Groundwater Hydrology and Management
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Week-1 Lecture 2
Introduction to groundwater 2

Hello everyone, welcome to the NPTEL course on groundwater hydrology and management week 1, lecture 2. We are very still very early in the lecture series for groundwater hydrology and management. So, the first week, as I mentioned in my breakup slides for the week, we would be looking at what will be offered in the following course, and also stressing on the importance of groundwater.

Groundwater is a very valuable source, but unless we understand why and why is it used so, much in India, it will be difficult to manage it properly. So, the understanding first comes followed that we will take you through the management part.

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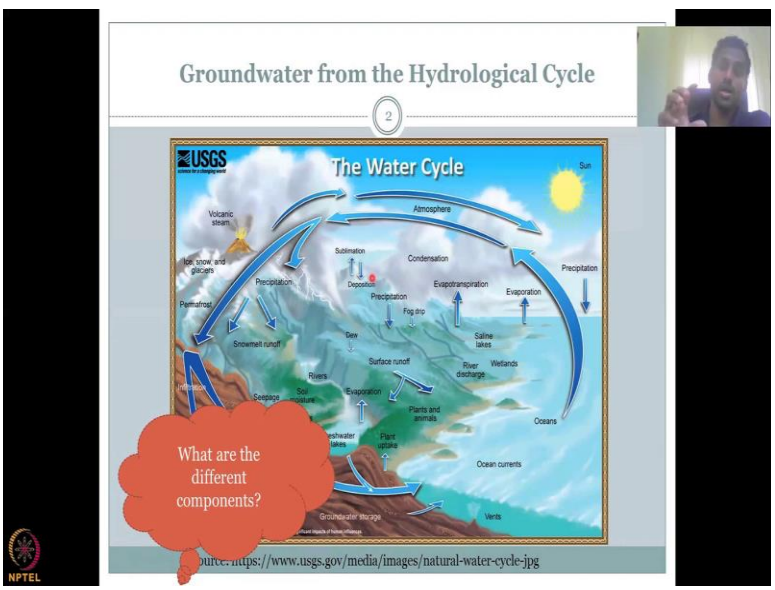

The hydrological cycle would be explained in most civil engineering science courses. In general, the multiple components and this is the overall hydrological cycle. Let me explain the hydrological cycle for those beginners. It is a cycle which can start from any point and then be cyclic in nature.

So, for ease of teaching it and understanding let us start from the atmosphere, which is the clouds. So, in the atmosphere we have clouds and clouds have water vapor which is being condensed. Once it condenses, especially after cooling down and multiple other processes, what happens you get precipitation. Precipitation can come as ice, snow and glaciers. It can also come as rainfall. Since in India most regions receive rainfall rather than snow.

We will focus on groundwater hydrology, estimations based on rainfall. I will mention some other things. For example, Ganges river gets rainfall, plus snowmelt. But we will focus on rainfall for the most part of the course. Some part of your ice and snow melts down and joins with your rainfall and then converts into your streams and rivers discharge et cetera. So you could see water falling on the slopes of the mountains.

And then it collects along the stream network and flows down into the freshwater lakes and rivers. After that, it can also flow down if there is no lakes, and rivers it can also flow down to the oceans, seas and base. This creates a loop from the atmosphere to the ocean, where again it gets evaporated back into the atmosphere. But before that, there are very, very important parts in the hydrological cycle, which is important to understand for the groundwater hydrology.

This figure is a very informative figure which has been widely used from USGS. Even in government records, we can find this image. Those who would like to have more information can go to this website and read about the different cycles but I would explain most important ones here. So, once you have your runoff, which is the conversion of precipitation into runoff water, you get it infiltrated and it goes into the groundwater.

So, this component what you see is a process higher than the precipitation because once precipitation occurs is only one process, the higher process is the water has to get down into the ground through infiltration. And once infiltration happens, there is relocation of water into different groundwater compartments which we will discuss in the future parts of the course.

So, water flows through as groundwater not like a river but it flows through pores and soil and solid materials. And then comes out into the surface water storages as freshwater, springs, seepage, et cetera. Part of it goes into the deep aquifers and then stays there in deep groundwater zones, but most importantly it comes back to the ocean. So, even the groundwater zone here the deep ones, you can see water can come out and seep into the oceans.

So, somewhere the salty water or saline water is evaporated. Only the water vapor goes up and while it goes up, it cools down forms clouds further condensation leads to rainfall, which is freshwater. You start with saline water; you end up with freshwater. Then what happens? Your freshwater goes through multiple processes, and then comes back to the ocean through groundwater, it goes to different groundwater components and either gets stored or flows through into the ocean.

So, now you have water coming back to the ocean, the cycle does not stop evaporation happens again. Some of the groundwater is taken by plants, and goes as evapo transpiration. We will go through all this in detail, but just I am telling you in the hydrological cycle, where does groundwater play a role. So, either it can get stored, it can flow, or it can be taken up by plants, and then mixes into the ocean.

After it mixes into the ocean, it can come back to the atmosphere as clouds precipitation, again, this it goes on and on. And this is driven by the sun. So you see the sun here, it is very aptly placed because if the sun does not work, the sun shuts down, plant life does not work. There is no transpiration, there is no evaporation from open surfaces, most of it would be gone. And so your cycle, which is your rain cycle will not happen.

Too much of that is also bad, which is what we are seeing in climate change scenarios, that too much heat or warming can increase your evaporation, thereby increasing floods and droughts. Droughts because there is no rain and floods because too much rain can come at a single point. So we have seen the different components and for groundwater, it is very important to understand there is groundwater storage, there is groundwater flow, even groundwater mixing into the ocean back. So this is an introduction for a hydrological cycle.

We will get back into the groundwater hydrology, which is a focused hydrological cycle within the overall hydrological cycle. So what you see is an overall hydrological cycle.

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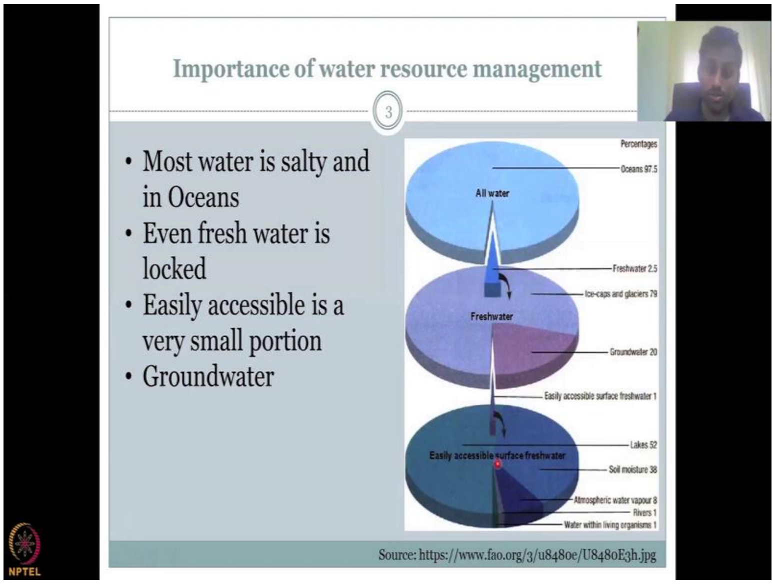

Let us see why it is very important to manage groundwater. Okay? First, let us take a step back and understand overall water resource management. Where is our water coming from? Where is it stored? Okay, so we will answer these questions now. Overall, all of the water if you take in the planet and do an analysis, this is the results out of the 100 percent of water that we have from the planet 97.5 percentage is in oceans.

Which means it is either saline or not usable, not accessible, because how do you access water from the Pacific Ocean? Are you going to put a big pipe and then pump it out? No. first energy et cetera is not there but most importantly, the quality of water, which is saline salty, you can use it. Then comes this 2.5 percent which is freshwater. So out of the 97.5 or 100 percent 97.5 is salty water in oceans 2.5 is freshwater. Not all this freshwater is usable.

So now of the 100 percent of freshwater, so this circle is 100 percent of the 2.5. So do not think it is another 100 percent. So all the freshwater icecaps and glaciers have 79 percent which means on top of the Himalayas, the big alps and all the big snow regions, Finland, Iceland, et cetera. And then you have your glaciers and Arctic's. So, you have all this together combining to be around 79 percent.

Which leaves us to 21 percent of available freshwater easily available freshwater or relatively easily of the 21 percent only 1 percent is easily accessible surface water, whereas the remaining 20 percent is groundwater. So, now comes the big picture in the freshwater, the accessible water is groundwater, the biggest component because you are not going to sit and melt icecaps and glaciers, there are some countries which are thinking of taking glacier water for drinking.

But how do you sustain that? Right? So, but groundwater is kind of decentralized, it is everywhere, so you could easily access it and then take it up. But is it sustainable is the question so that is what this whole course is about. So, the 1 percent, which is easily accessible, is in the form of lakes, soil moisture, atmospheric pressure, rivers water within living organisms.

So, what whatever you see as big big rivers Ganges and the Brahmaputra et cetera all this is not only for India, but for the world. If you combine all the big rivers all the lakes dams et cetera which are storing water is only within the 1 percent of freshwater. So, how much percentage will it be on the total that is such a very small portion. So, of the water resources if your demand is high for freshwater what do you do.

You will have to eventually go for groundwater because it is 20 percent of your freshwater. So mostly water is salty in the oceans even freshwater is locked. For example, in glaciers icecaps, snow it is locked, it is not easily accessible. Easily accessible is a very small portion and of the portion, groundwater ranks highest which is 20 percent of freshwater, not all 20 percent can be easily extracted because sometimes groundwater gets locked into the soil the rock materials, you can leave that part. But science and technology has increased the access to groundwater.

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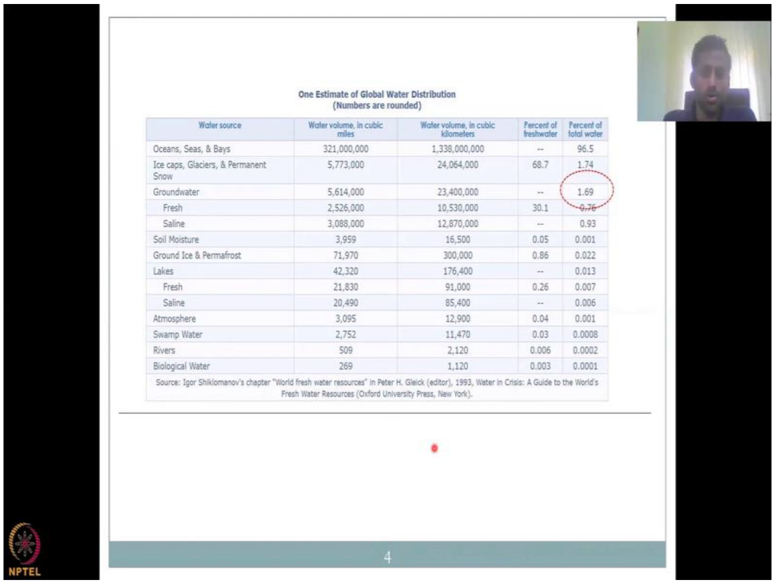
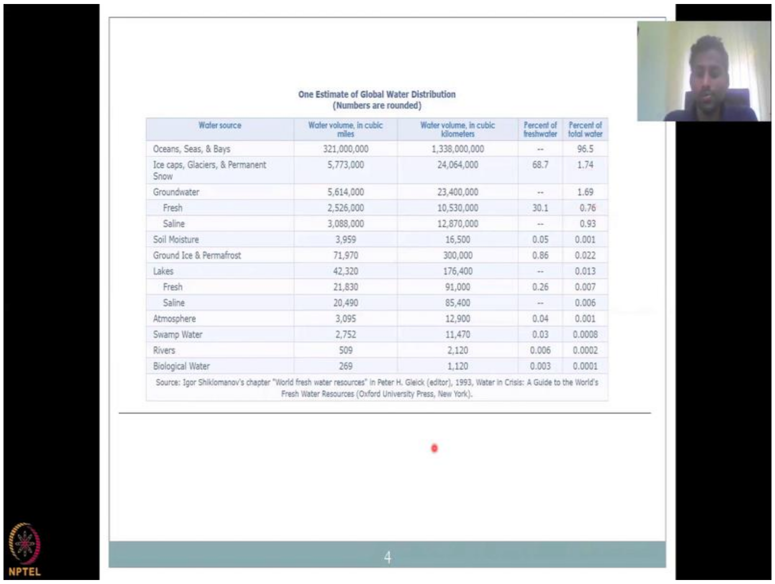


One Estimate of Global Water Distribution
(Numbers are rounded)

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of freshwater	Percent of total water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.5
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	--	1.69
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.93
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001

Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).



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Let us see another record similar percentages by a different study and you will understand that of the freshwater a 96.5 percent is an ocean season based icecaps glaciers permanent snow is 1.74. So, 1.69 is the actual percentage of groundwater of the total of that as I said, fresh groundwater is only 0.76 whereas 0.93 is all saline groundwater you cannot use it.

It is locked. either locked or it is too salty you have heard that people say groundwater has a color to it and has a smell or it has a salty taste it is because it is from the regional groundwater aquifer or from the parent material rock the rock characteristics will come into the water. Either way, if you look in the previous figure you have if you do the calculations around point 5 percent of your total freshwater is in the form of icecaps, glaciers et cetera.

If you take just the groundwater it equates to roughly around 0.05 percent of the total water in the world. As per that estimate here it is 0.76 and even the 0.76 you have around some water which is fresh but not accessible coming back down soil moisture, ground ice, permafrost lakes et cetera. You can see that the percentage is very very, very small 0.007 to 0.006 in your lakes and atmosphere et cetera and rivers is only 0.0002.

Biological water is 0.0001 which is in our bodies, the animals et cetera. So, the driving note here is the groundwater is the next biggest available water resource on the planet for freshwater which is easily accessible. So, the first would be your big big lakes, icecaps, glaciers melts, and snows but it is not accessible. So, if you do the accessible calculation, then groundwater ranks high above your lakes, rivers et cetera as the biggest contributor for freshwater or bigger source for storing freshwater.

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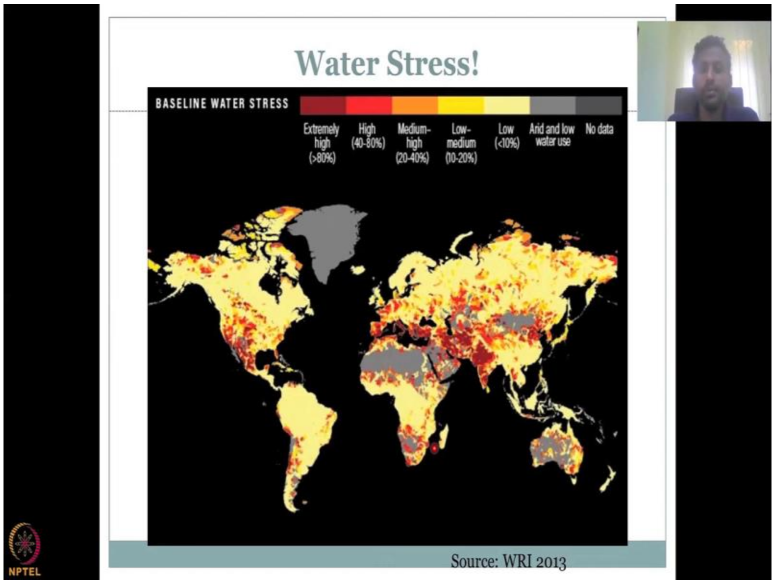

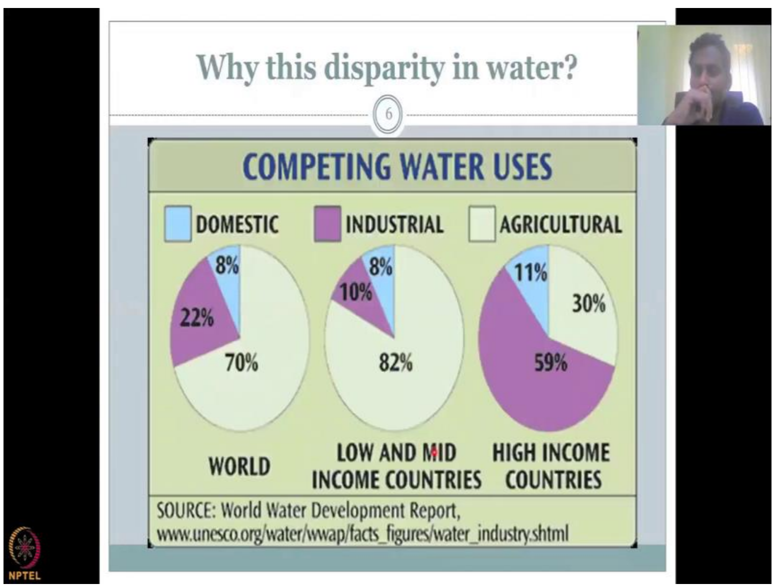

On this note, so, we have understood where the water is how the bifurcation is for groundwater, on this note. water stress looking at, let us take the WRI report is very dirty, you could see that baseline water stress is pretty high in India. So, most of course material would be focusing on India, because we would like to produce more groundwater manager professionals capacity in India.

So, the course will be tailor made for Indian professionals a lot. So, if you look at India here, the subcontinent we could see a big red color which shows that the water stress is going to be high and very high extremely high. So is this good for India? No, and there are multiple reasons why this is happening, why you see the color pattern you have because some regions are low, some regions are arid and low water use or so no data et cetera, et cetera.

But Most of India is in the red color, which is kind of concerning. Why is this stress different between different countries you can see US, China, Australia have better water resources whereas the developing nations do not have that much water right which is high stresses. Why is it? It is important to understand the disparity in water to better understand this question of this is in water stress across the globe.

Let us analyze the competing water resource users you have domestic use you have industrial and agriculture there are multiple more users, but let us focus on the key high water consuming sectors one is domestic the what we drink what we use for bathing, clothing, washing, your maintenance, sanitation et cetera many of your industrial for industrial purposes and then agriculture, for your farming livelihood options et cetera.

What do you see here is half the world almost 70 percent of the water is used for agriculture, whereas you have 22 percent use for industries and 8 percent use for domestic. This is the world average. So, if you give the world 100 liters of water 70 liters is going to be used for agriculture 22 percent would be used for industries, whereas 8 percent would be used for domestic so it is a good standard.

If you come to low- and middle-income countries, the 8 percent is the same. So, we are almost on average to the world average. But then the industry of demand is less only 10 percent and agriculture demand is more 82 percent. So, most of the water is spent on agriculture in developing and lower income countries not only for them, because they are going to export the food to develop countries.

For example, Vietnam, Philippines, Thailand with can grow rice for the entire planet and send it to Russia, US, the Europe countries et cetera. Right? So, that water that effectively can be used for industry is being more consumed for agriculture in low- and lower-income countries India included. If you come to the high-income countries, they do not use that much water for agriculture, only 30 percent.

And that to it will be for very specific crops like your almonds in US sugarcane and then you have corn which are giving some value for the industries also brewing industries and other industries. Table grapes and other wine vineyards. So, those kinds of industry. later agriculture they have most of the other food is kind of exported I am sorry, imported from other countries. They export very less also.

So, 59 percent is used for industry. So, now you could see that high-income countries are smart in using the water for industry, which can create more jobs, which can create more income for the country. Whereas low- and middle-income countries use most of the water for agriculture, which is a sole purpose of feeding the public. And it has very less profits compared to the industry.

So, the same water, you can look at how a high-income country uses for example, Singapore would buy all the food, materials, crops, rice, chicken, anything related to food, they can be sourced from neighboring countries like Malaysia. And they can put all their water into industries or banks and those kinds of things. Whereas the agricultural countries, low income mid countries are keeping low income because they do not use their water for high end products.

I am not saying that these countries should also get into industries what I am saying is the profit and the value of agriculture is kind of low. And that is why low- and middle-income countries become low because either way you still have to eat, Right? So, if you have an industry which can give good water related profits, why can agriculture become that too? So, we need to think in those terms to bring up the nation because India itself is an agricultural nation.

If you use now this understanding in this figure, can you see wherever the red marks are the regions where agriculture is predominant. For example, even the US this is where you have your almonds and orchards growing in Amazon exported to every country, including India. And then you have your rice and other cultivations in the subcontinent, Southeast Asian countries, and then you have agriculture happening in some parts here.

And Middle East is always highly stressful water because of the high you know, temperature and desert kind of an ecosystem. So, we cannot compare that not much agriculture here. But most agricultural countries, here we have, very high stress, because most of the water is used for agriculture, not industries, and they do not get much profit out of it. So, that is why they become still drought.

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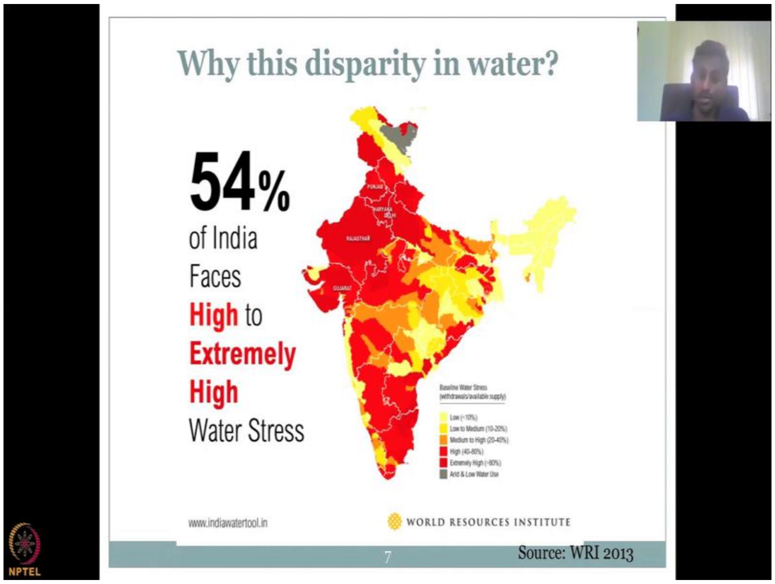

Moving on, within in India also let us now take a case study found within India 54 percent of India faces high and extremely high-water stress. Same report, if you look at just for India, you could find, astonishingly that, above 50 percent of India, let us take the population more than 500 million people are going to be under high or extremely high-water stress conditions. This is not good news, because we need to push further in conserving water.

And if you look at where this is more prevalent, you could see mostly the states with high agricultural activities, Punjab, Haryana, and also the desert, ecosystem kind of regions, and mostly your rice wells in the south. So, there is a big need to push for better water management resources.

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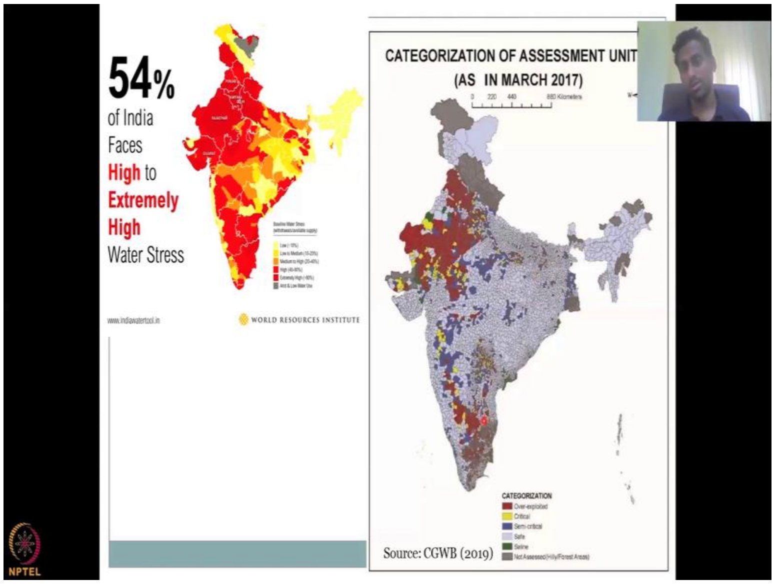

And this is also the reason why your groundwater is being abused. So, this is a report from the central groundwater board the very recent one, which dates to 2017. And they have categorized the blocks in India where water depletion is pretty high. We will not get into the details of how it is characterized, because we will have different lectures, for now let us understand that overexploited, and critical are very, very concerning, especially the red color.

And if you look at it, it is almost following your water stress conditions, which means groundwater is also being stressed in these regions. And along the regions where there is a tremendous amount of pumping, pumping for agriculture, there is not much pumping for industries, there are one or two blocks you will find. So, one block in maybe Bangalore or in Chennai, you can find a lot of water being used, but most of the water is used for agriculture.

So, if you see a combination of blocks like this, like this, then that means there is high demand on groundwater. And they are extracting more than they should, which is over exploiting. On this note, I think it is clear that we should understand where groundwater hydrology comes into picture from the overall hydrology. We have also understood where groundwater fits in the overall water budget of the planet.

There might be different estimates, but still, it is less than 1 percent of the total water in the planet is groundwater, less than 1 percent. And within that one percent, some are not accessible. So, there is still a very small portion of accessible water. However small it is, it is the biggest, easily accessible freshwater resource in the world. So on one hand, it is already less. On the other hand, it is the biggest source, easily accessible.

And on the third, it is access everywhere for agriculture. Because of the ease and accessing groundwater, through pumps, and science and technology, a lot of people have started to over use the groundwater. So, this firms the base of this course why groundwater has to be taken away from hydrology and studied in focus. So, this discussion what we have now forms the basis for it. So, we would have to look at groundwater in a separate lens.

And to understand that, how to manage it, it is very important to understand the physics behind groundwater, the equations behind it and put it on track for better management activities in the years to come. The multiple agencies that work on groundwater management and groundwater monitoring, but there is a big need on local hands on participation. So, that we could all combine collectively and use it on the same way all combine and collectively manage groundwater. And with this I would like to conclude today's lecture. Thank you.