Rural Water Resources Management
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Week 03 Lecture 04
Groundwater

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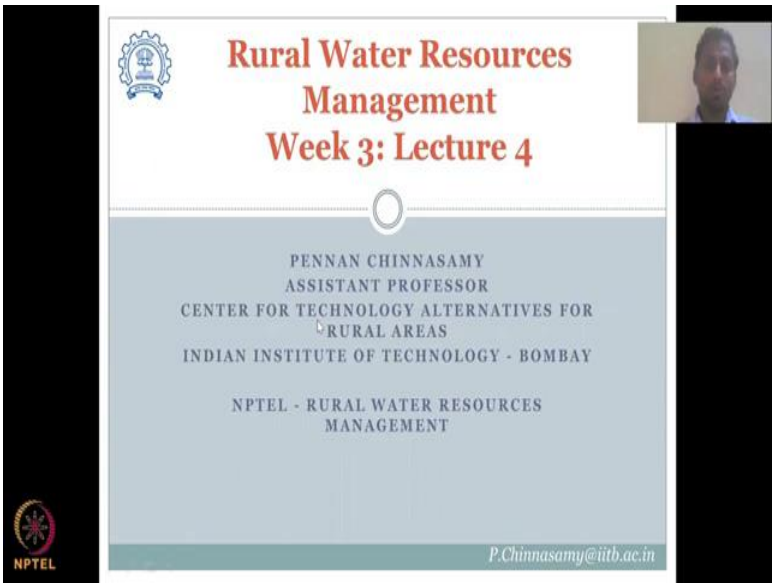

Welcome everybody, to the NPTEL course on rural water resource management, week 3, lecture 4. In the last lecture we looked at groundwater as a hydrological cycle component, groundwater storage and groundwater induced base flow. So we looked into the some properties of groundwater and in today's lecture we will see how groundwater has been managed or monitored across India, because it is a important resource for rural water management, but we will be spending one more extra lecture on groundwater.

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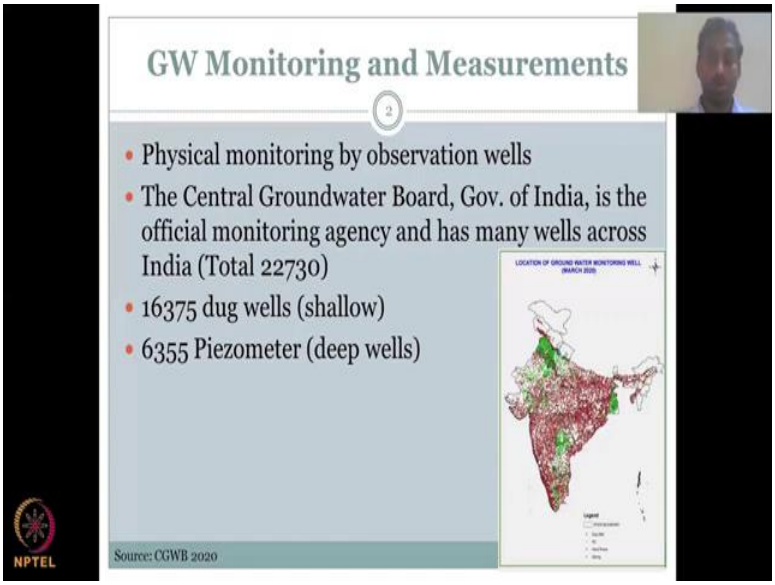

Let us start with groundwater monitoring and measurements. As I said previously, the Central Groundwater Board in short called as CGWB is the authority for groundwater monitoring and measurements in India. This is a central government agency. On top of this, every state has their own monitoring and measurement agencies for groundwater, mostly it will be with the PWD which is the Public Water Department or Irrigation Department, etc.

So, they will have their own wells or they have in collaboration with farmers, they will have a monitoring network where they look at water depletion, they monitor the water levels at regular intervals and have access to these wells.

Let us look at the central government program. So it is based on physical monitoring by observation wells, it is along modeling, they do not assume but they actually measure which is very important for groundwater monitoring. The Central Groundwater Board is the official monitoring agency as I mentioned and has a total of 22730 wells as per the latest reporting.

So and the location of the wells is given in the figure here wherein you see a lot of wells along the most important states for agriculture, some less number of wells in Rajasthan because it will be deserted area or very semi-arid, terrain conditions, not much groundwater, etc. And you do not see wells in the hilly regions.

So, if you remember the lecture from previous week, and also the couple of lectures before this, we mentioned that for the groundwater to be available, you should have a soil plus weather material, if it is purely rock as you can find in the hilly regions, you would not have that much groundwater.

So, it is not that important to monitor regularly in these regions. So along the borders, you do not see much groundwater monitoring, but if you see in central India, wherever there is good agricultural activities, you see a good spread of monitoring wells.

Around 16375 dug wells are for shallow aquifers, please understand the difference as we explained earlier, a shallow aquifer would be from the top of the land surface up to a confining layer impervious layer. After the impervious layer, you do have another aquifer which could be your deeper aquifer. So, that is monitored by piezometers, it is around 6355 piezometers for accessing deep wells.

So, what is the difference between these two? The dug wells are mostly in shallow which is approximately 30 meters and you would normally measure it with a tape or you would have a static measuring device. But for piezometers which is a tube, which goes very deep into the ground more than 30 meters. So in some of regions you say that groundwater is at 300 meters.

So, in Chennai I would remember people complaining that the groundwater level has fallen to very, very low levels like around 300, 250 meters, etc. So, at that level you cannot have a tape and a measure, so you would have an automatic monitoring device and that setup is called a piezometer. A piezometer which is one which goes down in the deeper aquifers.

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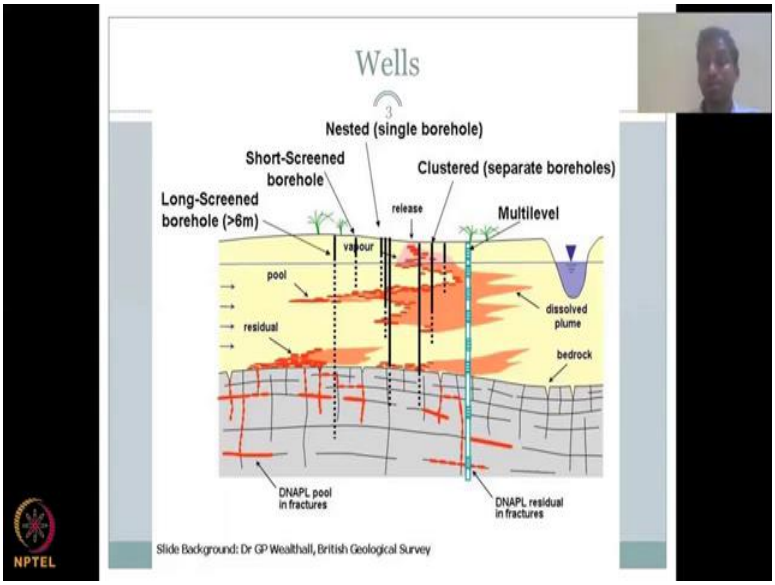

So now we understood that the government is actually monitoring both shallow aquifers, most of the wells is tapping into the shallow aquifers. Let us see how you put in, let us differentiate between shallow monitoring wells and a deep monitoring wells. So this image is

from the courtesy of British geological survey, where they have done a lot of work in Nepal and bordering regions of India on assessing our water, how they would do it is almost common across. So let us look at different methods.

So, the first one is just normal long and deep well. So, this could be your piezometer, where you would put in your bore well and a piezometer at the bottom and it is screened along the well, which means water can come in through all areas into the well and you would actually measure the water level from here. Sometimes you do not need to go deep as the bedrock but still here you could see the fractures present and water is present. So, it is okay to measure into the very fractured network.

Then you have a short well which is for mostly your dug wells. So, the 15,000 plus, 16,000 plus wells that we saw in the previous slide is mostly of this nature. And then you have the difference between them you could see clearly that it is measuring the shallow aquifers, the water is moving from left to right and into your streams, you could see that the other well is also screened from that same level, from the water table, but goes throughout the aquifer until the bedrock which is here.

Then you have a nested single bore well. So, this is a very important phenomenon, because you would like to see at a single point how the shallow aquifer responds and how the deep aquifer responds. Because in this example, you have it isolated. So, you have a deep aquifer monitoring and then you have a shallow aquifer monitoring.

But in this diagram, what you see is a nested, nested means together nested. So, in nested configuration, you have around three different wells monitoring the same aquifer, very, very close that is what is called nested, so that you capture the same aquifer dynamics. So you have here, it is going into the shallow aquifer the first one, the second one would be going into somewhat between the shallow and the deep aquifer and the third one is going to deep aquifer.

So, at a single point, you are measuring three different aquifers at the same location. This will give you a better understanding of how the shallow and the deep aquifers react to pumping, because some instances when you pump too much shallow water, the deep aquifer is also suffering because there is less recharge happening.

And then you have clustered separate boreholes, so similar to nested but cluster and a little bit separate. So you have it spaced out evenly to measure water and also the pollutants how they

move. So these wells can also be used for water quality assessments because they can take a sample out, for water levels, you do not need a sample, we just put a meter in or a tape in and measure, we will come to the devices later. But for water quality, you would take a sample of and then take it to the lab or do in situ water quality measurements.

And then you have a multi-level, where, wherein you could actually take water from different depths by openings at different levels. This is mostly for water quality assessment, where you would stop and then take a sample here from the seepage. So when water is coming in from the side, you take a sample and then go down take another sample, take another sample.

So these are for the water quality, but I am showing it mostly for also water levels. So, you now have a difference of opinion between how you would monitor a dug well, which is a shallow well, which is using a single well monitoring well. Then you can also monitor a deeper or a nested or clustered well.

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So what are the different methods that we could use for measuring ground water level and how are they connected? So for this, you could have a steel tape and chalk, which is basically steep tape with measurements and you put in chalk one, so when you put the steel tape inside the well, the chalk could be washed away by water and when you pull it out, you know where the chalk has been washed away. So that would give you the depth from the top how deep the aquifer is or water level is.

Then you have similarly electric tape same method but it gives you a light bulb or a sound when it touches the water because the electrical connection is made. Pressure transducers put

in piezometers, where piezometer is a well which goes deep. As I said pressure transducers is an instrument, where it can actually record a pressure difference between because of the height of the water and when there is a change in water, it would record the change in pressure on the instrument, it is a very sensitive instrument which means it can easily captures even small changes in groundwater level and it is one of the best methods to use, but it is a little bit expensive.

An acoustic probe, ultrasonic, etc. use the sound wave properties to go in and come out to tell the water levels from the well and floats, poppers, air lines, etc., etc. So, floats and poppers are same like it just floats on the water and then you make an electrical connection etc. So, these are for non-flowing wells, which means a well which is it yes, it recharges so, it flows into the well, but then it is stationary, it does not move up and down when you see the water.

So, because at a very quick instance you cannot put the chalk in and take and then say it is moving, the water is moving. So, you will have to wait till the water stabilizes. So, that is what we call non-flowing wells. So water can recharge let us say it recharges in the night; in the morning, when you come and see the water will be at a particular level, you take a measurement out.

So to be consistent, it is always good to measure the water level at the same time every day. So for example, every month you want take a sample you go on the first day of the month, the first day of the month, you should at the exactly same time, let us say 6 o'clock in the morning, you will go to 6 o'clock and take the measurement, so that it is comparable.

Then you have the flowing wells, where you have a well like the artesian well. So, the artesian well is a well where even without pumping the water will come out, why will it come out? Because of the principle I told earlier, water flows from high potential to low potential, high pressure to low pressure. So, this water inside the aquifer, the confined aquifer or the deep aquifer is under tremendous pressure because of the mass on top of it.

So, it will be pushing the water down, it has pressure, it cannot go anywhere, the water because underneath is also an impervious surface. So, the water is under tremendous pressure and when you put in a well, just a bore a hole inside what happens is, you will see water just gushing out. Because outside atmospheric pressure is much lower than the pressure inside. So the water will come out until the pressure inside the confined aquifer is equalized.

So how do you measure flowing within that? Same transducer, pressure transducer can be put in because it is very accurate it can quickly measure and a manometer or pressure gauge on top of the well, where it measures the water or the pressure difference. So in most cases, you will be using as the central groundwater board etc., you will be made using a tape method. So this is the tape method and electric water level tape method, pretty expensive for the technology.

And what you do is, you would lower this probe, you could see the probe, you could lower this probe and this is a meter which has the markings of SI units, which is centimeters or meters. And then you would leverage it in, so you could see me putting the meter into the groundwater level, groundwater wells in both the cases. And then when it goes in and probe touches the water the connection is made.

So there is one wire which goes on this side and another wire on the other side, those are not connected, so the two wires are not connected. But when the probe is also connected to these two wires, so when the probe touches water, water makes the connection between the two wires and then you hear a beep or light. So the beep sound or light will come around here and you would stop lowering the probe and that level you would read off from your meter. So that is basically how you would measure groundwater level.

Please understand that from the base of the well, so if this is the land, this is the well you would measure from here going down. So, it is a depth to water level, then you will have to convert it back to height of water level. So from here, you know 0 you would estimate the water level by just knowing the distance from the top to the water level. So for example, let us do an exercise.

From here the water base is zero 0 you know that the well is at 15 meters and the water is at 10 meter depth. So, what would you do? You would subtract 10, 10 from 50 to get 40 meters. So, from 0, the water level is at 40 meters and that is how you establish head. In the groundwater class, I would go through again on these exact same methods, but here it is good to understand how you collect groundwater level data.

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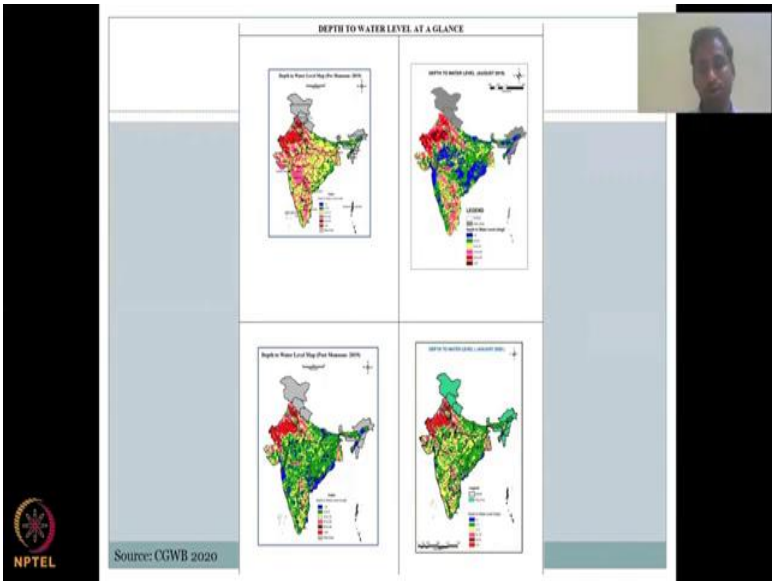

So, now, we have collected the data. So, what is what a Central Groundwater Board do? They collect four times a year and these are the months or seasons they collect pre monsoon. So, somewhere in the peak of summer June or I would say May and then you have another collection during the peak of your monsoon, here it is August and the post monsoon, after the monsoon as one or two months, so let us say it stops in September, you can take it in October, and then November, December, January for the winter.

So, approximately three months in between they take a sample. So, these depths to water level gives a lot of inferences. So, here they do not do the head which I told earlier, they do a simple depth to water level. So basically lower the meter and from the ground how deep is your groundwater level.

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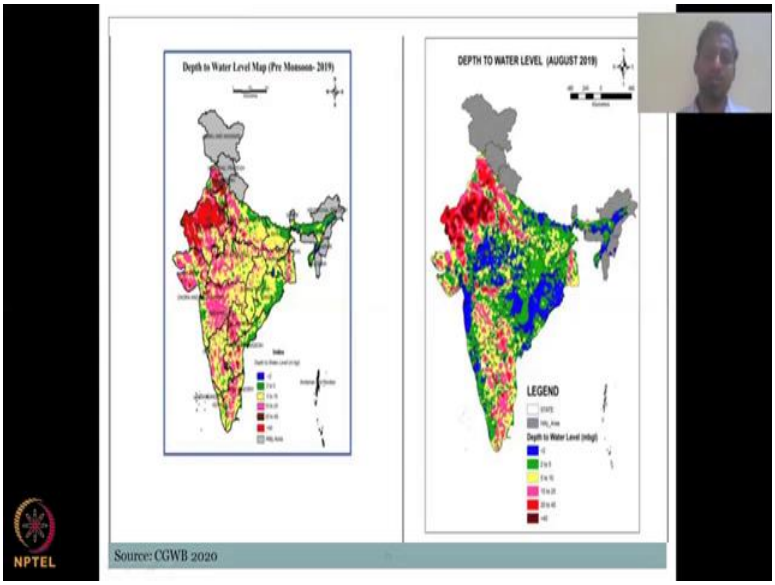

Let us see what this exercise helps us to understand. First taking the pre monsoon or the peak summer. So summer you have the depth to water levels in meters below ground level. So meters below ground level MGL, a unit MBGL meters below ground level.

Now what you find here is less than 2, 2 to 5 the coloring is the same. So I read it up from here, starting from 10, 10 to 20, 20 to 40 and greater than 40 meters. So anything greater than 40 meters is pretty deep. So, they would say that it is pretty red in color, which means kind of dangerous, whereas less than 2 is okay, it is a good number.

In the summer season here in the pre monsoon level, you would see that most of the hilly regions are still okay in the blue and green color, I would say the coloring scheme is really good, how they picked up the colors for the levels because it tells a warning signal. So here blue and green means good water, water is blue in color. So, when you see blue and green color, that means the water levels are healthy.

So, here along these regions it is healthy, the hilly areas they do not collect water levels as I mentioned, because it is very hard to drill down and get the water. So, there is no point of setting the water levels there not much has been done and then along the borders. So, you would see that wherever the Western Ghats is the water levels are pretty okay compared to the central and the eastern part, north eastern part.

So along Rajasthan and Gujarat and central India the water levels are pretty bad in terms of depth, which is really concerning because as the depth increases you have to supply more energy to take the water and as the depth increases the water quality changes and the time of

recharge also changes. So, it takes longer time for water from a deep aquifer to recharge. So, it is very important to understand this map of pre monsoon water levels the summer.

So, once you understand this, then we have your summer is gone. The monsoon comes in in June, July, August. So, you have the peak August monsoon month and you could see that most of central India is turning into blue and Western Ghats in Maharashtra where we are from the water levels are pretty healthy along the Western Ghats.

After the Western Ghats, you could see it is not that good. This is because of when the precipitation I taught you. It is because of the orographic effect, the rainfall picks up on one side of the Western Ghats, whereas on the other side it is totally dry. So what you see here is the central India is now turning into blue in terms of healthy water levels. So what levels within 2 meters from the ground, whereas the Rajasthan part and other parts are still really, really bad in terms of groundwater, but it is turning slightly into pink from dark red and red into pink.

And then you have the southern region where tremendous agriculture activity is happening. Still, you do have less groundwater but also it is because of monsoon is not the same. So most of you gets the monsoon by June, July, whereas this part gets it later and we will see it in the next images.

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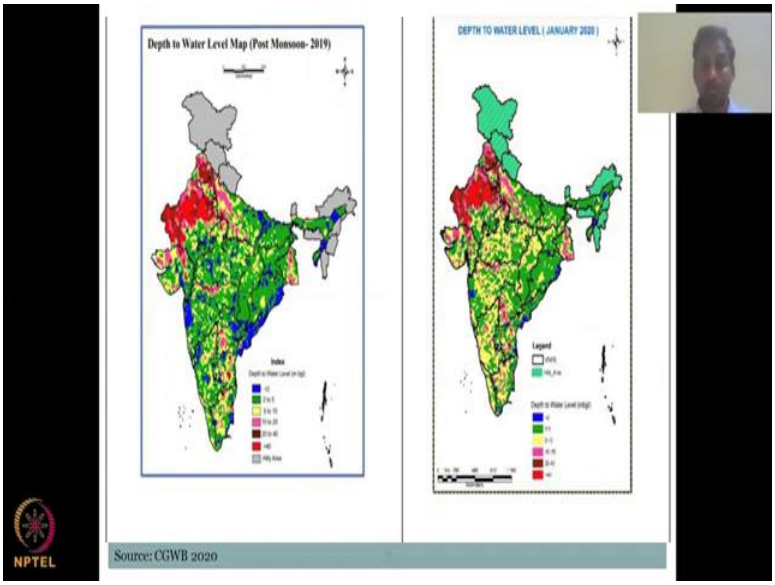

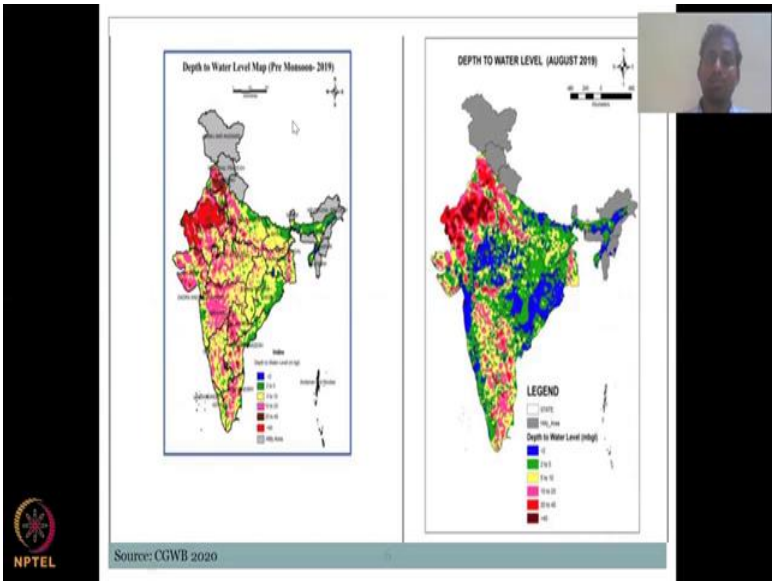

And this is a post monsoon map, mostly around September, November. And you could see that most of these regions which were blue have turned into green which is still healthy. So 5 to 10 is yellow whereas 2 to 5 is green. So, somewhere it is still okay to be pumped. So, from 2 to 5 meters, they are pumping the water, the water levels are not fluctuating much. And now, you see slowly the southern part of India also turns green.

So, there is a land between the precipitation that occurs on the Western Ghats and central India and then one or two months later, Tamil Nadu, Kerala, Andhra, Karnataka gets their rainfall, gives a share of rainfall. So, you see that water levels have actually stabilized in most of India except your Rajasthan and Gujarat regions.

And then in the winter season January, again the water level slowly starts to deplete, it could be because of water use or also because the water would be slowly going into base flow, the groundwater and the base flow goes into the rivers, rivers goes into the oceans and seas. So, the water continues to move and this understanding is very important that it is not like water will just stay there, groundwater. So, up to some level it stays but once it goes beyond a level it will start moving to the 0 level which is a sea and ocean.

So, what do we see here if the pre monsoon, which is the pre monsoon of 2019 is the same or similar from the pre monsoon in 2020, then it is okay. Because every year, you kind of take the water and put it back during the precipitation monsoon season. But if it is not the same, imagine like a bank account.

So you have a bank account, you have money before four months you make some money and during the precipitation peak season which is a monsoon you put back some more money and

if the first year of analysis and second year of analysis are the same, the water levels are same, you are okay. It is sustainable we would call, most literally it is sustainable, because whatever water you use the precipitation is putting it back into the normal water aquifer, so you are fine.

But that is not the case because what is happening is slowly it comes low. So, let us say if it was 10 meters in pre monsoon conditions, in the next year it becomes 11 meters and slowly the depth to the water level is increasing. And that is why you see more and more of these blocks converting into red color, red color is pretty bad in terms of the water.

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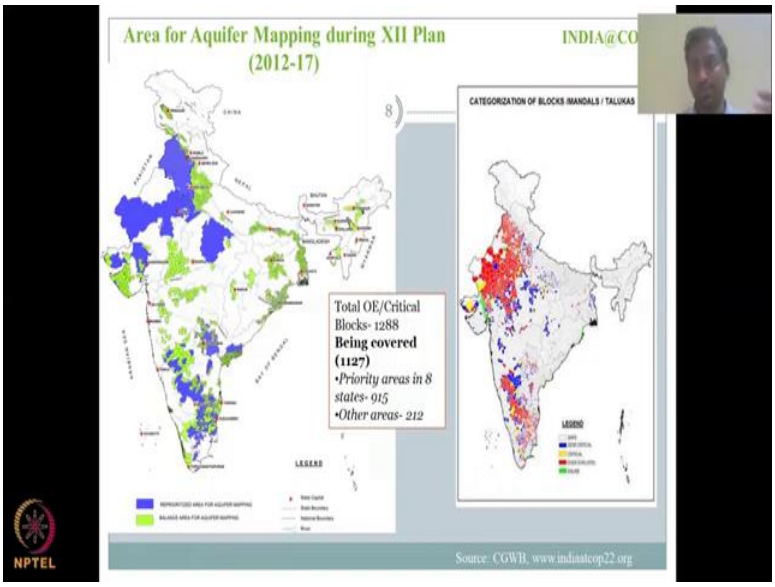

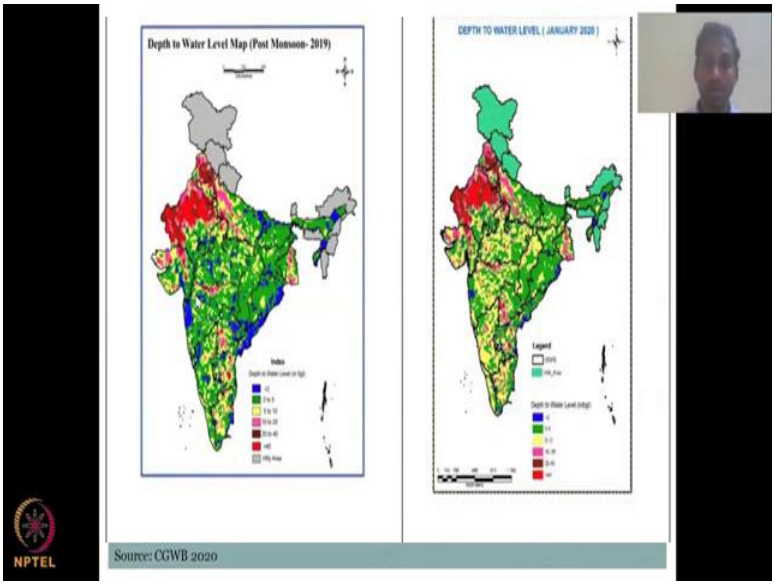

So, now the exercise has been done. So they have 4 times a year and then they estimate how much water recharges, so if you know the rainfall and if you know how much level the water

level has increased, for example, from 10 meters it has increased 2 to 5 meters and here you had all these regions around 10 to 20 meters the groundwater and later after the pre monsoon, post monsoon it has come to green color which is two to five meters.

So by that you need to understand that the recharge has happened. So, if the water use is equal to your water you put in it is safe and semi-critical and if you almost come close to the water use is almost equal you become critical because you need some water for the ecosystem services and rivers as I mentioned, but then when it goes above your groundwater available for example, your extraction is more than your recharge, groundwater recharge then it is enters the over exploited state.

So the Groundwater Mapping Committees of India to Central Water Board etc. So, they have actually put in a plan to map aquifers, so because unlike your surface water, aquifers and groundwater do not have a watershed boundary. They do not follow an administrative boundary. A dam can be put in a state and you can make sure that the water does not go to another state by channelizing the water.

But you cannot do that for groundwater. Rivers can be stopped, blocked by check dams but you cannot do that for groundwater. So that is why they have been doing an aquifer mapping. So you could see here where they are mapping and how did they pick these locations? Because they know how many, this is the Central Groundwater Board and understanding where the safe, semi-critical and critical blocks are. They have colored it red for overexploited blocks.

So if groundwater is more abstracted than the recharge, then it is an overexploited. So, those are the blocks they want to map the aquifer. So that they could do some water management plans, groundwater management plans. So, this is where we need to be careful in understanding how many areas have been demarcated. So, for example, total overexploitation critical blocks are 10288 of which the aquifer mapping and some management activities are going around in 1927 blocks.

The priority areas in eight states including Rajasthan, Gujarat, etc. and other areas around 212. So in other areas, you have 212 blocks for example, in Tamil Nadu, Kerala, there are some blocks that are there monitoring. So, these are the areas for prioritized aquifer mapping, they want to map the boundaries of the groundwater storage and by mapping they have now a

better idea to put in structures or control the demand of water by saying you cannot pump more than this volume or you cannot use a particular crop.

For example, if it is sugar cane or banana, you cannot use groundwater. So, that kind of regulations they can put once they have the aquifer mapped the boundaries and they have this map of where the critical blocks are. So, almost Rajasthan, Gujarat, Punjab, all these regions are under the scanner for better water management.

And also people are slowly understanding that if the groundwater is being depleted beyond a point, then your river flow is also reduced and because of that, your surface water irrigation or the water you use from the rivers and dams for irrigation also is questioned, it reduces. So that is where slowly farmers and every agency is putting more focus on mapping the groundwater, reducing the use of groundwater and also managing better recharge techniques for groundwater.

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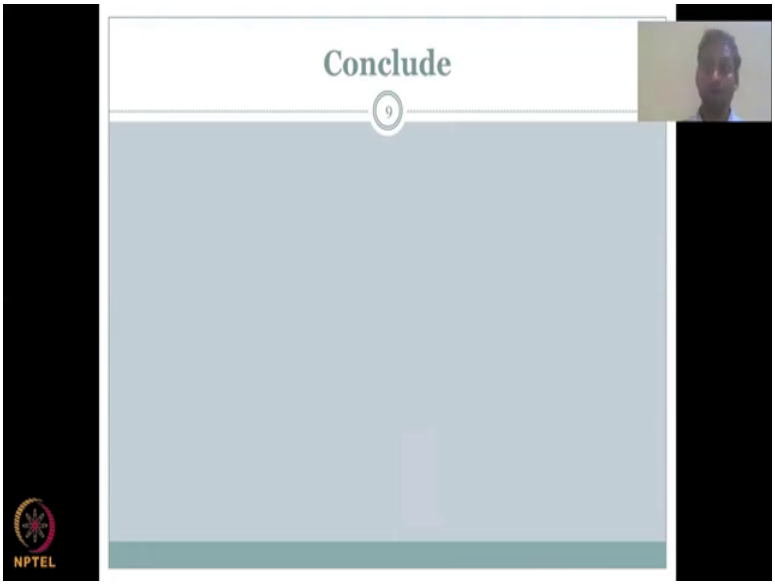

With this we are covering the ground water sector. And in the next lecture, I will go through the recap of for this week and some more examples, and we would conclude hydrological examples. Thank you.