Advanced Hydrology
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Lecture – 19

Good morning, and welcome to the next lecture of this video course on advanced hydrology. In the last class we started the chapter five, which is on surface water. In that we started by looking at the overall rainfall runoff process in the catchment, and then we looked at that in a catchment there are many storage components, in which the rain water gets stored or gets strapped for some time, and then it comes out of it slowly alright. Many of these storage components in the catchment have different characteristics alright, and many of these storages or the components will interact with each other alright. Because of this this interaction and the and the characteristics of these storages are different and very complex. Because of all these reasons the overall a catchment hydrology or the overall response of the catchment to rainfall is extremely complex process to model.

Then what we did is in the last class is we looked at the two concepts. One is the hortonian overland flow concept, and the saturation overland flow concept. We said that in the hortonian overland flow concept, the catchment is or the sub surfaces saturated from the top alright, and the in the saturation overland flow the subsurface is saturated from below due to the hills slope hydrology. Related to that, we looked at a concept called the variable source area in which we said that the amount or the fraction of the area of the catchment contributing runoff at different times is different, because of this variable source area concept. Then we looked at the definition of a stream flow hydrograph, we said that it is just a graph or tabular form of flow in the river or in a stream as a function of time. Then we classified this stream flow hydrograph into three different you know types which we said it can be either annual and within the annual actually we said that they can be three types. One is the perennial hydrograph, other could be the intermittent hydrograph, and the third one could be a Fibral.

And the difference between these three we said is that in the perennial hydrograph, the contribution from base flow or from the ground water significant. In the intermittent stream flow hydrograph the contribution from base flow is moderate or you know small but in the Fibral hydrograph there is hardly any contribution from the base flow. Then we moved on and we said that what is a storm hydrograph? And then we define the overall characteristics of a storm flow hydrograph different components that is the rising limb, the falling limb, the peak, the crest and so on. We looked at all that, and then we looked at also the recession curve equation by Horton all right it is called the normal depletion curve. Then we moved on and we looked at the three different methods of the base flow separation. What were those through those three methods, well the first one was the simple straight line method, the second one was the fixed base method and the third one was what is called the variables slope method.

Then, towards the end we said or we defined what is a phi index? We wrote the equation for calculating or estimating the phi index. What is a phi index? phi index is nothing but a method of estimating abstraction from the precipitation of the rainfall hyetograph. What you do in a phi index is, you just a draw a line on the rainfall hyetograph and you say at everything above that line is a effective rainfall or the direct runoff hydrograph and everything below is the losses all right. What we would do today is, we would look at an example of calculating phi index given the rainfall data. because I said that there is a parameter call the M, which is the number of effective rainfall ordinates or the number of time intervals which is very difficult to estimate initially all right. So, there is a twiline error or I treaty procedure involve. So, in order to demonstrate that we would like to get started today by looking at an examples, so first I will a list out the data and then we will have go to the board actually to solve this example today.

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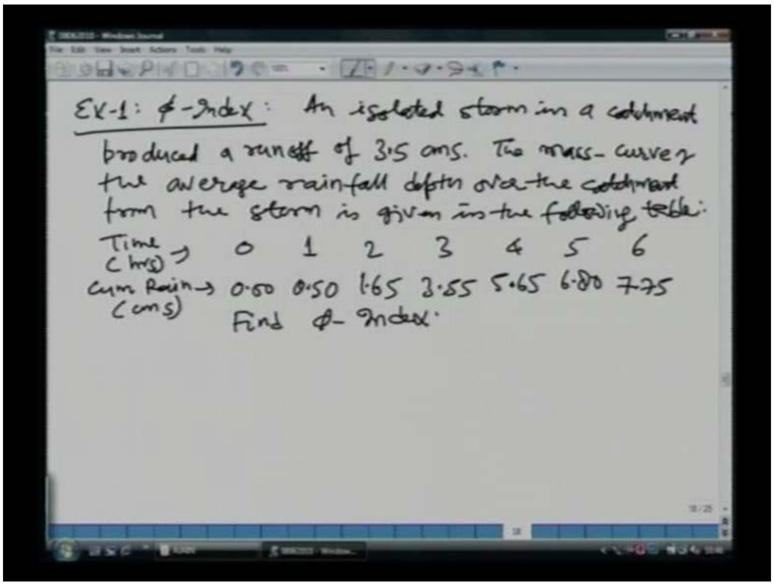

So, let us look at it. So, in this chapter this is going to be our first example and it will be on calculation of the phi index. And the example goes like this, an isolated storm in a catchment produced a runoff of 3.5 centimeters. So, the runoff is given to us also the data that is given to us is the mass curve of the average rainfall depth over the catchment from the storm is given in the following table. That is, time from the beginning of the storm in hours and then the a cumulative rainfall in centimeters, that is given to us all right. The data that are given is for these interval 0, 1, 2, 3, 4, 5 and up to 6 hours a, during the or at the beginning you have 0 of course, then you have 0.50, 1.65, 3.55, 5.65, 6.80, and 7.75.

You see that a what is given to us is the mass curve or the cumulative rainfall curves so, the rainfall is increasing during the storm. What we have to do in this example is, simply find the value of phi index. So, what I would like to do is then go to the board and start looking at this solution of this example. So, let me try and do that.

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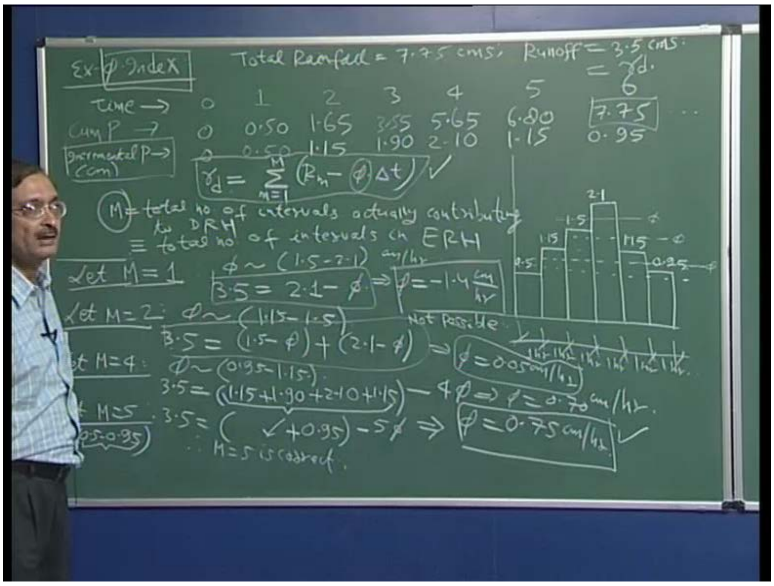

So, we are looking at an example on phi index all right in which, the mass curve of the a data is given to us and we have to find out what is going to be the phi index all right. So, I am not going to repeat the data here, but we did do need to find out the rainfall hyetograph that is the data we are going to need. So, you have the mass curve and what you do is you subtract the excessive values to calculate the rainfall depth in that particular hour. So, let me do that anyways you have 0 1 2 3 4 5 and 6 then you have cumulative rainfall, which is 00.5, 1.65, 3.55; then 5.65, 6.80, 7.75.

This is the data we have just seen, I am just copying that. So, this is the total amount of rainfall during the storm event in 6 hours. What we need to find out is the incremental rainfalls that is also in centimeters in every hour. So, for 0 it is going to be 0; what will be the rainfall during the first hour all right, well it will be this value minus this value all right it is the same 0.50. Then what will be the next value during the second hour that is between first and second hour this is the rainfall mass curve.

So, you will subtract the successive values, that is this minus this all right and it would be 1.15, next value will be this value minus this. So, I will keep writing these and you can easily find that it will be 1.9 2.1 and 1.15 and 0.95. So, the second row we see here it is the rainfall hyetograph. And then what we can do is we can plot this rainfall hyetograph and then we put a phi line on this arbitrarily anywhere and then we can keep doing on the trials. So, if you plot it I will do that roughly; these are the values we are going to have 0.5 here, second is 1.15, third one is 1.5 this is 1.5, next is 2.1 it is coming from here, 1.15 again this is 1.15 and the last one is 0.95 which will be between this and this two values.

So, let me do this here it will 0.95. So, this is the rainfall hyetograph data that are given to us. Now, what we have to do is we have to find out the value of this phi index and also given to us is or we can find out that the total rainfall is this much which is 7.75 centimeters; and also given to us is that the runoff is how much is 3.5 centimeter.

What is the formula for calculating the phi index. Well, we have looked at it in the last class, it is r d is equal to summation of m going from 1 to M of R m minus phi delta t. This is the equation, from which we can find the phi index this particular variable all right. So, this summation is running from m is running from 1 to M and then in the last class we had said that what is this M; this is something very important to understand all right. And this is, I am going to say is the total number of intervals actually contributing actually contributing to the direct runoff hyetograph all right. So, M is the number of intervals on this rainfall hyetograph which are actually contributing to the direction of hyetograph all right. That is to say, if you draw a phi line here then how many intervals are contributing this one and this one two.

But, we do not know that. Right the key is that we do not know the value of M which we actually have to find using trial and error. All right, this is also then you can see is equivalent to the total number of intervals in your effective rainfall hyetograph all right. Once we draw a phi line, on the rainfall hyetograph everything above this becomes the effective rainfall hyetograph all right.

So, the number of intervals in the effective rainfall hyetograph then becomes the M or the total number of effective intervals all right. So, with this background what we are going to do is, we will start our trials in which we would assume this value of M; we can start with 1 or 2 or 3 or 4 and then keep on trying different values such that our assumption is correct. All right, so let us see how we can do this. Now, I am going to say that let your M is equal to 1 all right when I say M is equal to 1 that there is only one interval which is contributing to the effective rainfall hyetograph.

So, where will you draw the line or the phi index line on this curve, if there is only one interval which is contributing to the effective rainfall or the direction of the hyetograph;

it has to be somewhere here. So that, if this is your phi index then what will be the value of phi, well it has to be between 1.5 and 2.1 all right. So, this is my assumption when I say M is equal to 1 then my phi value has to be between 1.5 and 2.1. If that is not the case, then the assumption is wrong. So, let us say that what I am assuming is that the phi is between what 1.5 and 2.1 and these values are in centimeters per hour. If that does not come out to be true then my assumption is wrong, I will modify the value of M and I will keep on doing it unless until I get the value of phi which is correct as far as my assumptions are concerned.

So, with this m is equal to 1 what I do is I apply this equation. So, if you did that r d is given to me this runoff is nothing but r d this is 3.5 centimeters. So, what I will do is r d is equal to 3.5 centimeters is equal to the summation running from 1 to M, M is equal to 1 so, there is only one term here all right. So, that one term is what corresponding to that particular effective value of rainfall all right. So, that is 2.1.

So, this will be equal to 2.1 minus; phi is what we want to find out which we do not know delta here this particular problem I have taken equal to 1 hour all right. All of these are all this delta t is, these 1 hour for simplicity. but it can be any other value all right keep that in mind this delta t does not have to be uniform it can be different all right and it can be some fraction also all right 10 minutes, 20 minutes and so on. So, this equation then will give me what the value of phi as minus 1.4 centimeters per hour.

Is this correct? Does it look like correct value? Obviously no, because phi index is something positive it cannot be negative. So, you say not possible. Then what you do? You refine or modify your gas for the M. So, now you say let your M is equal to 2; that means, what is your assumption your phi should be what when you are saying two then you are trying to draw the phi line now here. These are the two effective intervals all right. So, the phi line is here what is it is value it should be between what and what 1.15 and 1.5. So, it should be between 1.15 to 1.5. If the phi does not come in this range then your assumption was wrong. So, apply this is this equation again and you say the r d which is 3.5 centimeters is equal to what now this summation will run from m is equal to 1 to 2 because now M is 2 all right. So, it will go from 1 to 2 terms one corresponding to this, other corresponding to this.

So, you will have 1.5 minus 5 plus 2.1 minus 5. So, there are two things here. So, you can say it is 1.5 minus phi delta which is 1 plus, the other one is 2.1 minus phi. This will give you this equation, you can solve for phi easily this will give you your phi is equal to 0.05 centimeters per hour. Is this correct? Or is this as per our assumption? No. The phi value has to be between this and this if M is equal to 2. So, you see that we are doing these trials all right. So, we start with the M is equal to 1, M is equal to 2 and 3 and 4 and so on. So, what I am going to do is the next step is, I will say I will jump M is equal to 3 and I will take M is equal to 4. If you take 4 hours then where does your phi line have to be it has to be 1 2 3 4 so, it will be somewhere here.

Let us say, this is your phi line and then the value of your phi should be between 0.95 and 1.15. This is 0.5 all right this is below this one. So, as per this assumption your phi should be between 0.95 and 1.15. Apply the same equation again, how many terms you will have; summation will run from 1 to 4, so there will be 4 expressions in this corresponding to 1 2 3 4 these 4 pulses of rainfall. I will do this quickly and then what you should be able to get is you have 3.5 is equal to what 1.15 plus 1.90 plus 2.10 plus 1.15 all right. All of these value this, this, this and this. Minus, minus, what minus phi, minus phi, minus phi 4 times. So, you will have 4 phi delta t is 1. So, this will give you, your phi as; you can verify this as 0.70 centimeters per hour.

Is it all right? The assumption is that, the phi should be between 0.95 and 1.15. What the answer comes out there 0.7, which is again not correct. So, what you do is, you increase the value. All right, so in the next trial you say M is equal to 5. So, that you will have 3.5 as you will have; your line will be here this also goes in all right. So, the phi will be between 0.5 and 0.95. Let me just do it here your phi should be between 0.5 and 0.95. So, that your 3.5 is equal to what; you will have all of these things I will not write it again actually whole this thing goes in here, plus there is one more term which will come in which is 0.95 I think you can see that. So, all of this thing plus 0.95 minus what, now we have phi terms so, it will be 5 phi that should you should be able to calculate your phi is equal to what; it will come to be 0.75 is this correct well it is why, because if you see that range it is 0.75 centimeters per hour which is in this; that means, the assumption of M is equal to 5 is correct all right and then this is your answer.

So, you see that a finding the value of phi is not an easy task it is a manual trial and error. Although, you can see that it is easy to code this; you can write the computer program which should be able to do all this for you. Now, one thing I would like to point out here is that although, I have taken a trials from M is equal to 1, 2, 4 so on all right. But looking at the data it should be very easy to minimize your effort; in the sense that you look at the data and see that how many intervals would be there approximately. For example, you know that runoff is how much 3.5 all right. So, when you draw a line or initially when you guess your initial guess should be such that your runoff is more than or equal to or approximately 3.5.

I started with 5 here, this was only for demonstration purposes, you know that this whole value is 2.1. So, if you draw a line here everything above cannot be 3.5 right it will be much less than 3.5 all right. So, your initial or the first guess actually should have been may be somewhere here or this one. So, when you look at the data and when you are solving it in the exam or doing it in your some other field case it is very good idea to minimize your effort. So, with this what we will do is we will move back to our Tablet PC. So, we have seen the 5 index all right, what we are doing actually is we are looking at the abstraction from the precipitation.

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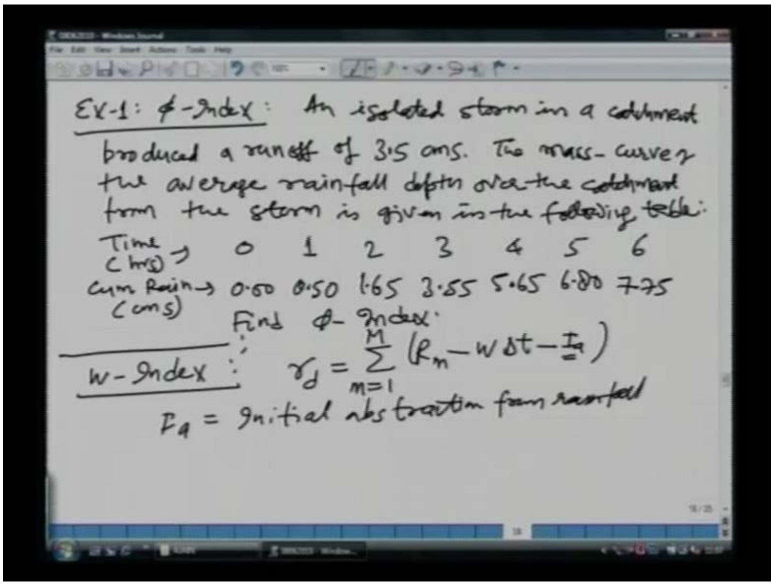

So, this was the example we have seen all right. Now, the next thing we would look at is what is called another index which does a similar thing as phi index, but it is known as the W index. I am sure you may have seen this earlier in your under graduate hydrology. In the W index, the only difference in the phi index and the W index is that phi index does not account for the initial abstractions. What do you mean by the initial abstractions; well the initial abstractions are the interception storage or the depression storage or initially what are the losses from the precipitation.

Now W index does account for that. So, if you have some estimate of these initial abstractions we can use the W index which will be slightly more accurate than the phi index all right. but will not go into the a too much details of that, except saying that your r d for the W index we can calculate like this; the procedure will be exactly same which we have demonstrated here you have R m minus W delta t minus I a. So, what we have done is we have thrown this additional term I a which is your initial abstraction, which you have to estimate somehow. So, let me write it down where I a is the initial abstraction from your rainfall or precipitation all right. So, this is the about the two indices which is phi index and the W index.

There is another way of accounting for abstraction, we have another co-efficient you know normally we represent in a catchment which is called the runoff co-efficient; which is another way of accounting for abstraction.

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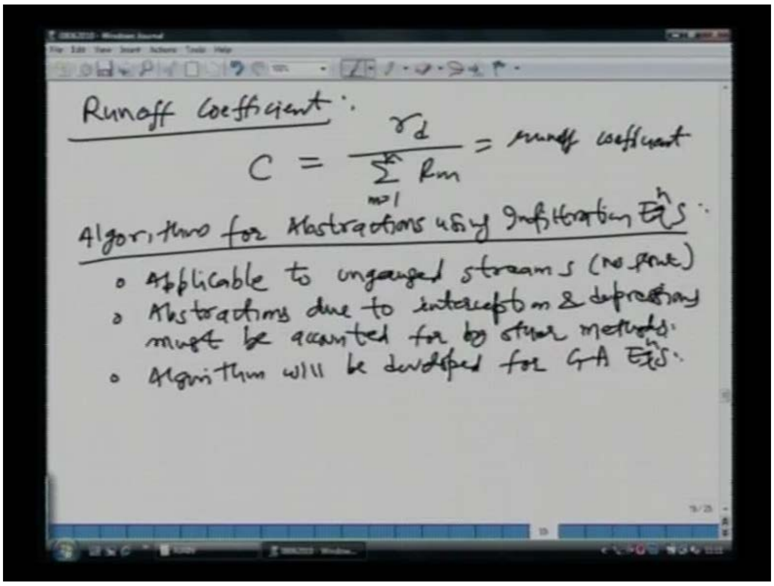

So, will just say that runoff co-efficient, we can calculate which is defined as C is equal to the r d is the runoff depth and divided by m is equal to 1 to M of your R m or the total rainfall. So, this is your runoff co-efficient. So, you what you do is you take the runoff depth, you divide by the total rainfall all right that will give you the runoff co-efficient; I am sure you are familiar with this concept. So, we are seeing these two or three different methods of accounting for abstraction or somehow representing what are the losses or abstractions from the precipitation then we are doing the rainfall runoff modeling. Now, one striking similarity in all these three methods is that you need the flow data. The exampled which we have just looked at we knew the not only the rainfall data, but we also knew the runoff, what is the total runoff; It was 3.5 centimeters in that particular example. For W index also you need that for runoff co-efficient also you need to find out what is r d or the runoff depth all right and the runoff depth you need the flow data.

Now, this kind of you know approach is not suitable when you do not have the flow data of the scene flow data. So, what we are going to do next is we look at a method which is a very comprehensive and very robust method of accounting for abstraction all right. Then we do not have the flow data all right. So, what we will actually do is that the we will develop what is called an algorithm for abstractions using infiltration equations. Now, what will do is just look at the basic concepts of a few characteristics of this method this would be applicable before we actually go to this. I would like to go very slow with this, this is applicable to the un-gauged catchments or rather I should say streams; because we are talking of the flow data all right. So, there no flow data is available.

The second feature is that, the abstractions due to interception and depression or your initial abstraction that is; must be accounted for separately by other methods and then incorporated in this method. So, the algorithm which we are going to develop will not actually look at the initial abstraction, all right if we can estimate it, we can incorporate it in this method. But as far as this algorithm is concerned we will not account for that. All right, the algorithm will be developed for the green ampt equations, as it says that will develop the algorithm using the infiltration equation.

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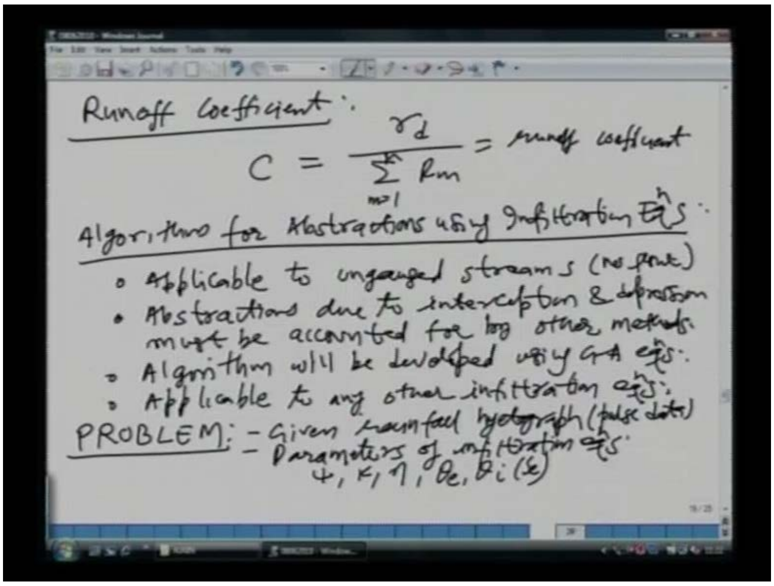

And the second feature of this method is going to be that the abstractions due to interception and depression that is initial abstractions, interception and depression must be accounted for separately by other methods that is. So, as far as derivation of this method is concerned we will not look at the initial abstractions, but you can use some other methods and those estimations can be accounted for in this derivation also.

But, as far as this class is concerned will not do that. The next thing about this method is that, the algorithm will be developed will be developed using or for the green ampt equations. As I said that, we will develop a very general method or algorithm for accounting for abstractions from the precipitation using infiltration equations, and in this case we will use the green ampt equations which we have already seen in this course. The next feature is going to be that, or rather I should say that; this method or algorithm which we will develop is easily extended or can be applicable to any other infiltration equations. Although, we will develop this for the green ampt equations, but hortonian or Horton or any other equation can also be used for calculating the infiltration. So, these are the features all right. So, let me first define what we are actually going to do.

All right, so first I will define the objective of this problem, what are the data which will be using; what are the principles? And then will go from there. So, what is given to us is that given the rainfall hyetograph or the what is what do mean by that given the rainfall data all right in the pulse data representation; we have seen earlier all right. So, that is given to us also what is given are the parameters of the infiltration equations which is the green ampt equation in this case; and what are those parameters well, it is the section head, hydraulic conductivity, porosity of the soil, effective porosity all right it is the same thing actually and theta I in terms of s e that is all right. So, if we know all these parameters of actually we need to know all these parameters all right.

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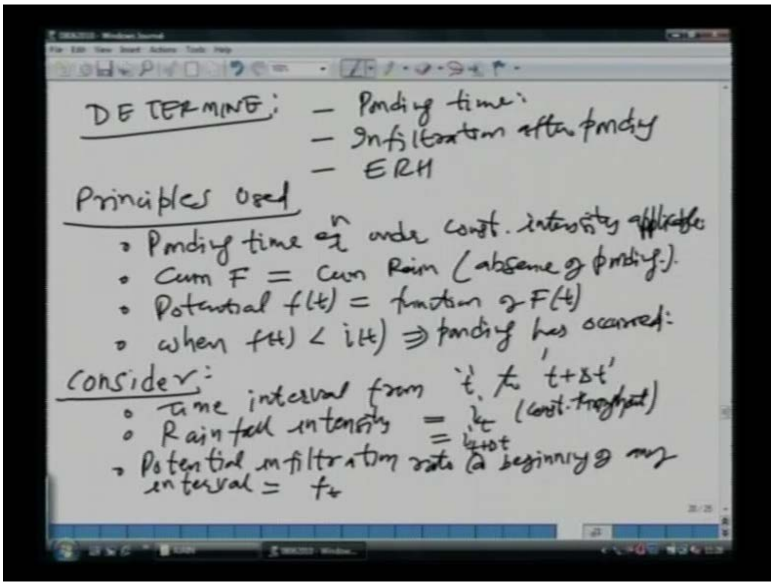

So, these are the things that are given. What we have to find is determine or what you would like to be able to do is, find out what will be the ponding time; as we have seen in using this green ampt equation, estimation of the ponding time is very important.

Because up to ponding time we can use the in rainfall intensity as the infiltration beyond that we use the green ampt equations. So, we find the ponding time and then we also find the infiltration after the ponding, and then once we have found out the infiltration after ponding we can find what is called the ERH or the effective rainfall hyetograph. So, you see that we are if we have the rainfall data only there is no flow data available to us we can use the rainfall data and the infiltration equations; we need the parameters of that. So, will develop this algorithm all right or a flow chart through which we should be able to find the effective rainfall hyetograph all right. So, will take the rainfall hyetograph, subtract the infiltration, and we find the effective rainfall and once we have the effective rainfall as we all know we can use many rainfall runoff modeling techniques. In this the effective hyetograph rainfall is converted into runoff all right.

So, in doing so what will be the principle or the bases employed or used; in developing this algorithm what we will do is use certain basic principles and one of them is that the ponding time equations or equation which we had seen under the constant intensity is applicable. What does this basically mean is that, we can use the ponding time equations which is valid only when the rainfall intensity is uniform during a particular interval all right.

So, we want to process our data such that the in your rainfall hyetograph; your rainfall intensities are uniform throughout. If it is one hour, it is uniform throughout if not you may want to convert your data at a find the time interval like thirty minutes or ten minutes or whatever but the computational effort will increase. So, we want to be as accurate as possible; however, then we have to pay price for that. So, that is the number one, and then the next one is that the cumulative infiltration is equal to the cumulative rainfall.

That is the assumption or principle will use, then in the absence of ponding. So, then there is no ponding or before the ponding we know that all the rainfall that falls becomes infiltration goes in all right. So, cumulative infiltration before ponding is equal to the cumulative rainfall. The next one is that, the potential infiltration rate is available as a function of capital F or cumulative infiltrations all right. So, this method will need an equation in which the small f is related to capital F using some function and we have that function from the green ampt equation. The next thing is when your f of t is less than i of t at any time means; means what as soon as the intensity of rainfall becomes higher than the rate of infiltration that is then the ponding has occurred. This is the method we will use or the concept we will use which is very important. So, what we basically do is we will compare the rate of infiltration with the rate of rainfall.

For each time interval delta t all right let us say you have twenty hours of data at thirty minute interval; so, at each delta t we will find out what is small f we know what is small i all right we compare those and then we should be able to find out what will be the infiltration. However, before we go to that we need to consider three different possible ponding cases all right and before I even go to that, let us define our time domain very carefully. So, what we are going to do is we will consider a time interval; a general time interval from t to t plus delta t. The rainfall intensity is equal to i of t all right which is constant throughout; throughout means throughout that delta t during that interval.

So, that would mean what, that is also equal to your I at time t plus delta t, which is not the case for the infiltration; infiltration is continuously going down all right as a function of time you know but I is constant. The next thing is, the potential infiltration rate at the beginning of any interval is equal to let us say f t.

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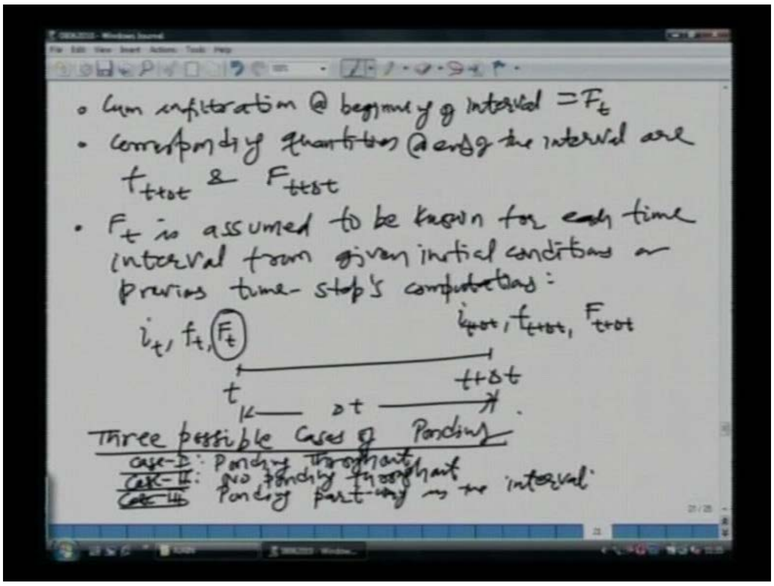

Let us move on, the cumulative infiltration at the beginning of the interval is equal to capital F t and the corresponding quantities all right. That is, small f and capital F at the end of the interval let us say are small f t plus delta t and capital F t plus delta t. And the main concept is that, the capital F of t is assumed to be known for each time interval; the given initial conditions or the previous time stab computations. So, what does this all mean is we have listed out you know many principles here or some definitions basically. So, if you look at graphically this is what we are doing. We are defining a very general time interval the beginning time is t, at the end time is t plus delta t. So, what is this duration this is delta t; which can be 1 hour, 20 minute, 30 minute, or few minutes whatever depending upon the need all right.

What is the value of infiltration, it is infiltration rate that is f t the cumulative infiltration is capital F t and the rainfall is small i t. So, all the variables at the beginning we have subscript t. Similarly, here you have i t plus delta t small f t plus delta t and capital F of your t plus delta t right.

So, at the beginning of the interval we have defined our various variables at the end of the time interval delta t we have defined our variable all right. And important assumption we have made here is that the cumulative infiltration at the beginning of the each time interval is known. What does that mean; that means, this particular variable is known at the beginning of each time interval, how is that true. Well, what we are going to do is, in the beginning or when the there is no rainfall at t is equal to 0 we know the initial conditions. Initially, we would know what is the cumulative infiltration which is 0. So, we get started for the first time interval, we will find out everything at the end of the time interval. Once we know the cumulative infiltration at the end of the time interval, that becomes the initial condition for the next time interval all right.

So, f of t plus delta t for a previous time stab is nothing but f of t for the next time interval. So, for each delta t as we marched had in time the capital F of t is known all right. Once we have the capital F t, we have a relationship between capital F and small f all right. So, we can always calculate rate of infiltration once we know the cumulative infiltration. So, what we are going to do is then we will develop this algorithm for any general time interval delta t and we will march ahead in time so that, we can calculate the rate of infiltration and also the cumulative infiltration. Now, before we go to that it is important to understand that what could be the relative magnitudes of rainfall and rate of infiltration all right for each interval. There could be three possible cases of ponding for which we need to analyze each and every time interval. This is a very important concept and what I would like to do is, look at the three possible cases of ponding.

Three possible cases of ponding all right and what would those be, well it would be; I would say case one which would be ponding throughout. What may happen in any time interval is that, there is a ponding throughout that time interval that is case one this is a way we are defining the three possible cases. Then we may have a case two in which we say there is no ponding throughout. So, we are marching at in time we are analyzing each and every time interval. So, one possible case we said case one was there is ponding throughput that is possible other case can be there is no ponding all right and there could be a third case also in which there will be ponding partway or somewhere in the particular interval. So, what we will do is we will look at these three cases graphically all right in order to understand and how we can establish which case belongs to or which corresponding you know case belongs to this particular case.

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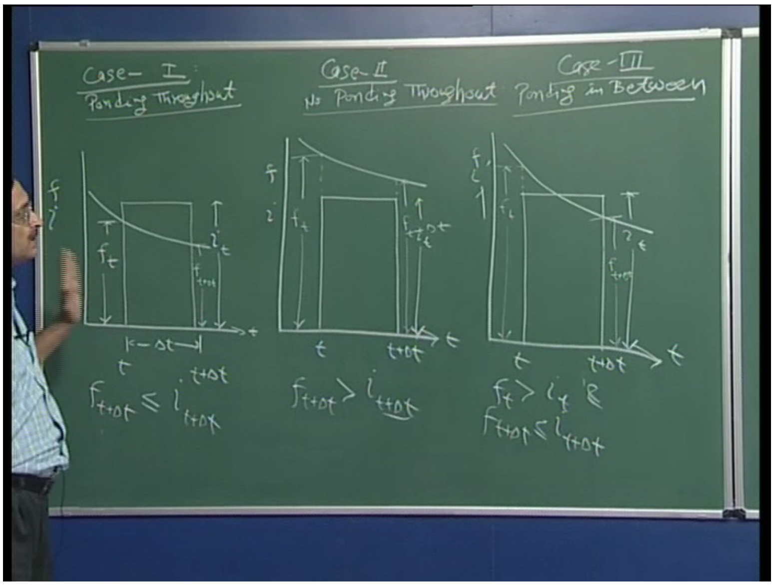

So, I will go to the board and then we will look at these three cases in a graphical form. First we will look at case one, which is ponding throughout, case two is no ponding throughout and then will have case three, which is ponding somewhere in between or partway during the interval. Now, what we are doing is we are looking at let us say time on the x axis for the three cases here and on the y axis we are looking at either the rate of infiltration or I in all the three cases. All right, now we know that let me first say that this is your I, this is your delta t, this is your time t, this is time t plus delta t, all right then the interval is delta t. What is what does this look like this is your rainfall impulse all right, this is I which is constant during this interval delta t; that is one of the assumptions we have made right. So, this is your i t this value of this pulse is rainfall intensity which is constant all right.

So, i t is equal to i t plus delta t, am not repeating it here. So, let me first draw this in all the three cases. It is very important to understand these three ponding cases, because this is will need to classify each and every interval either as case one or as case two or as case three and for that we need to know the relative magnitude of this intensity and infiltration. So, right now they all look very similar they are all same all right. So, we have case one in which there is ponding throughout. When is there ponding, when will the water pond on the ground, when the intensity of rainfall is higher than the rate of infiltration. So, our infiltration curve will be below this during the whole interval. So, clear. So, this is the case when the infiltration curve is completely below the intensity curve. So, if you define these things you have, what is this; the way we have defined this is f at time t, which is rate of infiltration its coming from here time t, this is your time t and what is this is small f at t plus delta t.

You see that, for case one when there is ponding throughout your small f t is less than i t at time t and also your rate of infiltration at the end of the interval that is f t plus delta t is also less than this all right. So, this is these are the conditions which we are actually going to use in our algorithm. Now, if you come to the no ponding throughout; where would your infiltration curve be. When is there is no ponding all right the what does that mean whatever is the rainfall that goes into the ground everything infiltrates, there is no ponding. So, in that case your intensity of rainfall is what it is less or higher? it is less than the infiltration all right. So, the infiltration curve will be like this in this case. So, at this time this is your f at t and this is your f at t plus delta t is this one. So, you see that in case this is the rainfall intensity which is lower than what the soil can take. So, everything will go in and there will be no ponding all right.

So, for the no ponding case or for the case two when there is no ponding throughout what are the conditions at the beginning of the time interval your infiltration rate is higher than the rate of rainfall which is also towards the end of the interval. So, you see that there is a big difference in these two and once you have the relative magnitudes of small f and i they will be able to classify a particular interval l either case one or case two or case three which we are going to look at. So, what will happen in the case three then. If you see here what we are saying in case there is that there is ponding in between all right. So, ponding actually occurs during this interval all right.

So, what does that mean; that means, that there is no ponding at the beginning, but there is ponding at the end right. So, it is somewhere in between. So, the infiltration curve will be something like this. So, here you have; this is your f of t, this is your f at t plus delta t. So, these are the three cases all right. I am going to write that, f at t plus delta t is less than or equal to i t plus delta t; that is the condition all right for case one. At the beginning, we have this at the end also we have this condition where I is greater than this. If you come here what is happening at the end at the end its the other condition where f is greater than i at t plus delta t. Keep in mind that i t plus delta is equal to the i of t. And then for the third case we have f of t is greater than i of t all right f of t is greater than i, but or you can say and f at t plus delta t is what is less than or equal to i t plus delta t.

So, you see that we have these three ponding cases I wanted to demonstrate this all right very clearly it should they should be very clear in your mind. If there is any question or any doubt you should try to read it or go through it and try to understand it and if is the there is any doubt will not be able to proceed further. Because what we are going to do is at the each time interval; at the beginning we will look at the relative magnitudes of f and i, at the end we will look at this, how will do that we will calculate this f using the green ampt equations.

And once we compare this, will be able to find out which case it is and we can use the appropriate equations accordingly. So, we have seen that there are three possible cases of ponding all right now the next thing you know or the next step in developing this algorithm is look at the flowchart all right. So, what will do is we take a rainfall hyetograph all right the first rainfall impulse we compare various values of small f with I and then we March ahead in time. I am afraid I am running out of time today will have to come back and look at this algorithm in the next class. So, I would like to stop here and then will come back and complete this algorithm tomorrow.

Thank you.