REMOTE SENSING FOR NATURAL HAZARD STUDIES

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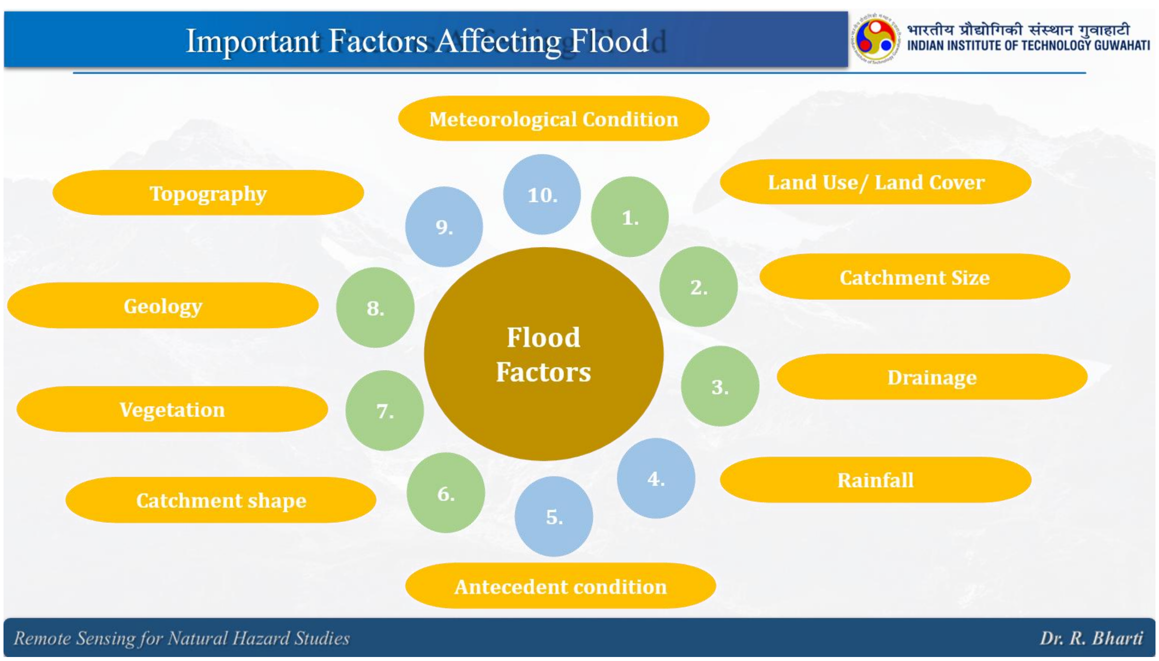
Lec 13a: Introduction to Floods - I Part A

Hello everyone, welcome to Module 5. Today, we will start with Lecture 13, where we will have the Introduction to Floods. So, this is Part 1 of Lecture 13. As usual, we will have the second part after this lecture. So, in this lecture, we will learn about the flood, the different causes that trigger it, the various positive and negative aspects of floods, and then we will also learn about the different types of floods. So, let us start with the basics of floods.

So, here you can see that there are different images, which show the flood and the impact of the flood, so that you can understand. So, a flood is essentially an overflow of water on land that is normally dry. So, as we all know, a flood is a difficult situation, and many of us might have experienced flooding. So, a flood is a deadly natural disaster, but it is also very important for agriculture and for maintaining the life of plants and animals. So, this is a disaster that has both positive and negative sides. So, let us understand this flood in detail. So, a flood is the inundation of a normally dry area caused by an increase in water in a river or stream.

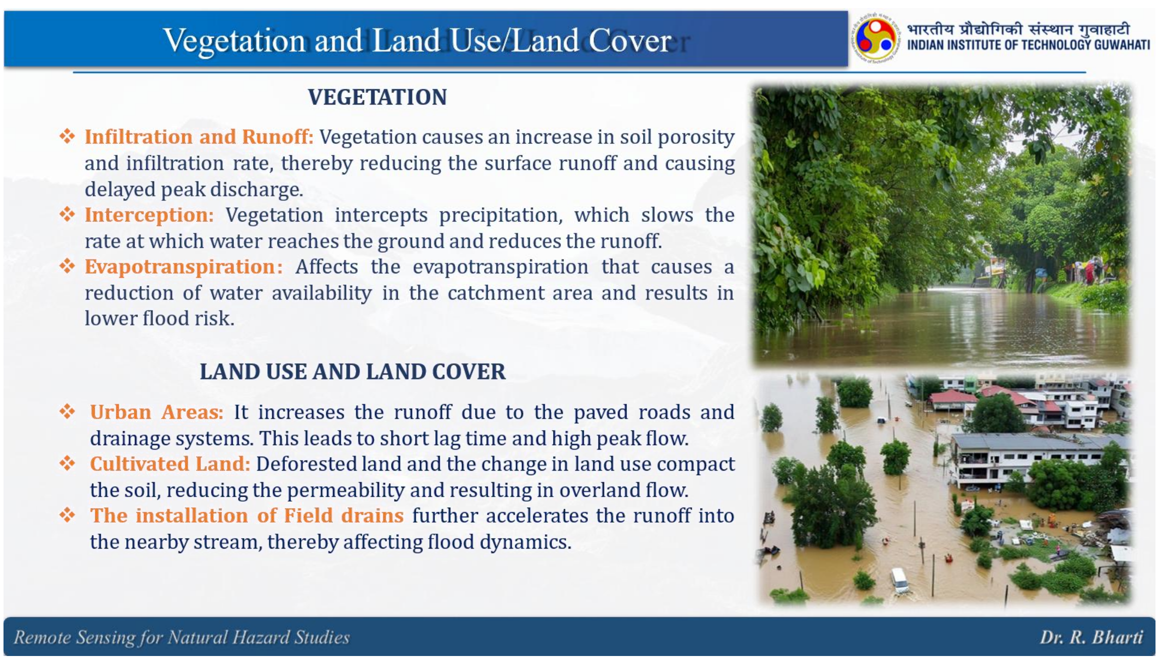
A flood occurs when a system crosses the geomorphic threshold. So, when we see a cross-section of a river, we normally have the water up to this level. So, what is the geomorphic threshold for this section? This is the geomorphic threshold. So, once the water reaches this level and when we have extra water, it will start spilling outside, which is crossing the geomorphic threshold. It is considered a temporary condition. We have this situation because of some heavy rainfall, maybe the breaching of a dam, or perhaps there is a blockage in the pathways. So, an overflow of inland or tidal water could be the case in a flood; then we have rapid runoff of surface water. So, in a flood, what happens is that we have an excess amount of water that cannot be controlled or maintained by our fluvial system, and it overflows. So, here it is rapid runoff of surface water. This is the scenario in which we have the flood. When we talk about the factors, we have two different ones. The first one is intrinsic, and then extrinsic.

When we talk about intrinsic factors, we have heavy precipitation and then aggradation of riverbeds, and for the extrinsic factor, we have the breaching of the dam. This is one of the examples. Now, when we talk about heavy precipitation, aggradation of riverbeds, or breaching of dams, all result in some excess water. Excess water is not being accommodated by our fluvial system, and because of that, it crosses the geomorphic threshold of that particular river or maybe a lake. So, then we have overflow, and this is the situation when we have a flood in our river system. So, I have used some of the images to help you understand the impact of the flood. So, this particular image is from Assam; you can see how people are surviving. Then this image, this one, is from Haflong. So, this is from 2022, and you can see that all the railway lines are blocked, this particular image is from Vijayawada city; this is from 2024. So, that might have helped you understand the impact of a flood if you have not experienced one.



Then, when we talk about the important factors that play a critical role in floods, the first one is land use and land cover; next, we have catchment size, then drainage, and finally rainfall. Then the antecedent condition, this is the antecedent moisture condition, then the catchment shape, then we have vegetation, then the geology of that area, what is the topography of that area, and then the meteorological conditions. So, here all these play a critical role. So, one by one, we will try to understand all these parameters or the factors that are playing a critical role. So, when we talk about vegetation infiltration and runoff, this vegetation plays a critical role.

Vegetation causes an increase in soil porosity and infiltration rate, thereby reducing surface runoff and causing delayed peak discharge. Then the interception of the vegetation intercepts precipitation, which slows the rate at which water reaches the ground and reduces the runoff. So, ultimately, if this is the catchment and here you have these tributaries or streams, where do we measure the discharge? Here, and then we try to make this curve. Now, here, when we try to see the response of precipitation and at what rate the discharge has taken place, the vegetation will play a major role because it will delay the process. So, what happens when there is precipitation is that it slows the rate at which water reaches the ground and reduces the runoff. Then, it also plays a critical role in evapotranspiration. It affects evapotranspiration, which causes a reduction in water availability in the catchment area and results in a lower flood risk. Now, let us talk about land use and land cover.



So, land use and land cover are two parameters, but we always consider them together because land use is how we are utilizing the land, and land cover is what the natural land cover is, how it was before we utilize it. So, it is very difficult to segregate the two.

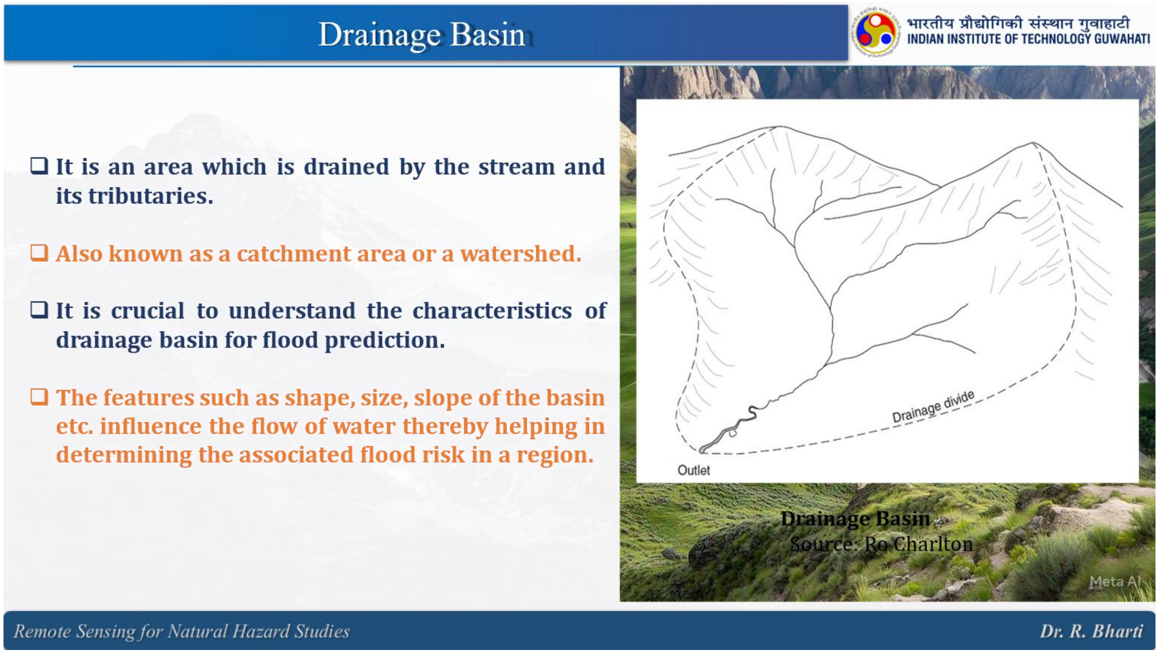
So, when we talk about this land use, land cover, urban areas, and cultivated lands, these two different forms will help you understand the role of water, how it is taking place, and how it is governing this flood. In urban areas, what happened? It increases runoff due to the paved roads and drainage systems. This leads to a short lag time and high peak flow. I will try to explain this in the next few lectures. So, when we have the peak flow and the precipitation together, we will plot them and try to see what the lag time is and how we derive the high peak flow. So, then comes the cultivated land, deforested land, and the change in land use compact the soil, reducing the permeability and resulting in overland flow. Due to this land use and land cover conversion, the permeability changes, which result in overland flow. The installation of field drains further accelerates runoff into the nearby stream, thereby affecting flood dynamics. So, the dynamics will be very different when we have the installation of a flood. Field drains are. So, here you can see some examples of how it flows and then how it can cross the geomorphic limit and how it is causing flooding in this area.

When we talk about the soil, we all know that floods have a direct relationship with the soil type. So, the rate of infiltration is affected by soil texture, and soil thickness affects the absorption of water in the soil. So, let us say that here we have a column of soil. So, if I put this sandy soil here, what will happen? Permeability is high; that means it will have high permeability.

So, the water that comes from this rainfall will go inside this, and then the overflow or surface runoff will be less. When we have clay soil, we should remove the sandy soil and replace it with clay soil. What will happen if permeability is low? So, here, this permeability is less than that of your sandy soil. So, in that case, whatever water we are getting from this precipitation, we will have overflow, and this overflow will cause flooding in the downstream area. Then comes the geology of that region; the impact of geology on the drainage basin and its corresponding response are given here.

So, when we have permeability, the response to precipitation is slow; if it is impermeable, then it will be very quick. So, let us try to understand if we have a column of soil, if permeability is high, that means if you have heavy precipitation here, it will have a slow response to the precipitation water will be accommodated into this. So, you will have a slower response. If it is impermeable, what will happen? Nothing will go here, and everything will be in the form of surface runoff. So, that is the meaning of this table. When we talk about the drainage size and shape, let us talk about the larger basin. So, let us say I have a larger basin like this, and here we have an outlet point where we are measuring the discharge correctly. Now, suppose we have precipitation in this region, then this water will take a longer time to reach this particular point, but this discharge will be the cumulative of all the water falling in this particular area, so this is the meaning of a larger basin. When we talk about the elongated basin, we will have the same condition as the larger basin, but in an elongated form. So, let us say it like this, and here we are measuring the discharge.

So, what happens when we have heavy precipitation in this region is that this stream will quickly deliver this water to the mainstream, and then it will quickly reach this particular point. So, respond quickly but with a gentle peak, because this takes a long time taken by the water to travel. So, the peak will be gentle in the other one; it will be like this. So, that is the difference when we talk about drainage density; high drainage density reduces the flow path and causes rapid runoff. So, what is the rate of density here? So, if you have a higher density, you will have rapid runoff.



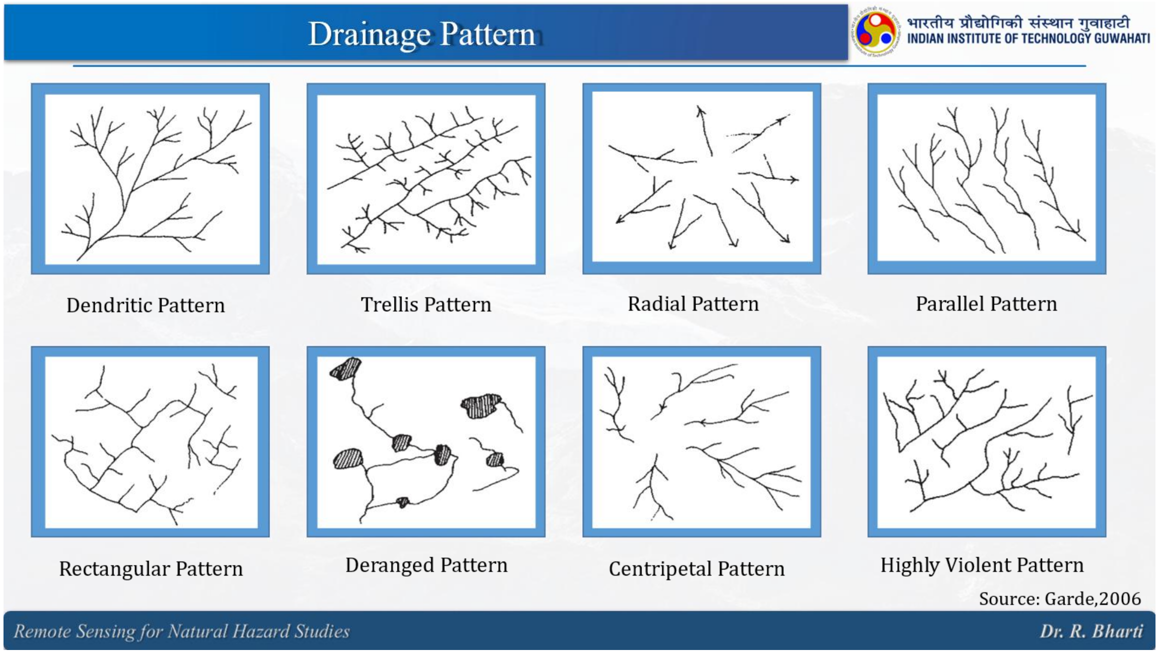
We have another parameter: drainage basin topography. Travel time increases over the steep slope, regardless of whether it has a steep slope. or whether it has the gentle slope that will also help the water to reach this particular discharge point.

In the upland area, the steep slopes are related to thin soil, leading to a rapid response because below this thin soil, we have rocks that may be permeable or impermeable, but at least they will be less permeable than the soil. Because of that, you have a rapid response. Rainfall patterns are influenced by altitude and aspect. So, this is the altitude; you can calculate the slope, and then we have the aspect. What is the aspect of that? So, once you have the digital elevation model, you can calculate the altitude, the slope, and the aspect, which is the direction of the slope. Then comes the channel and floodplain resistance. The channel shape, the roughness of the riverbed, and the bank affect the flow velocity of the river channel. So, you can try to visualize what the different shapes are, channel shapes, what the roughness of the riverbed and the banks? So, that controls the flow velocity. Overflow banks are slowed by the roughness of the floodplain's surfaces. So, I will try to show you some examples in the form of images so that you will be able to understand this channel and floodplain resistance. Then there is floodplain storage. When the river exceeds its capacity, the surplus water flows into the surrounding floodplain areas. This stores the floodwater temporarily and reduces the downward flow. So, let us say that you have a river system, and some of the reasons you have floodplains. So, these floodplains are the adjacent areas that can accommodate the extra water temporarily, and this reduces the surface runoff in the mainstream. So, this will also delay the flooding. Then, conveyance losses in the dry region may occur; the channel may lose water due to a high rate of evaporation and leakage by exfiltration through the boundary of the channel. So, if there are some other areas that are being fed by this water. Then, the antecedent condition. It is basically the antecedent moisture condition. It refers to the state of the drainage basin before the rainfall begins. In areas with saturated soil due to previous rain, even a small amount of water can cause huge runoff. Let us take the example of dry soil. So, let’s collect some saturated soil and dry it, and then try to pour a glass of water here. What will happen? Immediately, this will start flowing. This will not be absorbed correctly.

So, because it is in a dry condition, it is not even behaving like sandy soil or clay soil, but once it reaches its normal moisture condition, it will start the percolation, then this overflow or surface runoff will be less, but suppose this particular soil is already saturated, and if you are pouring 1 glass of water, what will happen? The entire glass of water will be coming downstream as your discharge. In snow-laden areas, subsequent precipitation can lead to snow melting and eventually cause flooding downstream. So, this is very obvious. Then you have the rainfall intensity. Intense rainfall exceeds the soil's infiltration capacity and leads to rapid runoff. Because what will happen? The soil will get saturated, and then you will have runoff, which will be directly proportional to your rainfall. Rainfall duration is longer than the rainfall duration activates the runoff from greater distances, thereby extending the channel network.

So, what happens when we have intensity and duration? So, if you see the graph correctly, let us say this is for the precipitation. So, what is the peak precipitation here that you can measure in millimeter? or centimeter. So, what are the intensity and the duration? If it is for a longer duration, what will happen? This will feed more water to the fluvial system, and then we will have more problems related to floods. So, when we talk about the drainage basin, it is an area that is drained by the stream and its tributaries, also known as a catchment area or a watershed. It is crucial to understand the characteristics of a drainage basin for flood prediction. Because, unless you know your area, how will you be able to predict or model correctly? So, this is one example of a drainage basin.

The features such as shape, size, slope of the basin, etc., influence the flow of water, thereby helping in determining the associated flood risk in a region. So here you can see this is the shape of this drainage basin, and these are the main channels; these are the tributaries. and now we also know what the slope is, and the basin size that is clear from this, and the shape is. So, all these are very, very important parameters when we consider the drainage basin or the catchment.



So, there are different drainage patterns. So, here is an example of a dendritic pattern; then we have this, then we have another form, then we have this parallel pattern, then a rectangular pattern, then a centripetal pattern, then a highly violent pattern. So, you can see how it is getting violent because it has too many mainstreams and tributaries,

Drainage Texture

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- Drainage texture is the relative spacing of drainage lines.
- Influenced by various factors such as climate, lithology, climate, geology as well as relief.
- It can be classified into fine, medium and coarse with drainage density being an important indicator.
- Drainage Density (first defined by Horton, 1932) can be defined as the total stream length per unit area of drainage area.

The values of drainage density at various settings.

Type of Area	Drainage Density (km/km^2)
Steep Impervious area	~ 0.93
Highly permeable basin	~ Zero
Humid Region	2.0 - 0.6

(Source: Garde,2006)

The texture and corresponding drainage density indicated by Smith (1950) and Strahler (1957)

Texture	Drainage Density (km/km^2)
Fine	15-150
Medium	5-15
Coarse	<5

(Source: Garde,2006)

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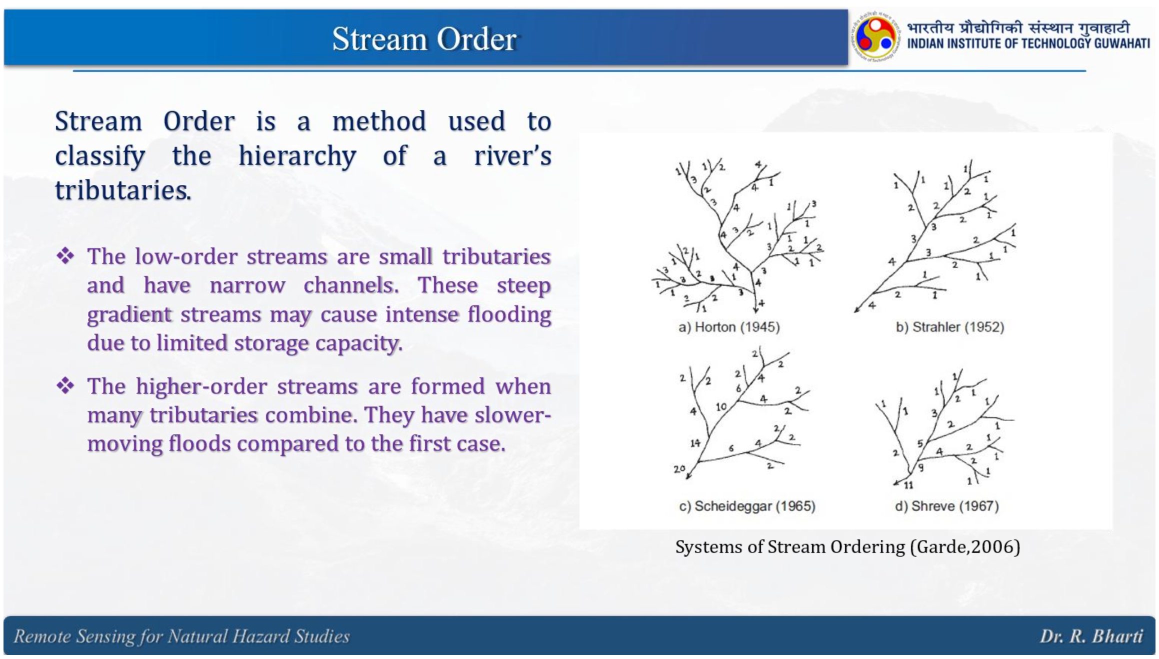
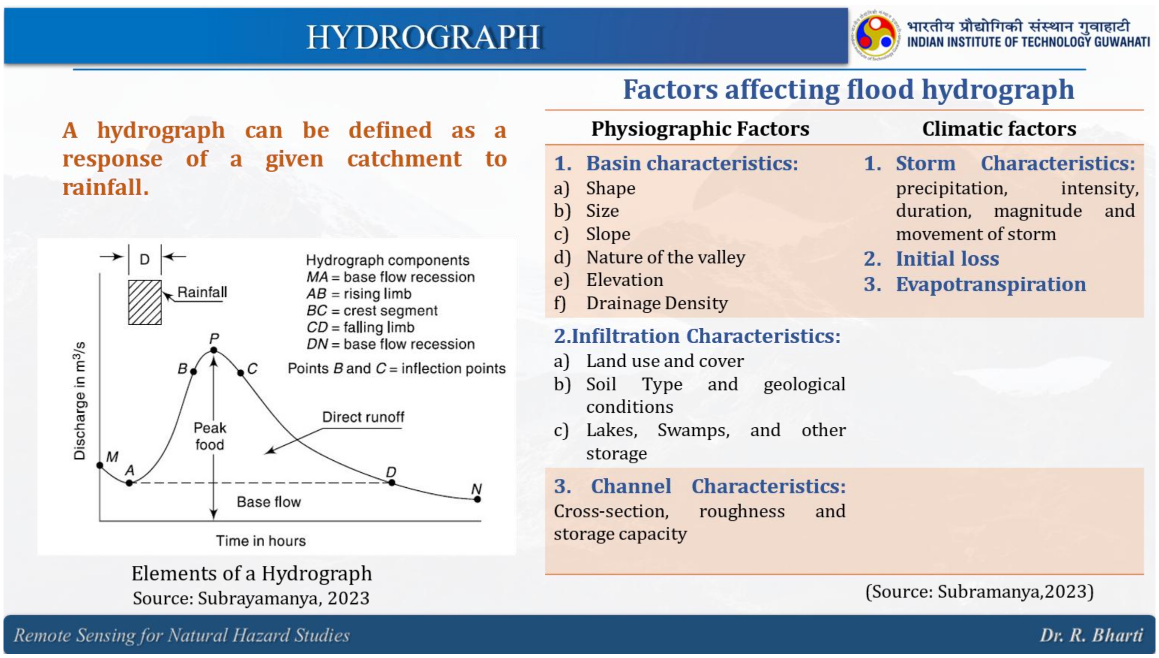
So, when we talk about the drainage texture, the drainage texture is the relative spacing of drainage lines, influenced by various factors such as climate, lithology, geology of that particular area, and relief as well. It can be classified as fine, medium, and coarse, with drainage density being an important indicator. So, here the drainage density will be used to have different drainage textures. Drainage density can be defined as the total stream length per unit area of the drainage area. So, using this, you can calculate it. So, here we have a drainage density of approximately 0.93 km per square kilometer. We have this steep impervious area, a highly permeable basin; it is 0 in a humid region, which is 2 to 0.6; this is from this paper. Then we have the texture and the corresponding drainage density. So here it is from Smith and Strahler. So, here, when we have the fine texture, the drainage density is in this range. When we have a medium texture, it is in the order of 5 to 15. When we have a course, it is less than 5. So, this is how we define the drainage texture.



Then we will talk about the stream order because there are many ways you can order the stream channel. So, here one is given by Horton, then Strahler, and then we have different ones. So, the stream order is a method used to classify the hierarchy of river tributaries. You can see here how the number is given. The low-order streams are small tributaries that have narrow channels. These steep-gradient streams may cause intense flooding due to limited storage capacity. Higher-order streams are formed when many tributaries combine; they have slower-moving floods compared to the first case. So, I will try to explain the Strahler one correctly. So, let us say this is one catchment area, and here there are two tributaries that are meeting, and they are forming one bigger tributary. So, here we will name it 1-1, first order, and then when the first two orders meet, this will become the second order. Then, from here, the first two orders are meeting, and they are making the second order. Then these two second orders, when they meet, create this third order stream, and then similarly, if you have another 1-1, you have 2, and when these 2 are meeting 2 and 3, this will remain the higher order. So, 2-3 means third order only, and if there is another one that is coming in third order, then this will make it fourth order. So, this same thing is explained here; this is how we order the stream. So, the higher the order you have, the more water there is because this is coming from all these streams.



So, let us talk about hydrographs, which is one of the very important characteristics. So, a hydrograph can be defined as the response of a given catchment to rainfall. This is a typical hydrograph; here you can see that the discharge is given, and the x-axis is the time. Now, let us say this is the discharge one, this is the discharge, and here you have different elements. So, when we talk about this hydrograph, we have different elements. So, here you have the rising limb. So, A to B is your rising limb, then B to C is the crest, then you have C to D, which is the falling limb, and then DN is the base flow recession, this is the line that connects A and D. So, depending on the shape of this hydrograph, you will be able to say or comment on the status of your catchment area with respect to a given rainfall, So, here when we talk about these factors that are affecting the flood hydrograph, the basin characteristics, storm characteristics, initial loss, and evapotranspiration will all lead to this graph. So, they have a very important role here. Then, you have infiltration characteristics, and then you have channel characteristics. So, we will continue this discussion in the next section. Thank you. Thank you very much for listening. So, we will continue with this lecture 13.

Thank you.