Groundwater Hydrology and Management
Professor Pennan Chinnasamy
Centre for Technology Alternatives for Rural Areas
Indian Institute of Technology, Bombay
Lecture 14
Indian Aquifers

Hello everyone, welcome to NPTEL course on Groundwater Hydrology and Management. This is week 3, lecture 4. In this week are looking at some important components of Groundwater Hydrology and we have been defining what is groundwater? How is it stored? And what are the key components?

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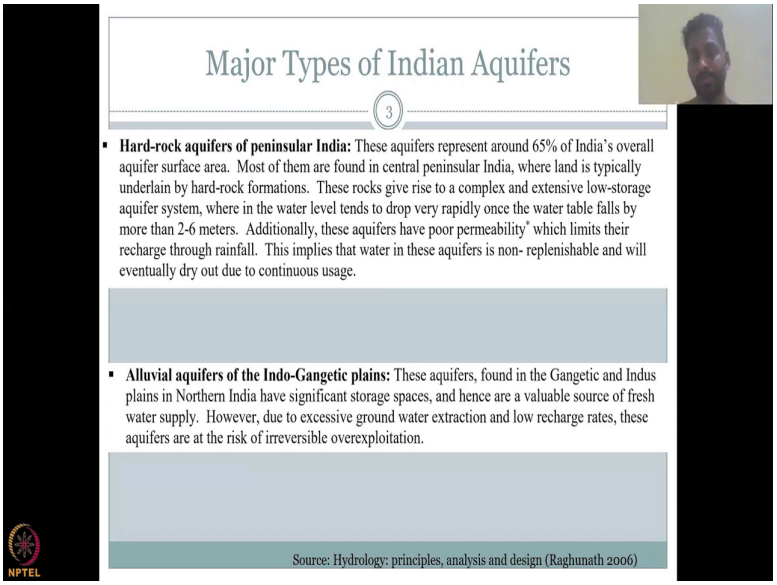

In today's lecture, we will be applying the understanding to differentiate the different Indian aquifers in subcontinent. Since, as I mentioned earlier this course will be focused more on the Indian groundwater system, we will be looking at the Indian aquifers. At this point, I also want to stress that groundwater is very important for India. It is one of the most important freshwater resource in India if not the most.

It accounts to almost all of the Rabi season, cropping in major seasons and major regions of India. And also, we are ranked number 1 in groundwater extraction. So, the major types of Indian aquifers are hard-rock aquifers of peninsular India which is present around 65 percent of India and it covers most of the surface area. The central India would be housing most of these hard-rock aquifers.

So, aquifers were defined in the previous lecture wherein, it is the unit of storage inside the groundwater profile where you have pore spaces and solid medium and waters is filled in the pore spaces. The aquifers can be confined and unconfined. So, what do you mean by hard-rock aquifers? It is underlined by hard rock formations the rock is hard well all are hard.

So, you would ask me what is the difference hard-rock means, it is hard to crack and whether So, because of that there is least weathering and the weathering is almost on a single line or a fracture and because of that there is less pore spaces the rocks are kind of platy and are, or on top of the other with less space in between. So, suppose you have a rock like which is having different dimensions it is not smooth, it is not circular.

So, what happens they cannot overlay on each other and so there is space in between however, if it is platy like this and there is only cracks in between it still can gel together with less space and that less space gives rise to only less groundwater. So, as the writing says on here, these rocks give rise to a complex and extensive low storage aquifer system no storage because water takes time to get into this system and also it is hard to extract water out.

And it rapidly falls once you extract more and more water and the permeability is very low, how much water can pass through the system is very low, pass through the rocks is very low. So, there is both recharge low, storage space is low and also when once you pull it out, the next recharge is very slow and there is no connectivity much between the aquifers. So, this implies that the water in these aquifers is not replenishable are not quickly replenishable and will eventually dry out when you use it continuously.

Given that it is almost present in 65 percent of India. It is scary to say that this is the water that is being depleted constantly and is not being recharged. So, all the benefits that the farmers and industries and domestic users were enjoying by using water from these hard-rock aquifers will soon face shortage, if not now and their attitude in using water has to change or will be changed. What are the remaining aquifer? Remaining aquifers are called alluvial aquifers are the Indo-Gangetic plain or alluvial aquifers.

So, you do have a alluvial aquifers to the southern plains in the Kaveri delta and in the western side along the Narmada region. So, most of it is in the Indus, Ganges and Brahmaputra region, but the majority of alluvial is formed in the Ganges plains. So, these are in the northern India and have significant storage spaces and is a very valuable source of

freshwater supply. The Ganges basin, the Ganges area totally can support more than a billion population both using surface and groundwater.

When you say a billion population is supported that means, almost one person every seven of the world population is supported by the Ganges basin, such an important basin, and there is a lot of groundwater storage there. However, due to excessive groundwater extraction, and not as fast recharge rates, which means the extraction is happening 10 times the natural recharge rate, you are taking money like 10 times in a day and putting only once in a day the salary or less take in a month.

So, that means you are extracting at a much faster pace than the natural recharge. These aquifers are always at risk of irreversible over exploitation. What do you mean by irreversible? Is once you go below a particular water level, you cannot recharge the water and that actually would cause tremendous stress on the groundwater ecosystem in the Ganges basin.

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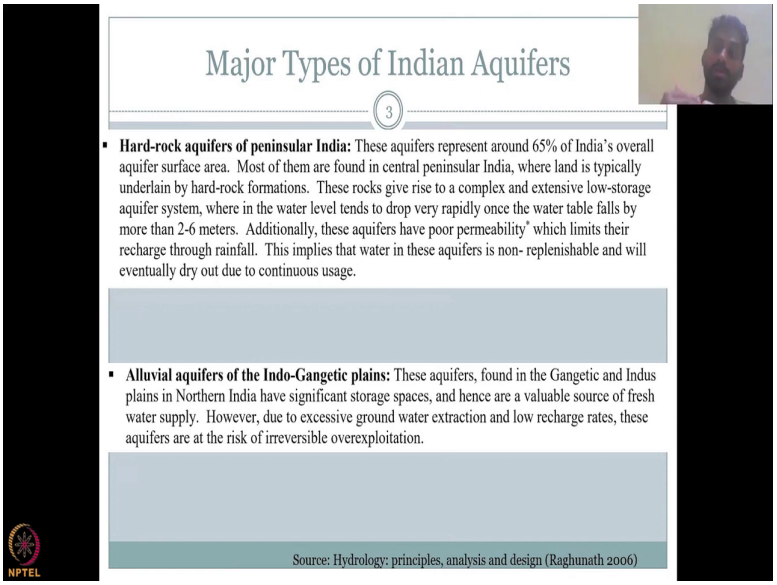

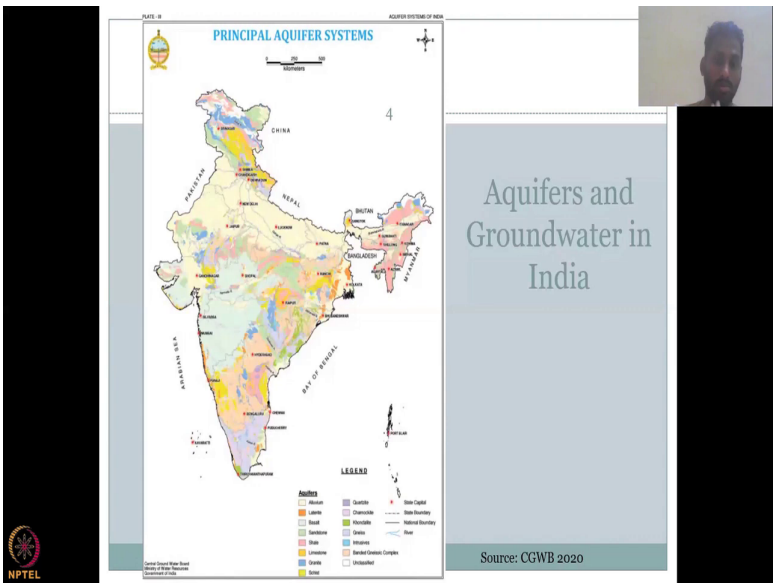

Let us look at this visually because visually you could make more sense of what is happening and what are the driver forces, so principal aquifer system. First, we will deal with the alluvial aquifers. Alluvium is the term which comes from deposition of minerals, solids and sediments through water. So, you have water carrying the sediments and it deposits along the way.

So, these waters could come from the Himalayas and in between regions, it carries a lot of sediment and sediment are fine particles, if they get deposited then water can get into these sediments because of the pore space. Sediments have a lot of pore space. So, most of the yellow region here, which is the Indus, the Ganges, the Brahmaputra, or all alluvial aquifers, very high yield.

There is some here also due to the Ganges basin and etcetera and here you have some on the Kaveri Delta region. Here you could see on an Narmada Tapi region, what else do we have? We have the laterite in orange, very less amount. So, let us concentrate on the major aquifers. So, first is your alluvial on the picture and then you have the hard-rock basalt aquifers. So, the term basalt comes because of the nature of the rock the name of the rock, and basalt itself is a hard-rock.

So, when in the previous slide when we mentioned hard-rock aquifers, it is not the term given to the formation of rock it is the rock itself is a very hard rock and it does not disintegrate that fast. There are multiple types of hard-rocks and that is what we are seeing here in this image. The blue colour which represents the basalt and the orange colour, more in the laterite and

limestone etcetera and granites, granites in the blue colour all constitute your hard-rock aquifers.

In Southern India in Tamil Nadu and Kerala region you have the Quartzite and those also constitute your hard-rock aquifers very, very less groundwater potential and nieces, G and E, SIS. This is all these are your geological terms for the name of the rock and the rock is a type of a hard-rock because it does not have enough space, porosity is low, permeability is low, it is very hard to weather the rock and because of that there is less groundwater storage potential in the aquifers.

Moving on we also have shale along the north-eastern region pretty much covering the north-eastern region and here you have the hilly regions, cyst formation very, very hard-rock not much groundwater potential. All those are the Himalayan regions and you would expect a very less groundwater potential there. So, the principal aquifer systems is again based on the geology.

First is you need to have a container to pour the water and that container or that storage unit is your groundwater aquifer. And the aquifer is a function of your geology means you see here is alluvial aquifer etcetera. So, here do not confuse between the unconfined aquifer, confined aquifer and alluvial. Alluvial and the names you see here is predominantly the rock material, but when you say confined versus unconfined, it is the presence of a impermeable membrane or a rock surface and how it recharges.

So, it is more of a function of recharge whereas here it is a function of the geologic material. So, you can have a hard-rock confined aquifer you can have an hard-rock unconfined aquifer. So, the unconfined, confined can be added to your hard-rock and so, there is only two types of aquifer system based on the recharge and movement of water which is confined and unconfined.

And the geology can pull be put in front as hard-rock aquifer or alluvial confined aquifer, alluvial unconfined aquifer. Here we are just looking at the base material which gives the space and rock materials for your porosity to happen and that porosity stores groundwater.

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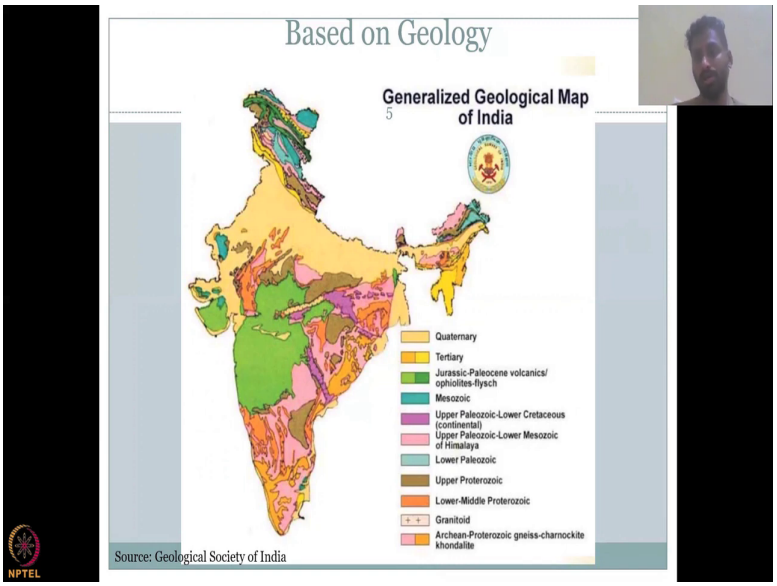

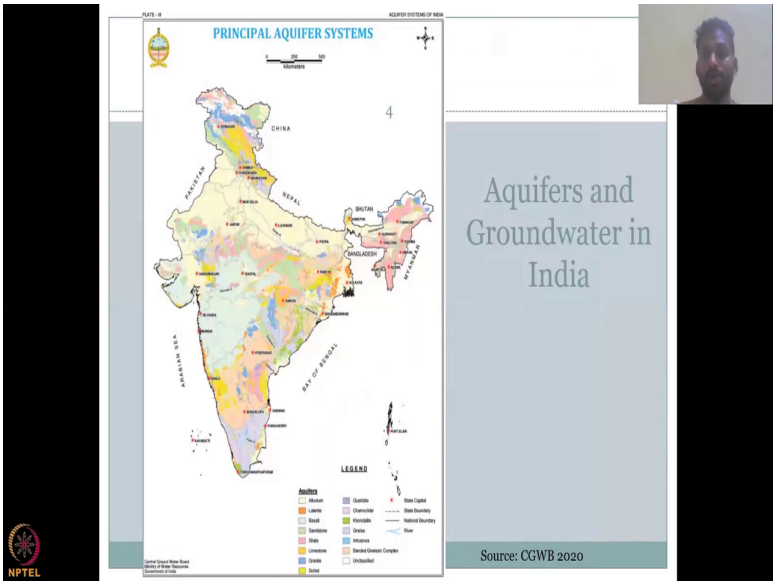

Now, we will take another map by the Geological Survey of India, the previous one was from the Central Groundwater Board, where they do a lot of work on groundwater, whereas this one is based purely on the geology. If you look closely, the geology does not change much between years or even decades, because only the weathering happens, but the material is the same.

So, if you go here and see quaternary it is only going to be quaternary for 100 years, 1000 years and it can change only the density or how it weathers, geology is the same it does not change much. So, this is a permanent property of the location and depending on how it weathers the porosity formation happens and, in that groundwater, can recharge. So, based on

the alluvial aquifers, you can also have the same method here most of central India is having the Jurassic Geology content.

Whereas, along with your upper Palaeozoic and lower Mesozoic of Himalaya Geology type and your alluvial aquifer plane where you have Indus, Ganges, Brahmaputra etc, those are the quaternary geology. So, the geology also coincides with the alluvial aquifer mapping. So, that is what I want to show here that your geology plays the key role in formation of these alluvial aquifers. And then when water comes in the storage happens and depending on rainfall and your extraction, recharge and discharge, the groundwater yield and potential can be mapped.

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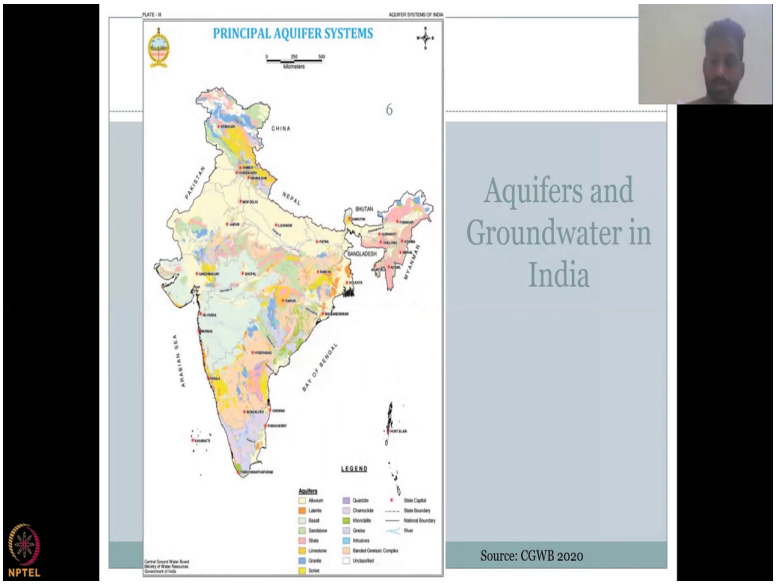

So, you could see that both the aquifer map and the geology map are almost similar and they derive the names between each other. The geology plays the vital role in hydrology we call it hydrogeology, which means a geology which is used to explain the hydrological component. Here it is the groundwater storage. And so, we call the groundwater parameters in the geology, plus hydrogeological components.

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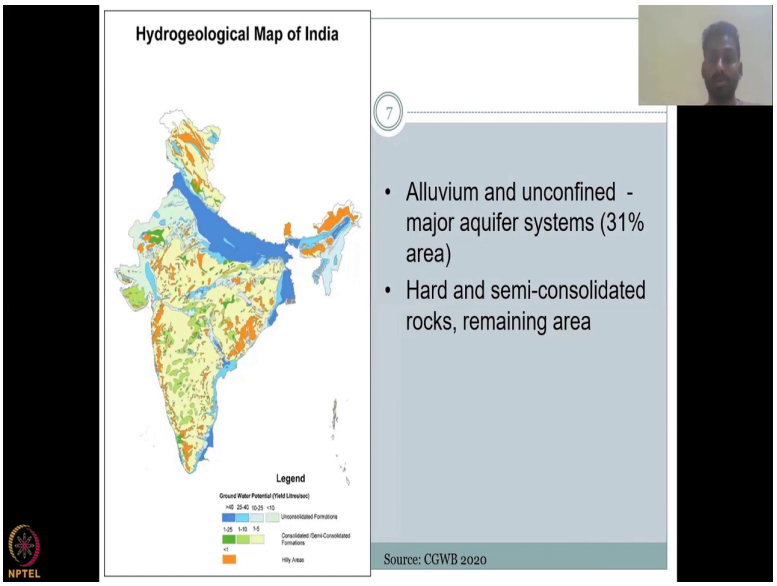

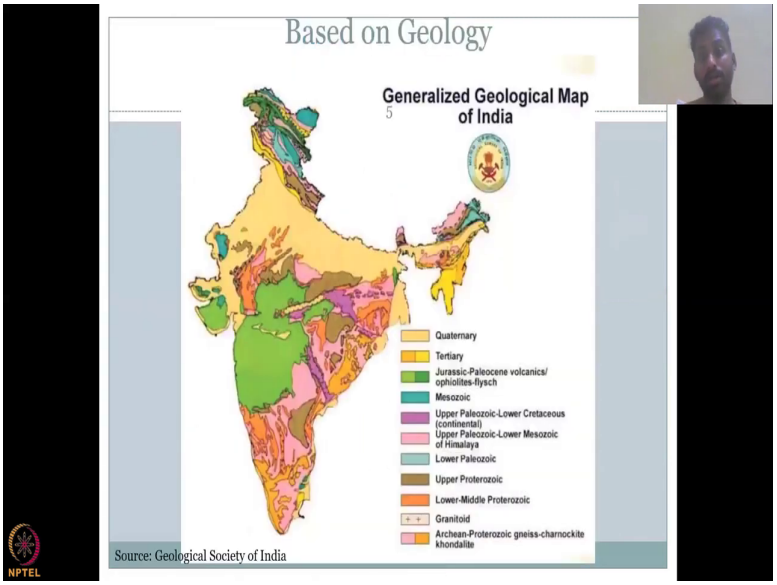

Moving on, let us take a look at the groundwater potential and yield that happens in these different aquifers. The aquifers are mapped again as per how much groundwater you can extract per second and it is given a yield at litres per second. So, you have the alluvial and unconfined the major prefer systems, one of the major aquifer systems with 31 percent of the area, you have dark blue and light blue which are covering them.

You could clearly see that along the major channels of the Ganges basin, if I put the Ganges shapefile on top of it, you can see all the major rivers and tributaries of the Ganges along this blue dark blue area. And that area has almost more than 40 litres per second yield. And that

matches with your quaternary map, which is a geology based on sedimentation. There is a lot of sediments moving and that said there is still a young soil.

When we say young because it is not stopped, still you have sediments coming in settling in and deposition making these layers up. And these layers can give way too confined and unconfined aquifers as we discussed earlier. So, here your alluvial aquifer system, which is one of the major aquifer system is predominantly placed in the northern region and also along the coastal regions.

Why would it be on the coastal region? Because most of the sediments from the inland are brought to the oceans and deposited. So, while it comes to the ocean the deposition happens right before it merges into the ocean, we call that as a delta or a fan. So, water brings all the sediments and then when hits the ocean, it starts to spread and deposit all the sediments. Now these sediments are fine particles as I said very small.

And when they are put together there is a lot of porosity, a lot of pore spaces in between. So that is where water can go in. To understand this better, you can think like a sponge. Take your normal sponge that you use to wash your vessels at home a yellow sponge with a lot of holes in it and that holes represent your porosity.

So, now if you fill water what happens the water goes into the holes and gets stored and when you lift it, some water will come down but still water is stored in the sponge due to surface tension and holding capacity of the sponge. The same way here your alluvial aquifers, water gushes through and so if you go and play in the beach, in with the sand you pour water just flows through and that constitutes an alluvial aquifer and what happens is water goes through, it is easy for the water to go through and easy to extract the water.

The alluvial aquifers are not as sandy as your beach, but still, it can hold and that is one of the reasons it can hold the water for a longer time. So, moving on the hard-rock areas are mostly in the central region and semi consolidated rocks. The rocks are hard and slightly weather, not fully whether those two constitute the major portion of the Indian aquifer system. So, now if we look at this, is it very sustainable?

Someone can ask me is it sustainable to use so much water in a year if that major groundwater aquifer systems are hard-rock and semi consolidated? The answer is a simple no. If your major aquifer system is a hard-rock, semi consolidated rock, with very low

porosity, which means low groundwater storage and low groundwater yield, you can see the yield here just 1 to 25 litres per second, max.

Then what happens is, your use does not justify the recharge rate and the geology in the country. So, something serious would happen if we do not change the groundwater use pattern. Because we may be using it for, improving the productivity, sustaining crops, fighting climate change, because when there is a flood or a drought, there is less watering for the crops to grow.

So, you use groundwater all these things are good. But if we do not use it, cautiously, we will lose around water because most of the aquifer is the heart of semi consolidated rock, unlike other regions we want. The hilly areas are also present mostly along the borders of the country on the north. And those have very, very low potential less than a litre per second. And if you think how much water is needed for domestic use, you would understand that these waters are not that much conducive to use.

That is why a lot of people walk miles to collect water for drinking and bring them back home. So, if you go to the central part of India, here, we have the consolidated and semi consolidated formations, there is a lot of lag in the recharge time, which means you might have a good rainfall here, you might have a good water availability. However, it takes longer time for the groundwater to recharge.

And as a result, you would only see the benefits 2 or 3 years later. And this is a reason why people have to understand that just because we had a good year of rainfall does not mean our groundwater is going to come up it will take time. So, you should not deplete your groundwater because the next year could also be a drought year. So, to fight the droughts, we have to be careful, it is like always as a small amount of water should be kept as a safe limit and we will be discussing these limits that the central Groundwater Board has proposed in the next lecture.

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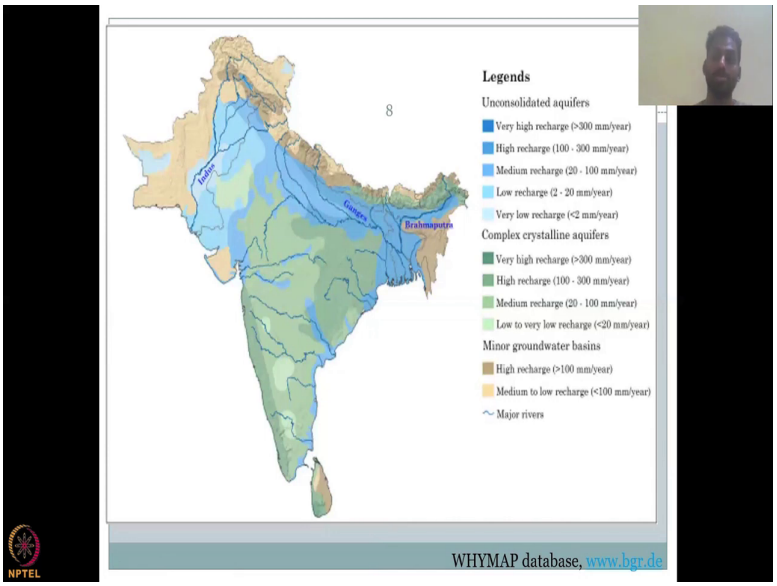

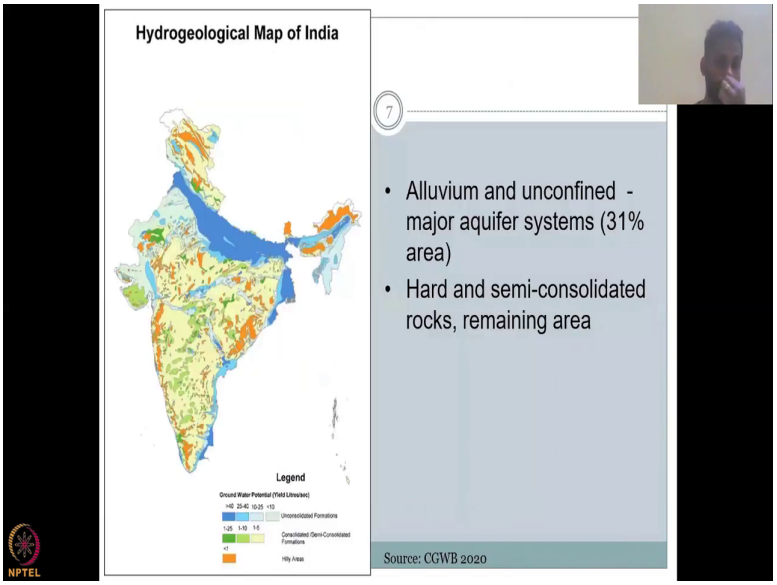

Moving on, there are multiple authors that have looked into this aquifer system of India because of the very high dependence and high utility of these aquifers. For example, this map from Germany, you could see that the Indus and the Ganges basins have very high yield, very high recharge the previous image we saw the yield potential as in litres per second here it is millimetres per year, which is means a thickness of water per year. And here we are going to look at the recharge potential.

So, if the recharge is high, the yield is also high because if you can get water into the system, you can also get water out of the system easily. So that is why you see the same aquifers map where the yield was high, the recharge rate is also high. And these are mostly along the

unconsolidated aquifers, they are unconsolidated, they are unconfined most of them and they have lot of pore spaces for storing the water.

And if you plot the river networks along this, you can clearly see that wherever the major rivers are, especially the perennial rivers, you see a healthy unconsolidated aquifer. Because there is always movement of sediments and rocks and that gives rise to this kind of an aquifer, and you have good recharge and yield.

Let us take for example, the Indus Basin, the Ganges tributaries, the Koshi, all draining through Bangladesh would give a very good aquifer system so in fact, the entire Bangladesh region is blessed with a good aquifer system. There are some water quality issues, but it is pretty good in terms of water. Both surface water and groundwater. Similarly, a Brahmaputra region also has good groundwater yield totally because of the aquifer led by the formation of unconsolidated sediments.

Moving into the central location, it is formed by more complex crystalline hard-rock aquifers, some regions have very high. So, if you look at this region is almost as high greater than 300 millimetres per year is almost as high or higher. Then the Ganges basin in some regions. Why would that be possible? Because this region if you know very carefully, this region is the Western Ghat region whereas you have a lot of these Western Ghats and slopes, the big hill rain range and these hill ranges have a lot of erosion which gets deposited and that deposition becomes your aquifer.

So, if you have a hill region like this, the hill on the top is slowly eroding. So that is why when you go near hills, you see rocks falling down. You see a lot of small broken rock materials, always there is erosion. The erosion happens because it is exposed to sunlight and water. These two elements would break the rocks very, very slowly. It is not like every day you could see a hill breaking.

It is a very slow process and cumulative process. So, when there is a big rainfall what happens most of the erosion happens all these broken materials are piled up along the foot of the hill. And you know that this side of the Western guards gets a lot of rainfall compared to the rain shadow region. So, on this side, there is a thick formation of aquifer because of your sediments and erosion, erosion and sediments, but rivers also bring the water down along

with the water, that is sediments which come down so that forms a good aquifer and has very high recharge rate.

So, most of central India does not have that high recharge rate it is very in the medium and low range. And then when you go to the southwest region and the hilly regions, you have the minor groundwater basins with very low recharge compared to the unconsolidated complex, and not many major rivers are present. If you look at the ground regions, there is not many major events present.

So, all the major rivers are in the alluvial aquifers, look at this Kaveri, Krishna, Narmada, Brahmaputra, Ganges and also you have the hilly regions with good rainfall in the high complex, highly complex soil and aquifers. So, we have discussed aquifers, we have discussed the Indian aquifers and how the Indian aquifers are delineated based on the geology.

And then after the geology, we looked at how it is based on the ground potential to store the water which is your porosity as a function of geology and we came into terminologies like alluvial aquifer hard-rock aquifers, etcetera. Then we also look at formations. How the rock is? What type of rock is formed in the geology map, along with the rivers? In this particular image we have clearly seen that there are multiple physical factors river, rainfall, geology, which influence the type of aquifer and the yield in aquifer.

So, this information should be carried forward and if you see there is not much difference in the central India but if you go to small scales, you will find some heterogeneity, which we will be discussing in the next lecture.

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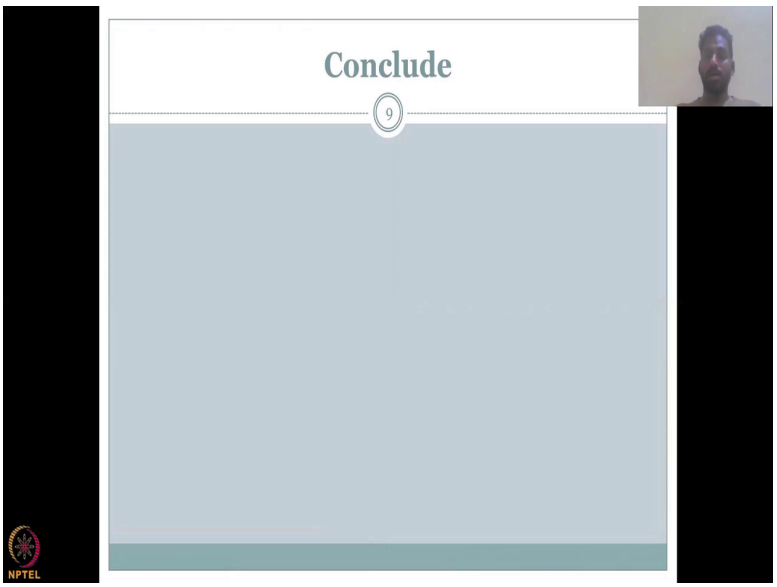

I would like to conclude the chapter on Indian aquifers and we will be soon discussing the hydrological parameters to groundwater flow. Thank you.