Groundwater Hydrology and Management
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Lecture 43: Aquifer Fencing

Hello everyone, welcome to NPTEL course on Groundwater Hydrology and Management, this is week 9, lecture 43. In this week we have been looking at the stratification of the aquifer, how to layer aquifer based on data, what is a borelog or litholog, we have seen how single column sample has been taken and different layers have been identified and we also saw how to take multiple cores or lithologs and then connect them between them, what to connect the understanding and information between them. This is very important for understanding the layering the dominant layer typologies and to estimate where the water is coming or where the water is going to be stopped.

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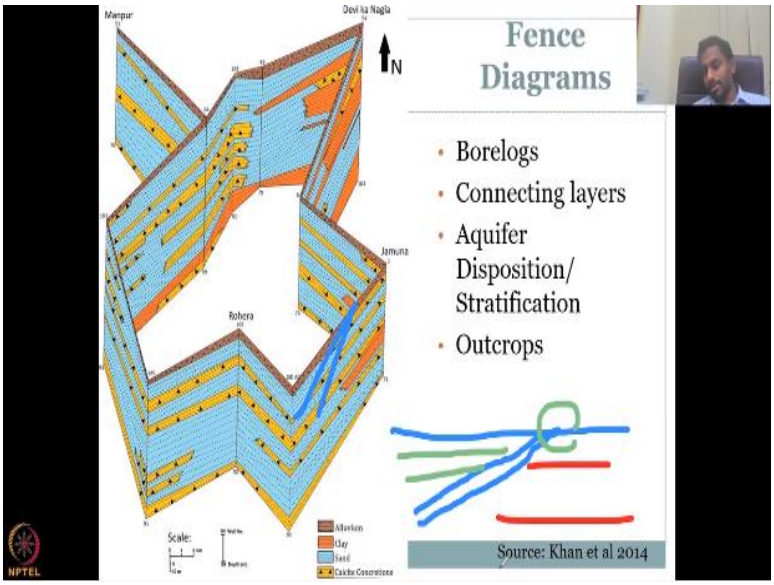

With this we are going to move on creating more understanding using fence diagrams, these fence diagrams are driven by borelogs data, you can see each borelog data is given on this each line, then each line is connected based on the layers. Let us take a boundary for example, so this is your watershed boundary, where you had all these wells, this is the or your borelog, you have all these borelog in your watershed boundary and you try to see how the layers are matching between each others.

Now, you see that the top soil which is gravel in brown is very thin, if you see from the top of the fence it looks like all are same elevations, however it is not the elevation difference is available in these regions. So, every log has its own number and name and there is an elevation until which it has been done, so you see a thinning or thickening of the layers depending on how the layer has been formed.

So, if you look at here, look at this layers and all you would see that it is all parallel, so all these three wells, well one, well two, well three for example, have had the same thickness at the same height, so you can easily make a parallel and that is how the layering happens.

But after some time it stops, it stops abruptly, you can see here, the layer just stops. So, you should also stop on the diagram so for example, from this data point to the other data point it is there, however in this litholog there is no yellow color aquifer or layer, so it has to be stopped, the same here also and then if you have an angle.

For example, the orange you can see an angle coming in, zoning in if you have an angle then that angle can be used to understand that it is going to small thin, thin and then pinch out, which means it just goes as negligent, for example I will just draw it here so the layer, layer will go like this the thickness will be big and then slowly small, small, small and then nothing, so that is where it ends.

So, this would be a different material, this would be a different material but this layer which is you know in between the layer and which is going to be thin and stopped because not always parallel, you cannot expect the deposition or the layer forming to be a parallel phenomena.

So, what we see in the fence diagram, since it looks like a fence, they create these diagrams to understand where the lithology is different, where it is same and how it quantifies the thickness of the aquifer and or the water bearing regions. So, the connecting layers are formed in the multiple lithologs.

And then the aquifer deposition stratification is understood, both are all same meanings then as I said borelog is same as borehole core sample or lithologs and just the name differ between the region, but the understanding is the same. Same way aquifer disposition, which means how is the aquifer layer or stratification can be understood by this data and fence diagram.

Also you will be able to look at the aquifer pinching and the aquifer coming out called outcrop. So, what is an outcrop? For example, if an aquifer just a thick rock permeable impervious rock just comes out of the aquifer and then cuts through an aquifer it is called outcrop, why is this important, it is important to know how the water would flow and why suddenly there is no water on one side of the outcrop.

For example, you have a layer it is a ground surface and you have a thick layer which goes like this and this is cutting your other aquifer types, because it is cutting and it comes out a little bit, you call it an outcrop, an outcrop would actually kind of divide the land underground into couple of layers or stop a particular layer, for example, this layer stops and then another layer is here, the dominant layer is here, it is kind of a division and that actually gives you an idea of what kind of water is present, why the water is different on one side of the outcrop.

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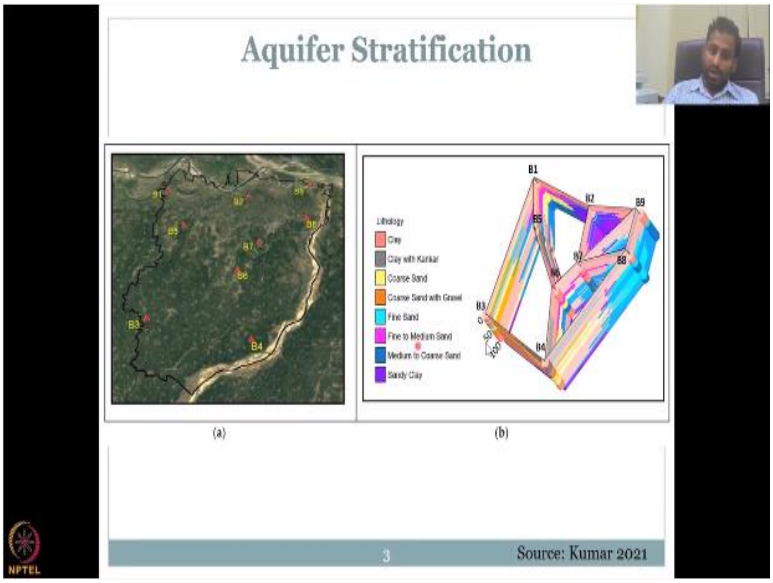

Moving on let us take another aquifer stratification example, again I am using it very cautiously that the word is different stratification, fencing, disposition all are about layering of aquifers, so do not get confused when you read books or papers, that is why I am using it thoroughly, intermittently and you know changing the terminologies because it is all the same.

So, you have a watershed area done by Kumar et al, you could see that they have taken the lithologs or the boreholes or the borelog in these locations, you could see it is not equally spaced, nor it is gridded which means it is like fully represented for example, here there is no data, so they will take where it is feasible and where they want to do some interventions.

So, if you look at it then they would connect these logs together to create an understanding and since it is a 3D, if you have 1D which is the depth and x, y is your 2D, so the z which is the depth, so this is the land and this is x, y plane, we call x and y, so it is spread in x, y plane and then you have the depth as y, I am sorry z, the depth is z.

So, you have different depths which can be converted to a 3D model, see a paper is just a paper, so this is just one sheet is an x, y plane, but if you add a thickness to it, then it becomes a 3D paper, because these thickness what you see or a thick layer like this becomes your 3D dimension.

Now, I could do like this and this to see that I am not only having a 2D plane but also the thickness also I could see like for example, like this, so you can see the x, y plane and also the thickness, in this fashion you can only see the x, y plane, in this fashion you can only see the z plane, only the thickness but then when I tilt it a little bit you could see that the x, y can be visible and the y, z thickness can also be visible.

That is why you can see this tilted land it is not that the land is tilted because look at here B1 is here and then B2 is here, so it is not like B2 is almost on the same line, so they will tilt it in the model when you put these data and then supply these data points, then you can tilt, when you tilt it then you could see clearly how this aquifer is present.

So, it is just like a small toy where you could tilt and see up, down like you see interior of a car nowadays online, you can just click and turn the car, same thing like this, so what you see here is in B1, you can see B1 you have the predominant layers of clay and then I see fine to medium sand and then I see coarse sand and then medium to coarse sand etcetera. So, it is not the same this coloring is not the same as here, whereas here you get more fine sand, B8 and B9, so B8, B9.

So, the process of which the materials have been formed is different and that is evident in the different colorings of the layers, it is good to have these colorings and as many layers as possible, when you do a model there is no point having this many layers because of the computing power which is needed and also most of these properties if you remember in the porosity, hydraulic conductivity lectures the properties are also in the same range, so they will just club everything and then make it one or two, three dependent dominant layers.

And you see also the position of the layers is different, you can see here violet on the top which is sandy clay, here it is on the bottom, why that would be or fine to medium sand is at the bottom, it is on the top here, why that would be the case is because this blue color which is your sand which is being deposited on top of each other can push down the other layers.

So, let us look quickly between B3 and B4, 0 is the top of the ground and then you go down to the depth, so it is all 100 meters deep core, sample has been taken, 100 meters and then you could see that in some places the thickness is small, some places is big it is because they did not dig deep enough but clearly visible is one side which is the B9, B8 this side has more fine sand, so if you have fine sand if you pour water on it, it will just drain, no point of having aquifer recharge activities.

Whereas, here it is clay with coarse sand and coarse sand with gravel which will have more water holding capacity, specific retention is high, so you could see how these are placed and how they talk to each other in terms of understanding the layering of the aquifer.

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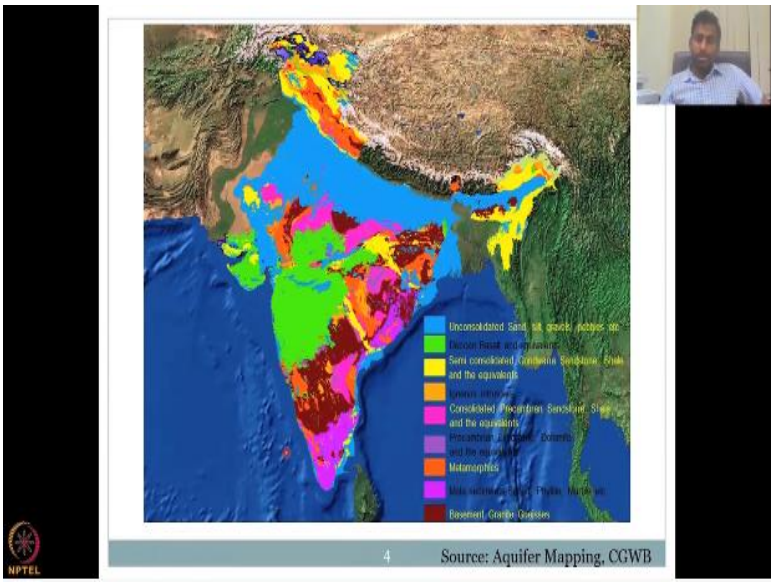

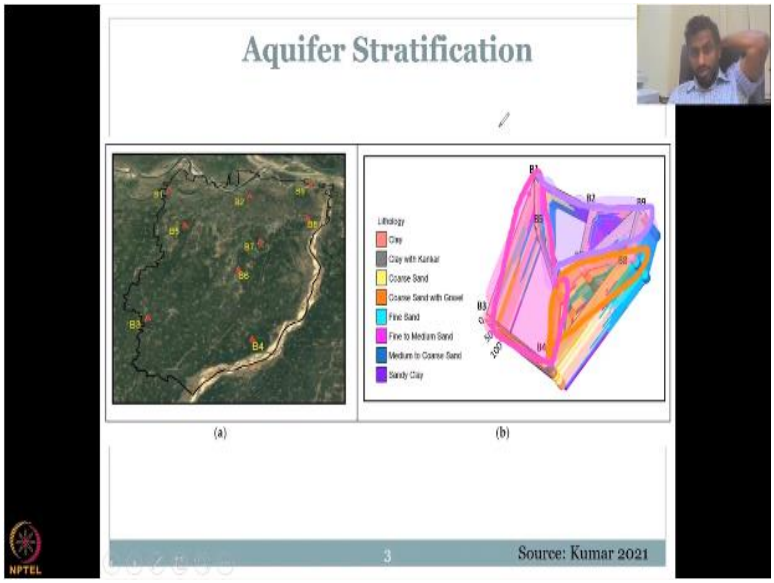

Let us move on, now if you do this for the entire India, so just going back you could say that I could color this area before we talk about the India scale, what can happen is for example this is all pink, so I can color this, I do not have much colors online, let me try, so I can color all this aquifer pink, so because on the top it is pink and this blue or violet let us take a mixture of those, so this is a blue, violet I can extend that to here also and then this part is kind of yellowish orange.

So, now you see three different aquifers, let me draw the line, so that you could actually understand how this is done, so this is all orange and then you have your pink which runs like this and then you have your violet which runs like this. So, now if I change the image, if I am going back, now you could see that it is three distinct layers which is or aquifer on the top it is being demarcated from the top plane.

Because that is the dominant on the top, that is the same way this India map has been created, wherein they would look at the core samples, the borelog data and the litholog data taken at multiple points, they take it at multiple points and they would for example, like this and they would just sorry, not like this and then they take the top of the borelog and then they match it together, the matching is done, all the aquifer is mapped.

So, this is how the aquifer mapping is done at an India scale, they do not want to keep it like in one aquifer for the entire country, it is not possible and it is not correct, so it is good that the samples have been taken and at least the top, the top layer or the dominant layer throughout the median has been identified.

What you see here is of the vertical column, of the vertical column they will take the dominant one type of the aquifer and here you can see unconsolidated sand silt is in the blue that is why you see in the previous one also there is a blue color correct, which is saying it is sand and it is along the riverbed, so that is where a lot of these deposition happens.

And then you have recon basalt equivalence which is the hard rock region and then you have your semi consolidated sandstone, shale and the equivalents around here mostly the hilly regions, igneous intrusive also the hilly regions, consolidated precambian pink in central India and then metamorphose, meta sediments etcetera.

So, the idea is each core is now taken and when it drastically changes from the different core they would change the dominant material, so please understand that the dominant material has been changed throughout depending on the borelog data and the whole India map can be made, for sure they would have taken the data and used in understanding these maps or making these very, very important maps.

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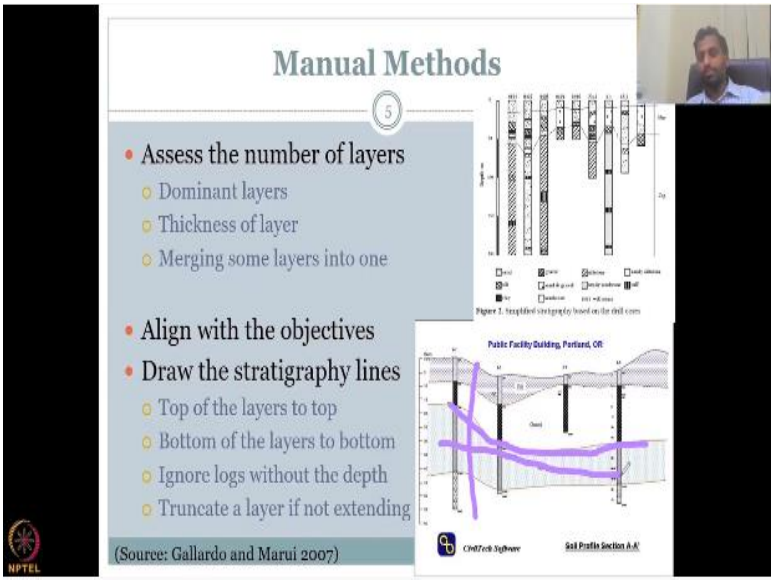

Now, let us look at how it is done, I have showed you how the data is available, so the data you would did and then take and put it across as coarse and in a graphical sheet like this and then you would make the layerings or understand how many layers are dominant for example, this data would be the same as this one, which means with seven, five layers but then they will club everything into a dominant layer which is what you have three layers here, three maximum four layers one, two, three, four.

So, let us see how manually you do the joining of these layers, so how is it done manually, assess the number of layers per core, so each core you take or litholog or borelog and then you take the dominant layers you understand how many dominant layers by the sample and other things, you then estimate the thickness of each layer, so each layer thickness is estimated, merging some layers into one.

Here is what I said, some layers have to be merged to one, otherwise you will have these many multiple thin, thin layers without making sense because you want to store water and you want to use it later for agriculture, there is no point having multiple layers which do not give add more value to the system.

So, how else would you do with the mapping, you would have to align it with your objectives, my objective is to understand the deep aquifer recharge, I will go as long as

deep and then ignore the top much because I will be focused on how is the water coming down and how is it being clubbed together into an aquifer, down deep back of us you would not see much bifurcations only in the up regions you will see more bifurcations.

And different types of layers because of active things which happen on the top, like erosion you have, deposition, alluvial, columbium where rocks move all those stuff. Then you draw the stuff stratigraphy lines, manually this is just a manual methods I am talking about, you understand where the top is, top of the layers to the top, so top to top you connect one line, same here let us do it quickly for you again, so this layer draw black layer this is the top to top is connected, in the grayish layer the top to top is connected but then this layer is given off.

Because ignore logs without that depth, you do not have that depth or you do not have that sample, if you do not have that sample you can run through with the interpolation, so what you are doing here is this basically interpolating the type of rock from one point to the next point because there is no data, for example, if I have a data well, if I have a well here which has different, different materials around this area.

So, then what would happen is you would draw from here this level and then come back, same thing from here it will go on to Canada and it will not come back, so the layer would not come back because we are looking at one direction and more importantly the layer has to capture the dominant layer, not all layers together, so think about it from the top you connect the top to top, if you have one layer and there is no the same type of layer you just interpolate it throughout, interpolation is how you fill a gap which is in between two known values, so you interpolate it.

The surface is a continuous data, every inch you have surface but your observation is a point data, only at some locations you have points, so it is up to you to make sure you arrange them in a particular fashion so that you have the layers I am saying the layers arranging so that you have the dominant layers and you connect the layers, if you do not have the layer it is better to ignore that well because it might be like just in that well you did not have that data, if you have it in other data it could have mixed, it could have been a sampling error.

If no logs without depth which is here, this log is only suitable for the topmost layers not the bottom layers, here the bottom layer is the third layer, it is not interested in that. Then truncate a layer if not extend, if you are not seeing the layer extending it is better to truncate.

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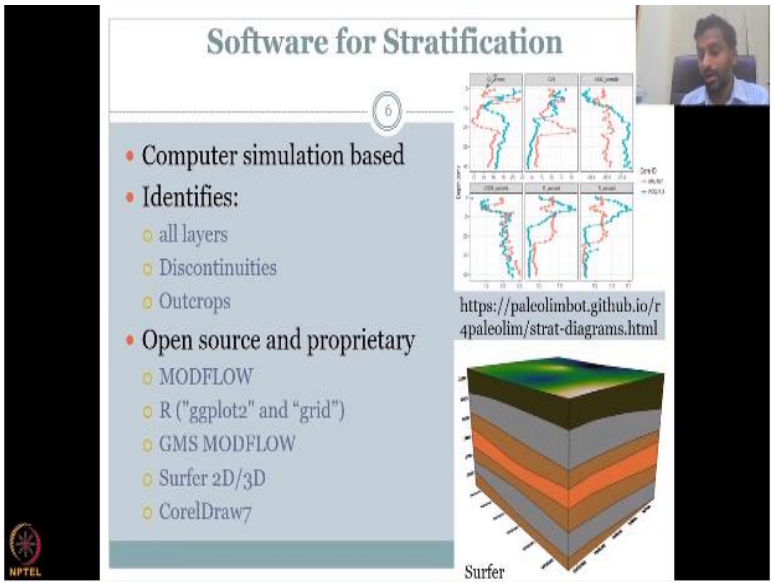

So, that is the manual method, now let us look at the software methods. There are multiple, multiple softwares available in the market and the softwares can be open source which is free or it can be proprietary software, which is you have to pay. So, the software is like a computer simulation model, it simulates the aquifer layers based on your data, what does it do?

Let us look at the core function, so it is a computer simulation based algorithm, there is a lot of mathematical, statistical models where it interplays one point to near another to make a surface. So, like this surface again you should understand that all the surface was made by just points and interpolation, we had a point a data like for example, it was data here, there was data here, there was data here you just interpolated it between them based on a method and then you got a surface.

It identifies all layers, all important layers or non-important layers are identified because it is a model it can do all the connections, it can actually look at if it is different, different

connections different, different layers thicknesses it can capture. Discontinuities can be easily monitored through your interpolation techniques.

Because you do not know how do you, see if there is only two points and you are making a surface it is okay, I can interpolate but then there is a well here, there is a well here, there is a data point here then all these data points have to be influencing this interpolation that is difficult to do by hand and that is where a simplified model is okay to do by hand otherwise it is better to use a software like this.

Where it will tell you if the discontinuity is happening or which means a layer is going and then it stops, it is a discontinuity or the layer is cutting through other layers which is an outcrops, all these can be perfectly modeled using the interpolation between the wells and then it picks up the type of your layer. Please understand that there is multiple models as I said and all of them are based on the interpolation statistical methods, it is better to choose from literature some model that has already worked for your area.

Let us take another look if you have multiple wells or multiple data points for lithologs, how do you know which one has more weightage to influence your output, that is also taken by your softwares. So, for example, I have four, five, let us add one more six, so this is equi distant from this line, this line, this line and this line, so which one should you choose to make the boundary of an aquifer? In a software it will choose everything and then finalize one or finalize one theme.

However, in a manual you have to do one pairing at a time, so it is very difficult it is better to do it using computers and especially the well trained models such as MODFLOW, R, R is an open source statistical model and a mapping model or graphing model, so using ggplot2 and grid you can do that, GMS MODFLOW is a proprietary version whereas just smart flow from the USGS is a free version.

You can use either of them, Surfer 2D, 3D has been widely used across the world, it is expensive but it has been tested by a lot of people, so a lot of scientists and researchers, so it is better to use your Surfer if you have the budget because it has been widely used and CorelDraw is also new and it has been widely used.

So, this is a Surfer package where it has a 3D version and as I said you can pull, turn it around upside down and then look at it, whereas here which is your R based model, it is not as robust with many buttons and graphics but it gets a job done, basically it gives you from 0 to 40 centimeters in each slot which turns in each experimental setup, it can take and look at what is the dominant layer and also the nutrient properties based on the samples that is taken from the ground.

So, we have now seen that it is very important to have these layerings done, so that we understand that the layer has to have only dominant identification points, if it is very small the layer should not be called for example, it is a clay layer it is only 10 percent clay or it is the first clay that you see, no, so all have to be weighted in and then you give it to the model, the model will tell you how many layers is possible and how many layers is not recognizable or not recommendable, if you go to the deep aquifers you will always see one or two dominant aquifers. So, please think about it and then we will see you in the next class with more examples on these methods and technologies.

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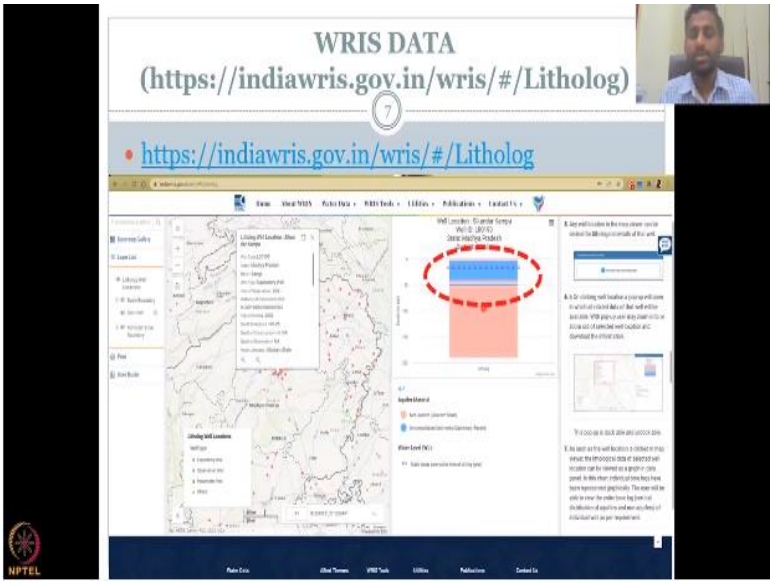

Before we finish I am going to show you the introduction to the data for this which can be bought from the WRIS website the website link is given on the top slash litholog, so litholog is same as borelog and borehole sample, what you could see is you could go and

zoom into this website each and every location which has a data would be highlighted, it will tell you the year of the data which is 2001 and other aspects.

Most importantly the data pulls out like this, where you have a litholog and a layering already done, so everything is done, you do not have to worry about which layers to choose, how many layers are there etcetera, it is all done for your benefit and then you just use it inside these people especially Zach who has worked a lot on these systems to improve the groundwater hydrology in India.

So, this COVID did not have much engineers working on field projects, so it is important to take data from these websites which already have the data and it has given you the water level, static water level data, what is static it is not a pumping well, if it is pumping then it moves up and down as a dynamic well, this is a static well taken by the state board which I will be checking with you guys in the next lecture on important data for groundwater management, with this I will conclude and then talk more about these lines and other things in the next class, thank you.