Groundwater Hydrology and Management
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Lecture 41: Groundwater data in India Part – 1

Hello everyone welcome to NPTEL course on Groundwater Hydrology and Management. This is week 9, lecture 1, in this week we have been noticing some groundwater concepts and how to construct a groundwater aquifer layer understanding, in the previous weeks we have been looking at the concepts of groundwater hydrology, the parameters that are important and most importantly we were looking at the axis and recharge discharge.

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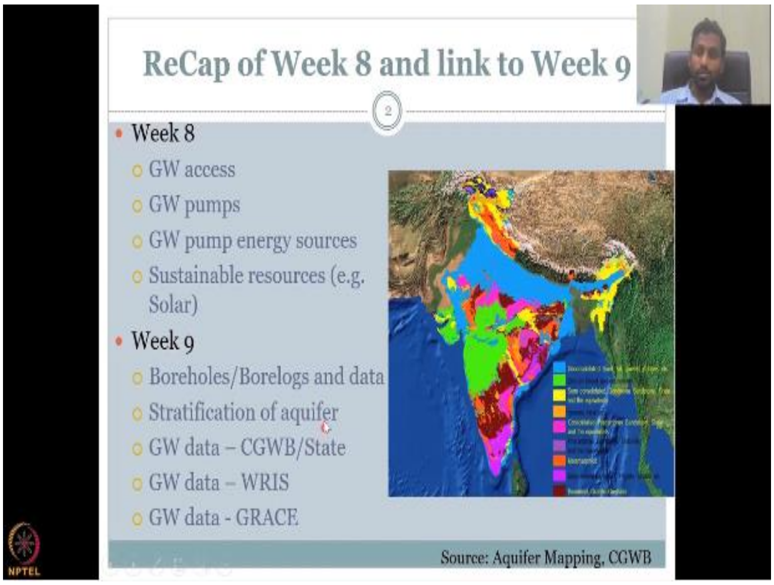

What will we be doing this week, let us see in a more constructed manner. First let us do a recap of week 8 and how it is linked to week 9. In week 8 we looked at groundwater access as a problem, how does groundwater being accessed? Everyone knows by now that India is the key groundwater extractor in the world, extracting about 245 to 265 kilometer cube water annually and there is tremendous stress on the aquifer.

However, the water axis it is accessed through the groundwater pumps, so we looked at each concept of where the groundwater axis is mostly happening, what are the key uses through wells, dug wells, driven wells, or drilled wells and then we looked at their different pumps that are used, low suction pump, high suction pump and manual or treadle pumps kind of things.

We notice that as per the use, as per the demand the well type and the pump type differs, then we looked at the source of energy for the pump and most importantly we noticed the pump energy is unsustainable because it uses lot of diesel or electricity, these are not from renewable sources and that is why I am saying it is not sustainable for long term, also they give pollution to the environment because diesel pumping has a lot of issues.

So, what has happened is there has been considerable action on the ground in converting these pumps to more eco-friendly pumps, example sustainable resources like solar, windmill, manual and livestock, you would see cows in villages which would go around and round and then they would turn a gear which pulls up water and solar pumps is very common nowadays along with wind powered pumps.

On the whole we notice that the axis is increasing, the type of pumps are increasing and there is also some renewable sources coming in. So, now we are going to leave this phase of the course where we looked at the components, the recharge discharge and access to the water and now we are going to construct the aquifer itself. How, is the aquifer constructed, how do we know what layers are there, how do you know which water we are going to use.

That we are going to look at in this week onwards, so from this week onwards we will be looking at the aquifer layers, how you estimate these aquifer layers, what is the data that is needed, how do you get the data, where do you get the data and what are the steps in creating your first kind of conceptual model.

So, we will be looking at boreholes and borelogs and data associated with it, where in borehole we already saw in the groundwater access slides, where I was talking about drilling wells, drilled wells where there is a motor which comes and drills and then you have a borehole which becomes a well.

So, from the data you correct from point one we will be establishing the layers of the aquifer which is called stratification of aquifer and will be using central groundwater board data and the state waterboard data to understand the ground water level fluctuations, where the data is available, so it is more about where is the data available, because establishing the water level, the head everything has been taught in class.

Then we will also look at WRIS data, where do you get this data, what data is available, how do you access this data etcetera, then I will explain one satellite which is very unique, very special satellite called GRACE, this is the only satellite that actually monitors groundwater from space, so I will show you how, what is the principle it works, and those who have knowledge of GIS and remote sensing can easily download it.

Now, with all these data you can understand how this map is created by the central groundwater board which is an aquifer map, because it is not only created by the layer rains which is happening but also the data which is taken at different depths and the dominant aquifer is mapped for India.

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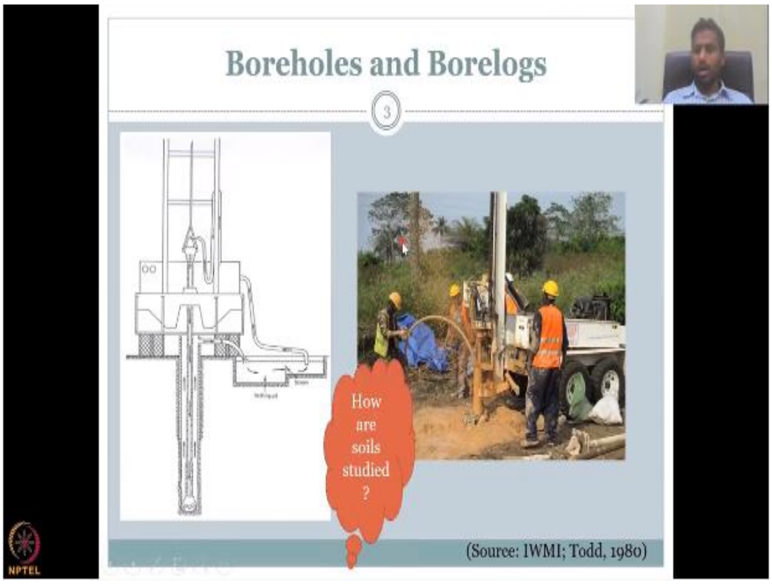

So, let us move on to today's lecture which is the boreholes and borelogs. As I said in the groundwater access slides, we looked at this truck coming in and putting a drill into the ground and then adding columns to it and digging very deep, mostly the deep aquifers.

It goes to couple of meters and this method was called the drilling method, so while you are drilling I told that there is a lot of debris that come out, the rocks, the sediment, the water you can see here it comes out, but what do you do that is it does not come out by itself, you have to pull it out, you pull it through the auger, you put it through the drill bit.

So, here at this bottom you have a drill bit which is looking something like this, it looks like an x mark or a very irregular shape like a blade of your mixie, take a mixi just visualize it that you attach attached at the bottom and it spins, when it spins it eats out the rock, the layers on the side and then you take it out.

Now, if you take it in regular samples, the depth of this rock type by the motors etcetera, you can establish what layers are present in the aquifer, we are not able to do that now, why? Because most of the time what happens is when a farmer needs a well, he calls this truck, the people go there, they put down the instrument, they add the columns, drill, take the debris out and go.

There is no documentation at regular intervals what soil is coming out, what rock type is coming out and what water is coming out because the water may be salty, they just take it and drink and say ‘oh it is bad, it is good’ and then they do some test and then they give it, but most probably you should also take the rock samples and understand what is the property and that is like your soil analysis. So, just for the sake of how soil is done I am going to show you some slides, so that you can now relate between the soil and how the deep aquifer rocks aquifer types are done.

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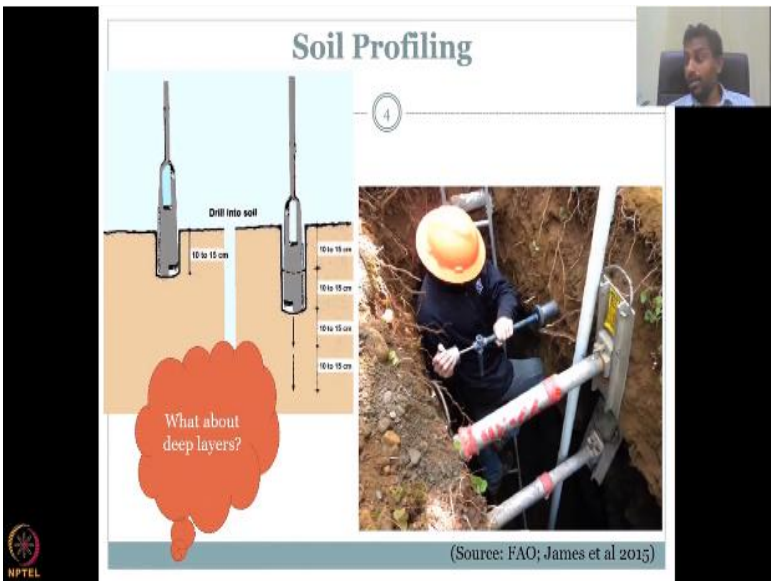

So, how is soil study, how do you take a soil sample? You take an auger method, you have this drilling method and then the top you have a drill which is you just rotate and it goes in and you pick the depths at which the instrument should go in, in the inside the instrument there is a column, a steel column, a steel pipe, it is basically a steel pipe which is cylindrical and it collects soil.

So, when you drill this cylinder will be pushed inside and then it takes the sample out and then the sample is then taken to the lab and analyzed for chemical and physical properties but then here what happens is you have at different depths also you can take, can this be done for deep aquifers for aquifer mapping, no because you cannot hand drill it to that beam, so this is one way of doing the sample.

What is the other way? They use an excavator, they dig a big hole, they dig a big hole and then you go inside, you can see the scientist, here he goes in with the ladder and then he pushes a small auger or cylinder inside, so you can see the cylinder, it goes inside takes a sample out, so at different depths they will measure, so you can see a pipe which is being used to measure different depths, he will go inside different depths and take the sample and come out.

Now, the sample is then tested for chemical and physical properties, the idea is can you do this for aquifers, no you cannot, but you need it, so why do they need to do different steps, different depths is because they want to understand how the material changes. Similarly, you need to do it for aquifers, especially for aquifers to understand where the water is and where the water is held in the aquifer, so that is where you need heavy artillery or heavy machinery.

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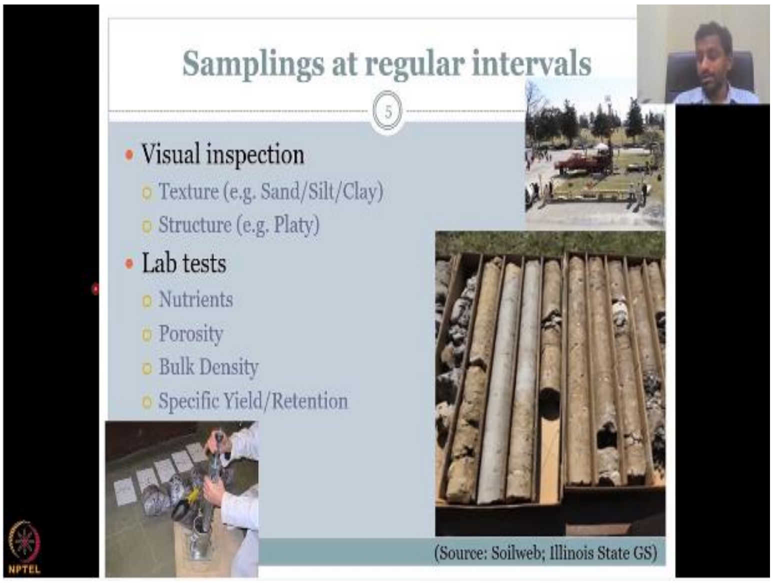

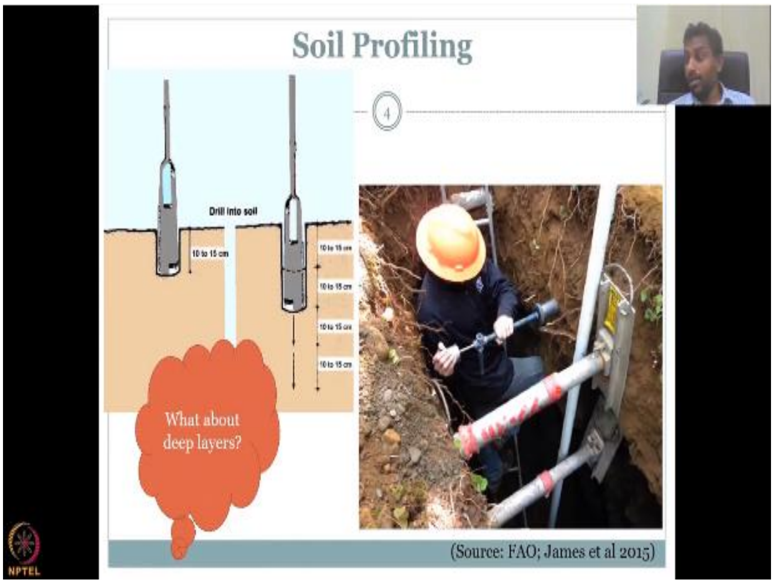

Samplings at regular intervals is very much needed and at varying depths, what you see here is the same drilling machine which has to be parked and instead of drilling for water now you are going to drill for the sample, the soil at the top and the different rock and other materials at the bottom, then each sample is taken to the lab as you can see here for physical and chemical property assessments, they take the sample push it inside the lab containers and they do the experiments.

So, what happens is when you push this rod and then take a sample out, you will have different depths of rods, so the rod is taken like this, first you push one rod in, take the sample and then you attach another rod push it in, take the sample because the depth is going to increase, the thickness is almost the same what you take out, what you can take on because sometimes the rods would not go in, so you will see less samples in it but our idea is from A to B what is the dominant rock type, what is the dominant soil type I will take it out and then I do a visual inspection.

The visual inspection can be used to understand the texture which is the combination of sand, silt and clay or individual items, is it sandy, is it silty or clay, then it is used to understand the structure, just looking at it they will know is it platy, is it prismatic, is it like grainy or bulky those kind of things.

These data are important first visually to understand how deep one should go because if you are going to see all very hard rocks like this there is no point in going more and more deep because your instrument will face technical problems and there will not be any water, so at the end of the day you are mapping for water not for oil or not for rock, this is purely for aquifer mapping.

If you go to a geology course you will have different depths, you will go very, very deep, even kilometers deep, here we go 600 meters those kind of things. So, then some of the samples from here are taken to the lab for lab tests, wherein nutrients are analyzed, nutrients as in chemicals for example, if this material has a lot of arsenic, then you should be understanding that arsenic can mix in the water, same way if it has fluorides or iron content then the water is mixed with this content because of geogenic contamination.

It is unfortunate you will see this is the water people drink in villages because they do not have other resources. So, that is why groundwater management is an important course, if you understand these layers of soil and rock, if you understand the chemical properties of it, you can tell the people like do not drink the water.

So, the lab test should be done, then the porosity, the physical parameters of porosity, bulk density, specific yield, specific retention, hydraulic conductivity everything is estimated, all these have already been taught in class, all you have to do is go back to your notes, check what these properties are and now I am going to show how these samples are taken for these tests.

Because slowly we are coming to the end where we are going to look at data, construct an aquifer and then how to read an aquifer map, then we will go to case studies because we have only three more weeks. So, moving on you can take these samples to the lab and get it tested for nutrients and porosity, physical parameters, chemical parameters.

And you can establish a record of what is happening at each drill spot, is this happening in this when you do the water level analysis, no, it should happen but however they do not have time as I was mentioning if you give them a sheet and say okay document every 5 meters what is the rock, what is the water, take a sample put it in a bag.

They do not have time, they said ‘no sir, I have to go to another well to put another well’, they will come to that location, either you give a location or they look at the surrounding and say ‘okay here's where the water could be’, they put and then take the sample out drill, drill and then go to the next drill and go on.

There is no data available, it is not only here, but most countries, they should be having a log but they only have a log of where they put the wells but not what type of rock, what water came etcetera, they should maintain it regularly.

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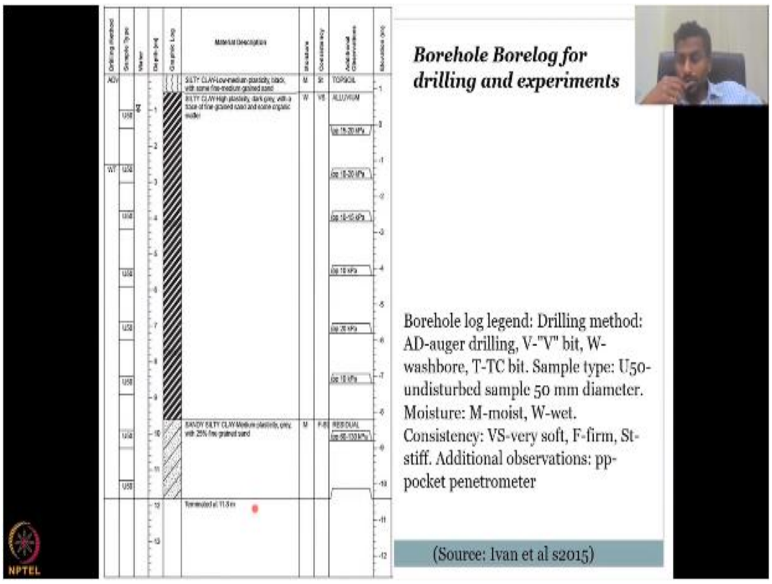

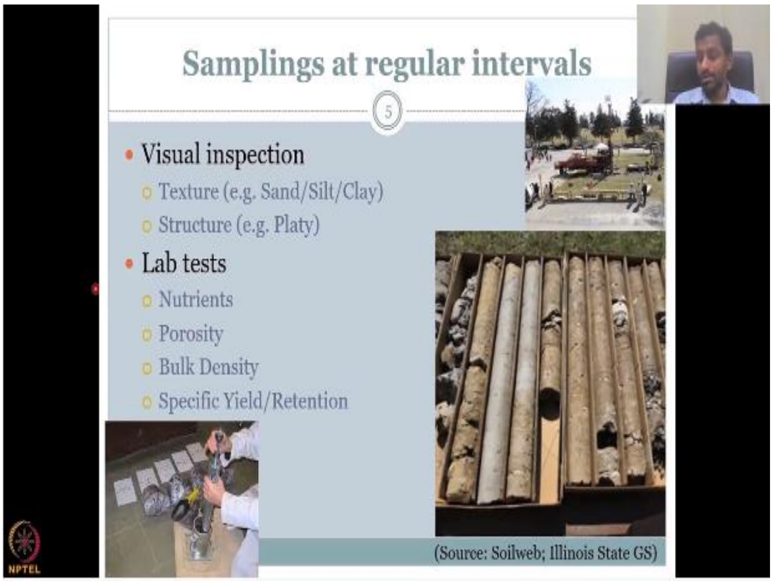

So, moving on let us now see what we can do, how do you enter it in a piece of paper or a data sheet. So, this is called a borelog sheet wherein you enter the data of the samples that you took. Let us go through what the columns read, the first column is your drilling method, there is only one machine but the drill bit what you attach at the bottom may be different depending on the depth and depending on the rock.

So, initially you start with the ADV which is a auger drilling V is a bit, so bit is that mixi component as I said, the blade, so that blade and an auger type of blade with a drilling bit is sent in and mostly that auger type is only for the shallow aquifers or unconfined aquifers.

Then when you go deeper and deeper you use the WT method, where W is the washboard and T is TC bit, the bit changes it is not the V bit, not the V shaped bit but maybe TC bit, I am not getting into the engineering of the designs and stuff, all you have to know is when you have a mixi and when you put for example, tomatoes and fruits you use one blade and then when you throw the juice out and then you put hard things like coconut, pepper and those kind of things then your mother uses a different kind of a blade.

So, that blade differs not because of the mixi but what you have to put in, same here the bit will differ based on the rock type, if you want a carpentry, if you are using it on a wood you use one bit, if you are using it on a steel a drill, a steel drill you will use a different bit.

Basically, the bit is maybe I can draw it just for understanding, so this is your drill, the thick thing that you have, the instrument like your drill, we had a drive point, you had to hit it, so the nail kind of, this is the nail part, maybe I can draw it again, this is the nail part and then here you can have different types of sharp mixi components as I said, the blades and that is what is changing here the drilling method.

Moving on then we go to the sample type, here all these samples are taken in a undisturbed 50 millimeter diameter cylinder, it is called U50, so basically you slowly push this cylindrical container which is 50 millimeters in diameter and then you take a sample out, keep it separately and then you go again, drill take a sample, drill take a sample and go like that.

So, you could see here almost they took one, two, three, four, five, six, seven, eight, nine, nine samples in 11.8 meter depth, so almost 1 meter once they would take a sample. Now, think does the person who comes for water for putting a well, borewell do they have this time? They do not, but they should be documenting it because the data is missing now, throughout India you have so many borewells but we do not have borelogs, there is no data about what these wells are.

So, every meter you take a sample and keep it separately like this, so this is every meter one, one sample, then you go and say where the water depth is, so here the water depth was just one meter below the surface, so that is good, so the water is set but still you drill and see what the material is and this is the depth as I said and as I was initiating in the in the previous slide and here it was stopped at 11.8 meters.

So, after 11.8 meters depth the machine would not have gone in or your constraint for power or depth of the tool and or you found something very straightforward that it is not going to change, like for here the graphic of the log, the visual, the visual interpretation, the physical interpretation, lab interpretation is now drawn in the sheet of paper saying from the top to 0, maybe half a meter you have silk clay, low medium plastic thing and you can see a legend is used.

Then a crossbar diagram legend is used to say from about 50, not 50 meters sorry, it is 0.5 meters, so 0 to 0.5 meter to silty clay, then from 0.5 meters to around 10 meters it is silty clay high plasticity with the trace of lime grain sands or some organic matter, why is organic matter present because it is the top, at the top you should understand that there is some decay happening, the plants, the trees, the leaves and sunlight and water are acting, so there is some decay and that decay of organic matter is on the top soil.

When you go down from around 9.5 meters to 11 meters it is only sandy silt clay, medium plasticity, gray color 25 percent fine grain. So, after that maybe the person drilling the scientists would say ‘no it is enough’, because it would not change its only bedrock is going to come and the water is enough, so this depth 11 meters water is enough so let us stop here and then take the sample, take enough with the sampling.

So, that is the two, three columns that we saw, then what happens is the material description as we went every description, the visual, the texture the chemical properties can be put here, it can be left some space so that you can add after your lab visit. Then the moisture, you take a sample and then say is the water having, is the soil or the material having water and that is given as M for moist and W for wet.

So, why is the top moist and below wet, because the top might be evaporated, plants and animals act on it also, they graze and then stuff but most importantly wind is acting, sunlight is there, so it dries, evaporates, whereas the bottom right below the bottom of the top soil, the top soil which is only a couple of centimeters deep, you have a wet soil and rock type.

Then when you go down again it becomes moist, it is not wet not fully water but moist, again why is also wet because the water table is there, once the water table is there all the pores are filled with water, there is no vacant space for air to be present, so it is not moist, it is wet.

And again please see that at this depth, it is the water table but why are we having wet here because dominant layer is what we have to say, every meter you take a sample, not every centimeter. So, every meter you take a sample and throughout it you can say it is dominant species because you cannot afford to do sampling at every meter, every centimeter or any millimeter, so you have to take one chunk and say this is the dominant species.

The next column gives you the consistency of the material is it ST which is stiff, or VS which is very soft and then FST which is firm and stiff, stiff means very hard and it is firm it is extra hard, more like it is the barren material, so you do not want to go deeper than that. So, the borehole is the hole that you dig for the well and the sample you take out can be called a borehole sample or a borelog sample.

So, additional observations and observations can be also taken like pp which is the pocket penetrometer to understand what is the pressure, how much pressure you should be exerting to get in, I have another slide to show what exactly these mean and how it is useful because for here you can see the pressure to go in is very less 20 kilo Pascal but when you go down further and further the penetration is going to be very tough and that is where you stop.

Otherwise your drill bits will break, your instruments will break, your technical issues will come and it is better to stop because the physical understanding is also you are good now you know the water, here we are not drilling for petrol, here we are not drilling for rock types, here we are drilling for aquifer types, which is a mix of rock type and the water availability. So, this is a one well, one well you take and you put a sample of the sheet.

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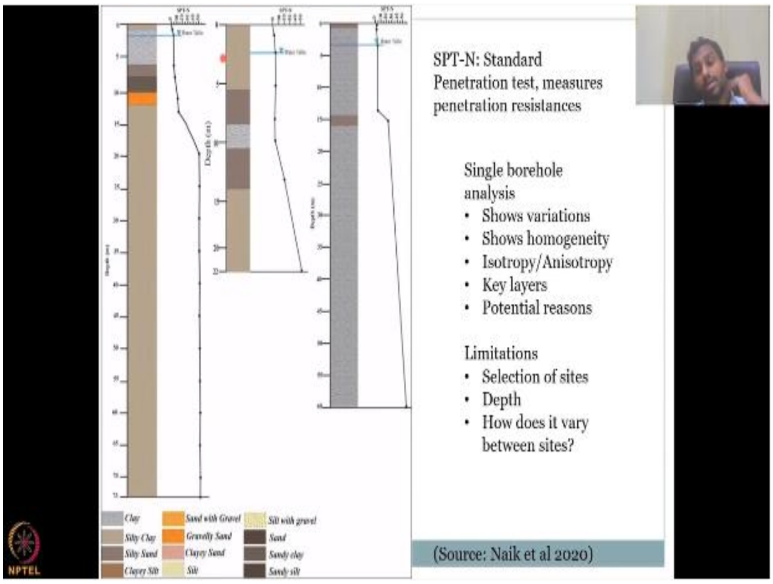

So, now let us look a comparison between wells, each one is one, one site but in the same area, same boundary of the study site. What they have done is for example, make at all they have taken a sample and categorized the material at each depth, so the 0 is the same and from 0 they found that the first sample has a lot of clay on the top and then when you move down there is some sandy clay, followed by a thick sand

and then some sand with gravel or gravelly sand and then we go down more clay, silty clay.

Whereas some meters apart you have only clay and then you have sandy clay, again pure clay on top of it is silty clay and then silty, then here almost homogeneously it is clay. So, what is happening here is there is variations, so what do you read from a single borehole analysis, that is what is important and also tell about what is the standard penetration test.

So, this study for each well they have also measured this standard penetration test along with the water table. So, what does the standard penetration test give you? It gives you the resistance of penetration, which means higher the resistance, if it is high resistance you cannot penetrate in, if it is low then you can penetrate through and the drill can work, so it is a very standard test.

So, what they have done is when they moved down, you could see in the first let us go each, each sample by sample. When the first sample they went down after 10 meters depth they could see a sudden jump in the penetration resistance and then it becomes stable, so once you hit a stable rock, a stable penetration, most probably you will give up because you say that it does not change and also it is very high 50, the penetration test is at 50 they will normally stop because after that you would not have much differences, you would not have much water.

The same is happening for the second, here the depth is much less here they drill for 73 meters but here you could see that they drilled and then suddenly it rises to 30, 40 and then 50, when it goes above 50 they stop, it is like metric they have, if you go above 50 do not drill it, it will break or the there is no water going to be there because if it is going to be hard for penetrating how is water going to go there and steer.

So, that is the part but they try, they try to see maybe it is an aquitard, it was a impervious layer and then when you go into the impervious layer there is water, they will try, they go like couple of 10 meters deep but then if they see no changes they stop.

Same thing here from a clay layer they go and suddenly there is an aquitard or an impervious layer, so suddenly the penetration jumps, but below the penetration test also below the aquitard also there is a very thick solid rock and so it just keeps on increasing after 50 they stop. So, what you see interesting here is that the depth is changing.

The depth from which on the top they dig is changing, they stop, the stopping point is changing because they now understand that it is maybe an undulating surface like this and the bedrock is reached, no more water is going to be there let us stop. So, from the surface it might be the same, on the top its all looks the same but when you go down there is variations.

So, what does these analysis show you? It shows you that the single borehole analysis, the single bore variations between the layers, between the depths, so as the depth changes there is some variations it also shows homogeneity, so for example, from 15 meters to 73 meters it is the same.

So, the same log shows you variations and homogeneity. Isotropy and anisotropy which is all discussed in the previous lectures, isotropy means it changes the direction along the direction it does not change or change the property, xyz we discussed and then the key layers, the key layers are also identified because the dominant layers are taken and mapped in this borelog graphics.

So, all this is important but how does it tie with other logs is also important, so each log will have potential reasons, why this particular layer is there and why water is there because of the porosity, the nutrient property, the physical properties, hydraulic conductivity specific yield etcetera.

There is also limitations, let us quickly look at what are the limitations. Selection of sites, how do you pick this point is a limitation, what science have you used to say this point we are going to drill and take, a lot of people do not have that understanding, they just randomly dig and then say I am going to take a sample, how do you relate between sites is also missing.

The depth, how deep you go can be limited by your understanding or by your technical measurement device but maybe there is water underneath we do not know so that depth is also limiting. How does it vary between sites then there is less understanding of it, so why does clay come here whereas less clay is here they do not understand when they drill I am saying so that is a limitation why they do not do these drill log experiments.

But we will see this in the next class, how do these individual single layers talk to each other and a beautiful aquifer map can be done will be analyzed in the next lecture. I will see you with that in the next session thank you.