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SECTION – A (IRRIGATION)

SECTION - B (HYDROLOGY)

SECTION–A

[IRRIGATION]

CHAPTER - 1
IRRIGATION AND METHODS OF IRRIGATION

1.1 GENERAL UNDERSTANDING
Plants require water and air for their survival. Different types of plants require different quantities of water and at different time, till they grow up completely. Water is normally supplied to these plants by nature through direct rain of through the flood waters of rives. The supply of water by nature does not match the requirement of crops. Thus to control the nature, man discovered various methods by which the eater can be stored during the periods of excess rainfall and to use that strode water during periods of less rainfall or no rainfall. The art of the science by which it is accomplished, is generally termed as irrigation.
The Following are the main concerns of irrigation.
1. How to apply i.e., what should be the method of irrigation Border flooding method, furrow irrigation method, sprinkler irrigation method, drip irrigation method etc.
2. How much to apply i.e., how much moisture the soil can hold in its pores (moisture holding capacity of the soil).
3. When is apply i.e, when has the soil moisture level depleted to 30 to 60% of moisture holding capacity and when is the time to irrigate. In other words what should be frequency of irrigation.

1.1.1 Definition of Irrigation
Irrigation may be defined as the science of artificial application of water to the land in accordance with the crop requirements throughout the crop period for full-fledge nourishment of the crop.

1.1.2 Crop Yield and Productivity
The crop yield from irrigation is expressed as quintal/ha or tones/ha. The productive of the crop is expressed as crop yield per mm of water applied.

1. Increase of Yield Productivity can be Achieved by following Methods
(i) Land shaping or land leveling.
(ii) Suitable crop rotations and crop planning.
(iii) Using high yielding varieties of seeds.
(iv) Using chemicals and fertilizers: inputs like NPK, FYM, green manure (nitrogen-rich crops).
(v) Methods of irrigation such as sprinkler drop, furrow etc.
(vi) Lining of canals, distributaries and water courses by an economical lining material.
(vii) Drainage of irrigated land by surface and subsurface drainage.

1.1.3 Advantage and Disadvantages of Irrigation
1.1.3.1 Advantage of Irrigation
1. Direct Advantage
(i) Increase in Food Production
Increase in crop yield due to irrigation leads to increases in food production, thus developing people as well as society.

(ii) Protection against Drought
The provision of adequate irrigation facilities in any region ensures protection against failure of crops from famine or droughts.

CHAPTER - 2
SOIL-MOISTURE-PLANT RELATIONSHIP

2.1 SOIL MOISTURE

1. Water added to a soil mass during irrigation is held in the pores of the soil and is termed as soil moisture.
2. Soil moisture causes the soil to appear wet or even damp depending upon the amount of moisture present in the soil mass.
3. Soil pores which do not contain liquid water remain filed with air or eater vapor.

2.1.1 Basic Physical Properties of Soil

1. Soil provides the necessary medium for water to be used by plants through their roots that are present in the same medium.
2. Water acts as a medium to carry large amounts of nutrients essential for the growth of a plant.
3. The rate of entry of water into the soil, its retention and then its movement and availability to plant root are physical phenomena that contribute to the growth of vegetation.

> Hence there is need to understand the physical aspects of soil in politic to water for efficient management of irrigated agriculture.

2.1.2 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.

Porosity, $n = \frac{V_V}{V_T}$

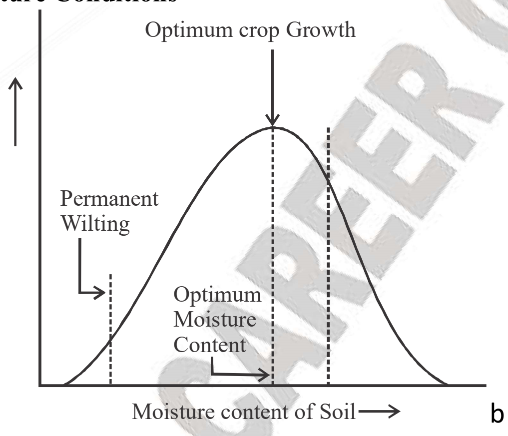
Where, V_V is volume of pores, V_T is total volume n is porosity

In general there are two types of soil pores viz.,

1. Capillary of small pores
2. Non-capillary or large pores
(i) The capillary pores hold a large amount of eater held by the soil at saturation due to capillarity and prevent it from being drained off under gravity.
(ii) On the other hand, 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.
(iii) Capillary pores induce greater water holding capacity while non capillary pores induce drainage and aeration.
(iv) The relative magnitude of these types of pores in a soil depends on its texture and structure.
(v)A sandy soul has more non-capillary pores which result in better drainage and aeration but low water holding capacity.
(vi) On the other hand clayey soil has more capillary pores which result in better water holding capacity but poor drainage and aeration.

CHAPTER - 3
WATER REQUIREMENTS OF CROPS & CANAL IRRIGATION

3.1. WATER REQUIREMENTS OF CROPS
1.The term water requirements of a crop means the total quantity and the ways in which a crop requires water, from the time it is sown to the time it is harvested.
2. The water requirement varies with the crop as well as with the place.
3. In other words, different crops will have different water requirements, and the same crop may have different water requirements at different places of the same country depending upon the variation in climates, type of soils, methods of cultivation and useful rainfalls etc.

3.1.1 Limiting Soil Moisture Conditions


1.Growth of most crops is retarded by either excessive or deficient amounts of soil moisture content.
2.Excessive moisture content in the soil results in filling the soil pore spaces completely with water thus driving cut air from the soil in the root zone.
3.On the other hand, soils having deficient amounts of moisture hold it is so tightly that plants are required to expend extra energy to obtain it.
4.In between these two extreme soil moisture conditions, there is a moisture content designated as optimum moisture content at which plants grown most rapidly, resulting in the optimum growth of crops.

3.1.2 Crops Seasons and Crops of India
1.There are two main crop seasons of India viz. Rabi and Kharif. The crops grown during these crop seasons are designated as Rabi crops and Kharif crops. Rabi crops are also known as winter crops and Kharif crops are known as monsoon crops (See the details in table).
2.Sometimes in between the Rabi and Kharif crops intermediate crops are grown, in which case the crops may be classified as Hot weather crops, Kharif (or monsoon) crops and Rabi (or winter) crops. Often-the Hot weather crops and the Kharif crops are combined designated as Summer crop (See the details in table below).

CHAPTER - 4
WATER LOGGING AND RECLAMATION OF SALINE SOILS

4.1 WATER LOGGING

1. Water togging is a phenomena in which productivity of land gets affected due to the high water table to flooding of root zone of the plants and making the root zones of the plants ill-aerated.

2. The life of a plant depends upon the nutrients like nitrates, and the form in which the nitrates are consumed by the plants is produced by the bacteria, under a process called nitrification. These bacteria need oxygen for their survival. The supply of oxygen gets cutoff when the land becomes ill aerated, resulting in the death of these bacteria, and fall in the production of plant's food (i.e. nitrates) and consequent reduction in the plant growth.

4.1.1 Other Problems Created by Water Logging are

1.The normal cultivation operation, (such as tilling ploughing, etc) cannot be easily carried out in wet soils. In extreme cases, the free water may rise above the surface of the land making the cultivation operation impossible.

2.Water logging also leads to salinity.

If the water-table has risen up, or if the plant roots cones within the capillary fringe, water is continuously evaporated by capiliarity. Thus, a continuous upward flow of water from the water-table to the land surface, gests established. With this upward flow, the salts which are present in the water also rise towards the surface, resulting in the deposition of salts in the root zone of the crops. The concentration of these alkali salts present in the root zone of the crops has a corroding effect on the roots, which reduces the osmotic activity of the plants and checks the plant growth, and the plant ultimately fades away. Such soil are called saline soils.

Whenever there is water logging, there is salinity.

4.1.2 Causes of Water Logging

1. Over and Intensive Irrigation

When a policy of intensive irrigation is adopted, then the maximum irrigable area of a small region is irrigated. This leads to heavy irrigation in that region resulting in heavy percolation and subsequent rise of water-table. Hence, policy of extensive irrigation should be preferred.

2. Seepage of Water from the Adjoining High Lands

Water from the adjoining high lands may seep into the sub-soil of the affected land and may raise the water-table.

3. Seepage of Water through the Canals

Water may seep through the beds and sides of the adjoining canals, reservoirs, etc , situated at a higher level then the affected land resulting in high water-table. This seepage is excessive, when soil at the site of canals, reservoirs, etc., is very previous.

CHAPTER - 5
CANAL DESIGN

5.1 SEDIMENT TRANSPORT

Water flowing in a channel has a tendency to scour its surface. Silt, gravel or even large boulders are detached from the bed or sides of the channel and moved d/s by the moving water. This phenomenon is known as Sediment transport.

5.1.1 Importance of Sediment Transport

1.Sediment transport phenomena cause large scale scouring and siltation of irrigation canals.
2.Bed levels may change by direct scouring or deposition of sediment, and thereby leading to change in flood levels.
3.Scouring and silting of the river banks may create sharp and irregular curves, which increases the flow resistance of the channel, thereby, flood levels gets raised for the same discharge.
4.Silting of reservoir and rivers is an important aspect of sediment transport. The storage capacity of the reservoir is reduced by silting, thereby, reducing use and life of the reservoir. Natural rivers used for navigation are frequently silted up. This leads to drastic …. the clear depth for navigation, thus, requiring costly dredging.

5.1.2 Sediment Load

Sediment load is the burden of sediment carried by the flowing water in a canal. The sediment moving in water has been classified as:
1. Bed load
2. Suspended load

(i) Bed load
Sediment load moves along the bed with occasional jumps into the channel.
(ii) Suspended Load
Sediment load is maintained in suspension due to the turbulence of the flowing water.

5.2 MECHANISM OF BED FORMATION

1.The channel bed may get distorted into various shapes by the moving water, depending upon the discharge or the velocity of the water.
2.At low velocities the bed does not move at all, but it goes on assuming different shapes as the velocity increases.
3.When velocity is gradually increased then a stage is reached when the sediment load comes just at the point of motion. This stage in known as threshold stage of motion.
4.On further increase of velocity, bed develops the saw-tooth type ripples.
5.As the velocity is increased further, larger periodic irregularities appear, and are called dunes.
6.When they first appear, ripples are superimposed on them. But at higher velocity, the ripples disappear and only the dunes are left.

CHAPTER - 6
CANAL HEAD WORKS & SEEPAGE THEORY

6.1 INTRODUCTION
An irrigation canal takes its supplies from a river or a stream. In order to divert water from the river into the canal it is necessary to construct certain works or structures across the river and at the head of the off taking canal. These works are termed as canal headworks or headworks.
The canal headworks may be classified into the following types
1. Storage headworks
2. Diversion headworks

1. Storage Head Works
Consists of a dam constructed across the river to create a reservoir in which water is stored during the period of excess flow in the river.
(i) From the reservoir water is supplied to the canal in required quantity as per the demand.
(ii) A storage headworks storage water in addition to its diversion into the canal.

2. Diversion Head Works
Raises the water level in the river and divert the required quantity into the canal.

Our prime focus will be to study in detail about diversion headworks

The various purpose served by a diversion headwork's are as follow:
(i) It raises the water level in the river in order to increase the commanded area.
(ii) It regulates the supply of water into the canal.
(iii) It controls the entry of silt into the canal.
(iv) It provides some storage of water for a short period.
(v) It reduces the fluctuation in the level of supply in the river

6.2 TYPES OF DIVERSION HEADWORKS
The diversion headworks may be classified into the following types.
1. Temporary diversion headworks
2. Permanent diversion headworks
1. Temporary Diversion Headworks
It consists of a super or bund constructed across the river to raise the water level in the river and divert it into the canal.
(i) These bunds are constructed almost every year after the floods, because they may be damaged by the floods.

2. Permanent Diversion Headworks
It consists of a permanent structure such as weir or barrage constructed across the river to raise the water level in the river and divert it into the canal.

CHAPTER - 7
DAMS AND RESERVOIRS

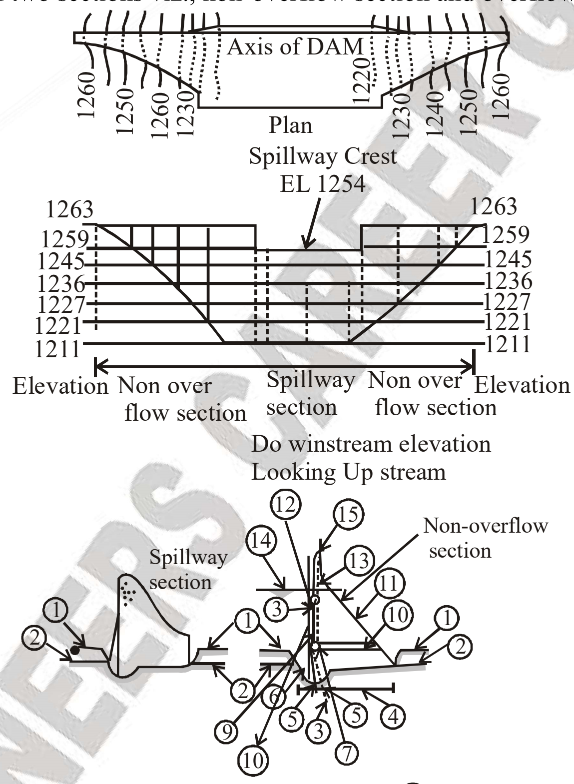
7.1 INTRODUCTION
A dam is barrier constructed across a river in order to create a reservoir for impounding water or to provide the facility of diverting water from the river or to retain debris flowing in the river along with water.

1. A gravity dam is solid masonry or concrete structure with an approximately triangular cross section, so that the external forces exerted on it are resisted by its own weight. It is also called a solid gravity dam.

2. It is mostly straight in plan but in some cases it may be slightly curved as well.

3. A sound rock foundation is an essential requirement for the construction of a gravity dam.

4. The dam consists of two sections viz., non-overflow section and overflow (or-spillway).



① River Del-level ② Foundation Rock level ③ Vertical Dram
④ Base Width ⑤ Grout Hole ⑥ Cutoff Trench ⑦ Drainage Gallery
⑧ Entrance Gallery ⑨ Axis of DAM ⑩ Upstream face
⑪ Downstream face ⑫ Inspection Gallery ⑬ Inspection Shaft
⑭ Maximum water level ⑮ Crest

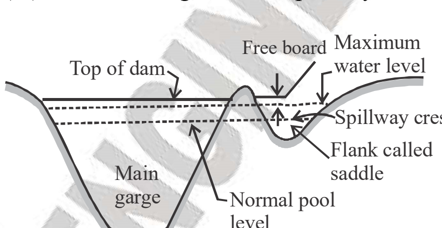
CHAPTER - 8
SPILLWAYS, ENERGY DISSIPATORS & SPILLWAY GATES

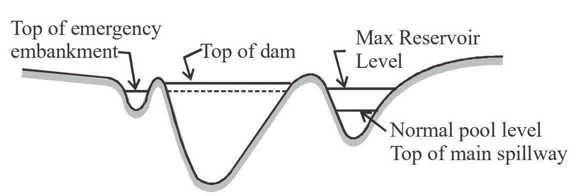
8.1 INTRODUCTION
1.A spillway is a waterway provided to dispose off surplus flood waters from reservoir after it has been filled to its maximum capacity.
2.Spillways are provided for almost all the dams and these acts as safety values for the dams.
3.A spillway may be located either within the body of the dam or at one end of the dam or entirely away from the dam in the saddle as an independent structure.
4.It is essential to provide a spillway of sufficient capacity so that the surplus flood water is discharge keeping the water level in the reservoir below some predetermined maximum level and no damage is done to dam.

8.1.1 Essential Requirements of A Spillway
The essential requirements of a spillway are as follows
1.The spillway must have sufficient capacity
2.It must be hydraulically and structurally adequate
3.It must be so located that it provides safe disposal of water i.e., spillway discharges should not erode or undermine the d/s toe of the dam.
4.The bonding surfaces of the spillway must be erosion resistant to withstand the high scouring velocities created by the drop from the reservoir surface to tail water.
5.Some devices for dissipation of energy on the d/s side of the spillway will be required.

8.1.2 Spillway Capacity
The required capacity of a spillway (i.e. the maximum outflow rate through the spillway) may be determined by flood routing which requires following data.
1.In flow hydrograph (plot of rate of inflow v/s time).
2.Reservoir capacity curve (plot of reservoir storage v/s reservoir water surface elevation).
3.Discharge curve (plot of rate of outflow through spillway v/s reservoir water surface elevation).

The required capacity of a spillway depends on the following factors.
(i) The inflow flood
(ii) The available storage capacity.
(iii) The discharge capacity of other outlet works.
(iv) Provision of gates in a spillway.





WORKBOOK

Example 1. At an energy dissipator structure below a low spillway, the discharge is $19 m^2/sec$ and the energy loss is 1m at the hydraulic jump forming therein. Determine the depths of flow at both ends of the jump

Solution.

Given, $q = 19\ m^2/s$; Energy loss, $H_L = 1m$

Energy loss for hydraulic jump,

$$H_L = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

and $\frac{2a^2}{g} = y_1 y_2 (y_1 + y_2)$

$$y_1 y_2 (y_1 + y_2) = \frac{2 \times (19)^2}{g}$$

$\Rightarrow y_1 y_2 (y_1 + y_2) = 73.6$ …(i)

$$1 = \frac{(y_2 - y_1)^3}{4y_1y_2} \quad \text{…(ii)}$$

Let $\frac{y_2}{y_1} = x \quad \Rightarrow y_2 = xy_1$

Putting the value of y_2 in equation (i)

$y_1^2 (y_1 + xy_1) = 73.6 \quad \Rightarrow xy_1^3 (1 + x) = 73.6$

Similarly putting in (ii), we get

$$\frac{(y_1x - y_1)^3}{4y_1\, y_1\, x} = 1 \qquad \frac{y_1^3 (x-1)^3}{4y_1^2\, x} = 1$$

$$\Rightarrow\ 4x = y_1 (x-1)^3 \qquad \Rightarrow y_1 = \frac{4x}{(x-1)^3}$$

Substituting the value of y_1 in equation (ii), we get

$$x\left[\frac{4x}{(x-1)^3}\right](1+x) = 73.6$$

$\therefore$ By hit and trial, we get $x = 2.8$,

$$y_1 = \frac{4 \times 2.8}{(2.8-1)} = \frac{4 \times 2.8}{1.8^3} = 1.92m$$

and $y_2 = y_1x = 1.92 \times 2.8 = 5.377m$.

GATE QUESTIONS

1. Water emerges from an ogee spillway with velocity = 13.72 m/s and depth = 0.3 m at its toe. The tail water depth required to form a hydraulic jump at the toe is

[GATE - 2008]

(a) 6.48m (b) 5.24m
(c) 3.24m (d) 2.24m

2. Which one of the following equations represents the downstream profile of Ogee spillway with vertical upstream face? (x, y) are the coordinates of the point on the downstream profile with origin at the crest of the spillway and H_d is the design head.

[GATE - 2005]

(a) $\frac{y}{H_d} = -0.5\left(\frac{x}{H_d}\right)^{1.85}$

(b) $\frac{y}{H_d} = -0.5\left(\frac{x}{H_d}\right)^{1/1.85}$

(c) $\frac{y}{H_d} = -2.0\left(\frac{x}{H_d}\right)^{1.85}$

(d) $\frac{y}{H_d} = -2.0\left(\frac{x}{H_d}\right)^{1/1.85}$

SOLUTIONS

Sol. 1. (c)

Water depth required to form a hydraulic jump may be given as

$$y_2 = \frac{y_1}{2}\left[-1+\sqrt{1+\frac{8V_1^2}{gy_1}}\right]$$

$$= \frac{0.3}{2}\times\left[-1+\sqrt{\frac{8\times(13.72)^2}{9.81\times0.3}}\right] = 3.24\text{m}$$

Sol. 2. (a)

For a spillway having a vertical u/s face, the d/s crest is given by the equation,

$$X^{1.85} = -2H_d^{0.85}\times y$$

$$\Rightarrow x^{1.85} = -2H_d^{0.85}y\times\frac{H_d}{H_d}$$

$$\Rightarrow x^{1.85} = -2\frac{H_d^{1.85}y}{H_d}$$

$$\Rightarrow \frac{x^{1.85}}{-2H_d1.85} = \frac{y}{H_d}$$

$$\Rightarrow \frac{x^{1.85}}{-2H_d^{1.85}} = \frac{y}{H_d}$$

$$\Rightarrow \frac{y}{H_d} = -0.5\left(\frac{x}{H_d}\right)^{1.85}$$

ESE OBJ QUESTIONS

1. By considering the channel index as 5/3, the setting of an orifice type irrigation outlet to have proportionality is

[ESE - 2015]

(a) 0.90 (b) 0.67
(c) 0.30 (d) 0.15

2. In a ski-jump bucket provided in an overflow spillway, the lip angle is 30°, and the actual velocity of flow entering the bucket is 30 m/s. The maximum vertical height attained by the trajectory of the jet, measured above the lip of the bucket, is nearly

[ESE - 2015]

(a) 45m (b) 35m
(c) 22 m (d) 11 m

3. Which of the following outlets are of semi-modula^{r} type?
1. Khanna's module
2. Adjustable proportional module
3. Submerged pipe outlet
4. Open flume outlet
5. Kennedy's gauge outlet

[ESE - 2014]

(a) 2, 4 and 5 (b) 1, 2 and 4
(c) 2, 3 and 5 (d) 3, 4 and 5

4. The flip bucket energy dissipator for a spillway is suitable where:
1. The tail water depth is low.
2. The rock on the downstream is fragile and is erodible.
3. The rock on the downstream is good and non-erodible.

[ESE - 2013]

(a) 1,2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

5. A discharge of 72 m^3/s is to be allowed through siphon spillways of 2 m width and 75 cm depth with working head of 8 m. The number of spillways to be provided will be (Take coefficient of discharge for the spillways = 0.64)

[ESE - 2012]

(a) 2 (b) 4
(c) 6 (d) 8

6. A ski-jump bucket is generally used as an energy dissipator when the tail water

[ESE - 2010]

(a) Is greater than 1.1 times the required conjugate depth for the formation of hydraulic jump; and the river bed rock is 'good'
(b) Depth is lesser than the depth required for the jump formation; and the bed of the river channel is composed of 'sound' rock
(c) Depth is equal to the depth required for the jump formation, and the river bed rock is 'good'
(d) Depth is 1.3 times the required for the jump formation and the river bed is composed of 'weak' rock

7. Which one of the following equations represents the downstream curve of the "Ogee" spillway (where x and y are the co-ordinates of the crest profile measured from the apex of the crest, and H is the design head)?

[ESE - 2004]

(a) $x^{185} = 2H^{\circ}\text{-}^{85}y$ (b) $x = 2H^{r85}y^{\circ,85}$
(c) $jc^{a85} = 2H^{1}\text{-}^{85}y$ (d) $x = 2H^{a85}y^{1,85}$

8. The ideal condition for energy dissipation in the design of spillways is the one when the tail water rating curve

[ESE - 2003]

(a) Lies above jump rating curve at all discharges
(b) Coincides with the jump rating curve at all discharges
(c) Lies below jump rating curve at all discharges
(d) Lies either above or below the jump rating curve depending upon discharge

WORKBOOK

Example 1. Determine the time required to irrigate a strip of land of 0.04 hectares in area from a tube well with a discharge of 0.02 cumec. The infiltration capacity of the soil may be taken as 5 cm/hr and the average depth of flow on the field as 10 cm.
Also determine the maximum area that can be irrigated from this tube well.

Solution.
Given, Area of the strip, A = 0.04 hectares = $0.04 \times 10^4 \text{ m}^2 = 400 \text{ m}^2$.
Discharge, Q = 0.02 cumecs = 0.02 m^3/sec = $0.02 \times 60 \times 60 \text{ m}^3/\text{hr} = 72 \text{ m}^3/\text{hr}$.

Infiltration capacity of soil, f = 5 cm/hr $\frac{5}{100}$ m/hr = 0.05 m/hr

Average depth of flow on the field, y = 10cm = 0.1 m.
Approximate time required to irrigate a strip of land, $t = 2.303\,\frac{y}{f}\log_{10}\left(\frac{Q}{Q-fA}\right)$

or $t = 2.303\times\frac{0.10}{0.05}\times\log_{10}\left(\frac{72}{72-0.05\times 400}\right)$

= 2.303 × 2 $\log_{10}$ (75/52) = 0.651 hr = 39.06 minutes

Maximum area that can be irrigated,

$$A_{max} = \frac{Q}{f} = \frac{72}{0.05}\text{m}^2 = 1440\text{m}^2 = \frac{1440}{10^4}\text{ha} = 0.144\text{ha}$$

ASSIGNMENT

1. Assertion (A): Sprinkler method of irrigation has higher water application/use efficiency.
Reason (R): Sprinkler, system causes lees interference in cultivation and other farming operations.
Of these statements
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2. A sprinkler irrigation system is suitable when
(a) The land gradient is steep and the soil is easily erodible.
(b) The soil is having low permeability
(c) The water table is low
(d) The crops to be grown have deep roots

3. An Indian irrigation project designed to serve a command of more than 2000 hectares and up to 10000 hectares, is known as a :
(a) Major irrigation project
(b) Minor irrigation project
(c) Medium irrigation project
(d) None of them, since irrigation projects are classified on the basis of their costs.

4. The method of growing crops on ridges, running on the sides of water ditches, is known as
(a) Flood irrigation
(b) Furrow irrigation
(c) Check irrigation
(d) None of them

5. In a field under furrow irrigation, 'furrows' are referred to represent
(a) Ridges on which crops are grown
(b) Narrow ditches carrying water
(c) Both (a) and (b)
(d) Neither, (a) nor (b)

6. Pinpoint the correct statement.
(a) Irrigation helps in adopting mixed cropping
(b) Mixed cropping means sowing of a different crop after a particular crop has been grown
(c) Over-irrigation may lead to saving in fertilizers
(d) Irrigation helps in avoiding mixed cropping

7. 'Flood irrigation' method of irrigation fields, works best on
(a) Level or gently rolling terrain
(b) Steeply rolling terrain
(c) Both (a) and (b)
(d) None of the above

8. In a mildly water scarce area, the drip irrigation could be preferred for growing:
(a) Wheat
(b) Fodder
(c) Rice
(d) Fruits & vegetables

9. Border method of irrigation is well suited to
(a) Soil having-infiltration rates that are neither low nor high
(b) Coarse sandy soils having high infiltration rates
(c) Clay soils having very low infiltration rates
(d) Soils having salts which require frequent leaching.

10. In an irrigation system, water was delivered to the field in ditches spaced about 30 m apart, and was allowed to seep into the ground to maintain the water table at such a height that the water is available to the crops through the capillary fringe. This method of irrigation is called
(a) Trickle irrigation
(b) Furrow irrigation
(c) Border irrigation
(d) Sub irrigation

GATE QUESTIONS

1. A sprinkler irrigation system is suitable when **[GATE - 2004]**

(a)The land gradient is steep and the soil is easily erodible

(b)The soil is having low permeability

(c)The water table is low

(d) The crops to be grown have deep roots

SOLUTIONS

Sol.1. (a)

The conditions favouring the use of sprinkler irrigation method are:

(i)When the land topography is irregular.

(ii)When the land gradient is steeper and soil is easily erodible.

(iii)When the land soil is excessively permeable.

(iv)When the water table is high.

(v)When the seasonal water requirement is low.

(vi)When the water availability is difficult and scarce.

ESE OBJ QUESTIONS

1. An identified source of irrigation water has ion concentrations of Na^+, Ca^{++} and Mg^{++} as 20, 10 and 8 mille equivalent per liter, respectively. The SAR of this water is approximately.

[ESE - 2011]

(a) 2.06 (b) 6.67
(c) 2.67 (d) zero

2. Assertion (A): In the border strip method of irrigation, the size of the strip depends on soil characteristics, slope of the land and discharge.
Reason (R): Border strip method is a controlled type of subsurface irrigation method.

[ESE - 2010]

(a)Both A and R are true and R is the correct explanation of A
(b)Both A and R are true but R is not a correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

3. Assertion (A): Sprinkler method of irrigation has a higher water application/use efficiency.
Reason (R): Sprinkler system causes less interference in cultivation and other farming operations.

[ESE - 2002]

(a)Both A and R are true and R is the correct explanation of A
(b)Both A and R are true but R is not a correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

SOLUTIONS

Sol.1. (b)
SAR = Sodium Absorption Ratio

$$= \frac{Na^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}} = \frac{20}{\sqrt{\frac{10+8}{2}}} = 6.67$$

Sol.2. (c)

Sol.3. (c)
Sprinkler system consists of network of pipes running across the field. Thus it will cause interference in cultivation and other operation.

WORKBOOK

Example 1. The depth of moisture in root zone at field capacity and permanent wilting point per m depth of soil are 0.5 m/m and 0.2 m/m r respectively. Compute the field capacity and permanent wilting point. Take dry weight of soil as 13.73 kN/m^3.

Solution.

Given,

Depth of moisture in root zone at F.C. per meter depth of soil, $d_a = 0.5$

Depth of moisture in root zone at P.W.P per meter depth of soil, $d_2 = 0.2$ m

Take depth of soil = 1m

$\therefore$ Field capacity

$$= \frac{\text{Wt. of water retained in the root zone corr. to F.C}}{\text{Weight of dry soil}}$$

$$\frac{\gamma_d \times d_w}{\gamma_d .1} = \frac{9.81 \times 0.5}{13.73} = 0.3572 = 35.72\%$$

Permanent wilting point

$$= \frac{\text{Wt. of water ret. in the root zone corr. to PWP}}{\text{Weight of dry soil}}$$

$$= \frac{9.81 \times 0.2}{13.73} = 0.1429 = 14.29\%$$

Example 2. A loam soil has a field capacity of 25 percent and wilting coefficient of 10%. The dry unit weight of soil is 1.5g/cc. If the root zone depth is 60 cm, determine the storage capacity of the soil irrigation water is applied when moisture content falls to 15 percent. If the water application efficiency is 75%, determine the water depth required to be applied in the field.

Solution.

Given,

Field capacity, FC = 25%, Wilting coefficient WC = 10%

Dry unit wt. of soil, γ_d = 1.5 gm/cc; Root zone depth, d = 60cm

Water application efficiency = 75%

Moisture storage capacity of soil in the root zone depth

$$= \frac{\gamma_d}{\gamma_w} \times d \times (FC - WC)$$

$$= \frac{1.5}{1} \times 60 \times (0.25 - 0.10) = 13.5\text{m}$$

Now, when moisture content falls to 15%, the deficiency of water depth created

$$= \frac{\gamma_d}{\gamma_w} \times d \times (0.25 - 0.15)$$

$$= \frac{1.5}{1} \times 60 \times (0.25 - 0.15) = 9\text{cm}$$

Hence, the net irrigation requirement = 9 cm

$$= \frac{\text{Net irrigation requirment}}{\text{Water applicable efficiency}} = \frac{9}{0.75} = 12\text{cm}$$

Example 3. The following data pertains to healthy growth of a crop.

(i) Field capacity of soil = 30%

(ii)Permanent wilting point = 11%

(iii)Density of soil = 1300 kg/m^3

(iv)Effective depth of root zone = 700 mm

(v)Daily consumptive use of water for the given crop = 12 mm

For healthy growth moisture content must not fall below 25% of the water holding capacity between the field capacity and the permanent wilting point. Determine the watering interval in days.

Solution.

Given

Field capacity of soil (FC) = 30%; Permanent wilting percentage (PWP) = 11%

Density of soil, (γ_d) = 1300 kg/m^3; Effective depth of root zone, (d) = 700 mm

Daily consumptive use of water = 12 mm

Determine water interval (T) in days

Key: Moisture content does not fall below 25%

ESE OBJ QUESTIONS

1. Consider the following statements regarding design of channel by Lacey and Kennedy:
1.The theoretical concept of slit transportation is the same in both the theories.
2.Lacey improved upon Kennedy's formula.
3.There are no defects in either the theories of Lacey or of Kennedy.
Which of the above statements are correct?
[ESE - 2017]
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

2. Statement (I): The shear stress exerted by the stream flow on the bed is responsible for the movement of bed sediment particles.
Statement (II): The trap efficiency is a function of the ratio of reservoir capacity to the total inflow. A small reservoir on a large stream has a low trap efficiency.
[ESE - 2016]
(a)Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
(c)Statement (I) is true but Statement (II) is false
(d)Statement (I) is false but Statement (II) is true

3. Statement (I): A channel in alluvium running with constant discharge and constant sediment charge will first form its flow section and then its final longitudinal slope.
Statement (II): If a channel in alluvium has a section too small for a given discharge and slope steeper than required, degradation and aggradations happen and then the flow section attains final regime.
[ESE - 2016]
(a)Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
(c)Statement (I) is true but Statement (II) is false
(d)Statement (I) is false but Statement (II) is true

4. A channel designed by lacey's theory has a mean velocity of 1.1 m/s. The silt factor is 1.1. then hydraulic mean radius will be
[ESE - 2016]
(a) 1.13 m (b) 2.27 m
(c) 3.13 m (d) 4.27 m

5. A barrage on a major river in the Ganetic plains has been designed for a flood discharge 7000 m^3/s. It has been provided with a waterway of 360 m length. The looseness factor of this barrage is
[ESE - 2016]
(a) 1.7 (b) 1.1
(c) 0.7 (d) 0.1

6. The conditions to be satisfied for a channel in 'Regime' as per Lacey are
1.Constant discharge
2.Silt grade and silt concentration are constant.
3.The channel is flowing in unlimited incoherent alluvium of the same alluvial character as that transported.
Which of the above statements are correct?
[ESE - 2016]
(a) 1 and 2 only (b) 1, 2 and 3
(c) 1 and 3 only (d) 2 and 3 only

7. Leaching is a process
[ESE - 2003]
(a)By which alkali salts present in the soil are dissolved and drained away

GATE QUESTIONS

1. The base width of an elementary profile of a gravity dam of height H is b. The specific gravity of the material of the dam is G and uplift pressure coefficient is K. The correct relationship for no tension at the heel is given by

[GATE - 2008]

(a) $\frac{b}{H}=\frac{1}{\sqrt{G-K}}$ (b) $\frac{b}{H}=\sqrt{G-K}$

(c) $\frac{b}{H}=\frac{1}{G-K}$ (d) $\frac{b}{H}=\frac{1}{K\sqrt{G-K}}$

2. While designing a hydraulic structure, the piezometric head at bottom of the floor is computed as 10 m. The datum is 3 m below floor bottom. The assured standing water depth above the floor is 2 m. The specific gravity of the floor material is 2.5. The floor thickness should be

[GATE - 2003]

(a) 2.00m (b) 3.33m

(c) 4.40m (d) 6.00m

3. The live storage requirement for a reservoir is to be determined by

[GATE - 1993]

(a) Topographical survey

(b) Annual demand

(c) Double mass curve analysis

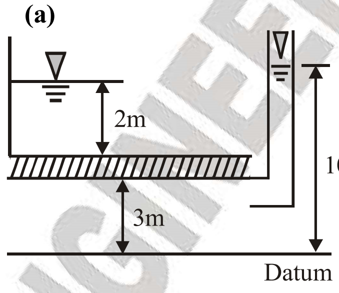
(d) Mass curve analysis

SOLUTIONS

Sol. 1 (a)

Tension will not be developed at the heel with full reservoir, when $b \geq \frac{H}{\sqrt{G-K}}$

Sol. 2 (a)



G = 2.5

Pressure head = 10 – 3 = 7 m

At critical condition

Uplift = Downward pressure

$7 \times \gamma_w = (\gamma_w \times 2) + (\gamma_{floor} \times t)$

$\frac{5\gamma_w}{\gamma_{floor}} = t = \frac{5}{G} = \frac{5}{2.5}$

$\therefore$ t = 2m

Sol. 3 (*)

Super passage

SECTION-B

[HYDROLOGY]

ESE OBJ QUESTIONS

1. Which of the following statements are correct as regards aquifer characteristics?

1.The storage coefficient is the volume of water released from storage from the entire aquifer due to unit depression of peizometrix head.

2.The storage coefficient is the same as the specific yield for water table aquifer.

3.Both the aquifer constants, viz, storage coefficient S and Transmissivity T are dimensionless numbers.

[ESE - 2016]

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

2. Which of the following are pertinent to the realization of hydrological cycle?

1.Latitudinal differences in solar heating of the Earth's surface.

2.Inclination of the Earth's axis

3.Uneven distribution of land and water

4.Coriolis effect.

[ESE - 2012]

(a)1, 2 and 3 only (b) 1, 2 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

3. What is 'Hydrology Cycle'?

[ESE - 2009]

1.Processes involved in the transfer of moisture from sea to land.

2.Processes involved in the transfer of moisture from sea back to sea again

3.Processes involved in the transfer of water from snowmelt in mountains to sea.

4.Processes involved in the transfer of moisture from sea to land and back to sea again.

4. The quantitative of the balance between water gains and losses in a certain basin during a specified period of time is known as which one of the following?

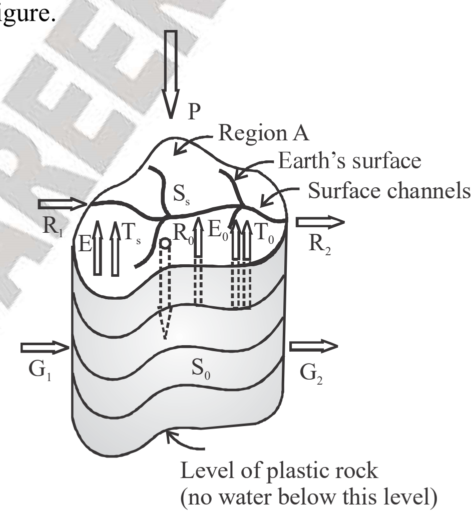
1. Water budget
2. Hydrologic budget
3. Groundwater budget

Select the correct answer using the codes given below:

[ESE - 2007]

(a) 1 only (b) 2 only
(c) 3 only (d) None of these

5. Regional hydrological cycle is shown in the figure.



The correct hydrological budget equations

[ESE - 2002]

(a) $P + R_1 - R_2 - E_S - T_S - I = DS_S$
(b) $I + G_1 - G_2 - R_g - E_g - T_g = DS_g$
(c) $P - (R_2 - R_1) - (E_S + E_g) - (T_S - T_g) - (G_2 - G_2) = D\,(S_S + S_g)$
(d) $P - R - G - E\ T = DS_S$

WORKBOOK

Example 1. The average normal rainfall of 5 rain gauges in the base stations are 89, 54, 41and 55 cm. If the error in the estimation of rainfall should not exceed 10%, how many additional gauges may be required?

Solution.

The mean rainfall is obtained as:

$$P_x = \frac{91.11 + 72.23 + 79.89}{3}$$

$$\text{Now, } \sigma^2 = \frac{\begin{array}{c}(89-56.8)^2 + (54-56.8)^2 + \\ (45-56.8)^2 + (41-56.8)^2 + \\ (55-568)^2\end{array}}{5-1}$$

Or $\sigma^2 = 359.2$

$\therefore \sigma = 18.95$

The coefficient of variation is calculated as :

$$C_V = \frac{19.95}{56.8} = 0.33367$$

$$N = \left(\frac{C_V}{0.10}\right)^2 = \left(\frac{0.33367}{0.1}\right)^2 = 11.13 \equiv 12$$

Thus additional no. required

= (12 – 5) = 7.

Example 2. The normal annual rainfall of stations A,B, C and D in a catchment is 80 mm, 91 mm, 8.5 mm and 87 mm respectively. In the year 2007, the station D was inoperative when stations A, B and C recorded annual rainfall of 91.11, 72.23 and 79.89 mm. Estimate the missing rainfall at station D in the year 2007.

Solution.

Normal precipitation of all the station A, B and C are within 10% of that at station D.

(87 → $87 \times 1.1 = 95.7$

→ $87 \times 0.9 = 78.3$)

Hence simple arithmetic average will he used.

$$\Rightarrow P_x = \frac{91.11 + 72.23 + 79.89}{3}$$

= 81.08 mm

Example 3. Find the missing rainfall at station X.

Rain gauge	Normal	Actual
A	1125	875
B	910	1021
C	765	915
X	830	?

Solution.

As the normal ppt of other-stations-A, B and G are not within in 10% of normal ppt at station x.

(830 → $830 \times 1.1 = 913$

→ $830 \times 0.9 = 747$) Hence

$$\frac{P_x}{N_x} = \frac{1}{3}\left[\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right]$$

$$\frac{P_x}{830} = \frac{1}{3}\left[\frac{875}{1125} + \frac{1021}{910} + \frac{915}{765}\right]$$

$\Rightarrow P_x = 856.5$

Example 4. The annual rainfall at station X and the average annual rainfall at 18 surrounding stations during 1952 to 1970 are as follows:

Annual rainfall in cm at X.

30.5, 38.9, 43.7, 32.2, 27.4, 32.0, 49.3, 28.4, 24.6, 21.8, 28.2, 17.3, 22.3, 28.4, 24.1, 26.9, 20.6, 29.5 and 28.4.

18 stations average annual rainfall in cm:

22.8, 35.0, 30.2, 27.4, 25.2, 28.2, 36.1, 18.4, 25.1, 23.6, 33.3, 23.4, 36.0, 31.2, 23.1, 23.4, 23.1, 33.2 and 26.4.

Explain how the consistency of the record at station X can be verified and how to determine the year in which a change in regime has occurred.

Solution.

CHAPTER - 4
SURFACE WATER HYDROLOGY (*RUNOFF*)

4.1 RUNOFF
Runoff may be referred to as stream flow, river discharge or catchment yield. It is normally expressed as volume per unit time.
Based on the time delay between precipitation and runoff is classified into two categories:
1. Direct runoff
2. Base flow

4.1.1 Direct Runoff
It is that part of runoff which enters the stream immediately after the precipitation. It includes surface runoff prompt interflow and precipitation on the channel surface. It is sometimes termed as direct storm runoff or storm runoff.

4.1.1.1 Surface Runoff
It has two components:
1. Overland flow (flow of water over land before joining any open channel)
2. Open channel flow
Over land flows are small and the flow is taken to be in laminar regime. Length of overland flow is generally small. Open channel flow are in turbulent regime.

4.1.1.2 Interflow
1. Water which infiltrates the soil surface and then moves laterally through the upper soil horizons towards the stream channels above the main groundwater table is known as the Interflow. It is also known as subsurface runoff, subsurface storm flow, storm seepage and secondary base flow.
2. If the lateral hydraulic conductivity of the surface layers are substantially greater than the overall hydraulic conductivity, it is a favourable condition for the generation of interflow. Generally interflow more slowly than surface runoff.
3. Depending upon the time delay between infiltration and its **outflow from** the upper crusts of the soil the interflow is sometimes classified into prompt interflow and delayed **interflow.**

4.1.1.3 Direct Precipitation
Direct precipitation onto the water surface and into the stream channels will normally represent only a small percentage of total volume of water flowing in the streams. This component is usually ignored in runoff calculations.

4.1.2 Base Flow or Ground Water Flow
1. The delayed flow that reaches a stream essentially as groundwater flow is called base flow. Many times delayed interflow is also included under this category.
2. The infiltrated water which percolates deeply becomes groundwater and when groundwater table rises and intersects the stream channels of the basin it discharges into streams as the groundwater runoff.
3. Ground water flow is sometimes referred to as base flow, dry weather flow, and effluent seepage.
4. For the practical purpose of analysis total runoff in stream channels is generally classified as direct runoff and base flow.

WORKBOOK

Example 1. Rainfall of 12, 30, 40, 44 and 17 mm were recorder on 3rd, 9th, 10th, 16th, and 17th days of a particular month. Compute the antecedent precipitation index for the first 20 days of the month and sketch its variation with time. Assume that API of the last day in the previous month is 85 mm and the value of the recession factor K is 0.90.

Solution.

The API of any day 't', denoted by I_t . I_t is obtained from equation $I_t = K.I_{t-1} + P_t$, where P_t is the precipitation of t^{th} day. I_0 = 85 and K = 0.9. The tabular calculation is shown below.

Day t	Precipitation in mm P_t	I_{t-1}
1	0	85.00
2	0	76.50
3	12	68.85
4	0	73.97
5	0	66.57
6	0	59.91
7	0	53.92
8	0	48.53
9	30	43.68
10	40	69.31
11	0	102.38
12	0	92.14
13	0	82.93
14	0	74.64
15	0	67.18
16	44	60.46
17	17	98.41
18	0	105.57
19	0	95.01
20	0	85.51

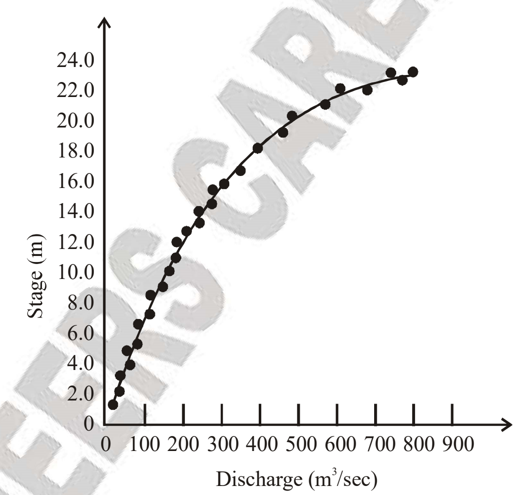
Day t	$K.I_{t-1}$	$I_t = K.I_{t-1} + P_t$
1	76.50	76.50
2	68.85	68.85
3	61.97	73.97
4	66.57	66.57
5	59.91	59.91
6	53.92	53.92
7	48.53	48.53
8	43.68	43.68
9	39.31	69.31
10	62.38	102.38
11	92.14	92.14
12	82.93	82.93
13	74.64	74.64
14	67.18	67.18
15	60.46	60.46
16	54.41	98.41
17	88.57	105.57
18	95.01	95.01
19	85.51	85.51
20	76.96	76.96

Example 2. Given below are the monthly rain-fall P and the corresponding runoff R values covering a period of 18 months for a catchment. Develop a correlation equation between R and P.

Month	P	R
1	5	0.5
2	35	10.5
3	40	13.8
4	30	8.2
5	15	3.1
6	10	3.2
7	5	0.1
8	31	12.0
9	36	16.0
10	30	8.0
11	10	2.3
12	8	1.6
13	2	0.0

CHAPTER - 5
STREAM FLOW MEASUREMENT

5.1 INTRODUCTION
1. Water flowing in a stream is called stream flow.
2. If the stream flow is unaffected by the artificial diversion, storage etc. then it is called runoff (virgin stream flow).'Thus stream flow represents the runoff phase of hydrological cycle.
3. Out of the various processes in hydrological cycle, like evaporation, precipitation, evapo-transpiration etc. stream flow is amenable to fairly accurate measurement.
4. Stream flow is measured in units of discharge (m^3/s)
Flow characteristics of a stream depend upon:
(i) Rainfall characteristics
(ii) Catchment characteristics
(iii) Climatic factors
(iv) It is rather difficult to measure the discharge of flow in the natural streams directly as it is done in the case of flow in pipes or laboratory flumes using the flow meters. But it is very easy to make a direct and continuous measurement of stage in the river which is nothing but the height of the water surface in the river above some arbitrary datum. The higher the stage in the river, the higher is the discharge.



Hence two step procedure is followed for discharge measurement in a stream.
(a) Discharge in a given stream is related to elevation of the water surface (stage) through a series of careful measurements.
(b) Stage of the stream is observed routinely and discharge is estimated by stage-discharge relationship.

5.2 MEASUREMENT OF STAGE
Stage is defined as the water surface elevation measured above a datum (can be MSL or any arbitrary datum,
1. Manual stage measurements are done using
(i) Staff gauge (ii) Wire gauge