Availability and Management of Groundwater Resources
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Lecture - 32
Estimation of Subsurface Runoff, Types of Wells, Well Hydraulics (Continued)

Welcome you all, in the part 3 of the module 7, estimation of subsurface runoff, types of well and well hydraulics. So, we have covered the two different lectures in just discussing about the runoff; the runoff cycle and the factors affecting the runoff.

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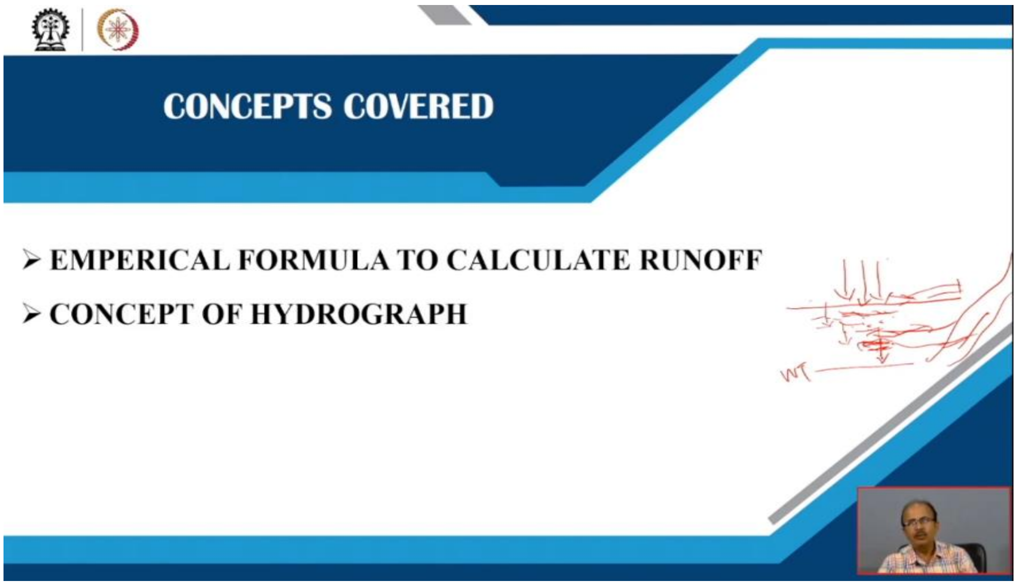

In this lecture we will try to concentrate on the some of the calculation of the runoff through the empirical formula and also, we will learn about the hydrograph, which is a very important graph which shows about the discharge per unit time from any stream channel or any tube or it helps in knowing about the consideration of the runoff in any land area. So, with this whatever concept we have generated we have seen that during on the earth surface.

We have seen on the earth's surface the rainfall amount falls and if these rainfall amounts is being intercepted and you are just intercepted by tall trees and tall water then, it reaches to the earth's surface and it just fulfills the storage space on the earth's surface which is known as the depletion storage and then since the soil layer underneath soil layer is remaining dry. So, infiltration takes place and then percolation starts and ultimately the water rain water reaches to the water table.

So, we have seen the condition for reaching the water that is the rain water to the aquifer and just makes the groundwater. Now, in this lecture we have also seen that when the rain will start and it will remain for a longer duration then what is happening the underneath soil layer becomes saturated with water. Once underneath layer soil layer will become saturated with water the infiltration will totally stop and even the percolation will stop.

And there will be no under underneath movement towards the aquifer rather, what is happening the surplus rainfall amount of water which remains either in the small, small ditches on the surface and then this surplus rain water will move towards the topography of the land surface and ultimately joins the river channel and this we have called as an runoff, which is known as the surface runoff.

So, we have learnt about the surface runoff and subsurface runoff. So, subsurface runoff; this is the surface runoff surplus rain water through the land surface and the surplus water which in the vadose zone moves laterally because, here also the water remains. So, when the underneath soil layer of this will become saturated definitely it would not allow water to move down rather; it laterally this water will flow and this is known as the groundwater flow and this will ultimately join to the river channel.

So, this concept is clear now, what is runoff or surface runoff and what is subsurface runoff; what are the different stages of the runoff cycle and what are the different factors which are just affecting the runoff. So, based on this whole discussion in the two different lectures now we will start to see how the calculation of runoff is being done with the help of the empirical formula. So, we will also learn the concept of the hydrograph.

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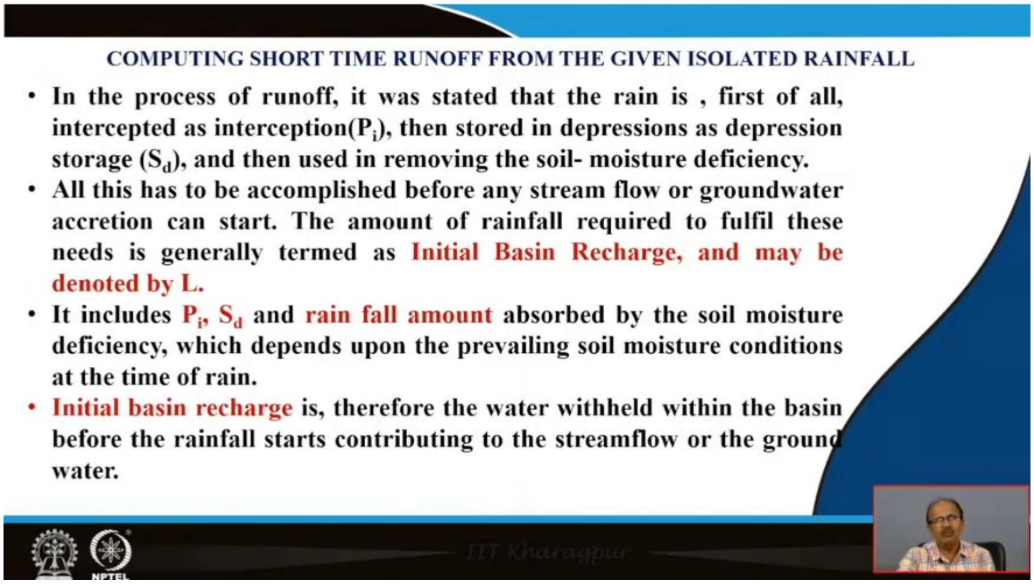

Now, prior to it just before reaching the empirical formula we are just trying to compute the short time runoff from the given isolated rainfall. So, how can we calculate the runoff from the given isolated rainfall without any empirical formula? So, we will take the concept we will start from the concept that in the process of runoff it was stated that the rain is first of all intercepted as interception.

So, here the precipitated water has become the intercepted water that is Pi. Then the remaining rain water is just reaching to the ground surface and stored in depression and here it remains in the depression storage and then used in removing the soil moisture deficiency. Then it reaches to the soil layer and just removes the soil moisture deficiency of those very layer of the soil.

All this has to be accomplished before any stream flow or groundwater acquisition can start. So, this whole thing is occurring before any stream flow is there or groundwater accretion will start. So, what is in true sense the amount of rainfall required to fulfill these needs is generally termed as initial basin recharge and this thing initial basin recharge is denoted by L. So, L includes, what?

L includes Pi that is the intercepted amount of water rain water then Sd, that is the water being filled up in the storage structure that is small ditches on the earth's surface. And the rainfall amount absorbed by the soil moisture deficient soil moisture condition. Whatever the rainfall amount is being absorbed this if we will make the sum of this whole will contribute the total L that is the initial basin recharge of any area.

So, this is very, very important to find out the initial base in the; charge of any area. And we can just find out the amount of the Pi that is the intercepted water, then the Sd depression storage water and the rainfall amount. Now, initial basin recharge therefore the water withheld within the basin before the rainfall starts contributing to the stream flow or the groundwater.

So, this initial basin recharge is very important because here through this only we can understand about the water without; within the basin before the rainfall starts. So, this is initial basin recharge is very important.

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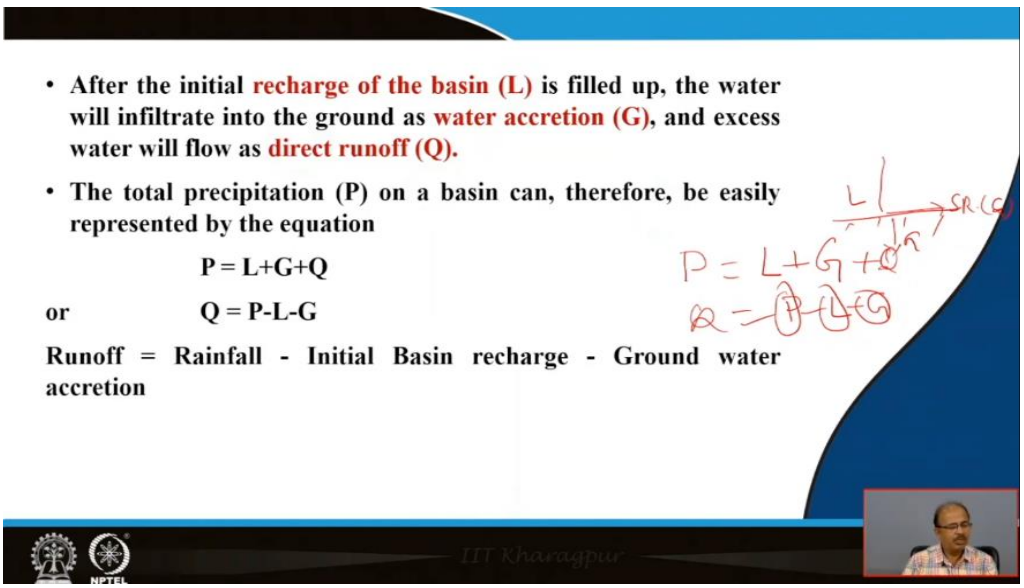

Now, after the initial recharge of the basin L is filled up now, L is totally satisfied. The water will infiltrate into the ground as water recreation capital G and excess water will flow as direct runoff. So, suppose initial basin recharge on the surface is L and your water accretion is your G and then the surplus water excess water it is moving as a surface runoff and that is your Q it is Q.

So, the total precipitation on the basin can be represented by P represented by

$$P = L+G+Q,$$

Then,

$$Q = P - L - G$$

means total precipitation you have to reduce this much amount; initial basin recharge.

And then the G, this will give you the rainfall - initial base in the charge - groundwater accretion will give the runoff value. So, this is very important, just through this also we are calculating the runoff amount.

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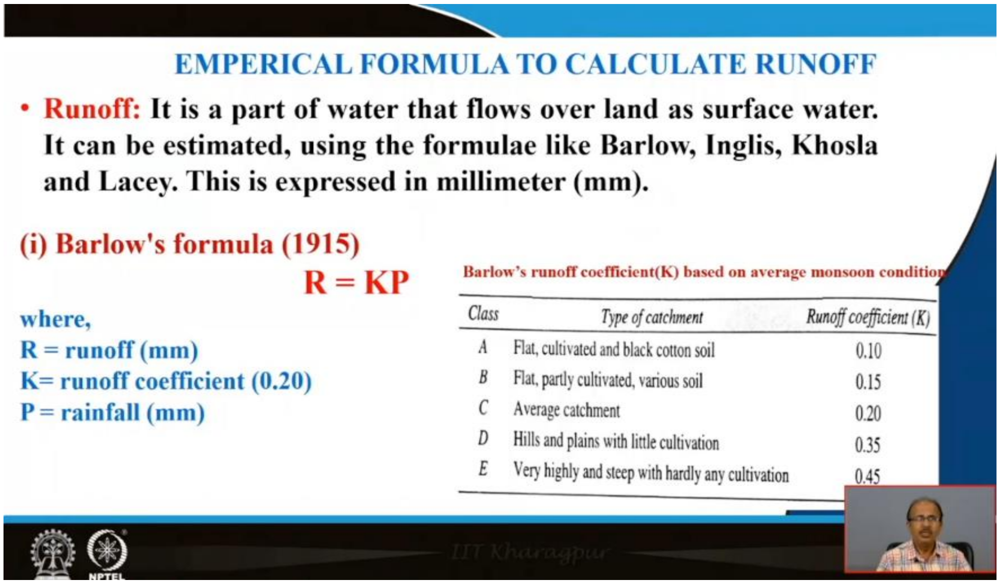

Now, the different empirical formula basically we are using some of the important your empirical formula for the calculation of runoff because, it is expressed in the millimeter and formula like Barlow, Inglis, Khosla, Lacey these are some of the important formulas through which we can able to calculate the runoff. So, first of all Barlow's formula.

In which even in the year 1915

$$R = K * P$$

where R is the runoff in mm

K is the runoff coefficient in which is given 0.20 and

P is the rainfall amount is in mm.

So, apart from this, Barlow has given one equation that

$$R = K * P$$

but here, Barlow runoff coefficient is based on some average monsoon conditions also. You can see the class and then type of catchment and runoff coefficient value K is given A type class A type flat cultivated and black cotton soil. So, such type of; if the land area is flat then cultivated and black cotton soil is there, then such type of condition the runoff coefficient will be 0.10.

So, direct from the literature also we can take the value of the after seeing the condition of the land and we can find out the runoff of that very area. Then B class you can see flat partly cultivated various soil. So, here; partly cultivated but the area is flat so the runoff coefficient is 0.15. See the average catchment, average catchment means you are not unable to guess which type of land is there so it is 0.20. Now, D is the hills and planes within little cultivation.

So, if the area is having hills and plains area and with little cultivation then we can take as per the Barlow we can take it as 0.35. And for the very highly and steep with highly hardly any cultivation then, your runoff coefficient will be 0.45. So, this condition has been given by the Barlow for different types of the land areas and the stage of cultivation

$$R = K * P.$$

So, this is very important where R is the runoff in millimeter run of K is the run of coefficient 0.20 and P is the rainfall that is in mm.

So, whatever area is there we can able, we can just put the value of K here and it will be multiplied by the rainfall amount that is the P. So, in this way we can find out the runoff with the help of the Barlow’s formula.

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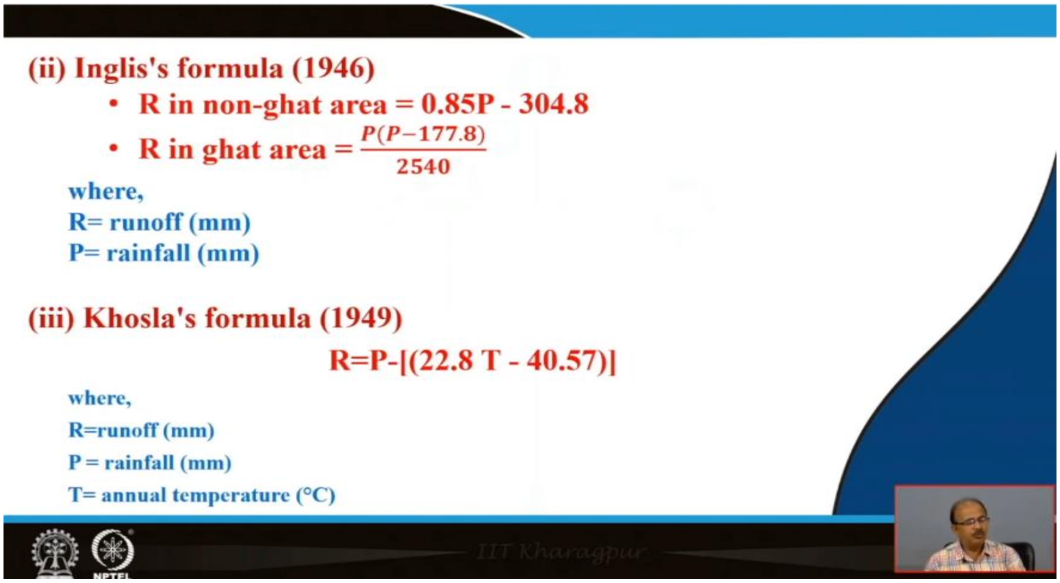

Now, with the help of Inglis formula, how can we find so in the case of Inglis formula

R in non ghat area

$$R= 0.85P - 304.8$$

In ghat areas

$$R = \frac{P(P - 177.8)}{2540}$$

So, this is the formula, so we can just use the formula and we can find out the R that is run off in mm and P what is given is suppose given it is in mm. Now, third is very important formula known as Khosla formula very important.

Just like the Chaturvedi formula which we have discussed in the earlier one earlier. So, there in the Khosla formula, we are seeing

$$R = P – (22.8 T - 40.57).$$

So, this is the Khosla formula through which we can compute the run-off amount of any land surface area where Khosla formula is

$$R = P – (22.8 T - 40.57).$$

where, T is the annual temperature in degree centigrade and P is the rainfall and R is the runoff in mm. So, this is also a very important formula, Khosla formula.

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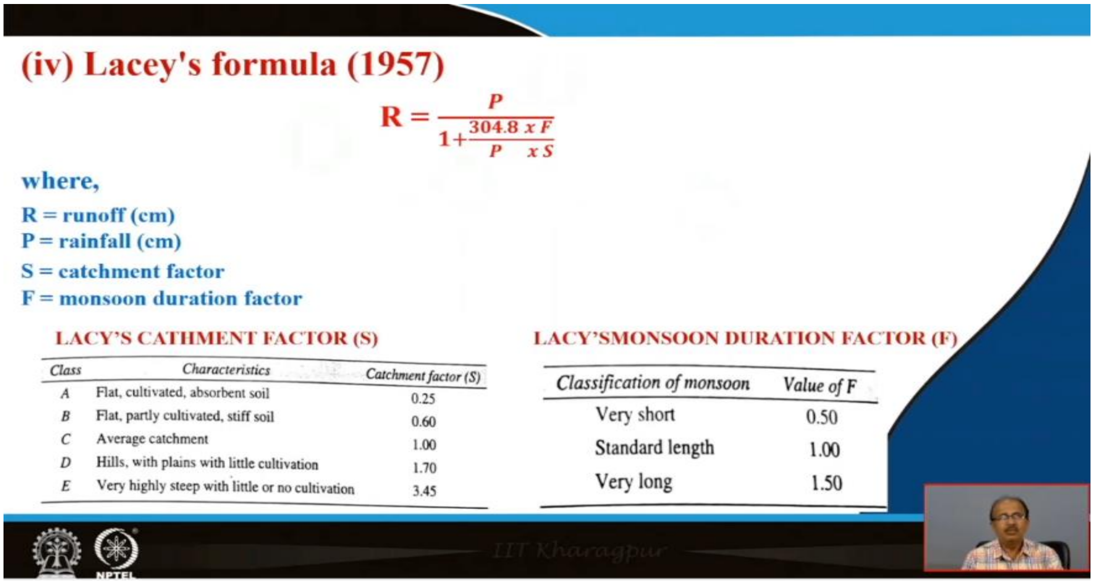

And then the next formula is the Lacey formula, Lacey formula 1957 and it was given; you can see the

$$R = \frac{P}{1+\frac{304.8\ F}{P\quad S}}$$

So, what is happening in the R is the runoff in centimetre then P is the random rainfall in centimeter so S is the catchment factor and F is the monsoon duration factor. So, the unit can be converted into the same type.

So, no problem for this runoff and rainfall only thing is that we should think about the catchment factor and monsoon duration factor before finding out the R value of any area. So, Lacey has given the catchment factor also and monsoon duration factor also the class A we have seen that flat cultivated adsorbent soil it is 0.25, then flat partly cultivated stuff soil 0.60, then average catchment in which we are unable to know about which type of this land is generally taken as average 1.00.

Then hills with planes with their little cultivation it is 1.70 and the very highly steep with little or no cultivation it is generally remaining 3.45. But this is the value of S that is the catchment factor, now Lacey has also derived the monsoon duration factor also and here you can see the classification of monsoon is only divided into three different categories; very best and standard high and very long.

So, the very best very short in standard length and very long very short of 0.50 standard length is 1.00 and very long is 1.50. So, this is generally the Lacey formula which helps us in finding out the runoff through the delivery factors mentioned as in the slides.

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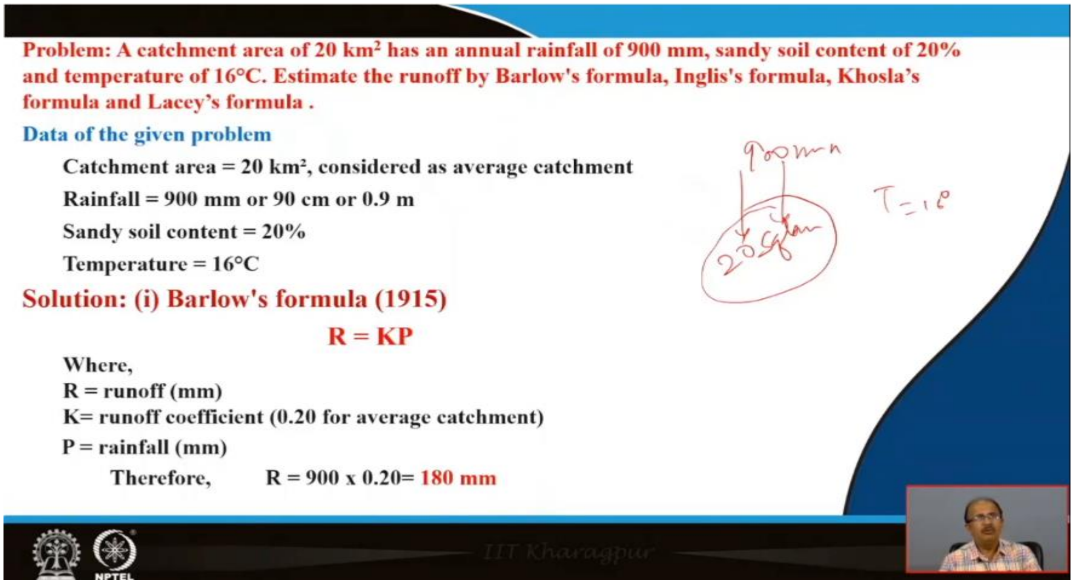

Now, after knowing the Barlow's, Khosla, Inglis, analysis your formula just one small numerical is there concept based numerically there. A catchment area of 20 km^2, has an annual rainfall of 900 mm, the sandy soil content of 20% and temperature is 16 ^{0}C. Estimate the runoff by Barlow's, Inglis, Khosla and Lacey formula.

Solution:

Data of the given problem

Catchment area = 20 km^2, considered as average catchment

Rainfall = 900 mm or 90 cm or 0.9 m

Sandy soil content = 20%

Temperature = 16°C

(i) Barlow's formula (1915)

$$R = KP$$

Where,

R = runoff (mm)

K= runoff coefficient (0.20)

P = rainfall (mm)

Therefore, R = 900 x 0.20= 180 mm

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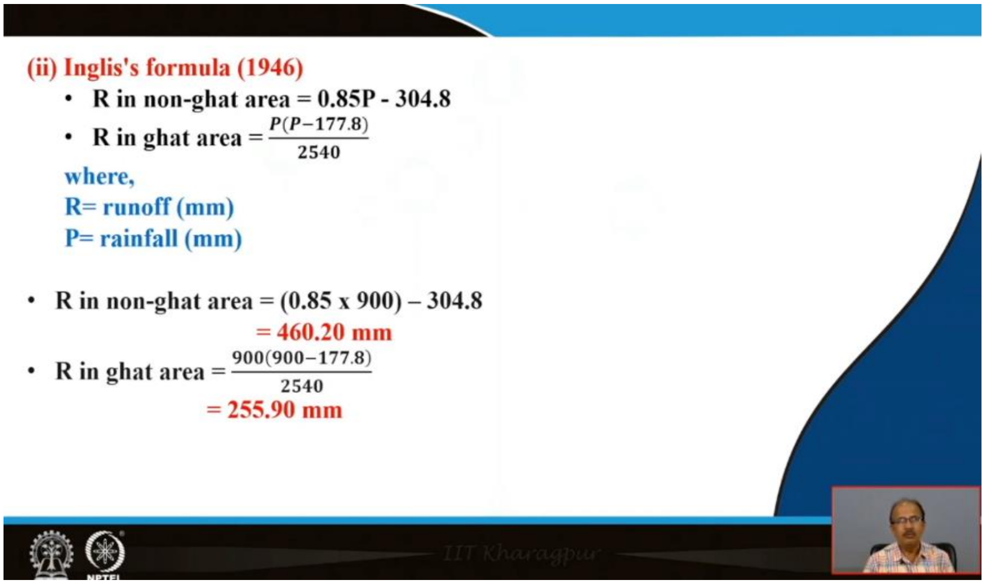

Now, Inglis formula,

(ii) Inglis's formula (1946)

- R in non-ghat area = 0.85P - 304.8
- R in ghat area = $\frac{P(P-177.8)}{2540}$

where,

R= runoff (mm)

P= rainfall (mm)

- R in non-ghat area = (0.85 x 900) – 304.8

= 460.20 mm

- R in ghat area = $\frac{\mathbf{900(900-177.8)}}{\mathbf{2540}}$

= 255.90 mm

So, in this way what we have seen that we have seen that the for different area different type of area, the runoff is also remaining different and by the different types of formula also the different values of runoff is coming. So, let us see what will happen at the last.

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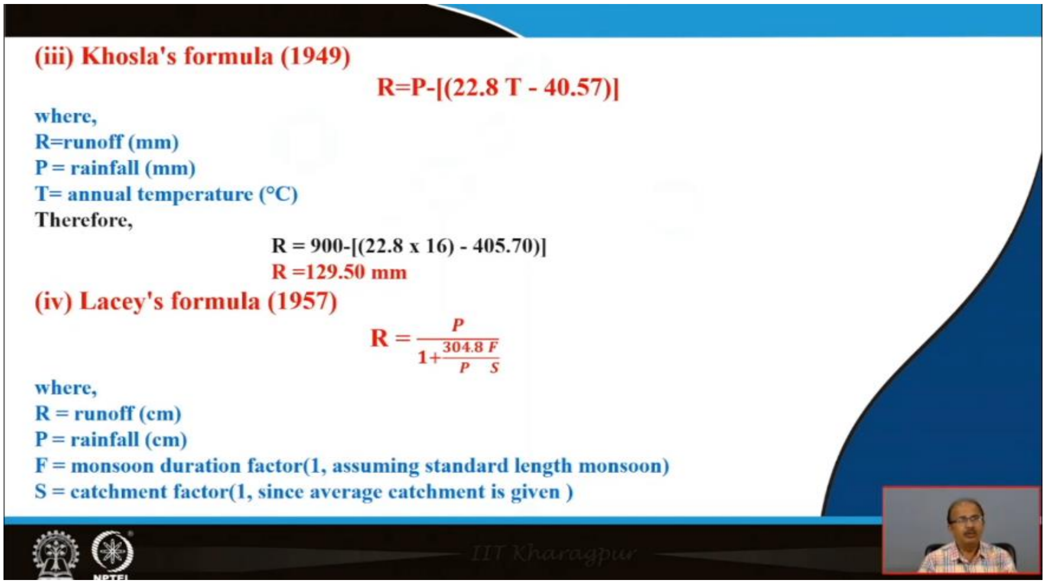

Now, the third is the Khosla formula. So, here Khosla has given one formula which is very important generally,

(iii) Khosla's formula (1949)

$$R=P- [(22.8\ T - 40.57)]$$

where,

R=runoff (mm)

P = rainfall (mm)

T= annual temperature (°C)

Therefore,

$$R = 900 - [(22.8 \times 16) - 405.70)]$$

$$R =129.50 \text{ mm}$$

(iv) Lacey's formula (1957)

$$R = \frac{P}{1+\frac{304.8}{P}\frac{F}{S}}$$

where,

R = runoff (cm)

P = rainfall (cm)

F = monsoon duration factor

S = catchment factor

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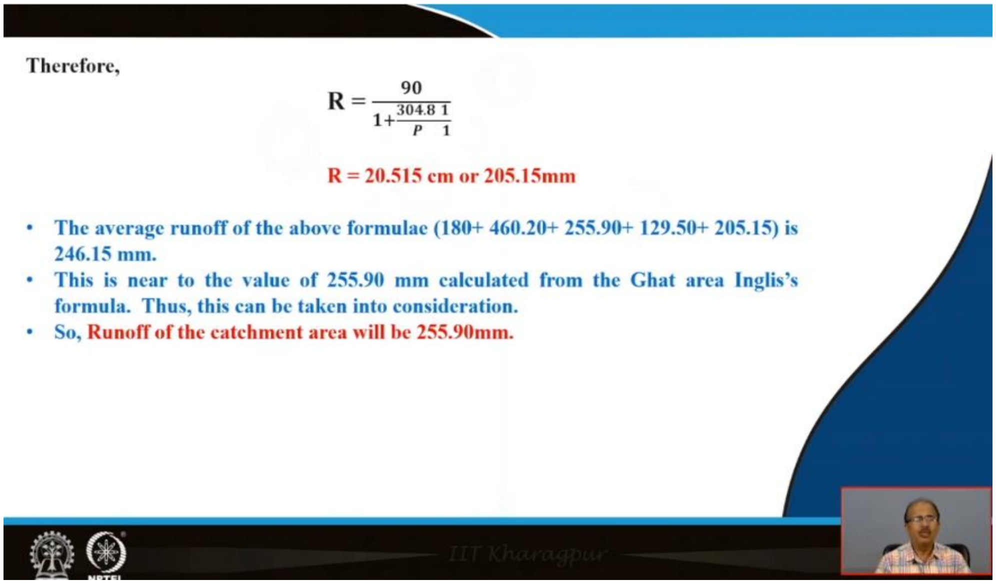

Now, just putting the value in their formula R

Therefore,

$$R = \frac{90}{1+\frac{304.8}{P}\frac{1}{1}}$$

R = 20.515 cm or 205.15mm

- The average runoff of the above formulae (180+ 460.20+ 255.90+ 129.50+ 205.15) is 246.15 mm.
- This is near to the value of 255.90 mm calculated from the Ghat area Inglis's formula. Thus, this can be taken into consideration.
- So, Runoff of the catchment area will be 255.90mm.

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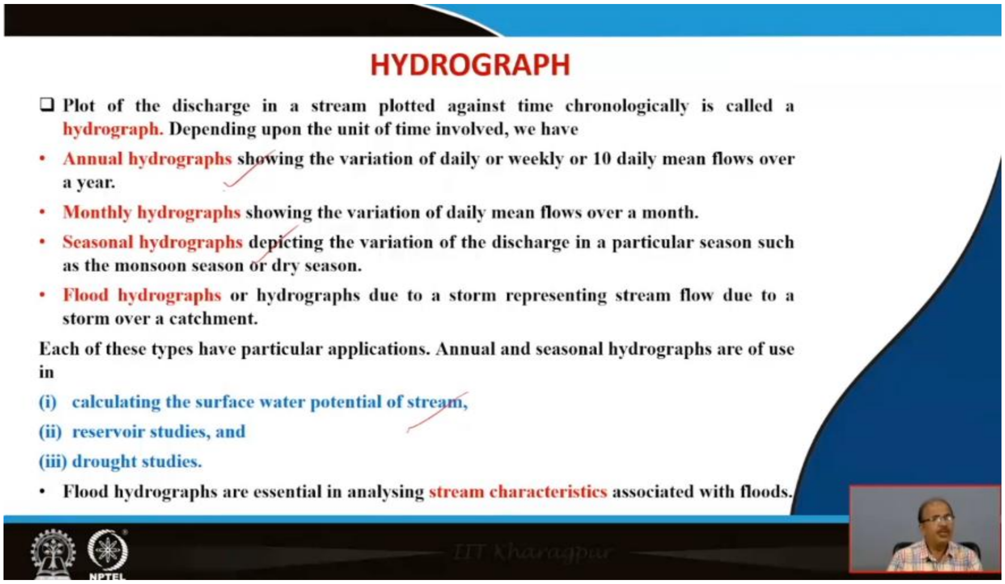

So, through this empirical formula we can find out the different types of your different formulas through which we can find out the you runoff at any land surface to the any land surface to our country. Now, plot of the discharge hydrograph; it is very important because it shows the discharge per unit time it is called as hydrograph. So, plot of discharge is a stream plotted against time chronologically. It is called hydrograph.

And it depends upon the unit of time involved, hydrograph is depending upon the unit of time involved. So, first sensitivity of different types so annual hydrographs which shows the variation of daily or weekly or 10 daily mean flows over a year. So, for over a year your monitoring is there and through which we can just derive the annual hydrographs of any area. Monthly hydrograph is showing the variation of daily mean flow over a month.

So, when for a month we are doing such thing, it is giving the monthly hydrographs. And seasonal hydrographs depending on the variation of the discharge in particular season such as the monsoon season or dry season. So, here in the case, we are getting the signal rainfall and seasonal hydrographs and then the flood hydrographs flood hydrographs are hydrographs due to a storm representing stream flow due to the stream over a catchment.

So, this is very important lord hydrographs also. So, what we have seen is that each of these types; they have particular application; annual and seasonal hydrographs are of use in this annual one and seasonal this is used in calculating the surface water potential of stream. So, how much water, surface water is just showing the potential in the stream then reservoir study and then the drought study.

This can be done with the help of this thing that is the annual hydrographs and the seasonal hydrographs. So, flood hydrographs are essential also in analysing the steam characteristics associated with floods.

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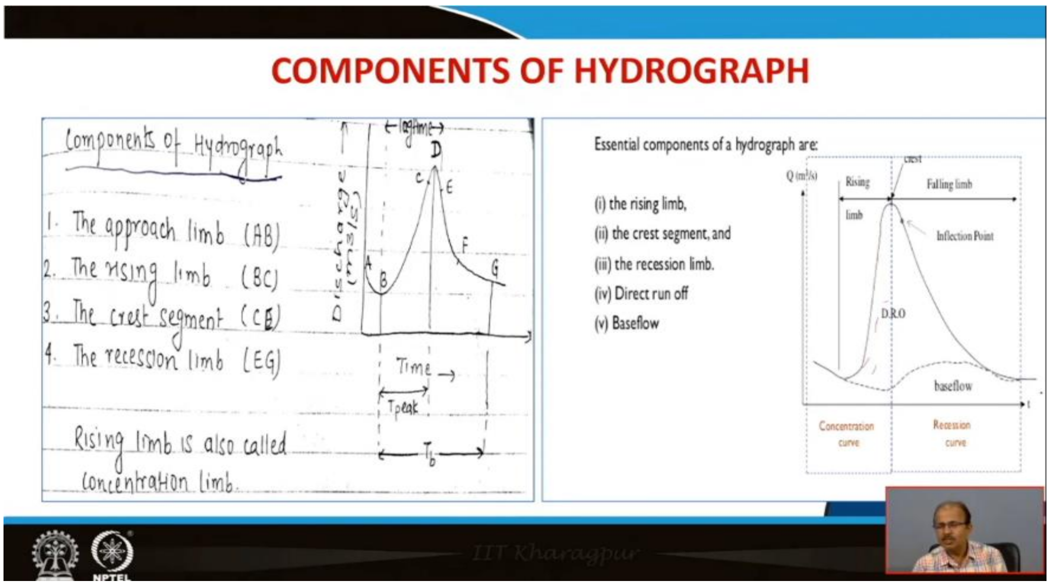

Now, just this we will see the components of hydrograph just this is x axis time versus discharging there. So, x axis time and y axis your discharge is there it starts the unit is meter cube per second while time is in hour. So, this is just components; you can see the approach limb in this one is the approach limb and the rising limb is the BC the crest segment is the C to E and the recession leave is this EF you can see EG also.

So, rising limb we also called it concentration ring. So, this rising limb because from here to here is the rising limb it is also called a concentration curve or concentration limb. Whereas, this one your recession limb is also called a recession curve. So, what we are seeing; that any hydrographs this hydrograph is very important then only we can able to just check the discharge of the water in a time period settled given time period from a certain point of your stream channel.

So, how much water is flowing? So, this can be find out and then through the graph we can show that this is the condition of the discharge versus time in the form of hydrograph. So, this the rising limb is this one this portion is rising limb this is the crest segment then the recession limb and this portion total portion is your direct runoff this total portion is the direct runoff we are generally telling a DRO and the remaining your this flow is the base flow.

This much amount of water which is ultimately reaching to any river this is a base flow. So, we have seen the runoff is a very important factor in knowing the availability of the groundwater resources inside the surface and we have seen the runoff is having a cyclic behaviour during the summer to monsoon and monsoon to again host monsoon and several factors affect the runoff.

And based on the different empirical formula we can calculate the runoff amount to any section of the river or to any area on the land surface. If the other factors your details about the precipitation, then the other factors are given, we can calculate the runoff amount. So, with this thank you very much to you all, thank you.