Soil and Water Conservation Engineering
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Lecture – 33
Hydraulic Design Components

Welcome students to our third lecture on the design of different components of drop spillway. We have already discussed in a previous classes, what is the design discharge including the freeboard.

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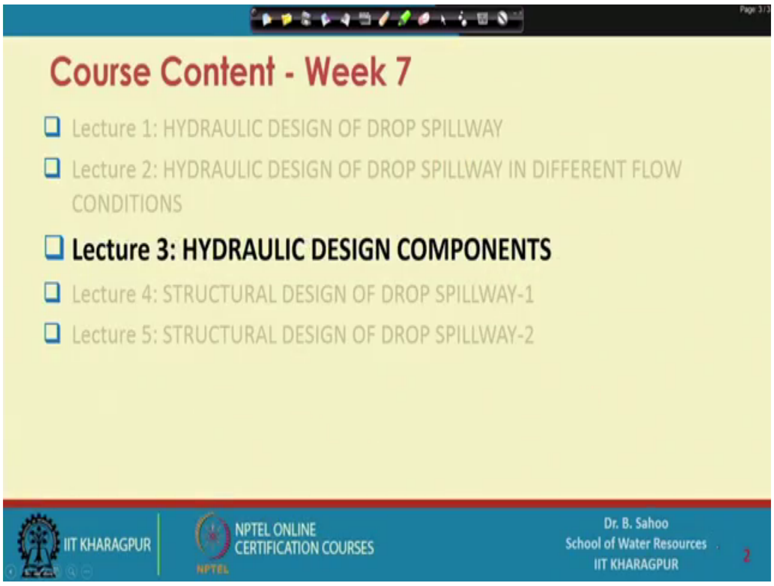

So, in this lecture we will be talking about, how to design the different hydraulic different components using the hydraulic principles.

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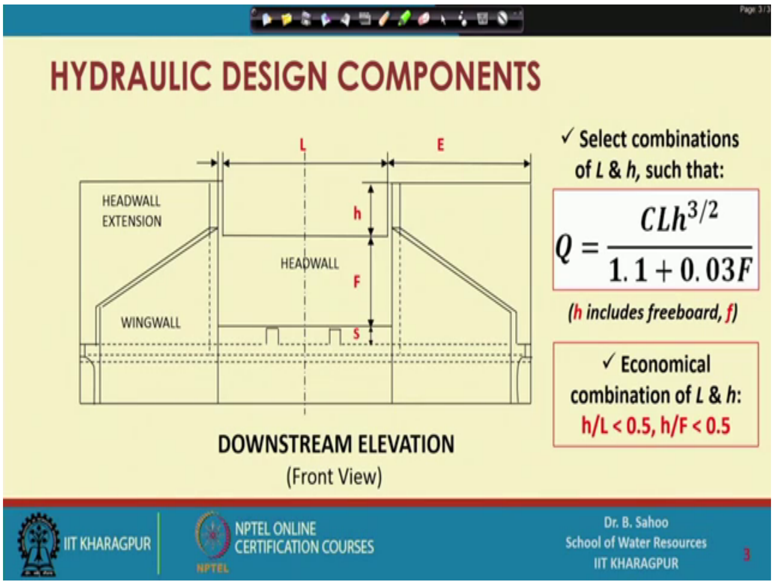

Basically to design the drop structure, 3 aspects are more important; first is to estimate what is the design discharge.

The design discharge is a function of L h and if we are considering a free board, then f also accounted form; you can see this equation Q equal to CLh to the power 3 by 2 divided by 1.1 plus 0.03 capital F. We are using this equation when the freeboard is considered that means, for freeboard we are providing an additional discharge of 0.1 plus 0.03F times Q. So, that is your excess discharge which you provided as the freeboard.

Then another thing you have to consider that for economical section small h divided by capital L and small h divided by capital F should be less than 0.5. If small h divided by capital F is greater than 0.5 then it will invite more scouring; for this generally we use small h divided by capital F is less than 0.5. So, I have to select a combination of L and small h such that these criteria are fulfilled.

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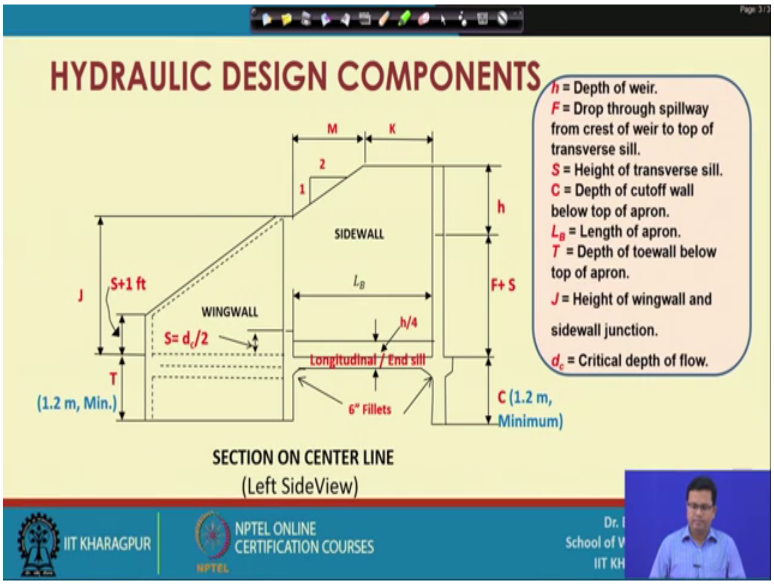

This figure shows the left side view of the drop spillway, the different components are listed in this slide, you can say that the value of T and C, the cut off wall and toe wall, the depth of cut off wall and toe wall is provided as it should be minimum should be 1.2 meter. This value provided generally to avoid any piping failure of the hydraulic structure. The longitudinal and end sill is given as small h divided by 4 and S that is your height of transverse sill is equal to d c by 2, d c is your critical flow depth.

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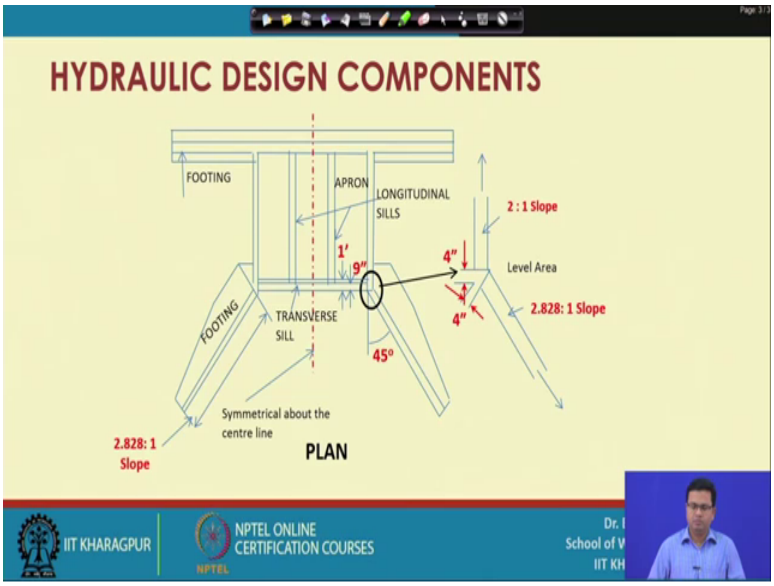

This figure shows the top view of the drop structure, you can see the wing walls are provided at 45 degree from the vertical and these are having a slope of 2.828 is to 1 and other dimensions are given in this figure.

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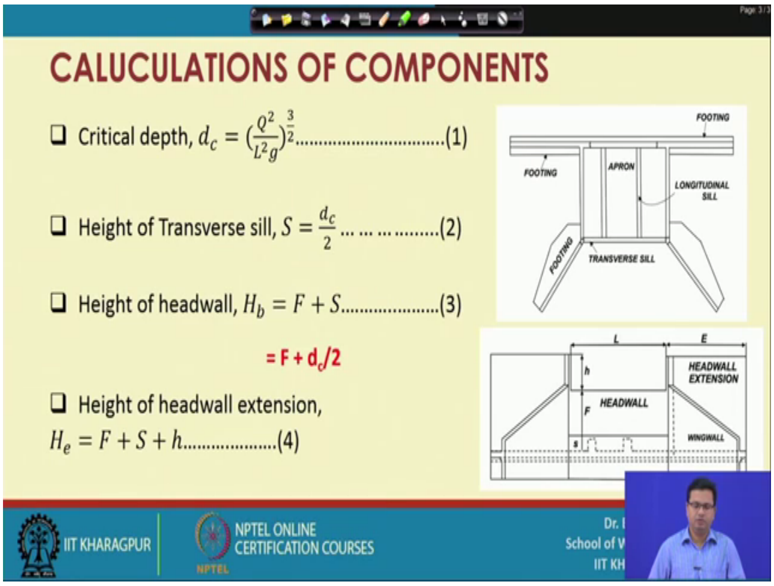

For estimating the different components of this drop spillway first you have to estimate the critical depth, because generally after the drop there is a responsibility of hydraulic jump and you have to estimate critical depth in this case there is in this case there is no submergence flow there is no tail water here.

So, d c equal to estimated as d c equal to Q square divided by L square g whole to the power 3 by 2; you know already this from this hydraulic principles. Then the height of transverse sill is estimated as half of this d c value, height of headwall H b is estimated as F plus S you can see from this figure, F plus d c divided by 2, height of head wall extension is equal to F plus S plus h that is given by equation number 4.

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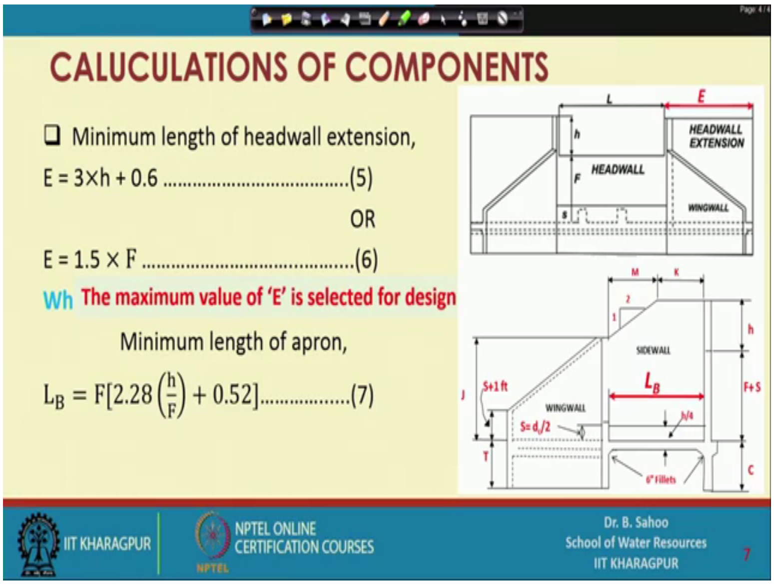

The minimum length of headwall extension is given by these 2 equations 5 and 6 which estimated as 3 into h plus 0.6 and 1.5 into F. Among these 2 values the maximum value is selected for designing of E which is nothing but the headwall extension E as marked in this slide.

Similarly, the minimum length of apron is estimated as F into 2.28 into small h divided by F plus 0.52 and you know that the small h divided by F is always less than 0.5.

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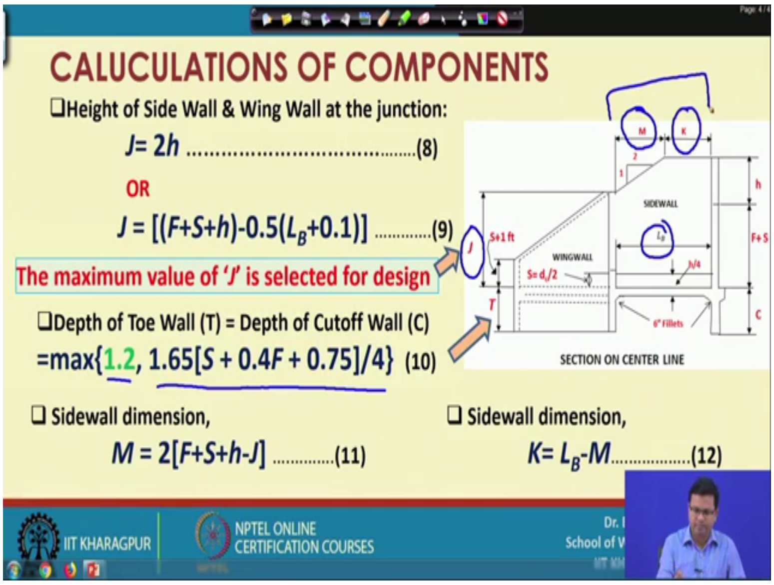

The height of side wall and wing wall at the junction is given by J, you can see from this figure; this is J that equal to 2 h or F plus S plus h minus 0.5 into L B plus 0.1 and the maximum value of these equations 8 and 9 is selected for designing the value of J.

Similarly, the depth of toe wall you know that the depth of toe wall or cut off wall should be minimum 1.2. So, that is we have given here you have to select in between 1.2 and 1.65 into S plus 0.4 F plus 0.75 divided by 4. Then the sidewall dimension that is M as mud in this figure is estimated as 2 into F plus S plus h minus J and we can estimate the value of K as L B minus M because L B equal to K plus M as shown in this figure.

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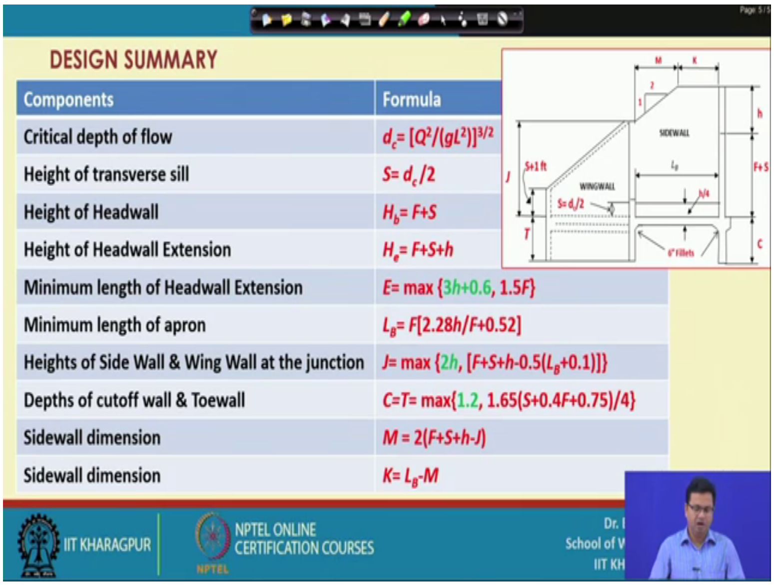

So, I have given in this table the total summary of the different components of this drop spillway and all these components are given here simply you can use this table to estimate the different parts of this drop spillway. So, whatever we have summarized it is d c equal to Q square divided by g L square whole to the power 3 by 2. Height of transverse sill that equal to d c by 2, height of head wall that you can F plus S, F is known already height of headwall extension that equal to F plus S plus h, minimum length of headwall extension is given by the maximum value among 3 h plus 0.6 and 1.5F, minimum length of apron is given by F into 2.28 into h divided by F plus 0.52.

Heights of sidewall and wing wall at the junction is given by the maximum value in between 2 h and F plus F plus h minus 0.5 into L B plus 0.1 and the depth of cutoff wall and toe wall is selected in between 1.2 that is the minimum value and 1.65 into S plus 0.4

F plus 0.75 divided by 4. The sidewall dimension is given by 2 into F plus S plus h minus J and the sidewall dimension K value is given by L B minus M. So, this table summarize summarizes all these components which is coming designed by knowing the value of Q the length of weir, then depth of weir, that is small h and the drop that is your capital F.

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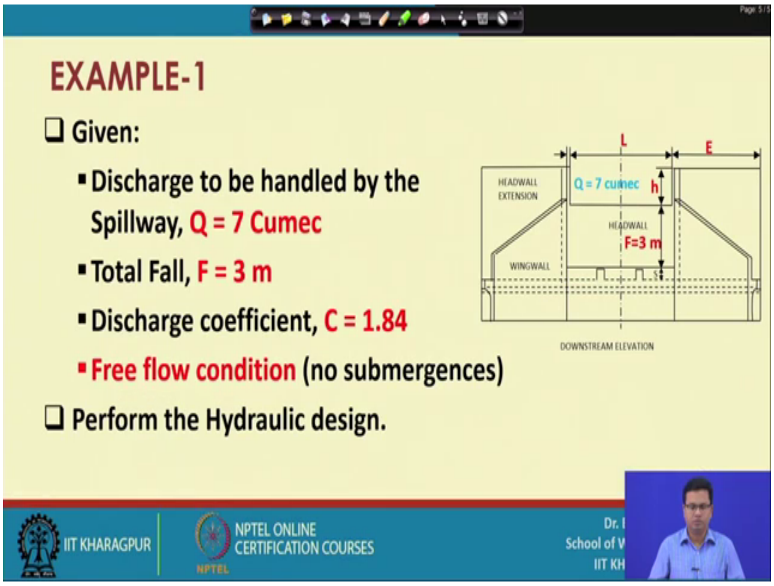

This is one example by if you solve this example many things will be clear about the design. Suppose the spillway discharge is given as 7 Cumec this is the design discharge total fall is given as 3 meter the discharge coefficient C equal to 1.84 which is for rectangular the free flow condition; that means, the hydraulic jump is allowed. So, you can estimate the value of d c, now you have to perform the hydraulic design. Before going for design of first approach is that where to select the value of L and h such that it will meet the criteria of Q that equal to C L h to the power 3 by 2 divided by 1.1 plus 0.03F which accounts for the free board also.

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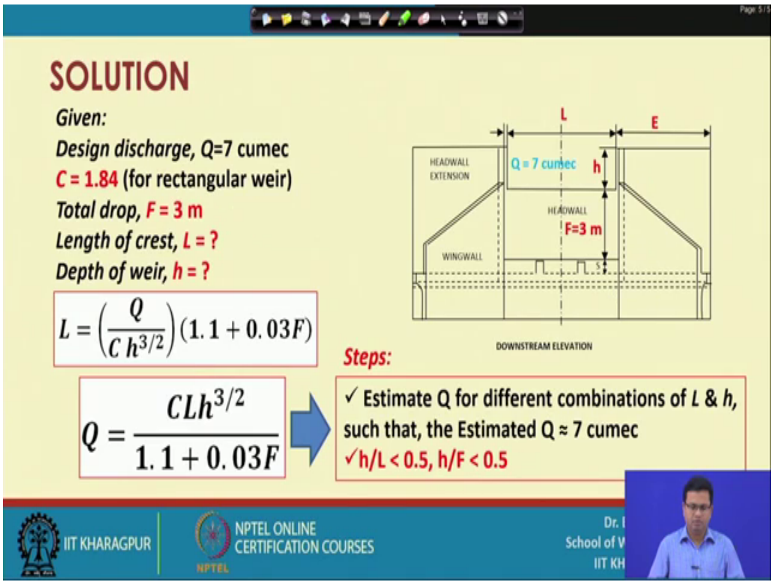

So, it is given so, by using this equation you can select in between small and small h and capital L such that small h divided by L and small h divided by F both are less than 0.5. And you have to assuming the small h and L values you can estimate the value of Q that is your revised design discharge such that this revised estimate of Q is nearly equal to 7 cumec.

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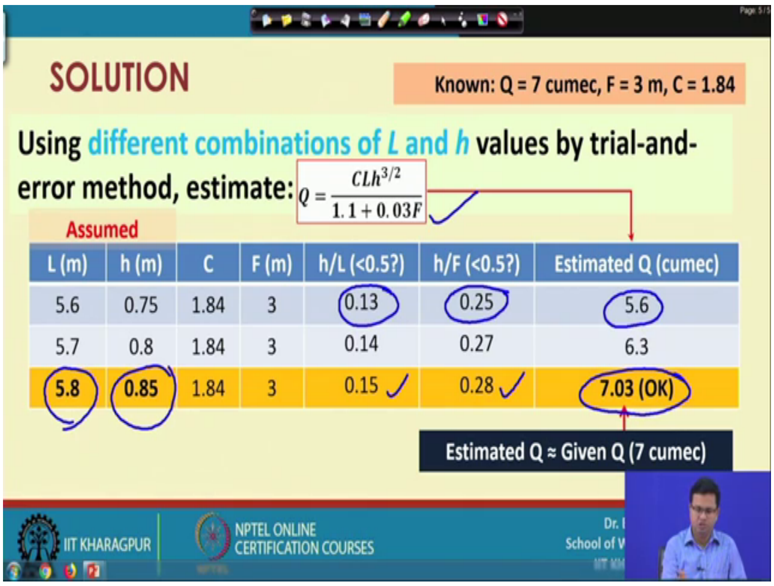

Now, coming to the selection of small h and L values; so, here I have assume the value of L as the first intends as 5.6 and small h equal to 0.75 since C equal to 1.84 and F equal to

3. So, I can estimate the value of small h by l that equal to 0.13 which is much less than 0.5 and it is as per my design criteria and the value of small h divided by F is coming to be 0.25 which is again as for my design criteria which is less than 0.5 and my estimated value is 5.6 which is estimated by using this equation, but this values much lower than that of my design Q value that is your 7 cumec.

Then finally, I have selected L equal to 5.8, h equal to 0.85 and correspondingly I am getting small h divided by L as 0.15 small h divided by F equal to 0.28 and both are less than 0.5 and I am getting the value of Q as 7.03 which is nearly equal to 7 cumec which my design discharge. So, from this table I can estimate that the value of L equal to 5.8 meter, h the depth weir is 0.85 meter and the design Q is 7.03 cumec.

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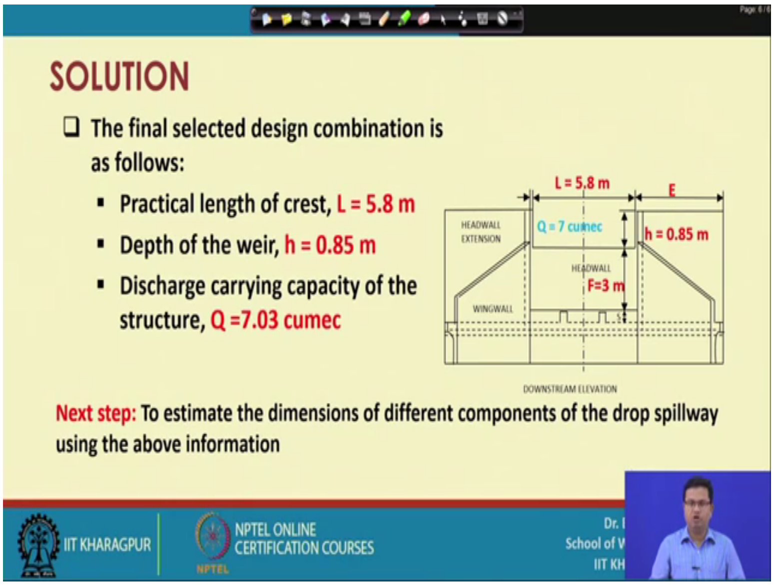

Now, by using these values I have to go for the computation of different components I can use the summary table or I can use or I can go step by step also.

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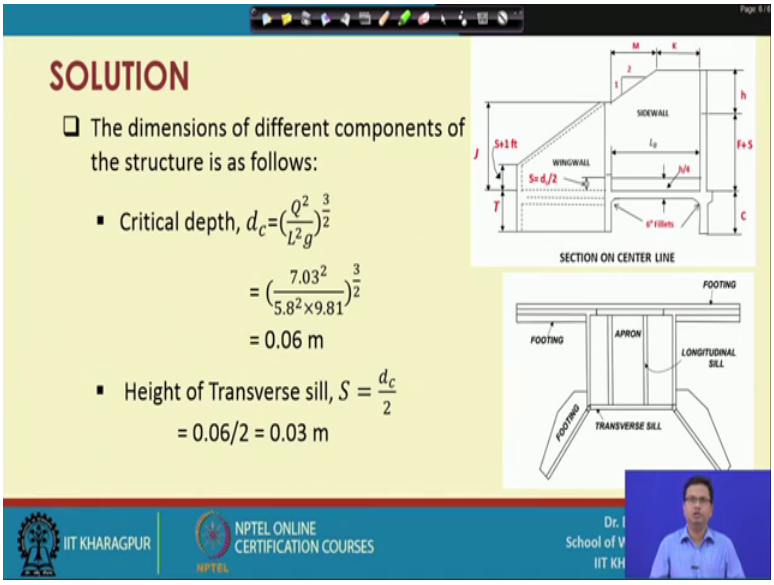

So, first thing I have get estimate what is my critical depth because is a free flow condition. So, the critical depth is estimated as 0.06 meter Q is known, L is known and g is 9.81. So, by using that those values known values I can estimate the what is the critical depth that equal to 0.06 meter, then height of transverse sill d c by 2 will be equal to 0.03 meter.

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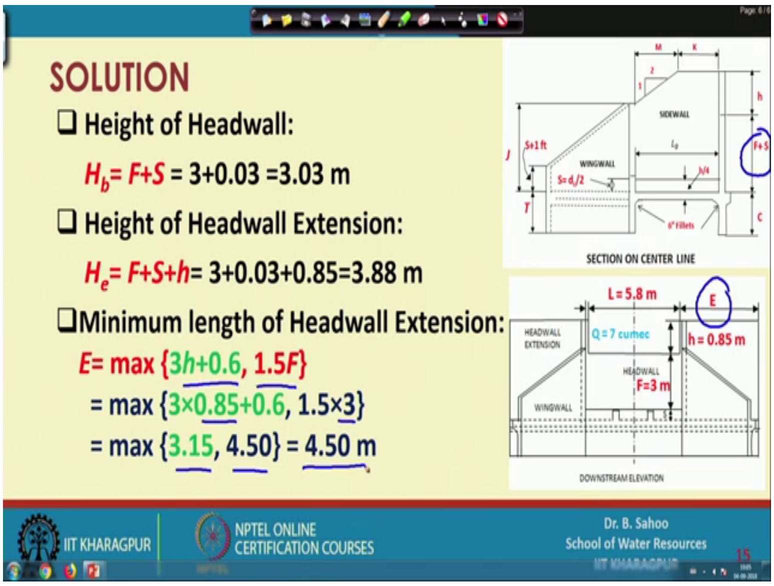

The height of head wall is given by F plus S so, that you can see from this figure. So, F plus S equal to 3 plus 0.03 so, the total fall is 3 meter. So, that is known so, will get 3.03

meter, the height of headwall extension is given by F plus S plus h. So, that is equal to 3.88 meter and the minimum length of headwall extension that is given by e. So, to select between the maximum between 3 h plus 0.6 and 1.5 F, by putting the values of h of 0.85 and F of 3 meter I can get that 3.15 value and 4.5. So, you have to select in between 3.15 and 4.5. So, my maximum value is 4.5 meter. So, the e equal to 4.5 meter.

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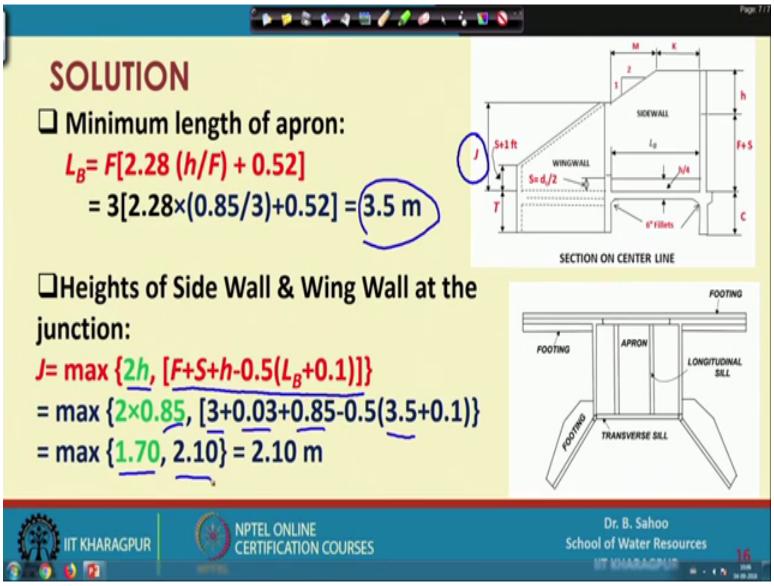

Now, the minimum length of apron that is L B so, that is given by F into 2.28 into small h divided by F plus 0.52, the value of h is 0.85, F is 3 meter. So, by using these 2 values the minimum length of apron is estimated as 3.5 meter. Similarly the heights of side wall and wing wall at the junction that is equal to J as you can see from this figure this is J value is estimated by considering the maximum value in between 2 h and F plus S plus h minus 0.5 into L B plus 0.1. So, L B is already known that is 3.5 meter. So, this value I have put here and small h F S and h are known. So, by that calculation I could estimate 2 value that is 1.70 and 2.10. So, among these 2 values you have to select 2.10. So, my J value is 2.10 meter.

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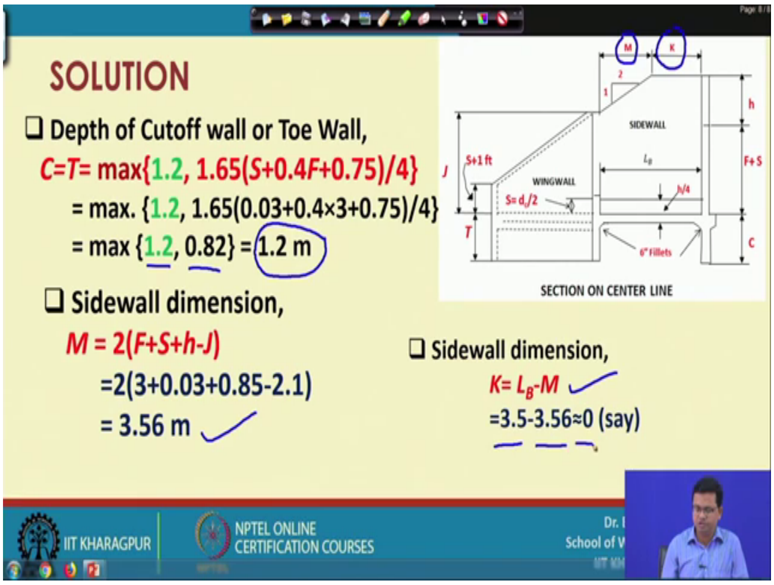

Similarly, the depth of cut off wall or toe wall is given by given by the maximum value among 1.2 meter because that is my minimum value as per the design considerations and 1.65 into S plus 0.4 F plus 0.75 divided by 4. So, by using these values I have to select in between 1.2 and 0.82. Naturally 1.2 is the maximum value so, I am getting C equal to T equal to 1.2 meter. Then the sidewall dimension the M value can be estimated as 2 into F plus S plus h minus J. So, that equal to 3.56 meter, then the value of K can be estimated as L B minus M. So, that equal to 3.5 minus 5.6 so, this is coming to be negative, negative values are allowed. So, you can take it approximately 0.

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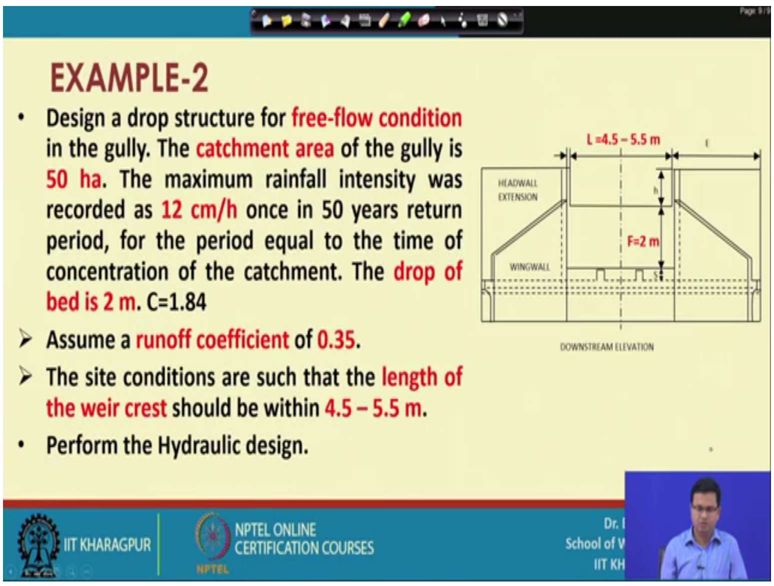

So, that completes my first question, now coming to the second example this is slightly different from the first example. So, here you have to design one drop structure under free flow condition the catchment area of the gully is given as 50 hectare. The maximum rainfall intensity is given as 12 centimeter per hour, which occurring once in 50 years of return period, for the period equal to the time of concentration of the catchment; that means, the design intensity is given as 12 centimeter per hour of rainfall.

The drop of bed is 2 meter, you have to take the value of C that is the discharge coefficient for the rectangular whereas, 1.84. Assume a runoff coefficient of 0.35 for the catchment. The site conditions are such that the length of the weir crest should be within 4.5 to 5.5 meter; that means, L can be selected as 4.5 to 5.5 meter. So, in this case the value of Q is not given, the discharge design discharge not given. So, further you have to estimate what is the design discharge?

So, the design discharge can be estimated by using the rational formula, which gives the peak design peak rainfall runoff. So, the design peak runoff can be estimated by using the formula Q equal to KIA, where K is the runoff coefficient, I is the design rainfall intensity which is given here 12 centimeter per hour and A that is your catchment area that is your 50 hectare. Once Q is known then we can follow the procedure whatever you adopted for solving the example number 1.

Now, we have to go for solving the problem and here the drop is given as F equal to 2, the drop of bed is 2 meter. So, drop F can be equal to 2 meter.

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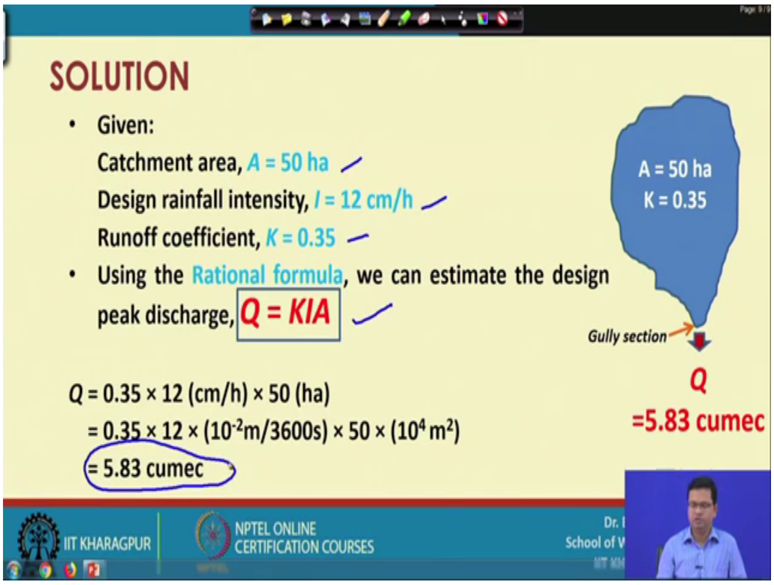

So, you can use the rational formula here, if you will use the rational formula Q equal to KIA, K is given 0.35, I equal to 12 centimeter per hour and A equal to 50 hectare. So, by putting these values after unit conversion you can get the value of Q as 5.83 cumec.

So, my design discharge is 5.83 cumec.

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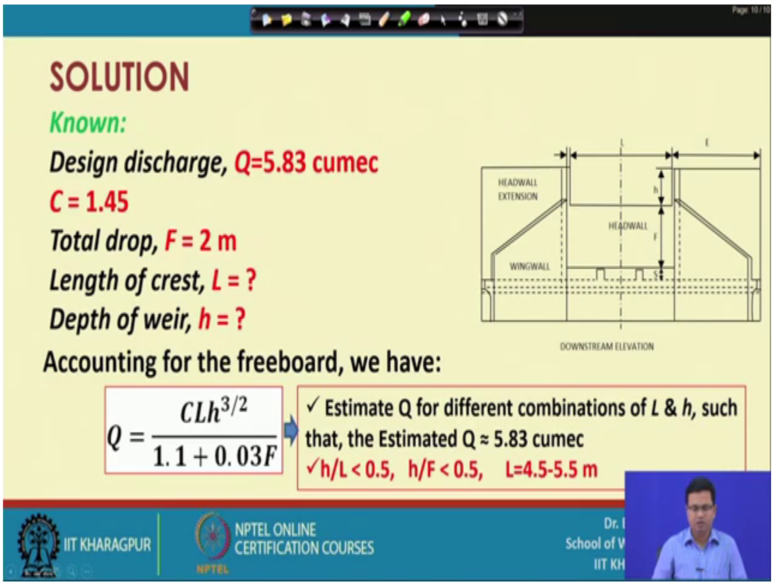

So, once Q is known, I can design my drop spillway. I have to use this formula Q equal to CLh 3 by 2 divided by 1.1 plus 0.03F and it has already accounted for the freeboard. So, now, you have to select the best combination of L and h such that is h by L and h by

F both are less than 0.5 and, L is in between 4.5 to 5.5 meter depending on the site condition. That means, I have to select first L within 4.5 to 5.5 meter I can start my trail from 4.5 and I can increase L value up to 5.5 meter.

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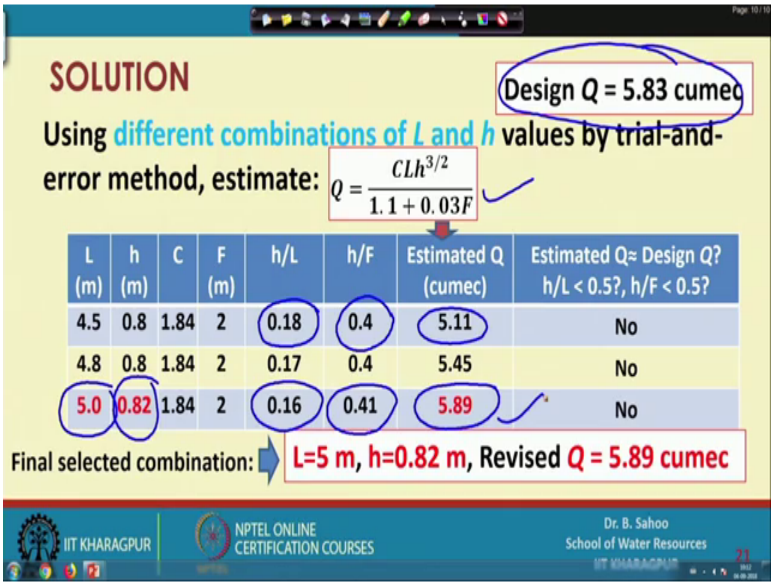

So, first I have taken the value of L as 4.5 and the assumed value of small h equal to 0.8, I am getting small h by L as 0.18 which is less than 0.5, small h by F is 0.4 and my estimated Q by using this equation is 5.11 cumec, but my design discharge 5.83 cumec.

So, I have to increase the design discharge; that means, I have to select higher L value. If will see I have taken L equal to 5 meter here, then h equal to 0.82, then I am getting small h by L as 0.16, small h by F equal to 0.41 and correspondingly I am getting Q equal to 5.89 by using the above equation. So, this is approximately not approximately, but it is approximately equal to 5.83 cumec. So, I can select this value as my revised Q value the design discharge valve. So, finally, I got L equal to 5 meter, h equal to 0.82 meter and my design discharge Q equal to 5.89 cumec.

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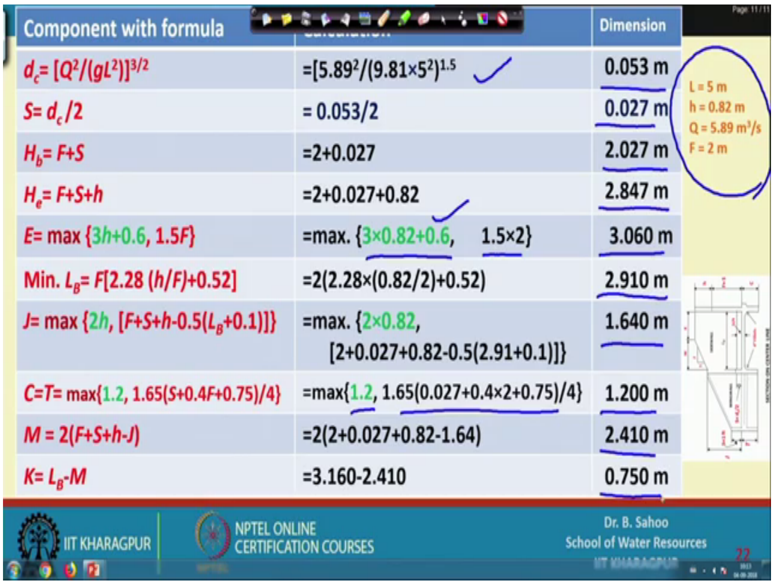

Component with formula		Dimension
$d_c = [Q^2/(gL^2)]^{3/2}$	$=[5.89^2/(9.81\times5^2)]^{1.5}$	0.053 m
$S = d_c/2$	$= 0.053/2$	0.027 m
$H_b = F+S$	$=2+0.027$	2.027 m
$H_e = F+S+h$	$=2+0.027+0.82$	2.847 m
$E = \max\{3h+0.6, 1.5F\}$	$=\max.\{3\times0.82+0.6, 1.5\times2\}$	3.060 m
Min. $L_B = F[2.28(h/F)+0.52]$	$=2(2.28\times(0.82/2)+0.52)$	2.910 m
$J = \max\{2h, [F+S+h-0.5(L_B+0.1)]\}$	$=\max.\{2\times0.82, [2+0.027+0.82-0.5(2.91+0.1)]\}$	1.640 m
$C=T= \max\{1.2, 1.65(S+0.4F+0.75)/4\}$	$=\max\{1.2, 1.65(0.027+0.4\times2+0.75)/4\}$	1.200 m
$M = 2(F+S+h-J)$	$=2(2+0.027+0.82-1.64)$	2.410 m
$K = L_B-M$	$=3.160-2.410$	0.750 m

Now, I can fill up the table the summary table by using the value of L h Q and F as given here. So, these values already know. So, by knowing these values I can put these values to estimate my critical depth that equal to Q square divided by gL square whole to the power 3 by 2 so, I am getting 0.053 meter. Similarly S equal to d c by 2 so, I am getting 0.027 meter, H b 2.027 meter, H e that I can get 2.847 meter. E I have to select in between the maximum value of 3 into 0.82 plus 0.6 and 1.5 into 2 so, I am getting this value as the maximum on so, that is I am getting 3.060 meter.

The length of the apron that is L B I am getting 2.910 meter and the value of J equal to 1.640 meter, the depth of toe wall and cut off wall is given by C and T. So, I am getting the maximum value among these 2 so, I am getting it is 1.2 meter. Similarly the value of M is 2.410 meter and value of K is 0.750 meter. Simply can you follow the steps whatever we have discussed in our previous example. So, I am for not going to details about this tables how to calculate. So, all these steps are already done in the example number 1.

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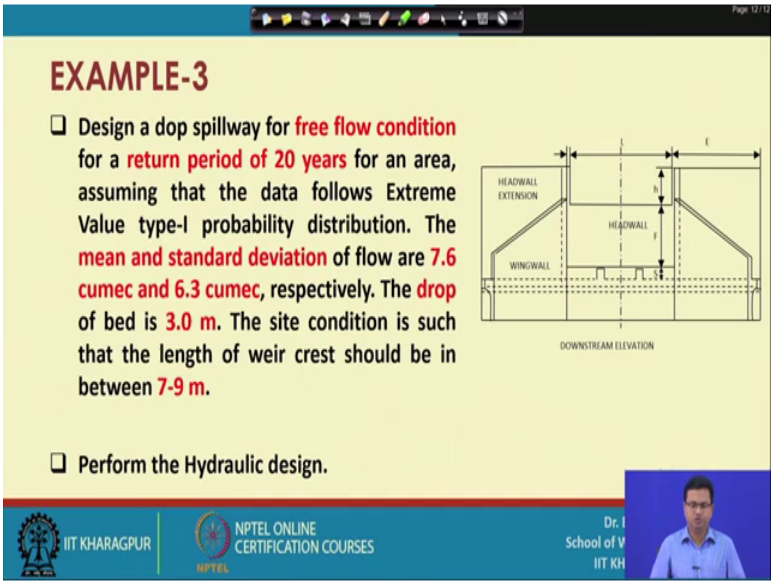

Now, coming to the third example, this is again slightly different from the previous 2 examples. So, here you have to design the drop spillway considering the frequency analysis, by using the probability distribution functions. The question is the design a drop spillway for free flow condition for a return period of 20 years for an area, assuming that the data follows extreme value type-1 probability distribution. The extreme value type-1 probability distribution nothing, but your gumball distribution. The mean and standard deviation of flow are 7.6 cumec and 6.3 cumec. So, the mean and standard deviations are given, the drop of bed is 3 meter that even F is given as 3 meter. The site condition is such that the length of weir crest should be in between 7 to 9 meter.

So that means L should be selected in between 7 to 9 meter. So, my first attempt will be to decide what is your Q value; design Q value, which is having 20 years return period. So, for that I have to use the gumball probability distribution on for that I have to use the mean and standard deviation values whatever given as 7.6 and 6.3 cumec.

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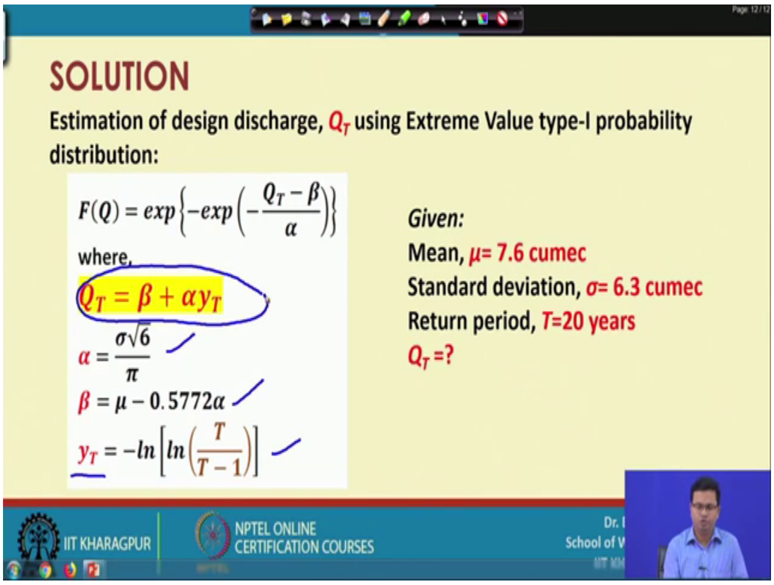

This equation shows the gumball probability distribution function; in this case Q T is my design discharge value having a return period of T. Here T equal to 20 years and that is given as beta plus alpha into y T, here alpha equal to sigma into square root of 6 divided by pi. So, sigma is nothing, but it is a standard division that is given as 6.3 cumec, beta is given as mu minus 0.5772 alpha.

So, mu is given as the mean value. So, mean value is 7.6 cumec and alpha is already completed in the previous step. So, once alpha is known I can estimate what is the value of beta, then y T is called as the reduced variate. So, that is a function of the return period. So, that can be estimated as minus l n of ln into ln of T divided by T minus 1. So, you have T is 20 years. So, once y T beta and alpha is know I can use these values in this equation Q T plus Q T equal to beta plus alpha y T to estimate my design discharge.

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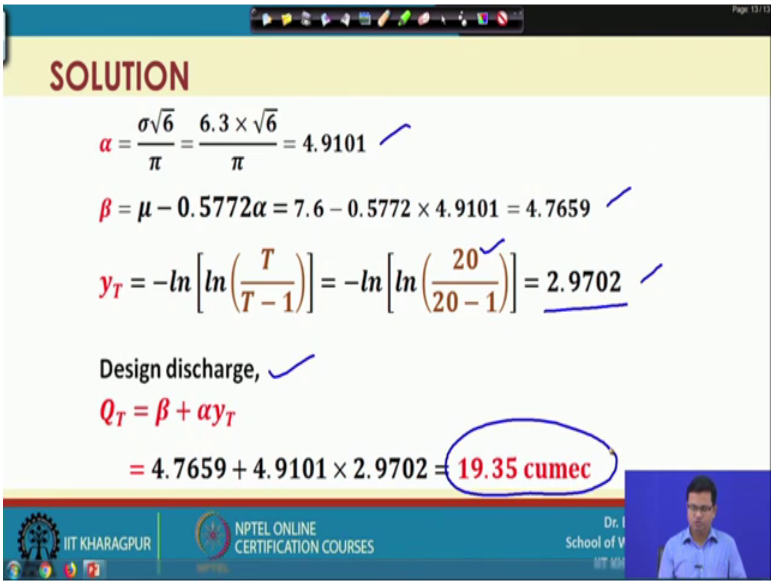

So, here the value of alpha is computed as 4.9101, beta is computed as 4.7659, y T is estimated as 2.9702 because T is 20. So, by using these 3 values alpha, beta and y T I can estimate my design discharge which is equal to beta plus alpha y T. So, that I am getting as 19.35 cumec. So, this 19.35 cumec is my design discharge. So, once this design discharge is estimated then we can use the simple procedure what about you have already done in the previous examples.

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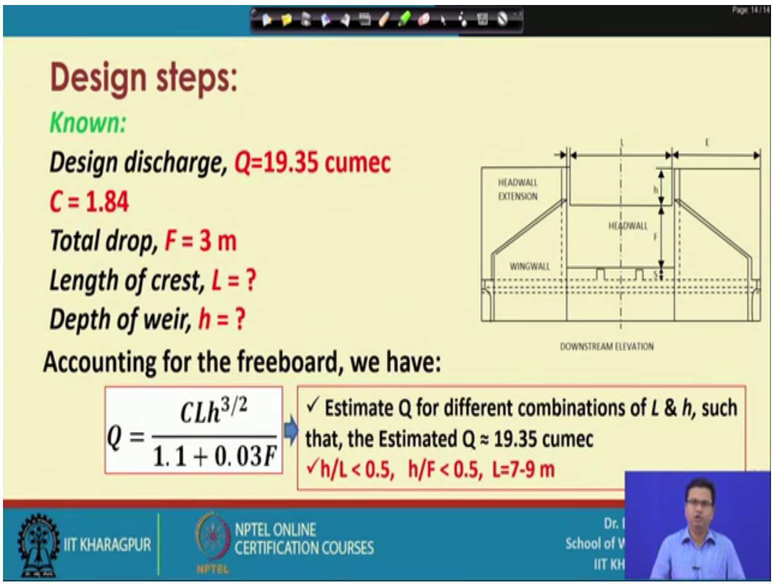

So, I have to use this equation Q equal to CLh to 3 by 2 divided by 1.1 plus 0.03F, F is given as 3 meter and C is equal to 1.84 and I have to again follow the same condition that is small h divided by L is less than 0.5, small h divided by F is less than 0.5 and L is should be selected that is within 7 to 9 meter. So, l should be within 7 to 9 meter and my design discharge 19.35; that means, have estimate the value of L and h in such a way that my estimated Q value is nearly equal to 19.35 cumec.

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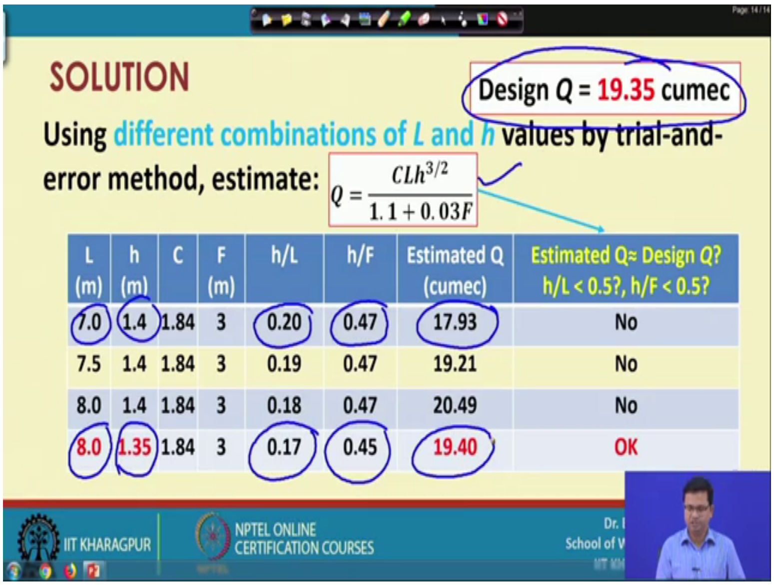

So, I can use this table so, I have started my assumption from L equal to 7. So, if I am using L equal to 7 and h equal to 1.4, then I am getting h by L equal to 0.2, h by F is 0.47 and both are less than 0.5 and my estimate Q value is 17.93 which is much less than that of my design Q value that equal to 19.35 cumec.

Now, I have to increase the value of L so, that the Q value will increase. So, if I have taken if I will taking L equal to 8 meter and h equal to 1.35 meter then I am getting h by L equal to 0.17 and h by F equal to 0.45 and my estimated Q value by using the above equation is 19.40 cumec which is nearly equal to 19.35 cumec. So, my revised discharge design discharge is now 19.4 meter and, the value of L equal to 8 meter and value of h equal to 1.35 meter.

So, now by knowing this small h, capital L and design discharge Q, I can now design my drop spillway by using the summary table.

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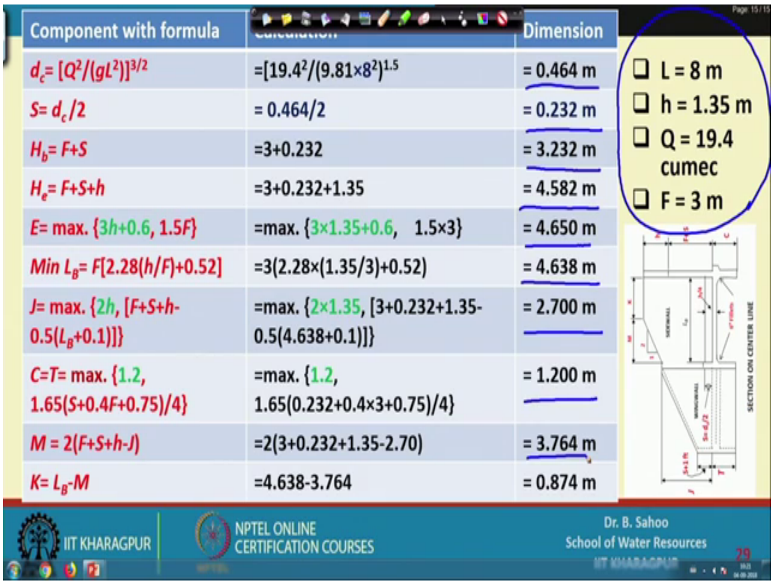

Component with formula	Calculation	Dimension
$d_c = [Q^2/(gL^2)]^{3/2}$	$=[19.4^2/(9.81\times 8^2)]^{1.5}$	= 0.464 m
$S = d_c/2$	= 0.464/2	= 0.232 m
$H_b = F+S$	=3+0.232	= 3.232 m
$H_e = F+S+h$	=3+0.232+1.35	= 4.582 m
$E = \max.\{3h+0.6, 1.5F\}$	$=\max.\{3\times1.35+0.6, 1.5\times3\}$	= 4.650 m
$\text{Min } L_B = F[2.28(h/F)+0.52]$	$=3(2.28\times(1.35/3)+0.52)$	= 4.638 m
$J = \max.\{2h, [F+S+h-0.5(L_B+0.1)]\}$	$=\max.\{2\times1.35, [3+0.232+1.35-0.5(4.638+0.1)]\}$	= 2.700 m
$C = T = \max.\{1.2, 1.65(S+0.4F+0.75)/4\}$	$=\max.\{1.2, 1.65(0.232+0.4\times3+0.75)/4\}$	= 1.200 m
$M = 2(F+S+h-J)$	=2(3+0.232+1.35-2.70)	= 3.764 m
$K = L_B - M$	=4.638-3.764	= 0.874 m

So, all the calculations are given in this table. So, by using these values of L, h, Q and F are shown in right hand side here I can estimate my d c that is the critical depth of flow. So, that equal to 4.464 meter, S equal to d c by 2. So, that equal to 0.232 meter, H b equal to 3.232 meter, H e equal to 4.582 meter, E is estimated as 4.650 meter, minimum length of L B equal to 4.638 meter, J equal to 2.7 meter and C equal T their both as 1.2 meter, M equal to 3.764 meter and K equal to 0.874 meter. So, all these steps whatever steps we have already done for solving example number 1, those steps can be followed. So, those steps are not repeating in this slide. So, this completes the example number 3.

So, today what we did. So, we have designed the components of drop spillway and for that we have to know what is my design discharge corresponding to my design discharge I have to select the value of small h and capital L, such that small h divided by capital L and small h divided by capital F both should be less than 0.5 to our any covering. And the value of L should be selected depending on the practical site condition and for designing discharge I have to use the formula Q equal to CLh to the power 3 by 2 divided by 1.1 plus 0.03F and this already as accounted for the free board condition.

So that means, the freeboard for freeboard what about the extra discharge is given that has been accounted for and the value of this extra or additional discharge of a freeboard is Q times 0.1 plus 0.03 F. So, by knowing all these values we can use in the summary table whatever I have given, to estimate all these components of the drop spillway. So, this ends our lecture here.

Thank you.