Surface Water Hydrology
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Lecture – 14
Initial Loss and Infiltration Process

In this very particular lecture, we will discuss two important concepts, one is initial loss and the other one is infiltration processes.

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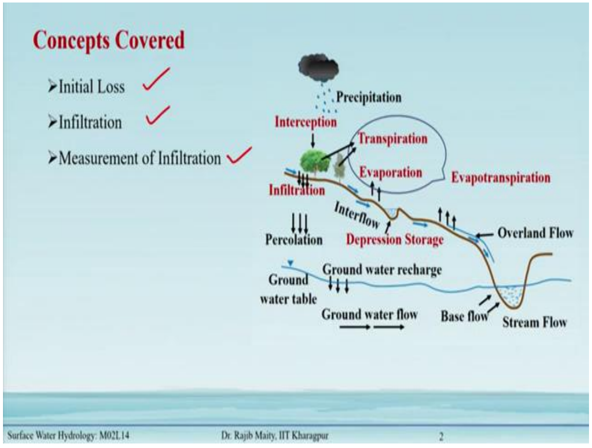

In this concept, first, we will cover this initial loss part. Then comes infiltration and the measurement of infiltration.

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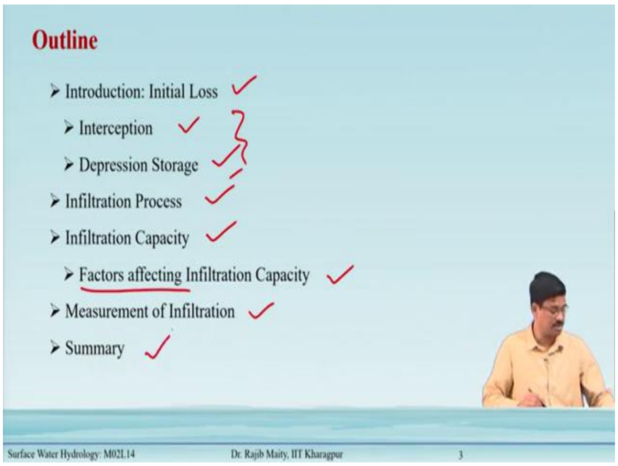

The outline of this lecture goes like this, so first, we will discuss this initial loss, some brief introduction. Then it comes to the interception and depression loss, that depression storage these are the two things that constitute this initial loss. And then, gradually start discussing the very important process for the infiltration process. And one of the most important concepts is called infiltration capacity, which we will discuss.

There are different factors are there that affects the infiltration capacity. And we will also include in this lecture the different measurements of the ways of or methods of field measurement of infiltration. And then, we will discuss the summary of this lecture.

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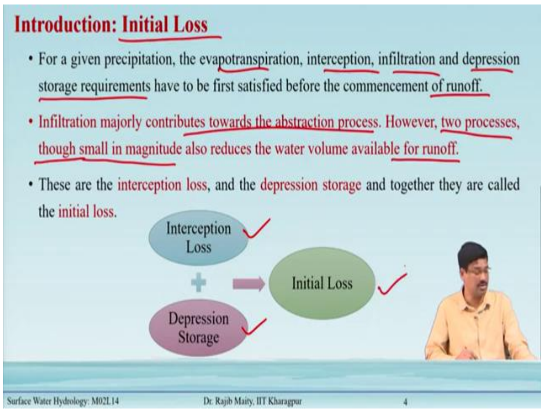

Introduction: Initial Loss

For a given precipitation, the evapotranspiration, interception, infiltration, and depression storage requirements have to be first satisfied before the commencement of runoff. Infiltration majorly contributes to the abstraction process. However, two processes, though small in magnitude also reduce the water volume available for runoff.

These are the interception loss and the depression storage and together they are called the initial loss.

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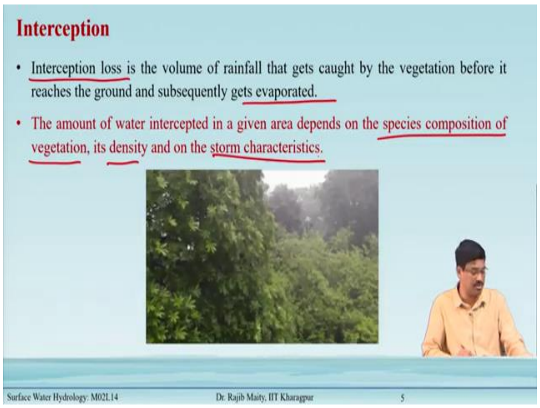

Interception

Interception loss is the volume of rainfall that gets caught by the vegetation before it reaches the ground and subsequently gets evaporated. The amount of water intercepted in a given area depends on the species composition of vegetation, its density, and storm characteristics.

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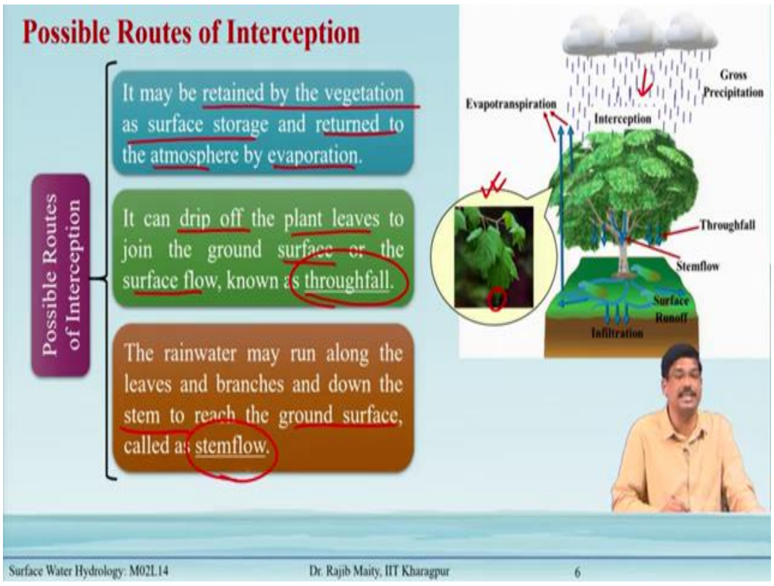

Possible Routes of Interception

There are three possible ways the interception can take place,

- It may be retained by the vegetation as surface storage and returned to the atmosphere by evaporation.
- It can drip off the plant leaves to join the ground surface or the surface flow, known as throughfall.
- The rainwater may run along with the leaves and branches and down the stem to reach the ground surface, called stemflow.

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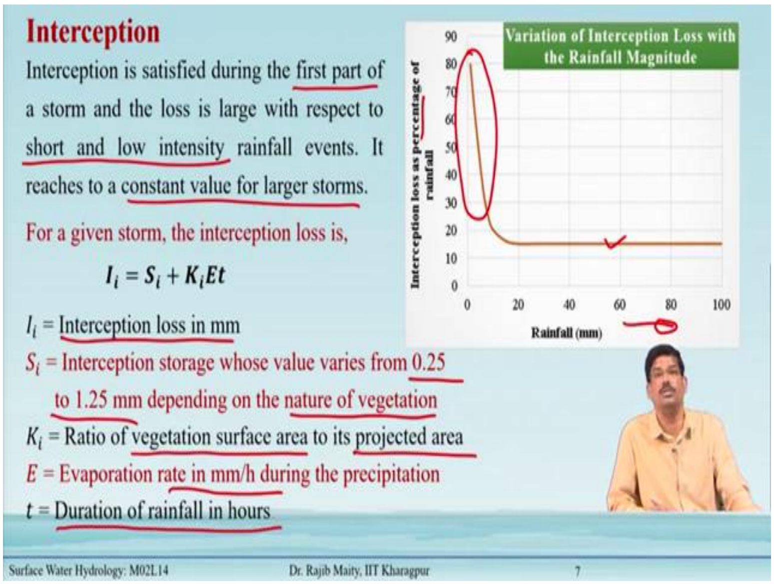

Interception

Interception is satisfied during the first part of a storm and the loss is large with respect to short and low-intensity rainfall events. It reaches a constant value for larger storms. Fig.1 shows the variation of intercepts and loss with the rainfall magnitude. So, as this rainfall magnitude increases it becomes a constant percentage, we can say how much is this initial loss. But for the initial part when the rainfall magnitude is less, this loss component is very high.

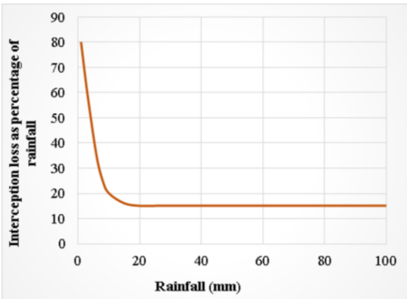

Fig.1 shows the variation of interception loss with the rainfall magnitude

Now, there are some equations through which the interception loss can be estimated. For a given storm, the interception loss is

$$I_i = S_i + K_iEt$$

I_i = Interception loss in mm

S_i = Interception storage whose value varies from 0.25 to 1.25 mm depending on the nature of vegetation

K_i = Ratio of vegetation surface area to its projected area

E = Evaporation rate in mm/h during the precipitation

t = Duration of rainfall in hours

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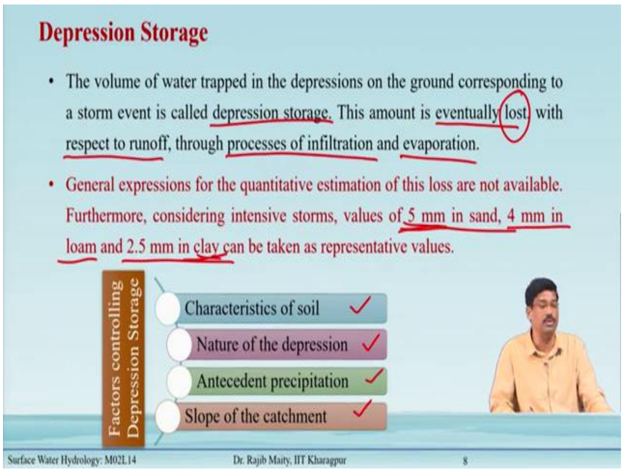

Depression Storage

The volume of water trapped in the depressions on the ground corresponding to a storm event is called depression storage. This amount is eventually lost, with respect to runoff, through processes of infiltration and evaporation.

General expressions for the quantitative estimation of this loss are not available. Furthermore, considering intensive storms, values of 5 mm in the sand, 4 mm in loam, and 2.5 mm in clay can be taken as representative values.

Now, various factors control this depression storage, this includes the characteristics of soil, nature of depression, antecedent precipitation, and slope of the catchment.

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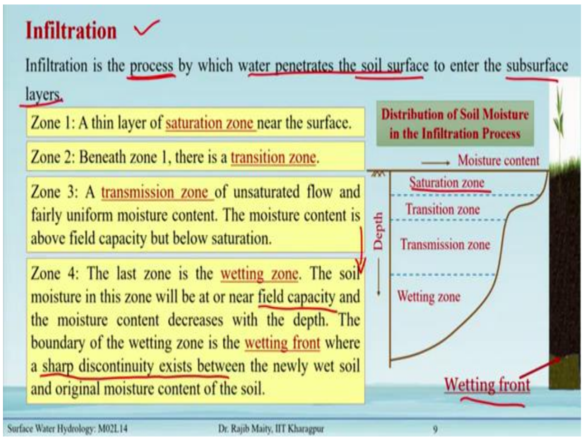

Infiltration

Infiltration is the process by which water penetrates the soil surface to enter the subsurface layers.

Zone 1: A thin layer of saturation zone near the surface.

Zone 2: Beneath zone 1, there is a transition zone.

Zone 3: A transmission zone of unsaturated flow and fairly uniform moisture content. The moisture content is above field capacity but below saturation.

Zone 4: The last zone is the wetting zone. The soil moisture in this zone will be at or near field capacity and the moisture content decreases with the depth. The boundary of the wetting zone is the wetting front where a sharp discontinuity exists between the newly wet soil and the original moisture content of the soil.

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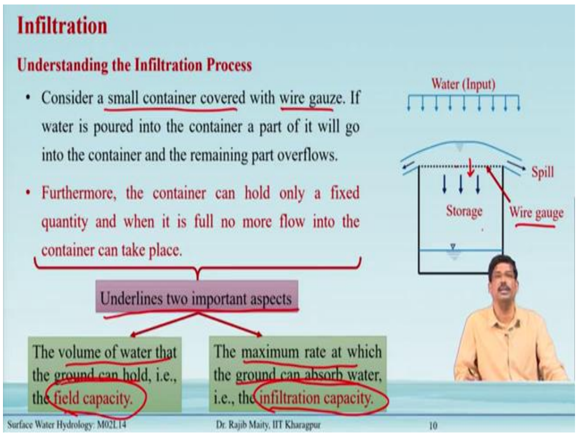

Understanding the Infiltration Process

Consider a small container covered with wire gauze. If water is poured into the container a part of it will go into the container and the remaining part overflows. Furthermore, the container can hold only a fixed quantity and when it is full no more flow into the container can take place.

So, there are two important concepts through which we can just describe the process in this natural field. The first one is the volume of the water that the ground can hold, this is called the field capacity. And the second one, the maximum rate at which the ground can absorb the water in this case, the maximum rate by which the wire gauze can pass the water below the storage space, is called the infiltration capacity.

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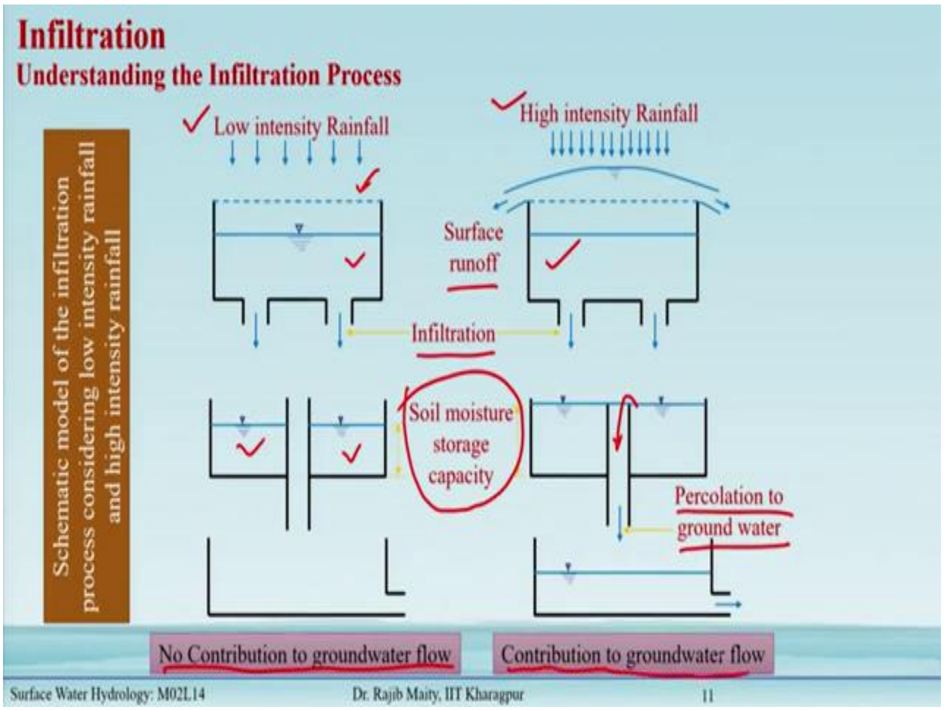

Now, if we want to see it further process, how after the infiltration takes place, how it goes in case of the low intensity and the high-intensity rainfall magnitude. We have taken the same one the container concept there is a cover as shown in fig.2. So, when the intensity of the rainfall is sufficiently low, then rainfall and everything is going through this wire gauze and getting stored in this container.

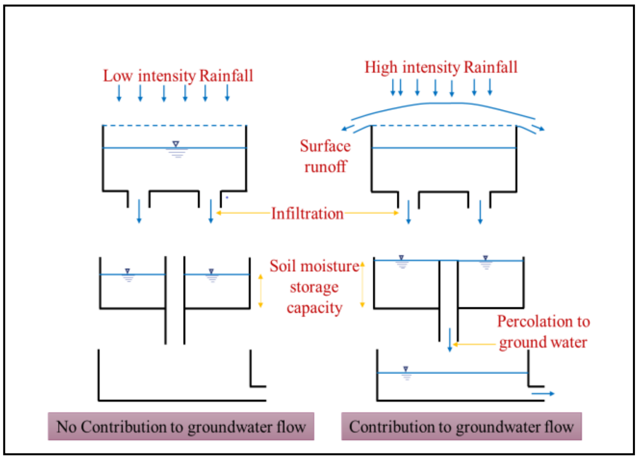

Fig.2 shows the infiltration process for low intensity and high-intensity rainfall

But when the intensity of rainfall is high, everything cannot come down. So, something will go and spill over this wire gauze, and that term as we have discussed in this hydrologic cycle, cycle the surface runoff. Now, after it penetrates this one, this one entity that comes that we can say as an infiltration. And once this infiltration takes place, we can assume that there is another storage place as you can see in fig.2, which we call a soil moisture storage capacity.

In both cases, there is another outlet. So, if this thing fills up, it will just spill over and come through this. And this concept is the percolation to the and the contribution goes to this groundwater part. In the case of low-intensity rainfall, there is no contribution to the groundwater flow. And in this case, when it fills up this soil moisture storage capacity, it comes down further. So, there is a contribution to the groundwater flow in the case of high-intensity rainfall.

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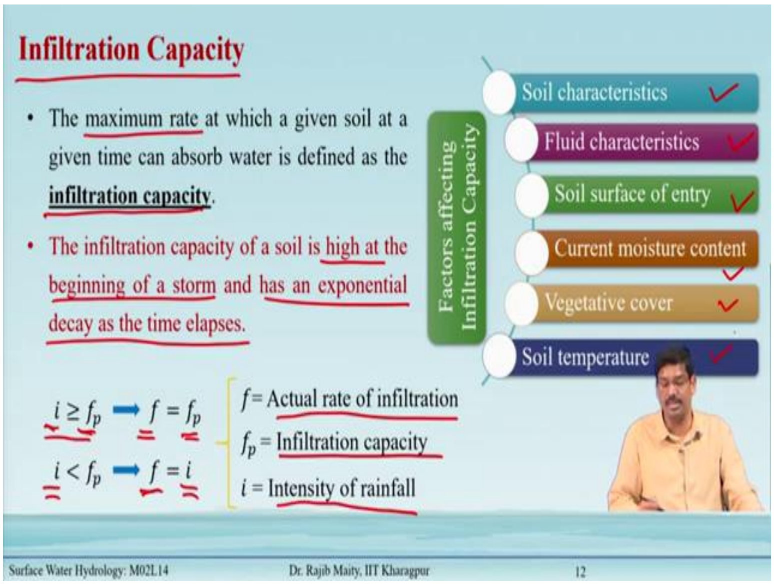

Infiltration Capacity

The maximum rate at which a given soil at a given time can absorb water is defined as the infiltration capacity. The infiltration capacity of soil is high at the beginning of a storm and has an exponential decay as time elapses.

When the intensity of this rainfall is greater than equal to the field capacity, then the infiltration capacity is equal to that actual rate of infiltration.

$$i \geq f_p \qquad f = f_p$$

But in other cases when the intensity of rainfall is less than the infiltration capacity, the time this actual rate of infiltration is equal to the intensity of rainfall itself.

$$i < f_p \qquad f = i$$

There are several factors are there that affect the infiltration capacity. The first one is the soil characteristics, fluid characteristics, soil surface entry, surface of entry, current moisture content, vegetative cover, soil temperature, these are some of the factors that affect this infiltration capacity.

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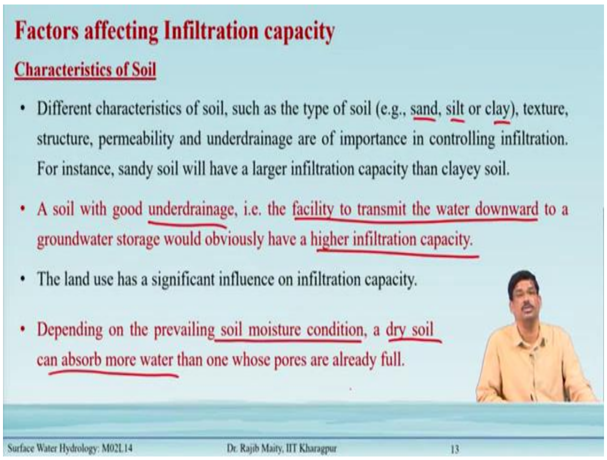

Characteristics of Soil

Different characteristics of soil, such as the type of soil (e.g., sand, silt, or clay), texture, structure, permeability, and under drainage are of importance in controlling infiltration. For instance, sandy soil will have a larger infiltration capacity than clayey soil.

A soil with good under drainage, i.e., the facility to transmit the water downward to groundwater storage would have a higher infiltration capacity. Land use has a significant influence on infiltration capacity. Depending on the prevailing soil moisture condition, dry soil can absorb more water than one whose pores are already full.

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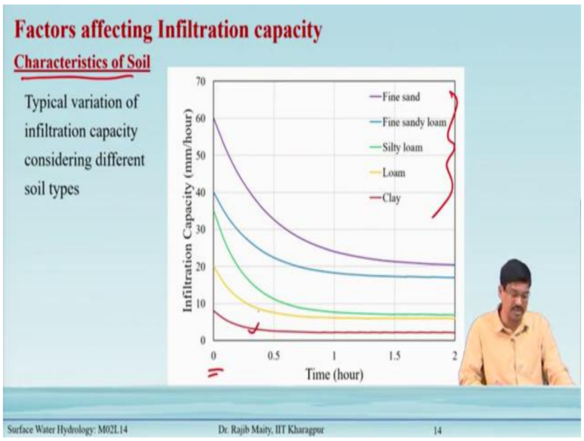

Typical variation of infiltration capacity considering different soil types is shown in fig.3, there is two major observation we can make from this fig.3. One is that towards the very initial time the infiltration capacity is very high for all different types of soil. It decreases exponentially and finally reaches a constant value. This is the number one to note that how it varies over time, the nature of the curve. And second thing is that the depending on the different types of this soil as it is shown by the different color lines. So, the clayey is the, the clay soil is the lowest infiltration capacity at any instants of time. Gradually it increases from loam to silty loam to fine sandy loam and then fine sand.

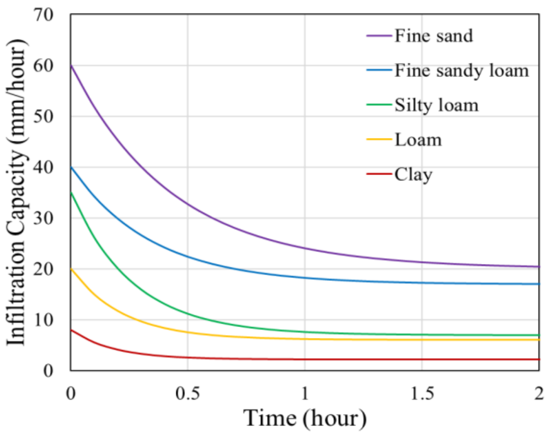

Fig.3 shows the variation of infiltration capacity considering different soil types

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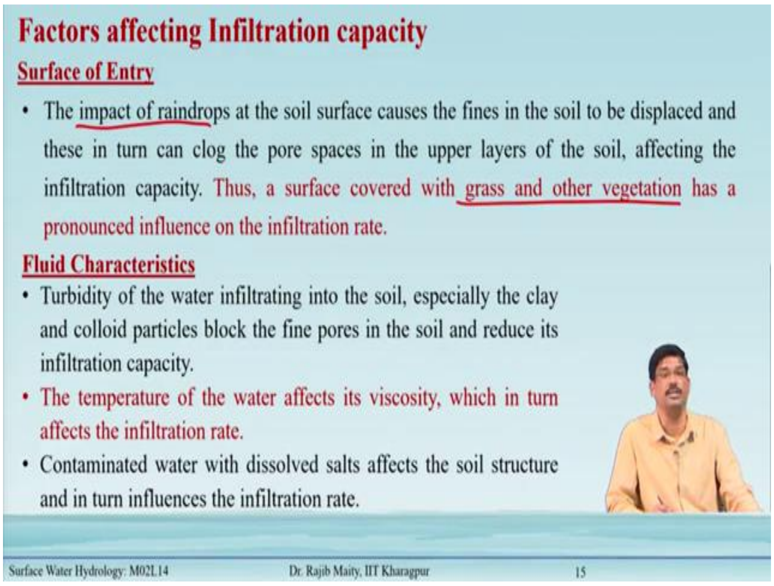

Surface of Entry

The impact of raindrops at the soil surface causes the fines in the soil to be displaced and these, in turn, can clog the pore spaces in the upper layers of the soil, affecting the infiltration capacity. Thus, a surface covered with grass and other vegetation has a pronounced influence on the infiltration rate.

Fluid Characteristics

Turbidity of the water infiltrating into the soil, especially the clay and colloid particles block the fine pores in the soil and reduce its infiltration capacity.

The temperature of the water affects its viscosity, which in turn affects the infiltration rate. Contaminated water with dissolved salts affects the soil structure and in turn influences the infiltration rate.

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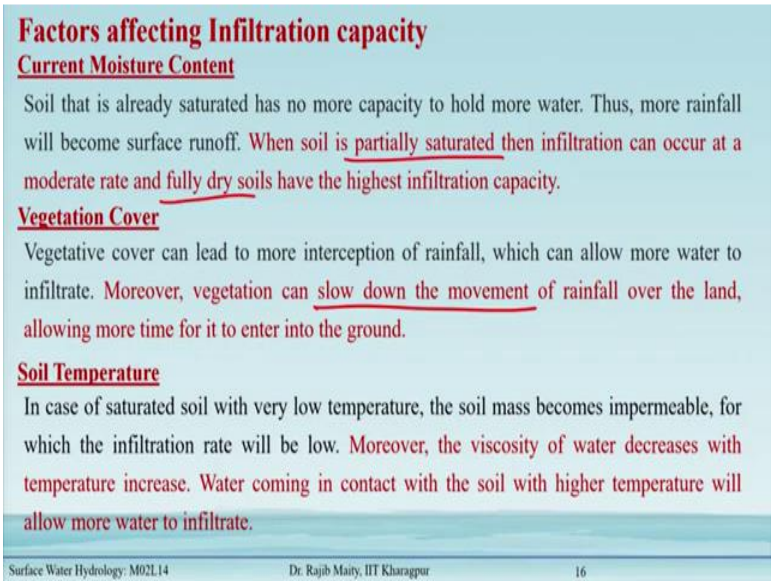

Current Moisture Content

Soil that is already saturated has no more capacity to hold more water. Thus, more rainfall will become surface runoff. When soil is partially saturated then infiltration can occur at a moderate rate and fully dry soils have the highest infiltration capacity.

Vegetation Cover

Vegetative cover can lead to more interception of rainfall, which can allow more water to infiltrate. Moreover, vegetation can slow down the movement of rainfall over the land, allowing more time for it to enter into the ground.

Soil Temperature

In the case of saturated soil with very low temperatures, the soil mass becomes impermeable, for which the infiltration rate will be below. Moreover, the viscosity of water decreases with temperature increase. Water coming in contact with the soil with a higher temperature will allow more water to infiltrate.

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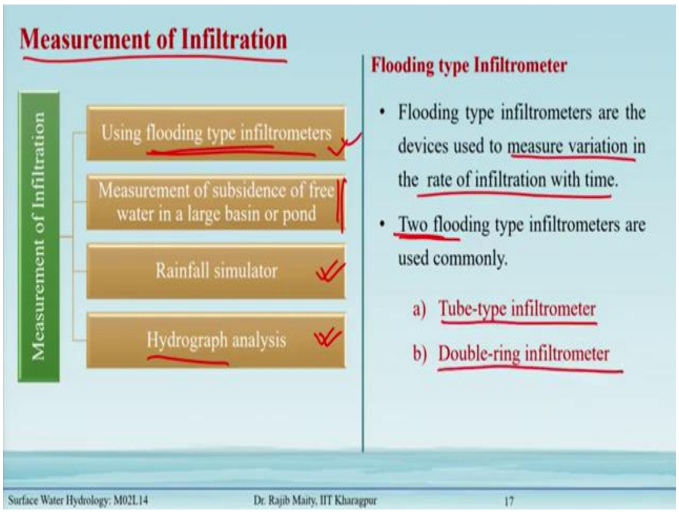

Measurement of Infiltration

There are different ways that we can measure this infiltration. They are as follows:

- Using flooding type infiltrometers
- Measurement of subsidence of free water in a large basin or pond
- Rainfall simulator
- Hydrograph analysis

Flooding type Infiltrometer

Flooding type infiltrometers are the devices used to measure variation in the rate of infiltration with time.

Two flooding-type infiltrometers are used commonly.

a) Tube-type infiltrometer

b) Double-ring infiltrometer

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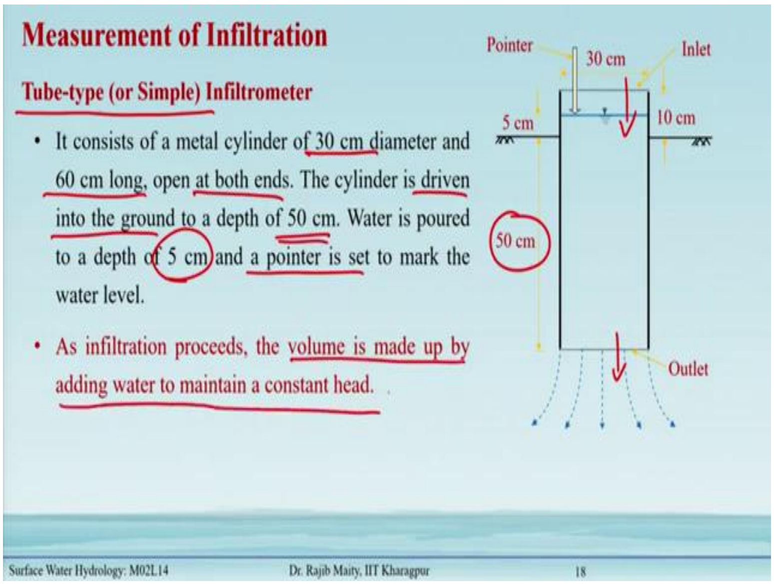

Tube-type (or Simple) Infiltrometer

It consists of a metal cylinder of 30 cm diameter and 60 cm long, open at both ends. The cylinder is driven into the ground to a depth of 50 cm. Water is poured to a depth of 5 cm and a pointer is set to mark the water level. As infiltration proceeds, the volume is made up by adding water to maintain a constant head.

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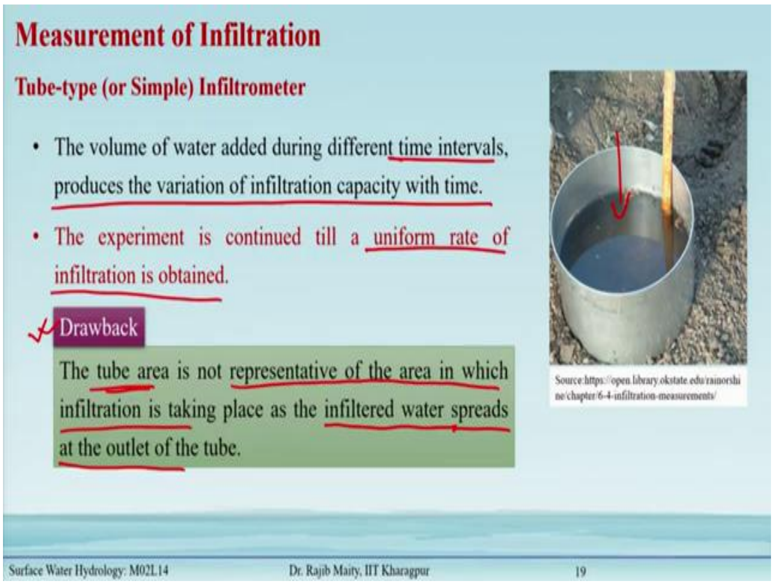

Tube-type (or Simple) Infiltrometer

The volume of water added during different time intervals produces the variation of infiltration capacity with time. The experiment is continued till a uniform rate of infiltration is obtained.

Now, this method is having one drawback, the drawback is that the tube area is not representative of the area in which infiltration is taking place as the infiltered water spreads at the outlet of the tube.

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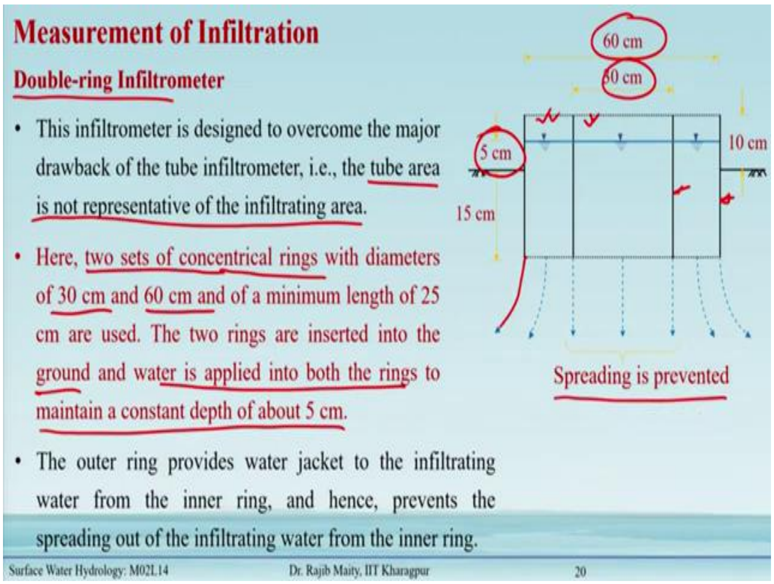

Double-ring Infiltrometer

This infiltrometer is designed to overcome the major drawback of the tube infiltrometer, i.e., the tube area is not representative of the infiltrating area. Here, two sets of concentrical rings with diameters of 30 cm and 60 cm and a minimum length of 25 cm are used. The two rings are inserted into the ground and water is applied into both the rings to maintain a constant depth of about 5 cm. The outer ring provides a water jacket to the infiltrating water from the inner ring, and hence, prevents the spreading out of the infiltrating water from the inner ring.

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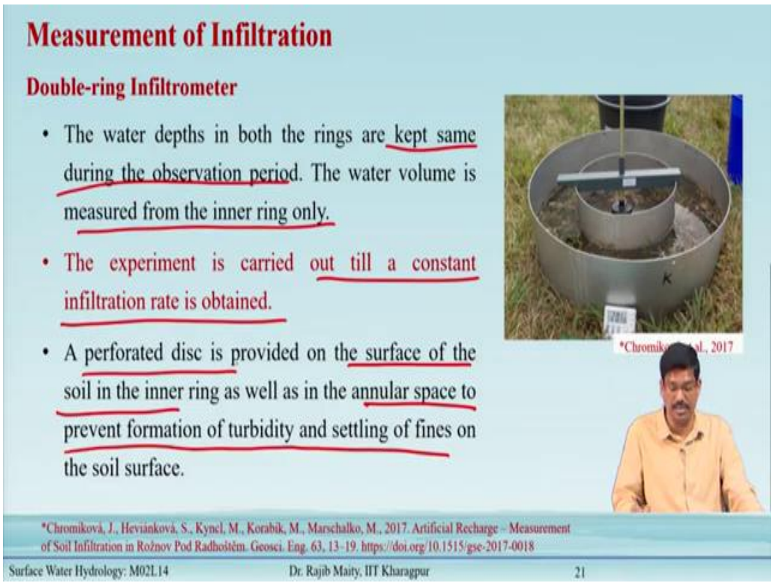

The water depths in both the rings are kept the same during the observation period. The water volume is measured from the inner ring only.

The experiment is carried out till a constant infiltration rate is obtained. A perforated disc is provided on the surface of the soil in the inner ring as well as in the annular space to prevent the formation of turbidity and settling of fines on the soil surface.

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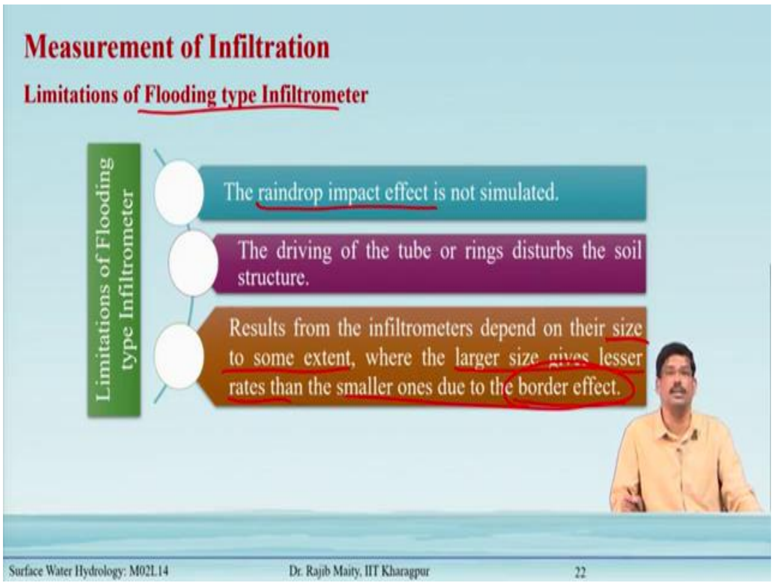

Limitations of Flooding type Infiltrometer

There are some limitations of this flooding type, both the types that we have to discuss, in general.

- The raindrop impact effect is not simulated.
- The driving of the tube or rings disturbs the soil structure.
- Results from the infiltrometers depend on their size to some extent, where the larger size gives lesser rates than the smaller ones due to the border effect.

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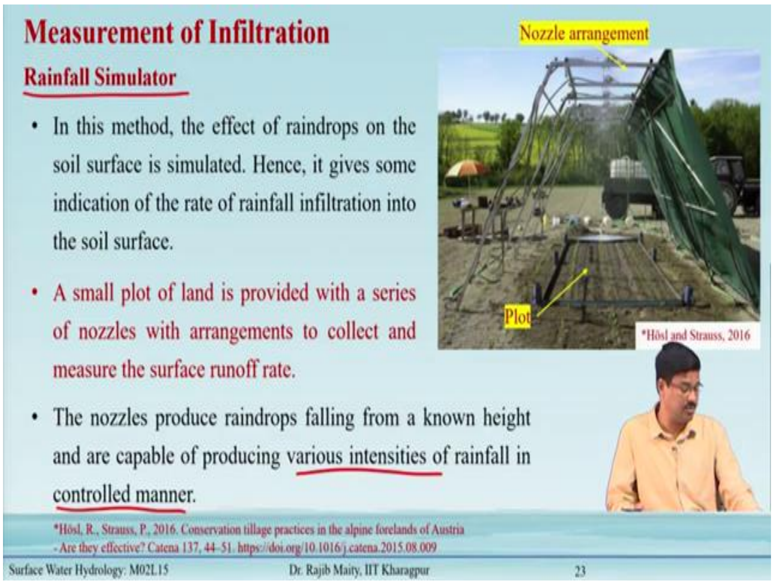

Rainfall Simulator

In this method, the effect of raindrops on the soil surface is simulated. Hence, it gives some indication of the rate of rainfall infiltration into the soil surface.

A small plot of land is provided with a series of nozzles with arrangements to collect and measure the surface runoff rate. The nozzles produce raindrops falling from a known height and are capable of producing various intensities of rainfall in a controlled manner.

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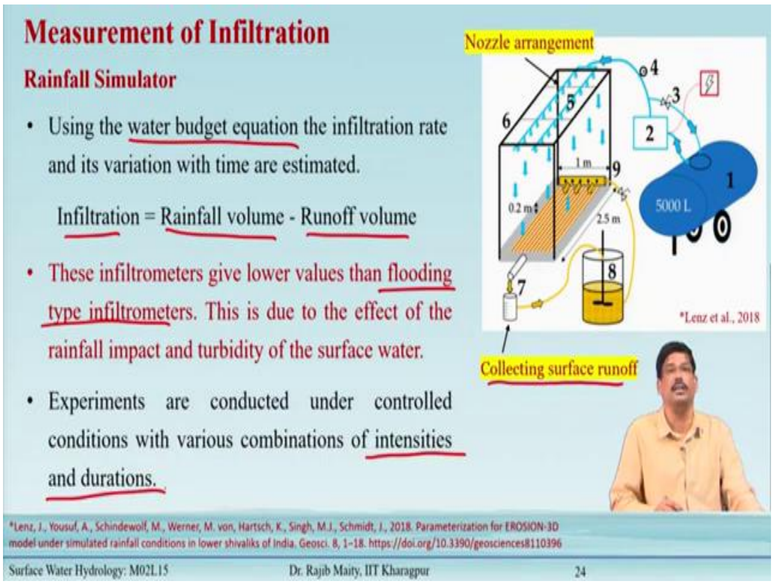

Rainfall Simulator

Using the water budget equation, the infiltration rate and its variation with time are estimated.

Infiltration = Rainfall volume - Runoff volume

These infiltrometers give lower values than flooding-type infiltrometers. This is due to the effect of the rainfall impact and turbidity of the surface water. Experiments are conducted under controlled conditions with various combinations of intensities and durations.

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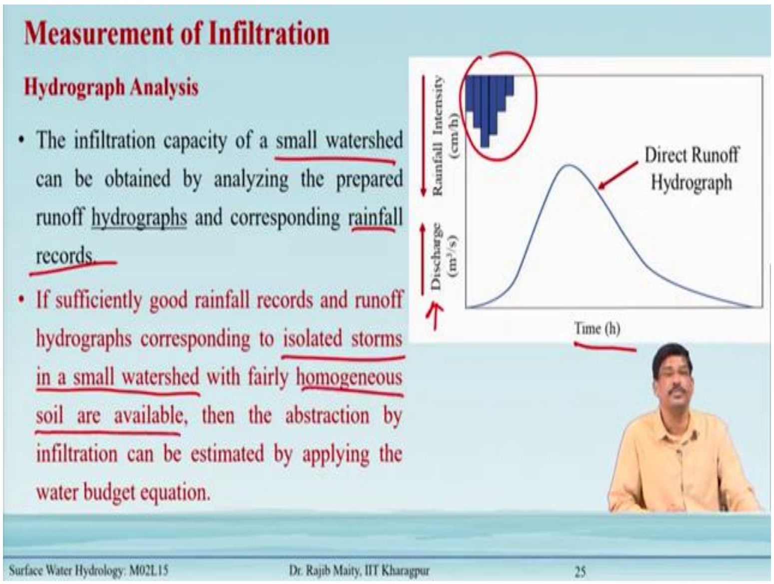

Hydrograph Analysis

The infiltration capacity of a small watershed can be obtained by analyzing the prepared runoff hydrographs and corresponding rainfall records.

If sufficiently good rainfall records and runoff hydrographs corresponding to isolated storms in a small watershed with fairly homogeneous soil are available, then the abstraction by infiltration can be estimated by applying the water budget equation.

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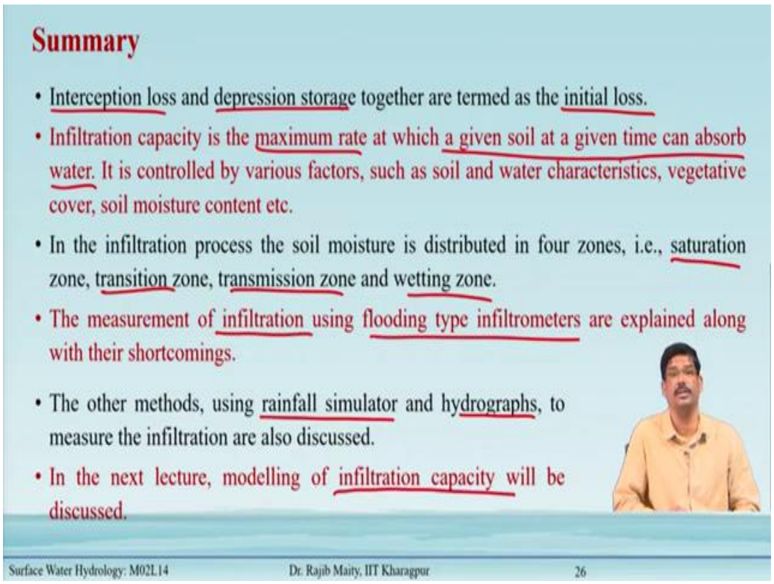

Summary

In summary, we learned the following points from this lecture:

- Interception loss and depression storage together are termed as the initial loss.
- Infiltration capacity is the maximum rate at which a given soil at a given time can absorb water. It is controlled by various factors, such as soil and water characteristics, vegetative cover, soil moisture content, etc.
- In the infiltration process, the soil moisture is distributed in four zones, i.e., saturation zone, transition zone, transmission zone, and wetting zone.
- The measurement of infiltration using flooding-type infiltrometers is explained along with their shortcomings.

- The other methods, using rainfall simulators and hydrographs, to measure the infiltration are also discussed.
- In the next lecture, modelling of infiltration capacity will be discussed.