Groundwater Hydrology and Management
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Lecture 34
Subsurface Recharge Methods

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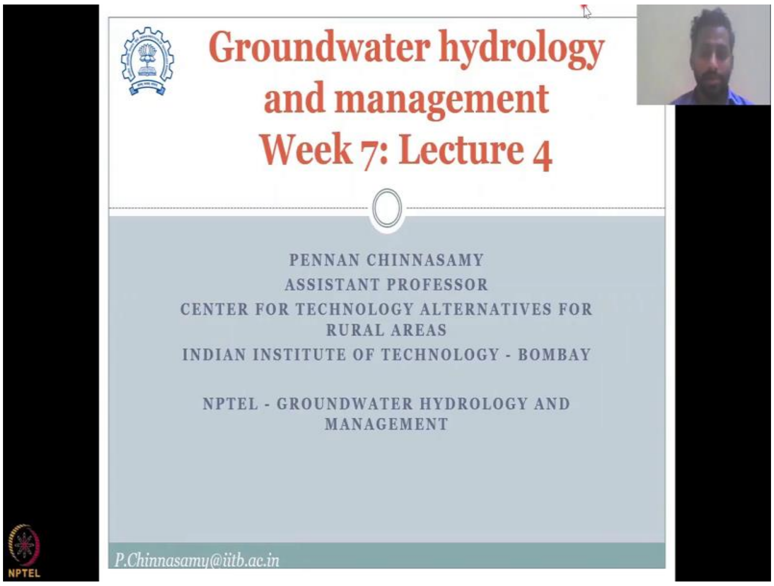

Hello, everyone. Welcome to Groundwater hydrology and management NPTEL course. This is Week 7, Lecture 4. In the past weeks, we had looked at what does groundwater recharge, how it happens, and in this week, we are looking at multiple methods through which recharge can occur, and most importantly, what is being recommended by the government of India.

These would help in fine tuning where you want to recharge, how you want to recharge, what are the pros and cons. In the previous lectures, we also looked at the different methods, direct, indirect methods that can be used. We are continuing with the direct methods, of which, in the previous lecture, we looked at direct methods as surface runoff and how you capture that and put it into the groundwater recharge.

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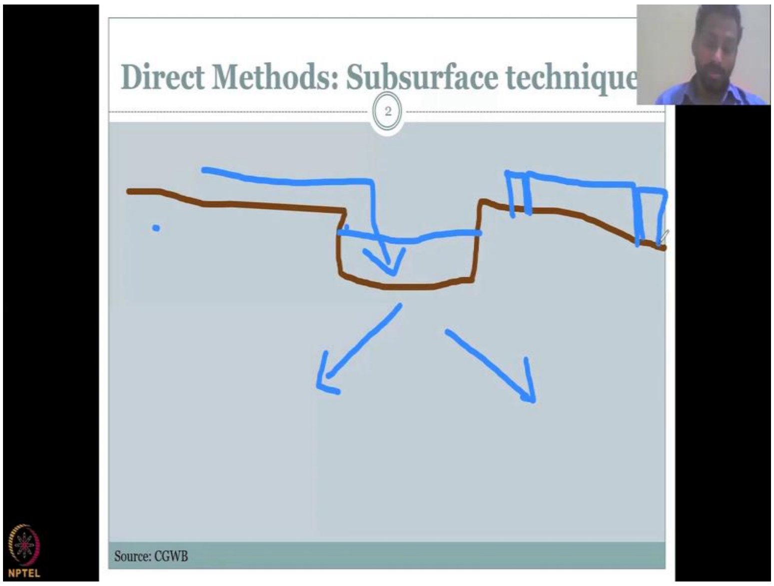

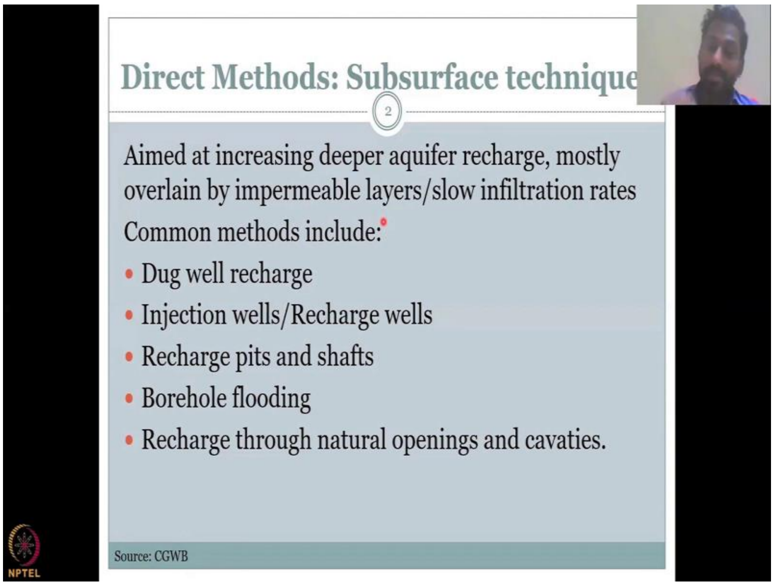

In today's section, we will look at another part of the director methods, which is subsurface techniques. Let us first define subsurface. So you have land, the land can be sloping, undulating, and based on that, the runoff was captured and recharged. Now, what happens is, this is subsurface. In subsurface, you do something to the land under the land.

You create a space, or evacuate a space and then you capture the water for recharge or you send the water in for recharge. The idea is you get water to this recharge, your land from where recharge can happen, or you have water inside these ditches, and that becomes the recharge, like a well.

So what is the difference between this and the previous one? We have same runoff as the source, but the other ones were tanks and ponds which are slightly up. So, still you need some bund or embankment on the top. And that is why it is different from the direct version, which is subsurface techniques.

Aimed at increasing deeper aquifers recharge mostly overlain by impermeable layers, slow infiltration rates. So this is a difference in aim or objective between the two methods, or I would say, some methods. In the previous one, we had, it is, the aim was to capture the surface runoff, and put it into the groundwater.

Whereas here, the aim is to increase the deep aquifer recharge. In the previous one, the shallow aquifer was recharging because surface runoff goes in slowly, slowly, infiltration happens. Here, it is more percolation and those kinds of things. And it is targeted at locations where the infiltration rate is very low.

The common methods include dug well recharge, I just had a small diagram today, so how you can create a well and with the well, the groundwater can be recharged. Injection wells or recharge wells. What is the difference is, the dug well is at shallow aquifers, at a very shorter depth in the ground whereas, your injection wells or recharge wells goes much, much deeper.

These are suited for confined aquifers, whereas dug well are more for unconfined aquifers. Recharge pits and shaft. And these are not wells, these are pits or shaft. Like in terms of, pits is a big, big land, which is evacuated and then inside that, water is sent in, whereas a shaft is a small tube like thing which goes in. We will have an explanation.

Borehole flooding, you flood a well. So you just create more water into a well. Recharge through natural openings and cavities. Of these, some of these common methods, we will discuss today in detail in class. The last two, we will not because it is not much done.

For example, recharge through natural openings and cavities, you already have cracks in the underground surface. We have rocks which have cracks. The idea is to recharge that water by sending water in. It is a lot of energy intensive methods, which we will not look at.

Same borehole flooding, is basically, you have a bore hole or bore, deep bore well, and you are putting water in and assuming water would recharge. So these are augmented recharge yes, but not much use of it in India, whereas the others, which I will be explaining today, are well, widely used.

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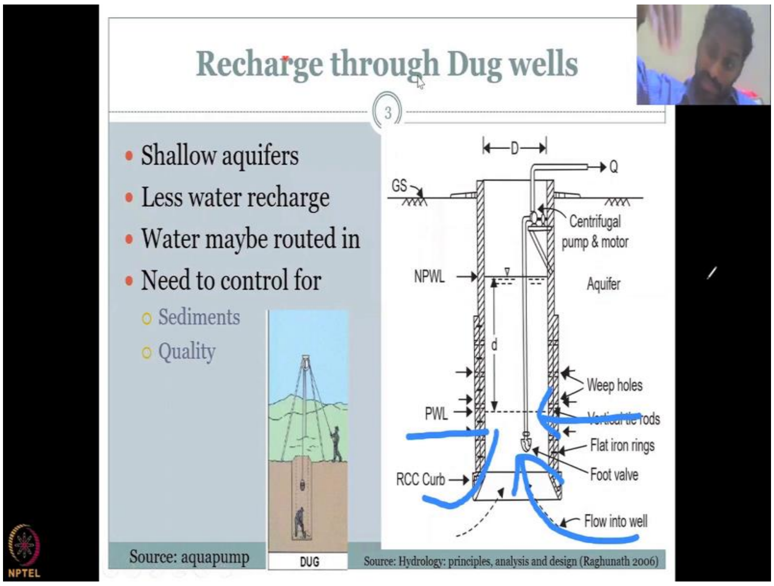

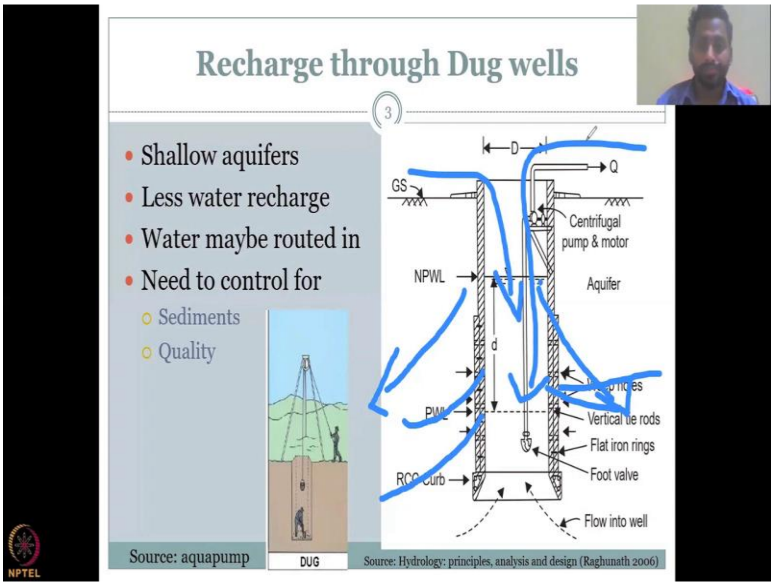

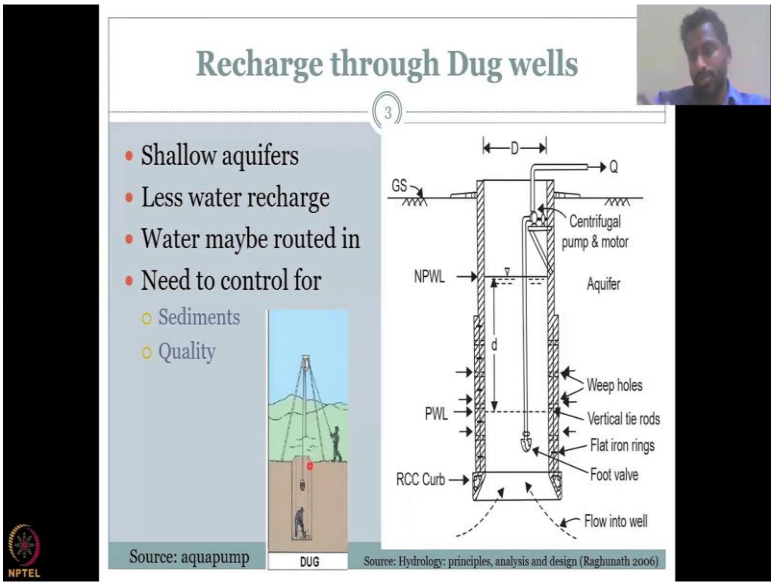

Let us start with recharge through dug wells. And what, let us define a dug well. A dug well is a type of a well, which is in the shallow aquifer. Mostly it is dug by hand or by small instruments. There is no big machinery involved. So if you look at the diagram below, you could see that a man is digging the well through a spade or a small tool, and then a person on the top is just pulling the debris out, like the soil, the rocks out.

So it is mostly dug by humans and a lot of these rural wells, dug wells are made by this kind of fashion. And there is always recharge happening. And that is the system why you wanted the wells. So recharge means, groundwater will recharge into the wells, and then you access the well water out. But the reverse can also happen, which means you can put water into these wells and then the wells can recharge.

Let us look at the scenario. So it is mostly for shallow aquifers. As I said, shallow is the lesser depth under the ground, and mostly for unconfined aquifers. It cannot pass through confined materials. So just be careful about is it confined or unconfirmed. Less water recharge, it is not much faster water recharge. There is no mechanisms to push the water recharge. And also, there is interference from other recharge. So you have to be careful is it full recharge or slow recharge.

Water may be routed into the wells. That is the only way to recharge these wells, which means you have to put water into the well. And from the well, the water would recharge into the groundwater. In recent years, I have also visited locations in Maharashtra, dry parts of Maharashtra and Rajasthan, where I saw a lot of people using a well as a tank. So basically buy the tanker water, or an NGO supplies drinking water through a tank.

But the tanker lorry cannot be saved. The water cannot be saved because they do not have, the village do not have tanks. So what they do? They put the water in the abandoned wells. And slowly, the water recharges the groundwater. So it is not for groundwater recharge, but however it does directly recharge. Need to control for sediments and quality. So because you are putting water into the wells, and the wells are open, so just look at the surface of the well, it is open.

So the idea is if runoff or surface water is pushed into the well, you need to be careful about the quality, otherwise the water would go into and pollute the environment, pollute the groundwater. I think this is common for any recharge method. It is more common here because there is no material to filter out the groundwater, unlike the ones you have in the recharge pits and gravel and other things which will filter water. Here, it is not, because you already expose the full aquifer.

Let us look at the recharge, how it happens. I will use this dug well as an example. For example, initially, your water was moving in through the walls of the well. And so, it is recharging the well. And then you use a pulley or some pump, and then you take the water out. So this is the normal scenario. Now, we want to recharge groundwater, not the well, but push water into the ground.

So how does that happen? So you want to take water on the top, then put it into the well. And slowly, when the water table rises, since the water table is at a higher potential in the well compared to the lower, so for example, this is the initial water level, and the water level is here in the well. So water would flow from high potential to low potential. And because of that gradient, there will be some movement of water out of the well. And once it comes back to the lower-level water, you put more water.

And that is how you would keep on adding water to recharge the groundwater, the overall groundwater. So this is where you use a dug well. Here, there is not much infiltration because it is already dug to a good depth, and that depth is enough for recharging the groundwater. So we moving on, I hope this is clear that we can use well, not only to access the groundwater but also push water into the aquifer through groundwater recharge.

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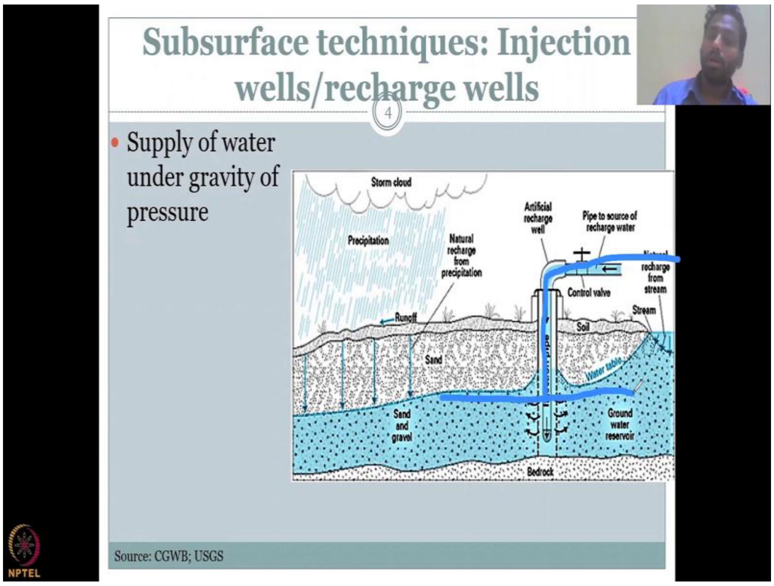
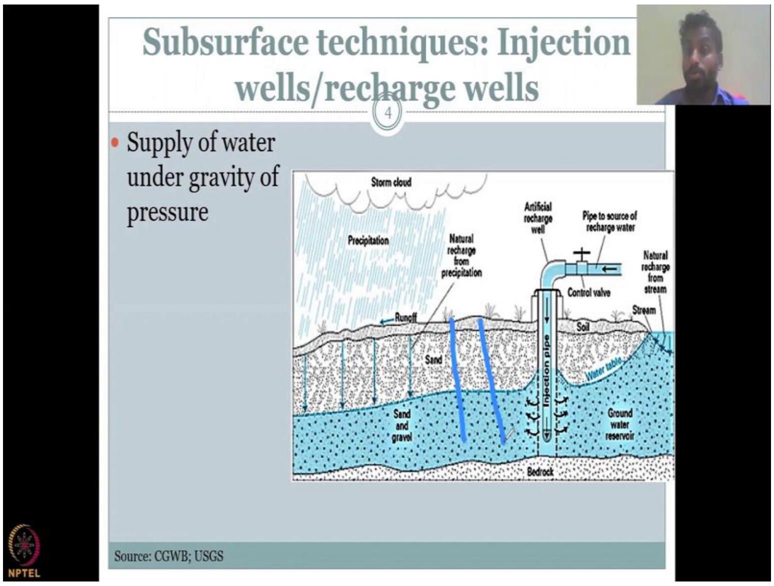
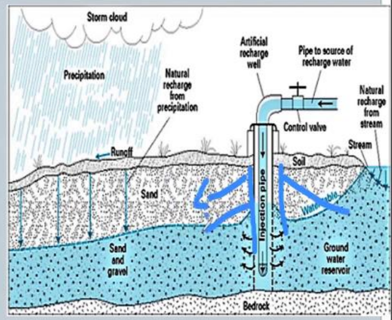




Subsurface techniques: Injection wells/recharge wells

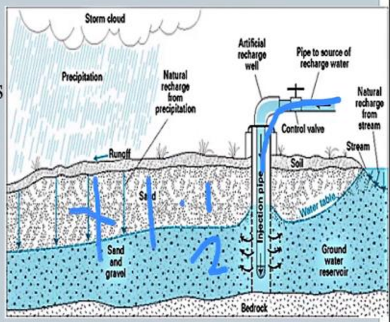
- Supply of water under gravity of pressure



Source: CGWB; USGS

Subsurface techniques: Injection wells/recharge wells

- Supply of water under gravity of pressure
- Cement ceiling is needed prevent leak
- Casing for alluvial



Source: CGWB; USGS

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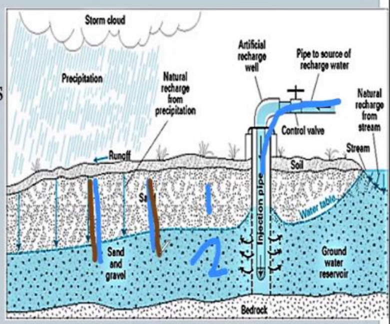
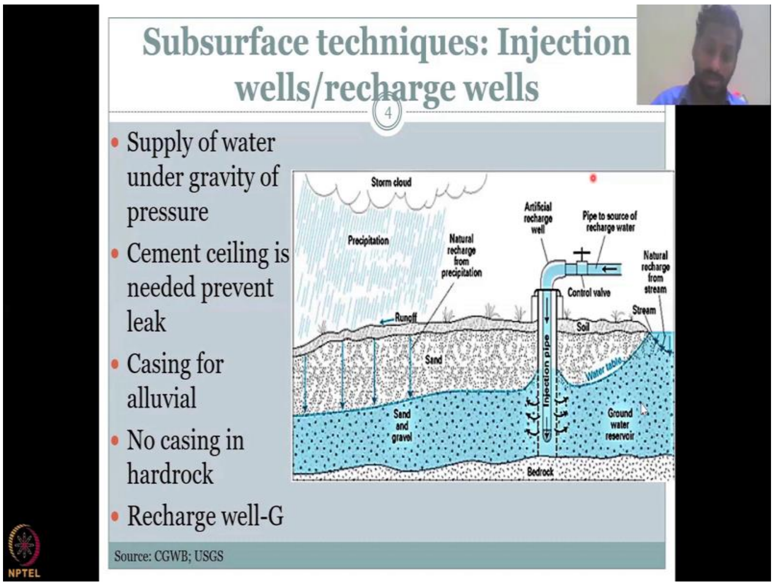


Source: CGWB; USGS



Then, we are coming to the subsurface condition. Another subsurface, under the ground. But this is the injection wells and recharge wells. The previous one is called the recharge well also. So it is not much different. But if you push water in through force or through energy, then it becomes an injection well, whereas a recharge well is just, you collect the water and put it in, and see how groundwater recharge happens.

So let us look at an injection well. So what is happening here is the supply of water is given to the aquifer under gravity or pressure. So I am taking water and I am supplying it through a pump into the aquifer. So the aquifer water table is here. Just look at the line, dotted line. And while I am pushing the water, water is coming out of this well and recharging the aquifer. So what is this injection well?

So in the land, you just make a well. It is a very small well, where only the injection pipe can go through. it is like a big pipe which goes through and the pipe is connected to a motor when it, motor pushes water inside the ground. And you only open along the pipe where you want to recharge. For example, you want to recharge along the groundwater shallow or unconfined or confined, then you do not have any pipe. All the water would, whatever water you push is going to be recharging from the water.

But these injection wells are mostly for targeted depth of the aquifer, where you want to recharge. So for that aspect, here, let us say for example, this is the shallow or the unconfined aquifer, and this is the confined aquifer. And your goal is to recharge the unconfined aquifer. So what you do is, you can push the water here and make sure you close the pipe in zone one and only open the pipe, so dashed lines you see, that means that the pipe is only open in the second section, and that is where your ground water is going to be moving due to pushing of the water.

It is a very, very innovative way, however; it is hungry for power, which means you have to push the water in. Cement ceiling is needed to prevent leak, also because you are pushing water in, water should not come up and then leak, which is such a waste. So there is always a good cement construction on the top to close the opening and the pipe connection, and that is why you need a pipe, very solid pipe to push the water. There are regions around the world where they are using it, especially where energy is cheaper than water.

So that is where they may use it. Casing for alluvial is needed. So if it is a alluvial soil, because when you push a water and then pull the water, the alluvial aquifer can actually collapse inside the well and for that you, always put a casing. The casing is just a tube which goes in and prevents the soil side from collapsing into the well. Let me draw it. For example, this is a ground and your well is like this. If you do not have anything then the sand particles can come in and collapse your well, which means close your well.

However, if you add a casing in the well, then what happens is a soil is kept away and it does not fall in. So in injection wells, normally you do have a casing to prevent the alluvial aquifer from collapsing. However, if the aquifer is not alluvial and it is a hardrock, you do not need casing. This is very common for almost all the wells types, because alluvial aquifers tend to move, it is very loosely bound. So they can easily collapse and come in.

Whereas a hard rock is a rock. Basically, water is held in the pore spaces of the rock, and the rock does not fall into the well, in most cases. So if you go to the villages, especially in the central, South India, you have all these hardrock wells. And along the side, they do not put any casing. It is too expensive to put casing.

So you could see actually the sides of the wells exposed, and then what type of rock it is, especially the dug wells. If you look at the dug wells, you would see that, you could see hardrock just jetting out, and it is just like that for the centuries, or how long they made the wells, at least before independence. So those wells are pretty well operating now, along the, as and when the groundwater recharge happens.

So in this you could see that there is a constant push of energy or a pump motor, which is pushing the water inside that ground water. Recharge well is through gravity, whereas injection well is through force. If you just let gravity to pull the water down, it will not pull because there is already water, or sometimes the pore space is too slow to accept the water. You need to push the water, and not through gravity. So gravity is too slow for this process. And that is why you need to augment it through artificial recharge method.

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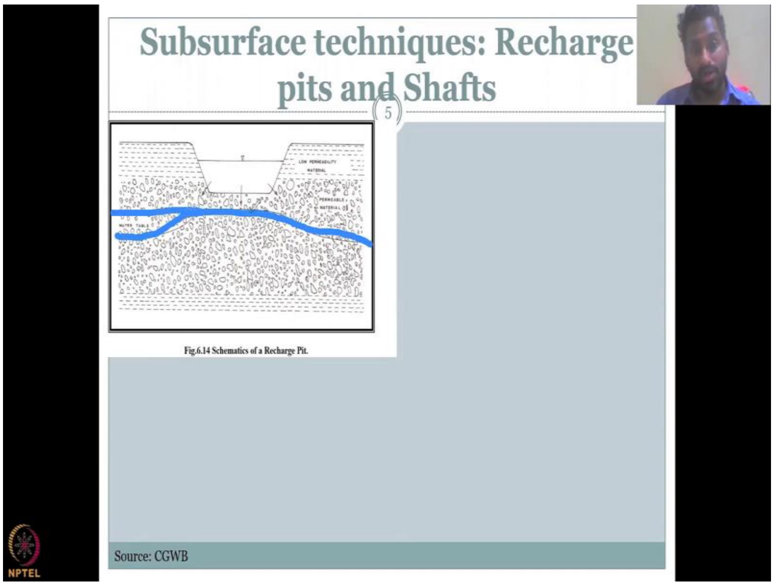

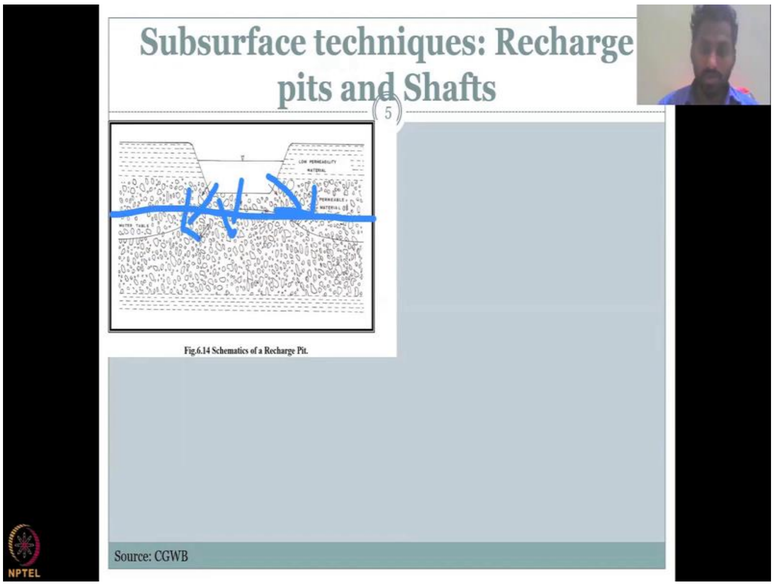

Subsurface techniques: Recharge pits and Shafts

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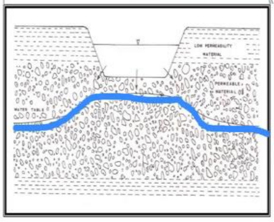

Fig.6.14 Schematics of a Recharge Pit.

Source: CGWB

Subsurface techniques: Recharge pits and Shafts

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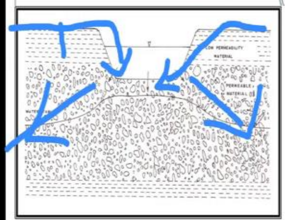

Fig.6.14 Schematics of a Recharge Pit.

- Dug in the subsurface
- Shallow recharge
- Flow can be routed

Source: CGWB

Subsurface techniques: Recharge pits and Shafts

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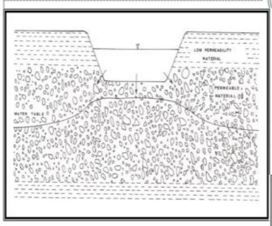

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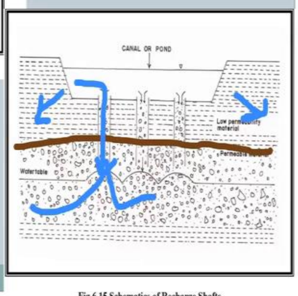
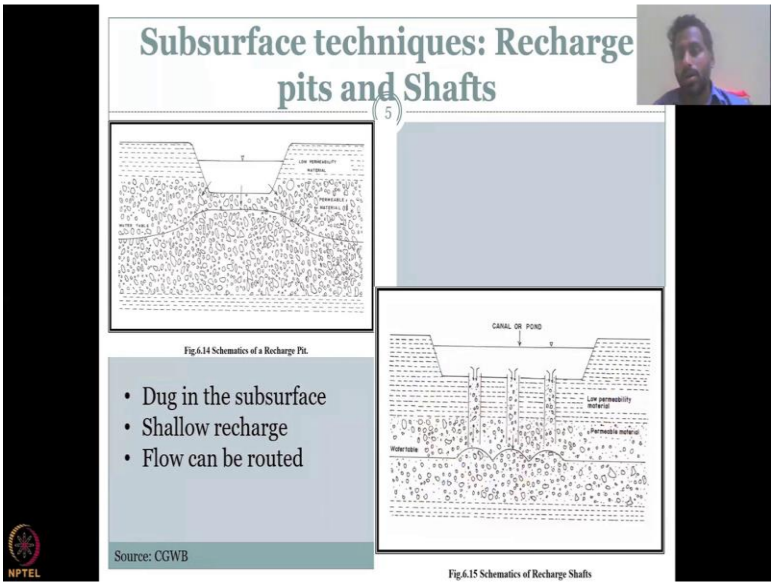


Fig.6.15 Schematics of Recharge Shafts

Source: CGWB



Then we have to go to the recharge wells, recharge pits and shafts. So we have already shown recharge well. A pit is just a small, kind of a well. So you can see here is, along the subsurface, you dig a small pit. A pit is a big hole, a big gap, and then you take the soil up, and if you put water in, slowly it will recharge. You could see the arrow mark recharging after you put a water table. Interestingly, only ground, under the ground, under the base of the recharge pit, the water is moving. That is because on the top it is low permeable material.

So you do not want that you cannot push water into these materials. The storage is very less. So it is better to just push the water down by just letting the water stand in this recharge pit, and slowly the water moves down into the aquifer. You could see, and this is common also in most of these recharge, artificial recharge methods, that there is a water table. And the water table is rising where your recharge is happening. It is not a straight line rise, initially. So initially, it was a straight line, and then when you put water into this recharge, and water from the recharge unit moves down, then what happens is, there is an influence on the water table.

And that influence is seen by a small mound or a peak, just below the groundwater recharge unit. This is common also, to most of these methods. It is dug in the subsurface, these recharge pits. It is for shallow recharge, not for the deep aquifer, because there is nothing to push water into the aquifer. the deep aquifer, I am saying. However, if you maintain a very healthy shallow aquifer, sometimes there is movement of shallow or unconfined aquifer into the deep aquifer.

And that takes time, but still the movement can be possible. Flow can be routed. Here also, you can route your top flow, like, surface runoff or any other flow, into this recharge pit and from the recharge spirit the water can move as recharge. Further recharge can be happening this way. So instead of directly coming down because of the impermeable, low permeable material, you put the water into these units, and from the unit the water is coming. So that is a big difference.

Moving on now, let us look at this shaft. So what is the shaft? So shaft is kind of injection well. It is not injecting water through force, but it is a well that is going deeper into the unconfined aquifer, connecting the unconfined aquifer to the confined aquifer, and it is mostly in the deep aquifers. So it is kind of a small shaft. A shaft is like a tube which runs vertically down, and it is perforated or open only in locations where you want the water table to be recharged. So let us look at this example, and normally, it is a combination from a recharge pit.

So you have a canal or pond or a recharge pit. And initially the water was only recharging in the shallow aquifer, let us say. Now, you want the water to go in to the deep aquifer. However, there is an impervious layer, there is an impervious layer here. So it is, water does not move. So what is, you could be doing is, you can have a shaft. A shaft is kind of a small well which is drilled down into the confined aquifer or the deep aquifers, and what happens is, water now moves through the shaft, not through the soil, it moves through the shaft down, and then recharges.

So, this shaft acts like a bridge to take water from the shallow aquifer through the impervious material and medium into the deep aquifer. And this is what is happening nowadays, a lot in India, because the recharge rates are so slow, one, and number two, the recharge to the deep aquifer is very, very slow. So to conserve more water, there are a lot of studies which are taking this water and putting it into the deep aquifer through these shafts. It is not rocket science, however, it has not been tested and widely used. And nowadays there are a lot of methods to use it.

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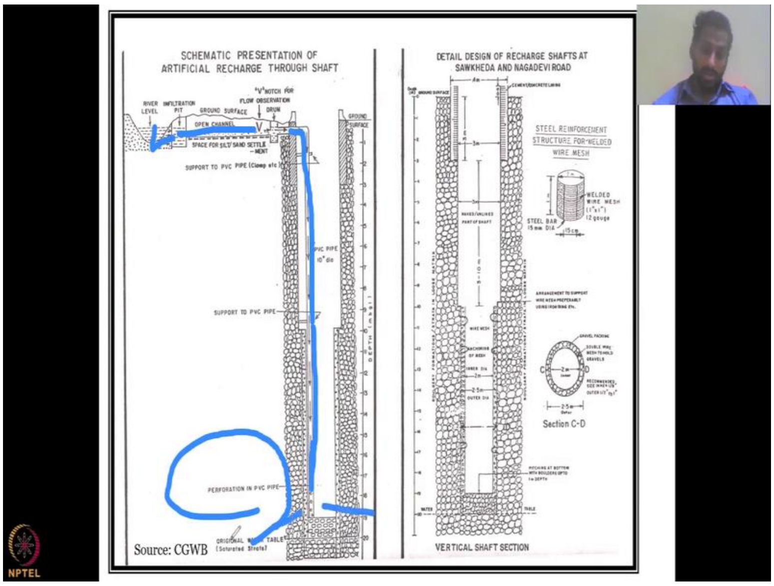
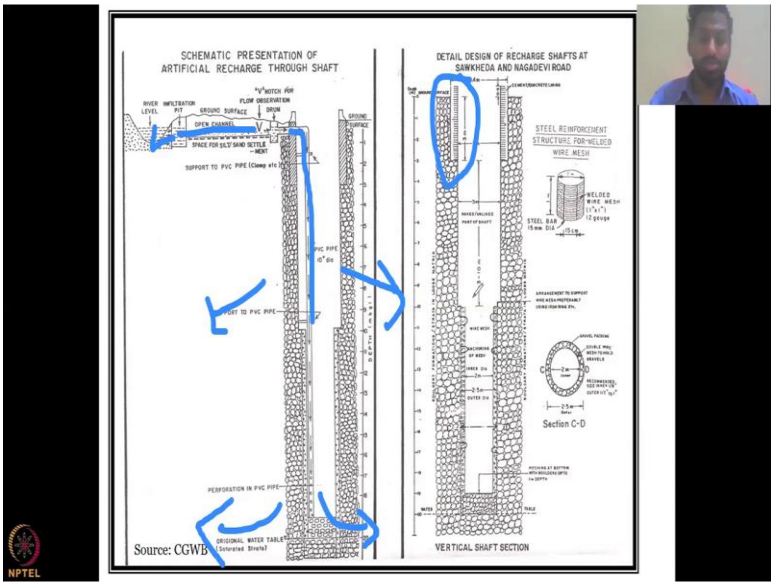
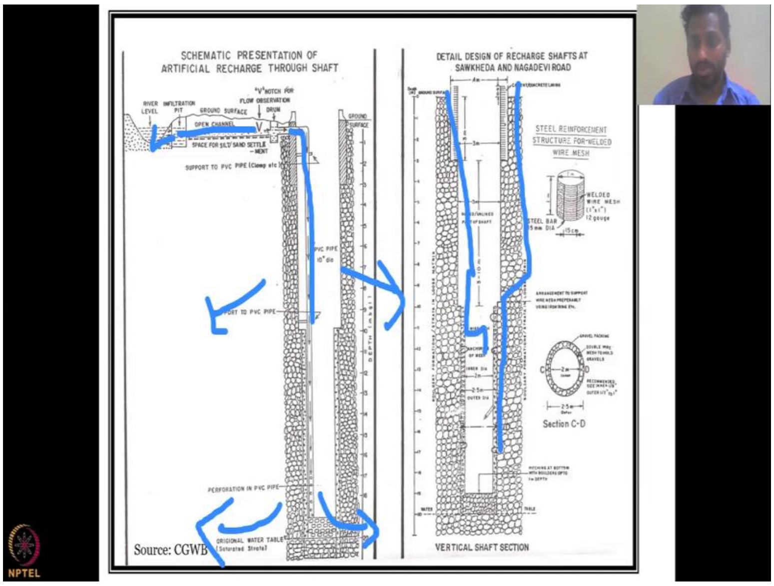
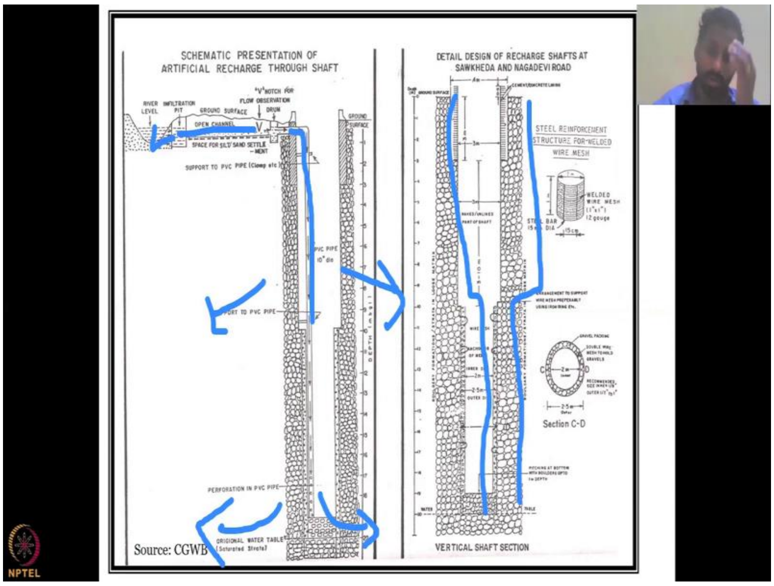





SCHEMATIC PRESENTATION OF ARTIFICIAL RECHARGE THROUGH SHAFT
DETAIL DESIGN OF RECHARGE SHAFTS AT SAWKHEDA AND NAGADEVI ROAD
STEEL REINFORCEMENT STRUCTURE FOR WELDED WIRE MESH
PVC PIPE
SUPPORT TO PVC PIPE
PERFORATION IN PVC PIPE
Section C-D
VERTICAL SHAFT SECTION
Source: CGWB
NPTEL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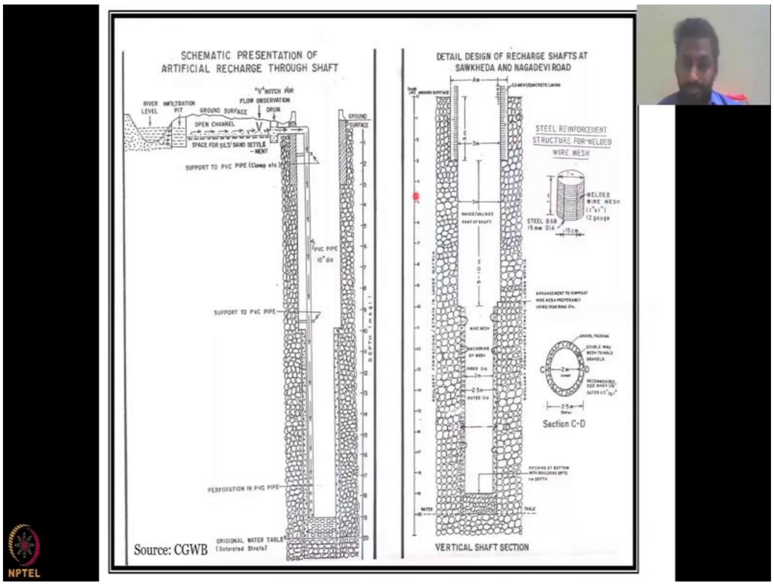
SCHEMATIC PRESENTATION OF ARTIFICIAL RECHARGE THROUGH SHAFT
RIVER LEVEL
INFILTRATION PIT
GROUND SURFACE
OPEN CHANNEL
DRUM
SUPPORT TO PVC PIPE
PVC PIPE
PERFORATION IN PVC PIPE
DETAIL DESIGN OF RECHARGE SHAFTS AT SAWKHEDA AND NAGADEVI ROAD
STEEL REINFORCEMENT STRUCTURE FOR WELDED WIRE MESH
WELDED WIRE MESH
Section C-D
VERTICAL SHAFT SECTION
Source: CGWB
NPTEL

So let us look at a quick schematic given by CGWB. You have your river water infiltration pit, and from the infiltration pit, which is a subsurface pit or pond or a recharge unit, from there water is taken and put into the shaft. And how does the shaft look like? It is like a tube which runs through the impervious layer. So for example, all these are impervious layer. And look at the depth. So the shallow aquifer, or the shallow recharge unit would only be until 2, 3 meters below ground.

Whereas your shaft can run further, further along like 20,30 meters. And then at the 30-meter interval, there is an opening where water can move. I will show you with some drawing for the water. So now, recharge water is taken or infiltration water is taken. Look at the arrow marks. Then, what was put into the tube. There is a connection to make the tube stand vertically. And while it goes down slowly, there is a perforated PVC pipe, which means a pipe with holes. And through the pipe with holes, water recharge happens like this.

Water is coming. Look at the arrow marks, and then what recharge happens like this. Water does not recharge here because this tube has casing. Actually, a tube itself is a cased tube, which runs down right. So this tube has casing, which prevents water from moving or losing out into the shallow aquifers. And most of the water is kept for the deep aquifers. This is just another schematic. Same thing. Another schematic showing how the top is having a steel part to prevent water from moving on the sides, and what are the different dimensions.

What one needs to notice that, the shaft need not go through, along a same thickness. Initially the shaft is big thickness, and then it can go like a smaller thickness into the deep, deep aquifers. Why this is happening is because it is expensive to drill all this, down to such depths, like 30 meters, 20 meters. So instead of drilling the entire volume down, which becomes a well, you are only deepening the part where recharge can happen, and connecting the top to the deep aquifer through recharge.

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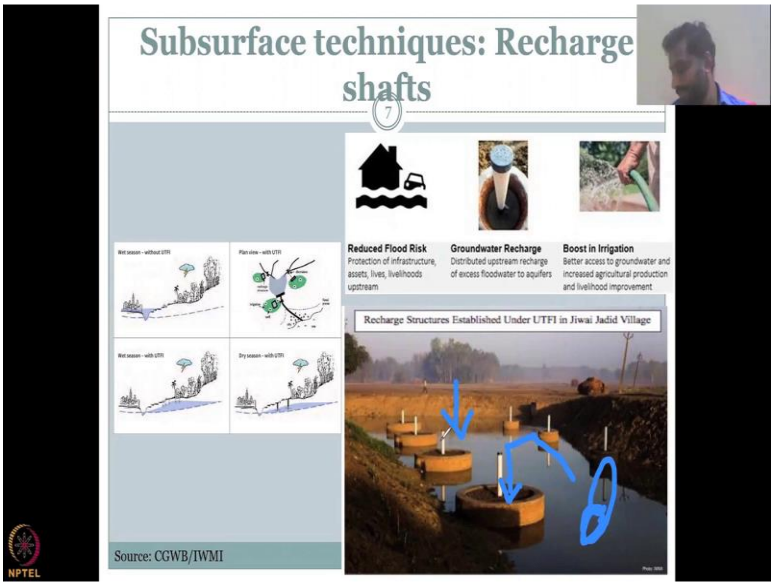

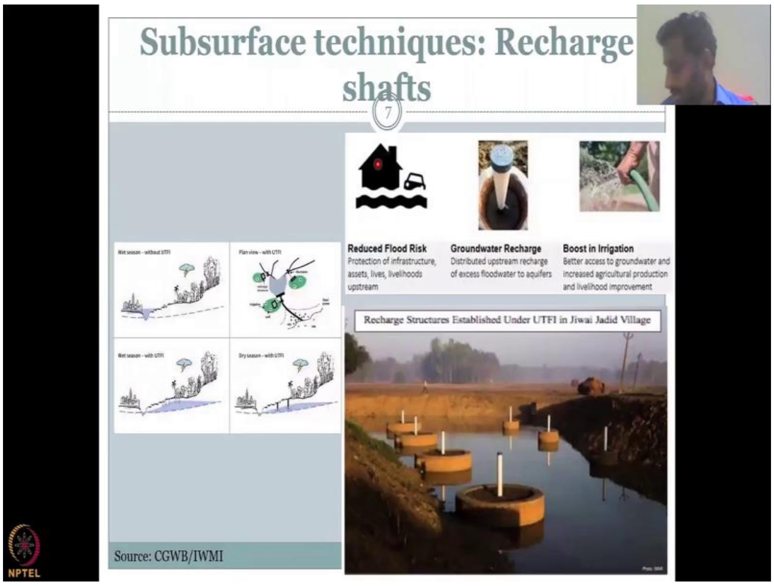

Let us take a case study, for example. And I am happy to share with you the work that IWMI is doing, The International Waters Research Management Institute, where I was also a part of this team before I joined IIT, Bombay. So let us look at the recharge shaft, and how they propose to use it. So basically, problem is there is a lot of floods. For them, more than groundwater, flood is a big thing.

And to reduce the flood, you can take the water, runoff water from the streams and put it into the groundwater. However, groundwater is taking the water slow. So for that, they are taking the water into shaft, and then pushing the water down so that it goes to a deep aquifer which has already been emptied through agriculture. So the idea is, take the flood water which is excess water from the surface, push it into the deep aquifers, and whenever there is agriculture, you can take it and use it.

Let us look at a schematic. This is a city, and this is the sloped land. Then, there is runoff happening, and then the runoff hits the village and flood is happening. This is without this shaft plan. Now, with the shaft, what is happening is, you are getting more water to recharge into the groundwater, thereby reducing the volume which goes as floods. So the flood is reduced near the UTFI.

And especially, during the dry season, the flood water which has been pushed into the ground can be taken out for agriculture. So it is not only reducing the floods, but also enhancing water supply during the dry season. Let us look at how it is done. So, water is taken from the major rivers or channels and put into this recharge pit, or a pond. And from the recharge pit and pond, water is pushed into the recharge shaft, which goes into a deep aquifer.

Now, the recharge pond, this recharge pond would maybe cater for the shallow aquifer, but the volume is not enough. You need more water to push into the deep aquifer to reduce flooding. And for that, these are the deep aquifer connecting recharge shaft where water is put and recharge deeper into the aquifer.

So it is a very clever way of doing it, and a lot of good research are also coming. Still, a lot of research is needed to look at the quality, the energy needed. Here is, energy is much less, but to set it up and all those things. And also, the cost et cetera, because you have to push water into the deep aquifers. And the successfulness of these shaft also greatly depends on the design, the stability of the soils et cetera. So these are good methods that we could use.

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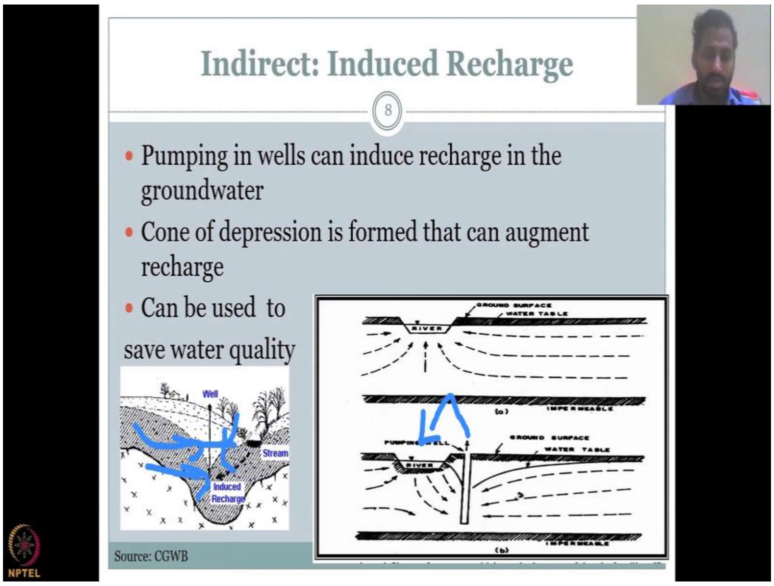
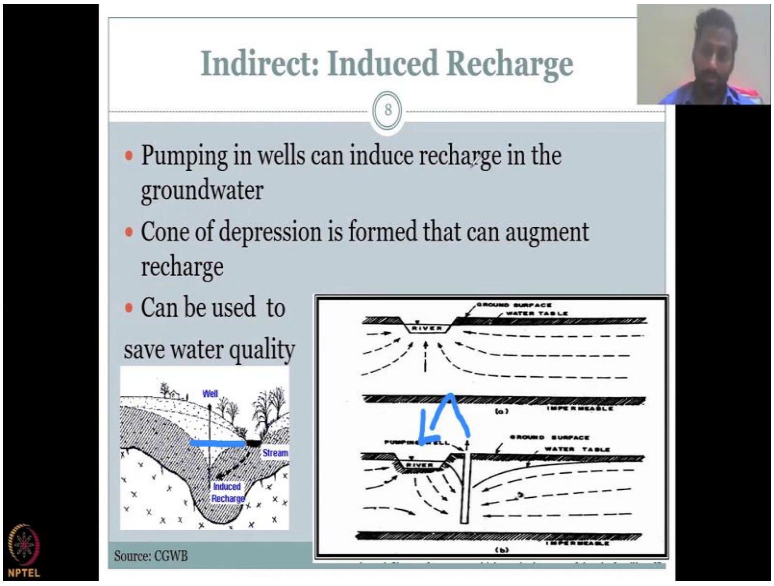
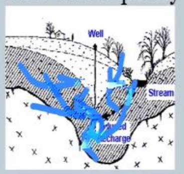


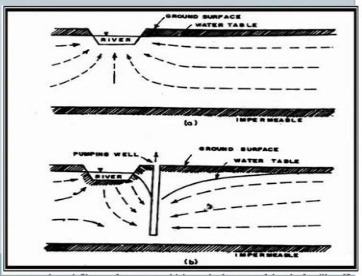


Indirect: Induced Recharge

8

- Pumping in wells can induce recharge in the groundwater
- Cone of depression is formed that can augment recharge
- Can be used to save water quality





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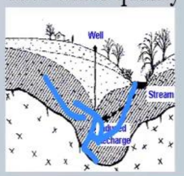

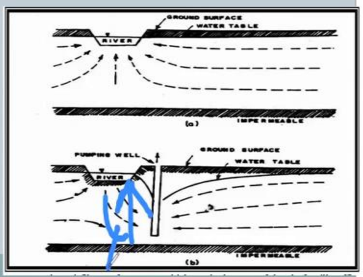

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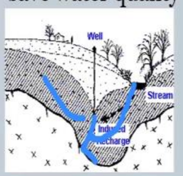

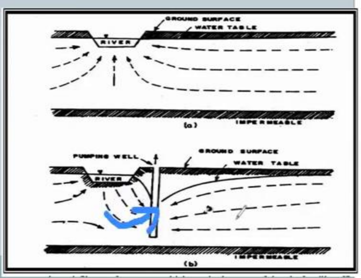

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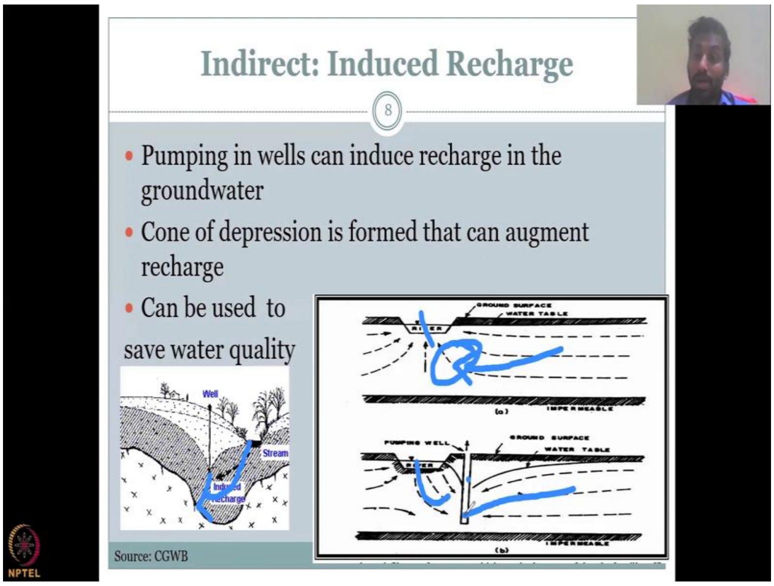

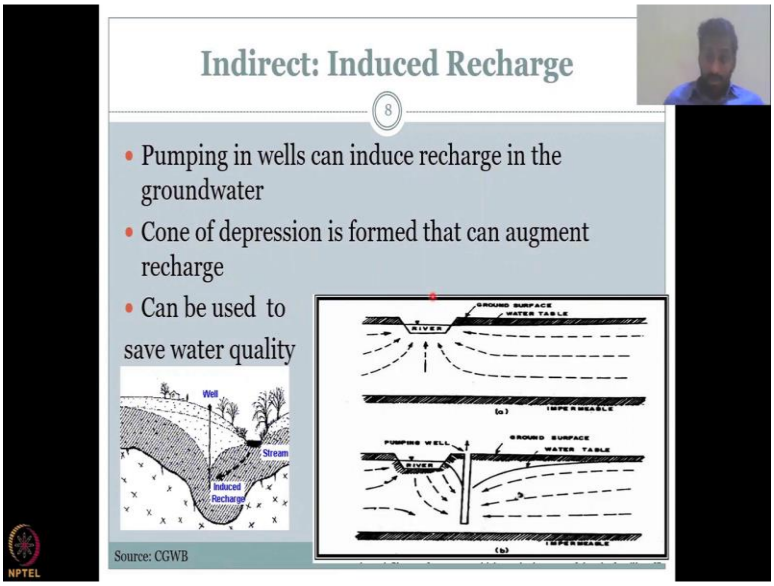

The last method for today is the indirect method. We are wrapping up. We have looked at all the direct methods. Now we are going to look at the last, which is the indirect method, indirect recharge method. And it includes an induced recharge. So it is not a natural, all of these are artificial recharge methods. Whereas your induced recharge is, you do something to promote the recharge. And that something is not actually a recharge work.

So for example, you are putting water into a well, and that the well is recharging. It is an artificial recharge method, and you are putting water in to directly impact the groundwater level. Here, you do something else. However, there is an induced effect on the aquifer. Let us see how it happens. So pumping in wells can induce recharge in groundwater. So take this example from CGWB. So this is the normal river, and then groundwater is recharging and going into the river. The river is raining river.

However, in induce, what happens is, you put a well right next to the river. And if you pull water very fast through a pump, like a groundwater pump, you are pulling the water, what happens is these lines will move much faster, and therefore this well is going to be recharged more. So you are pulling water from other sections, and inducing a recharge in the well. And that induced recharge can lead to a successful implementation plans because you are combining all water into one location.

In fact, in the city of New Orleans in the U.S., there is a lot of induced recharge activities to bring good water, and remove the good water out of the system, because there the land is below the sea level. Let us take another example to study this well. So initially, the recharge or the movement is very less into this area. Water movement into this area is very less. And that was because the water table was at the same distance as the stream. Just look at it. The water portion was at the same distance as the river.

However, what is happening now is, the water is taken from the stream and then goes into the recharge well, and then, thereby the water level in the recharge well increases because you are pulling water more. So because you are pulling, this river water which was initially going up, now is coming down because it was having more pull from the tube well. And that is what is inducing the recharge.

Because of this pull, sso for example, here, the water was only one direction. So from here, the water was recharging, and then going back to the river. However, now this, the same point is getting water from the river and also getting water from the neighboring location, thereby increasing the recharge into the well. So this is how both direct and indirect methods can augment and increase the recharge at a particular location.

So pumping in wells can induce recharge in the groundwater. Cone of depression is formed. As you can see here, a cone of depression is formed, which actually leads to more recharge water moving, and can be used to save water quality, as I said in the example, I gave.

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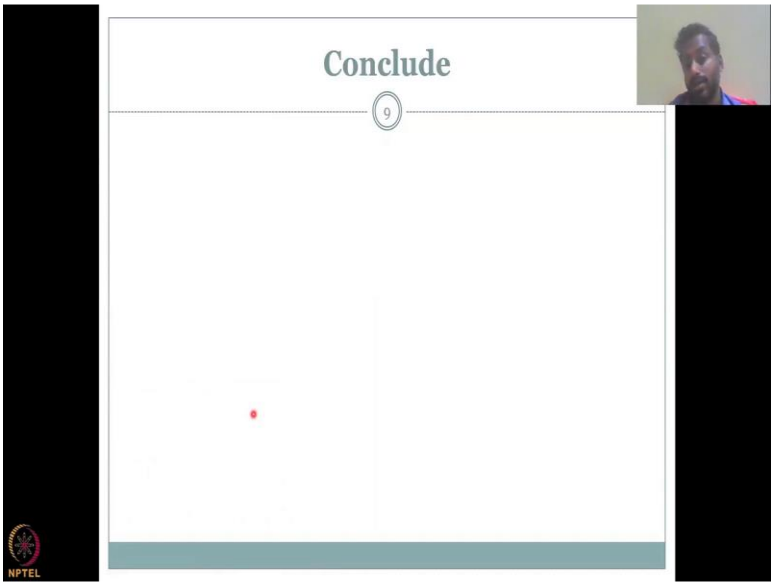

So with this, I conclude today's session where we wrap up the direct and indirect methods. I will see you in the next class. Thank you.