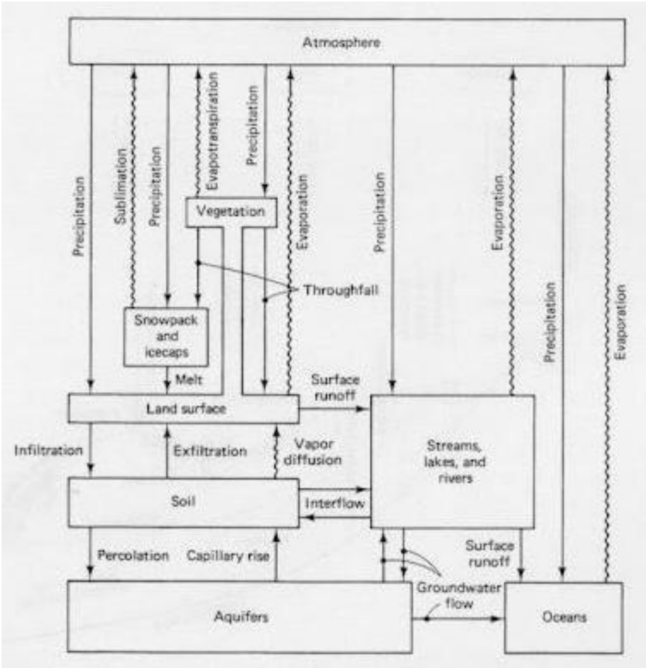
VTU July/August 2022
Scheme of Evaluation

Sub:	HYDROLOGY AND IRRIGATION ENGIEERING	Sub Code:	18CV63	Branch	**CIVIL**
	VTU July/August 2022				OBE
			Marks	CO	RBT

		Module-1			
	1a.	**Discuss various processes involved in ‘Hydrological cycle’ using Horton’s Engineering representation.**	**[10]**	**CO1**	**L2**



3M

Figure 1.1 is a schematic representation of the hydrologic cycle. A convenient starting point to describe the cycle is in the oceans. Water in the oceans evaporate due to the heat energy provided by solar radiation. The water vapour moves upwards and forms clouds. While much of the clouds condense and fall back to the oceans as rain, a part of the clouds is driven to the land areas by winds. There they condense and *precipitate* onto the land mass as rain, snow, hail, sleet, etc. A part of the precipitation may *evaporate* back to the atmosphere even while falling. Another part may be *intercepted* by vegetation, structures and other such surface modifications from which it may be either evaporated back to atmosphere or move down to the ground surface.

A portion of the water that reaches the ground enters the earth’s surface through *infiltration,* enhance the moisture content of the soil and reach the groundwater body. Vegetation sends a portion of the water from under the ground surface back to the atmosphere through the process of *transpiration.* The precipitation reaching the ground surface after meeting the needs of infiltration and evaporation moves down the natural slope over the surface and through a network of gullies, streams and rivers to reach the ocean. The groundwater may come to the surface through springs and other outlets after spending a considerably longer time than the surface flow. The portion of the precipitation which by a variety of paths above and below the surface of the earth reaches the stream channel is called *runoff.* Once it enters a stream channel, runoff becomes *stream flow.*

7M

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<tr>
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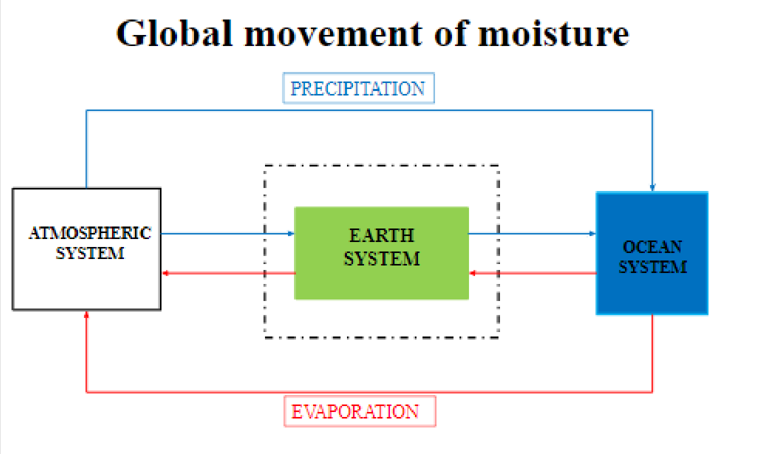
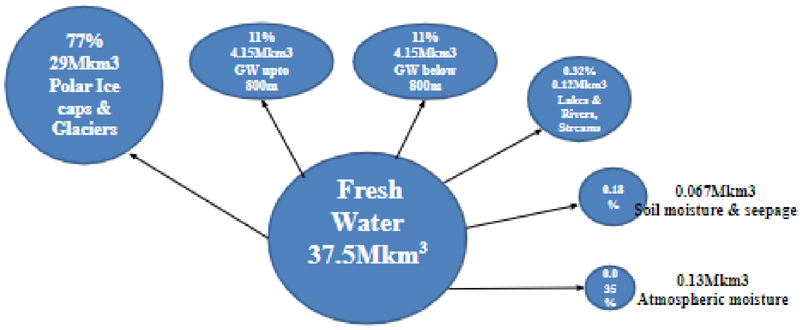
<td>1b</td>
<td>List the importance of hydrology with emphasis on global water availability


Global Water availability
• The total quantity of water in the world is approximately 1357.5Mkm^3.
• 97% of this water is contained in the oceans as saline water.
• Only 3% = 37.5Mkm^3 is Fresh water.

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<td>[10M]</td>
<td>CO1</td>
<td>L2</td>
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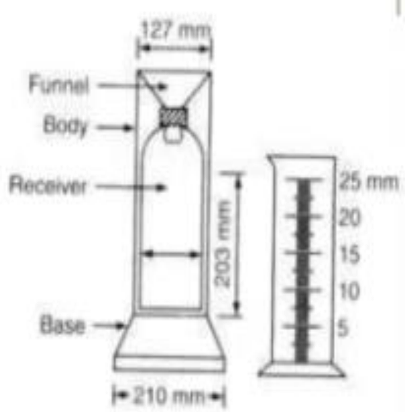
<td>2a</td>
<td>Define rain-gauge. Describe with a neat sketch, the principle of working of Symon’s non-recording gauge and its demerits.
SYMON'S RAIN GAUGE
o It gives the total rainfall that has occurred at a particular period.
o It essentially consists of a circular collecting area 127 mm in diameter connected to a funnel.
o The funnel discharges the rainfall into a receiving vessel.
o The funnel and the receiving vessel are housed in a metallic container.


4</td>
<td>[6M]

3M</td>
<td>CO2</td>
<td>L2</td>
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Advantages of Recording Gauge over the Non-recording Gauge.

- In recording gauge rainfall is recorded automatically & therefore, there is no necessity of any attendant.
- Recording rain-gauge gives the intensity of rainfall @ any time while the non-recording gauge gives the total rainfall in any particular interval of time.
- As no attendant is required such rain-gauge can be installed in far–off places also.
- Possibility of human error is obviated.

3M

2b **What is Precipitation? Distinguish between Convective and Orographic precipitation.** **[6M]** **CO2** **L2**

The term *precipitation* denotes all forms of water that reach the earth from the atmosphere. The usual forms are rainfall, snowfall, hail, frost and dew. Of all these, only the first two contribute significant amounts of water. Rainfall being the predominant form

Precipitation is classified according to the factors responsible for lifting and subsequent cooling. Types of precipitation are: 1M

Convective precipitation:

In this type of precipitation the which is warmer than the surrounding due to localised heating rises because lesser density. Air from cooler surroundi to take up its place thus setting up a c cell. The warm air continues to rise, under cooling & results in precipitation. Dependi the moisture, thermal & other conditions l showers to thunderstorms can be excepted i -ve precipitation. 2.5M

Orographic Precipitation

Orographic precipitation is caused by air masses which strike some natural topographic barriers like mountains, and cannot move forward & hence, rise up causing condensation & precipitation. Thus i mountain ranges, the windward slopes have heavy precipitation and the leeward slopes light rainfall. 2.5M

2c **Determine the optimum number of rain gauges in a catchment area using the following data** **[7M]** **CO2** **L3**

i) **Number of existing rain gauges = 08**

ii) **Mean annual rainfall at the gauges: 1000, 950, 900, 850, 800, 700, 600 and 400 mm.**

iii) **Permissible error = 6%.**

Solution:-

$m = 8$

$\epsilon = 6\%$

$$N = \left[\frac{C_v}{\epsilon}\right]^2 \qquad C_v = 100 \times \frac{\sigma_{m-1}}{\bar{P}}$$

2M

Avg. PcP → $\bar{P} = \frac{1000+950+900+850+800+700+600+400}{8}$

$\bar{P} = 775\,mm$

$$\sigma_{m-1} = \sqrt{\frac{\sum(P_i - \bar{P})^2}{m-1}} = \sqrt{\frac{225^2 + 175^2 + 125^2 + 75^2 + 25^2 + (-75)^2 + (-175^2) + (-375)^2}{8-1}}$$

$\sigma_{m-1} = 200$

2M

$$C_v = 100 \times \frac{200}{775} = 25.806\,\%$$

$$\therefore N = \left[\frac{25.806}{6}\right]^2 = 18.49 \simeq 19$$ Rain gauges required. (Optimal No of RG)

2M

∴ Additional 11 no of Raingauge stations are required.

Module-2

3a **What is meant by 'Evaporation losses? Discuss factors affecting evaporation** **[8M]** **CO2** **L3**

Evaporation Is the process in which a liquid changes to the gaseous state at the free surface, below boiling point through the transfer of heat energy. **2M**

- The rate evaporation is dependent on

  1) Vapor pressure at the water surface and air above

  2) Air and water temperature

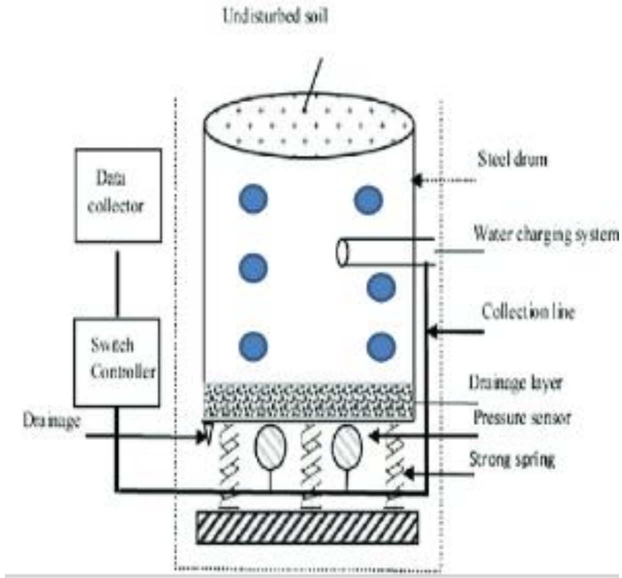
  3) Wind speed

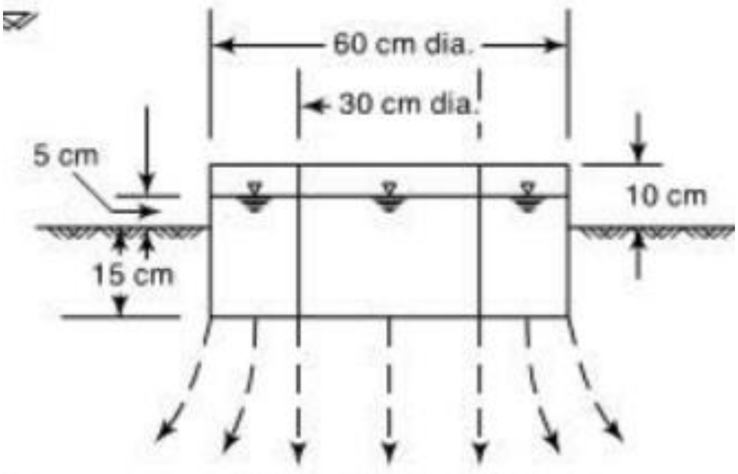
  4) Atmospheric pressure

  5) Quality of water

  6) Size of the water body

6M

3b	**Define 'Evapotranspiration'. Explain in brief the 'Lysimeter method' of estimating the same in the field.** It is the total water lost from a **cropped or irrigated land** due to **evaporation** from the soils and **transpiration** from plants. Denoted as **ET**.  LYSIMETERS A lysimeter is a special watertight tank containing a block of soil and set in a field of growing plants. The plants grown in the lysimeter are the same as in the surrounding field. Evapotranspiration is estimated in terms of the amount of water required to maintain constant moisture conditions within the tank measured either volumetric ally or gravimetrically through an arrangement made in the lysimeter. Lysimeters should be designed to accurately reproduce the soil conditions, moisture content, type and size of the vegetation of the surrounding area. They should be so buried that the soil is at the same level inside and outside the container. Lysimeter studies are time-consuming and expensive.	**[6M]** **2M** **4M**	**CO2**	**L3**
3c	**What is Evaporation, if 4.80 Litres of water is removed from an evaporation pan of diameter 1.22m and the simultaneous rainfall measurement is 9.0mm?** **Answer:** Area of pan = $\pi \times 1.22^2 / 4 = 1.1689 m^2$ Volume of water removed (Given) = $4.80 / 1000 = 0.0048\ m^3$ Therefore, Depth of water removed = 0.0048 / 1.1689 = 0.004106m = 4.106 mm Evaporation = Rainfall – depth of water removed = 9.0 – 4.063 = **4.894mm**	**[6M]** **6M**	**CO2**	**L3**
4a	**Discuss the factors that affect infiltration. Explain with a neat sketch, measurement of infiltration using double ring infiltrometer.** Factors Affecting infiltration: • Surface condition of soil • Soil characteristics (texture and structure) • Rain fall characteristics (intensities) • Antecedent moisture condition • Climatic conditions (Humid, arid) • Human activities (surface gets compacted, farm lands, pavements)	**[10M]** **4M**	**CO2**	**L3**



eter (b) Double-ring infiltrometer

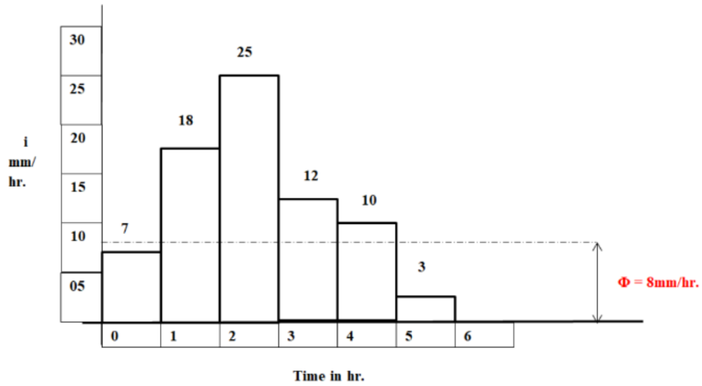
DOUBLE-RING INFILTROMETER This most commonly used infiltrometer is designed to overcome the basic objection of the tube infiltrometer, viz. the tube area is not representative of the infiltrating area. In this, two sets of concentrating rings with diameters of 30 cm and 60 cm and of a minimum length of 25 cm, as shown in Fig. 3.12(b), are used. The two rings are inserted into the ground and water is applied into both the rings to maintain a constant depth of about 5.0 cm. The outer ring provides water jacket to the infiltering water from the inner ring and hence prevents the spreading out of the infiltering water of the inner ring. The water depths in the inner and outer rings are kept the same during the observation period. The measurement of the water volume is done on the inner ring only. The experiment is carried out till a constant infiltration rate is obtained. A perforated disc to prevent formation of turbidity and settling of fines on the soil surface is provided on the surface of the soil in the inner ring as well as in the annular space.

6M

4b **A 6 hour storm produced rainfall intensities of 7, 18, 25, 12, 10 and 3mm/hour is successive one interval over a basin of 80sq.km. The resulting run-off is observed to be 264 × 10^5 m^3. Determine ϕ index for the basin.** **[10M]** **CO2** **L3**

Answer: Given data

Rainfall in mm	7	18	25	12	10	3
Time in hour	0-1	1-2	2-3	3-4	4-5	5-6



3M

Total rainfall = 75mm

Observed runoff = 264 × 10^5 m^3 *(this is in volumetric units, hence convert this into depth units)*

We Know that,

= runoff depth = 264 × 10^5 m^3 / 80 × 10^6 m^2

	= 33mm Therefore, $I_e \le \Phi \le I_m$ Ie = 75 – 33 / 6 = 7mm/hr 7 mm/hr ≤ Φ ≤ 25 mm/hr If Φ = 7mm, Revised Φ index value is (75-7-3) -33 / 4 = 8mm If Φ = 8mm, Then, 0 + (18-8) + (25-8) + (12-8) + (10-8) + 0 = 33mm which is equal to observed runoff. Therefore Φ index value is 8mm/hour.	7M		
	Module-3			
5a	**Define the following** **1) Basin recharge:** **2) Direct runoff:** **3) Drainage density:** **4) Form Factor:** **5) Overland flow:** 1) **Basin recharge:** Recharge basins temporarily store runoff, but release at least a portion of that runoff by infiltrating the water into the ground. Presence of artificial storage such as dams, weirs etc. and natural storage such as lakes and ponds etc. will affect the runoff. 2) **Direct runoff:** It consists of Surface runoff, Inter flow, and Channel precipitation, **but does not include Base flow**. 3) **Drainage density:** It is defined as the ratio of total channel length to the total drainage area. **4) Form Factor:** Temperature, wind speed, and humidity are the major meteorological factors, which affect runoff. Temperature, wind speed and humidity affect evaporation and transpiration rates, thus soil moisture regime and infiltration rate, and finally runoff volume 5) **Overland flow:** If the rate of precipitation is greater than the rate of infiltration, then the rainfall in excess of infiltration will start flowing over the ground surface and is also known as **overland flow.** When overland flow reaches a well-defined stream it is known as surface runoff.	**[10M]** 2M 2M 2M 2M 2M	**CO3**	**L2**

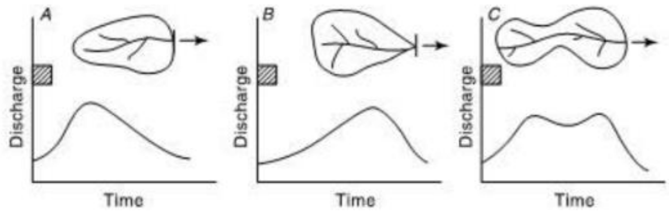
5b	**What is Runoff? List and explain factors affecting it.**	**[10M]**	**CO3**	**L2**
	Runoff means draining or flowing off of precipitation from a catchment area through a surface channel.	**1M**		
	The main factors affecting the runoff from a catchment area are: a) **Precipitation characteristics**-duration, intensity, areal distribution b) **Shape and size of catchment** – Fan, Leaf etc., c) **Topography** – slope and land features d) **Geologic characteristics -** surface and sub-surface soil type, rocks and their permeability e) **Meteorological characteristics -**Temperature, wind speed, and humidity f) **Storage characteristics of a catchment** - Presence of artificial storage such as dams, weirs etc. and natural storage such as lakes and ponds etc. g) **Precipitation Characteristics:** • Precipitation is the most important factor, which affects runoff. • The important characteristics of precipitation are • Duration, intensity and areal distribution.	**9M**		

6a	**How the hydrograph is affected by the following** **i) Shape of the basin** **ii) Non-uniform areal distribution of rainfall**	[6M]	CO3	L2

i)

SHAPE OF THE BASIN

The shape of the basin influences the time taken for water from the remote parts of the catchment to arrive at the outlet. Thus the occurrence of the peak and hence the shape of the hydrograph are affected by the basin shape. Fan-shaped, i.e. nearly semi-circular shaped catchments give high peak and narrow hydrographs while elongated catchments give broad and low-peaked hydrographs. Figure 6.2 shows schematically the hydrographs from three catchments having identical infiltration characteristics due to identical rainfall over the catchment. In catchment *A* the hydrograph is skewed to the left, i.e. the peak occurs relatively quickly. In catchment *B*, the hydrograph is skewed to the right, the peak occurring with a relatively longer lag. Catchment *C* indicates the complex hydrograph produced by a composite shape. **3M**



CLIMATIC FACTORS

Among climatic factors the intensity, duration and direction of storm movement are the three important ones affecting the shape of a flood hydrograph. For a given duration, the peak and volume of the surface runoff are essentially proportional to the intensity of rainfall. This aspect is made use of in the unit hydrograph theory of estimating peak-flow hydrographs, as discussed in subsequent sections of this chapter. In very small catchments, the shape of the hydrograph can also be affected by the intensity.

The duration of storm of given intensity also has a direct proportional effect on the volume of runoff. The effect of duration is reflected in the rising limb and peak flow. Ideally, if a rainfall of given intensity *i* lasts sufficiently long enough, a state of equilibrium discharge proportional to *iA* is reached. **3M**

If the storm moves from upstream of the catchment to the downstream end, there will be a quicker concentration of flow at the basin outlet. This results in a peaked hydrograph. Conversely, if the storm movement is up the catchment, the resulting hydrograph will have a lower peak and longer time base. This effect is further accentuated by the shape of the catchment, with long and narrow catchments having hydrographs most sensitive to the storm-movement direction.

ii)

6b	**Define 'Unit hydrograph'. With the help of a neat sketch, explain the various components of a flood hydrograph.**	**[6M]**	**CO3**	**L2**

Unit hydrograph is defined as the hydrograph of direct runoff resulting from **1cm** of effective rainfall accruing uniformly over the basin at a uniform rate for a specified duration –D hours

1M

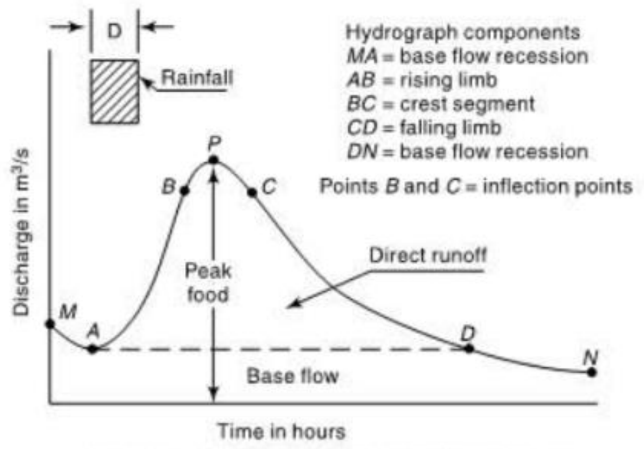


Fig. 6.1 Elements of a Flood Hydrograph

6.3 COMPONENTS OF A HYDROGRAPH

As indicated earlier, the essential components of a hydrograph are: (i) the rising limb, (ii) the crest segment, and (iii) the recession limb (Fig. 6.1). A few salient features of these components are described below.

Rising Limb

The rising limb of a hydrograph, also known as *concentration curve* represents the increase in discharge due to the gradual building up of storage in channels and over the catchment surface. The initial losses and high infiltration losses during the early period of a storm cause the discharge to rise rather slowly in the initial periods. As the storm continues, more and more flow from distant parts reach the basin outlet. Simultaneously the infiltration losses also decrease with time. Thus under a uniform storm over the catchment, the runoff increases rapidly with time. As indicated earlier, the basin and storm characteristics control the shape of the rising limb of a hydrograph.

5M

Crest Segment

The crest segment is one of the most important parts of a hydrograph as it contains the peak flow. The peak flow occurs when the runoff from various parts of the catchment simultaneously contribute amounts to achieve the maximum amount of flow at the basin outlet. Generally for large catchments, the peak flow occurs after the cessation of rainfall, the time interval from the centre of mass of rainfall to the peak being essentially controlled by basin and storm characteristics. Multiple-peaked complex hydrographs in a basin can occur when two or more storms occur in succession. Estimation of the peak flow and its occurrence, being important in flood-flow studies are dealt with in detail elsewhere in this book.

Recession Limb

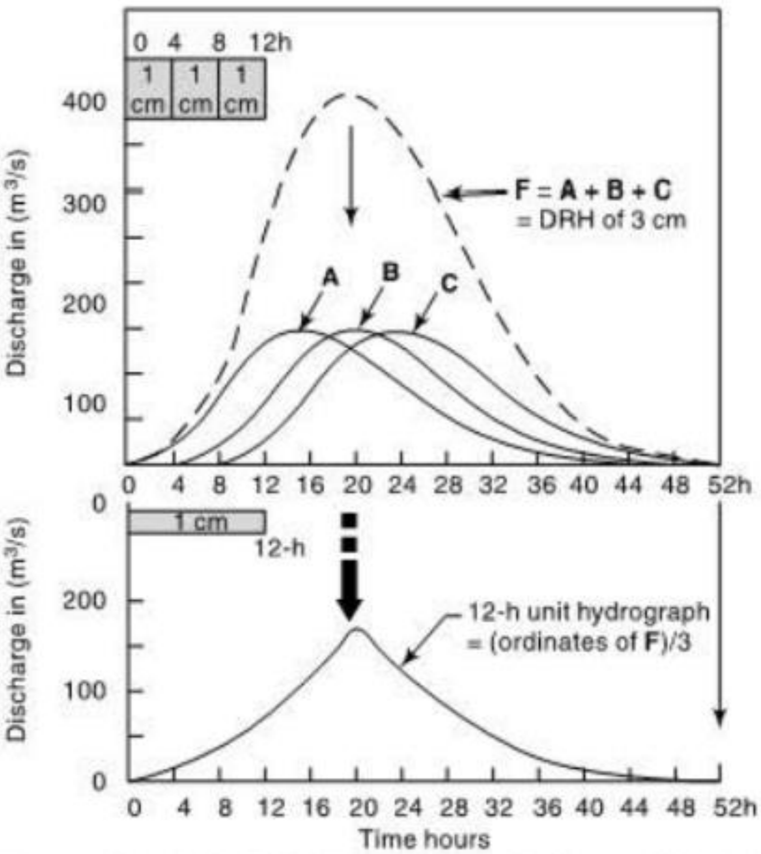
The recession limb, which extends from the point of inflection at the end of the crest segment (point *C* in Fig. 6.1) to the commencement of the natural groundwater flow (point *D* in Fig. 6.1) represents the withdrawal of water from the storage built up in the basin during the earlier phases of the hydrograph. The starting point of the recession limb, i.e. the point of inflection represents the condition of maximum storage. Since the depletion of storage takes place after the cessation of rainfall, the shape of this part of the hydrograph is independent of storm characteristics and depends entirely on the basin characteristics.

6c	**Given the ordinates of a 4-hour unit hydrograph. Derive the ordinates of 12-hour unit hydrograph for the same catchment. What is the peak value of discharge and the corresponding time interval observed in 4-hour and 12-hour unit hydrographs.**	[8M]	CO3	L3

Time (Hours)	0	4	8	12	16	20	24	28	32	36	40	44
Ordinates of 4-hour UH cm³/sec	0	20	80	130	150	130	90	52	27	15	05	0

Time (h)	Ordinates of 4-h UH (m^3/s)			DRH of 3 cm in 12-h (m^3/s) (Col. 2+3+4)	Ordinate of 12-h UH (m^3/s) (Col. 5)/3
	A	*B* Lagged by 4-h	*C* Lagged by 8-h		
1	2	3	4	5	6
0	0	—	—	0	0
4	20	0	—	20	6.7
8	80	20	0	100	33.3
12	130	80	20	230	76.7
16	150	130	80	360	120.0
20	130	150	130	410	136.7
24	90	130	150	370	123.3
28	52	90	130	272	90.7
32	27	52	90	169	56.3
36	15	27	52	94	31.3
40	5	15	27	47	15.7
44	0	5	15	20	6.7
48		0	5	5	1.7
52			0	0	0

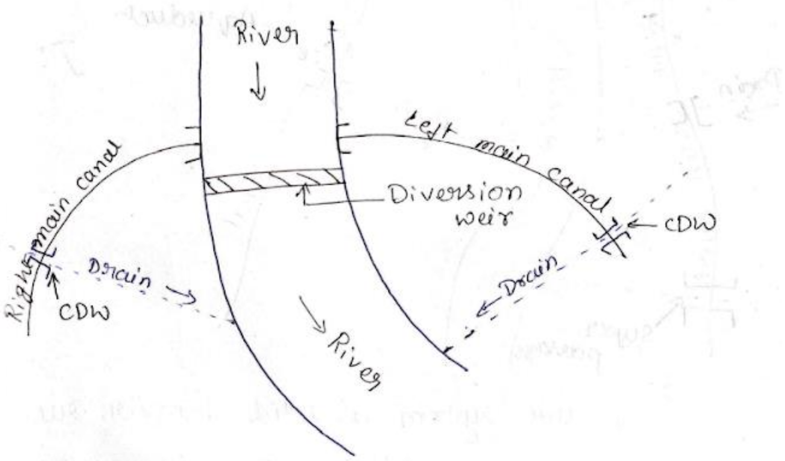
5M

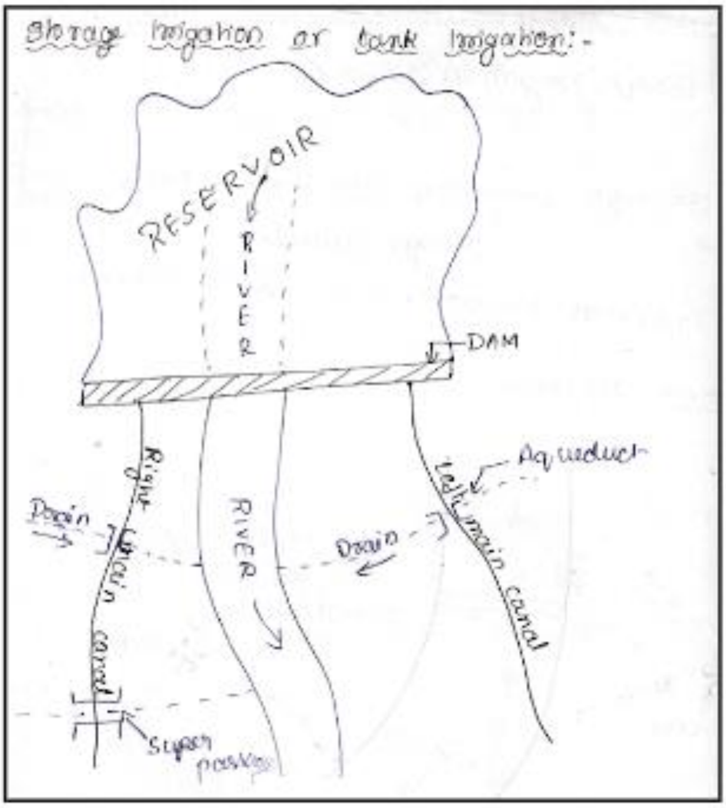


2M

Peak value of discharge observed in 4-hour is 150cumec at 16th hour and Peak value of discharge observed in 12-hour is 136.7cumec at 20th hour. 1M

Module-4

7a	**Define Irrigation. Discuss in brief the benefits and ill-effects of irrigation.**	[8M]	CO4	L2
	Irrigation may be defines as the process of artificially supplying water to soil for rising crops.	1M		
	Benefits and ill effects of irrigation **Direct benefits** • Increase in food production • Cultivation of cash-crops • Growing fruits and vegetables • Protection from drought or famine • Prevention of damage through floods • Domestic & industrial water supply • Generation of Hydro-electric power • Inland navigation • Increase in revenue from recreation facilities such as boating, swimming, fishing • Aquatic & wild life protection • Afforestation	3.5M		
	Excess irrigation & unscientific use of irrigation water may give rise to the following **ill-effects**. • The surrounding environment becomes damp & cold causing diseases like malaria. • Over irrigation leads to water logging problems, accumulation of salt near the root zones of crops, decreases the fertility of soil • Excessive seepage from unlined canals may cause water logging problems to the adjacent lands. • Introduction of an irrigation system in an area results in change in vegetation, flora & fauna. There by altering the ecology of the command area.	3.5M		
7b	**Distinguish between: Direct Irrigation and Storage Irrigation**	[6M]	CO4	L2
	Direct Irrigation:  CDW ← Cross Drainage works. In this system, water is directly diverted from the river into the canal by construction of a weir or barrage across the river without attempting to store water.	3M		

	 In this system a solid barrier, such as a dam, is constructed across the river and the water is stored in the reservoir or lake formed. Storage irrigation scheme is comparatively of a bigger magnitude & involves much more expenditure than direct irrigation scheme. A network of canal systems conveys water to the agricultural fields through various regulatory works.	3M		
7c	**What is Bhandara Irrigation? List its advantages and disadvantages.** Bandhara irrigation is a minor irrigation system suitable for irrigating isolated areas, up to 500 hectares. The bandhara is similar to a weir which is constructed across a small stream to raise the water level on the upstream side to divert the water through the canal. **Advantages:** 1) The water of small streams can be utilized for irrigation purposes by constructing a simple structure. 2) The culturable area is generally close to the source. Hence, there is less possibility of transmission loss. 3) As there is no loss due to transmission, the duty of water is high. **Disadvantages:** 1) Normally, the discharge capacity of small streams is low. Moreover, if bandhara irrigation is implemented on such streams, the people residing on the downstream side will not get water for their use. 2) The supply of water mainly depends on rainfall. So, in the period of drought, this system is practically useless.	**[6M]** 2M 2M 2M	**CO4**	**L2**
8a	**Define Duty and Delta. Derive the relation between them**	**[10M]**	**CO5**	**L3**

	Duty represents the irrigating capacity of a unit volume of water. It is the relation b/w the area of crop irrigated and the quantity of water required during the entire base period of the crop. **Delta (Δ)** is the total depth of water required by a crop during the entire base period of the crop. **Relationship b/w duty and delta of irrigation water** Let D is Duty in ha/cumec Δ is total depth of water supplied in m B is the Base period of crop in days Consider a field of area 'D' hactares and the water supplied to the field corresponding to the water depth 'Δ' m will be $= D \times \Delta$ ha-m $= D \times \Delta \times 10^4 m^3$ ---------(1) Also for the same field of area 'D' ha, 1 cumec of water is supplied during the entire Base period of 'B' days. Hence total quantity of watr supplied to the field = $1 \times B \times 60 \times 60 \times 24 m^3$ -----------(2) Equating equations (1) and (2) $D \times \Delta \times 10^4 m^3 = 1 \times B \times 60 \times 60 \times 24 m^3$ Therefore $\Delta = 8.64 \frac{B}{D} m$	3M 7M		
8b	**Define the following.** **i) Permanent wilting point ii)Field capacity** **Permanent Wilting Point:** It is defined as the minimum amount of water in the soil that the plant requires not to wilt. If the soil water content decreases to this point, a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. **Field capacity** or **water holding capacity of the soil:** is the water content of a soil after gravitational drainage over approximately a day. After heavy rainfall or irrigation of the soil some water is drained off along the slopes while the rest percolates down in the soil. Out of this water, some amount of water gradually reaches the water table under the force of gravity (gravitational water) while the rest is retained by the soil. This amount of water retained by the soil is called the field capacity or water holding capacity of the soil.	[10M] 5M 5M	CO5	L2
	Module-5			
9a	**Write an explanatory note on Canal classification on the basis of its alignment.** Based on **canal alignment, canals are classified as** • Contour canal	[10M] 3M	CO6	L2

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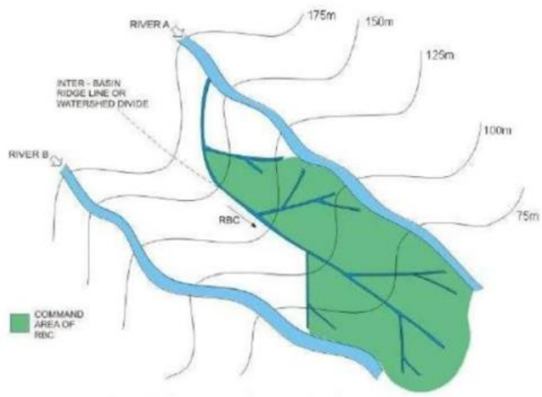
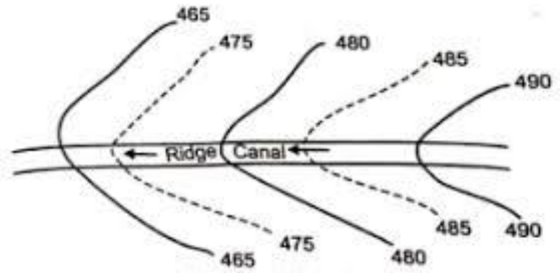
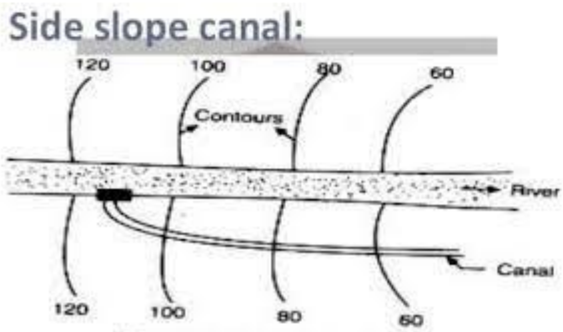


Watershed canal – Ridge canal



Side slope canal



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<td>9b</td>
<td>Enumerate the basic differences between Lacey's and Kennedy's theory.
1. The basic concept regarding silt transportation is the same in both the theories. In both the theories it is stated that the silt remains in suspension due to vertical force of eddies.

2. Kennedy assumes that the eddies are generated on the bed only and hence he derives the formula for finding out critical velocity in terms of depth.

3. Lacey proposes that regime section is semi-circular ultimately and eddies are generated along the whole wetted perimeter. He drives formula for mean regime velocity in terms of hydraulic mean radius. 3 Lacey states that as the shape of irrigation channel is fixed to a particular geometrical figure (generally trapezoidal) it cannot achieve final regime conditions and hence may be said to achieve</td>
<td>[10M]</td>
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initial regime. Kennedy assumes that when there is neither silting nor scouring the channel is in its regime.

4. Kennedy selects Kutter’s formula for designing irrigation channel. But in Kutters formula value of N is arbitrarily fixed. Lacey has not fixed any value arbitrarily.

5. Kennedy has made use of term “CVR” (m) but he did not give any basis for calculating m. He simply states that it depends on silt charge and silt grade.Lacey has introduced a term “silt factor” (f). He related f to mean diameter of the bed material and gave basis to calculate f. The formula is $f = 1.76 \sqrt{mr}$.

6. Kennedy gives no clue for calculating longitudinal regime slope. Lacey produced a regime slope formula.

7. Design based on Kennedy’s theory can only be achieved after making trials. Of course Woods has simplified the procedure by giving normal design table which provides BID ratio. Lacey gave very important wetted regime perimeter equation Pw = 4.825 Q1/2 He of course admitted that value of constant in the above equation is in no way constant and varies from 4 to 5.8 for regime channels.
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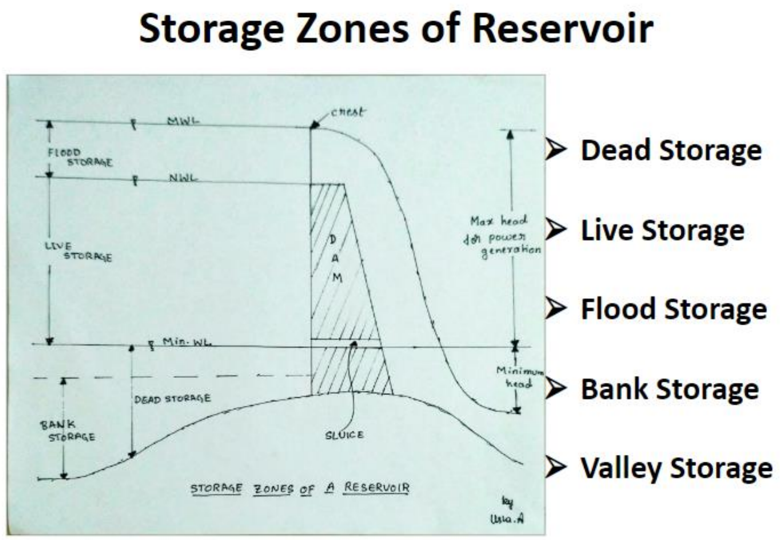
With a neat sketch, explain different zones of a storage reservoir.


Dead Storage: is the depth of reservoir storage created to cater for sediment deposition by the inflowing water. It is equivalent to the volume of sediment expected to be deposited during the life of the reservoir.

Live Storage: is the usable portion of the total storage of a reservoir. It is desirable to have additional live storage over and above the estimated one.
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Flood Storage: it is the water storage difference between normal water level and Maximum water level.

Bank Storage: it is the storage developed in the voids of the soil cover in the reservoir.

Valley Storage: it is the storage in the stream created after overflow of floods.

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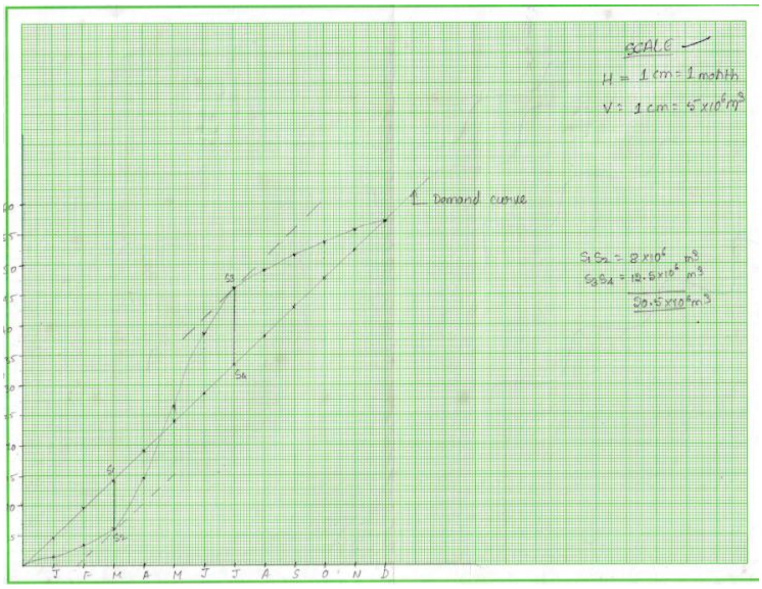
With a neat sketch, explain the step-by-step procedure of determining reservoir capacity for a specific yield using the mass-inflow curve.

Determination of storage capacity using mass curves

- The storage capacity of reservoirs is determined from mass curves of inflow and demand.
- Matching of the inflow and demand mass curves to the same scale, would indicate the time when storage is required.
- When inflow is low and demand is more, storage is required to meet the demand.
- Draw tangents parallel to the demand curve
- Measure the maximum vertical intercepts between tangent line and mass inflow curve.
- The vertical intercept indicates the volume by which the inflow is short of the demand.
- The maximum intercept or the summation of vertical intercepts represents the required capacity of the reservoir.
- When the demand curve is not straight but is curved, the two curves are superimposed one over the other to get the required capacity.



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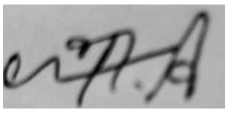
P. T.O



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