Introduction to Civil Engineering Profession
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Lecture – 06
Hydraulic and Water Resources Engineering

Today we will discuss about Hydraulic and Water Resources Engineering.

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You know water resources engineering is as old as civilization as one would say the first wave or when we the human beings from being hunters and gatherers, they started settling down and started getting into agricultural activities. So, that is about 10,000 years ago the civilization has started particularly on the banks of rivers or river valleys, they say that it started in Iraq and Syria in Mesopotamia and then slowly it spread to Nile valley and Indus valley and you all

know about Indus valley civilization and in fact, about Nile So, what a resources engineering is as old as that ok.

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Like for example, when people settle down on the river valleys they needed transportation and management of water when they started agriculture you need that for irrigation. Like canal systems of Nile valley, that is basically the beginnings of what we call even now we practice in many parts of the world called the flood irrigation or basin irrigation and some of these canals where they used to divert the water from Nile to these fields tanks.

There those canals are more than I mean they were used for more than 1000 years before they were abandoned and we all know about the drainage system for wastewater in Indus valley and we also know about aqueducts of Roman period.

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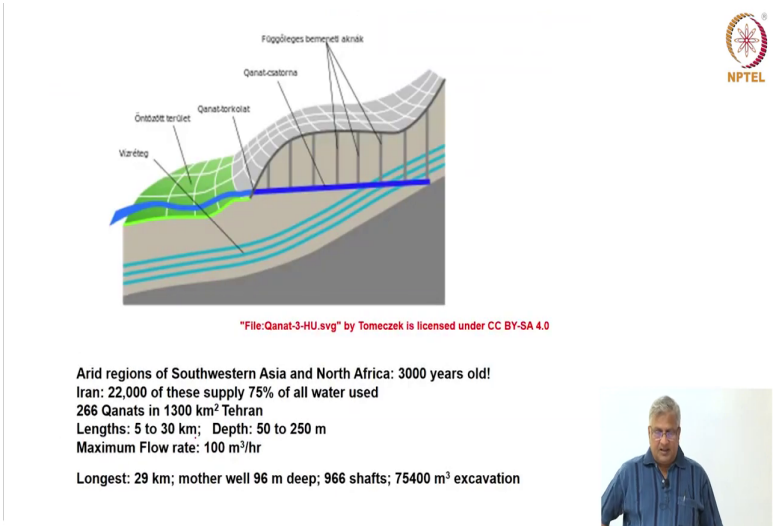

There is another thing called Qanat these are basically used in arid regions of southwestern Asia and North Africa, these are about 3000 years old and then they are still surviving basically Iran has like 22,000 of these supplies 75 percent of all the water used. What they do in these Qanats is basically whatever the water that is falling on the mountains or the hills that water seeps into the ground and then that blue line there you see that is actually a tunnel dug into the mountain from the base of the mountain and the capture the water and the water flows in this tunnel and then comes out of the mountain and then it is taken through canals to wherever they want to use this water.

These are Qanats and then they are about 5 to 30 kilometers land 50 to 250 meters depth and sometimes they carry as much water as 100 meter cube per hour, the longest is about 29 kilometers some of these things are still existing and working fine.

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Photograph of a Qanat

"193 Foggaras oder Quanat- Teil eines Bewässerungssystems" by fotoculus is licensed under CC BY-NC-SA 2.0"

Some pictures of these Qanats from the surface when you see that is basically there is a tunnel going underneath and then they have in fact, manholes and then things like that for inspection of these Qanats, all this is 3000 years old. So, its not something that we have been doing in the last few years. So, that is why I say hydraulic and water resources engineering is as old as civilization.

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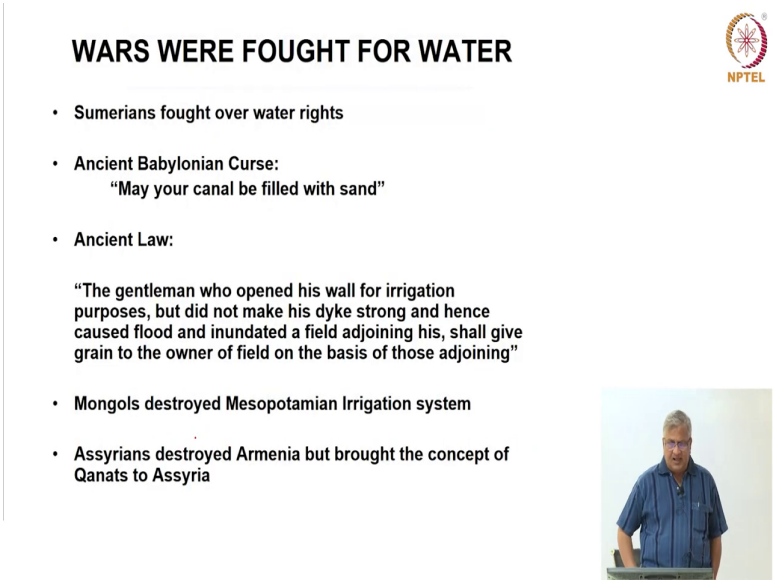

And another important thing was wars were fought for water like Sumerians they fought over water rights, who should get how much of water and you all know we still fight for water within the states within the countries and so on and so forth. Like there is an Ancient Babylonian curse like the say may your canal be filled with sand what it means is this is like cursing somebody a society, if your canal gets filled with the sand then you will not have water for irrigation and then the economy will be bad and then laws were formulated or policies were framed.

Like gentleman who opened his wall for irrigation, but did not make his dyke strong and hence caused flood and inundated a field adjoining his shall give grain to the owner of field on the basis of those adjoining; that means, people were aware of water law again its not that something new that we are doing now. Mongols destroyed Mesopotamian irrigation system its

like these days when there is a war one thing they do is they will attack the in a economic or infrastructure installations right to keep the I mean the enemies economic system down.

So, they were actually doing that for irrigation systems. Assyrians also destroyed Armenia, but then when they went to Armenia they found that these Qanats that I was discussing about few minutes ago is something pretty good. So, they destroyed them, but then the concept of Qanats they took it to Assyria.

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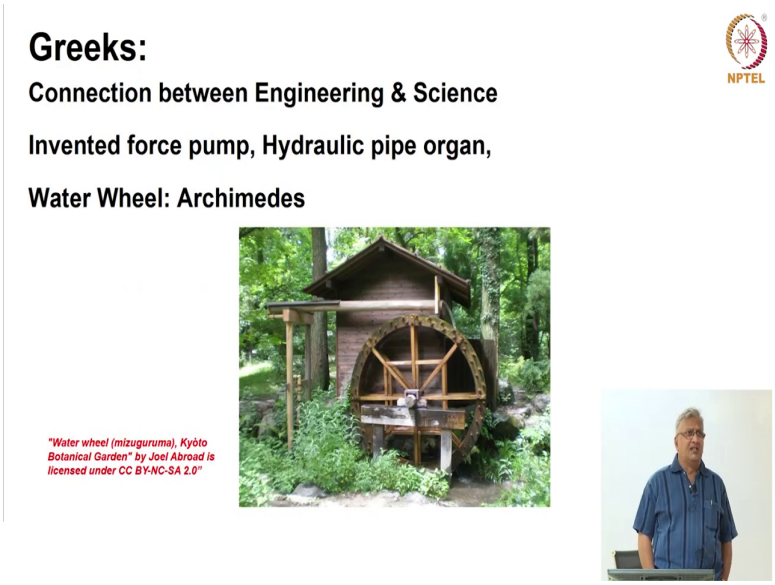

And I will jump. Of course, Greeks in the western world the Greeks were the first who got the connect the link between engineering and science. They said you would you been doing all this engineering, but we need to understand the basics of hydro science. So, they said that is very important. So, and then they invented force pump, hydraulic pipe, water wheel I mean Archimedes has invented water wheel and how to lift the water and use for many purposes.

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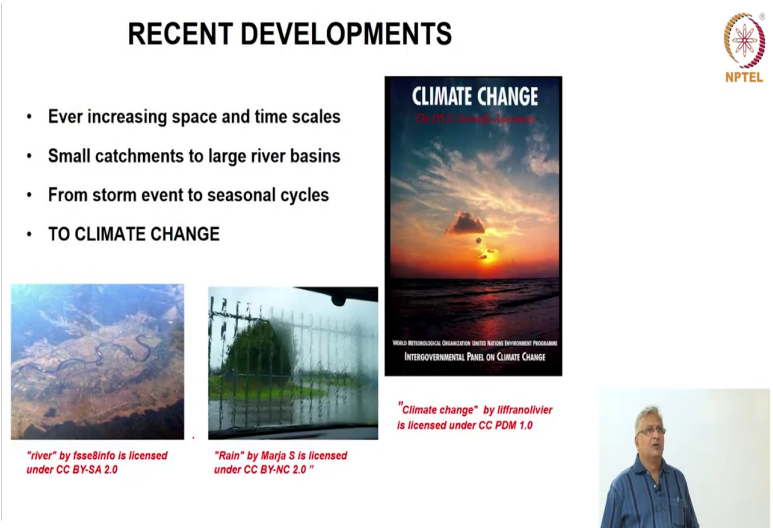

So, I just jumped from there to what stage we are in like recent developments. For example, presently we are as hydraulic and water resources engineers, we are concerned with ever increasing space and time scales. When I say spatial scale you can go and then say that I am interested in what happens in let us say IIT Madras lake, how much of water is there, how will I utilize this that is the smallest scale that I can start with and then I can also discuss about what happens to the water resources let us say in Ganga river basin.

So, we say small catchments we can think of studying hydrology or water resources in let us say IIT Madras campus starting from there, we can go and then look at what happens in you know a big river basin. And then we can start from a storm event let us say there is a 24 hour 100 year rainfall; like 100 years rainfall maybe like you know 300 mm of rainfall coming in 24 hours in Chennai in 2015 what kind of floods it cost.

So, that is the kind of timescales maybe few hours are and then we can go to what happens to the water resources let us say in Chennai basin are in whole of India, if I increase the spatial scales over a season or over a year because we have let us say what happens in monsoon season or we can increase the time scale to what we call the climate change.

Because the climate change is imminent and in another let us say from 20-50 if I design something now, let us say water distribution system I would be designing for 30-40 years to work, I mean it should work for 30-40 years and from now in 30-40 years what would be the climate, what kind of changes that would occur to the climate and what would be its impact on what I am designed now that would be you know a very crucial thing, that is why I said the recent developments have been in the direction of ever increasing space and time scales.

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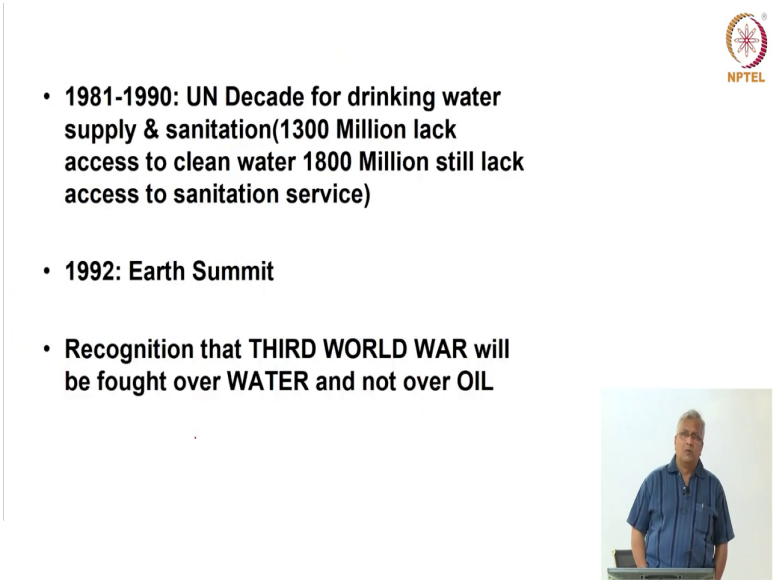

How water resources is engineering, how important water resources is engineering is, let us say 81 to 1990 United Nations declared that for a drinking water supply and sanitation, because millions lack access to clean water even now all over the world and millions still lack access to sanitation service. So, you would be surprised to know that even in India.

Now, in 2019, only 30 percent of whatever the wastewater that gets generated is actually being treated before it is let into the environment and what kind of you know environmental degradation it would cause, what kind of pollution it would cost to our water bodies, what kind of stress we would have for finding the sources for drinking water because of this pollution you can imagine. 1992 we had Earth Summit and of course, the society the world at large has recognized that Third World War will be fought over water and not over oil.

In this context I would like to say one good news is we do let us say India shares its waters with the neighbors for example, Pakistan as the water in the Indus river and we have an Indus River Treaty which came into existence in late 1950s at the insistence of world bank, at the time world bank was giving the money and then they said you two countries should sit together and develop water resources which is a common resource for both of your countries.

So, you have to come to an understanding and a treaty and this particular treaty actually survived all the you know wars we had with our neighbors that is, but we do understand everyone understand that water is important.

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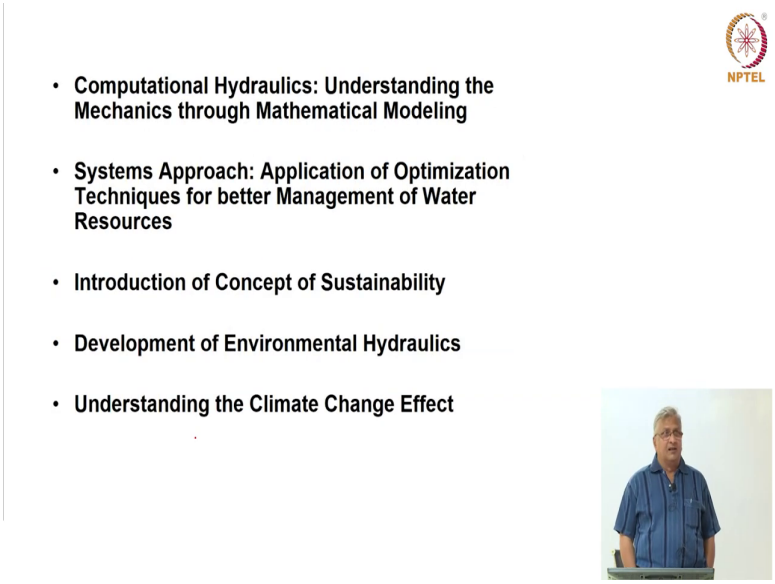

And another development that would that has taken place in recent years probably with the advent of computers, once the computers came in late 1950s and 60s and computational technology has been developed, we have developed what we call computational hydraulics which is basically understanding the mechanics through mathematical modeling.

We need to we do not have any other goal, but we need to understand the flow of water particularly when you talk about very large spatial scale and very large time scale and we want to see what is its effect in the future and so on and so forth. We will not be able to just based our decisions on observations the previous observations or the past observations because we have to go into the future and then we also cannot effort to make so many observations let us say Ganga river base and I want to understand the flow of water existence of water where it is

going from one location to another location, I need to have some kind of a model a mathematical model which I use for taking the decisions.

So, computational hydraulics that is understanding the mechanics through mathematical modeling has been a focus of attention in the last four decades. Another thing is what we call the systems approach that is whatever we do to the water at one location, you may have a consequence of it at a later stage or maybe at a later time. Let us say I was telling in my other class I think most of you I do not know whether you have attended or not, I did 1200. If you build a dam it will have many many consequences and some of these consequences may be felt may be 100s of kilometers downstream of the dam and then maybe after 30, 40 years or 50 years.

So, you need to get a systems approach, you have to see the interconnections and another thing is you need to have optimization techniques for better management of water resources. So, that has been another what you call advancement that has been made in a hydraulic and water resources engineering. We also of course, introduced a concept of sustainability, now 2015 onwards we have sustainable development goals which was follow up to our millennium development goals.

So, water resources also have to be developed with the concept of sustainability in the background. Another important this thing that has been made is in terms of environmental hydraulics like we talked about eco flows in rivers, how much of flow that we have to leave in the river so, that the ecology is not disturbed and then as I mentioned already about the climate change effect is also important.

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Since independence, India has made lots of you know advance in terms of water resources like we have built right after the independence we started building dams because we needed to get food security, we went through a lot of famines and then we needed to get food security; that means, we had to increase our irrigation potential and food production.

Large multipurpose dams were built like Bhakra Nangal Dam, Nagarjuna Sagar Dam in Andhra Pradesh and then Hirakud Dam in Orissa the picture that I am showing here is actually that of Hirakud Dams the spillway, these have been constructed for increasing the irrigation potential, the hydropower generation, water supply, the domestic water supply, industrial water supply one thing that I have not written here, but its also very important particularly in the context of Hirakud Dam the flood protection ok.

In fact, Damodar Valley Corporation that DVC on Damodar river is also basically a most of these things are multipurpose hydraulic large hydraulic I mean hydropower hydraulic structure schemes.

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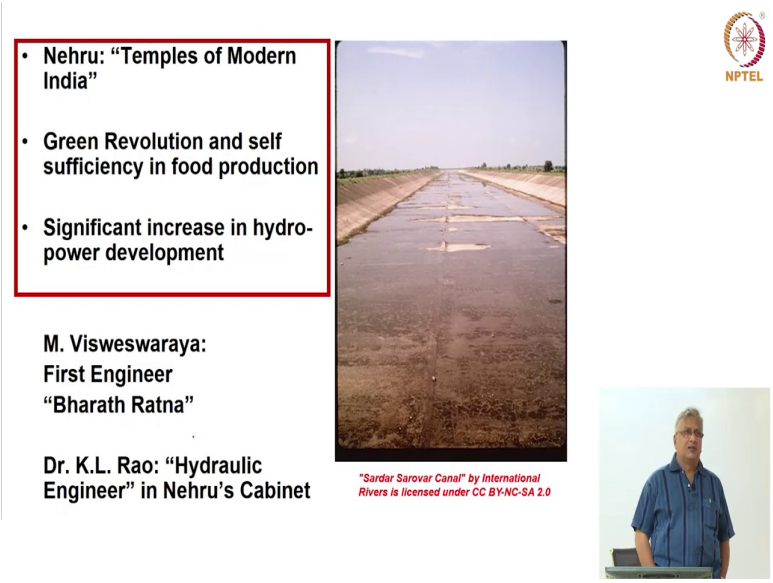

In fact, the prime minister at that time Pandit Nehru they call these structures as Temples of Modern India and they were required at the time because green they triggered the green revolution and self sufficiency in food production because by early 1970s India stopped actually importing the food grains otherwise we were depending on the other countries for our food.

And there also has been a significant increase in hydropower development and just to tell you how important hydraulic and water resources engineering is to the society and to the nation.

Mokshagundam Visvesvaraya is the first engineer who was awarded Bartha Ratna and then in fact, he was a hydraulic engineer and water resources engineer.

And in early 60s they realized the importance of hydraulic and water resources engineering for the development of the society and Dr. K L Rao was actually made a minister he is not a politician, he is actually a technocrat and then he was made a minister in the cabinet minister for water resources.

I just to give you an idea about how important these things are and the picture that I show you here about the canal is what we call Sardar Sarovar Canal, this is the canal which takes off from Sardar Sarovar Dam in Gujarat and then supplies water to you know very very water scarce areas like Kutch and then probably some of this water goes to Rajasthan too.

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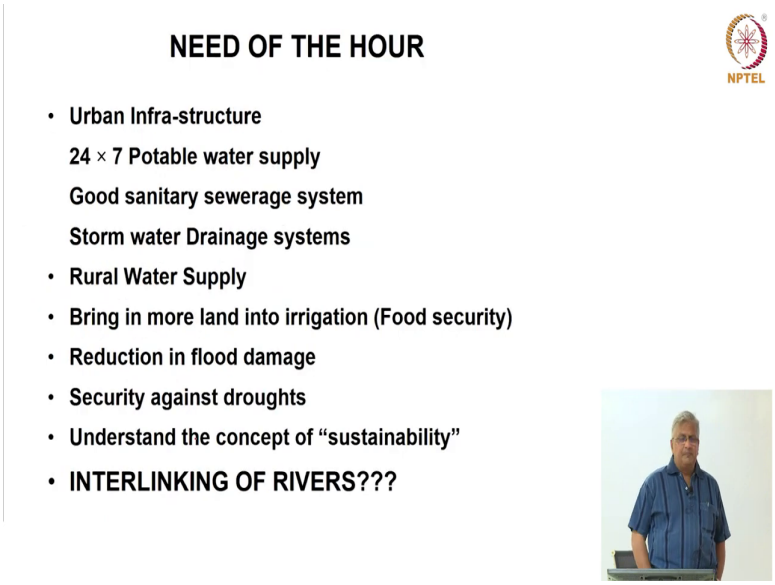

So, the need of the hour why we need to study hydraulic and water resources engineering is basically, one thing that is of importance is urban infrastructure. When we say urban infrastructure what comes to our mind as far as water is concerned is we need to get water supply to the houses when you open the tap the water should be flowing through that. So, and water should be available 24 hours and 7 days. 24 by 7 water supply which is taken for granted in many of the countries in the world unfortunately in India right now we do not have 24 by 7 water supply in any city

We only have in few very few places and maybe in very few cities in pockets of very few cities the water is available 24 hours and 7 days. Its not that we let us say for example, IIT Madras it is not that we do not get the water in our hostels or in our houses, but then water flows in the system only intermittently and we are required to build our own local you know water storage structures like sums and then overhead tanks and so on and so forth.

And these sums and overhead tanks get filled may be once in 2 days and once in a day and then from that we draw the water 24 hours a day that is fine. But then water should be flowing in the system pipe system 24 hours and 7 days just so, that to reduce the risk of public health because if the water is not flowing 24 hours in the pipeline system the water quality can get deteriorated.

So, 24 by 7 portable water supply is a policy of the Government of India and then eventually we have to do that and we need lot of work to be done. We do not have sanitary sewerage system in all the cities probably only Taiwan cities or metropolitan cities we have sanitary sewerage system, underground drainage system that is what we call even tire two cities many of them do not have, only now they are implementing this what we call sewerage systems and then we have to basically do for all the tire two cities, tire three cities and of course, we have to take it to our rural areas.

And the other one is storm water drainage system many cities even recently you see in the news and the you know media that, we have is rain probably that occurrence of rain is once in you know 10 years, once in 10 year rain itself many of our cities get flooded and then that will

have an impact on our economic activities. Storm water drainage systems very very important and how to design these storm water drainage systems, how to maintain the storm water drainage system, how to operate them its all part of your hydraulic and water resources engineering and the country needs that too.

And I already mentioned about rural water supply and then other one is all these urban infrastructure is always in the news because we have 40 percent of the people living in urban areas these days and of course, the urban population is also going to increase by leaps and bounds in future, that is why urban infrastructure I put it at the front before. But, if you look at the usage of water the bulk usage of water 85 percent of our water resources are actually being utilized for agriculture, domestic water supply we use only 6 percent of our water resources.

The 85 percent goes into agricultural sector and then we need to utilize this water in agricultural sector in a much better way. Right now the efficiency of water use efficiency in agricultural sector is very low and maybe 25 to 30 percent and we need to increase this water use efficiency to 60 to 65 percent if we want to bridge the gap between the production of food grains and what is our demand for the food grains in the future for the future population.

So, this basically we need to bring in more land into irrigation and we should get a better ways of irrigating, we should get better returns for every drop of water we use you know agricultural fields very very important. So, there again we require hydraulic and so, when you say irrigation engineering, its not just agricultural people, but its to do with water. So, civil engineers we have a background or knowledge of hydraulic and water resources engineering it will be called upon for that.

And of course, I do not have to tell you about the flood damage for example, 2015 floods in Chennai. In fact, accounted for 30 percent loss of money of the entire years loss of money due to you know natural disasters just one flood in Chennai accounted for 30 percent of you know economic loss. And you also heard of the floods in Kerala just last year and floods now its irony that in some places you have lot of excess water problem like floods and then in some

places like Chennai right now when Kerala and Maharashtra and Karnataka and Bihar and Assam are going through floods and then of basically excess water problem.

In Chennai we are desperately looking for one extra drop of water we have what a scarcity problem. And these things happen. And so, at the same time you have floods in one place and drought in the other place and in the same place floods at one instance and drought in another instance. 2015 we had floods 2016-17 we had severe drought already sitting in Chennai.

So, how do we manage this water? How do we manage the water between agricultural sector? Domestic water supply? Industries also need water and then we also have sometimes we have too much of excess water, we do not know how to store it, we do not know how to use it for the future, we say that if you build dams then they have other environmental problems all these things are completely interconnected.

And in fact, one would like to connect up the entire infrastructure let us say for urban infrastructure sewerage system, storm water drainage system, water supply and you know and even restoration of rivers for nice water France we need to have, because we also look at these rivers for recreational purposes that is what we are doing. Recently in Jaipur city they have actually restored one particular small Dravyavati river or they call it Amanishah Nullah which was in a dilapidated condition they basically restored it because they wanted to have a nice river front through the city.

So, all these activities should be looked at together simultaneously and design it so, that you know in the long run they are all sustainable.

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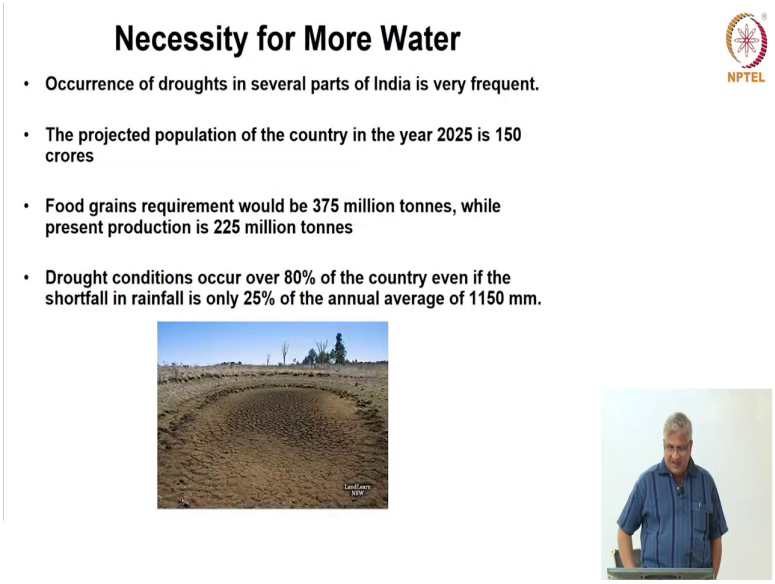

So, in this context in India they been talking about interlinking of rivers that is inter basin transfer of water. Basically the need I mean. In fact, they have been talking about interlinking of river since 1960, we have not yet implemented it and the reasons why we did not implement and why we still discuss about it is becomes apparent when you see these points. We need the interlinking of rivers the people who root for interlinking of rivers their arguments are of course, which are right.

Occurrence of droughts in several parts of in India is very frequent like peninsular India we have lots of droughts and then western part of India also we have lots of droughts, we do not have much of rain, we do not have much of water and projected population of the country is going to be 150 crores that is 1.5 billion and we would be the most populous nation in the world so.

Food grains requirements would be 375 million tons, while the present is only 225 million tons. So, you have to see how much of improvement we have to make in our agricultural sector and droughts occur 80 percent of the country in 80 percent of the country even if rainfall is only 25 percent shortfall there is only 25 percent shortfall in rainfall then 80 percent of the country is under drought.

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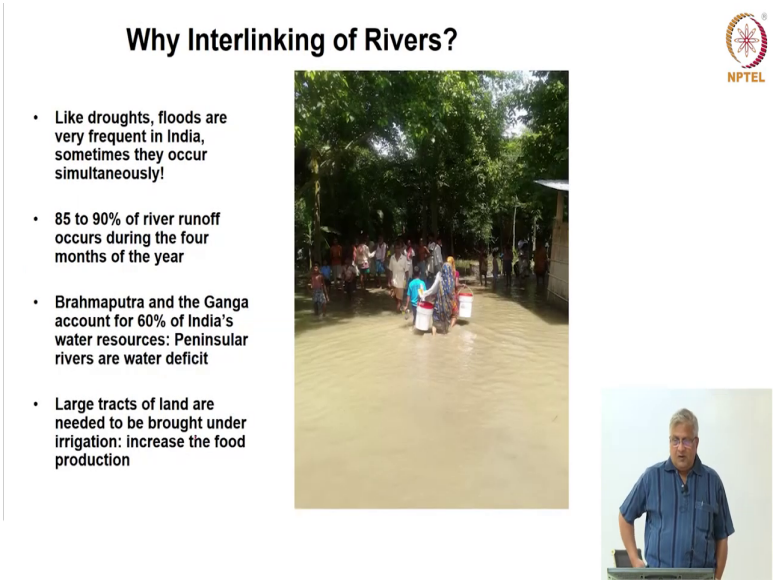

So, imagine what are the consequences of this. And then at the same time we have floods in other parts like droughts floods are very frequent they occur simultaneously and another important thing is because of the weather conditions in India, 85 to 90 percent of the entire what we call runoff; runoff is the water that is flowing in the reverse due to the rains it occurs in the 4 months out of 12 months only 4 months you get the rainfall and two rivers we have such a vast area.

And in that and so, many rivers only to reverse Brahmaputra and Ganga they account for 50 percent of Indias water resources and everything just goes off into the sea. The and we are not storing that much we are unable to store we are unable to divert that water Whereas, peninsular India in some of the rivers like Palar river which is south of Chennai between Chennai and miller if you look at Palar river, its flows once in 5 years or once in 10 years when there is the rate many times even that is not there all you see is just sand their. Large tracts of land needed to be brought under irrigation I already said.

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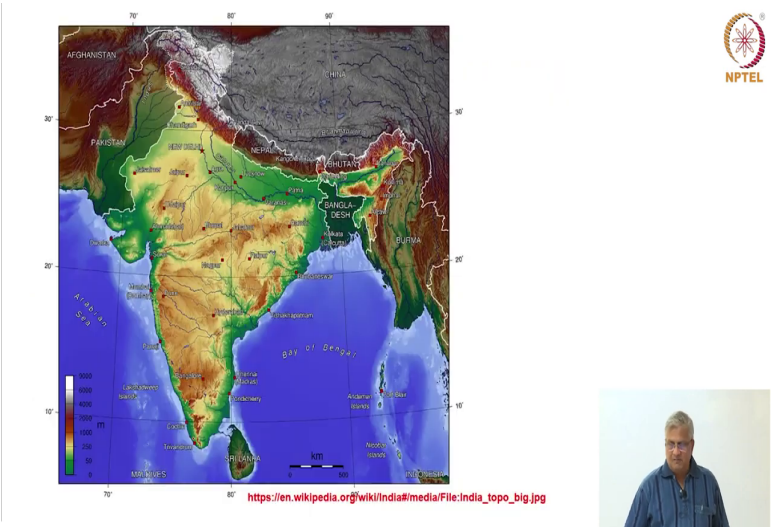

So, they said why do not we do a mega project? We have lot of water in Brahmaputra and then this lot of water is of course, causing lot of floods and the downstream areas in Assam as well as in Bangladesh. So, why do not we divert this water from Brahmaputra and probably

put it in Ganga, you build a huge canal and then put it in Ganga and we have no excess water in Ganga.

So, you take water from Ganga and you cross a Subarnarekha in border of Orissa and Bengal and then get down to Orissa and then put it in Mahanadi. Now from Mahanadi you go and take it to put it in Godavari and from Godavari you put it in Krishna, from Krishna you can put it in you know Penna river and then from there to Kaveri and then all the way down some other rivers.

So, you can redistribute the water wealth for the entire country by putting this so, called and of course, in the North Indian rivers many other rivers also they have linking of these rivers small small rivers so, that there is a redistribution of water for the entire country and then probably we will be able to solve our food problem and all the other water problem. Very nice idea, but the issue is what are the constraints?.

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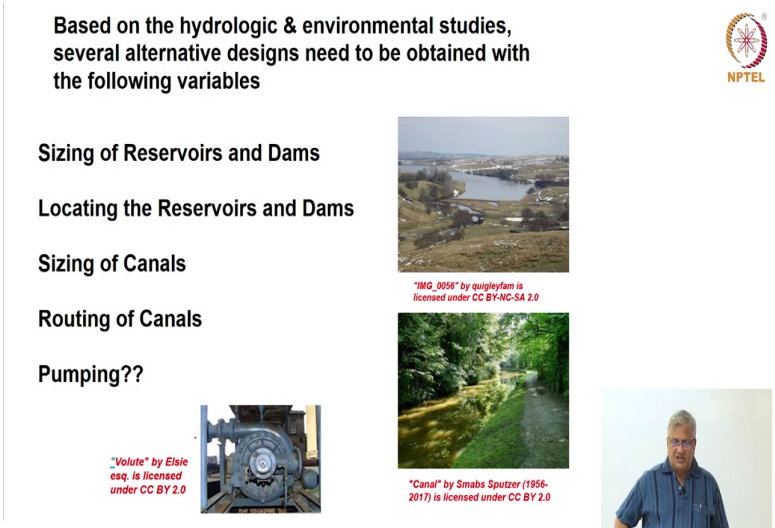

These are before we go to the constraints. We will discuss about as hydraulic and water resources engineers, we have to conduct hydrologic and environmental studies and we have to come up with several alternative designs basically we should define our goal and then we should say that like this particular project is the only way that we can solve these problems are attaining these goals and as engineers, we say what are the things that we can contribute.

What should be the size of the reservoir? What should be the size of the dam? This of course, depends upon how much of water is coming in, in that let us say Mahanadi we say I want to build a new dam. So, I ask what should be the size of the dam, what should be the size the reservoir.

This depends upon how much of water is coming in, it depends upon how much is already being utilized there, it will also depend upon how much those people are planning to utilize in

the future. You say that like you know I will take the water probably people from Orissa and saying I may not be using all this water. So, you may be thinking that I am wasting the water, but I have so, many other projects in my mind which I would use them in 2050. So, I do not want to give you the water they can say that and they have every right to say that.

So, sizing of reservoirs and dams that is where you need to do hydrologic studies as well as hydraulic studies. Then where do you locate these reservoirs and dams what is the best location for these things? We have to do that then from one dam to another dam which is on the downstream side you have to connect up using canals. So, how what should be the size of the canals and what should be the routing of canals? How do you I route this?.

Because when I connect up from Mahanadi to Godavari if I go take all the way through east coast, then you have many east coast rivers which are flowing into Bay of Bengal and you have to cross all these rivers and you have lot of you know urban centers you have to go take it through the urban centers. How do you do this routing of canals? Then just because I put the map Indian map from like this, I draw a link from north to south does not mean that the water will flow down south, it all depends upon topographical conditions we have, the levels we have, ground levels we have and so on and so forth.

So, sometimes we may like for example, if I want to take from Ganga to Narmada and then below to all those things if I want to take that route, then I have Sathpuras and Vindhyas coming in between. So, how do you cross them? You want to put tunnels and you want to go and then put pumps. So, many times we may need to pump water from one base into another, then in the case what should be the size of the pumps that becomes an important question that hydraulic and water resources engineers would like to answer.

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This is one issue the engineering issues, but we cannot run away from the other issues because constraints are you need land and land acquisition. We be we were working with the Kerala government back in 9th and 2016 and so, and we came up with one alternative saying that like you know there is a link canal which takes the water from one of the rivers to the Arabian sea we said why do not you just increase the width of this link canal to maybe 300 meters and then and we were asking only for about 20 kilometer stretch of this canal and then to 300 meters and then probably we can divert lot of these flood waters and then we can in Kuttanad area we can solve the flood problem we gave that idea.

And then very nice and in fact, it was a meeting with chief ministers and then all the technocrats and everybody this had very nice idea, but we cannot go in an implement because

we will never be able to acquire land in Kerala because land is very very costly they will not sell the land.

So, land acquisition is a problem then other is rehabilitation of the displaced people, that is also a you see that picture that I have given is basically there is a protest against Omkareshwar dam or Narmada river in 2007 by local people they would get displaced when you put these reservoirs and dams. So, they would protest. So, what do you do for them? How do we make these projects socially acceptable is a very important issue. In fact, there is a new field of research a new field of water resources engineering its called social hydrology.

So, how the hydrology actually gets affected by the response of the society and how we should take care of societal responses to our projects social hydrology is a very important. And then we also need to think about environmental impact that this humongous project when we bring in what would be the environmental impact you can you will have.

And the cost of the project when they formulated I think early 90s we had a meeting with at the time the minister for water resources. It was kind of estimated that 25 percent of Indian India's GDP is required to put this project in place when you bring in so, much of money and then invest it are we investing it properly how do we finance this? How do we manage this I mean bucks are that is why I put that Indian 2000 rupee note there the economics of it is also extremely important.

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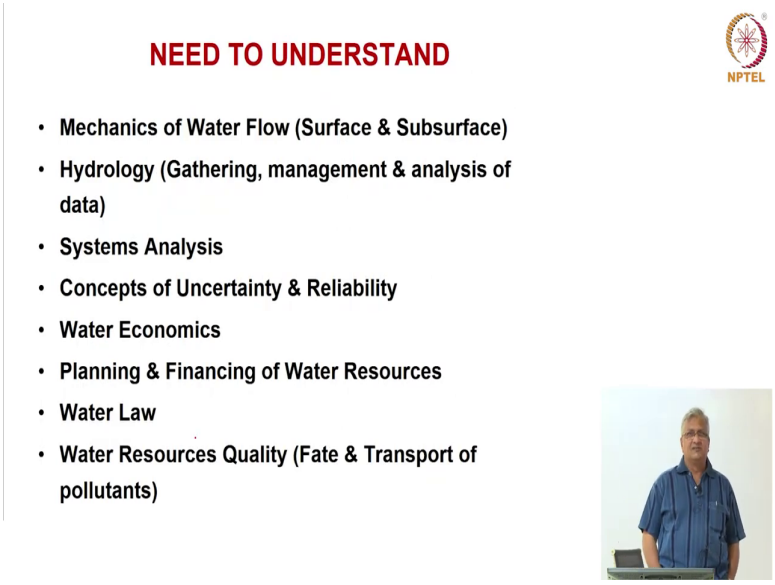

So, I just take one minute. So, we need to understand to summarize mechanics of water flow, that is basically surface in subsurface water flow, hydrology basically gathering management and analysis of data, water flow data, rainfall data then I said systems analysis and of course, whenever you understand nature you are not completely sure how mother nature behaves. So, there is always an uncertainty and then what are the projects that we bring in it has to have reliability.

So, uncertainty and reliability concepts we need to understand and water economics planning and financing of water resources of course, these days we are also extremely as hydraulic and water resources engineers probably you also need to learn about water law to settle the disputes between different parts of the country, different parts of the society and water resources quality fate and transport of pollutants.

So, these are all very exciting areas for either to do research are to be there in the profession because India is going to invest very very much money into the water sector it has to if it has to survive in the future.

Thank you very much.