Surface Water Hydrology
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Lecture 4
Surface Water Resource of India

In this lecture, we are proceeding a little bit more towards the introduction which will cover mainly the surface water resource of India. Remember that, we are still in module 1, where we are discussing, the hydrological processes and we are giving the introduction to this entire course, in general. But this introduction will be incomplete if we do not cover the surface water resources from the perspective of India.

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However, what we will start in this course, the two major things will be covered. The first one is the different sources of face water, and then the surface water resource of India.

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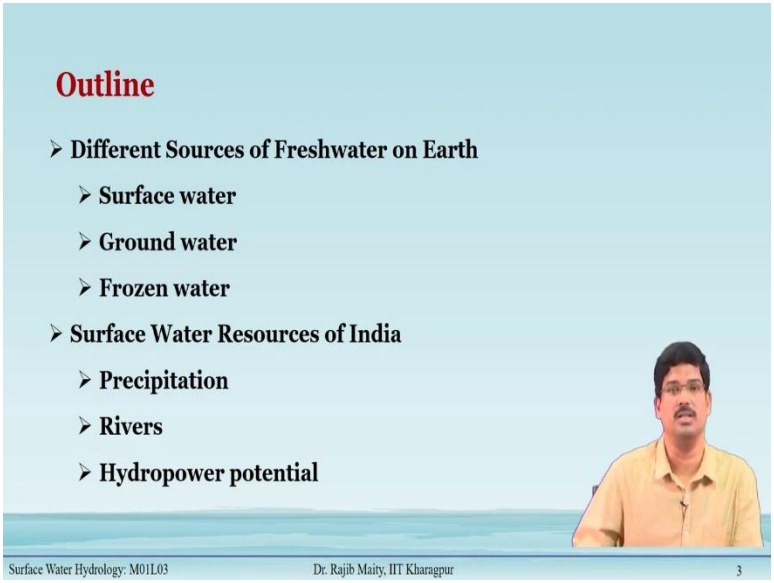

Now, these two things, a major concept that we will cover will be again divided into two-bit more elaborated parts. In the first part, we will see the different sources of fresh water on the earth and it is as you know, in the last class, we just discussed the freshwater percentage is very less, almost less than 1 percent. And again, this is having three major components. Now, the first one is surface water, then groundwater, and then frozen water.

Though this particular course will be mainly focused on surface water, we should know a little bit introduction about the other two major sources of fresh water as well, which will be covered in this particular lecture. Secondly, we will go to the surface water resource of India and as you know that main supply, your main source that it comes through the precipitation, and then it goes to the land surface, overland flow, it joins to some river.

And India is one of the river-dependent countries. So, we should know about it, in this lecture. And also, there are some other things, one of the most important parts of the surface water is also hydropower. The hydropower potential of India also will be touched upon in this lecture.

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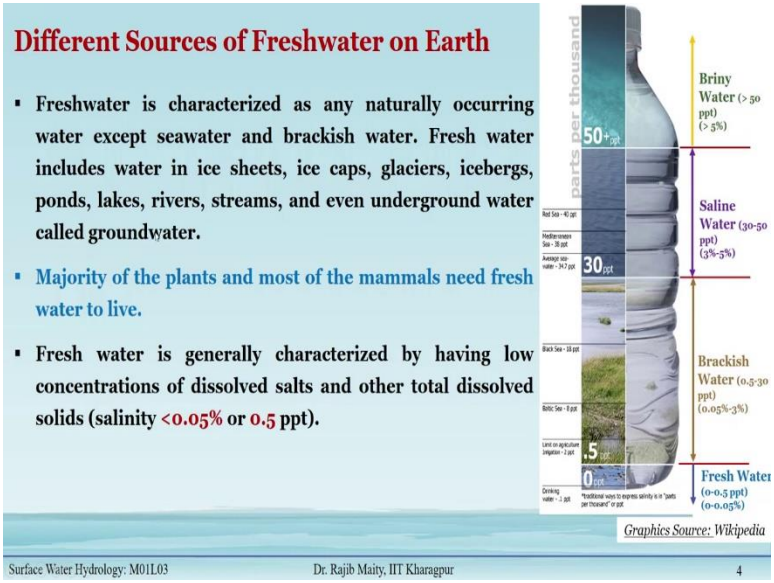

Different Sources of Freshwater on Earth

Freshwater is characterized as any naturally occurring water except seawater and brackish water. The freshwater is generally, there available in the ice sheet, ice caps, glaciers, icebergs, ponds, lakes, rivers, streams, and even underground, which is also known as groundwater. Now, living apart from a few majorities of the plants and the mammals, we depend on freshwater to live. And freshwater is generally characterized by having very low concentrations of dissolved salt in the form of its numerical values.

It should be less than point 0 % or 0.5 % parts per 1000 ppt. So, this illustrative diagram is showing that how these changes are there. So, first, if it is more than 5 % concentration or the 50 parts per 1000 then it is called known as the briny water. And then if it is from the 3 % to 5 % concentration in terms of ppt 30 to 50 ppt, it is called saline water.

Whereas the brackish water is the salt content of the brackish water is 0.5 to 30 ppt or in percentage 0.05 to 3 % and if it is below, 0.05 % or 0.5 ppt then we call it as a freshwater. But remember that freshwater and drinking water, are different. In the case of the drinking water, the standard says that it should be when less than 0.1 percent.

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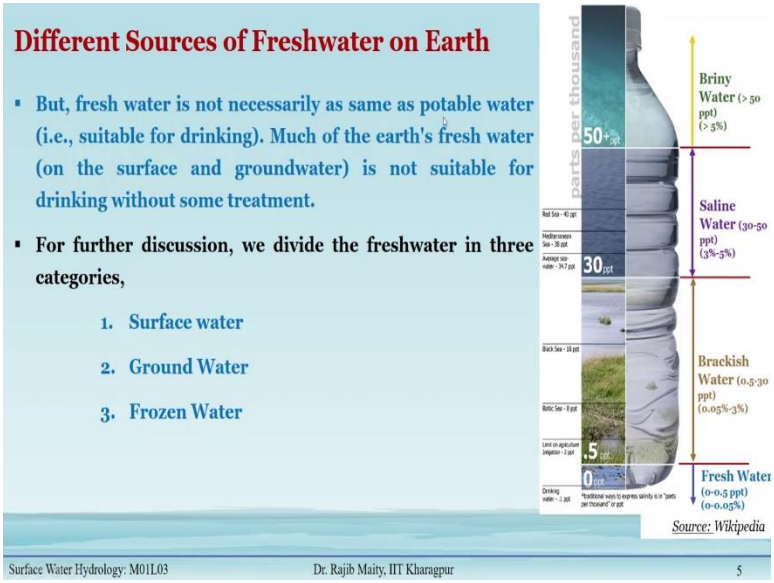

But freshwater is not necessarily as same as potable water (i.e., suitable for drinking). Much of the earth's freshwater (on the surface and groundwater) is not suitable for drinking without some treatment.

Now, if, we will discuss freshwater into three major categories. The first one is the surface water, the second one is groundwater and the third one is frozen water. As I was telling that surface water is the main focus of this course, but we should also know what is the percentage share of the other two major reservoirs of freshwater.

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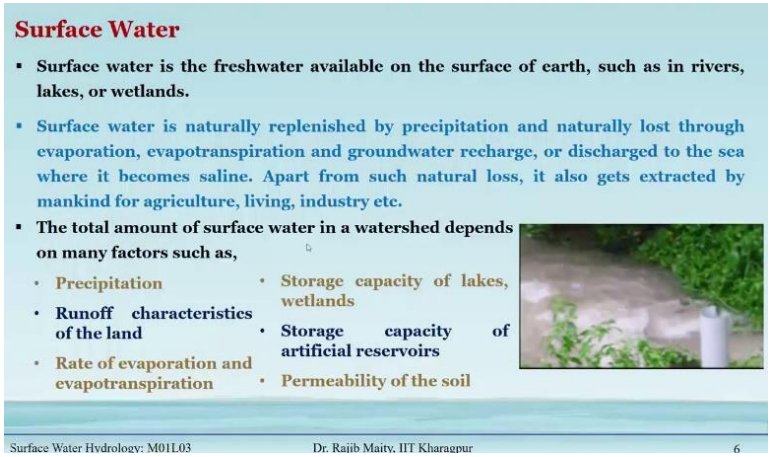

Surface Water

Surface water is the freshwater available on the surface of the earth, such as in rivers, lakes, or wetlands. Surface water is naturally replenished by precipitation and naturally lost through evaporation, evapotranspiration, and groundwater recharge, or discharged to the sea where it becomes saline. Apart from such natural loss, it also gets extracted by mankind for agriculture, living, industry, etc.

- The total amount of surface water in a watershed depends on many factors such as,
- Precipitation
- Runoff characteristics of the land
- Rate of evaporation and evapotranspiration
- Storage capacity of lakes, wetlands
- Storage capacity of artificial reservoirs
- Permeability of the soil

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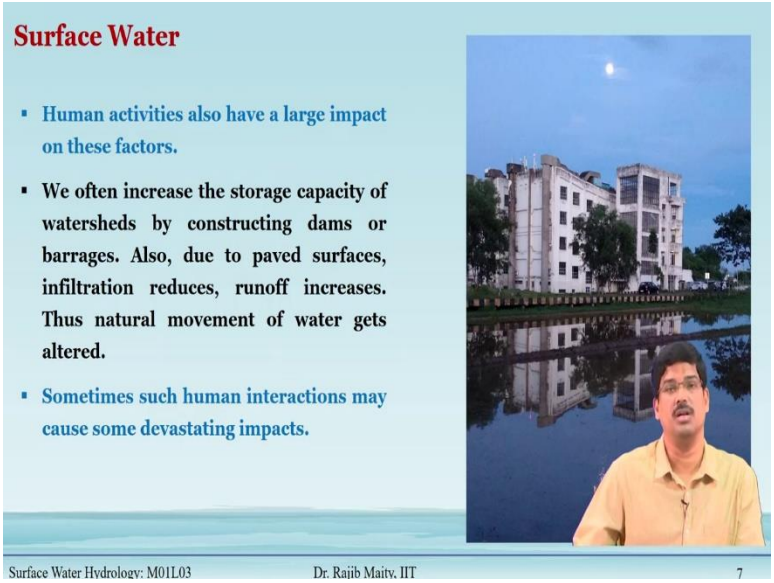

Apart from this, what is also important is that there are some roles of the human activities that also control some of these factors as well. Sometimes, what happens due to the different human activities through different constructions and all, we create some sort of obstruction to the natural flow of the water, either for its storage or for the developmental purpose. So, now this construction causes some surface paved and their infiltration may get altered.

If it is paved, then infiltration will be reduced, if it is storage, some natural storage is created, then what will happen that may increase also. Sometimes depending on the change in the land use land cover pattern the runoff also may change. So, this kind of change, alteration of this ground surface may alter the natural movement of the water also. So, that also causes changes in surface water availability. And sometimes it is improved, sometimes we target to, to increase the storage, sometimes some of the activities may also have some devastating impact on the, on the surface water resource availability. Sometimes such human interactions may cause some devastating impacts.

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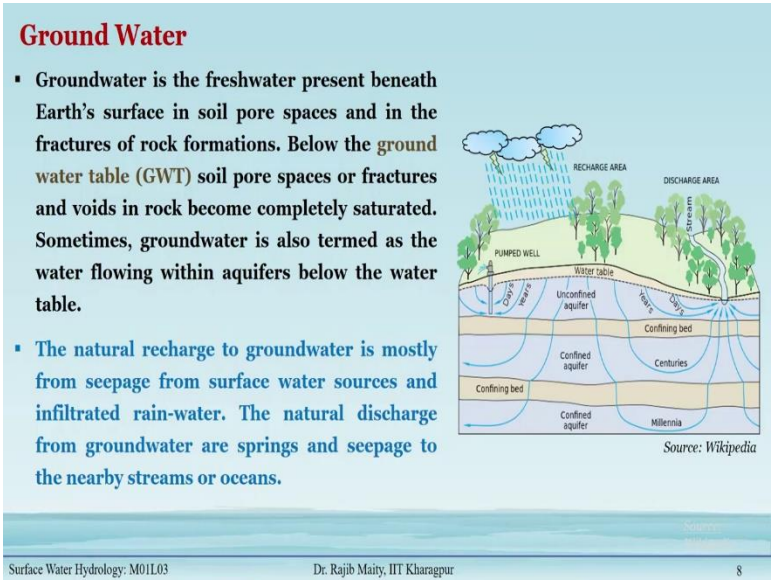

Ground Water

Next, we come to the groundwater. Groundwater is the freshwater present beneath Earth's surface in soil pore spaces and the fractures of rock formations. Below the groundwater table (GWT) soil pore spaces or fractures and voids in rock become completely saturated. Sometimes, groundwater is also termed as the water flowing within aquifers below the water table.

And sometimes this zone as you can see in this pictorial representation of the aquifer. The aquifer may be a confined aquifer or maybe an unconfined aquifer. If it is, if there is no other layer on the top it is exposed to the atmospheric pressure, then it is the unconfined aquifer or if it is between two, two impervious layers we call it a confined aquifer. And the water is getting stored in these layers and we extract that water for our different purpose.

Some water goes to the deep percolation and joins to the groundwater table also. So, this natural recharge from the groundwater is generally from some springs and the seepage to the nearby streams as well.

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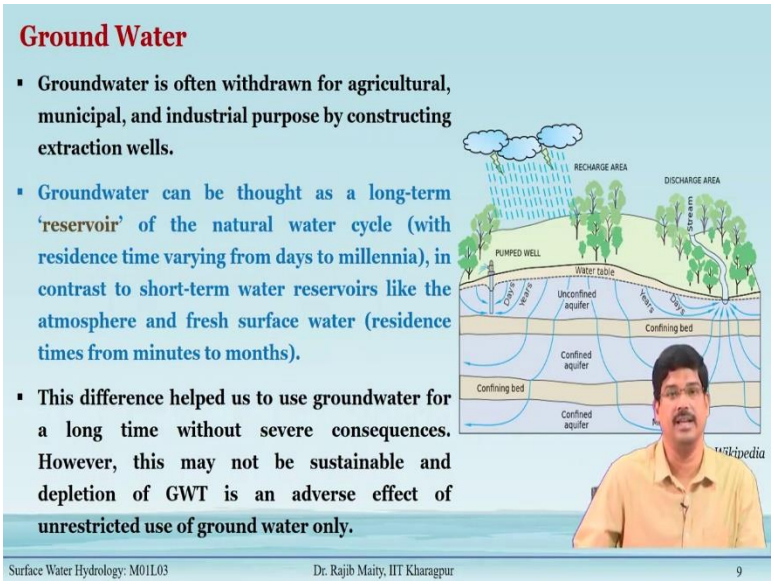

Groundwater is often withdrawn for agricultural, municipal, and industrial purposes by constructing extraction wells. Groundwater can be thought of as a long-term 'reservoir' of the natural water cycle (with residence time varying from days to millennia), in contrast to short-

term water reservoirs like the atmosphere and fresh surface water (residence times from minutes to months).

This difference helped us to use groundwater for a long time without severe consequences. However, this may not be sustainable and depletion of GWT is an adverse effect of unrestricted use of groundwater only.

However, there is a cautionary note here, that it may not be sustainable. And there is a problem related to the depletion of the groundwater table and which causes many adverse effects on our society if we go for the unrestricted use of the groundwater.

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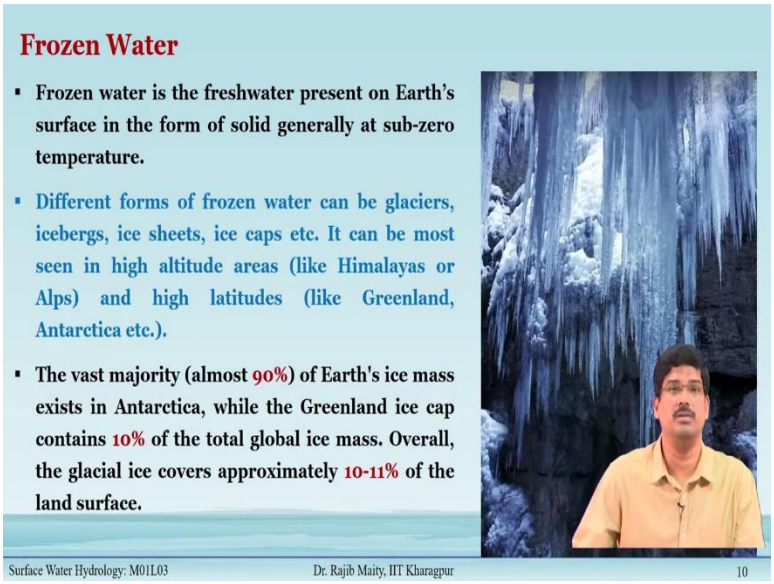

Frozen Water

Next comes the third category, which is known as frozen water. Frozen water is again another reservoir for the freshwater that is present on the Earth's surface in the form of solid generally, at the subzero temperature. Different forms of frozen water can be glaciers, icebergs, ice sheets, ice caps, etc. It can be, it is mostly seen in the high-altitude areas like the Himalayas or Alps and the high latitude like Greenland and Antarctica.

The image on the right-hand side is taken from the Alps region by me, and where you can see that there is a seasonal variation. So, in the wintertime, it is frozen and you can see that this is kind of hang, hanging, ice sheets are there, and it will melt again in the springtime.

Now, the vast majority about say 90 % of the Earth's ice mass is generally in Antarctica, while the Greenland ice cap is content 10 % of the total global ice mass, ice mass. Overall, the glacial ice cover approximately 10 to 11 % of the total land surface is covered under the earth.

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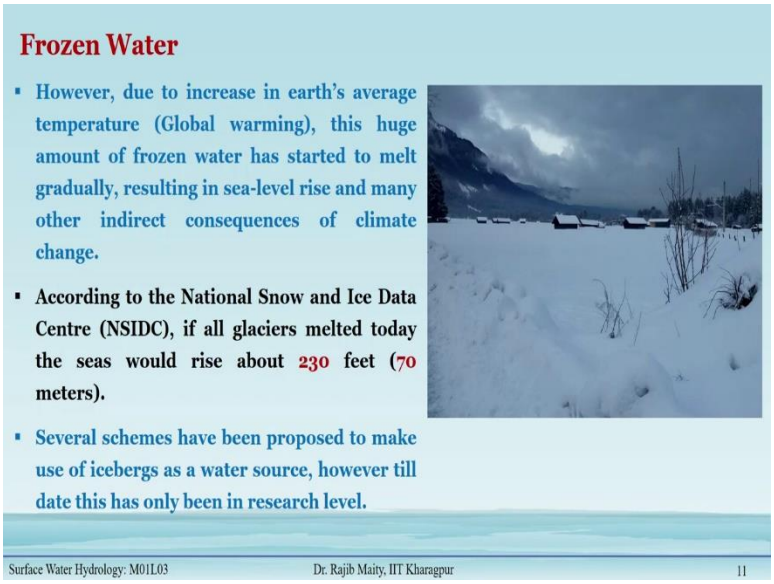

However, due to the increase in the earth's average temperature (Global warming), this huge amount of frozen water has started to melt gradually, resulting in sea-level rise and many other indirect consequences of climate change. According to the National Snow and Ice Data Centre (NSIDC), if all glaciers melted today the seas would rise about 230 feet (70 meters).

Now, several schemes have been proposed to make use of the icebergs as a water resource for us. However, these are not in, so far not in the, in the practical use, so far it is still in the research level only. So, why this information is important. So, so far as the surface water is concerned in different sources like rivers or lakes, or wetlands, these are some of the most easily accessible sources of freshwater to the human community and our ecosystem.

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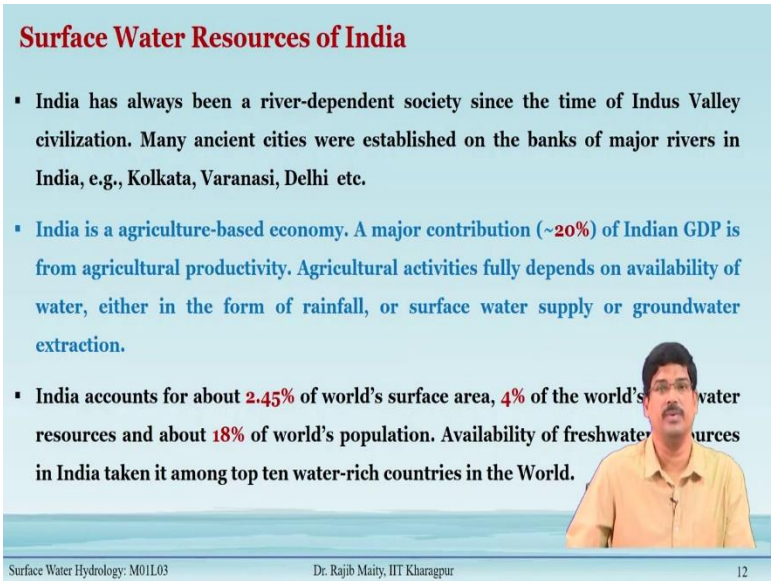

Surface Water Resources of India

Now, if we see the surface water resource of India, its particular characteristics, then we know that it is a river dependent society since that, since the ancient times in the Indus Valley civilization, from the long past most of the civilizations are developed around a river valley only. Many ancient cities are established on the banks of major rivers in India for example, Kolkata, Varanasi, Delhi, etc.

India is an agricultural-based economy, a major contribution there is almost about 20 % of Indian GDP is from agricultural productivity. Why this is important? Because agricultural activity fully depends on the availability of the water either from the rainfall or the surface water supply or from the groundwater extraction. So, this is one of them, one of the major sources that support our economy.

So, India accounts for about 2.45 % of world surface area, whereas 4 % of the world's fresh, world-fresh water resource and about 18 % of the world's population is there in India. So, the availability of freshwater resources in India has taken it among the top 10 water-rich countries in the world.

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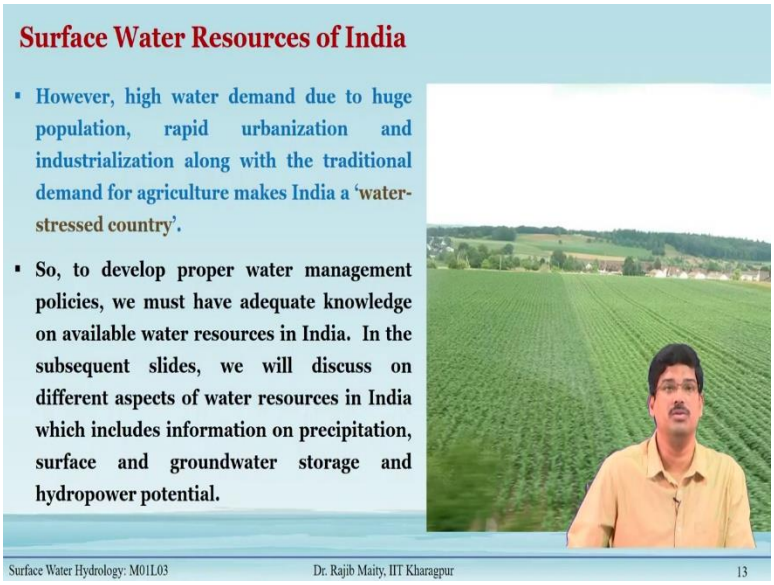

In India, high water demand due to the huge population rapid urbanization, and industrialization along with the traditional demand for agriculture makes India a water-stressed country. Not only that but there is some sort of redistribution of the available water resource is also there, which is creating or being reflected in the nowadays in the research, which is, we will see in the next lecture. The possible impact, as a possible impact of climate change.

So, the challenge in this perspective is to develop the proper water management policies. We must have adequate knowledge of the availability of water resource in India. So, in the next few slides, we will discuss the different aspects of water resources in India, which includes the information on the precipitation, surface, and groundwater storage and of course, one of the major application-wise the hydropower potential of the surface water in India.

So, while we discuss, we will discuss another thing is called the spatial and temporal distribution, in technical terms, it is called the spatial-temporal distribution that is over the space as well as over time, how the available water resource changes. It changes all over the world no doubt, but we are discussing specific to our India

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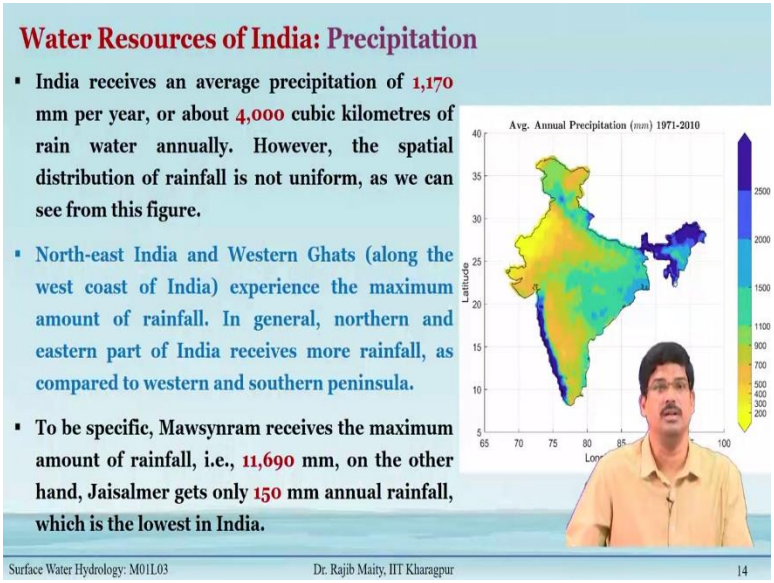

Water Resources of India: Precipitation

Now, India receives on average annual precipitation of 1170 mm and it is about 4000 cubic kilometers of rainwater annually. However, the spatial distribution of this rainfall is not uniform as you can see from Fig 1. Whereas, you can see that in the northeast part of India, which is very high, and also the Western Ghats spots, where you can see the blue tone, it indicates there is very high annual rainfall.

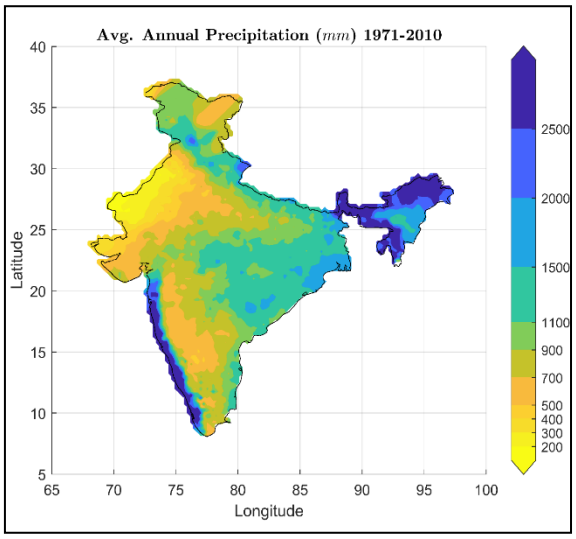

Fig 1: Spatial distribution of annual rainfall in India

Whereas, if we go to the northwest part near Rajasthan and another part here and in some parts of the Deccan Plateau, this rainfall is very less. And whereas, in the Gangetic plain or eastern side of India, it is moderate rainfall. So, North East India and the Western Ghats are the regions to experience the maximum amount of rainfall. In general, the Northern and the eastern part of India receives more rainfall as compared to the western and southern peninsula.

To be specific, there is a that is the Mawsynram, you may be knowing it is received, it receives the maximum amount of rainfall, which is approximately 11,690 mm per year. And on the other hand, the Jaisalmer is one city in the Northwest in Rajasthan, that receives only 150 mm of annual rainfall, which is the lowest in India. Now, this is all about the spatial variation of annual rainfall.

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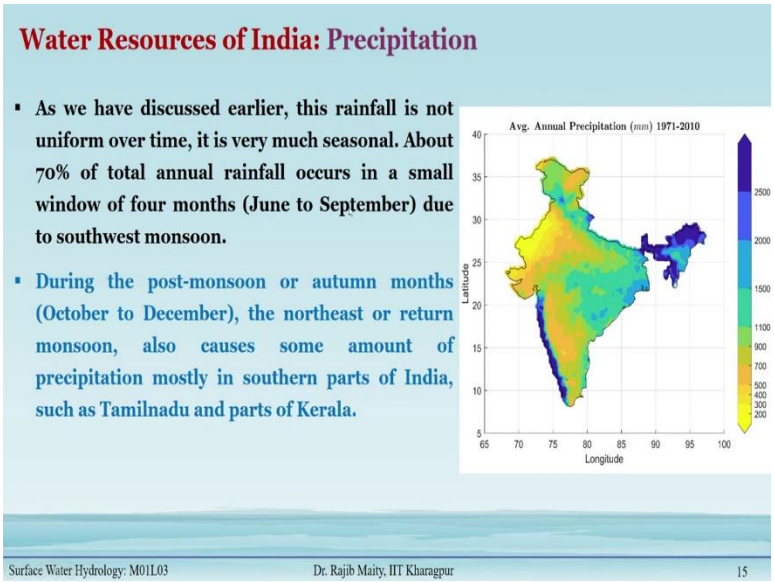

Now, if we take a specific location in India and we see how it varies over the year, then also we can see that there is there are some changes are there. Before discussing that, we can also discuss that the rainfall is not uniform over time, as I told you in general, for all the regions, about 70 % of the total annual rainfall occurs in a small window of four months from June to September. We call it monsoon season.

So, this monsoon season is mostly due to the southwest monsoon and India receives approximately 70 % of total annual rainfall. So, you can see that out of 12 months, only within four months itself we received 70 % of annual rainfall and the remaining 8 months gives the 30 % of rainfall. So, over time also it is, it is very much seasonal rainfall that we experience.

Not only that but there are some return monsoons that are also there that are called the in the autumn months and the -post-monsoon on the autumn months that is October to December, that northwest or the returning monsoon is also there. So, when it comes back that time, not the entire part of India, but some southern tip of this peninsula like the Tamil Nadu or the parts of Kerala, they received some amount of rainfall during this return monsoon time.

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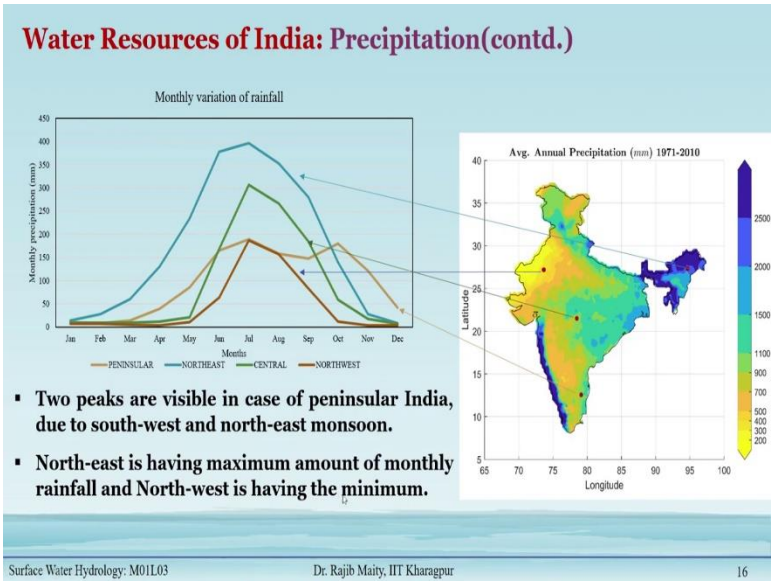

So, if I again see that, the spatial distribution is understood. Now, if I just take four different points, just random location one from the northeast, one from the northwest, in the central part of this, that Tamil Nadu region where it received the returning monsoon also. And if I see the annual variation of this, of this rainfall per month, as you can see here twelve different months are shown here and how much rainfall they, they received.

The northeast region receives the maximum amount of rainfall. However, it receives the maximum amount of rainfall from June to September compared to the other months during the

year. On the other hand, the lowest we are getting from the point, which is in the northwest part. In the center part that we see, it is the central part that we see that receives moderate rainfall.

Coming to the fourth point, which is from the Tamil Nadu region, there you can see that there are two peaks are there. The first peak is during the monsoon time and also there is another peak which is the post-monsoon time, this is due to that return monsoon that I discussed just now. So, the two peaks that are visible in case of many parts of this peninsular India, due to the southwest or the northeast, one is the southwest monsoon other one is that northeast monsoon. Northeast monsoon has the maximum amount of monthly rainfall and Northwest is having the minimum.

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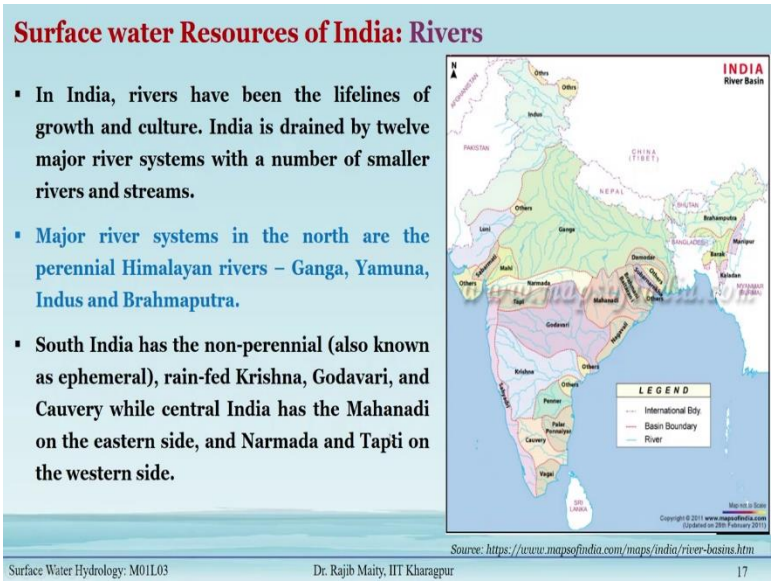

Surface water resources of India: Rivers

Now, coming to the river map of India, in India rivers have been the lifeline of growth and culture. And India is drained by twelve major river systems with a number of smaller rivers and streams. The major river system in the north ais the perennial and Himalayan rivers, Ganga, Yamuna Indus, Brahmaputra. South India has some non-perennial, which are also called the ephemeral rivers are there which are rain-fed like Krishna, Godavari, Kaveri.

Whereas, in the central part of India, there are Mahanadi is flowing, whereas Narmada and Tapti are there which are on the west slowing river basins are there, there. These are the major river basin but there are enormous small tributaries are there all over India.

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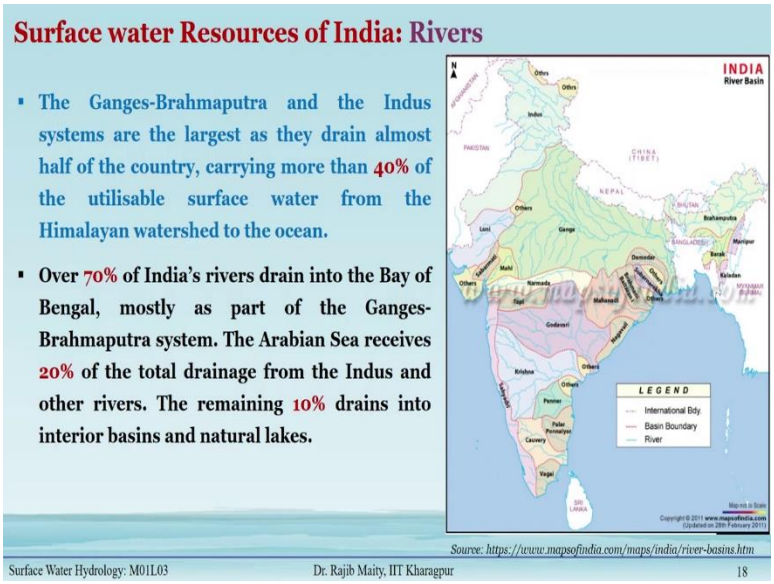

Now, among these, this Ganges Brahmaputra and the Indus system are the largest as they drain almost half of the country. It carries almost 40 % of the utilizable surface water from the Himalayan water set to the ocean. And over 70 % of India's river drains into the Bay of Bengal, mostly as part of the Ganges Brahmaputra system. The Arabian Sea receives almost about 20 % of the total drainages from the Indus and other rivers.

The remaining 10 % drain into the interior basins or the natural lakes. So, as you can see most of the river basins in India, drain towards the Bay of Bengal and there are some draining towards the Arabian Sea, which is less. So, this causes the silt load to be more towards the coast of the Bay of Bengal side as compared to the western side.

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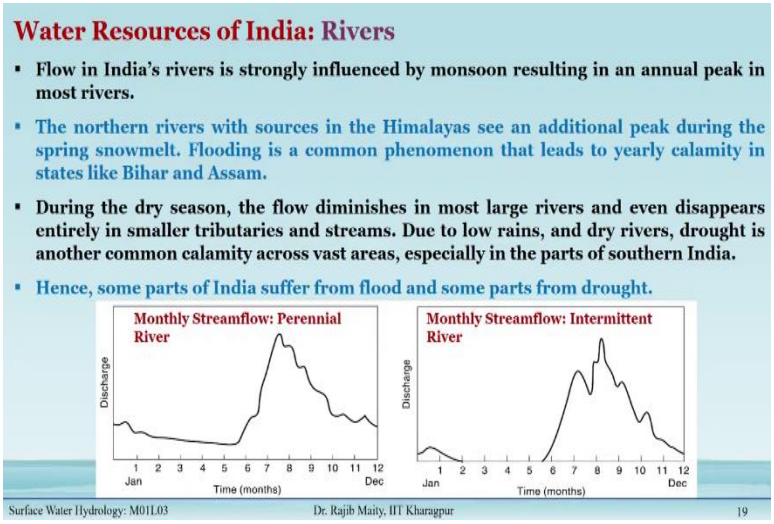

Water Resources of India: Rivers

The flow in India's rivers is strongly influenced by the monsoon resulting from the annual peak during the monsoon time itself. As you can see that during the precipitation we have discussed, most of the rainfall occurs from June to September. So, that reflects in the, in the river flows also. So, from June to September or even some more time, after the monsoon-like October or November, they get the maximum amount of discharge in this river system.

The northern rivers with the source in the Himalayas, see an additional peak during the spring snowmelt. So, when the temperature rises, whatever the snowfall that occurred during the monsoon time that melts, flooding is a common phenomenon that leads, leads to the yearly calamity in the states like Bihar and Assam that we sometimes hear from the news from here and there.

During the dry season again, on the other hand, the flow diminishes and most of the large river basin and sometimes they even disappear, that there is no discharge particularly to the South Indian River, the rain fade river, river basins, and that is why they are known as the accumulated rivers and it is more for the smaller-to-smaller tributaries.

Due to the low rain and the dry rivers, drought is another common calamity in India in many parts, particularly in southern India and also many parts, many other parts also. It may so happen it is noticed that some part of India is faced suffering from flood and another part is suffering from drought and this may happen even during the simultaneous time as well.

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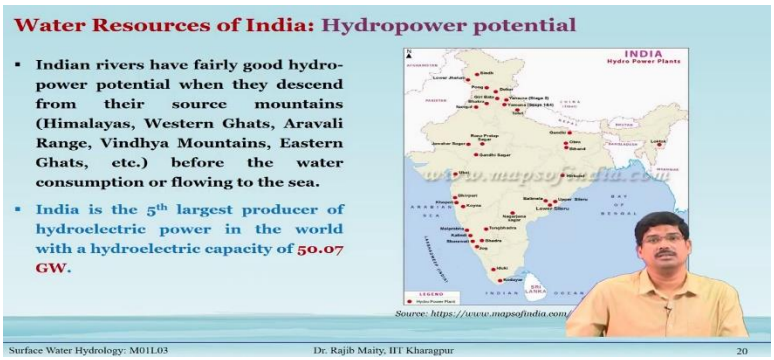

Water Resources of India: Hydropower potential

Now, coming to one of the major renewable sources of energy is called hydropower energy. Since there is a huge potential of this surface water particularly in the hilly regions of India, that is why the Indian rivers have fairly good hydropower potential, when they descend from their source of the mountains like say Himalayas or the Western Ghats or Aravali range, etc., before the water consumption and the flowing in the way in the seas, so, they are captured and they are, they have a huge potential of hydropower. In fact, as of now, India is the fifth-largest producer of hydroelectric power in the world, with a hydroelectricity capacity of about 50 gigawatts.

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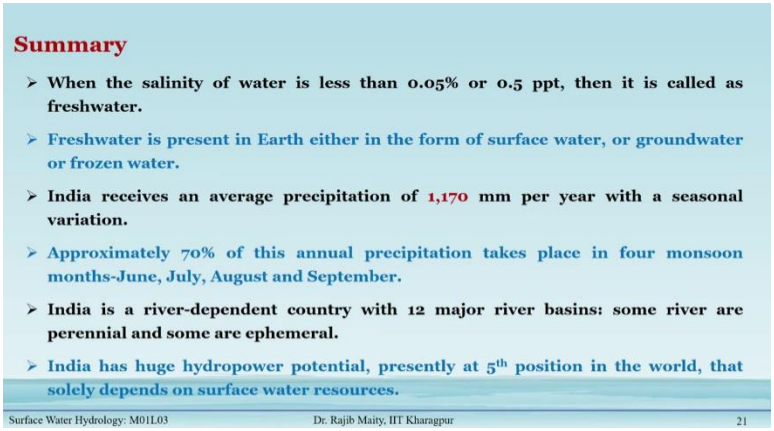

Summary

In summary, we learned the following points from this lecture:

- When the salinity of the water is less than 0.05% or 0.5 ppt, then it is called freshwater.
- Freshwater is present on Earth either in the form of surface water, groundwater, or frozen water.
- India receives an average precipitation of 1,170 mm per year with a seasonal variation.
- Approximately 70% of this annual precipitation takes place in four monsoon months-June, July, August, and September.
- India is a river-dependent country with 12 major river basins: some rivers are perennial and some are ephemeral.
- India has huge hydropower potential, presently at 5^{th} position in the world, that solely depends on surface water resources.