Engineering Hydrology
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Lecture 81
Design Flood

Hello, all, welcome back. In the previous lecture, we were discussing about design storm. Today, we are going to look at design flood, that is the flood caused due to design storm or the value of the flood which is used for hydrologic design. So, design storm when we were talking about we have seen different methods, different approaches to make use of design storm, that is by making use of frequency analysis we can find out the design storm or by considering the probable maximum precipitation, we can make use as design storm. But always we will not be going for making use of probable maximum precipitation as the design storm because it is a very high value and the design based on that value will not be economical. But for the structures which are of high importance such as dams and other similar kinds of structures like spillway etcetera, we use to go for making use of probable maximum precipitation and also the corresponding flood that is the probable maximum flood.

So, today let us see what are the different methods to calculate the design flood, because for different structures the return period which we will be using will be different. So, corresponding to that how to determine the design flood that is what we are going to study today.

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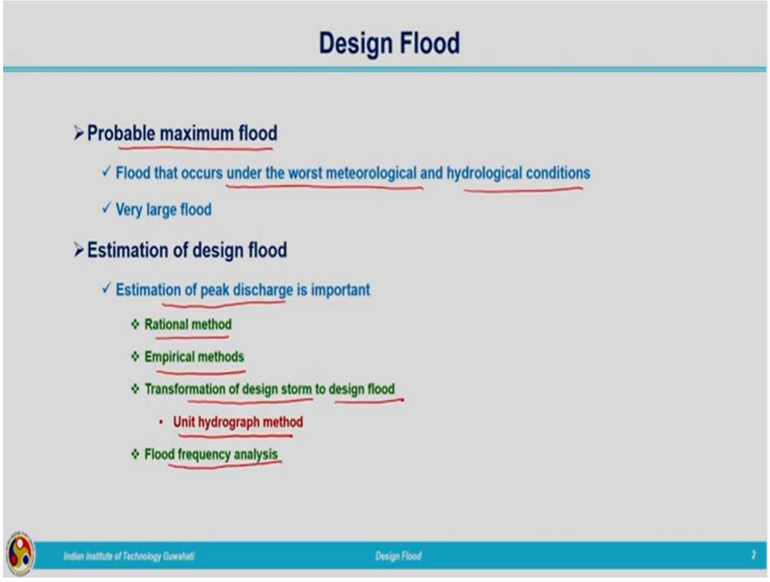

Let us move on to today's lecture that is related to design flood. Design flood can be probable maximum flood which is caused due to the probable maximum storm. So, flood that occurs under worst meteorological and hydrological conditions, this is the flood that occurs under the worst meteorological scenario. The value of probable maximum flood will be very large, it will be representing a huge value. So, always for all the design of structures, we will not be making use of this probable maximum flood. In the case of different types of hydrologic design, we will not depend always on probable maximum flood.

Now, coming to the estimation of design flood, we are having different methods for the estimation of design flood. Under this, we will discuss about estimation of peak discharge, which are very important while discussing about hydrologic design. We need to have the maximum value of the flood for which the hydrologic design has to be carried out or the structure has to withstand the worst event which will be occurring within that period that is, we will be considering certain return period for the hydrologic design within that period the structure should not fail. So, what should be the value corresponding to that design flood or how can we estimate that value. Different methods of estimation are there. First one is the rational method. Second, we will look into different empirical methods and transformation of design storm to design flood. Sometimes we will be making use of the design storm value to get the value corresponding to design flood. Under this we will be making use of the principle of unit hydrograph.

We have studied the principle of unit hydrograph, the main assumption behind unit hydrograph is the linearity principle. But in the case of design flood, we can make use of this unit hydrograph method if the design storm value is there. This method is suitable for hydrologic design, because once we determine the flood hydrograph by making use of unit hydrograph principle, it will be giving us the complete details about the flood hydrograph that is when the time to peak will be occurring, what is the time to peak of the flood, what is the peak value of the flood and all these details whatever we have studied under the unit hydrograph is applicable here. So, minute details related to the flood will be obtained if we are making use of the unit hydrograph method for determination of design flood. But there are certain limitations related to unit hydrograph. Sometimes the area of the catchment is very large, in that case this method will not be applicable. In such cases, we can do one thing, we can subdivide the catchments into big catchment into small, small sub catchments and the same principle of unit hydrograph can be applied to each and every small sub catchments. The next one is flood frequency analysis. Flood frequency analysis also we have seen different methods, probability plotting and Gumbel's method. The same methods we will be making use here also for finding out the design flood.

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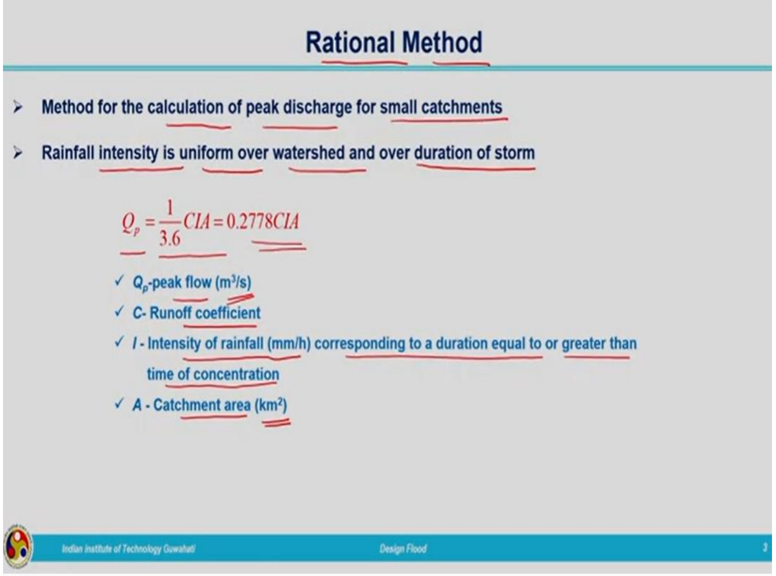

Different methods of estimation of floods includes rational method, some empirical formula, unit hydrograph method and the flood frequency approaches. First let us look into rational method. This is a method for the calculation of peak discharge for small catchments. This method when you are using for the flood calculation, you should be careful about the size of the catchment. For very large catchments, we cannot apply this. If the catchment size is very large then you can delineate the catchment into sub catchments and make the area to be very small. So, individually you can apply this formula to different sub catchments. So, this is an empirical method which is used for the calculation of design flood or peak flood.

In majority cases, especially in the case of urban catchments, we will make use of this rational formula for finding out the peak flow value. In this case, we are assuming rainfall intensity as uniform over the watershed for the duration of the storm. We need to find out the duration of the storm for which we are going to find out the design flood. This duration of storm for which we are considering, the rainfall intensity should be uniform. This is the same principle we have considered in the case of unit hydrograph also, that is the value which we are computing by using certain design storm, that storm should be uniform within the duration which we are considering. So, rainfall intensity should be uniform over the watershed and the storm which is considered should be of constant value within the duration which is considered. That is the reason we are specifying that the catchment area should be less. If the catchment area is very large, the rainfall which is occurring over the catchment will not be uniformly distributed.

The formula represented by a rational method is given by this equation that is

$$Q_p = \frac{1}{3.6} CIA = 0.2778 CIA$$

Let us see what are the parameters included in this equation. Q_p is the peak flow, the unit of which is in meter cube per second and C is the runoff coefficient, runoff coefficient is representing the land use characteristics of the watershed under consideration, I is the intensity of rainfall in millimeter per hour corresponding to a duration equal to or greater than time of concentration. So, this is very important factor, intensity of rainfall. So, when you are making use of this formula that is Q is equal to CIA, what value should be taken for intensity of rainfall? The value corresponding to intensity of rainfall is the one which is for a duration equal to or greater than time of concentration. Here what we are assuming that the rainfall is uniformly occurring over the catchment, uniformly distributed over the catchment. So, the time taken for water to reach from the extreme point to the outlet of the catchment is represented by time of concentration. So, the duration which we will be using for the selection of intensity of rainfall will be equal to or greater than time of concentration, because time of concentration is the time which is representing the point at which the entire catchment will be contributing to the outlet of the catchment. So, that is why we are making use of the duration as time of concentration or above that value.

Next term is capital A, that is the catchment area. Catchment area should be substituted in kilometers square. So, you need to be very careful while using this equation, because we have made use of a factor 1 by 3.6 or 0.2778 for making it in SI unit. When you are using this formula, the catchment area should be substituted in kilometer square and the intensity of rainfall should be substituted in millimeters per hour. Then you will get the peak flow in meter cube per second.

Now, next question is that how to get the time of concentration because intensity of rainfall, we have to choose corresponding to a duration equal to or greater than t_c. We will be having the intensity duration frequency curve. So, for different durations what will be the intensity of rainfall, we can choose from the corresponding IDF curve. Depending on the structure which we are going to design we can choose the return period and the intensity duration frequency curve corresponding to that return period can be chosen. And now, we need to take the intensity of rainfall value corresponding to a duration equal to t_c or greater than t_c. So, we need to calculate the value corresponding to t_c, then only we can finalize the duration of rainfall.

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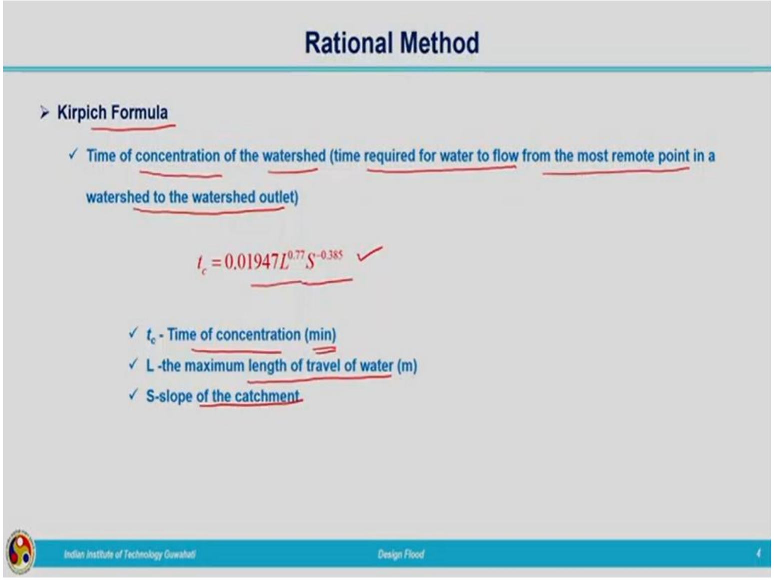

So, there are so many empirical equations for the computation of time of concentration, the one which we commonly use is termed as Kirpich formula. This formula gives us time of concentration of the watershed by using the expression

$$t_c = 0.01947 L^{0.77} S^{-0.385}$$

In this equation, t_c is the time of concentration, the unit of which is in minutes and L is the maximum length of travel of water. Maximum length of travel means, the length of the travel from the extreme point to the outlet point, that is considered as the maximum length of travel of flow, that is in meters and S is the slope of the watershed. So, the length L and slope S, these are the watershed characteristics. These values we can obtain from the catchment details, either you can make use of software GIS for finding all these values, total area can be obtained from the GIS analysis, also the slope of the area you need to make use of a digital elevation model for getting the elevation details of different, different locations in the watershed. So, by making use of that, you will get the average slope of the watershed and length from the extreme point, farthest point to the outlet of the catchment also can be obtained by making use of GIS. So, the time of concentration by using Kirpich formula is given by this equation, that is time of concentration is nothing but the time required for water to flow from the most remote point in a watershed to the watershed outlet. This particular term, time of concentration is very important, that we have discussed in several occasions when we were discussing about flow from the extreme point, farthest point to the outlet point. So, if we are calculating this value of t_c for that we need to have the knowledge about the length L and slope S. So, if these two values are obtained, you can calculate the time of concentration. This time of concentration can be considered as the duration of the rainfall and corresponding to that duration you can find the intensity of rainfall from the IDF curve. So, by making use of that intensity you can substitute in rational formula for computing the peak flow. This much about rational formula.

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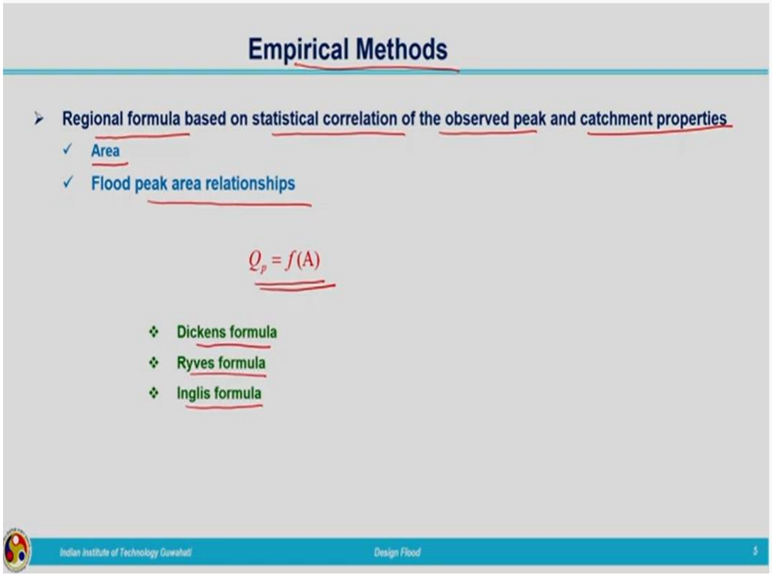

Now, let us move on to different empirical relationships. So, these empirical methods are developed for different regions. So, these are representing regional formula based on statistical correlation of the observed peak and catchment properties. Based on the flow details and catchment properties, the relationship between the peak and the area has been found out and that has been expressed in terms of equation for computation of peak flow. These are empirical in nature and these equations are applicable to the respective regions for which these formulae have been developed. Regional formula has been developed for different, different regions in India based on the catchment area and the flood experienced in the particular area, statistical analysis is carried out and based on that different formula have been derived.

The formula for flood peak can be written as a function of area,

$$Q_p = f(A)$$

A is representing the area and Q_p is the peak flow. Different formula which we consider under empirical methods are Dickens formula, Ryves formula and Inglis formula. So, these are the different empirical equations derived for finding out the peak flow on regional basis. For different regions relationships have been derived between the peak flow and the area of the catchment considered.

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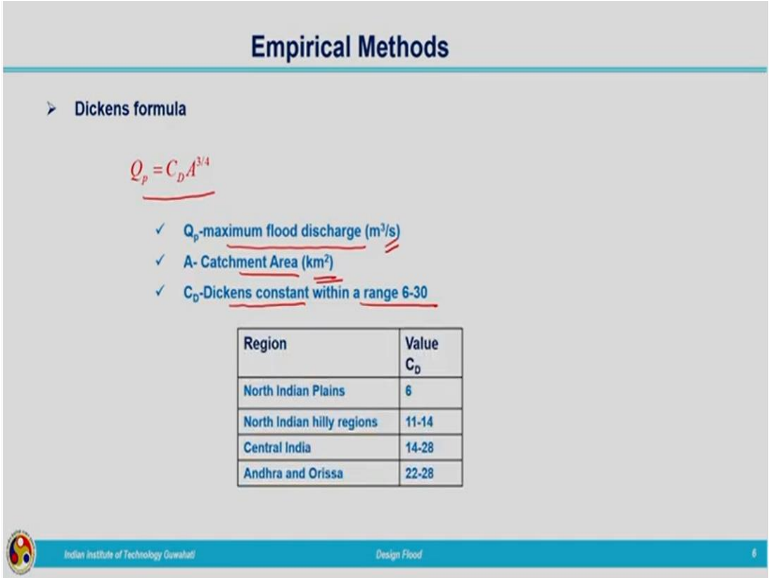

Let us look into one by one. First one is Dickens formula. It is given by

$$Q_p = C_D A^{3/4}$$

C_D is the coefficient corresponding to Dickens formula and A is representing the catchment area. Q_p is representing maximum flood discharge in meter cube per second and A the catchment area in kilometers square. Since these equations are empirical equations, you have to be very careful by substituting the different values, area should be substituted in kilometers square. Q_p we are getting in meter cube per second. Now, what are the values corresponding to C_D. So, C_D values are being given for different regions and these C_D values are developed based on the average rainfall in a particular area which are considered. C_D is the Dickens constant within the range of 6 to 30. So, these are given in tables. For North Indian plains the value of C_D is 6, and North Indian hilly regions it is 11 to 14, and central India it is 14 to 28, and the regions close to Andhra and Odisha it is 22 to 28. These are the values which can be used for the coefficient C_D. So, these C_D values have been derived based on the precipitation which is occurring in the area and also the flood values which are occurred in those particular areas that have been analyzed based on that the coefficients were proposed for different regions. So, these equations when you use for a particular location you have to be carefully chosen the values corresponding to C_D regarding the area.

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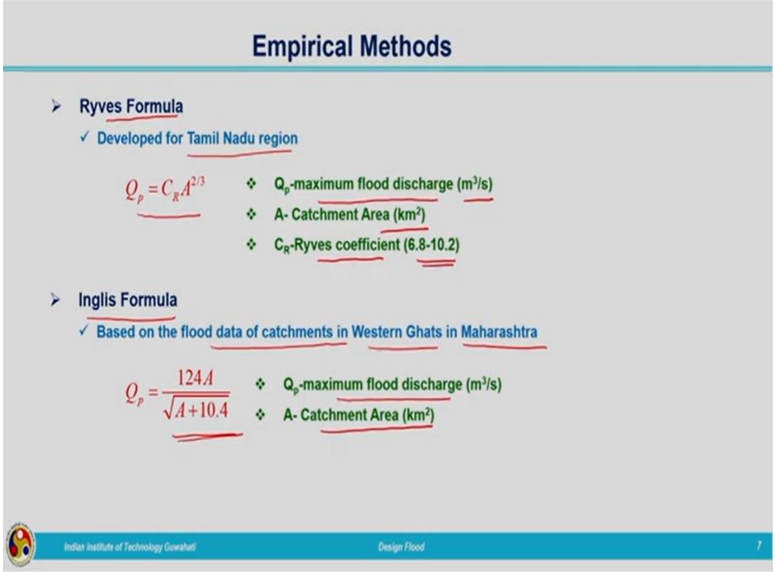

Now, next situation is Ryves formula, Ryves formula is also similar to that of the Dickens formula. This is developed for Tamil Nadu region and this is commonly used in the areas of Tamil Nadu, Karnataka and Andhra. The equation is given by

$$Q_p = C_R A^{2/3}$$

In this Q_p is nothing but maximum flood discharge in meter cube per second, A is the area of the catchment in kilometers square and next is the equation of C_R. As in the case of Dickens formula we are having values for C_R, C_R is Ryves coefficient which varies between 6.8 to 10.2, the values are between 6.8 and 10.2. So, you can understand this is only giving us a rough idea about the peak flow which can occur at a particular region, because no other factor is considered. When these equations have been derived whatever catchment properties are the and also based on the flood values will be changing. Now, there are a lot of changes taken place in the land use characteristics. So, definitely this formula has to be validated before using it for a particular catchment.

Last empirical method which we are going to discuss is Inglis formula. Inglis formula is based on the flood data of catchments in Western Ghats in Maharashtra, this is corresponding to Western Ghats in Maharashtra region. So, the formula is given by

$$Q_p = \frac{124A}{\sqrt{A+10.4}}$$

Q_p is the maximum flood discharge and capital A is representing the catchment area in kilometers square.

All these empirical relationships when you observe you can understand that these are developed as a function of area of the catchment. If you look at rational formula, rational formula is given by Q_p is equal to CIA, C is representing the catchment characteristics, based on the catchment characteristics that is the land use properties, C value will be changing. If C value is 1, we can compute Q as I multiplied by A, intensity of rainfall multiplied by area of the catchment, and that is representing our Q_p in the case of C is equal to 1 when we are using rational formula.

What is meant by C is equal to 1? C is equal to 1 is representing a condition that the area is completely impervious, if rainfall is occurring over a completely impervious area, then entire rainfall will be converted to runoff, there is no infiltration taking place, very small amount of initial losses will be there, when it is compared with the rainfall value, that value will be very less, infiltration is 0. So, that whatever rainfall is occurring on the catchment will be converted completely to the flow, runoff, that is why C value plays an important role there. Depending upon the type of the land use characteristics, C will be taking different values and we can compute the Q_p value in the case of rational formula, there we are making use of the intensity of rainfall. But in all other cases, by making use of the intensity of rainfall and the flood data, which has already occurred in those regions, these relationships have been developed between Q_p and the area alone. So, here we are considering only the area as the factor and we are finding out the peak flow. So, definitely these equations will be giving you an approximate idea about the peak flow which may occur in a particular area.

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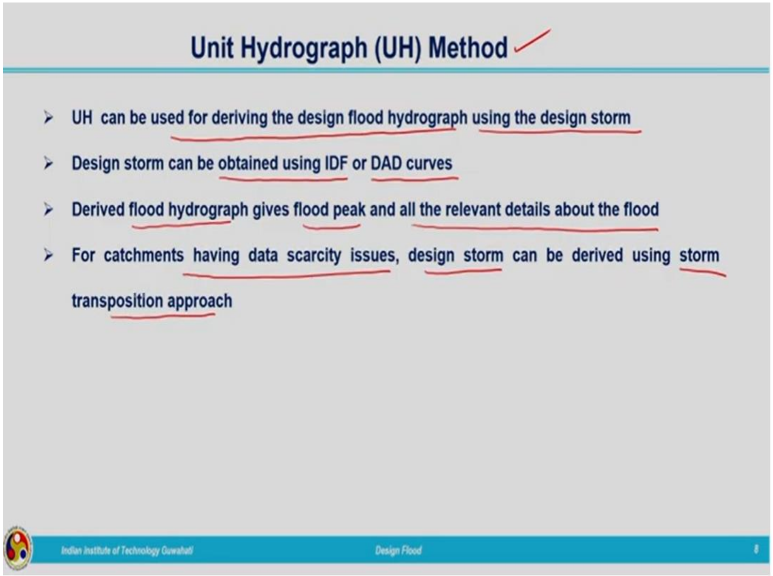

Now, next method is based on transformation of design storm to design flood. Under that, we will discuss about unit hydrograph method. Unit hydrograph can be used for deriving the design flood hydrograph using design storm. This is not new to you, we have solved so many examples related to the derivation of direct runoff hydrograph from the unit hydrograph. We know how to derive the direct runoff hydrograph based on unit hydrograph.

So, under the transformation of design storm to design flood, we can make use of this unit hydrograph method. For that we will be making use of the effective rainfall data that is effective rainfall we are calculating after deducting the losses, that effective rainfall can be converted to direct runoff ordinates by making use of the unit hydrograph. If unit hydrograph is not available to a particular catchment, we can derive the synthetic unit hydrograph by making use of the data from the climatologically and hydrologically similar catchment, similar neighboring catchment and that synthetic unit hydrograph can be utilized for finding out the design flood. So, those topics related to the derivation of DRH, we have already covered under the module of hydrologic analysis. So, I am not going to repeat it again. So, once the direct runoff hydrograph is obtained, you can add the baseflow to that component and you will get the total flow hydrograph. So, only thing is that, here we are discussing in the context of hydrologic design, how to determine the design flood. So, the value which we are using is from the rainfall data that is representing the effective rainfall or it can be design storm by making use of that design storm value and making use of the available unit hydrograph we can derive the flow hydrograph.

The design storm can be obtained using IDF curves or DAD curves, Depth Area Duration curves. We know how to get the intensity duration frequency curve and also how to derive the depth duration curves. So, based on certain duration, which we are considering for that we can get the intensity of the rainfall value, that intensity of the rainfall value is considered as the design storm, that way if we are determining the design storm that can be converted to the design flood by making use of unit hydrograph.

So, the derived flood hydrograph that is the flood hydrograph which is derived based on the unit hydrograph approach gives idea about flood peak and all the relevant details about the flood, that is when the peak will occur, how much will be the peak value all these details can be obtained from the flood hydrograph developed by using the unit hydrograph. So, this gives us an idea about the complete details about the flood hydrograph or the flood which is going to occur in that particular location.

So, for catchments having data scarcity issues, we can derive the design storm by making use of the storm transposition approach. All the catchments may not be having sufficient data to derive the design storm. In that case we have discussed about the method of storm transposition to make use of the data from the neighboring catchments. So, that method can be utilized for deriving the design storm and once the design storm is obtained, we can make use of the same unit hydrograph principle to derive the design flood. This method is having certain assumptions mainly the linearity principles. So, the flood value which we have derived is based on the assumption that catchment behaves as a linear system, but always it will not be like that, catchment is actually a nonlinear system, for simplicity we are making that assumption. So, the peak value which is calculated by using the unit hydrograph method has to be multiplied by a factor for making it use for the catchments which are nonlinear in nature. And also, this can be applied to small catchment, very large catchments are there, in that case, we have to subdivide the larger catchments into smaller ones and the principle of unit hydrograph can be applied or else if the catchment area is very large, we can make use of the principle of flood frequency analysis for determining the design flood.

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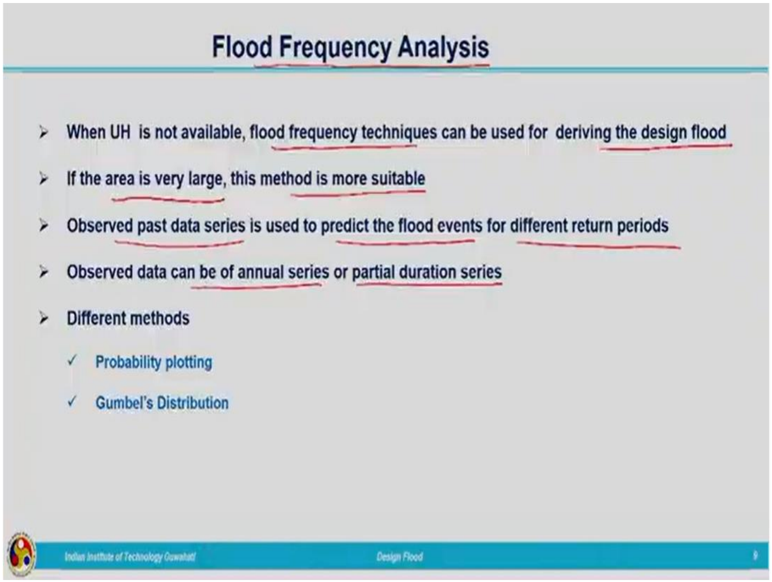

Sometimes it can happen the catchment is very large and in some other cases it can happen in such a way that unit hydrograph is not available for us to derive the flood characteristics. So, in that case, we can make use of flood frequency techniques for deriving the design flood. Unit hydrograph is available, if the catchment is large then also we can make use of flood frequency analysis. So, here in this case this method is applicable when the area is very large.

If the area of the catchment under consideration is very large, this method is more suitable than that of unit hydrograph approach.

Frequency analysis we have already discussed in the previous module. Same method we will be using here but our main intention is to find out the design flood. There when we were solving the problem, we were giving emphasis to the approach which we have used, that is we have done by making use of probability plotting and by means of Gumbel's method, we have given the importance to the approach which we have used. Here in this case, our intention is to find out the design flood for hydrologic design, any of those methods can be utilized here for carrying out the flood frequency analysis. For that, we will be collecting the past data series and this past data series will be utilized to predict the flood events for different return periods. Depending on the type of the structure for which we are going to carry out the hydrologic design, certain return period will be there, corresponding to that return period we need to find out the magnitude of the particular hydrologic event, it may be storm it may be flood. So, here we are talking about design flood. So, we need to find out the magnitude of the flood value corresponding to a particular return period which we are considering for the hydrologic design. For that we will be making use of the past data series, long series of data will be collected, frequency analysis will be carried out for that data series.

While talking about the data series, it can be annual maximum series or partial duration series. In the case of annual series, we are considering the peak value of streamflow, that way for every year we will be having one data point. There can be other peaks which are slightly lower than this highest peak. When we compare this second peak and third peak with the peak of next year, it may be higher than that value, but we are omitting that in the case of annual series. In the case of partial duration series what we will do, we will decide a threshold value, above that what are the values coming, those values will be considered, instead of considering single value, above the threshold value, what all are the values coming, all those values will be considered and form the partial duration series. Depending on the requirement, we will be choosing annual series or partial duration series. So, observed data series can be of annual series or partial duration series.

Different methods which we commonly used for flood frequency analysis are probability plotting and Gumbel's distribution. These two methods in detail we have seen in the topic of hydrologic statistics. So, I am not repeating it here. We will just solve one problem related to Gumbel's distribution here.

So, that much about flood frequency analysis. This is actually an application of the previous topics, because design flood computation is the determination of the flood value which has to be utilized for hydrologic design. It can be either probable maximum flood or it can be calculated based on rational formula or by making use of empirical equations for particular regions or by making use of the unit hydrograph method you can find out the design flood and by making use of flood frequency analysis also you can find out the magnitude of the peak flow. So, these are different methods to determine the design flood. So, that much about this module on hydrologic design.

We need to find out the design storm and design flood before carrying out the hydrologic design. So, the values of this design storm and the design flood depends on the return period for which the design needs to be carried out. It may be varying from 5 to 100 years or more than that or sometimes we will be going for making use of probable maximum precipitation and probable maximum flood for the hydrologic design. But always we will prefer to make use of the magnitude of the extreme event corresponding to certain return period than opting for probable maximum flood and precipitation. That is why we have to make use of the determination of designs storm and design flood by making use of any of these methods.

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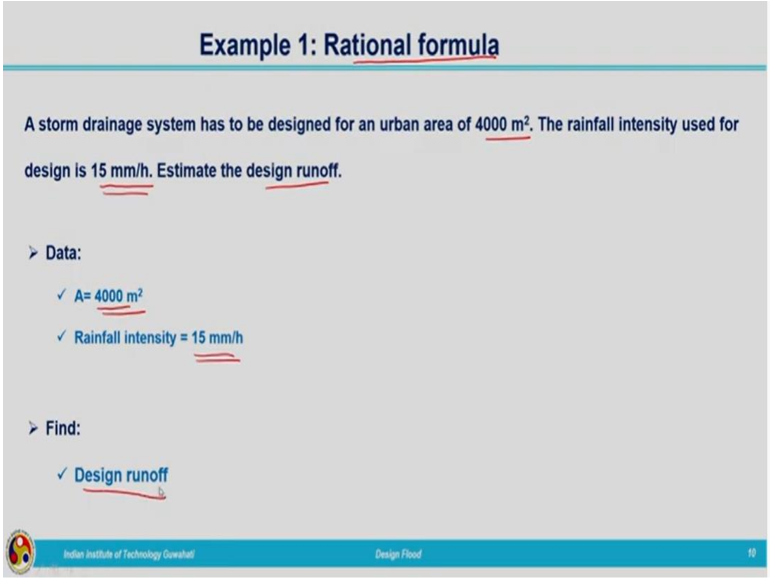

Now, let us solve some examples related to this. First example is on rational formula. Let me read out the question first. A storm drainage system has to be designed for an urban area of 4000 meters square. The rainfall intensity used for design is 15 mm per hour, estimate the design runoff. The question is related to rational method, area is given to you, rainfall intensity is given to you. So, this rainfall intensity might have determined for the required time of concentration, that we need not have to worry here because we have been given the intensity of rainfall. Sometimes this intensity of rainfall might not have given to you, especially when you do for hydrologic design then you will not be having the intensity of rainfall. In that case you have to first derive the IDF curve, intensity duration frequency curve, time of concentration by making use of the catchment analysis, either you can make use of Kirpich formula or some other formula which you find in literature and once that time of concentration is determined that can be considered as the duration for which the intensity has to be chosen. By making use of that duration, we can choose the intensity of rainfall from the intensity duration frequency curve. After that, you can make use of rational formula for computation of the peak flow. This method we commonly use in the case of small urban areas, where majority of the areas are paved or the imperviousness is very high, this rational formula gives a reasonable result.

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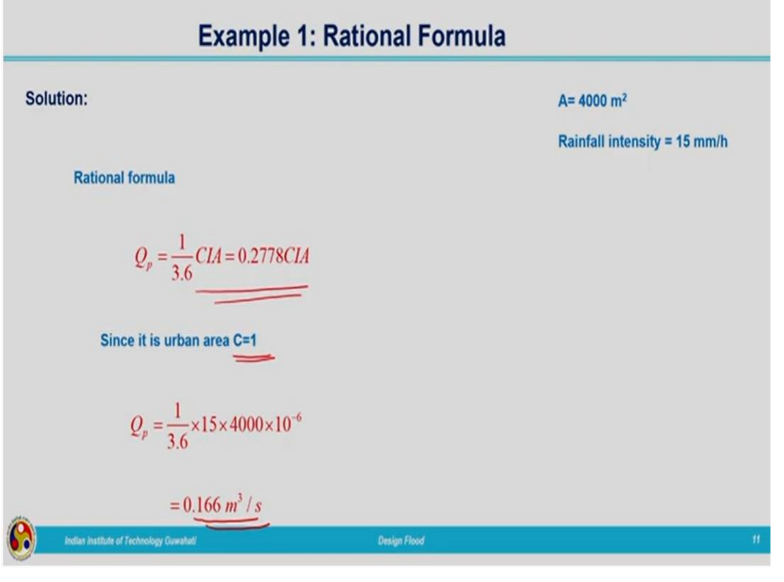

So, the data given are: area is equal to 4000 meters square, rainfall intensity is 15 mm per hour. One thing is not given to you, rational formula is given by *Q* is equal to *CIA*, one coefficient is there definitely, but intensity of rainfall is given to you, area of the catchment is given to you, *C* value is not given here, but it is mentioned in the question that it is an urban area. So, that we can assume that complete area is impervious and *C* value can be taken as equal to unity. By assuming that value, *C* value is unity, we can find out the design runoff by making use of the rational formula. Rational formula is given by this equation

$$Q_p = \frac{1}{3.6} CIA = 0.2778 CIA$$

We can substitute the values corresponding to *C*, *I*, and *A*. Since it is an urban area, we are going to consider *C* is equal to 1 and when you substitute the values for *C*, *I*, and *A*, you can compute Q_p as

$$Q_p = \frac{1}{3.6} \times 15 \times 4000 \times 10^{-6} = 0.166\ m^3/s$$

This is a simple way even though it is approximate for computing the Q_p value for a catchment were data scarcity is there. We do not have large number of data series to carry out the analysis and we do not have much idea about the unit hydrograph for the particular area, in such cases, simply by calculating the intensity value corresponding to the particular duration equal to or greater than time of concentration, you can get the intensity of rainfall that can be utilized for the computation of peak discharge.

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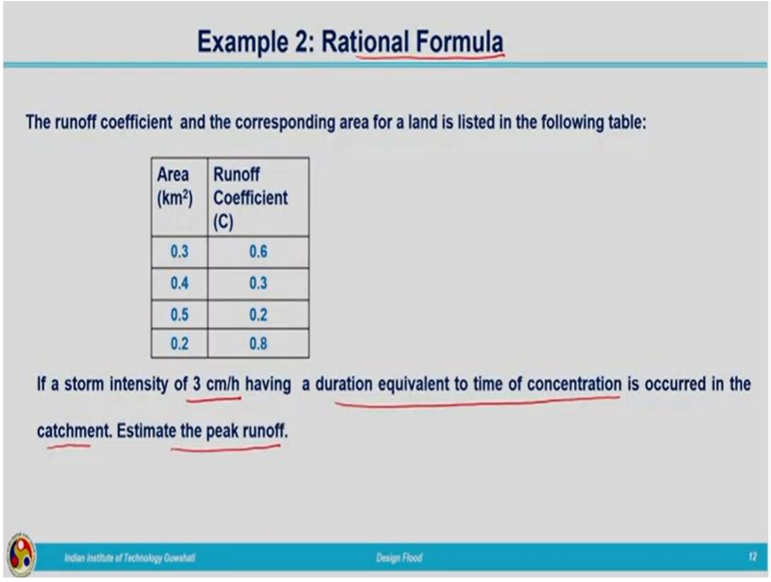

Now, let us move on to the second example. Again, it is based on rational formula. The runoff coefficient and the corresponding area details for a land is listed in the following table. Area in kilometer square and runoff coefficient corresponding to those areas are given to you. If a storm intensity of 3 centimeter per hour having a duration equivalent to time of concentration is occurred in the catchment, estimate the peak runoff? You have been given *C* value separately for different areas in a particular land area. Intensity of rainfall is also given to you. We need to find out the *Q* value. So, here in this case, we need to find out the equivalent *C* value. *C* value corresponding to each and every area, sub areas are given to you, so we can compute the equivalent coefficient of discharge can be calculated.

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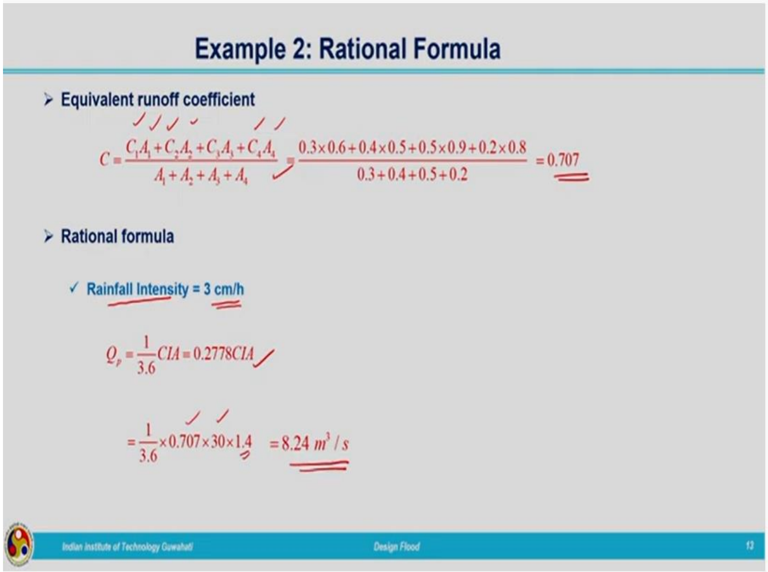

So, first let us determine the equivalent runoff coefficient. Equivalent runoff coefficient can be calculated by using this formula

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3 + C_4A_4}{A_1 + A_2 + A_3 + A_4}$$

So, weighted area runoff coefficient we are calculating that is why we are using this formula sum of C_1A_1 plus C_1A_2 plus up to C_4A_4 is divided by the total area will be taken. So, the equivalent runoff coefficient can be calculated by using this formula. Here we are having C_1, C_2 up to C_4 and A_1, A_2 up to A_4 values are given to us. We can just substitute in this equation and you can get

$$C = \frac{0.3\times0.6+0.4\times0.5+0.5\times0.9+0.2\times0.8}{0.3+0.4+0.5+0.2} = 0.707$$

This is the value corresponding to equivalent runoff coefficient.

Now, we can make use of rational formula. Rational formula requires rainfall intensity, which is given in the question as 3 centimeter per hour, we need to substitute in millimeters per hour, it will be 30 millimeters per hour and this is our formula corresponding to rational method i.e.,

$$Q_p = \frac{1}{3.6}CIA = 0.2778CIA$$

We can substitute *C*, *I*, and *A* in this. So, area we are taking as total area. The total area is coming out to be 1.4 kilometers square. So,

$$Q_p = \frac{1}{3.6} \times 0.707 \times 30 \times 1.4 = 8.24\ m^3/s$$

So, this is the way in which the land use characteristics are given to you, that is land use characteristics directly not given over here, corresponding to different land use present in the area, it will be taking different *C* values. Those *C* values are being given to us. That can be utilized here for finding out the weighted *C* value, after that you can substitute in the rational formula to compute the peak flow value.

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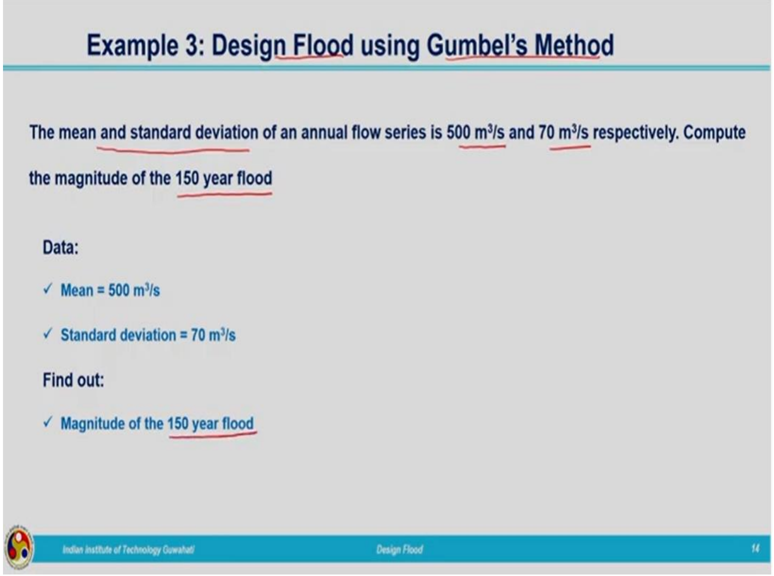

Now, one problem related to Gumbel's method or the design flood determination we can carry out. This is not new to you, you have already solved one example in the previous module, that is design flood using Gumbel's method, that is we are going to make use of frequency analysis.

The question is the mean and standard deviation of an annual flow series is 500-meter cube per second and 70-meter cube per second respectively. Compute the magnitude of the 150-year flood? You need to compute the magnitude of 150-year return period flood. Mean and standard deviation of the sample data is already given to you. Sometimes it may happen in such a way that you have been given the data series, from that you have to calculate the mean value and the standard deviation value, instead of that directly these values have been given to you. So, the data given our mean and standard deviation, and we need to find out the magnitude of 150-year flood, return period is 150 year.

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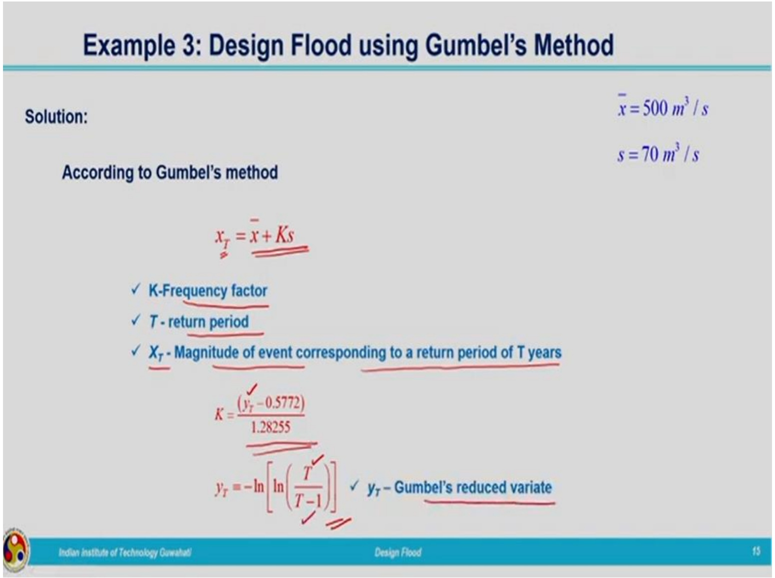

Now, we will move on to solve the numerical example, we know Gumbel's equation. Separately, we are having one particular equation for probability density function and another equation for cumulative distribution function. So, here we will be making use of the cumulative distribution function. According to Gumbel's method, we can write the magnitude of an event for a return period of T as

$$x_T = \bar{x} + Ks$$

Directly we are using that formula, I am not going to the part related to parameters of the cumulative distribution function, all those things. Here we are going to directly make use of the formula under frequency factor method. K is the frequency factor and T is the return period, x_T is representing the magnitude of event corresponding to a return period of T years. So, here in the question we have been asked to find out x_T for a T value of 150 years. What is K actually. The formula corresponding to K we have already discussed while explaining the frequency analysis using Gumbel's distribution, extreme value Type I distribution. So that K is given by

$$K = \frac{(y_T - 0.5772)}{1.28255}$$

This is the equation corresponding to K. Now, what is this y_T? y_T is nothing but the Gumbel's reduced variate, we are having the relationship of y_T and return period. So, we can compute the y_T value by making use of this equation corresponding to a return period of 150 years, that is what we are going to do. So, y_T the Gumbel's reduced variate is given by this equation

$$y_T = -\ln\left[\ln\left(\frac{T}{T-1}\right)\right]$$

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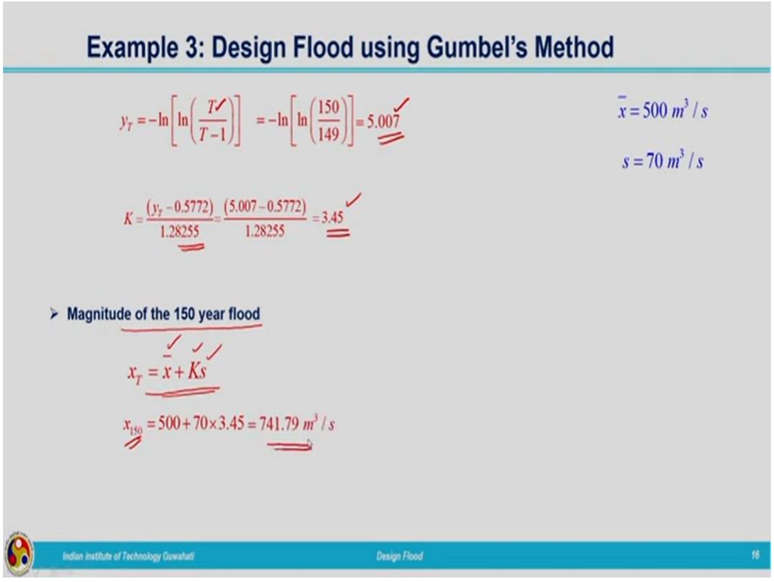

Let us calculate the value corresponding to Gumbel's reduced variate, y_T. Here we can substitute T is equal to 150. So, this can be calculated by using this logarithmic equation that is coming out to be

$$y_T = -\ln\left[\ln\left(\frac{T}{T-1}\right)\right] = -\ln\left[\ln\left(\frac{150}{149}\right)\right] = 5.007$$

y_T is obtained as 5.007. Now, by making use of this y_T we can find out the frequency factor K. K is equal to

$$K = \frac{(y_T - 0.5772)}{1.28255}$$

So, here we are substituting y_T value which is calculated here corresponding to a return period of 150 years. So, we can calculate the value of K as

$$K = \frac{(y_T - 0.5772)}{1.28255} = \frac{(5.007 - 0.5772)}{1.28255} = 3.45$$

Next step is to determine the magnitude of the 150-year flood. So, we can make use of the frequency factor expression x_T is equal to

$$x_T = \bar{x} + Ks$$

$\bar{x} = 500 m^3 / s$ and $s = 70 m^3 / s$ are given to us in the question, K we have determined over here as 3.45. We are just substituting in the equation of x_T, x_T is x_{150}, our return period is 150 years. So, this can be calculated as

$$x_{150} = 500 + 70 \times 3.45 = 741.79 \; m^3 / s$$

So, this is the magnitude of the 150-year flood corresponding to the data given to us and this is represented by means of a single value here. You can define a confidence interval and you can provide a range of values that is range within x_1 and x_2. So, within that range, any value can be taken up by this magnitude of 150-year flood. So, that I am not doing over here, for that you need to have more understanding about probability concepts.

So, here I am winding up the topic related to design flood. These type of problems, variety of problems you should work out then, whatever be the way in which the question is asked, you will be able to solve that. Mainly our aim is to find out the magnitude of the event corresponding to a particular return period or sometimes the magnitude of the event will be given to you, you may have to go for computation of the return period. That we have seen in the case of Weibull's approach, that is probability plotting method we have seen, frequency analysis by using the probability plotting approach, in that case we have discussed about the determination of return period corresponding to a given flood value. So, different types of problems can be derived on this topic. Try to solve as much number of problems. So, this is our last lecture related to this engineering hydrology.

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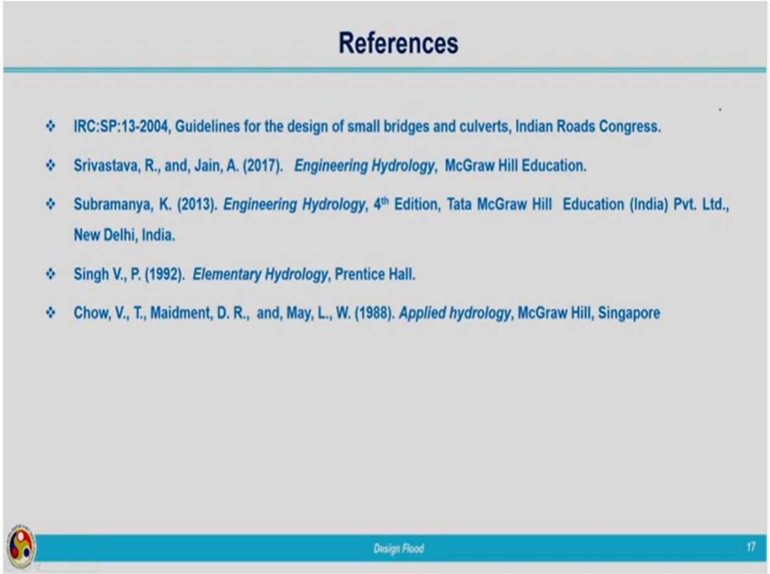

These are the references related to this particular topic. Here. I am winding up this lecture. Thank you.