Groundwater Hydrology and Management
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Lecture 12
Groundwater Hydrology Components 2

Hello everyone welcome to NPTEL course on Groundwater Hydrology and Management, this is week 3 lecture 2. The first two weeks we looked at the importance of groundwater management and why it is needed, in week 3 and week 4 we would look at the physics of groundwater hydrology and what are the important components. In the last class we looked at what constitutes groundwater what does it mean when we say groundwater, how is it formed etcetera. And then we looked at the concept of porosity.

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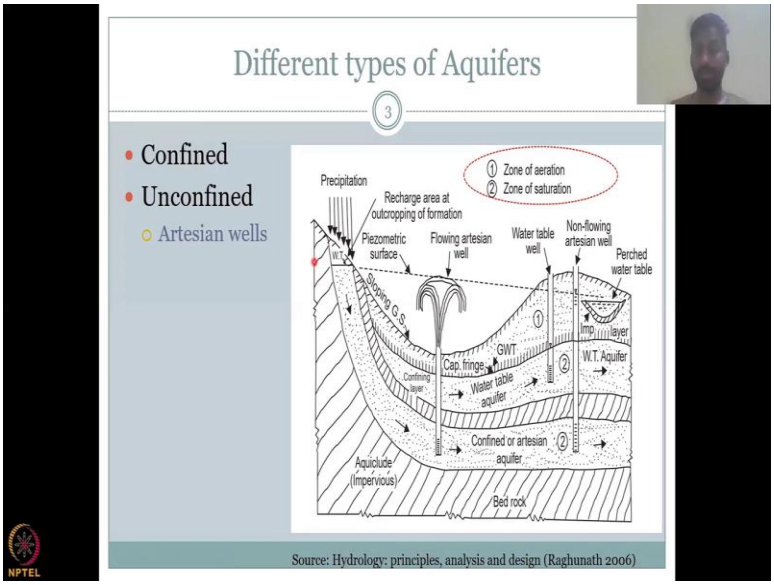

So, now, we have defined that the groundwater enters into the ground through infiltration, so precipitation is converted into groundwater after it infiltrates into the ground I am showing a conceptual model here this is a cross section of the land, which means if you have a cake you cut it and then you see the layers, so that is what you are seeing now, you are seeing a ground cut horizontally and you are seeing a plane vertically you cut on this side and you see a horizontal slice horizontal slice of the cake just imagine a cake we have a full cake you cut it and then you can see the layers out.

So, same way if you remove a slice of land you can actually see the layers of the groundwater components the geology and what constitutes groundwater. Let us move on, so what is an aquifer? Where is groundwater stored? So, groundwater is stored in aquifers, let us look at what an aquifer is. An aquifer is the unit of storage where groundwater is stored. So, in the previous lecture we described porosity and we mentioned that it is the pore space between the solid and soil material where it is filled with air but water can come in and it can aerate or then it can push the air out and get stored inside.

So, now, an aquifer is a bounded unit where groundwater can come in and you can extract it and it does not mingle with the other aquifers, it is one separated unit, this is needed so that we can establish a hydrological water budget think about a watershed you have precipitation you have the watershed boundary and along the boundary it is demarcated by elevation gradients because you have high elevations you have a watershed where water is being stored.

Same way here, you can view a groundwater zone as a layer where you have bounded conditions so that water does not flow out, this can be easily explained using a conceptual model. So, this is a conceptual model on the bottom you see and this image is a cross sectional view of the ground, imagine a cake you buy a round big cake and it has 4, 5 layers inside, outside you apply cream you do not see the inside but when you cut the cake and then remove a part you can see the layering in the cake and some cream or some intermediate layer which separates the different layers. So, same way, this is like cutting down the ground vertically you cut and then you see inside what is there from a direct view.

So, you are seeing a 2D surface of your ground you cut the ground and dig it and remove it now you see layers in the ground. So, that is what you are seeing, and now imagine yourself as a water droplet what would you do, when you fall down as precipitation you hit the ground and part of the ground water or the water which converts to groundwater would go in, part of the precipitation would go in and most of it would run off the water that comes into the ground through infiltration later gets reallocated through percolation and moves down the system through gravity.

So, now is where different layers react differently to form zones, the first zone as you see here is called zone of aeration this is the first zone that happens below the ground. So, this zone has a lot

of pore space and in the space there is limited water, it is not full of water so your rainfall that infiltrated can reallocate and get stored in the zone, that is called zone of aeration which means the zone has porous space and in the porous space there is lot of air, so that air can be pushed out by water and stored so that is called zone of aeration.

And moving down further into the soil profile, you have a layer where all the pore space is full of water and that pore space would not allow for more water to come in, so it establishes an imaginary line of water level and that is called water table. So, you have two zones here, basically it is one zone but because water is half full in the first zone it is called zone of aeration. In the second zone there is full of water it is full of water and this imaginary line that connects all the water level is formed and that is called water table and the zone where it is full of water all the pore space is full of water is called zone of saturation.

Then you have your wells that are accessing water from these two zones you have a well which is drilled and opened, so when you have a well diagram like this and dashed lines that is meaning that it is open only in that spot so that water can move in. So, your saturated water moves in and you pump it out the other wells we will discuss in due course of time but right now you should look at more how water moves down through gravity and water needs to go into the pore space to get stored and the storage unit is called an aquifer.

And there are different types of aquifers the first zone is there the second zone is there where zone of saturation is happening and then you have intermediate layers, now if you remember the analogy of the cake layer I am coming back to the cake you have, for example a chocolate layer on the top and on the bottom you have a vanilla layer and in between you have a cream layer that is separating the chocolate and the vanilla, same way under the ground you have some layers which would separate the geology or the soil and the geology below.

For example, here this dashed line represents an impervious layer, what is it doing? It is preventing water from moving down further, so even if this zone is full of water and it wants to push water down it will not allow this layer will not allow it to move down. So, basically water will come down and then move laterally because water is still coming through gravity it has to displace and move so it moves the water but laterally horizontally in the sideways direction and that constitutes groundwater flow.

So, what you see here is just groundwater, water is coming in stored in the in the zones but once it starts to move then it becomes groundwater hydrology or groundwater flow then what happens this layer even though it is confined it is a confining layer which means it prevents water from merging between the two layers there is some water which is there it could have been recharged very very long time ago or far away ago. So, if you see here it is the same water that goes into both the layers and this water which came from far away has gone into the confined unit it is confined on the top by this impervious layer and in the bottom by the bedrock.

So, both the impervious layer and the bedrock are now sandwiching this material the soil material or the weather drop inside it and there you have water. So, now think about a zone where you have on the top some water or some soil with half water and then below that you have full of water and you establish a water table and below that now an impervious layer which prevents water from mixing up and down and then if you go further down the impervious layer there is some water present in the soil system, it could be soil it could be weather drop or geology anything you can call it, so you have some water present in the matrix. Now, what would you call this?

This also is called a zone of saturation because water is fully present here the sandwich zone is making sure that there is no water escaping easily and water is still recharging very very far away so you have full of water, so this also is called a zone of aeration but the name aquifer is different. So, if you look at the aquifer labeling in the zone of saturation or under the water table it is a unconfined aquifer which means it still can be recharged from the top from through zone it comes to zone two so still recharge can happen.

However, the zone of aeration below or sandwiched between the two confining units which is your bedrock at the impervious layer cannot allow this water to recharge that easily so it is a confined unit. So, if you look at it there is multiple names given but, in most applications, and government records it will be called as a confined aquifer. So, you had now discussed a unconfined aquifer in this stage and then a confined aquifer below the impervious layer.

So, what are we seeing here? Recharge happens water gets distributed in two zones initially one going to the confined unit it is confined on the top and bottom water cannot go up and down but only sideways and then there is some rainfall on the top which recharges from the top goes into

the soil the first zone is met where there is less water, so water gets stored and once the water is stored up to a particular level across uniformly the system it forms a water table and a water aquifer.

So, you have a water table here and wells can be placed in either of these zones, so now what happens is in India if you pump too much on the top you actually deplete your shallow aquifers it is called shallow aquifers or unconfined aquifers because it is in the shallow depth and it does not have a confining unit on the top which means it can be recharged.

So, that aquifer is very important for agriculture and all the domestic water use, however farmers and potential stakeholders have depleted this aquifer totally and so more wells are placed in the deep aquifers it is called deep aquifer or confined aquifer in the confined aquifer the water does not recharge that fast so if you see here there is no way all this water can come from this small location in a short period of time, it will take long time for water to recharge here and move down into this aquifer.

Whereas here, you have water coming from along the surface so water can come easily and recharge comparatively. So, here it is very very very slow and this is where most of the farmers are using it now, the 265-kilometer cube per year you see has been achieved by using this water predominantly. So, we are actually in the declining stage and we need to conserve groundwater. So, this is how water is stored, water comes as rainfall part of the water goes as runoff, we are not worrying about it now but what happens to the water that recharges it gets distributed into two units or multiple units depending on the impervious layer so this is the impervious layer and then you have different access to the groundwater you have deep wells going into the deep aquifer and then you have shallow wells going into the unconfined aquifer.

So, moving on we looked at the different types of aquifers, let us look at some of the terms that are very important for aquifers, let us start from the bottom so at bottom we have the bed rock as it says it is the predominant parrot material in geology we say it is the rock for which actually weathers into the soil and multiple layers, so this is the unweather parent material and if it is on the top it starts to weather and then the soil is formed.

So, all the soil is a function of your bedrock it is coming from your bed rock and it is also called as aquilude or impervious layer because water cannot pass through it is called impervious which

means it cannot pass through. Moving on the top you go and you find an aquifer first, let us say it is an aquifer because we do not know what is on top of it, so we have an aquifer which has full of saturation so it is called zone of saturation water is fully present inside the pore spaces and that layer of rock material with full of water or soil material is called zone of saturation.

Now, when we move up there is suddenly a layer which is not weathered as much as this layer, for example like this and it prevents water from easily moving up and down vertical movement is prevented and that is called an impervious layer, so water cannot go through same as your bedrock and see the dashed lines are similar to both the situations. So, now you have an impervious layer at the bottom and the impervious layer on the top so in between the layer is having a confining aquifer.

So, you are confining an aquifer, if you break it do not ask me if it is going to change because a confining unit some recharge will happen but on hold it is still a confined aquifer. And it is not that easy to break but you can drill it, so you are drilling and putting more holes. So, now when we move above the impervious layer you find a soil material which is full of water and the water levels are connected through an imaginary line and that is called water table and then you move up when you move up further that this is the last layer before you come out of the ground into the above the ground level you have a another soil zone where a lot of root zone activity trees plants and animals live and those layers have a lot of pore spaces but the pore space also has some air and some water.

So, that is where water can be stored recharged etc and that is called zone of aeration. So, the zone of aeration and saturation have been discussed, we understand that though it is a function of a pore space being filled with water or not then we looked at confined aquifer where it is confined by confining layers, you have the impervious layer on the bottom and an impervious layer or a confining layer on the top it is called a confined aquifer.

Then you have unconfined aquifer which means on the top it is not having an impervious layer it has an impervious layer on the bottom that is fine. So, it is like a cup which is open on the top on the bottom it is not open so you can still pour water but when you close the cup then it becomes confined in the unconfined aquifer you have partition wells, so this is a artisan well which is flowing freely and it is this one is present in the confined layer.

So, what happens is when water is put in the confined layer there is lot of pressure and if the pressure inside the water is higher than the atmospheric pressure then water flows from high pressure to low pressure, so water will automatically come out and flow through these wells because your pressure is much much low on the atmosphere compared to what is inside in the aquifer, so it is like a balloon you water is held in inside a balloon in a pressure but when you press it just comes out because outside pressure is much lower.

And then you have this imaginary water table line, so you see this water table there is the line that connects all the saturated water levels but you also have a potentiometric surface and that is the pressure surface that is you can be drawing a line along the points where equal pressure is met and that pressure defines if the water is going to come out by itself or you have to put a pump and extract water.

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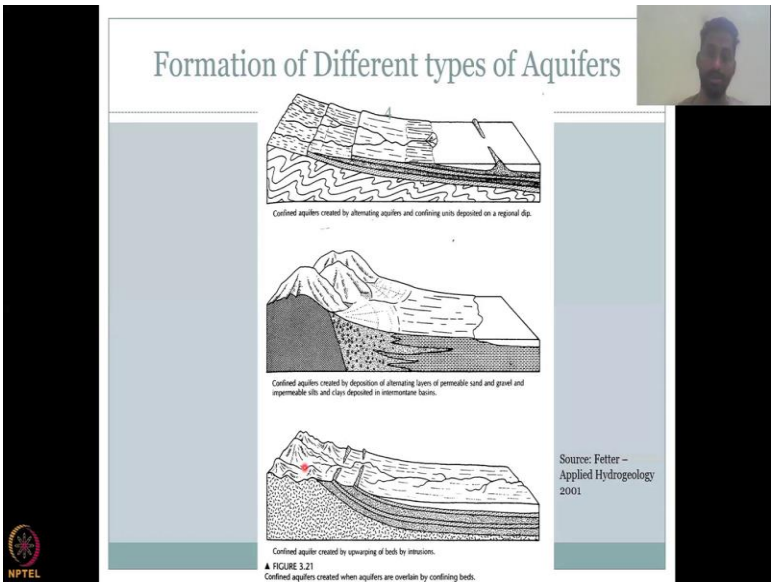

Moving on, we understood that from this there is a lot of aquifer types and most important is the layers are more important to define these aquifers, so how are different aquifers formed that is what we are going to look at in this section. So, you have confined aquifers from the top figure which are created by alternating aquifers and confining units deposited on a regional dip, so you have a regional dip so this is a slope which is going down and on the slope there has been deposition of rock materials and other sediments but however when it was depositing inside there was water present in a soil and on top of it the confining unit came.

So, initially there was water but when some deposition happens it gets locked and that is how a confined aquifer is developed. These happen on a large time scale, do not think that it's going to happen today or tomorrow it happens slowly when these plates move or when deposition happens like sediment deposition, movement of rocks in a river etcetera.

And you can see how a confined aquifer is locked here in this particular spot. So, moving on you also can see here layers forming because of this deposition along a depth, so your dip is there and on top of it layers are formed. The next figure shows confined actives created by alternating layers being deposited on permeable sand and gravel. So, these happen along the mountainous systems where you have a lot of these deposition of layers and they have permeability because they have permeability water gets in and some of the water is stored but again deposition is being happening due to erosion.

So, this is an erosion induced confined aquifer creation but again it is about you have a layer and it gets deposit on top by a process it could be by rivers, it could be by erosion or anything else. And then you have and it says intro montane, so intro montane is mountainous basins, so that is where you have folded mountains if you see the mountains are like this and then there is folds on it, so some of it erodes and then pushes down on the soil surface with water and that water becomes a confined aquifer storage.

Moving on, you have confined aquifers created by up wrapping of beds by intrusion you have saw your sea intrusion, so this is your land and you have sea and land intrusion and because of that there is some overlay or over a wrapping of a soil surface and suppose you have water here and the soil surface comes on top then it is confining. So, all these are processes where you have a confined unit declared.

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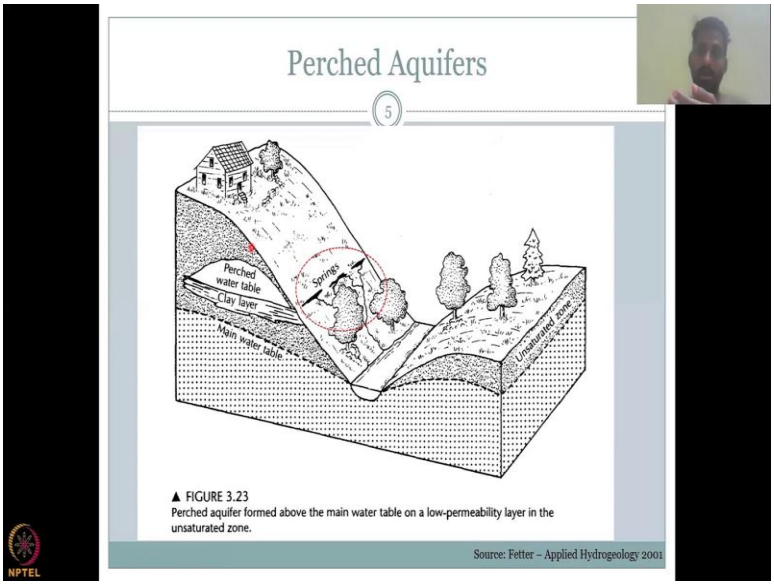

The last one which is not as common as the previous ones is called a perch aquifer approached means, what do you mean by perched is something that is kept differently and it is stays along a particular location, you say a cat is perched on top of a rooftop, a bird is perched on a tree which means a tree branch is there and on top of it just uniquely it is sitting.

So, it is not a common thing that is what it means, so if you have an aquifer you have a unconfined aquifer here and then you have a saturation zone here, what you see here is suddenly a very small layer of impervious geology is present for here it is clay layer, so it is an impervious layer but it is not fully present it is only in a small distance or small location what happens is water is moving from top to down due to gravity and it gets hit on top of the layer the clay layer and it becomes a perched water table.

So, you have to be careful here because water enters and it wants to go down but you finally have a clear layer it is not uniform, so it forms a small perched aquifer so it is a small aquifer which is perched along a small area because you have water coming and then it just gets hit water cannot stay there for long, so it eventually breaks your surface and comes out as springs or it can come down as recharge but it is not as fast as recharging through the other places. Suppose aquifer formed above the main water table on low permeability layer in the unsaturated zone.

So, if you can see this is saturated, why? Because water does not move down it cannot move down because of this layer so it gets stored and it becomes an aquifer. And this also gives rise to

springs which are formed by openings on the surface a weak openings and then if water is highly in a high pressure compared to the low pressure outside it will push from inside out and come out as springs waterfalls all those things you see.

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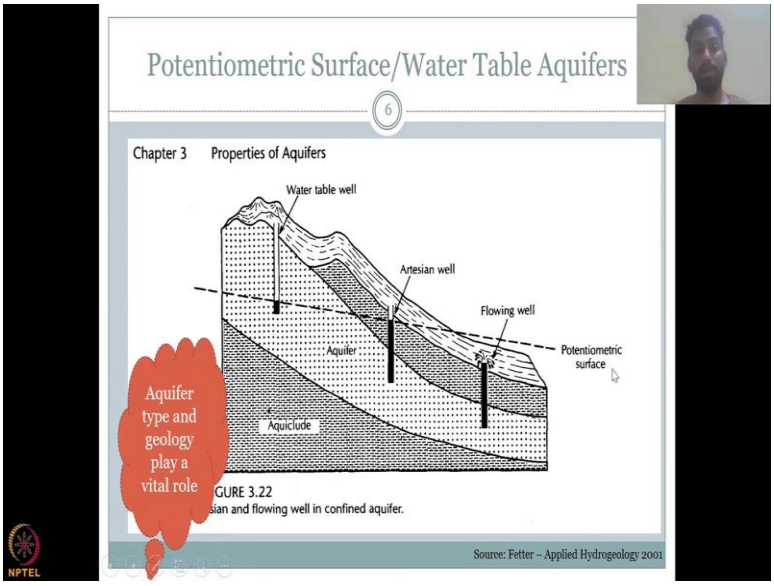

With this we come to the potentiometric surface and water table of aquifers we saw the different aquifers confined unconfined aquifers, and we are going to put well along these aquifers. So, what happens is we are taking one aquifer here and it is a confined aquifer because you have a confined unit on the top and a confining unit on the bottom. So, you have 3 water tank levels from 3 wells what a potentiometric surface is the pressure of water at that point the pressure is because of the mass which is pushing it on from the top.

So, the pressure on one well would be similar to the pressure on the second well the level because it is from the same aquifer, so the pressure here would be similar to here and that is why you have a line that goes along a tangent to show that the pressure is similar. Now, suddenly if one location you have a dip so if you see here the land is dipping and the well uh is not as tall as the others which means it is not above the potentiometric surface so then what happens the pressure inside the well is much higher than the potentiometric surface, so water would just flow. So, it will flow out until this pressure is brought down, so until this line which you see as potentiometric surface is brought down somewhere here, so one when that happens then your flowing well will stop.

So, if you look at boring when they put holes and put a well inside initially water would gush out without any water or a pump when you put it in water just crushes out and all the water would come out until it equates the pressure inside is equal to the pressure outside and then it equates it stops until then to equate that pressure water will just come out and just keeps on coming out until this entire thing, so you are going to just drain all the water if you do not use it well.

So, these are the different things, a water table is the imaginary line of the water that is being connected and here you have the water table given in the black line and the water table can push the water up here you what happens is it is cased, so water cannot rise up that fast but here it is on the on the rising limb.

So you have acquilude which is also another word for a confining unit and on top a confining unit giving a way to water table and potentiometric surface, we will also define the potentiometric surface through equations in the coming lectures. With this the aquifer type and geology play a vital role we come to understand that it is very very important to understand the different geologies that go in and how they play a vital role in creating these aquifers.

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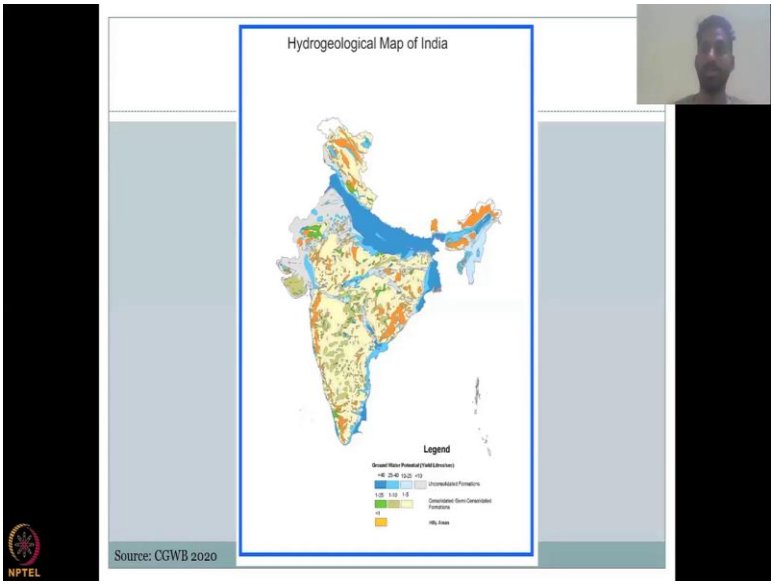

And with this the central groundwater board has made a hydrogeological map of India you could see that different aquifers are present along the boundaries of India based on the aquifer type the geology type is also given. So, here we have an unconsolidated formation or you can say unconsolidated or unconfined aquifers which are present mostly along the river basins it is

unconsolidated because still there is sediments forming and water coming in so it is a unconfined unit and then you have consolidated and semi-consolidated formations along the inner part or the central part of India where you have some confined units some permeable layers on the top and then impervious layer, so there is some confining of aquifers and also semi confined which means the formations are not as rigid, so water can be stored.

So, both unconsolidated unconfined aquifers are all present and all these give a raw idea of the geological formation gives a raw idea of where the hydrology can be where the groundwater can be present. So, in an unconsolidated formation you see a lot of groundwater potential, liters per second is greater than 40 liters per second because this it is unconsolidated it is not structured, so the solid can still have a lot of core space and lot of water.

The next comes your consolidated and semi consolidated so it is kind of structured or half structured and when you say structure the space also goes down and it may have a confining unit on the top because most of those layers under the confining unit as I said have a structure it is not as weathered as the above surface.

So, you have all these surfaces having more or less very low permeability and because of low permeability there is low water potential and then the hilly areas of course have less water because it is pure of rock and solid formations it does not have much poor space. So, with this we understand that the geology plays a vital role in the aquifers and I will see you in the next class to discuss more on this hydrology, thank you.