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PART - A

2 Marks Questions

Q.1

Sol. It is artificial application of water to the soil of land for the growth of agricultural crops.

Q.2

Sol. (a) Rainfall is uneven and unpredictable
(b) Reducing the mixed crop
(c) irrigation increasing crop yield

Q.3

Sol. (a) Increase in crop yield
(b) avoiding of mixed crop
(c) protection against famines etc.

Q.4

Sol. (a) over irrigation may lead to water logging
(b) may lead to seepage of nitrates.
(c) irrigation may lead to wet climatic conditions which may cause diseases.

Q.5

Sol. The region where irrigation is must for cultivation of any type of crop is called arid region Ex.- thar desert. kutch region etc.

Q.6

Sol. Rabi crops are the crops that are grown in the winter seasons (oct- november) and harvested in march-april (in spring) Ex.- wheat, mustard Barley etc.

Q.7

Sol. These crops are shown at the beginning of the mansoon season (june-july) and harvested at the end of the mosoon (sep-october) Ex.- Rice (paddy). Jowar, Bajra, cotton etc.

Q.8

Sol. Drip irrigation is also known as trickle irrigation.

Q.9

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

$0 < SAR < 10$ - Low sodium water

$10 < SAR < 18$ - Medium sodium water

$18 < SAR < 26$ - High sodium water

Q.10

Sol.
$$L_R = D_d / D_i = \frac{C_i}{C_d} = \frac{EC_i}{EC_d}$$

D_d = depth of irrigation water drained out per unit area.

D_i = depth of irrigation water applied per unit area.

C_i = salt content of irrigation water

C_d = salt content of drainage or leached water

E_c = electrical conductivity

Q.11

Sol. It is aligned along the ridge or natural watershed line. it is also known as ridge canal. it can irrigate areas on both sides of the ridge. in this cross drainage works are not required.



Q.12

Sol. $f = 1.76\sqrt{d_{50}}$
 "d" in mm
 $d_{50\%}$ = 50% particles are finer than that given size.

Q.13

Sol. $v = 10.8R^{2/3} \cdot S^{1/3}$

Q.14

Sol. Garret's diagram are used to design channel's it's use in Kennedy's theory

Q.15

Sol. A trapezoidal c/s is considered the best and most economical c/s for lined canal's because it provides max.- discharge capacity and stability of side slopes.

Q.16

Sol. **Flexibility of outlet** - it is defined as the ratio of rate of change of discharge in the outlet to the rate of change of discharge in the distributory.

$$\text{Flexibility} = \frac{dq/q}{dQ/Q}$$

Sensitivity - It is defined as the ratio of rate of change of discharge in the outlet to the rate of change of water level in the distributory

$$\text{Sensitivity} = \frac{dq/q}{dy/y}$$

Q.17

Sol. Barley, Cotton, sugar beet, date palm, sorghum etc.

Q.18

Sol. Average annual precipitation of India is 119 cm to 120 cm.

Q.19

Sol. Tipping bucket, weighing bucket, natural syphon or float type rain gauge etc

Q.20

Sol. $AI = \frac{PET - AET}{PET} \times 100$ also known as palmar index. $0 \leq AI \leq 1$

Q.21

Sol. Vapour pressure, wind velocity, temperature, atm pressure, size of water body, salinity, etc affects evaporation.

Q.22

Sol. Average pan coefficient of USWB class A Pan is 0.70 & for ISI Pan is 0.80

Q.23

Sol. $E_L = km(e_s - e_a) \left(1 + \frac{u_9}{16}\right)$

Q.24

Sol. **Influent River** - In the river the water table is lower than the river bed so seep's downward from the river into ground.

Effluent River - An effluent river is a river that receives water from the ground water table. The w.t is higher than the river bed, so water flows from the ground into the river.

Q.25

Sol. Compactness coefficient = $\frac{\text{Perimeter of the catchment}}{\text{Circumference of a circle}}$

$$\text{Farm factor} = \frac{\text{average width of the catchment}}{\text{axial length of catchment}} = \frac{B}{l}$$

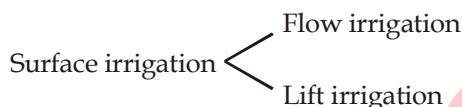
PART - B

5 Marks Questions

Q.26

Sol. **Surface irrigation**

- In this method, irrigation water is distributed to the agricultural land through small channels which flood the area up to a required depth.
- Water is applied and distributed either by gravity or pumping.
- This method is good for soils with low to moderate infiltration capacities and lands with uniform terrain.

(i) **Flow irrigation**

- Water available at higher level is supplied to a lower level by the action of gravity.

(ii) **Lift irrigation**

- Water available at lower is lifted to a higher level by mechanical or manual means and then supplied for irrigation (e.g. pumps etc.)
- Mostly tube wells are used for this purpose.

Flow irrigation can be further subdivided into :

- (a) Perennial irrigation
- (b) Flood irrigation

Subsurface irrigation

- In this method, water flows underground and nourishes plant roots by capillarity.
- Water is applied to the root zones, of crops by underground network of pipes.
- The network consists of main pipe, sub main pipes and lateral perforated pipes.
- This method is suitable for soils which are highly permeable.

It may be divided into following two types.

(i) **Natural Sub-irrigation**

- Leakage water from channels during its passage through sub soil irrigate crops sown on lower lands.

(ii) **Artificial Sub-irrigation**

- In this method, a system of open jointed drain is artificially laid below the soil.
- This is costly process, so recommended in areas where crops provided high returns.

Q.27

Sol. We know that the approximate time required to cover a given area with water can be calculated as

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

where,

Q = Discharge

y = Depth of water flowing over border strip

f = Rate of infiltration

A = Area of land strip to be irrigated

Given data

A = 0.04 ha = $0.04 \times 10^4 \text{ m}^2 = 400 \text{ m}^2$ Q = 0.02 cumecs = $0.02 \times 60 \times 60 = 72 \text{ m}^3/\text{hr}$

f = 5 cm/hr = 0.05 m/hr

y = 10 cm = 0.1 m



$$\therefore t = 2.303 \times \frac{y}{f} \times \log_{10} \left(\frac{Q}{Q - fA} \right)$$

$$t = 2.303 \times \frac{0.1}{0.05} \times \log_{10} \left(\frac{72}{72 - 0.05 \times 400} \right) = 0.651 \text{ hrs} = 39.06 \text{ minutes}$$

Now, maximum area that can be irrigated,

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

It may be noted that after irrigating this much of area, surface flow will stop and deep percolation will start.

Q.28

Sol. **DUTY :**

It is defined as the area of land in hectares which can be irrigated for growing crops if one cumec (1 m³/s) of water is supplied continuously to the land for the base period.

FACTORS AFFECTING DUTY OF WATER :

- (i) Type of crop
- (ii) Climatic condition of the area
- (iii) System of irrigation
- (iv) Method of irrigation
- (v) Quality of irrigation water
- (vi) Method of cultivation
- (vii) Time of irrigation and frequency of cultivation
- (viii) Type of soil and sub soil of the irrigated field
- (ix) Type of soil and sub soil of the area through which canal passes
- (x) Canal condition
- (xi) Topography of land
- (xii) Base period of crop

(i) TYPE OF CROPS :

- The crops which require large quantity of water have lower duty of water than for the crops which require less quantity of water.

(ii) CLIMATIC CONDITION OF THE AREA :

- If temperature is high, evaporation will be more and hence the duty of water will be less.
- If wind velocity is high, evaporation will be more and hence the duty of water will be less.
- If humidity is high, loss of water due to evaporation will be less, hence duty of water will be more.
- Further, if during the base period of a crop there is rainfall then less quantity of irrigation water will be required to be supplied the duty of water will increase.

(iii) SYSTEM OF IRRIGATION :

- In the perennial irrigation system the soil of the irrigated area remains continuously wet and hence less quantity of water is required for initial saturation of the soil.
- In the inundation irrigation system there is a wasteful use of water. As such for perennial irrigation system the duty of water is higher than for the inundation irrigation system.

(iv) METHOD OF IRRIGATION :

- Among various surface irrigation methods the duty of water is higher for furrow method than for any of the flooding method because water is not applied to the entire land surface so water losses are considerably less.
- Further as compared to the surface irrigation methods the duty of water is high for the sprinkler irrigation method as well as for the sub-surface irrigation methods and generally for the drip irrigation method the duty of water is the highest.



(v) QUALITY OF IRRIGATION WATER :

- If the irrigation water contains an appreciable amount of harmful salts, alkalis dissolved then it results in a lower duty of water due to the wastage of considerable amount of water.

(vi) METHOD OF CULTIVATION :

- If the land is properly ploughed upto the required depth and made quite loose before irrigation, the soil will have high water retaining capacity in the root zone of the plants. This will reduce the number of waterings and hence results in a higher duty of water.
- Further the use of modern methods of cultivation gives higher duty of water than the old conventional methods of cultivation.

(vii) TIME OF IRRIGATION AND FREQUENCY OF CULTIVATION :

- In the initial stage, the land to be cultivated may not be properly levelled and hence more quantity of water may be applied, which will result in a lower duty of water.
- The land slope may gradually improve with time then only the required quantity of water will be applied and hence the duty of water will be high.
- Frequent cultivation of land reduces the loss of moisture through weeds and evaporation from soil and hence results in a higher duty of water.

(viii) TYPE OF SOIL AND SUB-SOIL OF THE IRRIGATED FIELD :

- If the soil and sub soil of the field to be irrigated is coarse grained then due to high percolation loss duty of water will be low.

(ix) TYPE OF SOIL AND SUB SOIL OF THE AREA THROUGH WHICH CANAL PASSES :

- If the canal is unlined and it passes through coarse grained soil then there will be greater percolation loss, the duty of water will be low.

(x) CANAL CONDITION :

- In an earthen canal, the percolation loss will be high which will result in a low duty of water.

(xi) TOPOGRAPHY OF LAND :

- If the land to be irrigated is properly levelled then uniform application of water will be possible which will result in economical use of water and hence a higher duty of water.

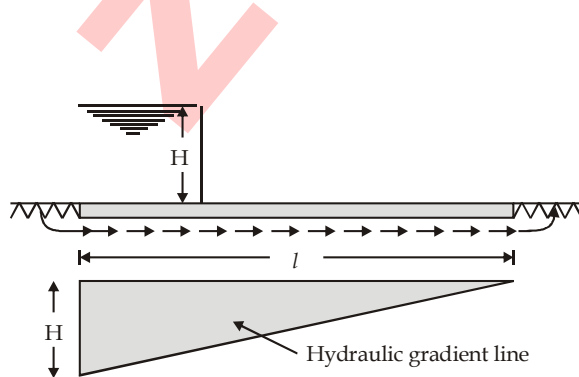
(xii) BASE PERIOD OF CROP :

- In general when the base period of a crop is long, more water may be required thus resulting in a lower duty of water.
- However, the requirement of water is not directly proportional to the base period of the crop.

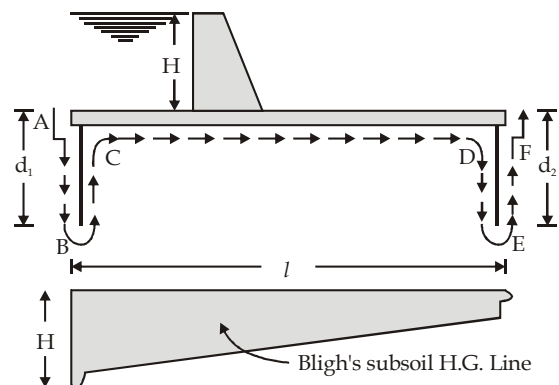
Q.29

Sol. **Bligh's Creep Theory**

- He developed a theory for the sub surface flow.



(a) Floor without vertical cutoffs



(b) Floor with vertical cutoffs

- He assumed that percolating water flows the outline of the base of the structure which is in contact with the subsoil.
- Length of path transverse by the percolating water is called length of the creep.
- He also assumed that the head loss per unit length of creep is constant throughout the percolating passage.

$$\text{Hydraulic gradient} = \frac{\text{Head loss}}{\text{Length of creep}}$$

Limitations :

- He made no distinction between horizontal and vertical creep.
- He did not indicated any significance of the term 'exit gradient'.
- He did not specify the necessity of providing a cut off at the downstream end of the floor.
- This method holds good as long as the horizontal distance between pile lines is greater than twice their depth.
- Loss of head does not take place in the same proportion as creep length.

Q.30

Sol. The following factors need to be considered for construction of dam :

- Purpose of dam i.e. dam is to be constructed for storage purpose or for hydro power generation or for irrigation etc.
- Number of beneficiaries to be served by the dam.
- Availability of hard rocks for abutments.
- The valley should be deep and narrow for large storage volume.
- The area upstream of the dam should open in a large expense so that sufficient volume for storage is available.
- Head available if the dam is to be used for hydro power generation.
- Seismic characteristics of the area where dam is to be located.
- Availability of approaches for the dam.
- Minimum dry weather flow of the river.
- HFL in the river reached in the past and expected in future.
- Amount of precipitation in the catchment.
- Number of people which will get affected by the construction of dam.
- Impact of dam on environment i.e. EIA (Environment Impact Assessment) studies.
- Design life of the dam.

Economic Height of Dam :

The economic height of a dam is that height of dam, corresponding to which, the cost of dam per unit of storage is minimum.

Q.31

Sol. Forms of Precipitation :

The various forms of precipitation are : Drizzle, rain, glaze, sleet, snow, snow flakes and hail.

Drizzle : When the size of water droplets is under 0.5 mm, and its intensity is <1 mm per hour. Because of the lightness, the droplets appear to be floating in air.

Rain : When the size of the drops is more than 0.5 mm. The upper size of water drop is generally 6.25 mm, as drops greater than this tend to break up as they fall through the air.

Glaze : When the drizzle or rain freezes as it comes in contact with cold objects, it is known as glaze.

Sleet : It is frozen rain drops cooled to the ice stage while falling through air at sub-freezing temperature.

Snow : Precipitation in the form of ice crystals resulting from sublimations (i.e. water vapour changed directly to ice).

Snowflakes Number of ice crystals fused together to form snow flakes.

Hail : Hail is lumps or bulbs of ice over 5 mm diameter formed by alternate freezing or melting as they are carried up and down in highly turbulent air currents.

Q.32

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Q.33

Sol. Number of rain gauge stations in a given catchment must be sufficient so that the error in precipitation measurement is not more than acceptable value.

Rain gauge station	I	II	III	IV	V
Annual rainfall (in cm)	100	120	190	95	125

Calculation of mean rainfall (P_m),

$$P_m = \frac{P_1 + P_2 + P_3 + P_4 + P_5}{5} = \frac{100 + 120 + 190 + 95 + 125}{5}$$

$$P_m = 126 \text{ cm}$$

Calculation of standard deviation, (σ_{n-1})

$$\sigma_{n-1} = \sqrt{\frac{(P_1 - P_m)^2 + (P_2 - P_m)^2 + \dots + (P_5 - P_m)^2}{n-1}}$$

$$= \sqrt{\frac{(100-126)^2 + (120-126)^2 + (190-126)^2 + (95-126)^2 + (125-126)^2}{4}}$$

$$\sigma_{n-1} = 37.98 \text{ cm}$$

Calculation of coefficient of variation (C_v) :

$$C_v = \frac{\sigma_{n-1}}{P_m} \times 100 = \frac{37.98}{126} \times 100$$

$$C_v = 30.143\%$$

Optimum number of stations, (N)

$$N = \left(\frac{C_v}{\epsilon} \right)^2$$

Where,

ϵ = Allowable degree of error in % age

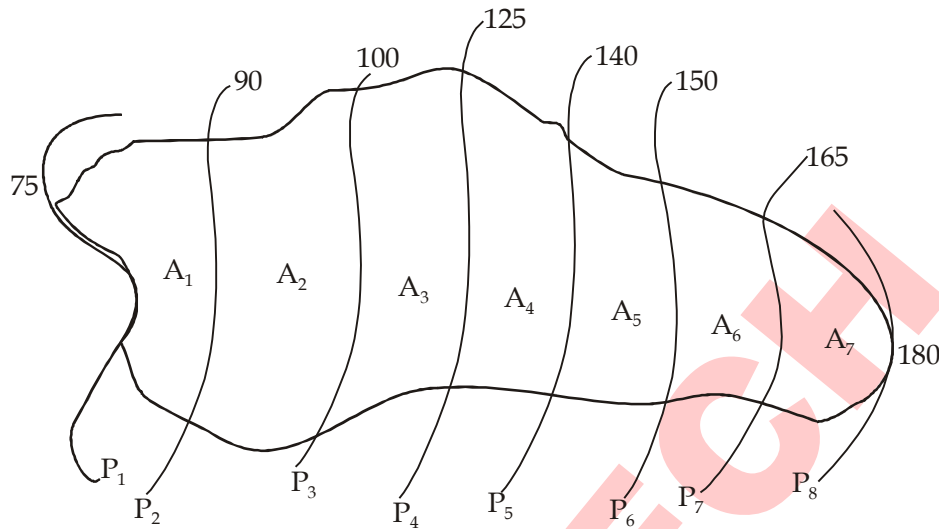
$$N = \left(\frac{30.143}{10} \right)^2 = 9.086 \approx 10$$

According to WMO, at least 10% of the total rain-gauges should be of self-recording type

$\therefore$ Number of recording type gauge station = 1 and number of non-recording type gauge stations = 9.

Q.34

Sol.



Isohyets (mm)	Area between Isohyets (sq. km)
P ₁ = 75	60 = A ₁
P ₂ = 90	275 = A ₂
P ₃ = 100	260 = A ₃
P ₄ = 125	150 = A ₄
P ₅ = 140	380 = A ₅
P ₆ = 150	215 = A ₆
P ₇ = 165	120 = A ₇
P ₈ = 180	<u>ΣA = 1460 km²</u>

In Isohyetal method,

$$\text{Average precipitation} = \frac{A_1 \left(\frac{P_1 + P_2}{2} \right) + A_2 \left(\frac{P_2 + P_3}{2} \right) + \dots + A_7 \left(\frac{P_7 + P_8}{2} \right)}{A_1 + A_2 + \dots + A_7}$$

$$= \frac{60 \left(\frac{75 + 90}{2} \right) + 275 \left(\frac{90 + 100}{2} \right) + 260 \left(\frac{100 + 125}{2} \right) + 150 \left(\frac{125 + 140}{2} \right) + 380 \left(\frac{140 + 150}{2} \right) + 215 \left(\frac{150 + 165}{2} \right) + 120 \left(\frac{165 + 180}{2} \right)}{60 + 275 + 260 + 150 + 380 + 215 + 120}$$

$$= 130.043 \text{ mm}$$

∴ Equivalent uniform depth = 130.043 mm

Depth of flow = EUD $\times$ Coefficient of run-off

$$= 130.04 \times 0.4 = 52.016 \text{ mm}$$

Volume of run-off = Depth of flow $\times$ Area of catchment

$$= 52.016 \times 10^{-3} \times 1460 \times 10^6 \text{ m}^3$$

$$= 75.84 \times 10^6 \text{ m}^3$$

Q.35

Sol. The calculations for determining the equivalent uniform depth are tabulated below :

Station	Area %	Fraction of Total area	Rainfall (mm)	Weighted Rainfall (mm) (Col. 3 $\times$ col. 4)
(1)	(2)	(3)	(4)	(5)
P	24	0.24	45	10.80
Q	21	0.21	57	11.97
R	37	0.37	65	24.05
S	08	0.08	67	5.36
T	10	0.10	78	7.80
	$\Sigma A = 100$	1.00		59.98 mm

Therefore the equivalent uniform depth of rainfall = 59.98 mm.

Q.36

Sol. Given,

$$N_x = 700 \text{ mm}, N_A = 1000 \text{ mm}, N_B = 900 \text{ mm}, N_C = 800 \text{ mm}$$

&

$$P_A = 100 \text{ mm}, P_B = 90 \text{ mm}, P_C = 80 \text{ mm}$$

10% range for normal precipitation of any of given station is between 700×1.1 and 700×0.9 i.e. between 770 and 630

As, normal precipitation of given station is above 10% of the missing station, we have to use normal ratio method

$$\frac{P_x}{N_x} = \frac{1}{m} \left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \dots + \frac{P_m}{N_m} \right]$$

$$\Rightarrow \frac{P_x}{700} = \frac{1}{3} \left[\frac{100}{1000} + \frac{90}{900} + \frac{80}{800} \right]$$

$$\Rightarrow \frac{P_x}{700} = \frac{1}{3} \times \frac{3}{10}$$

$$\Rightarrow P_x = 70 \text{ mm}$$

$\therefore$ The average precipitation at the missing station is 70 mm

Q.37

Sol. The various factors affecting evaporation from water surfaces are described below :

(i) **VAPOUR PRESSURE :**

The rate of evaporation is proportional to the difference between the saturation vapour pressure (e_w) at the existing water temperature, and the existing actual vapour pressure in the air, (e_a).

As per Dalton's law, $E_L = k(e_w - e_a)$

Where, E_L = Rate of evaporation (mm/day)

$$e_w, e_a = \text{In mm of Hg}$$

If $e_w > e_a$ = Evaporation takes place and

If $e_w < e_a$ = Condensation take place

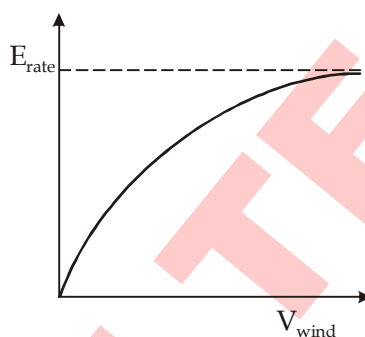
k = Constant depending upon various factors like barometric pressure, humidity, wind velocity etc.

(ii) TEMPERATURE :

Other factors remaining same, the rate of evaporation increases with an increase in water temperature because if temperature is more, the saturation vapour pressure (e_w) increase, thereby increasing the rate of evaporation.

(iii) WIND VELOCITY :

Increase in wind velocity increases the rate of evaporation upto a certain extent. Wind aids in removing the evaporated water vapour from the zone of evaporation, which increases the scope of evaporation. However, if the wind velocity is large enough to remove all the evaporated water vapour (critical wind speed), any further increase in wind velocity does not influence the evaporation.



(iv) ATMOSPHERIC PRESSURE :

As per Daltons law, if the atmospheric pressure (e_a) is less, naturally evaporation will be lesser. A decrease in barometric pressure, as in high altitudes, increase evaporation.

(v) WATER QUALITY :

Rate of evaporation varies according to the quality of water.

For example : Salinity decrease evaporation.

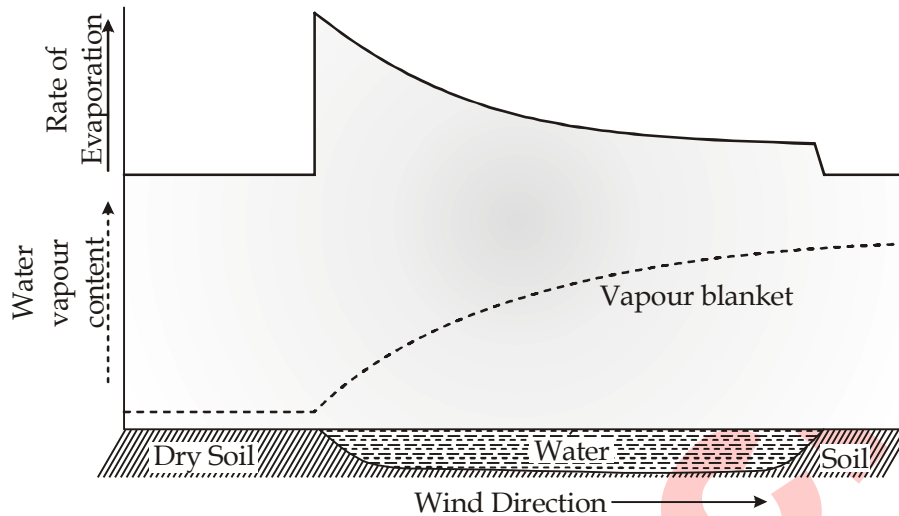
(For every 1% increase in salinity, evaporation decrease by 1%)

(vi) DEPTH OF WATER BODY :

The depth of water body influences the evaporation considerably. An increase in depth reduces the summer evaporation and increase the winter evaporation.

(vii) SHAPE AND SIZE OF WATER SURFACE :

Air moving across a large lake has a low water vapour content at the upwind edge and evaporation from the lake surface will gradually increase the water vapour content. Thus, a vapour blanket is created over the lake, the thickness of which increases in windward direction. There will be decrease in rate of evaporation as the vapour blanket in contact with water surface increase in thickness. Thus, larger the lake, the greater will be the total reduction in evaporation.



Amount of water evaporated from a water surface is estimated by the following methods :

(i) **USING EVAPORIMETER DATA :**

Evaporimeters are water-containing pans which are exposed to the atmosphere, and the loss of water by evaporation in them is measured at regular intervals.

Types of Evaporimeter :

- (a) Class A Evaporation pan (US weather Bureau)
- (b) ISI standard pan (Used in India)
- (c) Colorado sunken pan
- (d) US Geological survey floating pan (evaporimeter is kept floating in lake)

(ii) **ANALYTICAL METHODS :**

They are broadly classified into three categories :

- (a) Water-Budget Method (uses hydrological continuity equation for the lake)
- (b) Energy-Balance Method (uses the law of energy conservation)
- (c) Mass-Transfer method (based on theories of turbulent mass transfer in a boundary layer)

(iii) **EMPERICAL EQUATIONS :**

Emperical formulae are based on Dalton's law.

Meyer's Formula :

The lake evaporation as per Meyer's formula is given as :

$$E_L = K_M (e_w - e_a) \left(1 + \frac{\mu_9}{16} \right)$$

Where, E_L = Lake evaporation in mm/day
 e_w = Saturated vapour pressure at the water surface in mm of Hg
 e_a = Actual vapour pressure of overlying air at a specified height in mm of Hg.
 μ_9 = Mean monthly wind velocity in km/hr at a height of 9 m above ground.

Wind velocity is assumed to follow the $\frac{1}{7}$ power law.

$$\mu_h \propto h^{1/7}$$

μ_h = Wind velocity at height h in km/hr

Therefore, if wind velocity is given for any other elevation, wind velocity at height of 9 m from the ground can be calculated using above relation.

$k_m \rightarrow 0.36$ = For large and deep waters.

0.50 = For small and shallow waters.

Q.38

Sol.

Total rainfall, (P) = 10 mm

Antecedent moisture in root, (R) = 5 mm

Seepage loss, (L_s) = 2.5 mmPercolation loss, (L_p) = 2.0 mmSurface run-off, (L_R) = 3 mm

Moisture retained in soil = 1 mm

As per water budget equation

$$P + R - L_s - L_p - L_R - L_e = \text{Moisture retained}$$

Where,

 $L_e \rightarrow$ Loss due to evapotranspiration

$$10 + 5 - 2.5 - 2.0 - 3 - L_e = 1$$

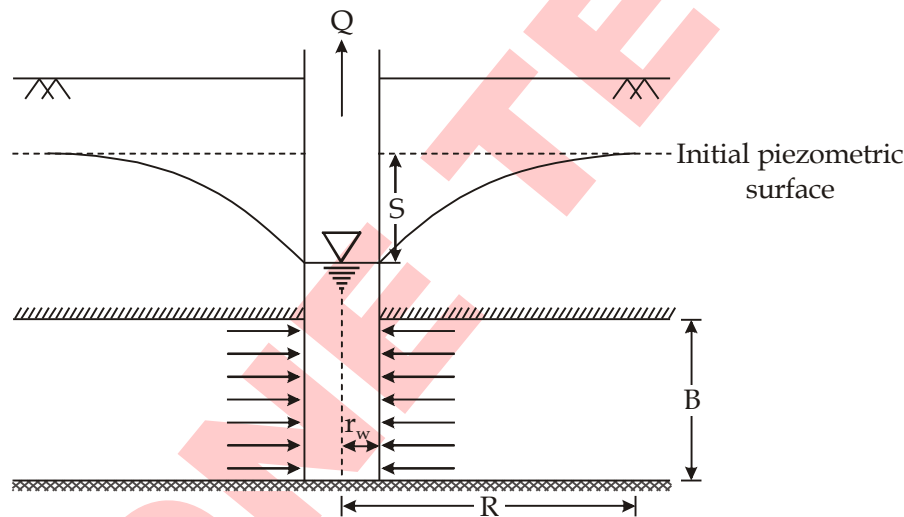
 $\Rightarrow$

$$L_e = 6.5 \text{ mm}$$

 $\therefore$ Amount of evapotranspiration = 6.5 mm

Q.39

Sol.



For confined aquifer case, the discharge is given by

$$Q = \frac{2\pi K B S}{\ln\left(\frac{R}{r_w}\right)}$$

where,

B = Thickness of aquifer = Length of strainer = 15 m

S = Drawdown = 3 m

K = Coefficient of permeability = 50 m/day

R = Radius of drawdown = 150 m

$$r_w = \text{Radius of tube well} = \left(\frac{0.3}{2}\right) = 0.15 \text{ m}$$

 $\therefore$

$$Q = \frac{2 \times \pi \times 50 \times 15 \times 3}{\ln\left(\frac{150}{0.15}\right)} = 2046.564 \text{ m}^3/\text{day}$$

$$Q = \left(\frac{2046.56 \times 10^3}{24 \times 60 \times 60} \right) \text{ lt/sec}$$

$$Q = 23.687 \text{ lt/sec}$$

PART - C

20 Marks Questions

Q.40

Sol. Given,

Moisture holding capacity of soil (per metre depth of soil) = 140 mm

Root depth of the crop = 30 cm

Allowable depletion of water = 35%

Daily water use by the crop = 5 mm/day

Area to be irrigated = 60 ha = $60 \times 10^4 \text{ m}^2$

Rate of delivery of water = 28 lps

Irrigation application efficiency = 40%

(i) Moisture storage capacity of soil = Depth of water stored in root zone
 $= 140 \text{ mm/m} \times \text{Root depth of crop}$

$$= 140 \times \frac{30}{100} = 42 \text{ mm}$$

$\therefore$ Allowable depletion depth between irrigations

$$= \frac{35}{100} \times 42 = 14.7 \text{ mm}$$

(ii) Frequency of irrigation

$$= \frac{\text{Allowable depletion depth between irrigations}}{\text{Daily water use by the crop}} = \frac{14.7}{5}$$

$$= 2.94 \text{ days}$$

(iii) Net application depth

$$= \frac{14.7}{0.40} = 36.75 \text{ mm}$$

(iv) Volume of water required

$$= \text{Area to be irrigated} \times \text{Net application depth of water}$$

$$= 60 \times 10^4 \times 36.75 \times 10^{-3}$$

$$= 22.05 \times 10^3 \text{ m}^3 = 22.05 \times 10^6 \text{ litres}$$

(v) Volume of water required to irrigate 4 ha plot

$$= 4 \times 10^4 \times 36.75 \times 10^{-3}$$

$$= 1.47 \times 10^3 \text{ m}^3 = 1.47 \times 10^6 \text{ litres}$$

Time to irrigate 4 ha plot

$$= \frac{\text{Volume of water required}}{\text{Rate of delivery of water}} = \frac{1.47 \times 10^6}{28}$$

$$= 5.25 \times 10^4 \text{ s} = 14.583 \text{ hrs}$$

Q.41

Sol. (i) Field irrigation requirement (FIR) :

It is defined as the amount of water required to meet the 'net irrigation requirements' plus the amount of water lost as surface run-off and through deep percolation.

$$F.I.R. = \frac{N.I.R.}{\eta_a}$$

where, $\eta_a \rightarrow$ Water application efficiency

(ii) 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.

If, $w_s \rightarrow$ Quantity of water stored in root zone
 $w_f \rightarrow$ Quantity of water delivered to the field

$$\eta_a = \frac{w_s}{w_f} \times 100$$

(iii) Water storage efficiency (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 the soil to the field capacity.

If, $w_s \rightarrow$ Quantity of water stored in the root zone
 $w_n \rightarrow$ Quantity of water needed to bring the moisture content of the soil to the field capacity.

(i.e., $w_n =$ Field capacity - Available moisture in the soil prior to irrigation), then

$$\eta_s = \frac{w_s}{w_n} \times 100$$

(iv) Water distribution Efficiency (η_d)

Water distribution efficiency evaluates the degree to which water is uniformly distributed throughout the root zone during irrigation and hence it is also known as uniformity coefficient. It is determined from the following equation :

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

Where, y is the average numerical deviation in depth of water stored from the average depth of water ' d ' stored in the root zone during irrigation.

(v) Consumptive use (or evapotranspiration) :

Consumptive use of water or evapotranspiration 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 is expressed as equivalent depth of water over an area in a given time period (mm/day)

Q.42

Sol.

$$W_r = \text{Water released from the canal} \\ = (150 \times 10^{-3}) \times (8 \times 3600) = 4320 \text{ m}^3$$

$$W_f = \text{Water delivered to the field} \\ = (110 \times 10^{-3}) \times (8 \times 3600) = 3168 \text{ m}^3$$

$$W_s = \text{Water stored in the the root zone of the plant by supplied water} \\ = W_f - \text{Run-off} \\ = 3168 - 445 = 2723 \text{ m}^3$$

$\therefore$ Water conveyance efficiency (η_c),



$$= \frac{W_f}{W_r} \times 100 = \frac{3168}{4320} \times 100 = 73.33\%$$

∴ Water application efficiency (η_a),

$$= \frac{W_s}{W_f} \times 100 = \frac{2723}{3168} \times 100 = 86\%$$

Moisture holding capacity of soil in root zone

$$= 200 \times 1.5 = 300\text{mm}$$

W_n = Moisture required in root zone

$$= \frac{50}{100} \times \left(\frac{300}{1000} \times 2.2 \times 10^4 \right) = 3300\text{m}^3$$

∴ Water storage efficiency (η_s),

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

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

Average numerical deviation,

$$y = \frac{|1.5 - 1.3| + |1.1 - 1.3|}{2} = 0.2$$

∴ Water distribution efficiency (η_d),

$$\eta_d = \left(1 - \frac{y}{d} \right) \times 100 = \left(1 - \frac{0.2}{1.3} \right) \times 100 = 84.62\%$$

Q.43

Sol. Volume of water required by each crop during their rotation period are calculated as follows :

Volume of water required for wheat :

$$\begin{aligned} &= \text{Area} \times \text{Intensity} \\ &= 2 \times 10^4 \times 7.5 \times 10^{-2} \\ &= 1500 \text{ m}^3 \text{ @ every 12}^{\text{th}} \text{ day in 10 hours} \end{aligned}$$

Volume of water required for cotton :

$$\begin{aligned} &= 0.4 \times 10^4 \times 7.5 \times 10^{-2} \\ &= 300 \text{ m}^3 \text{ @ every 20}^{\text{th}} \text{ day in 10 hours} \end{aligned}$$

Volume of water required for vegetables :

$$\begin{aligned} &= 0.4 \times 10^4 \times 7.5 \times 10^{-2} \\ &= 300 \text{ m}^3 \text{ @ every 10}^{\text{th}} \text{ day in 10 hours} \end{aligned}$$

Volume of water required for mustard :

$$\begin{aligned} &= 2.2 \times 10^4 \times 5 \times 10^{-2} \\ &= 1100 \text{ m}^3 \text{ @ every 40}^{\text{th}} \text{ day in 10 hours} \end{aligned}$$

This shows that maximum water is required for wheat, i.e., 1500 m³ in 10 hours.

∴ Water to be pumped in l/sec

$$\begin{aligned} &= \frac{1500}{10 \times 60 \times 60} \times 1000 \text{ l/sec} \\ &= 41.67 \text{ l/sec} \end{aligned}$$

∴ Capacity of centrifugal pump to be used by the farmer = 41.67 l/sec.

Q.44

Sol. Given,

$$Q = 50 \text{ m}^3/\text{sec}$$

$$\text{Slope (S)} = \frac{1}{4000}$$

Critical velocity ratio for soil (m) = 1.1

Kutter's rugosity coefficient (n) = 0.023

Trial 1

Assume depth of flow (1st trial depth y) = 2.5 m

$$\begin{aligned} \text{Then, Critical velocity (V}_0\text{)} &= 0.55my^{0.64} \\ &= 0.55 \times 1.1 \times 2.5^{0.64} \\ &= 1.088 \text{ m/sec} \end{aligned}$$

$$\text{Flow area (A)} = \frac{Q}{V} = \frac{50}{1.088} = 45.96 \text{ m}^2$$

We consider the section to be trapezoidal section having side slope of 0.5 H : 1 V

$$\text{Area (A)} = (B + 0.5 y)y = 45.96 \text{ m}^2$$

$$\begin{aligned} \Rightarrow B &= \frac{45.96}{2.5} - 0.5 \times 2.5 \\ B &= 17.134 \text{ m} \end{aligned}$$

$$\text{Then, Perimeter of channel (p)} = (B + 2y\sqrt{1 + 0.5^2}) = 22.73 \text{ m}$$

$$\text{So, Hydraulic mean depth (R)} = \frac{A}{P} = \frac{45.96}{22.73} = 2.02$$

Now, mean velocity of the channel (by Kutter's equation)

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

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

$$V = 1.10 \text{ m/sec}$$

Here, V is almost equal to V₀

Hence, the section should have

$$\text{Width} = 17.13 \text{ m}$$

$$\text{Depth} = 2.5 \text{ m}$$

$$\text{Bed slope (S)} = \frac{1}{4000}$$

$$\text{Side slope} = 0.5 \text{ H} : 1 \text{ V}$$

Q.45

Sol. Design procedure for Lacey's theory is as follows :

(i) Calculation of Velocity :

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

Where Q is discharge in cumecs, V is velocity in m/s and f is silt factor, it is given by

$$f = 1.76\sqrt{d_{\text{mm}}}$$

where d_{mm} is average particle size in mm

$$\text{Thus, } f = 1.76\sqrt{0.5} = 1.24$$

$$V = \left(\frac{5 \times (1.24)^2}{140} \right)^{1/6} = 0.617 \text{ m/s}$$

(ii) Calculation of hydraulic mean depth

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

$$R = \frac{5}{2} \times \frac{(0.617)^2}{1.24} = 0.768 \text{ m}$$

(iii) Calculation of area of channel section

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

$$A = \frac{5}{0.617} = 8.104 \text{ m}^2$$

(iv) Calculation of wetted perimeter

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

$$P = 4.75\sqrt{5} = 10.62 \text{ m}$$

For a trapezoidal channel with side slope of $\frac{1}{2} H : 1 V$, we get

$$P = B + 2y\sqrt{N^2 + 1}$$

and

$$A = (B + Ny)y$$

$$\therefore (B + 0.5y)y = 8.104 \quad \dots(i)$$

$$B + 2y\sqrt{(0.5)^2 + 1} = 10.62 \quad \dots(ii)$$

Solving (i) and (ii), we get $y = 0.9 \text{ m}$ and $B = 8.6 \text{ m}$

(v) Calculation of bed slope

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

$$S = \frac{(1.24)^{5/3}}{3340 \times (5)^{1/6}}$$

$$S = \frac{1}{3051.68} \approx \frac{1}{3052}$$

Q.46

Sol. Given,

Discharge,

$$Q = 100 \text{ m}^3/\text{s}$$

Bed slope,

$$S = \frac{1}{2500}$$

Maximum permissible velocity,

$$v = 2 \text{ m/s}$$

Manning's coefficient,

$$n = 0.013$$

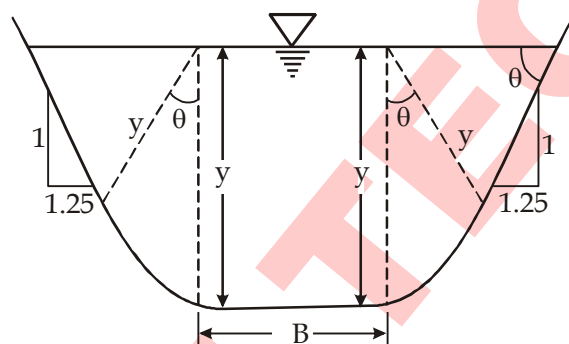
Side slope = 1.25 H : 1 V

$$\cot \theta = 1.25$$

 $\Rightarrow$

$$\tan \theta = \frac{1}{1.25} = 0.8$$

$$\theta = 38.66^\circ = 0.6747 \text{ rad}$$



From Manning's equation, we get

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

 $\Rightarrow$

$$2 = \frac{1}{0.013} \times R^{2/3} \times \left(\frac{1}{2500} \right)^{1/2}$$

 $\Rightarrow$

$$R = 1.4822 \text{ m}$$

Area

$$A = \frac{Q}{v} = \frac{100}{2} = 50 \text{ m}^2$$

 $\therefore$

$$R = \frac{A}{P}$$

 $\therefore$ Perimeter,

$$P = \frac{A}{R} = \frac{50}{1.4822} = 33.73 \text{ m}$$

Since for a lined canal (trapezoidal section)

$$A = By + y^2(\theta + \cot \theta)$$

and

$$P = B + 2y(\theta + \cot \theta)$$

$$\therefore 50 = By + y^2(\theta + \cot \theta)$$

 $\Rightarrow$

$$50 = By + y^2(0.6747 + 1.25)$$

$$\Rightarrow 50 = By + 1.925y^2$$

...(i)

$$\therefore 33.73 = B + 2y(\theta + \cot \theta)$$

 $\Rightarrow$

$$33.73 = B + 2 \times y(0.6747 + 1.25)$$

$$\Rightarrow 33.73 = B + 3.85y$$

$$\Rightarrow B = 33.73 - 3.85y$$

...(ii)



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

$$50 = y(33.73 - 3.85y + 1.925y)$$

$$\Rightarrow 50 = y(33.73 - 1.925y)$$

$$\Rightarrow 0 = 1.925y^2 - 33.73y + 50$$

$$\Rightarrow y = 15.9 \text{ m}, 1.635 \text{ m}$$

$$\therefore y = 1.635 \text{ m} \quad (\text{neglecting larger non feasible values})$$

Putting the value of y in equation (ii), we get

$$B = 33.73 - 3.85 \times 1.635 = 27.43 \text{ m}$$

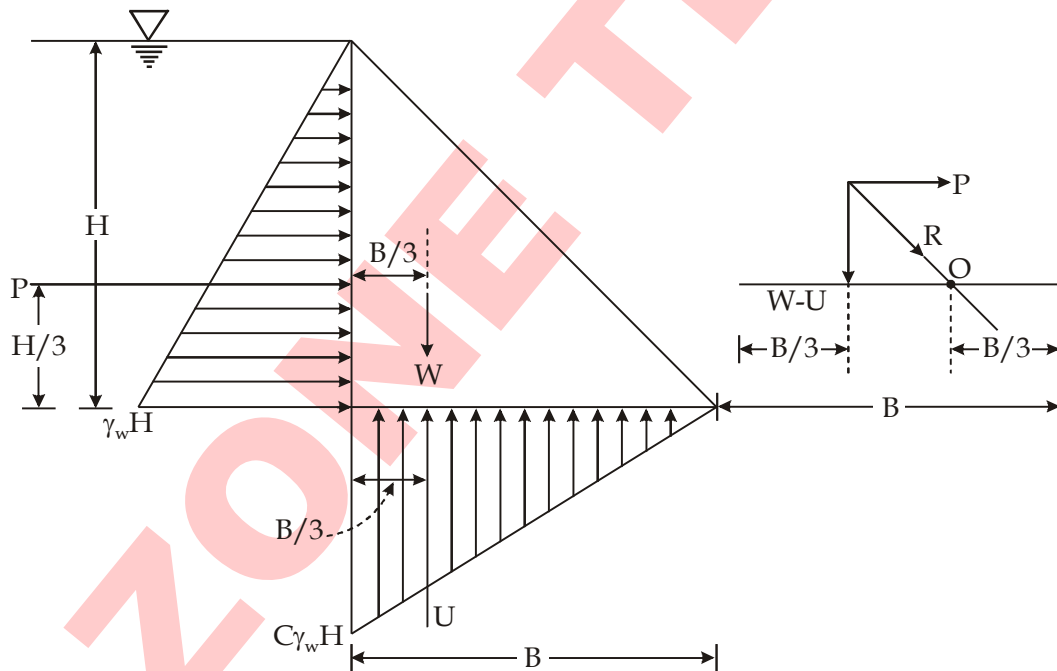
Hence, Bed width, B = 27.43 m and Depth, y = 1.635 m

Q.47

Sol. The elementary profile of a gravity dam, subjected only to the external water pressure on the u/s side, will be a right-angled triangle having zero width at the water level and a based width (B) at the bottom. In other words, the shape of such a profile is similar to the shape of the hydrostatic pressure distribution.

When the reservoir is full, the base width is governed by :

- (i) The resultant of all the forces, i.e. hydrostatic water pressure, uplift pressure and self-weight of dam passes through the outermost middle third point (i.e. lower middle third point).



Taking moment of all the forces about point O i.e., the point through which resultant is passing, (for no tension to develop, R must pass through outermost middle third point).

$$(W - U) \frac{B}{3} - P \left(\frac{H}{3} \right) = 0 \quad \dots(i)$$

$$W = \frac{1}{2} \times B \times H \times \gamma_w \times S_c$$

$$P = \frac{1}{2} \gamma_w H^2$$

and

$$U = \left(\frac{1}{2} C \gamma_w H \right) B$$

Where $C \rightarrow$ Constant whose value is recommended to be equal to 1.0 in calculation and is zero when there is no uplift.

$$\therefore \text{Equation (i) becomes } \left(\frac{1}{2} B H \gamma_w S_c - \frac{1}{2} C \gamma_w H B \right) \frac{B}{3} - \frac{1}{2} \gamma_w H^2 \times \frac{H}{3} = 0$$

$$\frac{B^2 H \gamma_w}{6} (S_c - C) = \frac{\gamma_w H^3}{6}$$

$$\Rightarrow B^2 (S_c - C) = H^2$$

$$\Rightarrow B = \frac{H}{\sqrt{S_c - C}}$$

If B is taken equal to or greater than $\frac{H}{\sqrt{S_c - C}}$, no tension will develop at the heel with full reservoir.

when $C = 1$, $B = \frac{H}{\sqrt{S_c - 1}}$

If uplift is not considered, $C = 0$

$$B = \frac{H}{\sqrt{S_c}}$$

(ii) The dam is safe in sliding :

The frictional resistance $\mu \Sigma V$ or $\mu(W - U)$ should be equal to or more than the horizontal forces $\Sigma H = P$.

$$\mu(W - U) \geq P$$

$$\mu \left(\frac{1}{2} B H S_c \gamma_w - \frac{1}{2} C \gamma_w B H \right) \geq \frac{\gamma_w H^2}{2}$$

$$\mu (S_c - C) \frac{1}{2} B H \gamma_w \geq \gamma_w \frac{H^2}{2}$$

$$\mu (S_c - C) B \geq H$$

$$\Rightarrow B \geq \frac{H}{\mu (S_c - C)}$$

If $C = 1$, $B \geq \frac{H}{\mu (S_c - 1)}$

If no uplift is considered, $C = 0$

then $B \geq \frac{H}{\mu S_c}$

Q.48

Sol.

(i) Divide Wall :

The main functions served by the divide wall are :

- (a) It separates the under sluice from weir proper. Since the crest level of the under sluices is lower than of the weir proper, the two must be separated and this is being done by the divide wall.
- (b) It helps in providing a comparatively less turbulent pocket near the canal head regulator, resulting in deposition of silt in this pocket and thus to help in the entry of silt free water into the canal.
- (c) Divide wall keeps the cross currents, if at all they are formed, away from the weir because cross currents leads to vortices and deep scours.

(ii) Guide Banks :

The functions of guide banks are :

- (a) Guide banks confine the flood water of alluvial rivers within reasonable waterway and provide a straight non-tortuous approach towards a work constructed across the river.
- (a) Guide banks tends to prevent the river from changing its course and out flanking the work.

(iii) Sediment Ejector :

Sediment ejector are those silt control devices which remove the silt which has already entered the canal from the head. These are provided in a canal a little distance downstream from the head of the canal.

(iv) Fish Ladder :

A fish ladder is a man-made structure, like a series of steps or pools, that allows fish to bypass obstacles such as dams to migrate upstream. Water flows through the ladder, creating a current that guides fish, while the pools provide places for them to rest between swimming up the steps. This restores connectivity to rivers, helping fish like salmon and shad reach their spawning grounds and maintaining healthy fish populations.

(v) Head regulator :

A head regulator controls the flow of water from a main river or canal into a smaller, off-taking canal by using gates to regulate the supply, prevent excess silt entry, and protect the canal from floods. It functions as a gatekeeper at the source of the canal, ensuring that only the required amount of water enters for irrigation or other uses while filtering out debris.

The seepage may endanger the safety of a hydraulic structure on permeable foundation in the following two ways :

(i) By piping or undermining :

If the water percolating through the foundation has sufficient force when it emerge at the downstream end of the floor it may lift up the soil particles at the end of the floor. With the removal of the surface soil there is further concentration of flow into the resulting depression and more soil is removed. This process of erosion progressively extends backwards towards the upstream side and results in the removal of soil and developing pipe like formation beneath the floor. The floor may subside in the hollows so formed and fail which is known as failure due to piping or undermining. This problem can be solved by providing sufficient length of the floor and by providing piles at the U/S and D/S ends of the floor.

(ii) By uplift pressure :

The water percolating through the foundation exerts an upward pressure on the floor which is known as uplift pressure. If the uplift pressure is not counter balanced by the weight of the structure, it may fail by rupture. This can be prevented by providing sufficient thickness of the floor or by providing pile at the U/S end of the floor so that the uplift pressure is reduced on the D/S side.



Q.49

Sol. The calculations are tabulated below:

Time (hr)	FH (m ³ /s)	Base Flow (m ³ /s)	DRH (m ³ /s)	1 cm UH = $\frac{\text{Col.4}}{\text{DRD}}$
(1)	(2)	(3)	(4)	(5)
0	5	5	0	0
12	15	5	10	4.17
24	40	5	35	14.58
36	80	5	75	31.25
48	60	5	55	22.92
60	50	5	45	18.75
72	25	5	20	8.33
84	15	5	10	4.17
96	5	5	0	0
			$\Sigma O = 250$	$\Sigma U = 104.17$

Where $\Sigma O = 250 \text{ m}^3/\text{s}$; $t = 12 \text{ hr}$; $A = 450 \text{ km}^2$

$$\therefore \text{DRD} = \frac{0.36 \times 250 \times 12}{450} = 2.4 \text{ cm}$$

$$\text{Check : DRD of unit hydrograph} = \frac{0.36 \Sigma U \times t}{A} = \frac{0.36 \times 104.17 \times 12}{450} = 1.00 \text{ cm}$$

Q.50

Sol. One of the most common methods to develop a correlation between monthly rainfall, 'p' and run-off 'R' is to fit a linear regression line between R and P.

The equation for straight line regression between R and P is

$$R = aP + b$$

Where, coefficients 'a' and 'b' are given as :

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P)^2}$$

$$b = \frac{\Sigma R - a \Sigma P}{N}$$

Where, N is the number of observation sets.

The above correlation obtained is considered good if the value of correlation coefficient (γ), as calculated below lies between 0.6 and 1.0.

$$\text{Correlation coefficient } (\gamma) = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{\sqrt{[N(\Sigma P^2) - (\Sigma P)^2][N(\Sigma R^2) - (\Sigma R)^2]}}$$

For the given data, calculations for computing the run-off rainfall correlation are shown below in the table.

Month	P(cm)	R(cm)	R ²	P ²	PR
1	4	0.2	0.04	16	0.8
2	22	7.1	50.41	484	156.2
3	28	10.9	118.81	784	305.2
4	15	4.0	16.0	225	60.0
5	12	3.0	9.0	144	36.0
6	8	1.3	1.69	64	10.4
7	4	0.4	0.16	16	1.6
8	15	4.1	16.81	225	61.5
9	10	2.0	4.0	100	20.0
10	5	0.3	0.09	25	10.5
	$\Sigma P=123$	$\Sigma R=33.3$	$\Sigma R^2=217.01$	$\Sigma P^2=2083$	$\Sigma PR=65.32$

$$N = 10$$

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P)^2} = \frac{(10 \times 653.2) - (123 \times 33.3)}{(10 \times 2083) - (123)^2}$$

$$a = 0.4273$$

$$b = \frac{\Sigma R - a\Sigma P}{N} = \frac{33.3 - (0.4273) \times 123}{10}$$

$$b = -1.9258$$

$\therefore$

$$R = aP + b$$

$\Rightarrow$

$$R = 0.4273P - 1.9258 \text{ (P and R are in cms)}$$

Calculation of correlation coefficient,

$$\gamma = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{\sqrt{[N(\Sigma P^2) - (\Sigma P)^2][N(\Sigma R^2) - (\Sigma R)^2]}}$$

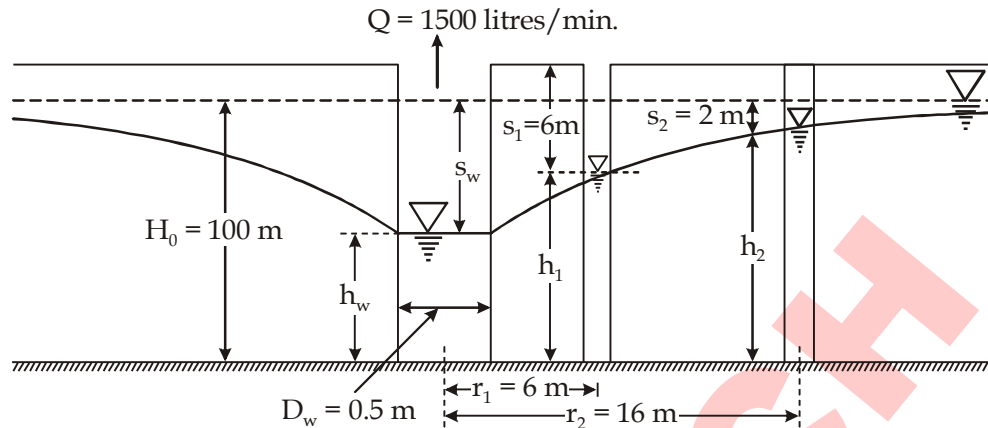
$$\gamma = \frac{(10 \times 653.2) - (123 \times 33.3)}{\sqrt{[(10 \times 2083) - (123)^2][(10 \times 217.01) - (33.3)^2]}}$$

$$\gamma = \frac{2436.1}{\sqrt{(5701)(1061.21)}} = 0.9904$$

Since, $0.6 < \gamma < 1$, hence our correlation is good

Q.51

Sol.



Given :

Diameter of the well, $D_w = 0.5$ mSteady state discharge, $Q = \frac{1500 \times 10^{-3} \text{ m}^3}{60} = 0.025 \text{ m}^3/\text{sec}$

Using the Dupit's formula for unconfined aquifer,

$$Q = \frac{\pi k (h_2^2 - h_1^2)}{\ln\left(\frac{r_2}{r_1}\right)} \quad \dots(i)$$

Now,

Height of water table above base of well at distance r_1 ,

$$h_1 = H_0 - s_1$$

$$h_1 = 100 - 6 = 94 \text{ m}$$

Height of water table above base of well at distance r_2 ,

$$h_2 = H_0 - s_2$$

$$h_2 = 100 - 2 = 98 \text{ m}$$

Putting these values in equation (i), we get

$$0.025 = \frac{\pi \times k \times (98^2 - 94^2)}{\ln\left(\frac{16}{6}\right)}$$

$$\Rightarrow \pi k = \frac{0.025 \times \ln\left(\frac{16}{6}\right)}{(98^2 - 94^2)}$$

Using the Dupit's formula between r_w and r_1 At $r = r_w$, height of water table above base of well = h_w (say)At $r = r_1$, $h = h_1$ 

Thus,
$$Q = \frac{\pi k \times (h_1^2 - h_w^2)}{\ln\left(\frac{r_1}{r_w}\right)}$$

$$\Rightarrow 0.025 = \frac{0.025 \times \ln\left(\frac{16}{6}\right)}{(98^2 - 94^2)} \times \frac{(94^2 - h_w^2)}{\ln\left(\frac{6}{0.25}\right)}$$

Solving, we get $h_w = 79.672$ m

Thus, draw-down in the well being pumped,

$$s_w = H_0 - h_w$$

$$s_w = 100 - 79.672 = 20.328 \text{ m}$$

