Groundwater Hydrology and Management
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Lecture 32
Direct Artificial groundwater methods

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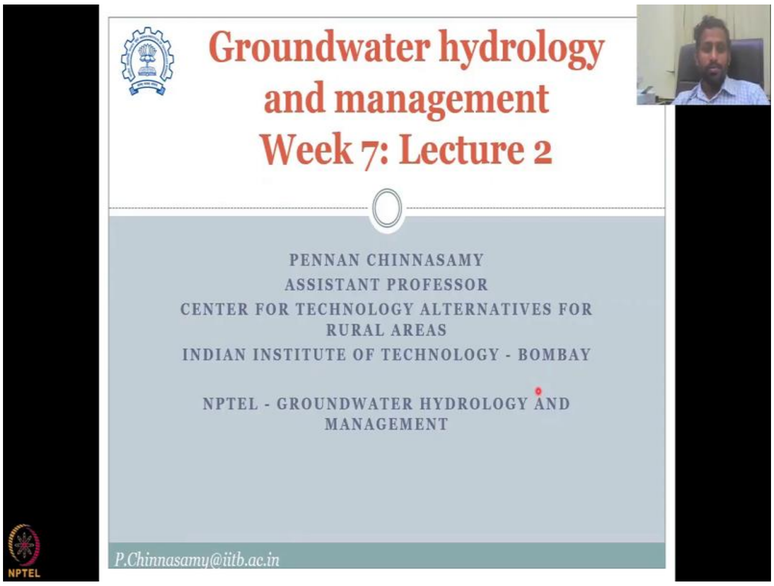

Hello, everyone. Welcome to Groundwater Hydrology. This is Week 7, Lecture 2. In this week lecture series, we are looking at the recommendations from the manual shared by Central Groundwater Board on what type of artificial recharge networks we could make and where it can be applied.

In the last lecture, we looked at the multiple different types, indirect, direct methods, combination methods, and then we looked at different types within the major subheadings. In this lecture, today's lecture, we will get into more details of every particular type, and how it is used in the real world, what are the issues, pros and cons.

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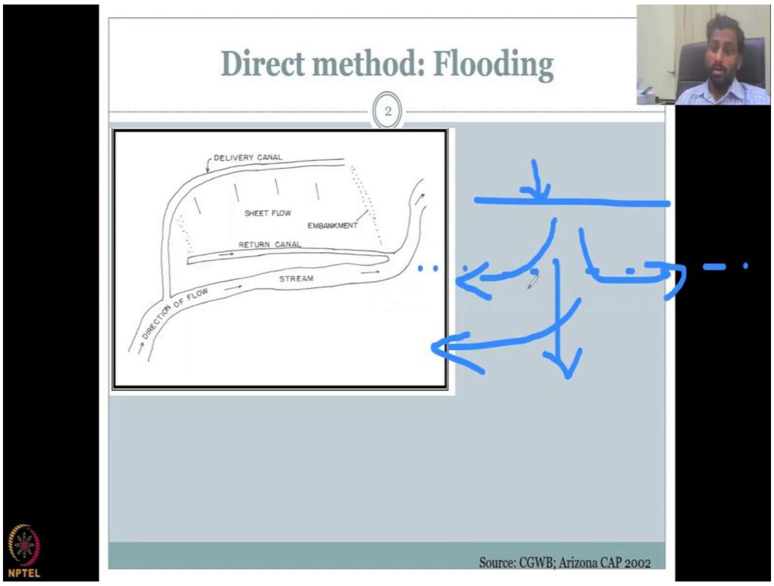

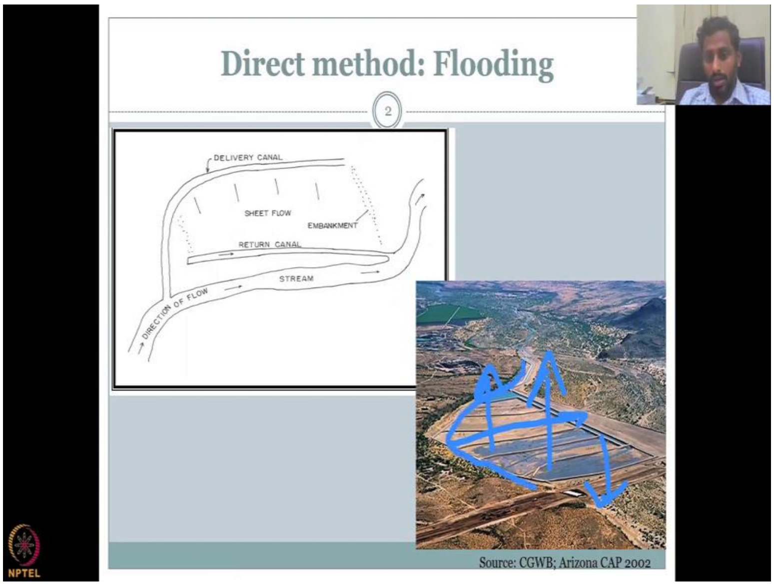

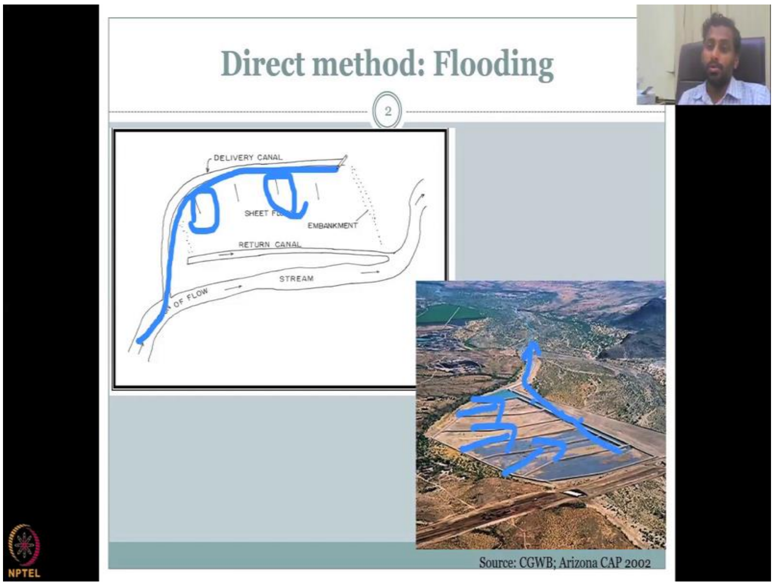

Let us get into this, today's class. The direct method. So, as the name suggest, you are directly applying water and making increased contact between the water and the land thereby letting the water go into the land as surface, subsurface connection, go in as infiltration, percolation, into the groundwater. This is the major aim of this method. Rainfall is kind of a direct method, but it does not give enough time. So the whole point is increasing that time.

Flooding. So what does flooding mean? Flooding means ponding of water on top of the surface. And floodings are different of levels. You can have flooding to your ankle, which is called a massive flood in Singapore because cars are very expensive. And if water goes into the car, people can sue you. Whereas, in countries like, developing countries like Bangladesh and stuff, you still have water still your hip and knees, and they call it as a flood. So you see the flood is very qualitative.

What you call flood is qualitative. In this example for groundwater recharge, flooding is a couple of centimeters of water thickness on top of the land, because that is how much water you can afford to put on land. You cannot fill the land till like, 1 meter, like your hip level. Then it is not going to be helpful, it will erode the material off. You need a very slight amount of water, 1 to 2 centimeters thickness, and always there.

Think about a agricultural field where you have flood irrigation, where which means just normal irrigation. You apply water to the field, it slowly goes in. Here, what you are doing is, you are putting the water in and no transpiration happens. There is no plants and other things, water would go in and recharge, rather than plant taking the water and transpire.

So here is how water comes. It comes through a channel, it can be a stream, it can be a river, it can be a canal from your dams, and then you make a sub, small diversion and that diversion envelopes a land. It covers a piece of land, and that is your recharge basin or where the recharge is going to happen.

So water flows through the delivery canal. And you have sheet flow. As I said, flood irrigation or sheet flow is where you release water and it forms a sheet thickness on top of the land. We have the land, and a sheet of water is there which actually infiltrates, recharges the ground. So water moves and then flows as sheet until your return canal, because you do not want to waste the water.

You do not want to just pond the water without nothing. You want the water to be flowing slowly on top of the land, and once it hits a particular point in the land, or covered a maximum distance, then you can say you can return the water back to the stream or river. So only some water is going in. Think about if you start ponding the water, then what is evaporated, its lost. You do not want that to happen, you want the water to move.

And while it moves, it actually recharges, it keeps on moving. Think about a river. Water is flowing, It is constantly flowing, which means there is constant movement of water. However, there is recharge, because you are maintaining a thickness of water above the ground. If you shut down the water, water will move, and then there is no recharge.

Here, you are in motion, but at any time snap, you just click a time snap, there is thickness of water, and that water recharges in the ground. Same thing happens here. You have water going in, it goes as a sheet, the sheet recharges, and whatever water does not contribute to the recharge, goes back to the river. So you are reducing the evaporation.

If this is not there, if the return canal is not there, then it is like a big swimming pool or a pond or even a recharge pond, we will see that example also, where water just evaporates. Yes, some recharge enters, but maximum water evaporates. So, the net water is lost. However, in systems where losses are okay, you still need recharge to happen. You have to give that water.

So you have these canal deliveries, and then water comes in as sheet flow and recharges this area. Under the recharge, it can move different ways. As you know, this is the land, when water comes in, it can recharge like this. We have seen a lot of diagrams of how the groundwater recharges. It does not just go one dimension, it can go lateral also. So at the end of the day, you establish a water level, water table, an imaginary line of thickness of aquifers full of saturated.

Let us take an example. This is in the Arizona region. And you can see like how a big land has been carved out for recharge. And as I said it is, nothing is growing on the land. You see there is nothing growing on the land, it is only for recharge. And it is placed at a good location where around it, there is a lot of agricultural fields which can use the groundwater. So if you can recharge here, these lands would get all groundwater and you can pump here.

You can see a big agricultural area right downstream of the canal. So water is coming in and then it goes through this canal, and it gets recharged, it goes back to the main supply channel and goes out. And what they have done is, they have kept this area so that water can grow as a feet, as a good sheet on top, and that sheet recharges the groundwater up to a particular level, and then goes off.

If you stop this connection between, back connection to the channel, as I said, then there is water loss from here, this evaporation. All you want is more groundwater recharge. However, evaporation is also happening. So this is how water moves. So, assuming water is moving from this way, it goes this way.

And you have a lot of this part, the delivery channel and then lot of inlets for water to go this way. Water was going that way. And recharges. It recharges as much and then goes to this point, the main return canal, and then goes back down. So this is how water can be diverted off the main channel. So look at it. Water is diverted off the main channel, led into a ground recharge and then help in improving the groundwater status.

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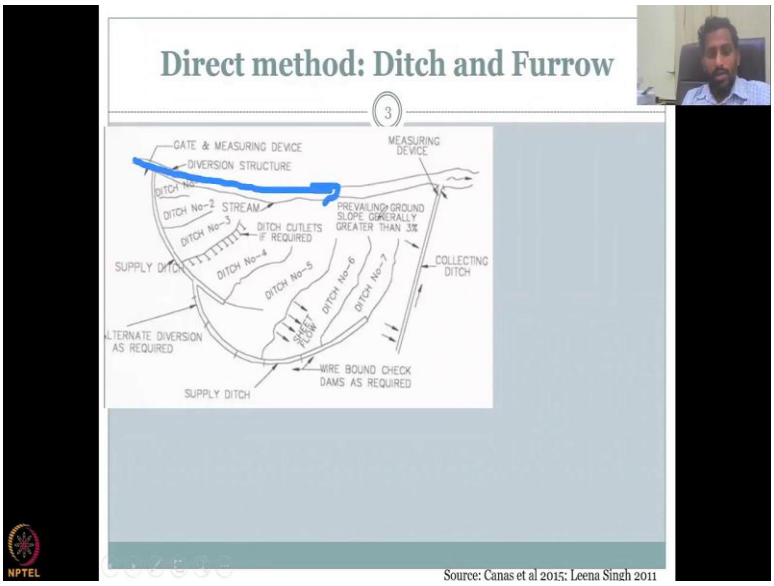

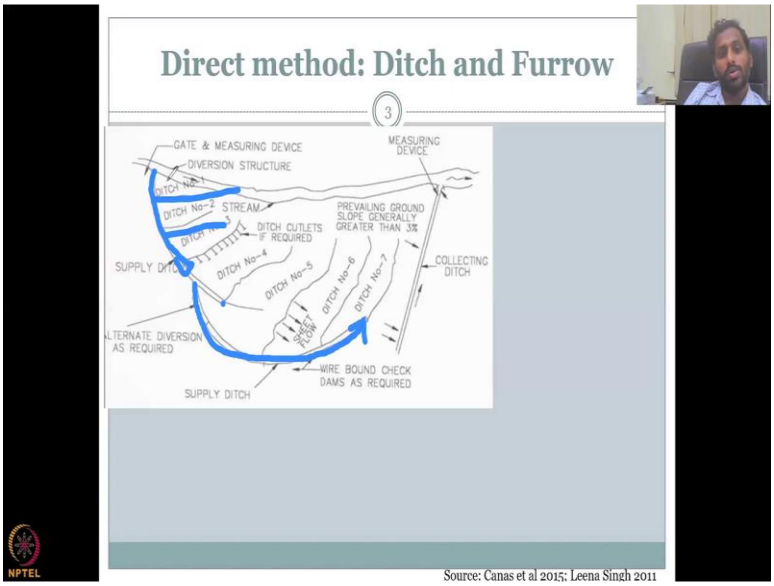

Direct method: Ditch and Furrow

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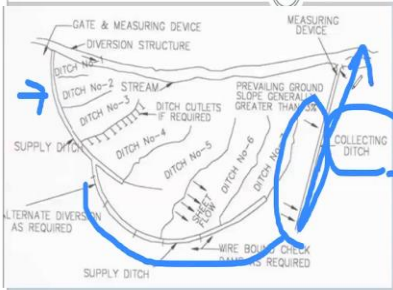

Source: Canas et al 2015; Leena Singh 2011

Direct method: Ditch and Furrow

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Let us look at another direct method, direct recharge method. It is a very famous method called Ditch and Furrow. Here, the name, as the name says ditch, which is a big, embedded dug part of the land, you create a ditch and inside the ditch there are multiple connections to farrows or furrows, and these furrows actually enhance groundwater recharge. Let us look at how this works. This is how water is flowing.

So just keeping that in mind. I will remove this. The gate and machine device is here to just check how water is coming, how much water is going in. Because all those, almost all these methods, it is good to have a monitoring network, so that tomorrow someone can ask, you are putting all this water in. How much is the recharge? I put so much land, I have given you so much land, what is the benefit? For that, it is good to have monitoring.

It is expensive, but if you do not have money for that, it is okay, you do not have to do, gate and a measuring device. So gate is mostly important to divert the water. So, very minimalistic construction is there. No cements, nothing. It is just a diversion of the water through a gate or a small channel. So water is coming here, it is called a supply ditch, the major channel that comes. And after that, there is multiple branched ditches which come from the main ditch.

You see, here. And then it also has, deeper ditches are called furrows. So you have all these ditches that are coming, and then alternate diversion as required. So sometimes water can just stop here, and maybe that is all the land is in that particular area to recharge. So you take another land here and then do it.

So you have three ditches in this diagram at least, the major ditch which is supplying the water, so this is a major ditch from the major channel, it takes water and then from the major ditch, there are branched ditches or furrows that take the water and recharge. Then there is an alternate ditch just to extend the ditch, and then there is a collecting ditch. All this water which is not entering the furrows, which is not entering into the groundwater, can go back to the collecting ditch. It just gets collected and goes back to the major river.

So, here is where you could see that how it differs from the flood, irrigation flood recharge type is, this deals on ditches, that is the only major difference. And the water is brought back as a canal. Here, the canal is not bringing back from the initial water, it is bringing back only from the surface runoff and the groundwater discharge that comes in.

Understand that these collecting ditches can also take the groundwater, unless you line it inside. So if you do not line this path, for example, if you do not line this ditch, then what happens is there is a big ditch and groundwater can recharge and then go under and come. So all this surface water can come and also the groundwater can also recharge like this, and then come out to the mainstream as baseflow.

So you need to be careful on making these. However, it is a very successful method. And then there is some slope analytics that you can look at, and other things you can consider. It may not be only ditches, it can also be sheet flow. So think about the previous example, water can be taken and after it takes water, it can be applied on the top as a flood recharge method, which is called sheet.

So moving on, you are taking water, putting into ditches and then collecting the remaining water. Each ditch would recharge by itself, and then the groundwater gets healthy. What is one thing you need to note that almost all these are next to the river and stream, which means there is a potential of this groundwater to go back to the river. We have already looked at these conditions. When the water level is high in the groundwater, it can go into the stream or river if the stream or river are in the lower groundwater potential.

Let us take an example here, from Colombia. So you could see that the head ditch, this is the head ditch which is bringing the water, and there are multiple small ditches along the slope. So here the slope is mentioned. So what is pushing the water from one point to the other is the slope, and that is what is bringing the stream also there. If it is a flat land, why would water move here? It will not, it just stays there.

So there has to be a gradient. And that gradient is established by a topographic elevation difference. And that is what is here, you can see, a slope, a slope and a slope 3 percent. If it is too much, then water just runs away, it does not have, give time for recharge. So you can look here that there are some water which is flowing and then it goes into these ditches inside the steep slope. So the major ditch, and then it goes into the small zigzag furrows.

And these zigzag furrows are making the water pass through this. Because of the elevation, water will definitely come, but if it is a straight line, water would just go, like very fast. However, if it is like a zigzag, then you are making water slow down in your path. And that slowing down gives more time for recharge, and groundwater recharge would happen.

So in other words, just not making a line but making it zigzag in the recharge area would make water flow more time and then recharge, compared to this, which is very straight. That is why you see in some areas, they would make the river meander so that it recharges into the groundwater. I am using these images from other countries because these have been published.

You can see the publication down. And it is hard to get these images for NPTEL course without the citation. So for a citations I am giving examples from foreign countries, however, this works well in locations where you have a sloping land and also, a clear land. There is no vegetation on these lands. Just look at it. There is no vegetation.

So compared to the neighboring land, here is also a slope, but there is vegetation. It could be land use cover by forest or it can be also an agricultural field. However, here, there is nothing. So this is the other important aspect, which I spoke about in the previous lecture of suitability, limiting factors, land use land cover, availability of land. Do you have so much land to give for a recharge? But in most of these areas, if you could see, the land is available. Only thing is, water is not available.

So if you have 10 acres, you should be willing to sacrifice 1 acre to recharge for the 9 acres, the 10 percent, is a rough estimate I am saying, but that is how normally it is, at least you have to recharge. In some locations, you have to recharge 90 percent of the land for 1 percent or 10 percent of the agricultural area. And that depends also on you. If you want to do it, if you have the money and luxury to do it, you can do it.

See think about areas like deserted area, semi-arid areas. You have so much land, but you cannot just go everywhere. You have to concentrate your water, put it in one small area to recharge, and then you use it as a groundwater resource for a pond or a lake etc.

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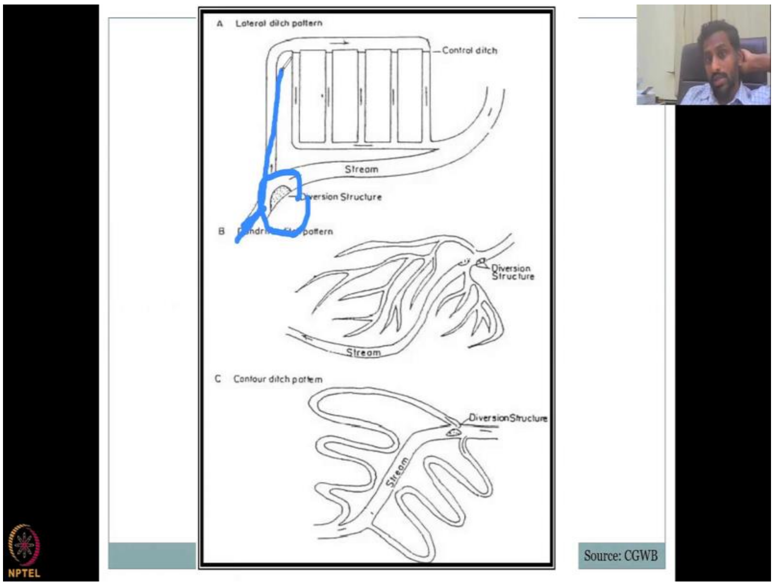
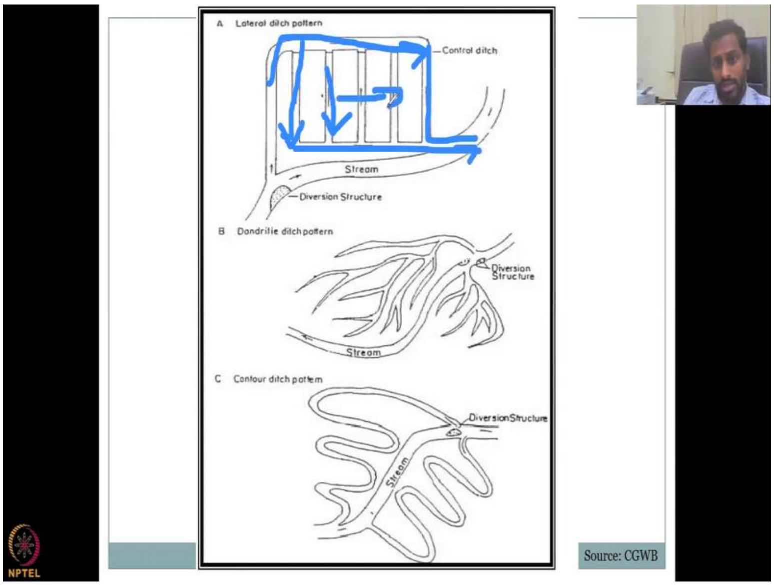
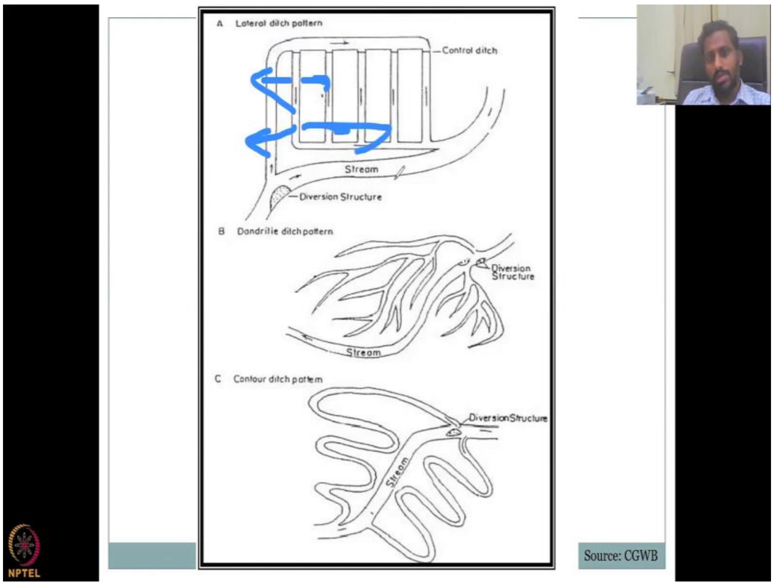
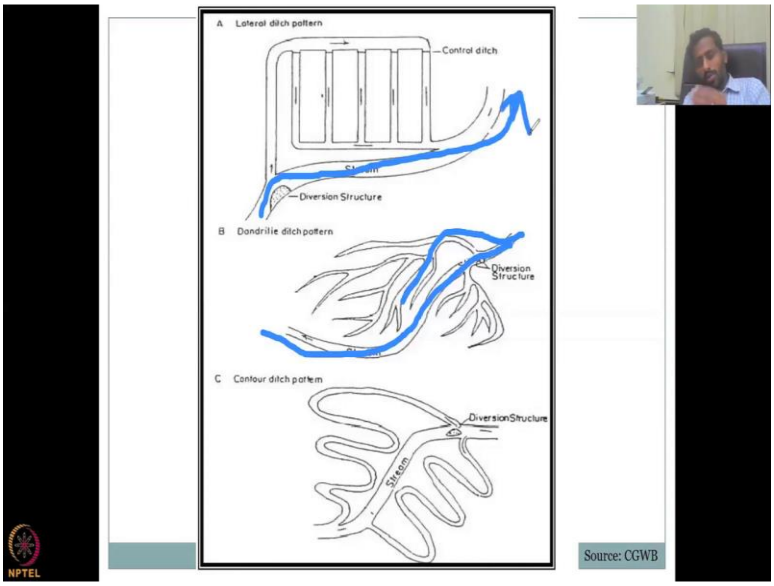





A Lateral ditch pattern
Control ditch
Stream
Diversion Structure
B Dendritic ditch pattern
Diversion Structure
Stream
C Contour ditch pattern
Diversion Structure
Stream
Source: CGWB
NPTEL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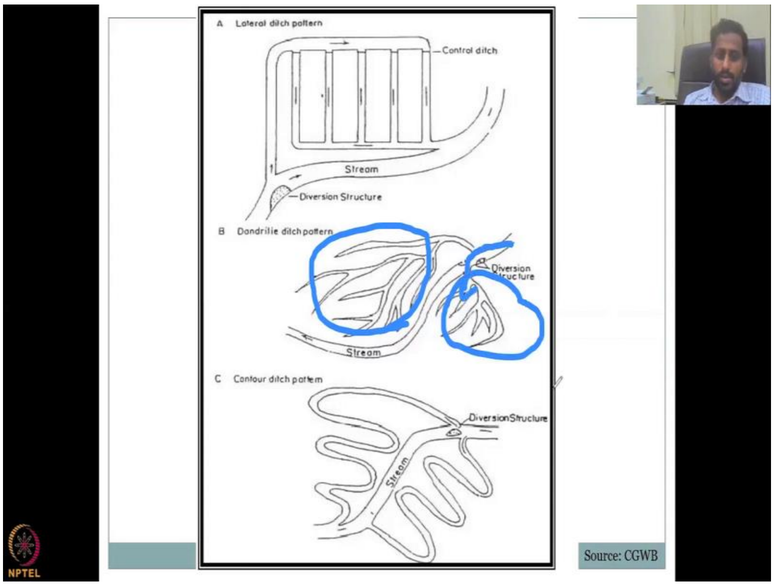
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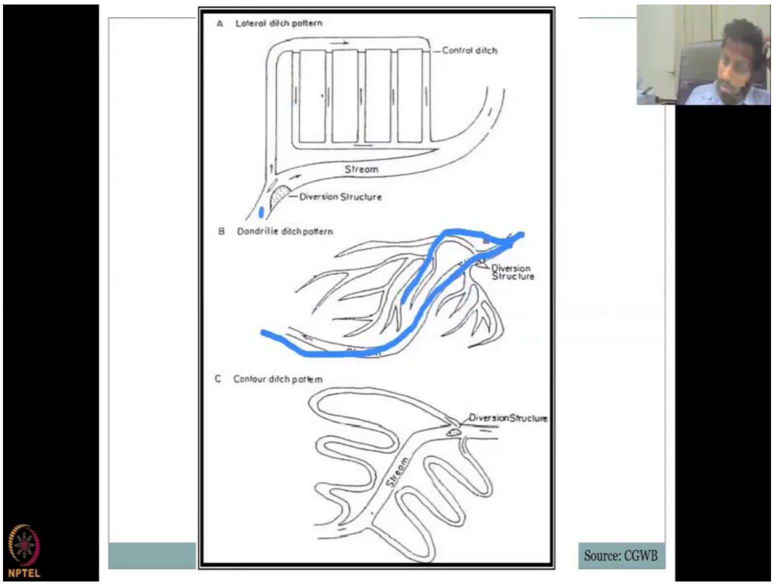

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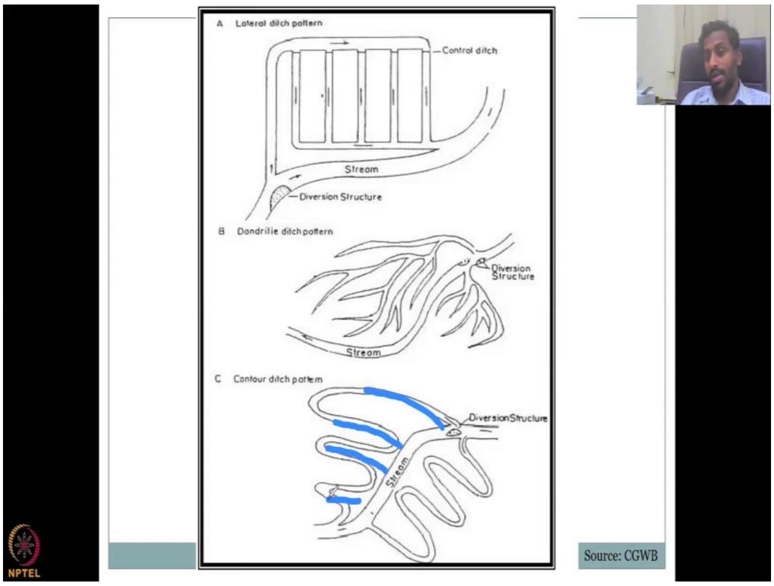

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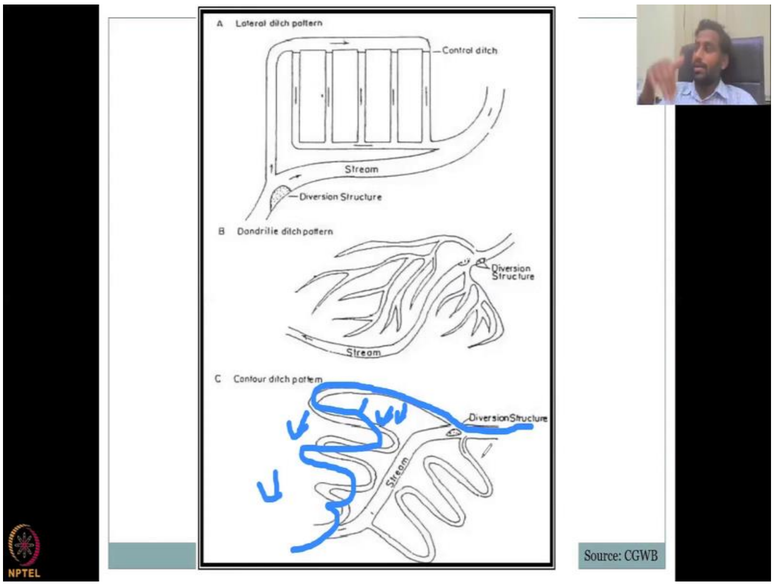

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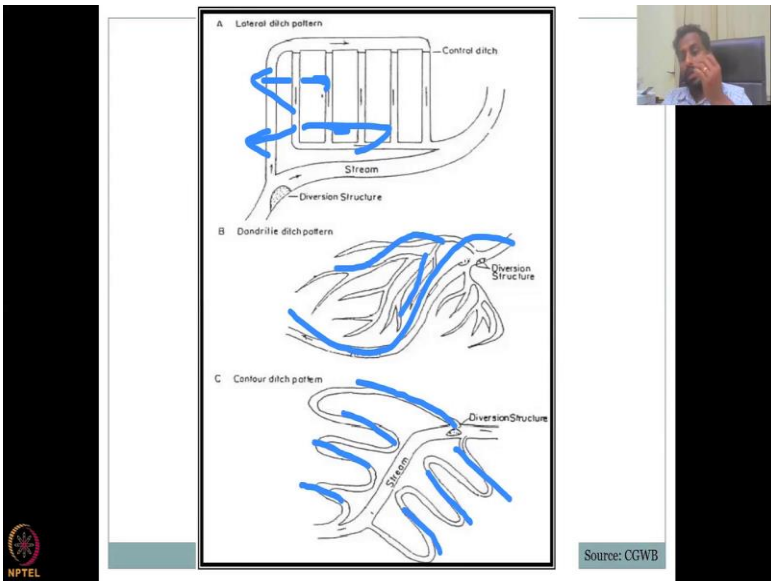

Moving on, there is another example given by the CGWB book. There are three different ditch furrow methods. One is the lateral ditch pattern, three different patterns where you have a diversion structure. And look at the diversion structure. It need not be cemented, just could be a mud wall, a small embankment rise which makes the water go in the opposite direction or just make it turn.

So you come in like here, it may not be a big gate or a constructed, cemented structure. It can just be a big lump of mud or soil, then the water will go like this. And then as I said, you are there to make the water move in different paths. It is not only the major ditch, but also the sub ditches.

So the sub ditches are there which is called lateral ditch pattern, you have lateral ditch moving and the control ditch will come back to the main channel, the lateral ditch will also come back to the main channel after recharging like this. So recharge would happen mostly on these areas. So this is how recharge is happening.

Moving on, the other, Dandrille ditch pattern. This is, Dandrille is a similar way. You just make some diversions and then make it flow through natural carvings, natural ditches in a Dandrille fashion, which is like fingering like a flower pattern. And all this water need not come back to the stream. There is no connection to the stream.

However, most of the time you make small diversions, not the entire water is going, still the stream is flowing. You could see that still the stream is flowing in both these examples. Only a part of the water is taken away. So you need to understand how much recharge volumes you could send and only that volume has to be diverted. If we divert too much, then it is an overkill. You do not send too much water and then waste all the water resources.

The next one, which the CGWB talks about, is the Contour ditch pattern, where is at elevation differences. What is a contour? A contour is an elevation line, an equiotential elevation line. So basically this line is one elevation, this line is another elevation, another and another. They are different. And we know that water flows from high elevation to low elevation. The same principle, they will be using for this program.

So how does water come? Water comes like this. A small diversion is there so water would move in a torturous pattern. It will move up and down and then come back to the main channel. However, because it is moving at the elevation, parallely to the elevation lines, then groundwater would be recharged like this. Groundwater can be recharged just because of the fact that it is moving along these lines where the contours or the major elevations are changing.

So the contours are where the elevations are different. So this elevation is different from this and if you do a ditch on that line then there is a contour ditch. And each contour differs as much as you want. Like, you can have 10 meters difference between them, 5 meters, it depends on your accuracy, how much land you have, and then you can make these contours as simplified as possible for water to enter. And wherever it enters, it can recharge.

So all these three, if you look at it, what is majorly done is water is taken, it is made to extend the path in which it has to flow, rather than just flowing out it flows through multiple paths to come back to the stream line, and while these multiple paths are making the water slow, the ground water is getting recharged.

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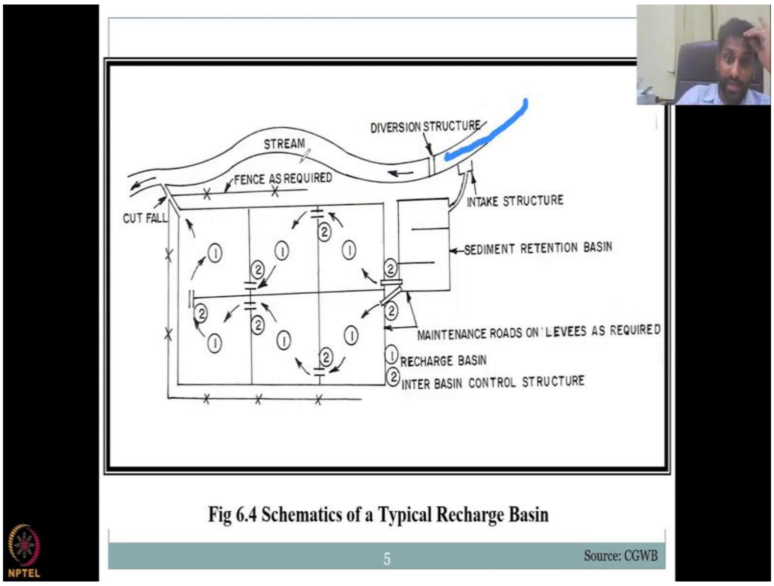
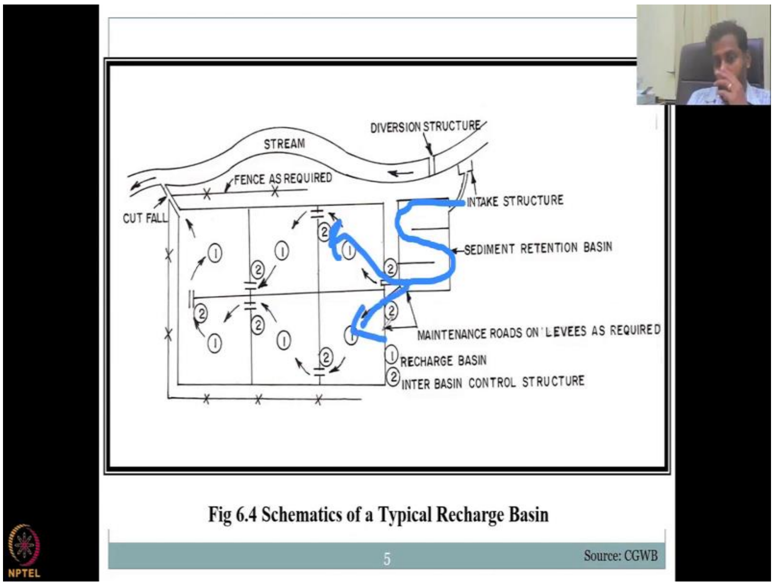




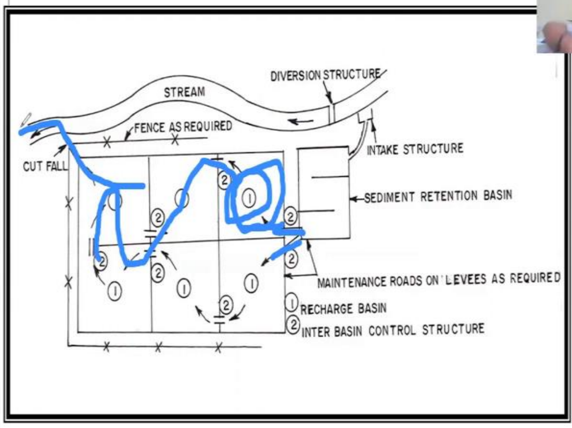
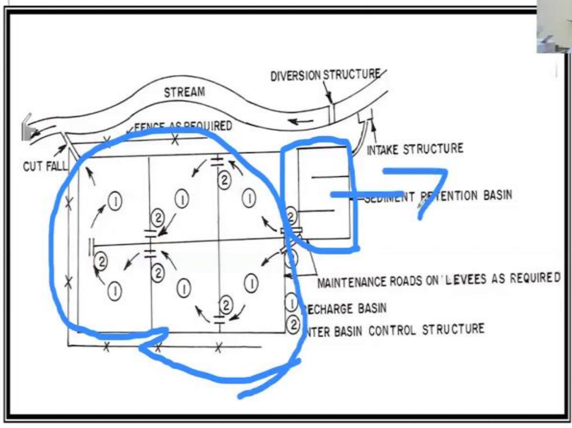


Fig 6.4 Schematics of a Typical Recharge Basin



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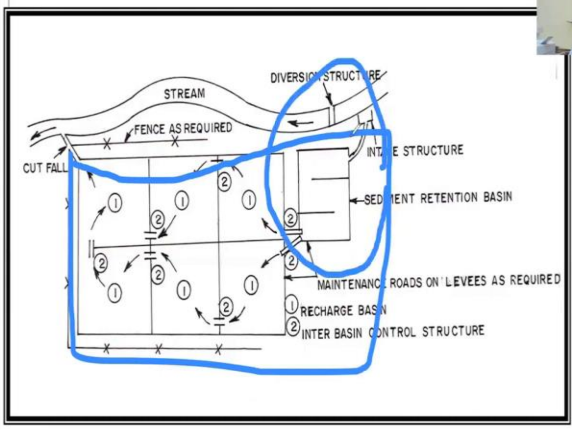

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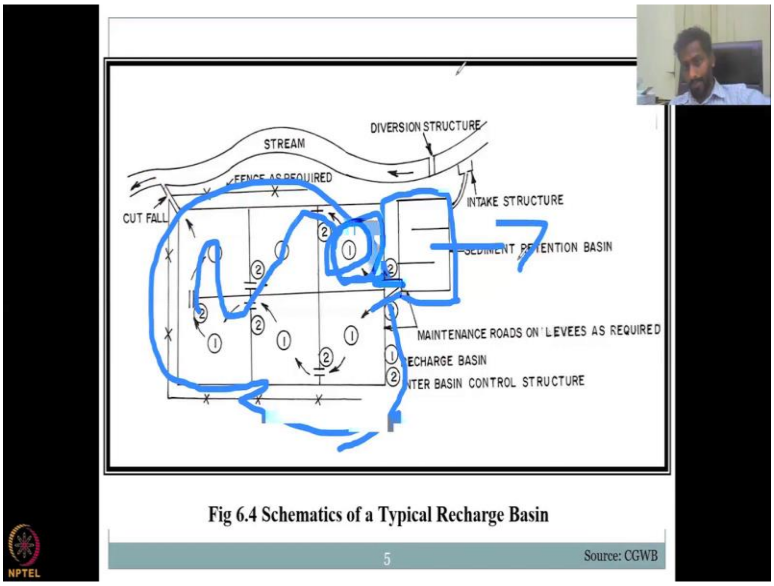

So moving to the last direct method under the flood or applying the water to the top surface of land. Direct method, increasing the contact of water to the land. The next one is called the recharge basin. So as basin, what it is is, it is a holding land. In watershed hydrology, terminologies basin means something that is catching the water and holding it.

Watershed means it sheds the water. Basin, catchment, it holds the water. Think about your sink basin. Same thing. It holds the water. And we are going to construct that for groundwater recharge. It is not a basin for surface water, it is not a land lake, pond for surface water. Here the major use is surface water. So let us see how water comes.

Water comes through this particular channel through this stream. And there is a diversion structure. And this structure, this is a more engineered aspect. Look at how much they have to do for a recharge basin compared to a flood recharge and ditch recharge. A ditch is just digging. You can use a JCB, there is sedimentation happening, then to cover those negative impacts, this kind of method is done. Just let me go back and show quickly.

So these methods may have sediments coming in the stream which gets into these ditches and the ditches get filled up. Same thing here. These furrows can fill up with sediment after some time because you are slowing down water. When you slow down water for recharge, also, the sediments in the water will fall down, and then they would actually accumulate in the furrows, which means the furrows have to be dug and maintained every single time as depends, as per the need.

So you, here you have the water flowing. And then there is an intake structure. So there is water coming in, and you take it for the sediment detention basin. So the first aspect is, you divert the water, part of the water is coming down, whereas most of it is going in a parallel fashion. And then the water which is coming down in the intake goes into the sediment retention basin, where it is allowed to rest.

It is allowed to stay for some time just to make the sediments drop. You are making it go in a fashion where it gets bumped by the walls of this tank and then comes back. It hits the walls, it loses velocity of water, and whenever it loses velocity, the sediments fall down. So when the sediment fall down, it is called as sediment retention basin. You are reducing the sediment load and then just taking the water on the next phase, Phase 2.

So what is happening is, there is a reach, this entire thing is called a recharge basin where number 1 is these small segments of the recharge basins where recharge is occurring and then there is an inter-basin control. These networks or canals or tubes, whatever it is, that is taking water from one section to the other section of the recharge basin.

So what is happening here is you take water, you let water move the sediments, and then water flows into this basin. It first recharges or just fills up this small partition, and then it goes into this channel to the next partition, and then another partition etc. It slows down the water, but here, the sediments are not there, so only water recharge is happening. And then there is a cut fall where water gets back into the mainstream.

So you are not consuming the water. There is also less water evaporated. Most of the water is sent in, recharged, and then this sediment can only be cleaned. Think about the previous example. In the previous example, you had to dig the furrows, wherever the furrows are to remove the sediments. But here, all you have to do is maintain this recharge sediment retention basin.

All you have to do is just dig this section of the infrastructure, you do not have to remove any sediments from this part because most of the sediments are taken away from this space. So you are actually sacrificing a part of your recharge basin, the entire thing is a recharge basin, you are sacrificing a part of it so that you can remove the sediments and then the, only the water that goes into the recharge basin will actually recharge and sediment is less.

It is the same principle. You take water from the main channel, apply it as a sheet flow, let the water recharge, slow down the water, let the water recharge, and then you continue back into stream.

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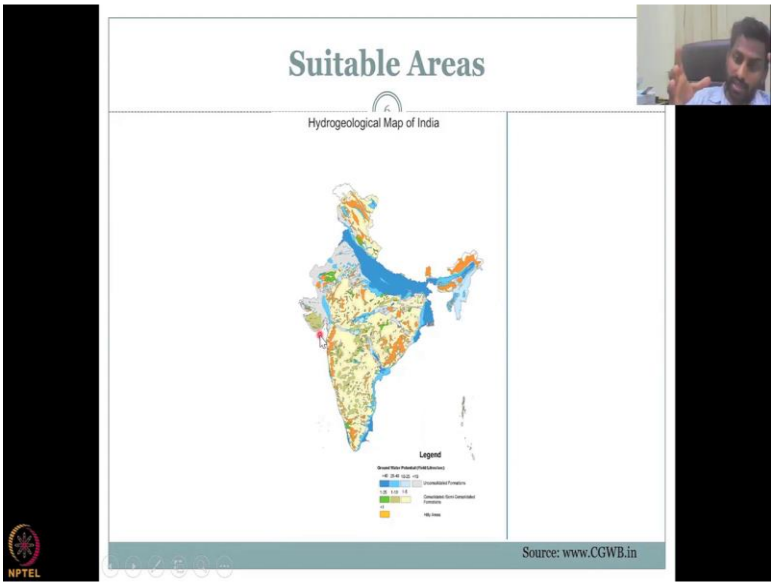

All these methods have been explaining the direct method. So where are, where could these be suitable, is the question. The suitability comes on the understanding of the recharge potential of the land. So where you have good water flow and less sediment, because if is sediments is too much, then recharge may not happen. So it is good in the alluvial aquifers, unconsolidated materials, and the semi consolidated materials that you find here.

For the, because it is faster recharging, the unconsolidated, water potential is high, same as your semi consolidated green color. So both the blue and the green are good for these kinds of networks, because you are supplying water from the main channel and then bringing the water back to the main channel. But in between, there is recharge happening.

And for that, the potential of the land to accept the water faster is better, and those are available in the unconsolidated formations and also the semi consolidated formations. In the majorly consolidated formations where you have hard rocks and cracks, this may not be a suitable exercise.

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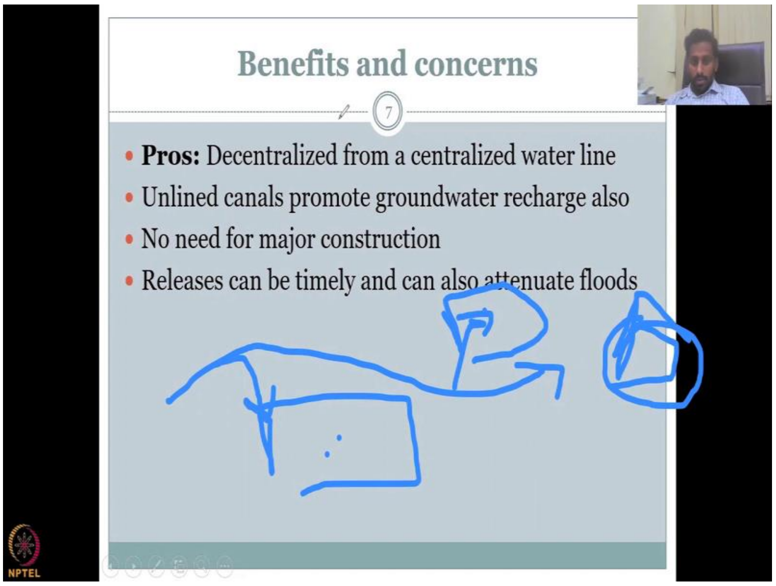

So there are some benefits and concerns,.which I would like to go through, just for this method, the direct method. Pros. It is decentralized from centralized a water lins. So the stream and the canal is a centralized distribution from a major dam. However, you can make sub diversions as a decentralized groundwater. So this is very, very good and helpful for taking water from one source and then distributing it in, among other resources.

Unlined canals promote groundwater recharge also. So these ditches and furrows, since they are unlined, no cement on the sides, at the bottom, it can also recharge. So it is very important to have that aspect also for ground water recharge.

No need for major construction, no big budgets needed for maintaining a cement or a wear, or a canal, nothing. You have to dig and most of these government schemes which are we talking in this lecture, the next lecture series, you would look at how you could carefully use the government schemes to maintain and manage these kind of systems.

Releases can be timely and can also attenuate floods. Suppose, there is a major flood in the river. You could use these basins as to shift 30 percent of the flood, 40 percent of the flood into recharge basins. Think about it. You have a big flood coming. This is a major stream, and then you have this land.

If there is a big flood, then what you can do is you put a diversion of water into it, and then a diversion of water here. So then what happens is this population of houses and then cities can be less affected by flood because you have upstream, taken part of the flood and kept at the recharge basin. So it can be timely, it can help a lot in attenuation of floods.

The Cons, the negatives. Care has to be taken that the water is not lost before the canal end area farmers get water. Because you are taking water, some water is lost. So the downstream people may lose some water because groundwater is, your land only recharging, not downstream. So there could be some negative impacts of channelizing water. Even though you are putting it back, some water is lost.

So you should always be aware, is it going to be affecting my groundwater or surface water availability in the downstream community. Requires area clearances and getting area might be challenging, especially near the streams, because the near the streams and rivers are the most fertile land because of the water resources and because it brings a lot of sediments, the sediments have nutrients.

So it might be difficult to get a piece of land along these rivers or canals for recharge, but that is one of the challenge, as I said. And it requires clearing of land. Look at all these images that I have shown. There is a big piece of land that you clear and nothing grows on it. So you have to maintain that it is going to be a land used only for recharge, nothing else. No houses, no crops, no forests can grow.

Benefits need to be shared. Normally, it is not because you are pulling water, putting it into your groundwater, but the downstream people may lose some water, some fish might be lose because some fish might come into your land. So all this has to be thought about well and documented. How this can be negotiated is when you talk to downstream farmers and say okay, I am going to build this , this is my might impact your water, if so, let us know, so that we can share some profits and benefits.

Might need to quantify lateral spread. So numbers is very important because you are going to talk to these farmers. It is important to say how much water you are going to take, how much is released into the groundwater, how much you are putting it back into the canals. So you need to quantify these lateral spread areas.

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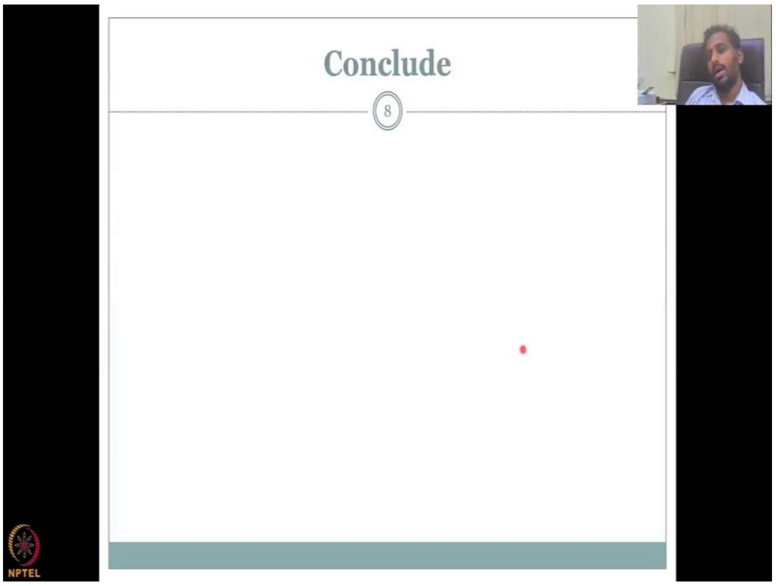

So, with this, I have gone through Direct methods. We have talked about all the positives of this. And overall, it is a positive way of doing groundwater recharge. And in the next session, I would look at more other methods, Indirect and the Combination of this methods. I will see you in the next class. Thank You.