**Soil and Water Conservation Engineering**
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**Lecture - 09**
**Modifications in Universal soil loss Equation – Part II**

Welcome friends. Welcome back to NPTEL online certification course entitled Soil and Water Conservation Engineering. I am Rajendra Singh, professor in Agricultural and Food Engineering department, IIT, Kharagpur. We are in week number 2. It is lecture number 9 and the topic today is Modifications in Universal soil loss, equation part 2 that simply means that it is a continuation of previous lecture.

In the previous lecture also, we saw modifications in universal soil loss equation that was part 1 and today, we continue onwards go to part 2; just to give you an idea about the course contain for this week. Once again, in lecture 6, we started with soil loss estimation and there we saw the use of the one of the most popular equations known as Universal soil loss equation for estimating the soil loss.

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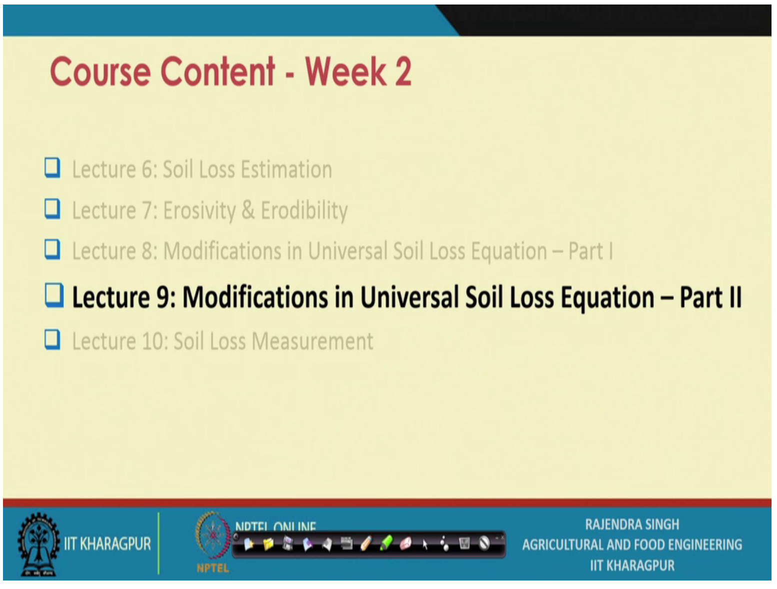


Lecture 7 we spent on determining two important components of universal soil loss equation that is erosivity and erodibility. And in lecture 8, we saw that universal soil loss equation has been modified to modified universal soil loss equation and just to remind you in modification is that rainfall erosivity index or rainfall erosivity factor which is a part of universal soil loss equation that is replaced by a runoff factor.

And in the runoff factor they are 2 unknowns that is V Q which is surface runoff volume which is normally determined using SCS curve number and in lecture 8, in part 1, we covered that modification universal soil loss equation. The second unknown is Q P or peak rate of runoff and in today lecture; lecture 9 we will go through the modifications inverse of soil loss equation part 2 and we will start with the how to find Q P. And then we will further go ahead and in last lecture of this week, we will cover soil loss measurements.

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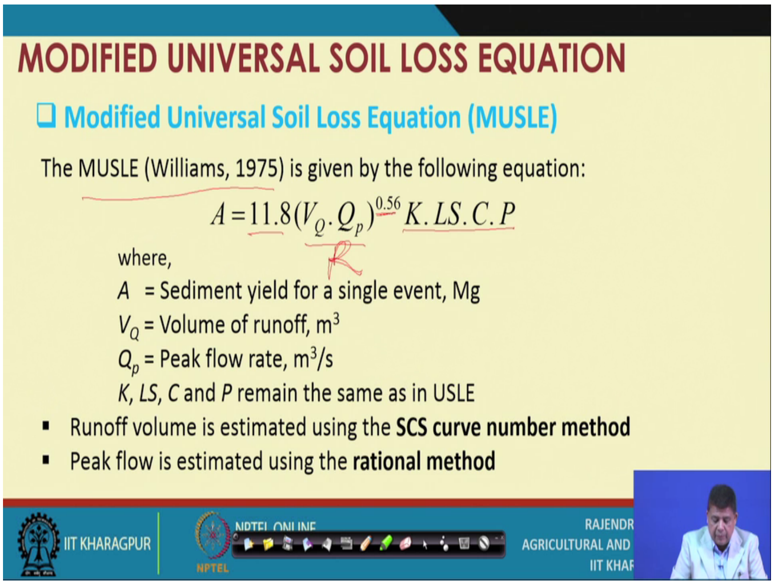


So, let us begin with today's lecture, just to give you once again idea about the modified form of universal soil loss equation. So, the modified form of universal soil loss equation is given by William's in 1975 and it is given by the following equation A equals to 11.8 V Q times Q P to the power 0.56 and K. LS. C. P and you remember the universal soil loss equation original form is A equals to R. K. LS. C. P. So, basically this R which is the rainfall erosivity index that is replaced by runoff factor here and here just now I mentioned that V Q is volume of runoff. And this runoff volume is estimated using the SCS curve number method and the other unknown is Q P that is P flow which is estimated using rational method.

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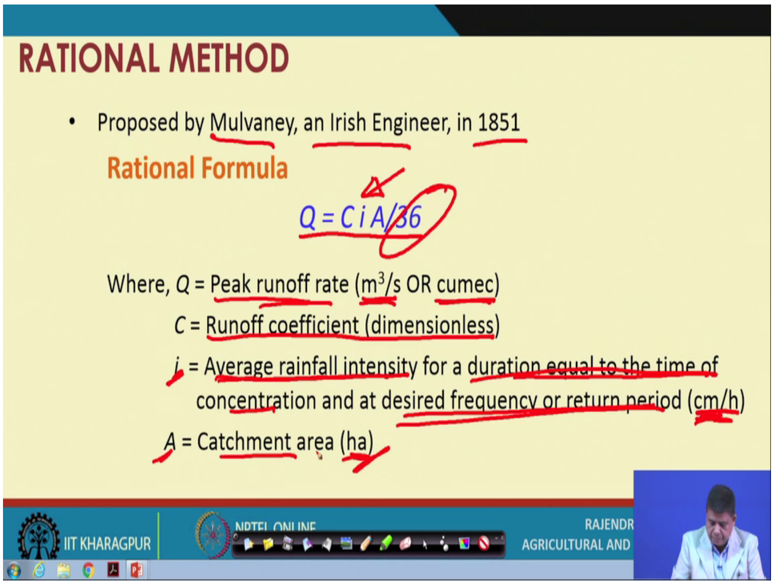


So, rational method let us start with rational method, it is proposed by Mulvaney a an Irish engineer way back in 1851 and this is given by this relationship Q equals to C i A by 36, where Q is the peak runoff rate in cubic meter per second of cumec. C is a dimensionless runoff coefficient, i is the average rainfall intensity for a duration equal to the time of concentration and at desired frequency or return period and the unit used is centimeter per hour and A is the catchment area in hectares.

So, once again because we are using this C i A by 36 a like any empirical equation if we have to use this constant 36, then we must always remember that unit of i is in centimeter per hour and unit of A is in that is catchment area in hectares; that we have to remember. And like while discussing about the universal soil loss equation few lecture back, I told you that there are certain things, as a student you are always expected to remember. And rational formula is one such thing that if you have read hydrology, if you say that you are agricultural engineer, then it is expected that you will always remember rational formula along with its variables.

So, just repeat you rational formula is Q equals to C i A by 36 where Q is the peak rate of runoff in cubic meter per second or cumecs, C is runoff coefficient i i definition of i is little tricky. So, you must remember that is a average rainfall intensity in centimeter per hour, but it is define for a duration equal to time of concentration and a desired frequency or return period. So, these two qualifiers are very important while defining i for in case of rational formula and A is catchment area in hectare. So, this is rational formula is all about.

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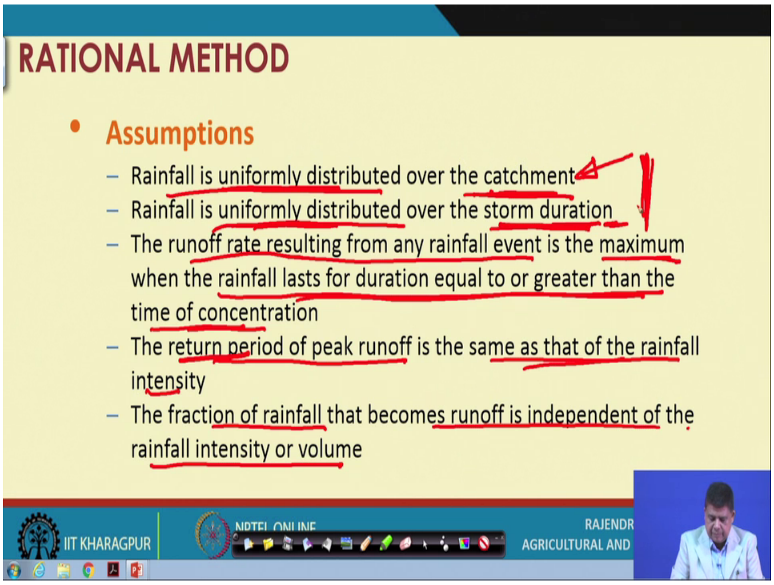


Now, there are certain assumptions of rational formula and these are the assumptions of rational formula that is rainfall is uniformly distributed over the catchment second assumption is rainfall is uniformly distributed over the storm duration. The third assumption reads that rainfall rate resulting from any rainfall event is maximum when the rainfall last for duration equal to or greater than the time of concentration the fourth assumption see is that the return period of peak, runoff is the same as that of rainfall intensity and the last one says that the fraction of rainfall that becomes runoff is independent of rainfall intensity or volume. Let us take this assumptions one by one and basically, you can see here it the first one says that whatever be the area of your catchment rainfall is assume to be uniform throughout.

So, be they area of 10 hectares or 10 square kilometers the assumptions say that rainfall uniformly distributed over the entire catchment second is about the storm duration, the again the assumption say that the storm duration could be of 1 hour or 5 hour duration, but rainfall intensity remains, it is assumption that rainfall intensity remains uniform over the entire duration. The third one is the basic reason behind the definition of intensity of rainfall you remember, we define rainfall intensity is in rational formula is ever rainfall intensity having a duration equal to time of concentration and that comes because of the assumption that it is assumed that the runoff rate will be maximum when the rain fall last for duration equal to or greater than the time of concentration.

So, if a rainfall event occurs for a duration equal to time of concentration or longer duration, then the runoff rate will be maximum that is a peak rate of runoff will be generated and the next one is that the return period of peak runoff is same as that of that is there is a equivalence between the rainfall and runoff that is the assumption. So, these are the assumptions and as you can very well imagine, if you just concentrate on the first 2, we know that there are hardly any rainfall or other in other words we see many rainfall events where it rains at one part of the area town campus whatever you call and it does not rain next or maybe 500 meters away you will find that there is no rain.

So, it is very hardly, it is difficult to get a rainfall event where the rainfall uniformly distributed over the entire area of interest same things true with the distribution of rainfall over the storm duration we know that any given rainfall event the intensity of rainfall goes up and down, it rain is very heavily for some duration then becomes milder and then might become very heavy. So, hardly there is any rainfall event where the rainfall is uniformly distributed over the storm durations.

So, these are the assumptions which bring question mark to rational method, but practically it is seen that it gives a pretty good estimation of peak rate of runoff and that is why it is quite properly use this in spite of these limitation as for as the assumption are concerned.

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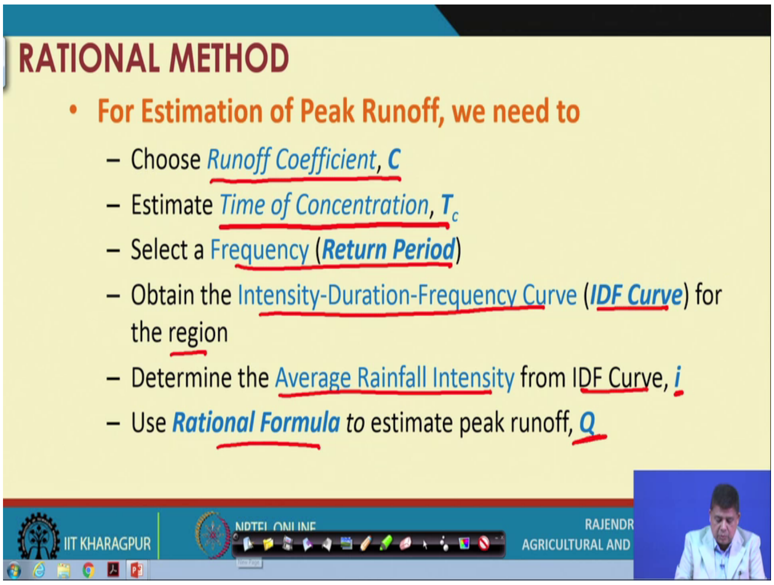


Now, for estimation of peak runoff using the rational method these are the steps we need to follow that is we have to choose the runoff coefficient C for the watershed we have to estimate the time of concentration T c, we have to select a frequency or return period for defining the rainfall intensity,. We have to obtain the intensity duration frequency curve or idea curve for the region, then we have to determine the average rainfall intensity from IDF curve which is i in the C i A by 36 and then finally, use the rational formula to estimate Q Q P or peak rate of runoff. So, these are the steps we need to follow, let us see one by one; how to do these or take these steps.

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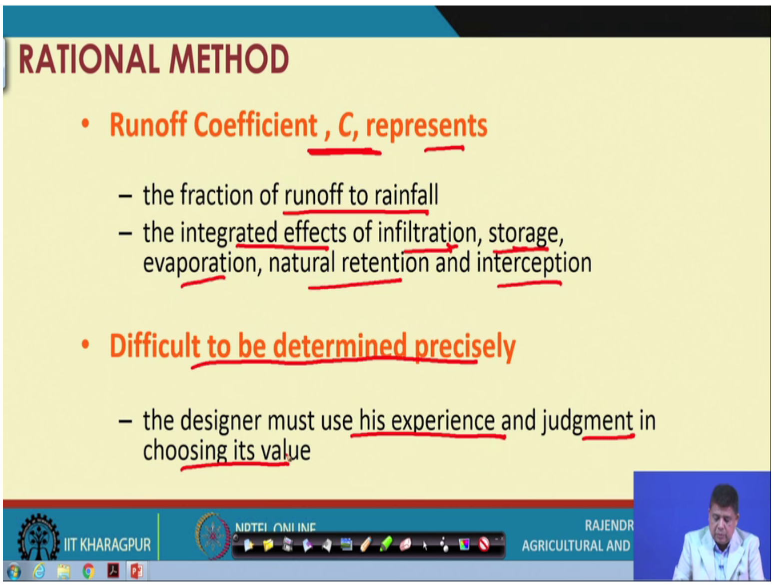

So, first thing is runoff coefficients C which basically represents the fraction of runoff to rainfall that is a part of rainfall get convert into runoff that is represented by C at basically, it represents integrated effects of infiltration storage evaporation natural retention and interception. So, a lot many abstractions which we consider in hydrological cycle before when rainfall occurs there are certain abstraction before rainfall get convert into runoff to the integrated effect of all those abstractions are represented by this runoff coefficient C. And as you can imagine because each of these process are quite complex is very difficult to determine the precise value of C and so, that designer must use his or her experience and judgment in choosing its values.

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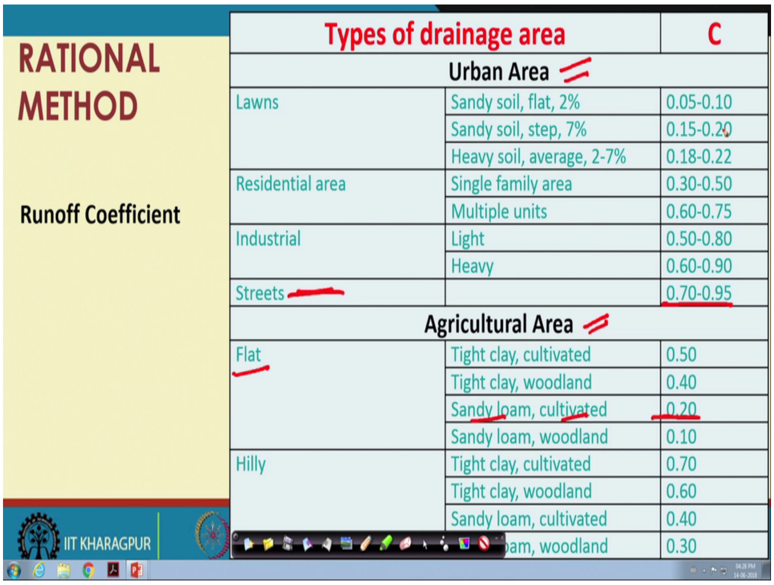


So, it is a little subjective matter and there are standard tables available for obtaining the value of season of coefficient and for that the drainage area is divided into urban area and agricultural area and then various kinds of users are here and then value of C is recommended accordingly. For example, if you see streets which is supposed to be quite impervious in nature; that means, and that means, no absorption of rainfall takes place there and the value of C is 0.7 to 0.95.

This means that because absorption is less almost 70 to 95 percent of the rainfall gets converted into runoff, then if you look at the agricultural area say flat agricultural area and if you look at the sandy loam soil which is cultivated the value of C is 0.2 that simply means that only 20 percent of rainfall is getting converted into runoff. So, depending upon whether we are in urban area or agriculture area depending upon various kinds of uses the value of C can be red and also there is a range. So, that is where the experience of the modular or user comes into picture.

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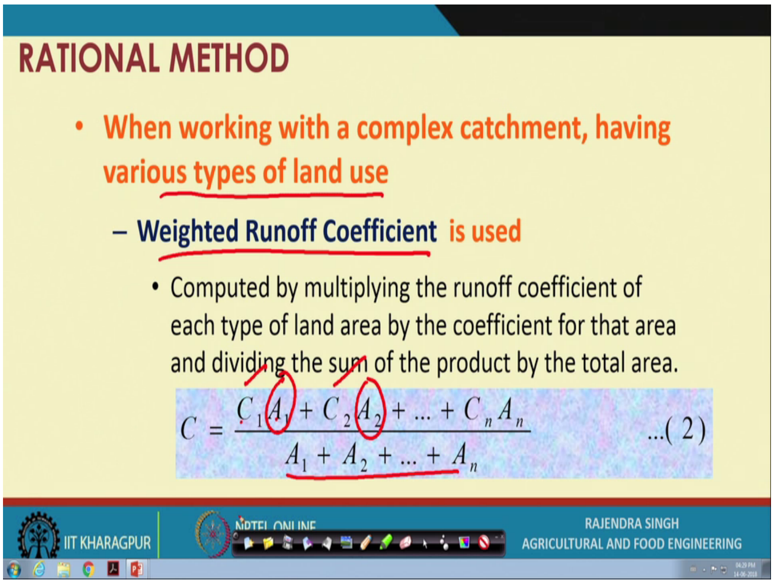


Now, many times; when we work in a catchment the there is various types of land uses are possible like we saw in the case of when we were discussing SCS curve number, then also we saw that because of the land you changes curve number changes. And then we have to use the weighted curve numbers same concept is use here that we have to use weighted runoff coefficient; that means, we in a in a given area if land suppose there are different land uses over 2 land area.

So; obviously, for corresponding to these land uses, we have to get the value of runoff coefficient from table and then we have to get the weighted runoff coefficient for the area by first multiplying the corresponding values of C and A summing up for all land uses that will be the numerator and denominator will be the total area of the catchment under consideration. So, this is how the weighted runoff coefficient is obtained.

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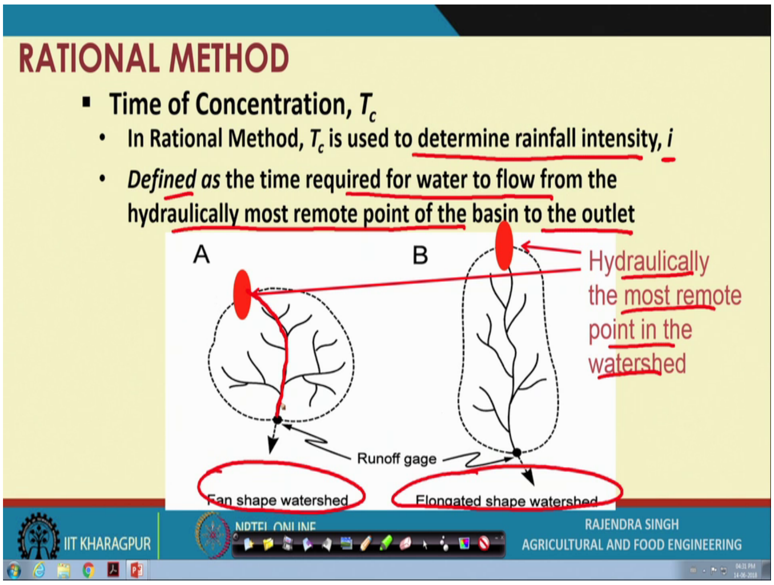


Then next important thing is time of concentration we have to find. So, in rational method T c r time of concentration is used to determine rainfall intensity because remember we define i for a duration equal to time of concentration and time of concentration is defined as the time required for water to flow from the hydraulically most remote point of the basin to the outlet.

So; that means, for defining T c; for finding of the T c, we first have to find out hydraulically, the most remote point in the watershed and; obviously, it depends on the shape of the watershed also. So, if a it could be a fan shape watershed it could be elongated shape watershed. So, depending upon that if it is a elongated then; obviously, it will be longitudly placed with respect to outlet wherein, if it is a fan shape then it may be little down either on left or right depending upon the fan shape basically. So, here basically the time of concentration means that time required for a drop of water root travel following the following the stream path to the outlet.

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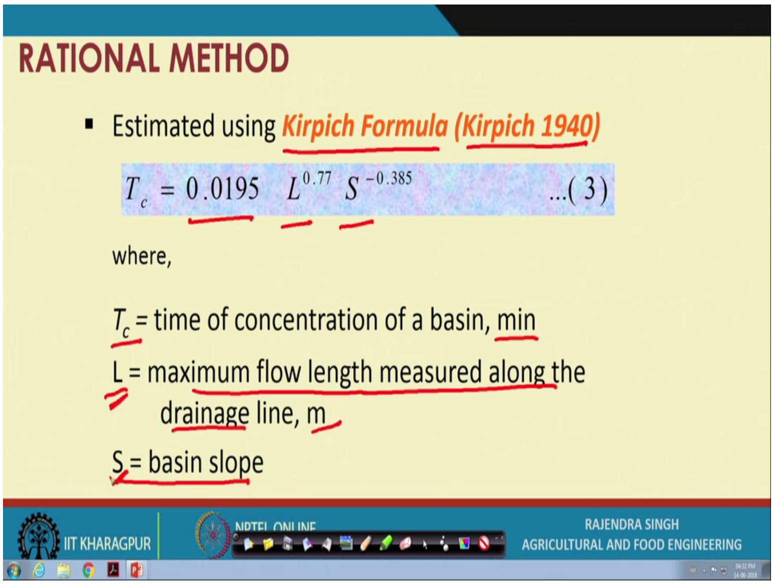


So, that time is defined as the time of concentration and typically time of concentration is estimated using a formula famous formula known as Kirpich formula which was given by Kirpich 1940 and as per this formula T c is equal to 0.0195 L to the power 0.77 S to the power minus 0.385 where time of concentration T c is in minutes L is the maximum flow length measured along the drainage line.

Just now we saw how L is found out in meters and S is basin slop. So, that is simply means that in order to use the Kirpich formula, we should know the maximum flow length and the basin slop. So, these two components we have to know and then we can use Kirpich formula to find the time of concentration.

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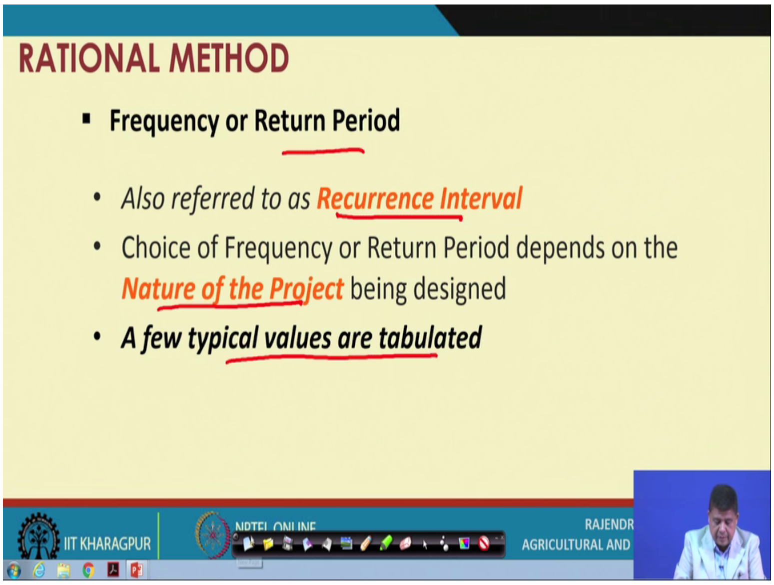


And then also associated is that because i is defined for time equal to time of concentration and a for a given frequency. So that means, we have to also decide on a frequency or return period which is also referred to as recurrence interval return period or recurrence interval and choice of frequency or return period basically depends on the nature of project how risky the structure we are going to design and a standard tables are available for referring these values.

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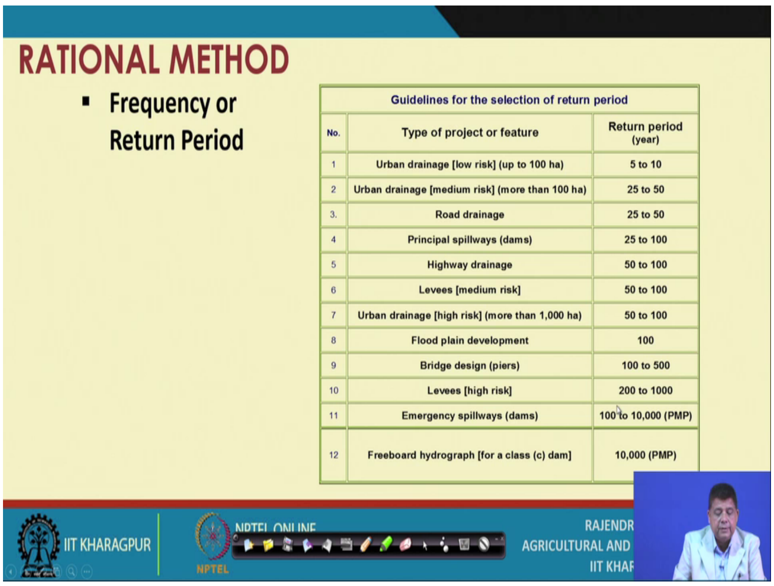

For example, we can see this table where guideline for selection of return period is the title. So; obviously, depending upon the structure, say for example, if you are having simple road drainage then the return period could be 25 to 50 years where in if you see serious structure, we are going to design. For example, if you are going to design a emergency spillway for a dam where the risk to life of people is too high, then we take 100 to 10,000 years return period and PMP means probable maximum precipitation. So, so depends on what kind of structure we are designing based on that recurrence interval or return period is chosen.

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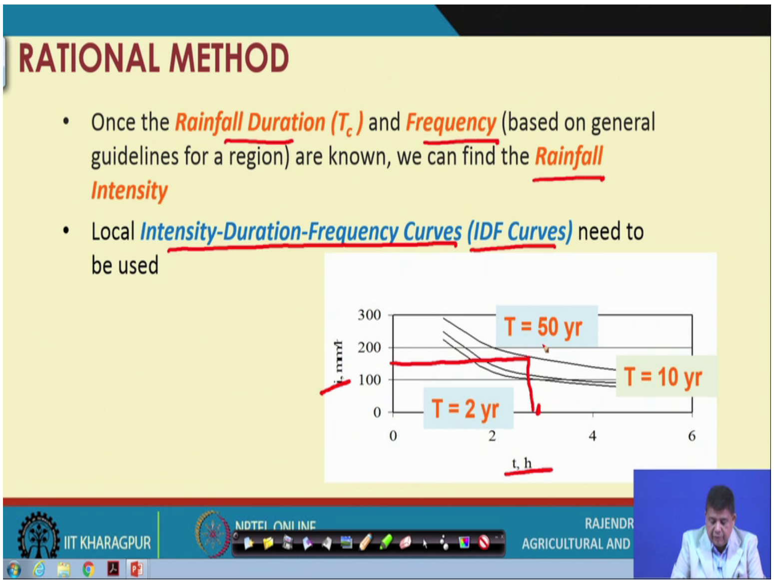


Then once the duration rainfall duration T c the time of concentration and frequency that is rainfall duration frequency are obtained then we can find the rainfall intensity at for that we use the rainfall duration frequency curve i intensity duration frequency curve IDF curve which is popularly known which basically relates i that is rainfall intensity in millimin per hour to storm duration T in hours.

So, here this i is plotted against T for difference return period. So, for example, if our T of interest is say 3 hours somewhere here and our T value is 50 so; obviously, we can find out using this relationship what is the intensity which we are interested or intensity for duration equal to time of concentration and of desired frequencies. So, this is how we use IDF curve to find out the intensity duration frequency curve and once everything is decided then we have to simply use the rational formula.

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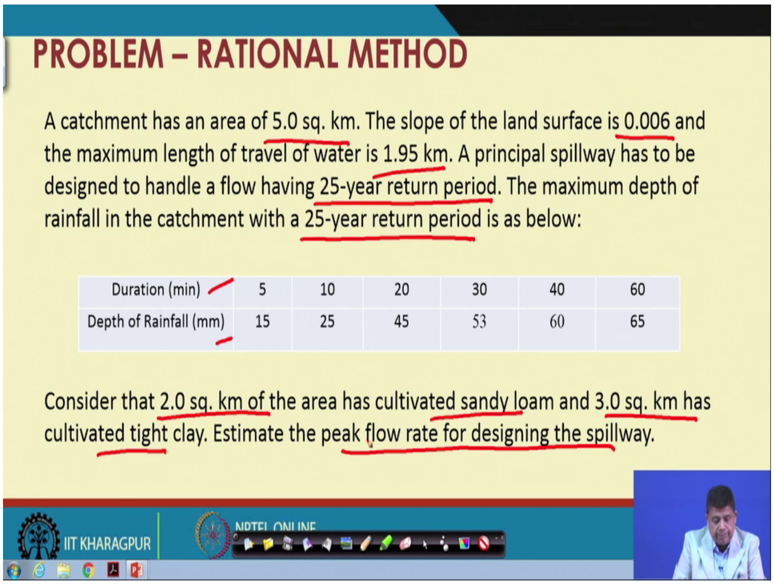


So, let us take a problem and see how to solve using rational formula. So, to problem states that is catchment has a total area of 5 square kilometers and slope of land in 0.006 maximum length of travel is 1.95 kilometers. And a principal spillway has to be designed to handle a flow having 25 year return period the maximum depth of rainfall in the catchment with 25 year return period is given below.

That means, intensity duration frequency characteristics are tabulated here there is for different durations the depth of rainfall for 25 year return period is given here consider that 2 is square kilometer area has a cultivated sandy loam and 3 square kilometer has cultivated tight clay estimate the peak flow rate for designing this spillway. So, almost all data or information is given and we have to design you find the peak flow rate using the rational formula.

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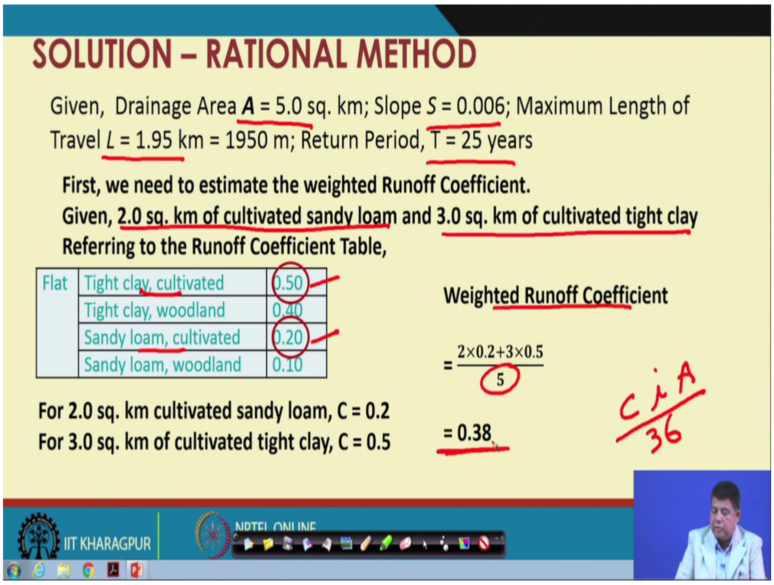


So, coming to solution, we have been given drainage area A remember, we have to finally, use the equation C i A by 36 this is the formula we have to use. So, area is given 5 square kilometers, but remember the unit here is hectare. So, we have to; obviously, convert slope is given at 0.006 length of travel is given an 1.95 or 1950 meters return period is given a 25 years. Remember in 5 square kilometers of total catchment area, we have 2 land uses; 2 square kilometer of cultivated sandy loam and 3 square kilometer of cultivated tight clay. So obviously, we have to read the runoff coefficient table and we find that for cultivated tight clay the values is 0.5 and cultivated sandy loam the value is 0.2.

So; obviously, the corresponding value we have obtained for both kind of land uses for weighted runoff coefficient we can find out by first multiplying 3 multiplying the area and the sea and then summing up that is 2 into 0.2 plus 3 into 0.5 divided by the total area; so, based on that our weighted runoff coefficient value comes out to be 0.38.

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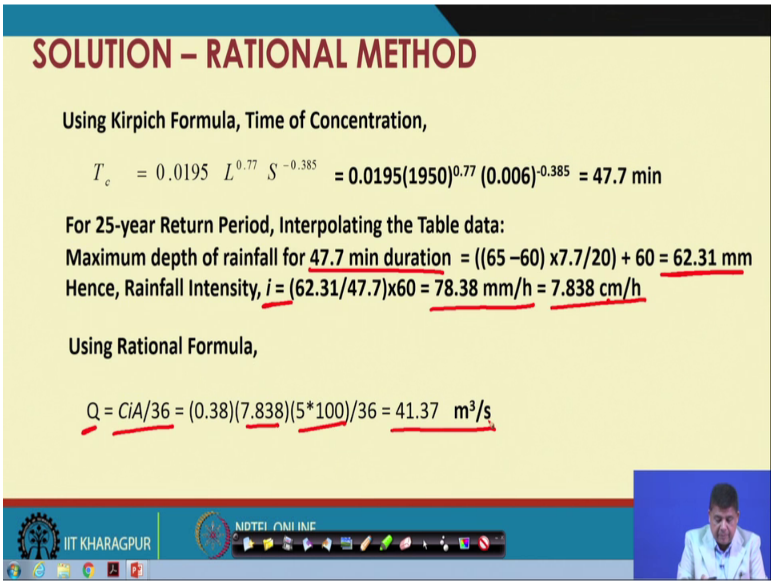


Then; obviously, we have to use the Kirpich formula for obtaining the time of concentration. So, T c is given by this relationship we already know the value of L and S. So, L putting the value of L and S we get T c equals to 47.7 minutes and for 25 year return periods we have to interpolating the table data. So, if we really want to go back to our table then we have to obtain the values so; obviously, from this 47. point 47.7 minute duration, we have to get the value of maximum depth of rainfall which will come out to be 62.31 millimeters and then rainfall intensity, we have to calculate which comes out to be 78.38 millimeter per hour or 7.838 centimeter per hour.

So, i is known to us C already we have found out; A is already given. So, using C i A by 36 that is using a formula K equals to C i A by 36 by putting the values i you have to use in centimeter per hour a we have to use in hectare. So, that is why 5 square kilometer in multiplied by 100 and then divided by 36, we get the value which comes out to be 41.37 cubic meter per second that is the that is the peak flow rate that we have be obtained using the rational formula.

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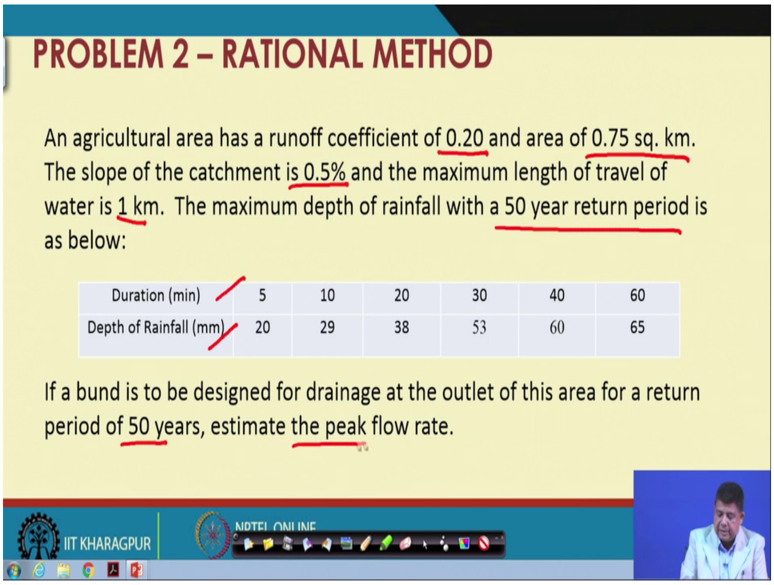


Let us take another problem to see how to once again use the rational method. So, an agriculture area has a runoff coefficient of 0.2 and area 0.75 square kilometers. The slop of catchment is 0.5 percent, maximum length of travel of water is 1 kilometer. The maximum depth of rainfall with 50 year return period is given here, that is for different durations, the depth of rainfall is given. If the bund is to be designed for drainage at outlet for this area for return period of 50 years, estimate the peak flow rate that is the problem.

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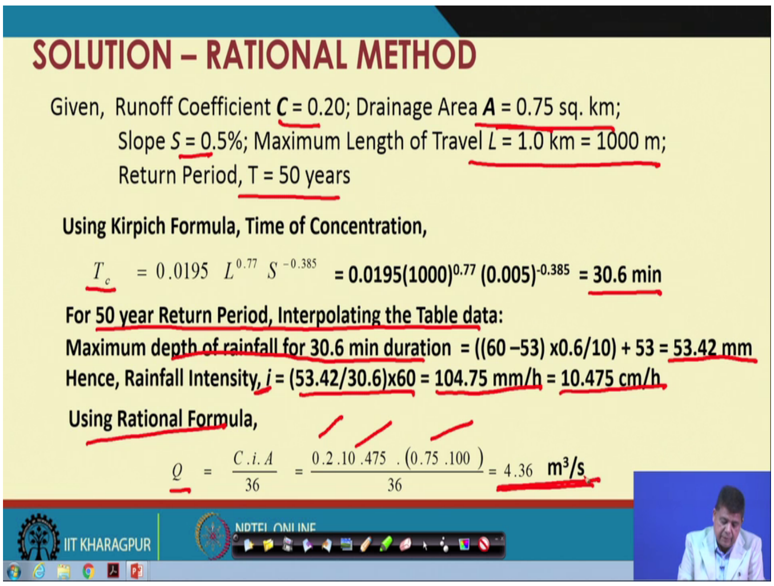

So, coming to solution the value of C is given drainage area is given slope is given maximum length of travel is given return period of 50 years is given. So obviously, we can use Kirpich formula to obtain the time of concentration supporting the values in Kirpich formula, we get a value of 30.6 meters minutes. And then again given the 50 year return period table data, we have to interpolate the value correspond to 30.6 miters and which if you do then maximum depth of rainfall for 30.6 minute durations we obtain 53.42 millimeters. And that means, the rainfall intensity we have to convert for hour this is only for 30.6 minutes.

So, then we get the rainfall intensity is 104.75 millimeter per hour or ten 0.475 centimeter per hour. So, that is the intensity and then you can use rational formula Q C i A equal to 36 C value is already given 0.2 here rainfall intensity in centimeter per hour, we have obtained ten 0.475 and area drainage area has to be used in square hectares. So, we have 0.75 square kilometers. So, 0.75 multiplied by 100 and then divided by 36, we get a total peak flow rate of 4.6 cubic meter per second or cumec. So, that is what our intense was that we need to estimate the peak flow rate using the rational method and that is how we saw the rational method and application in estimating the peak flow rate.

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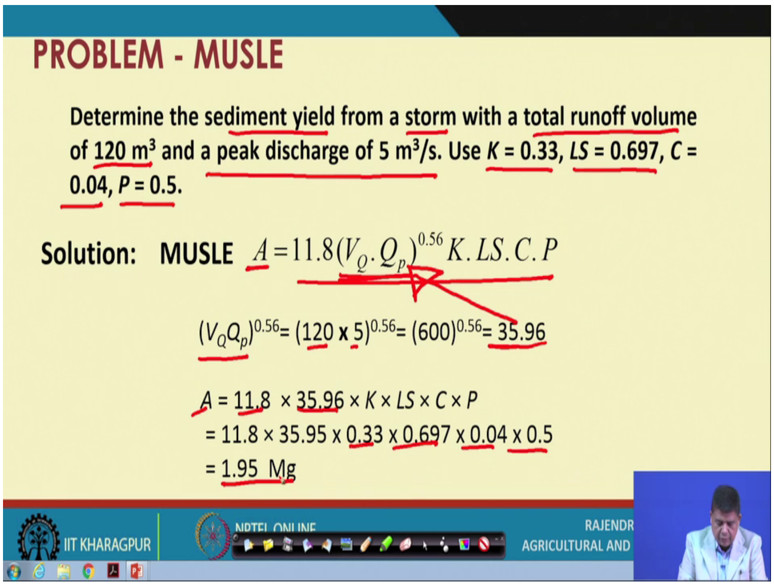


Now, we can take a problem straightway on modified universal soil loss equation because now we know how to determine various component parameters or variables.

So, the problem is determine the sediment yield from a storm with a total runoff volume of 120 cubic meters and a peak discharge of 5 cubic meter per second use K equals to 0.33 LS equals to 0.697 C equal to 0.04 and P equals to 0.5 and MUSLE or modified Universal soil loss equation a is given by this formula. So, almost all variables are already values are straight away given here. So, first thing we have can determine is this component. So, V Q Q P to the power point 6.

So, one value of V Q is 120 Q P is 5 already given. So, using this, we get the value component value of 35.96 and then we can put the value together equation a equals to 11.8; 35.96 that is the value which we obtained for V Q Q P to the power point 6 K. LS. C. P. value of K. LS. C. and P. are straightaway given. So, using this relationship we can get the soil loss 1.95 mega grams or tones. So, that is how we can use the modified Universal soil loss equation, once, we know all the variables or the components of the equation.

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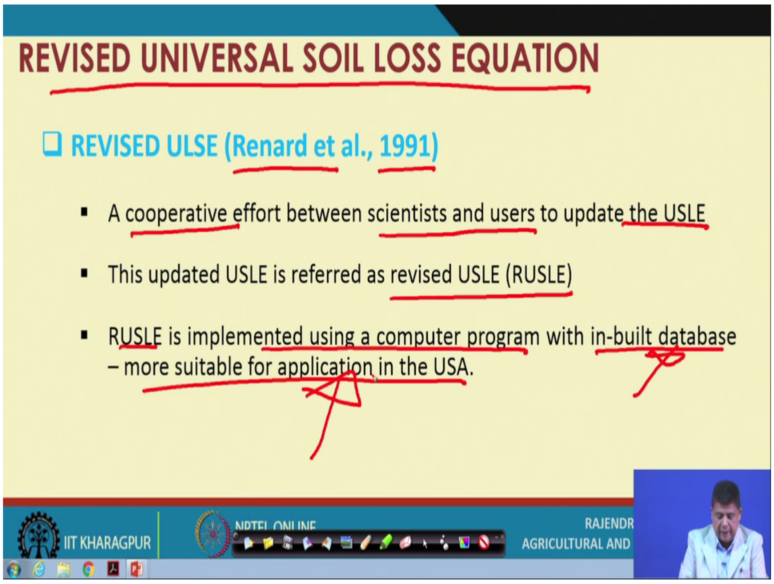


There is one more variation of universal soil loss equation is available and that is referred to as revised universal soil loss equation. So, this is a third one; we had universal soil loss equation, we had modified universal soil loss equation now we have revised universal soil loss equation which was proposed by Renard and others in 1991.

So, basically REVISED USLE is a cooperative effort between scientist and users to update USLE. So, USLE has been updated and we will see what are the various new things that has been brought into this updated version which is referred to a revised USLE or RUSLE. So, we saw USLE, MUSLE and now we have RUSLE the most important thing change is that RUSLE is implemented using a computer program with inbuilt database which is more suitable for application to the USA.

So, basically there is a computer program now at there is a database, but only problem limitation is that this database has been generated primary for United States of America. So, that is the only limitation, but good thing is that all computations can be done using a computer program.

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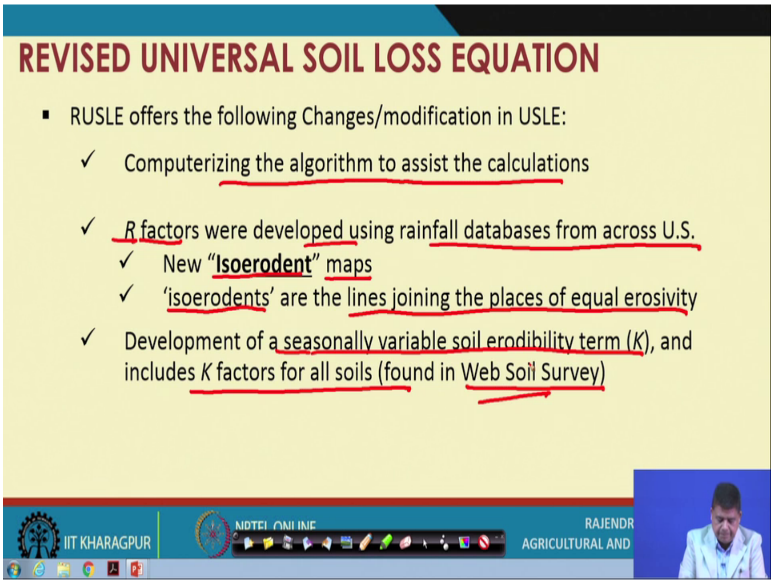


And the changes offered in the RUSLE are; obviously, computerizing the algorithm to assist the calculation. So, user does not have to bother, then R factor were developed using rainfall data bases from across U.S. So, all the database that was available across the us does have been used for getting the R factor value and that simply means that new Isoerodent maps have been generated and used and just for your reminding you for reminding you, Isoerodents are the lines joining the places of equal erosivity.

So, equal erosivity maps have been generated and used in case of RUSLE and; obviously, next change is that seasonally variable soil erosibility term K which includes for all soils found in the web soil survey has been developed that is now K has been developed for all kinds of soils number one and number two the because from one season to other the crops type could change. So, soil erodibility of the soil characteristics could be affected. So, seasonally variables soil erosdibility term has been generated for use in case of RUSLE.

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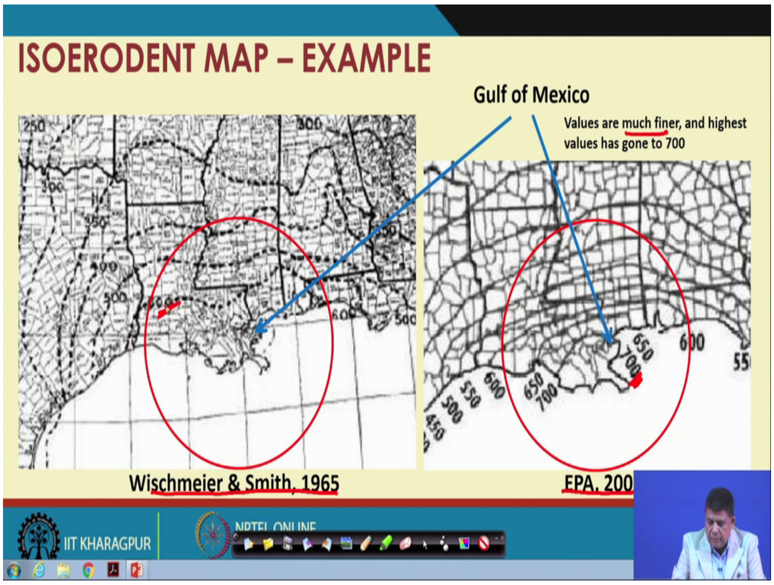


And just to give an idea this is the Isoerodent map example and this one the older one was used by Wischmeier and Smith in 1965 and new one is developed by EPA that is environmental protection agency in 2001 and if we just June in the same that is Gulf of Mexico area.

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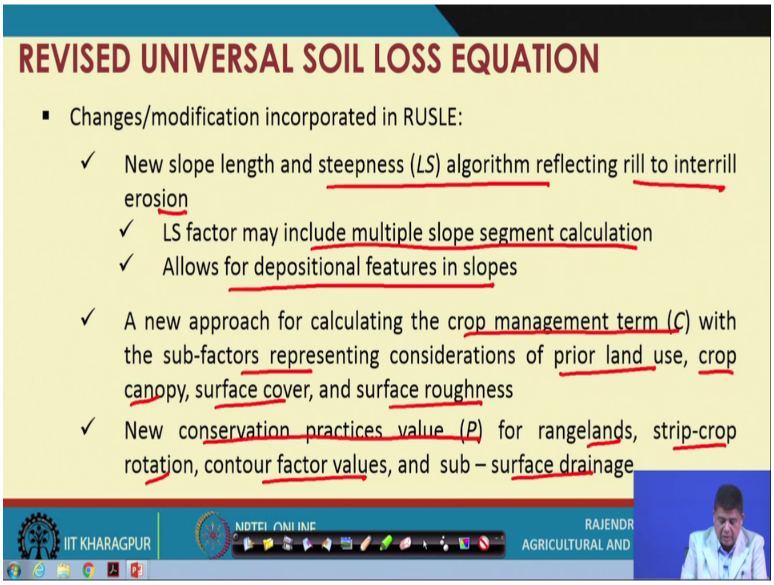

So, you can see you here the isoerodent maps are the values are much finer and highest value has gone even up to 700 as compared to the 600 that was the limit in case of alien map. So, much finer value of erosivity index can be obtained using the new isoerodent maps and other changes are the new slope length and steepness algorithm reflecting rill to interrill erosion has been incorporated the LS factor may include multiples slope segment calculations that is slope could change and it also allows for depositional feature.

In case of USLE, we were not allowing any kind of solve deposition, but here RUSLE allows deposition also and there is a new approach for calculating the crop management terms C with sub factors representing prior land use crop canopy surface covered. And surface runoff that was much better value of C is now available and also, there is a new conservation practice value P for rangelands strip crop rotation contour factor values and subsurface drainage.

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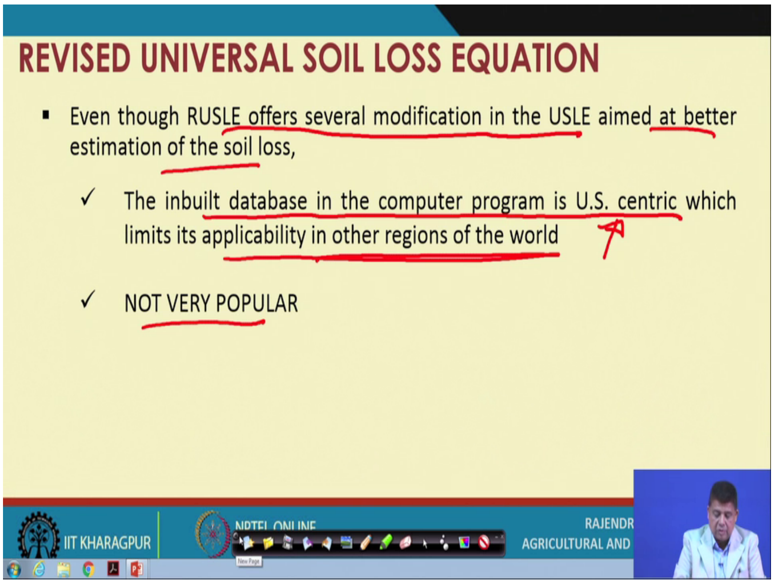


So that means, new conservation practices have been also incorporated in revised universal soil loss equation, but the issue is that even though it offers several modification USLE aimed at better estimation of soil loss it is not. So, popular because of the simple reason not very popular because of simple reasons that the inbuilt database in the computer program is U.S. centric which limit its applicability in other regions of the world.

So, there are 7 modification done in RUSLE, but its application has remained limited to united states because the database which is inbuilt in the program that is more US centric. So, this is one of the major limitations that is why revised simplex method revised universal soil loss equation is not very popular and with this, we come to the end of this class.

So, we really saw how to use rational method for estimating Q P grade of runoff for use in the modified universal soil loss equation. And then we saw the application of rational method as well as modified universal soil loss equation and then finally, we saw the latest revision that is revised universal soil loss equations. So, all 2 versions; we have covered in last three lectures also.

Thank you very much.