Irrigation and Drainage
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Lecture - 46
Subsurface Drainage Design

Hi welcome to lecture number 46, this is an Subsurface Drainage Design. So, in this lecture we are going to see, we are going to estimate the steady state flow of I mean drainage water to the drains. So, in this we going to derive an equation using Hooghoudt, Hooghoudt formula we call; so, for and seeing the steady state conditions.

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So, next is before going into the details to the drainage design principles. So, the basically this is the drainage design whenever we are talking, so, it should require developing some criteria. So, the drainage design should specify the operation of the system and the physical configurations that fulfil the drainage objectives. So, you have to see what is our drainage objective whether to dispose the excess water on the surface or to remove excess water from the root zone as well as the soils. So, based on the objective, you have to specify those objectives ok.

So, then they consider the irrigation and drainage systems as integrated water management systems. So, the drainage system should be in such a way that we should integrate with the irrigation management and the minimised deep percolation loss through improving the water management system. So, water management through water management the drainage system should be able to minimise the deep percolation.

And then, the characterised the establishing the water table depth at the midpoint between laterals and drainage coefficient; so, you drainage system should be able to you know equate the water table depth, water table depth from the top surface at the midpoint and the drainage coefficient ok. So, midpoint laterals and the drainage coefficient. So; that means, in a day the amount of water which is resulting from the drains. So, there is drainage coefficient that will that should be equate the depth to water table at the mid way ok.

And the specify option regarding reuse of drainage water. So, whether the drainage water needs to reused back as irrigation water or not. So, that also needs to be specified. So, these are the main basic things we need to consider before designing drainage system.

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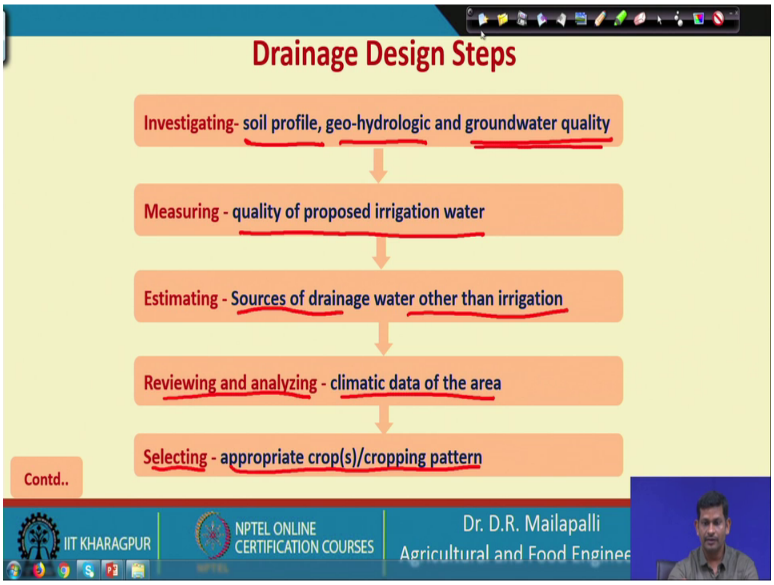

So, that the next is, these are the steps we need to follow design the drainage step system. The first one is the investigation. So, we need to investigate the things like soil profile, geo hydrologic and ground water quality. So, these things need to be understood before installing or before planning a drainage system. So, soil profile, so whether it is a layered soil or clay soil or any like sandy soils all those things and geo hydrologic. So, geo hydrologic in the sense the hydraulic conductivity in different places and different depths and quality of ground water and measuring involves the quality of propose irrigation water. So, you need to check whether the quality is to I mean in to you know artificially irrigate the plant or not.

And estimating the surface of the sources of drainage water other than irrigation as are there any other sources you know of drainage water other than irrigation. And reviewing and analysing the climate data of the area is very much required in order to understand the peek discharges from the particular area and selecting appropriate crops or cropping pattern. So, and what kind of crops you are going to grow in that land which is after drainage ok.

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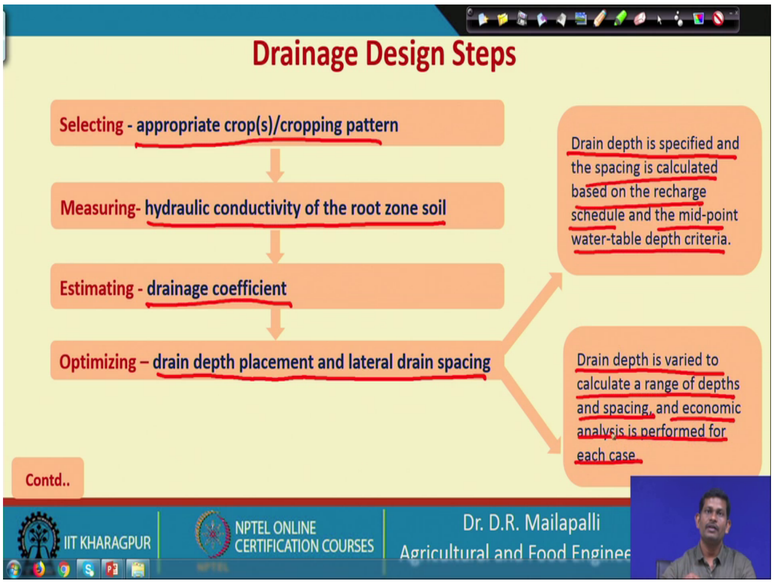

So, this also then after that the next step is a selecting appropriate crops cropping patterns. So, that is and then you have to measure the hydraulic conductivity and root zone of the soil based on the particular soil type and the drainage coefficient which is the amount of water which is being drained from the area in 24 hours. So, that is drainage coefficient and optimising drain depth and placement of lateral drain. So, once all these things are done, so need to optimise the drain depth that is a top to I mean drainage from the soil surface how deep you are going to install and also the spacing between the drains ok.

So, here if you see the two ways drain depth is specified you can specify drain depth and the spacing is calculated based on the recharge schedule and the midpoint water table criteria. So, here the first peaks I mean for the drain depth and then you have to iterate length for which you get the you know equal length for each iteration, you are going to see these calculations and the drain depth is varied. Now the drain depth is changing and calculates the range of depths and spacing's and economic analysis is performed in this case.

So, you get a combination of drain depth and spacing and you would be deciding based on the economic criteria which depth or which spacing needs to be I mean decided.

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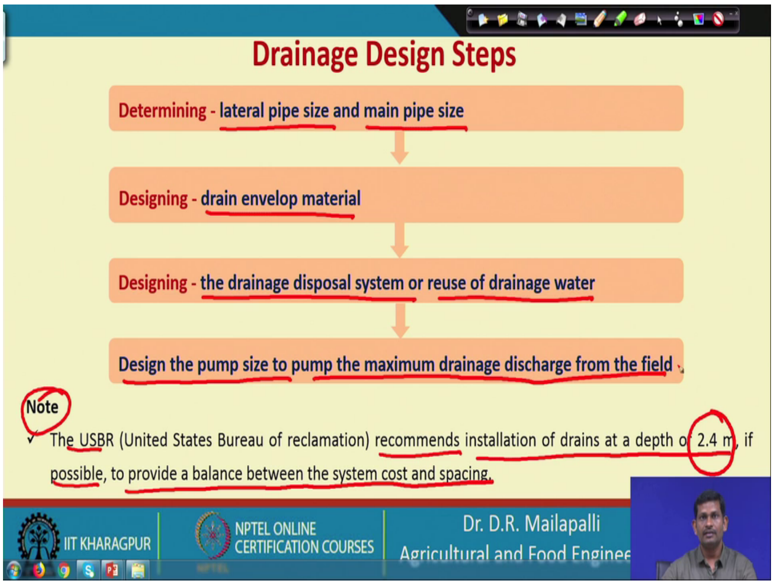

So, the next is once the drain depth and drain spacing is decided then the lateral pipes size and main pipe size or needs to be decided. We discussed this in the previous lectures the drain pipe sizes and then after the drain envelope material. So, we need to find out the drain envelope material which is generally greater than 10 times hydraulic conductivity of the soil material and after that you have to design the drainage disposal system or reuse drainage system. So, whether then you have to design the drainage disposal system whether you need to dispose the drain water or if you are going to use reuse that system back to the irrigation system irrigating the crop, then you have to I mean design the drainage system for reuse purpose.

And then finally, the design the pump size and pump maximum drainage discharge from the field. So, once the drainage water is coming to the main ditch right, so then the outlet us coming to the picture. So, whether you need to pump out or the gravity outlet. So, those things and the basically there is a note the United States bureau of reclamation. So, recommends installation of drains at a depth of 2.4 meter if possible to provide a balance between the system cost and spacing. So, that is what USBR found the 2.4 is the ideal for a cost effective or drainage or design drainage system design.

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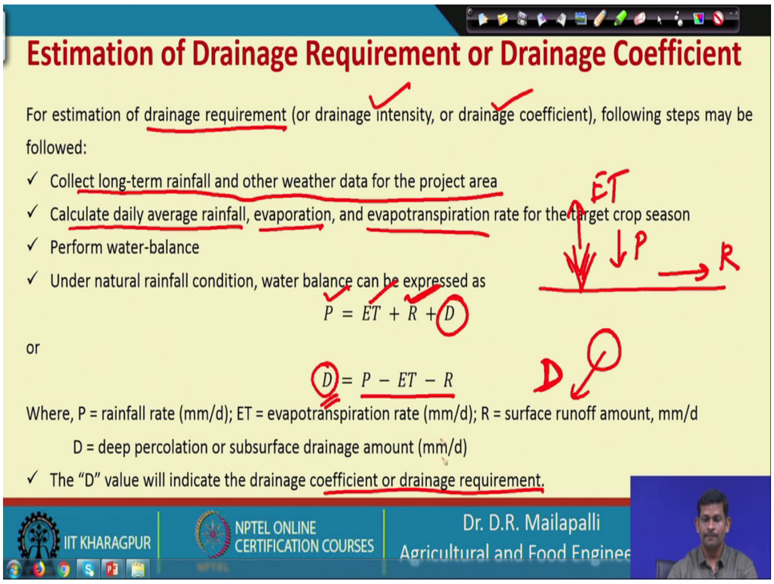

So, then after that, how to calculate the drainage coefficient using the water balance equation? So, for example here, estimating the drainage requirement or drainage coefficient; so, for the drainage requirement or drainage intensity or drainage coefficient we call also call different names drainage intensity drainage coefficient. So, these steps may be followed the first collect the long term or rainfall and other weather data for the project area. So, this is the number 1 and number 2, calculate the daily average rainfall evaporation and evapotranspiration rate for the targeted crop season ok.

So, the ETs estimated and the R the average rainfall and sorry average and the P is the precipitation ok, so R is the surface run off. So, then using the water balance equation D is the drainage. So, the drainage is equal to P minus ET minus R. So, I mean generally if you have the drainage system here right. So, this is drain water and this is precipitation and this is R rainfall and if you have a crop, then there is a ET taking place ok.

So, using this balance; water balance so, D will be estimated, D is equal to P minus ET minus R ok. So, since we are balancing for daily. So, D will get the drainage water per day. So, that will be equal to the drainage coefficient.

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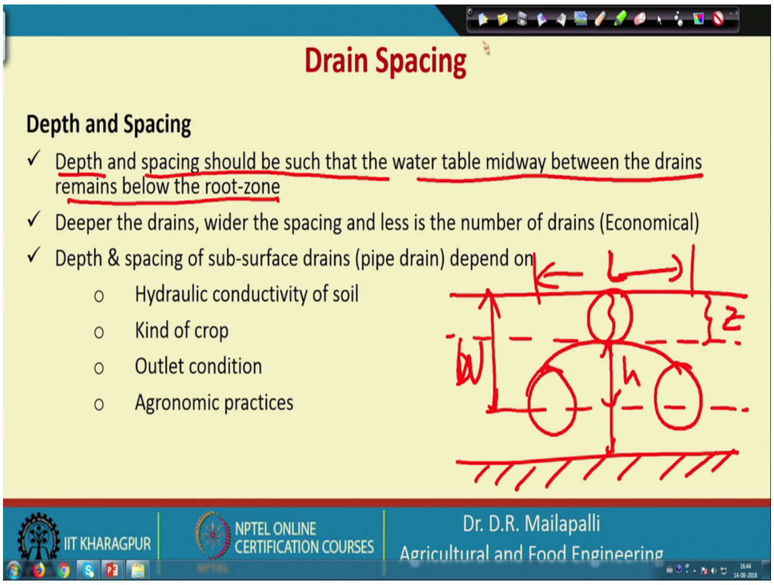

And then the next is drain spacing. So, the drain spacing, basically the depth drain depth and spacing should be such that the water table midway between the drains remains below the rules on this is the, so as I mention in the beginning of the slide.

So, the basic you know the basic in the criteria in. So, in the basic criteria in selecting the depth and spacing is. So, in the midway if you see the midway. So, this is the D and of course, this is H ok. So, so this is basically the water I mean the root zone depth, let say z this is we are interested in. So, the drain spacing whatever we are giving drain spacing and drain depth. So, drain depth and sorry w and drain spacing this is l. So, this will be decided in such a way that in a day. So, this area needs to be drained off ok, this you needs to be drained off. So, this is the criteria.

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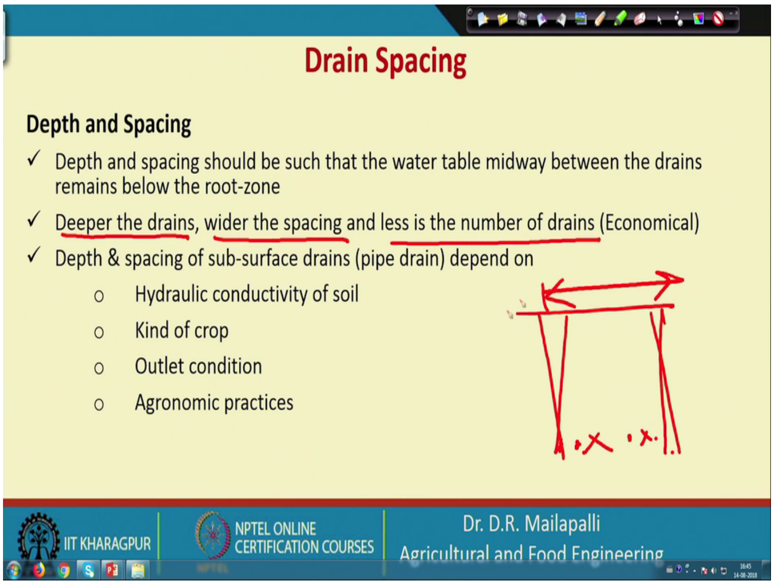

And so, deeper the drains wider spacing and less is the number of drains. So, this you can go deeper right. So, you can go very deep right and so that will allow you know keeping the drains in wider spacing, so that you can save some money. Because at the working everything will be minimised and also the number of pipes number of laterals; so, that will be reduced. So, and that is economical.

So, but the depth and spacing of subsurface drains it basically depends on the hydraulic conductivity of soil and the crop to be grown and outlet condition and argonomic practices. So, all these things needs to be considered before deciding a drain depth and a spacing.

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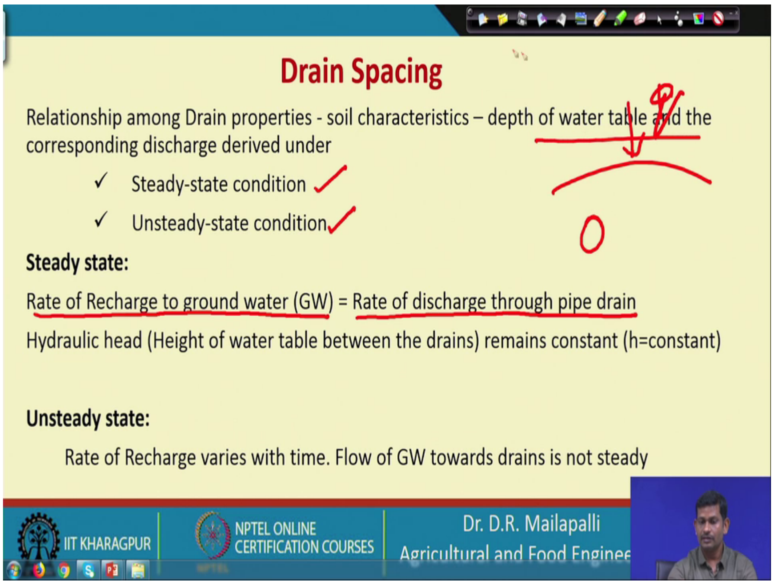

So, the drain spacing of formula it could be like a steady state condition and on steady state conditions. So, in the previous lecture in the last week, we were discussing the steady state condition. So, what are the things during steady state condition? So, the main assumption here steady state rate of recharge to the groundwater will be equal to rate of discharge through the drain pipe. So, the rate of recharge which is taking place let us take q. So, that will be, sorry so that will be equal to the drain discharge.

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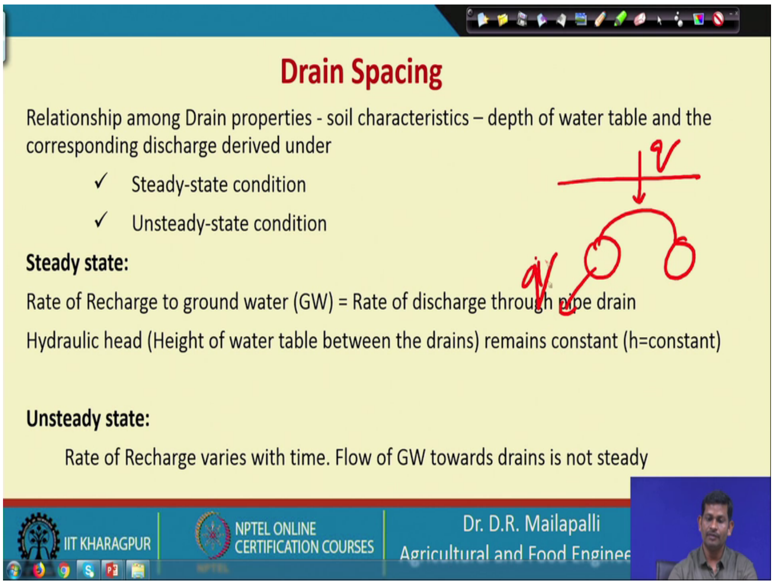

So, there is a q and this q. So, this will be equal in this case and hydraulic head, the height of water table between drains remain constants.

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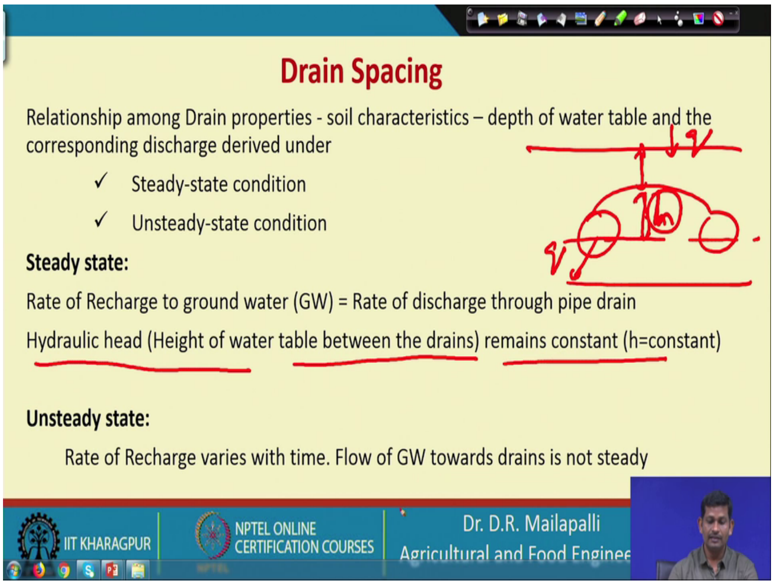

So, h is constant the same thing, if you see the h which is like here. So, this is constant in case of steady state condition ok. So, the q is recharge and q this is drain flow. So, this is one assumption that next one is h is constant and the steady state the other ones other assumptions are like the soil is homogenous and isotropic.

So, then case of unsteady case the terms are you know vary like rate of recharge varies with time flow of ground water towards the drain is not steady. So, these things we have already discussed in the previous week.

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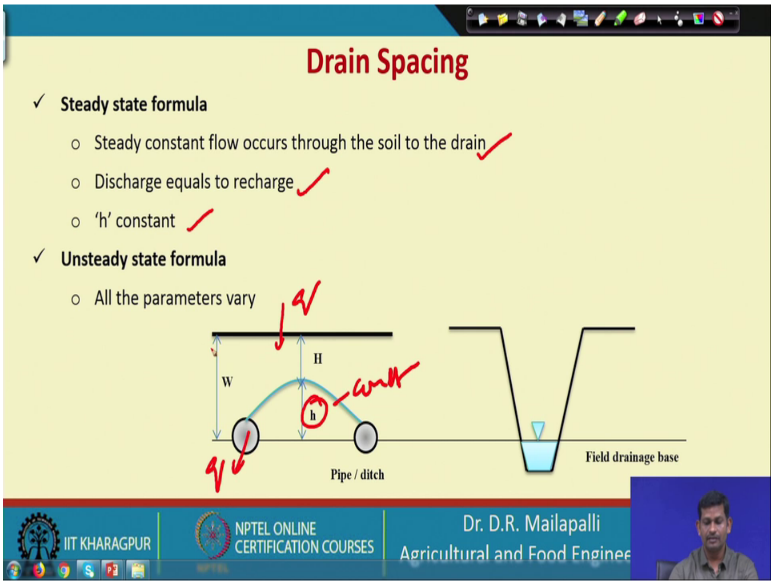

And then for the steady state formula, steady constant flow occurs through the soil in drain the discharge equals to recharge h is constant right. So, here, so let us say this is a q and this is the q. So, q is equal to q and h is constant ok, in case of whereas, unsteady all are going to change like this q is going to change. And the drain discharge is going to change and h is going to change under unsteady state condition.

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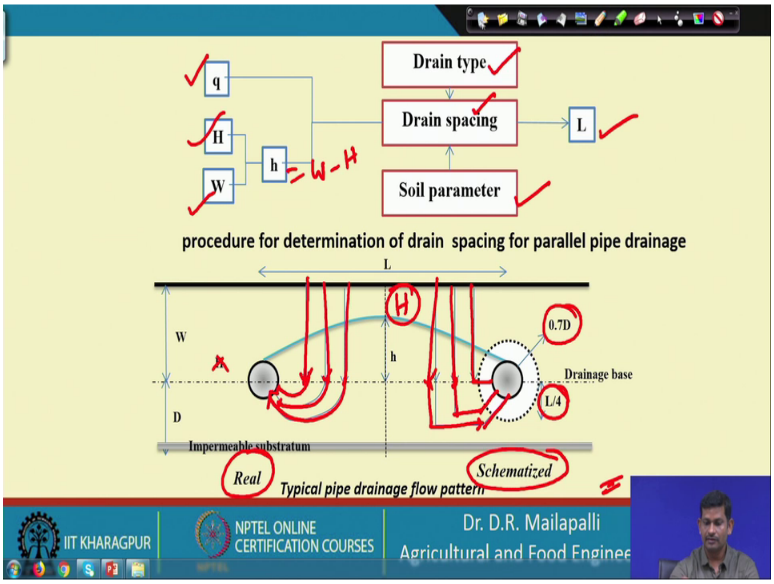

So, the procedure also we explained the last class like knowing small q; that is the drain discharge and H is the suppose this is H. So, H is the root zone you can say root zone depth, W is the drain depth and you can estimate h which is equal to capital W minus capital H right. So and then so knowing the soil parameters like hydraulic conductivity right and drain type. So, what kind of drain is tile drain or ditch or drain space formula will be used and finally, L will be calculated. So, this is the way the same schematic of finding out drain spacing and here this picture.

So, clearly shows the assumption this is the real field and this [vocalised-noise] schematized field for moulding purpose ok. So, if you see there is a vertical flow is taking place initially and then towards the drain this is the way the radial flow goes whereas, for making the modelling simple. So, the vertical flow and then horizontal flow and then radial flow vertical flow lateral radial vertical and horizontal and it ok. So, this way and also the horizontal flow is influence rate L by 4 distance and then the radial flow is influence 0.7 d from the drainage space.

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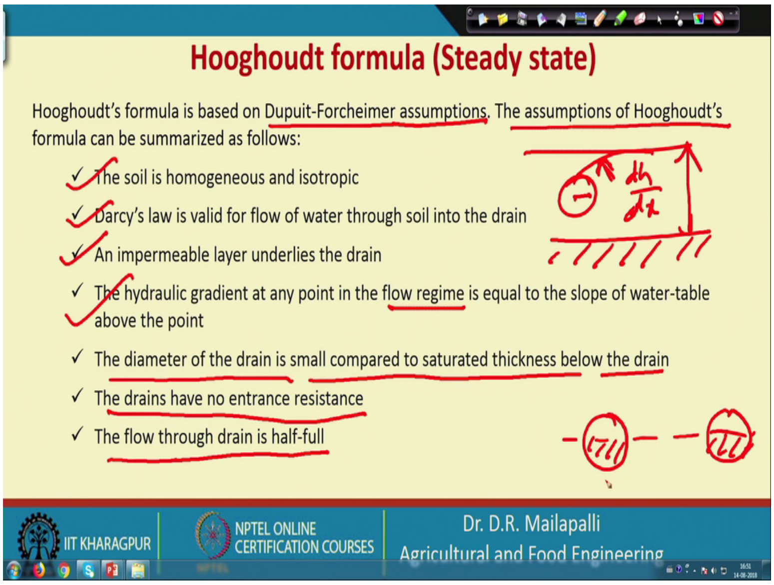

So the Hooghoudt formula here, so this is based on Dupuit Forcheimer assumptions right, Forcheimer assumptions. So, assumptions are Hooghoudts formula can be summarised as follows.

The soil is homogeneous and isotropic so; that means, the aquifer properties or soil properties will not change the distance and the direction all the time. So, and Darcy's law is valid for water through soil into the drain because it is completely saturated] conditions. So, the Darcy's lies very well valid for the Hooghoudt assumption.

And an impermeable layer underlines underlies the drain. So, always there is an impervious layer which underlines the drain and then the hydraulic gradient at any point in the flow region is equal to the slope of the water table. So, hydraulic gradient that is the dh by d x right dh by dx at any point or it dictates the flow region. So, dictates the flow process or flow direction.

The diameter of the drain is small compared to the saturated thickness below the our drain. So, whatever the diameter of the drain; so, this will be smaller than the saturated thickness ok. So, that is the thickness of the equipper the drains have no entrance resistance. So, the entrance resistance are considering 0, the flow through drain is full half full. So, at least half full we should maintain right in the in the drains ok. This is half full we need to maintain the drains ok.

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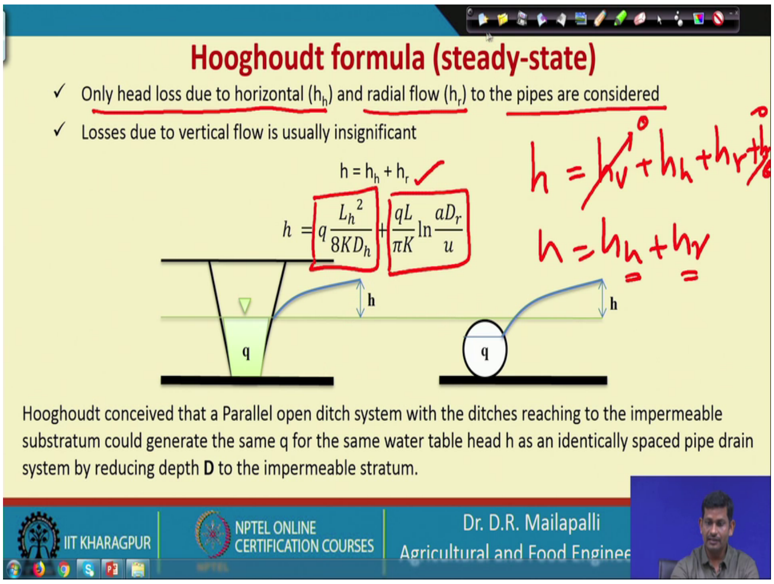

So, based on the assumptions, so only head loss due to horizontal and radial flow to be pipes are considered. So, since it is we mentioned this is steady state right. So, basically h is equal to h v plus h plus h r plus h e right. So, h v and h r we are neglecting here right. So, assuming the, I mean based on the Hooghoudt assumptions.

So, now h is equal to h h plus h r that is h due to horizontal flow and h due to radial flow. So, this is the one and so, this is for h h. So, we have defined or derived this equation in the previous lecture and whereas, h r; so, this is from Ernst equation, this is also we have shown in the previous week.

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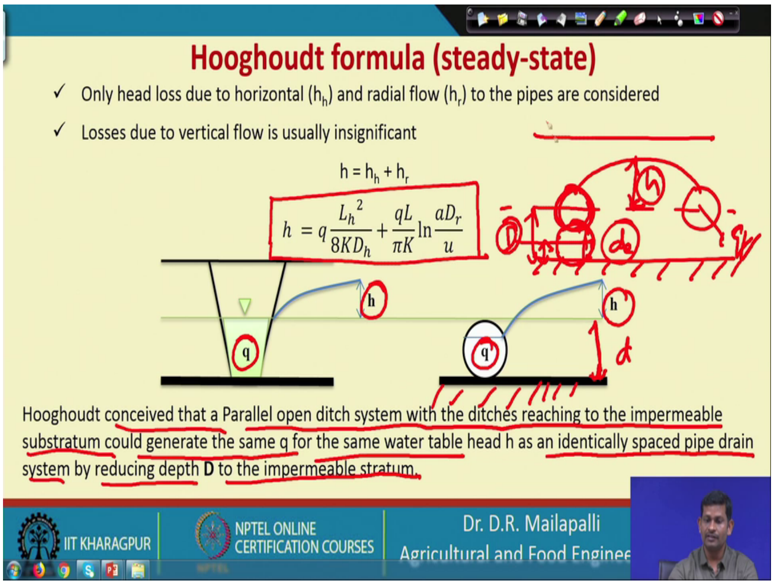

So, combining these two, so we will give the head at the. So, you get head at any point from the drain space ok.

So, this one, so Hooghoudt conceived that the parallel open ditch system with the ditches reaching to the impermeable substratum could generate the same q for the same water table head h as an identically spaced by drain system by reducing depth d to the impermeable stratum. So, here the in order to make the open ditch system right to a pipe drain system or the pipe drain system to open drain system.

So, what he assumed is so for the same hydraulic head for same hydraulic head and from same discharge right from the days discharge can be possible can be possible when the pipe drain is the pipe drain is installed at the pipe drain is installed at the impervious layer at the impervious layer. So, this how it is achieved by reducing the by reducing the d to an equivalent depth small d ok.

So, if you remember if you remember here right. So, this is impervious surface the actual case ok. So, and this one is the capital D this is the capital D ok. So, here this is a small h small h ok. So, the pipe drainage system can be converter or converted into a open ditch system right by putting this drain by putting this drain to the by assuming that this pipe drain is exactly sitting at the sitting at the impervious surface and then h will not change and q will not change for the same h and q right sitting uh. So, how it is possible? So, this when you put it in the down right; so, the depth here is no more capital D that will be equivalent depth D a that is equivalent depth da. We are going to see that.

So; that means, [vocalised-noise] see for making these, you can still you can completely you know eliminate the radial flow. So, it is now completely the horizontal flow ok.

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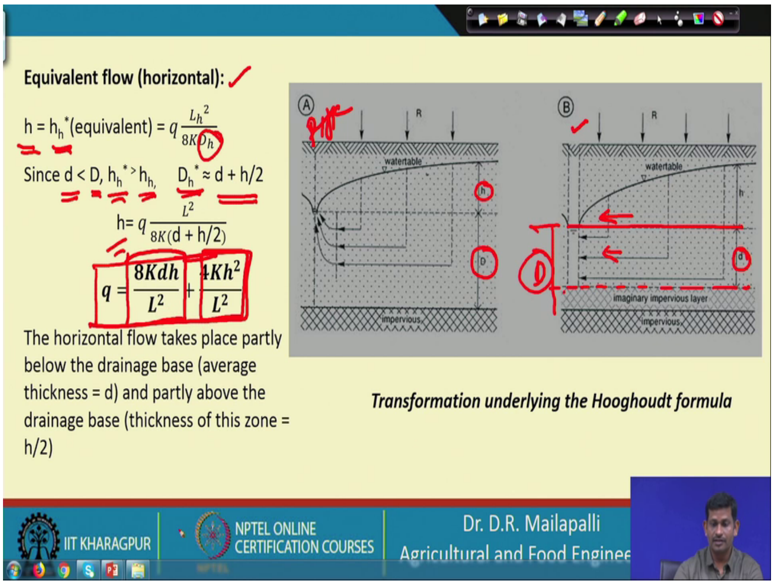

So, here so, equivalent flow; so, basically the horizontal flow. So, h is equal to which is horizontal equivalent q is equal to l h square by 8 K into dh star dh star is equivalent or depth.

So, since d the small d is less than capital D ok, the small d is less than, so this is open ditch and this sorry this is the pipe drain and you are converting that into open ditch system. This is open ditch system. If you see this initially this is impervious surface and which is the drainage installed at d distance from impervious surface and then h is the height of the water table from the drain base.

So, here open ditch system. So, this is imaginary impervious layer imaginary impervious layer and this is the capital D. Now small d which is less than you know the capital D. So, since d is small the less than cap small less than capital D h h is greater than h h dash is greater than h h ok. So, you know why because if you see the equation. So, when d is getting smaller h is going to bigger.

So, then dh star will be equal to d plus h by 2. So, this is another assumption, so d plus h by 2, so h half of the h will be the original or capital D. So, putting the value small h is equal to q into l square right q into l square divided by 8 K in to substitute d star h here right. So, then finally, you will get q is equal to 8 K d h by l square plus a 4 K h square by l square ok.

So, here if you observe clearly the horizontal flow takes place partly below the drain base, so here h square. So, this is above the drain base and this is below the drain base. So, the horizontal flow is taking place. So, not only you know the horizontal flow is taking place. So, above the drain base so and below the drain base. So, above the drain base as well as below the drain base, so, these two parts horizontal, I mean flow to the drain is taking place.

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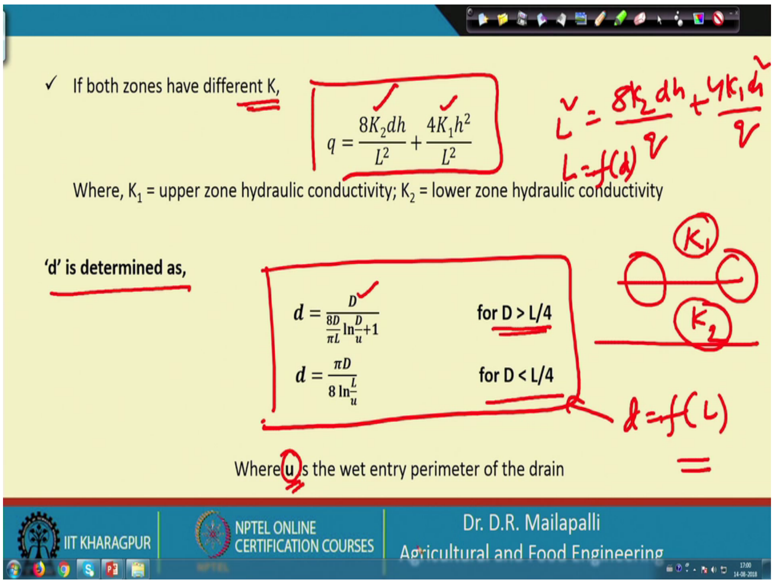

So, then if the both zones have different case suppose you have this is the drain base. So, below the soil you have K, let us say K 2 and above soil you have K 1. So, it has a 2 soil layers, then q is equal to 8 K 2 d h by L square plus 4 K 1 h square by L square. So, where K 1 K 2 or the hydraulic conductivities of the bottom layer and top layers ok.

So, d whereas, small d is given or estimated as small d is equal to capital D by 8 capital D pi l ln of d by u plus 1 when d greater than L by 4 and for d less than L by 4 you get small d is equal to pi d by 8 l n by L by u where u is the wet entry perimeter wet entry perimeter of the drain ok.

We are going to see how to calculate wet entry perimeter so; that means, so with equation and with these condition you can estimate the one value, but remember here if you see so here this equation, so the same equation can be written like L square which is equal to 8 K 2 dh by q plus 4 K 1 h square by q ok. So, here L is a function of d ok, L is a function of d, but here d is the function of again l ok.

So, if you see in this equation our d is a function of l. So, that is why this is an implicit equation. So, we will be we will be calculating this is implicit equation, we have to use trial and error method for calculating the drain spacing here.

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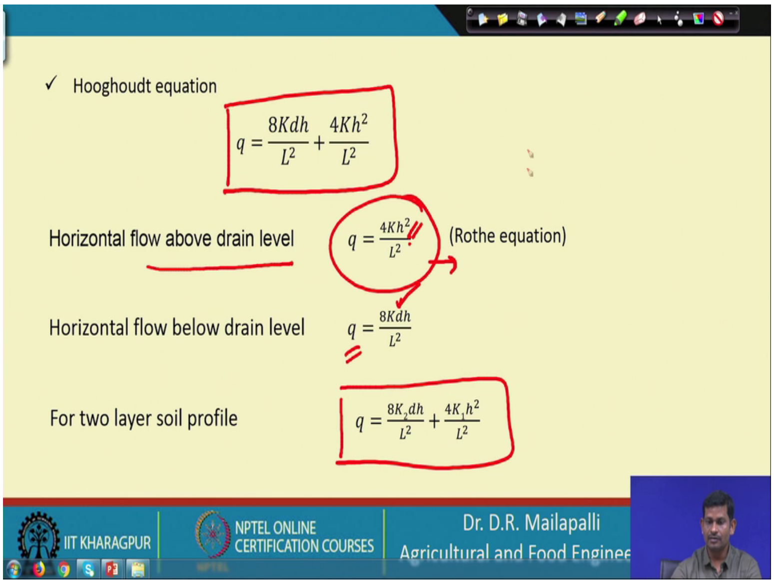

So, in the Hooghoudt equation, so this the, previously I explained you can turn this equation into q is equal 8 K d h into, if it suppose both layers have the same q K then this is the equation horizontal flow above the drain level. So, this is because it does not contain any d term which is supposed to be the depth below the drain base. So, this is this represents the flow above or horizontal flow above the drain. So, since it is contains d, so this is the flow which is below the drain. So, this again combines both horizontal flows at above and below drain base.

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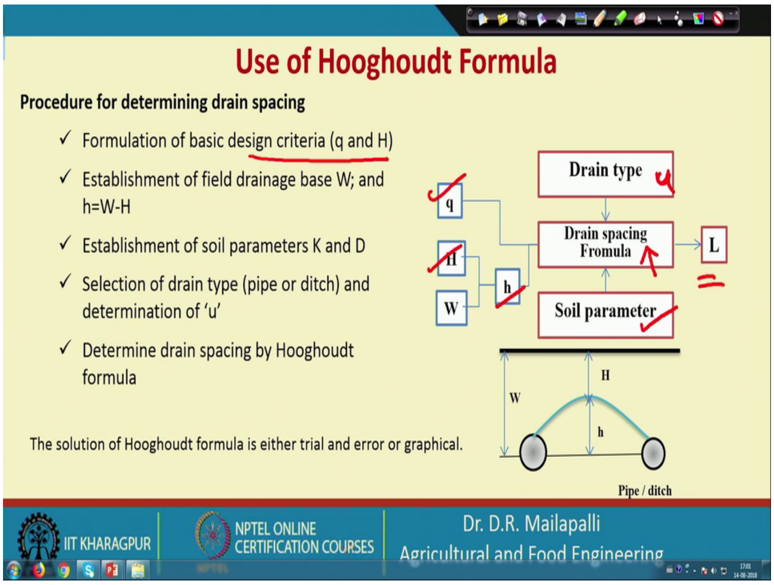

So, using Hooghoudt formula the process for determining drain base, so, already explained the first thing is formulation basic design criteria q and H right and then you can find out small h and small parameters like K and d and select and also for pipe you get u drain type based on the pipe and envelope you get this u and determine [vocalised-noise] you use Hooghoudt equation and find out L value.

So, the solution of Hooghoudt formula is either trial and error or graphical solution. We are going to see that how the trial and error and graphical solution can be done.

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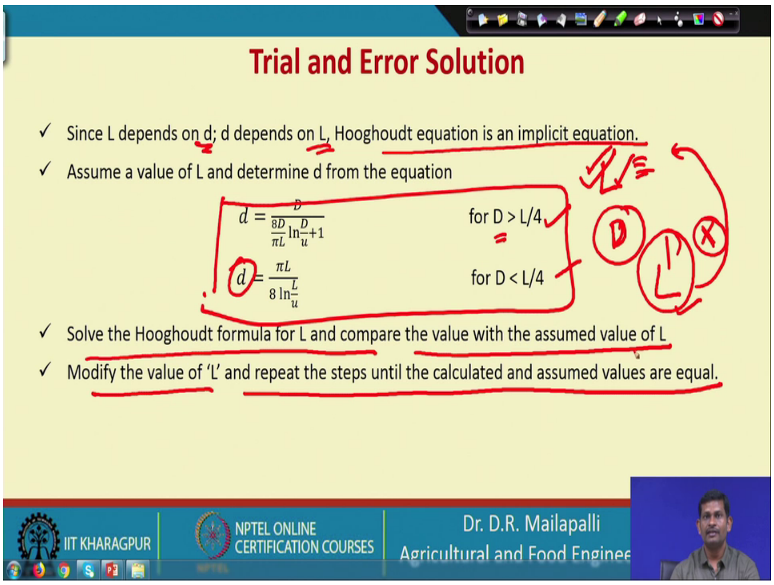

Here there trial and error equation since L depends on small d and d depends on capital L, the Hooghoudt equation is implicit equation and if you see this. So, this is the way for first we have to assume some initial guess L right. So, knowing the [laughter], find out capital D. So, and for the particular knowing the L and a particular drain space like capital D right and you will be deciding you know which formula needs to be used find out small d. So, once you know the small, d go back to the Hooghoudt equation and you can find out new L that is L dash and you can compare this l dash with the previous L if these two ones are closer. So, then your spacing is correct and all other parameters are very good guess.

So, so he has solved the Hooghoudt formula L compare the value with the assumed L and modify the value of L and repeat the steps until the calculated and assumed values are equal. Suppose if these are not equal right, if these are not equal and you have you have to you are going to change this initial guess L ok. This initial guess L and then repeat the steps and find out new L dash right and again compare the previous one and the calculated one. So, these steps need to be repeated until these two ones are closer or almost equal.

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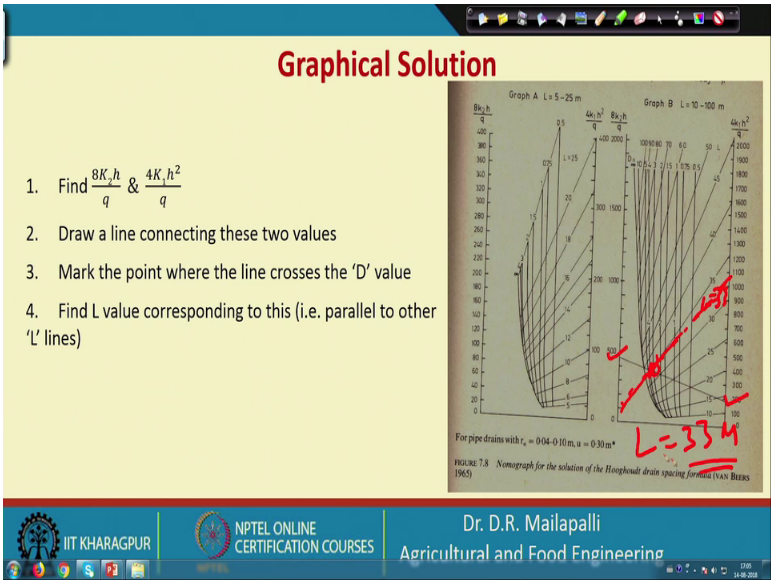

So, there is a graphical solution also available. So, since the Hooghoudt equation contains 2 terms. So, that is eight K 2 h by q and 4 K h square by q. So, in the 2 graphs are available based on the length; so, graph a for l equal to 5 to 25 meter and graph b for l equal to 10 to 100 meter. So, based on you know the assumed length, so you can go ahead with these 2 graphs. So, here y 1 axis contains 8 K 2 h by q and y 2 axis contains four K 1 h square by q similarly the other graph the same things ok.

So, so first calculate 8 K 2 h by q for example, here and similarly calculate other term and combine these 2 things and for a particular d. So, these d values are given right for particular d. So, identify knowing the d value right you can find out the corresponding you know or interpreted.

So, for example, this is the value 8 K 2 h by 2 l 4 k L h square by q you calculated and you located 2 points here and let us say d is equal to for d is equal to 3 this is the 3 ok. So, the corresponding L value you need to calculate I mean this is the L value. So, now, L is equal to some 33 or something like that ok.

So, now L is equal to 33 meters. So, this graphical solution is here right compared to the previous you know calculated. So, I mean solution. So, in this lecture, we observed the design criteria design principles and what are the steps involved in designing subsurface drainage system then the Hooghoudt assumptions and the Hooghoudt formula.

So, since the Hooghoudt assumption for making the horizontal flow; so, in the mainly the Hooghoudt basically assumed the tile drainage system to be a open ditch system by taking the tile drain to the impervious surface impervious surface and the and finding out the equivalent depth. So, he has given the formulas for calculating equivalent depth d value, based on the length and drain space drain depth ok. Based on these two things, so and Hooghoudt formula and these two conditions will be helpful in finding out the drain spacing by following either trial and error method or use a graphical solution yeah.

Thank you so much.