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Internal Assessment Test 2 – Oct. 2019

Sub:	***Hydrology and Irrigation Engineering***					***Sub Code:***	***15CV73***	***Branch :***	***CIVIL***
Date:	07/09/2019	Duration:	90 min's	Max Marks:	50	Sem / Sec:	A&B		OBE

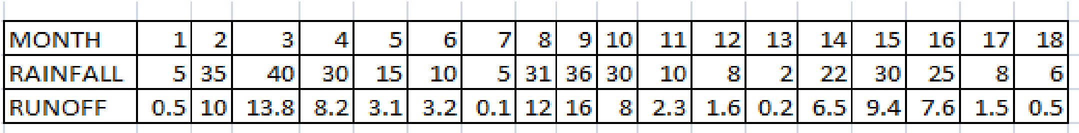
Answer any FIVE FULL Questions MARKS CO RBT

1 (a) Define runoff. What are the factors affecting runoff. [05] CO1 L2

(b) Explain empirical formulae for the estimation of yield? [05] CO1 L2

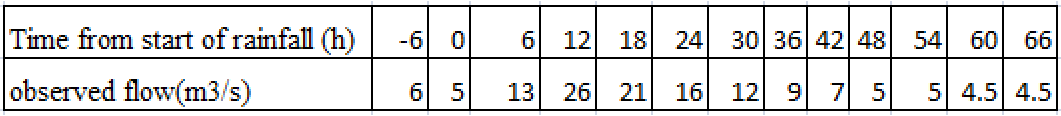
2 (a) Explain rainfall runoff correlation. [05] CO1 L2

(b) Given below are the monthly rainfall (P) & the corresponding runoff (R) values for a period of 18 months for a catchment. Find the correlation co-efficient between R and P. [05] CO1 L2



MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RAINFALL	5	35	40	30	15	10	5	31	36	30	10	8	2	22	30	25	8	6
RUNOFF	0.5	10	13.8	8.2	3.1	3.2	0.1	12	16	8	2.3	1.6	0.2	6.5	9.4	7.6	1.5	0.5

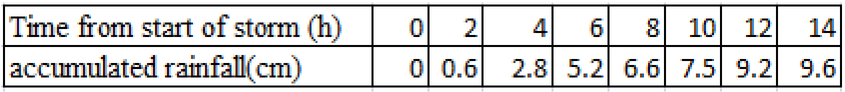
3 (a) Rainfall of magnitude 3.8cm and 2.8cm occurring on two consecutive 4-hr durations on a catchment of area 27km^2 produced the following hydrograph of flow at the outlet of the catchment estimate the rainfall excess and Φ-index. [05] CO1 L2



Time from start of rainfall (h)	-6	0	6	12	18	24	30	36	42	48	54	60	66
observed flow(m3/s)	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5

[05] CO1 L2

(b) A Strom over a catchment of area 5km^2 had duration of 14 hrs. The mass curve of rainfall of the storm is as follows:



Time from start of storm (h)	0	2	4	6	8	10	12	14
accumulated rainfall(cm)	0	0.6	2.8	5.2	6.6	7.5	9.2	9.6

If the Φ-index for the catchment is 0.4 cm/h. determine the effective rainfall hyetograph & the volume of direct runoff from the catchment due to the storm. [05] CO1 L2

4 (a) Explain the factors affecting of evaporation. [05] CO1 L2

(b) Write the formulae for the estimation of evaporation rate with their notations [05]

5 Draw the neat sketch and explain the ISI standard class A pan. [10] CO1 L2

6 Explain with neat diagram of a (a) Simple infiltrometers b) Double ring infiltrometers [10] CO1 L2

7 Explain the analytical methods of evaporation estimation. [10] CO1 L2

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Internal Assessment Test 2 Sultion – May. 2019

Sub:	**Hydrology & Irrigation Engineering**							**Code:**	15CV73
Date**:**	15/05/2019	Duration:	90mins	Max Marks:	50	**Sem:**	VII	**Branch:**	CIVIL

Q.1 a) Define runoff. What are the factors affecting runoff?

Runoff can be described as the part of the water cycle that flows over land as surface water instead of being absorbed into groundwater or evaporating. **Runoff** is that part of the **precipitation**, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains, or sewers.

Factors affecting Runoff

- Type of precipitation (rain, snow, sleet, etc.)
- Rainfall intensity.
- Rainfall amount.
- Rainfall duration.
- Distribution of rainfall over the watersheds.
- Direction of storm movement.
- Antecedent precipitation and resulting soil moisture.

1. **Precipitation:** The runoff is clearly a function of precipitation, its intensity, its duration and its coverage. More the intensity more will be the runoff. The infiltration rate reduces after some time; hence more the duration, proportionately more will be the runoff. Similarly, more the area covered by the storm, more will be the runoff. Direction of movement of a storm over the catchment area has a definite effect on the runoff. If the storm moves in the direction of the flow, the base period of hydrograph will be less and more peak flow may be expected. On the other hand, if the storm over against the flow direction, then the base period will be comparatively more and less peak flow may be expected.

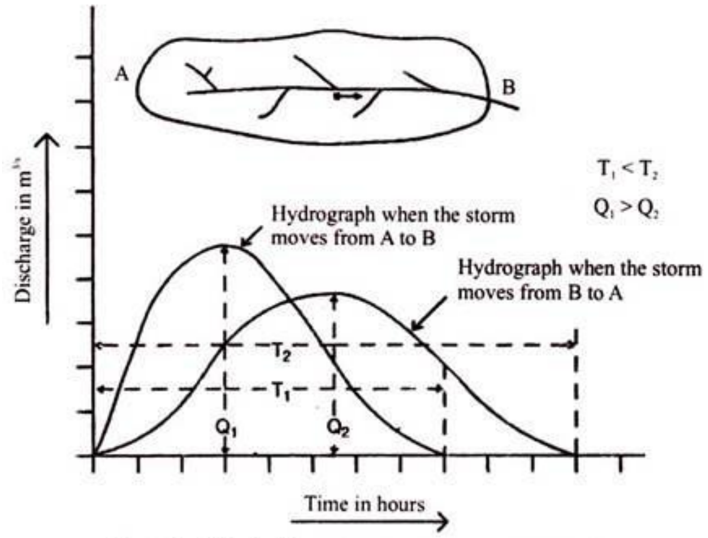


Fig. 2.7: Effect of the storm movement on runoff

Factor # 2. Size and Shape of the Catchment Area:

The size of catchment has a definite effect on the runoff. More the area, more will be the runoff. So also, the shape will have a definite effect on the runoff.

In case of a fan-shaped catchment area, the base period of the resulting hydrograph will be less and thus more peak flow may be expected. In case of an elongated catchment, the base period of the resulting hydrograph will be comparatively more and thus more will be the infiltration losses and less will be the runoff (Fig. 2.8).

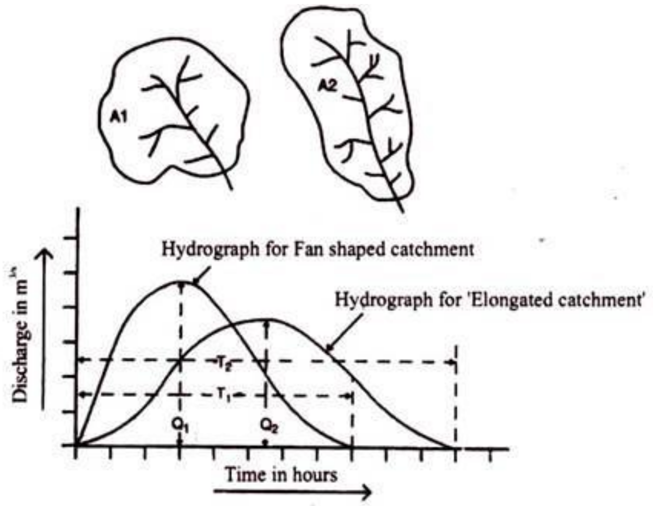


Fig. 2.8: Effect of the shape of catchment on runoff

The average value of:

i. Manning’s coefficient,

ii. The shape factor,

iii. Stream order,

iv. Drainage density,

v. Stream density,

vi. Circularity ration,

vii. Elongation ratio,

viii. Compactness coefficient, and

ix. The slope of the channel and so on of the catchment thus definitely influences.

Factor # 3. Geographical Conditions:

The nature of the soil, its permeability, has an effect on the infiltration rate and has indirect effect on the runoff. Impervious tock outcrops will increase the runoff. Also, impervious sub-surface layers at higher levels than groundwater table level increase the runoff.

Factor # 4. Meteorological Conditions:

The temperature has an effect on the evaporation and infiltration and may indirectly affect the runoff. The barometric pressure, altitude and wind will not only affect the storm and its movement, but may also affect the runoff.

Factor # 5. Drainage Net:

The rainwater after meeting all abstractions, first flows through small rivulets and then flows to bigger ones. The pattern of the various tributaries normally known as drainage net or drainage pattern will affect drainage of the surface low. In each case, the draining time will differ and will affect the infiltration and thus indirectly the runoff.

Other factors affecting run off are:

- Cultivation in an area,
- Contour bunding,
- Ploughing,
- Deforestation, and
- Urbanization and so on have a direct effect on the runoff.

Q.1 b Explain empirical formulae for the estimation of yield?

Solution:

Yield : The total quantity of surface water that can be expected in a given period from a stream at the outlet of its catchment is known as yield of the catchment in that period. The annual yield from a catchment is the end product of various processes such as precipitation, infiltration and evapotranspiration operating on the catchment.

Empirical Equations: The importance of estimating the water availability from the available hydrologic data for purposes of planning water-resource projects was recognized by engineers even in the last century. With a keen sense of observation in the region of their activity many engineers of the past have developed empirical runoff estimation formulae. However, these formulae are applicable only to the region in which they were derived. These formulae are essentially rainfall-runoff relations with additional third or fourth parameters to account for climatic or catchment characteristics

Consider a rainfall of uniform intensity and very long duration occurring over a basin. The runoff rate gradually increases from zero to a constant value a indicated in Fig. 7.1. The runoff increases as more and more flow from remote areas of the catchment reach the outlet. Designating the time takenJ^ Jconccntra- from the farthest part of the catchment to reach the outlet as tc= time of concentration, it is obvious that if the rainfall continues beyond tc, the runoff will be constant and at the peak value. The peak value of the runoff is given by :

Qp = CAi for t>tc

where C = coefficient of runoff = (runoff/rainfall), A | area of the catchment and

i = intensity of rainfall. This is the basic equation of the rational method. Using the commonly used units, Eq. (7.1) is written for field application as

Qp= 1/3.6 C(Itc,p) A

where

Qp = peak discharge (m3/s)

C = coefficient of runoff

(Itc,p) = the mean intensity of precipitation (mm/h) for a duration equal to tc and an exceedence probability P

A = drainage area in km2 .

The use of this method to compute Qp requires three parameters: tc, (itcp) and C.

"TIME OF CONCENTRATION (tc)

There are a number of empirical equations available for the estimation of the time of concentration. Two of these are described below.

US PRACTICE : For small drainage basins, the time of concentration is assumed to be equal to the lag time of the peak flow. Thus

Tc= Tp of = CtL(LLca/$\sqrt{}$S)n

where tc = time of concentration in hours, CtL, L, Lca, n and S have the same meaning

KIRPICH EQUATION (1940):

This is the popularly used formula relating the time of concentration of the length of travel and slope of the catchment as

tc = 0.01947 L0J7 ST0385 (7.4)

K1= $\sqrt{}$L3/H

where tc = time of concentration (minutes)

L = maximum length of travel of water (m), and S = slope of the catchment = A H/L in which AH= difference in elevation between the most remote point on the catchment and the outlet.

Tc= 0.01947K10.77

RAINFALL INTENSITY (itcp)

The rainfall intensity corresponding to a duration tc and the desired probability of exceedence P, (i.e. return period T= 1/P) is found from the rainfall-frequency-duration relationship for the given catchment area . This will usually be a relationship of the form of Eq. (2.15), viz.

itc,p = KTx/ (tc+ a)n

RYVES FORMULA (J884)
$Q_p = C_R A^{2/3}$

Where Q = maximum flood discharge (m^3/s) A = catchment area (km^2) and C_R = Ryves coefficient

This formula originally developed for the Tamil Nadu region, is in use in Tamil Nadu and parts of Karnataka and Andhra Pradesh. The values of C_R recommended by Ryves for use are:

C_R = 6.8 for areas within 80 km from the east coast
=8.5 for areas which are 80—160 km from the east coast
=10.2 for limited areas near hills

INGUS FORMULA (1930):

This formula is based on flood data of catchments in Western Ghats in Maharashtra. The flood peak Q_p in m /s is expressed as

$Q_p = 124A / (A + 10.4)$

There are many such empirical formulae developed ill various where A is the catchment area in km .

$Q_p = C_f A^{0.8} (1+0.8\log T)$

Q_{TP}= Maximum 24-h flood with a frequency of T years in m^3/s , A= catchment area n km^2 , C_f= a constant with values between 0.18 to 1.88.

Q.2 Rainfall Runoff Relations:

Type of Runoff 1- surface runoff 2- subsurface runoff 3- Base flow

Surface the runoff: it is that portion of rainfall, which enters the stream immediately after the rainfall.

Subsurface runoff: that part of rainfall, which first leaches into the soil and moves laterally without joining the water table, to the streams, rivers, sea or wadis.

Base flow: it is delayed flow, defined as that part of rainfall, which after falling on the ground surface, infiltrate into the soil and meets to the water table.

Total Runoff= surface runoff + base flow (including subsurface runoff)

Surface Storage

The balance between rain intensity, infiltration and runoff involves another, very important factor - surface storage. The runoff balance equation can therefore be written as follows:

Runoff = rainfall - infiltration - surface storage

Figure 12 demonstrates the surface storage effect on runoff from a storm of 82 mm. Raising the storage from 1 mm (Figure 12a) to 15 mm (Figure 12b) results in reducing the runoff from 36 to 11 mm. The 25 mm reduction in runoff is much greater that the storage itself.

The runoff from a given rainstorm is a function of:

i. rainfall intensity distribution and sequence, during a particular rainstorm event;
ii. soil infiltration rates;
iii. the soil surface storage capacity.

Soil Infiltration

On many cultivated or bare fields the soil infiltration ability is commonly limited by surface crusting rather than by deeper profile conditions. As a result, rainwater falling on bare ground cannot penetrate, and runs off sideways, even on very gentle slopes. The rapid drop in infiltration rate (IR) of most of the bare soils during rainstorms is due mainly to the surface seal. The seal is less permeable, by a few orders of magnitude, than the subsurface horizon. Surface seal, as well as most of the other crust formations, results from three processes.

- Physical disintegration of soil aggregates and their compaction, caused by the impact action of raindrops.
- Chemical dispersion of the clay particles. The low electrical conductivity of the rainwater as well as the organo-chemical bonds between the primary particles of the surface aggregates, control the rate and degree of dispersion.
- Soil infiltration rate can be described mathematically as a function of the cumulative rainfall and several soil parameters. Morin and Benyamini (1977) described the infiltration rates (I_t) of bare soils under rain by the following equation:
- $I_t = I_i + (I_i - I_f) \exp(- ?pt)$ (1)

where: I_i = initial infiltration rate of the soil - mm h^{-1}

I_r = final (constant) infiltration rate of the soil - mm h^{-1}

t = time from the beginning of the rain - hours

? = soil coefficient related to aggregate stability while forming the crust

p = rain intensity - mm h^{-1}

Q.4 a Explain the factors affecting evaporation.

Solution:
Factors affecting Evaporation
1. **Vapour pressure difference**: The number of molecules leaving or entering a water body depends on the vapour pressure of water body at the surface and also the vapour pressure of air. Higher water temperature leads to high vapour pressure at surface and tends to increase the rate of evaporation. High humidity in air tends to increase vapour pressure in air and in turn reduces rate of evaporation

2. **Temperature of air and water**: The rate of emission of molecules from a water body is a function of its temperature. At higher temperature molecules of water have greater energy to escape. Hence maximum evaporation from water bodies takes place in summer. It has been estimated that for every 1o C rise in atmospheric temperature increases 5 cm of evaporation annually.
3**. Wind Velocity**: When wind velocity is more the saturated air (humid air) is drifted away and dry air comes in contact with water surface which is ready to absorb moisture. Hence rate of evaporation is dependent on wind velocity. It has been estimated that 10% increase in wind velocity increases 2 – 3% of evaporation.
4. **Quality of water**: The rate of evaporation of fresh water is greater than saline water. (Specific gravity of saline water is greater than that of fresh water. It is established that saline water has lesser vapour pressure and it is observed that evaporation from fresh water is 3 – 4% more than sea water.
5. **Atmospheric pressure and Altitude:** Evaporation decreases with increase in atmospheric pressure as the rate of diffusion from water body into the air is suppressed. At higher altitude the atmospheric pressure is usually lesser and there by evaporation rate is higher.
6. **Depth of water body:** Evaporation shallow water bodies is greater when compared to deep water bodies as the water at lower levels in deep water bodies is not heated much and vapour pressure at lower levels is also reduced.

Q.4 b Write the formulae for the estimation of evaporation rate with their notations
Solution:

1. DALTON’S LAW OF EVAPORATION

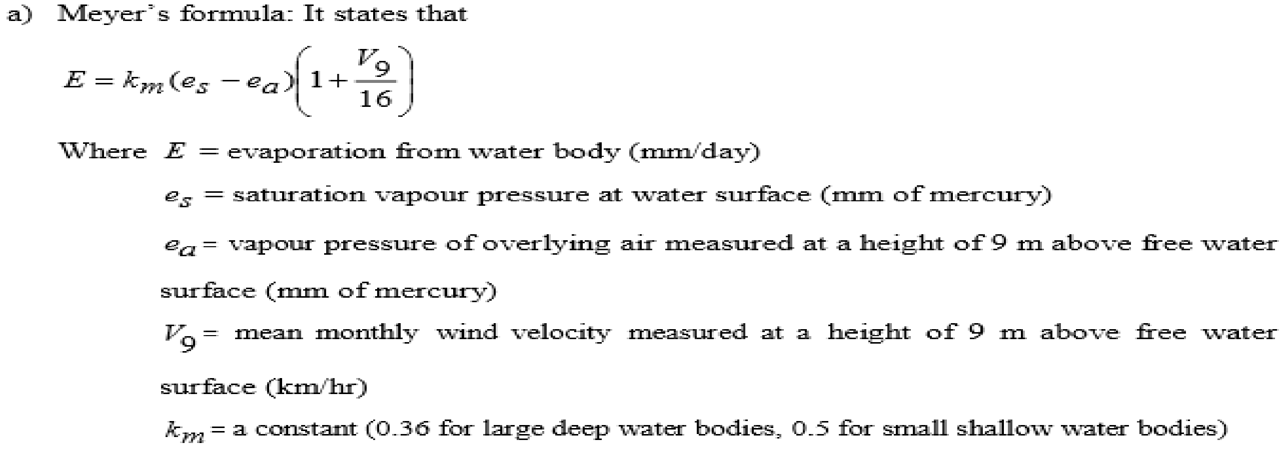
The rate of evaporation is function of the difference in vapour pressure at the water surface and the atmosphere. Dalton‘s law of evaporation states that ―Evaporation is proportional to the difference in vapour pressures of water and air. i e

E α (ew – ea) or E = k (ew – ea)

where E = daily evaporation ew = saturated vapour pressure of water at a given temperature ea = vapour pressure of air k = proportionality constant Considering the effect of wind Dalton‘s Law is expressed as E = kl (ew – ea) (a+b V)

where V = wind velocity in km/hour kl , a & b are constants for a given area.

Based on Dalton‘s law of evaporation, various formulae have been suggested to estimate evaporation. 2) Meyer‘s formula: It states that



a) Meyer’s formula: It states that

$$E = k_m (e_s - e_a)\left(1+\frac{V_9}{16}\right)$$

Where E = evaporation from water body (mm/day)

e_s = saturation vapour pressure at water surface (mm of mercury)

e_a = vapour pressure of overlying air measured at a height of 9 m above free water surface (mm of mercury)

V_9 = mean monthly wind velocity measured at a height of 9 m above free water surface (km/hr)

k_m = a constant (0.36 for large deep water bodies, 0.5 for small shallow water bodies)

Where E = evaporation from water body (mm/day) s e = saturation vapour pressure at water surface (mm of mercury) ae = vapour pressure of overlying air measured at a height of 9 m above free water surface (mm of mercury) 9V = mean monthly wind velocity measured at a height of 9 m above free water surface (km/hr) m k = a constant (0.36 for large deep water bodies, 0.5 for small shallow water bodies)

Q.5 Draw the neat sketch and explain the ISI standard class A pan.

The popularly used evaporation pans are 1. ISI standard pan or Class A pan 2. U S Class A pan 3. Colorado sunken pan 4. U S Geological Survey floating pan.

ISI standard pan or Class A pan

This evaporation pan should confirm to IS – 5973:1976 and is also called Class A pan. It consists of a circular copper vessel of 1220 mm effective diameter, 255 mm effective depth and a wall thickness of 0.9 mm. A thermometer is assembled to record the variation in temperature. A wire mesh cover with hexagonal openings is provided at the top to prevent entry of foreign matter. A fixed gauge housed in a stilling well as shown in figure is provided. During evaporation measurement a constant water level is maintained at the top level of fixed gauge. For this purpose water has to be added or removed periodically. The water level measurements are done using micrometer hook gauge. The entire assembly is mounted on a level wooden platform.

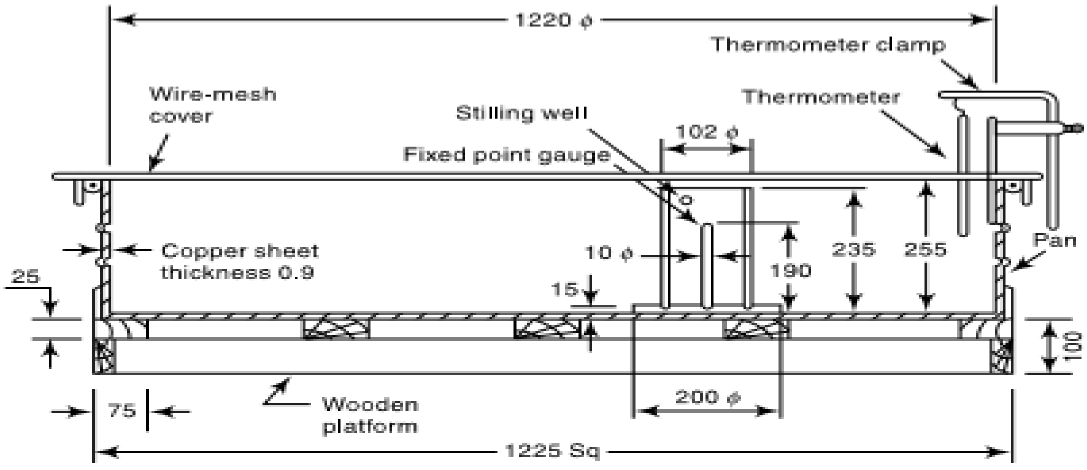


Fig. 3.2 ISI Evaporation Pan

Q.6 Explain with neat diagram of a (a) Simple infiltrometers b) Double ring infiltrometers

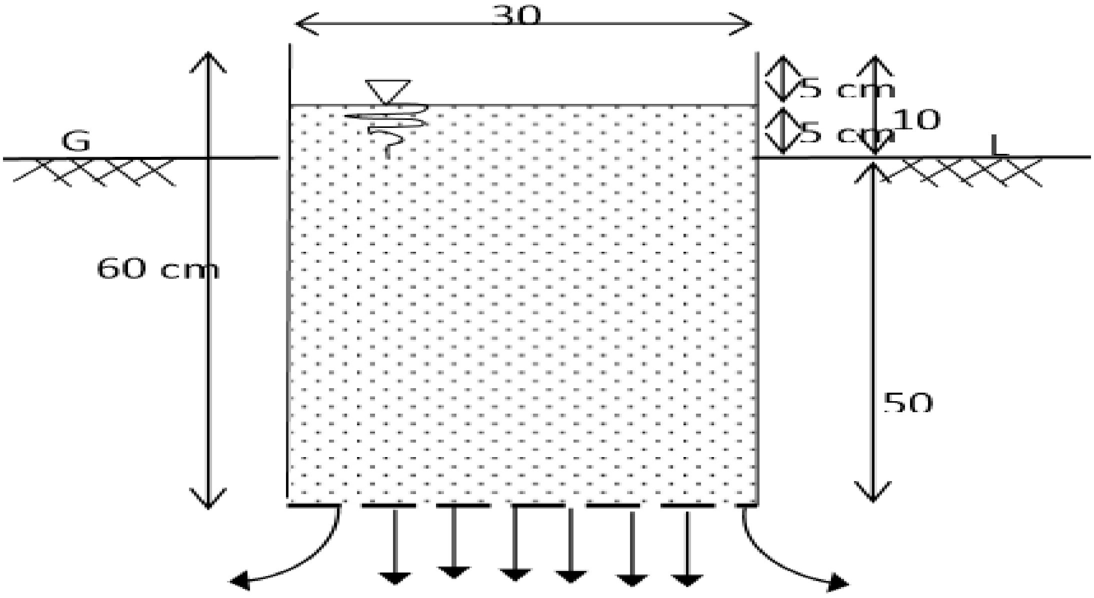
Q.7. Explain the analytical methods of evaporation estimation.

Ans.6. Infiltro-meters are of two types.
a) Flooding type Infiltro-meters
b) Rainfall simulators

In flooding type Infiltro-meters water is applied in form of a sheet, with constant depth of flooding. The depletion of water depth is observed with respect to time. In case of rainfall simulators water is applied by sprinkling at a constant rate in excess of infiltration capacity and the runoff occurring is also recorded.

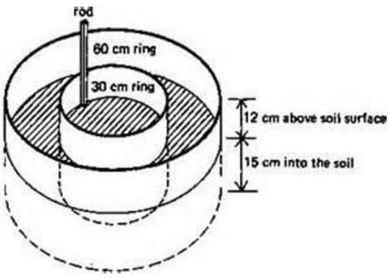
Infiltro-meters adopted in practice are, 1.Simple (Tube Type) Infiltro-meters 2. Double ring Infiltro-meters.

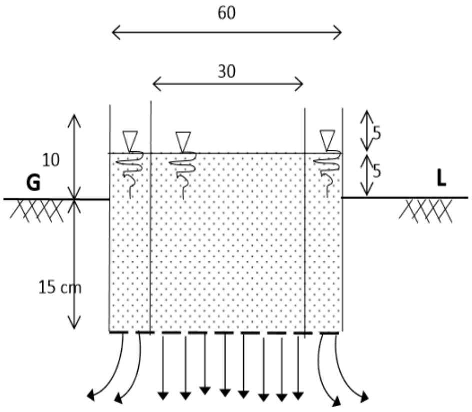
1. Simple (Tube Type) Infiltro-meters It is essentially a metal cylinder with openings at both ends. It has a diameter of 30 cm and length of 60 cm. This is driven into the ground as shown and water is poured from the top till the pointer level as shown. As infiltration continues the depleted volume of water is made up by adding water from a burette or measuring jar to maintain constant water level. Knowing the volume of water added during different time intervals the infiltration capacity curve is plotted. The experiment is continued till a uniform rate of infiltration is obtained, which may take 2 to 3 hours.



2. Double ring Infiltro-meters

A tube infiltrometer has a drawback that infiltration in it does not represent or simulate the actual field conditions because the water tends to disperse laterally after coming out at the bottom. To overcome this draw back a Double ring Infiltro-meter is widely used. It consists of two consecutive rings driven into the ground as shown in the figure below. The inner ring has a diameter of 30 cm and outer ring has a diameter of 60 cm. They are concentrically driven into the ground as shown in figure. A constant water depth of 5 cm is maintained in both the rings. The outer ring provides a water jacket to the water infiltrating from the inner ring and thus simulates the natural conditions. The water depths in both the rings are maintained constant during the observation period. The measurement of water volume added into the inner ring is only noted. The experiment is carried out till constant infiltration arte is obtained. To prevent any disturbance or accidental fall of foreign matter the top of the infiltrometer is covered with a perforated disc.





Ans. 7
Analytical Methods of Evaporation Estimation

1. Water Budget Method
2. Energy Budget Method
3. Mass Transfer Method

(1) Water Budget Method

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E_L + \Delta S + T_L$$

P = daily precipitation

V_{is} = daily surface inflow into the lake

V_{ig} = daily groundwater inflow

V_{os} = daily surface outlow from the lake

V_{og} = daily groundwater outflow

E_L = daily lake evaporation

ΔS = increase in lake storage in a day

T_L = daily transpiration loss

All quantities are expressed in units of volume or depth

P, V_{is}, V_{os}, and ΔS can only be measured.

V_{ig}, V_{og}, and T_L can only be estimated.

If the unit of time is kept very large, estimates of evaporation will be more accurate. It is the simplest of all the methods, but the least reliable.

(2) Energy Budget Method

- It involves application of the law of conservation of energy
- Energy available for evaporation is determined by considering the incoming energy, outgoing energy, and the energy stored in the water body over a known time interval
- Estimation of evaporation from a lake by this method has been found to give satisfactory results, with errors of the order of 5%, when applied to periods less than a week

$H_n = H_a + H_e + H_g + H_s + H_i$

H_n = net heat energy received by the water surface $= H_c(1-r) - H_b$

H_b = back (long wave) radiation from the water body

H_a = sensible heat transfer from the water surface to the air

H_g = heat flux into the ground

H_s = heat stored in the water body

H_e = heat energy used up in evaporation $= \rho L E_L$ (E_L = evaporation, L = latent heat of evaporation, ρ = mass density of the fluid)

H_i = net heat conducted out of the system by water flow (advected energy)

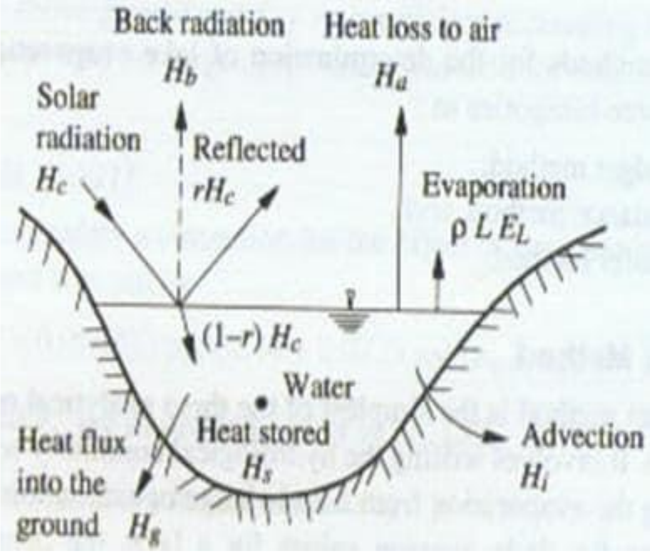


Figure: Energy Balance in a water body

This is the energy balance in a period of 1 day. All energy terms are in calories/ sq.mm/day.

If time periods are short, H_s and H_i can be neglected as they are negligibly small

All terms except H_a can either be measured or evaluated indirectly

H_a is estimated using Bowen's ratio

$$\beta = \frac{H_a}{\rho L E_L} = 6.1 \times 10^{-4} \; x \; p_a \frac{T_w - T_a}{e_w - e_a}$$

p_a = atmospheric pressure (mm of mercury)

e_w = saturated vapour pressure (mm of mercury)

e_a = actual vapour pressure of air (mm of mercury)

T_w = temperature of water surface (°C)

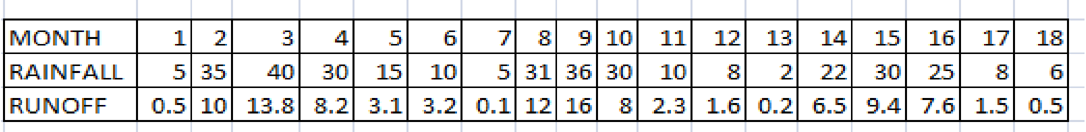
T_a = temperature of air (°C)

Comparison of Methods

- Analytical methods can provide good results. However, they involve parameters that are difficult to assess.
- Empirical equations can at best give approximate values of the correct order of magnitude.
- In view of the above, pan measurements find wide acceptance in practice.

Note: Numerical Questions 3 a & b, 4 a & b solutions are given below:

2 (b) (Given below are the monthly rainfall (P) & the corresponding runoff (R) values for a period of 18 months for a catchment. Find the correlation co-efficient between R and P.)



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RUNOFF	0.5	10	13.8	8.2	3.1	3.2	0.1	12	16	8	2.3	1.6	0.2	6.5	9.4	7.6	1.5	0.5

Problem : (2b)

Given below are the monthly reinfall (P) and the Corresponding runoff (R). values for a period of 18 months for a Catchment. Find the Correlation Co-efficient b/w R & P.

Month :	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Reinfall (P) :	5	35	40	30	15	10	5	31	36	30	10	8	2	22	30	25	8	6
Runoff (R) :	0.5	10	13.8	8.2	3.1	3.2	0.1	12.0	16.0	8.0	2.3	1.6	0.0	6.5	9.4	7.6	1.5	0.5

$= \Sigma P = 348, \quad \Sigma R = 104.3, \quad N = 18$

$\Sigma P^2 = 9534 \quad \Sigma R^2 = 1040.51 \quad \Sigma PR = 3083.3$

$(\Sigma P)^2 = 121104 \quad (\Sigma R)^2 = 10878.49$

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P^2)} = \frac{18(3083.3) - (348 \times 104.3)}{(18 \times 9534) - 121104}$$

$a = 0.380$

$$b = \Sigma R - a\Sigma P$$

$$= \frac{104.3 - (0.380 \times 348)}{18}$$

$$= \underline{-1.55}$$

$$r = \frac{(18 \times 3083.3) - (348 \times 104.3)}{\sqrt{[(18 \times 9534) - 121104] \times [(18 \times 1040.51) - 10878.49]}}$$

$$= \underline{0.964}$$

3(a) Rainfall of Magnitude 3.8 cm & 2.8 cm occurring on two Consecutive 4-h durations on a Catchment of area 27 km² produced the following hydrograph of flow at the outlet of the Catchment. Estimate the rainfall excess & φ index.

Time from start of rainfall (h)	-6	0	6	12	18	24	30	36	42	48	54	60	66
Observed flow (m³/s)	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5

→ It is Seen that the Storm hydrograph has a base-flow Component. For using st-line method of base flow separati

$N = 0.83 \times (27)^{0.2} = 1.6$ days $= 38.5$h

by inspection, DRH starts at t = 0, has the peak at t = 12h ends at t = 48h

∴ (48 − 12 = 36h) N = 36h more satisfactory

∴ In the present case DRH is assumed to exist from t = 0 to 48h.

Area of DRH = Total direct runoff due to storm

$= 60 \times 60 \times 6 \times (8 + 21 + 16 + 11 + 7 + 4 + 2)$ φ

$= 1.4904 \times 10^6 \, m^3$ ①

Runoff depth = $\frac{\text{Runoff volume}}{\text{Catchment Area}} = \frac{1.4904 \times \cancel{10^6}}{27 \times \cancel{10^6}} = \underline{0.0552 \text{ m}}$

= $\underline{5.52 \text{ cm}}$ = rainfall excess

Total Rainfall = 3.8 + 2.8 = 6.6 cm

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Duration = 8h

φ index = $\frac{6.6 - 5.52}{8} = \underline{0.135 \text{ cm/h}}$

(3b)
~~2~~. A storm over a catchment of area 5.0 km² had a duration of 14 hour. The mass curve of rainfall of the storm is as follows:

Time from start of storm (h)	0	2	4	6	8	10	12	14
Accumulated rainfall (cm)	0	0.6	2.8	5.2	6.6	7.5	9.2	9.6

If the φ index for the catchment is 0.4 cm/h, determine the effective rainfall hyetograph & the volume of direct runoff from the catchment due to the storm.

The depth of rainfall in a time interval $\Delta t = 2h$

Time from start of storm t, (h)	Time Interval Δt (h)	Accumulated rainfall in time t (cm)	Depth of rainfall Δt (cm)	$\phi \times \Delta t$ $\phi\Delta t$ (cm)	ER (cm)
0	—	0	—	—	
2	2	0.6	0.6	0.8	0
4	'	2.8	2.2	'	1.4
6	|	5.2	2.4		1.6
8	|	6.7	1.5	|	0.7
10	|	7.5	0.8	|	0
12	|	9.2	1.7	'	0.9
14	2	9.6	0.4	0.8	0

$\underline{0.4 \times 2 = 0.8}$

In a given time interval

Δt, effective rainfall (ER)

ER = (actual depth of rainfall $- \phi\Delta t$)

∴ Total Effective Rainfall

= Direct runoff due to storm

= Area of ER hyetograph

$= (0.7 + 0.8 + 0.35 + 0.45) \times 2 \quad \underline{4.6\ \text{cm}}$

Volume of Direct runoff

$(4.6\,\text{cm}/1000) \times 5.0 \times (1000)^2 = \underline{\underline{23000\,m^3}}$

~~Rai~~ Intensity of ER (cm/h)
0
0.7
0.8
0.35
0
0.45
0