Geomorphology
Prof. Pitambar Pati
Department of Earth Sciences
Indian Institute of Technology – Roorkee

Lecture- 48
Fluvial Process- IV

So, friends welcome to this lecture series of geomorphology and today we will continue with this fluvial process. So, if you remember the last class, we are talking about these channel habits depending upon the grain size, depending the bed load, depending the waters slope so, all these factors, so, we have 6 channel habits identified and those 6 channel habits they change with time depending upon all these variables.

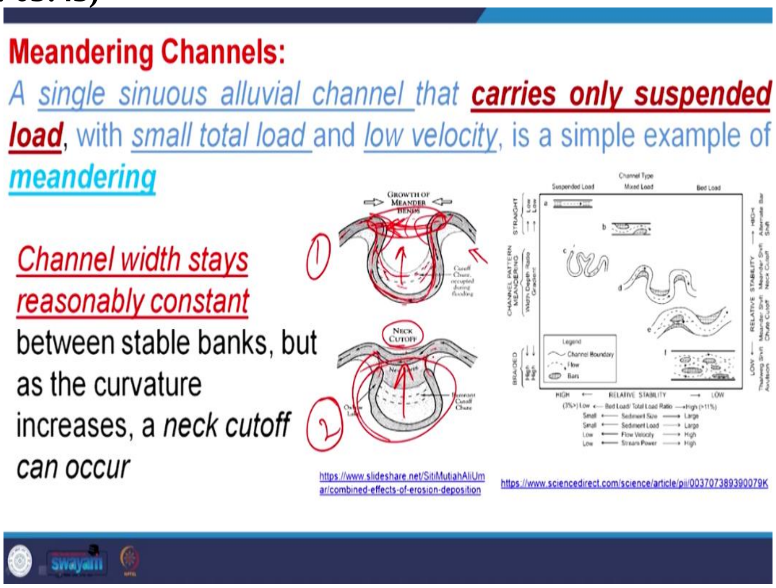
So, last class we are talking about these channelization or artificial straightening of channels. So, we found that artificial straightening, though some advantages are there, some disadvantages is also there. So, by artificial straightening, we reduced these stream length, so, that the navigation time the fuel decreases, but, in artificial straightening, we reduce the flood risk of this area where we are going for this artificial straightening.

However, with some time with some 1 2 3 4 years or so, we are increasing the risk of flooding in the downstream because much water can easily be passed through this artificial straightening channel and that will be in the downstream it will create severe floods similarly, artificial straightening also, it erodes the river bank and river bank collapse will be there. So, that sediment production will be very high and due to high sediment production, again the riverbed aggradation occurs and the flood situation comes as it was earlier.

And today we are going to discuss about the other types of channels or the other channel habits like this meandering channel, the braided channels like that anastomosing channels like that. So, to start with this meandering channel, what a meandering channel is and how it forms, how it changes, what is the significance of meandering channels in geomorphology. And whether this meandering channel types they produce some types of economic wealth for us and how it is studied this meandering channels, they are associated with point bars.

And the point bars as you know it is capped by a clay sheet and at the base we have gravels and we have coarse sands like that. So as point bar migrates, so we will get a continuous sheet of clay, which is capping the sand. So many times this may be a potential sites for petroleum hydrocarbon accumulations, and in it is in fluvial environment. So, let us talk about how this meandering channels forms and how they behave with a change in grain size. And we will change it slope like that.

(Refer Slide time: 03:43)



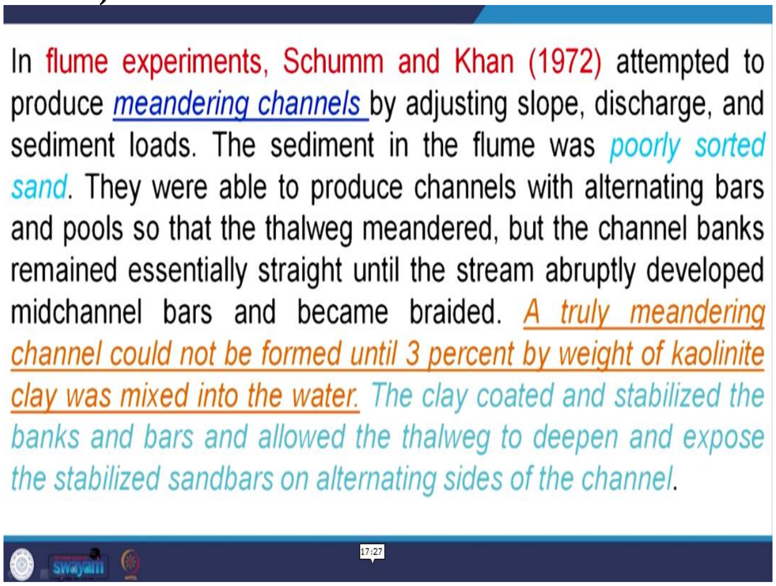
So, single sinuous alluvial channel that carries only suspended load mind it here this point to understand is it carries only suspended load and small total load and low velocity. It is simple example of meandering. So 3 factors are there, these 3 factors influence these meandering or meanders, very well first is it carries only suspended load. Second thing that in this total load is very small and it is low velocity.

So, low velocity channel, it will be total suspended load would be and less total load will be. So, these are the 3 essential conditions for forming a meandering channel and channel width stays reasonably constant. Though this channel changes its position from one place to lateral migration will be there. But, this width of this channel, this distance between 2 banks remain constant. So, it is channel width stays reasonably constant between stable banks but as the curvature increases the neck cutoff can occur.

So, we know about this neck cut off chute cut off like that. So, if you see here in this first case, and this is the second case, here, this is an example of meandering channel, this is the direction of flow water flow or the channel flow. Now, see here, earlier, this channel was migrating or channel was passing through here, later on it here. And finally, it is moving here. And with time, if you see here with time this channel it moves in this way, this width is moving this way. And if you see, gradually, these 2 points, they are coming closer and closer you see here.

They are coming closer and closer. And finally, the system these 2 systems will join together. And finally, this will be a channel is a single channel will be developed here and this part remained abandoned. So, the channel migration takes place from here to in this directions. So, this is called neck cut off. So, neck cut off that means a part of this channel is a remain cut off and once the remain cut off, so, during flood time, this cut off part it receives much sediment as suspended loads and a sites for silt and clay deposition.

(Refer Slide Time: 06:30)



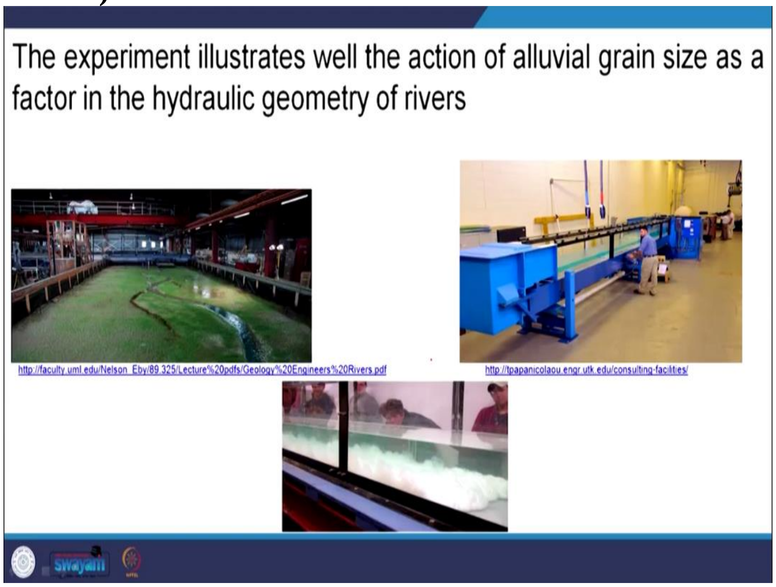
So, in flume experiment was carried out by Schumm and Khan in 1972 to produce meandering channel in laboratory artificially with some variables. So, changing variables like slope, discharge, sediment load, so all these parameters were changed or adjusted very minutely and found out there is no meandering channels are developed until or less this system or this experiment was fed with clay particles or clay, without these clay particles, there was no meandering channel developed.

So, here in this experiment, poorly sorted sand was used that means sand it is starting from very fine to coarse particles sand particles were used, and they were able to produce channels with alternating bars and pools. So, that the thalweg meander but the channel banks remain essentially straight until the stream abruptly develops the mid channel bars then becomes braided. So, a truly meandering channel could not be formed until 3 percent by weight of kaolinite clay was mixed with water.

So, that means I want to say here, this experiment says once we have coarse grain material or coarse grain bed loads or coarse grain loads like sand it will not or it will never produce a meandering channel. So, the essential criteria to produce a meandering channel is it must have clay size particles within that. So, that this experiment said until or less they used 3 percent by weight kaolinite within the system, this meandering channel was not formed.

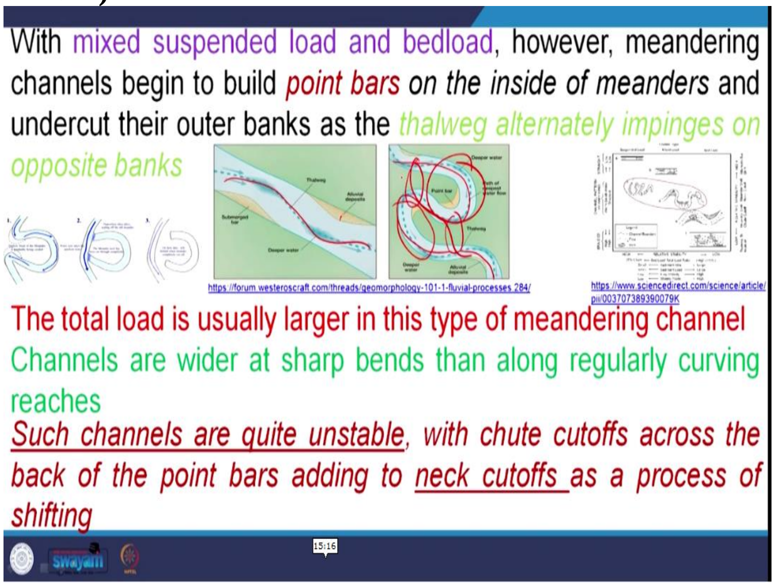
So, the what is the mechanism why clay was added what is the mechanism why clay was responsible for formation of meandering channel which explained here, the clay coated and stabilized the banks and bars and allows these thalwegs to deepen and expose the stabilized sandbars on alternating sides of this channel. So, once the alternative side of this channel bars were stabilized, the thalwegs moved. And finally, it forms meanders.

(Refer Slide Time: 09:02)



So, this experiment illustrates well the action of alluvial grain size as a factors in the hydraulic geometry of rivers. So, either it will be a straight channel; it will be a meandering channel or a braided channel that depends upon the grain size. So, this experiment says until or less we have clays with the system clay within this element. So, it is not possible to create a meandering channel.

(Refer Slide Time: 09:29)

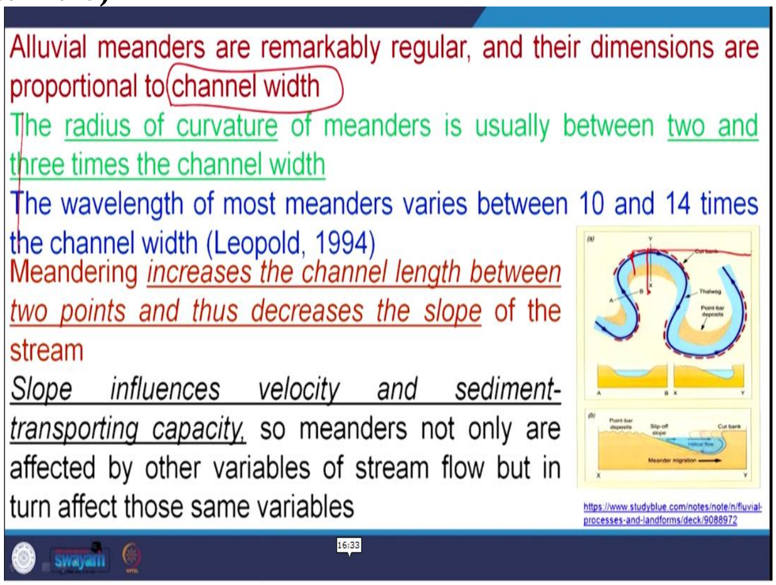


With mixed suspended load and bed load however, meandering channels begin to build point bars on the side of the meanders and undercut their outer banks as the thalwegs alternatively impinging on opposite bags. So, here if you see once we are creating some bars we are using this clays. Finally, the thalwegs is moving like that and with more and more movement of the thalwegs finally, we are getting a meandering channels.

So, meandering channels with time this part becomes cut off this part become cut off. So, this channel will be like this. So, this part of the system becomes abandoned and this part of the system becomes abandoned with time. So, total load is usually larger in this type of meandering channel channels are wider at sharp bends and along regular curving reaches. Such channels are quite unstable with chute cut offs across this banks of this point bars adding to neck cut offs is a process of shifting.

So this meandering channel the shift frequently and this forms point bars and that is why the point bars migrates and this point bar migration that we have already discussed. It creates in wells, porous and permeable sand below at the basal level and it is capped by a clay sheet. So they are the potential site for petroleum hydrocarbon exploration for geologists.

(Refer Slide Time: 11:19)

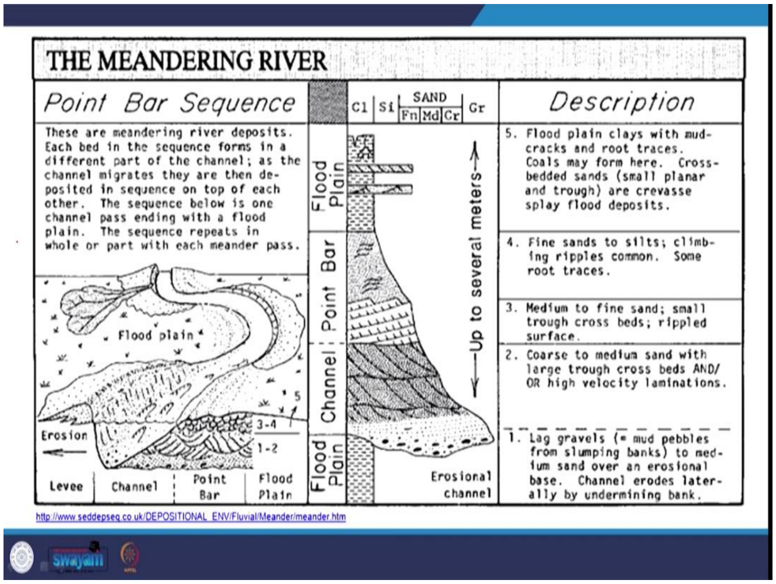


Alluvial meanders are remarkably regular, and their dimensions are proportional to these channel width here, it has to be noticed this, how large the meander will be? What will be the curvatures of this meander? What should be this wavelength of this meanders? That all depends up in the channel width, so channel width it says that the radius of curvature of meanders is usually between 2 and 3 times of this channel width. So if this is the width of this channel, this radius of curvature here, there it is, a curvature will be 2 to 3 times of that.

And similarly, the wavelength will be 10 to 14 times of this channel width. So, that means here is some mathematical relationship existing between this channel width and this in radius of curvature and wavelength of this meanders meandering increases the channel length between these 2 points and hence decreases the slope. And once the slope decreases slope influences the velocity and sediment transporting capacity. So, meanders not only are affected by other variables of the stream flow, but also it is affect those the same variables.

So, that means, I want to say this wavelength and this curvature, it is dependent upon this channel width and once this curvature increases. So, here it decreases the slope. So, because its length is decreased and length is increased, sorry, the length is increased and the slope is decreased. So, the decreasing of slope, it affects other parameters, or other factors like sediment migrations and velocity of these channels. So, that influence the total fluvial system.

(Refer Slide Time: 13:26)

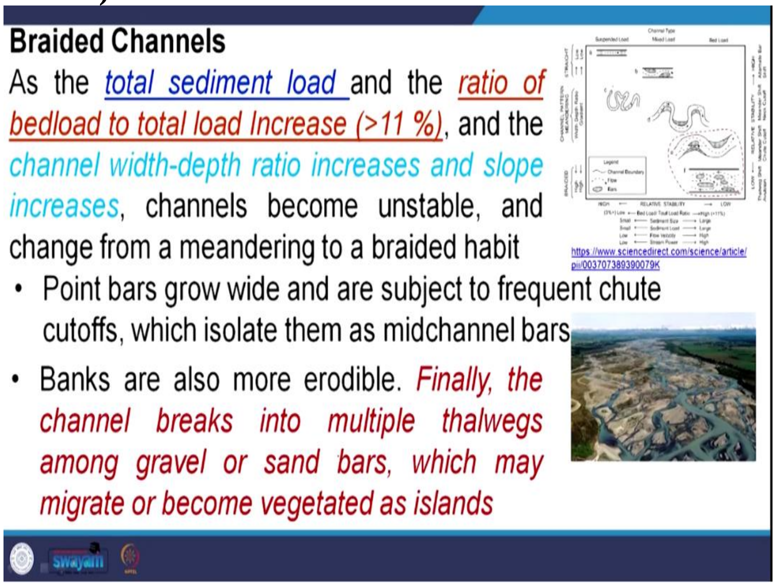


So, here this image shows, the geology of the stratigraphic relationship of this point bars, if you see here, this, this part, it is suppose this channel is here, it is channel is moving in this way, this part is representing the sites of erosion and this site is representing the sites of deposition. So, erosion means here gradually erosion moves in this way and deposition moves in this way. So that at this basal part this side you will get this coarse grained sand and as this channel migrates in this way, it comes under this flood plain and finally it is capped by clays.

Similarly, it is here it is mentioned in this stratigraphic cross sections here, this is this basal section of this point bar it is composed of these boulders, pebbles cobbles, coarse grained sands and here, this channels the total system is this channel, this upper part of this channel, it is cross bedded sand and here this point bars this ripple marks sand is there and fine sand is there and finally, once the system is away from this flood plain during flooding this type of deposit silt and clay deposition is there.

So that in stratigraphically if you compare here, the lower part is composed of sand, porous and permeable materials, pebbles boulders and the upper part it is capped by clay and silt so that it is a good condition for petroleum hydrocarbon reservoir. So in the fluvial environment wherever the petroleum hydrocarbon exploration, it is going on, these are the potential sites and these point bars were migrated point bar the floodplains within the floodplains they are the potential side for petroleum hydrocarbon explorations.

(Refer Slide Time: 15:27)



Then the other site of this channel, or other channel have it is the braided channel that we have discussed one is straight channel, one is meandering channel. Another is the braided channel. The braided channel that means it is name itself says it is braiding that means branching that means one channel is branched into different channels and different thalwegs not channels. So the channel will be same but due to development of bars. The thalwegs will be multiple thalwegs.

And they join together they diverts from each other. And again, they merge, but this channel remains one, this channel is bound by 2 separate banks, and within that, there are different bars that are migration of the bars. So, this thalwegs migrates and thalwegs shifts from one place to another, and they at coincides and diverges finally its form a braided channel systems. So, the total sediment load and the ratio of bed loads to total load increase greater than 11 percent and the channel width depth ratio increases.

And the slope increases channel becomes unstable and changes from meandering to braided habit. Here, those parameters that we are discussing here, like the grain size, the channel width the slope they all are different from this, this range which meant for this meandering channels, here the total sediment load increases, but in meandering channels the total sediment load was very small and the ratio of bed load to total load increases bed load to total load that means, bed load here is more as compared to total load.

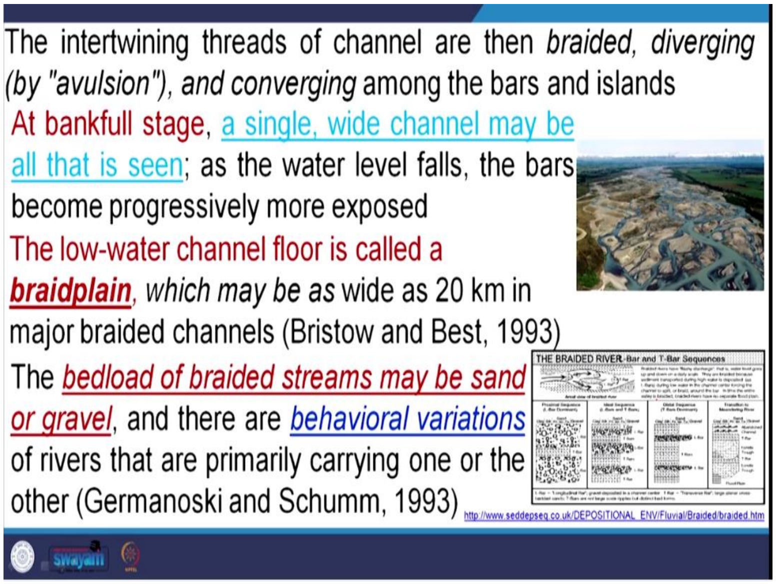
But, meandering channel it is suspended load clays for here bed load increases total load increases channel width ratio to depth ratio increases channel will be more wider than compared to depth but in meanderings and in straight channel width depth ratio was less. So, here we are getting a wider channel with a more load with a more bed load and the slope is also more there in the meanderings and straight the slope was also very less.

So all these factors that defines its channel characteristics are more in terms of or in case of braided channel. So channels become unstable, and changes from meandering to braided habit. So all these factors if you increase that, so, channels become unstable, and finally it will convert to a braided channel. So if you see from this photograph, it is a braided channel, you see number of channels and these are these bars here, these are the sand bars and this channel is multifurcation or bifurcation multifurcation of channels and finally, you are getting this is the channel width.

So channel is confined within that that means, it is channel is defined like that, but within that a single channel, we are getting multifurcation of channel. So within this is the bank to banks, they are bounding this channel and here, there are 100 of bars through which the thalweg is changing thalweg is moving here and there. Point bars grow wide and are subject to frequent chute cutoff, which isolate them from mid channel bars here, you see here.

These are the mid channel bars are there and finally, this mid channels bar, they are separating 2 sides or 2 different channels at different parts. Banks are also more erodible finally, the channel breaks into multiple thalwegs among gravel or sandbars, which may migrate or becomes vegetated as islands. So, this is the mechanism which is responsible for formation of the braided channels.

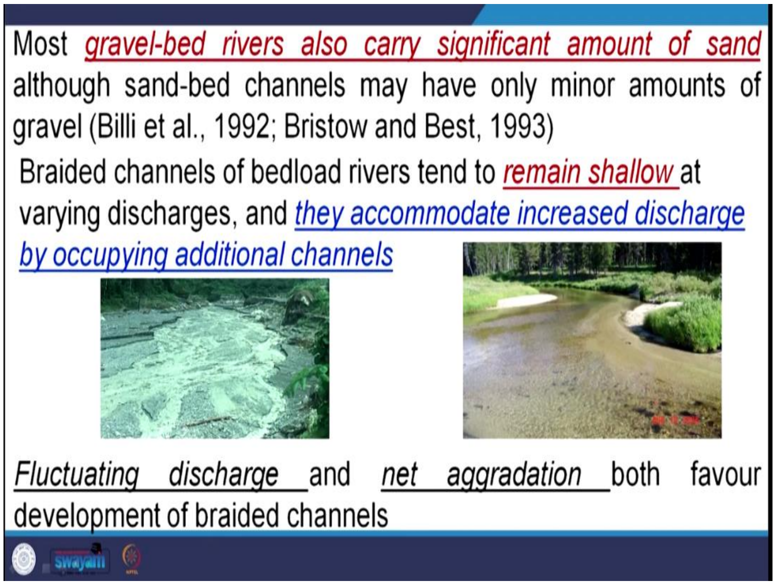
(Refer Slide Time: 19:57)



The intertwining threads of channels are then braided diverging by avulsion and converging among the bars and islands at bank full stage a single wide channel may be seen at all and water level falls, the bars become progressively more exposed. So, this type of rivers or this type of channels during bank full stage you cannot distinguish the bars they are submerged, but once the water level decreases, so, the bars are exposed and finally, when find out how multifurcate channels are there. So, the low water channel floor is called braid plain.

So, when there is low water conditions and this water level at that position that projected plains that is called braid plains which maybe as wide as 20 kilometers in major braided channels, the bed load of braided streams, maybe sand or gravel and there are behavioral variations of rivers that are primarily carrying one or the other. So, this braided channels they carry gravels coarser sands and gradually once they move from distance, this becomes separated, the gravels and coarse sands remain at the upper reaches and this fine sands and clay particles they move further and forms the flood plains.

(Refer Slide Time: 21:50)

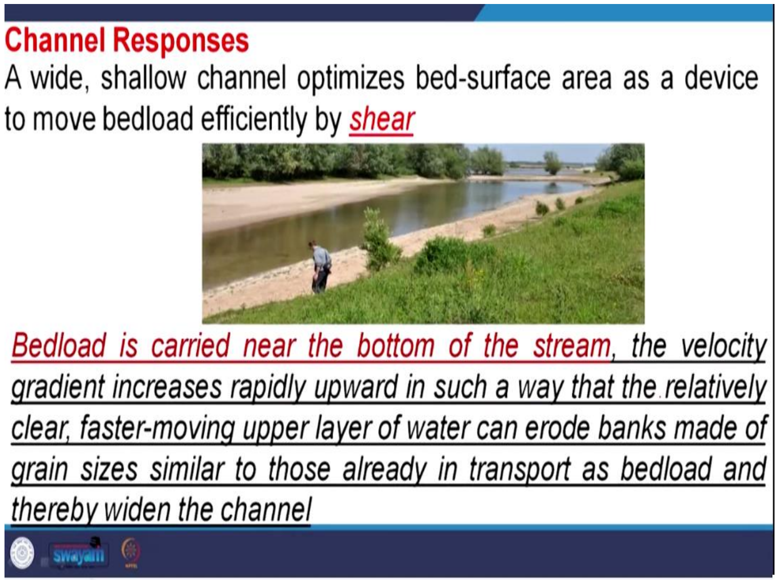


Most gravel bed rivers also carry significant amount of sand although sand bed channels may have only minor amounts of gravels. So, that means here gravel bedded, river gravel bedded channels, may contain sufficient or significant amount of sand with that, but sand bed channels they rarely transport gravel this depends upon the stream competency. So, gradually the stream competency decreases downstream.

So, once the stream competency decreases the size the larger size become separated at the upper reaches and finally, gradually smaller and smaller size they are transported downstream braided channels of bed load rivers tend to remain shallow at varying discharges and they accommodate increased discharge by occupying additional channels. So, here these science is braided channels of bed load rivers tend to remain shallow. So, once there are shallow channels, that means the shearing action shearing force between these grains and this water will increase.

So that they accommodate increased discharge by occupying additional channels. So that is why additional channels are developed, because to accommodate the discharge, fluctuating discharge and net aggradation both favour development of braided channels, fluctuating discharges are there net aggradation is there, channels aggradation that means sedimentation, it is shallowing up. So that is why it increases of braided channels are developed.

(Refer Slide Time: 23:36)

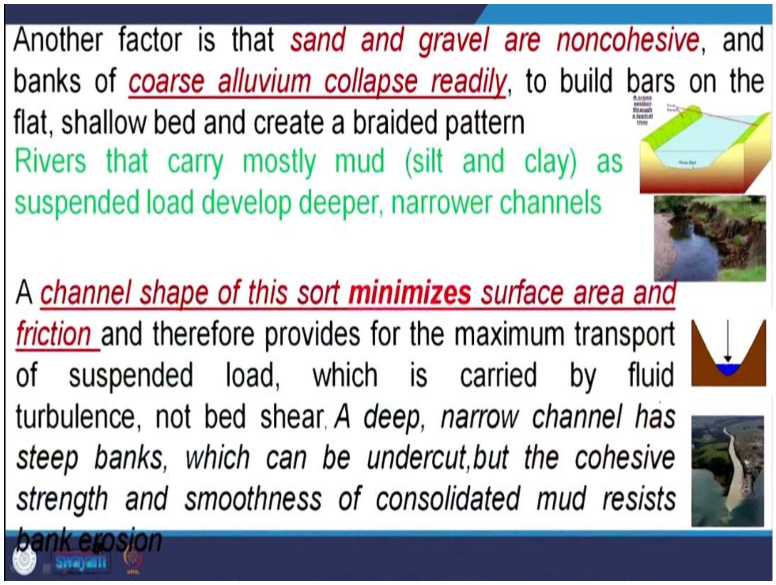


So how channel respond to this grain size that we will discuss here a wide channel or a shallow channel optimized bed surface area is a device to move bed load efficiently by shear that we are discussing few minutes back so once the channel becomes shallow, it is becomes more shearing force between these loads and this water. So, the interface between water and sediment is shearing force is more.

So, this sediments are transported in a shallower channel by shearing forces by shearing between this water and this grain size bed loaded carried near to this bottom of the stream, the velocity gradient increases rapidly upward in such a way that this relatively clearer, faster moving upper layer of water can erode banks made up of grain size similar to those already transported as bed load as they were widen and finally, the channel wides so, now, as last class we in last to last class, we are talking about this velocity gradient in the channel.

So, velocity is more near to the surface and at the middle of this channel so now we have a wide channel. And if we are taking this velocity gradient, these contours will be very close to because it is a shallow channel and more width. So contours are very closely spaced. So that this water on the surface of this channel that will move faster. And once this fast move water interacts with the bank, it will erode those bank material and fall within this bank material followed in surface. So that is the banks becomes wider and wider and sediment load increases.

(Refer Slide Time: 25:41)



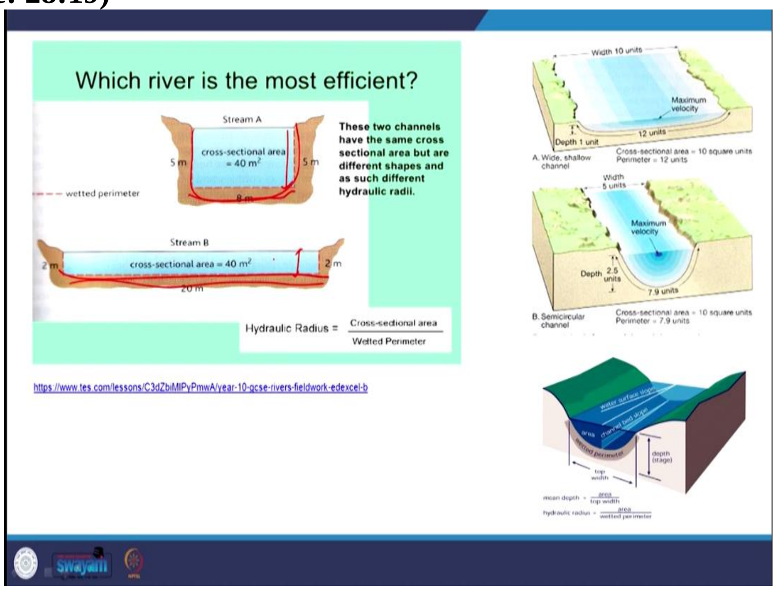
Another factor is that sand and gravels are noncohesive. And banks of coarse, alluvium collapse readily, to build bars on the flat shallow bed and create a braided pattern. Rivers that carry mostly mud silt and clay as suspended load develop deeper and narrow channels. So this is the reason behind it. So because the sand, which is mostly this composition of the constituents or the upper reaches at the braided channel, there are non-cohesive nature.

So that water can easily eroded. And that is why the eroded material that becomes a supplement for the formation of these braid bars bar development, however, this channels which is passing through fine silt and clay particles due to their adhesive force they remain intact. So that is the channel will be more smooth here. So that is why the rivers that carry mostly the mud silt and clay as suspended load develop deeper and narrower channels, but which is carrying sand will be shallow and wider channels.

So channel shape of this sort minimize the surface area of friction and therefore provides for the maximum transport of suspended load, which is carried by fluid turbulence not by bed shear. A deep narrow channel had steep banks which can be undercut, but this cohesive strength of this and smoothness of consolidated mud resists bank erosion. So, this is derived that means, once we are decreasing or increasing the grain size that means, we are changing the grain size, the channel behavior, bank behavior the channel habits they are changing.

So, which is the channel which is transporting sand particles are coarser particles, there are 4 different kinds that different behavior as compared to these channels which are transporting silt and clay particles. So, here mostly it is suspended load, but in the coarse of particles, they are transported through bed load. So, a deep and narrow channel has a steep bank which can be under cut, but the cohesive strength of these and the smoothness of this cohesive strength of this clays, the remain intact. So, this bank will be stable, but in terms of shallow channels which is carrying the sand with that, so, this bank will be unstable.

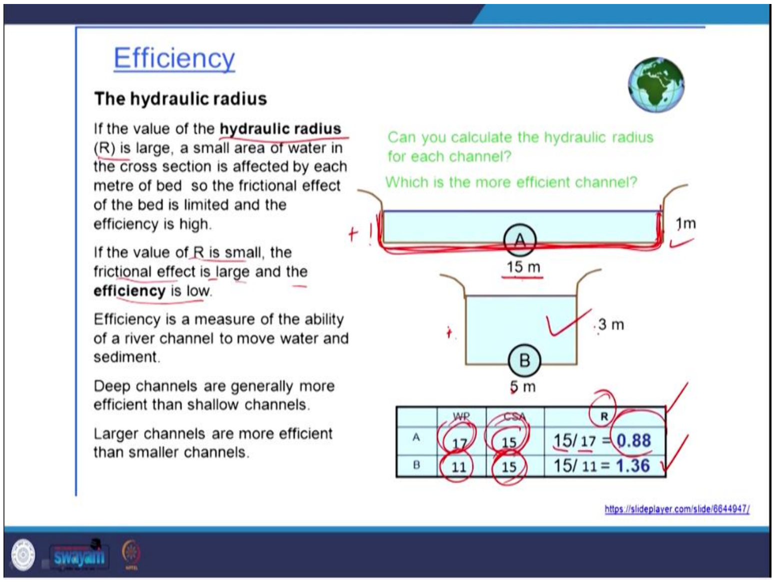
(Refer Slide Time: 28:19)



So, now the question arises if there are 2 types of channels we are discussing one is a shallow channels wider channel carrying the sand with it as the prominent load and another is this deeper channel and narrow channel which is carrying silt and clays as a suspended load, then, which type of channel is more efficient, so, which river is the most efficient river either it is a channel which is narrow or the channel which is with which more width.

So, here, 2 types of channel one is deep channel with less width and deep is more, one other is wider channel depth is less so which channels more efficient. So, to compare that, here, we talk about this hydraulic radius of this channel. So hydraulic radius that defines the efficiency of channel. So, what is this hydraulic radius?

(Refer Slide Time: 29:22)



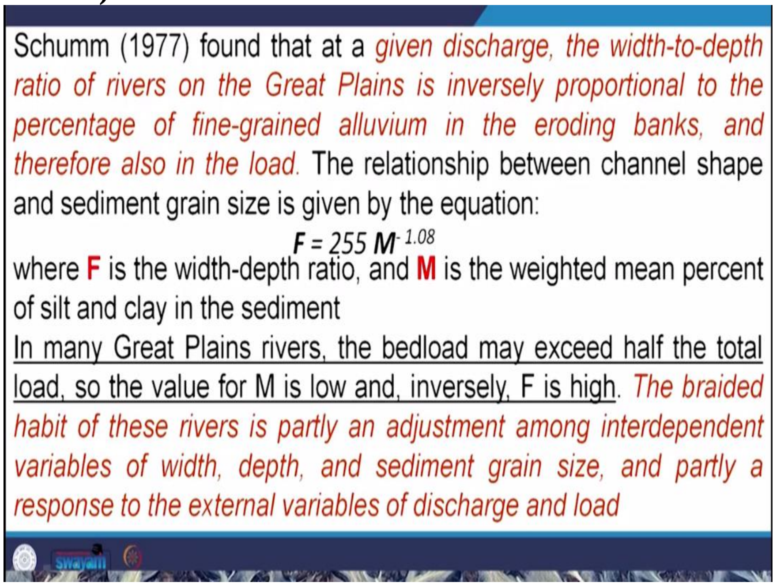
So, if the value of hydraulic radius R is large, so, a small area of water in the cross section is affected by each meter of bed. So, frictional effect of this bed is limited, and this efficiency is high. So, that means, if we are reducing hydraulic radius, or if you are increasing hydraulic radius, a small area of water in the cross section is affected by each meter of bed. So, this frictional effect of this bed is limited and this efficiency is high.

So if the value of R or hydraulic radius is small, the frictional effect of the large and the efficiency is low. So, here if you see, efficiency is a measure of ability of river channel to move water and sediment deep channels are generally more efficient than shallow channels, larger channels are more efficient than smaller channels. So, here if you compare then this particular case, this is wetted perimeter 15 + 1 + 1 = 17 meter.

So, in this case it is 5 + 3= 8 + 3= 11 so, here it is 11 meter but cross sectional area both case is this 15 into 1 = 15 meter here 5 into 3 = 15 meter. So, hydraulic radius will be 15 / 17 =0.88 and 15 / 11 in this case it is 1.36 so, that this river is more efficient, because here the hydraulic radius is the efficiency is a measure of hydraulic radius, if the value of R is small, the frictional effect is large and the efficiency is low.

So, here hydraulic radius is low and this efficiency is low, but here hydraulic radius is more the efficiency is more. So, that means, if narrow channel, which that which much depth, it is more efficient to capacity it is more efficient to transport water and sediment as compared to a shallow and a wider channel. So, a larger channel is more efficient as compared to a small channel. Similarly, a deeper channel is more efficient than a shallow channels. So, that means, you can summarize here, this hydraulic radius is a measure of the efficiency.

(Refer Slide Time: 32:00)

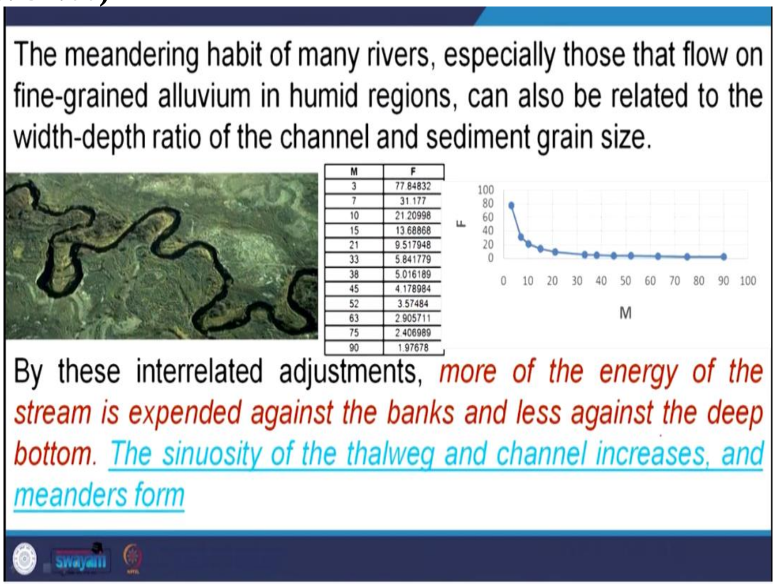


Schumm 1977 found that at a given discharge, the width to depth ratio of a river on the Great Plains is inversely proportional to the percentage of fine-grained alluvium in this eroding bank and therefore, also in the load. The relationship between the channel shape and sediment grain size is given by this equation here, $F = 255M^{-1.08}$ where F is the width depth ratio and M is the weighted mean percent of this silt and clay of this sediment. In many great plains rivers the bed load may exceed half the total load.

So, the value of M is low and inversely, F is high. The braided habit of these rivers is partly an adjustment among interdependent variables of width depth sediment grain size and partly the response to the external variables discharge and load. So, that means a channel habit, how this channel will be how efficient the channel will be. So, that depends upon these how wider channel or it the narrow channel it is a deeper channel, and what is it is hydraulic radius.

What is it is wetted perimeter; this wetted perimeter as we know here, this is the wetted perimeter. So, here wetted perimeter will be 15 + 1 + 1 =17 here wetted perimeter will be 5 + 3 + 3 that means 11. So, wetted perimeter is here then it is area of cross section area will be here then hydraulic radius will be here area by wetted perimeter. So, more this hydraulic radius more efficient the river is.

(Refer Slide Time: 34:00)



So, the meandering habit of the rivers specially those flow on the fine grained alluvium in humid region can also be related to width depth ratio of this channel and sediment grain size by these inter related adjustments, more of this energy of the stream is extended against the bank and less against the deep bottom the sinuosity of thalwegs and channel increases and meanders are formed.

So, these are the mechanisms how we can create a meandering river, a river straight braided river or a straight river by changing this variable of this grain size slope this width depth all these types of parameters that we can change accordingly and we can create different types of channels. Similarly, in the natural environments also, this type of model can be applied to create meandering channels to create straight channels.

So this is very much useful for water recharge purposes. For example, we are creating a meandering channel in a particular area. So that means more time the water will interact with the surroundings so that more recharges will be there or if we are straightening that means within a less time we are discharging high amount of water. So that means there will be less chance of recharge of this area. So artificial recharges this can be used this idea can be used for artificial recharge zone, creating artificial recharge zone and diverting channels in different habits within that systems. So I think we should stop here and we will meet in the next class. Thank you