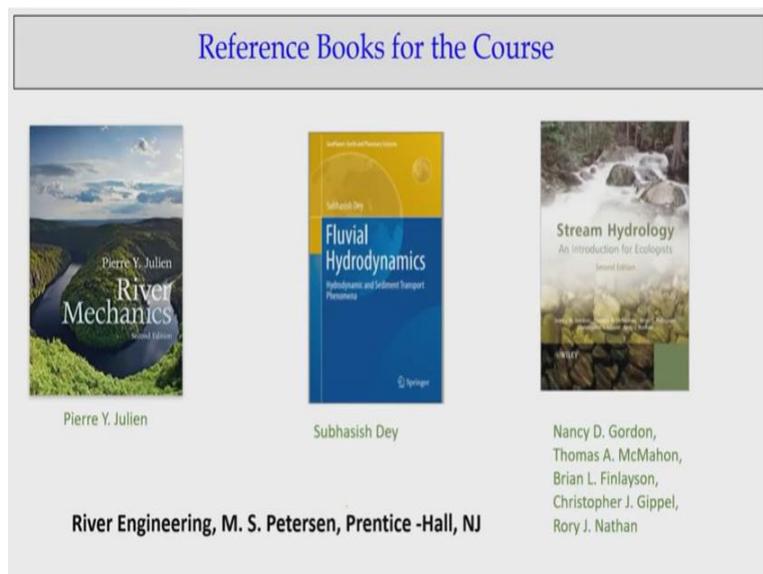


River Engineering
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Lecture – 18
River Training Work

Welcome all of you for these interesting lectures here we will not talk about much about mathematics talk about the art of river training work it is a combination of science and art and with the experience of hydraulic engineers, sediment specialist and the river engineers they try to train the rivers for different purposes. So, looking that most of the experience in the United States of America that is what I will share today.

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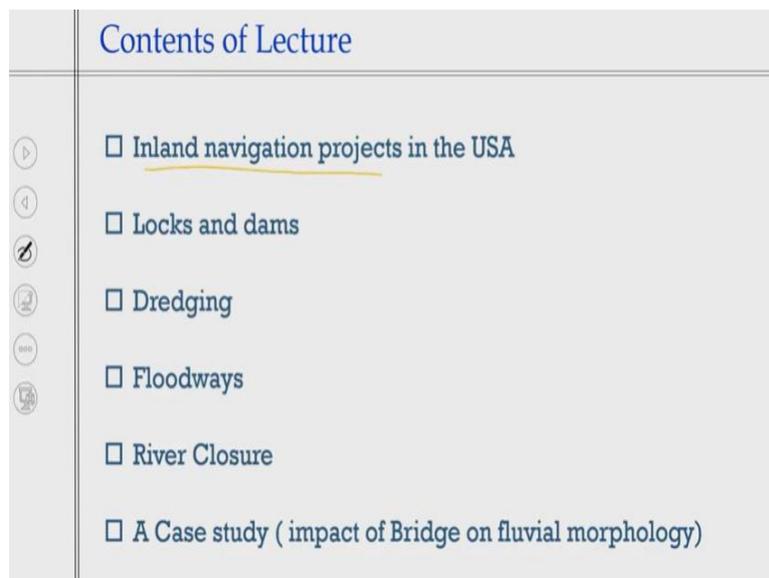


And some of the advanced country how they have been managing the floods and they how they have been making the river is navigable so that they can use as inland waterways. So, the basic idea of that what the experience is there and most probably I will be following this book the river engineering by M. S. Petersen that is the books we are following it and partly we are following its river mechanics books.

This is the engineering concepts though mostly you know it when you construct a any river training works it is a combinations of geotechnical engineering combination of hydraulic engineers and new constructions materials. So, it is it is not a just a river engineering this is a combinations of geotechnical engineering river specialist and also the advanced techniques geotechnical techniques what nowadays we have been using it.

So that is the reasons is a quite introductory levels but then many new things are coming it like geotextile materials and all geotube and all the things water is coming off but I will just highlight it what is the experience of the rivers engineering works in the united states of America.

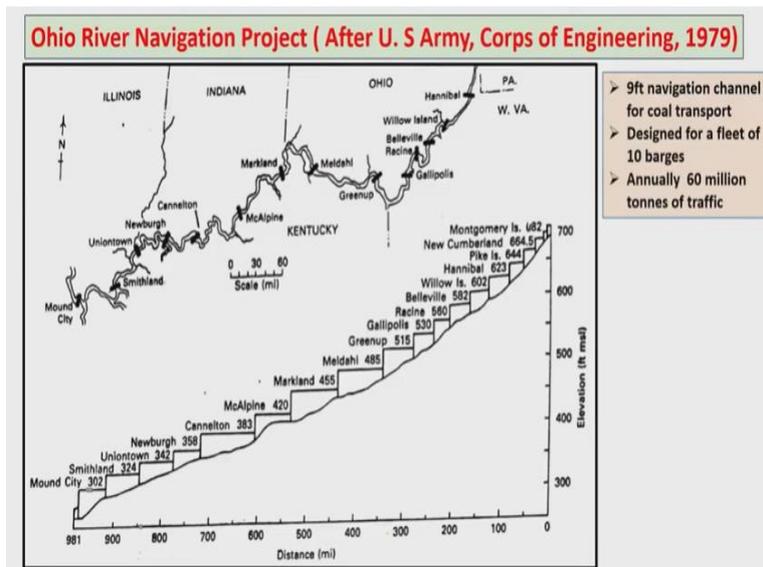
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Contents of Lecture	
<input type="checkbox"/>	<u>Inland navigation projects in the USA</u>
<input type="checkbox"/>	Locks and dams
<input type="checkbox"/>	Dredging
<input type="checkbox"/>	Floodways
<input type="checkbox"/>	River Closure
<input type="checkbox"/>	A Case study (impact of Bridge on fluvial morphology)

Let me look at the next figures which are very interesting figures slides were showing to us before that this is a content what I will talk about inland navigation projects in the United States of America and we will talk about the lock and dams configurations what is there at the introductory levels. Then we will talk about Dredging's the floodway's even we will talk about the river closures at the end we will have a case studies on Brahmaputra rivers that is what the impact of the bridge constructions on fluvial morphology that is the case study that is what will present at the last.

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Now if you look at that points if you look at this Ohio river navigations projects which is way back in 1979 by the U.S army Corps of engineers if you look at this rivers and you can look at this all these dam and locks ok so if you look at that from upstream to down streams how many series of the cascading dam and lock structures are there and this is for the longitudinal profiles distance versus elevations.

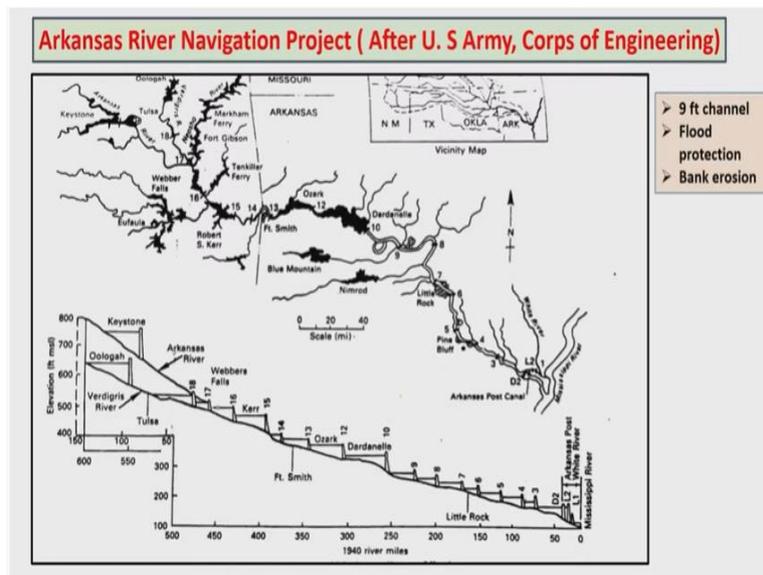
And if you look at that for each project, they have a like Montgomery projects who is having the elevations 682 Mel dahl projects the elevations 485 and you have McAlpine project 420 meters elevations and the Uniontown is 342. So if you look at this longitudinal profiles of the rivers and the intervention structures you can see that more than 15 structures are there which was constructed way back just after the world war I and world war II this is the channels is a navy 9 feet navigation channels which is very famous for transporting the coals from the upstream to the downstream locations.

And it has been designed for fleet of the 10 barges and that period you used to carry about 60 million tons of the traffic. So, you can understand it after the World War I and World War II these projects the river navigation projects play vital roles for economic growth in the United States of America because they constructed a series of the dam structures so that throughout the years, they can have a 9 feet navigation channels.

The depth of the feet will be 9 feet because of that they construct a series of dam structures if you can look at the series of dam structures and that ponding elevations you can see it. So, this is the way they make it the river is a navigable and throughout the rivers throughout the

seasons they have a 9 feet navigation channel flow or the river flow more than that. So that is what they have designed it and that is what it took almost 30 to 40 years to construct all these major structures makes this river each river was navigable and it has been a navigable river that is what if you see that the major interventions what is done in Ohio river navigations projects.

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Similar way if you look at this Arkansas river navigation project which is part of USA is part of the Mississippi river basins and if you look at the reservoirs you can see that series of the reservoirs okay all are the cascading reservoirs and the dam and the locks. So, all these are cascading reservoirs and all again if I plot the longitudinal profiles here the unit in some miles and we have the elevations and you can see this the dam structures each dam structures having a number and each number having this lock and dam positions.

So they have the ponding and they also have a keeping these waters ponding waters at the different levels and the lock and dam structures so that the any navigations can flow smoothly from upstream to downstream and it can carry the significant amount of though it can transport the significant amount of the upstream coal or other materials. So they make this river is navigable and based on these a cascading the dam and lock structures and that is what if you can see it and that is what it is made them to make it one of the successful projects to connecting the rivers no doubt.

There are the advantage and disadvantages like it has certainly helped the flood protections the bank erosions but the sedimentation was the bigger issue but that is what the strategy is?

How to maintain the cascading segmentations because of the series of the cascade dams? Those are the issues still the many of the engineer's hydraulic engineers are trying to find out the solutions how to optimally use the cascading dams' project so that you can reduce the sedimentations.

But no doubt this type of extensive river training works for navigable the channels navigable for making the navigable channels so that there will be a two-way traffic movement of the vessels can be done it that is what this thing and many of the text is very clearly said that because of these are the projects was the after the world war II gives us a boom to the economy of the United States of America. So that is the point what we to know it.

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Locks and dams

- Dams are required to sustain an adequate navigation depth
- Locks allow ships to navigate in a river steepened by artificial cutoffs
- Locks and dams must be spaced to maintain the navigation depth throughout the pools
- In river navigation projects the lock is usually located near the bank at one end of the dam to minimize the adverse effects of spillway discharge on traffic.

Locks and Dams

Source: Julien, P. (2018). River Engineering. In River Mechanics (pp. 379-426). Cambridge, Cambridge University Press. doi:10.1017/9781107072015

The same way if you look at that that means what is the locks and dams you can understand it say locks and dams. So basically, it is required to dams you know it is required to sustain a adequate navigation step that is what is 9 feet depth of the water minimum that should be there and the locks is to allow the ships to navigate in a rivers steepened by artificial cut-offs.

So if you look at this figures, this is the part of the rivers this is the left bank this is the right bank and you can see these are the spillway gates and the stilling basins and there are the gate piers are there and if you take the cross sections you can see with a gate upper pool lower pool and the stilling basins with the baffles will be there spillway crest and the riverbed.

So if you look at that so more detail we are not going it mostly you can get any hydraulic engineering's how to design all the aspects the how to design the spill gate how to design the

stilling basins, the gate piers and spillway gates that is not we are discussing here but that is the arrangement for a barrage or the dams to flow through that. But to passing through the ship okay we need to have a lock arrangement.

So, if you can see there is a lock arrangement this is the lock chain this is the upper gate this is the lower gate this is a lower lock approach this is the lower guard while an upper guard. So, ships come from these goes to this lock chambers then goes through this. So, this is the arrangement many of the things there will be the one side the dam another side will be the lock arrangement which facilitates a ship to pass through those ones within having the upper and lower with the storage and the lower lock approach.

We will talk more details in the next slides. So, if you look at that must be spaced to maintain the navigation step throughout the pools and the river navigation project lock is generally located near the bank at one hand that is what is you can see the peak to minimize the adverse effect of the spillway discharge on traffic. So that is the basic ideas and you can just see that the lock and dam basic features which may vary from location to locations.

It may vary the design of the spillway stilling basins and all the most difficult things of lock and dam arrangement will have a locks with you have upper lock approach lock chambers lower lock tools and there are upper guard wall and you have a lower gate you will have a lower guard walls which is facilitates the ships to go through these lock arrangements and the gates will be gate and the piers to maintain this your pool depth that is the idea the maintain the pool depth that is what is necessary to have the gate and you have the also the lock.

So this is the typical arrangement but it varies from depending upon the geology depending upon the site locations, depending upon economy and we try to make it differently but typical structures like this will have the arrangement for the spillway and the gate arrangements for storing and having the pool of water depth and there will be facility of the lock which facilitates the ships can pass through these ones.

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Locks and dams

- ❖ **Lock**
 - ✓ Provides adequate depth for navigation
 - ✓ Enables vessels to gain access to lower or higher water levels on either side of the dam
 - ✓ Consists of
 - Open chamber
 - gate at upper (to fill water)
 - gate at lower pool (to discharge water)
- ❖ **Undersized locks**
 - ✓ Make large tows very slow and cautious for entering
- ❖ **Large locks**
 - ✓ More expensive
 - ✓ Longer filling and emptying time



Lock

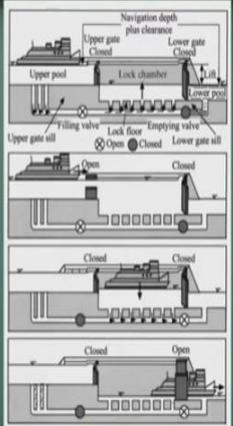
Now if you look at next part you can see that is a lock arrangements you can see this upper lock and the lower locks you can see it and it facilitates this is the lock arrangements its opens and closes and that is the reasons the locks is adequate depth for the navigations gain access to the lower or the higher water levels on either side of the dam it is have open chambers it has a gate at the offer to fill up fill the waters and you have a lower pool which is discharge the waters.

So that is what we do it is a costly its expensive and it depend upon how much time its take the fill this the chambers the larger filling times emptying times that is what also matters how locking times we do it when the ships goes through these lock systems.

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Navigation Through Lock

- Locks admit water to fill the chamber from the upper pool and discharge to the lower pool to empty the lock
- The water surface in the lock chamber is brought to the same elevation as that of the upper pool by opening the filling valves
- The upper lock gates are then opened for the tow to move into the lock chamber.
- The upper lock gates and filling valves are then closed, and the emptying valves are opened to bring the water surface in the lock down to the level of the lower pool.
- The lower lock gates are then opened, and the tow moves out of the lock chamber into the lower pool



Navigation Through Lock

Source: Julien, P. (2018). River Engineering. In River Mechanics (pp. 379-426), Cambridge: Cambridge University Press. doi:10.1017/9781115107072.015

Now if you look at very interesting figures which is given through the P. Julien book on river engineering and the chapters which is a river mechanics book. So, if you look at that if you can try to understand these figures very interesting figures which is showing it how do we have arrangement for a lock system. There will be upper pool there will be the lower pool and you have the lock chambers.

So that is there and you have upper gate and the lower gate for to do this filling this is the filling valve. So, if you look at the water can come from upper pool can get into the from the lock floor it can get into this lock chambers then you will have the lower pools and you have the lift okay you have lower gate sill. Now if you see that a ship enters the ship enters to the pool that is time, we upper go gate is open and that is what it enters into that and that time it has a closed here.

And the ship enters to the chambers to the lower chambers. As soon as also the water is extract from this so that it can goes below down okay to the levels of the lower pool that is what its arrangements again the water goes out from these and the ships goes down. As it goes down it comes too closer to the same level of the lower pool. At that time, we close this gate, open this gate that is what initially close it still goes to that regions.

Then we open the gate and the ship pass through it then you have these things it is very mechanical way of arrangements. But you know it needs to design the all the structures like gate these filling valve arrangements with a filling chamber. All it depends upon how much time it takes to filling the chambers, emptying the chambers and based on that we designed these lock chambers upper pool and lower pool and also filling value and emptying valves.

So this these are very typical figures and quite interestingly its indicating for us the how a lock arrangement is there for the navigation properties that is what is showing that so that is what is here the same thing is telling it here that locks admits the water fill the chambers from the upper and discharge to the lower pool to empty the lock. Okay the overlock gates are the open for the two to move into the lock chambers the upper lock gates and filling valves are then closed.

The emptying valves are open to bring the water surface in the lock down to the level of the lower pool it is the same things what I discuss it and the lower lock gates are then open then

two moves out of the lock chambers into the lower pool. So, this is a very nice arrangement how do a ship goes from upper pool to lower pool through a navigational lock that is the very interesting things is there and we have a navigational lock arrangement typical navigational lock arrangement.

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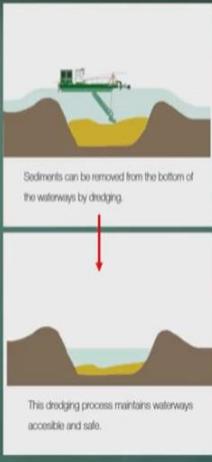


Now more details you can see its figures it is quite you can get it nowadays you have a google images are there you can see this the gate so and you can see this how the ship is passing through it and how these great openings are happening it all you are like you can understand it nowadays you all have a the google is a source of information nowadays you can get all sorts of information's how the lock can get and how the civil engineering structures are there for dams and the locks arrangements it is not that difficult.

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Dredging

- Dredging is a process of digging and removing of river bed or bank material.
- The purpose of doing this is to deepening or widening the navigation channel
- The equipment used in this process are generally of either mechanical or hydraulic type.
- Mechanical dredges remove bed material by a dipper or bucket
- Hydraulic dredges pick up the dredged material by means of suction pipes and pumps.



Now if you look it that way the next part is nowadays, we have been advocating that dredging a river okay dredging a pond what is that how much cost effective it is those things I am not going details but very introductory levels I will talk about the dredging towards the river management. So, if you look at that the so often, we have the sedimentations of the rivers that because of natural sedimentation river the river aggradations happens it the river becomes more shallower and shallower or we confine the river.

As we confine the river the more the sedimentation happens in aggradations happens so because of the aggradations happens it rework flow carrying capacity decreases. So, flow carrying capacity decreases so that is what it happens it because of embankments because of confining the rivers because having the levees we also confine the rivers because of that there will be the sedimentations.

Okay there will be the sedimentations so if you do not remove that sedimentations no doubt the carrying capacity of a river decreases with the time. So, decreases with that and that may be slowly it will have the dangers to the embankment where the flood protection structures what we have so the basic idea is that to dredge that materials means remove that digging and remove this river bed or widening the river.

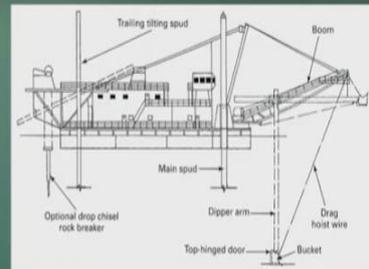
So, we can increase the width of the river or increase the depth of the rivers that is what you call its deepening or widening the navigation channels or the river channels okay. So that to have more carrying capacity so we basic idea is to increasing more carrying capacities of the rivers so that it so the equipment generally we use either the dredges are defined it is a mechanical type or the sorry dredges are generally two types one is mechanical type other is hydraulic types.

In mechanical dredges we have bed materials which is have a dipper or bucket to this thing i will show the figures for that the hydraulic dredges is a pick of the dredge materials by means of suction pipe and the pumps okay when you talk about hydraulic dredges that means it is just pump the bed materials okay and it have a suction pipe and it have the pumps and it has a disposal part. But in a case of mechanical grazers it is a dipper and it is having a bucket that is what it helps us to dig the materials and remove this material from the bed.

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Dipper Dredge

- These dredges are used to excavate **hard compacted material and blasted-rock** fragments.
- It can operate with very little guiding space and can be **accurately controlled** near the bridge like structures.



Dipper Dredge

(Source: Chu et al. 2009)

Now if you look at that dipper dredges if you look at this dredges part there is fixed it here and there is a top hinged buckets are there and dipper arms are there and drag hoist is there just it is dipping that things okay with the buckets we are just removing it we can just understand it way we dig a soils okay the dig soils okay that that the concept will follow it and this is what the river bed.

So, we can have a dipper or we can have buckets you can have a dig the soils and as you dig the soils then you can take it okay and to make it stable. So you can put this main spud so fix this dredges and take this bed materials from that okay that is what we do it basically excited hard compacted materials blasted rocks we can all do it nowadays technologies are there or the dredges having very high end dredges are there we can actually dredge the rivers with having this part.

It can operate very little guidance space and accurately control the near the bridge locations like the structures okay you can accurately dredge the critical locations like a bridge location you have a bridge pier you have a bridge abutment those are the critical structures we can use this type of structures to dredge the materials.

(Refer Slide Time: 23:14)

Bucket Dredge

- Bucket dredges use interchangeable buckets (clamshell, orange peel, dragline) for different operational purposes.
- An open bucket digs into 9 m³ of bed material, and then closes to be raised and emptied.

Bucket Dredge

(Source: PT Timah)

Now if you look at the bucket dredges so which is you can see it is a the bucket concept is there and that bucket chain is there the ladder is there and buckets are moving like this and there are the ladder of pivot and the dumping of these materials and you have this ladder hosting wire side wires and the head wires. So, if you look at that these are all mechanical components what I am talking about and as a river engine is, we try to know it how much of dredging can happen it because of these bucket dredges.

So basically, the bucket dredges use the interchangeable buckets okay that is what you can see the chain of the buckets are there and different operational propose you can have a different type of buckets okay. An open bucket can have a 9-meter cube or volume of the bed materials then close to the rest and emptied. So, because then it is closed then emptied so that is the process goes on. Okay, so it is very interesting so we have the dredges with a bucket which can have a dredge the bed materials as a bucket and try to store it here okay store it here.

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Hopper dredges

- These are the are self-propelled seagoing vessels used primarily for **maintenance dredging** and progressive deepening by successive passes.
- It collects the concentrated material in contact with the channel bottom through **suction pipes** and store it in hoppers.
- These dredges are emptied by opening of the bottom doors and dumping of the entire contents in a few seconds.

Hopper dredges

Source: Philip Spadaro, Intell Group.

So that is same way if you talk about the hopper dredges which is basically it is a self-propelled sea going vessels maintenance dredging's we are progressing deepening by successive passes okay. Most of the times what we do it readings a progressive deepening it is not like in a one day we do it okay that is the idea of a river engineering is not that do a deepening in one time okay you do a progressive deepening you can understand it how the river response is helping it.

Otherwise the dredging of the channels dredging of a of seafronts does not make the sense that is the reasons we do progressive deepening okay or we do a maintenance dredging. We do the dredging's just to maintaining the 9 feet depth or maintaining the draft requirements we do not go for high level of dredging things. So, it collects the connected materials in through the channel bottom through a suction pipe stored in the hoppers okay that is what is there.

This is the suction pipe and it also stores in the hoppers the dredges are emptied by opening the bottom doors dumping of this entire content of the few seconds okay. It takes the dredging materials and then dumps it and come back it that is what the hopper dredge okay hopper dredge is there and you can see that dredged part and taking these materials and filling the digged materials and dumped the dredging materials after where we have to dispose the dredging materials that is what we look at.

(Refer Slide Time: 26:32)

Dustpan dredges

- ① Suitable for dredging only non-cohesive material in waters without significant wave action.
- ② These drags are equipped with:
 - pressure water jets that loosen the bottom material and
 - a wide-flared and flat suction line intake for sediment removal
- ③ • It normally discharges into open water through a relatively short pipeline, up to 100 ft (30 m) long; a longer disposal line requires a booster pump.



Dustpan Dredge

Same way if you look at that dustpan dredges okay very interesting part you can see this dredger is just like a dustpan okay you can see in any house how you remove the dust okay; we use the dustpan the exactly same concept we have the dustpan dredge. The basic idea is that is a pressure water jet that loosens the bottom materials wide flare flat suction lines intake for sedimentary removals okay that is there.

Two components first components are having the pressure water jet which loses the bottom materials the bed materials. The second one is that it has a flat suction line intake okay that is what is that flat suction line intake okay so that is the take the sedimentary from that this normally discharge into the open water through a relatively short pipeline up to 30-meter-long or a longer dispenser line requires a boosting pump.

So, you can dump it within 30 meters or if you do not want to deposit do the disposals within the 30 meters you can have a booster pump okay. So, because it is a mix of the sediment and the waters you can use a booster pump to dispose at a far a distance or a location where you want to do the disposals. So if you look at this dustpan dredge is very interesting dredges part ok it is have a that it has a two component one is a pressure water jets that loosens the bottoms then we have a white flat flared and flat suction intake.

And you need to have a booster pump if you want to take the dredge materials beyond the 30 meters you can have the booster pumps okay. More mechanical designs and all the things we are not going here but these are things we can use it like a alluvial rivers where you have a

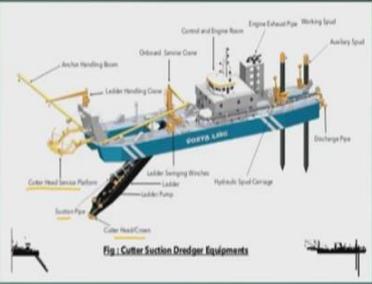
very loose sand and the silt materials or the clay materials which we can loosen with help of pressure water jets.

Then we can suction line take the sediment from that and you can dispose it because you have a booster pump on that these are things we can do it and which is necessary now when you talk about making national waterways of our country to navigable may be the dredger is can be used for some of the dredgers to do a maintenance dredging's.

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Cutterhead Dredge

- These are the most efficient and versatile, and thus the most widely used.
- It has a **rotating cutter** around the suction pipe intake and can dig and pump alluvial material including compacted clays and hardpans.
- It generally consists of a cutter head, baskets, ladder, suction line, A-frame, H-frame, pumps, gantry, spuds, and a pipeline up to 90 cm in diameter.



Cutterhead Dredge

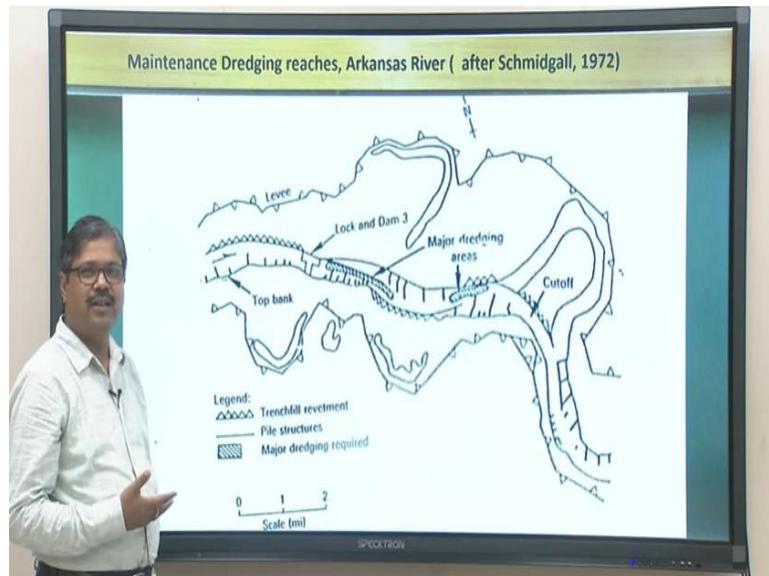
Let I show the figures how we have same way you have the cutter head dredge okay. So that is a suction pipe cutter head and you have the dredge so it is a cutting okay that is the reasons it is the most efficient and versatile. It is having a rotating cutter around the suction pipe intakes okay it is cutting the thing and it has dig and pump the alluvial materials including the compacted clay and the hardpans.

Okay so because it is having a cutting tools okay that means is a cutter head is there that is what into like a you have the very hardpan the clay materials are there that is what you want to remove it you can use these things because it has a rotating cutter okay around the suction pipe intakes and that is what it helps to do remove these compacted layers and the hardpan formation.

Generally, it have a cutter head baskets, ladder suction line. A-Frame, H-frame, Pumps, gantry, spuds, and a pipeline up to 90-centimetre diameters okay pipelines can have. So, if you look at this the basic structures what is there in these things. Nowadays these

technologies are there many of our country maintaining national waterways we have been also using maintenance dredges.

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Let I put it how a river like Arkansas rivers we have been using different strategies to make the river navigable it is not only solutions of the dredging the rivers. If you look at these rivers very interesting river which is 1972 way back in United States of America how they do the maintenance dredging's. How they have the river training works so if you look at the levee structures you can see that they are very far away there is a levee structures that is what is to protect the flood plain.

And they have given and half rivers space okay that is not the levee is just parallel to the rivers that is not the concept. You see that levee were constructed so far away river has one space like for exit pool these the positions they have given enough space that cut-off rivers which are morphologically cut-off and they put a cut-off thing are here. So, if you try to understand it the first, they have given enough space to the rivers confined the river through the left levee and the right level and that is what is designing it.

If you look at that and within that they try to look at all these geomorphological variability in terms of river cut-offs, meanders though the history of the rivers tell about the morphology of the river tells about what are the space of the rivers that is not a big issue we can use a series of satellite data's we can find out the river space and we can design what could be the space, what will be the layout for the levee.

Okay the second part is that if you look at there is a lock and dam structures here there are the series of the spur things are there see there are the series of the spur and there are series of the spur structures are there to confine the river or divert the river from that not only that there is a Trench fill revetment okay. So again, I am talking about is a Trench fill revetment there is a trench in that they have filled the revetment that is what is there the Trench fill revetment see this well designs the Trench fill revetments are there.

After doing so much things okay having the levee the spur the pile structures are all sort of spur structures still, they need to find out the depth they want to have a major dredge. So, this is the dredges materials okay so it is not only the dredging is a solution for that they construct they confine the rivers they know to have a stage wise confinements like the levee is a higher discharge confinement then within the inline structures are there which is confining it with having this protective like a Trench filled revetment.

We have all spur structures still it is not possible to get the 9 feet depth of water that is the reasons they maintain the dredging's this is the maintenance dredging that is a combinations of the all these river training works have been followed by the United States of America to maintain this river navigable it is not that easy that is what the point is to highlight it and that is what it is happening this how these structures are there how the they construct the cut-off they construct the levee they construct the all the river training work the Trench fill revetment and also where they need a major dredged work

So, the dredging or the minima at the last option is there to dredge the river and that is what they try to look it where they can do it where they cannot get the 9 feet depth of water for river navigations. That is my idea to convey you.

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Floodways

- Used to divert floodwaters into a topographic depression near the river (or into a lake or sea).
- Outlets are consists of spillways or control gates.
- Used in case of emergencies of high flood.
- Contains high portion of sediment load.

104

Hirakud Dam, Mahanadi

Red River Floodway

<https://www.gov.mb.ca/mit/wms/rfj/index.html>

Let us come to talk about the floodway's okay many of the times you know it that we have the discharge is much higher order when you talk about 10 year flood, 100 year flood and when you talk about the flood we should not talk about only the fixed discharge okay we can talk about peak discharge also we should talk about the flood volume how much of flood volume is coming how much volume of water is coming for that specific flood of 100 years 10 years or 5 years.

So, if you can try to understand it then naturally the river has one space it has one flood plain but with the times, we have enclosed the part of the flood plains. So, we have constructed the embankment we have constructed the series of the dam structures like for example of Hirakud dam projects okay which is one of it was one of the largest dam early 70s 50s 1950s and 60s and these time structures store as enough waters.

So that storage can reduce the flood peak and the flood volume the down streams of this step projects that is what is the strategy to us there but there are new studies coming it that you can have a float flood storage you can have a very low laying area you can store the waters and many of the time they call it as the floodway's or the flood divergence or the many of in in Germany they talk about flood folders.

So basically, the low laying areas which are designed to store the excess flood waters, return period of 10 years, 100 years or 2 year return period flood. So nearby the area the depression areas near the rivers where you can store and after it is that is the reasons you can have a series of the wetlands and you can design the wetlands such a way that they can store the

floodwaters during the 2 years or 10 years or 100 year floods that is what the idea is to commit and that is what it to design it the things.

So there should be outlet the spillway and we should have a control devices okay so to manage this we should have a control devices okay so you can have a control of gate arrangement and all synchronized you have to manage the floods so that you can store the waters in a low depression area, man made reservoirs are you can store the flood wave waters in a less vulnerable part of the things that is what we stretch it basically its emergencies for the high flood it contains high proportion of sediment load.

But you should know it when you do the flood managements there are also the huge sediment loads how do we manage that sediment loads and that is what as a river engineers we engineers we should look it we you can store the waters for the time being during the flood periods then you can release it but what happened to the sediments whether that one is going to deposit and as it deposits it has advantage for agriculture or not those cost benefit analysis needs to be done it to look at the flood storage during the extreme flood like 2 years, 10 years, 100 years floods and that is where we manage it to have a different type of storage mechanisms.

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Channel Conveyance:

- Lowering the flood levels by **increasing the discharge capacity** of the river channel
- This can be achieved by:
 - Reducing the **roughness** of the river bed
 - Enlarging the conveying **cross section**
 - Shortening the river channel and thus **steepening the channel slope**
 - Clearing the banks and the floodplain from **vegetation** and other obstacles
 - Eliminating **sandbars and islands**
 - Smoothing the banks with **revetments**

Schematic of River Corridor

River Longitudinal Profile

<https://www.slideshare.net/stevenheath148/river-profile-36231118>

Now if you look it this is what earlier concept of the river corridors okay it is what I discussed in the last class I am not going this but if you look it main channel you have a lot of things okay it is a river it is nowadays it is manmade canals okay it is a river which is supporting the ecology it is a supporting the flood plain is supporting these islands it is for

having the left bank right bank all you can see that flood plain for instance you can have all these ecologies life cycles are there.

But let me talk about that what we try to do it that basically we try to have a channel conveyance that means we need to know increase the flood carrying the river carrying discharge that is what is our idea. So, you need to increase the river carrying capacity how to do it you just look at the very simple is that $Q = A \text{ into } V$ $V = 1/n R \text{ to the power } 2/3 S_0^{1/2}$ okay I am using the uniform flow concepts this is the mannings equations.

See i can increase the discharge of the rivers either have to increase the flow area or increase the velocity. To increase the velocity i have to reduce the n value we should reduce the n value increase the S_0 value that is a very simple thing with two simple equations of manning equations and the flow rate is equal to area into discharge. If you want to increase the discharge in a river that means I either have to increase the flow area reduce the n value so that the velocity will be more or have to increase the bed slope that is the three concepts where we can use it to increase the carrying capacity of the river.

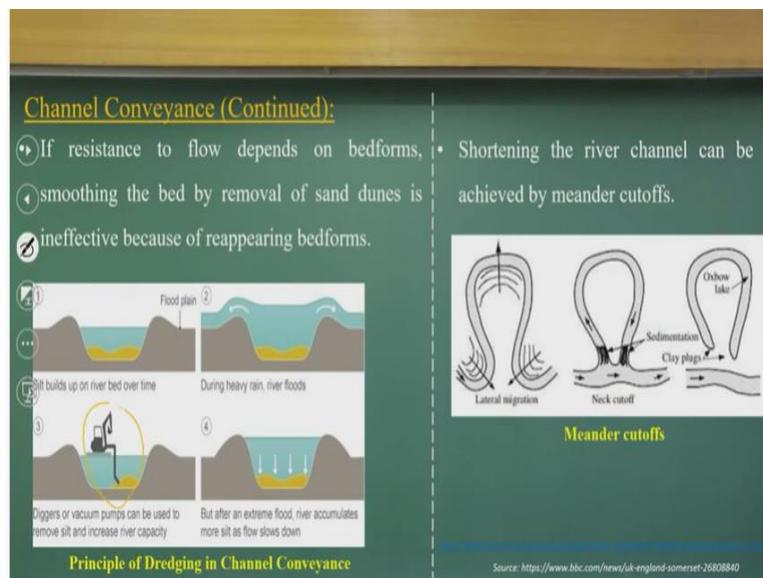
That is very simple things reduce the roughness of the bed materials that is what is we look it to reduce the n value we you want to try to remove this natural vegetations but you try to know it river has the ecology that is you try to look at how much of ecology aspect of the river we are losing it that should be quantified. We can increase the cross section river that is what is very easy that as you increase the cross section of river you can stiffening the increasing the channel slope we can do it okay or you can have a clearing the bed and flood plain from these vegetations that means you want to decrease the n value.

So all what you are talking about all with respect to these n values and this and remove the sandbar the islands that is what is you can increase the both you can do it increase the flow area as well as you are decreasing the mannings roughness capacitance that is what you do it smoothing the bed with revetment that means again you are talking about that make it the river bank resistance is as close becomes a 0 so n value you want to reduce it so by putting the bank materials with revetments.

But when you do these type of things you try to locate what is the ecological disturbance we are doing it that that that the part we always should look it because that is the part we have to

deviate it in terms of ecological benefit or ecological loss what we are doing it as we are increasing the carrying capacity of rivers that is very basic things what you can understand it.

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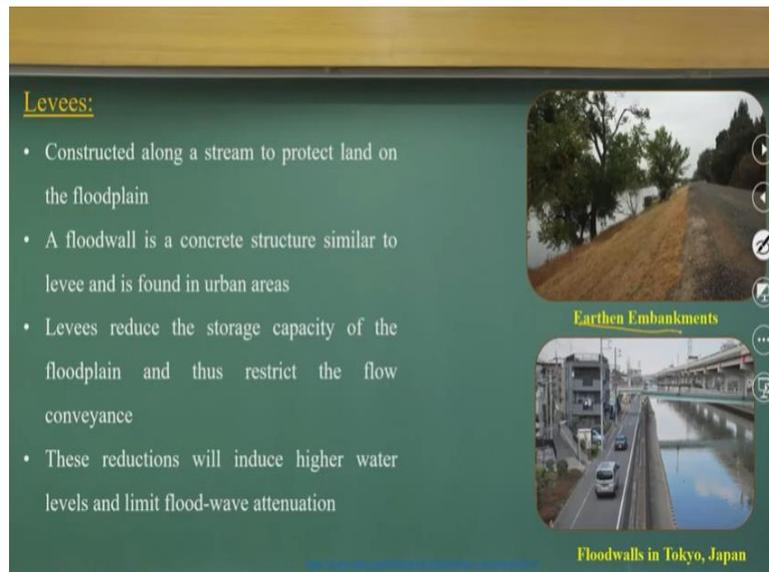
Now if you look at that or you can have dredging the channels we already discussed it that we can have the dredge the channels as you see in these figures we have the dredging the channels and these two previous are showing it how the sedimentations happens it okay how the sedimentations happens during the flood. So there are the lot of sediments goes it and that can have a deposition of the sediments at this point and you have a that is what is the point we have a natural levee you have a natural levee formations because of sedimentations of this okay and as this flood after the stream flood again the silting of happens it this is cyclic process happening.

Please try to understand it the river have a episodic events like 10 years 20 years events it does episodic depositions and the erosions that is you try to understand it when you talk about river depositions and all so that is the idea you have to look it and as already I discussed about the cut-off channels river meanders and having the river cut-off channels.

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Levees:

- Constructed along a stream to protect land on the floodplain
- A floodwall is a concrete structure similar to levee and is found in urban areas
- Levees reduce the storage capacity of the floodplain and thus restrict the flow conveyance
- These reductions will induce higher water levels and limit flood-wave attenuation



Earthen Embankments

Floodwalls in Tokyo, Japan

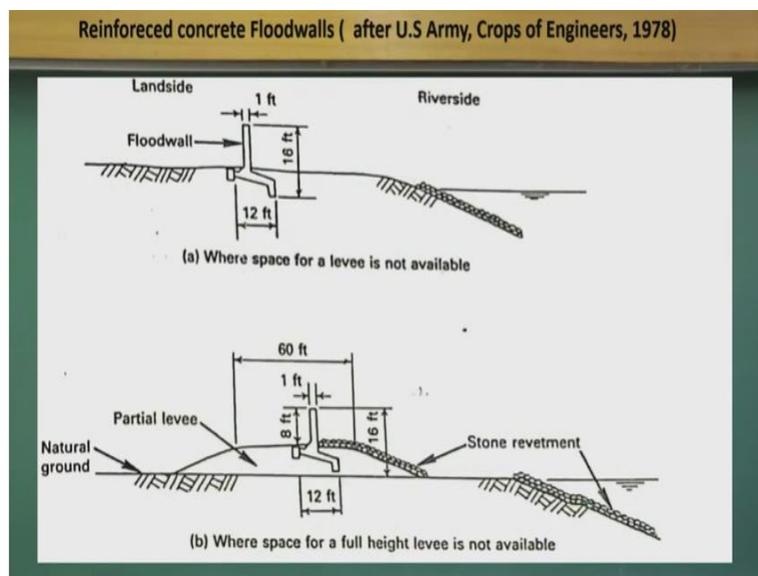
Now if you look at that when you have embankments you people have known the urban embankments or the levee many parallel to our rivers systems if you talk about in coastal part of peninsular regions you talk about Ganges river the we talk about Damodar rivers we have a series of embankments which we many of the times we do not feel that the embankment because we have been dual proposed embankment the embankment come roads or embankment come the highways.

So, for examples if you look at the Ganga rivers where the two national where highways are confining it the ganga rivers from starting from Bhagalpur to Patna. So, this what we consider is a national highway but it is the embankment of the ganga rivers the confining in the left bank and the right banks with the different national highways. So, if you look at that way we have the structures in our country there are lot of embankments are there and you have a how to make urban embankment how to design the embankment levels and what type of risks we can take it as embankments which partly discuss in hydrology courses we are not talking about here.

So but nowadays people talk about floodwalls okay you can see the Tokyo cities okay there are the structures okay the similar way can look at this the left bank and right bank of the Sabarmati rivers with a riverfront developments you can see these are the roads, these are the floodwall which is not the roads and if you look at the structures and you can try to understand it what is the height of this floodwall okay it is a flood wall which is a concrete structure similar to the levee and that is what is mostly founded in urban areas and its levee reduces storage capacity of the river and the flood plain restrict the flow in the conveyance.

Reduction will be higher water levels limited flood wave attenuation that is what you can understand it as we put the floodwall what is going to happen it will reduce the width of the rivers as we reduce the width of the river restrict at the conveyance that will induce the higher water levels and the higher the water levels and the flood wave attenuations behaviour will change it that is either river engineering we try to know it what will be the effectiveness or performance when you design a floodwalls okay. That is, we do a hydraulic design of the flood wave walls mostly we follow in urban areas where we can afford to have the flood walls okay.

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Now if you look at that is the flood walls which is given 1978 by U.S. Army, Corps of the engineers there is a reinforced concrete flood walls see if you look it there is a riverside this is the landside you have the floodwalls which is a 16 feet height okay 16 feet okay you can understand it okay these are concrete structures and it have either the shape like this to stability of this part and create the floodwall like these structures okay.

The same way they have the where this space of the flow highlight is not available they can have a the revetment then there is area which can be used during the non-flood periods then you can have a revetment again the same 16 feet, 8 feet and 1 feet the flood walls and then you will have a partially levee and you have natural grounds. So if you look at that the way back we had a concept of the flood walls okay.

If you look at me we have a major cities nowadays we have think about the flood wave concepts which it is it expensive but it is a long durations and we can protect wells because we have the flood wall having these stone revetment having a 16 feet flood wall and that is what is designing the flood wall such a way that it can sustain the water pressures and you can have a protect the natural ground or the landside.

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Specifications of Levee placement:

- Determined by the stage of the design flood along with an allowance for freeboard
- Anticipated aggradation of the riverbed
- Must prevent breaching as a result of seepage, piping etc.
- Include tides and wind waves effects in coastal areas
- For meandering rivers placed outside meandering belt

Coastal Area Levee

Meandering belt

Now if you look at the basically if you look at that levee designs I am not going more details because that is what is in generally discussed in geotechnical engineering how to design an embankment it is like you have to have a seepage control devices you should have the should not be over topping of these embankments you should have a proper free board for that all the things are there when you talk about embankment, designing of embankment that is what is there in part of geotechnical and this.

So basically you should talk about the embankment breaching because of seepage and the piping or over toppings and you when you have a talk about coastal areas you can talk about the tides and this and the stage we define it the design flood along with the allowance for the free boards that is what you did and you should anticipate it whenever you have these embankments river is going to stage of aggradations that deposition sedimentations will be there depositions will happen then aggradations of river will happen that is anticipated that is the way the strategically.

You have to look it that how to confine the rivers as well as should not have a or should have a minimum aggradation or you have to look it how to manage this aggradation because of embankment based confining the rivers space that is the idea you should think it.

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And if you look at the floodwalls okay its very nice structures okay this is the river side the land side. So you can see the structures and you can see this revetment you can see this road inside the rivers which can be used during the non flood periods and you can make it a river is a riverfront development or you can make it river is a place where you can really enjoy our life.

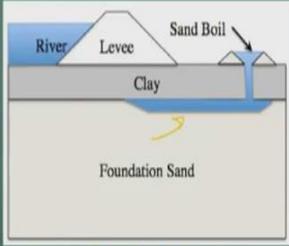
We have all these facilities with a floodwall riverside space and we have a the protections work under this that is the way it is very manage with that and this is okay naturals you know it that crown width should have this the width of for the traffic whether you want to design for one way road traffic or two-way road traffic you can use the width for that but this is what river conditions that.

So we can make it river is beautiful when you make a proper river front development that is the things wanting to convey it so we can have a protect the river as well as we can make this place will be a one of recreational facility of this river with as you have seen these photographs we can make a river front development as river is friend to us it is not reversely.

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Seepage prevention:

- Underground seepage in pervious foundations beneath causes:
 - The buildup of excessive **hydrostatic pressure** beneath the impervious top layer
 - **Sand boils or piping** beneath the levee itself unless seepage control measures are provided
- Principal control measures include
 - Riverside impervious blankets
 - Landside seepage berms
 - Pervious toe trenches
 - Pressure-relief wells
 - Cutoff trenches
 - Sheet piling



The diagram illustrates the cross-section of a levee. On the left, a river is shown. A levee structure sits on top of a clay layer. Below the clay is foundation sand. A sand boil is shown as a vertical column of sand rising from the foundation sand through the clay layer. A yellow arrow indicates the direction of seepage from the river, through the clay, and into the foundation sand, eventually emerging as a sand boil. The text 'Seepage in Levee' is written below the diagram.

Source: Incorporating Uncertainty into Backward Erosion Piping Risk Assessments

So that is now if you look it is very interesting part as we you look at seepage in the levee i am not going more details you can talk about you just can refer to any geotechnical books how the levee should design it to reduce as much as seepages problems. But you can have the seepage effect like there for example here it is a sand boiling is happening it and you have to have a protect two trenches pressure relief walls, cut-off trenches, sheet piling impervious blanket landslide, seepage berms all the things are there in geo technical you can design to reduce these sand boils or the failure of embark levee to have a protections for the seepage. That is, we can you look at more details here and I am not going much detail how to make these things.

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Control of floods and groundwater table (Continued):

- The efficiency of the drainage system can be improved by the construction of drains, ditches, and canals
- Aggradation or degradation of the riverbed and the floodplain affects the drainage
- Landside local surface drainage through the levees is usually possible with
 - **Levees along the tributary channels**
 - **Culverts with flood gates**
 - **Pumping plants**
- For major tributaries, levees are constructed **along the tributaries**, tying to the main channel levee and extending upstream to the limits of **backwater influence**

If you look about control of the floods at the tributary level or the main rivers it is a composition of different strategies to be followed it is not a one-way thing like for examples

you can talk about the levee structures, you can have a culvert and with the flood gates to control it. So, we can have a control flow mechanism with a culvert and the gates you can have some locations where the gravity flow cannot occur during the extreme flood event the flow congestions happens it, those reasons, we can have a pumping plant.

So if you look at that there is a series of flow control devices the with a culvert and flood gates, embankment pumping plants it is not a one way solutions and the these are the strategies nowadays has been following it the urban areas where we know it there are lot of flooding's happens it we have the culvert with the gates and the pumping arrangements and we prepare the drainage like this.

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Control of floods and groundwater table (Continued):

- Culverts can be equipped with control devices or flap gates
- These control devices have automated open/close mechanism to permit inflow/outflow when the water level on the landside is higher/lower than on the riverside of the levee
- Pumping stations are usually required for land drainage when the main river is at high stage



The image contains two photographs. The left photograph shows a large industrial water pump structure situated in a river, with a person standing on a platform nearby. The right photograph shows a concrete river culvert structure with a gate, situated in a river. Below each photograph is a caption: 'Water Pump in River' and 'River Culvert'.

So the basic idea is that and to say it is urban flooding's and all the things we try to look it this way if you look at this you can have water pumping or also we can have a river culvert with a gate arrangements this culverts can be design it depending on the extreme flood scenario what would be the scenario and these are things nowadays available in a HECRAS river model with different structures inline structure the side structures.

All these combinations you can look it what could be the level of this the gate structure what could be the pumping at what time we should take it all the scenario we can generate it and can be used as a design for the gate arrangements of or the culvert arrangement pumping capacity all we can do nowadays with a tool of HECRAS river models with having a different structure combinations of inline structures and the site structure we can implement it and you can look it.

During the extreme flood events during these normal flood events how do you manage all these infrastructures like pumping infrastructures the controlling pipe structures and those things are possible if you have a properly design these drainage structures also the control structures that you have to have an idea and nowadays we have all the tools are available but we have the data you have to try to look at that how we can make it a very effective flood management with a combinations of all flood control flood storage and the pumping facilities that what can be simultaneously used for effectiveness of the floods in a river or in urban area.

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River closure

- Required for construction of dam on river.

Types

- Dam construction beside the river
- Complete closure and flow diversion
- Partial closure and flow contraction

Feni River Dam Closure, India

<https://www.semanticscholar.org/paper/The-Feni-river-closure-dam-reviewed-Stroeve/87970ee236b55fb40b8697cd7738b5362b14e1e>

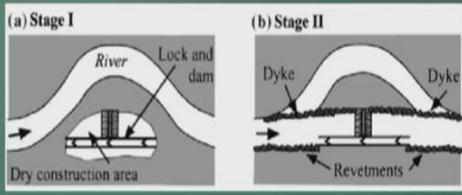
The slide features a diagram of the Feni River Dam Closure in India. The diagram shows a cross-section of the river with a dam structure. Key components labeled include 'SONARPUR STATION', 'AZAMPUR STATION', '27M REGULATOR', and 'FENI RIVER CLOSURE DAM'. A scale bar indicates 0, 1, 2, 4 km. A north arrow is also present. The slide includes navigation icons on the right side.

Some are times we go for the river dam closures that is very simple things we close the rivers like a Feni rivers how do we close it to have a structures if you can look it construction beside the rivers completely closures flow diversions partial closures flow contractions we go step wise stage wise you go it to close the rivers okay construct the dam. So, you first construct the dam beside the rivers then you complete the closures and flow divert it and partial closure and flow contractions. All we do it so it is a stage wise dam construction what we do it things.

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Dam construction beside the river

- A dry construction site can be found next to the river.
- River is then diverted on the structure after construction.
- Possible for only low structures.



(a) Stage I (b) Stage II

Dam construction beside the river

Source: River Mechanics: P.Y Julien

And here I am showing it very simple thing the dam constructions beside a river. So you can see that the it started dry constructions area where you in a dry area we are constructing the lake we are constructing the dam and the later on we put the dykes and the divert the rivers and that is what these are cut-off channels so we make a in a dry area the lock arrangements the dam and later on we just put the revetment of the rivers and close this band and make it this channel.

So that is the reasons we go for step by steps the constructions beside the rivers what we get it and it all depends upon what geology is there what is the morphology of the rivers what type of stepwise constructions we should do it.

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Partial closure and flow contraction (cofferdams)

- In large river where entire flow can not be diverted
- Important considerations:
 - Elevation of the second or the third largest historical flood
 - Backwater effects
 - Property damage
 - Considerable scour on alluvial streams



Flow contraction with cofferdams

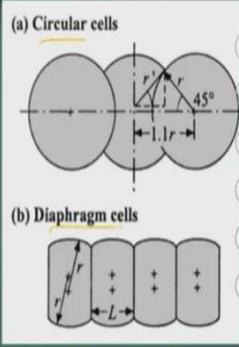
<https://www.civileblog.com/wp-content/uploads/2015/09/coffer-dam.jpg>

Next if you look at that partially closure we do it with a cofferdams and that what if the partial clue of our closures of the flow contractions we do it with a cofferdams if you look at the structures of the cofferdams and filling these materials that is what is showing that how we can design it the back water report properties damage and the scour on alluvial streams. So, we can do a flow contraction with the cofferdams these are temporary structures we construct it and you can see that the temporary constructions part.

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Cellular cofferdams are designed with

- **Circular cells**
 - Cells are stable.
 - Cell width is equal to the cell height
 - Require less steel for high structures
 - Failure is local – damage limited to one cell
- **Diaphragm cells**
 - Individual cells are unstable.
 - Cell width is equal to the cell height
 - Require less steel for low cofferdams.
 - Failure may extend to adjacent cell



Cofferdams Cell

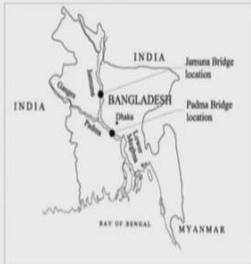
Source: River Mechanics: P.Y Julien

Which is having the cellular cells like the things or diaphragm cells that is what you provide it and it has a one advantage and disadvantage to make a cofferdam cells that is what you call then you fill the materials that is what we do it.

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**Performance review of Jamuna Bridge River Training Works
1997-2009**

- The design scour depths were exceeded substantially, and scour holes of almost 45 m below average flood levels
- Locally substantial shifting of the rock of the slope protection is observed, leaving the underlying geotextile exposed.
- Regular inspection and maintenance as specified is needed to keep the River Training Works in optimal condition.



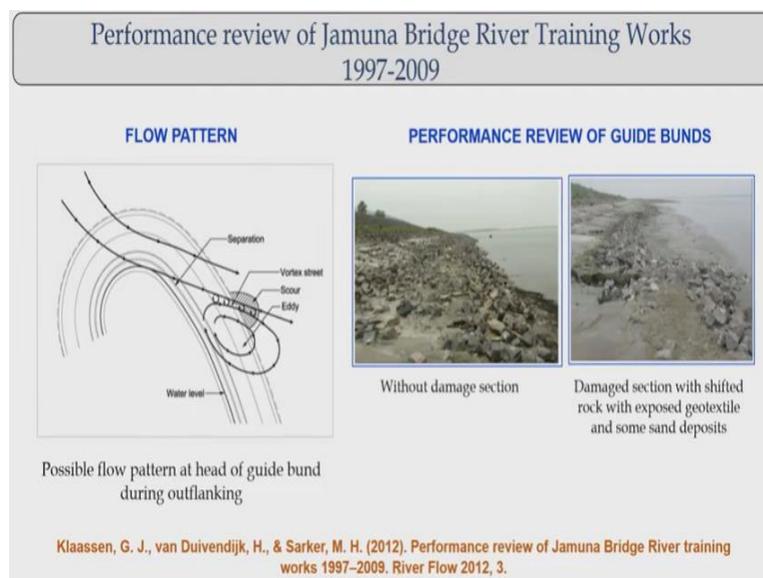
Location of Jamuna Bridge and of proposed Padma Bridge in Bangladesh

Klaassen, G. J., van Duivendijk, H., & Sarker, M. H. (2012). Performance review of Jamuna Bridge River training works 1997–2009. River Flow 2012, 3.

Let me I close this lectures with a showing this the performance of river Jamuna bridge river training works if you can look it Jamuna bridge locations which is one of the largest bridge on the Brahmaputra rivers in Bangladesh there was a lot of problems with that it had the scour holes almost 45 meters below the average flood levels is one of the highest scour holes you can see in that and it has make it because of shifting of the river.

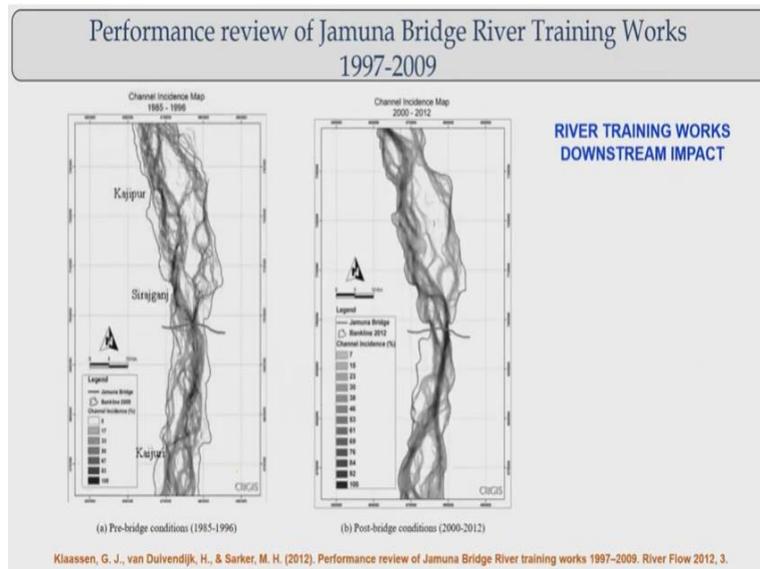
Considerably it is very difficult to have a protect the slopes and that is what they are doing with the geotechnical and they try to make it river this bridge constructions and they try to look it what the morphology affect is there that is what is the papers in river flow 2012.

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If you look at this part you can see that one of the cases the river has changed the course and it has changes the flow separations vortex street, scour rule and eddy's because of that there is damage sections you can see that the guide bund the damage is there and that is what it happens the flow behaviours during these a particular floods where is the guide bund out flanking happened and possible the flow patterns very interesting if you look with next figures.

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The looking this figure you can understand it that this is the map of channel incidence map of 1985 to 1996 it is showing it the same location see that cut the points is a more the chance to rivers there this is before constructions this is the after construction of this bridge and you can see how the morphology of the rivers of the downstream has changed it, it also changing the up streams.

So you just look at that within the 20 years by just a constructing a bridge with a confining the flow depth with a guide bund and all there are extreme conditions are there are the chance of the failure of guide bund but the long terms the morphology of the rivers which is much braided here is the braiding patterns has reduced here in downstream as well as it is affecting the bridging patterns in the up streams the river has a response and that what is makes us try to understand it.

How it happens? It takes longer time like if you say that is almost 10 to 12 years it is a responding the river because of this confinement in terms of reducing this channel morphology. So, with this let me complete its today lectures.

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The study of mathematics, like the Nile, begins in minuteness but ends in magnificence
-Charles Caleb Cotton

And with thanking my student groups but let have the quote the study of the mathematics like the Nile river begins in minuteness in the significance that is what hold good for river engineering. Thank you all for this lecture.