Soil and Water Conservation Engineering

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Lecture – 13
Problems on Contour Bunds

Hello friends. Welcome to NPTEL online certification course on Soil and Water Conservation Engineering. I am Rajendra Singh, Professor in agricultural and food engineering department of IIT Kharagpur. We are in week number 3, this is lecture 13. And today we will deal with Problems on Contour Bunds. Just to give you an idea about the course content that we are covering in this week.

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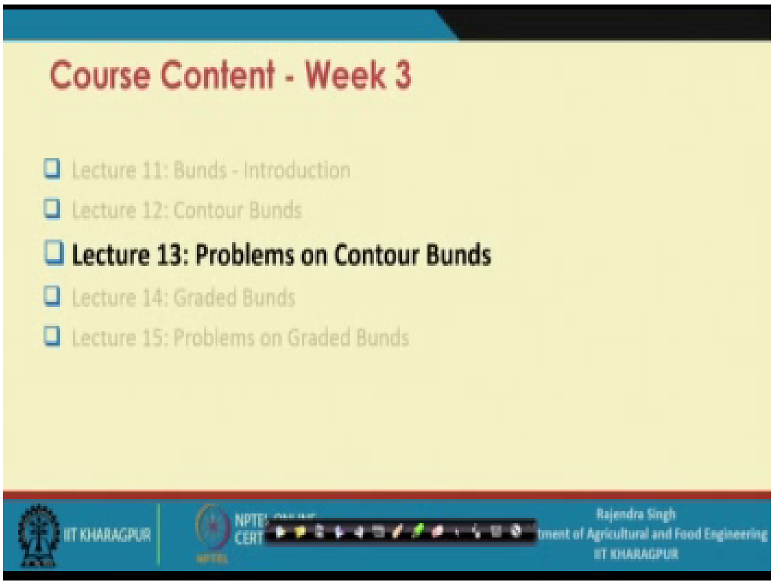

We started this week lecture 11 introducing bunds. Then the last lecture that is lecture 12 we went through various parameters the concepts of designing contour bunds. And today's lecture, we will apply some of those principles to see how to solve problems dealing with the design of contour bunds.

A lecture 14 we will go through graded bunds, another kind of bunds, which we have read already. And in lecture 15 we will go and solve problems on graded bunds. So, let us begin today's lecture with problem number 1.

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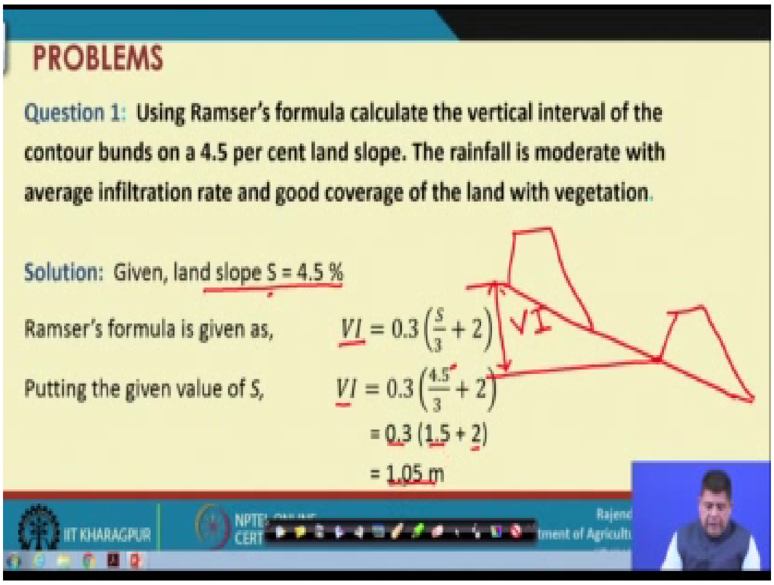

The first question is using Ramser's formula; calculate the vertical interval of the contour bunds on a 4.5 percent land slope. The rainfall is moderate with average infiltration rate and good coverage of the land with vegetation.

So, it is straightforward problem, where we have to use Ramser formula for finding out the vertical interval for contour bunds for a land, condition where the slope is 4.5 percent.

Now, we have been given in this problem. Land slope which is generally designated by S 4.5 percent and we know Ramser formula which is straightforward is VI, that is vertical interval VI is equal to 0.3 S by 3 plus 2. And S is already known to us. It is 4.5 percent. So, just we put the value of S in this formula, we get VI equals 2 0.3 4.5 divided by 3 plus 2 or 0.3 solving this we get 1.5 plus 2 and overall we get VI equals to 1.05 meters.

You remember what is vertical intervals? Should I repeat that? I think let us repeat that vertical interval is, we said that we construct a series of contour bunds. And if we take 2 consecutive bunds and then corresponding point between these 2 bunds let us say upstream toe we select. And if we find out the vertical distance between these 2 points, that is referred to as vertical interval. So, this is the vertical interval we are talking about. So, for this given condition we got it 1.05 meters in this problem.

But there is another catch. Because in Ramser formula only S is considered; that is, land slope is considered. So, that means, we need to do some more modifications into this as per the given condition.

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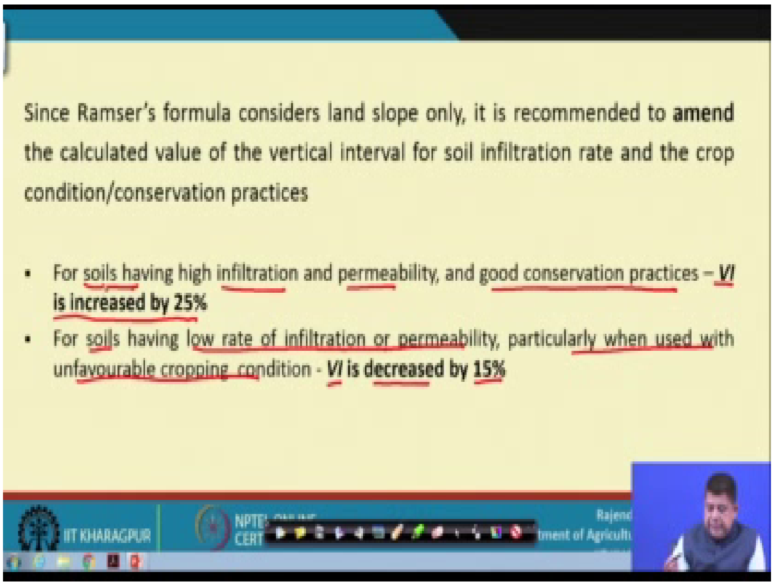

And the condition says that since Ramser formula considers land slope only. It is recommended to amend that is the value; we have calculated 1.05 that needs to be amended calculated value of vertical interval for soil infiltration rate and the crop cover condition or conservation practices.

So, by considering the just the land slope we have calculated the value of vertical interval, which is 1.05 meters, but then we have to also take into account the soil infiltration rate and crop condition or conservation practices which is also given in the problem.

So, for that we know there are 2 conditions; that is, for soils having high infiltration and permeability. And good conservation practice it is recommended that VI is increased by 25 percent, that is the calculated VI is increased by 25 percent.

The other condition says that for soils having low rate of infiltration or permeability, particularly when used with unfavourable cropping condition, then VI is decreased by 15 percent. So, by using Ramser formula, first we have to calculate the vertical interval, and then apply this knowledge about the soil condition and crop or conservation practice condition and accordingly we have to increase or decrease the increase or decrease the calculated vertical interval.

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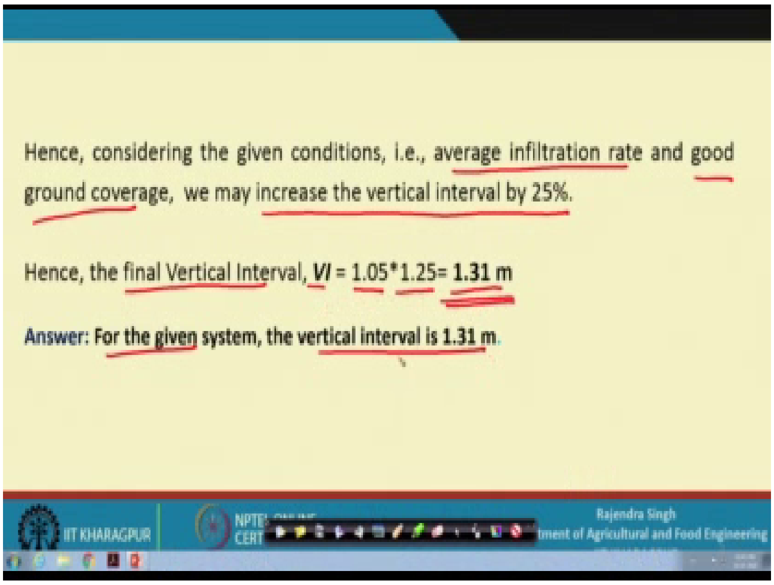

Now, in the problem we have been given that we have average infiltration rate and good ground coverage. That simply means what we belong to first condition. And we may increase the vertical interval by 25 percent. So, the final vertical interval will be vertical interval which is calculated 1.05 times 1.25, because we are enhancing by 25 percent. So, the final vertical interval will be 1.31 meters.

So, for the given system, the vertical interval is 1.31 meters that is the final answer using Ramsers formula. So, this is how we have to straight forward apply in this particular problem, we saw that we had to straight forward apply Ramsers formula. Where land slope was given.

So, by putting the land slope into our equation Ramsers formula we found out vertical interval. But we also know that Ramser formula only considers the land slope, and it is recommended that based on the soil characteristics and the cover characteristics or the conservation practice characteristics. We need to amend the value either to increase or decrease. And accordingly we took our decision and for the given conditions in this problem we have to increase the vertical interval by 25 percent. And that is how we got the final value of 1.31 meters.

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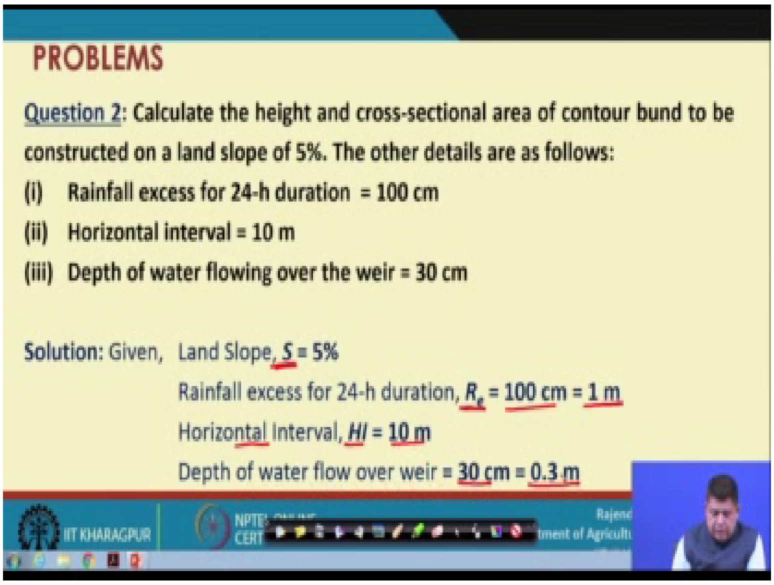

Let us take another problem which says that calculate the height and cross sectional area of contour bund to be constructed on a land slope of 5 percent. The other details are as follows. Rainfall excess for 24-hour duration is 100 centimetres. Horizontal interval is 10 meters, and depth of water flowing over the weir is 30 centimetres. So, we have been given land slope. We have been given rainfall value for which we need to design the bund. The horizontal interval is already given and depth of water flowing over the weir is also given. So, we have to calculate the height and cross sectional area of the bund.

So, coming to solution first let us see what are the data available the data given are land slope along with the symbols which we use. Normally the symbol will the land slope symbol we use is capital S. Rainfall excess for 24-hour duration we have use the symbol R suffix e, R e and that is given as 100 centimetres in SI units we are converting, and we are writing as 1 meter. The horizontal interval which is which is designated in HI is given in 10 meters. And depth of water flow over weir is 30 centimetres or 0.3 meter. So, these are the values which are already given to S.

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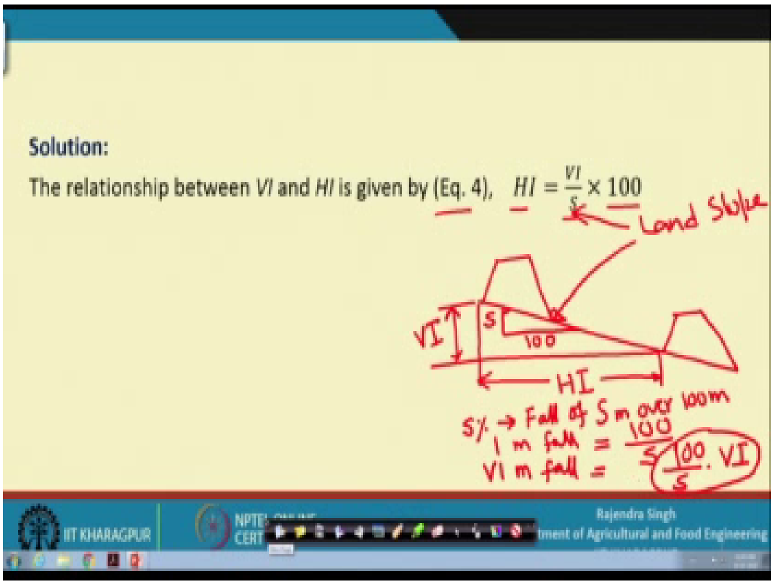

Now, we know that the relationship between VI and HI is given by in the equation number being referred here is the equation number that was used in previous lecture. That is lecture number 12 basically and that says that HI equals to VI by S into 100 and in fact, you do not even need to remember the formulae. If you just understand the fundamentals understand the basics, what is HI? What VI? What is slope? Then basically you do not even need to remember the formula. For example, I will show you this.

So, these are our 2 neighbouring bunds. And we said that the horizontal interval between these 2 is referred to as HI. And the vertical interval between these 2 any corresponding point, we can take is referred to as vertical interval VI. So, this is these are the 2 symbols VI and HI. And S here is land slope, S here is land slope; that is, this is basically the land slope is belongs to this land here, this S percent.

Now, when we say S percent means what? That is there is a S meter of fall over 100 meter. S percent slope means S percent means a fall of S meter over 100 meter horizontal distance. So, that is how S by 100 we are writing.

Now, 1 meter that simply means what? 1 meter fall will be equal to what? 100 by S. And what we are trying to find out? What is equivalent of VI meter of all that is vertical interval is nothing but the fall or difference in elevation which is in slope terms it is a fall of VI. So, VI meter fall will be equal to 100 S times VI. So, this is HI, and this is nothing but HI. So, here the same formula is written here HI equal to VI by S into 100.

So, I mean you do not need to remember the formula if you just understand the concepts you can derive the equations. Anytime you require if you remember well and good, but you do not have to put yourself under pressure for memorizing the formula because you can always derive the formula from first principles most of these.

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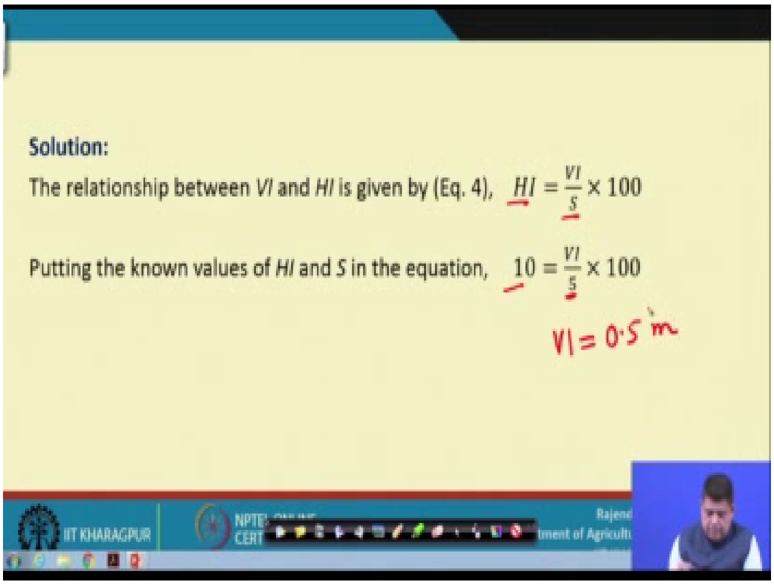

So, once we once we know that so now, we know that HI was given as 10 meters so, by putting the value here in this equation 10 equals to VI by 5, that is S is given as 5 S is given as 5. And HI is given as 10 by putting these values in this equation we can calculate the value of VI, which will be obviously, you can calculate yourself it will be 50 by 100 or 0.5 meters. So, VI equals to 0.5 meters.

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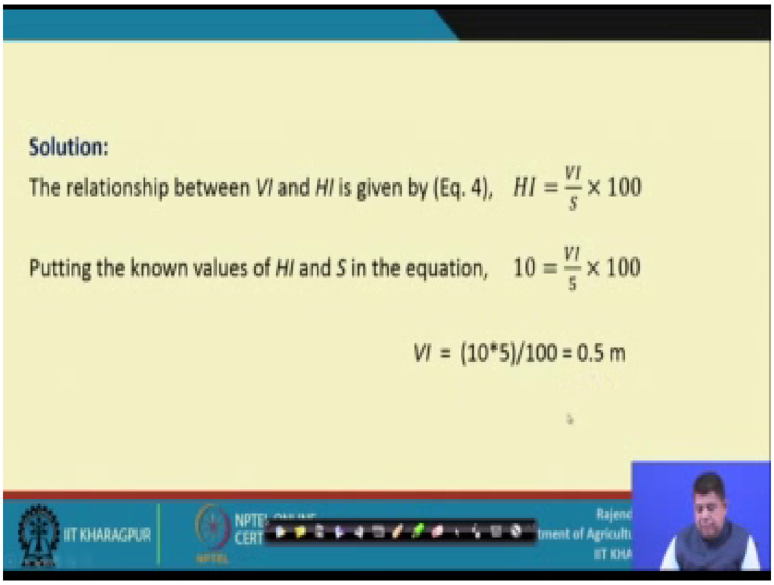

So, that is why. So, that simply means first thing we have calculated is vertical interval which is 0.5 meters for the given data.

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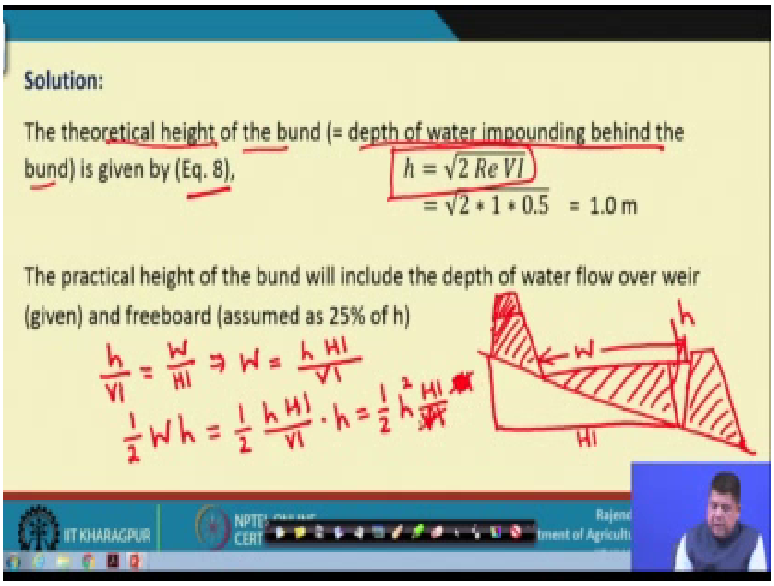

Now, the next important thing which we have to do is that we have to calculate the theoretical height, because we have to calculate the height in cross section. The theoretical height of the bund which is also equal to depth of water impounding behind the bund, which is given by equation number 8 which we derived in the previous class.

And that is given by h equals to which is the theoretical height of bund under square root of 2 times R e times vertical interval.

Now, this again is I mentioned that you would actually do not need to remember any formula you can always derive this formula also. So, let us try to derive this formula.

So, for this formula again I have to draw the definition sketch. So, these are the 2 neighbouring bunds. This we can little bit increase the height also just to. So, that they look similar. So, this is one bund, and this is the neighbouring bund. And this is what we are calling as h that is the h we are calculating. And let us say that the width of this impounded water is w. So, this is h, this is w.

Similarly, we can also say that this is vertical interval. And this is horizontal interval that we have we know already just now we also derived. So now here we applied the principle of equivalent triangles so that means, h by VI is equal to w by HI. That is the horizontal a vertical of this. And base of this these 2 triangles. Or from here w is equal to h times HI by VI.

And then the other side is that this is nothing but the area of impounded water. Here for simplicity we are neglecting this. So, this is nothing but area of the triangle this triangle. And area of this triangle is half w into h or we can put the values of w which we calculated half h HI by VI times h, or half h square HI by VI. So, this is the volume of water or area of the water that is collected this is one side of this story.

The other side is; so, half h square HI VI, VI gone. So, it is basically it is nothing but half h square. No half h square HI v this VI is not there. So, this is HI VI is there so, half h square HI VI. So now once again on the other side what is given us the volume of water which is available.

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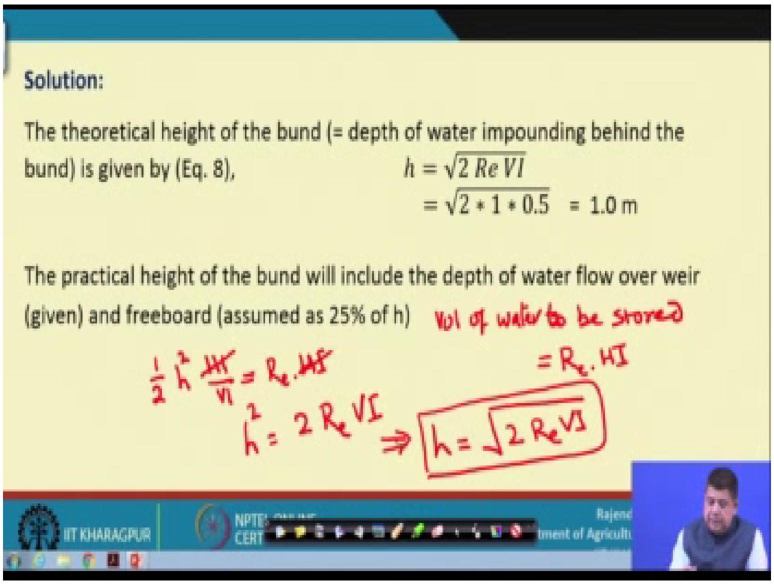

Volume of water to be stored is nothing, but rainfall which is here R e times HI because that is the total area. And into one which is perpendicular to the board so, R e equal to HI. So now, we have to equate volume of water to be stored and volume of water that is stored. Half h square HI by VI equals to R e times HI. So now, HI HI gets cancelled here. And h square will be 2 times R e VI or this leads to h equals to square root of 2 R e VI.

So, you do not have to remember the formula. You can derive from the first principles if you know if you understand the concept. So, this is how h is we obtain that the height of the impounding or the height of the bund vertical height of the bund will be h equal to that is h equals to under root 2 R e VI. And because the value of R e is known to us, and VI is known to us that is R is 1 meter and VI half meter we calculated. So, h value comes out to be 1 meter.

Now, practical height of this is the theoretical height. So, practical height of bund we every time we know will include the depth of water flow over the weir which is given as 0.3 meters. And of course, freeboard which we assumed typically assumed as 25 percent of h.

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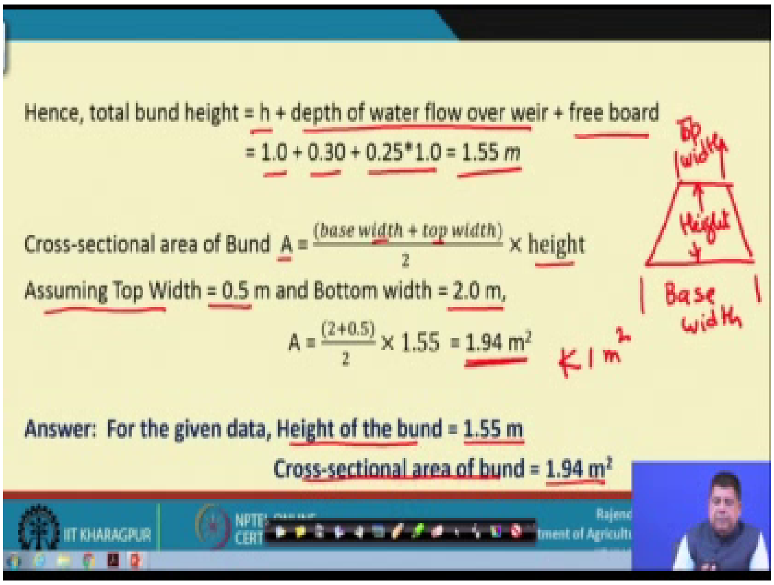

So, using that the total height of the bund will be h plus depth of water flow over weir plus freeboard that is 1 meter plus 0.3 plus 0.25 into 1 that is 25 percent of 1 meter and total it comes out be 1.55 meters. So, that is what it is the total height bund height.

Now, cross sectional area this is nothing but a trapezoidal cross section we are talking about all the time, that for bund we are using trapezoidal cross section. So, this is your base width. This is top width, and this is nothing but height. So, we know that the area of cross section of a trapezoid is half times sum of top width and base width into height. So, this is same thing, which being used even here. Area equals to half base width plus top width multiplied by height.

And now here what we are doing is that we are assuming top width we remember in the theoretical part we said that for Indian condition, it is recommended that top width could be 0.5 meters and bottom width could be taken as 2 meters that is a theoretical value recommended. And as a thumb rule and let us say that we are assuming that our base width and top width is remains the same.

So, then putting the value of top width and based width as 2 and 0.5 meters in this problem and height we have already calculated 1.55 meters the total cross sectional area will comes out will be 1.94 square meter. You remember, another thumb rule was there that in no case when these values were given recommended. It also said that no case the cross sectional area of the bund should be less than, should not be less than 1 square meter. So, in this case it is 1.94 square meter. So, that condition is being met.

So, that means, now we have solved the required answers that is we have obtained the required answer that is height of the bund we have calculated it is 1.55 meters. And cross sectional area of bund we have calculated is 1.94 square meter. So, this basically this problem demonstrates that formulae are to be used, but you need not remember the formulae.

You can always obtain them from the first principles provided you understand the concepts. So, that eases the pressure on you otherwise, you have to remember the formula and if you forget anything then; obviously, the answer will be completely wrong. So, you please try to understand how to derive the formula while solving the problems.

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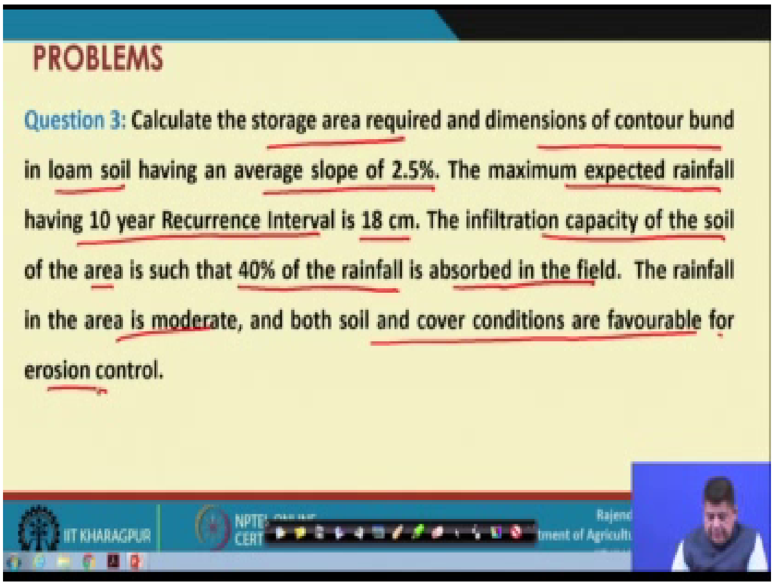

Now, we take up another problem that is third problem, which says that calculate the storage area required and dimensions of contour bund in loam soil having average slope of 2.5 percent.

The maximum expected rainfall having 10 year recurrence interval is 18 centimeters. The infiltration capacity of the soil of the area is such that 40 percent of rainfall is absorbed in the field. The rainfall in the area is moderate in both soil and cover conditions are favourable for erosion control.

So, in the previous case the previous problem we saw we were straightaway given the rainfall. But here rainfall is given, but at the same time infiltration capacity is given. So, that means, we have to find out how much runoff really we have to handle in this particular problem.

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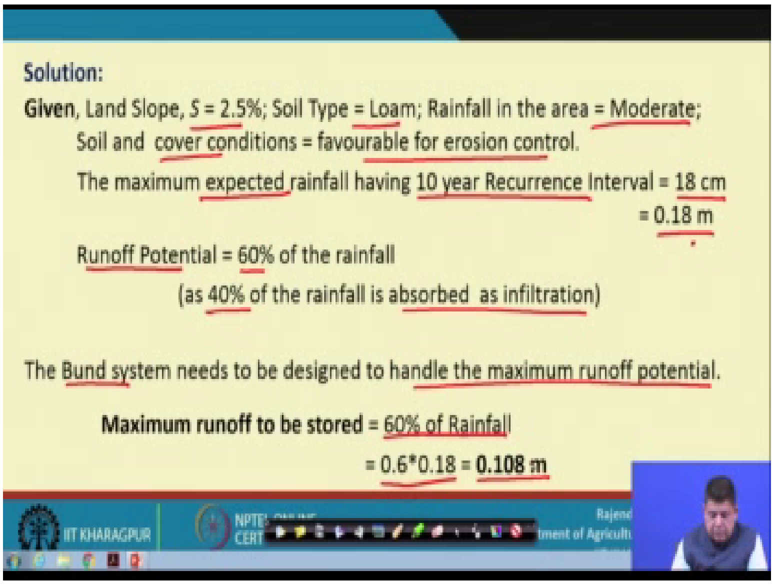

So, let us see that what are the data which are available and what we need to calculate. So, here the land slope is given as 2.5 percent. Soil type is loam, rainfall is moderate in the area, soil and cover conditions are favourable for erosion control. And maximum expected rainfall having 10 years recurrence interval is 18 centimetres or 0.18 meters.

And also it is the given in the problem that 40 percent of the rainfall is absorbed infiltration, that simply means that 60 percent of rain rainfall gets converted into runoff which is which normally we term as runoff potential. So, runoff potentially is 60 percent of the rainfall.

So, and the bund system we need to design to handle the maximum runoff potential, that is we want to handle this particular runoff that should be absorbed within the bund. So, maximum runoff to store will be 60 percent of rainfall or 0.6 of 0.18 that is the rainfall value. So, 0.108 meters that is the maximum runoff depth we have to conserve, or we have to handle the bund should be able to handle.

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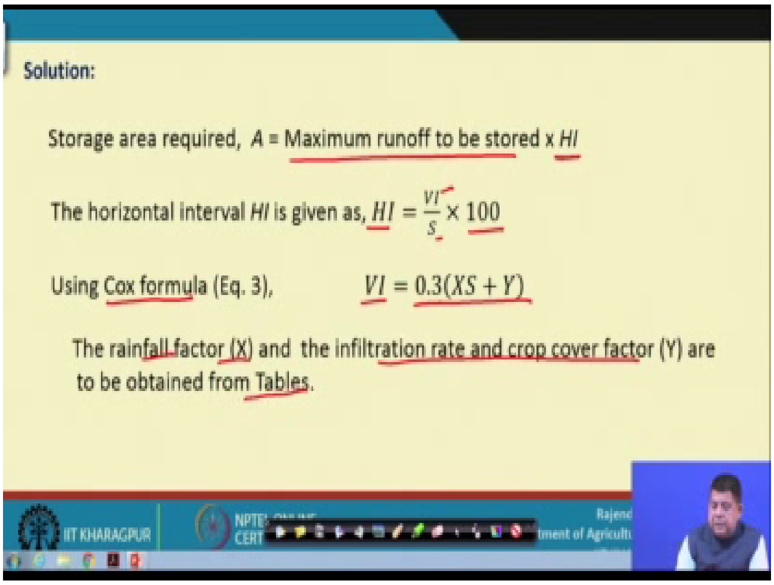

Now, the storage area required will be; obviously, in the maximum runoff to be stored times, horizontal interval because that is the catchment area we always say, that whatever rainfall occurs within 2 bunds we want to conserve within in between those 2 bunds. So, the total storage area, or the total storage area required will be to handle the maximum runoff to be stored times HI. And the HI is a we know just now we derived this equation HI is equal to VI by S into 100. In this case, neither HI or VI are given.

So, we have to use one of the formulas, we saw that there is a general relationship there are Ramser formula, and there is a cox formula and I said the cox formula is most commonly used.

So, let us say that we use cox formula for finding out vertical interval. And the cox formula is given as 0.3 x S plus y; where x is the rainfall factor. And y is the infiltration rate and cover crop factor and these have to be obtained from standard tables. So, let us see that what are the values given, in tables for given conditions.

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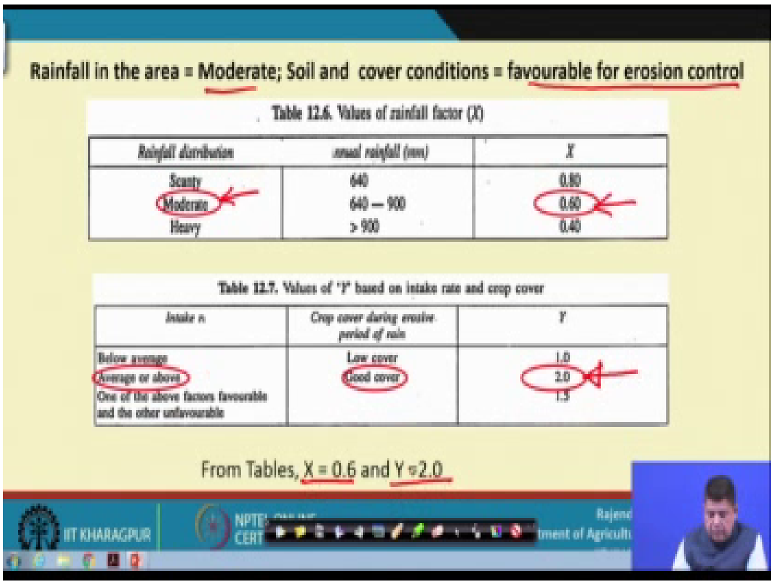

So, for our case rainfall is moderate. So, rainfall for rainfall we have to refer the upper table, and when it is moderate the value of x is 0.6. So, for our case value of x is 0.6.

Similarly, soil and cover conditions we are given that if they are favourable for erosion control and when they are favourable for erosion control. Then we have to use the maximum value of 2. And so, y value is equal to 2. So, x and y comes out to be 2 0.6 and 2 in our case.

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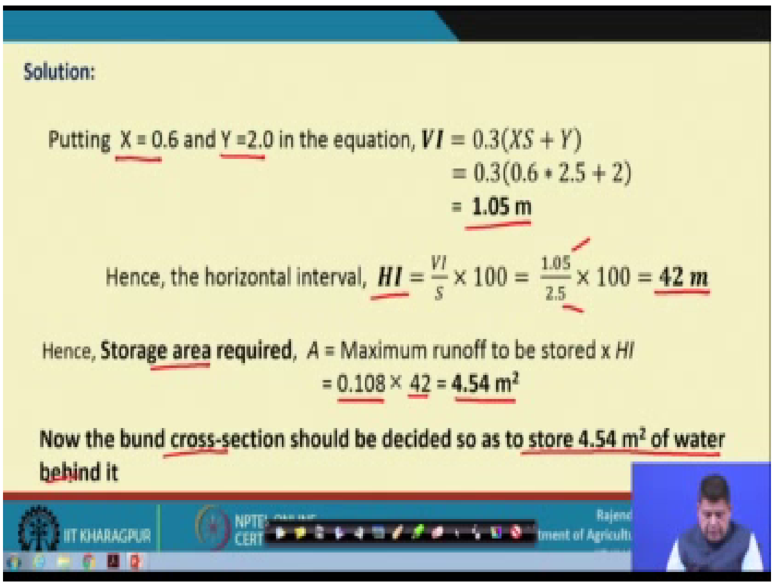

So now coming back to Ramser formula and putting x equals to 0.6 and y equals to 2 in the equation, we get vertical interval equals to 1.05 meters. And thus the horizontal interval which is VI by S into 100 where S is the land slope, by putting the values of VI and S given values one VI is already calculated S is given as 2.5. So, the value which we get is 42 meters

So, a storage area required is point 0.108 times 42 or 4.54 square meters. So, the bund cross section should be decided. So, as to store 4.5 4 square meter of water behind it so, this is how we got what is the total storage volume that is required.

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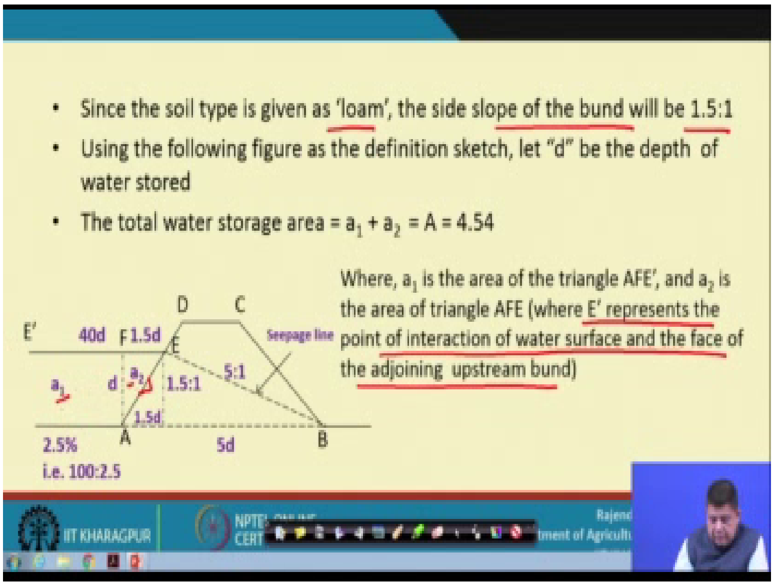

Now, for that let us say that was our soil type is given as loam. So, the side slope of bund will be 1.5 is to 1. So, this is 1.5 is to one this slope we are saying is 1.5 is to 1. And definition sketch let us say that we are saying that this is d depth of water. The total storage area will have here 2 components; that is, a 1 and a 2, that this is the, what we drew earlier also we drew this form this area.

So, there are 2 areas a 1 and a 2, that is where a 2 is the area of triangle AFE and a 1 is the area of triangle AFE dash where E D dash represents the point of intersection of water surface and the face of the adjoining upstream bund. So, if you go further this water surface will meet the face of that dam. So, that is how these 2 area. So, basically this is the storage area some of the say a 1 and a 2 is the storage area that is available with us.

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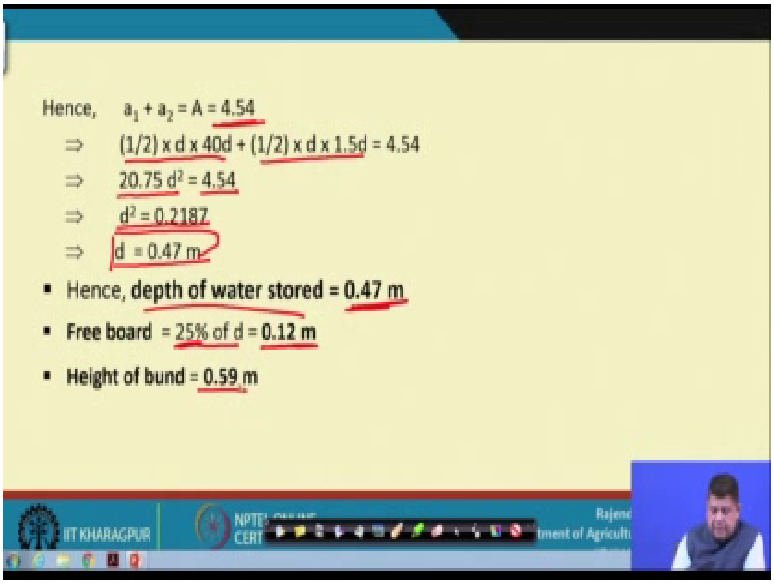

So, here a 1 plus a 2 has to be equal to 4.5 4. And a 1 a 1 and a 2 from these are nothing but simple triangles. So, basically in terms of d we can write half times d into 40 d and half times d into 1.5 d. And then by simplification it comes out to be 20.75 d square equal to 4.54 or d square equals to 0.2147 or d comes out to be 0.47.

So, the depth of water that is to be stored in order. So, that we have a area of 4.5 square meter is 0.47 meters. And, but every time we use a free board and 25 percent. So, if we 25 percent of 0.47 is roughly point one 2 meters. So, height of dam is sum of 0.47 plus 0.12 that is 0.59 meters that is the total height.

And for base width we already saw that we use the seepage line concept.

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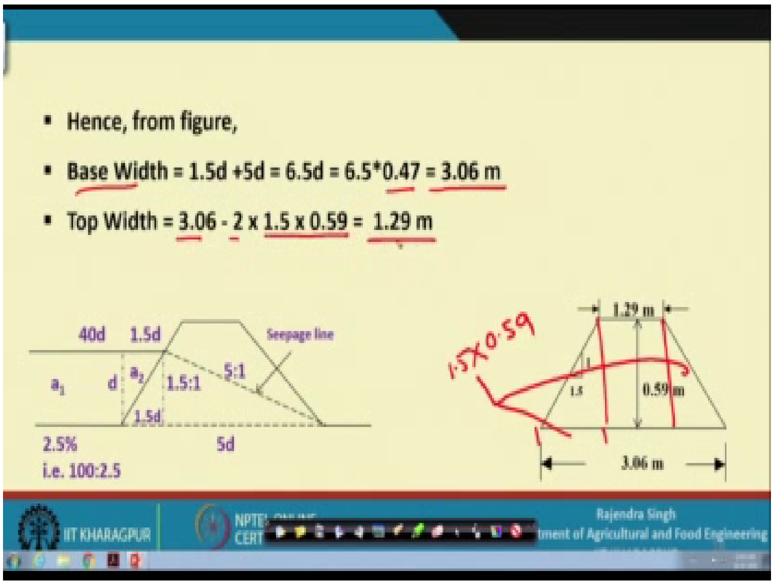

That is for stability, seepage line must pass through the base of the dam. And seepage line we defined that is the top fretic line is referred to as seepage line. And the slope is 5.5 is to 1. So obviously, this is the total base width which has 2 components this which is equal to 1.5 d, and this which is equal to 5 d that simply means that the total base width is 6.5 d and 6.5 d and because we know the value of d already 0.47 meters; that means, base width will be 3.06 meters.

And the top width will be; obviously, this is what we have to deduct from the base width. And this is nothing but a 1.5. So, this is this portion is 1.5 times the h which is 0.59 the total height. And same is true with this. So, this and this both are this and that is why from top width we deducting 2 times of 1.5 into 59. So, this comes out to be 1.29 meters. So, that is the top width.

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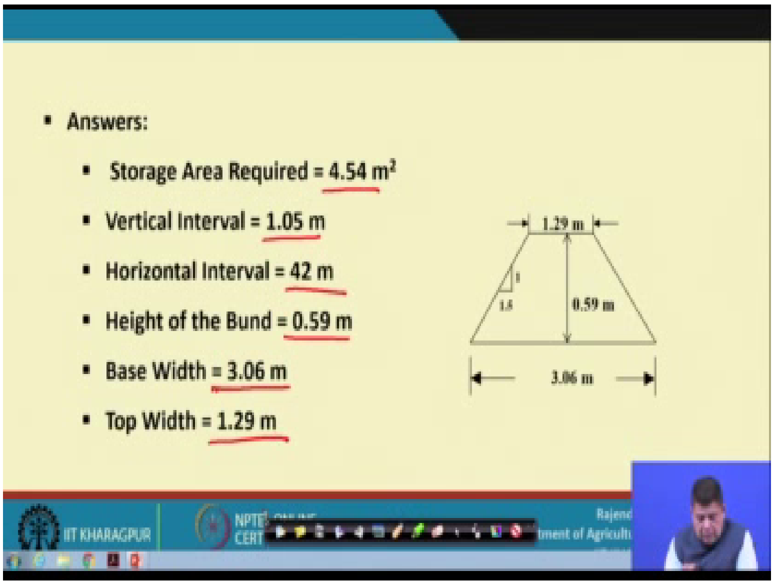

So, thus we can write that the total answer we can write that storage area required for 4.5154 meters. Vertical interval 1.05 meter, horizontal interval 42 meters, height of the bund 0.59 meters, base width 3.06 meters and top width of 1.29 meters. So, this is how we solve the problem.

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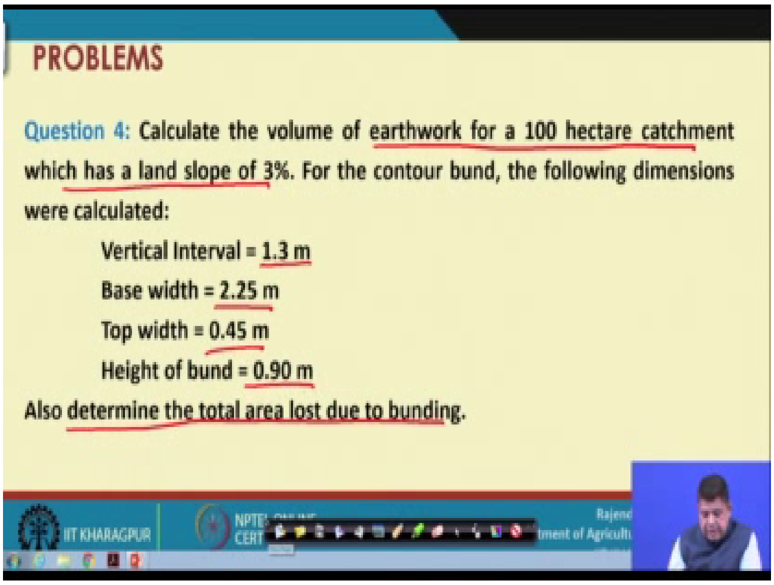

Now, let us take the last problem. That is a calculate the volume of earth work for a 100-hectare catchment which has a land slope of 3 percent. The following dimensions are given the vertical interval is given base width is given top width is given, height of the bund is given and we have to also determine the total area lost due to bunding. So, let us say how to handle this problem.

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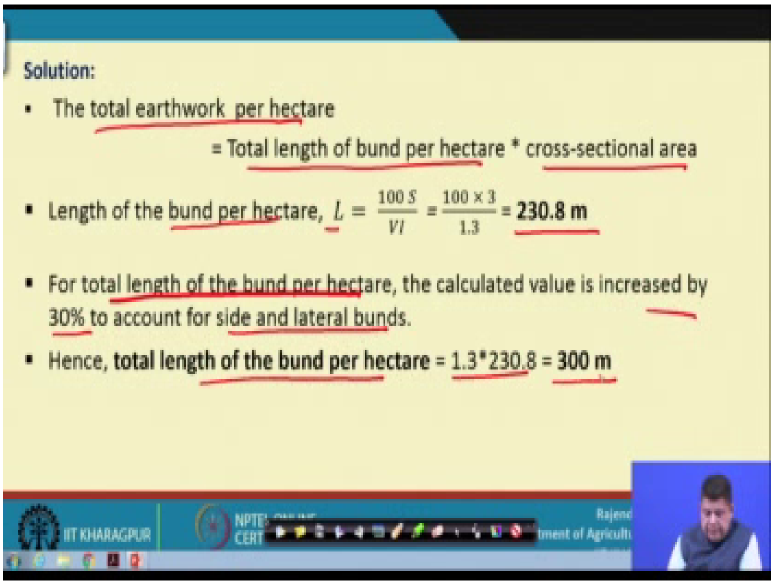

So, first thing we require to calculate the total earth work per hectare is the total length of bund per hectare times cross sectional area. Because that is the total earth work required. And length of bund per hectare is given by 100 S by VI or it comes out to be well putting the values of S and VI it comes out to be 238.5 meters

And the for total length of the bund per hectare, we also add 30 percent to account for side and lateral bunds. So, total length of bund will be 1.3 times or 238 or 300 meters.

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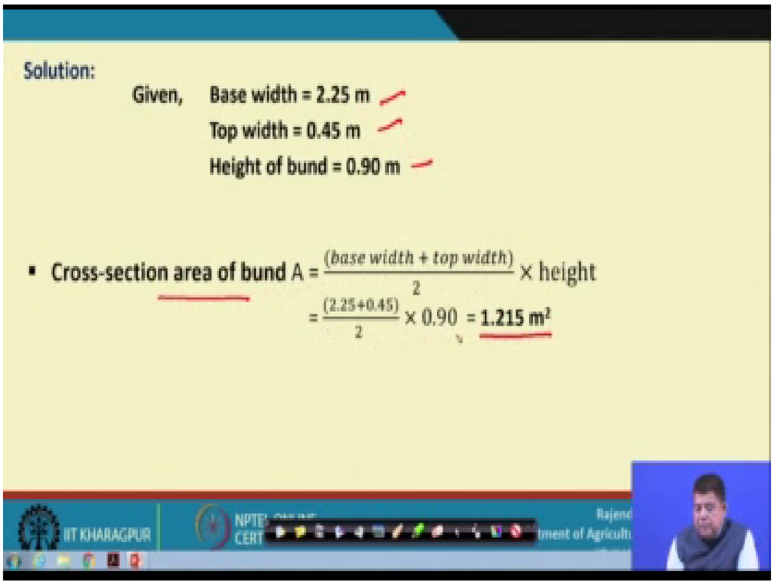

So now given the base width, top width and height of the bund the cross section area of bund can be easily calculated we know the, this is a trapezoidal section. So, the cross sectional area comes out to be 1.215 square meters and once cross sectional area is known.

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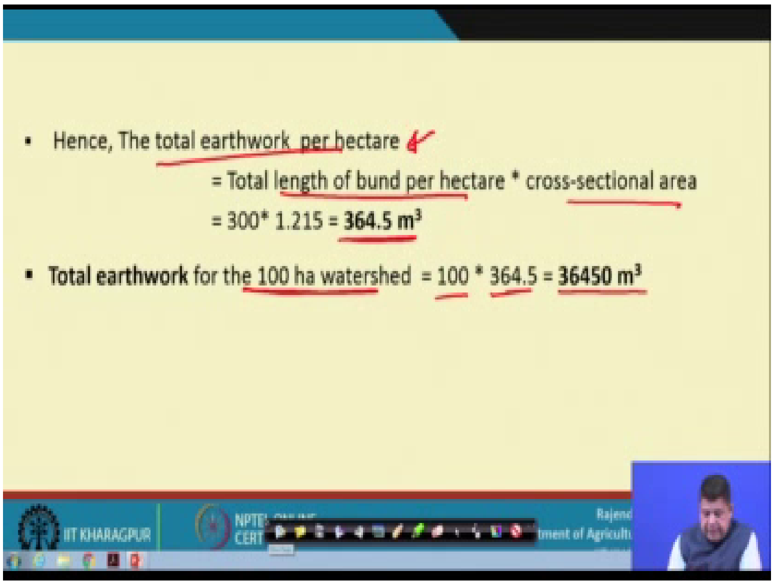

And the length of the bund is known, then the total earth work per hectare will be total length of the bund per hectare, times cross sectional area or it comes out to be 364.5 cubic meters and because the total area of the watershed is 100 hectares. So, the total earth work will be 100 times 364.5 or 36450 cubic meters. Because these calculations we are making is always for per hectare area.

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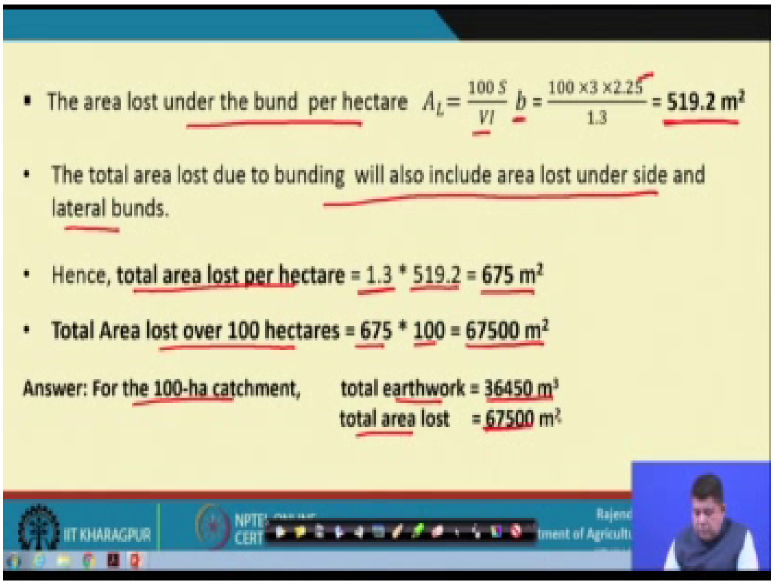

Similarly, we can also calculate the area lost. The area lost under the bund per hectare is given by 100 S by VI times b that is the base width. And base width is already given here. So, all the values are known if you put in this equation. A L comes out to be 519.2 square meters. And we, but we also need to consider the area lost due to side and lateral bunds. So, that is why we have to also add 30 percent here. So, total area lost per hectare is 1.3 times of 519.2 or 675 square meters and for 100 hectares. The total area lost will be 675 into 100 or 67500 square meters.

So, for the 100 year catchment the earthwork required is 36450 cubic meters. And total area lost is 67500 square meters. So, this is the answer which we get.

So, with this we have seen 4 different problems. First problem was direct application of Ramser formula, in equation in problem number 2 we were given the direct rainfall value, and we had to calculate the height and the cross section. In problem number 3 we were given runoff potential or re infiltration potential, and then we had to first calculate the runoff potential. In problem number 2 we assumed the top width and bottom width, but in problem number 3, we calculated for actual water that was to be stored. And in problem of 4, we saw how to calculate the area lost and the total earth work which is required to be done.

So, with this we have probably covered all gambles of problems or design that could come. But you have to of course, practice some more problems and we will put some problems into assignment as well.

Thank you very much.