Geomorphology
Prof. Dr. Pitambar Pati
Department of Earth Science
Indian Institute of Technology Roorkee

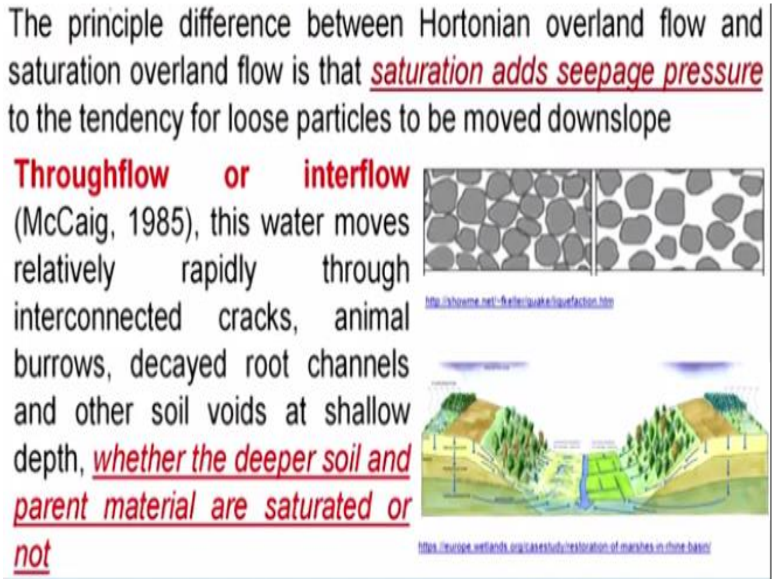
Lecture-45
Fluvial Process -I

So, friends, welcome to this lecture of geomorphology and today, we will continue with this fluvial geomorphology that we were talking in the last class. So, in the last class we have concluded that the hortonian overland flow and this saturation overland flow both they contribute this sediment as well as water to this stream systems. And today we will talk about this throughflow system.

This throughflow that means it is an interflow it is otherwise called inter flow. These are due to this cracks, this animal burrows, the decayed root canals like those. So, these are the free space during raining this water moves through this free space quickly as compared to these other type of flows. So, this type of contribution or this type of quick movement of water through these open channels, so, they erode this material around them and finally, these contribute this sediments.

So, this is one another type of flow as compared to this surfacial flow, these are the subsurface flows generally. So, these cracks and irrespective of this nature either it is natural or there artificial, the root canals, the animal burrows, they are a very good contributor for this sediment erosion and water flow from the river system.

(Refer Slide Time: 01:49)

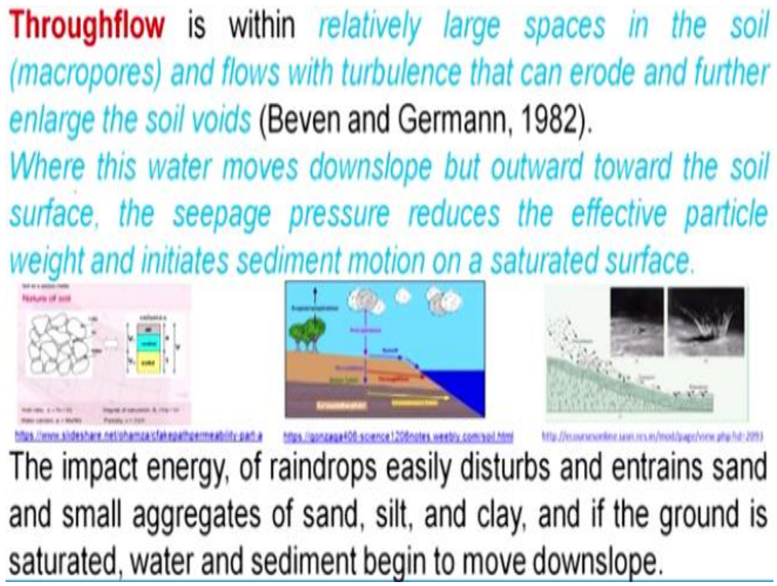


The principle difference between this hortonian overland flow and the saturation overland flow is that saturation adds seepage pressure. So, the tendency for the loose particle to be moved downslope, here if you see if it is saturated now see here, this system is saturated, so saturation, it adds seepage pressures, so seepage pressures that means it is outward, so, that means it will lose the sediments, it will decrease the adhesive power of this grains.

And once the sediments are in loosed that means, it will be transported along with the water. So, sediment and water together they transport downstream throughflow or interflow is what this water moves relatively rapidly through interconnected cracks, animals burrows, decayed root canals and other soil voids at shallow depths. Whether the deeper soil and the parent material of saturated or not, it is not necessarily.

But here this is one term which is called throughflow, throughflow means suppose we have cracks, we have burrows animal burrows we have root channels which is decomposed that means, there are free spaces available. So, during raining some waters, they quickly flow through this type of cracks and this is called throughflows or interflows. So, they also losened the sediment from this inner part of this soil and or this subsurface soil and this contribute sediment to this water.

(Refer Slide Time: 03:35)

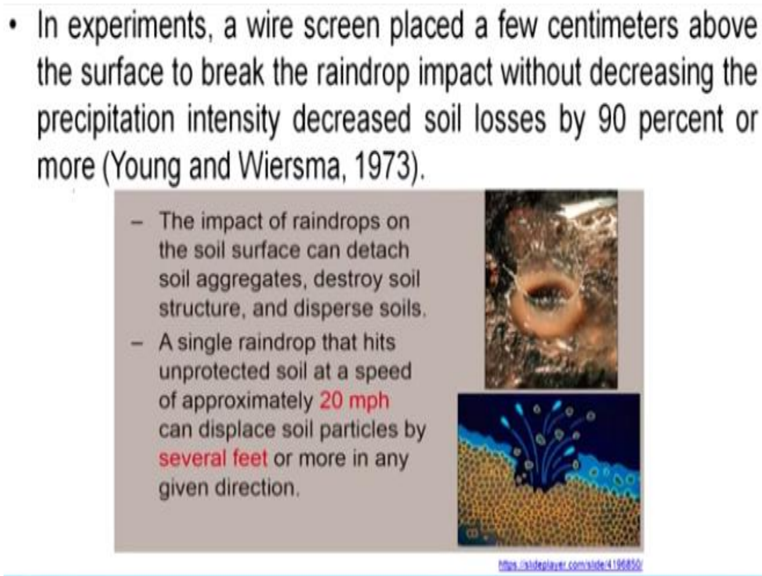


Throughflow is within a relatively large space in the soil or micropores and flows with turbulence that can erode and further enlarge soil voids where this water moves downslope, but outward towards the soil surface. The seepage pressure reduces the effective particle weight and initiates sediment motion in a saturated surface. So, that means it is creating it is increasing the sediment load or sediment contributions, the impact energy of raindrop easily disturbs.

And entrains the sand and small aggregates of sand, silt and clay. And if the ground is saturated water and sediment begin to move downslope when we are talking about a stream, that means we are taking this stream water is flowing along this water sediment is flowing. So now we need water and sediment both to create a stream. So in this way, we are creating water that means through rainwater through groundwater.

And we are we are entraining sediments particles and due to saturation, we are losing the sediment particle and due to increasing the seepage pressure and finally we are contributing those sediments with water. So now we have water and sediments both are transporting that means we are approaching to create a stream.

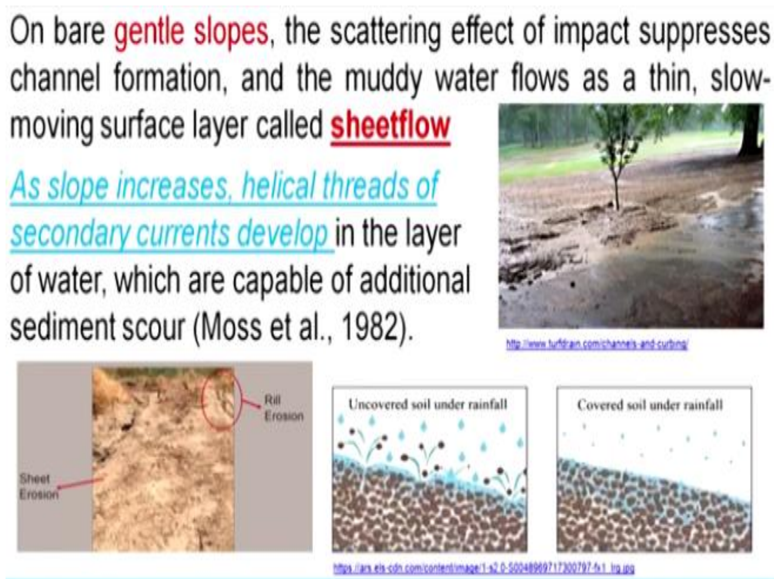
(Refer Slide Time: 04:59)



In an experiment, a wire mess wire screen placed in few centimeters above the surface of this break surface to break the raindrop impact without decreasing the precipitation intensity, decrease the soil losses by 90% or more. So that means, if we are creating a shield somehow it is here it is a net if we are placing a net on this surface and allowing these raindrop to interact with the soil as compared to the barren land.

This soil loss or these sediment particles to loose from the soil, the probability decreases 90%. So that is why it can if it is applied to the real world, it is like this vegetation cover where this vegetation is cover vegetation cover is there on the surface. So that means here, this sediment entrain or the sediment losing by raindrop, it decreases by 90%. That is why vegetated areas that contribute less sediment as compared to barren land. And it vegetated area; there will be more infiltration as compared to this other part.

(Refer Slide Time: 06:14)

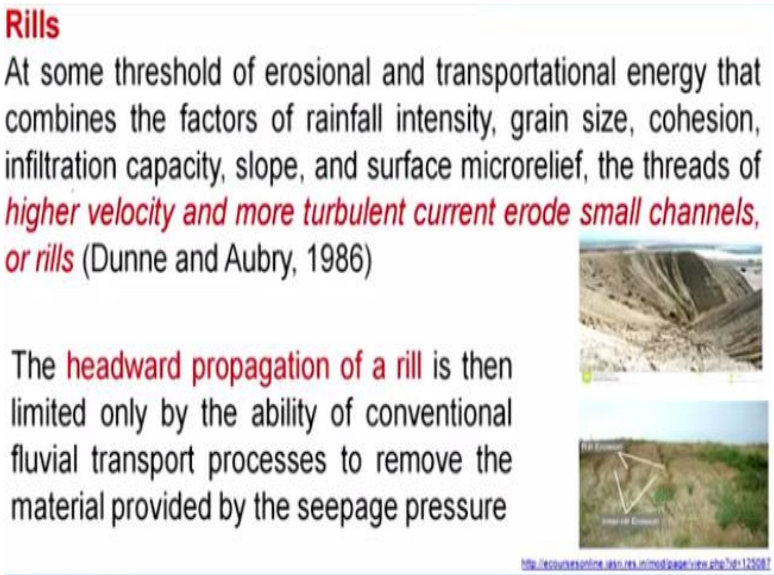


On bare gentle slopes the scattering effect of impacts of suppresses channel formation and muddy water flow as a thin slow moving layer that is called sheetflow, here sheetflow, it is another type of flow that means, a thin film of water it is flowing on the surface carrying the sediments and very interestingly, sometimes you can notice that the sediment is floating the sediment particle is floating on the surface due to surface tension so, this is a sheetflow.

So, it is a forms on the gentle surface and it is sediment laden water it is flowing as a sheet of material. As slope increases helical threads of secondary current develops in this layer of water, which are capable of additional sediment scours. Now you see it in the initial stage, a sheetflow was occurring. So once where increasing the slope that means here you see this type of movement.

That means here increasing slope, this type of helical movement, we are introducing the helical moment and helical moment they are capable of eroding more sediments at compared to the sheetflow. So that means by this way, by different type of movement by different type of slopes, different type of landscapes, vegetation cover without vegetation cover, we are approaching to create a stream with water sufficient sediments within that.

(Refer Slide Time: 07:42)

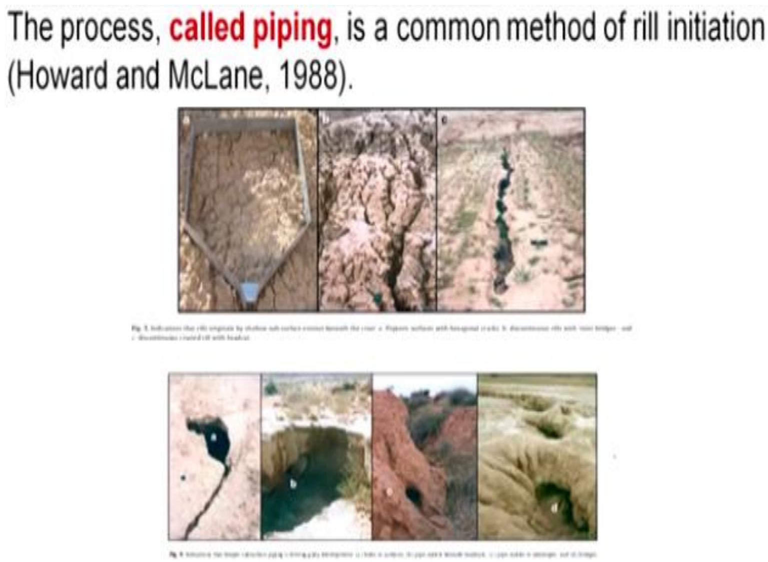


So here first order streams are the rills, they are developed, so, rills that means very narrow, very small, even if it is not a mapable scale, the rills are not a mapable scale of 1 is to 50,000 scale. So here at some threshold of erosional and transportional energy that combines the factor of rainfall intensity, grain size, cohesion, infiltration capacity, slope and surface micro relief, the threats of higher velocity and more turbulent current erode small channels or rills.

So, these are the characteristics features. So, all those characteristics you will find in those rills. So, if you see here, these are the rills so, rills they grow on the sloping surfaces. And finally, they grow headward and erode more regions, they expand this area of the river and they contribute sediments from these headlands and contribute to the downstream. So, they play a major role in expanding river systems.

The headward propagation of rills is then limited only by the ability of conventional fluvial transport process to remove the material produced provided by these seepage pressures. So, that means, if we are removing this material which has contributed by the rills, so, that means, we are allowing the rill to grow further.

(Refer Slide Time: 09:16)



The process is called piping is a common method of rill initiation piping that means, simply percolation now, if you see here, it was an experiment and here these are this if you take this is a surface expression, but, here if we zoom it, you will find this type of small cavities that means, it is going down water is percolating down. So, this cavity here this cavity they will mix their coalescence with time and finally, forms the rill.

So, in the surface the rills are the initial time if you see these rills they are simply their points through which the water is percolating downward and with the time these points they grow their size and the coalescence and forming a linear channel is called rills.

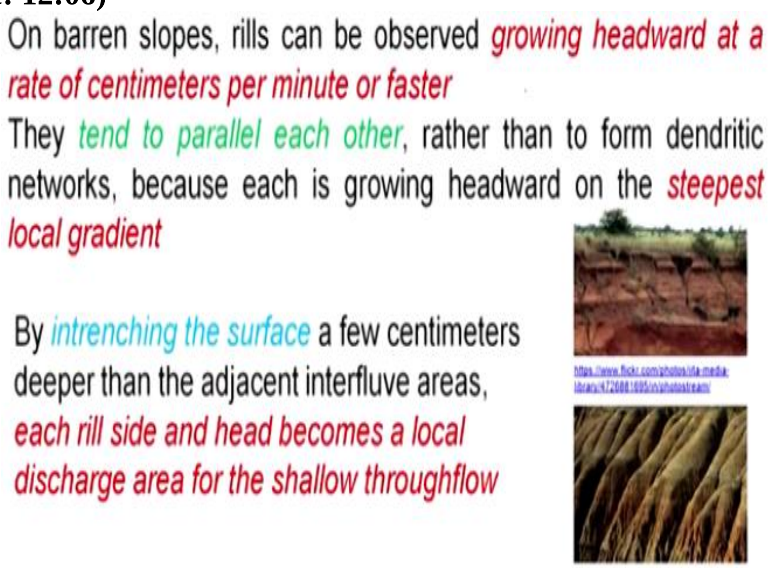
(Refer Slide Time: 10:10)

So rills it collects surface runoff at its steep headward end and the resulting waterfall migrates upstream extending the rill into previously undissected upland and capturing other rills, if you see here. Suppose, here this is a rill which is growing and this way the rills this is growing now, 2 rills there meeting here, similarly, here, this rill is growing and it is capturing here this rill is growing and it is capturing here this rill is growing and it is capturing here. So, there are different rills they are joining together here.

So, rill that collects surface runoff at it is steep headward end and the resulting waterfall migrates upstream now, see here once we are creating the rills and a sloping surfaces there, so, the rill will migrate upstream. So, more and more upstream with migrates more and more water it collects more sediment it is collect and finally, it is expanding the river area, river basin area. So, basinal area increment the rill these rill plays a major role.

So, increase of this river basinal area, on barren slopes, rills can be observed growing headward at a rate of centimeters or minutes are faster. So, it is very noticeable in this arid regions or this region which is dry, even if in front of you once there is a if there is rainy, the heavy rain and if you notice it, you see, this rills can very fast they can migrate and more and more sediment can easily be eroded and it can further move downward. So, they tend to the parallel with each other rather than from the dendritic network because each is going headward on the steepest local gradients.

(Refer Slide Time: 12:06)



Here, this rills if you see, they are mostly parallel to sub parallel with each other by the intrenching this surface few centimeters deeper than this adjacent interfluve area, each rill side and head becomes a local discharge area or they shallow throughflow. So, here throughflows occurs and rills develops and further increase of rills. Further aerial growth of these rills, they collect more and more sediments and rill development becomes a dominant over creep surface, creep surface you might be remembering when we are talking about this mass wasting process and sheetflows on this convex hillslopes a few 100 meters down from this ridge crest.

(Refer Slide Time: 12:57)

And slope concavity begins. So, these are these areas, there the potential places where rills developed.

(Refer Slide Time: 13:08)

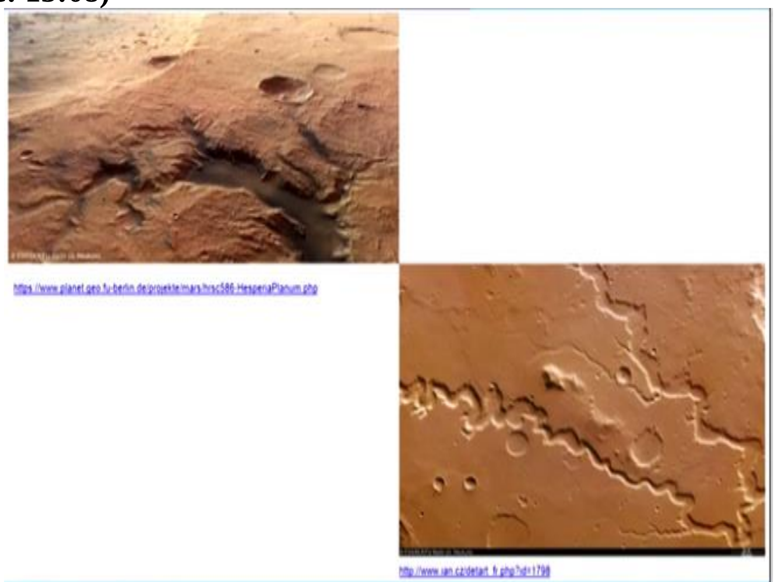
And there is a particular type of erosion that is called sapping that occurs where the land surface intersects the water table or groundwater table and spring emerges there. So, if you see here, these are the loose sand and this is cross cutting, the grounded table is cross cutting and the water is flowing downstream here. So, it is eroding this way and further this erosional process, they will expand in this way. Similarly, it will expand in this way and finally.

It is forming a surface where permanent water table will cut to the surface and there will be generation of streams this is the situation so, there erosion by groundwater flow undermines the overlying sediment and rock and cut a steepheaded rill or channel that can expand head ward and branch into drainage network even without overland flow sapping has been involved to explain drainage network on mars as well as those on the earth.

So, if you go to the mostly the sapping you will find in the coastal areas where the slope is very less and this groundwater table is very shallow. So, there at some places you will find this intersection of slope and the groundwater table and finally, this permanent stream or new stream that emerged out that is called sapping. So, this has been interpreted this mars surface that the sapping might have played major role in reshaping this mars surface as evidence available, this stream nature.

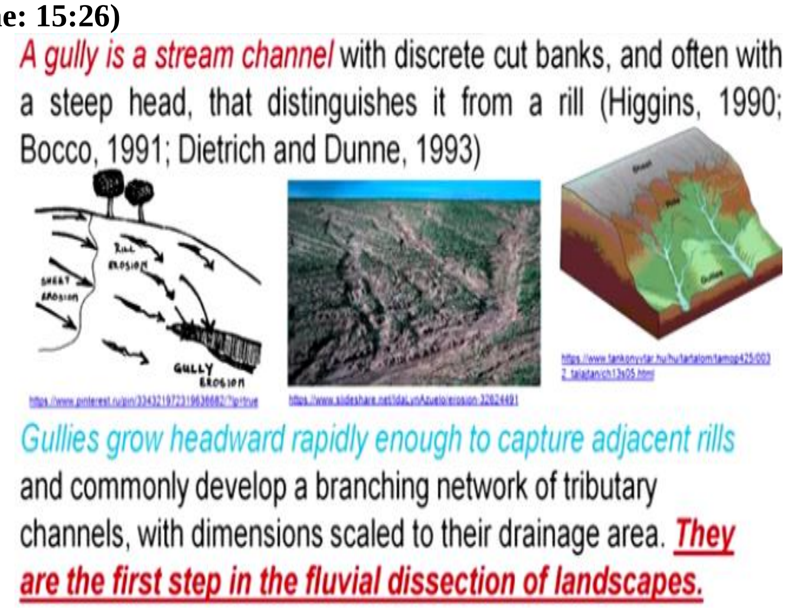
Or this whatever; this paleo channels that are available in the mars surface that can be interpreted to this presence of this due to this sapping process. So, these are some of these photographs from this mars geomorphology.

(Refer Slide Time: 15:08)



And mars surface, you see, these are these channels, and this is these are the channels. So here probably this interaction of this intersection of this groundwater table as well as the surface, so this is called sapping.

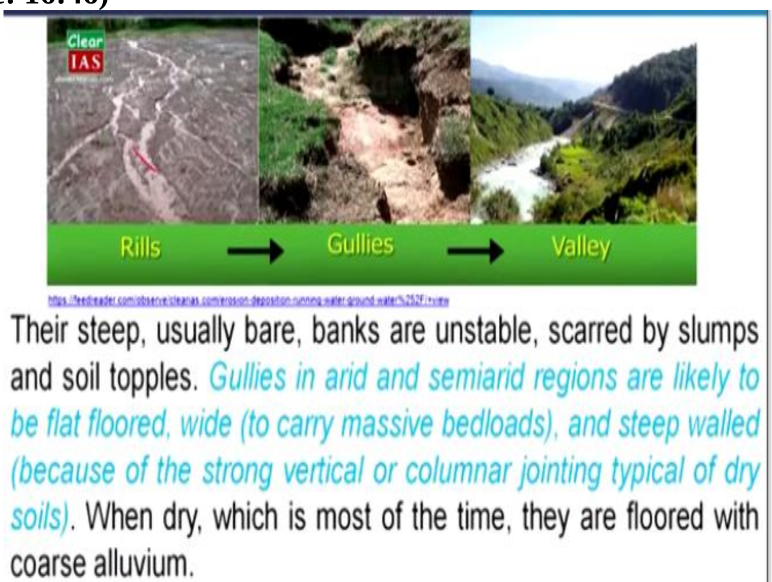
(Refer Slide Time: 15:26)



So once rills, the join together and the width increases they form gullies. So gullies, is a stream channel with discrete cut banks and often with a steep head that distinguishes it from rills. So these are the characteristics that meant it has discrete cut banks, and often with steep head that distinguishes from the rills, so rills with further growth, they convert to gullies, gullies grow headward rapidly enough to capture adjacent rills.

And commonly develop a branching network of tributary channels with dimension scaled to their drainage area; they are the first step in the fluvial dissection of landscapes. So, this is very important to say. So, gullies, they are the first step for fluvial dissections. So, whenever we go for mapping rills we cannot map but gullies can be mapped. So, that is why gullies that present they are the first step for the fluvial dissection of an area. So here if we are increasing our scale mappable.

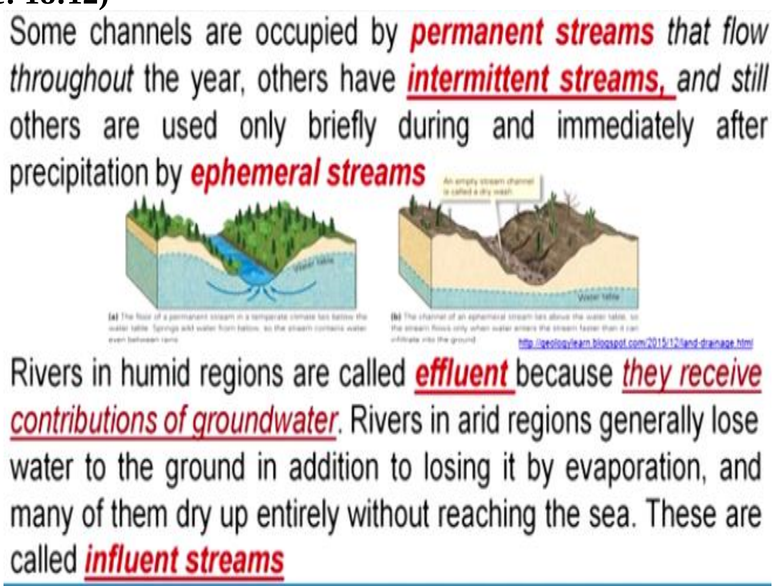
(Refer Slide Time: 16:46)



And it is not mapable, but this is mapable and this is mapable so, that means, rills, further growth it is gullies, further growth, it is valley. So, these are the first these are the first order streams, as though actually these are the first order streams, but we cannot map it in our mappable of scale. The scale we generally used in mapping one is 50000 scale, we cannot map it. That is why we ignore it. And if we map it to this map will be very clumsible 1000 of lakhs of rills will be there. So that is why we ignore it. And we consider these are the first order streams.

So there is steep usually bare, banks are unstable, scarred by slumps and soil topples. Gullies in arid and semiarid regions are likely to be flat floored, wide and steep walled because of this strong vertical and columnar joints typically dry soils. So when dry which is the most of this time, they are floored with coarse alluvium. So this gullies they have transportation capacity more transportation capacity than the rills. Because this width is more water capabilities more the sediment is more. That is why they can transport more sediments.

(Refer Slide Time: 18:12)



Some channels are occupied by permanent streams that flow throughout the years. Other have intermittent streams, and still others are used only briefly during immediately after precipitation. That is called ephemeral streams. So intermittent streams permanent streams and ephemeral streams and few minutes back, we are talking something called influent effluent river systems. So now here it is mentioned, rivers in humid regions are called effluent.

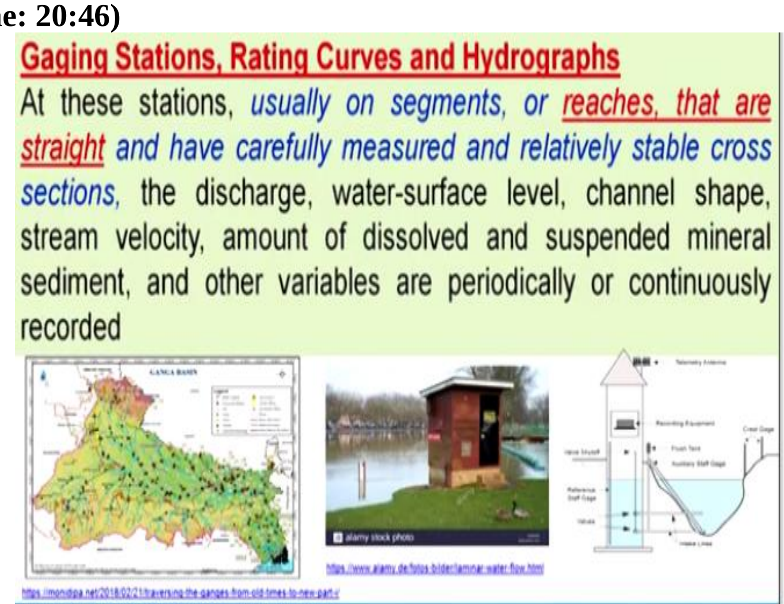
Because they receive contribution from groundwater. So once we are receiving from groundwater, they are called effluent river here. They are groundwater is there and it is contributing from there. So this is called effluent streams. River is arid regions, they generally lose water to this ground in addition to losing it by evaporation and many of this dry up entirely without reaching this sea, and they are called influent stream.

So, influent means river is going down influent, the effluent river, water is coming up. So, if it a groundwater table, it is receiving water from this river or the from the channel that is called influent and water or the stream which is receiving water from this groundwater that is called effluent. So, mostly the arid region rivers which is groundwater is much below the surface during rainy season. Whatever these ephemeral streams are there is water percolates down and they are called influent streams.

And in humid regions where what groundwater table is very close to the surface and somewhere at this ground contributing to the river system and that is called in effluent streams. So, now, we will talk about some of the practical aspects of this river system or channel system, it is gauging stations, rating curves and hydrographs what are those things and what is the utility in fluvial geomorphology gauging stations that means measuring stations.

We measure what we measure discharge, water discharge, sediment discharge, water fluctuation time with time and space because in a river entire length we have number of gauging stations for example, if you see here, these are the position of the gauging stations in the Ganga plains rivers these points.

(Refer Slide Time: 20:46)



So, that means, one point to another point we gauge we measure how much water is discharged for example, water is discharging this much amount of water is discharging here under the downstream the water is increasing or water is decreasing. So, that means we can say how much water is being contributed there or how much water is losing in between. So, how much sediment is transporting here, how much sediment is reaching that level.

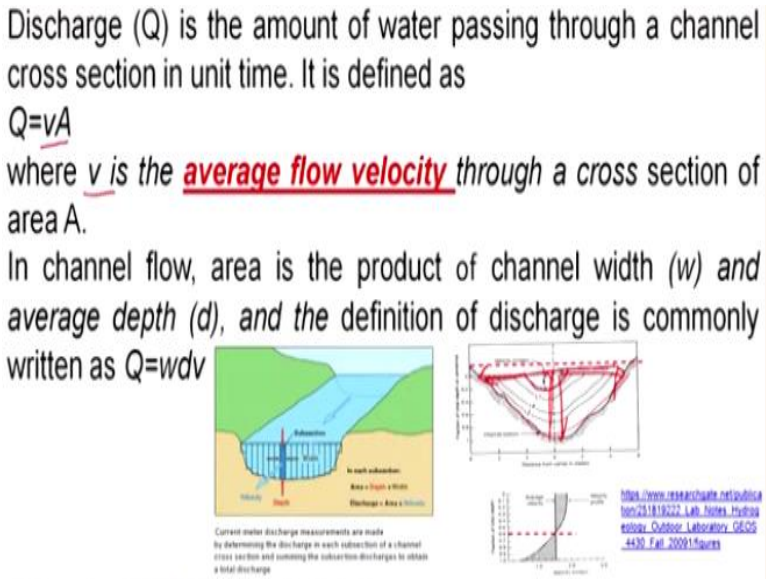
And how much within the flood plain within that riverbed how much sediment is depositing. So, that means, these are useful for planning purpose for applied aspect and rating curves and hydrographs. Rating curves that means, this water fluctuation graphs. So, at the annual water fluctuation graph from that we can say where there are flooding from the rating curve we can say where there is flooding.

And what is the time taken for the flood to flood water to reach from these stations to that station and for this prediction purpose for this alarm purpose or this management purpose. We need this type of measurement and at this stations or this gauging stations usually the segments or reaches that are straight is some requirement are there prerequisite there where we will place these gauging station, we cannot place it everywhere throughout this river length.

So choose those spaces where the river reaches our segments there are straight and have carefully measured and a relatively stable cross sections where suppose, there is a river cross section there is changing with time. So, that means the river is getting wider and wider and very frequently river wide changes those are not suitable places for gauging station establishment. So that means we have to choose those places either it should be a straight segment.

And this cross section area should be relatively stable. The discharge the water surface level, the channel shape, stream velocity, amount of dissolved and suspended minerals of the sediment and other valuables are periodically and continuously recorded. So, these are the works of these gauging stations, these are the material or these are the parameters that we measure at these gauging stations at different places along this river basin of the river distance.

(Refer Slide Time: 23:18)

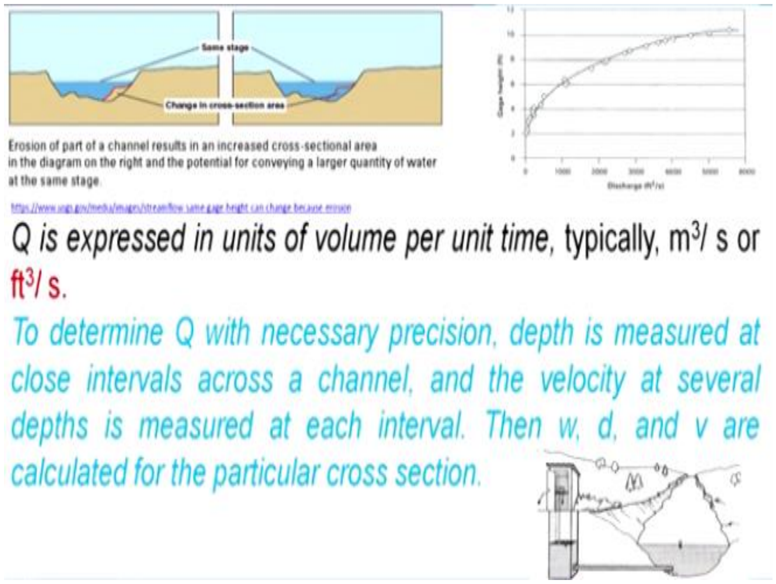


So, here discharge Q is the amount of water passing through a channel cross section per unit time, it is defined as Q = v * A where v is the average flow velocity because, average flow velocity means, velocity at different levels if we average it out similarly, velocity at different lateral level and vertical level we average out at a particular cross section and we assign this velocity because, if you see here, the velocity contours here in a river cross section 1.3 1.57 1.9 like this.

So, that means the velocity it is more at this middle part, similarly, you are going towards the bank from this middle the velocity is decreasing. Similarly going towards depth the velocity is decreasing. So, that means we average out and assign either this; the vertical velocity as well as the lateral velocity we averaged out and assign a number here, so, this is called average velocity. How it is measured here, we segment into different columns and for each column from top to bottom.

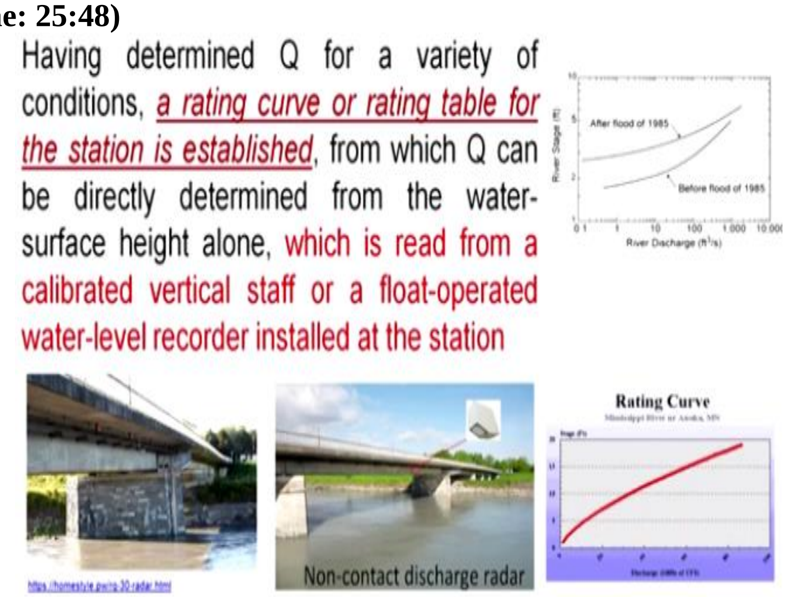
We measure this velocity and assign a number and finally, we average out for each columns and give this velocity for a particular cross section particular. So, that means here v is the average flow velocity through a cross section of area A, this is area and this Q will be the discharge, in channel flow area is the product of channel width and average depth d and the definition of a discharge is commonly Q = w d v. So, this is the discharge of a river.

(Refer Slide Time: 25:11)



Q is expressed in a unit of volume per unit time typically, meter cube per second or feet cube per second to determine Q with necessary precision depth is measured at close intervals across a channel and the velocity at several depth is measured at each interval, then w, d and v are calculated for the particular cross sections. So, after measuring these cross sections, we measure how much water is flowing per unit minute or for the unit second in that particular area. So, this is the discharge.

(Refer Slide Time: 25:48)

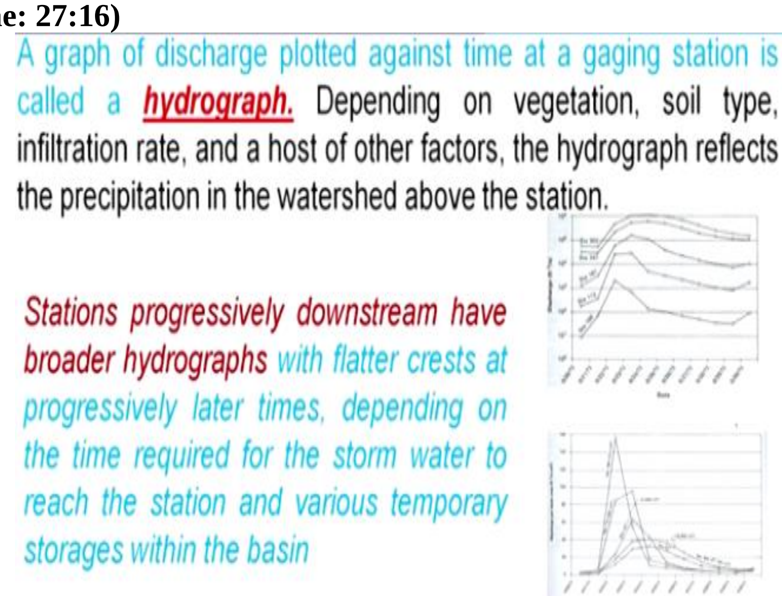


Having determined Q for a variety of conditions, a rating curve or a rating table for the station is established a variety of condition that means in a dry season pre-monsoon during monsoon post monsoon flood situations. So, all these times all these different situations, this Q or discharge is measured and it is plotted with time. So, with plotting that means, we are getting a rating curve or rating tables for a particular station that is valid for a particular station.

Similarly, for other station we measure and different rating curves we measure we compare whether this but not necessarily this rating curves will be match together for what one station is independent to another station because the discharge is different, the sediment is different, the width is different, the height is different. So, for which Q can be directly determined from this rating curve from the water surface height alone which is read from a calibrated vertical staff.

And they float operated water level recorder and installed in the station, nowadays we have sensors, digital sensors we are using the ridged and here these are the rating curves. These are these measuring stations where measurement is done and nowadays through the sensors also we are measuring. So, the rating curves are prepared.

(Refer Slide Time: 27:16)



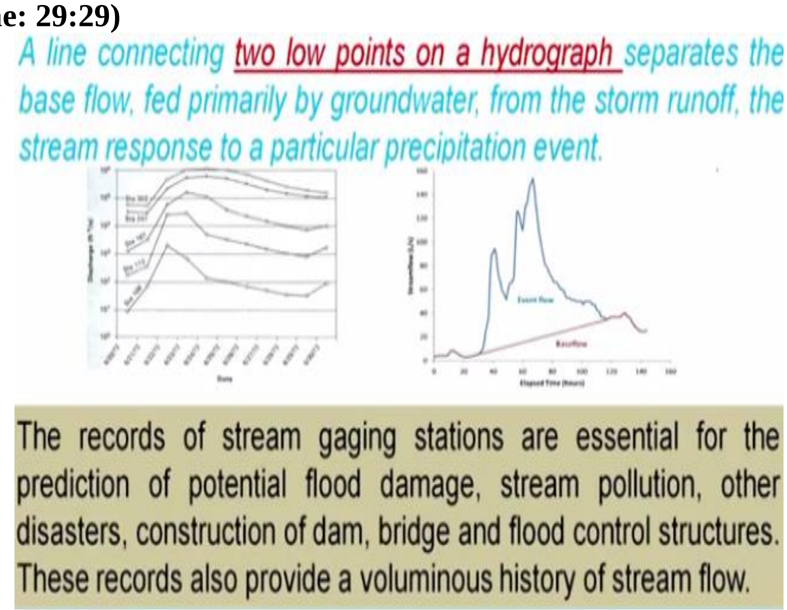
A graph of discharges plotted against time at a gauging station is called hydrograph. So, the time it will see here with the time and discharges. So, in this Ganga plain rivers the discharge because they are from glacier fed, so, during glacier melt and during daytime you will find more discharge, but that water which reaches at this gauging station that may be in the evening, so, the evening time will get more discharged because the water is glacier melting in the daytime this water percolate.

Or the water it time needs to water to come to this gauging station, from morning to evening or on daytime to evening. So, that is why this hydrograph is a graph of discharges plotted against the time and the gauging station, it is called hydrograph. Depending upon vegetation, soil type infiltration rate and a host of other factors, the hydrograph reflects the precipitation in the watershed above the stations.

So, whatever the information we receive from gauging station from the hydrograph, it is valid for the upstream not from the downstream. So, that means, we can predict about this upstream situation, what are the soil type is there, what are the vegetation is there, what are the infiltration rate is there and what are other factors are there that all that can be told about this upstream from this measuring stations, stations progressively downstream have broader hydrographs.

So, that means if you see here in this figure, this is upstream and this is downstream and further once we are moving of this station 108 station 302. So, that means we are further moving downward. So this shape of this hydrograph, you see it getting broader and broader. So this station progressively downstreams have broader hydrographs with flatter crest, at progressively later times, depending upon the time required for the stormwater to reach this station at various temporary storage within the basin. So, that means once we are moving downstream, the shape of the hydrograph is changing.

(Refer Slide Time: 29:29)



A line connecting to low points of a hydrograph separates the base flow fed primarily by groundwater from the storm runoff, the stream responds to a particular precipitation event. So here this is called base flow that means this is the permanent water it remains there. This is headward this groundwater and this is the storm water or event water which is either due to melting or something else now the storm or the discharge or the rain water heavy rain or whatever may be.

So, this rating curves from the rating curve hydrograph this part it is called permanent flow or it is called base flow. The records of stream gauging stations are essential for this prediction of potential flood damage, stream pollution or other disasters, construction of a dam bridge and flood construction, flood controls structures, these records are provided a voluminous history of the stream flow.

So, that means, this measurement is important for this purpose for the planning purpose. For this steam pollution measurement purpose, for dam establishment purpose, so bridge construction propose. So, all this developmental propose we are measuring this and we are creating this hydrographs. So, why we need this hydrograph on why we need the measuring stations because whatever the data we generate from this hydrograph or measuring station.

We required for this a purpose for example, suppose we are going for flood potential flood damage, we want to predict it where this when what time this flood water will reach at which segment of this variable represents. Similarly in stream pollution, which part of the stream is getting polluted water and which part of the stream is more polluted. Similarly, other disasters like flood situations and what suppose.

For example, we are going to construct a dam which part will be more discharging which part of this river is the contributing more discharges and suppose, we are establish a bridge or construct a bridge, whether the sediment characteristics the sediment of what type of sediment is passing through the saltation suspension and traction and it will damaged this river when the bridge pillar like that. Similarly, flood control structures we are going to establish.

So, all those factors, all those purpose, we need this sediment data, we need the hydrograph data we need to discharge data, the amount of sediment discharge, the amount of water is discharged, is not it? So that means hydrograph plays a major role in planning purpose. So I think we should stop it here. And we will meet in the next class. Thank you.