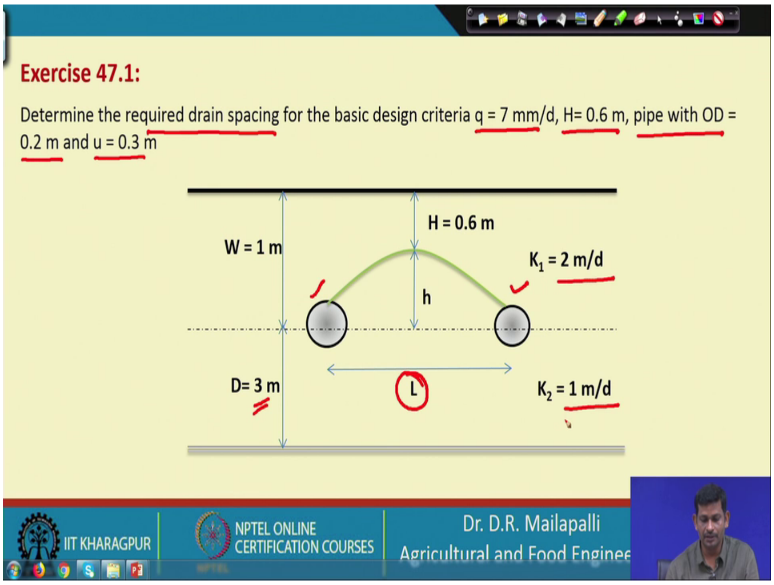
Irrigation and Drainage
Prof. Damodhara Rao Mailapallli
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 47
Subsurface Drinage Design (Contd.)

Hi, this is lecture number 47 on Subsurface Drainage Design, we will continue with the surface subsurface drainage design.

(Refer Slide Time: 00:25)

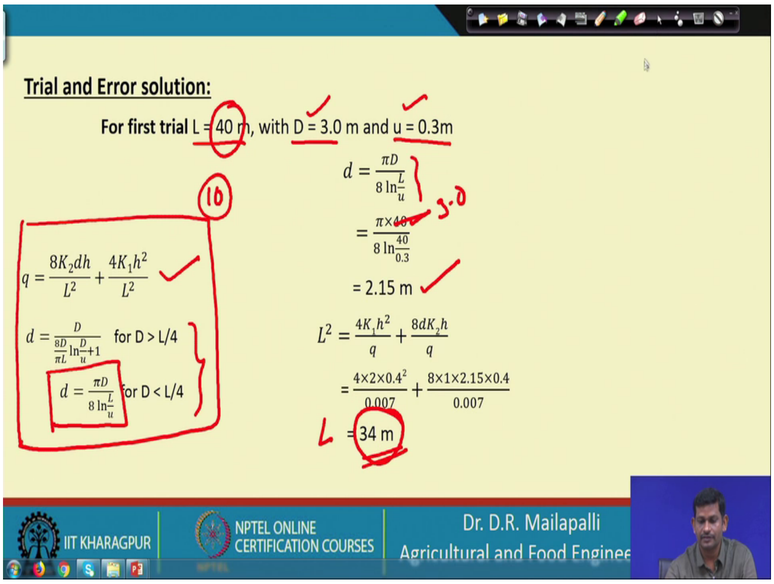


So, in this I mean from the previous lecture using the Hooghoudt equation so, there is an example. So, determine the required drain spacing for the basic design criteria q or say recharge or the drainage discharge which is equal 7 mm per day and H is 0.6 meter. So, that is we are expecting the highest water table at the center of the 2 drains is 0.6 meter and pipe with outer diameter is 0.2 meter and u which is equal to 0.3 meters that is the wetted parameter of perimeter ok.

So, schematically you can say so, this is the 2 drain pipes right. And so, W that is the base I mean the top to the base is the 1 meter and D capital D which is from the base to the impervious layer that is 3 meter and you have to find out drain spacing. 2 layers so, the top layer that is 2 meter per day and bottom layer hydraulic conductivity is 1 meter per day. So, with this find out what is L drain spacing.

So, we need to bring the Hooghoudt equation and then the criteria's into the picture and the using the trial and error method we are going to find out the length L. So, let us see this so, here.

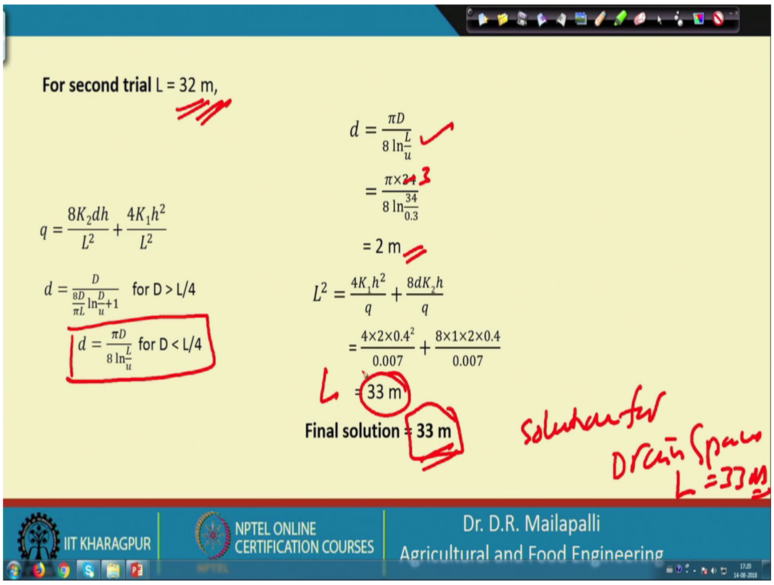
(Refer Slide Time: 02:11)



So, the first trial let us say L is equal to 40 meter and D which is equal to 3.0 meter and u is equal to 0.3 meter. So, these values are given in the previous example right and previous slide. So, if you see this equation right. So, this is Hooghoudt equation and these are the conditions ok. So, L is equal to 40 so, when L equal to 40. So, L by 4 will be 10 and your D is 3.0. So, since D is less then L by 4 so, we are going to use this equation to find out small d so, that is here. So, you are going to find out small d. So, pi into D 40 by 8 ln so, this is this is supposed to be pi not this is not D. So, this should be 3.0, this is D.

So, then putting the values you get small d is 2.15 and L square and now you substitute that into the drain space formula that is L square 4 K L h square by q and you get L as this is L so, L as 34 meter. So, if you see the initial guess was 40 meter and after calculation you get 34 meter. So, this L and the initial guess L they are not the same. So, what we are going to do? We are going to I mean put we are going to see another trial by putting L equal to 34 ok. So, that is the next trial with L is equal to.

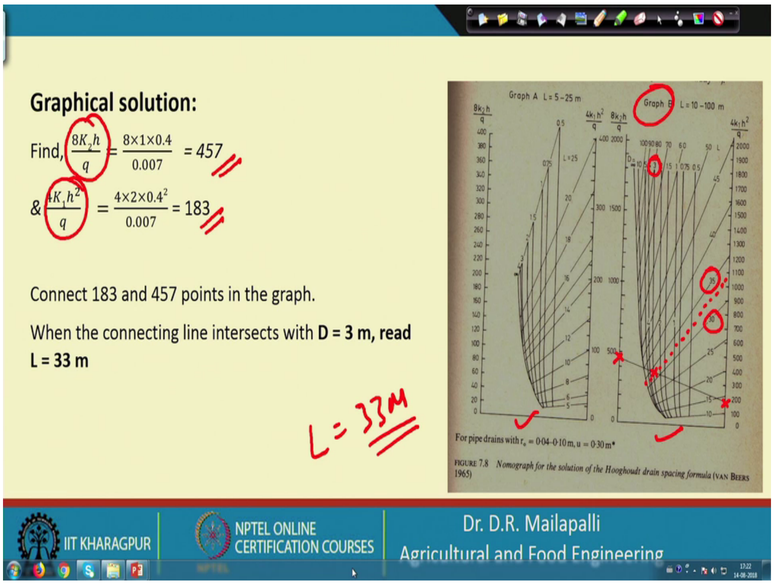
(Refer Slide Time: 04:23)



So, let say L is equal to 34 or even 32. So, close to that so, this is the second guess. So, now, L by 4 is that is 8; that means, still it is less than right less than I mean D is less then L by 4 and we are going to use the same equation ok. And this is supposed to be 3 meter and you get 2 meter small d right and then the finally, you get L is equal to 33.

So, the final solution 33 the initial guess is 32 the very close. So, you can take L as 33 meter here. So, that is the solution for drain spacing, drain spacing that is L equal to 33 meter. So, the same problem can be solved using the graphs. So, that is called graphical solution we can also see the graphical solution here.

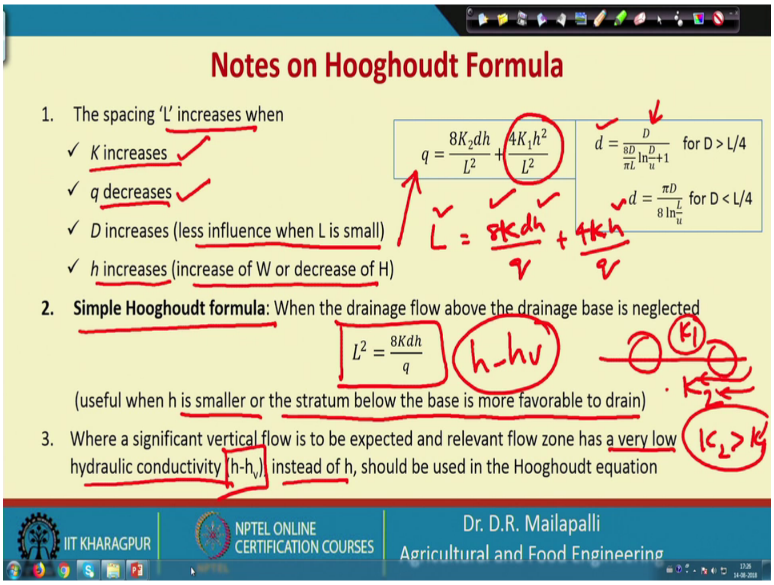
(Refer Slide Time: 05:29)



So, how this is different from the elliptical solution? So, here the 2 things the first number 1 is you have to find out 8 K 2 h by q and 4 K 1 h square by 2 by q. So, these 2 terms if you substitute the values so, one is 457, 183 ok. So, either you use this one or this graph or this graph so, since we already see this thing as about 30, 32.

So, let us consider the graph B so, in the graph B if you see 8 K 2 h q that is 457 so, 447 that is already there. And similarly for 4 K 1 h 2 so, this is another one 2 points and D is equal to 3 right. So, this is D is equal to 3 and then you follow the line and see this is this is exactly hitting this point ok. And the corresponding I mean the corresponding this is the line ok. So, this is this is 30 and 35 that is the drain spacing it should be between 30 and 35. So, if you do the interpolation linear interpolation you get you know L is equal to 33 meter which is almost same as the previous you know solution.

(Refer Slide Time: 07:07)



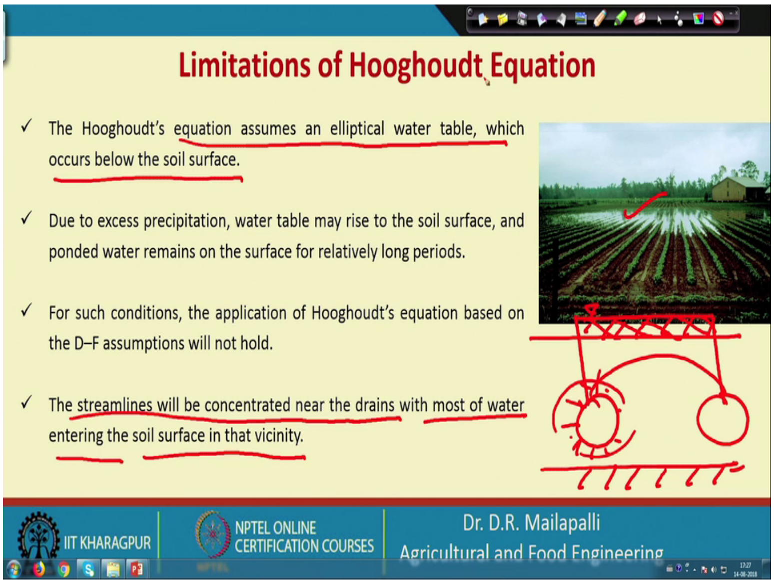
So, there are some notes on Hooghoudt formula so, if you observe the formula q is equal to 8 K 2 D h by L square plus 4 K 1 h square by L square. So, the spacing L so, the same thing you write down like this L square is equal to 8 K d h by q plus 4 K h square by q ok. So, when do you expect L to be increased? So, when you have the K increase right K increase L is going to be increase and q decrease right, q decreases q decreases and also L is going to increase and capital D increases. So, less influence when L is small right capital D; that means, you are coming here. So, the capital D increases. So, that means, d is going to be increased when capital D increases d is going to be increase ok.

And then h also increase, suppose you are increasing the h and L is going to increase ok. So, these are observations from the formula. So, that means, what is the influence of this? What is the when what indication you are going to get? For example so, if the soil is you know permeable so, it has hydraulic conductivity. So, that means, you can increase the spacing I mean lateral spacing in that case. So, here if you are expecting less q right drainage discharge is low from the area right low from the area. So, then or the recharge which is taking place is low then it can also increase the lateral spacing ok. So, h increases so, h increases in the sense so, vertical flow is increasing right vertical flow is increasing. So, in that case also you can increase the line spacing.

So, and simple Hooghoudt formula so, in this equation what happens you can eliminate still the water flow or horizontal flow above the drain. So, then you will left with the horizontal flow below the drain. So, that is L square into 8 K D h by q. So, this is simple Hooghoudt formula we call. So, this is useful when h is smaller or the stratum below the base is more favourable to drain. So, you have this is the base right. So, below the drain has more favourable to the drain that means, suppose K 2 and K 1. So, K 2 is more than K 1. So, then the top is you know less permeable and bottom is permeable. So, you get you know the horizontal flow at the bottom.

So, whereas, significant vertical flow is to be expected and relevant flow zone has a very low hydraulic conductivity. So, instead of h it should be used to Hooghoudt equation. So, suppose the vertical you have know vertical flow is dominating right. So, in that case so, the h will be considered as h minus h v. So, that is we have to include h v also into the picture.

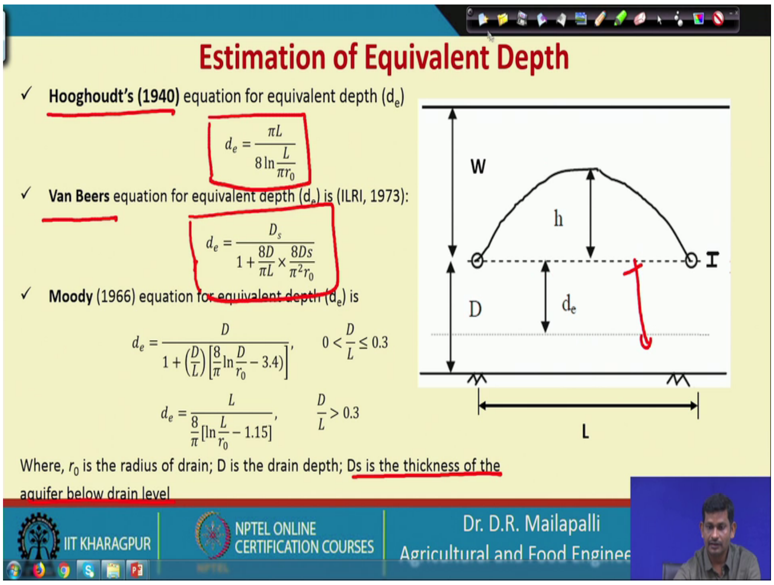
(Refer Slide Time: 11:07)



Then the limitations here the Hooghoudt equation assumes an elliptical water table if you see the water table. So, I have been drawing several time this is elliptical water table which is occurs below the soil surface. This is what the Hooghoudt equation assumes. But, what happens? So, if the water table is just rising up right, rising up and accumulating the water on the top surface just like here if you are seeing. So, then Hooghoudt equation you know is has a limitation in this kind of scenarios.

So, the streamlines will be concentrated near the drains with most of the water entering the soil surface in the vicinity. So, in this case what happen? So, most of the streamlines into concentrated because, the ponding on the surface. So, most of the I mean this will be concentrated near the drains. So, this is one limitation.

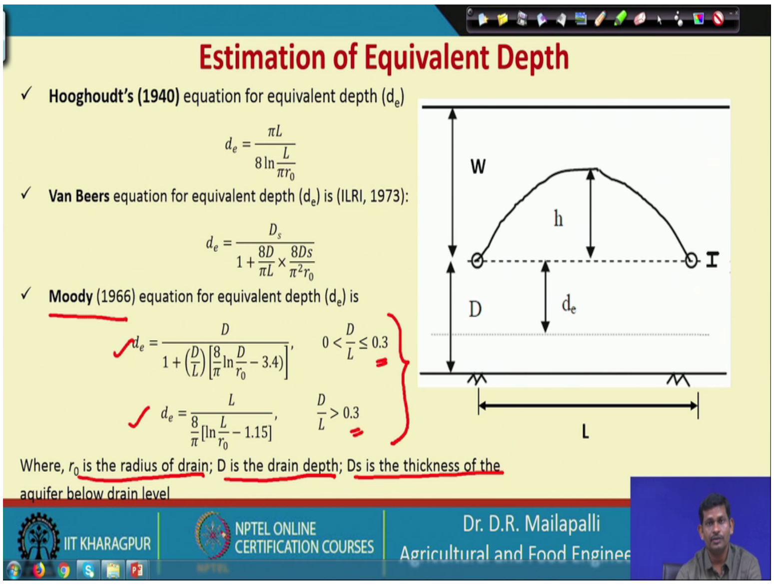
(Refer Slide Time: 12:09)



And the next is estimation of equivalent depth. So, this is a very important when the Hooghoudt, Hooghoudt you know consider the pipe drainage system to a deep ditch system by introducing the equivalent depth concept.

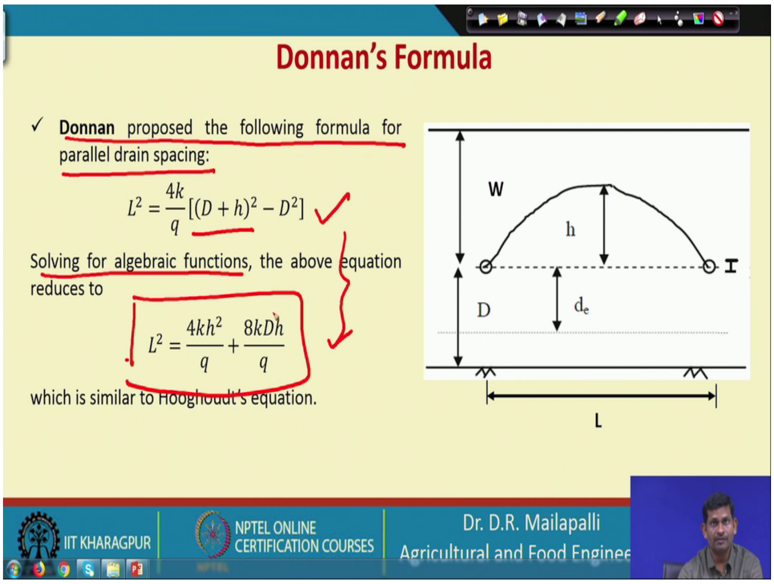
So, equation of equivalent depth d e the Hooghoudt has given this formula the pi L by 8 ln into L by pi r naught so, and Van Beers equation. So, that is equivalent depth is estimated with D s by L plus 8 D by pi L into 8 D s by pi square into r naught ok. So, where the D s is thickness of the aquifer below the drain level ok. So, D s is the thickness of the aquifer below the drain level so, below the drain level ok.

(Refer Slide Time: 13:11)



So, then Moody also has given an equation for equivalent depth. So, which is D by 1 plus D by L 8 by pi ln of D by r naught minus 3.4 and he have 2 conditions; so, 0 D by L less than equal to 0.3 and the D by L greater than 0.3. So, based on these 2 conditions so, d e will be estimated with different formulas. So, r naught is the radius of the drain and D is the drain depth ok; so, then D s is the thickness of the aquifer below drain level.

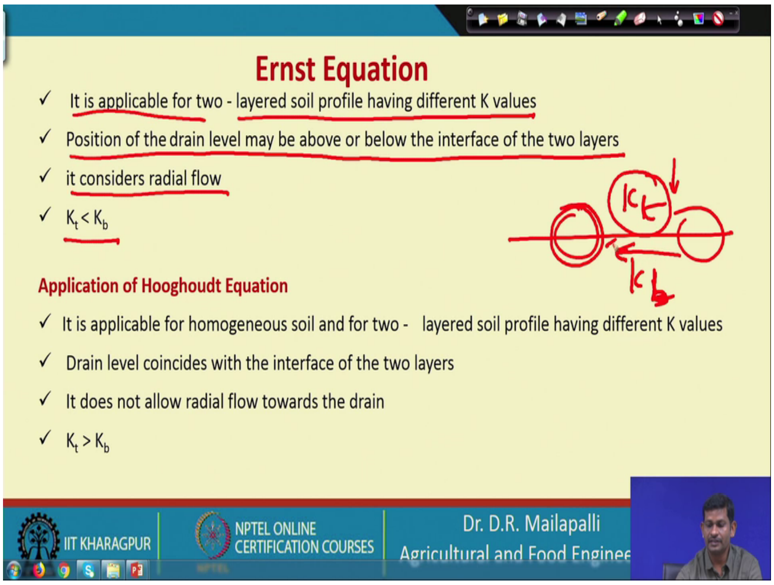
(Refer Slide Time: 13:51)



So, then there is a Donnan's formula so, Donnan proposed the following formula for parallel drain spacing. So, this is L square 4 k by q into D plus h square minus D square.

So, this is almost by solving the algebraic functions and if you look at the Hooghoudt equation and Donnan's equation they are they are almost similar right 4 k q D plus h square minus D square. So, this results in the same formula, but only thing here this would be equivalent depth ok, that is the drain depth.

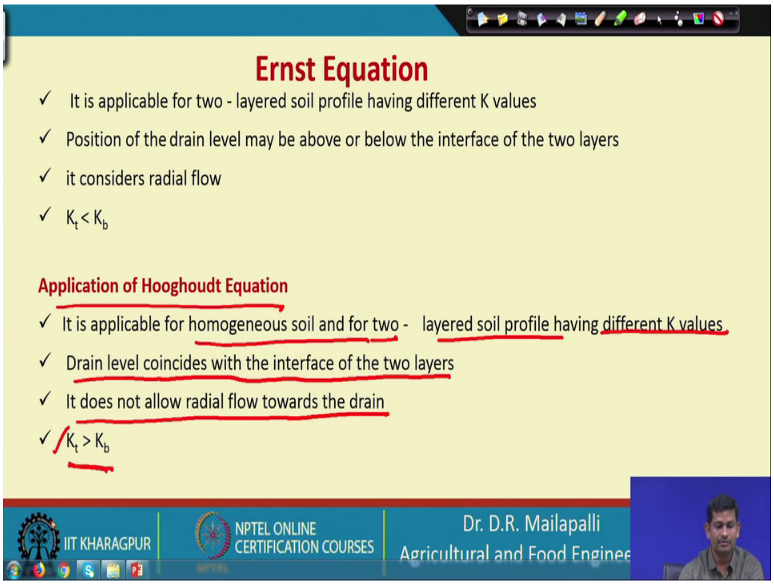
(Refer Slide Time: 14:33)



So, then let us revisit Ernst equation so, it is applicable for 2 layered soil profile having different K values. So, if you remember the Hooghoudt equation we have K 1 and K 2 based on the drain which is installed exactly h 3 base right; so, which is above K 1 and below K 2 something like that ok. So, Ernst equation will be work for the 2 layered system and the position of the drain level may be above or below the interface of the 2 layers ok. It consider the radial flow of course, the Ernst equation consider the radial flow and K t are less than K b. So, this is K t this is the top and this is the below right.

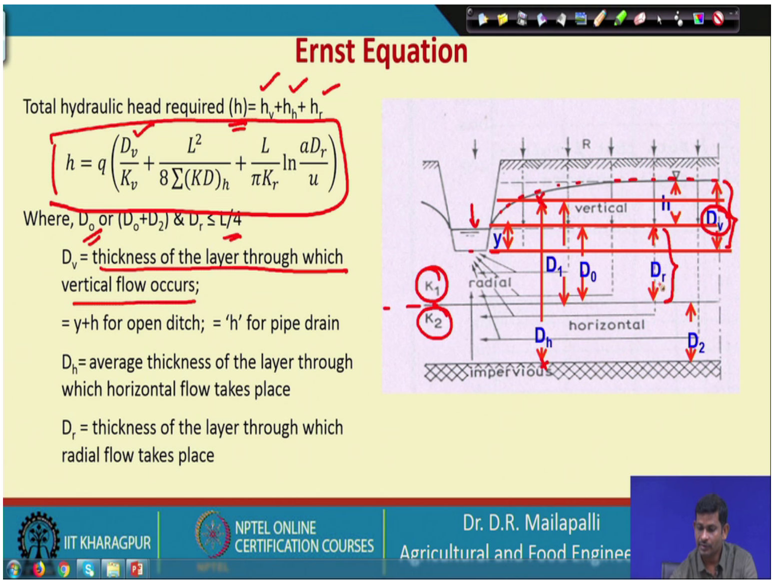
So, in this case K t is less then K b right less than K b so; that means, the vertical you know the vertical head will be almost negligible and mostly the flow is taking place with the horizontal or the radial in this case.

(Refer Slide Time: 15:47)



The application of Hooghoudt equation, it is applicable for homogenous soil for 2 layer soil system having different K values ok, the similar to Ernst equation. So, this is also applicable and the drain level coincides with the interface of the 2 layers. So, the and it does not allow radial flow towards the drain, that K t which is greater than K b. So, in the Hooghoudt equation the top layer is more permeable than the bottom layer

(Refer Slide Time: 16:29)

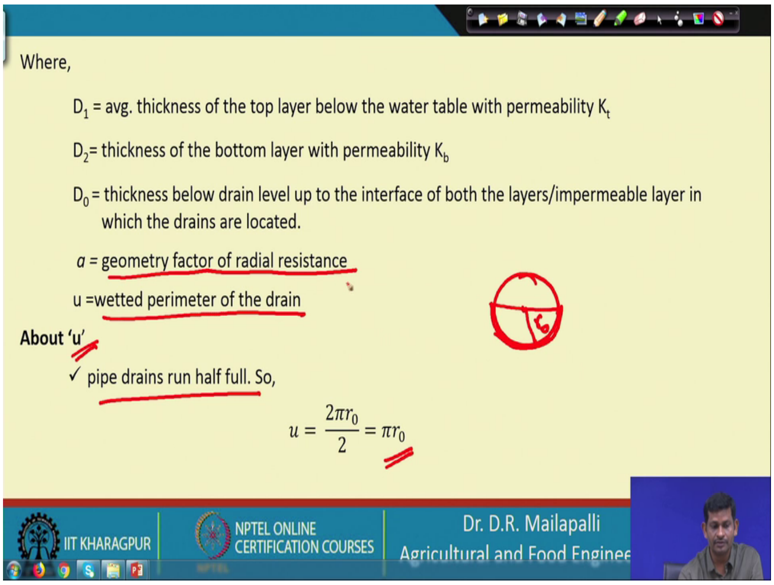


So, in case of Ernst equation, the total hydraulic head required h is equal to vertical, horizontal and radial ok. So, that if you combine all these, you know the vertical, horizontal radius. So, this equation looks like this is the total equation Ernst equation and where D naught or D naught plus D 2. So, here there is a schematic, this is open ditch system if you see.

And this is the drain you know water table, this is the water table and there is a horizontal look at this is the K 1 right, this is the 2 layers K 1 here and K 2 here the 2 layers here. So, drain is installed at above I mean K 1 or the layer 1. So, from the drain bottom so, this is the D v, D v indicates the thickness of the layer through which vertical flow occurs. So, vertical flow we concentrating here right whereas, the radial flow concentrating from here to the top layer right, only within the top layer. And horizontal like D h so, D h is concentrating in the both layers that is the K 2 and K 1 ok. So, from this point to this point right.

So, these depths are very important and y is the water level in the drain y is the water level in the drain ok. So, then D v is the thickness of the layer through which vertical flow occurs. So, D naught or D naught plus D 2 and D r which is less than L by 4; so, D r the thickness of you know the aquifer 3 which radial flow is taking place will be less than equal to L by 4 ok.

(Refer Slide Time: 18:49)

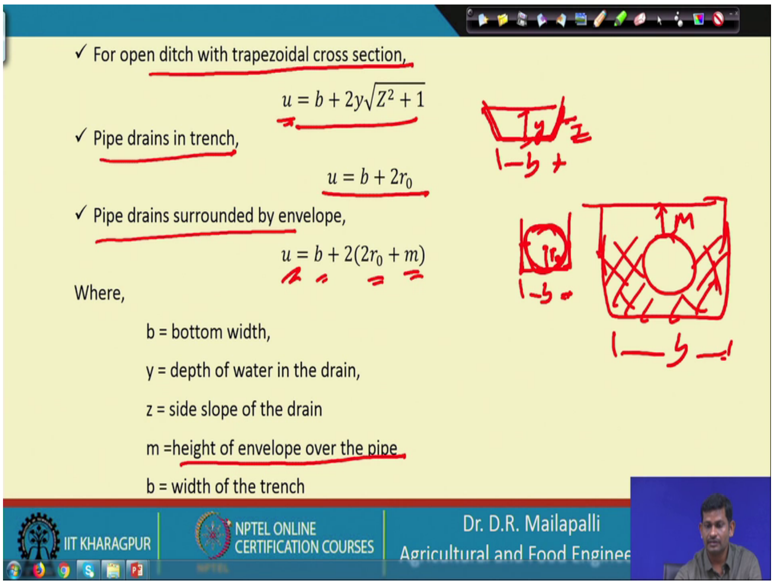


So, with this concept with this concept let us explore the other details for example, if you see the previous if you see the previous I mean this thing. So, here basically aD r right in this formula this is aD r and u. So, these are very important we are going to discuss how do you estimate the aD r and u in the following slides.

So, here about u so, u is the pipe drain run half full basically. So, in that case so, since the pipe drain is half full that is the assumption ok. So, in case of in the circular, you get u as you know half of the perimeter the half of the half of the perimeter of cycle. So, that is pi r naught so, if this is r naught. So, this is the one so, where u is the wetted perimeter of the drain, a is the geometry factor of the radial resistance and that we are going to estimate.

So, let us let us find out I mean in the in the previous week I discussed on how to estimate u for different shapes. So, and here for example, for open ditch a trapezoidal cross section.

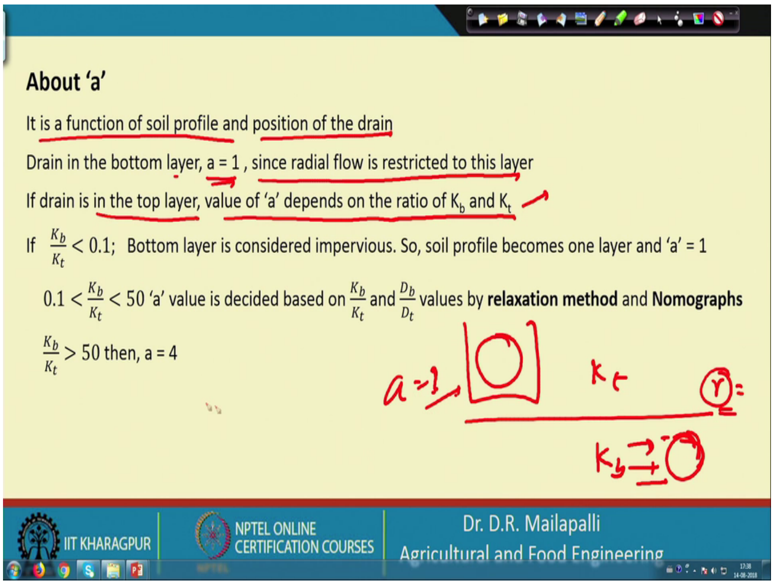
(Refer Slide Time: 20:15)



So, u is so, this is the trapezoidal cross section. So, b is the you know width and then this is the depth y and the slope right Z. So, in that case so, u is equal to b plus 2 y square root of Z square plus 1. So, this is the u this is the u perimeter. The pipe drain in trench suppose, trench contains a pipe drain right a pipe drain is a trench then u is equal to if this is the b and if this is r naught ok. So, here you get r naught plus r naught so, there is 2 r naught so, u is equal to b plus 2 r naught.

The pipe drain surrounded by envelope, suppose you have a pipe drain which is surrounded by let us say the envelope right. So, in that case u is equal to b, b is the width of the trench right which width of the trench and 2 into 2 r naught plus m. So, m is the height of the envelope over the pipe. So, height of the envelope over the pipe this is m. So, this way you can estimate the u value that is wetted perimeter for different you know conditions.

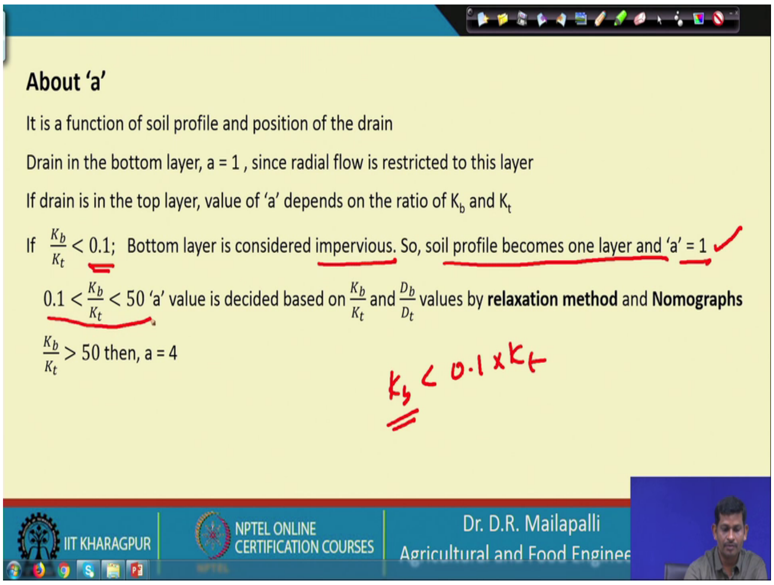
(Refer Slide Time: 21:42)



And then what about a? a D square right. So, a so, it is the function of soil profile and position of the drain so, these 2 things of soil profile as well as the drain position. So, drain in the bottom layer if the drain is at the bottom layer then a is equal to 1. So, bottom since radial flow is restricted to that layer. So, since there is no radial flow I mean radial flow is restricted a will be 1, if the drain is in the top layer the value of a depends on the ratio of K b and K t. So, K b is the top layer hydraulic conductivity, K t is the bottom layer hydraulic conductivity.

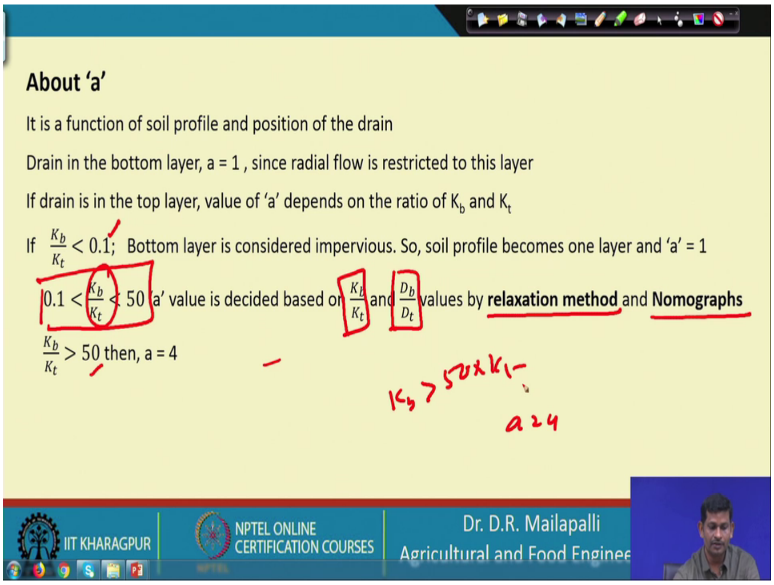
So, suppose you have the 2 layers K b and K t right if the drain is installed on the top drain is installed in the top layer and you have and the depends on K t and K b, you can estimate the a value ok, a is depends on K t and K b. But whereas, if the drain is at the bottom layer suppose here right so, in this case so, the mostly the horizontal flow is in plane say and radial flow can be I mean is not is independent of the radial flow would not be an issue here. So, a is equal to 1 in that case. So, in let us see the second case that that is drain is installed in the top layer.

(Refer Slide Time: 23:19)



So, in that case what happen? If K b by K t is less than 0.1 the bottom layer considered is impervious and then. So, the soil profile becomes 1 layer and a equal to 1. So, mostly K b and K t is less than 0.1 so; that means, the top layer top layer has less hydraulic conductivity or sorry the bottom layer has so, suppose K b less than equal 0.1 times K t. So; that means, bottom layer has impervious surface impervious layer and the soil profile becomes one layer. So, then that a is equal to 1.

(Refer Slide Time: 24:05)

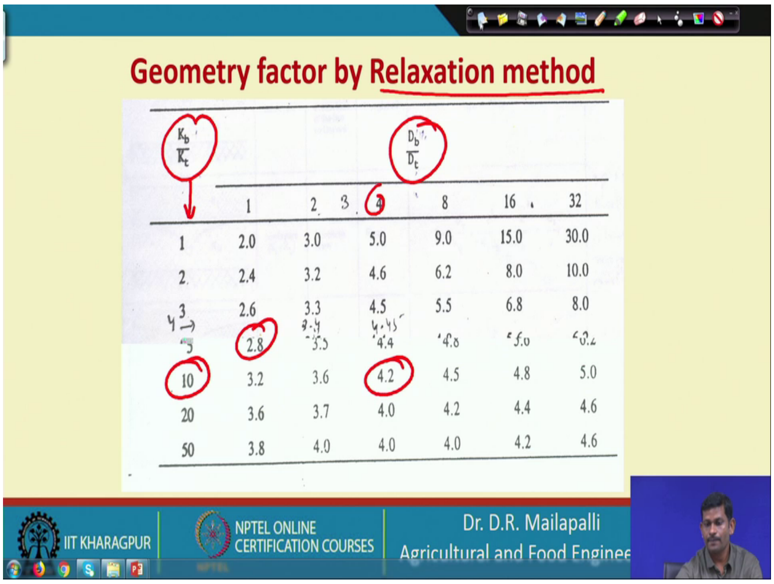


So, but 0.1 K b and the next one is here K b is greater than K b by K t greater than 50.

So; that means, K b greater than 50 times K t so, it is more pervious then a is equal to 4. So, in between 1 and 4 right in between 1 and 4 so, we need to I mean a is equal to 1 and 4 can be estimated like 0.4 point that all depends on the ratio between 0.1 and between 50.

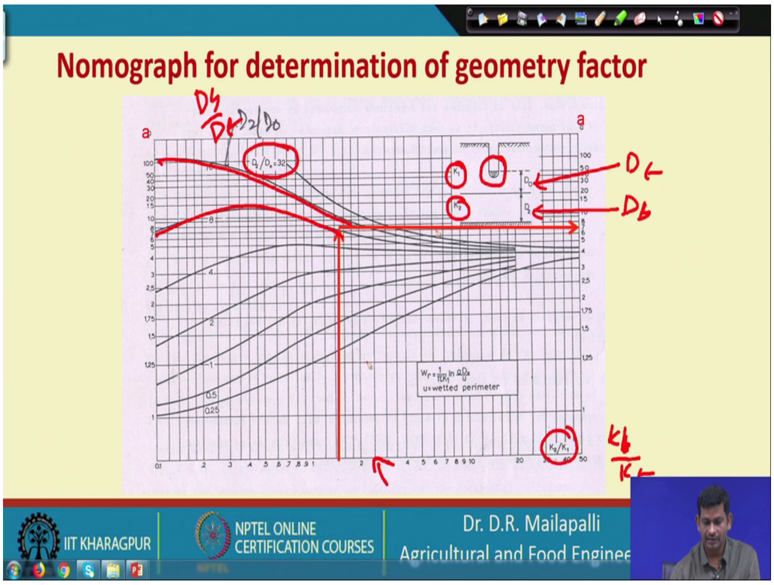
So, it decided K b by K t and D b by D t. So, that is aquifer depth or aquifer thickness of the bottom layer thickness the top layer. So, using relaxation method and Nomographs these 2 things can be used to find out the a value. So, let us see how we would find out a values.

(Refer Slide Time: 24:59)



Based on K b by K t and D b by D t so, here there is a table it is called relaxation method table. So, K b by K t values are here and D b by D t values are here and the corresponding you know the a values are for example, K b by K t is 10 and D b by D t is 4 right and the corresponding values 4.2.

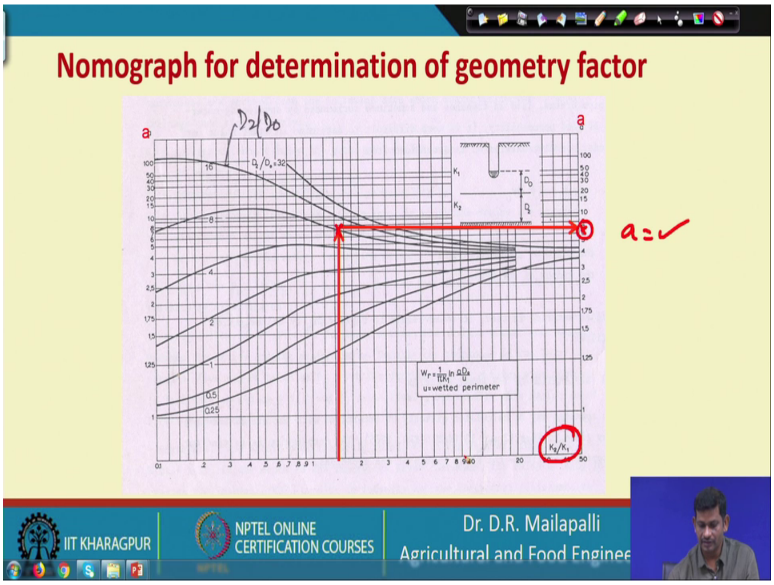
(Refer Slide Time: 25:30)



And then there is a Nomograph also available. So, here for example, this is the I mean the drain installation. So, the drain is at the top layer drain is at the top layer and K 1 top layer hydraulic conductivity, K 2 bottom layer hydraulic conductivity and D naught this is. So, the this D 2 is D b right, D 2 is D b and D naught is D t ok. So, this is D t and this is D b.

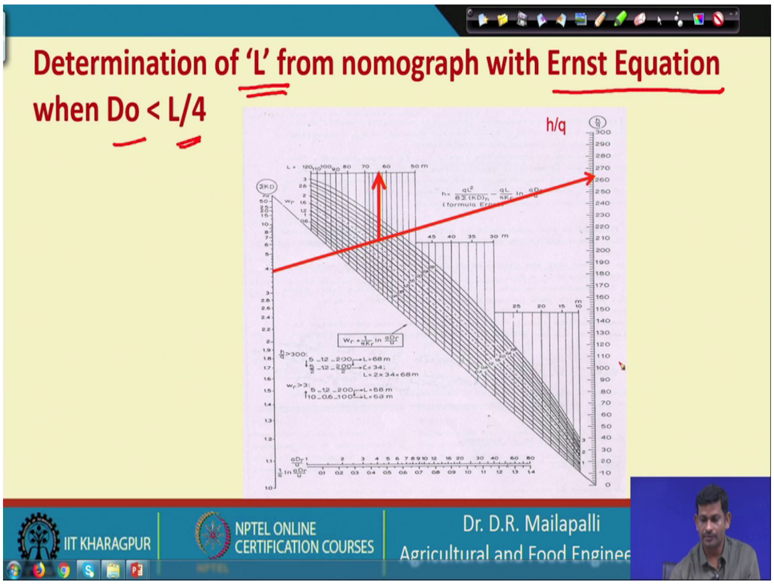
So, D 2 by so, this is D b by D t in our case right. So, here what happens so, K 2 this is K 2 by K t by K b sorry K b by K t right K b by K t. So, knowing the K b by K t value here ok and then see this is D b by D t values, this curves are is curves are D b by D t values for a particular risk curves ok.

(Refer Slide Time: 26:47)



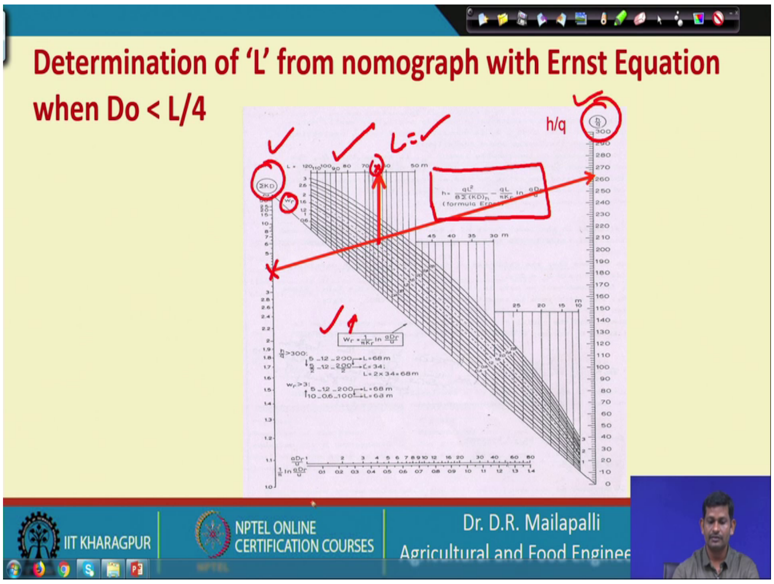
So, just knowing the you know K knowing the K b by K t and D b by D t. So, then you will be finding out the point where it is going to intersect and from there just project on to the y axis right. So, that will give the corresponding a value that will give the corresponding a value here ok. So, this way you can estimate the a values ok.

(Refer Slide Time: 27:21)



And so, from this graph this is a combination of all the things. So, this graph L can be determined from the Nomograph using Ernst equation. So, when D naught is less then L by 4. So, D naught is what? This is the top of I mean D naught is here you know our case which is this is. So, D naught is D b D t D naught is D t D naught is D t. So, knowing D t, know if the D t is less than L by 4 so, L can be estimated using the following Nomograph.

(Refer Slide Time: 28:11)



So, here if you observe this Nomograph clearly right. So, one axis so, this y axis is h by q right if you refer to the Ernst equation. So, the Ernst equation will be this is the formula. So, in this is so, y axis one y axis has sigma K D the other y axis h by q. So, these are known values. So, knowing these 2 you just draw a line combining these 2 and these are all the W r lines, where W r is 1 by pi K r into ln of a D r by u right. So, now, see after finding W r so, then the corresponding I mean you just project it on to this line, this is another sub axis line sub x axis line and that will give the L value. So, that will give the L value.

So, in using Ernst equation you can find out the drain spacing by knowing the K D value right sigma K D, the K 1 D 1 plus K 2 D 2 something like that based on the number of layers and h q h by q value right. So, then W r so, these values will be known and based on that you can find out the drains spacing.

So, thank you so, this is all about this lecture. So, in this lecture basically we solved some example for a Hooghoudt equation using the trial and error method ok. So, we use the both theoretical base like analytical method as well as graphical method in order to find out the drain spacing by knowing certain soil parameters. And then after that we move on to the equivalent depth formulas and then Ernst equation.

So, in the Ernst equation so, how to find out you know a and u and then I mean using the Nomograph we can find out these values as well as for the 2 layered system. And finally, by knowing the, you know by knowing the h by q right sorry q by h value and then W r and also the sigma K D you can find out the drain spacing form I mean drain spacing.

Thank you.