Groundwater Hydrology and Management
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Lecture 13
Groundwater Hydrology Components 3

Hello everyone, welcome to Groundwater Hydrology and Management NPTEL course this is week 3 and lecture 3. In the week 3, we are looking at the major concepts and about physical groundwater hydrology what are the major components that is needed to understand groundwater hydrology.

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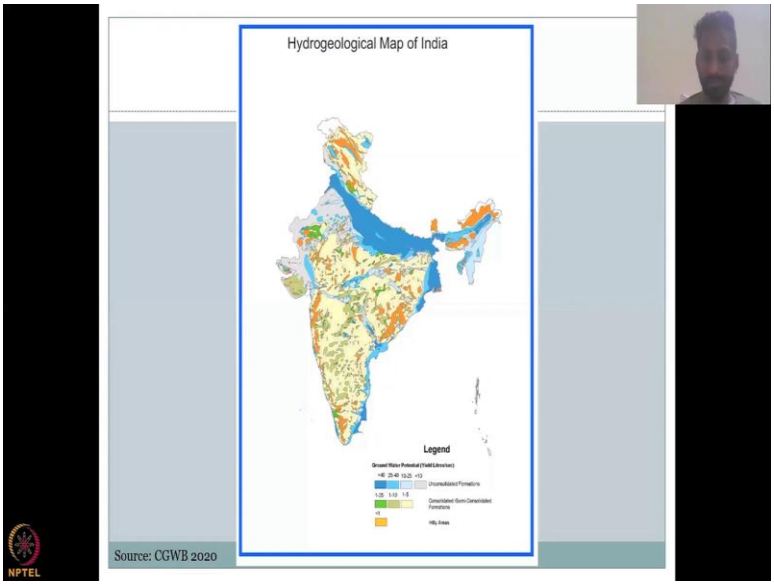

In the last lecture we looked at the hydrogeological map of India which is made by the central groundwater board and since it is a static map which means it does not change much you could see different years of this publication I have used the recent one from the recent book and what you see here is a map of India which demarcates the different geological aspects related to groundwater hydrology.

The last class we looked at the fact that the aquifer is a function of the geology and the porosity and the porous space present inside, in continuation we look at this map to understand the different formations in India. Remember that this may not be the same across the world, so you would need to understand different geological settings but since this course would focus mostly on Indian groundwater issues we would be discussing this map. First, let us look at the blue

color, the blue color is the highest water yielding aquifers and it is given as a rate of yield in liters per second.

And if you look at these blue regions, you could clearly understand that these with the coincides with the regions where there are massive or big rivers and streams good water bodies in short. So, this would be your Ganges basin, the Brahmaputra on this side, the Kaveri basin here, Narmada and all are good rivers that are perennial, and also have good water potential surface water.

So, the ideology is with good surface water potential there is also good groundwater potential and these also demarcate unconsolidated formations. When we say formations, it is the formation of the geological unit or the rock and they are mostly unconsolidated which means they are not a packed jam packed or has a structure it is broken in some areas and not broken irregular and that irregularity causes a lot of space in between the rocks.

For example, if you have platy rocks like plates it will be jammed together and space between the rock is very less but if you have uneven rocks like this then you have space in between the rocks and that space is important to store water and that is why you have more water stored in these kind of porous material and it also depends on where it is located because you have a water flowing in these regions the water can easily enter your formations and the formations have the potential to store it for a long time and that is why you can extract it.

So, the groundwater potential is very high from greater than 40 liters per second to less than 10 liters per second, so all these blue regions and then this region has less than 10 this is your Indus valley region and most of your blue coin size with the flowing reverse the massive flowing reverse of the Indus uh the Ganges, the Brahmaputra etc Kaveri.

Moving on but that is not the major in terms of area it is not the major aquifers in India what is the major is the yellow green color which is in the central parts of India and that correlates to the consolidated or semi-consolidated formations, which means it is either arranged in a particular matrix the soil and the solid particles or it is semi-arranged.

So, when it is semi arranged or arranged in a particular fashion then the porous space is less, so when the porous space the space where water can enter is less, then the extraction is also less so

this is the understanding that the central groundwater board wanted to give a hydrological map which is based on the porous space as a function of the consolidation of the formations and the hilly areas are very very low eventually there is no pore space in the hilly area so it is less than 1.

If you look at the green color that is where you have more space for water to enter within the consolidated and semi-consolidated and it has 1 to 25 liters per second mostly Rajasthan, Kerala, Maharashtra regions and then you have the other regions yellow where it is mostly in the central parts of India and the underlying fact here is we need to understand where the formations are and how much water yield can be taken so that you do not over stress the aquifer system.

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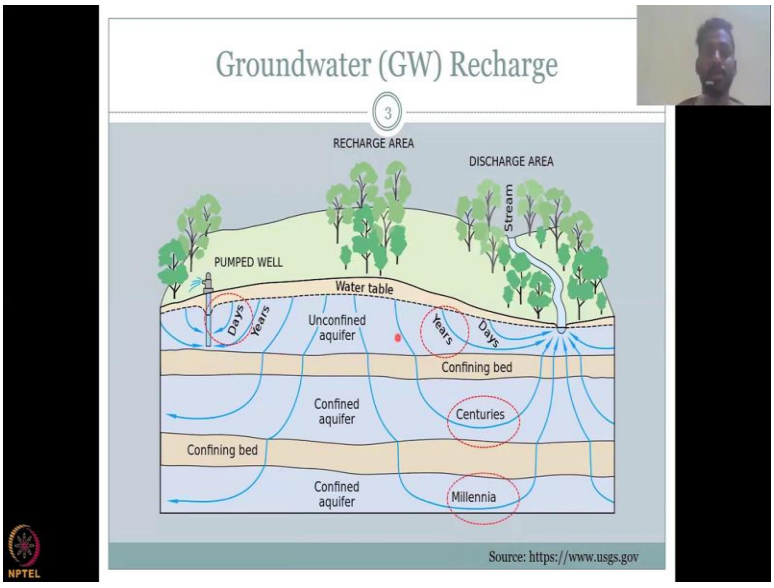

That note, since we have looked at the porous space is important we have looked at what is an aquifer then we have looked at what is the confining unit and the different aquifers in the second lecture. So, let us jump into the recharge aspect, how does groundwater recharge happen? I am going to be very brief here because we have a week just to discuss the recharge and discharge aspects, so the groundwater recharge is the process by which the rainfall or any other surface water body gives water into the ground into the aquifer unit. So, as I said the aquifer is a unit of storage and if water comes in it is recharged, if you lose water it is discharged. So, the recharge area is almost on the top surface and it is a surface where land use land cover should be managed to slow down the water and recharge.

So, you have trees and plants that can slow down the surface water like rainfall it can be slowed down runoff can be slowed down and recharged once it recharges it forms the imaginary water table as I said it is the line at which the water level is kept along the aquifer. So, here horizontally this is one aquifer, let me turn on my pointer this is one aquifer this is number two aquifer at number three and what you have here is a combination of multi three aquifer systems which are divided by confining units it can be called as an aquitard, aquiclude confining bed different names are existing.

So, the major objective of my presenting of this particular slide is not about the recharged process but the recharge time, so you can see here clearly that the recharge happens and the first layer is the unconfined layer where water can easily come in from the surface there are multiple regions where the recharge can happen there is multiple regions rainfall goes in groundwater gets recharged and it gets extracted in your pump same way this side rainfall comes in groundwater gets recharged and then goes into the stream as base flow.

So, now how long does this take? This takes anywhere from days to years because there is a good area contributing to the recharge contributing as in all along the area you have recharge points. So, it can go in and the distance that it has to cover is very small to get into the water table which is only this distance, so you have a very small distance to cover so that the through gravity it moves down and then mixes with the water table this takes anywhere from days to years.

Now, if we have a good rainfall here, so which aquifer would recharge it is this shallow or unconfined aquifer because rainfall happens within 5 days, 6 days it can recharge into your system the farmers are happy to see the water in the wells. Then I hit a groundwater confining unit along the conceptual model, what we see as we go down deeper you see a confining unit and that confines the upper unconfined aquifer and below that another aquifer which is called the confined aquifer, so this aquifer or soil or geological material or matrix has water in it in the pore spaces however it is confined on the top and bottom by confining unit so it is called a confined aquifer.

So, now the recharge water has to go through the surface go into the zone of aeration this is a zone of aeration where still air is present go into a zone of saturation and then come down this

takes longer than the unconfined aquifer, how long? It can take more than many years and so it can be anywhere from a lot of years decades to centuries 100 years and this water can also contribute to the stream flow down the area it cannot be readily accessed in this image by the well because the well is being separated by the confining unit.

Then we go down to another impervious layer until the bedrock and you see another confined aquifer, so three aquifers are there, one is unconfined and two confined aquifers as we move deeper the deepest confined aquifer takes very less recharge from the top because water takes a long time to come down and it is impervious so only some water can go through whatever the impervious layer is still some water can pass through because of gravity and that water does take a millennia which means thousand years to move down and that is the concern here if a water takes thousand years to move down, and you put a well here because of science and technology you can easily access the ground water and then the problem is you will take all the water out suddenly and there is no water in the aquifer.

So, this water can also go into the streams and can support your trees and plants when it is being pulled up. So, this is a slide on the recharge time and some parts of the processes of recharge. Now, a question can come, how many unconfined units can a system have and how many confined units can a system have? Let us answer the second question first, the number of confined units can be plenty it can depend on the number of confining layers, so we do not know unless we drill down and see how many layers in the cake we do not know how many layers are put in, so it depends and using a geology of area we can estimate roughly how many layers are there or the dominant layers.

How many unconfined layers will be there? There is only one because the surface is on the top and under the surface at once when you come in it is the unconfined aquifer. So, most probably the unconfined aquifer is on the top and if even if you have an impervious layer on the top there will be a very small unconfined or an unconfined unit.

So, only when this confined unit is coming out or jutting out then you do not have a unconfined so at least one you will have and at the most one, so you will cannot have more than one unconfined aquifer because the confining unit would be there and then another unconfined cannot happen. Confined aquifer may be present or may not be present, so for example if there is

no confining units and the surface is directly connected to the bedrock then it is all a unconfined aquifer, so you do not have a confined aquifer in this case. Moving on, as I said the unconfined takes days please remember these two years the confined aquifer first confined below the unconfined can take years a couple of decades to centuries, whereas the deeper most confined attribute can take millennia.

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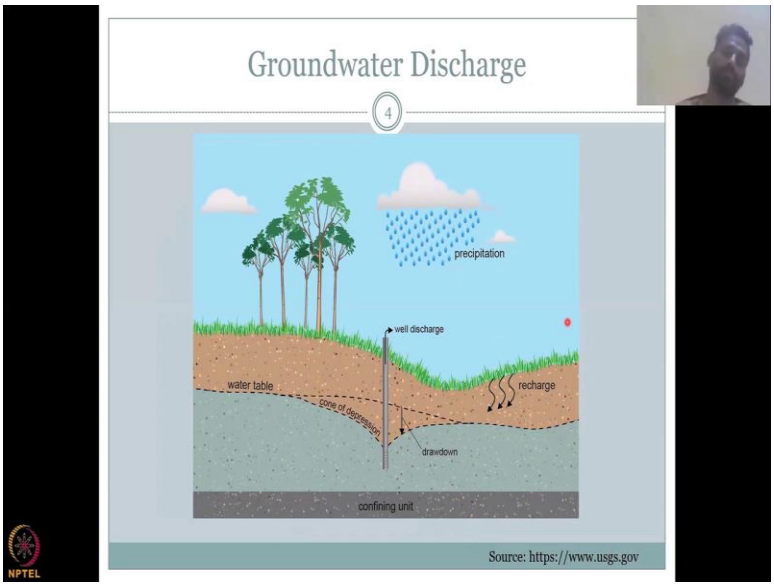

The other types of recharge that can happen is by induced recharge, so for example you can induce recharge through the process of pumping but first let us look at pumping because pumping is an action. So, groundwater discharge is the process by which you take water from the groundwater and when you take it there is the water table lowering and formation of cone of depression or drawdown.

So, this imaginary line is brought down because you are pumping water so all the water here in this area is pumped out as discharge still recharge can happen but the discharge is pulling the water and part of the discharge which you apply to the field can come back as recharge. So, the recharge source may not only be the precipitation it can be your groundwater also you pump groundwater you put it on the surface part of it is taken by plants part of it recharges.

So, whenever we say discharge it is the act of pumping or losing water from the aquifer there is a natural discharge process which we saw in the earlier slide the natural discharge is the

groundwater entering into the streams that is called natural discharge, whereas this is called the pumping groundwater through groundwater discharge.

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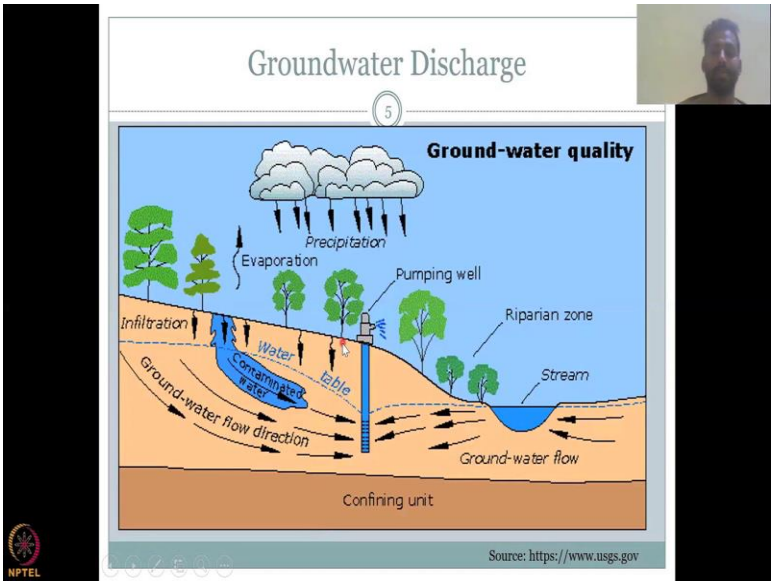

Some more groundwater discharge images to discuss the fact that you can actually pull water from different resources within the aquifer, so here we have only one aquifer it is the unconfined aquifer because the confining unit is at the bottom and there is no aquifer on the top with a confining unit just one aquifer and there is no confining unit on the top so it is uncomfortable you have ready recharge happening infiltration water moving down and there are some contamination also, for example you have a polluted lake or a polluted stream or a natural pollutant by geogenic contamination, I will come to these terms later but then you can also have a stream on the other side with water.

So, now what happens is when you start pumping you pull water laterally into the groundwater well, so this is your well and you have removed the screen here which means water is moving inside. So, you should understand that it not only pulls your groundwater but as and along the table is being reduced, so this is the water table and as an along the groundwater table is being reduced it starts to pull water which are equal at the water table height, for example this water in the stream it may not pull this water which is far away but it can easily pull this water because it is nearby and the water table would be conducive to bring that water the cone of depression is

started because of the discharge because of the pumping velocity and because of that there is lot of lateral water moving inside.

So, the water table is lowered and along with the groundwater you could you may also pull the contaminated water or water from a lake or something so that is why if you have a pump next to a sewage system, let us say a toilet outside and you have a well some of the pumping by the well can also pull water from your septic tanks if it is leaking, so be careful of where you put the water wells.

Same way, you can pull water from streams so instead of water coming from groundwater into streams as base flow now you are pulling the water from the stream into the ground water bill and extracting it as discharge. So, let us break it, from the stream into the ground water is called recharge but the stream water if it passes through the recharge and comes out into the well it is discharged.

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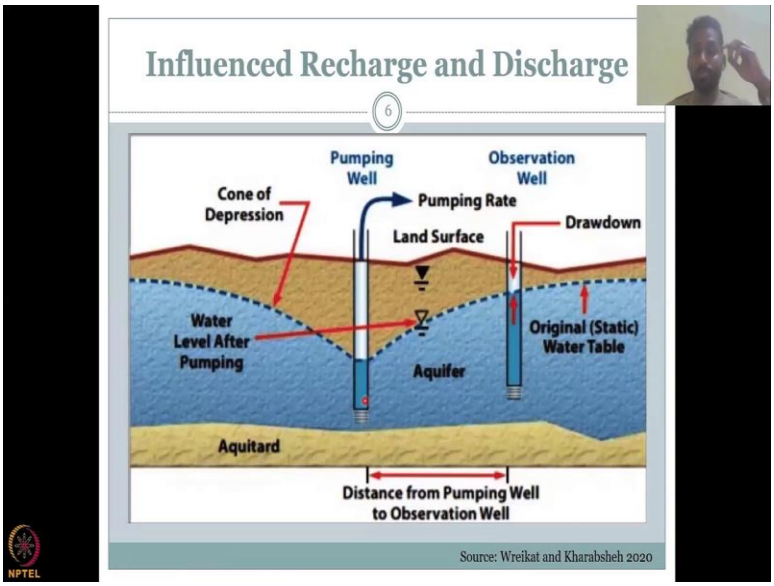

Influence recharge and discharge is another important factor that we should look at because when we discuss recharge and discharge it is not at a small scale because we are inducing recharge and discharge or we are pumping using a motor or a pump electric or solar powered pump, when you do that what happens is you are actually pulling at a much much faster pace and you turn the dynamics or the gradient of groundwater flow. So, initially the water table would have been here somewhere a straight line if you do not have the wells, now you have the wells

and it is opened here in the aquifer and you are pumping, how many aquifers do we have? We have only one aquifer it is an unconfined aquifer and aquitard is there at the confining yield at the bottom.

So, what are we going to do is, we are going to see an influence recharge and influence discharge and because you start pumping here because you pump at a very high rate what happens is water from here would move into this well which is an observation well there is no pumping you can see here there is no pumping and it will go into this pumping well.

So, suddenly this well will get more water, more water because it is being pulled from another suction and that creates an artificial recharge first in the observation well. So, first your water table goes up because you are pulling down and then slowly when this water table goes down then also this will come down. So, the rate of water coming into the observation well, so we are just monitoring here we are not monitoring here, the rate of our water level recharge is induced by somewhere else pumping, you are pumping somewhere else, so it is inducing and causing the water to come into the well.

Secondly, when you pump too much when you continue pumping then what happens all the water inside your observation well is also going to be pumped, so initially it was recharging but when you continue pumping then you are going to pump all the water out and that will be influenced discharge. So, initially there is this water there is no pumping, there is no point of losing water in this well in the observation well, but why is it losing water it is because surrounding area is pulling water.

So, this is the fact that even though you do not pump your groundwater, you would see your groundwater fall and then the farmer asked the question, why is my groundwater falling, when I am not pumping? So, it could be two reasons, one the base flow which means the groundwater is normally flowing and so it might flow and reduce.

But most importantly the second factor is someone around you is pumping at such a high pace that it is influencing your wells and pulling all the water down initially you would have seen a high water level a good recharge and then suddenly you are saying, oh I am happy my wells are recharging even though it is not rainfall happening but then as soon as that happens you have to

be aware that somewhere your water level is coming up so sooner or later if the pumping does not stop, your water level will change and that is what happens.

So, for example if you have a industry pump, for example it could be an industry for making using a lot of water for a product and or it could be a mass farming or a water distribution plant where it takes on water for distribution, what happens is it can suck all the water at a higher volume and when it takes all the water from this aquifer from this water table it influences the region around it and that influence depends on the pumping rate and also the cone of depression that it causes, the cone of depression is for example you have a water table like this and here's where your pump is.

So, when you start pumping it will fall down like this the water table and when it falls down you get an initial recharge and then a discharge but more importantly the influence of the corn of depression goes as far as the material allows it to go the solid material, for example if water is locked in the aquifer there is no connection between the rocks then whatever you pump it would not affect the nearby well but if it is like an alluvial aquifer where it is well connected across the system across the aquifer, then what happens is you pull down and you influence the neighboring wells.

So, you have to be very careful and that is why if you take the water level readings in a particular village where extensive farming is happening, you do not see that only the village water level coming down, you see the neighboring villages also suffering and the water level coming down. The same does not apply for recharge because recharge is a very slow process, it is not like one village recharges all the villages around it will recharge now because it is very slow however pumping is a very fast rate and when you pump you indirectly influence the neighboring wells and pull out the water.

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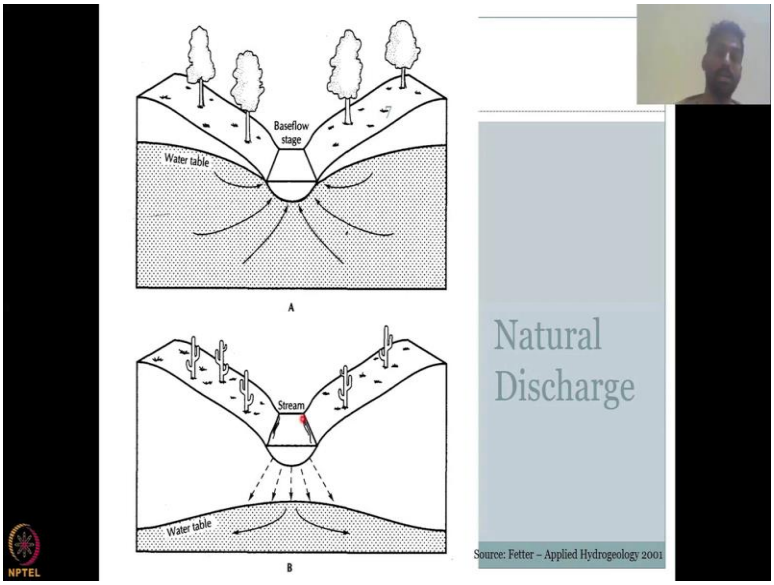

That is your influence discharge and recharge because of anthropogenic stresses or actions. Let us look at the natural causes, naturally the water table is at the water table of the stream, so the level of the stream or we call the stream stage is normally at the same level of the water table in a good aerated environment or an environment where there is good rainfall, there is good recharge and the water table is healthy.

So, what happens in this kind of thing is your water table normally would supply water from the groundwater into the stream and that is where you see when you go to a river or a stream network you see that it is the stream is at the lower elevation and the mountains and ridges are there and water flows.

So, the water would be contributing to the stream and that is natural discharge, which means water comes from your groundwater into the stream which is natural discharge. For the stream it is a positive so it is called a gaining stream the stream gains water from the water table all these appropriately work on the pressure difference. So, the water table is at a higher level and therefore it has a higher potential and water flows from high potential to low potential which is at a lower elevation.

So, water flows from high elevation to low elevation in a street the water table is losing the groundwater is losing here it gives water the volume is losing and so it is called a natural

discharge the aquifer is losing water it is natural discharge the stream is gaining water so it is called a gaining stream.

The reverse of that is in a desert situation where a stream is at a higher level than the groundwater table and it is not readily influencing the groundwater table maybe the layer the sediments and the rocks under the stream are making like an impervious layer, so that is why readily you do not see the water coming down but slowly there will be water trickling why the same principle the stream water is at a higher potential than the water table so water will be leaking, in this venue it is called natural recharge for the ground water table.

Whereas the stream is actually losing water so it is called a losing stream. So, here we have seen both natural recharge and natural discharge where natural recharge happens due to the difference in the potential of where the water level is and also because of movement of water from rainfall into the ground through gravity.

We also saw induced recharge and induced discharge where you pump water out of a system gives you discharge of water and it is induced and also by inducing your pumping and inducing your discharge you can also recharge some locations and that is called induced recharge. So, with this we have covered the basics of some groundwater parameters which are very important to discuss now in detail uh how you estimate groundwater flow etc etc I will see you on the next class, thank you.