Rural Water Resource Management
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Week 04
Lecture 02
Aquifers

Hello everyone, welcome to NPTEL course Rural Water Resource Management, week 4 lecture 2. This week we will be looking at components for understanding Ground Water Hydrology, more focus will be kept on how to understand the properties to recharge better and store water in the groundwater aquifers. And then what are the losses that happen?

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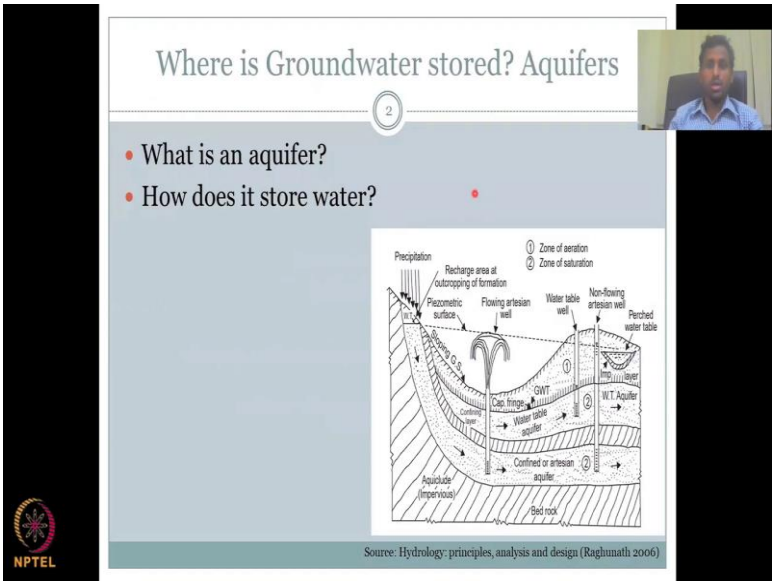

So, this week, the groundwater hydrology started with understanding where the water comes in through the hydrological cycle, we also looked into how the space, void space where water can be stored, reduces as you go along the depth, so, which is like this, when you go down deeper, the water would not be stored more because the size of the void spaces, the space where water can enter is reduced drastically.

So, where is groundwater stored, so, what is it called, we call it as voids and water gets in. But there is a name given for it, so aquifers. So, we would be learning about this term when you go more technical into groundwater, we will call it as groundwater aquifers.

Last week when we spoke about groundwater components I said the government of India has a plan on mapping the aquifers which is the boundaries of the water supply schemes and within that where the boundaries of the aquifers the water, groundwater aquifers are because

then they can supply water to irrigation or domestic water supply. So, what is an aquifer? So, an aquifer is the medium which stores your water. It can be made up of rocks, you can have a consolidated aquifer where purely rocks are there. And within the rocks there are spaces where the water can be stored.

Then you have partially weathered rocks which are called semi consolidated or fractured rocks where water can be stored in the fractures and those are called fractured aquifers. Then when you go up further you have the unconfined aquifers which is not under tremendous pressure of another layer on top of it. So, it is open and water can infiltrate. So, we saw that in different terms also.

So, the zone of aeration, zone of saturation is purely depends on the amount of water, so please differentiate between saturated and unsaturated. Like the term says it is a degree of water available in the aquifer so if is full we call saturated aquifer.

If it is not full we call unsaturated aquifer even 10 percent, 50 percent the same term is there Unsaturated. Only when it is fully with water we call it as saturated aquifer. Moving on, how does it store water as I said there are pore spaces and those spaces store water but it also has to stay there for longer time. If it is keep on moving down, then there is no point of calling it as an aquifer.

It should be slower, relatively slower such that plants can take it up, trees can take it up, farmers can take it for their agricultural fields or even your domestic pumps can take it for domestic use drinking water, even government schemes are there for drinking water purposes.

So, moving on, what do we have is how does water get stored. So, let us start with the precipitation. You do have a porous medium and multiple porous mediums, in this example, we have two porous mediums on the top and one porous medium in the bottom, so three layers. And in between the layers you have a impermeable layer which is separating the whole chunk on the top from the bottom.

So, now you had three layers and then now you have an impermeable layer which is dividing the whole three into two sets one plus two, and then another one at the bottom. Let us start from the top. So, all these have porous medium. Let us understand that all these three have porous medium. Depending on the water, it is called saturated or unsaturated. So, now let us

look at where the aquifer, the term aquifer comes, water gets recharged, it goes into the porous medium, first phase it is still not saturated fully.

So, it is called unsaturated aquifer. This part where you can see is an unsaturated aquifer not much water then water comes down here you have a saturated aquifer after the water table is reached and water does not flow down more but laterally. So, you have a saturated aquifer you also have another saturated aquifer on the bottom. So, depending on the saturation of water you can have an unsaturated aquifer or a saturated aquifer. Now, coming back to the terms of confined or unconfined.

So, is this aquifer confined? Yes, it is a confined aquifer, why? Because your water is coming into the porous medium, right here it is not confined. If you confine this what happens? Precipitation cannot come in, so please understand that confined means it is not like blocked on all sides, somewhere it has to recharge, somewhere water has to come in. So, that is this part you can leave that part. Then water comes in through the porous medium and actually recharges saturates the porous medium and then it becomes a confined aquifer because it is confined between two impermeable layers.

So, one layer on the top and one layer at the bottom so, it will move laterally or it can get stored in one place it is called a confined aquifer. The first water table or first aquifers are another aquifer type, where it is first in held somewhere because of a geological process, we will get into that in the next slides, but please understand that here we have a confined unit and that is why it is called a confined aquifer.

Another type of aquifer exists on the top which is not confined which means on the top there is no confining unit it is pure land, it is a permeable land water can come in so, it is an unconfined aquifer. So, aquifer can be called saturated, unsaturated, aquifer can be called confined or unconfined then there is another aquifer which is totally based on the nature of the rock consolidated, unconsolidated or semi consolidated.

So, let us get into that and understanding here is we understood what is the aquifer, we understood how water gets stored in the aquifer it is by porous space and also a potential gradient should not be too dynamic or too high. If it is too high water just goes down, for example, water is entering here will we call this as an aquifer? No, because water does not stay there for long, it enters and because of the sudden paths, it just moves down.

But after that, the water table, a stable water table is reached we call it as an aquifer. And then we have a non-regular case where we have a perched water table or a perched aquifer, it is formed because suddenly when the weathering was happening or the plates were moving, some deposition of an impermeable surface happened intermediately and that stayed, it did not move.

So, water cannot move in and break it. So, water gets stored, there is a perched water, it is not common. So, please understand that it is one off and you want to see it much common in nature, but still it is a good to be understanding that such a situation happens.

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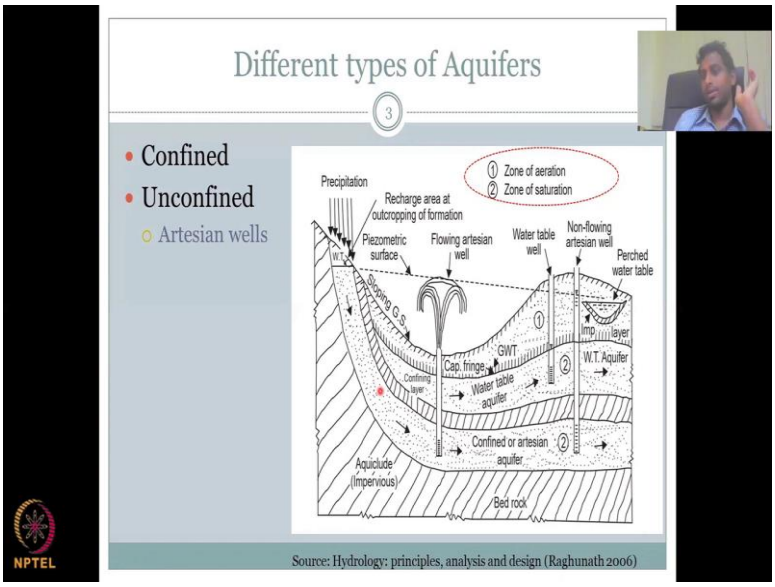

Let us continue with the different types of aquifer, we discussed the zone of aeration versus zone of saturation. So, you have a saturated aquifers and unsaturated aquifers. Then depending on the confining unit presents is it present or not? Then we had a confined aquifer versus an unconfined aquifer. You see this is the confining layer as it is mentioned here. And so number 2 is called the unconfined aquifer for the term aquifer to be used, you should have a water table established. So, you have a water table established and therefore there is an aquifer.

Then you have precipitation coming down and it is being sandwiched between 2 impermeable layers. So, it is called a confined or artesian aquifer, artesian only when there is a well so if you do not have a well it is normally called as a confined aquifer. Other terms here that we did not look previously is the aquiclude. What is an aquiclude?

For us understanding for this course, it is good to understand that aquiclude, aquitard, bedrock, all these units, all these surfaces are highly impervious, water cannot move in. So, you can just think about these terms as a block for groundwater movement vertically.

So, what happens it will not move vertically but it can move laterally, it forms like a pathway for lateral movement. So, it is aquitard, aquiclude, bedrock these kind of terms or impermeable layer, confining layer, all these are impervious layers or less permeable layers, which means the water cannot move in, it has to move sideways. So, different types are confined and unconfined aquifers very commonly used. So, if you go to groundwater books from the Government of India, they would mostly talk about confined aquifers and unconfined aquifers.

How many unconfined can you have? Only one right so, because on the top of the surface you have the only one open surface you have one unconfined aquifer. But underneath you can have after you have an impermeable layer it becomes a confined layer another layer can come here if possible because nature is complex you can have many layers those all would be unconfined aquifers, you will not have a confined in between an unconfined aquifer because already this layer is there which is impermeable.

So, you can have an unconfined aquifer and after some time, after another impermeable layer you can have another unconfined aquifer. So, please understand that it is not just one unconfined aquifer you can have, within the unconfined aquifer there are different wells, even the wells are called confined aquifer wells, unconfined aquifer wells. And an artesian well is just free flowing water, just water comes out because of the potential difference that is also not much common.

All the wells you see in the field, most of them I would say 99 percent of them, you still have to put the pump to extract the water only when you put in the borewell and establish the well or develop the well you will see water gushing out because the initial pressure is to be released. Once that is released it is a normal well you will have to put a pump and then extract them.

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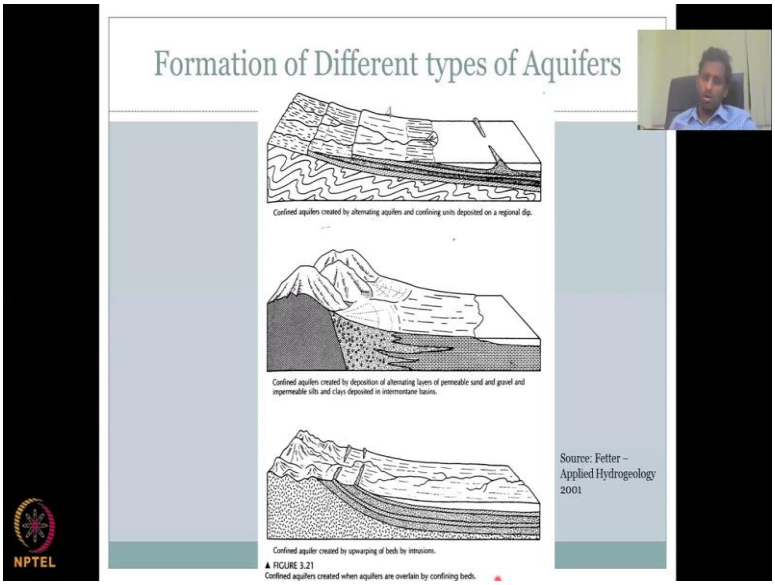

Formation of different types of aquifers now we know what is a different type of aquifers. It is just keeping two unconfined and confined. Let us see how they are formed. Confined aquifers are created by alternating aquifers and confining units deposited on a single dip.

So, this is your dip, you could see here and as I said there could be multiple unconfined aquifers. So, the first aquifer on the top is confined. So, think about a full confined aquifer right here. And then suddenly there is a deposition of a confined aquifer or confining unit impermeable layer, it pushes down and it is a confining unit then another layer, another layer.

So, by movement, by plates moving by your landmass moving or by deposition. So, it says here is a deposition on a dip. So, this is your dip and on top of it water related movement can deposit or sand can be deposited by wind. So, by different drivers deposition happens the key driver is water because water takes sediments, etc. So, suppose you have a dip and water sedimenting and confining layer on top then what happens this layer becomes your confined unit and then afterwards it is an unconfined unit on the top, on top of here and then another layer comes, another layer comes.

So, you are creating more layers by deposition and that deposition would lead to multiple confined units with one unconfined unit on the top. So, this is your unconfined unit on the top and then underneath it you have a confined unit then you have an impermeable layer and then another unconfined unit impermeable layer with another confined unit.

So, that is one process by deposition, on a dip, dip is a land which is dipping in and then you have and it could be your oceans, your waves, waves can deposit material and then it can

become unconfined and confine those kind of things. So, confined aquifers the second figure can also be created by deposition of alternating layers of permeable sand and gravel at impermeable silts and clay deposits in intermontane basins.

An intermontane basin is where mountains are there, and watershed with a lot of mountains. What happens on the top of the mountains is lot of erosion because it is there high potential weathering is happening, rocks break movement comes down. So, when it moves down and you have an unconfined aquifer, confined aquifers is spared by version of alternating layers of permeable sand and gravel and impermeable silt, the silt and clay in the mountain basin like it could be from the rocks, it could be from the deposition of rainfall through surface runoff streams etc., depositing so, you have an unconfined unit but unfortunately your silt clay can be deposited on the top.

So, now what happens this silt and clay layer becomes impervious, water cannot move down further it is very hard so it will move this way. So, the sand and silt underneath it becomes a confined aquifer. Same way another big storm comes another silt can be formed on top, silt and clay on top of your sand.

So, sand deposits and permeable gravel are always coming down right you could see big stones coming down, sand coming down but the silt and clay can be deposit by a big event, big flood so after a flood so, that is why you do not have these confined, unconfined happening multiple times it is only when there is a big 100 years flood or a big event, a big movement of rocks then you find these confined units forming.

So, you can visualize unit which was first unconfined became confined because a layer got across on top of it so, that is this figure explaining. The next one is confined aquifer created by outcropping of beds by intrusion, you have a sea beds and because of intrusion of waterways, waves, etc. Then you have your confined units created, it is a more complex geological process, but understanding is clear that two different forces have to combine imply and then it gets deposited.

So, this is one way, this is another way and then it gets one below the other, dipping or deposition, etc. So, confined aquifer is formed when up wrapping of belts by intrusion, so intrusion happens and because of that there is up wrapping, up wrapping on top, one on top of the other and if the up wrapping unit is impervious layer, it becomes confined unit, you can see how units are formed.

Confined atmosphere, when aquifers are over line by confining beds. So, this is the simplest term to tell how confined aquifers are formed, it is formed when aquifers, like unconfined aquifers are overlaid by confining beds, confining material, confining layers. So, any layer which goes on top of a unconfined aquifer converts the unconfined aquifer into a confined and all this is at a big, big timescale, do not think that tomorrow I am going to have a confined aquifer upgrade from an unconfined aquifer it will not happen that way. If it is a big flood, and then sudden movement, there is an earthquake, that is fine. But those processes do not happen every day.

So I am trying to say, that happens in one location in a big flood comes in the Ganges, you do not expect next year another one would happen. So, please think about it, in an earthquake zone like Nepal you will see more often happening, but again it is a big movement, big force that has to come through.

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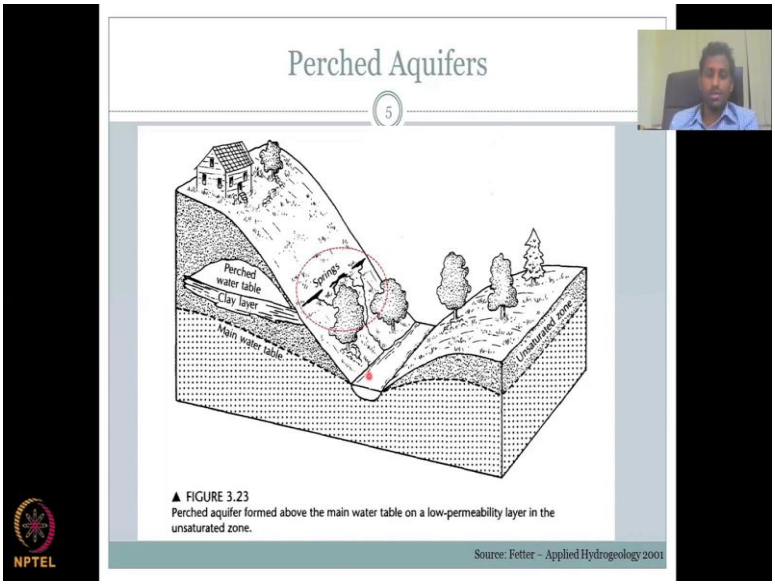

The Perched aquifer story. So, this is very interesting as I said it is not that common. But as an ground water hydrologist you should also know that where this can happen. So, as I said suddenly there is a clay layer all this could be a porous layer, let us say sand silt and suddenly you see a clay layer because it was not, it got deposited there and it did not move. So, all the clay would have moved but this just stayed there or it did not weather out, all the others whether because of soil exposed to sun and water, but this clay layer never got exposed, so what happens is it stays.

Now, let us imagine a rainfall happening. So, you have precipitation happening all these materials would take the water through infiltration, gets stored so it becomes an unsaturated aquifer and here you have aquifer which is saturated because the water table is reached. But on top of it you have a unconfined aquifer and inside that water can get stored not all the water goes off because there is a big void space, water just goes and gets stored in the pocket and that is called a perched water table.

And when a farmer unfortunately hits it within a couple of distance he or she can pick the water, but then in the water drill, the bore drill cannot go further. So, water, all the water can be used, they will be happy for some time, but then it runs out faster, but another farmer has to go deeper and then get all the water from here.

Another thing you could see is because when the water table just gets up, when the water volume gets up, up, added up, suddenly it has to get released and how does it get released through springs. So, when you drive through mountains, especially in Maharashtra, through the gorges and hilly regions, you would see that because they broke the hills to put the roads you will see water gushing out from the hills and also because of the water recharging and coming out and there could be some perched water table and it sees some openings or weaker sections in the land where water can come out and that is how water comes out.

What is it called when all the springs combined together as a big spring it becomes a waterfall, so all these are related through the groundwater, not just rainfall, but groundwater is the key. So, all springs are fed by groundwater. So, when water comes on the top and comes down it is a river or overland flow stream, etc. only when water goes down under and comes out it is called spring, it springs out.

So, that is why the name comes spring and then it mixes into your river as normal. Tapers are going to be form about the main water taper on a low permeability there in the Unsaturated Zone. We have seen this where it is weak and then you have water.

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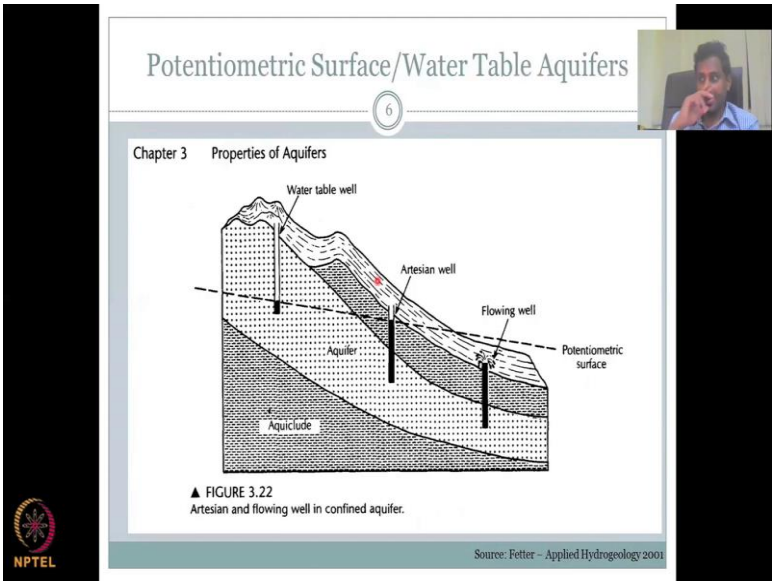

Properties of aquifers and water table of the aquifers as I said the water table is established for a particular region based on the level of water in the aquifers. So, you have a level and the water table is reached that is your potentiometric surface the potential head we call it and water moves from high potential to low potential so if you want to see the gradient or the direction of water moving it will be from your left to the right in the screen.

So, the properties of aquifers are water table of the well is here and Artesian well is right on the surface on the surface you will see water so there is an Artesian well some water would flow but most importantly water is at the brim at the ground. So, you will easily take the water out because the water level is there and a free flowing well is some well which is lower at a lower elevation or at a higher pressure. So, the potential is high compared to the atmosphere.

So, it just go from high potential to low potential. So, all of these wells are tapping on the aquifer. But this opening of the well is below the potential of potential surface so that is why water comes up. Again it is not that common but it is good to understand, here what do you see a confining unit on the top, a confining unit on the bottom and you have your aquifer.

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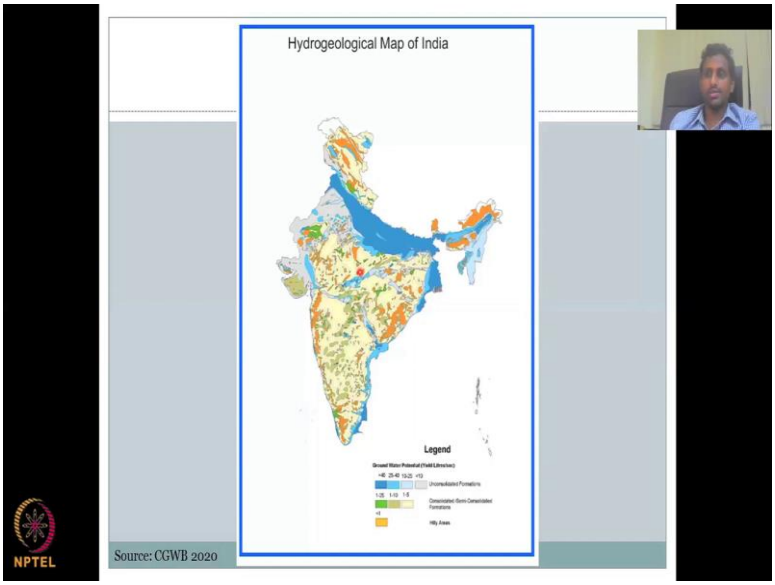

So, you understood that all these are based on the rock type and that is why the geology is very important. So, let us go back to the geology and the Central Groundwater report has done this beautiful map of mapping the key geologic material across India and from that knowledge from knowing about the rocks because every rock has its own porous space has its own fractures of volume how much water it can store we could easily estimate what is consolidated, unconsolidated aquifers.

So, let us look at this legend groundwater potential yield liters per second, yield is given as liters per second if it is unconsolidated formations where formations are not confined, it is not consolidated. So, you have more potential for water to be taken up, consolidated to semi consolidate some broken parts are there but most of the rock is still consolidated.

So, it is not broken, but still the rock is tight. So, which means the pore space is very limited that is consolidated. If it is semi consolidated some weathering is there. So, little bit more pore spaces that all these would yield a very low yield compared to the unconsolidated formations, the consolidated formations almost like soil silt, clay.

So, we have more space, then the hilly areas, hilly areas are very, very less because there is nothing much of pore space it is just hills and water hits and flows. So, and the elevation is also there, the slope is there. So, water hits and then flows. So, this would also give you an idea where you do agriculture right if you know the yield you know related agriculture. So, here you can put rice, sugarcane etc. but here you have to be very careful on what type of

crops you use, because the yield is very less so, that is the cautious that you can get from these kind of hydrological maps.

The other thing I would like to also touch upon is, it is not uniform. So, suddenly you have a high yielding aquifer and then you move down you have a low yielding aquifer and then wherever the rivers and streams are, you have a high yielding aquifer.

And then there could be alternated, unconsolidated, consolidated, etc. and hilly areas can become consolidated after it is a little bit weathered. So, a little bit weathering you have also, weathering gives you more space, pore space for water to be stored. Think about a rock if you crush it, there is more space inside the rock water can go inside the rock, but if you just have a rock, it cannot go much because it is on the surface it might get wet but it does not get it. So, that is the understanding from biological maps and using that we can also name aquifers as unconsolidated aquifers, consolidate aquifers, etc., etc. With this the aquifer types formations have been covered. I will see you in the next class. Thank you.