Engineering Hydrology
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Module 4 - Lecture 51
Summary of Module 4

Hello all, welcome back. We have covered detailed topics on surface water in previous couple of lectures.

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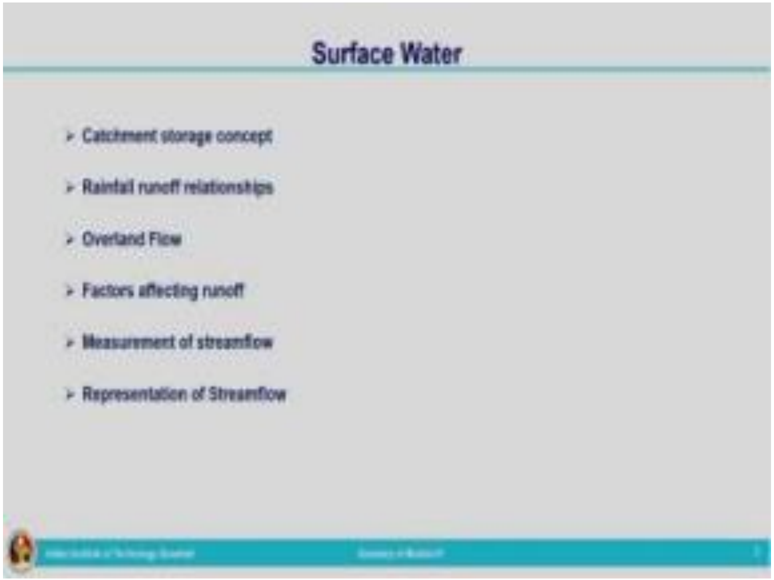

Let us revisit into that. The topics which we have covered in this module are catchment storage concept, rainfall runoff relationships, overland flow, factors affecting runoff, measurement of streamflow and representation of streamflow. In the previous lecture, we have seen representation of streamflow and after that we have completed our syllabus related to surface water.

Let me revisit into all these. First one we have covered catchment storage concept. When we talk about a catchment whenever there is a storm, some part of the water will be utilised for satisfying different storage components on the ground surface and beneath the ground surface. So, general way when we classify the storage it is divided into two: retention and detention. Retention is the one in which the water is stored for long time, detention during the time of storm and after that it will be drained away.

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So, this is the general classification of storage. One is the retention and the other one is of detention and again different classification coming under catchment storage components are interception storage, depression storage, surface storage, soil moisture and subsurface storage, groundwater storage, overland flow, channel storage.

In the case of surface flow, we are having flow as overland flow and in the case of subsurface when we talk about from the unsaturated region, there will be interflow once the subsurface storage or the soil moisture storage is satisfied, the interflow will be starting and in the similar way, as far as groundwater is concerned, there is groundwater storage and also groundwater flow. Then coming to the surface, we are having the overland flow and also channel flow. So, all these in detail we have covered and whenever a storm is occurring, all these storages mainly surface storages will be satisfied and then the flow will be starting, surface flow or overland flow will be starting.

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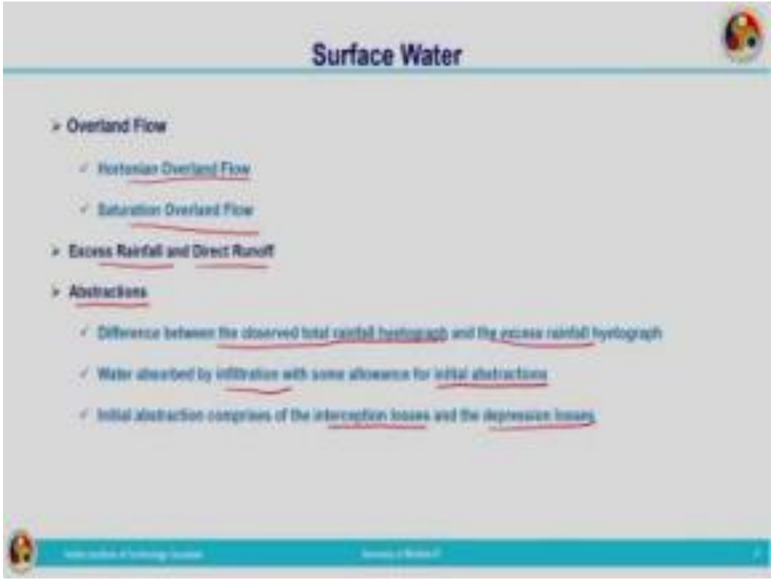

So, coming to overland flow, when we were discussing about overland flow two types we have seen: Hortonian overland flow and saturation overland flow. So, in the case of Hortonian overland flow, the surface is getting saturated from the top, that is we are considering some amount of water which is falling as rainfall will be infiltrated into the ground and after certain time the surface layer will become saturated because the rate of infiltration will be less than that of the rainfall intensity and at that time what will happen, the surface layer of the soil will become saturated. So, in that case what is happening, the soil surface is saturated from the top and whenever rainfall is occurring again and again then the overland flow will be starting. This is mainly because of the saturation of the ground surface from the top and in the case of saturation overland flow, on the other hand, in a hilly region or steeped areas what will happen, whenever rainfall is occurring water will be infiltrating into the ground and because of the gradient or the head, interflow will be starting, because of this interflow soil beneath the ground will be saturated. So, here in this case the saturation of the soil is taking place from bottom because of the interflow, the saturation is taking place and when we come to the downhill portion whenever rainfall is occurring, that surface is already saturated from the bottom and whatever rainfall is falling will be flowing as overland flow. That is in the case of Hortonian overland flow the surface is saturated from the top and in the case of saturation overland flow the surface is saturated from the bottom because of that the overland flow is taking place.

So, here in the entire course of engineering hydrology, whenever we are discussing about overland flow it is Hortonian overland flow. We are not looking into saturation overland flow. And after that we have covered the topic of excess rainfall and direct runoff. Once the storm has occurred and the storage components are satisfied, remaining water will be coming as excess rainfall and that excess rainfall is the contribution towards the direct runoff. So, it is very important whenever we are dealing with any water resources project, any study related to flooding, we need to have the idea about how much is the excess rainfall, that is after the storage components are satisfied remaining how much water is there for contributing as runoff. After that we have seen what is meant by abstractions, that is the difference between the observed rainfall and the excess rainfall, that difference where it is going, it is lost as abstractions. So, during the time of rainy season or during the time of storm, we will be considering only the infiltration losses and the other losses such as interception and depression together as abstractions. So, that is water absorbed by infiltration and initial abstractions. Initial abstractions are including interception losses and depression losses. So, these three are considered as abstractions during the time of rainfall. In addition to this there are so, many other losses that is not considered while calculating the excess rainfall.

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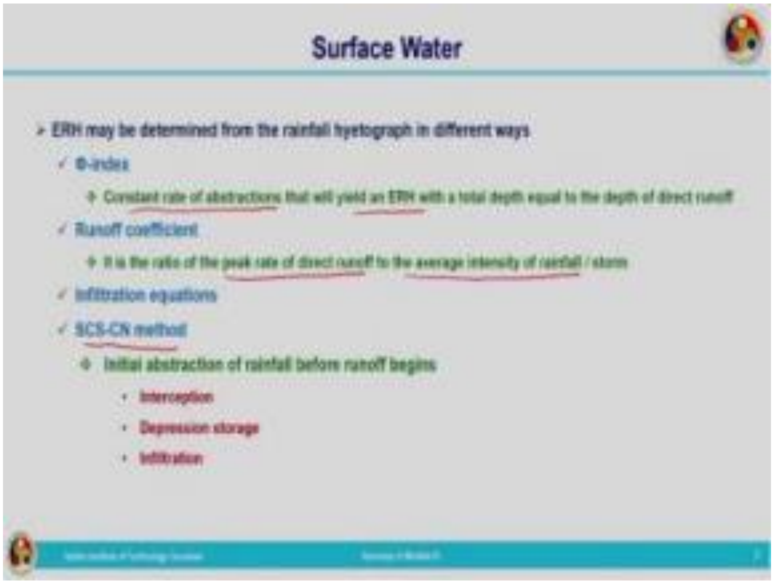

After that we have covered different methods for estimating effective rainfall. So, effective rainfall determination we have started with $\phi - index$. What is $\phi - index$? $\phi - index$ is the constant rate of abstractions that will give us effective rainfall hydrograph, that is we are assuming the abstractions which are taking place in a catchment is represented by a constant value, constant rate. So, that constant rate is inclusive of infiltration and also other initial abstractions. So, if we are having that idea about that $\phi - index$ value, once we deduct that value from the intensity of rainfall for a particular time duration we will get the excess rainfall and after $\phi - index$ we have seen runoff coefficient. Runoff coefficient is the ratio of the peak rate of direct runoff to the average intensity of rainfall. So, if the rainfall and runoff is available to us we can calculate the runoff coefficients. So, once the runoff coefficient is calculated in that particular catchment for any intensity of rainfall, we can calculate the runoff which is producing. So, these two methods that is $\phi - index$ method and the runoff coefficient methods are applicable to gauged catchments, because for the determination of $\phi - index$ and also for the determination of runoff coefficient, we need to have the runoff measured at the outlet point.

If it is ungauged there is no way to calculate these two values that is $\phi - index$ and runoff coefficient. In those cases, that is not the case of ungauged catchments, we will be making use of infiltration equations and another method we have seen termed as SCS curve number method. In infiltration equations, we can make use of any infiltration equation and we will be quantifying the quantity of water which is infiltrated into the ground, that we will be deducting from the total rainfall value, that will be giving us the excess rainfall. In the case of $\phi - index$ instead of that exponential curve, because infiltration rate we have seen it is represented by means of an exponential curve in the case of Hortan's infiltration equation. So, that infiltration curve will be superimposed on the rainfall hydrograph and below the infiltration curve what is coming is considered as the abstraction and above what is coming that will be representing the effective rainfall. So, what we will be doing? We will be deducting the quantity of water which is coming below the infiltration curve from the total rainfall value to get the excess rainfall.

So, after infiltration equation, we have seen fourth method for the determination of direct runoff as SCS-CN method. The full form of this method is Soil Conservation Service-Curve Number method. So, this is actually developed for agricultural watersheds in US. So, in this initial abstraction which are considered are interception, depression storage and infiltration. All these three are considered together as initial abstractions and the hypothesis which is made under this SCS curve number method is the ratio of actual retention of rainfall to the potential maximum retention is equal to the ratio of direct runoff to the potential rainfall minus initial abstraction. So, in this the hypothesis made is that the ratio of the actual retention to the potential retention will be equal to the actual runoff to the potential runoff. So, based on this the final equation of SCS curve number method is developed.

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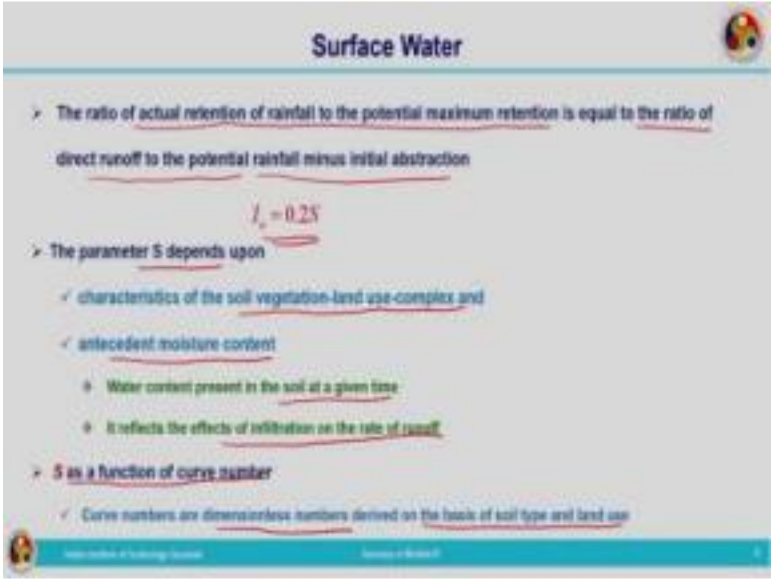

So, here the initial abstraction was found out to be 0.2 times the potential retention, that is potential retention is the maximum water which can be retained within the catchment. So, from the experimental study conducted in small small watershed, it is found out that the initial abstraction can be considered as or assumed as 0.2 times the potential retention. The parameter *S* is depending on the characteristics of the soil-vegetation-land use complex that is it has got influence of soil, vegetation and also land use. What is the kind of soil group, what is the type of vegetation and what kind of land use, whether it is a forest area, whether it is a residential area, urbanised area. So, that way this potential retention depends on all these factors. In addition to that, it is depending on the antecedent moisture content also. So, this antecedent moisture content is nothing but the moisture content prevailing in the soil at a given time, because this water content or the moisture content prevailing in the soil is very important. If it is in a very dry state, the storage will be maximum whatever rainfall is falling, entire water may get infiltrated into the soil in the relatively dry state. But in the case of saturated condition, the rainfall is occurring for a long time and in that stage if we check the soil moisture condition, it will be almost in a saturation state. So, whatever rainfall is occurring it may flow on the surface, amount of water getting infiltrated into the soil will be of very less quantity. So, antecedent moisture condition is having a great role in the case of computing excess rainfall in the case of SCS method.

So, that is it reflects the effects of infiltration on the rate of runoff. If the soil is in the saturated state, the water which is infiltrating into the ground is almost negligible and entire water which is falling as rainfall will be converted to runoff or if it is the first rain or beginning of the rainy season, initially the infiltration will be more and then once the soil becomes relatively saturated surface layer becomes relatively saturated, then only the runoff will be starting. All this depends on the type of the soil, vegetation land use and also the antecedent moisture content present in the soil.

After understanding the relation between all these, *S* is derived as a function of curve number. So, the maximum potential retention is expressed in terms of curve number. A function is provided by a SCS-CN method. So, these curve numbers are dimensionless numbers derived based on the soil type and land use. The curve number is also depending on the land use and the soil type and at the same time antecedent moisture content also. So, there is a relationship which is representing the potential storage and the curve number and by making use of the relationship between the curve number and the potential retention, we can calculate the value corresponding to *S* and we can make use of the formula provided by a SCS-CN method for the computation of excess rainfall or direct runoff or else the method has provided different curves for different curve numbers by taking into account of different soil type, different land use conditions and antecedent moisture conditions, that curve can be utilised for finding out the excess precipitation.

There are so many models which are present, which are available for studying the rainfall runoff relationship that I have not explained over here. We will see some of them in the next module. So, here we have looked into four techniques only for the computation of excess rainfall.

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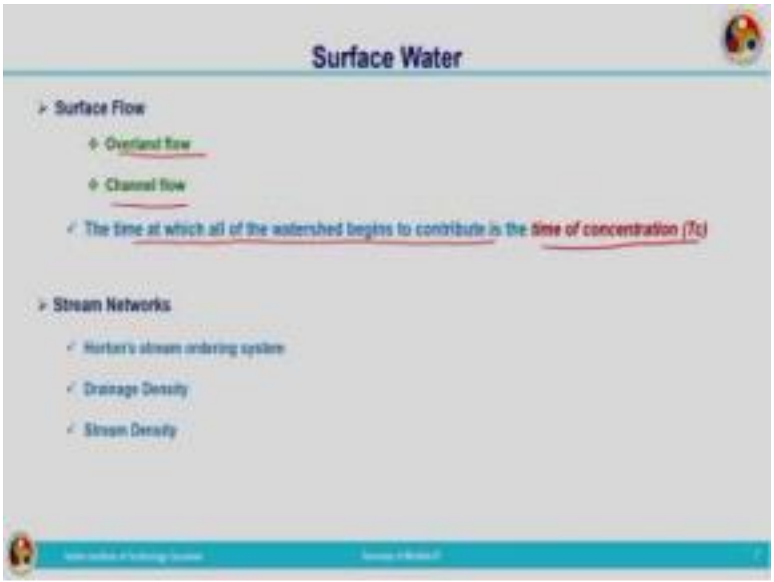

After that, we have moved on to surface flow. Surface flow was incorporating overland flow and also channel flow, that is whenever rainfall is occurring after satisfying the storage components water starts ponding on the ground surface. Initially itself overland flow will not be starting, water starts ponding on the surface and that ponded depth will overcome the surface retention forces then it starts flowing. So, initially the flow will be taking as a sheet flow over a large area. So, that is termed as the overland flow or sheet flow. It cannot travel for long distance as sheet flow. After certain time what will happen? It will be forming its own channels, small small channels will be formed and water will be concentrated into those small channels finally, ending up in a large channel.

So, that way when we talk about surface flow, overland flow and also channel flow both should be understood carefully. Then we have seen time of concentration, this is very important whenever we are talking about watershed hydrology, that is the time at which all the watershed begins to contribute. Whenever rainfall is occurring, the runoff is quantified as the quantity of water reaching at the outlet point. So, the water contribution from the nearest points that is the points which are close to the outlet will be contributing water at the outlet at a faster rate and the water or the rainfall which is falling at the extreme end of the farthest points in the watershed will be contributing runoff at the outlet point at a later time. So, the time taken for the farthest point to contribute water to the outlet point is termed as the time of concentration.

After understanding the overland flow and channel flow, we have gone through stream networks. Stream networks are very important whenever catchment hydrology is dealing with, because these streams are the agents which are collecting the water from different parts of the catchment and making the flow through them to reach at the outlet point, and under stream networks we have covered Horton’s stream ordering system, drainage density and stream density. So, these terminologies are very important, because whenever we are talking about high drainage density is there for a catchment, then the efficiency of the catchment to drain of water is high and easily the water will be drained off to the outlet point. So, when we were discussing about the urbanised catchment, we know the peak is very high, peak is reached earlier because of the well-developed drainage systems in the urban area. So, there in that case drainage density will be high, hydraulic efficiency will be very high.

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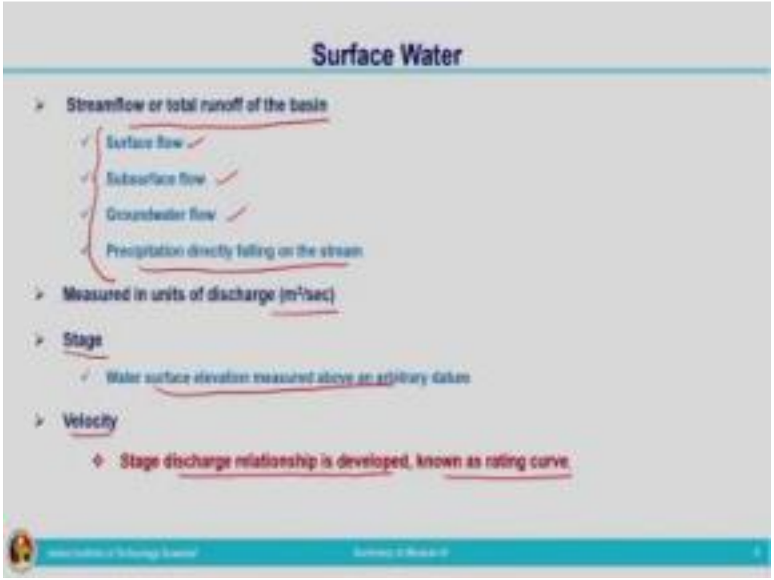

After understanding overland flow and channel flow, we have moved on to streamflow or total runoff of the basin. This streamflow or total runoff is consisting of all these four components, that is surface flow, subsurface flow, groundwater flow, and also the precipitation directly falling on the stream, that is whenever we are having a surface flow, overland flow and channel flow combined together and subsurface flow, infiltration is taking place and because of the gradient interflow will be starting that also will be contributing flow at the outlet. In addition to that there will be contribution from groundwater also and all these three components that is surface flow, interflow, baseflow along with that the contribution from rainfall on the stream together contributes to the streamflow or total runoff at the outlet of the catchment, and the unit of streamflow which we express is in terms of meter cube per second, that is the unit of discharge is used for expressing streamflow, and whenever we are talking about streamflow it is difficult to measure streamflow directly. In that case it is found that, if we know the water level measurement, how much is the depth at a particular location and corresponding width also can be measured and along with that if velocity is also measured, we can calculate the stream flow easily than directly going for the measurement of streamflow. So, that is termed as the stage measurement. Stage is representing the depth of water level with respect to an arbitrary datum that is the water surface elevation measured above an arbitrary datum and we will be measuring velocity along with stage to compute the streamflow.

So, once we know the water level or the stage at a particular gauging station and also the velocity, we can calculate the streamflow. So, what we will be doing for different stages different water levels, we will be plotting the curve with respect to discharge. So, stage discharged relationship will be developed that is known as well-known rating curve. So, for a particular stream, this rating curve can be developed and kept and whenever we are having the stage value by making use of this rating curve, we can get the idea of streamflow. Always there is no need to go for measuring velocity. If the water level is known to us based on that by making use of the rating curve, we can get the corresponding streamflow. So, for important gauging stations, rating curves will be already developed. So, by making use of that rating curve, we can get an idea about how much streamflow is there corresponding to your particular water level.

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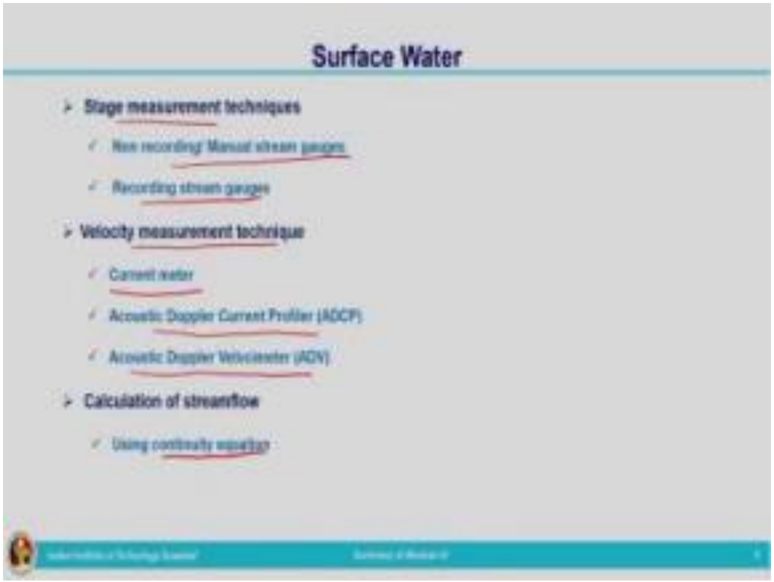

Then, we have seen different methods of stage measurement. Stage measurement includes the non-recording and manual stream gauges and also recording stream gauges. In detail we have seen all these gauges and after that we have moved on to velocity measurement techniques in streams, mainly we are making use of current metre. So, conventionally we used to use current metre. Two types of current metres we have gone through and when we talk about advanced velocity measurement techniques, those are Acoustic Doppler Current Profiler and Acoustic Doppler Velocity metre. All these are working on the Doppler effect. These two advanced techniques are working on the principle of Doppler effect. So, even though we have not gone through in detail methodology related to these two, but basically what it is we have understood. So, these are the three ways of measuring velocity and once the stage and velocity are measured, we can calculate streamflow by making use of the continuity equation and talking about the average velocity, average velocity is not the one which we are measuring by using these instruments. These instruments when as far as current metre is concerned, current metre is giving the velocity at that particular location where we are measuring and in the case of ADCP, it will be giving the profile of velocity, that is entire cross section velocity, direction and the magnitude will be given to us. But what we want for computation of streamflow by using continuity equation we will be measuring the velocity at a depth of at a water depth of 0.6 times the water depth that velocity is considered as the average velocity and in the deeper streams, what we will be doing? We will be measuring the velocity at different location that is it 0.2 times the water depth the velocity is measured and also at 0.8 times the water depth the velocities measured. The velocities at these two depths are measured and the average is taken as the average velocity.

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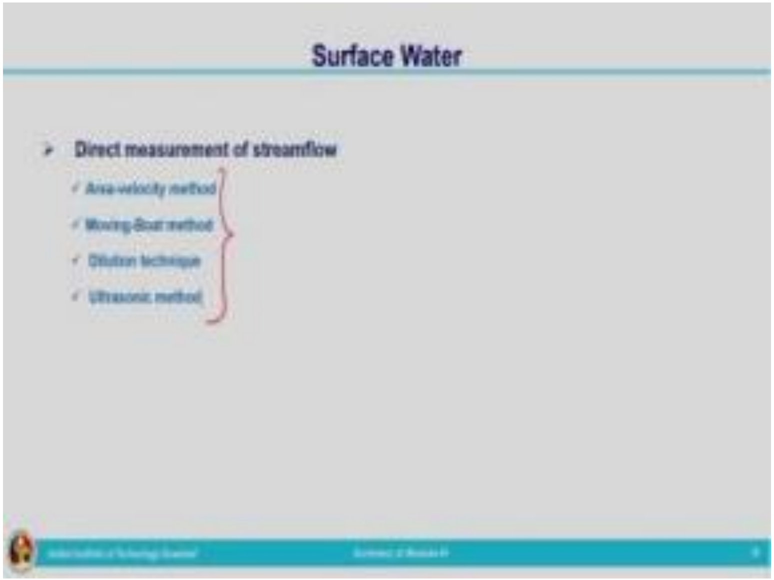

So, different ways of measurement of streamflow includes: area velocity method, moving boat method, dilution technique, ultrasonic method. So, these four methods we have covered for understanding or for the direct measurement of streamflow.

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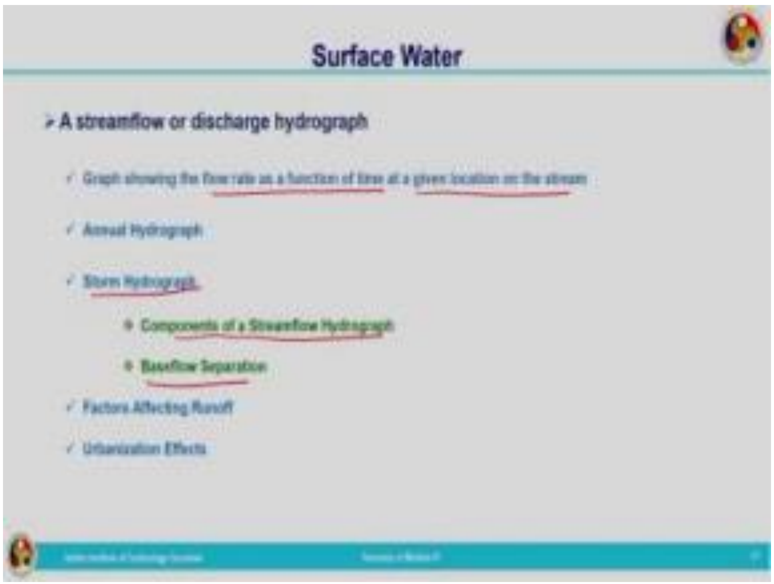

After measuring the streamflow, we are having the streamflow details, how it can be represented for the study purpose. So, streamflow is represented by means of a streamflow hydrograph. It is nothing but the graph showing the flow rate as a function of time at a given location of the stream. Different hydrographs we have seen annual hydrograph and storm hydrograph. Annual hydrograph is nothing but this streamflow is plotted for entire year and storm hydrograph is the graph which is plotted only for the period of storm and also after certain time. Storm hydrograph is plotted for a certain period of storm.

Then after understanding storm hydrograph we have seen different components of storm hydrograph and also different techniques for separating the baseflow. After studying all these things, that is the after seeing a hydrograph, detailed description of hydrograph, components of hydrograph and base flow separation, we have seen the factors influencing runoff. Different factors are there, climatology factors are there, catchment characteristics are there, depending on the type of catchment how much is the runoff coming, all these are different. So, we have seen in a fan- shaped catchment how the hydrograph will be and also in the case of an elongated catchment, how it will be looking like. So, in both the cases the peak flow will be different. In one fan-shaped one, the peak flow will be high, peak will be reaching faster than compared to an elongated watershed. In some other shapes of the watersheds also how the hydrograph will be changing, we have gone through.

Then we have seen the urbanisation effects on storm hydrograph. In urbanised catchment, we will be having well defined drainage system and the hydraulic efficiency of this system will be high and the water will be draining to the outlet point at a faster rate, because of that the peak will be attained faster in the case of urbanised catchment. Not only that, the imperviousness is more compared to rural catchment in the case of urban catchments, imperviousness value is high because of high imperviousness water infiltrating will be taking place at a reduced rate and the majority of the water which is flowing on the impervious areas will be contributing as runoff. That is the reason why in the case of urbanised catchment the peak will be very high and the time to peak is attained very fast because of the highly efficient drainage systems.

So, that much we have covered under this topic of surface water. Now, in the next lecture, we will move on to the fifth module. Thank you.