Rural Water Resources Management
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Week 01-Lecture 02
Importance of water resource management in India and Introduction to Hydrological Cycle and representations

Welcome to the Rural Water Resource Management course, week 1, lecture 2.

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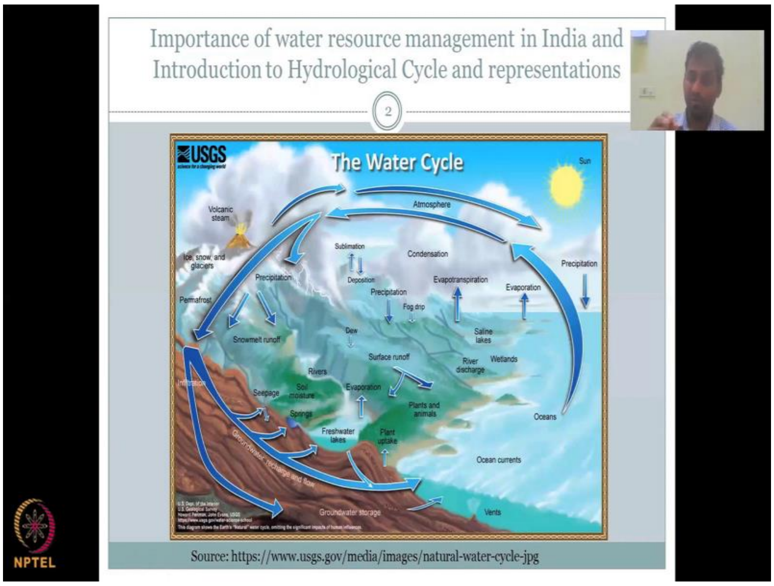

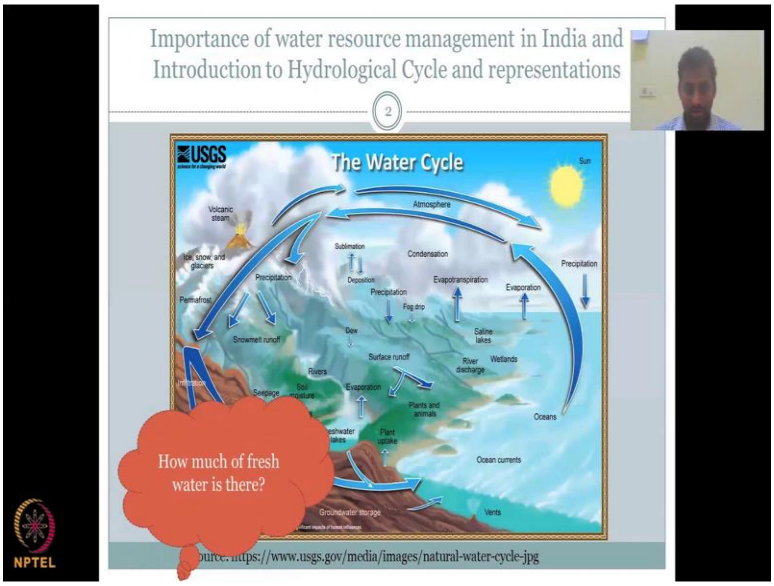

Today we will be looking at the different parameters of the hydrological cycle and why it is important for understanding to manage India's rural water resources. So, importance of water resource management in India and introduction to hydrological cycle and representations. Let us look at this water cycle or the hydrological water cycle, USGS from the US, stands for the

US Geological Survey and they have done a very comprehensive representation of a hydrological cycle.

Please understand that this has been done for the US region, but most of it would still applied for Indian context. If you look at major hydrological components, soil research, etc. we still follow the US norms. So, that is why I am using the representation of US Geological Survey. So, let us start here in this entire cycle, we could start anywhere and it has to come back to the starting point.

So, for convenient purpose, let us start with the atmosphere. In the atmosphere, we have clouds, which convert or condense water into precipitation. So, it has a couple of different formats, but we will go through that when we look at each component in depth in the coming weeks. So, let us say one type of precipitation is rainfall. So, water from, water vapor from the clouds convert into precipitation, then it hits the land and converts into runoff.

So, you could see here that some permafrost and snow are also being converted into runoff, which is basically water moving on the land and you could see precipitation flowing into the rivers as runoff. Whenever the arrow comes down, it means it is going from the top through the atmosphere to the ground. And whenever it is in up direction it is coming from a lower potential to a different potential or from the ground to in this case from the ground into the rivers and lakes.

So, some of the water gets infiltrated and moves into the groundwater. And within the groundwater, you have multiple directions one goes in as deep aquifer or deep groundwater and then there is some shallow groundwater. Then what happens is some of the runoff converts into rivers and then gets stored as lakes, ponds etc. So, you could see some of them being stored, but some do manage to come out of any storage units and then come back to oceans.

When it comes to the oceans, please understand after some time it does evaporate. So, that is captured by this term. So, as I said it goes from the land to the atmosphere by the top arrow. So, you could see that evaporation happens and all these freshwater gets converted back into water vapor and then clouds. So, this is how a simple cycle I have explained but we will go into depth in each component which is relevant to India and especially Indian rural regions.

So, when we talk about rural regions, we would eventually do not consider volcanic steam, ice, snow, glaciers, permafrost, etc., because most of the rural regions in India is going to be arid or semi-arid, which means not that much so far or I will say even zero snowfall probability. So, most of the agriculture can be using snow water melt which is coming from here down for example, into the Bihar regions, the water has a lot of snow melt composition.

But we would as a land hydrological process we would look into what are the driving forces, driving parameters here. Please understand that all this is there, but we also have a Sun. Why would the Sun be there? Because in the water cycle, it is one of the most important drivers. All this would shut down if there is no evaporation. For example, let us take two components which are very, very important here, which is precipitation, which is conversion of your cloud material into the water vapor, into liquid phase and comes to the ground. So, that is your precipitation.

And then the second part is your evaporation, or evapotranspiration. So, if your precipitation does not happen, there is no water on the land, everything is in the cloud. Same thing, if evaporation transpiration do not happen, then the water is stuck on the ground, for example, the oceans would be full of water, and no water evaporates up, and the plants do not transpire water back into the atmosphere, so the cycle would be stopped.

So, this cycle is driven by your Sun. If the Sun shuts down, there is no evaporation. If there is no evaporation, there is no water vapor forming clouds and the cycle of Sun and Moon also helps in cooling down and condensing the water vapors. So, the precipitation will not happen if there is no Sun and all of it would be one phase which means the cycle would be stopped, whatever water remains in the ground will be there, it will not evaporate and there is no plant life etc., etc. So, that is why they have put the Sun in this picture very, very carefully.

So, this is a very general representation of a hydrological cycle. We will get into the details as I said on each component which is necessary for rural India. Before that, let us look at how much water is there, how much fresh water is there for the world and then for India, so that we have a context, we have to build a context like yes, I have seen cycle, the water cycle with different components, but how much how much is there for human consumption or human related like food, agriculture, drinking water, etc.?

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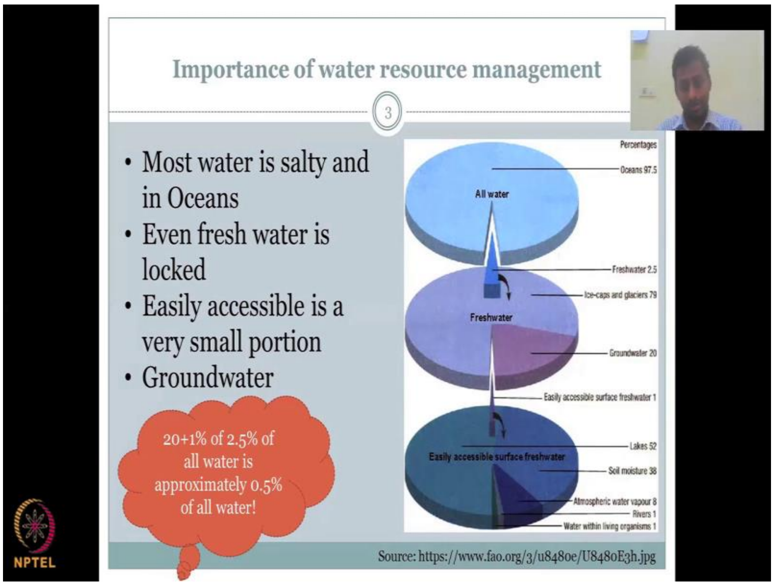

It will be a very interesting effector, that is why if we know how much we have, we get to understand that the importance of water resource management as the title of the slide suggests. Let us take the water, total water what you see here is around 97.5 percent of the total world, water is in oceans, oceans, seas, all the salt water. So, all of this is saline water or salt in, high in salt content, which is not usable.

So, that would not consider as a freshwater, freshwater do not, does not have that much salinity. So, if you look at it only 2.5 percent of the total water in the world is freshwater; plants do not grow on ocean water, please understand. Humans do not consume it without high intensive treatment like desalination plants. So, it is important to understand that of the hydrological cycle we are only looking at 2.5 percent of freshwater to manage. So, it is very, very important to manage this 2.5 percent and even the 2.5 percent not all is usable.

Let us break it down. So, of the 2.5 percent of the freshwater; 80 percent, almost 80 percent, 79 percent is locked in icecaps and glaciers. So, what you see as glaciers and icecaps moving in the Antarctic, Arctic is all freshwater because it is snow ice when you melt it, you can drink it or after purification. But it is not readily usable.

So, the readily usable is only the remaining 21 percent, of which 20 percent is groundwater, which is under the ground, and there are different stratifications, so right now, all the groundwater is put into this pool of 20 percent. Not all the groundwater is easily accessible, very, very subtle amount, a very small amount is accessible. Let us get into the details of that when we talk about groundwater.

However, of the 21 percent, which is easily or relatively easily accessible 1 percent is easily accessible as surplus water. And of the surface water that 1 percent; 52 percent is easily accessible surface freshwater which is your lakes, ponds, your big, big rivers, dams, etc. etc. So, all these water that you see for example, in Ganges, Nile, Yamuna everything would contribute to 52 percent across the world I am saying, this is not for India, again this is for the world.

Of the 1 percent, 38 percent is in soil moisture, which is the water which is held in the soil, which is readily accessible to the plants. So, understand that the soil moisture is a key component for plant growth and for living organisms in the soil. So, the soil moisture which is held in the soil, the water particles, water molecules that are held in the soil is around 38 percent.

The remaining is atmospheric water vapor, rivers, water within living organisms etc. So, if you combine all this, we get around 1 percent of fresh, easily accessible water of the 2.5 percent, now, I am going up, so all this is 1 percent of the 2.5 percent and of the 2.5 percent of the global water. So, you have a very, very small component. Most water is salty, and in oceans again, there has to be a process by which the salt water from the oceans convert to water vapor which is driven by your Sun evaporation, and then comes back down.

Not all of the ocean water is evaporated, there is only a limited amount of evaporation happening limited clouds, so you do not see all the water in the oceans evaporate. Even freshwater is locked, please understand this, it is a very important point even though we have 2.5 percent, not all the water is readily accessible. Easily accessible is a very small portion, very small, as I said 1 percent of the 2.5 percent of the total water…

So 20 to; 20 plus 1 percent is the total water available, easily available of the 2.5 percent which accounts to 0.5 percent of the total water volume. I am pulling down groundwater here also, because in recent years, the access to groundwater has increased. Because of scientific technologies, there is a lot of pumping that happens and a lot of new innovations in pumps, cheaper, cost effective pumps have come to the market. So, a lot of people are easily accessing ground water.

Is it sustainable? That is a different question. We will come to that when we talk about the rural water management, it is not sustainable. But still in this context of the slide, how much water is available, how much can we access. So, if you do the numbers 20 plus 1 percent of the 2.5 percent is accessible and putting all the groundwater which is approximately still only approximately 0.5 percent of the total water which is a very, very small component. So, it is very important to manage water.

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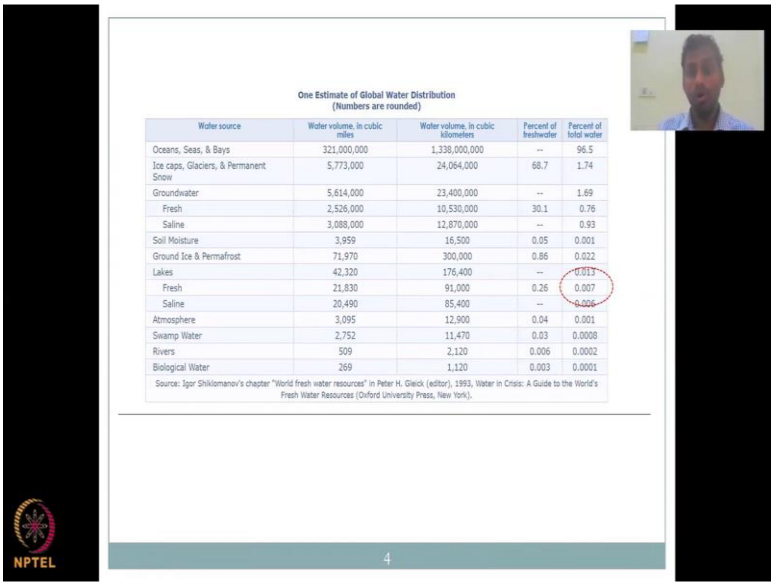

One Estimate of Global Water Distribution
(Numbers are rounded)

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).

Let us look at the numbers as a table. So, if you have 100 percent total water, you have 96.5 percent locked in the oceans, seas and base, icecaps, as I said the solid ice water which is locked, freshwater which is locked in icecaps, glaciers and permanent snow, you cannot access. Groundwater is around 1.7 percent of the total water.

You would see some differences between FAOs estimations in the previous slide and some people some scientist estimations here, but almost they agree in terms of the volumes, so the percentages might be just a little bit off, but it is almost the same, how much water is easily accessible is very, very small.

So, of the groundwater 0.76 percentage is freshwater and then of the total water and saline, so it is not all the groundwater that is usable as I said in the previous slide. If any other soil moisture which is very, very small, given for the plants to consume until you have groundwater, lakes and even the lakes have bad quality water which is saline, which is not potable, so only freshwater is very small.

So, if you look at the numbers, even lakes and rivers 0002 of the total water volume is very, very small. So, if you add up all these numbers 0.76 in the groundwater 0.007, 0.002 in the rivers it approximates to around 0.5 percent. So, this is a difference between the estimates in this and we had 0.5 percent approximately, here we have around 0.7877 percentage. But still again, it is a very small volume of water at an annual scale. So, it is very important to store it.

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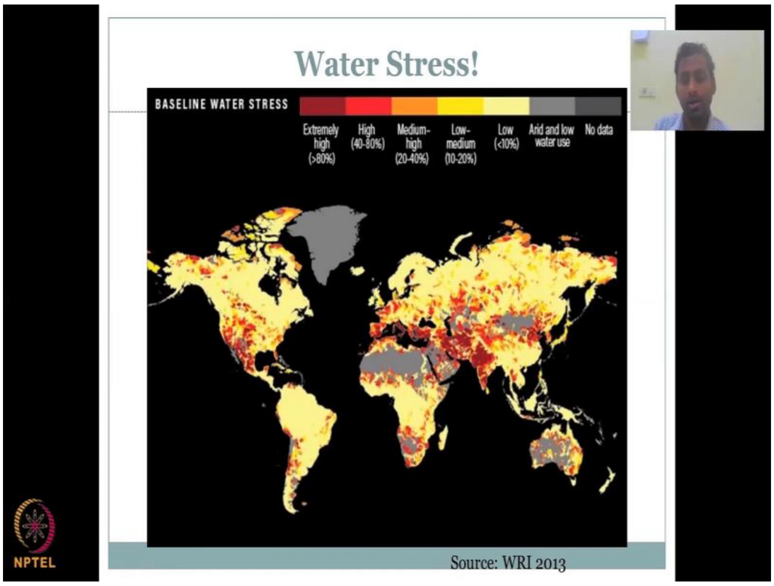

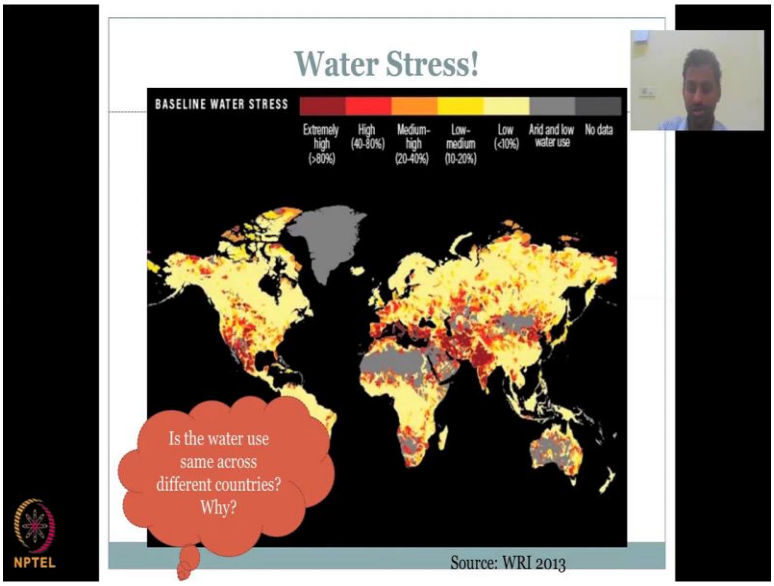

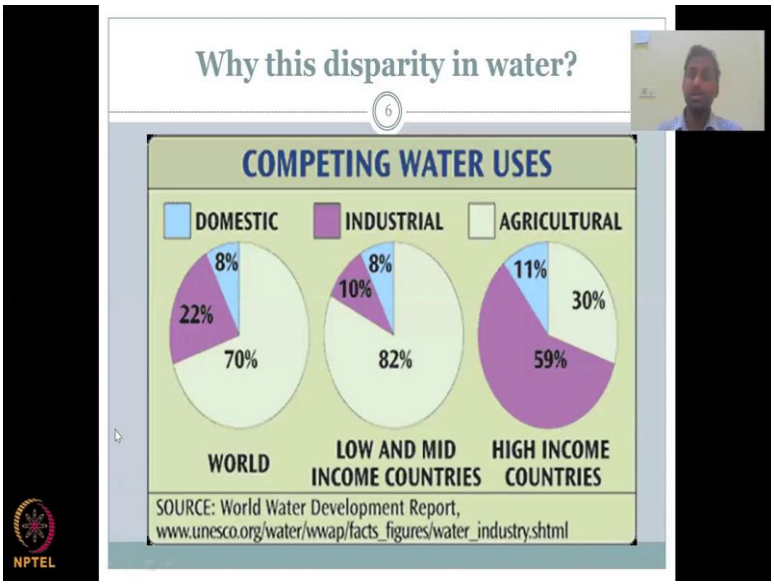

Because of this what has happened? This picture from WRI shows where the water stress is high, where it could be very, very high in the near future. So, this is the baseline water stress, you could see that India and all the countries along the equator with the higher temperature regime are facing extreme water stress.

Also, those regions which have agriculture as the major crop or livelihood, we will see, we will have a lot of water stress. This also shows a high contrast between developing nations, under developed nations, for example, here in Asia and then developing nations like India and highly developed nations like US and Europe etc., you could see that there is a stark difference in the water stress.

Are they managing the water well? What are they doing different? This is very important to understand before we jump into the management of water. So, on the water stress is not the same across countries, this is, this needs to be understood.

Although we have a similar rainfall patterns, similar temperature regimes, we have different water stress, why is that? Why is this disparity in water? Because of how a nation uses the water how a country categorizes the water use. Let us take the world example. In the world 70 percent is of the water is given in agriculture, this is the average. In 20 percent is used in industry and 8 percent for domestic. So, the human consumption is very, very small; on the whole agriculture takes more water this is the average world across the world.

So, if you come to low- and middle-income countries or low underdeveloped and developing nations, India comes in this ranking also, you would see that if 100 liters of water is there, India would spend approximately 82 liters on agriculture, whereas 10 percent is given to industry and 8 percent for domestic, so the 8 percent is still almost the same. So, we are not going above and below, but if you look at where does the water most of the water goes?

It goes into agriculture, most importantly, it goes above the world average. So, if the average is 70 percent, still this low- and middle-income countries are pushing a lot of water in for agriculture and the agricultural produce does not get that much price. On the other hand, if you look at high income countries like the US, Australia, Europe, you would see most of the water is used for industrial applications; cars, computer technologies, etc., etc. Whereas 11 percent is domestic, so they have a higher quality of life.

So, they would have higher access to water, almost double. So, their quality of life how they use water resources is pretty high. So, they will have a higher consumption which is. But if you look at the agriculture, they are very, very small compared to the average and the high and low middle-income countries. This clearly shows where the priorities are. So, for low- and middle-income countries it is agriculture, where they put a lot of effort and water into agriculture.

Whereas in high- and high-income countries, developed countries, the water is put in industry and because of this maybe the industry produces getting much, much higher benefits, economic benefits compared to agricultural produce. And that is one of the reasons maybe the high-income countries are still high-income countries and low- and mid-income countries are still getting poorer and poorer by day.

Because the agricultural produce is not getting the price, there is climate change impacts on agricultural produce, there is losses, whereas in industry it is almost the same, you are kind of mitigated against climate change. So, this is the reason why we see this water stress being different in different countries, it is not only the population, it is also the livelihood of the people. The population is very less, but then the livelihood of options of the people where the water is spent is very, very important.

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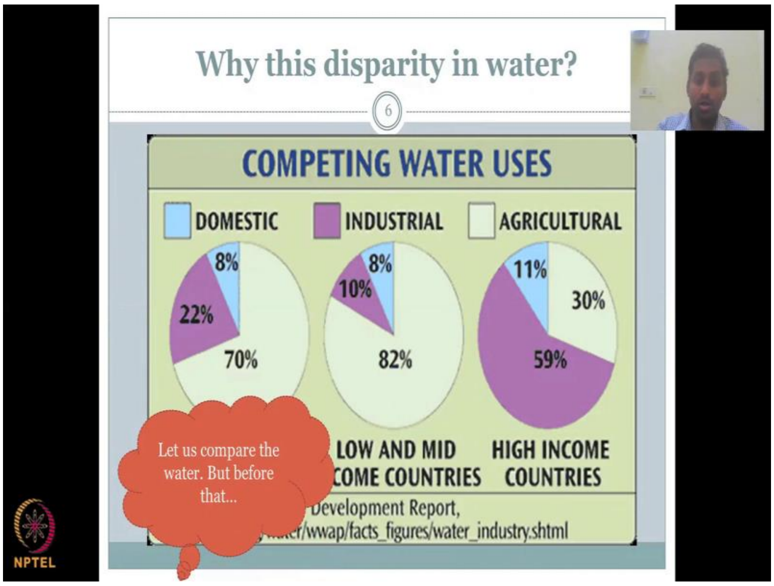

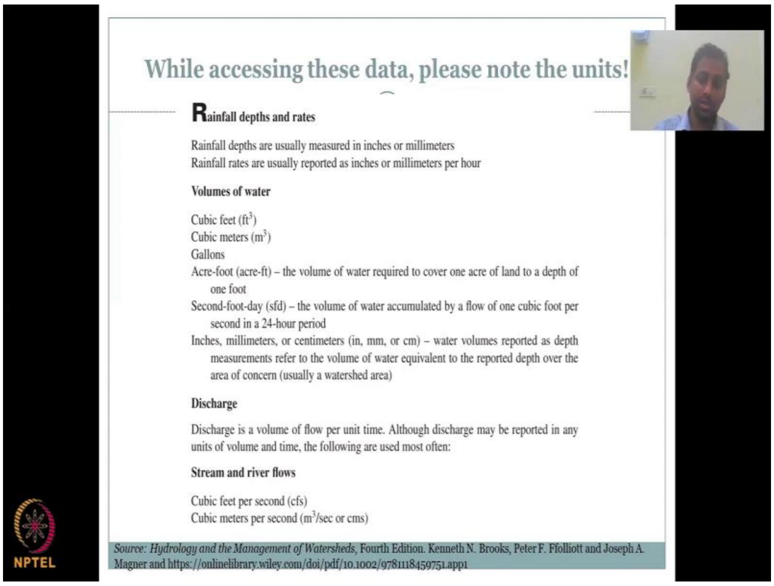

Let us compare the water but before that the most important part when we start the hydrological cycle, when we want to do these different percentages, we need to calculate the water and while accessing these data, please note the units; units are very, very important in this research.

So, when you do hydrological cycle, you as we saw in the hydrological cycle, there are multiple parameters, multiple variables, multiple compartments of water and each one would have a different unit. It is very important to bring all the units into one, which is normalize it and so that we understand how much is rainfall, how much is groundwater, how much is stream water, the domestic use, etc. So, please look into this carefully.

So, for example, let us take some examples rainfall are always measured as depths or weights; depths as a thickness. So, when you go to the news, they will say we had rainfall around 15 millimeters over the monsoon. So, 15 millimeters is a thickness, it is a scale one dimensional thickness, you can convert that into a volume if you multiply it by the area which you see here volumes of water.

And you can also convert the rainfall into a rate, you could see that 15 millimeters across the monsoon I said, so, 15 millimeters across 3 months. So, if you divide the number of days you can get per day how much is the rate. Normally, the amount of rainfall is given as per day, like every day these millimeters is recorded or an intensity which is rate per hour or most importantly you in the national context, you will describe it as a unit per year, because all the water balance components are per year.

So, you would say 600 millimeters in a arid region in Gujarat per year, if it goes to Maharashtra for example, along the Western Ghats you get around 3000 millimeters per year. So, this is a thickness you can convert it into a rate, all these are dependent on the research you do. So, the first point I would like to stress here is please look into the data and the units.

If your units are not the same, you need to convert them before you compare between rainfall, groundwater, industry use etc. If you do not, then it will just not make sense, the additions will not add up. So, volumes of water is also present, you can do it as cubic feet, also within the units, within the rates, depths and units, you also have different ways of expressing a unit or dimension.

For example, you can tell volume of water in cubic feet, gallons, cubic meters, acre foot, etc. etc. Acre foot is an area times a thickness which is foot, so, all these things please go through the books I have recommended have it, but most importantly when you download the data the unit would be given.

Discharge is the amount of water which comes into rivers is flow unit per time. For example, you tell cubic meters per second of speed, the velocity of water in the river. So, rainfall is in precipitation comes in as millimeter thickness of water, depth that converts into runoff as a velocity. So, all these you can still convert it back into volumes, normally volumes is good. So, if you convert rainfall into volume, you convert discharge into volume, you can get into comparing it.

So, we can see here cubic feet per second, if you compare that are converted to per day, then you just multiply number of seconds per day and you will get a cubic feet or a cubic volume. So, this is how you convert everything into one unit.

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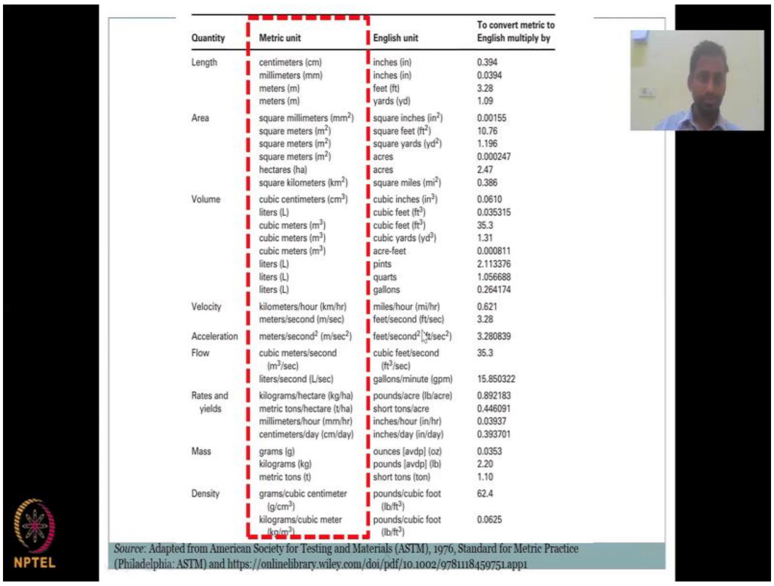

Quantity	Metric unit	English unit	To convert metric to English multiply by
Length	centimeters (cm)	inches (in)	0.394
	millimeters (mm)	inches (in)	0.0394
	meters (m)	feet (ft)	3.28
	meters (m)	yards (yd)	1.09
Area	square millimeters (mm^2)	square inches (in^2)	0.00155
	square meters (m^2)	square feet (ft^2)	10.76
	square meters (m^2)	square yards (yd^2)	1.196
	square meters (m^2)	acres	0.000247
	hectares (ha)	acres	2.47
	square kilometers (km^2)	square miles (mi^2)	0.386
Volume	cubic centimeters (cm^3)	cubic inches (in^3)	0.0610
	liters (L)	cubic feet (ft^3)	0.035315
	cubic meters (m^3)	cubic feet (ft^3)	35.3
	cubic meters (m^3)	cubic yards (yd^3)	1.31
	cubic meters (m^3)	acre-feet	0.000811
	liters (L)	pints	2.113376
	liters (L)	quarts	1.056688
	liters (L)	gallons	0.264174
Velocity	kilometers/hour (km/hr)	miles/hour (mi/hr)	0.621
	meters/second (m/sec)	feet/second (ft/sec)	3.28
Acceleration	meters/second^2 (m/sec^2)	feet/second^2 (ft/sec^2)	3.280839
Flow	cubic meters/second (m^3/sec)	cubic feet/second (ft^3/sec)	35.3
	liters/second (L/sec)	gallons/minute (gpm)	15.850322
Rates and yields	kilograms/hectare (kg/ha)	pounds/acre (lb/acre)	0.892183
	metric tons/hectare (t/ha)	short tons/acre	0.446091
	millimeters/hour (mm/hr)	inches/hour (in/hr)	0.03937
	centimeters/day (cm/day)	inches/day (in/day)	0.393701
Mass	grams (g)	ounces [avdp] (oz)	0.0353
	kilograms (kg)	pounds [avdp] (lb)	2.20
	metric tons (t)	short tons (ton)	1.10
Density	grams/cubic centimeter (g/cm^3)	pounds/cubic foot (lb/ft^3)	62.4
	kilograms/cubic meter (kg/m^3)	pounds/cubic foot (lb/ft^3)	0.0625

Source: Adapted from American Society for Testing and Materials (ASTM), 1976, Standard for Metric Practice (Philadelphia: ASTM) and https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118459751.app1

As I said there are multiple units, so, please do not get confused of how these units are organized, all hydrological books, most of the good books would have a unit table, either in the front or in the appendix just check it. And you can also get these conversion rates in online modes. So, you can look here, you can convert centimeters into inches just multiply.

So, there are two basic units one is metric and one is English units. Because we were under the British rule, we have a confused system that some of the units are still in English and some of it are in metric or SI units as we know. So, most of the world uses the metrics, but some English units are still being used.

For example, if you go to a shoe shop in India, you still order by feet, inches and stuff, if you tell your height, it is foot and inches, whereas in other countries it will be centimeters. When we go for a distance, it is kilometers, not miles. So, this confusion does exist. So, please, when you do the calculations for water, area, etc., please make sure you understand which unit you are using.

For example, area, we do have hectares and square kilometers, it is a very common term, but you can, when you look at some mitigation reports, you look at as acres, which is English units. So, you see, you need to convert these two units, otherwise, this calculation will go wrong, just look at how much difference the decimals it will come. So, always convert them and be careful. So, that is one very important point I would like to mention before I conclude.

So, we talked about the hydrological cycle. We looked about some components in the hydrological cycle before we introduced how much freshwater do we have to conserve and then we looked into some units and before the next class, please go through some of the units to have an understanding, because we will be discussing about rates; rates of how water is being used. Thank you.