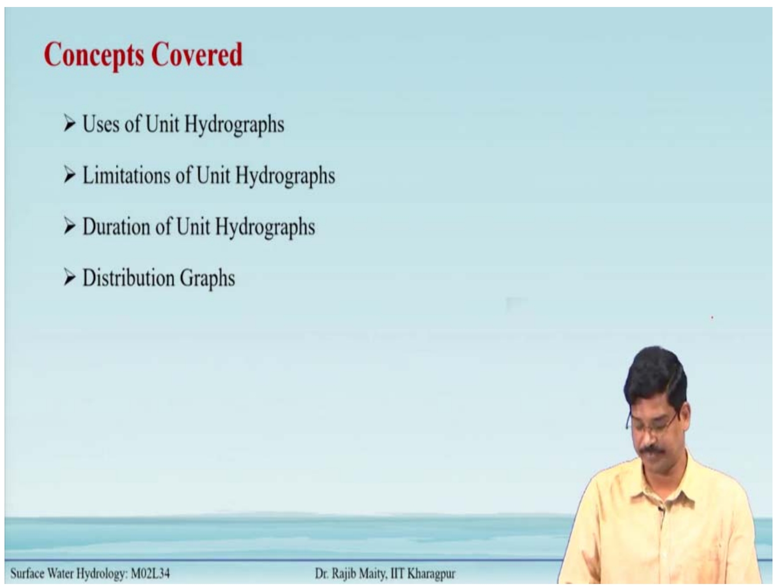
Surface Water Hydrology
Professor Rajib Maity
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 34
More on Unit Hydrographs

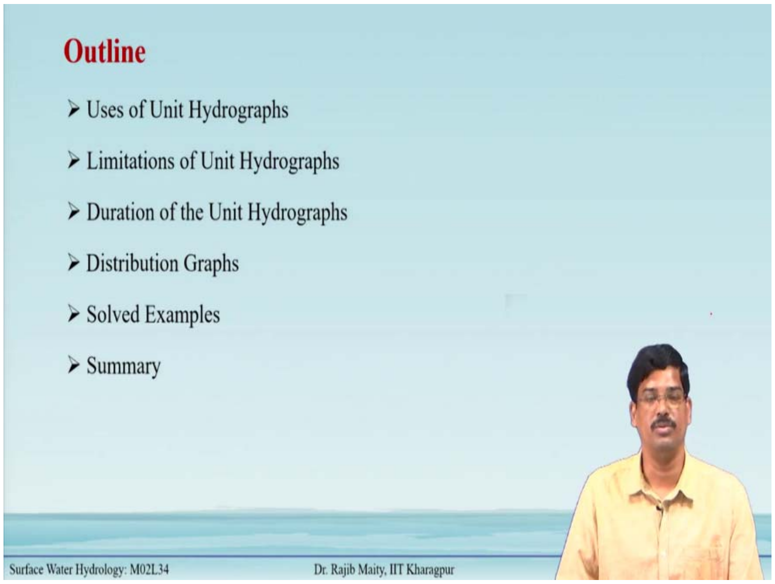
In this lecture, we will discuss more information about unit hydrograph before going to some other advanced topics like synthetic unit hydrograph and instantaneous unit hydrograph in the upcoming lecture.

(Refer Slide Time: 01:17)



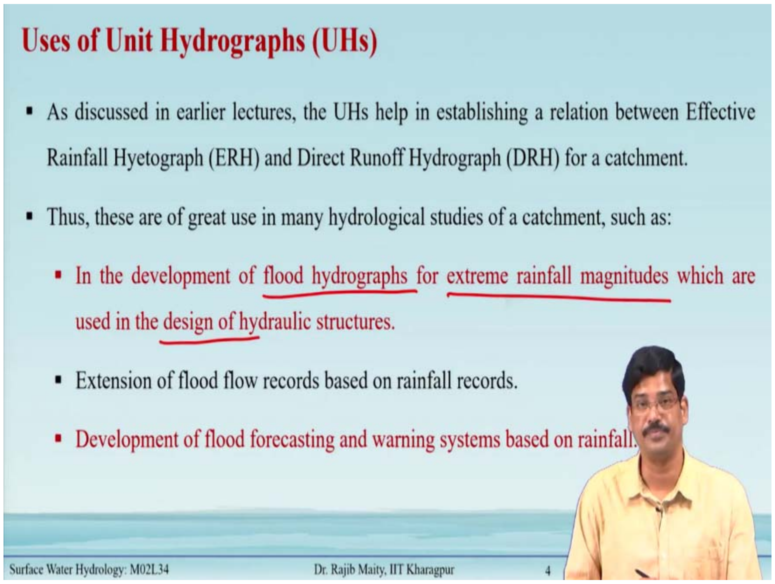
The concept will cover the uses of unit hydrographs, limitations of unit hydrograph, duration of unit hydrographs, and one more parallel way of expressing the same information for a catchment known as distribution graphs.

(Refer Slide Time: 01:39)



The lecture outline for this lecture goes like as follows. First, the uses of unit hydrograph; then there are some limitations of the unit hydrograph that we will discuss. There are some guidelines for selecting the duration of unit hydrograph for a particular basin that we will discuss. We will discuss the concept of distribution hydrograph with some example problems before going to the summary.

(Refer Slide Time: 02:05)



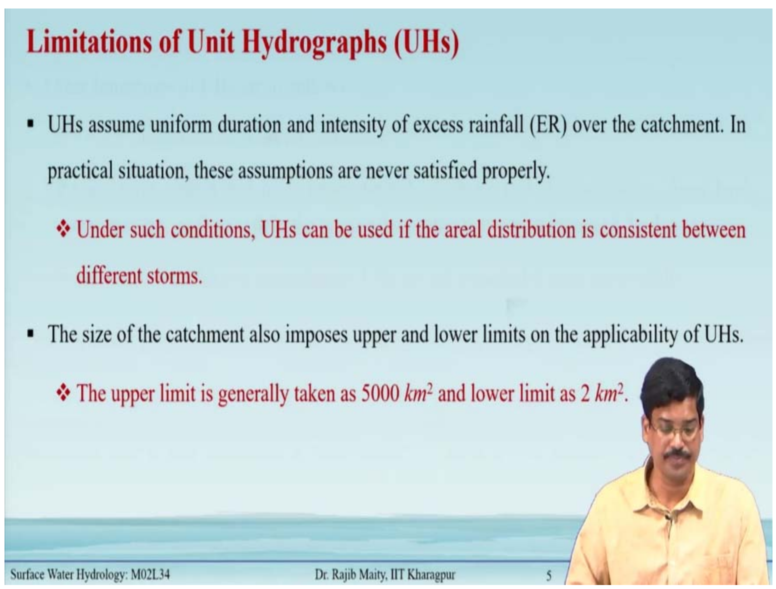
Uses of Unit Hydrographs (UHs)

As discussed in the earlier lectures, the UHs help to establish a relation between Effective Rainfall Hyetograph (ERH) and Direct Runoff Hydrograph (DRH) for a catchment.

Thus, these are of great use in many hydrological studies of a catchment, such as:

- In the development of flood hydrographs for extreme rainfall magnitudes which are used in the design of hydraulic structures.
- Extension of flood flow records based on rainfall records.
- Development of flood forecasting and warning systems based on rainfall.

(Refer Slide Time: 04:05)



Limitations of Unit Hydrographs (UHs)

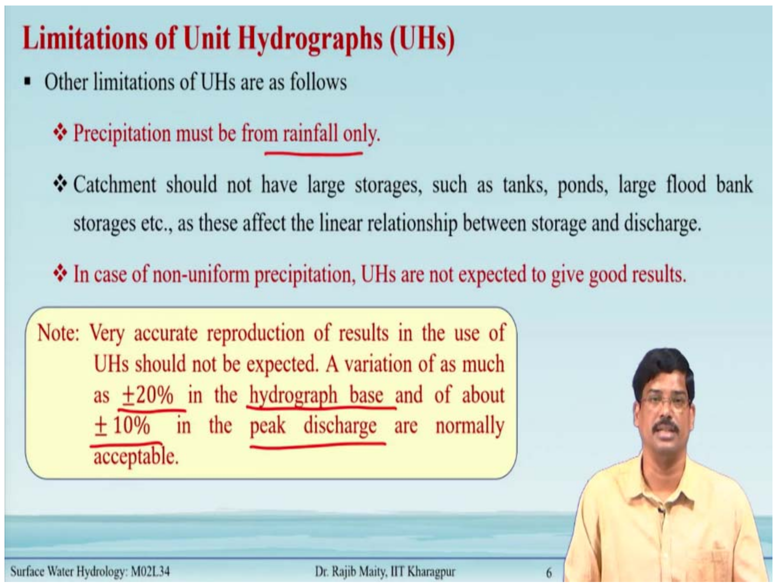
- UHs assume uniform duration and intensity of excess rainfall (ER) over the catchment. In practical situation, these assumptions are never satisfied properly.

Under such conditions, UHs can be used if the areal distribution is consistent between different storms.

- The size of the catchment also imposes upper and lower limits on the applicability of UHs.

Under such conditions, the upper limit is generally taken as 5000 km^2 and lower limit as 2 km^2.

(Refer Slide Time: 05:35)

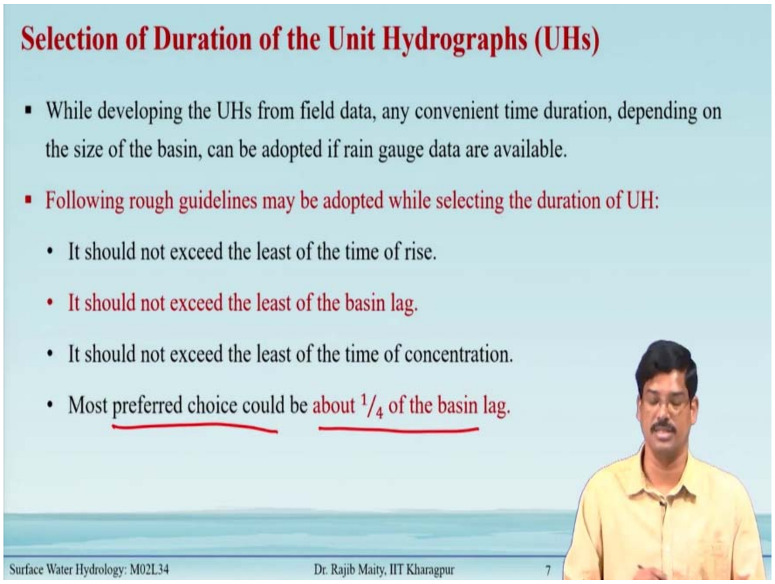


Other limitations of UHs are as follows

- Precipitation must be from rainfall only.
- Catchment should not have large storages, such as tanks, ponds, large flood bank storages etc., as these affect the linear relationship between storage and discharge.
- In case of non-uniform precipitation, UHs are not expected to give good results.

It may be noted that very accurate reproduction of results in the use of UHs should not be expected. A variation of as much as ±20% in the hydrograph base and of about ±10% in the peak discharge are normally acceptable.

(Refer Slide Time: 07:21)



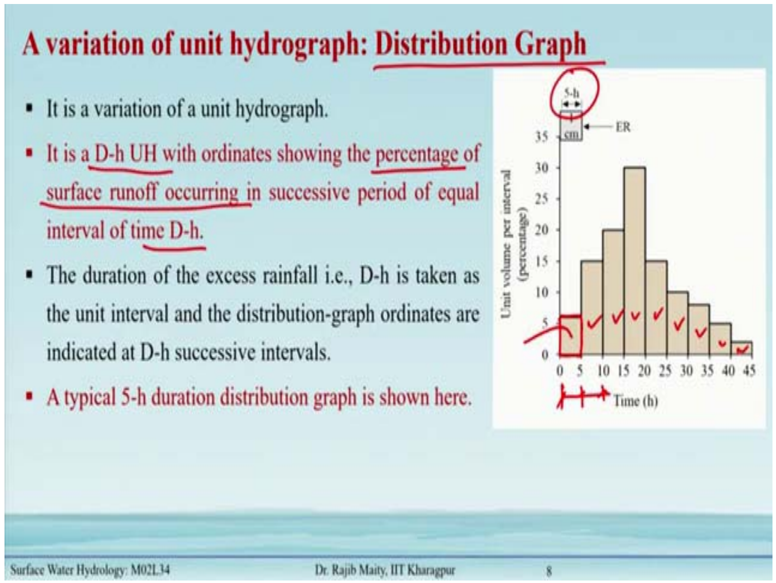
Selection of Duration of the Unit Hydrographs (UHs)

While developing the UHs from field data, any convenient time duration, depending on the size of the basin, can be adopted if rain gauge data are available.

Following rough guidelines may be adopted while selecting the duration of UH:

- It should not exceed the least of the time of rise.
- It should not exceed the least of the basin lag.
- It should not exceed the least of the time of concentration.
- Most preferred choice could be about 1⁄4 of the basin lag.

(Refer Slide Time: 08:37)



A variation of unit hydrograph: Distribution Graph

In the case of a unit hydrograph, it shows the actual discharge magnitude, but in the case of a distribution graph, it shows the percentage of the surface runoff occurring in the successive period of the equal time intervals of D-hour. Under the unit hydrograph, the total area is 1 centimeter of rainfall excess. So, if we consider the total area below the unit hydrograph, it is 100 %. However, if we consider one small time interval and the percentage of the total flow in that interval, the distribution graph shows the percentage of flow in that time interval. The successive time intervals/periods should be equal to the D-hour.

So, D-hour means that the unit hydrograph always comes with a duration. In fig.1, it says the unit hydrograph duration is 5 hours. So, it is a 5-hour unit hydrograph. So, here in this one, when we express the percentage, we are dividing the time base into each successive 5-hour periods.

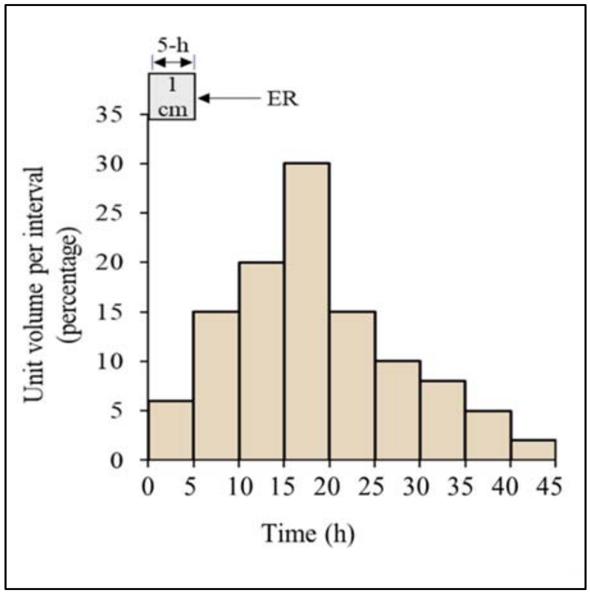
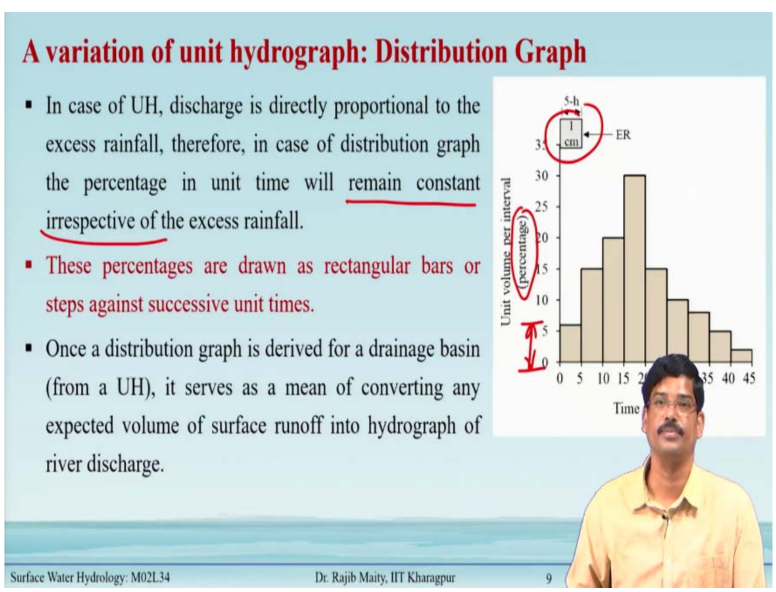


Figure1: The 5-h duration distribution graph

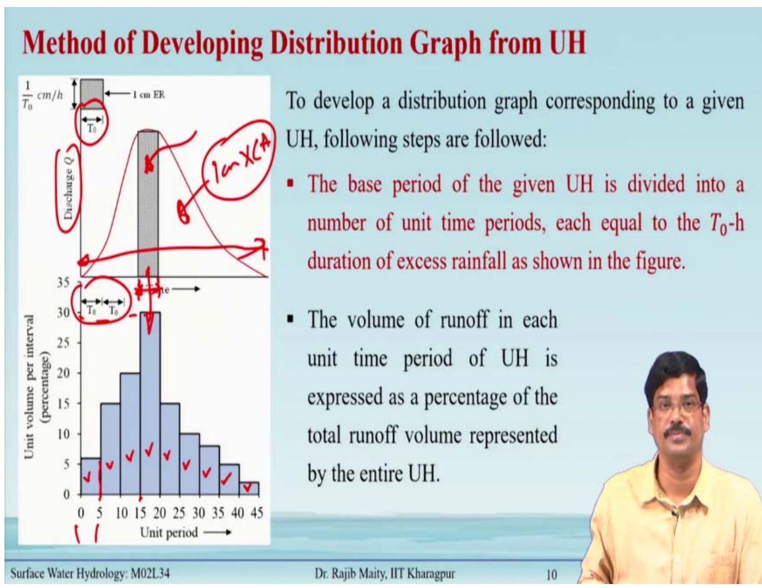
In figure 1, the first block shows that percentage of the total volume of this runoff that is being drained out from the catchment in this first 5-hour period. Similarly, all these successive blocks show the percentage of the total runoff that is occurring. So, generally, it is a traditional practice that the unit of this interval, this interval of this distribution graph the ordinates indicate the D-hours of this unit hydrograph to link it to the unit hydrograph.

(Refer Slide Time: 11:02)



In the distribution graph, the percentage in the unit time will remain constant irrespective of the excess rainfall. That means the heights of the blocks will remain constant even if there is a change in the rainfall excess magnitude because, so far as the distribution graph is concerned, it is given in terms of the percentage. So, the percentages will remain same in the 5-hour periods. In this particular example, for each 5-hour periods, the percentage of the total rainfall excess are drawn as rectangular bars. Once a distribution graph is derived for a drainage basin from converting any expected volume of the surface runoff into the hydrograph of the river discharge.

(Refer Slide Time: 12:40)



Method of Developing Distribution Graph from UH

The development of a distribution graph from a particular unit hydrograph is expressed in figure 2. To develop this distribution graph corresponding to 1 unit hydrograph, the first thing is that the base period of the given UH is divided into a number of unit time periods, each equal to the T_0-h duration of excess rainfall, shown in figure 2. Here, this entire base is divided into those successive time periods. Now, the volume of the runoff in each unit time period of this unit hydrograph is expressed as a percentage of the total runoff volume represented by this entire unit hydrograph.

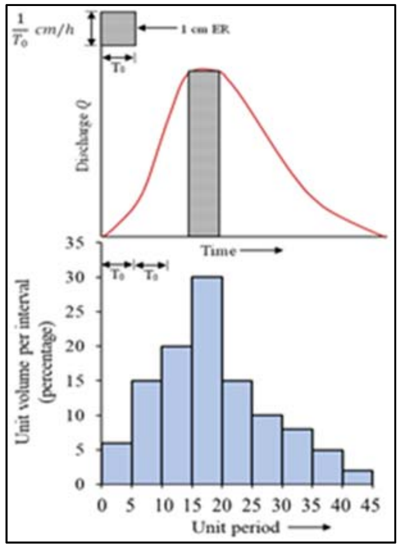
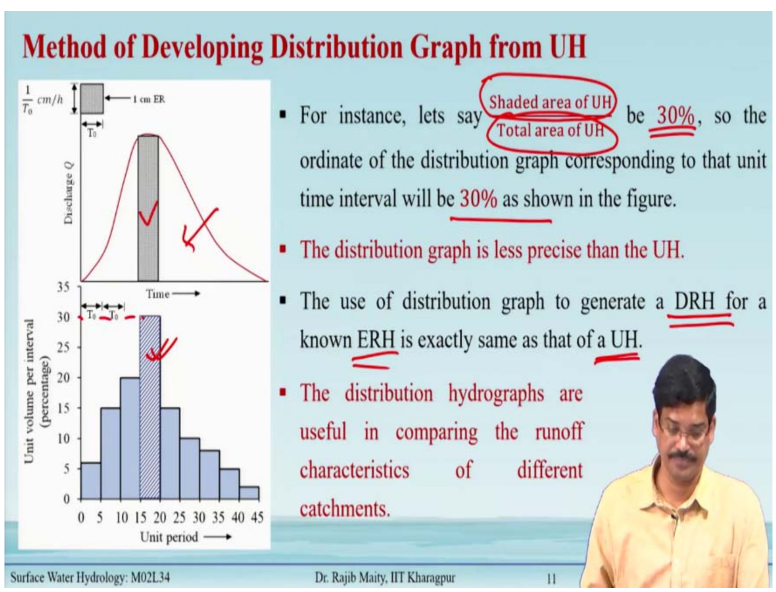


Figure 2: The Developing Distribution Graph from UH

In figure 2, the discharge rate taken on the y-axis and x-axis gives the time. So, if we multiply these two, we get the total amount of runoff that has come out. If we divide each shaded area by the total amount of this runoff, we can calculate that percentage. In this way, all these bars are plotted one after another.

(Refer Slide Time: 15:10)

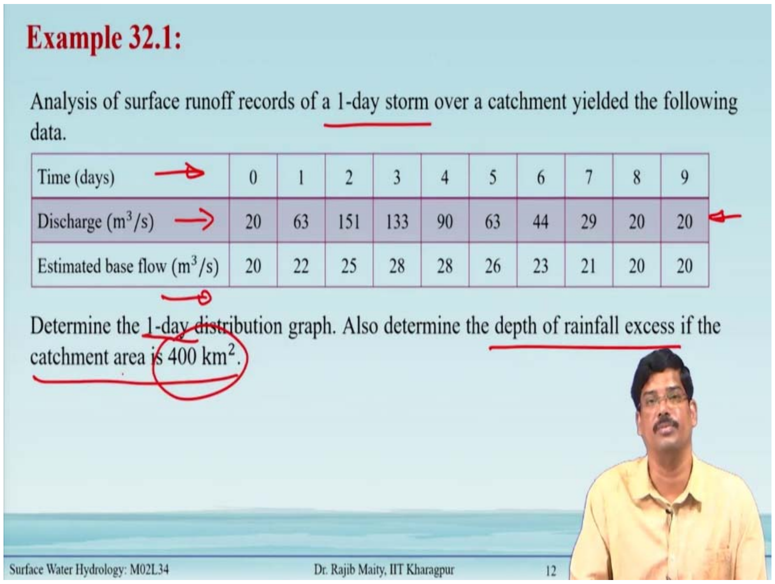


For instance, we may consider the (Shaded area of UH)/(Total area of UH) be 30% (shown in figure2), so the ordinate of the distribution graph corresponding to that unit time interval will be 30% as shown in the figure2.

The use of this distribution graph to generate the direct runoff hydrograph for a known excess rainfall hydrograph is the same as the unit hydrograph.

The distribution graph also be used to calculate the percentage of the rainfall that is coming out as the runoff since this individual area shows the percentage. Then we can add up all such successive time units to get the total amount of rain that that is coming out as runoff. Thus, the distribution hydrographs are useful in comparing the runoff characteristics of different catchments.

(Refer Slide Time: 16:39)



Example 32.1:

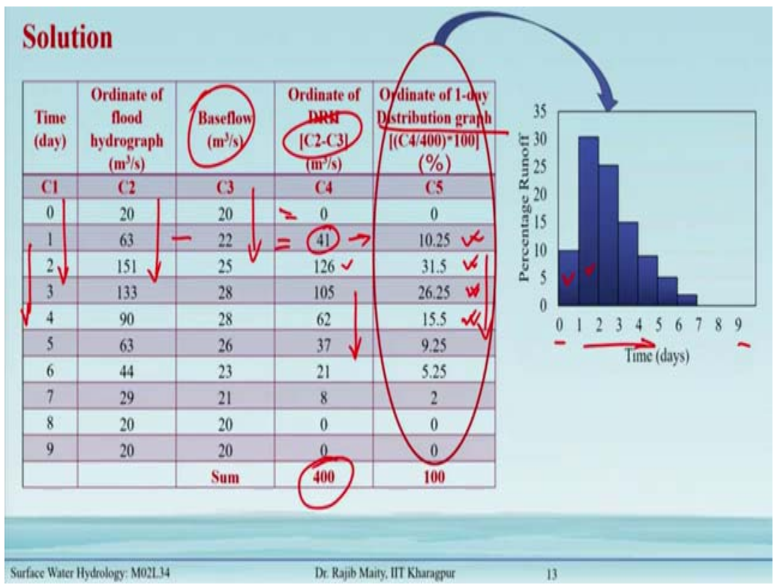
Analysis of surface runoff records of a 1-day storm over a catchment yielded the following data.

Time (days)	0	1	2	3	4	5	6	7	8	9
Discharge (m^3/s)	20	63	151	133	90	63	44	29	20	20
Estimated base flow (m^3/s)	20	22	25	28	28	26	23	21	20	20

Determine the 1-day distribution graph. Also determine the depth of rainfall excess if the catchment area is 400 km^2.

So, from there I can say that it is the resulting of this one centimeter of rainfall excess gives that total amount. So, this 400-kilometer square is the area is given. So, I can, from there I can calculate what is the total depth of rainfall excess.

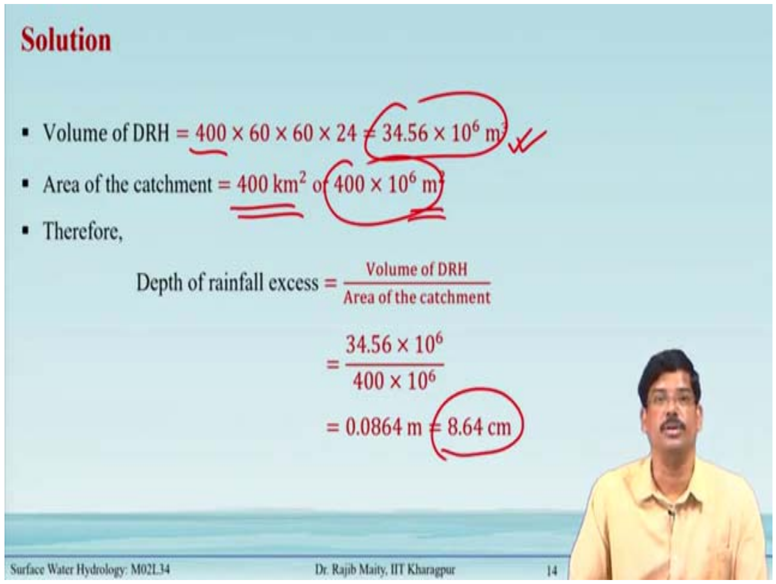
(Refer Slide Time: 18:21)



Solution

Time (day)	Ordinate of flood hydrograph (m³/s)	Baseflow (m³/s)	Ordinate of DRH [C2-C3] (m³/s)	Ordinate of 1-day Distribution graph [(C4/400)*100] (m³/s)
C1	**C2**	**C3**	**C4**	**C5**
0	20	20	0	0
1	63	22	41	10.25
2	151	25	126	31.5
3	133	28	105	26.25
4	90	28	62	15.5
5	63	26	37	9.25
6	44	23	21	5.25
7	29	21	8	2
8	20	20	0	0
9	20	20	0	0
		Sum	**400**	**100**

(Refer Slide Time: 20:27)



And, the corresponding percentage of runoff in each successive time intervals are calculated as shown in the table. The resulting distribution graph is shown in Fig. 3.

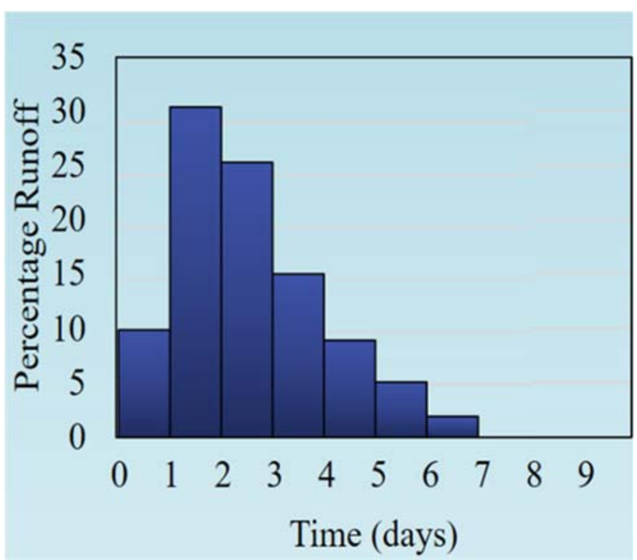
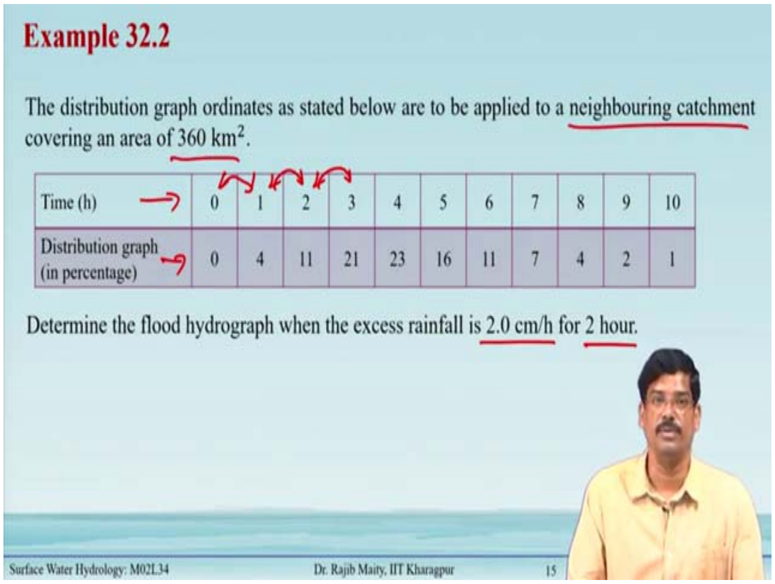


Figure 3: The distribution graph of Example 32.1

(Refer Slide Time: 21:22)



Example 32.2

The distribution graph ordinates as stated below are to be applied to a neighbouring catchment covering an area of 360 km^2.

Time (h)	0	1	2	3	4	5	6	7	8	9	10
Distribution graph (in percentage)	0	4	11	21	23	16	11	7	4	2	1

Determine the flood hydrograph when the excess rainfall is 2.0 cm/h for 2 hour.

Solution:

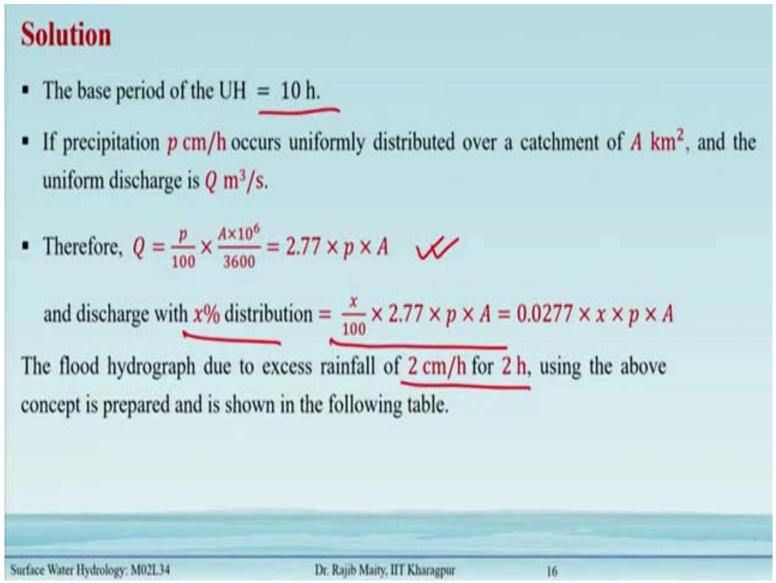
The base period of the UH $=$ 10 h.

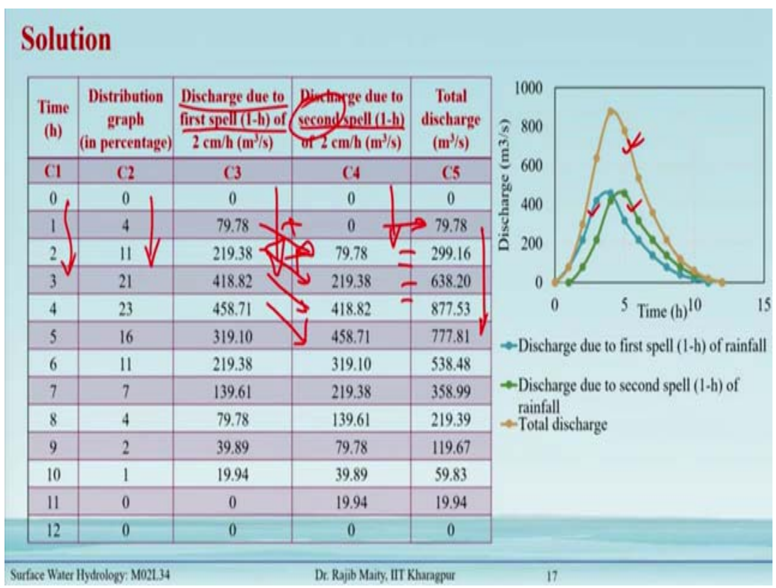
If precipitation p cm/h occurs uniformly distributed over a catchment of A km^2, and the uniform discharge is Q m3/s.

Therefore, $Q = \frac{p}{100} \times \frac{A \times 10^6}{3600} = 2.77 \times p \times A$

and discharge with $x\%$ distribution $= \frac{x}{100} \times 2.77 \times p \times A = 0.0277 \times x \times p \times A$

(Refer Slide Time: 23:16)





Solution

Time (h)	Distribution graph (in percentage)	Discharge due to first spell (1-h) of 2 cm/h (m³/s)	Discharge due to second spell (1-h) of 2 cm/h (m³/s)	Total discharge (m³/s)
C1	C2	C3	C4	C5
0	0	0	0	0
1	4	79.78	0	79.78
2	11	219.38	79.78	299.16
3	21	418.82	219.38	638.20
4	23	458.71	418.82	877.53
5	16	319.10	458.71	777.81
6	11	219.38	319.10	538.48
7	7	139.61	219.38	358.99
8	4	79.78	139.61	219.39
9	2	39.89	79.78	119.67
10	1	19.94	39.89	59.83
11	0	0	19.94	19.94
12	0	0	0	0

The flood hydrograph due to excess rainfall of 2 cm/h for 2 h, using the above concept is prepared and is shown in the following table.

Time (h)	Distribution graph (in percentage)	Discharge due to first spell (1-h) of 2 cm/h (m^3/s)	Discharge due to second spell (1-h) of 2 cm/h (m^3/s)	Total discharge (m^3/s)
C1	C2	C3	C4	C5
0	0	0	0	0
1	4	79.78	0	79.78
2	11	219.38	79.78	299.16
3	21	418.82	219.38	638.20
4	23	458.71	418.82	877.53
5	16	319.10	458.71	777.81
6	11	219.38	319.10	538.48
7	7	139.61	219.38	358.99
8	4	79.78	139.61	219.39
9	2	39.89	79.78	119.67
10	1	19.94	39.89	59.83
11	0	0	19.94	19.94
12	0	0	0	0

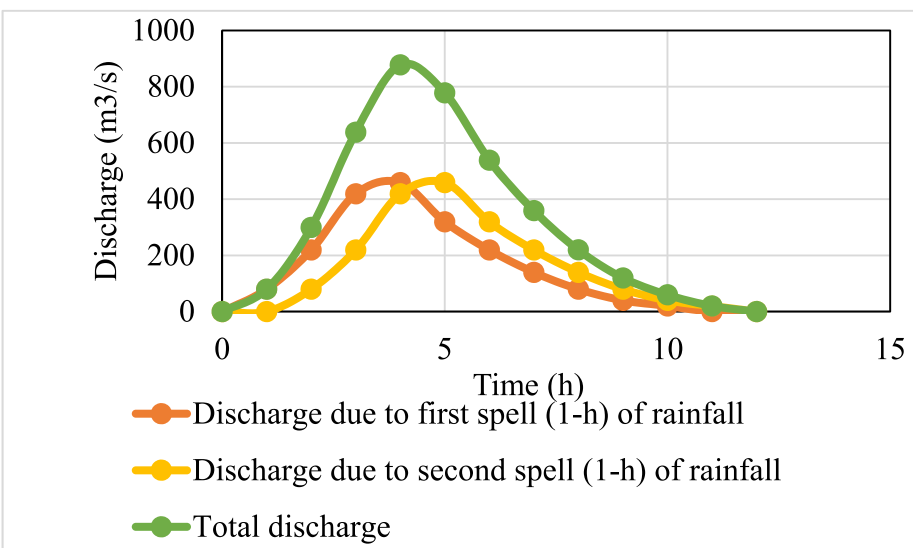
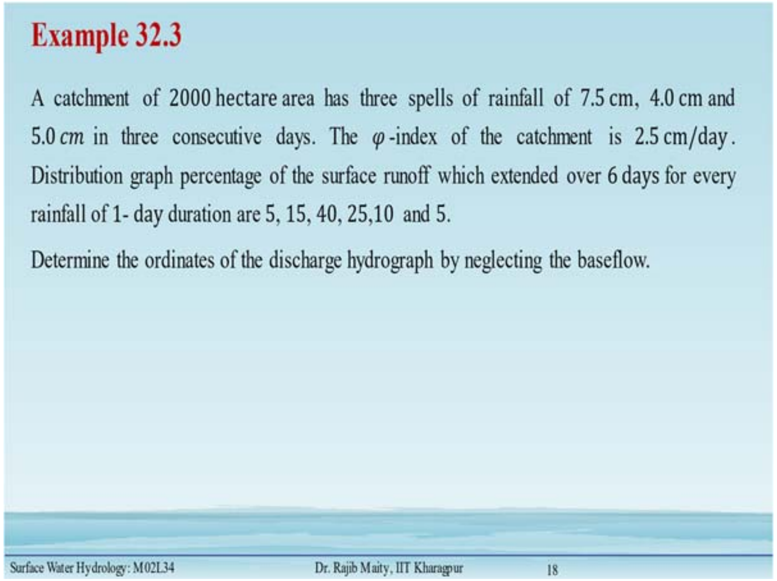
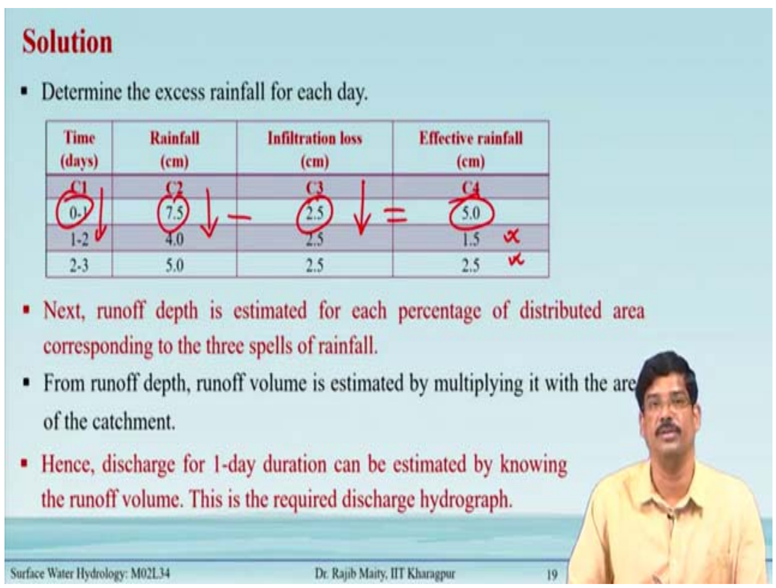


Figure 4: Flood Hydrograph of Example 32.2

(Refer Slide Time: 26:43)





Example 32.3

A catchment of 2000 hectare area has three spells of rainfall of 7.5 cm, 4.0 cm and 5.0 cm in three consecutive days. The φ-index of the catchment is 2.5 cm/day. Distribution graph percentage of the surface runoff which extended over 6 days for every rainfall of 1- day duration are 5, 15, 40, 25, 10 and 5. Determine the ordinates of the discharge hydrograph by neglecting the baseflow.

Solution

Determine the excess rainfall for each day.

Time (days)	Rainfall (cm)	Infiltration loss (cm)	Effective rainfall (cm)
C1	**C2**	**C3**	**C4**
0-1	7.5	2.5	5.0
1-2	4.0	2.5	1.5
2-3	5.0	2.5	2.5

Next, runoff depth is estimated for each percentage of distributed area corresponding to the three spells of rainfall.

From runoff depth, runoff volume is estimated by multiplying it with the area of the catchment.

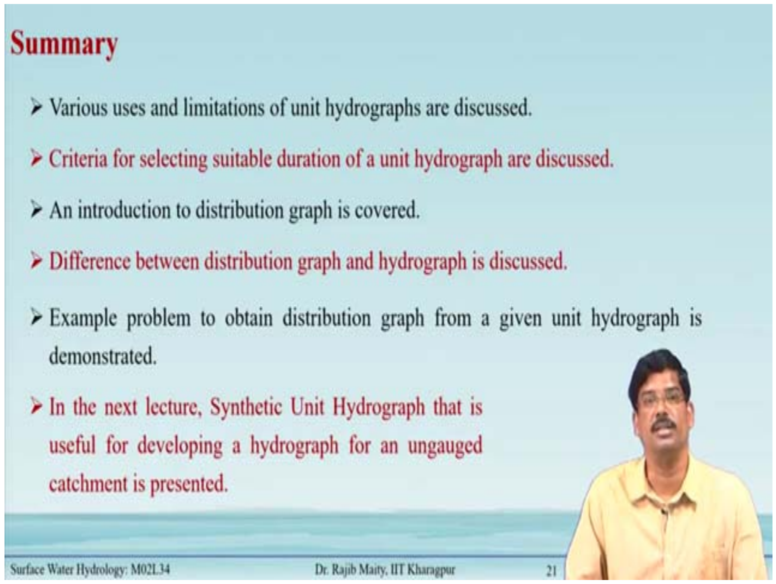
Hence, discharge for 1-day duration can be estimated by knowing the runoff volume. This is the required discharge hydrograph.

Given: Catchment Area (C.A.) $= 2000$ hectare $= 2000 \times 10^4$ m^2

All the calculations are performed in tabular manner as shown in the following table.

Time (days)	Distribution graph (in % age)	Distributed Runoff depth for rainfall excess (cm)			1-day Runoff depth $[C3_a + C3_b + C3_c]$ (cm)	Runoff volume $[\mathrm{C4} \times \mathrm{C.A.}]$ (m^3)	Ordinate of discharge hydrograph $[\mathrm{C5}/(24 \times 60 \times 60)]$ (m^3/s)
		5 cm (Day 1)	1.5 cm (Day 2)	2.5 cm (Day 3)			
C1	**C2**	**$C3_a$**	**$C3_b$**	**$C3_c$**	**C4**	**C5**	**C6**
0-1	5	0.25	--	--	0.25	50,000	0.579
1-2	15	0.75	0.075	--	0.825	1,65,000	1.910
2-3	40	2	0.225	0.125	2.35	4,70,000	5.440
3-4	25	1.25	0.6	0.375	2.225	4,45,000	5.150
4-5	10	0.5	0.375	1	1.875	3,75,000	4.340
5-6	5	0.25	0.15	0.625	1.025	2,05,000	2.373
6-7	0	0	0.075	0.25	0.325	65,000	0.752
7-8	--	0	0	0.125	0.125	25,000	0.289
8-9	--	0	0	0	0	0	0

(Refer Slide Time: 31:48)



Summary

In summary, we learned the following points from this lecture:

- Various uses and limitations of unit hydrographs are discussed.
- Criteria for selecting suitable duration of a unit hydrograph are discussed.
- An introduction to distribution graph is covered.
- Difference between distribution graph and hydrograph is discussed.
- Example problem to obtain distribution graph from a given unit hydrograph is demonstrated.
- In the next lecture, Synthetic Unit Hydrograph that is useful for developing a hydrograph for an ungauged catchment is presented.