Engineering Hydrology
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Lecture – 49
Representation of Streamflow

Hello all welcome back. In the previous couple of lectures, we were discussing about surface water. Different processes related to surface water we have already seen and we were with the measurement of streamflow in the previous lecture. For the measurement of streamflow, we were measuring the stage or the water level and also the velocity by making use of different techniques and once the width is also measured, by means of width and the depth of water level, we can calculate the area of cross section and by making use of the continuity principle, we can compute the stream flow by taking the product of velocity and cross-sectional area. So, in this case we are considering the average velocity. So, how to calculate average velocity, that also we have seen.

Today, let us move on to the topic of representation of streamflow. Representation of streamflow means, the measured values for different time intervals are there with us and how to represent that data in a graph, that is what we are going to see in today's lecture. The representation of discharge versus time is termed as streamflow hydrograph.

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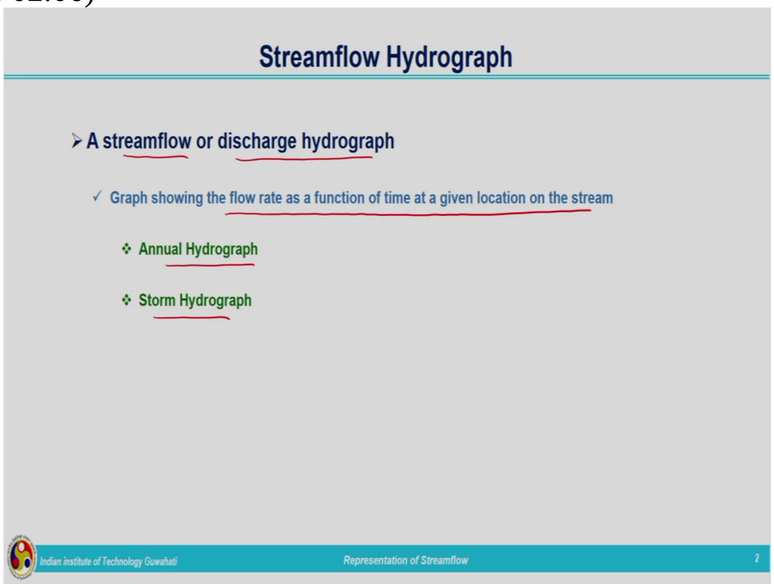

We already know how to calculate the streamflow at a particular gauging station. Water levels and the corresponding velocities at a particular gauging station will be measured based on that we will be calculating the streamflow. If it is continuously observed over time, then we can get the streamflow details corresponding to all the time. So, this is similar to that of a rainfall hyetograph, in the case of rainfall hyetograph we are plotting rainfall intensity with respect to time. It is a discrete curve, but, when we talk about streamflow hydrograph, this is also plotted with respect to flow rate, with respect to time, but this is a continuous curve, that is the graph showing the flow rate as a function of time at a given location on a stream, that is our stream flow hydrograph. So, if you are plotting the water level or the stage at a particular station with respect to time, then it is termed as stage hydrograph. So, usually for hydrologic analysis, we will be making use of the streamflow hydrograph in which the streamflow or the discharge at a gauging station is plotted with respect to time.

Different ways of representing streamflow hydrograph, one is annual hydrograph, second one is storm hydrograph. From the, name itself it is clear that annual hydrograph will be representing the flow data for the entire year and storm hydrograph is the one which is representing the streamflow at the gauging station corresponding to a particular storm. Let us see one by one.

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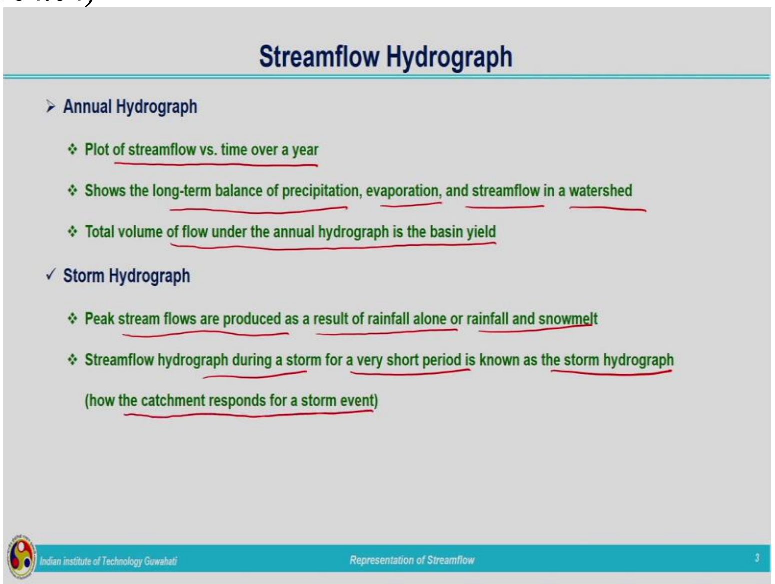

First one is the annual hydrograph. The plot of streamflow versus time for a complete year is the annual hydrograph. So, if you are measuring the streamflow for the entire year, and it is plotting as a hydrograph that is what is termed as the annual hydrograph. This shows the long-term balance of precipitation, evaporation and streamflow in a watershed. From the annual hydrograph we can understand how the water balance is taking place, how the streamflow variation is taking place in a catchment. Because if you are considering the data corresponding to the entire year, in certain months, we will be having rainfall, during some other months we will not be experiencing any rainfall. So, the representation of streamflow, we know already streamflow is consisting of surface runoff, interflow and also baseflow. During the monsoon season only, the contribution from the rainfall and interflow will be coming, rest of the season will be getting water in the rivers by means of baseflow.

So, if we are analyzing the annual hydrograph we will get a clear picture of the contribution of water to the stream from surface runoff, interflow and also baseflow. The total volume of flow under the annual hydrograph is the basin yield. So, whenever a catchment, watershed, or basin is concerned, the total streamflow which is observed there at the outlet point is termed as the basin yield, that is the total volume of flow under annual hydrograph. Annual hydrograph is representing the flow variation or streamflow record against time in a single graph for the entire year. So, the total volume of flow under the annual hydrograph is termed as the basin yield.

Second one is the storm hydrograph. Storm hydrograph is the one which represents the stream flow versus time during the time of a particular storm or rainfall. So, peak streamflows are produced as a result of rainfall alone or rainfall and snowmelt. Some of the catchments will be getting water due to rainfall and snowmelt and some other catchments will be experiencing runoff based on rainfall only. So, the peak streamflows are observed during the time of rainfall and in the catchments where the snowmelt is also taking place, it is a combination of rainfall and also snowmelt. So, streamflow hydrograph during a storm for a very short period is termed as storm hydrograph, that is in the annual hydrograph, we are plotting the streamflow versus time for the entire year. But in the case of storm hydrograph we are not considering the entire year, we are considering the period corresponding to that particular storm or snowmelt is taking place, that is, it is the response of catchment corresponding to a storm event.

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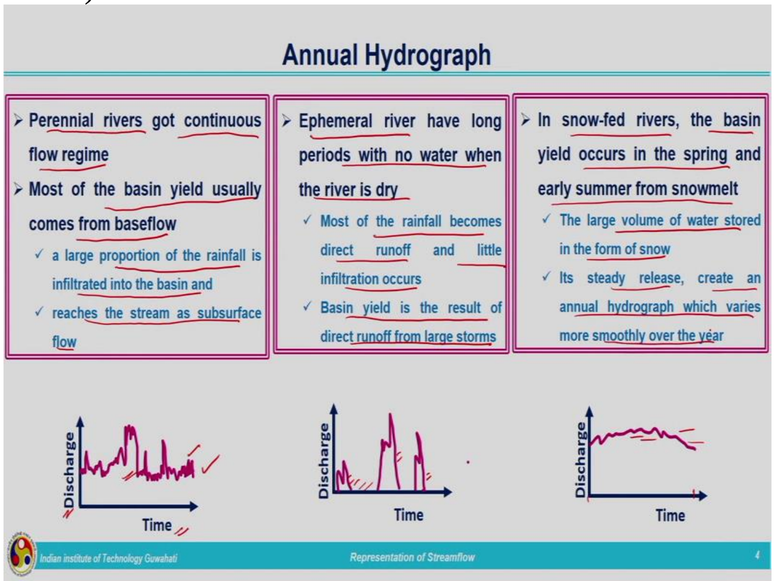

Now, we can see different types of annual hydrographs. When we plot along the *x* axis we are having time, this is corresponding to the entire year and along the *y* axis we are having the streamflow or the discharge in meter cube per second. So, here you can observe that these lines are representing the discharge variation or the streamflow variation in a particular catchment or basin. So, when you observe the curve you can see for the entire period of one year it is displaying the flow or discharge, that is for the entire period we are having streamflow in the river. Second one is the one in which we are having streamflow at certain periods only. In this the time is for the entire year and you can observe that the peaks are there, or the flow details are there corresponding to certain period of year, not for the entire year. And there is a third kind of annual hydrograph. Here, you can see from beginning to end we are having streamflow and there is not much variation taking place in the streamflow value. From the beginning to end it is approximately of the same value, a slight variation is there but still more or less it is following a similar trend, there is no peaks coming into picture.

So, you can compare all the three graphs. In the first one we are having flow for the entire period of year, but there are so many spikes coming over the graph and in the second graph, certain periods only we are having streamflow, in between we are not having any streamflow records. And in the case of third one for the entire one year we are having water flow in the stream but there is not much variation in the representation of the streamflow values, it is more or less a steady value. So, the first one is corresponding to the streamflow hydrograph from the perennial rivers. Perennial rivers means the rivers which are having water all throughout the year. So, it got a continuous flow regime, that is why we are having a streamflow representation like this. For the entire period, we are having the flow within the river and most of the basin yield usually comes from baseflow. In this case most of the basin yield is coming from baseflow, but the spikes are represented by the storms. A large portion of the rainfall is infiltrated into the basin and reaches the stream as a subsurface flow. So, for the entire period of year, we are getting streamflow means, even though there is no rainfall, water is contributed towards the stream as streamflow. So, definitely it should come from the baseflow. So, majority of the water during the time of storm will be getting infiltrated into the ground and it will be meeting the groundwater table and water will be flowing towards the stream in the form of baseflow. That is the reason why we are experiencing flow all throughout the year.

In the second one we are experiencing streamflow during certain periods only. These are corresponding to ephemeral rivers, which are having periods with no water when the river is dry. You might have observed certain rivers are dry during non- monsoon season. So, the river will be flowing only during the time of rainy season, that is most of the streamflow which is coming to those type of rivers is due to rainfall. So, in such regions, the infiltration component will be less and whatever form the precipitation is occurring, majority is coming as runoff and meeting the stream. Since the infiltration component is less the contribution from storm to the groundwater is very less, because of that the baseflow component will not be there. Even if it is present it will be of small quantity, that is why certain period it is seen as dry. Most of the rainfall becomes direct runoff and little infiltration occurs and basin yield is the result of direct runoff from large storms.

In the first one we have seen basin yield is from baseflow, that is the groundwater contribution. The second one from the streamflow hydrograph itself, it is very clear that certain periods we do not have any water in the river it is representing the dry season in which the river is dry and the basin yield in such cases is coming from the surface runoff that is mainly from the storm.

And in the case of third one, here you are observing almost there is not much variation in the flow value. So, these are representing the case of snow-fed rivers. The basin yield occurs in the spring and early summer from snowmelt. During summers and spring because of snowmelt the streamflow will be observed there at the gauging station and this is mainly a due to snowmelt. The large volume of water stored in the form of snow, its steady release creates an annual hydrograph which varies more smoothly over the year. Due to snow melt and this is gradually released, because of the gradual release the streamflow records are more or less uniform or smoothly varying over the entire period.

I hope with these three representations it is clear to you what are the three types of annual hydrographs. In one, the basin yield is from the base low. In such cases we will be having flow throughout the year, that is the representation of perennial rivers. In the second case in the case of ephemeral rivers, we will be having the flow records only during the monsoon season or whenever the precipitation is occurring, especially rainfall is occurring and other seasons it will not be showing any streamflow data. In the case of snow-fed rivers there will be flow, streamflow records, but it will be smoothly varying. There will not be any spikes due to rainfall present in those types of annual hydrographs.

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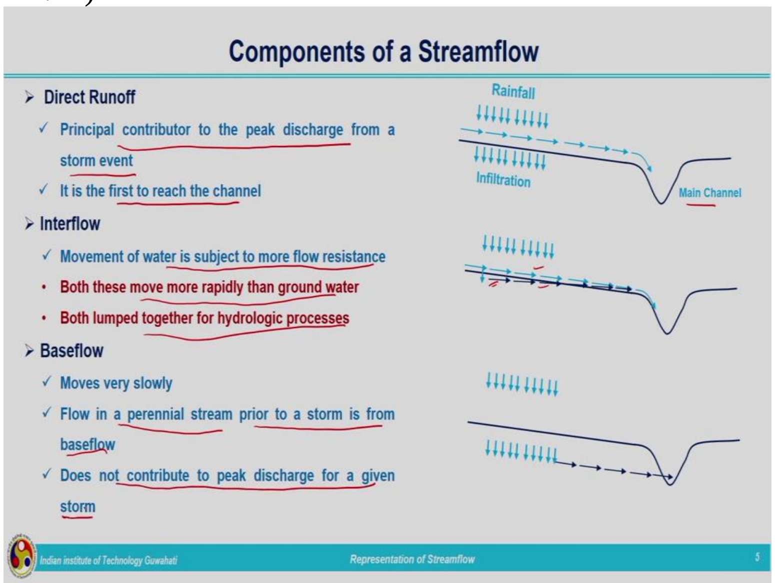

Now, let us move on to the components of streamflow. First one is the direct runoff and this is the principal contributor to the peak discharge from a storm event. During the storm event, initially, the catchment storage components will be satisfied. After that, we will be having the overland flow and it will be joining channels and channel flow will be starting. Finally, it will be contributing to the outlet of the basin. So, the principal contributor to peak discharged is from a storm event, that is from the direct runoff. Schematically we can represent this, let this be the main channel and we are getting rainfall over the catchment. And what will happen? Infiltration will be taking place initially and other storage components also will be satisfied. After that we will be getting the overland flow and channel flow. Finally, it will be meeting the main channel in this way. It is the first to reach the channel, that is rainfall is occurring infiltration is taking place whatever remaining water, excess rainfall will be forming the overland flow and finally, it will be meeting the main channel. So, this is the first one to reach the channel. The second one is interflow contribution from the subsurface. So, movement of water is subject to more flow resistance. So, when the flow is taking place, beneath the ground surface, the resistance offered by the soil pores will be more. It will not be as smooth as the overland flow. In this way schematically, we can observe this precipitation is there and we are having the surface runoff and after the surface runoff started we will be having the interflow, that is due to infiltration, water is moving into the ground surface and because of the gradient, lateral flow of the subsurface water will be taking place and that also will be contributing to the stream known as the interflow. So, because of the more resistance for the flow beneath the ground surface, the rate with which it is flowing will be less compared to the surface runoff. That is why at the beginning we will be having the surface runoff and after certain time only the interflow will be starting. But there are some cases, we need to look into the catchment properties also. Because if the interflow contribution is coming from nearby area of the stream, it can reach faster than the runoff contribution from the farther away point of the drainage basin. So, the water which is coming as runoff from the farthest point will be taking more time than that of the interflow taking place from the nearby places to the channel. So, in this case you can observe that we are having the surface runoff and at the same time we are having interflow. Interflow is starting at a later time compared to surface runoff. But during the time when entire catchment is contributing runoff to the outlet point by that time interflow also might have contributed to the streamflow. So, these two together always combined together when we discuss about streamflow. So, both these move more rapidly than groundwater and both lumped together for hydrologic processes. Even though three components are contributing towards streamflow, that is the direct runoff, interflow and baseflow, we will be combining direct runoff and interflow together because these two are moving at a faster rate compared to baseflow, that is the contribution from the groundwater.

Now, let us see the case with baseflow. Again, the same schematic representation, rainfall is occurring, infiltration is taking place. This infiltrated water is percolating deeper into the soil and finally it will be meeting the groundwater table. Hence, a contribution coming from the groundwater towards the stream. So, the rate with which the baseflow contribution is coming to the streamflow is at a slow rate and flow in a perennial stream prior to a storm is from baseflow. We have seen the case with different annual hydrographs. In that case we have seen in the perennial rivers all throughout the year there will be streamflow or water present in the river. So, that is mainly due to the contribution from baseflow. But this baseflow is not contributing to peak discharge for a given storm. For a given storm the peak discharge is mainly from the surface runoff.

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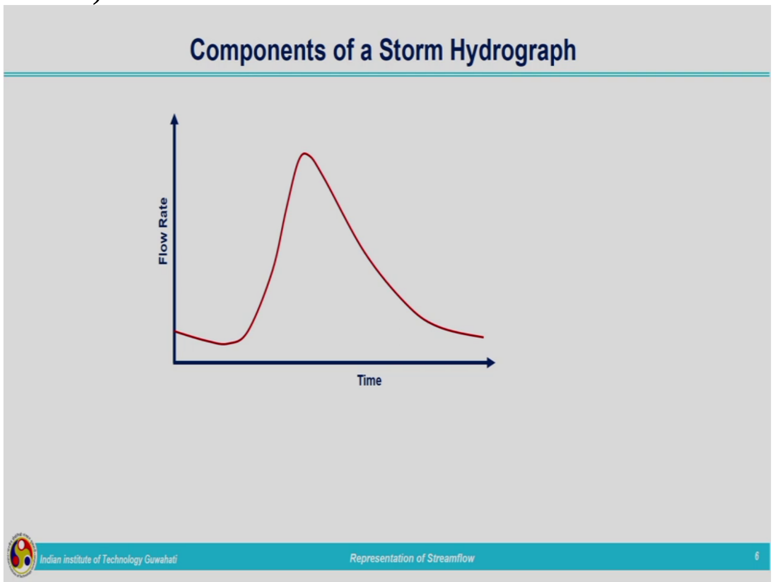

Now, let us see different components of storm hydrograph. Different hydrographs which we have observed are annual hydrograph and also storm hydrograph. So, for a particular period, shorter period during the time of storm and just after the storm, the flow records are plotted that is our storm hydrograph. So, now, let us look into the components of storm hydrograph.

So, this is a storm hydrograph. We are plotting flow rate along the *y* axis or the discharge along the *y* axis. Different names are the flow rate, discharge, stream flow, whatever way you are calling it is plotting along the *y* axis and time along the *x* axis. This is a schematic representation of hydrograph. Always the hydrograph will not be looking like this, it will not be a smooth curve because you imagine the case of a stream, where the water from different channels are meeting, in such cases one channel will be contributing first, other one will be coming at a later stage. So, that there will be spikes when we observe the streamflow data. It can be smoothened by means have different techniques, but usually we will not be getting a very smooth curve like this.

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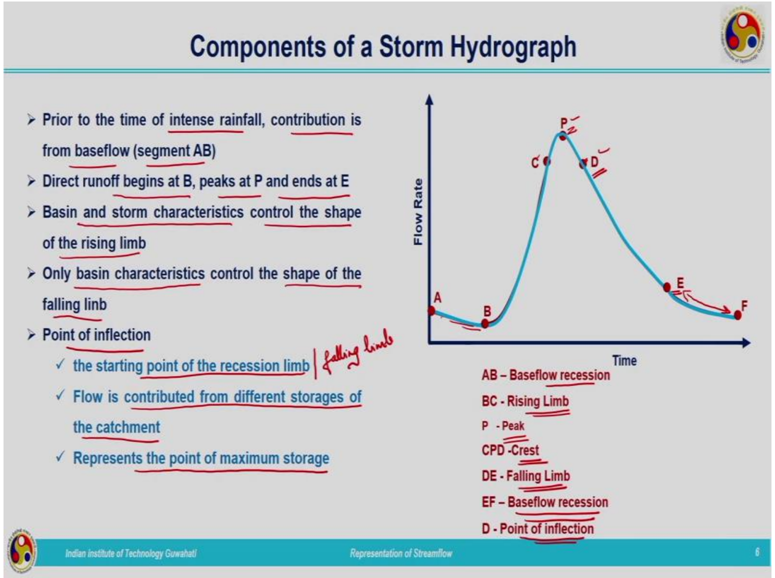

So, we can see different components of the storm hydrograph with the help of this figure. So, it is starting from the point A and up to B you can see there is a recession taking place and from this point B onwards it is increasing. So, prior to the time of intense rainfall, contribution is from baseflow that is represented by this segment AB. Even though there is no rainfall, we will be observing flow. So, that is from the baseflow contribution, that is the groundwater flow contribution. So, that is represented by this segment AB. AB is termed as the baseflow recession. Now, from B to C you can see it is rising. From B onwards the runoff is started and it is rising and BC is called rising limb of the hydrograph and when the increase in flow rate is taking place, increase in flow rate means there is contribution coming from runoff, that is after satisfying the storage components, overland flow started and contribution of runoff has reached the outlet point. So, this BC is the representation of the storm characteristics and also catchment characteristics. Then from that it is peaked up to point P. P is representing the peak of the hydrograph. Then you can see it has dropped down to point D. So, CPD is representing the crest, actually we cannot expect a sharp peak, that is expected only in certain watersheds. Since the peak value is consisting of the contribution from different areas of the watershed, it may be having certain spikes present or fluctuations present. So, that part is represented by the crest and the peak point from that is chosen as the hydrograph peak. So, CPD is representing the crest and from D the recession in the flow is taking place, that is representing the falling limb. DE is representing falling limb, that is there is a recession in the flow is taking place. Then from E to F again it is representing base flow recession. When it reaches the point E, all the contribution from runoff is stopped only the contribution related to this part is from baseflow, that is termed as the baseflow recession. D is a point of inflection. So, here I have told you, the crest is represented by CPD. So, what is meant by this point D? D is the point termed as point of inflection, that point is very important because, this point is considered as the time at which all the storage components are completely satisfied. Once it reaches this point by this time, already the storm has stopped and the entire catchment has started to contribute flow towards the outlet point. After that what will happen? Recession in the flow takes place, that is the withdrawal from the storage will be starting, beyond this point D.

Direct runoff begins at B peaks at P and ends at E. So, you can see B P E, the direct runoff is from B to E. The peak is occurring at the point P. So, depending on the characteristics of the catchment, we may have the sharp peak or flat peak. Then basin and storm characteristics control the shape of the rising limb because I have already told you B is the point where the runoff starts. So, the shape of the rising limb is characterized by the basin and storm characteristics. Then coming to the falling limb, the shape of the falling limb depends only on the basin characteristics because, by the time, the peak is attained, the storm has already stopped. So, when we discuss about the shape of the falling limb, there is no contribution coming from storm characteristics, it is purely based on the basin characteristics. Now, coming to the point of inflection, point of inflection is the starting point of the recession limb. Recession limb is also termed as falling limb. So, the point of inflection is nothing but the starting point of the recession limb. So, at this point, the flow is contributed from different storages of catchment and after this the withdrawal of the flow from the storage is will be taking place and this point of inflection is representing the point of maximum storage.

I hope different components of storm hydrograph is clear to you. This thing should be very clear, when we move on to the hydrograph analysis that is the next module. So, the components of hydrograph are important and regarding the time related components we will discuss at the time of hydrograph analysis.

When we talk about the streamflow, it is the contribution from surface runoff, interflow and baseflow. Since baseflow is taking too much of time to contribute towards streamflow, we have combined surface runoff and interflow together and baseflow separately. So, whenever we are doing the study related to surface runoff or excess runoff, we need to separate the baseflow contribution. So, for that different techniques are available, let us see one by one.

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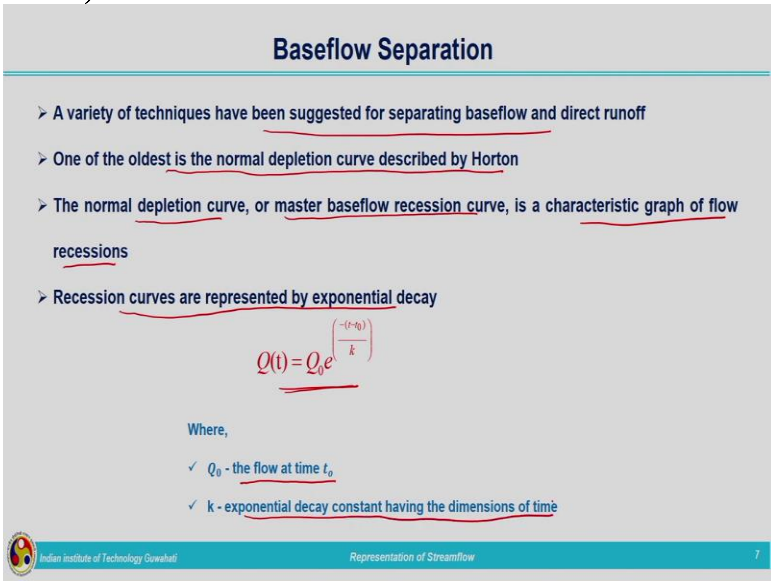

Variety of techniques have been suggested for separating baseflow and direct runoff, that is what is the contribution coming from groundwater and also from the surface flow and interflow, that we need to separate. So, one of the oldest method is the normal depletion curve described by Horton. Horton has carried out studies related to streamflow, surface runoff, interflow and he has proposed the normal depletion curve, that normal depletion curve method can be utilized for base flow separation. So, what is this normal depletion curve? Normal depletion curve or the master baseflow recession curve, it is a characteristic graph of flow recessions. It is representing the flow recessions. So, recessions curve has been represented by means of an exponential decay which is given by the formula

$$Q(\mathrm{t}) = Q_0 e^{\left(\frac{-(t-t_0)}{k}\right)}$$

So, the recession curves have been represented by an exponential relationship that is given by this, it is proposed by Horton and in this Q_0 is the flow at time t_0 and k is the exponential decay constant having the dimensions of time. So, for different times t-t_0, t_0 is the beginning of the storm and for different time we can get the ordinates related to this recession curves. So, this equation can be utilized for plotting the recession curve.

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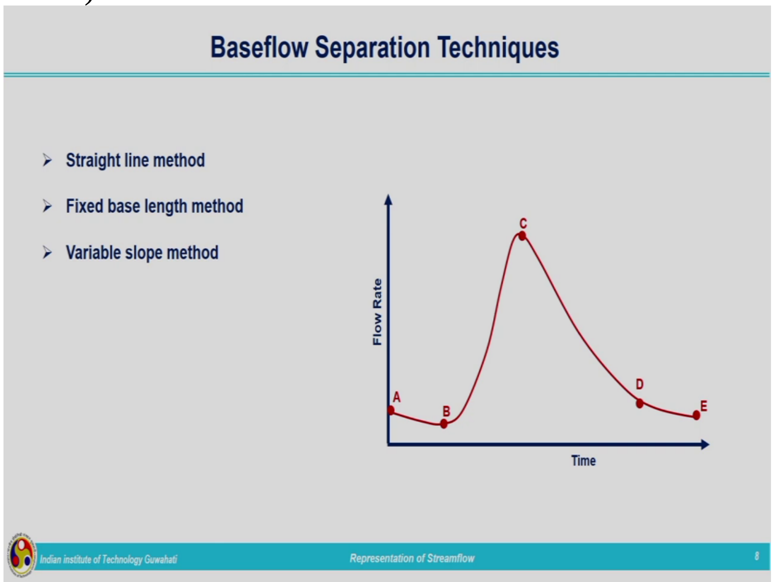

Now, let us move on to baseflow separation techniques. Different techniques are there: straight line method, fixed base length method, variable slope method. So, we are having the storm hydrograph over here and let us see different methods for separating the baseflow from direct runoff.

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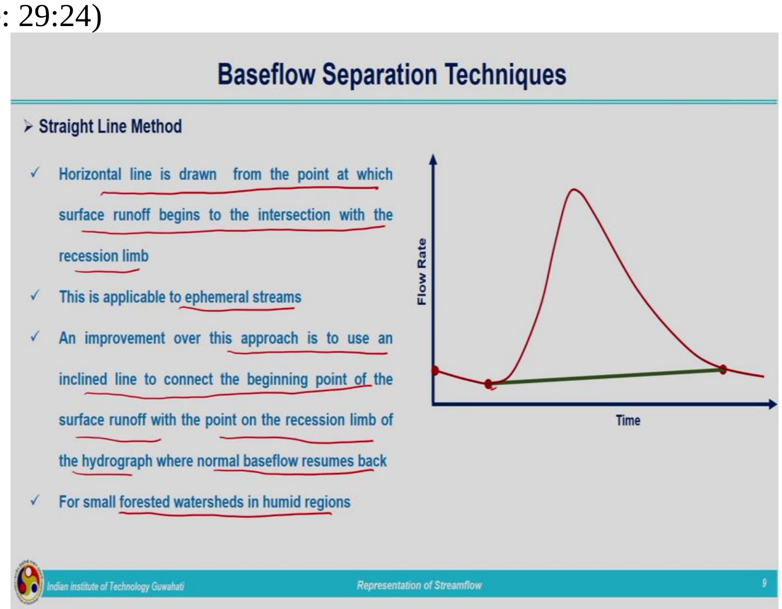

First one is the straight-line method. In this a horizontal line is drawn from the point at which surface runoff begins to the intersection with the recession limb. Initially, we will be having baseflow contribution only and baseflow recession will be starting and at the time of storm or at the beginning of storm also there will not be any contribution from rainfall. As all the storage is get satisfied, the contribution from rainfall towards the streamflow starts and the rising limb starts. So, that particular point is represented over here, beginning of the rising limp. So, what we will be doing? We will be joining the beginning point and the end point where the recession curve is ending and only the baseflow contribution will be there after that. Those two points will be connected by means of a straight line and beneath that straight line whatever is present that will be deducted from the total flow. So, this is applicable to ephemerals streams and an improvement over this method is to use an incline line to connect the beginning point of the surface runoff with a point on the recession limb of hydrograph where normal baseflow resumes back. Instead of joining by means of a straight line, we can have an incline line also. For small forested watersheds in humid regions, this method can be applied. But always this is an approximate method, always it will not be giving you the accurate value. So, this hatched portion is representing the baseflow.

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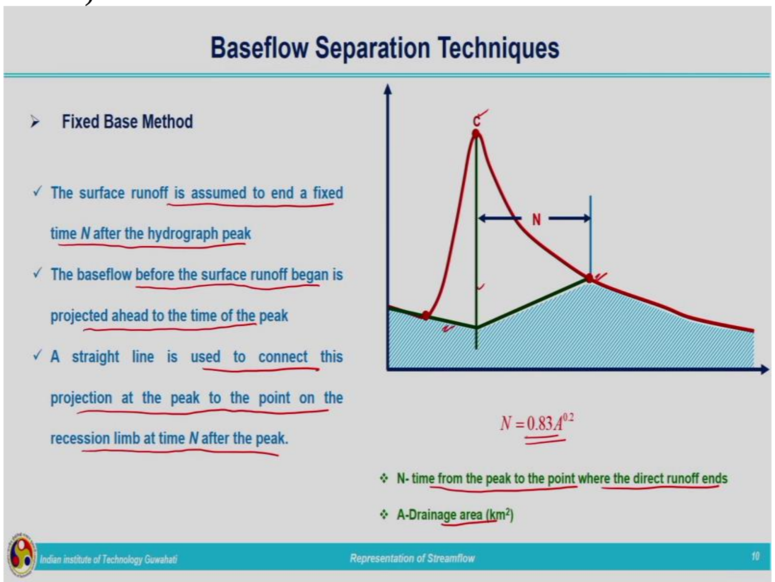

So, now, in the case of fixed base method what we are doing? The surface runoff is assumed to end at a fixed time *N* after the hydrograph peak. Hydrograph peak when it is occurring, entire catchment is contributing water towards the outlet point. So, then we may be getting a flat peak or sharp peak depending on the storm characteristic and also the basin characteristics. So, what we are telling, the storm runoff will be stopped after a fixed time from the peak. That let us see schematically. So, C is representing our peak, it is approximated by means of a single peak point, it may be a flat peak also. So, in that case you can consider the ending of the flat or the central point of the flat region. So, from there we are considering certain days number of days, where the surface runoff contribution will get stopped, that is marked by N and N can be calculated by using the formula

$$N = 0.83A^{0.2}$$

So, N is the time from the peak to the point where the direct runoff ends, A is the drainage area in kilometer square. So, in this method what we are doing? The base flow before the surface runoff has begun is projected ahead to the time of the peak. So, we have dropped a perpendicular from the peak and baseflow contribution line is projected forward like this. Then, a straight line is used to connect this projection at the peak to the point on the recession limb at time N after the peak. So, we have already marked that particular point N days after the peak. So, we will be connecting this line with that particular point and below what is coming that will be subtracted from the total streamflow. So, that subtracted one will be providing you the baseflow. This is fixed base method.

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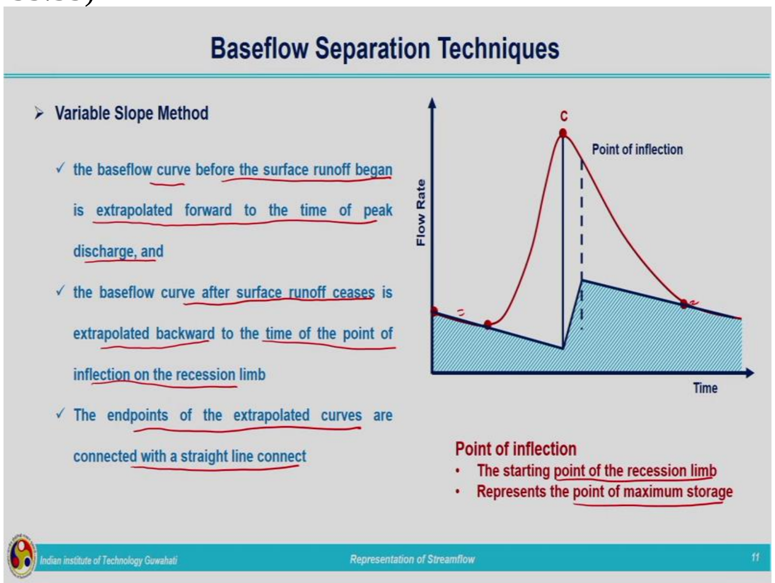

The third method is the variable slope method. In this case, the baseflow curve before the surface runoff has begun is extrapolated forward to the time of peak discharge. So, you can see here that is our beginning baseflow region that is extended like this. It is joined with the line from the peak and then what we are doing? The baseflow curve after surface runoff has ceased is extrapolated backward to the time of the point of inflection on the recession limb. Here this is the point where the contribution from runoff stops. So, from that particular point, we will interpolate from there the baseflow contribution only will be shown after that, that baseflow contribution after the recession limb will be extrapolated backwards this way. Then from the point of inflection we will be dropping the perpendicular, that is point of inflection is the starting point of the recession limb and it represents the point of maximum storage. After that what we will be doing the endpoints of the extrapolated curves are connected by means of a straight line. This way we will be connecting and beneath these lines the extrapolated lines whatever marked by that blue lines will be hatched and that is representing our baseflow. That needs to be deducted from the total streamflow to get the direct runoff.

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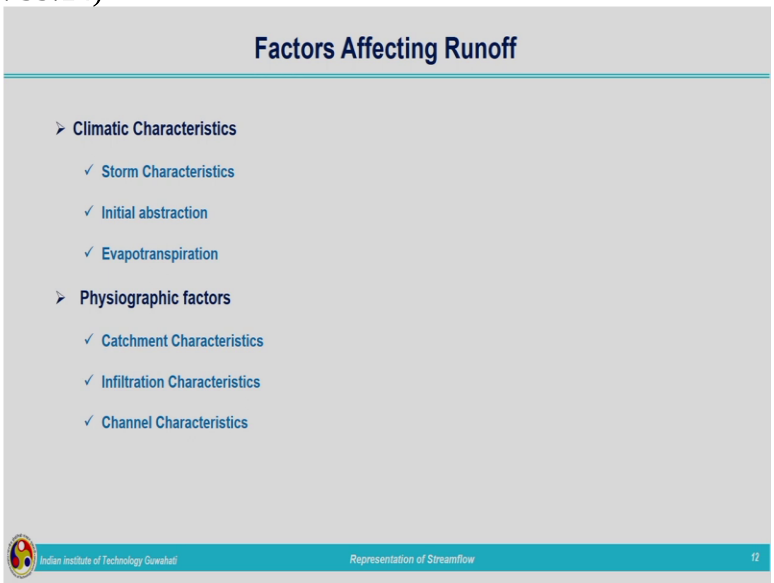

Now, let us see different factors affecting runoff. When we talk about runoff or the streamflow, which are the different factors influencing. First one is the climatic characteristics, it includes the storm characteristics, initial abstraction and also evapotranspiration. Then second one is classified as physiographic factors. In physiographic factors it includes the catchment characteristics, infiltration characteristics, and channel characteristics. So, factors which are affecting runoff includes climatic characteristics and also physiographic characteristic. Climatic characteristics includes the storm characteristics, initial abstraction and evapotranspiration and physiographic factors involve the catchment characteristics, infiltration characteristics and channel characteristics.

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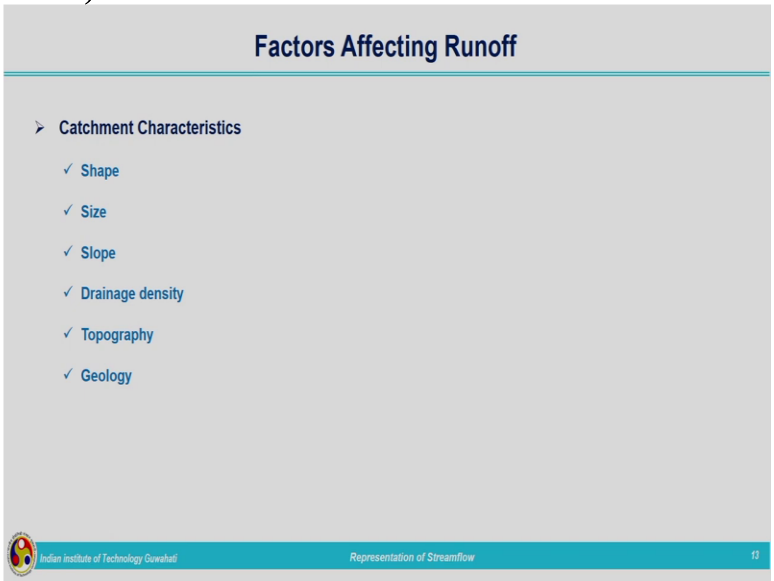

Coming to catchment characteristics. It includes the shape, size and slope, drainage density, topography and geology. Definitely, depending on the catchment characteristics, the contribution of water towards the drainage basin outlet will be different. If it is a steep catchment or the slope is more, the water reaching at the outlet will be at a faster rate compared to a flat terrain. So, shape, size and slope and also drainage density affects the runoff characteristics. If more drainage density, faster the rate at which the water will be reached at the outlet point. Topography, geology all these matters, all these affects the stream flow which is measured at the outlet point.

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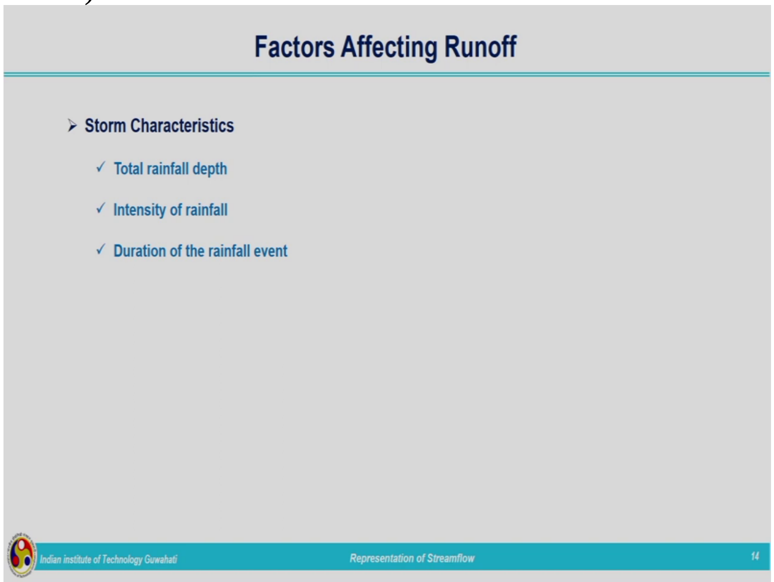

When coming to storm characteristic. It includes the total rainfall depth, intensity of rainfall, duration of the rainfall event. If it is for a very short duration, maybe entire water may be lost as initial abstraction. It will not be contributing anything towards the runoff component. And if the storm is lasting for a long-time, duration is very high in such cases, even after satisfying the storage components, runoff will be starting and it will be contributing towards the streamflow.

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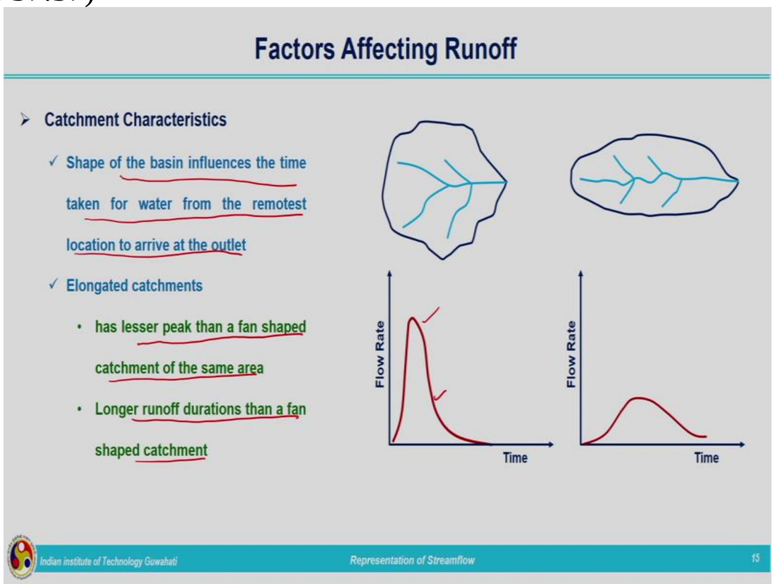

Now, different factors affecting runoff, that is, we were discussing about catchment characteristics, in detail we can see. The shape of the basin influences the time taken for water from the remotest location to arrive at the outlet. That we have seen, the time taken by water to travel from the remotest point to the outlet point is termed as the time of concentration. So, depending upon the shape of the basin, the time or the time of concentration will be different. So, that matters how much is the runoff value, it depends upon time of concentration. So, if the watershed is having this shape, which is having stream networks like this, it is termed as fan-shaped watershed and you can compare it with the elongated watershed. It is a very lengthy watershed. In both cases when you see, if we plot the storm hydrograph in the case of fan-shaped watershed, we are getting a hydrograph like this, which is having a peak coming fast. In the case of elongated watershed, you are having a flat peak, that is the entire watershed is contributing and the peak is attaining for a long time, gradually the peak is attaining. But in the case of first one, fan-shaped with more drainage density, very good drainage system is available for the flow to take place, in that case peak will be attained faster rate compared to the other one. Elongated catchments have lesser peak compared to fan shaped catchment of the same area and longer runoff durations than a fan shaped catchment. So, you can compare the hydrographs in both the cases, one is having a sharp peak and in the other case it is having a flat peak.

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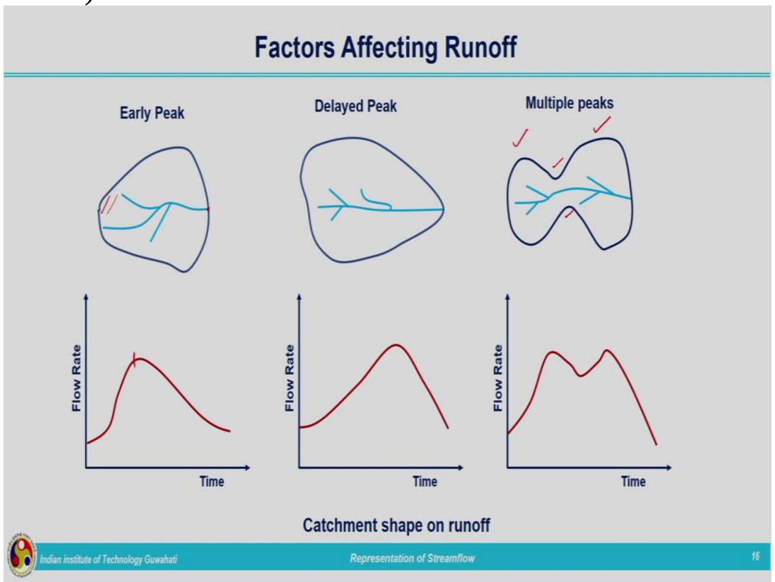

Now, coming to catchment shape on runoff. Different catchments we can consider. Here in this case we are having the catchment wider near to the outlet point. Our outlet point is here and stream is starting from the farthest point and away from the outlet point, the watershed is reduced in width. Second one is on the other hand, at the outlet point the width is less. It is becoming wider as the distance from the outlet point is increasing. Then third one is having a shape as shown in this. So, streams are present in the watershed like this and we can plot the corresponding hydrographs from all these watersheds. In the first case, you can see the peak at this point as attained at a faster rate and it is skewed towards the left. So, peak is attained early and after that also contribution of flow coming from the farthest point. But the peak is due to the major area that is very close to the outlet point. That is why we are having is skewed peak in the first case. Second case you can imagine how it will be, maximum area is far away from the outlet point. So, definitely the, we will be having a skewed peak towards the right. So, it will be like this. Initially the runoff which is reaching at the outlet point will be less and after certain time only entire catchment will be contributing water to the outlet point, that is why the peak will be skewed towards the right-hand side. Now, in this case, third one how it will be? In the case of third one, you can understand that we are having maximum area here and also, we are having large area compared to the central portion. So, in this case the hydrograph will be having multiple peaks, that is initially, initial area contribution will be high, then because of the reduction in area the contribution is reduced. Again, the farthest area is more compared to in between area. So, initially the flow will be rising then reducing then when the entire catchment starts contribution at the outlet point it will be increasing. So, these are the different types of hydrograph which we can experience from different shapes of watersheds. In the first case we are having early peak, second case delayed peak and in the third case we are having multiple peaks.

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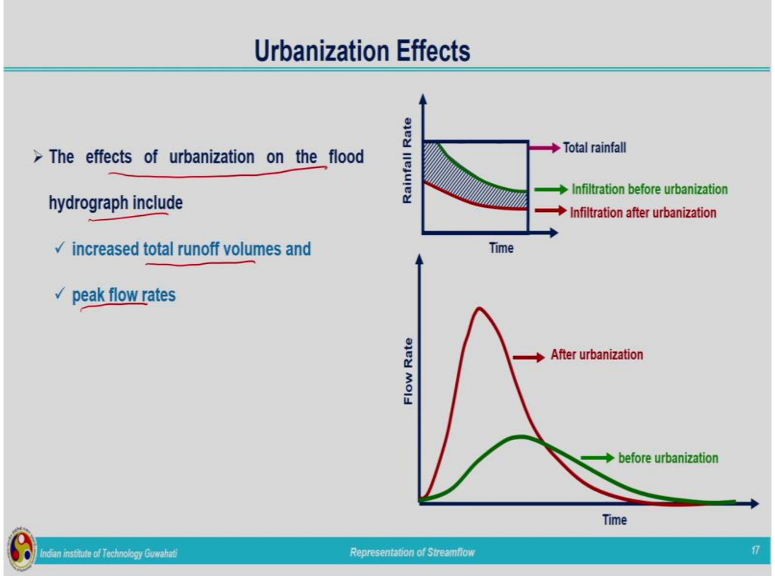

Now, very important thing which you need to understand what is the influence of urbanization on the hydrograph. So, the effects of urbanization on the flood hydrograph include increased total runoff volume, then peak flow rates. We can see by means of a graph, flow rate along the *y* axis and time along the *x* axis, this is the one which is having a flat peak and the time taken for the runoff is very large. So, you can understand that this is before urbanization and in the case of after urbanization peak will be very high and time taken to peak to attain will be less. This is after urbanization. Now, when we are plotting the rainfall rate versus time, if a uniform rainfall intensity we have considered out of that total rainfall, this green line is representing the infiltration before urbanization. In the case of before urbanization, impervious areas will be less. So, we will be having more and more infiltration taking place. So, that is represented by this green curve and in the case of after urbanization what will happen? Impervious areas are increased due to that, the water which is infiltrating into the ground gets reduced, because of that the runoff volume will be increasing. So, this much amount of extra water is contributing towards runoff because of urbanization. Additional excess rainfall caused by urbanization is marked by this hatched area.

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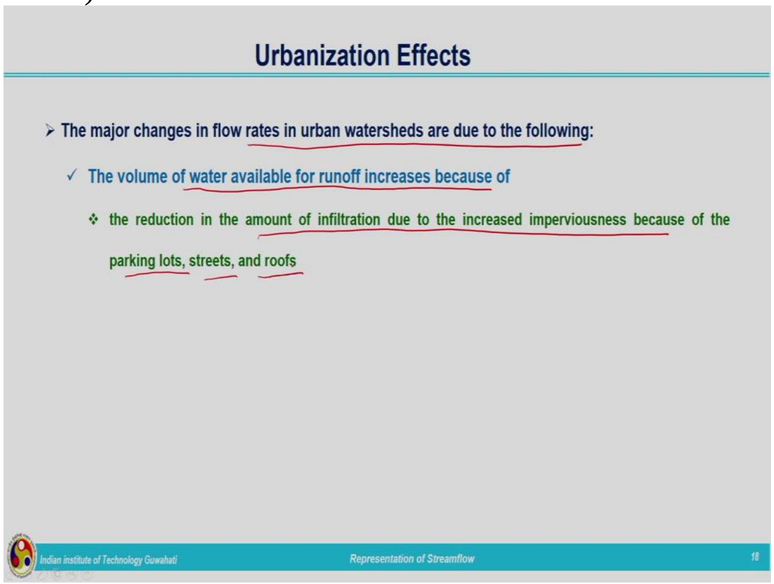

Now, major changes in flow rates in urban watersheds are due to the following reasons: that is the volume of water available for runoff increased because of the reduction in the amount of infiltration due to the increased imperviousness, because of the parking lots, streets and roofs. In the case of urbanized area, paved areas are more because of the paved characteristics water infiltrating will be less.

We have seen two types of hydrographs: annual hydrographs and also storm hydrographs. So, different components of hydrographs we have seen and the factors influencing the hydrographs also we have seen and after that the urbanization influence on runoff also we have studied.

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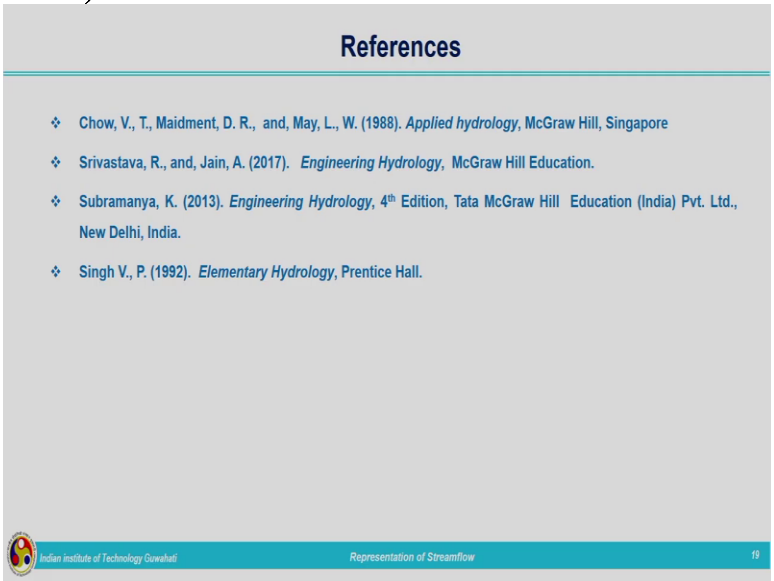

Now related to the reference material. These are the references related to the topic which we have studied in this lecture. So, here I am winding up this lecture. Thank you.