River Engineering
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Lecture No -21
River bank Protection and Control Structures (Part –II)

Very good morning to all of you let us go for the next lectures on River bank protections and the control structures, this is the second part of River bank Protections as we discussed in the last class about River revetment. Today we will talk about the spur, permeable spur, impermeable spur and how we can decide the layout of the spurs those the things we will discuss in detail but however the more design and all the things will not go much details like for examples.

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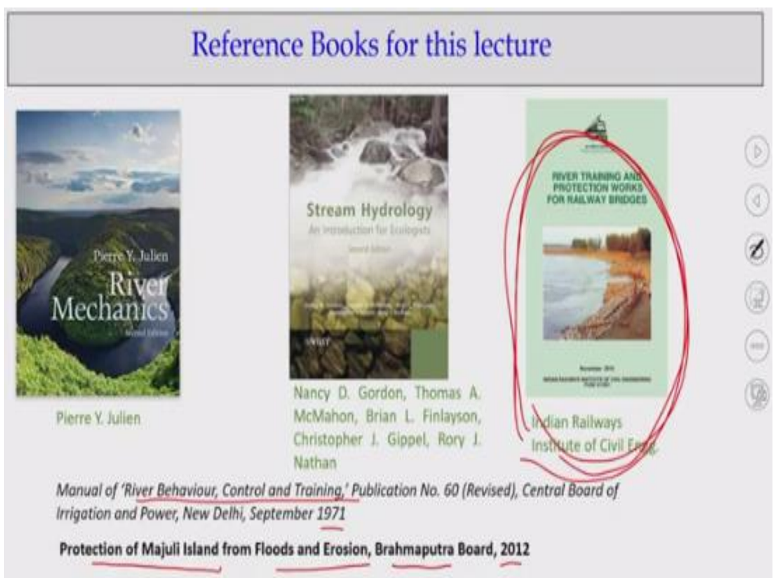

We are following mostly for the Indian conditions as you know it River Bank protections work extensively has been done for many river like Ganga, Brahmaputra, Brahmini many river we have successfully completed River bank protections and we have lot of experience how to protect the River bank or how to understand the river behavior and control and training which is much earlier 1971 and 2012 report about protections of Majuli Island which part of the Brahmaputra Rivers on the flood and erosions.

That is the part I will cover it again, I to repeat it we are not going more detail design components you can follow any of the Indian standard codes to how to design that part or you can go more details about this book which is published in year 2016, so that is the major aspect what I want to talk about you.

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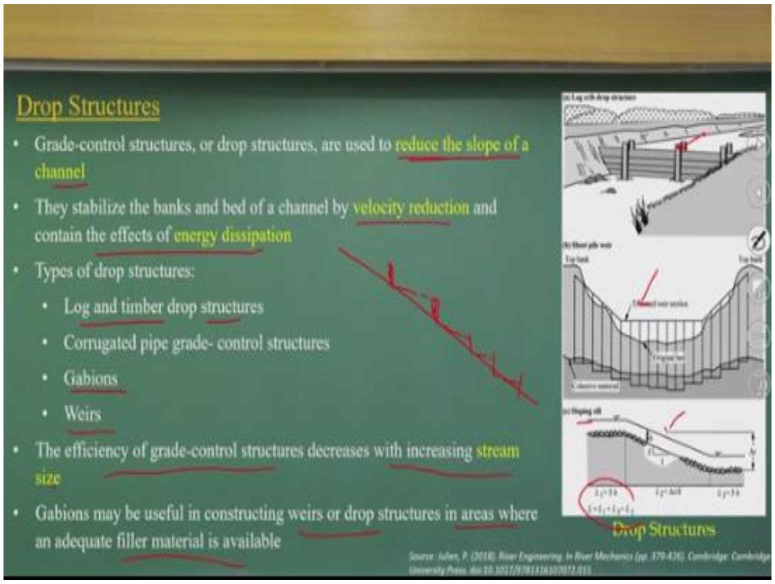

Now I would talk about the many of the times, when we have a Rivers we have the very large gradient rivers and we want to reduce the slope of a channels so we want to reduce a slope of channels, so what we try to create? We create a small structure, like a structure what is there small crib or the timbers these are validate for the hilly regions where you have a steep gradient of slope and if you construct a small drop structures.

So, for like here is a timbers or sloping up roots like a drop structures that means slowly you depositions will be there and it can modify the slopes, so it can reduce the slope of a channel to stabilize the bank and basically it is also does, because of the step wise we have this drop structures which velocity reductions also effective on energy dissipations. So we can have a very simple structures log and timbers drop structures, or you can have a Gabions, or you can have a small weirs.

This is what we do it when you talk about this, so the basically the efficiency of grade control structure decrease the increasing the stream size, the Gabion may be useful constructing weirs drop structure where adequate filter materials are available. So the basically these are small structures are used as a drop structures to reduce the velocity and start the sedimentations, that is what is that and how to design all these things as a drop structures you can follow any of the text books on this but you can understand it is a very easy concept to know it how we reduce the slope of a stream.

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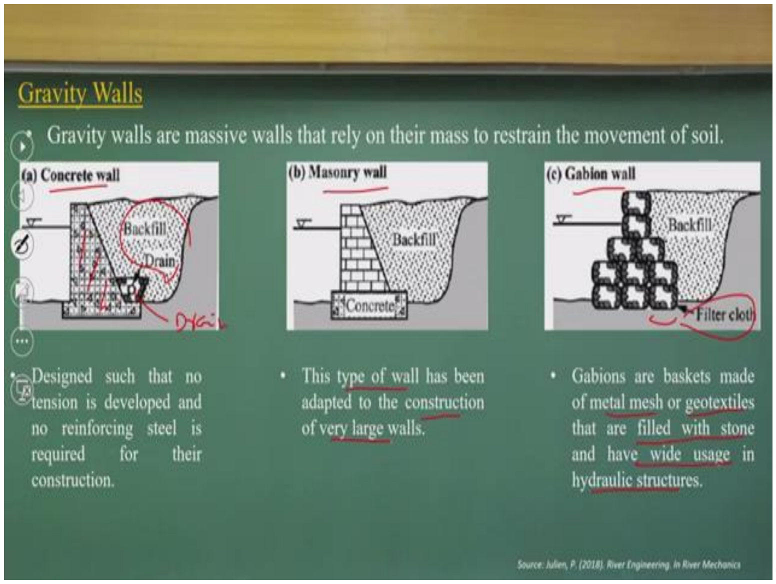

Same way if you want to make it the bank is protected you can have a concrete walls, these where you have a small streams and you want to protect certain stretches of the river bank you can think for to have a concrete wall so you can have a backfill you can have a drain systems and, or you can have a Masonry wall with a backfill and concrete things, or you can have a Gabion wall, so you can have a back filters.

So basically Gabions has a baskets with a metal meshes or geotextiles that are filled with stones and have a wide usage in hydraulic structures, nowadays Gabions play the major roles and you can have a filter cloths and this is what you can have, this is typical wall you can construct it is very large and here you can have the concrete walls, these are the basic structures you can protect a smaller reaches the more vulnerable.

Because it is quite expensive to have this type of structures where you go about a channels where the depth is more than 5 to 6 meters then cost will be much, much larger.

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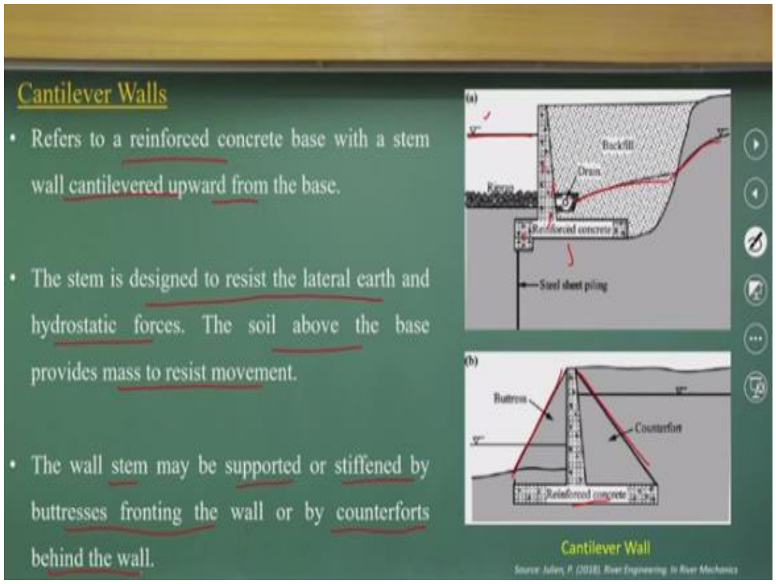

And if you go for the next part if you see that you can have a stone riprap and the river is flood level is here you can have a reinforced concrete of base with a stem with a wall cantilever a part of this base. These are good when you talk about the smaller rivers as well as you can consider this retaining wall the cost is so expensive but this is what is showing it the drain also it is showing the groundwater tables, how it is there.

You can have this reinforced concrete wall like this with having the waters in the both the sides, so we can have a cantilever wall. So the basically the stem is designed to resist the lateral soils and the hydrostatic forces the soil above the base provides a mass to resist the movement, which is very basic things. Well stem may be the supported or stiffened by the buttress front of the wall that is what is here counterforts behind the walls.

So these are the small structures, it is not used for a larger river like Brahmaputra but smaller streams and you have a vulnerable reach you can think for this type of protections work.

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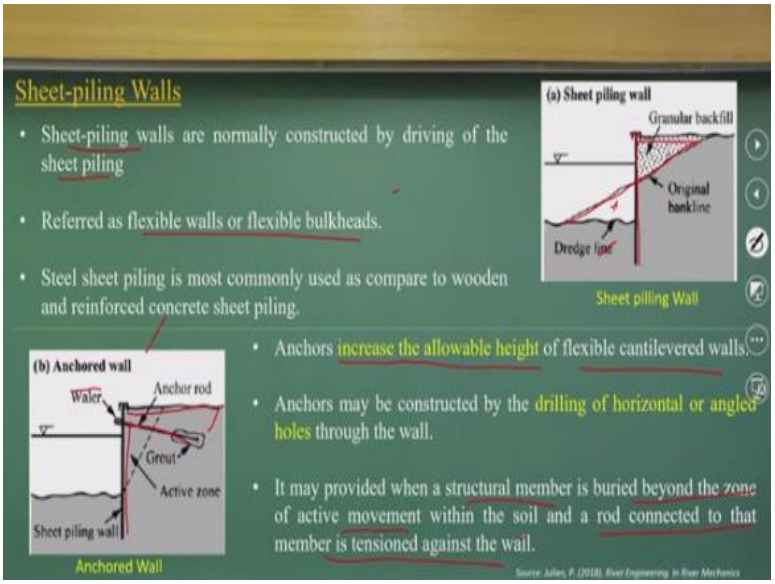

If you go for the next ones in a smaller case scale we can have this Sheet-piling wall. So we can have a sheet-piling; this is filling materials, this is the dredged part, so you have these original bank lines then you have a cut and fill and you create the sheet piles. So basically a flexible wall or flexible bulkheads can be sheet piling walls normally constructed by the driving the sheet piling that is what we do it.

And you can have a anchors the increase the allowable heights with flexible cantilevers, if you look at that you can have anchors and you can have the sheet piling things. And you can do the geotechnical design of the sheet piling what could be the depth and what type of anchoring you should provide and what the strength of anchoring? Those things you can look it as a geotechnical perspective to design the sheet piling.

And whether it can have a cotton field or it can have a anchored wall. So it may provide a structural members is buried beyond the zone of active movement within the soil and rod is connected to that member tension against the wall. So you can design exceed filing wall okay these are small structures. We can construct it along a small rivers where we have the much vulnerable stretches

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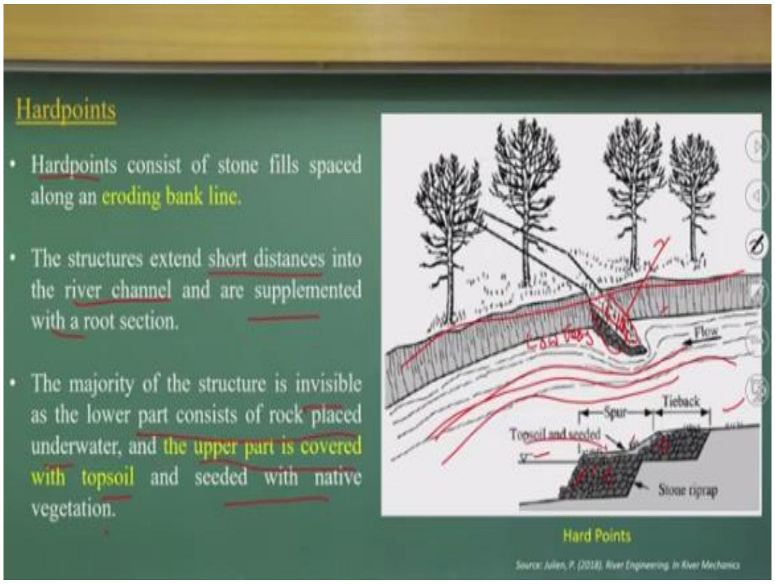

Now let us come back to the, many points we cannot make it the bank protections with the revetment of the walls, we try to look it to divert the flow from the bank. That is the idea that flows should not come closer to the bank. We can deflect the flow from the river. So what you look at that we do a small is a hard points, like if you look at that if I construct a hard point here. If you look it, this is a bank line.

And if I construct a hard point here so you can understand it, the flow will be deflected. So you draw just look at the stream lines just look the stream lines, so flow will deflect it. Because of the deflections of flow these regions will have a low velocity zone. So that way we are protecting that bank. So that is what the deflections are happening it so we need to these type of structures the petrubate into the river.

We can construct it which will be the hard point which will be deflects the streamlines. As the flow stream lines will be deflected it these regions will have a low velocity regions. As it is a low velocity regions so there will be not bank erosions will happen there, so we divert the flow. That is what we do it. The structure extends the short distance into the river channel and it is supplemented with a root sections. it is not only this hard points it should have a spur like with a tieback and the top soils.

The majority of the structure is invisible lower part of considered rock placed under the waters, upper part is covered with the top soil seeds native vegetations we can put it like that with a native vegetations and all. The basic idea is that, deflect the flow from this erodible bank constructing this hard points, which is not much technically or the stones with have a tiebacks and you can have a scour and with the top soil with the seed you can have the vegetations layers.

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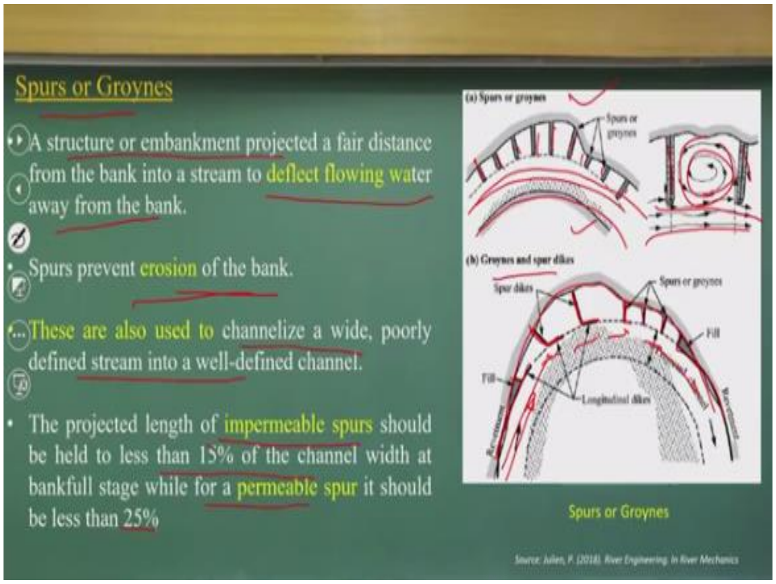

So if you look at the next slides which are talking about as a engineering points we talk about the spur and groynes which is a structure or embankment projected a fair distance from the bank into the stream to deflect the flowing water from away from the bank. If you look at these structures if i have a series of spurs structures, because of that flow will be deflected from this erodible bank.

If you look at the spur more details what will happen it, the flow will deflect and here it will create a zone with a low velocity zones. So that is the reasons it prevents the erosions on the bank it is used to generalize the wide channels like for example, if you look at these figures which is having a series of the groynes and the spurs you can understand it. This is what the erodible banks.

And there are the different shape of the spurs structures are there. These spurs have the flow which is deflected by these and because of this spur so it is a deflected, so it is away from this bank. So this layer series of the layout of the spur with different size, shape we can put it. The basic idea is that the deflect this main streamlines the away from the bank which is the erodible bank. So the basic idea is to channelize the wide poorly defined stream into well defined channels.

And the projected length of impermeable spur, the spur where water cannot pass through, it can help to less than 15% of channel width but in case of permeable spur for where through the water can pass through the sediment can pass through. It can go up to at maximum should we be less than the 25%. That means 25% of the length of the rivers we can put the permeable spur, but in case of impermeable spur we can put it at most the 15% of channel width we can put this type of structure the small structures.

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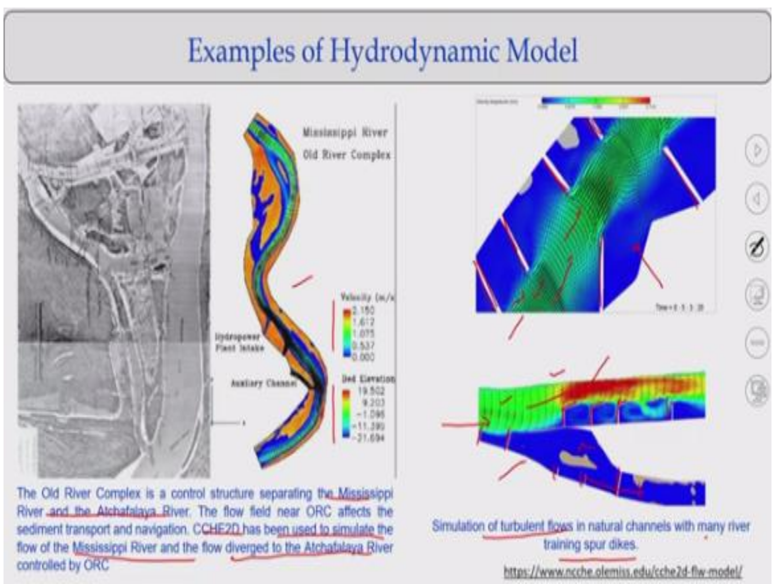

Now if you look at more details here you can understand, it because of these spur structures how this improving the channels this is a mathematic models there. So because of this spur structures layouts and if you look at these velocity vectors, now it is river is confined with these and these are the higher velocity zone this is the lower velocity zone. So it channelized the river as well as it is protects the banks. That is what it happens in this case there are the spurs.

And these spurs are confined the river with a smaller width as well as it is a protecting this. And if you look at these figures, we with having the channel bifurcations there are series of the spurs structures are there and because of presence of these structures, you can see this velocity zone. This is the higher velocity zone this is a lower velocity zone. So it is deflect the flow from these zone it goes through that once.

So there are very, very less flow in this branching part where each the main flow is go through these ones also it makes a deeper channel through these ones. So same way there are lot of study has been done it with a simulating the turbulent flow with a series of the main river with natural channels this is the Mississippi rivers and this two rivers the hydropower plants and if you look at velocity distributions and the bed elevations how varyings are there.

So you can try to understand it how these concepts are there and you can use these CCHE2D models can be simulated for the flowing measure around the bar, flow diverged to this thing. So you can understand it, how the mathematical models can be help us to know the layout of the spurs and what could be the dimensions, what is the length and what will be the layout for that.

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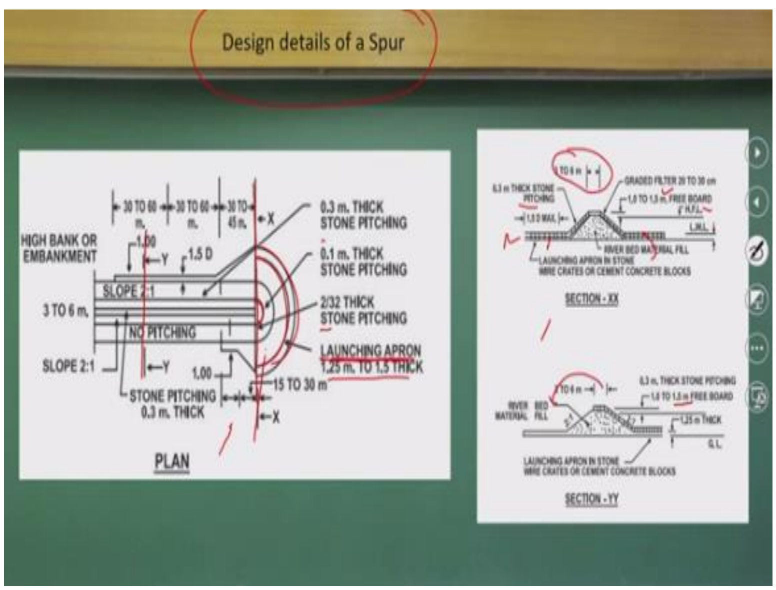

Now if you look at the typically spur is embankment structures if you look at that and there is more details about design of detail spurs is available in IS code. Here I have to graphically I am showing that spur will have this type of cross sections, if you can understand it will be the embankment and having a stone pitching from front sight, upstream sights, as well as the downstream sights.

This embankment could have a width the top width would be 3 to 6 meters depending upon the one a routes or two way routes you are planning it and you have a high flood levels and you can have a free board 1 to 1.5 meters and you can have a stone revetment in the both the sides. If you taking a cross section at these points if you take a cross section at y locations means here you can see that there is a embankment and there is a stone revetment.

It is indicating for us where is the high flood levels the free boards, but the downstream of this we should not provide any revetment because it is not necessary to have a revetment as you can see it. To protect these, the scour hole positions are these look we should have a launching apron and that launching apron can have a this thickness the stone pitching thicknesses are there and it could have a layer wise and the dimensions is given here.

If you look it that way the spur is, impermeable spur is nothing else is a embankment is constructed with a stone revetments using the Gabion mattress and to protect these scour hole formations you should provide the launching apron and that what is the stepwise launching apron and that is what will be show you that what conditions are coming it. So that is why it is the basic structures of a design detail of a spurs.

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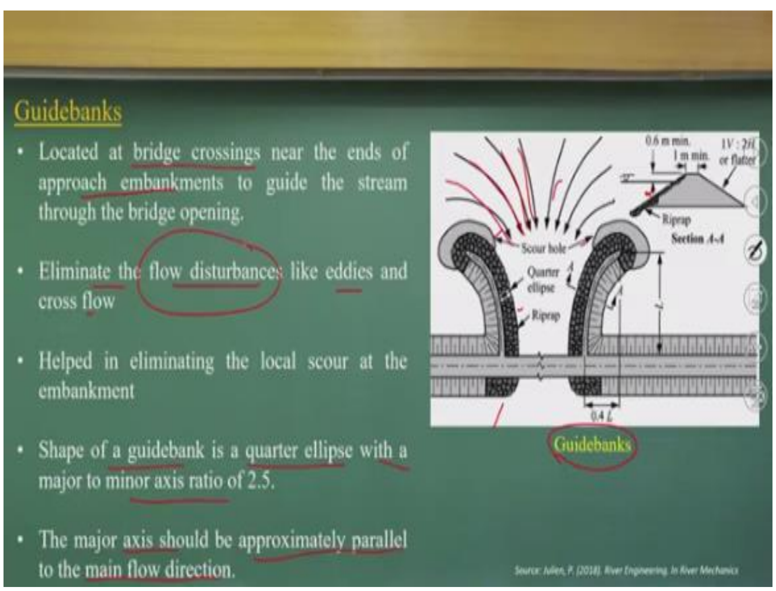

Many of the times we confine the rivers it is coinciding having the guide bunds, so if you look at the guide bunds that means basically then locate at the bridge cross section near the end of the approach you can have a guide bund. So if you try to look it when you have the guide bund both those sides you will have to have a stone riprap and you will have a flow convergence to this. So you will have the scour holes here.

To protect this, if you see this there will be a stone riprap, the high flood levels and there is a geotechnical design of this embankment considering the for top width, considering this free board all we can design with a as a guide bunds. More details we do it with having a physical modeling studies or mathematical modeling. The shape of the guide bund which is you can see it is a quarter ellipse with a major minor axis ratio of 2.5.

So major axis should be approximately parallel to the main flow directions so that is what it and basic the idea is to reduce the flow disturbance like eddies and the cross flow. So we should try to layout a guide bund such a way that it should not create the float disturbance like eddies or the cross flow. So just trying to trace that you try to look it how will have the guide bunds.

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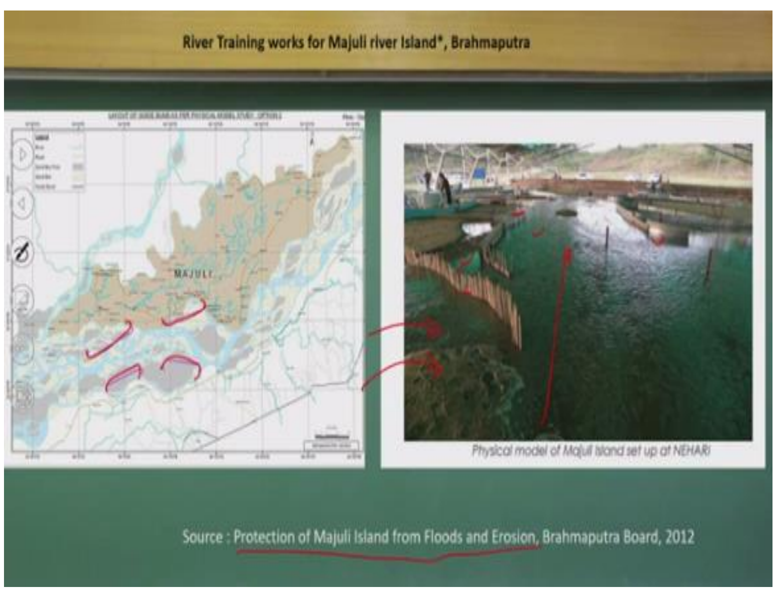

And if you look at the next part which is done it for Majuli River Islands which is there in the reports, protections of Majuli River Island and divergence in 2012. You can see these rivers and they want to have a guide bund at these locations and for that this physical model set up with a permeable spur, with a guide bund. So it has been created that physical model set up to try to know it that how they performs the guide bund also permeable spur.

How they are performing it to diverting the flow and channelizing the flow. That is what if you look at the figures, here you can see the channels, you can see that island and you can see this the guide bund and same things is put in in a physical models. Before implementing these structures we can try to look it what type of things we can do it because it is a quite expensive for implementing these structures.

And as you know it if you want to implement any things in the structures you cannot remove immediately. So that is the reasons first a series of physical experiment is to be done it try to know it how the flow is happening it the scour hole formations the channel deepening is happening it. How effective impermeable or permeable spurs those are things we should look at by measuring this flow velocity stream lines with a different flow conditions like 10 year return period flood, 50 year return period flood or 5 year return period flood.

So those thing we can conduct the experiment and we can try to understand what is happens it same way you can implement on these rivers that is the strategy we followed it for any big river training works.

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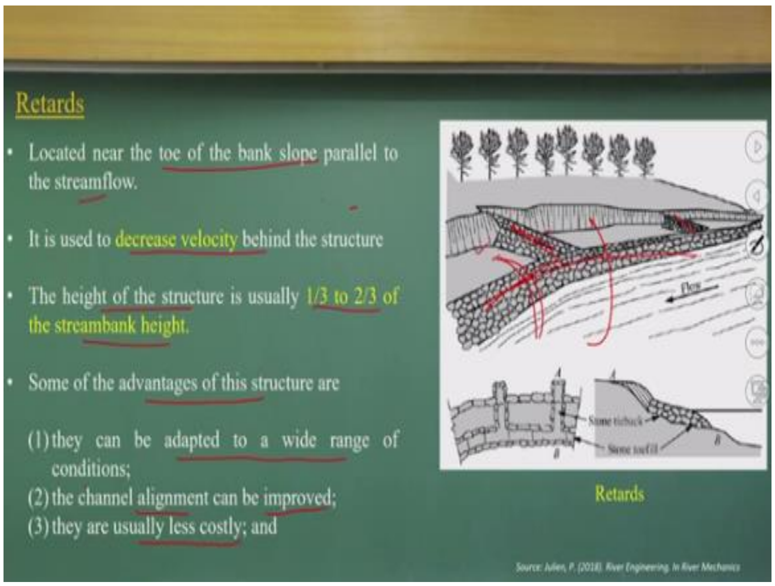

Now if you look it, many of the times we also have a retards, this is a very simple structures. So basically we can create a flow parallels, it is not embankment we allow these things to overtops it. That is, what is that a two of bank slope parallel to the stream used to decrease the velocity behind the structures. So the basic idea is that as the flow exceed is in that places you will have a flow reductions.

The height of the structure usually one third to two third of the stream bank height, that is a retards so you can see it is a retards. Some of the advantages of these structures are that it can adopted to a wide range of conditions, channel alignment can be improved and usually less costly. So you are not protecting the bank, you are creating a retards which is a far away from the bank but which we they have a one third to two third height of the stream bank height, so that it will reduce the velocity in these zones the high erodible zones.

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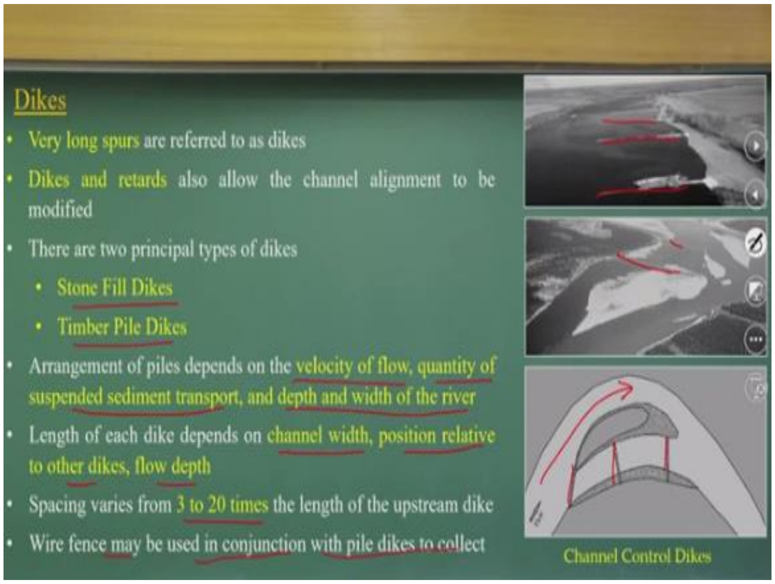

Now if you look it, we also have a since the dikes or the spurs a stone for fill dikes and timbers dikes and you can see this flow controlling structures what is constructed it because of that flow is that and you can see in photographs the series of dike structures. Nowadays it is easy to see the dikes structures any of the satellite imageries. So, arrangements of piles depending upon the velocity of flow the quantity of the suspended sediment transport depth and width of the river.

The length of the dike depends upon channel width the positions related to other dikes and flow depth the spacing varies 3 to 20 times of the length of the upstream dike and the wier fence may be used to conjunctions of the pile dikes to collect, the more the sediment reduce the velocity. So if you look in this way we also have a very long spur, so basically dikes are very long spur occasional, spur is a shortest dikes are the longest.

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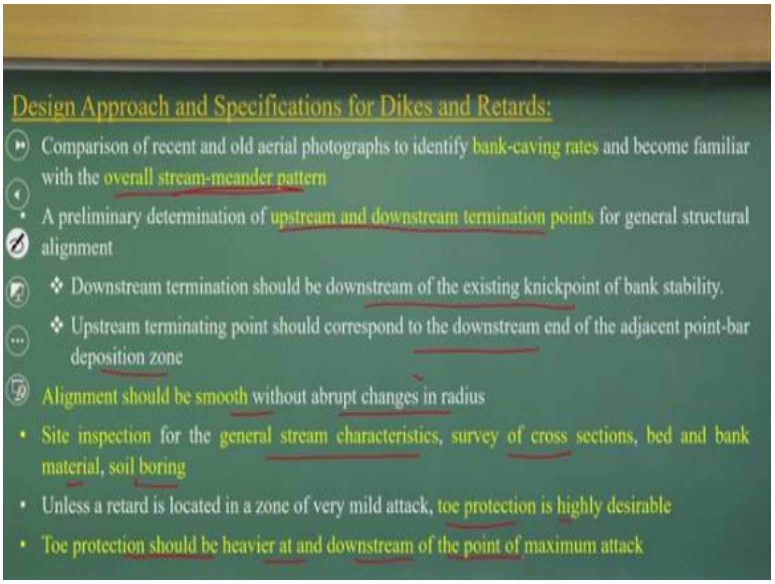

Now let us look at that what are the design approaches which are very qualitative ways of design approach is that we should familiar with overall stream meandering patterns, whenever you construct the dikes we should have a the knowledge of river meandering patterns as we discussed. That means it needs to have a through morphological studies last 100 years and 200 years, try to know it what could be the pattern of the stream meandering patterns.

That is the scale we should work it, that upstream and downstream terminations points, the downstream terminations points should have existing knickpoint of the bank stabilities and the upstream turning point should correspond to downstream and adjacent point bar deposition zones and alignment should be smooth. That should not be about changes in the radius then you have the more problems.

The site inspection is there to know about stream characteristics, survey of cross section, bed and bank material and the soil boring and there should be always have a two protections is a necessary and the two protection should be the heavier at the downstream point of the maximum attack. So these are general guidelines but detailed design of the dikes also we are the retards, we look at as a geotechnical design and the hydraulic designs conducting at the physical experiments or the mathematical studies for that stretch of the river.

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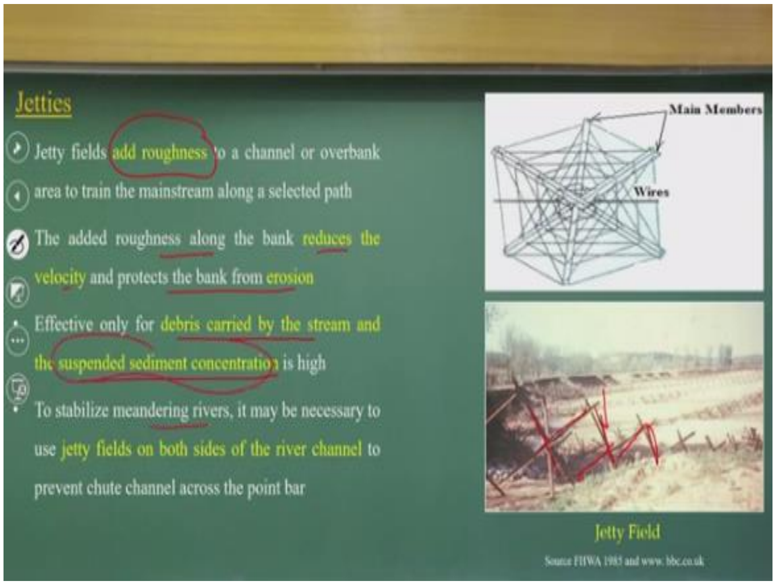

I will show a one of the case studies what we did it for the Brahmaputra rivers end of these my presentations. So if you look at that many of the times it is not that way to measure this so expensive work for a larger rivers what we try to do it with, Jetty field. The basic idea of the Jetty field it is a just a wire mass basic idea is that to add a roughness or reduce the velocity in the flow on the bank or the channels on a selected path as it is reduce the velocity.

And if I have a lot of sediment loads then the sedimentations can start it the depositions can start it. So adding the roughness it reduce the velocity protect the bank from the erosions and if it is effective if debris is carried by the steam, if the steam is having a lot of debris and these debris can plonk up it here and that what it gives additional resistance and that what make it the sedimentations if you have a lot of sediment concentrations flowing over that.

It stabilizes the meandering river it is necessary to have a Jetty field in both the side of the river to prevent the chute across the point bars.

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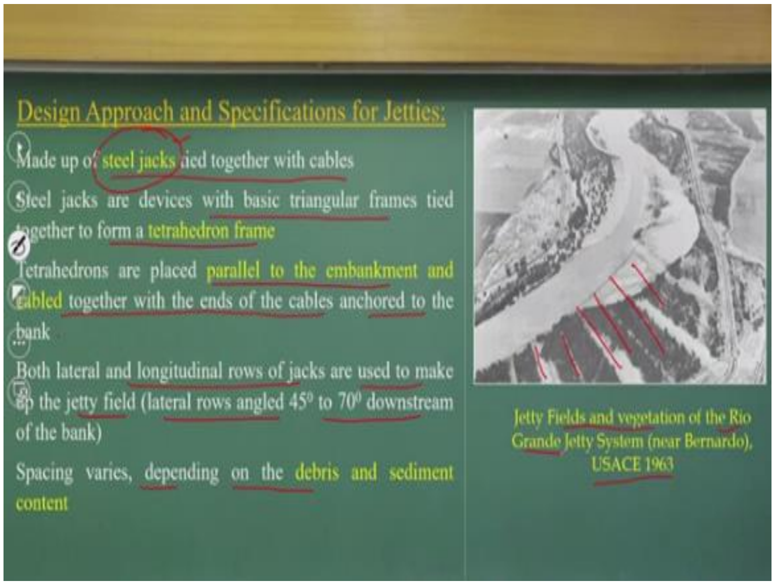

If you look at same concept, design approach specification objectives if you can see that Jetty fields looking from the satellite data you can see the Jetty fields. So the basically it is a steel jacks tied together with the cables. So the jacks that divide the basic triangular frames tied with together with a tetrahedron frames, tetrahedron frames are placed parallel to the embankment and the cable together with the end of the cables anchored to the bank.

Both the lateral longitudinal row of jacks are used to make the Jetty field. So we do not put a single Jetty there could be a series of the Jetty field we can put it lateral will have an angle like this spacing varies depending upon the debris and sediment. So you can see it the jetty fields which is that steel jacks but still it is a costliest river like Brahmaputra or where we want to stabilize the river for certain years.

We cannot go for a steel jacks with the cables which is followed in US association of civil engineering 1963 with having a Jetty field and the vegetations of Rio Grande Jetty systems, that is what you can see in the photographs, that is what not really possible like country like India.

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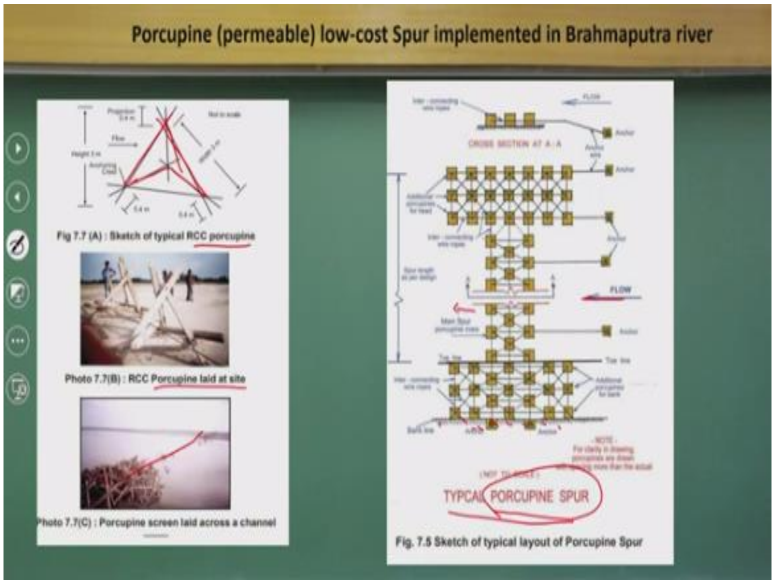

So what we do it? We do a very simple concept which is called the porcupine low cost permeable spur implementing Brahmaputra Rivers or the some of other smaller rivers, so we can have a the RCC porcupines, the same concept which is a stables can be laid at the site and you can see the photograph of RCC porcupine the dumping of that circular and we can create a porcupine spur so you can see the top layout.

The top layout of the porcupines so it can have a anchoring and you can have a series of porcupine structures with anchoring. So that we can create a field and this is your embankments so we can anchor it and it is the flow directions and you can try to look it work as the field porcupine spur field. So because of a series of the porcupine structures we put it and that porcupine structures is reduce the velocity and that reductions of the velocities help us to do the sedimentations.

And that is the side sedimentations because of that this bank is protected as well as channel also divert from these places.

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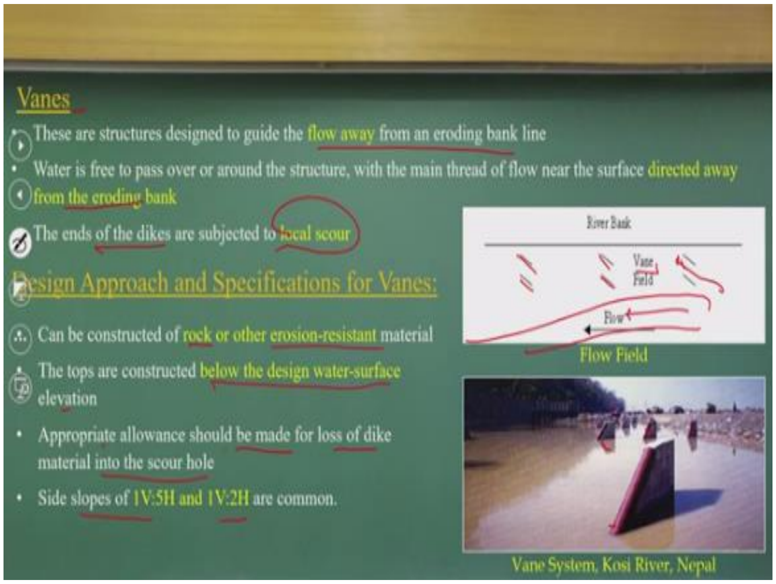

Now if you look at other one is a smaller stock structure is called the vanes, if you look this photographs you can understand its advanced systems. You can look at this structures the basic idea is the same thing flow away from the eroding bank lines and it is directed away from the eroding bank; the end of the dikes are subject to a local scour that is what you have to look it so these are the bank filled.

And it is the flow which is divert from that it can have a rock or erosions resistance materials, it can design water surface elevations appropriate allowance should be made to loss of the dikes material into the scour holes and side slope can be provided. So just you look it these are the smaller structures which is also implement in Kosi River in Nepal, if you look at this small structures can divert the flow away from the eroding bank lines.

And that is what is create the field the flow stream lines will go like, this will not attack here so this type of structures also put it in river bank to divert the flow this is good for a smaller rivers where we can have a flow diversions like this.

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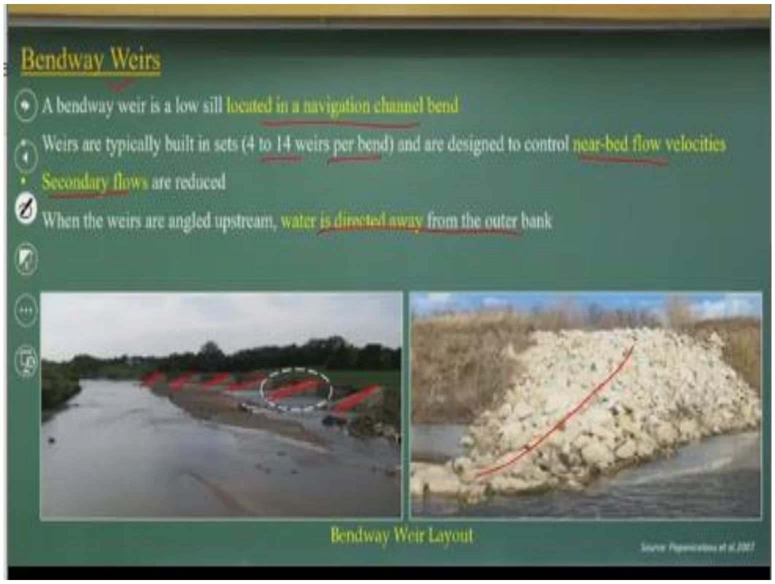

So that this is called bendway weirs, this is the last layout what I am talking about you, you can see these bendway wires which is US association of civil engineering are prepared the guidelines to prepare this type of structures, dumping of this with the slope in a bend. Idea is that loosely located the navigation channel bend the weights are typically built with 4 to 14 weights per bend and designed to control near-bed the flow velocity.

And which reduce the secondary flow and water is directed away from the outer banks that is what is happens. The same structures, but here is a cost effectiveness because of a small structures. We put it as weir as you have seen this thing which help us to this more design guidelines and all you can look it bend away weirs which is there in US crop of armies and all.

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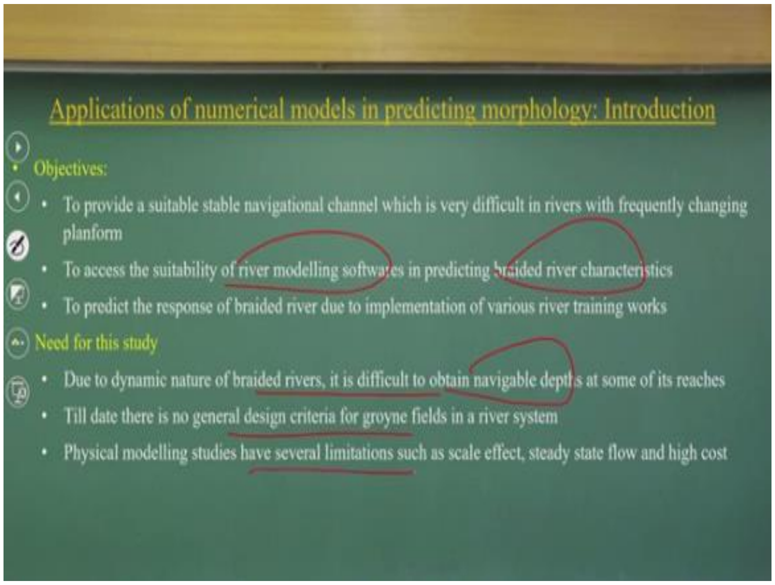

Before concluding so I am to show you that one morphology studies what we have done for the Brahmaputra rivers basic idea is to know it using the mathematical models whether we can predict the certain morphology of Brahmaputra Rivers with or without river training works. So the basic idea is that using river modeling works can we predict the braided river morphologies and basic objective is that to get a navigable flow depth.

Because there is enough the guidelines for a braided river systems how you have to put the groyne fields and physical modeling as it is you know it is a having the scale effect, it has a steady state flow conditions are the high cost.

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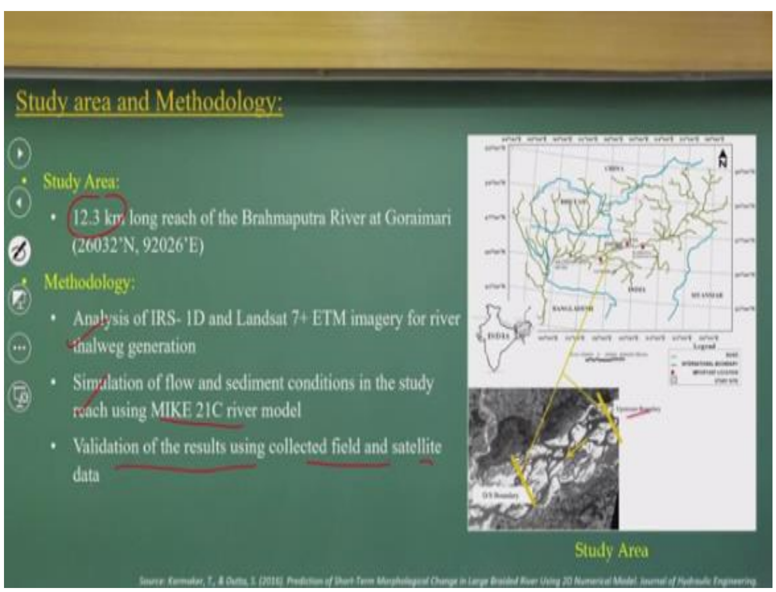

Both the things you know it very well, now if you look at this River stretches which is here with the middle part of the Brahmaputra River about 13 kilometers we use the satellite data, we use the river models and we try to collect the field data and satellite data to validate the prediction of morphology the hydrodynamic and the beds are the correct. Is it acceptable by using these simulations models which is having the upstream boundary condition, downstream boundary conditions.

And more details are there in the journal of hydraulic engineering, that is what you can cross that for it.

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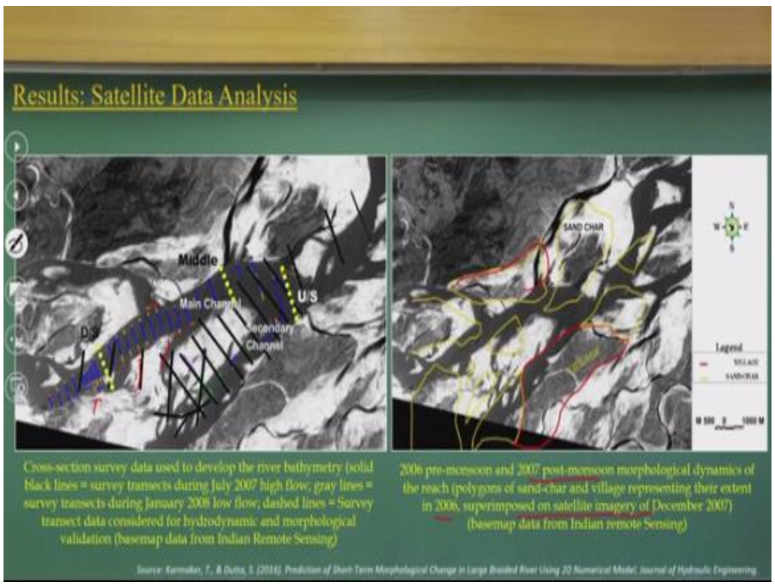

Now if you look it is a quite interesting study and challenging study we did it, these are the survey transect and each transects we measure the velocity flow depth and so this is a showing it. In that how the bar positions with a 2006 pre-monsoon 2007 post monsoon within the year. How the thing has changed the polygons are the sand chars and village representing that extend in 2006 impose of December 2007.

So that much of morphology change is there in sand chars and all and we are fitting this data into the two dimensional hydrodynamic models with sediment transport.

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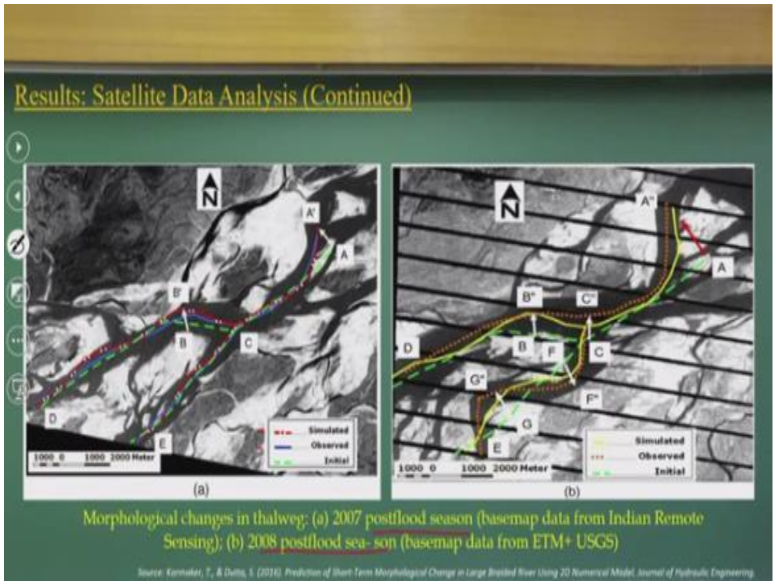

So if you look at that we try to predict the Thelweg lines, so if you look at that simulated verses observed the Thelwag line prediction is quite enough, by fractions points and these. The same way you can look it simulated versus observed how this conditions has changed and how the predictions are there with a morphological cases 2007. Preflood series sessions to 2008 the post flood seasons how the best map with the satellite data we just compare it whatever we predict it how accurate they are.

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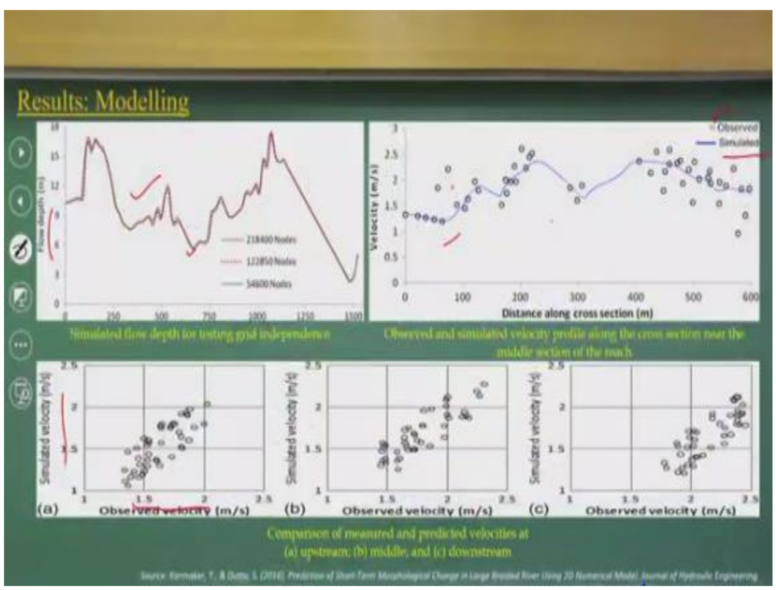

So that way if you look it next part look at the velocity the velocity ranges from one point to two meter per second. The simulated velocity within the range, but there will be scatter that there is uncertainty velocity measurement in the field also the river models is what you consider the turbulent structures and all there is certain degree of uncertainty and that is the reasons you can have the scatter plot.

But more or less if you look it the range of the velocity predictions are fairly good, but in case of the flow depth I think it is quite interesting this flow depth is considered much accurately even if in a braided Rivers with if you look at the observed and the simulated part. Observed are the dots points distance along these cross sections and the velocity if you look it which is varies from 1.5 to 2 meters only it is following that trend.

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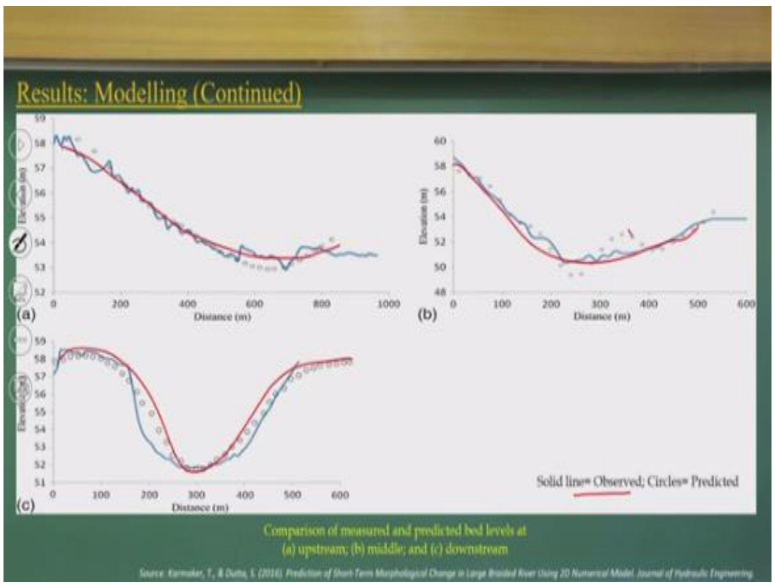

Now if you look at the river cross sections, this is what we have a observed is a solid lines and the circulars is a predicting things, I think it is a predicting very well and these the cases. And this is the cross sections at different points and you can see these comparisons of predicted measure the bed level of upstream middle and downstream sections.

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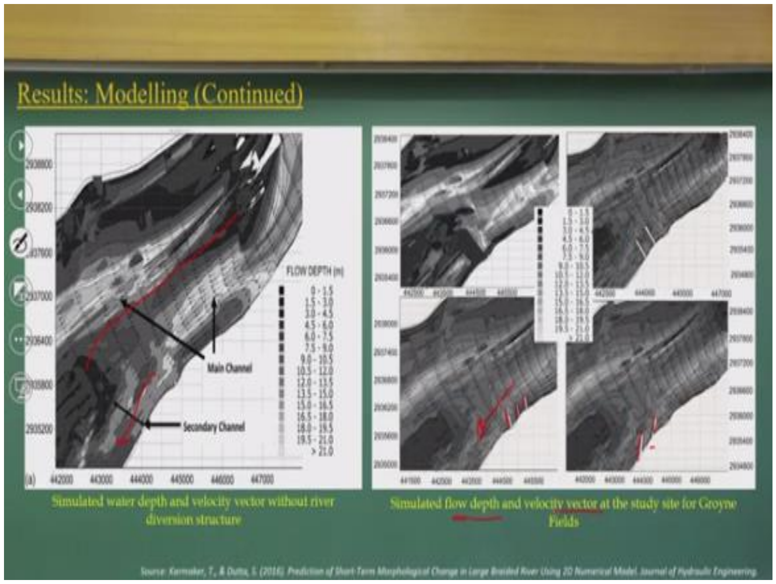

So for similar way, if you look at next part if I put the river training structures, like there are the primary channels there are the secondary channels and if I put the spur structures with a simulated and calibrated models I can see that how the flow velocity vectors are changing it. Whether these banks is protected or not whether it's a closing down these secondary channels or not all these things we can do as studies once you have a calibrated validated models for a certain stretches.

So you can see this velocity vectors and how complexity is velocity vectors are there and that is what showing in the flow depth and velocity vectors, it is a showing in the groyne fields or the spur field if you put it in different spur field how does it is behave. So nowadays it is can be done it before implementing the field we can know it how effective the ground fields the study what we try to do it and summaries on this way.

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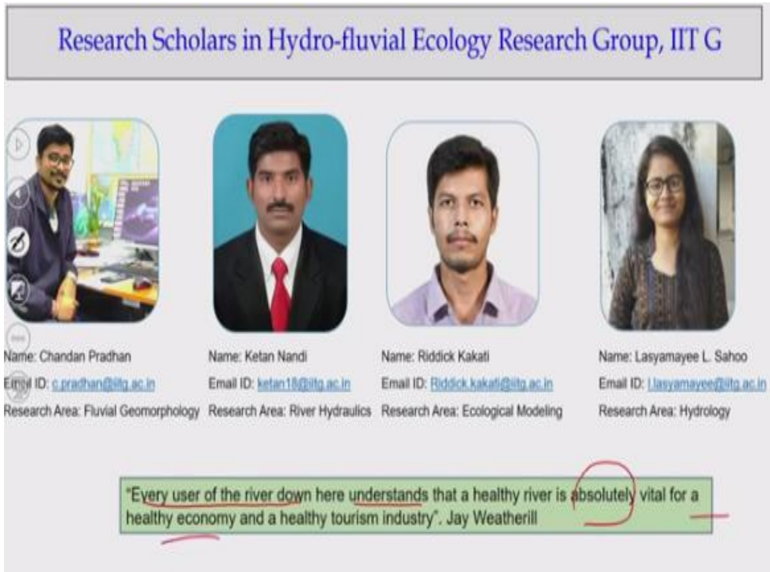

So let us have a concluding this lectures with river control structures that every users of a river down here should understand that a healthy river is absolutely vital for a healthy economy and healthy tourism industry with joy weather thank you very much for this lecture.