Groundwater Hydrology and Management
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Lecture 60
Conceptual Model/ 3D model

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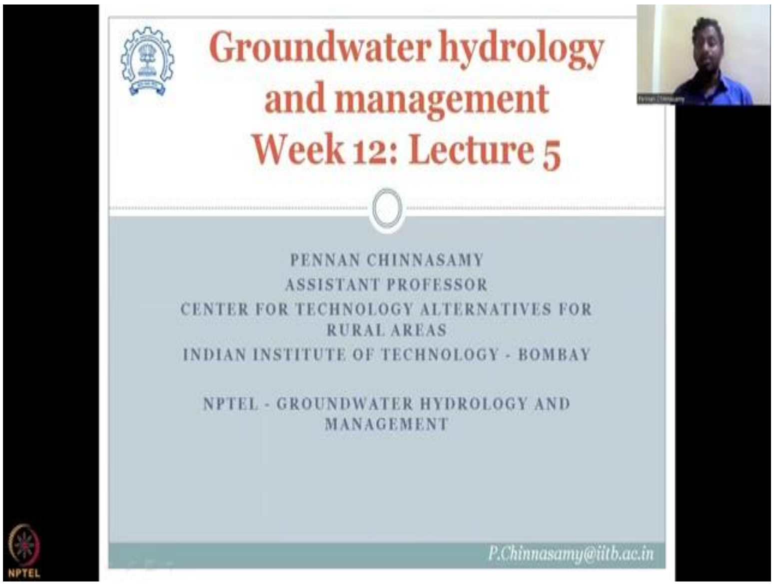

Hello everyone, welcome to the NPTEL course on Groundwater Hydrology and Management. This is week 12 lecture 5, we have come to the last lecture of this NPTEL course. And I really hope that this journey that you took in the course has sensitize you on groundwater hydrology, created an awareness of what are the parameters involved in groundwater management and the data that is needed.

While speaking about data, that is, what is the focus for our lectures in the current week and the last week. So, we will focus again on this little bit on the data path, what do you do with all this data and then slowly finish off this lecture and the course together.

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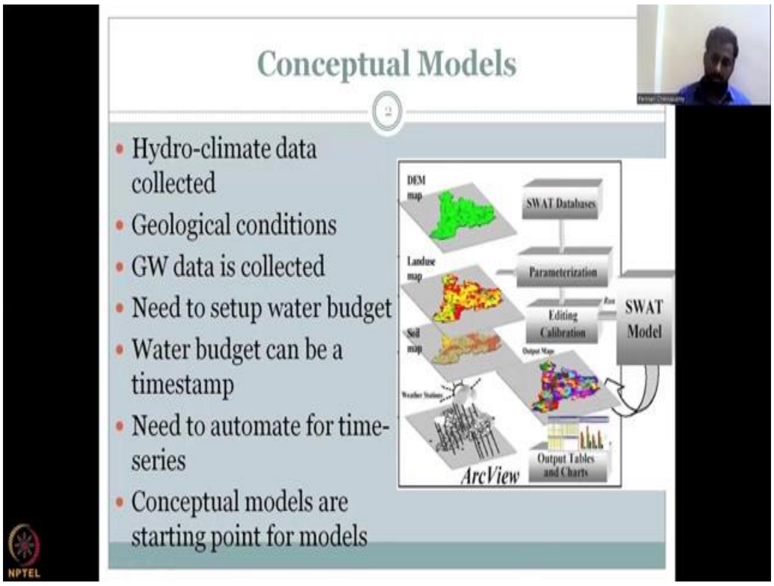

So, what we have seen is, there is a lot of data that comes into the database because we have started with a less understanding of groundwater hydrology, then we establish the water balance from which you collect different data and put it in to the water balance, but the water balance is a time slab stamped event for example, if you say precipitation, it is an annual precipitation or monthly precipitation you use and then you use a monthly groundwater level monthly ET monthly soil moisture etcetera.

What has happened is there is no connection between this timestamp and the next timestamp or the previous one, t equal to 0 t minus 1 or t plus 1. So, this is where you are in need of a simulation model that can capture all this data and then evolve automate from one time stamp to the other. But before that is done, there is something called a consumption model.

Consumption model aggregates all the data that you collected from the field into one pictorial diagram and from the picture you do get a better understanding of what is happening in the real life scenario because, for example, you look at groundwater level and quality separately in a database. When you bring them in a conceptual model, then you understand the groundwater level is declining and the aquifer type is changing as the groundwater level declines and that is why the groundwater quality is bad, unless you bring 3 datasets already asset water level, the aquifer type and the water quality.

So, unless you bring all these 3 different data and marry them together as one conceptual model, it is difficult to understand what is happening. And that is what the conceptual model helps in clarifying by bringing all the data together.

So, we have collected Hydro-climate data ranging from rainfall, and I have shown you about temperature, wind speed and other things but rainfall storage, river discharge, soil moisture, we have looked at data on geological conditions from the lithograph and more whole data which include your stratification, layering of your aquifers and also we looked at high permeable, low permeable rocks, solids, etc. porosity, all these comes under the geological conditions because it is the base rock that actually disintegrates into soil okay.

So, when it disintegrates, you have the porosity and other things formed and sedimentation also occurs due to geological influences. Then we have collected groundwater, which is level, the groundwater level before which we collected the climate and the geological setting, the layering of the aquifers, then groundwater data is collected. So, we set up the water budget, did not we? We just said okay, this is the water level, we also use crase here for small example. And then we said for rainfall for the ET losses, the storage is declining or increasing okay. So, that is what we set up as a water budget, but the water budget was only for one timestamp and it is not giving us a full picture of a longer time series.

More to the time series how do these data react or interact between each other it is not clear. For example, how much of rainfall is actually getting into the groundwater and how much of that groundwater is going into base flow all these need to be calculated and that is where model actually helps to break these boundaries and then bring them as one entity for example, water which comes as rainfall is the same water which infiltrates pushes the water into pore space and then goes into a groundwater aquifer comes back to base flow etcetera. But we need to keep a check on that water always so that we know the volume and movement of water.

So, consumption models are starting point for models, we use them as leverage point where you start using them for understanding or setting up a hydrological model. Any groundwater model would ask for a consumption model starting this is very similar to how you learn to solve physics problems and mathematic problems. When you are taught these, what do they say?

Read the question, take the data from the question and draw it for example, you have a train moving 100 kilometers per hour, how many stations would pass before it stops in a 0 speed those kind of questions or cannon balls fired and it with a particular velocity it goes and then makes a trajectory and falls down and what is the energy differences at each stage. So you will draw it you draw an angle and all this excess. Similarly, when you collect all this data, you create a consumption model, which can be used to better understand the need of the model. Let us take an example here from the SWAT database, okay.

So, this model is actually taking all the data from different different sources, for example, BM, is your elevation data, how your elevation changes, influences the rainfall, conversion into runoff, and the runoff going into as infiltration and groundwater. So, that changes based on the slope and angle of the slope and then you have your land use map especially it influences your groundwater recharge, infiltration, and ET because if there is more ET, there is less water going in, and less water stored in the groundwater, we are just going to focus on groundwater storage, as is groundwater class.

Then you have the soil map, which can be of different soil types in a given location. And every soil would behave differently for a particular slope and rainfall. For example, there are some soils which are hydro phobic, which actually do not return water. So if you have such a soil, your model will say no water should infiltrate, but it does not filtrate. So these kinds of things are built in to the model when you have data for it. And last, of course, your weather models etcetera.

So, all these can go into a database SWAT is kind of a hydrological model for surface water. But I am just using this diagram here because it gives a clearer picture of you collect all this database together, pile them up, and then give it to us what database so for you to get ground water database, and then some parameterization happens some calibration happens, you tweak the parameters, you tweak the hydrologic conductivity, the permeability, the thickness of the aquifer all these parameters, you tweak and then finally calibrate the model and validate the model you will get outputs as a layer or output tables and charts.

So, where does conceptual model come? So, does it come here in a surface water model? As I said, it is not much necessary, but for groundwater models, it is necessary.

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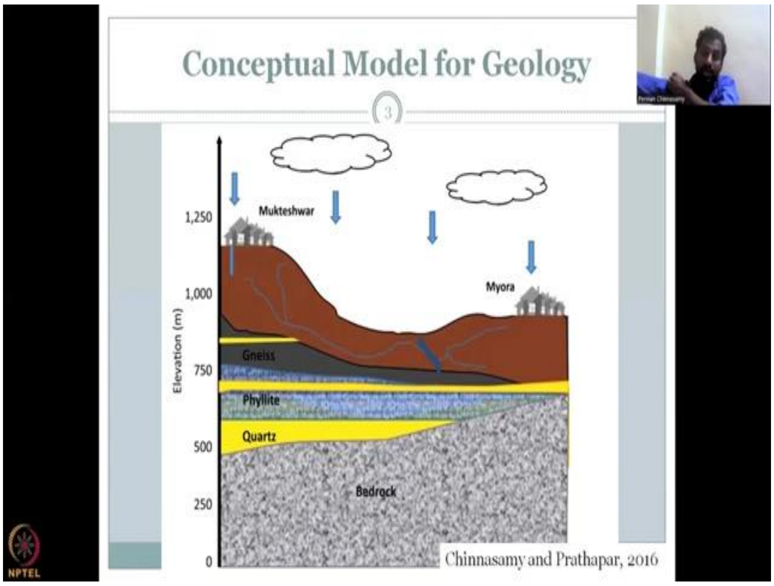

Let us take an example from Chinnasamy and Prathapar 2016. What you see here is we collected different ground realities and aquifer types from more logs. So, we take, for example, distance and a depth. So for a one kilometer radius, for example, we have taken all the locations of the borehole. And we know that when we drilled the borehole in this location Mukteshwar, there was gneiss, and then some phyllite, quartz, and then bedrock. So, there were different layers, whereas in Myora, it was only 1 or 2 layers.

So this was, for us, it was easy to differentiate, because we had this location of the logs. And then we put it in a diagram, where you have the axis as the depth, from 0 level could be the bottom most 0. And, and from there, the bedrock, the you can build up the elevation profile, and how the aquifer material changes. And also with some rainfall and river network, we know that water flows down and forms into a street. So water from here comes down, and in Myora also comes down to this drainage point.

And how that drainage point looks down is also a question where there is lots of interactions, this conceptual model example is purely given to show you only about the geological setting, not much, because this is what you would then think within yourself and say, should I have four layers or 3 layers in my model, etcetera. So, for example, if I know that here, there is only 2 layers, and then just 50 meters, 100 meters out, I have 3 to 4 layers, then what happens is, there is a dilemma how much layers I want, or can I simplify all of this into 1 layer. And that is what happens in the consumption model.

Initially, you put everything in the paper and you draw the model, then when you want to export this finding into the groundwater model, the next step. So, the first step is data collection, second step is creating the consumption model and the third step is converting the consumption model input simulation. So, this third step is where your inferences from the conceptual model will help. The most important inferences, how many layers? Looking at this geology time, we could clarify that there is some differences in the layers. So let us club them, because some there is not much difference between the gneiss and the phyllite, for example.

For example, and I am saying that if there is not much different then I club both of them as a gneiss, okay, G N E I S S is gneiss. So, what happens here is you are clubbing layers, why would I club layers, because the model runs faster, you have less anisotropy and heterogeneity to account for because you assume that all are same, so now the model will be more homogeneous and more isotropic.

So, your parameters also would be shared between these two equally. And that could be a good point for the modeling part because the models take a lot of band space, like a lot of computing power. And also it may crash if it is too much layers, because there is too much interactions you want to simplify.

As I said, in the modeling part, you can make a model as complex as possible to mimic nature, or you could make it less complex simplify, but run well. So that is where you have to have a balance and give and take policy, so that it is a win win for everyone. So, think about it, but this conceptual model does help you in thinking that way of where should I put my recharge structures, where should I put my layers, how many layers and even monitoring stations for that aspect.

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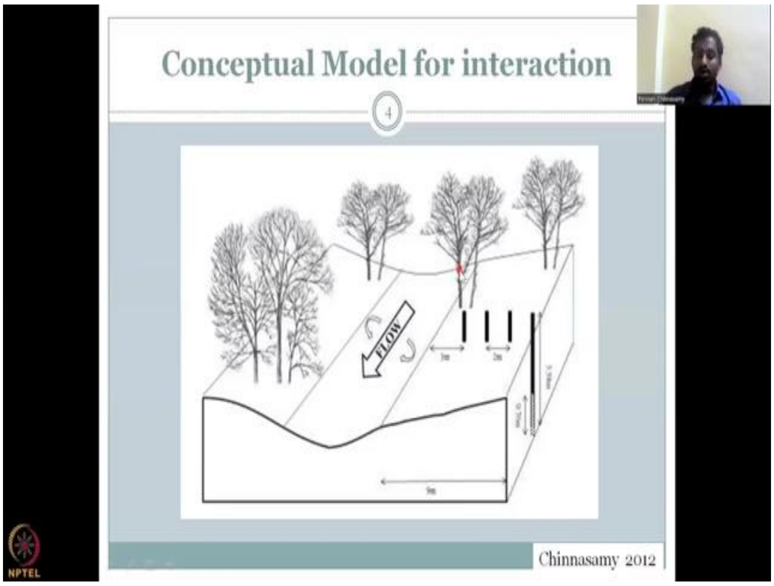

Let us look at another groundwater model conceptual model, where you could see that water is flowing from top to bottom the stream is flowing and while the stream is flowing? Some water is being lost into the banks, riverbanks and then it comes back okay. So, this is kind of a losing stream and then gains downstreamy.

So, when the water comes here in the top, put the point so, when water comes down, you see that the part of the stream is losing water because the water goes into the ground and into the ground, both the sides of water go and that is been recorded in the wells that have been kept 3 meters away from the river bank.

The river wetted perimeter, so, 3 meters 2 meters, so, there are 3 piezometers and the depth of the piezometers is through 3.58 meters. And we have a screen size of 0.76 meters to just think about 1 layer they want to monitor. So, here is the point water goes in, mixes with the groundwater aquifer and then comes back out here as a gaming stream. So, this analogy and hydrology could be understood well, when we draw it because when I draw it, I know the there are trees, I can put the specific tree types and how much water they would take.

Thereby I am climbing well ahead on the water uptake of the plants and the water quality change because when water goes into the ground, it gets filtered out and when it comes back out, there is some better quality of water. So, this aspect can be learned from the groundwater conceptual model.

And now, when I put it into the modeling sphere, where you have for example, more flow simulation model, you notice that my understanding would help in putting some parameters in the model and also fine tuning the results when I know it is not happening for example, if the gaining and losing phenomena is not caught by the model, simulation model, then… and it is asking me to change the river discharge or the well height then I say no no, that is not possible because as per the conceptual model, and as per my first field work, you know the field and consumption model this is not correct.

At the end of the day the model is still a model it tries to mimic nature, it cannot mimic fully. So, you are the best person to tell the model what is right and wrong, because you will be having for example a field visit and you would have seen the recharge and discharge zones in the field. So, you will be in a better position to tell or fine tune the model.

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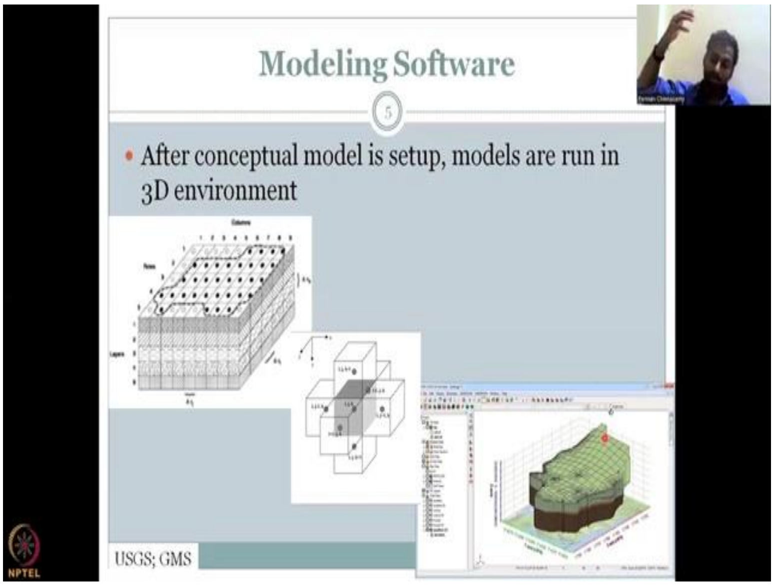

So, this is an example of conceptual models. And these conceptual models are then fed into a modeling software after the conceptual model setup of models are run in a 3D environment. Some models are 1D but nowadays, because computing power is available, free open source models are available 3D is kept because in a 3D you also look at the spatial lateral movement and downward movement along with the 3 axes. I showed you the 3 axes for example, you would have it like this, okay, so one going down one going X and Y? So, but the X and Y may be similar to each other.

So, you can make it 2D or 1D, if only one vertical, you want to look at it. It is all simplifying your model, depending on the data you have, and the complexity you want to show in a modeling exercise. However, 3D is better and 3D is the best because at least it gives you the three dimensional availability and shows how water can move from x plane to y or y to z, and then from vertically to laterally and vice versa. So, for all this, I would support to run a 3D model, which is a higher advanced level of groundwater management and understand.

So, let us see how a 3D model is set up. First the conceptual model is done, as I said, your fieldwork is taken you data collection is put in. And here you see in a mod flow setting mod flow is what we will be using to show you, which is called modular flow. And that is a one of the leading groundwater models in the world, because it is open source, and lots of people use it.

And lots of forums are there to help you out with workflow. It is a very, very good model that can actually simulate ground water hydrology based on your inputs. So, what is the first thing I said, it is a conceptual model, where you have agreed to tell the model that it is only five layers 1 to 5, and all of them are equally spaced, which never happens, even a cake layer, you have seen, it is not the same thickness everywhere. But that is what this model is saying. Or at least visually that it is the same.

And there are different widths given here for the width. Then once you set up the layers, then you put where the wells are, where the wells because the wells will give you the groundwater level in the layer. Right, so then you divide your boundary into grids and each point in the grid either has data or does not have data.

So, you can choose the size of the grid based on your data availability, and how fine you want to see the model. Again, understand that when you over parameterize it or over grid the model, then it takes long time to run. And sometimes it is not cater to do that, right. So each grid antic taking out.

So, this is the mod flow grid as columns and rows, I am just taking one single cell out. So, how does any model, model that route flow is for that one cell, it will look at how much is incoming, outgoing water and then based on the soil type and the demand and corner depression, the water movement is given, either it moves x direction y direction, or z direction, what is the velocity based on the velocity the other neighboring cells get activated, and then the water comes in from the central cube, center grid.

So, this is how one water moves from one gride to the next gride, we discuss about water coming from precipitation into the ground into the aquifer. Something similar here is happening. But there are other parameters also working at time t equal to 0. So, at time t equal to 0, suppose my water is in the center block. And at time t equal to 1, it moves forward to this block.

And like this, it moves, the movement is monitored by the modeling software. And at the end, it gives you the net moving velocity, the net reduction and the volume change because of this movement. So, this is how a paid version of mod flow looks like. It is called the GMS software provider. And you can see on the left hand side, there is all these data that can come in and put on top of this model, including groundwater levels, the thickness of the aquifer, rainfall, evapotranspiration rates, from your cropping calendar, etcetera.

What you also see is they have reduced the number of wells when the family is around, but the other regions is having 1 or 2 more layers. So, based on the data, the number of layers is fixed, and from the conceptual models also. But again, as I said in the upper elevation regions, you can see some other layers happening, but it does not make much difference. Because there is not much water movement on top, it may be assumed to be of one particular type.

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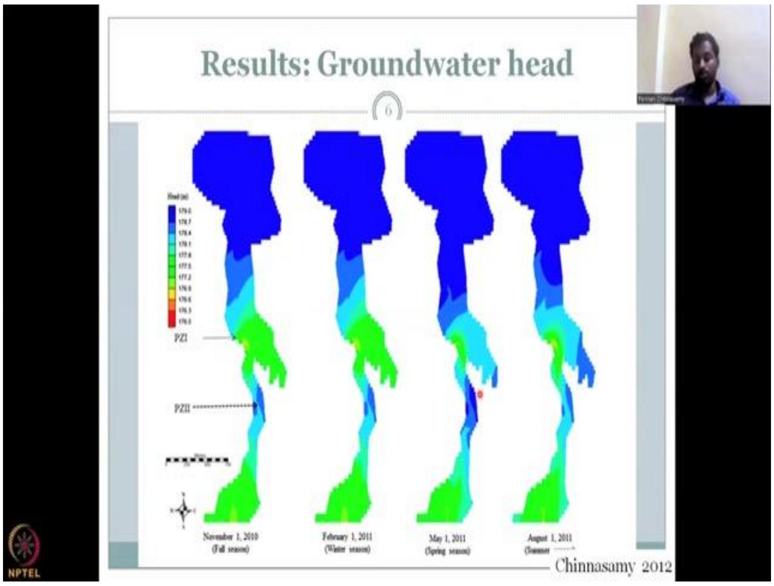

Let us look at some of the results that comes out of a groundwater model. You can look at as a 3D visual to see how the water moves in and out or a planet or 2D. This is a 2D plane top so from the top you are looking at a model and what it says is there is a hydraulic head high on the north and then there is a movement due towards the south 2010.

This kind of 5 years old, but the science and information is the same, you set up the model you give it rainfall and other data then you see how the water moves from 1 cube to the other and that aggregate movement will give you the hydraulic head distribution or groundwater level recorded in the WRIS website.

So, what do you see here is a hydraulic head is form and then it slowly moves down from north to south, the river flows, I did not put the river network in because that would kind of not show you the grids. So, you can see the grids as boxes. So, normally it is not a box, it is an uneven surface.

So, groundwater moves from top to bottom, and then suddenly in this point within the medium range, which is green, you see some red regions and those could be because of the you know, how much you spend, how much you get from these countries, and then water just comes down you could see that there are some piezometers also monitored by different faculty.

So, all faculties can take part in a result and change it to based on their research question and what we see here is a seasonal difference. So, that is where the timestamp comes, you see water moving from north to south, but then water also moves along the region, along the time scale.

So, from November to February, May, and August, you see a different change in the groundwater movement, you can see the hydraulic head high head varies, and there are some localized hydraulic heads created because of the ecosystem that is working in that region, which is trees and rocks, which enable more infiltration and then losing and gaining streams. So basically, this is just to show you how a groundwater model will give you output and what you could use the groundwater output for.

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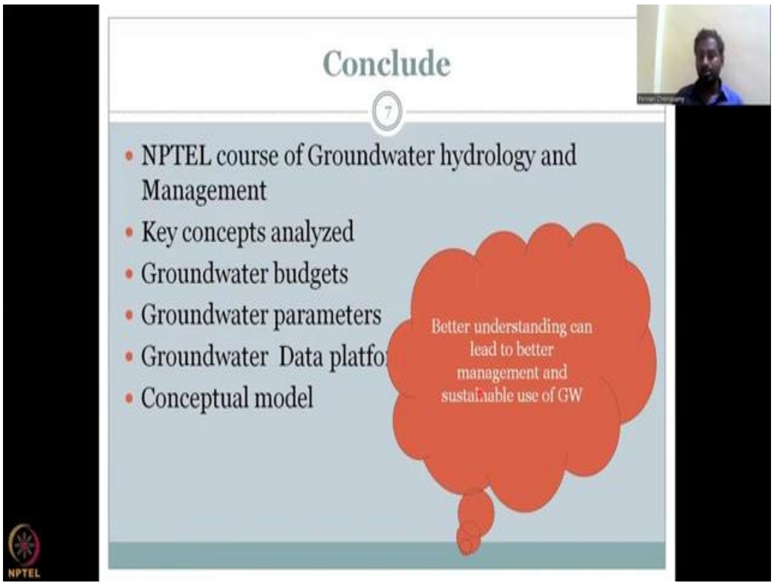

So, with this, I would like to conclude today's lecture and in fact, it was the last lecture of the series, where we looked at very important part of groundwater hydrology and management. Mostly, the hydrology was understood using the scientific background. And some management scenarios were discussed, where both the government and the public can have a win win situation, not exploiting water. Remember that, for the agricultural productivity increase in India, groundwater played a very vital role. And so we need to respect and run service so that the development is sustainable.

We have analyzed key concepts in this 12 week extent. And we also expressed or analyzed more focused groundwater relationships, and analyzed different concepts on groundwater quality, water availability, and how they mix and match between each other. We have established groundwater budgets, as I said, the groundwater budgets could be very, very complex or simple, based on the data that we have. And since we have had good data in the recent years, there are the budgets that will be setup.

Once you know the groundwater budget, it is as important to let the budget move for which you need groundwater parameters. So, for example, if you have a water level enable, unless you know the hydraulic conductivity around the web, the water cannot pass, it will just be stuck inside and this you could see most probably in large diagonals, because there will be cemented on the sides or the big rocks, which prevent the water from moving. So, once the water budget is set up, the key groundwater parameters are analyzed, and all the conductivity thickness, specifically retention etcetera.

Then we looked at where can we get these data, which kind of platforms that we can use and WRIS website has been very helpful if given the groundwater data, which is monitored by the CGWP. So now, the CGWP is giving water level data and location. Using the location you could create a consumption model based on the data you are having and from the data and from your conceptual model, there can be multiple multiple new revelations you can take, or we refine your research question to answer a very focused discussion focused ground water problem.

So, I hope that this course has lead for better understanding of the conceptual part of ground water and ground water moment which comes just ground water hydrology. Please remember India is the highest ground water user in the world, so there is always a need for better ground water managers and capacity built on ground water conservation.

Conservation happens with better understanding which can lead to better management and sustainable use of ground water. Again there are multiple more data and parameters that needs to be discussed but for a bigenner's class I think we have covered very lot and I hope you use it well for your exams and most importantly in your future situation where you have to address ground water. With this, I would like to conclude the final lecture for Groundwater Hydrology and Management NPTEL course.