Groundwater Hydrology and Management
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Lecture 03
Introduction to Groundwater 3

Hello everyone, welcome to NPTEL course on Groundwater Hydrology and Management week 1, lecture 3. The previous lectures, we looked at how and why groundwater is very important in the hydrological cycle. Then we focused on the different aspects in groundwater use between developing and under developing nations, how groundwater is being used, especially in underdeveloped and developing nations for agricultural activities.

We then also looked into the disparity in water use, which is leading to a disparity in water stress. And we also looked at within India, the water stress is leading to further depletion of groundwater. In today's lecture, we will look more deeper into the hydrological cycle, we will also bring some concepts from the central groundwater board in assessing the water stress.

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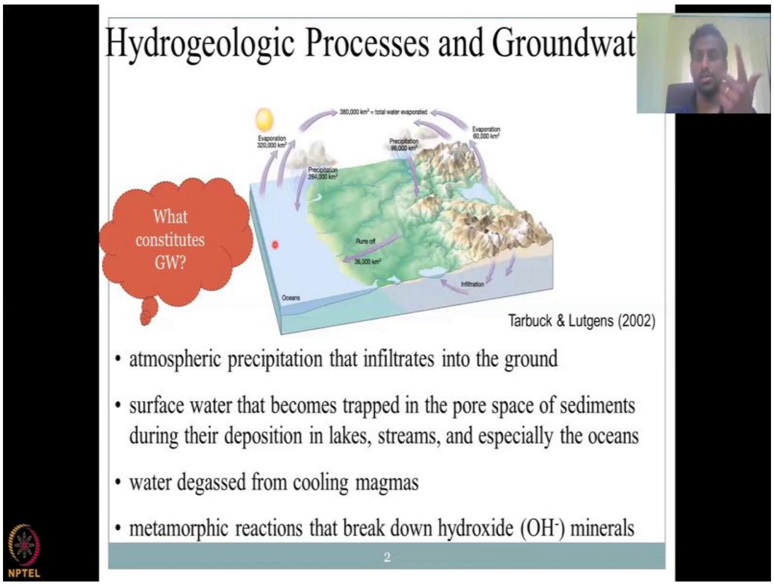

Let us understand the hydrogeologic process for groundwater. What we see here is the hydrological cycle overall with a mass balance or water balance which shows how much water is available as an example for a particular area and how the different water sources are contributing to the atmosphere and then coming back as rainfall.

Here you could see that evaporation from the oceans is contributing 320,000-kilometre cube water to the total water which is 380. So, big portion of water does come from the oceans whereas evaporation also comes from your mountains and freshwater resources like lakes, rivers etcetera. And it comes back again as some amount of rainfall which we have here on 96000 kilometre cube as rainfall along the slopes and on direct onto the ocean because ocean has a bigger space in area.

So, on top of the ocean there is a good rainfall event also 294000 kilometer cube. So, if you add them it goes to the 380000 kilometer cube which is the total. Of the 96, some goes as runoff and some is converted into infiltration through your recharge activities into the ground. The water can come back into the oceans or small freshwater bodies or rivers, lakes, etc and then eventually flow to the ocean.

Lake water, ponds, etc. may not flow back, it can be evaporated, but those which also go into deep aquifers or deep groundwater paths eventually go to the oceans. So now, what constitutes groundwater, is it a different source of water? No, it is coming from the same precipitation atmospheric process. Either it can be from snow converted into water. So, snow is kind of a solid phase and then ice melting etcetera. So once they melt, it is called snow melt.

And that snow melt can come down from high elevations into rivers, water storage systems such as ponds, lakes and aquifers and they can come down into the ground through infiltration. So, infiltration is the process by infiltrating water into the soil it can move further as groundwater component.

So, what are the different sources? Atmospheric precipitation that infiltrates into the ground is the key source. And of the atmospheric precipitation, rainfall is the key source. There are multiple different ways in which precipitation can happen. One is snow, hail, sleet, drizzle, etcetera, due but we will focus on rainfall more because the rainfall process is easier to understand the flow into the rivers, lakes etcetera. And you can also relate it directly to your infiltration.

Surface water that becomes trapped in pore space of sediments during the deposition and lakes, streams and especially the oceans is also a source for groundwater. which means suppose you have a lake, suddenly it can be trapped by some debris, for example, you have an erosion; a lot of sand is going to be deposited on top of a lake. what happens your water is pushed down or the water gets locked in the system.

Once the water gets locked, it cannot move anywhere, either it constitutes or comes back to the other groundwater resources by further pressure or it stays there as a perched water table.

So, some surface water body can be stored. Water degas from cooling Madmax which means your lava material is there, when lava flows the hot molten material magma, when it flows, it can also degas and water is a by-product. So, that water can be stored in your rocks and sediment as a groundwater source.

And then, there are some reactions that break down into hydroxide minerals. So, the point here is we are not focusing on the deep deep-water ground waters resources etcetera because that is not what we use and what we can manage. Normally management options do not take that water, we do not do fracturing to take that water. So, we will focus more on the water that is annually used for example, groundwater for drinking water etcetera so that you could better manage the resource.

So, this post will be focusing on the hydrogeological process and the groundwater hydrology up to the confined or deep aquifers not very deep aquifers just to the deep aquifers, which are being used and exploited for agriculture for industries and when demand and also rural domestic demand. So, that is the focus for this course.

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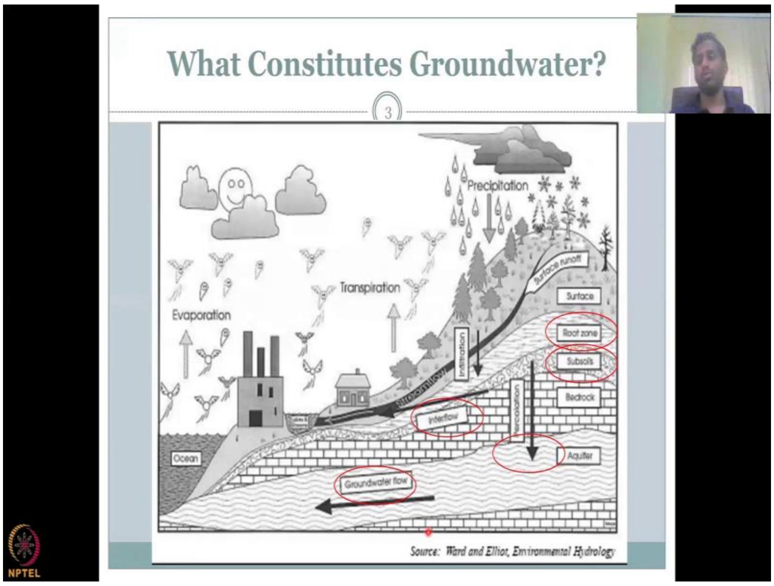

Let us look in at the total diagram of what constitutes groundwater. And in here you have the stars as snow and snow can convert into surface runoff which is easily explained using the rainfall. So, rainfall can hit the surface and convert into surface runoff. So, water is hitting, water hits it goes as surface runoff. So, what are you see pooling floods all those are discharged or surface runoff due to rainfall.

Let us start from the clouds, you have precipitation, precipitation can fall on the ground part of it or most of it can go as runoff. It depends on the land use, if we have urban, centres, houses etcetera, most of the water goes off whereas, if you have agricultural land or a forested land for a good part, then water can infiltrate. Water infiltrates and goes into the root zone.

So, you can see here water first infiltrates while runoff also it can infiltrate. while the river water and upon lake water can infiltrate. So, it just needs extra time. It is much much slower compared to the surface runoff process. So, when there is a slope and so, this is your land as slow water is falling as soon as water falls most of the water was runoff and very little water goes down as infiltration and that is because the infiltration rate is much slower than the precipitation rate and or the surface runoff discharge or the process that continue to surface runoff.

Moving on, after infiltration, some water goes in the infiltration can come from streamflow, surface runoff, precipitation and or stored water bodies like here. So once it goes in, it hits the root zone. The first part is you have your soil, the top surface. what was in the top part is organic matter and etcetera which is okay, but then when it goes in it goes as a root zone. That is where the plants have their roots extended and it can easily take the water the ground water.

After the root zone you have the tree root zone, there is a plant root zone there is a tree root zone, both are not the same, just a depth difference. But we can combine both of them as a general root zone. So, the water can go into the root zone after the plant has taken it up, after the relocation of water has been done, subsurface in the lateral direction so this is vertical and this is horizontal or lateral. So, water moves vertically and then it can go spread out laterally also and then can continue to go down.

Why is it going down? It is because of gravity. So, gravity is the force which is responsible for the groundwater hydrology component. It drives the system otherwise, water can just go up from precipitation. It comes on because of gravity it hits, infiltrates because of gravity etcetera. And once in the surface subsurface also inside the soil, water will move down to the root zone because of gravity not just because of the plants pulling capacity.

So, once water moves to the root zone, some soil would be taking up the water, depends on the properties of the soil and some plants will be taking up the water. At least plants will take it up and transfer it, evapotranspiration happens whereas, your soil just stores the water. It is called soil moisture.

Then we have the subsoils. The subsoils is when you have a soil layer below the root zone where water can also enter so, then some part of the infiltrated water would go into the subsoils and that is where percolation happens. Percolation is further movement of water or the relocation of water under the subsurface.

And then you have your bedrock an aquifer. So, bedrock would be your confining unit, which is impervious most of the time, but then you can have some water going through. So, it is a very slow process and then finally, it can come to your aquifer after it bypasses your root zone and subsurface soils. While you are in the root zone and subsoils, after you have crossed it, groundwater can also go laterally, rather than vertical it can move laterally because of the bedrock or the impervious surface.

Some water can go on the side and come out into oceans, then evaporate go back to the rainfall and come back again. So, this cycle can go on. What do you see here is the remaining water after interflow after subsurface flow, some water does enter the aquifers. The aquifer is the storage part for groundwater where a lot of porosity or space is available for the groundwater to be stored and groundwater to move.

Please do not think it is like a river, like the diagram here is showing is just a soil material with a lot of holes, soil or rock material. It is a medium with a lot of holes where water can be stored and if the holes are connected water flows. We will get through each definition in the coming lectures.

So, percolation is the important phase where the precipitation converts in to groundwater resources, because before that infiltration is the initial part, but most of the water can be taken up by plants or soil. It need not go down through. So, that part will be very careful in understanding that only after percolation we have the concept of groundwater hydrology.

And some part of this water can go up due to capillary rise, it is very very small, but still we need to acknowledge it. So, capitllary rise can happen because of the nature of the soil, water can be pulled up and stored here even plants can pull up, trees can follow. And again, do not imagine this as a river flowing. There are rivers that flow under the ground, especially in caves.

But groundwater per say does not flow like a river, but it is flowing through pores and it goes through a medium; mesh of materials. It is not an empty space like your river is there is not an empty space where water can flow. It is with materials and so it is very complex in nature. And groundwater will eventually join the oceans or evaporate in your local water bodies.

So, now you understand that compared to surface hydrology, groundwater hydrology is much more complex. You have here is all your surface hydrology components whereas, your groundwater is more complex because of the complexities in the water reaching the aquifer and also how it flows through a porous medium. It is not a river where you can put a dam and then store all the water, it is it can just bypass it because that is the way it was initially flowing. So, it is a porous medium, medium with lot of holes, be it sediments or rocks, soil etcetera and then through that water can move.

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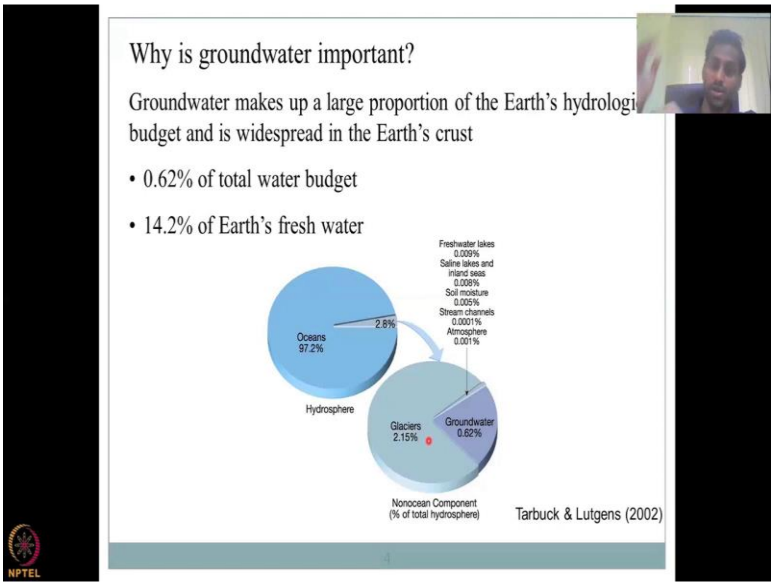

So again, why is groundwater important? Let us look at one more analysis. Groundwater makes up a large portion of earth's hydrological budget; water budget and it is widespread in the earth's crust. It is not just located like the oceans are located only in some areas not in the land, groundwater is located everywhere. Even under the oceans, you have groundwater aquifers, and that is where it might be seeping and leaking into the ocean.

So, 0.62 percent of total water budget. Compare this with FAO, which was 7.69 and the other study, which was 0.5 of the total water budget is from groundwater. So, only 14.2 percent of earth's freshwater is accessible. Only 14.2 of earth's freshwater because most of it is in glaciers etcetera. The 14.2 is because some groundwater water cannot be accessed. Even though groundwater can be 20 percent, it cannot be accessed.

So, in the previous slide says 2.5 percent, here, it is 2.8 percent. And that 2.8 percent, almost 90 percent or 80 percent goes into your glaciers and the 20 percent plus 1 percent is here. So, that 21 percent equates to only 0.62 percent. And that 0.62 percent is also not fully used, because you get some of our water is stuck.

So, please understand that there is a hydrosphere which is the hydrological budget of all the water resources and no ocean component in this one, okay? So, because you have taken the ocean out, so, you put this as a 100 percent. All these is to drive the factor that groundwater is high commodity compared to the freshwater available, but the stress is making it very unsustainable.

And also on top of that, why is the stress there because the freshwater availability on the planet is very less. We have been taking that everywhere there is water, atmosphere, there is water, there is water in snow ice, but it is such a small portion when you convert it to freshwater and even a smaller portion when you say accessible freshwater. For example, freshwater is inside our body, but can we access it? No, we need to replenish it.

So, when we drink, we replenish it because we also have a sweat and our water comes out of your pores etcetera when we transpire. So, we also are like a small mini hydrological cycle, we drink water and then we excrete water and also, we transpire water.

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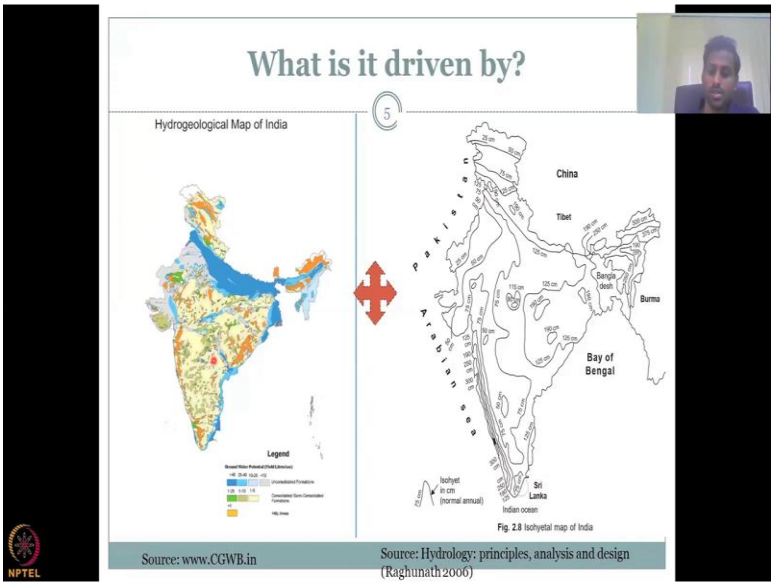

What is it driven by? So, what is your all these budgets and hydrology driven by? The first and foremost thing is your precipitation. Let us look at an isohyetal map from Professor

Raghunath book, you can see that India has a unique and very different land use land cover pattern, which enables different hydroclimatic zones.

So, you can have the driest of the driest regions 25 centimeters, and one of the top precipitation regions in the world around here Cherapunjee, etcetera and along the Western Ghats. So, think about 25 centimeters here, whereas you get 250 centimeters on this side, 500 centimeters on this side. So, that is 5000 millimeters of rainfall.

And here along this coast, you get around 3000 millimeters of rainfall along the Western Ghats. So, that is why you have so much rain in Kerala and etcetera. So, almost double you get here. However, here on the side, you do not even get 10 percent of it. So, 5 ercent of that comes in and which is very, very less compared to how much water. So, there is a big differences in water availability, and this also drives us stress and because of that, it also drives the need for groundwater access.

The other thing which drives this first you need rainfall to eventually recharge. The other thing is you need a material to store the water and here the material is the hydrogeology wherein, it is the geology the rock, the sediment, the materials where the water can store. So, mineral water is not just a unique one process, it is a combination of processes. It has to start from your rainfall get into the soil, the soil has to have conditions to promote their own water storage and groundwater flow, which you see from the maps here.

And then what do you have to be stored, if water just flushes through, it is not on water. It just moves through and go somewhere else, it has to be stored, slowly it has to be released. So if you look at here, you have good groundwater in areas here along the Ganges, Indus, Brahmaputra, which is also regions with good decent rainfall, also the Brahmaputra.

And then you come to central India, where you have a medium aquifers or groundwater storage units, where they have consolidated some consolidated formations of rocks, and those rocks cannot store much water. And that is why you have the less yield. Yield is how much you can take out. And this part is also if you remember the stress diagrams, this part is also the regions where high water stress is being predicted.

Why water stress is not very good here, because you have good rainfall, and you have good potential of the aquifer to permit store and use the water. Whereas here, you have less rainfall first, so you the farmers are forced to take water. And on top of it, the geology does not support storage of big water storage units. It is very small, small water that you could start.

Moving on, it is a combination of your geology and hydrology. And so you have the hydrogeological map and geology is very, very important process for groundwater movement and storage.

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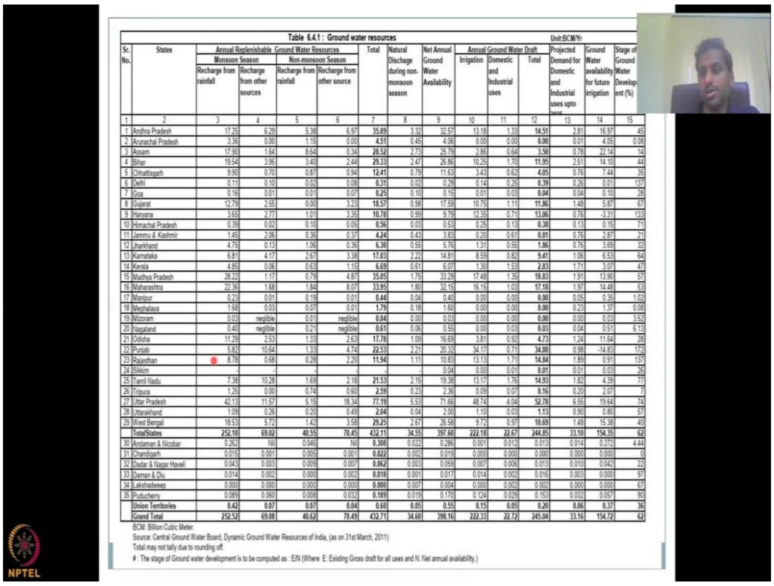


Table 6.4.1 : Ground water resources

Unit:BCM/Yr

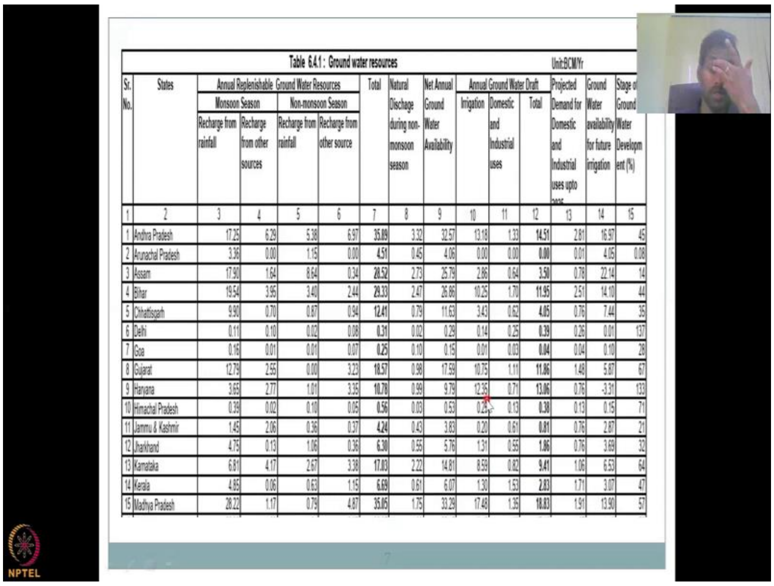
Sr. No.	States	Annual Replenishable Ground Water Resources				Total	Natural Dischage during non-monsoon season	Net Annual Ground Water Availability	Annual Ground Water Draft			Projected Demand for Domestic and Industrial uses upto 2025	Ground Water availability for future irrigation	Stage of Ground Water Development (%)
		Monsoon Season		Non-monsoon Season					Irrigation	Domestic and Industrial uses	Total			
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other source									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Andhra Pradesh	17.25	6.29	5.38	6.97	**35.89**	3.32	32.57	13.18	1.33	**14.51**	2.81	16.97	45
2	Arunachal Pradesh	3.36	0.00	1.15	0.00	**4.51**	0.45	4.06	0.00	0.00	**0.00**	0.01	4.05	0.08
3	Assam	17.90	1.64	8.64	0.34	**28.52**	2.73	25.79	2.86	0.64	**3.50**	0.78	22.14	14
4	Bihar	19.54	3.95	3.40	2.44	**29.33**	2.47	26.86	10.25	1.70	**11.95**	2.51	14.10	44
5	Chhattisgarh	9.90	0.70	0.87	0.94	**12.41**	0.79	11.63	3.43	0.62	**4.05**	0.76	7.44	35
6	Delhi	0.11	0.10	0.02	0.08	**0.31**	0.02	0.29	0.14	0.25	**0.39**	0.26	0.01	137
7	Goa	0.16	0.01	0.01	0.07	**0.25**	0.10	0.15	0.01	0.03	**0.04**	0.04	0.10	28
8	Gujarat	12.79	2.55	0.00	3.23	**18.57**	0.98	17.59	10.75	1.11	**11.86**	1.48	5.87	67
9	Haryana	3.65	2.77	1.01	3.35	**10.78**	0.99	9.79	12.35	0.71	**13.06**	0.76	-3.31	133
10	Himachal Pradesh	0.39	0.02	0.10	0.05	**0.56**	0.03	0.53	0.25	0.13	**0.38**	0.13	0.15	71
11	Jammu & Kashmir	1.45	2.06	0.36	0.37	**4.24**	0.43	3.83	0.20	0.61	**0.81**	0.76	2.87	21
12	Jharkhand	4.75	0.13	1.06	0.36	**6.30**	0.55	5.76	1.31	0.55	**1.86**	0.76	3.69	32
13	Karnataka	6.81	4.17	2.67	3.38	**17.03**	2.22	14.81	8.59	0.82	**9.41**	1.06	6.53	64
14	Kerala	4.85	0.06	0.63	1.15	**6.69**	0.61	6.07	1.30	1.53	**2.83**	1.71	3.07	47
15	Madhya Pradesh	28.22	1.17	0.79	4.87	**35.05**	1.75	33.29	17.48	1.35	**18.83**	1.91	13.90	57
16	Maharashtra	22.36	1.68	1.84	8.07	**33.95**	1.80	32.15	16.15	1.03	**17.18**	1.97	14.48	53
17	Manipur	0.23	0.01	0.19	0.01	**0.44**	0.04	0.40	0.00	0.00	**0.00**	0.05	0.35	1.02
18	Meghalaya	1.68	0.03	0.07	0.01	**1.79**	0.18	1.60	0.00	0.00	**0.00**	0.23	1.37	0.08
19	Mizoram	0.03	negligible	0.01	negligible	**0.04**	0.00	0.03	0.00	0.00	**0.00**	0.00	0.03	3.52
20	Nagaland	0.40	negligible	0.21	negligible	**0.61**	0.06	0.55	0.00	0.03	**0.03**	0.04	0.51	6.13
21	Odisha	11.29	2.53	1.33	2.63	**17.78**	1.09	16.69	3.81	0.92	**4.73**	1.24	11.64	28
22	Punjab	5.82	10.64	1.33	4.74	**22.53**	2.21	20.32	34.17	0.71	**34.88**	0.98	-14.83	172
23	Rajasthan	8.78	0.68	0.28	2.20	**11.94**	1.11	10.83	13.13	1.71	**14.84**	1.89	0.91	137
24	Sikkim	-	-	-	-	**-**	-	0.04	0.00	0.01	**0.01**	0.01	0.03	26
25	Tamil Nadu	7.38	10.28	1.69	2.18	**21.53**	2.15	19.38	13.17	1.76	**14.93**	1.82	4.39	77
26	Tripura	1.25	0.00	0.74	0.60	**2.59**	0.23	2.36	0.09	0.07	**0.16**	0.20	2.07	7
27	Uttar Pradesh	42.13	11.57	5.15	18.34	**77.19**	5.53	71.66	48.74	4.04	**52.78**	6.55	19.64	74
28	Uttarakhand	1.09	0.26	0.20	0.49	**2.04**	0.04	2.00	1.10	0.03	**1.13**	0.90	0.80	57
29	West Bengal	18.53	5.72	1.42	3.58	**29.25**	2.67	26.58	9.72	0.97	**10.69**	1.48	15.38	40
	TotalStates	**252.10**	**69.02**	**40.55**	**70.45**	**432.11**	**34.55**	**397.60**	**222.18**	**22.67**	**244.85**	**33.10**	**154.35**	**62**
30	Andaman & Nicobar	0.262	Nil	0.046	Nil	**0.308**	0.022	0.286	0.001	0.012	0.013	0.014	0.272	4.44
31	Chandigarh	0.015	0.001	0.005	0.001	**0.022**	0.002	0.019	0.000	0.000	0.000	0.000	0.000	0
32	Dadar & Nagar Haveli	0.043	0.003	0.009	0.007	**0.062**	0.003	0.059	0.007	0.006	0.013	0.010	0.042	22
33	Daman & Diu	0.014	0.002	0.000	0.002	**0.018**	0.001	0.017	0.014	0.002	0.016	0.003	0.000	97
34	Lakshadweep	0.000	0.000	0.000	0.000	**0.000**	0.007	0.004	0.000	0.002	0.002	0.000	0.000	67
35	Puducherry	0.089	0.060	0.008	0.032	**0.189**	0.019	0.170	0.124	0.029	0.153	0.032	0.057	90
	Union Territories	**0.42**	**0.07**	**0.07**	**0.04**	**0.60**	**0.05**	**0.55**	**0.15**	**0.05**	**0.20**	**0.06**	**0.37**	**36**
	Grand Total	**252.52**	**69.08**	**40.62**	**70.49**	**432.71**	**34.60**	**398.16**	**222.33**	**22.72**	**245.04**	**33.16**	**154.72**	**62**

BCM: Billion Cubic Meter.

Source: Central Ground Water Board, Dynamic Ground Water Resources of India, (as on 31st March, 2011)

Total may not tally due to rounding off.

: The stage of Ground water development is to be computed as : E/N (Where E: Existing Gross draft for all uses and N: Net annual availability.)



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Unit:BCM/Yr

Sr. No.	States	Recharge from rainfall (Monsoon)	Recharge from other sources (Monsoon)	Recharge from rainfall (Non-monsoon)	Recharge from other source (Non-monsoon)	Total	Natural Dischage during non-monsoon season	Net Annual Ground Water Availability	Irrigation	Domestic and Industrial uses	Total	Projected Demand for Domestic and Industrial uses upto 2025	Ground Water availability for future irrigation	Stage of Ground Water Development (%)
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14	Kerala	4.85	0.06	0.63	1.15	**6.69**	0.61	6.07	1.30	1.53	**2.83**	1.71	3.07	47
15	Madhya Pradesh	28.22	1.17	0.79	4.87	**35.05**	1.75	33.29	17.48	1.35	**18.83**	1.91	13.90	57

Depending on this, there is a lot of calculations done to understand how much groundwater we have, how much is recharging, etcetera. And it is given in different units, we will be using the unit billion cubic meters per year by Central Groundwater Board. And this gives you an example, you do not have to worry about how do you calculate all this these will be calculated in the following lectures.

The idea of this slide is to zooming in is to just show you a calculation let us take Madhya Pradesh, for example. It has annual replenishable groundwater resources which means count for groundwater, and it gets replenished annually. It is like your salary every month you get in money and you can use it throughout the month. So, for example, you are getting money on the month end of the 30/31 and then you use from 1 to 30. So, you use it and then it gets replenished in the month end.

So same way you have estimates for annual groundwater use. So, these are the positives recharge is 28.22 BCM per year and then you have recharged from other sources 1.17, this could be your surface water storage, other things but recharge from rainfall is biggest. Then you have non-monsoon recharge which is not from rainfall and it has from other sources, other industries rivers which are flowing can recharge etcetera.

The total comes to 35.05 billion cubic meters per year and the natural discharge naturally water will go into your oceans I showed you in the hydrological diagram. So, that component is very small. And if you subtract that from 35.05, you get 3.29. There are some decimals, so you will see some adjustments. So 33.29.

Now, this is the natural draft, natural extraction. Let us come to the human anthropogenic extraction. So, for irrigation that is the biggest use of water 17.48 out of 33 17.48 more than 50 percent is used for agriculture and then your domestic and industrial use still not as big but close, very very close to your natural discharge which means the natural release of water.

Then you have your total, So, if you subtract all this from 33.29, you will get around 18.83 which is your net total draft. So, 17.48, 135 Gets you 18.83 which is your total draft, you should add this with your discharge also or you can subtract this from 33.29. Getting that you get it percentage of groundwater development.

These two are projected groundwater use for industry. So, this 1.35 can go up to 1.91 and groundwater availability for future irrigation which is the remaining part is given here 13.90 Either way, what you see here is the stage of groundwater development. So, almost 60 percent of your groundwater in Madhya Pradesh is used every year.

So, it still is ok or not okay number so, they will call it semi critical or safe, why because you are getting 100 rupees and out of the 100 rupees only 60 you are using the remaining 40 you are saving like a bank account fixer etcetera. The 40 would not saving because it is a leaky account, water will go to some other place it moves into the oceans etcetera. So, under that circumstances 60 percent is still okay.

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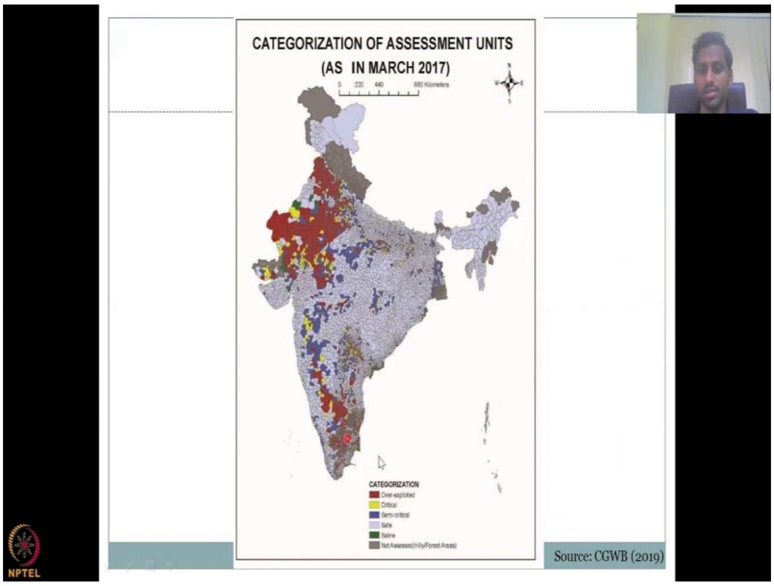

So, the government does not put a cap on that value, I will come to the image here. So, you have critical or critical so, it will be around 70 critical to safe, which means not big management activities are needed at this stage. So, we looked at a particular state and I just took the top on this so that we could have the titles also.

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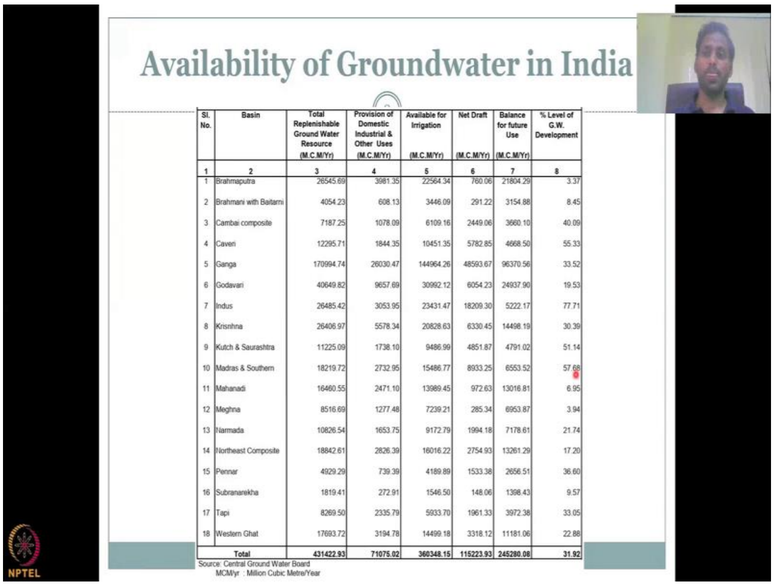

Sl. No.	Basin	Total Replenishable Ground Water Resource (M.C.M/Yr)	Provision of Domestic Industrial & Other Uses (M.C.M/Yr)	Available for Irrigation (M.C.M/Yr)	Net Draft (M.C.M/Yr)	Balance for future Use (M.C.M/Yr)	% Level of G.W. Development
1	2	3	4	5	6	7	8
1	Brahmaputra	26545.69	3981.35	22564.34	760.06	21804.29	3.37
2	Brahmani with Baitarni	4054.23	608.13	3446.09	291.22	3154.88	8.45
3	Cambai composite	7187.25	1078.09	6109.16	2449.06	3660.10	40.09
4	Caveri	12295.71	1844.35	10451.35	5782.85	4668.50	55.33
5	Ganga	170994.74	26030.47	144964.26	48593.67	96370.56	33.52
6	Godavari	40649.82	9657.69	30992.12	6054.23	24937.90	19.53
7	Indus	26485.42	3053.95	23431.47	18209.30	5222.17	77.71
8	Krisnhna	26406.97	5578.34	20828.63	6330.45	14498.19	30.39
9	Kutch & Saurashtra	11225.09	1738.10	9486.99	4851.87	4791.02	51.14
10	Madras & Southern	18219.72	2732.95	15486.77	8933.25	6553.52	57.68
11	Mahanadi	16460.55	2471.10	13989.45	972.63	13016.81	6.95
12	Meghna	8516.69	1277.48	7239.21	285.34	6953.87	3.94
13	Narmada	10826.54	1653.75	9172.79	1994.18	7178.61	21.74
14	Northeast Composite	18842.61	2826.39	16016.22	2754.93	13261.29	17.20
15	Pennar	4929.29	739.39	4189.89	1533.38	2656.51	36.60
16	Subranarekha	1819.41	272.91	1546.50	148.06	1398.43	9.57
17	Tapi	8269.50	2335.79	5933.70	1961.33	3972.38	33.05
18	Western Ghat	17693.72	3194.78	14499.18	3318.12	11181.06	22.88
	Total	431422.93	71075.02	360348.15	115223.93	245280.08	31.92

Source: Central Ground Water Board
MCM/yr : Million Cubic Metre/Year

Moving on how much available water is there as per base and size. Initially we saw state, state is more important because the administrative boundaries is where you can do management work, you cannot do management across different states because some states may not be accepting the same project, correct? So, what happens here is we are still showing the the base invoice because basin is how the water comes through the hydrology through the climate, weather and also your watershed approach.

So, looking at that, your Ganges is the biggest preferential groundwater resource and also it uses very, very low. So, that is why it have only 33 percent of the groundwater is used. So, of the river basins, the Madras and Southern region basin which includes a small small rivers in the southern Chennai region is highest because it is also industrial and also urban use driven groundwater depletion the irrigation is also there so 60 percent of the water is used.

So, if you do a basin wise calculation all are safe, which is wrong, you cannot do that because some blocks might be within your base and your basic size is pretty big. And within the basin one or two blocks can be notorious and pump all the water out and that is where it will disrupt the system and you need to put some controls or management activities.

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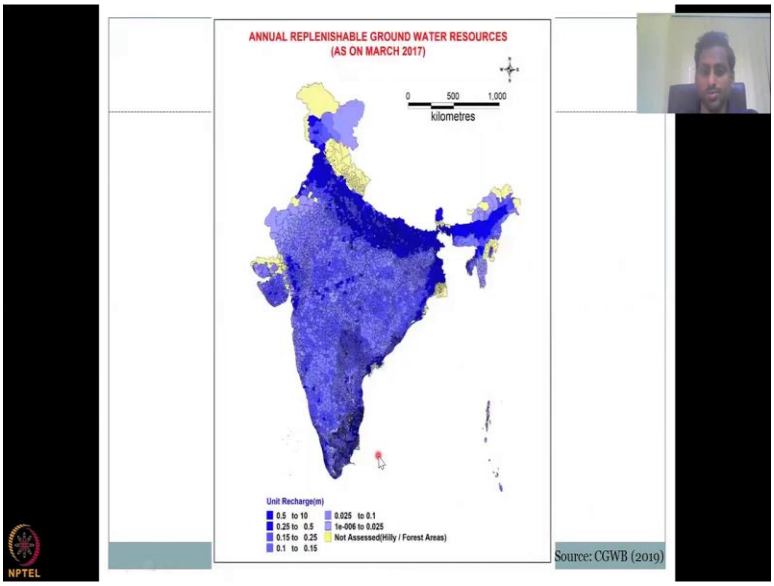

This is the annual replenishable groundwater resources as per the rainfall diagrams and where water can replenish. So, unit recharge is up to 0.5 here and very, very less in the light blue colors. So, you can see most of the Ganges, Indus basin, Brahmaputra, all in dark blues, and along the deltas, where the water river water discharges into the ocean, you have a good dark blue color showing recharge anywhere from 0.5 to 0.25. After that it is pretty slow recharge rates. So we need more activities.

And if you look at this image and this image, you could see clearly wherever there is a slower recharge rate and less rainfall that is where people are actually consuming more and more groundwater. Rajasthan, Haryana, Punjab etcetera, etcetera Gujarat. So, and here in the southern region also Andhra, Karnataka, Tamil Nadu, some parts of Kerala also. So, it is very important to understand these red color zones where immediate actions have to be taken to preserve groundwater.

Red color means you are using more than your annual recharged. So, if 100 rupees is coming into your account, you are using 120 rupees which means you are using a credit card or something. So, eventually you need to pay it off and that is where it is marked in red. And the government is telling that we need to kind of these images are telling we need to take stringent actions or management activities to color change the color, change it to a more critical or semi critical stage.

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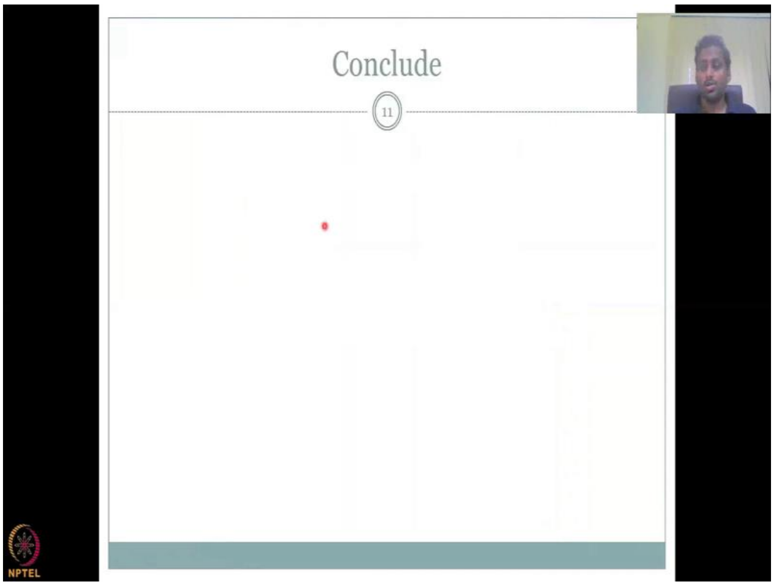

So with this, I would like to conclude the lecture. We have gone through how water comes into the groundwater hydrological system and how groundwater data, this recharge estimates can be used to understand the water budgets. And then, we ended up as hydrology and geology should be considered to understand the groundwater part and demand and access etcetera. I will see you in the next class, thank you.