150}{1000} \times 2.2 \times 10^4$ m³

(mm to m) ← 1000 ; → Area (hectare to m²)

$= 3300$ m³

$\therefore \eta_s = \frac{2723}{3300} \times 100 = 82.52\%$

water distribution efficiency, $\eta_d = (1 - \frac{y}{d}) \times 100$

Average depth of water stored in the root zone.

$d = \frac{1.5 + 1.1}{2} = 1.3$

Numerical deviation from depth of penetration

at the head end $= (1.5 - 1.3) = 0.2$ m

at the tail end $= (1.3 - 1.1) = 0.2$ m

$\therefore$ Average numerical deviation, $y = \frac{0.2 + 0.2}{2} = 0.2$ m

$\therefore \eta_d = (1 - \frac{0.2}{1.3}) \times 100 = 84.62\%$

(Ans.)

[Same Type] - [S.K. Garg] Example-2.7 / [Micheal] Example-7.11

S.K. Garg

Example – 2.6: 2016, 2014, 2012

The depth of penetrations along the length of a boarder strip at points 30 meters apart were probed. Their observed value are 2.0, 1.9, 1.8, 1.6 and 1.5 meters. Compute the water distribution efficiency.

Solution:

$$\text{Mean depth}, D = \frac{2.0 + 1.9 + 1.8 + 1.6 + 1.5}{5} = 1.76 \text{ meters}$$

Abosolute values of deviations from mean are,

$(2.0 - 1.76)$, $(1.9 - 1.76)$, $(1.8 - 1.76)$, $(1.76 - 1.6)$, $(1.76 - 1.5)$

$= 0.24, \ 0.14, \ 0.04, \ 0.16, \ 0.26$

Average of Absolute values of deviations from mean,

$$d = \frac{0.24 + 0.14 + 0.04 + 0.16 + 0.26}{5} = 0.168 \text{ meter}$$

∴ The water distribution effeciency,

$$\eta_d = \left(1 - \frac{d}{D}\right) = \left(1 - \frac{0.168}{1.76}\right) = 0.905 = 90.5\%$$

(Ans.)

Comments:

$\eta_d = 0.905 < 1$;

Hence, It was not uniformly distributed throughout the field.

Method of Irrigation

B.C. Punmia

Example - 2.1: (Border Strip method)

Find the time required to cover an area of 0.1 hectares when a tube well is discharging at the rate of 0.03 cumec for irrigation of rabi crops. Average depth of flow is expected to be 7.5 cm. Average infiltration rate for the soil may be taken as 5 cm/hour.

Solution:

Given, $Q = 0.03$ cumec $= (0.03 \times 3600)\ m^3/hour = \frac{0.03 \times 3600}{10^4}$ ha-m/hr

$\therefore Q = 0.0108$ ha-m/hour

$y = 7.5\ cm = 0.075\ m$

$I = 5\ cm/hour = 0.05\ m/hr$

$A = 0.1$ hectare.

We know,

$$t = 2.303 \frac{y}{I} \log_{10}\left(\frac{Q}{Q - IA}\right)$$

$$= 2.303 \times \frac{0.075}{0.05} \times \log_{10}\left(\frac{0.0108}{0.0108 - 0.1 \times 0.05}\right) \text{ hours}$$

$$= 0.9327 \text{ hrs} = 55.96 \text{ minutes} \simeq 56 \text{ minutes.}$$

(Ans.)

Example - 2.2: For the above example, Find the maximum area that can be irrigated by the avaiable discharge of 0.03 cumec.

Solution:

Maximum area that can be irrigated, $A = \frac{Q}{I}$

$$= \frac{0.0108}{0.05} = 0.216 \text{ hectare}$$

(Ans.)

* same type - S.K. Garg - Example - 1.1

Michael

Example-8.4 (Check-Basin method)

An irrigation stream of 27 liters per second is diverted to a check basin of size 12m × 10 m. The water holding capacity of the soil is 14 percent. The average soil moisture content in the crop root prior to applying water is 6.5 percent. How long should the irrigation stream be applied to the basin to replenish the root zone moisture to its field capacity, assuming noss due to deep percolation. The average depth of crop root zone is 1.2 m. The apperant specific gravity of the root zone is 1.50.

Solution:

Net irrigation requirement = Field capacity - Avaiable moisture content

$= (14 - 6.5) = 7.5\%$

→ apperant sp. gr.

$\therefore$ N.I.R $= (7.5 \times 1.5) = 11.25$ cm/m of the depth

→ root zone depth

Hence, Net Irrigation depth $= (11.25 \times 1.2)$ cm

$= 13.5$ cm

Total volume of water required in the check basin

= Area of Basin × Net irrigation depth

$= \left(12 \times 10 \times \frac{13.5}{100}\right) = 16.2 \text{ m}^3$

$\therefore$ Required duration of irrigation $= \frac{(16.2 \times 1000)\,l}{27\ l/sec} = 600$ sec.

(Ans.)

2010, Class test

Example- 8.6 (Furrow Method)

Furrows 90 m long and spaced 75 cm apart are irrigated initial furrow stream of two litres/sec. The initial furrow stream reached the lower end of the field in 50 mins. The size of stream was then reduced to 0.5 litre/sec. The cut back stream continued for 1 hours. Estimate the average depth of irrigation.

Solution: Given,

$q = 2$ litre/sec.

$L = 90$ m

$w = 75$ cm $= 0.75$ m

$t = 50$ min $= 0.833$ hrs.

Average depth of irrigation by innitial irrigation,

$$d = \frac{q \times 360 \times t}{w \times L} = \frac{2 \times 360 \times 0.833}{0.75 \times 90}$$

$\therefore d = 8.89$ cm.

Average depth of irrigation by cut back stream,

$$d = \frac{0.5 \times 360 \times 1}{0.75 \times 90} = 2.67 \text{ cm.}$$

$\therefore$ Net average depth of irrigation $= (8.89 + 2.67)$ cm

$= 11.56$ cm.

(Ans.)

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Example - 8.9 (sprinkler Method)

Determine the required capacity of a sprinkler system to apply water at the rate of 1.25 cm/hr. Two 186 meters long sprinklers are placed at 12m intervals on each line. The spacing between lines in 18m.

Solution:

we know,

$$\text{required capacity}, q = \frac{S_l \times S_m \times I}{360} = \frac{12 \times 18 \times 1.25}{360}$$

$= 0.75$ litre/sec/sprinkler

∴ system capacity = total discharge of all sprinklers

$$\text{No. of sprinkler} = \frac{186}{12} = 15.5 \simeq 16$$

∴ system capacity = (0.75×16) = 24 litres / sec.

(Ans.)

2016 / 2004

Example – 8.11 (Sprinkler system)

Determine the system capacity for a sprinkler irrigation system to irrigate 16 hectares of maize crop. Design moisture use rate is 5 mm per day. Moisture replaced in soil at each irrigation is 6 cm. Irrigation efficiency is 70 percent. Irrigation period is 10 days in a 12 day interval. The system is to be operated 20 hours per day.

Solution:

Given, $A = 16$ hectares

$F = 10$ days

$H = 20$ hours

$d = 6$ cm

we know,

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

$= 2780 \times \frac{16 \times 6}{10 \times 20 \times 70}$

$= 19.063$ litres/sec.

(Ans.)

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2013

Example - 8.8 (Sprinkler Method)

Determine the uniformity co-efficient from the following data obtained from a field test on a square plot bounded by four sprinklers:

Sprinkler — 4.365 X 2.381 mm nozzles at 2.8 Kg/cm²

Spacing — 24 m X 24 m

Wind — 3.5 Km/hr from south west

Humidity — 42 percent

Time of test — 1.0 hour

S	8.9	7.6	6.6	S
8.1	7.6	9.9	10.2	8.3
8.9	9.1	9.1	9.4	8.9
9.4	7.9	9.1	8.6	9.1
S	7.9	6.6	6.8	S

Note: S indicates location of sprinklers.

Solution:

The computations are shown in the following tabular form:

Observation (m)	Frequency (n)	Application rate X Frequency	Numerical deviations	Frequency X Deviations (X)
10.2	1	10.2 X 1 = 10.2	(10.2 - 8.6) = 1.6	1.6 X 1 = 1.6
9.9	1	9.9 X 1 = 9.9	(9.9 - 8.6) = 1.3	1.3 X 1 = 1.3
9.4	2	9.4 X 2 = 18.8	(9.4 - 8.6) = 0.8	0.8 X 2 = 1.6
9.1	4	36.4	0.5	2.0
8.9	3	26.7	0.3	0.9
8.6	1	8.6	0.0	0.0
8.3	1	8.3	0.3	0.3
8.1	1	8.1	0.5	0.5
7.9	2	15.8	0.7	1.4
7.6	2	15.2	1.0	2.0
6.8	1	6.8	1.8	1.8
6.6	2	13.2	2	4
	$\Sigma n = 21$	$\Sigma mn = 178$		$\Sigma X = 17.4$

$$\text{mean} = \frac{\Sigma mn}{\Sigma n} = \frac{178}{21} = 8.48$$

uniformity co-efficient, $Cu = 100 \times \left(1 - \frac{\Sigma X}{\Sigma mn}\right)$

$$= 100 \times \left(1 - \frac{17.4}{178}\right)$$

$$= 90.22\ \%$$

(Ans.)

Example-8.5 (Furrow Method)

The data obtained from a test furrow in a sandy loam soil are given below:

Stream size (liter/min)	Distance (meters)	Advance time (minutes)	Wetted perimeter (cm)	Cross sectional area corresponding to depth of flow (cm^2)
92.00	20	1.75	25.39	60.00
	40	5.75	25.62	73.00
	60	10.91	26.39	103.00
	80	17.83	26.70	108.40
	100	23.67	27.11	111.65
	110	27.75	27.42	112.28

compute the furrow irrigation.

Solution:

Accumulated inflow (liters)	Accumulated storage (litres)	Wetted Area (cm^2)	Accumulated infiltrations Volume (litres)	Accumulated infiltration depth (cm)
$(92 \times 1.75) = 161$	$\frac{60 \times (20 \times 100)}{1000} = 120.0$ * ($1 cm^3 = 10^{-3}$ liter)	$25.39 \times (20 \times 100) = 50780$	$(161-120) = 41$ litres	$\frac{41 \times 10^3}{50780} = 0.81$ * (1 litre = 1000 cm^3)
529	372.0	103280	157	1.52
1003.72	618.0	158340	385.72	2.44
1640.36	867.2	213600	773.16	3.62
2177.64	1116.5	271100	1061.14	3.91
2553.0	1235.08	301620	1317.92	4.37

(Ans)

2018 (sprinkler method)

Find the discharge capacity of a sprinklar system from the following data:

(i) crop : wheat

(ii) Depth of irrigation to be applied = 5 cm.

(iii) Peak water requirement = 0.625 cm/day.

(iv) Area = 7.5 hectares (250m × 300m)

(v) Overall Irrigation efficiency = 80%.

(vi) operating hours = 20 hrs/day.

Solution: we know,

$$q = \frac{Ad}{FHE} \times 2780$$

Here, A = 7.5 hectares

d = 5 cm

E = 80%.

No of days, $F = \frac{5}{0.625} = 8$ days.

∴ operating period = 20 hrs/day.

∴ discharge capacity, $q = \frac{7.5 \times 5}{8 \times 20 \times 80} \times 2780$

$= 8.14$ litres/sec.

(Ans.)

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Flood

Flood and It's Causes:

Introduction:
A flood is usually caused by rain, heavy thunder storms and thowing of snow. It is considered to be a temporary condition of two or more acres dry land either,

(i) over flow with tidal water

(ii) Rapid run off / surface water

(iii) Mud flows

Definition of Flood:
An area goes under and remain under water for some times, it is called inundation. When inundation causes damage to properties and crops, disrupts communication and brings harmful effect to human beings as well as flora and fauna, Then it is known as Flood.

Or,
A flood may be defined as an over flow coming from some river or from some body of water.

Or,
Any flow which is relatively high and which over tops the natural or artificial banks in any reach of a river may be called a flood.

Causes of flood:

1. Increase of surface run-off due to heavy rainfall and longer storm duration.

2. Inadequate cross-drainage work.

3. contraction of river section.

4. Bank erosion.

5. Changing of river course from time to time.

6. Silting up of river bed.

7. Obstruction in river flow.

8. Failure of dam

Where does flooding occurs:

(i) Flooding is the most world-wide natural disasters. It occurs in every country wherever their is rainfall and coastal hazards.

(ii) They are most likely to happen to occur in tropical countries.

(iii) Most flooding occurs during the period of spring.

(iv) Most common floods happen around the world-largest river.

Types of Flood:

The most common types of flood is as follows:

1. **Riverine Flood:** In riverine flooding, relatively high water levels overtops the natural or artificial banks of a stream or river. The nature of riverine flooding can vary significantly in terms of cause, timing, depth, between different locations.

2. **Flash Flood:** It occurs when soil absorption, runoff or drainage can't adequately disperse intense rainfall and is usually caused by slow moving thunderstorm.

3. **Storm surge:** It is an abnormall rise in water level in coastal areas, over and above the regular astronomical tide caused by forces generated from a severe storms wind, waves and low atmospheric pressure.

4. **Dam failure:** Although dam failure is rare, but thier effects can be significant.

Causes of flood in Bangladesh:

Generally two types of causes are responsible for flood in Bangladesh. (i) Natural causes (ii) Human related causes.

Natural Causes:

1. Rain-fed floods generally happen in deltas of south-western part of the country.

2. 70% of the total area is less than 1m above the mean sea level.

3. Tropical storms bring heavy rains and coastal flooding.

4. 10% of the land area is made up of lakes and rivers.

5. Snow melting from Himalayas takes place in late spring and summer.

6. Bangladesh experiences heavy moonsoon rains, specially over high lands.

<u>Human Related Causes:</u>

1. Urbanization of flood plain rapidly increasing the magnitude and frequency of flood.

2. Global warming rises the sea level, increases snow melting and rainfall in the region of Bangladesh.

3. Deforestation in nepal and the Himalayas increase the runoff, which acts to deposition and flooding downstream.

4. Building of dam in India has increase the problem of sedimentation in Bangladesh.

5. Poorly maintained embankment leak and collapse at the end of high discharges.

Benifits of Flood:

Every matter in the world has some bad sides and good sides. Flood has also some good sides. Some benifits of floods are given below:-

1. Soil fertility: Flood increases the soil fertility by the replenishment of essential nutrients in soil, which helps in growing more crops and also producing more.

2. Hydro electricity: Building dams and other structures can make use of the powerful mass of water travelling along a junction of a river

3. Awareness: Flooding awareness is a vital component of flood prevention and protection. For high risk areas and flood warning facilities during then and they will prepare themselves according to them.

Disadvantages of flood:

(i) It can cause damage to properties and crops.

(ii) It can cause damage to home.

(iii) It can cause loss of lives.

(iv) It can kill animals.

(v) It can cause damage to vehicles.

(vi) It can cause many diseases by polluted water.

(vii) It can disrupt the communication.

Standard Project Flood: (SPF)

The flood that is likely to be exceeded in magnitude only at rare occasions and thus constitutes a standard for the design of structures, that would provide enough flood protection is defined as Standard Project Flood.

Maximum Probable Flood: (MPF)

The flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region, is defined as Maximum Probable Flood.

Design Flood:

A design flood is the flood discharge adopted for the design of a structure after careful consideration of economic and hydrologic factors.

Its importance:

(i) It is adopted for the design of hydraulic structure like spillways, bridge openings, flood banks.

(ii) Design flood is directly related to project feature

(iii) Design flood can be adopted for –

(a) prevention of damage to the structure downstream.

(b) prevention of damage to crops and lands.

(c) reduction in diseases resulting from inundation of flood water.

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Method of Estimating Design Flood:

Various method have been used for estimating floods. In general The following methods are used in the estimation of the design flood:

(i) Increasing the observed maximum flood by a certain percentage

(ii) Envelope Curves.

(iii) Emperical Flood formulae.

(iv) Rational Method.

(v) Unit Hydrograph Application.

(vi) Frequency Analysis (or Statistical Methods)

Describe two of these methods in details:

(i) Rational Method:

In this method, it is assumed that the maximum flood flow is produced by a certain rainfall intensity which lasts for a time equal to or greater than the period of concentration time.

The concentration time is the time required for the surface runoff from the remotest part of the catchment area to reach the basin out let.

When a storm continues beyond concentration time, every part of the catchment would be contributing to the runoff at out let and Therefore it represents condition of peak runoff. The runoff corresponding to this condition is given by-

$$Q = CAI$$

where, C = Runoff co-efficient
A = Area of the catchment
I = Intensity of Rainfall
Q = peak Runoff.

If A is in acres and I is in Inches/hour, Then the runoff is obtained in ft^3/sec. without requiring any conversion factor.

In SI System, When A is in Km^2 and I is in cm/h ; the flow rate is given by –

$$Q = 2.778\, CAI \quad \text{where, Q is in } m^3/sec.$$

The intensity of rainfall should be corresponding to a duration equal to concentration time and return period. This requires an estimate of concentration time which is usually provided by an emperical formula given by Kirpich (1940) –

$$t_c = 0.0195 L^{0.77} S^{-0.385}$$

where, t_c = time of concentration (min)

L = Maximum length of travel of water along the water course (m)

S = slope

A given catchment may have distinctly different characterestics requiring the use of different run-off co-efficient for different subareas with in the catchment. In such cases –

$$Q = 2.778\, I\, (\Sigma C_i A_i)$$

where, C_i = Run off co-efficient of ith subcatchment and

A_i = Drainage area of ith subcatchment

(ii) Frequency Analysis / Statistical Method / Probability Method:

In this method, the predictions for the future flood are made on the basis of the avaiable records of the past floods. This method can be safely used to determine the maximum flood that is expected on a river with a given frequency, if sufficient past records are avaiable. Secondly, the prediction will be precise only if there has occured no appreciable change in the regime of the river during or after the period of records.

These probability methods are, however, unable to give precise results, where lesser number of past records are avaiable. For success of any probability method, sufficient past records, must, therefore, be made avaiable.

 # Chance Flood: If a flood of given magnitude occurs with an average frequency of 100 years, then there exists $\frac{1}{100} \times 100 = 1$ percent chance for this flood to occur and such a flood is generally called 1 percent chance Flood.

 # 5% Chance Flood: A flood having an average frequency of 20 years (i.e. flood which is likely to be equalled or exceeded once in 20 years) can be designated as $\frac{1}{20} \times 100 =$ 5% chance flood.

Probability of Occurance:

The probability of occurance or exceedance,

$$P = \frac{1}{T}$$ where, T is the reccurence interval

The probability of non-occurance,

$$q = 1 - P = \left(1 - \frac{1}{T}\right)$$

The binomial distribution of the event occuring r times in n successive years as,

$$P_{(r,n)} = {}^{n}C_{r} \cdot p^{r} \cdot q^{n-r}$$

$$= \frac{n!}{(n-r)!\, r!} \times p^{r} \times q^{n-r}$$

if r = 0, then, $P_{(0,n)} = \frac{n!}{(n-0)!\, 0!} \times p^{0} \times q^{n-0}$

$$\therefore P_{(0,n)} = q^{n}$$

Hence, The probability of an event not occuring at all in n successive years would be equal to q^n.

$$\therefore P_{0,n} = (1-p)^{n}$$

Also, The probability of an event occuring at least once in n successive years (R) would evidently be equal to $1 - q^n$. This probability is called Risk.

$$R = 1 - q^{n} = 1 - (1-p)^{n} = 1 - \left(1 - \frac{1}{T_r}\right)^{n}$$

Describe the method of estimating a T_p year flood using Gambel's Distribution.

This is one of the most widely employed distributions to describe the flood data. According to Gambel's theory of extreme events, The probability of occurrence of an event equal to or larger than a value X_0 is given by:

$$P(X \geq X_0) = 1 - e^{-e^{-y}} = \frac{1}{T_p}$$

where y is called the reduced variate given by,

$y = a(x - x_f)$ where, a and x_f are the parameters of the distribution.

When the sample size, say $n > 200$, they are given by,

$$a = \frac{1.28255}{S_x}$$

$$x_f = \bar{x} - 0.45005\, S_x$$

where, $\bar{x}$ = mean = $\frac{\Sigma x_i}{n}$

S_x = standard deviation = $\sqrt{\frac{\Sigma (x_i - \bar{x})^2}{(n-1)}}$

However, for small samples, the perimeters a and x_f are to be estimated using the following equations:

$$a = \frac{\sigma_n}{S_x}$$

$$x_f = \bar{x} - \frac{\bar{y}_n}{\sigma_n} \times S_x$$

where, σ_n and $\bar{y}_n$ are called the standard deviation and the mean of the reduced variate

Let y_T be the reduced variate corresponding to a return period of T_r,

$$P = \frac{1}{T_r}$$

$$\Rightarrow 1 - e^{-e^{-y_T}} = \frac{1}{T_r}$$

$$\Rightarrow e^{-e^{-y_T}} = 1 - \frac{1}{T_r}$$

$$\Rightarrow e^{-e^{-y_T}} = \frac{T_r - 1}{T_r}$$

$$\Rightarrow -e^{-y_T} = \ln\left(\frac{T_r - 1}{T_r}\right)$$

$$\Rightarrow e^{-y_T} = -\ln\left(\frac{T_r - 1}{T_r}\right)$$

$$\Rightarrow -y_T = \ln\left[-\ln\left(\frac{T_r - 1}{T_r}\right)\right]$$

$$\Rightarrow -y_T = -\ln\left[\ln\left(\frac{T_r - 1}{T_r}\right)\right]$$

$$\therefore y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$$

Let, x_T denote the magnitude of the flood with a return period of T_r years,

$$y_T = a(x_T - x_f)$$

$$\Rightarrow y_T = \frac{\sigma_n}{S_x}\left[x_T - \bar{x} + \frac{\bar{y}_n}{\sigma_n} \times S_x\right]$$

$$\Rightarrow \frac{y_T S_x}{\sigma_n} = x_T - \bar{x} + \left(\frac{\bar{y}_n}{\sigma_n}\right) \times S_x$$

$$\Rightarrow x_T = \bar{x} + \frac{S_x}{\sigma_n}(y_T - \bar{y}_n)$$

$$\therefore x_T = \bar{x} + K_T S_x \quad \text{where, } K = \text{frequency factor} = \frac{y_T - \bar{y}_n}{\sigma_n}$$

Write down the procedure to estimate the design flood for any return period using Gumbel's Distribution.

Procedure:

Step 1. From the given data on flood peaks for n years, the mean $\bar{x}$ and standard deviation S_x are computed using the following equations:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{and,} \quad S_x = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{(n-1)}}$$

Step 2. For the known sample size n, the values of $\bar{y}_n$ and σ_n are obtained from Gumble's Distribution Table.

Step 3. For the given return period T_r, the reduced variate y_T is calculated using,

$$y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$$

Step 4. With the values of $\bar{y}_n$ and σ_n obtained in step 2, and y_T obtained from step 3, the frequency factor K_T is calculated using,

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$$

Step 5. With the values of $\bar{x}$ and S_x obtained in step 1 and K_T obtained in step 4, the magnitude of the flood x_T is computed using,

$$x_T = \bar{x} + K_T \cdot S_x$$

Annual Series:

Annual series is that series, which include only the highest values that occur with in each year of period of record.

Partial Series:

Partial series is that series, which include all the values that occur with in the period of record.

Return period:

A return period, also known as a recurrence interval or repeat interval, is an average time or an estimated average time between two events such as earthquakes, floods etc.

Flood Management

What do you mean by Flood Management?

Flood Management: The term 'Flood Management' or 'Flood Control' is commonly used to denote all the measures adopted to reduce the damages of Life and property due to floods.

The total flood control is neither possible nor desirable.

Write down the factors that governing flood damages.

Factors governing flood damages:

Urban flood versus flood in rural areas should be treated differently.

Urban Flood:

1. Duration
2. Extent

Rural Flood:

1. Timing
2. Duration
3. Depth of Rainfall
4. Extent

What are the options for Flood Management?

Options for flood Management:

There are two options: (i) structural options or measures.

(ii) Non-structural options or measures.

What do you mean by: (i) structural measures.
(ii) Non-structural measures.

(i) Structural Measures: Structural measures are any physical construction to avoid or to reduce the possible impacts of flood hazards or the application of emerging techniques or engineering technologies to achieve the hazard resistance and resilience system.

The structural measures are:

(i) storage reservoir
(ii) Detention reservoir
(iii) Levees
(iv) Flood walls
(v) Flood ways
(vi) channel improvement
(vii) Water shed management

(ii) Non Structural Measures: Non-structural measures are the measures not involving any physical construction which use knowledge, practice to reduce the disaster reach and impacts, in particular through policies and laws, public awareness raising, training and education.

Non structural measures are :

(i) Flood plain zoning.

(ii) Emergency evacuation and relocation.

(iii) Flood forcasting and warning.

(iv) Flood insurance.

(v) Flood Proofing.

Write short Notes on:

- Structural Measures:

(i) Storage Reservoir: The purpose of a storage reservoir is to temporarily store a portion of flood water so that the flood peaks are flattened out. The reservoir may be idealy situated immediately near to the upstream so that River can discharge safely.

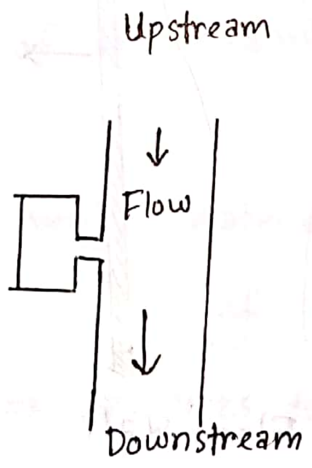

Fig. Storage Reservoir

(ii) Levees: Levees are the earthen banks constructed parallel to or along the course of river to confined it to a fixed course and limited cross sectional width. Continuous care should be taken to the earthen embankment.

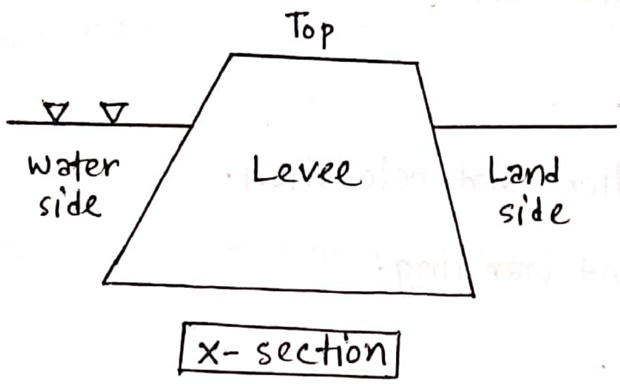

Fig. Levee

(iii) Flood wall: Flood walls are the concrete or masonry structures to confined the river in a manner similar to the levees.

Function: These are used to protect the important structures against flood.

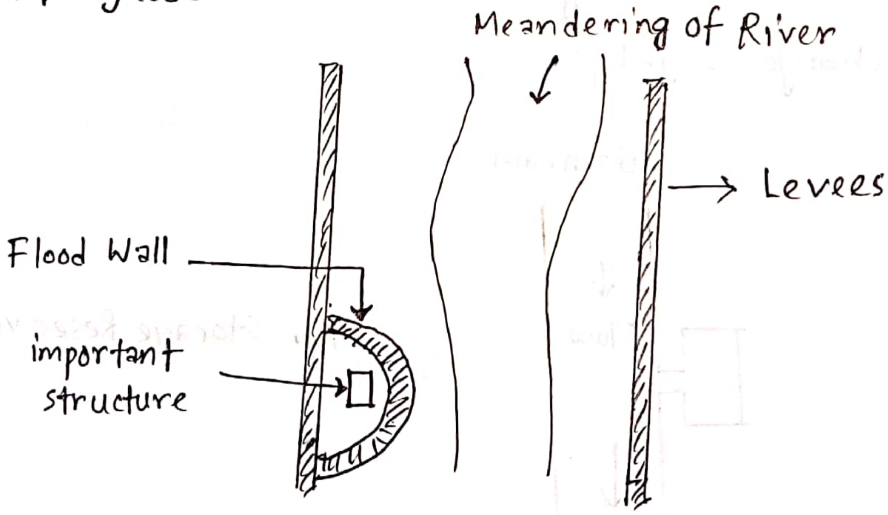

Fig. Flood wall

(iv) Flood ways: Flood ways can be natural or manmade channels into which a part of the flood will be diverted during high stages.
The location of flood ways is controlled essentially by the topography.

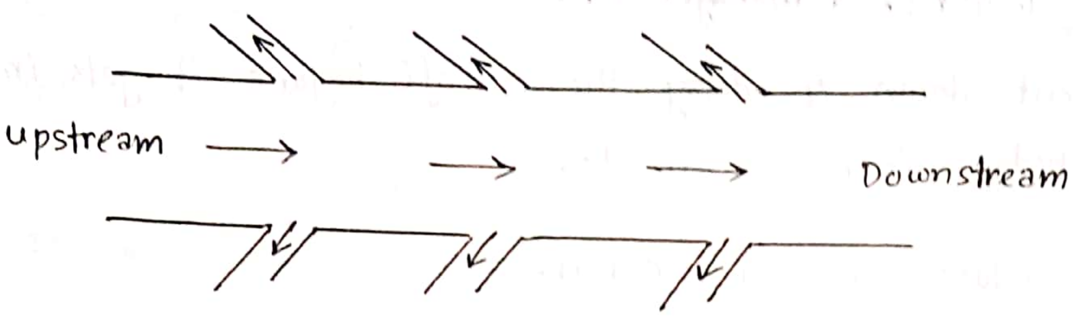

Fig. Flood ways

(v) Channel Improvement: For flood control, it is necessary to improve the channel. It can be done by -

(i) Deepening or Widening the channel.

(ii) Reduction of channel roughness:

(a) by removing the sand bar from the channel.

(b) by removing the broken trees.

(iii) Re-alignment of the channel. (applicable for short channel)

(vi) Water shed Management: Watershed management is a term used to describe the process of implementing the land use and water managment practices to protect and improve the quality of water and other natural resources with in a watershed by managing the use of those lands and water resources in a comparative manner.

Aims of watershed management:

(i) To cut down & delay the runoff before it gets into water body, river, ocean etc.

(ii) To reduce the soil erosion.

(iii) To modify the peak flow.

(iv) To enhance the ground water discharge.

Measures of watershed management:

(i) Surface Vegetation: It increase the infiltration capacity and reduce the surface runoff.

(ii) By providing check dam, contour terrace, contour bunds, contour trenching etc.

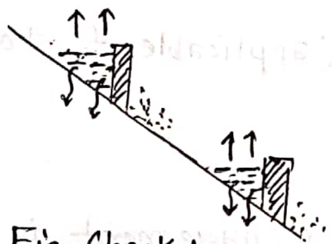

Fig. Check Dam

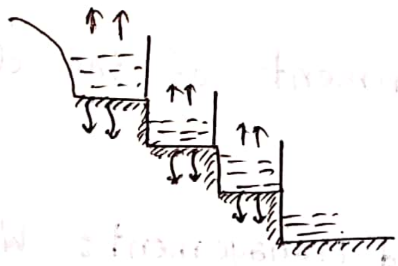

Fig. Contour Terrace

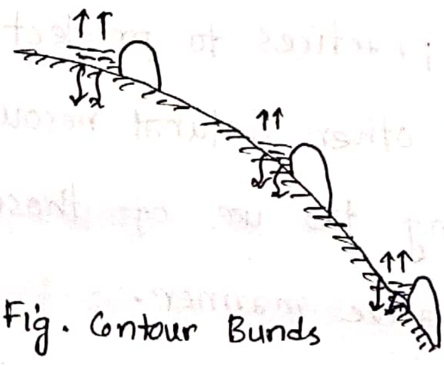

Fig. Contour Bunds

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Non Structural Measures:

(vii) **Flood Forecasting:** Flood Forecasting technique can be broadly classified into three categories:

(a) Short range forecast: 12-40 hrs before the flood hazard. It can be done by analyzing rainfall depth only.

(b) Medium range forecast: 2-5 days before the flood hazard. It can be done by analyzing both rainfall depth and run off data.

(c) Long range forcast: More than 5 days before the flood hazard. It is done by analyzing Meteorological data, Hydrological data, Raddar data, satellite data etc.

(viii) **Emergency Evaquation and Relocation:** Emergency evacuation is the urgent immediate escape of people away from an area that contains imminent threats, an ongoing threats or a hazard to lives and property.

The sequence of an evacuation: (i) Detection (ii) Decision (iii) Alarm (iv) Reaction (v) Movement to an area of refuge (vi) Transportation.

(ix) **Flood control Economies:** Flood control cost includes:

(i) capital cost involved in the construction of the structure.

(ii) Interest cost or cost expenditure.

(iii) Sinking fund and taxes.

(iv) Operational expenses and maintenance cost

Benefits of Flood control Economics:

(i) **Direct Benefits:**

(a) prevention of damages to the downstream structures.

(b) prevention of losses of life and property.

(c) Prevention of damages of crops.

(ii) **Indirect Benefits:**

(a) Money saved under insurance.

(b) Reduction in flood prone diseases.

(c) Higher yields from intensive cultivation of protected land.

(X) **Flood Proofing:** Flood proofing is defined as any structural or non structural measures that intended to prevent damages from flooding to a building.

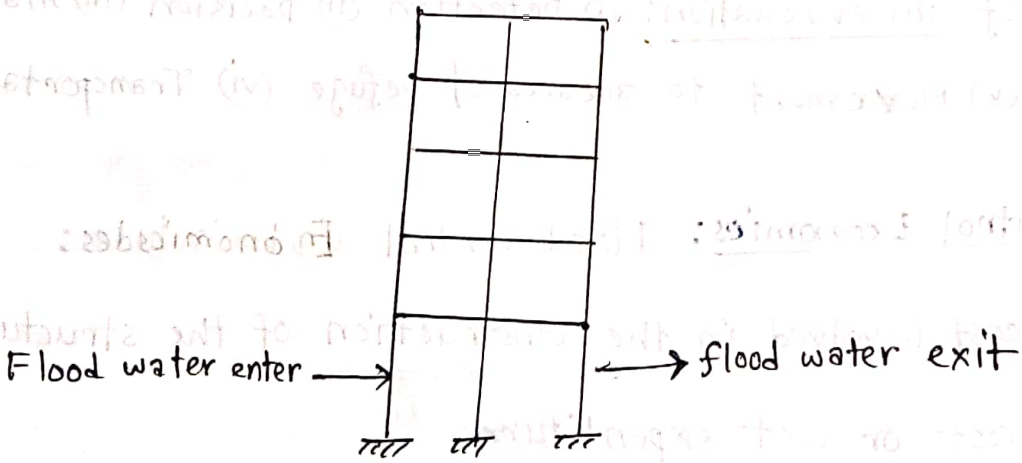


Fig. Flood Proofing Technique.

(xi) Flood Plain Zoning: Flood plain zooning means dividing the entire flood area into different zones and to restrict the occupancy of the flood plain to uses which will suffer little or no damage during flood.

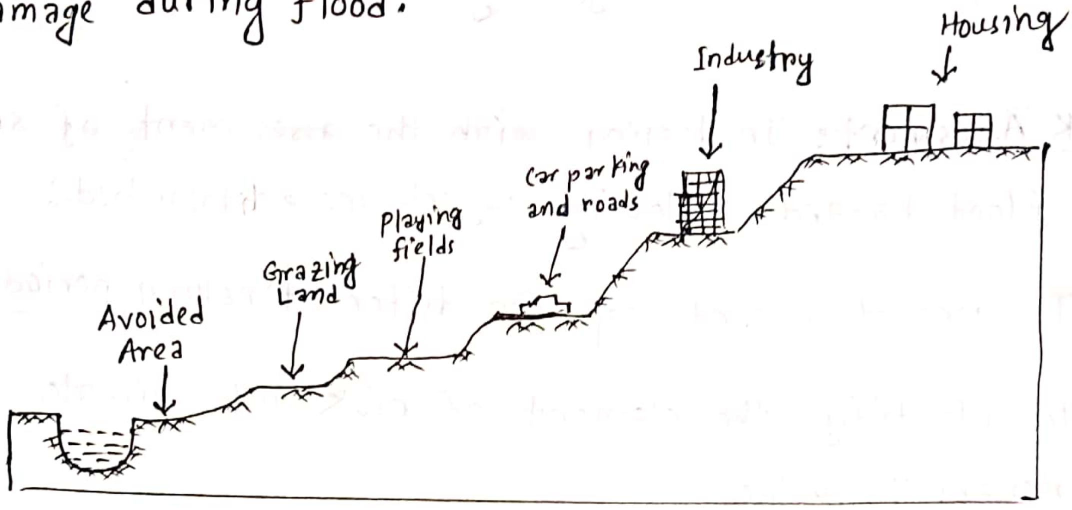


Fig. Flood Plain Zoning

(xii) Flood Plain Management: Flood plain management should minimize the costs of flood plain occupances which consists of:-

(a) The initial cost of development.

(b) The cost of flood protection.

(c) The residual flood damage.

(d) cost of relief and rehabilization.

The various tools of flood plain management are as follows:

(i) Flood hazard surveys,

(ii) Flood plain zoning.

(iii) Flood proofing.

(iv) Flood insurance.

Flood Risk & Vulnerability Analysis

Risk:
Risk is defined as the expected losses of lives, person injured, property damaged and other economic activity that distrupted due to particular hazard for a given area and reference period.

Risk Assessment:
In dealing with the assessment of seismic and flood hazards following objects are established:

(i) To generate hazard map for different return period.

(ii) To identify the element of risk and estimate the vulnerability value.

(iii) To calculate the damages and risk due to particular hazards.

Vulnerability:
Vulnerability is the inability to resist a hazard or to respond when a disaster occurs. For instance, people who live on the plain are more vulnerable to floods than people who live higher up. In actual fact, vulnerability depends on several factors:

(i) People Age

(ii) Stage of heath

(iii) local environment

(iv) sanitary conditions, the quality and state of local buildings, their location with respect to any hazard.

Characterestics of Vulneribility:

(i) Vulnerability is multi-dimensional such as physical, economical, environmental, social etc.

(ii) Vulnerability is dynamic i.e. changes over time.

(iii) Vulnerability is scale dependent i.e. vulnerability can be expressed at different scale from human to household to community to country resolution.

Sediment Transport

Sediment Transport:

Whenever water flows in a channel (natural or artificial), it tries to scour its surface. Silt or gravel or even larger boulders are detached from the bed or sides of the channel. These detached particles are swept down stream by moving water. This phenomenon is known as Sediment Transport.

Describe the importance of Sediment Transport in designing irrigation canals.

Importance of Sediment Transport:

1. The phenomenon of sediment transport causes large scale scouring and siltation of irrigation canals, thereby, increasing their maintenance.

2. The design and execution of a flood control scheme is chiefly governed by the peak flood levels, which, in turn, depend upon the scour and deposition of sediment.

3. Silting of reservoirs and rivers is another important aspect of sediment transport. The storage capacity of the reservoir is reduced by its silting, thereby reducing its use and life.

Sediment Load:

The sediment in a canal is a burden to be borne by the flowing water, and is, therefore, designated as sediment load.

Types of Sediment Load: Sediment load can be divided into two types: (i) Bed Load.

(ii) Suspended Load.

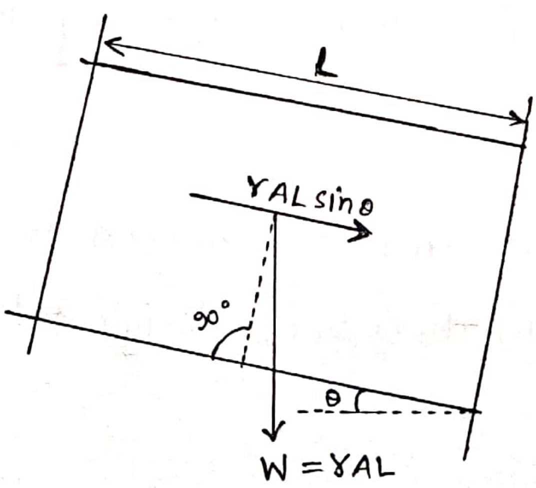
(i) **Bed Load:** Bed load is that in which the sediment moves along the bed with occasional jumps in to the channel.

(ii) **Suspended Load:** Suspended load is the one in which the material is maintained in suspension due to turbulance of the flowing water.

Mechanics of Sediment Transport:

In the study of mechanics of sediment transport, it is assumed that the soil is incoherent or in other words no cohesive forces between the particles $(c = 0)$ such as in sand or gravels.

The basic mechanism behind the phenemenon of sediment transport is the drag force exerted by water or fluid in the direction of flow on the channel bed. This force, which is nothing but a pull of water on the wetted area, is known as Tractive Force or Shear force or Drag force.



Let us consider a channel of length 'L' and cross sectional Area 'A'.

The volume of water stored in the channel reach $= AL$

weight of water stored $= \gamma_w AL$ where, γ_w = unit wt. of water $= \rho_w g$

ρ_w = density of water

Horizontal component of this wt. $= \gamma_w AL \sin\theta = \gamma_w ALS$ [$\because$ θ is very Small Hence, $\sin\theta = \tan\theta = S$]

where, S = Slope of the channel bed

The horizontal force exerted by water is nothing but tractive force.

Average Tractive force per unit of wetted area = unit tractive force

$$\text{Unit Tractive force}, \tau_o = \frac{\gamma_w ALS}{\text{Wetted Area}}$$

$$= \frac{\gamma_w ALS}{\text{Wetted Perimeter} \times \text{Length}}$$

$$= \frac{\gamma_w ALS}{P \cdot L}$$

$$= \gamma_w \left(\frac{A}{P}\right) S$$

$$\therefore \tau_o = \gamma_w RS \quad \left(\because R = \frac{A}{P}\right)$$

where,

R = Hydraulic mean depth of Channel

S = Channel bed slope

γ_w = unit wt. of water

P = wetted perimeter

Average Unit tractive force is also called Shear stress.

Critical condition or Threshold point:

As the flow velocity increases steadily, a stage is reached when the shear force exerted by the flowing water on the bed particles will just exceed the force opposing their movement. At this stage, a few particles on the bed will just start moving intermittently. This condition is called the incipient motion condition or simply critical condition or the threshold point.

Design of Irrigation Channel
Part - (I)

Canal: A canal is an artificial channel, generally trapezoidal in shape constructed on the ground to carry water to the fields either from the river or from a tank or reservoir.

Classification of canal:
Based on the type of boundary surface, canals may be of the following types:

(i) Rigid boundary canals.

(ii) Mobile boundary canals.

(iii) Alluvial canals.

(iv) Non-Alluvial canals.

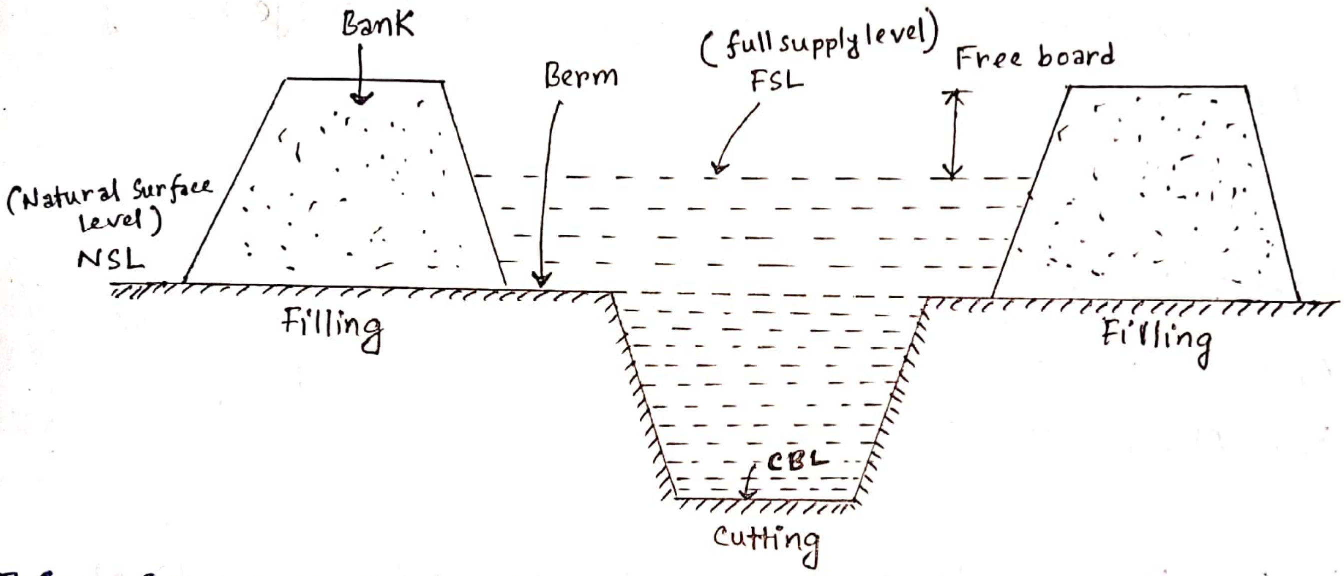
(i) **Rigid Boundary Canals:** The channels whose boundaries are fixed and rigid, are called Rigid Boundary canals/channels. In these channels, the amount of silt entering and leaving is almost same.

(ii) **Mobile Boundary Canals:** When the channels are constructed in erodible strata, their boundary tends to change continuously with the flow of water, such channels are called Mobile Boundary canals/channels.

(iii) **Alluvial Canals:** The soil which is formed by the transportation and deposition of silt by the agency of water over a course time, is called Alluvial soil. The canals which are excavated in such soils, are called Alluvial canals.

(iv) Non-Alluvial soil: The soil which is formed by the disintegration of rock formation is called Non-Alluvial soil. The canals passing through such soils have no tendency to shift their courses, are called Non-Alluvial canals.

Cross-section of an irrigation channel:



Some Important Short notes:

Berm: Berm is a horizontal distance left at the ground level between the inner toe at the bank and top edge of the cutting.

purpose of providing Berm:

1. The silt deposited on the sides is very fine and impervious. It, therefore, serves as a good lining for reducing losses, leakage and then consequent breaches.

2. It provides additional strength to the banks and gives the protection against erosion and breaches.

3. The possibility of breaches get reduced because the saturation line comes more in the body of the embankment.

4. It protects the bank from erosion due to wave action.

5. Berms can be used as borrow pit for excavating soil to be used for filling.

6. They provide a scope for future widening of a channel or canal.

Free board: Free board is the vertical distance between the FSL and top of the bank.

Free board in a channel is governed by the consideration of size of the canal, its location, water surface fluctuation etc. The main purpose of providing free board is navigation.

Bank: Bank generally refers to the land alongside a body of water.

The main purpose of providing bank is to detain or retain water to use. It is also used as means of communication and inspection purpose.

Borrow pites:

When the earthwork in filling exceeds the earth work in excavation, the excess earth has to be brought from somewhere else, The pits which are dug for bringing earth are known as borrow pit. If such pits are excavated outside the channel they are known as external borrow pits, if within the channel, they are known as internal borrow pits.

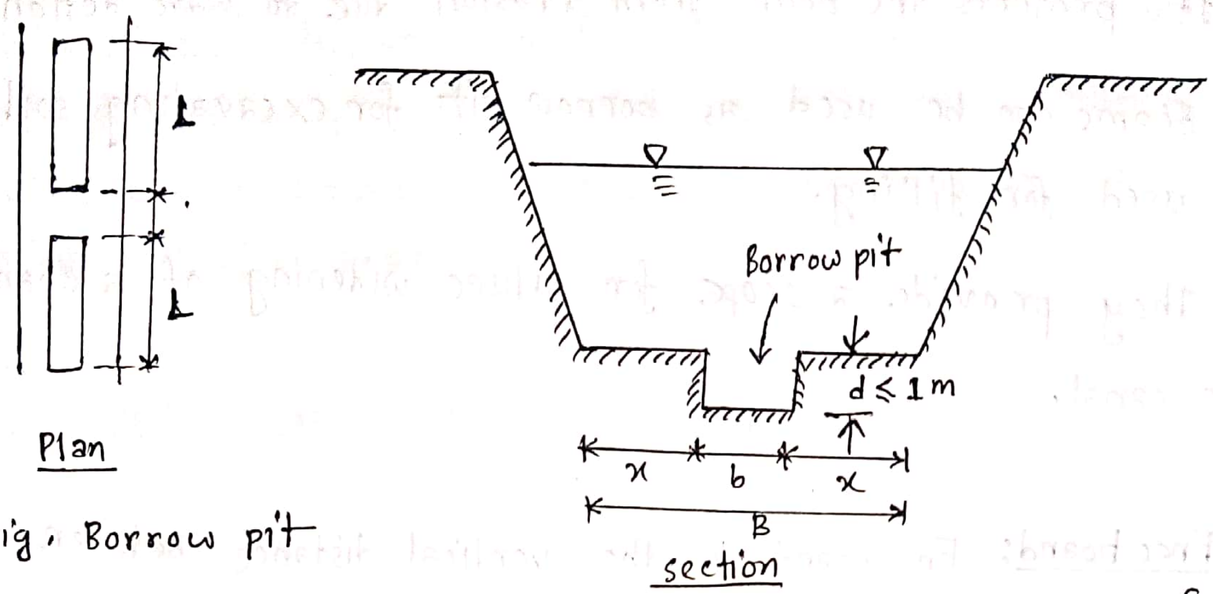


Fig. Borrow pit

x should be more than 5m for small channel and 10m for large channel.

Spoil Bank:
When the earth work in excavation exceeds the earth work in filling even after providing the maximum width of the bank embankment. The extra earth should be deposited economically.

To dispose of this earth by mechanical transport may become very costly and economical mode of its disposal may be found in the form of collecting this soil on the edge of the bank embankment itself. The soil is therefore deposited in form of heaves is termed as spoil Bank.

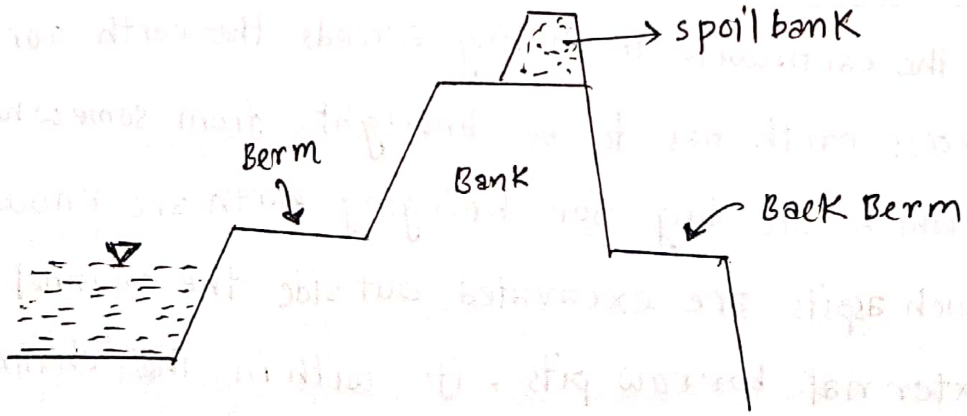


Fig. Spoil Bank

Back Berm / Counter Berm / Pusta:

After providing sufficient section for bank embankment, the saturation gradient line may cut the downstream end of the bank. In such case, the saturation line should always be kept covered by 0.5 m with the help of counter berm, or back berm as shown in figure:

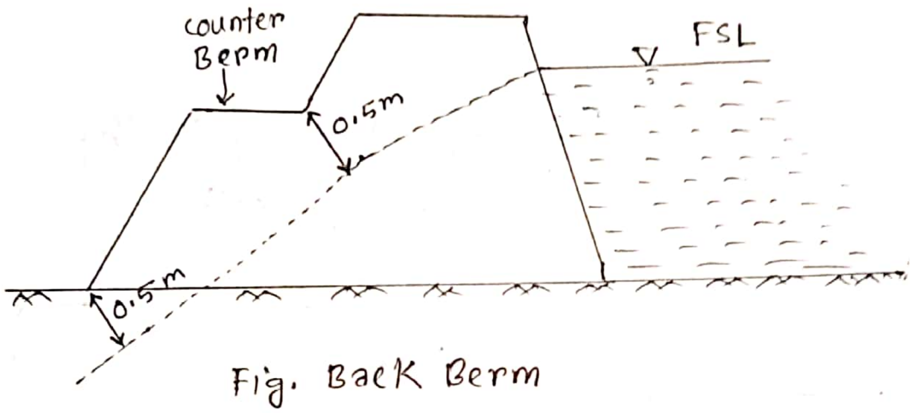


Fig. Back Berm

Dowla and Service Road:

Service roads are provided on canals for inspection purposes and may simultaneously serve as the means of communication in remote area.

A dowla is provided on the side of the inspection road. It is provided as a measure of safety for driving on the service road. It also prevent erosion of the inner bank slope due to rain. Top width of dowla is kept from 0.3-0.6 m and it is about 0.3 m high.

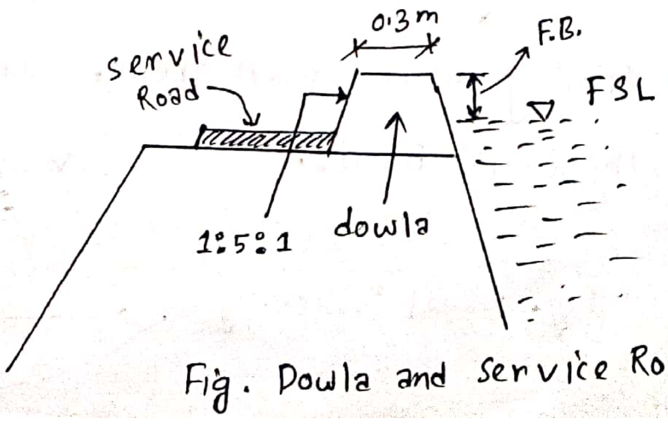


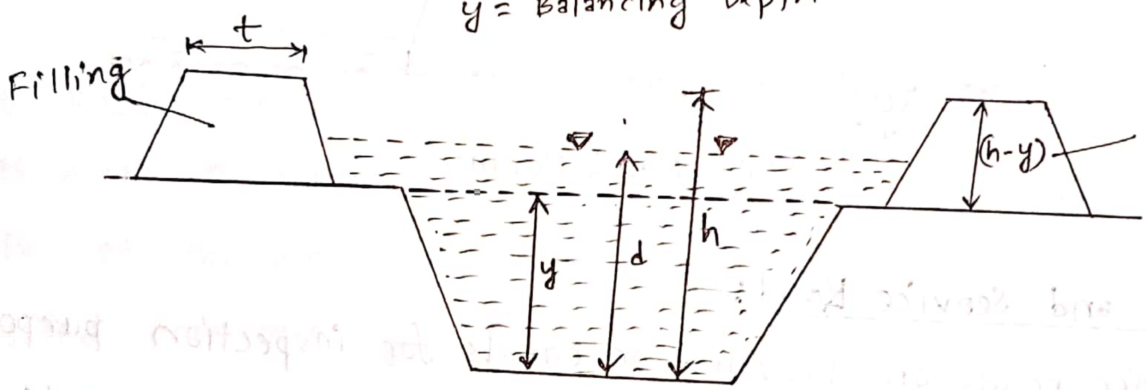
Fig. Dowla and Service Road.

Balancing Depth: For a channel section, if the depth of cutting is such that the quantity of excavation or cutting is equal to the earth work in filling, required for making bank, then the depth of cutting is known as Balancing Depth.

For a given cross-section, there is only one depth of cutting for which the cutting and filling will equal.

Figure: Balancing Depth

y = Balancing Depth



Reasons for channel Breaching:

Canal Breach or tearing of the banks takes place when canal is in filling. The reasons for channel Breaching are:

1. Breaching due to defective design and construction of the bank.
2. Breaching due to exposure of saturation gradient line.
3. Breaching due to rush of water through rate holes.
4. Piping near downstream toe may ultimately cause subsidence of the canal banks.

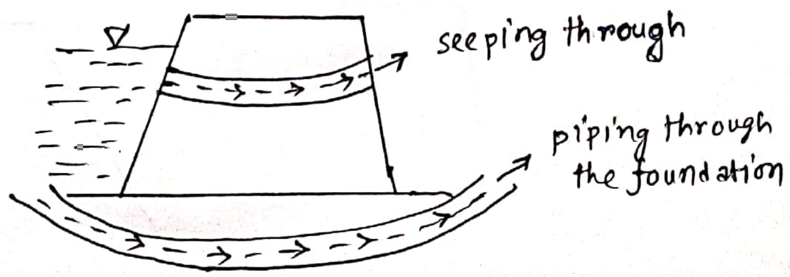


Fig. Canal Breaching

Design of Irrigation Channel

Part - II

Regime Channel or Stable Channel:

If the velocity of flow in the channel is more ; the bed and the banks are likely to be eroded and similarly, if the velocity is less , the silt which was formerly carried in suspension is likely to be dropped.

Therefore, while thinking to design a properly functioning channel, one must think to design such channel in which neither silting nor scouring takes place. Such channels are known as stable channels or Regime Channel.

Methods of designing irrigation channel:

1. Kennedy's Method.
2. Lacey's Method.
3. Graphical Method.

Basis for designing Regime Channel:

The basis for designing such an ideal, non-siting, non-scouring channel is that,

whatever silt has entered the channel at his head is kept in suspension, so that it does not settle down and deposite at any point of the channel. Moreover, the velocity of the water should be such that it does not produce local silt by erosion of channel bed and slopes.

Discuss the salient features of Kennedy's theory for designing of irrigation channel.

Kennedy's state of silt theory:

Kennedy stated that, The silt carried by water flowing in a channel is kept in suspension solely by the vertical component of eddies which are generated over the full width of the channel and rise up to the surface. These eddies are generated due to the friction of the flowing water with the channel surface.

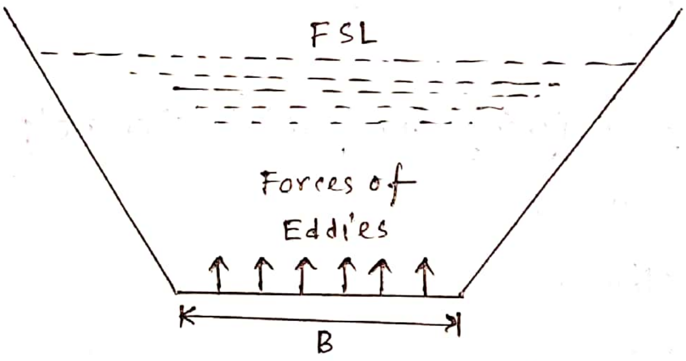


Fig. Kennedy's Theory

The vertical component of these eddies try to move the sediment up, while the weight of the sediment tries to bring it down, thus keeping the sediment in suspension.

Therefore, The silt supporting power of a channel /canal is proportional to the width of stream and not to its total wetted perimeter.

Based on this concept, Kennedy defined the critical velocity (V_0) in a channel as the mean velocity (across the section) which will just keep the channel free from silting or scouring, and related it to the depth of flow by the equation,

$$V_0 = C_1 \cdot y^{C_2}$$

where, y = depth of the channel

C_1, C_2 = co. depending upon silt charge/load.

$C_1 = 0.55$ & $C_2 = 0.64$ (in SI Unit)

Therefore, $V_0 = 0.55\, y^{0.64}$. Kennedy found this formula for the upper Bari Doab canal system. Hence it could not have been applicable in to other canals system due to the variation in the type of soil (silt) at various canal sites.

Kennedy realised that the critical velocity was affected by the grade of the silt, and in order to account for the effect of the silt grade, He introduced a factor 'm' called critical velocity factor (C.V.R)

Thus, the equation for critical velocity was modified as:

$$V_0 = 0.55\, m y^{0.64} \quad \text{where, } m = \text{C.V.R}$$

For determining the mean velocity of flow in the channel, Kennedy used Kutter's equation which is as follows:

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

where, n = Kutter's rugosity Coefficient

V = Mean velocity of flow, (m/s)

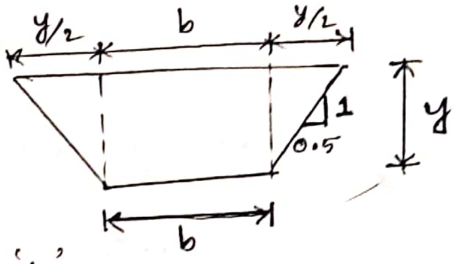
R = Hydraulic mean radius, (m)

S = Bed slope.

Describe the design procedure of regime channel by Kennedy's theory.

Case 1: When Q, n, m and S are known

Procedure:



1. Assume a value of y.

2. Calculate V_o from $V_o = 0.55\, m\, y^{0.64}$
3. Find A from, $A = \frac{Q}{V_o}$
4. Knowing y and A, Find bed width 'b' for a trapezoidal channel (side slope is $\frac{1}{2}H : 1V$)

   $A = by + \frac{y^2}{2}$

5. calculate perimeter and hydraulic mean depth.

   $P = b + y\sqrt{5}$ and, $R = \frac{A}{P}$

6. Calculate the mean velocity by kutter equation,

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

Case-2: when Q, n, m and $b/y = x$ ratio are known.

Procedure:

1. calculate A in terms of y. $A = by + \frac{y^2}{2} = y^2(x + 0.5)$

2. We know that, $V_o = 0.55\, m\, y^{0.64}$

   Find the depth 'y' from $Q = AV_o$

3. calculate width of the channel and Hydraulic mean depth

   $b = yx$ and $R = \frac{A}{P}$ where, $P = b + y\sqrt{5}$

4. Determine v from Kennedy's equation, $v = 0.55\, m\, y^{0.64}$

5. Determine slope from Kutter's equation by trial and error.

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Drawbacks / short comings of Kennedy's Theory:

1. Kennedy's theory is applicable for average regime channel only.

2. Silt grade and silt charge were not clearly defined.

3. Kennedy used Kutter's equation for the determination of mean velocity. as such the limitations of Kutter's equation is also incorporated.

4. Kennedy did not give any equation for the bed slope.

5. Shape of section i.e b/y is not known in advance.

6. The method involves trial and error.

Lacey's Regime Theory or Lacey's Silt Theory:

Lacey considered that The silt is kept in suspension by the vertical component of eddies generated at all points of forces normal to the wetted perimeter of the channel.

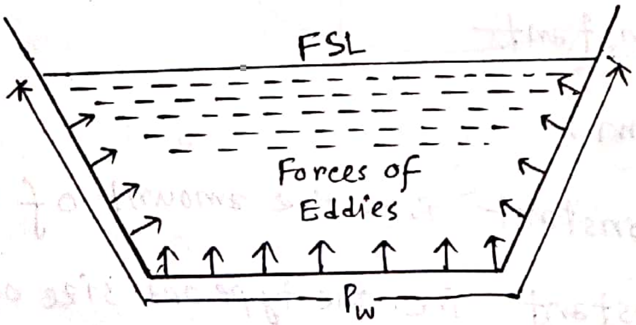

Fig. Lacey's Silt Theory

According to Kennedy's theory, a channel is said to be regime, if there is neither silting nor scouring in the channel takes place. But Lacey came out with the statement that, even a channel showing 'no silting, no scouring' may not be in regime condition.

Therfore, He classified regime channels into three regime conditions:

(i) True Regime.

(ii) Initial Regime.

(iii) Final Regime.

① **True Regime:** A channel shall be in True regime, if there is neither silting nor scouring takes place. For this condition to be satisfied, the silt load entering the channel must be carried through, by the channel section.

Conditions of True Regime: An artificially constructed channel having a certain fixed section and a certain fixed slope can behave in True regime only if the following conditions are satisfied:

(i) Discharge is constant.

(ii) Flow is uniform.

(iii) Silt charge is constant i.e. the amount of silt is constant.

(iv) Silt grade is constant i.e. the type and size of silt is always the same.

(v) channel is flowing through a material which can be scoured as easily as it can be deposited (such soil is known as incoherent Alluvium) and is of the same grade as transported.

(ii) **Initial Regime**: When only the bed slope of a channel varies due to dropping of silt and its cross section or wetted perimeter remains unaffected, even then the channel can exhibit 'no silting no scouring' properties, called Initial regime.

(iii) **Final Regime**: If there is no resistance from the sides, and all the variable such as perimeter, depth, slope etc. are equally free to vary and finally get adjusted according to discharge and silt grade, then channel is said to have achieved permanent stability, called Final regime.

In such a channel, The coarser the silt, the flatter is the semi-ellipse. The finer the silt, the more nearly the section attains a semi-circle.

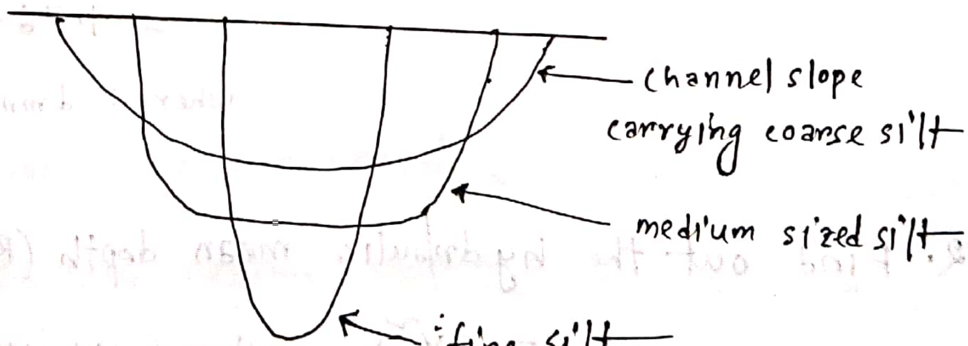

Fig. Characterestics of Final Regime

Difference between Initial Regime and Final Regime:

Initial Regime	Final Regime
1. Bed slope varies but cross section or wetted perimeter remains unaffected.	1. All the variable such as depth perimeter, slope etc are equally free to vary
2. sides of channels are subjected to a lateral restraint.	2. There is no resistance from the sides of channel.
3. These channels may be grassed or be of clayey soil.	3. These channels may be of silty soil.
4. Regime theory is not applicable to such channels.	4. Regime theory is applicable

Design procedure of Regime channel by Lacey's Theory:

1. calculate the velocity from the equation,

$$V = \left[\frac{Qf^2}{140}\right]^{\frac{1}{6}}$$

where,

Q = Discharge is in cumec

V = velocity is in m/sec.

f = silt factor

$= 1.76\sqrt{d_{mm}}$

where; d_{mm} = Average particle size in mm.

2. Find out the hydraulic mean depth (R) from the equation,

$$R = \frac{5}{2}\left(\frac{V^2}{f}\right)$$

where, V = velocity is in m/sec.

R = Hydraulic mean depth in m.

3. Compute area of channel section, $A = \frac{Q}{V}$

4. Compute the wetted perimeter, $P = 4.75\sqrt{Q}$

5. Knowing these values, the channel section is known, ...and finally the bed slope S is determined by the equation,

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

where, f = silt factor
Q = Discharge in cumec

Drawback's of Lacey's theory:

1. The concept of true regime is only theoretical and can not be achieved practically.

2. The silt grade and silt charge is not clearly defined.

3. The concentration of silt is not taken in to account.

4. Effect of silt attrition which decrease the silt size is ignored.

5. Silt factor 'f' excludes from the consideration of any fine particle.

6. Lacey's Equations are empirical.

7. The charactereshics of regime channel may not be same for all the cases.

8. Lacey's semi-eliptical shape is not practical.

Difference between Kennedy's Theory and Lacey's Theory:

Kennedy's Theory	Lacey's Theory
1. Kennedy assumed that silt is kept in suspension by eddies generated only at the bed.	1. Lacey advocated that such eddies generated throughout the perimeter of the channel.
2. Kennedy considered average regime channel and 'y' as a variable for critical velocity.	2. Lacey considered True regime condition and 'R' as a variable for regime velocity.
3. Kennedy considered critical velocity ratio 'm' according to silt condition.	3. But Lacey incorporated silt factor, $f = 1.76\sqrt{d_{mm}}$
4. Kennedy used Kutter's equation.	4. Whereas Lacey gave his own equation to determine regime flow.
5. Design of channel is not unique.	5. Design is unique.
6. Kennedy considered a trapezoidal channel section	6. On the other hand, Lacey considered a cup-shaped section (semi-ellipse)
7. Tedius and involves trial and error method.	7. Simple and straight-forward
8. Kennedy did not fix regime slope for his channel	8. Lacey fixed the regime slope
9. Applicable only to irrigation channel.	9. Applied to natural channels

Reddy

Rational Method

Example- 14.1

An engineer is required to design a drainage system for an air port with an area of 2.5 Km^2 for 50 year return period. The 50 year ~~return~~ rainfall intensity in that region is given by -

$$I = \frac{35}{(t+10)^{0.38}}$$

where I is intensity in cm/h and t is the duration in minutes. If the concentration time for the area is eliminated as 50 minutes for what discharge must be design the system?

* একক খেয়াল রাখতে হবে

Solution: Given, $t_c = 50$ min

$\therefore$ Intensity of rainfall, $I = \frac{35}{(50+10)^{0.38}} = 7.385$ cm/hr

Since the air port is fully paved, it may be considered as impervious.

Hence, run-off coefficient, $C = 1$

Therefore, $Q = 2.778\ CIA$

$= 2.778 \times 1 \times 7.385 \times 2.5$

$= 51.29\ m^3/sec.$

$\therefore$ The engineer must design the drainage system for a discharge of $51.29\ m^3/sec.$

(Ans.)

* [same type] - Excercise - 14.16

Example- 14.2

A small watershed consists of 1.5 Km^2 of cultivated area ($c=0.20$), 2.5 Km^2 under forest ($C=0.10$) and 1.0 Km^2 under grass ($c=0.35$). There is a fall of 22m in a water course length of 1.8 Km. The intensity - frequency - duration relation for the area may be taken as -

$$I = \frac{80\,T_r^{0.2}}{(t+13)^{0.46}}$$

where I is in mm/h, T_r is in years and t is in minutes.

Assume a runoff co-efficient of 0.35.

Solution: Given,

$L = 1150$ m

$S = 0.004$.

We know, $t_c = 0.0195\, L^{0.77}\, S^{-0.385}$

$= 0.0195 \times (1150)^{0.77} \times (0.004)^{-0.385}$

$= 37.15$ minutes.

Given,

$$I = \frac{1000\, T_r^{0.2}}{(t+20)^{0.7}}$$

$$= \frac{1000 \times 25^{0.2}}{(37.15+20)^{0.7}}$$

$= 112.12$ mm/hr.

$= 11.2$ cm/hr

Given, $A = 185$ hectares $= \frac{185}{100}$ $Km^2 = 1.85\, Km^2$ [$\because$ $1\, Km^2 = 100$ hectares]

Now, $Q = 2.778 \times 0.35 \times 11.2 \times 1.85$

$= 20.146\ m^3/sec.$

(Ans.)

* Same Type — Exercise - 14.17

S.K. Garg

Example - 7.55:

What return period you would adopt the design of a culvert on a drain if you are allowed to accept only 5% risk of flooding in the 25 years of expected life of the culvert?

Solution: Given, $R = 0.05$

$n = 25$ years,

we know, $R = 1 - (1-P)^n$

$\Rightarrow 0.05 = 1 - (1-P)^{25}$

$\Rightarrow (1-P)^{25} = 0.95$

$\Rightarrow 1 - P = (0.95)^{\frac{1}{25}}$

$\Rightarrow P = 1 - (0.95)^{\frac{1}{25}}$

$\therefore P = 0.00205$

$\therefore$ Return period, $T = \frac{1}{0.00205} = 487.8$ years.

say, 488 years.

(Ans)

Example - 7.54:

On the basis of isopluvial maps, the 50 year 24 hr maximum rainfall at Bangalore is found to be 16 cm. Determine the probability of 24 hr rainfall of magnitude equal to or greater than 16 cm occuring at Bangalore:

(a) at least once in 10 successive years.

(b) two times in 10 successive years.

(c) once in 10 successive years.

Solution: Given, $T = 50$ years.

Probability of Occurance, $P = \frac{1}{T} = \frac{1}{50} = 0.02$

(a) Probability of occuring at least once = Risk

$$\therefore R = 1 - (1-P)^n$$

$$R = 1 - (1-0.02)^{10} = (1 - 0.817) = 0.183$$

(Ans)

(b) Probability of occurrence twice in 10 years,

We know, $$P_{r,n} = \frac{n!}{(n-r)!\ r!} \times p^r . q^{n-r}$$

$$\therefore P_{2,10} = \frac{10!}{(10-2)!\ 2!} \times (0.02)^2 \times (1-0.02)^{10-2}$$

$$\therefore P_{2,10} = 0.0153$$ (Ans.)

(c) probability of occurrence once in 10 years,

$$P_{1,10} = \frac{10!}{(10-1)!\ 1!} \times (0.02)^1 \times (0.98)^9 = 0.167$$

(Ans.)

Example - 7.53:

A flood of a certain magnitude has a return period of 25 years (a) what is its probability of exceedance? (b) What is the probability that this flood may occur in next 12 years.

Solution: Given, T = 25 years.

(a) probability of exceedance, $P = \frac{1}{T} = \frac{1}{25} = 0.04$

(Ans.)

(b) probability of occuring at least once = Risk

$$\therefore R = 1-(1-P)^n$$

$$= 1-(1-0.04)^{12}$$

$$= 0.387$$

(Ans.)

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Example - 14.8:

A coffer dam is designed for 25 year flood and constructed. If you takes 5 years to complete the construction of main dam, what is the risk that the coffer dam may fail before the end of construction period? What return period in the design of coffer dam would have reduced the risk 10%.

Solution: Given, T = 25 year, n = 5 years

Risk, $R = 1-(1-\frac{1}{T})^n = 1-(1-\frac{1}{25})^5 = 0.1846 = 18.46\%$

if the risk reduced to 10%

$\therefore 0.1 = 1-(1-\frac{1}{T})^5$

$\Rightarrow (1-\frac{1}{T})^5 = 0.9$

$\Rightarrow 1-\frac{1}{T} = (0.9)^{\frac{1}{5}}$

$\Rightarrow \frac{1}{T} = 1-(0.9)^{\frac{1}{5}}$

$\therefore T = 47.96$ years say, 48 years.

(Ans.)

Exercise: 14.27

What is the probability for 200 year flood to be exceeded in any of the next 20 years?

Solution:

Probability of occuring at least once = Risk

$\therefore R = 1-(1-\frac{1}{T})^n$ Here, T = 200 year, n = 20 year

$= 1-(1-\frac{1}{200})^{20}$

$= 0.0954$

$\therefore R = 9.54\%$

(Ans.)

Gumble's Distribution

Reddy

Example - 14.6 :

From the analysis of avaiable data on annual flood peaks of a small stream for a period of 35 years, the 50 year and 100 year flood have been estimated to be 660 m³/sec. and 740 m³/s using Gumbel's method. Estimate the 200 year food for the stream. Given that, $\bar{y}_n = 0.54034$ and $\sigma_n = 1.12847$

Solution:

Using Gumbel's method,

$$y_n = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$$

$$\therefore y_{50} = -\ln\left[\ln\left(\frac{50}{50-1}\right)\right] = 3.90194$$

$$\therefore y_{100} = -\ln\left[\ln\left(\frac{100}{100-1}\right)\right] = 4.60015$$

And,

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$$

$$\therefore K_{50} = \frac{y_{50} - \bar{y}_n}{\sigma_n} = \frac{3.90194 - 0.54034}{1.12847} = 2.9789$$

$$\therefore K_{100} = \frac{y_{100} - \bar{y}_n}{\sigma_n} = \frac{4.60015 - 0.54034}{1.12847} = 3.5976$$

We know,

$$x_T = \bar{x} + K_T \cdot S_x$$

$$\therefore x_{50} = \bar{x} + K_{50} \cdot S_x$$

$$\Rightarrow 600 = \bar{x} + 2.9789 \times S_x \quad \text{......(1)}$$

Again, $x_{100} = \bar{x} + K_{100} \times S_x$

$\Rightarrow 740 = \bar{x} + 3.5976 \times S_x$ ...... (II)

From equation (I) & (II) we obtain,

$\bar{x} = 274.83 \ m^3/sec.$

$S_x = 129.3 \ m^3/sec.$

Now, For 200 year flood,

$$y_{200} = -\ln\left[\ln\left(\frac{200}{200-1}\right)\right] = 5.29581$$

$$K_{200} = \frac{5.29581 - 0.54034}{1.12847} = 4.2141$$

$\therefore x_{200} = \bar{x} + K_{200} S_x$

$= 274.83 + 129.3 \times 4.2141$

$\Rightarrow x_{200} = 819.71 \ m^3/sec. \simeq 820 \ m^3/sec.$

Thus, $x_{200} = 820 \ m^3/sec.$

(Ans.)

S.K. Garg

Example – 7.58: *** [$\bar{y}_n$ & σ_n দেয়া নেই]

For a river, the estimated flood peaks for two return periods by use of Gumbel's method, are given below;

Return Period (years)	Peak flood ($m^3/sec.$)
100	485
50	445

What flood discharge in this river will have a return period of 1000 years.

Solution:

Using Gumbel's method,

$$y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$$

$$\therefore y_{100} = -\ln\left[\ln\left(\frac{100}{100-1}\right)\right] = 4.60015$$

and, $$y_{50} = -\ln\left[\ln\left(\frac{50}{50-1}\right)\right] = 3.90194$$

We know, $$x_T = \bar{x} + K_T S_x = \bar{x} + \left(\frac{y_T - \bar{y}_n}{\sigma_n}\right) \times S_x$$

$$\therefore x_{100} = \bar{x} + (y_{100} - \bar{y}_n) \times \frac{S_x}{\sigma_n} = 485 \quad \text{......(i)}$$

and, $$x_{50} = \bar{x} + (y_{50} - \bar{y}_n) \times \frac{S_x}{\sigma_n} = 445 \quad \text{......(ii)}$$

From [eq^n (i) – eq^n (ii)], we obtain,

$$(y_{100} - y_{50}) \times \frac{S_x}{\sigma_n} = 40 \quad \text{......(iii)}$$

$$\Rightarrow (4.60015 - 3.90194) \times \frac{S_x}{\sigma_n} = 40 \quad \Rightarrow \frac{S_x}{\sigma_n} = 57.2894$$

Now, For 1000 years Return period,

$$y_{1000} = -\ln\left[\ln\left(\frac{1000}{999}\right)\right] = 6.90726$$

Similar to eqn (iii),

For 1000 years and for 100 years, we have,

$$(y_{1000} - y_{100}) \times \frac{S_x}{\sigma_n} = X_{1000} - X_{100}$$

$$\Rightarrow (6.90726 - 4.60015) \times 57.2894 = X_{1000} - 485$$

$$\therefore X_{1000} = 617.17 \text{ m}^3/\text{sec.}$$

(Ans.)

Mixed Problem

Reddi

Example - 14.9: **

The analysis of a 30 year flood data at a point on a river yielded $\bar{x} = 1200$ m³/s and $S_x = 650$ m³/s. For what discharge would you design the structure at this point to provide 95% assurance that the structure would not fail in the next 50 years? Given that, $\sigma_n = 1.11238$ and $\bar{y}_n = 0.53622$

Solution: Given,
Assurance $= 95\%$

$\therefore$ Risk $= (100 - 95) = 5\% = 0.05$

we know, $$R = 1 - \left(1 - \frac{1}{T_r}\right)^n$$

$$\Rightarrow 0.05 = 1 - \left(1 - \frac{1}{T_r}\right)^{50}$$

$$\Rightarrow \left(1-\frac{1}{T_r}\right)^{50} = 0.95$$

$$\Rightarrow 1-\frac{1}{T_r} = 0.95^{\frac{1}{50}}$$

$$\Rightarrow \frac{1}{T_r} = 1-0.95^{\frac{1}{50}}$$

$\therefore T_r = 975.3$ years.

Now, $y_T = -\ln\left[\ln\left(\frac{975.3}{974.3}\right)\right] = 6.88223$

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n} = \frac{6.88223 - 0.53622}{1.11238} = 5.705$$

$\therefore$ the design flood, $x_T = \bar{x} + K_T \cdot S_x$

$= 1200 + 5.705 \times 650$

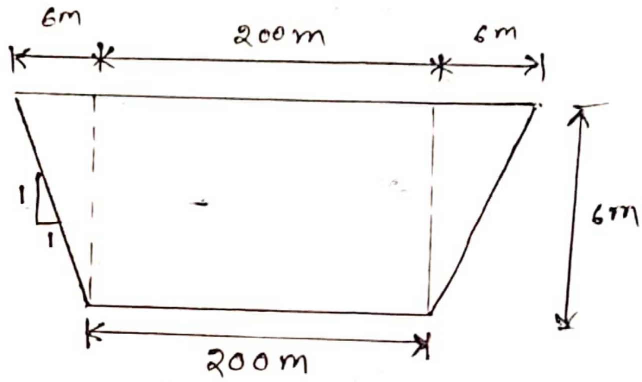
$= 4908.25\ m^3/sec.$

(Ans.)

Channel Improvement

A channel has a bottom width of 200 m, Depth = 6 m and side slope = 1:1. If the depth is increased to 9 m by deepening, determine the percentage increase of velocity of flow in the channel. For the same increase in cross-sectional area, if the channel is widened (instead of deepening), what is the percentage increase in the velocity of flow.

Solution:



From chezy's formula,

$$v = C\sqrt{RS}$$

$$\Rightarrow v \propto \sqrt{R}$$

$$\text{Area}, A_0 = \frac{1}{2} \times (200 + 200 + 6 + 6) \times 6$$

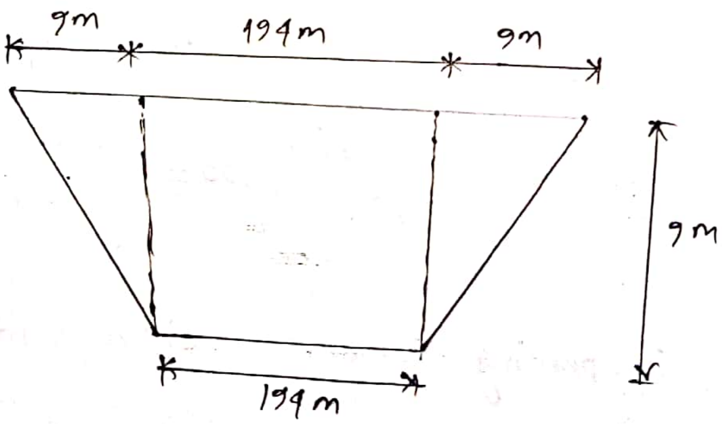
$$= 1236 \ m^2$$

$$\text{Wetted perimeter}, P_0 = 200 + 2 \times \sqrt{6^2 + 6^2} = 216.97 \ m$$

$$\therefore \text{Hydraulic mean depth}, R_0 = \frac{A_0}{P_0} = \frac{1236}{216.97} = 5.7$$

Case-1: (Deepening)

increased the depth to 9 m by deepening,



Now,

$$A_1 = \frac{1}{2} \times (194 + 212) \times 9$$

$$= 1827 \ m^2$$

$$P_1 = 194 + \sqrt{9^2 + 9^2} = 219.46 \ m$$

$$\therefore R_1 = \frac{A_1}{P_1} = 8.32$$

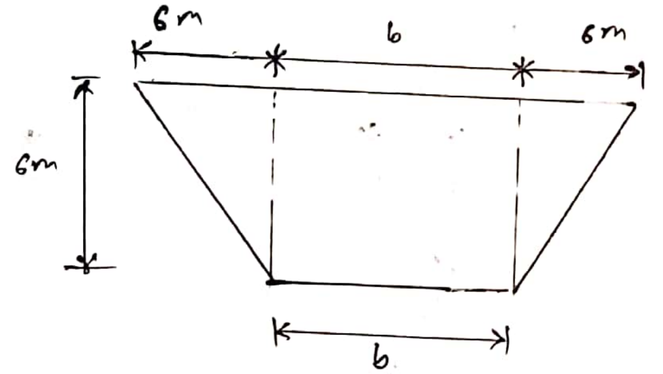
Therefore, velocity increase by deepening

$$= \frac{\sqrt{R_1} - \sqrt{R_0}}{\sqrt{R_0}} \times 100 = \frac{\sqrt{8.32} - \sqrt{5.7}}{\sqrt{5.7}} \times 100 = 20.82\%.$$

$\simeq 21\%$

Case-2: (Widening)

increased width for the cross sectional area (case-1) = 1827 m^2



$A_2 = \frac{1}{2} \times (b + b + 12) \times 6 = (b+6) \times 6$

Hence, $(b+6) \times 6 = 1827$

$\Rightarrow b = 298.5$ m

$P_2 = 298.5 + 2 \times \sqrt{6^2 + 6^2} = 315.47$ m

$\therefore R_2 = \frac{A_2}{P_2} = \frac{1827}{315.47} = 5.79$

Therefore, velocity increase by widening.

$$= \frac{\sqrt{R_2} - \sqrt{R_0}}{\sqrt{R_0}} \times 100 = \frac{\sqrt{5.79} - \sqrt{5.7}}{\sqrt{5.7}} \times 100 = 0.786\%.$$

Hence, Deepening is better than widening.

Balancing Depth

S.K. Garg

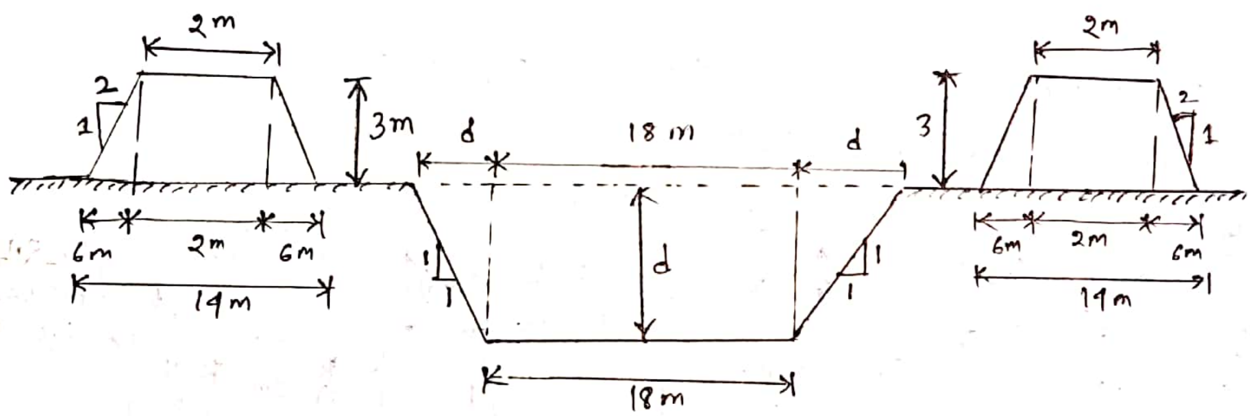
Example - 4.14:

Calculate the balancing depth for a channel section having a bed width equal to 18 m and side slopes of 1:1 in cutting and 2:1 in filling. The bank embankments are kept 3.0 m higher than the ground level (berm level) and crest width of banks is kept as 2.0 m.

Solution:

The channel section is shown in figure.

Let. d be the balancing depth.



Area of cutting $= \frac{1}{2} \times (18 + 18 + 2d) \times d = (18 + d)\,d$

Area of filling $= 2 \times \frac{1}{2} \times (14 + 2) \times 3 = 48$ sq.m.

Equating cutting and filling,

$$(18 + d)\,d = 48$$

$$\Rightarrow d^2 + 18d - 48 = 0$$

$$\therefore d = 2.36 \text{ m}$$

$\therefore$ Balancing depth $= 2.36$ m (Ans.)

2015

The following data refer to an irrigation canal:

(i) Bed width = 1 m

(ii) Side slopes = 2H : 1V (in filling)

= 1H : 1V (in cutting)

(iii) Top width of embankment on the either side of the canal = 3 m

(iv) Full supply depth = 5 m

(v) Free board = 1 m (Take the G.L as 100 m)

Determine the balancing depth. Draw a neat cross section of the canal illustrating the various dimensions and the levels.

Solution: The channel section is shown in figure:

Let, d be the balancing depth

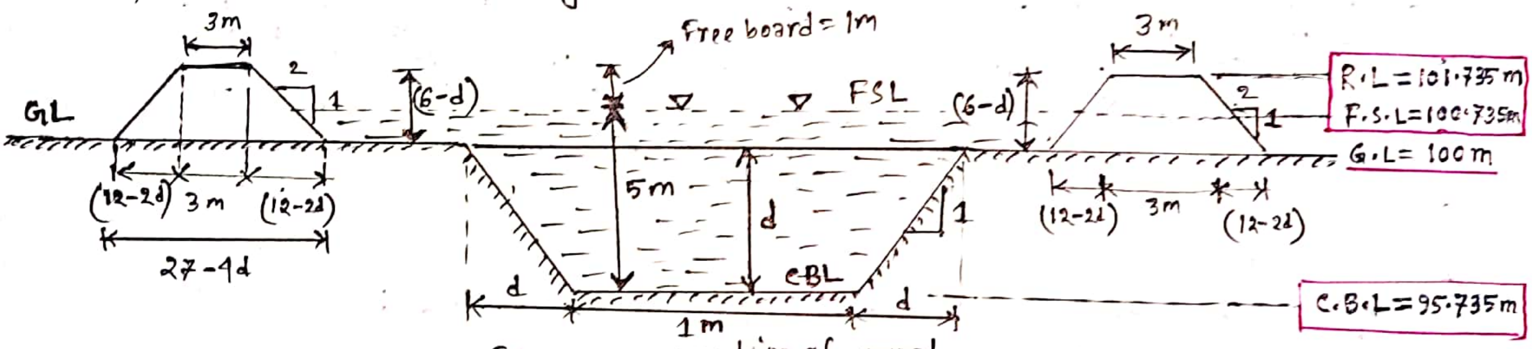


Fig. Cross section of canal

Area of filling $= 2 \times \frac{1}{2} \times (3 + 27 - 4d) \times (6-d) = (30-4d) \times (6-d)$

Area of cutting $= \frac{1}{2} \times (1 + 1 + 2d) \times d = (1+d)d$

Equating cutting and filling,

$$(30-4d) \times (6-d) = (1+d) \times d$$

$$\Rightarrow 180 - 24d - 30d + 4d^2 = d + d^2$$

$$\Rightarrow 3d^2 - 55d + 180 = 0$$

$\therefore d = 4.265$ m $\quad \therefore$ Balancing depth = 4.265 m (Ans.)

Kennedy's Silt Theory

S.K. Garg

Example - 4.18:

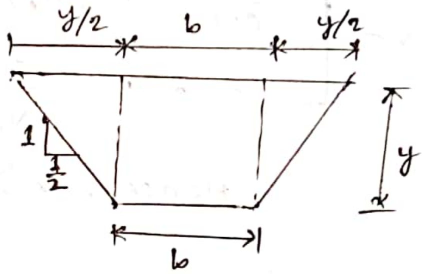
Design an irrigation channel to carry 50 cumecs of Discharge. The channel is to be laid at a slope of 1 in 4000. The critical velocity ratio (m) for the soil is 1.1. use Kutter's rugosity co-efficient (n) as 0.023.

Solution: Given, $Q = 50$ cumec.

$n = 0.023$

$m = 1.1$

$S = 1/4000$



Assume, depth, $y = 2m$

$$V_o = 0.55 m y^{0.64} = 0.55 \times 1.1 \times 2^{0.64} = 0.943 \text{ m/sec.}$$

$$A = \frac{Q}{V_o} = \frac{50}{0.943} = 53.02 \text{ m}^2$$

Now, $A = \frac{1}{2} \times (b + b + y) \times y$

$$\Rightarrow 53.02 = by + \frac{y^2}{2}$$

$$\Rightarrow b \times 2 + \frac{2^2}{2} = 53.02$$

$$\Rightarrow b = 25.51 \text{ m}$$

$$P = b + 2 \times \sqrt{y^2 + (\tfrac{y}{2})^2} = b + y\sqrt{5} = (25.51 + 2 \times \sqrt{5}) = 29.98 \text{ m}$$

$$R = \frac{A}{P} = \frac{53.02}{29.98} = 1.77 \text{ m}$$

using Kutter's equation,

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

Here,

$$23 + \frac{0.00155}{S} = 23 + \frac{0.00155}{1/4000} = 29.2$$

$$\therefore V = \left[\frac{\frac{1}{0.023} + 29.2}{1 + 29.2 \times \frac{0.023}{\sqrt{1.77}}} \right] \times \sqrt{1.77 \times \frac{1}{4000}} = 1.016 \text{ m/s}$$

Hence, $V > V_0 = 0.0943$ m/sec.

In order to increase the critical velocity (V_0), we have to increase the depth.

use depth, $y = 2.5$ m

$$V_0 = 0.55 \times 1.1 \times 2.5^{0.64} = 1.088 \text{ m/sec.}$$

$$A = \frac{50}{1.088} = 45.96 \text{ m}^2$$

Now, $A = by + \frac{y^2}{2}$

$$\Rightarrow b \times 2.5 + \frac{2.5^2}{2} = 45.96$$

$$\Rightarrow b = 17.13 \text{ m}$$

$$P = (b + y\sqrt{5}) = 17.13 + 2.5 \times \sqrt{5} = 22.72 \text{ m}$$

$$R = \frac{A}{P} = \frac{45.96}{22.72} = 2.02 \text{ m}$$

$$\sqrt{RS} = \sqrt{\frac{2.02}{4000}} = 0.0225$$

using Kutter's equation,

$$V = \left[\frac{\frac{1}{0.023} + 29.2}{1 + 29.2 \times \frac{0.023}{\sqrt{2.02}}}\right] \times 0.0225 = 1.111 \text{ m/s.} > V_o = 1.088 \text{ m/s}$$

Hence, increase the depth.

use depth, $y = 2.7\text{m}$

$$V_o = 0.55 \times 1.1 \times 2.7^{0.64} = 1.142 \text{ m/sec.}$$

$$A = \frac{Q}{V_o} = 43.78 \text{ m}^2.$$

Now, $43.78 = by + \frac{y^2}{2}$

$$\Rightarrow b \times 2.7 + \frac{2.7^2}{2} = 43.78$$

$$\Rightarrow b = 14.86 \text{ m}$$

$$P = b + y\sqrt{5} = 14.86 + 2.7 \times \sqrt{5} = 20.9 \text{ m}$$

$$R = \frac{A}{P} = \frac{43.78}{20.9} = 2.09 \text{ m}$$

$$\sqrt{RS} = \sqrt{\frac{2.09}{4000}} = 0.02286$$

Using Kutter's equation,

$$V = \left[\frac{\frac{1}{0.023} + 29.2}{1 + 29.2 \times \frac{0.023}{\sqrt{2.09}}}\right] \times 0.02286 = 1.139$$

$\therefore V \simeq V_o$

Hence, use the depth $= 2.7$ m, base width $= 14.86$m (say 14.9m) with slope $\frac{1}{2} : 1$ of trapezoidal section.

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Example – 4.7:

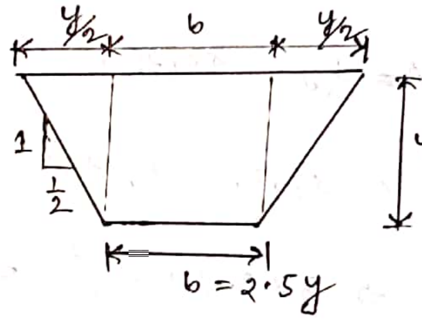
Design an irrigation channel to carry 40 cumec of discharge with $\boxed{b/y}$ (B/D) i.e. base-width ratio as 2.5. The critical velocity ratio is 1.0. Assume a suitable value of Kutter's rugosity co-efficient and use Kennedy's method.

Solution: Given, $Q = 40$ cumec.

$$\frac{b}{y} = 2.5 \Rightarrow b = 2.5y$$

$$m = 1\ m$$

Let, $n = 0.023$



use $\frac{1}{2}:1$ slopes,

Area of trapezoidal section,

$$A = by + \frac{y^2}{2}$$

we know, $Q = A V_0$

$$\Rightarrow 40 = \left(by + \frac{y^2}{2}\right) \times 0.55 \times 1 \times y^{0.64}$$

$$\Rightarrow 40 = (2.5y^2 + 0.5y^2) \times 0.55 y^{0.64}$$

$$\Rightarrow 40 = 3y^2 \times 0.55 y^{0.64}$$

$$\Rightarrow y^{2.64} = 24.24$$

$$\Rightarrow y = 3.3455\ m \simeq 3.35\ m$$

$$\therefore b = (2.5 \times 3.35) = 8.375\ m$$

Now, $A = by + \frac{y^2}{2} = 8.375 \times 3.35 + \frac{3.35^2}{2} = 33.67\ m^2$

$P = b + y\sqrt{5} = 8.375 + 3.35 \times \sqrt{5} = 15.87\ m$

$R = \frac{A}{P} = \frac{33.67}{15.87} = 2.12$; $V_o = 0.55 \times 1.0 \times 3.35^{0.64} = 1.192$ m/sec.

using Kutter's equation,

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

Assume, slope $= \frac{1}{4000}$

$$23 + \frac{0.00155}{1/4000} = 29.2$$

$$V = \left[\frac{\frac{1}{0.023} + 29.2}{1 + 29.2 \times \frac{0.023}{\sqrt{2.12}}} \right] \times \sqrt{2.12 \times \frac{1}{4000}} = 1.145 \text{ m/s} < V_o = 1.192 \text{ m/s}$$

Therefore, to increase the value of V, we must increase the slope.

∴ Use a slope = 3700

$$23 + \frac{0.00155}{1/3700} = 28.735$$

$$\therefore V = \left[\frac{\frac{1}{0.023} + 28.735}{1 + 28.735 \times \frac{0.023}{\sqrt{2.12}}} \right] \times \sqrt{\frac{2.12}{3700}} = 1.189 \text{ m/s} \ (\simeq V_o = 1.192 \text{ m/s})$$

Hence, use a trapezoidal section as follows:

depth, $y = 3.35$ m

base width, $b = 8.375$ m

side slope $= \frac{1}{2} H : 1V$

Bed slope = 1 in 3700

(Ans.)

Lacey's Silt Theory

S.K. Garg

Example - 4.9: Design a regime channel for a discharge of 50 cumecs and silt factor 1.1, using Lacey's theory.

Solution: Given, $Q = 50$ cumec.

$f = 1.1$

We know,

$$V = \left[\frac{Qf^2}{140}\right]^{\frac{1}{6}}$$

$$= \left[\frac{50 \times 1.1^2}{140}\right]^{\frac{1}{6}} = 0.8695 \text{ m/sec.}$$

$$R = \frac{5}{2} \times \left(\frac{0.8695^2}{1.1}\right) = 1.72 \text{ m}$$

$$A = \frac{Q}{V} = \frac{50}{0.8695} = 57.5 \text{ m}^2$$

$$P = 4.75\sqrt{Q} = 4.75 \times \sqrt{50} = 33.59 \text{ m}$$

$$S = \left[\frac{f^{5/3}}{3340\, Q^{\frac{1}{6}}}\right] = \left[\frac{1.1^{5/3}}{3340 \times 50^{\frac{1}{6}}}\right] = \frac{1}{5469.16} \simeq \frac{1}{5470}$$

For trapezoidal channel with $\frac{1}{2}H : 1V$ slopes

$$A = \left(by + \frac{y^2}{2}\right) \qquad \therefore\ by + \frac{y^2}{2} = 57.5 \quad \ldots\ldots (1)$$

$$P = b + y\sqrt{5} \qquad \therefore\ b + y\sqrt{5} = 33.59 \quad \ldots\ldots (11)$$

From equation (II) we obtain,

$$b = 33.59 - y\sqrt{5} \quad \ldots\ldots \text{(III)}$$

substituting the value of b in equation (I),

$$(33.59 - y\sqrt{5})y + \frac{y^2}{2} = 57.5$$

$$\Rightarrow 33.59y - \sqrt{5}\,y^2 + \frac{y^2}{2} = 57.5$$

$$\Rightarrow 1.736y^2 - 33.59y + 57.5 = 0$$

$$\Rightarrow y = 1.9 \text{ m}$$

From equation (III) we obtain, $b = (33.59 - 1.9 \times \sqrt{5}) = 29.34$ m

Hence, use a trapezoidal section as follows:

depth = 1.9 m

base width = 29.34 m

side slope = $\frac{1}{2}$ H : 1V

Bed slope = 1 in. 5470.

(Ans.)