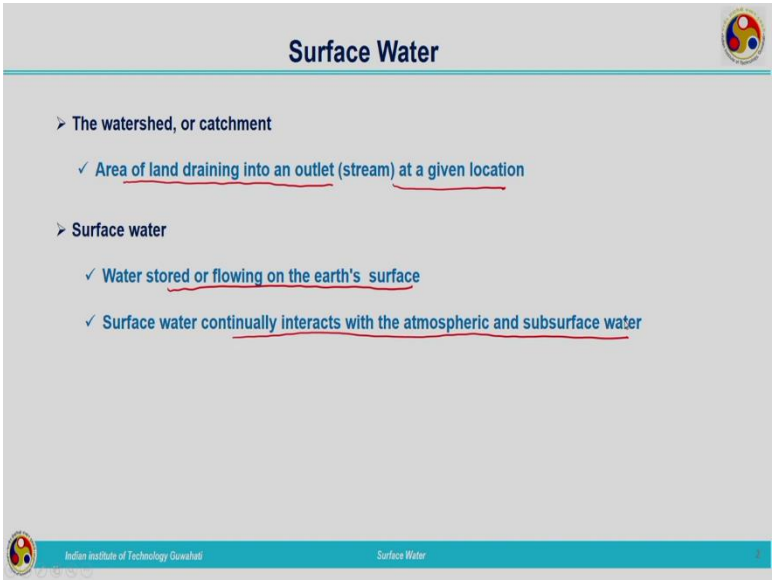
Engineering Hydrology
Professor Doctor Sreeja Pekkat
Department of Civil Engineering
Indian Institute of Technology, Guwahati
Module4 - Lecture 43
Surface Water

Hello all participants. Welcome to the 4th module of NPTEL MOOC on Engineering Hydrology. Till now, we have completed 3 modules. First module was related to introduction to the course on Engineering Hydrology. Second module was on atmospheric water and third module we have completed related to subsurface water.

Now, today we are going to the fourth module related to surface water. So, what is surface water? From the name itself it is clear that water which is present on the surface of earth that is termed as surface water. So, we need to study the processes, hydrologic processes related to surface water in this module.

(Refer Slide Time: 01:21)

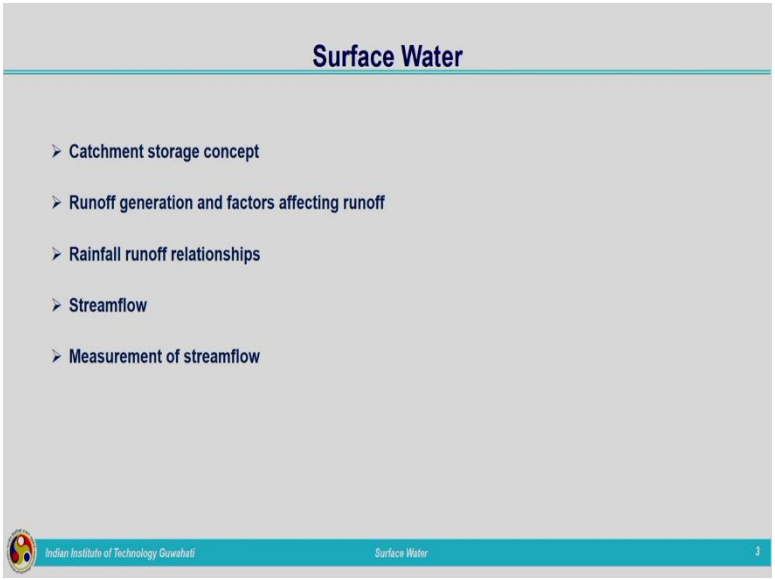


We have seen what is meant by a catchment. Watershed, catchment, basin, all these are representing same entity and watershed is defined as the area of land draining into an outlet. That outlet can be any water body such as streams, rivers, oceans etcetera at a given location. So, we know what is meant by a catchment or watershed and that is a land which represents a land and which allows or which drains water to the common outlet point which is having a definite boundary.

Now, coming to surface water. It is the water stored or flowing on the earth's surface. Surface water is having continuous interaction between the atmospheric water and subsurface water.

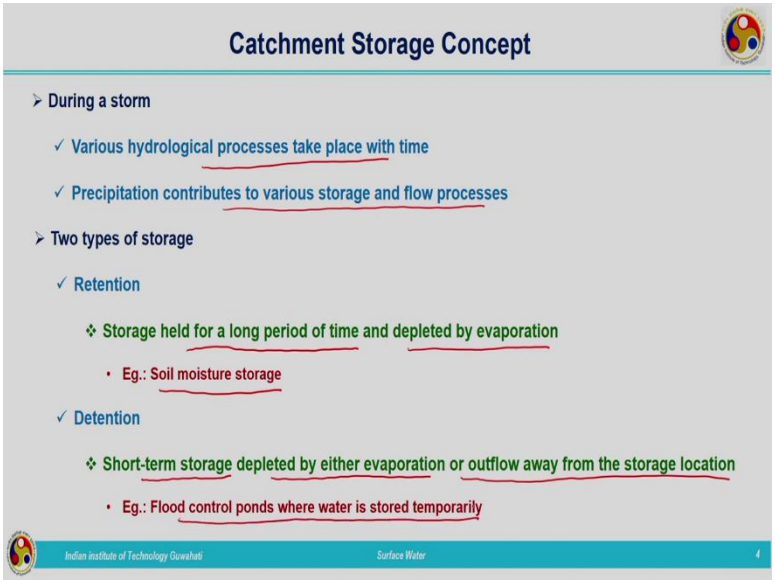
Whenever rainfall is occurring, it is falling on the ground. Due to the process termed as evaporation it is converted to vapor form and vapor is again converted back to liquid falling on the ground. This is a continuous process. So, the surface water is having continuous interaction with the atmospheric water. At the same time surface water is getting infiltrated into the ground also. So, that way it is having continuous interaction between the subsurface water and atmospheric water.

(Refer Slide Time: 2:46)



Now, in this module, we are going to cover details related to catchment storage concept, runoff generation and factors affecting runoff, rainfall runoff relationships, streamflow and measurement of streamflow. These are the topics which we will be covering under this module. So, we know the detailed meaning of catchment. So, we need to have an understanding about catchment storage concept. Let us move on to know that.

(Refer Slide Time: 03:20)



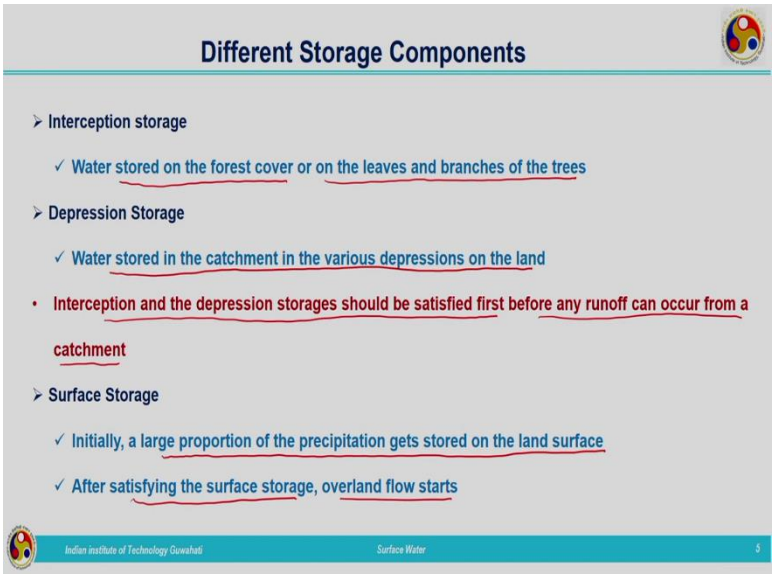
During a storm, whenever a rainfall is occurring, we know different hydrologic processes are taking place. So, during a storm, different hydrologic processes take place with time and this precipitation, maybe a rainfall contributes to various storage components and also different types of flow processes. Whenever precipitation or rainfall is occurring, we have seen different hydrologic processes taking place and the water is contributed to different storages and also different types of flow processes.

So, coming to storage, two different types of storages we commonly define. One is retention and the second one is detention. Retention storage is the storage which is held for a long period of time and depleted by evaporation, that is water is retained on the surface or subsurface, whatever it is. It will be stored for a long time and the depletion of this storage will be taking place mainly due to evaporation and the example related to retention storage is this soil moisture storage. So, in the soil, when infiltration is taking place, some amount of water will be stored within the soil pores and after that the interflow will be taking place depending upon the slope with which the flow is taking place. So, soil moisture storage is an example for retention storage.

And coming to detention, detention storage is the one in which short term storage is taken place. Water will be stored for a short interval of time, after that it will be drained off. So, this is a storage depleted by either evaporation or by means of outflow away from the storage location. So, this type of storage we commonly prefer during the time of flooding events. Artificially we will be constructing certain tanks to store water during heavy rainfall and after certain time, once the rainfall recedes, this detained water from the pond will be allowed to

drain off. So, the example for detention storage is flood control ponds where water is stored temporarily. So, during that peak time of peak rainfall, water will be stored, and once the rainfall recedes, the water is allowed to flow towards the outlet point wherever it has to be drained out. So, these are the different ways of defining storages in hydrology. That is, one is the retention storage and the second one is the detention storage.

(Refer Slide Time: 06:28)



Now, let us see different storage components which we generally talk about in hydrology. First one is the interception storage. Interception storage is the storage in which water is stored on the forest cover or on the leaves and branches of the trees. During a rainfall, water will be falling onto the ground and some amount of this rainfall will be stored on the leaves and the branches of trees and also the forest cover. So, this water may get evaporated back to the atmosphere without reaching the ground surface. So, the water which is stored on the leaves of plant branches is termed as the interception storage.

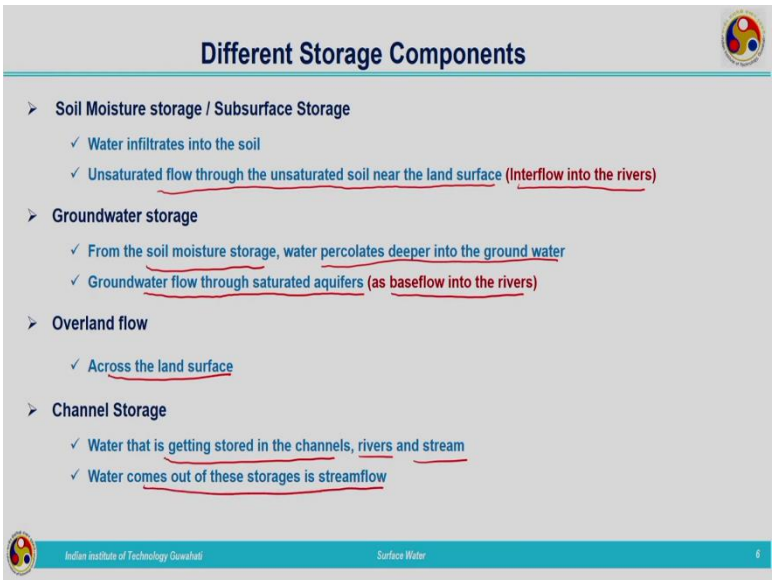
Second one is the depression storage. Depression storage as the name indicates, it is the water stored in the catchment in various depressions on the land surface. Different types of depressions will be present on land surface. Whenever water is falling in the form of rainfall or any other precipitation, these depression storages will be satisfied first then only the flow will be taking place. So, the water which is stored in the depressions is termed as the depression storage. Interception and depression storage should be satisfied first before runoff can occur from a catchment.

Next type of storage is surface storage. A large proportion of the precipitation gets stored on the land surface. During the time of rainfall, initially itself we would not be getting the flow.

After certain time of occurrence of rainfall only we will be having the flow taking place on the surface. So, first this interception and depression storages will be satisfied and at the same time during the time of rainfall land surface will be storing certain amount of water. So, this need to be satisfied before the starting of runoff.

After satisfying the surface storage, overland flow starts. Small amount of water will be retained on the surface as water depth or ponding depth and this cannot be maintained for long time. Once the depth exceeds a certain value, it starts flowing on the surface as overland flow.

(Refer Slide Time: 08:55)



Next is the soil moisture storage or the subsurface storage. Then comes the groundwater storage, overland flow and channel storage. So, when we talk about soil moisture storage, we can go back to the process termed as infiltration which we have seen in the subsurface hydrology.

During the time of rainfall, water is infiltrating into the ground. So, when water is infiltrating, some amount of water will be stored within the pores which is present in the soil. Once it is satisfied, the water starts flowing beneath the ground surface depending upon the gradient. So, finally, that water will be flowing towards the stream which is termed as the interflow, interflow into the river. That is the unsaturated flow through the unsaturated soil near the land surface.

Next is groundwater storage. In this, from the soil moisture storage, water again percolates deeper into the ground. Again, it will be moving in the downward direction and it will be

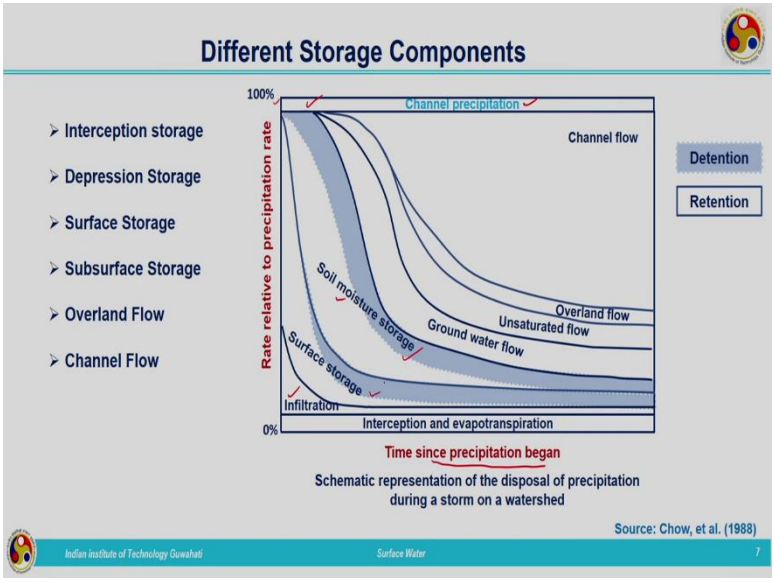
meeting the groundwater table. That way, the groundwater table will be rising and after certain time, there will be flow taking place from the groundwater.

So, from the soil moisture storage when it percolates again deeper into the ground, it meets the groundwater. And groundwater flow also takes place through the saturated aquifers which is termed as baseflow into the rivers. From the groundwater storage also, contribution of water comes to the streams. That is termed as the baseflow.

Next is the overland flow. Overland flow takes place across the land surface. When the land surface storage is satisfied, that I have already told, that is when water is accumulated on the land surface to a certain small depth, it cannot maintain that depth without flowing. Then the flow of water on the surface of the ground surface will be starting. That is termed as the overland flow.

Then next is the channel storage. Water that is getting stored in the channels, rivers, streams, that is the channel storage. How water is flowing towards the channel? Initially all the storage is will be satisfied. After satisfying the surface storage the overland flow will be starting. initially it will be like a sheet flow and after some time it will be forming its own small-small channels. Finally, it will be meeting the natural streams or artificial channels which are constructed for draining of the water and finally, these channels will be carrying water to the main outlet point, maybe the rivers, main rivers and from the rivers to the seas, it will be flowing. And water comes out from all these storages: that is overland flow, interflow and baseflow together is termed as this streamflow. The flow overland flow will be meeting the channel or the stream. Baseflow contribution will be the towards the streams and also interflow from the subsurface. Baseflow, interflow and overland flow together meeting at the stream at one particular point contributing towards the streamflow. That particular flow is termed as streamflow.

(Refer Slide Time: 12:36)



Now, we have seen different storage components: interception storage, depression storage, surface storage, subsurface storage, overland flow, channel flow. So, these different ways of representing storages and after that different types of flows and the quantity of water, what are the different percentage of water stored within each, let us see schematically.

So, this is taken from Ven Chow textbook on Applied Hydrology. This is the schematic representation of the disposal of precipitation during a storm on a watershed. Along the X-axis time since the precipitation began and along the Y-axis it is marked the rate relative to precipitation rate. So, totally we are having 100 percentage and out of the total rainfall different contributions are coming towards different storages and different flow components. Let us see one by one.

Initially, we are having a small amount of water which is stored as interception and evapotranspiration. Interception storage, depression storage and some amount of water is lost to the atmosphere through evapotranspiration and after that some amount is stored as infiltration. Water is getting infiltrated into the ground and we know how the shape of the infiltration curve is looking like. So, that way infiltration is marked over here. Then it contributes to the surface storage. Some amount of water is stored on the land surface and amount of water stored beneath the ground surface is termed as the soil moisture storage. Then comes the groundwater flow. Soil moisture storage, once it is satisfied, interflow will be starting. Again, the soil moisture which is again percolating deeper into it, it will be contributing towards groundwater. So, we will be having groundwater flow and unsaturated flow, then comes the overland flow. Once the shortages are satisfied, we will be getting a thin

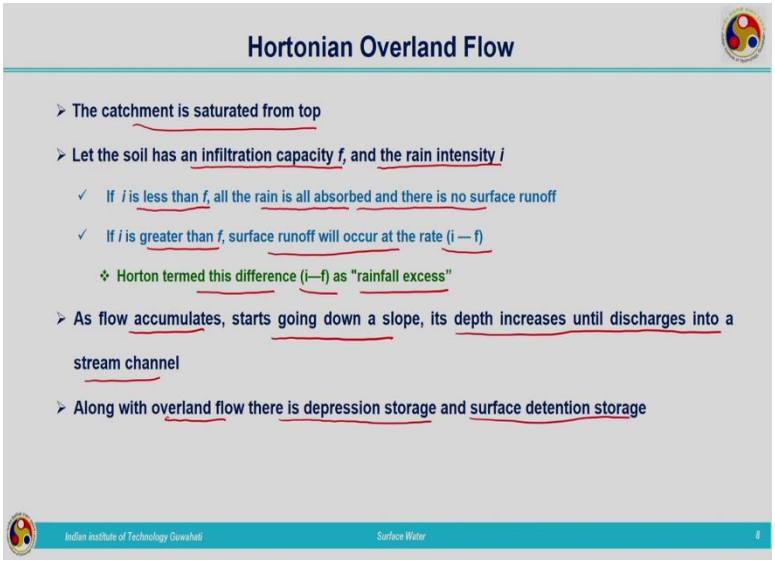
sheet flow over the ground surface, on the earth's surface. That is the overland flow. Finally, contribution comes to the channels or streams in the form of interflow, baseflow and also runoff, surface runoff that is from the overland flow. So, together will be coming at the channel. That is termed as the channel flow.

And now here you can see some amount of water from rainfall is again left. That is nothing but the channel precipitation. Whenever precipitation is occurring it is occurring everywhere, on the land surface and also over the channel or streams. So, that quantity is marked over here. So, this way we can schematically represent different percentages of water which is divided into different storages and different flow components.

In this itself we can divide. Different terminologies we have seen. Out of this we can divide it into two types that is retention storage and the detention storage. Out of that we are having the detention storage on the surface and also subsurface. Detention water which is stored as detention storage is marked over here, subsurface and also surface. Remaining all kinds of storage are retention kind of storage.

Now, we will look into overland flow. Overland flow whenever we are describing, different ways it can be described. One is termed as the Hortonian overland flow, second one is termed as the saturation overland flow. In this course we are dealing with Hortonian overland flow. Let us understand what is the difference between Hortonian overland flow and also saturation overland flow.

(Refer Slide Time: 16:47)



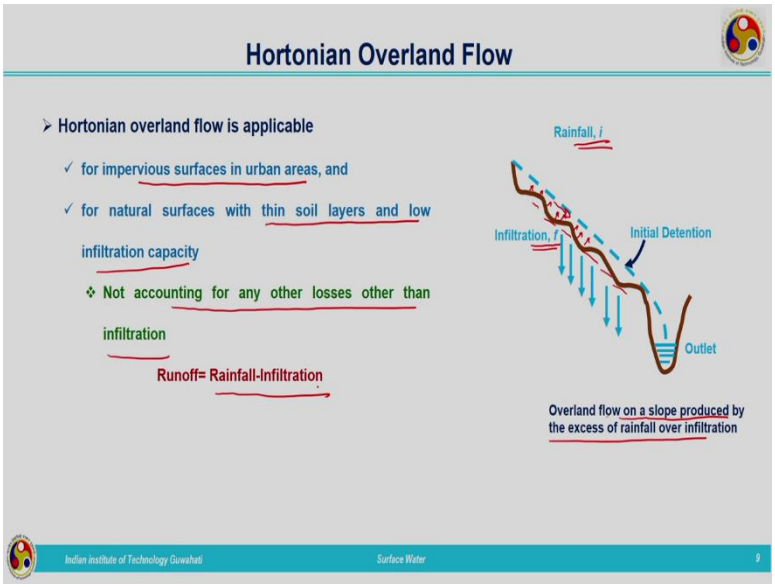
In Hortonian overland flow catchment is saturated from top. From the top of the catchment, top surface itself catchment is getting saturated. This can be explained by means of the precipitation intensity and infiltration rate. Let the soil has an infiltration capacity f and the rainfall intensity be i. If rainfall intensity is less than infiltration rate, then the rain which is falling on the ground will be completely absorbed by the soil or all the water which is falling on the ground as precipitation or rainfall will be infiltrated into the ground and there will not be any runoff.

And on the other hand, if i is greater than f, intensity of rainfall is greater than infiltration rate, surface runoff will occur at the rate $i - f$. That is f is the rate with which the water is getting infiltrated into the ground and i is the total intensity of rainfall. So, the difference between these two, $i - f$ will be coming as overland flow. Now, Horton termed this difference $i - f$ as rainfall excess. Based on Horton's study, the difference between the intensity of rainfall and infiltration rate is term as excess rainfall or rainfall excess.

Now, as the flow accumulates on the surface, that is the ponding depth, it attains certain ponding depth, then the flow starts and it starts going down a slope and its depth will be increasing until it discharges into a stream channel. Initially land surface storage will be satisfied. Slightly water starts accumulating on the ground surface. As the depth increases it starts flowing on the ground surface. When the flow increases, it will be starting as in overland flow or sheet flow on the ground surface and then it will be forming its own channels, different-different channels and finally, it will be contributing towards the streams or channels present. So, along with the overland flow, there is a depression storage and also

surface detention storage. Overland flow will be taking place along with that depression and the detention storage will be satisfied.

(Refer Slide Time: 19:22)



Now, coming to Hortonian overland flow. It is applicable to impervious surfaces in urban areas and also natural surfaces with thin soil layers and low infiltration capacity. Why lower infiltration capacity? Because during the time of infiltration, if infiltration rate is very high, all the water will be infiltrated into the ground. So, the surface layer will be always unsaturated. But when the infiltration rate is less compared to the rainfall intensity, even though infiltration is taking place, surface layer of the soil will become saturated. Then the remaining water will be coming as runoff on the surface of the earth.

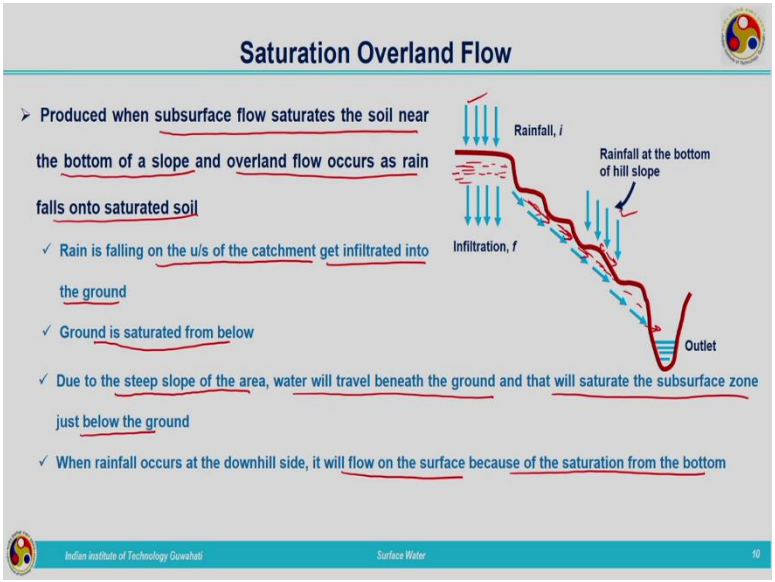
Now, we can schematically understand overland flow on a slope produced by the excess rainfall. Just let this be a schematic representation of a land surface. We are having rainfall in with intensity *i* and rainfall is occurring on the ground surface. It will be infiltrated into the ground with an infiltration rate small *f*. So, in this process what is happening? If the infiltration rate is less compared to rainfall intensity, the soil at the surface layer will be saturated and water will be starting to accumulating on the ground surface. Once it satisfies these storage components, it starts flowing according to the slope and will be collected in the streams or channels or whatever be the outlet point.

So, initial detention ponds or initial depression storage or interception storage will be satisfied. After that the overland flow will be starting and finally it will be moving on to the streams and in this it is not accounting for any other losses other than infiltration. In the

Hortonian concept of overland flow, we are considering only the infiltration and not bothered about any other losses from the rainfall.

So, runoff is considered as the difference between rainfall and the infiltration. Some amount of rainfall is occurring, out of that some amount is getting infiltrated into the ground. Difference between them, where it will go? It will be flowing on the ground surface as overland flow. That is runoff is equal to the difference between the rainfall and the infiltration.

(Refer Slide Time: 21:58)

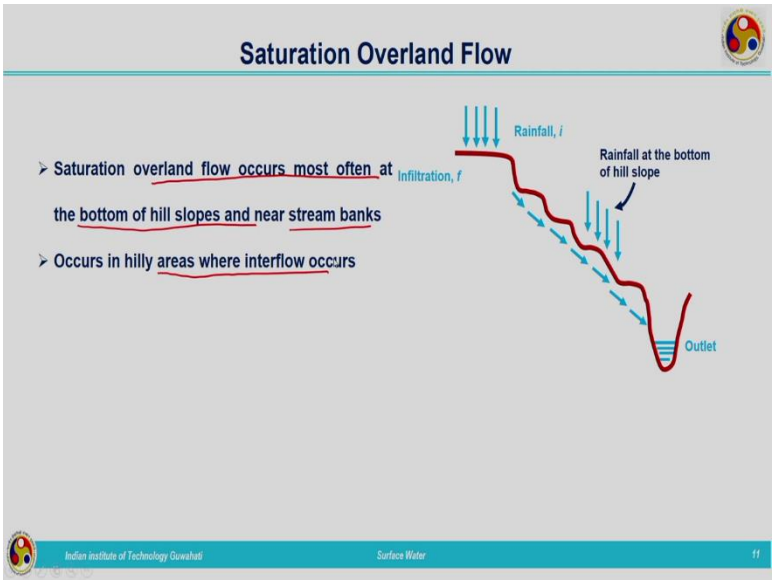


Next is the saturation overland flow. Saturation overland flow is produced when subsurface flow saturates the soil near the bottom of a slope and overland flow occurs as rain falls onto the saturated soil. I will explain this again. That is in this case, saturation overland flow case, subsurface is already saturated and if a rainfall is occurring on a saturated soil, water will not be infiltrating. All the water will be flowing on the surface as runoff. So, that is what is taking place in the case of saturation overland flow. How this is taking place? Let us see with the help of a figure.

So, let this be a land surface and we are having the outlet point maybe a channel or stream and rain is falling on the upstream of the catchment. It gets infiltrated into the ground. So, rainfall with intensity *i* is getting infiltrated into the ground with an infiltration rate of small *f*. So, when this process is continuing, what will happen? Ground surface will become saturated. So, this ground surface will be getting saturated because of the continuous rainfall. So, when it is becoming saturated, what will happen? Interflow will be starting beneath the ground surface.

Due to the steep slope of the area, water will travel beneath the ground and that will saturate the subsurface zone just below the ground. How it is taking place? Because of the slope, water will be moving in this direction. So, it will be contributing interflow towards the stream. So, this entire ground surface is saturated now. Now, you imagine the case where we are getting rainfall at the downward side. You can see initially it was here, saturated over in this region, subsurface flow started in this direction and we are getting rainfall on the downward direction of the catchment and already the surface is saturated. So, this water will not be infiltrated into the ground. It will be flowing as the surface flow. So, when rainfall at the bottom of the hill slope takes place, what will happen? It will flow on the surface because the subsurface is already saturated. That is saturation has taken place from the bottom.

(Refer Slide Time: 24:39)



So, saturation overland flow occurs most often at the bottom of hill slope or near the stream banks. It occurs in hilly areas where interflow occurs. So, you should understand the difference between overland flow, two types of overland flows: one is the Hortonian overland flow. Second one is the saturation overland flow.

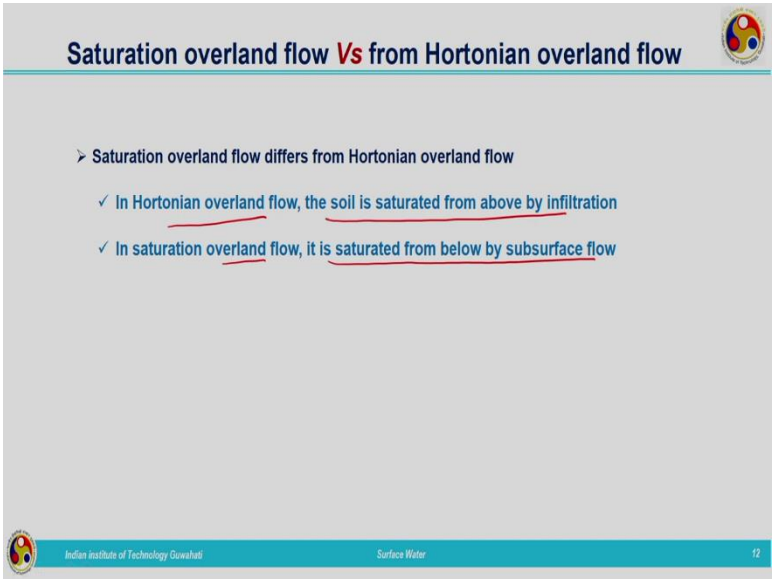
In one case the infiltration is making the surface saturated, that is in the case of Hortonian overland flow, the surface is getting saturated from the top due to infiltration because infiltration rate is at a small rate compared to rainfall intensity. So, the surface layer of the soil will be saturated, that is saturation is taking place from the top.

In the case of saturation overland flow, on the other hand, what is happening? Water is infiltrating into the ground and at the upper side, due to the slope or the gradient, the subsurface flow will be taking place which makes the saturation of the soil from bottom. So,

whenever there is a rainfall occurring at the downward side of the catchment, already the surface soil is saturated from the bottom and water will not be percolating into the ground. It will be overflowing on the ground surface.

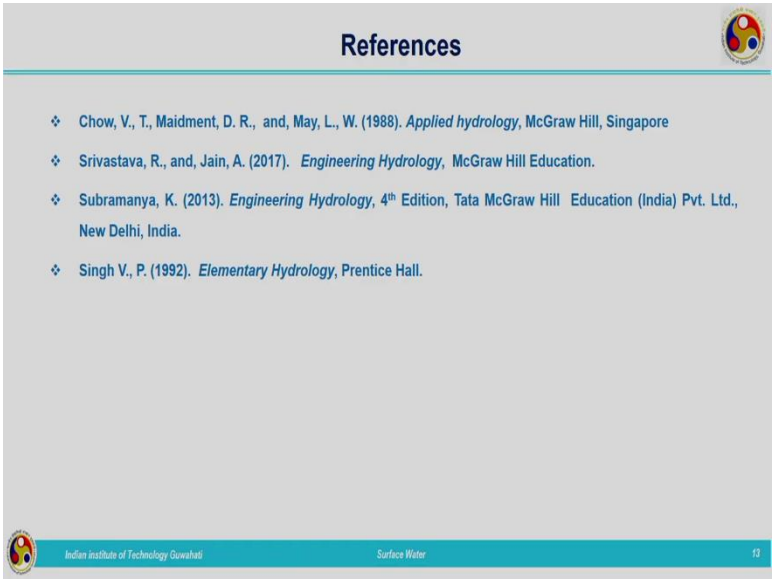
So, in one case, that is in the case of Hortonian overland flow, the surface is saturated from the top and in the case of saturation overland flow the ground surface is saturated from the bottom. These are the two differences between the two. In the case of Hortonian overland flow we are considering runoff due to runoff as a difference between the rainfall and infiltration. Only infiltration loss is taken into account. No other losses from rainfall is considered.

(Refer Slide Time: 26:35)



That is the difference between saturation overland flow and Hortonian overland flow is: Hortonian overland flow, the soil is saturated from above by infiltration and in saturation overland flow it is saturated from below by subsurface flow. These difference you should understand. So, hilly terrains, mainly the runoff is due to or the overland flow is of saturation overland flow and the other terrains, impervious areas and all, we are getting the overland flow as a kind of Hortonian overland flow.

(Refer Slide Time: 27:16)



So, here I am winding up this lecture. These are the references related to this topic. In this lecture what we have covered? We have started with third module on surface water. We have seen different storage components, surface storage, subsurface storage and after satisfying different storages the overland flow will be starting. Then we have seen different types of representation of overland flow: one is the saturation overland flow and the other one is the Hortonian overland flow. Difference between these two we understood, that is in the case of Hortonian overland flow, the surface of the land is getting saturated from the top and in the case of saturation overland flow, the saturation is taking place due to interflow or due to subsurface flow. Mainly we are dealing with a Hortonian overland flow, saturation overland flow we are not considering in this particular course. In the case of Hortonian overland flow, we are considering only the infiltration loss. We are not considering any other losses and the difference between the rainfall and the infiltration can be considered as the quantity contributing towards runoff. So, here I am winding up this lecture. Thank you.