Geographic Information Systems
Prof. A. K. Saraf
Department of Earth Sciences
Indian Institute of Technology-Roorkee

Lecture-55
DEMs and Dam Simulation and its Application in Groundwater Hydrology

Hello everyone! and today we are going to have a discussion on how to use the DEMs for dam simulations. These dams; DAM, we can call this as reservoir simulation and how these dams which we simulate, can be used in groundwater hydrology? Because nowadays you know that especially in hard rock part of India, water is a big problem especially in the summer months; say April, May, June and in some areas even in July month.

So how to augment groundwater using this rainwater? This simulation really can help decision makers to make appropriate decisions. And recently different states have started you know some projects just to augment groundwater and also rejuvenation of various streams. Like in Uttarakhand, they are also doing a rejuvenation of Rishi-panna River which is not perennial, it is an ephemeral channel which passes through Dehradun.

Also, we understand the similar kinds of projects are being planned in Andhra Pradesh. And in earlier, several such projects have been done by some non government organisations in Rajasthan also. So, what is happening that we are having almost sufficient rainfall or precipitation in total 1 year. But majority of that water which is coming on the surface of the earth in form of rainfall or precipitation is going waste as a surface runoff into either Arabian sea or Bay of Bengal.

Now say for example about roughly 95% of total water is going as a waste. So, if we start just recharging our groundwater regimes using this water, maybe of 1 or 2 percent then I am sure for at least for decade, we should be able to solve the water supply problem in the country. And these applications of DEMs and Dam simulations will really help. So, this is what we are going to discuss, the application part as well. This dam simulation we have seen through a demonstration also but very briefly I will touched here and then we will discuss about this ground.

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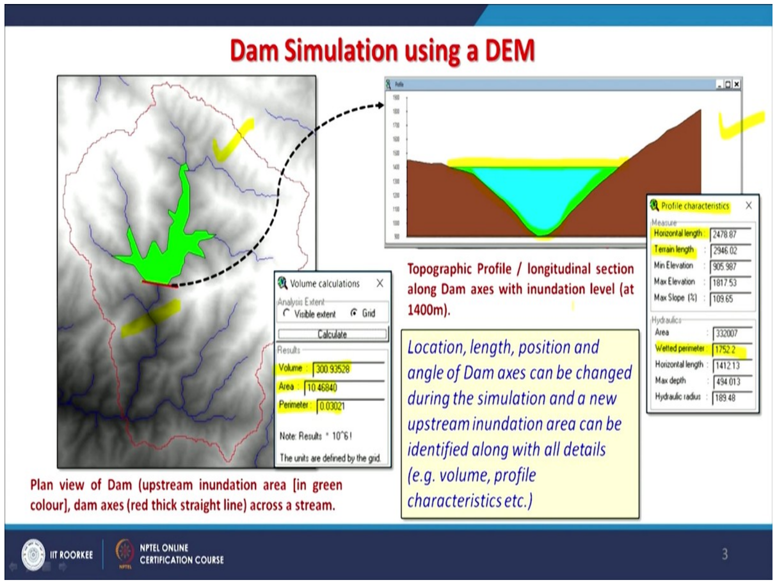

As you will see that the main input in Dam simulation is digital elevation model. That topography surface will help us to find out various options or various scenarios along a channel or in a watershed or basin. For example, here what we are observing that there is a watershed and in blue colour, the streams are also showing. These streams have been derived from surface hydrologic modelling and then a line has been drawn to indicate that here, the dam or reservoir access would be there like of this much length

Now the height of this dam access we can decide once we start getting this topographic profile. So, like in GIS software as soon as you draw a line, you can get a topographic profile like this. So that means in this part, I can fill with water and can create a dam in upstream or a reservoir in the upstream; inundate the water. So, by looking this topographic profile, I can fill with water.

Like here this topographic profile once I choose that, I want the water level of this meter; that is 1400 meter in this case. This is going to be the inundated area in the upstream. Now reservoir has been stimulated very easily. You can also get lot of other datasets like location, length, position and angle of dam; these can also be changes. So, if my requirements are not getting fulfilled or I am overestimating or unnecessary constructing a large Reservoir, I can either reduce the height of the Reservoir or I can go upstream.

And if I want more water than probably, I can come to this part and can create another reservoir having more storage of water. So, that means I can play with my system and can create the different kinds of reservoirs or different scenarios with which decision makers will make the appropriate decisions. Sometimes when we ourselves our decision maker then still no problem! we can do it this part also. So, here what we are seeing that even if I change the height of dam, the size will change accordingly specially the unidentate area.

So, on the right side, what you are seeing a topographic profile that is the section view or profile view and here you are seeing the reservoir in a plan, in a 2D. So, everything becomes very clear with simple simulations like this. Now of course, I just mention that many other parameters which are required to decide and to go for appropriate decisions or optimum decision then I need what is going to the volume? What is going to the area and perimeter of this reservoir? That to can be done.

If I do not have GIS or digital elevation model, I tell you with topographic maps, it is nearly impossible to estimate such things very accurate. So, what people have been doing? They were using just contour line and deciding based on that reservoir. But if I change the location or rotate my dam axis then again, it has to be calculated. But here things become quite fast and very accurate as well. Now about this profile which you are seen a topographic profile; lot of many parameters can also be derived here.

Important point is like horizontal distance and terrain length. Horizontal distance is this length which is the top of the water surface. Of course, it is in 2D. Recall the discussion when we had about you know planimetric length and our terrain length. Similarly, here horizontal length is the planimetric length and the terrain length is this one; which is this one. So obviously, the terrain length will always be more than your planimetric length.

Same would be also with the perimeter also. Now, these will have a two different like here wetted perimeter. So, wetted perimeter; the part of the water body which will touch the surface or the ground, that is perimeter. Not the perimeter of this polygon which you are seeing on the left image. So, this all parameters which are required for a civil engineer to decide or design a dam or reservoir can be extracted from this exercise; that is dam simulations employing digital elevation model in GIS.

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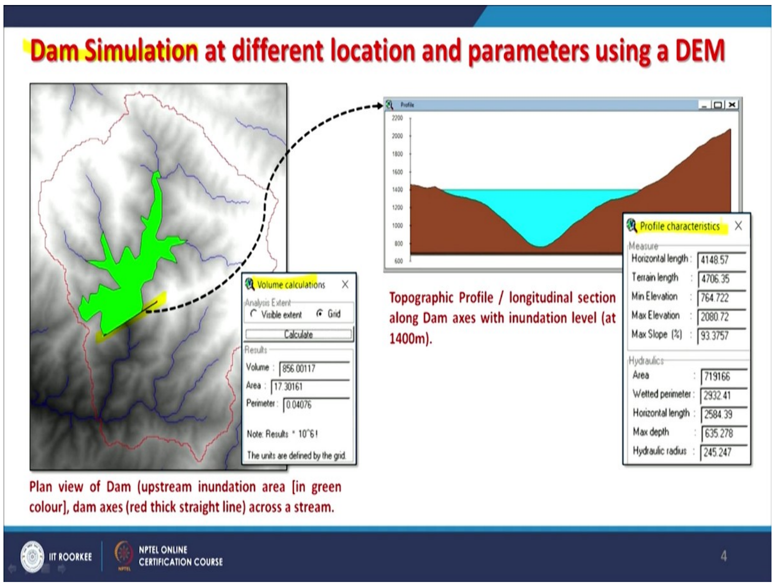

Similarly, if I change the position. Earlier I had like 1400? Now what I have done here? I have shifted the dam axis. In my earlier picture if you recall, dam was here. Now I have shifted the dam and rotated the dam axes, I am again getting some new values, new locations, everything. So, if out of these two options which one is better, decisions can be taken before really anything happens on the ground.

And thus, ultimate purpose of GIS; that is the modelling. Recall the definition of GIS, what it says that it's a computer-based information system will store and retrieve, analyst data which is coming from variety of sources and model as per user defined specification. So, here user is providing all the details; that location of dam, height of the dam and then the modelling is being done. Ultimate aim of the models to predict something which has not happened on the ground but before that, we want to do it.

So, this is what this platform will allow you and by this dam simulation, you can do lot of such thing. So, once I change the location of reservoir height of reservoir, height I have kept the same. Obviously other parameters; that is the volume calculations or profile characteristics will also change. Does not matter! I can store as separate. And suppose I had a target of a certain amount of volume of water which I want to store in reservoir.

So, if I achieve that one, fantastic! If I do not, I will go back, again shift my reservoir; may be to the downstream because if you go towards downstream, you can store more water but if I go to upstream then catchment area will reduce. So that judgment should also be made. Now this is the point which I was just touching in the beginning that the water which we require is very little or part of the total water which is available to us.

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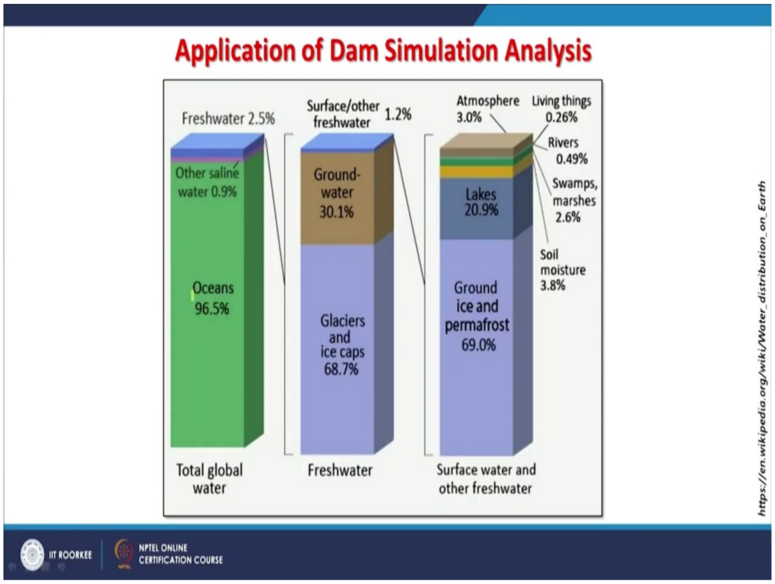

See 96.5% of the water is available in ocean but that is saline. And fresh water is just 2.5%. Out of this 2.5%, 30% is the groundwater which generally we take out and used for drinking, irrigation or whatever. Glaciers and ice caps which holds about 68% or 69% of total water and then out of this of the surface water or freshwater, 1.2; this is how it is store that lake's stores about 21%, the ground and ice and permafrost about 69%, river water just 4.49%. Because most of the water during monsoon time say in India, is going as a waste and does not stay in the river.

But of course, this is the data for the world so almost the same scenario in India also. So that means because the ground water is an issue. Lot of water is going as waste. So, we need to store the water, delay the runoff even for a few weeks or months and if we do it, we can recharge the groundwater regime and you know the ground water will be available for round year rather than surface water.

Because surface water, there are other issues like loss to the atmosphere in form of evaporation and can become easily polluted. And you know this turbidity and sediments; these are another problems but if we store water in form of surface water only for some time, may not be around the year then we can solve lot of problems of India in groundwater.

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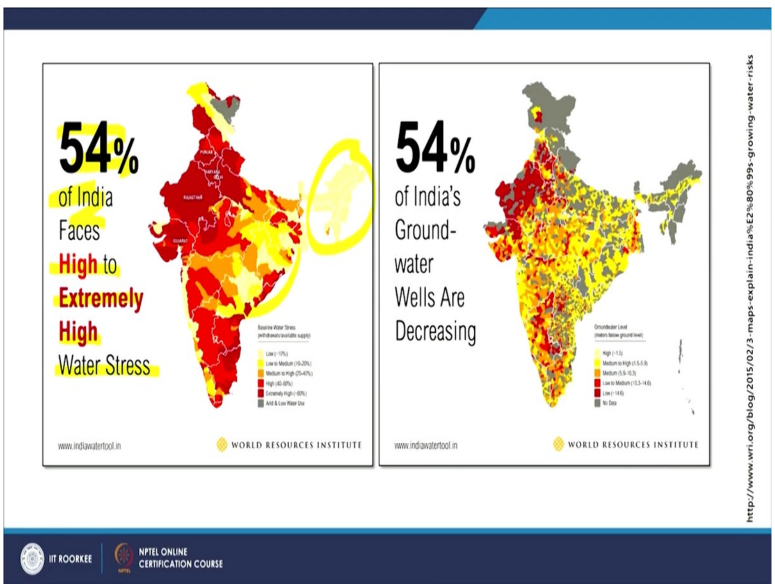

Now if we see that 54% of the India faces high or extremely high-water stress. So, except for Northeast and some parts of J and K or some parts of Andhra Pradesh and Odisha, remaining parts are really having big problems. And if we see that same percent, 54% India's groundwater wells are decreasing because they are exploiting more water. Very interesting figure, I want to share with you.

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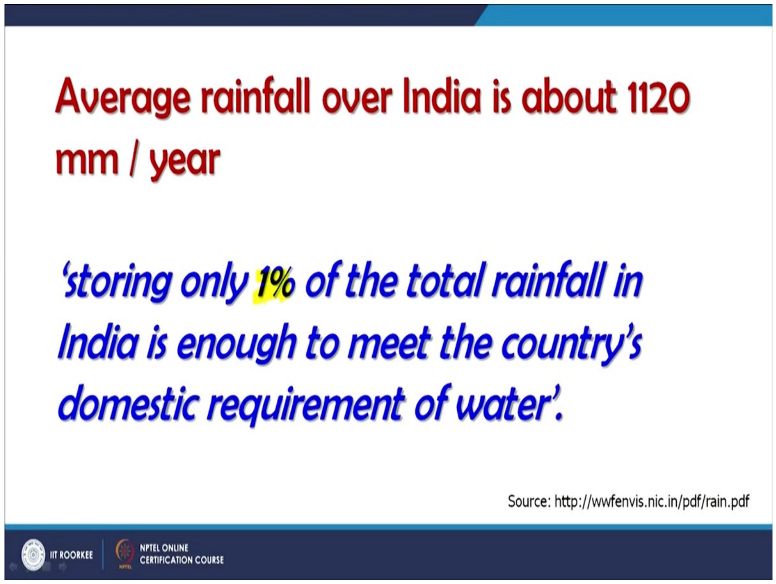

That the average rainfall over India is about 1120 millimeter per year and if we calculate the total volume of water falling over India in one year in form of precipitation, in last hundred year or more, it has remains same; that means the rainfall or precipitation which have been occurring hundred years back, it is almost same. The only thing at that time we had the population of 35 crores like and now we are having 135 crores.

At the time of independence; that was the situation. So, from 35 crores from 1947, in 2020 we are 135 crores. But the augmentation rainfall input has not changed, only the output; over exploitation of water. And that problem as I have been saying. Further I will add that this problem can be solved in 1- or 2-years' time if we start storing even 1% of extra water of rainfall for the domestic requirements; at least drinking water problem can be solved.

But if we had 2 or 3% of total rainfall goes in groundwater then irrigation and industrial requirements can also be solved at least for decade also. But if population keep rising like this then we have to create this one; may be 10% of total rainfall rather just 2 or 3%.

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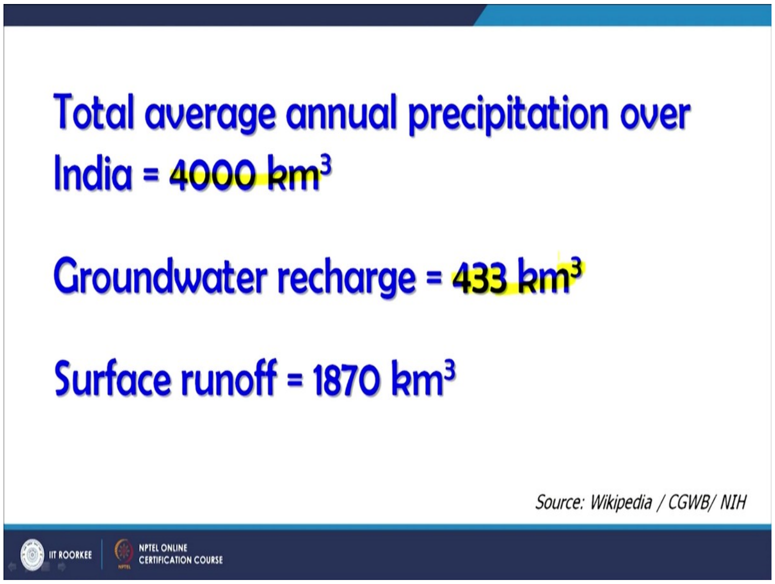

Now, total average annual precipitation over India which I was mentioning have remained almost constant in last more than hundred years which is about 4000 cubic kilometers, total. And In groundwater recharge, is just 433 cubic kilometer and rest is going as a waste. You are having surface runoff; maximum part is going a surface runoff. It is does not stored. Now, I will give you this all idea how to do it? How to solve this problem through a case history or study which we did few years back?

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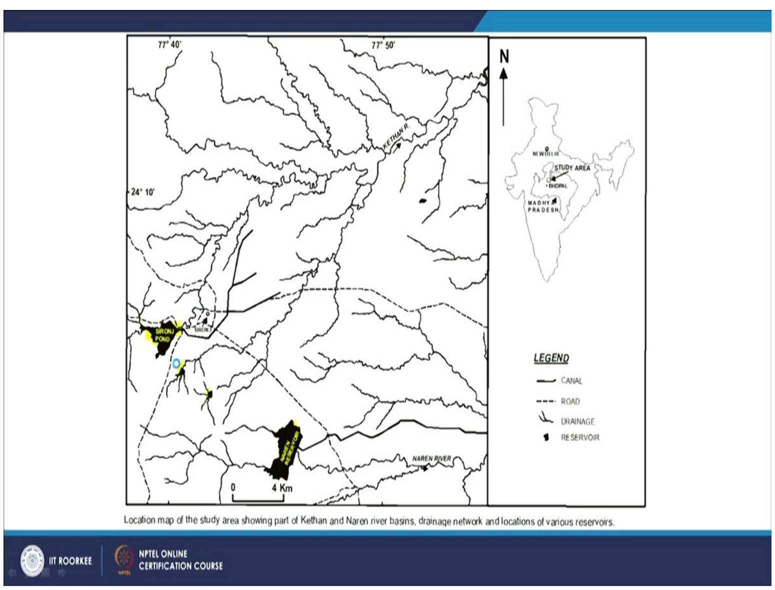

If you see in this figure, you would find that there are three or four reservoirs; 2 are big, 2 are very tiny relatively. One is here, Naren reservoir, another one is the Sironj reservoir. There is another small-2 reservoir also here. And this is hard rock terrain of central India Bundelkhand region.

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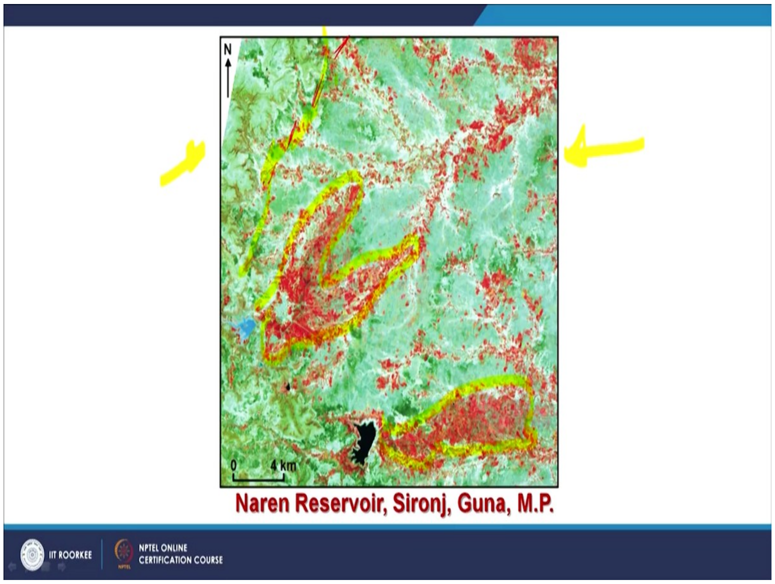

In the basement, you are having Bundelkhand Gneiss rocks or granite if we wish to call and, on the margins, you are having Deccan traps or basaltic across. Like here you are having basaltic rocks in this part and in this part, you are having weathered basalt and of course you are having thin soil. But the point which I wanted to or the things which I wanted to show you that see these reservoirs. This is an Indian Remote Sensing satellite; IRS LISS3 image and it's a false colour composite.

And therefore, the vegetation is appearing as in red colour because infrared channel which is having the maximum reflection, has been assigned a red colour. So, what do you would see that there is a reservoir and in downstream, I am having an influencing area or I call the benefit area. There is a reservoir, this blue colour one and then, I am having a benefit area like. But the interesting part is that the reservoir which is having larger inundated area having less benefit area as compared to the reservoir which is having the small inundated area.

So, what could be the reason? Because by analyzing satellite images; interpreting satellite images, we are developing a knowledge about local groundwater regime or local knowledge. Since in these areas, you do not have any reservoirs and therefore there is not such growth of vegetation as we are seeing in the other part. So, in future if you want that these areas should also become green or in false colour composite red then what do you need?

You need similar kind of reservoir along this area as well across these valleys or alluvial fills. These are all ephemeral channels and which have been blocked, the rain water has been stopped and then you are getting groundwater regime because there is no lift irrigation, there is no canal irrigation or any other thing. Simple reservoir and they recharging groundwater regimes. Farmers are exploiting that water and putting in their fields to get the crops. This is February image.

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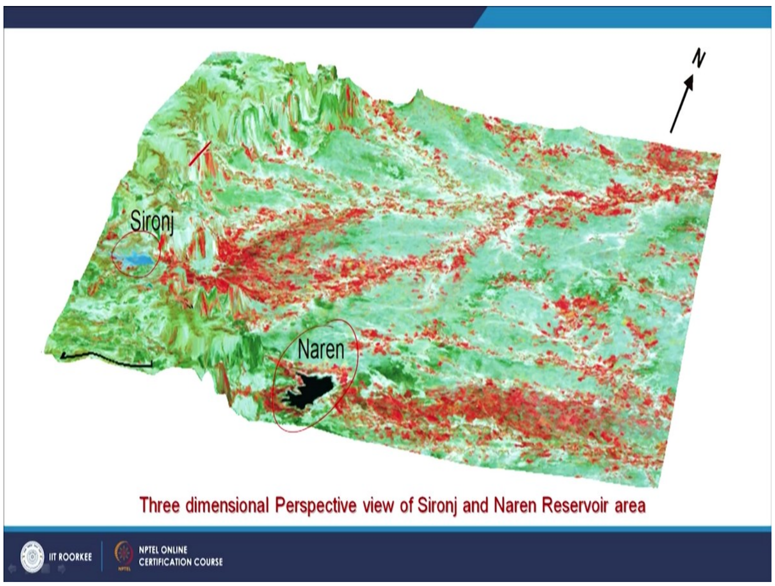

Now if you see that this blue-coloured reservoir, though in size it’s small but it is located in relativity on high grounds as compared to this Naren reservoir. And because of there is an elevation difference that means this reservoir is providing better hydraulic gradient as compared to Naren which is almost in same level. So, if you want to make this area greener then what we need to do? We have to learn from Sironj reservoir location and construct reservoir on little higher grounds.

Though we will have less size of catchment or watershed for this reservoir but nonetheless, they will provide better hydraulic gradient and better groundwater recharge. Otherwise, geology wise the entire area is same that on this side, you are having Deccan traps and on this side, you are having granite. Of course, there are some soils sands developed and along which agriculture is taking place.

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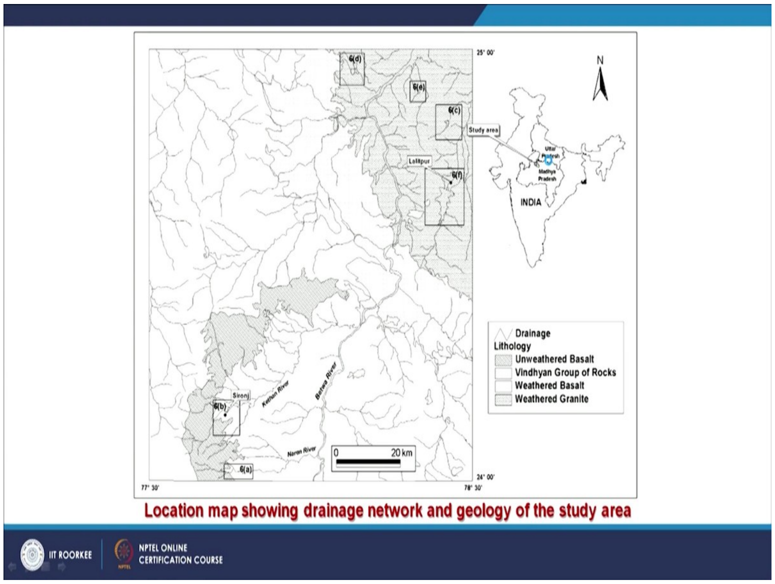

Location map showing drainage network and geology of the study area

So, there are many such reservoirs in these areas. If I cover a larger area, those Sironj and other reservoir are still here which you can see; Naren reservoir and Sironj reservoir but I am covering now a large area.

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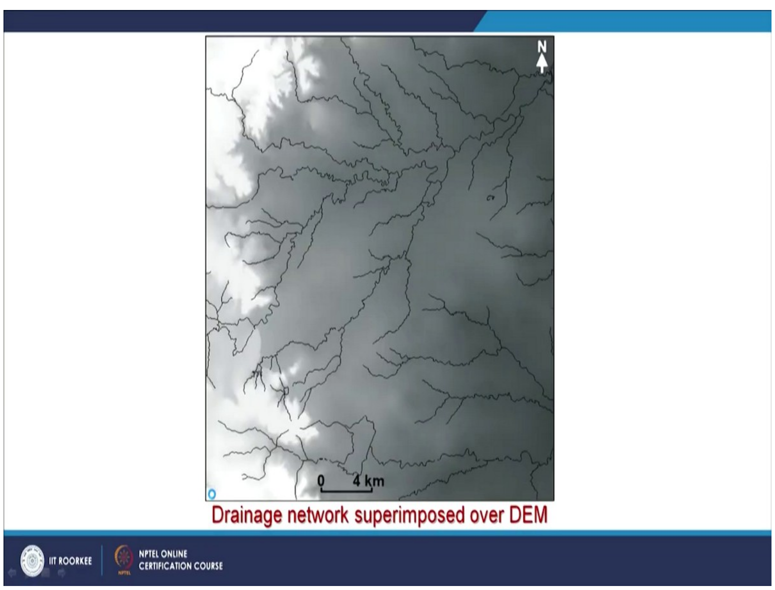

Drainage network superimposed over DEM

Because it will carry some important things.

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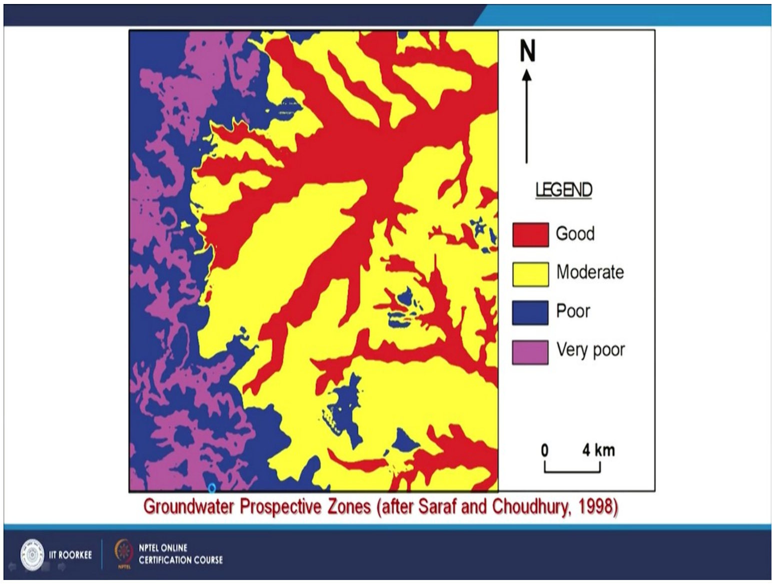

If I see a digital elevation model it looks like this for that area. So, implying GIS and giving weightage to different themes or different layers like for example geology, soil, geomorphology, water level or changes in water table between pre monsoon and post monsoon and using this ground water yield of different drops, a similar kind of maps for any hard rock terrain can be prepared which are groundwater prospective zones.

That means if anybody is looking for a well or sighting a well then, these red areas are the best suitable. And whereas if you go in the Deccan trap areas, these are the areas where these are not suitable at all. So very poor and poor colour are those areas which I was saying about the basaltic rocks. Rest of the areas are either moderate or good chances of getting water. So, these alluvial fields along these ephemeral channels are good to get the water. There are high chances.

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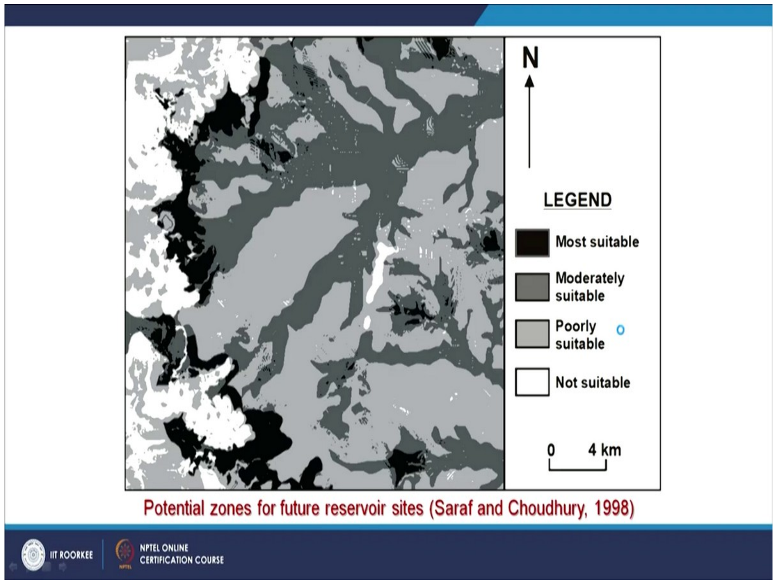

Similarly using again little different techniques with different weightages, we can also develop maps for any area in the country which is the potential zone for future reservoir sites in order to recharge the groundwater regime. Again, the dam simulation will come here directly. So, these are the areas; the black is the one which are the most suitable, not at the same level little higher and not too much higher that therefore, the watershed becomes small.

So just at the edge of those higher ground because we have learnt through that blue reservoir or Sironj reservoir that if it is located on higher ground, it will have large benefit area relative to submerged area. So that knowledge we developed and based on that knowledge, we can develop such maps.

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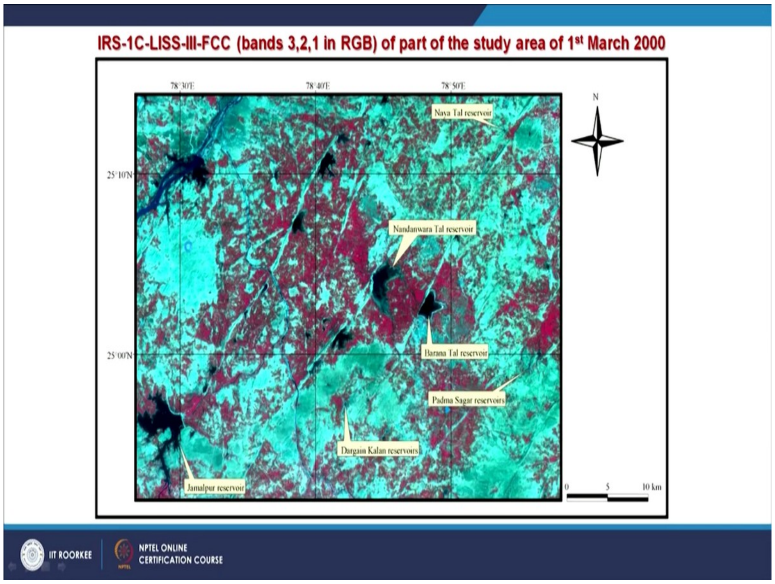

These are nothing but the GIS based modelling; getting information, arranging the information, putting in different layers, giving the weightage and finally coming 2. So, 2 output I have shown; one is the groundwater prospective zones and another one is the groundwater recharge structures locations, where you should locate. Now the weightage we have assigned to different layers or different categories within one layer, can be different in different areas.

So, each area has to be studied first through satellite images, getting some other datasets, preparing such thing and then you can do it. The biggest advantage you can take of already existing reservoirs and studying them that what is the submerged area? What is the benefit area? And then you design your weights for different things. Now we are still in the same area and exploiting something else. Here you can see lot of small-2 reservoirs are there, just to locate. This is the Betwa river which is going something like this.

And will meet the Chambal and then Chambal meets Yamuna and Yamuna meets Ganges. Now these white lines which you are observing here; these are the quartz reefs. These are geological structures which are already present and which are serving as a very long Dam access. So, people in past have exploited these quartz reefs and can created or could create small-2 reservoirs. Some might be even natural one and where ever you do not have such quartz reefs and inundation of water like in this part, you do not see vegetation.

This is again false colour composite image. So, what we are learning basically that even in hard rock terrain if we inundate water for some time, it will recharge groundwater regime in the surrounding, whatever be the geological conditions are there. And ultimately there will be growth of vegetation as you are seen also in this image. So, wherever you are having water; in the in the vicinity of water, you are having growth of vegetation. Wherever you do not have any water body, you do not have growth of vegetation.

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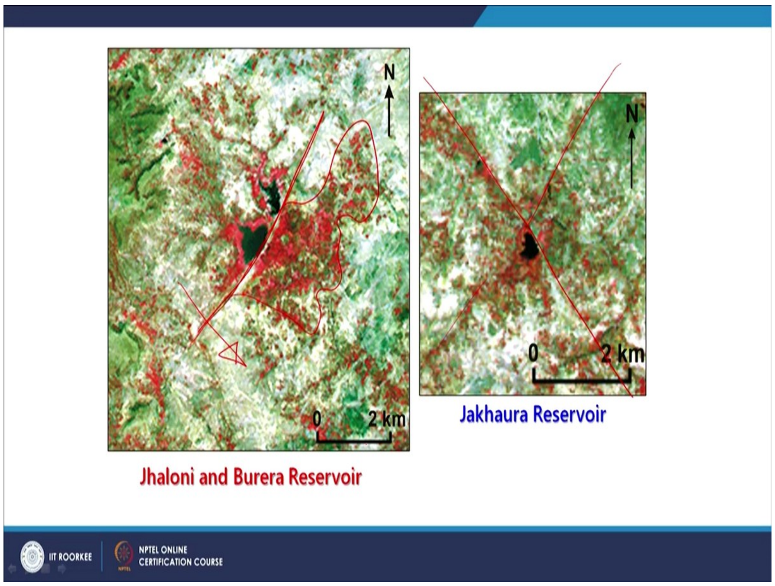

If I take individual reservoirs, you can see that this is the quartz reefs which is going something like this northeast southwest direction. And this is the down slope site along the reservoir in the upstream area especially in the perimeter of the reservoir and in the downstream area, you are having benefit an area. Likewise, another example and here what you are seeing in four directions, the water is available in form of groundwater and farmers are exploiting to put on their fields.

One is in the northwest southeast and other one is northeast southwest because these are the geological structures which are controlling. This northeast and southwest is generally the trend of these quartz reefs and whereas northwest southeast are the geological dikes which are present there. So only along, there is a maximum movement of water otherwise in other part, there is no harm. Because remember the early discussion what I mention that there is a quite sufficient rain precipitation over India.

The only thing we should hold and delay the runoff as much as possible. If we do it by few months, it will recharge the groundwater regime.

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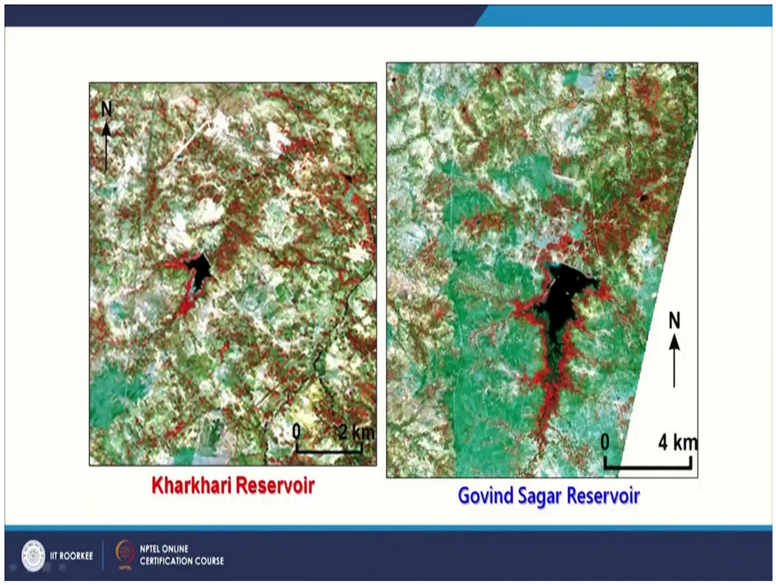

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Few more examples example is here. One more example is here. And here I would like to spend some time because this is my hometown in Uttar Pradesh. This reservoir was constructed more than 60 years back and at that time, the population of the town was roughly 35000. And since then, because of siltation and encroachment, the size of the Reservoir has reduced that means the capacity of holding water has also reduced.

But the population in the downstream of Reservoir has increased by manifold. Earlier we use to get 24 hours water in our taps. Now we do not get even for 24 minutes but recall again, the input which is coming in form of precipitation over India remain same. Only our management has got poor. We did not argument in the same way as we added to the population. Nothing loss! Still if we start doing this thing, in 2-3 years time, we can solve this problem.

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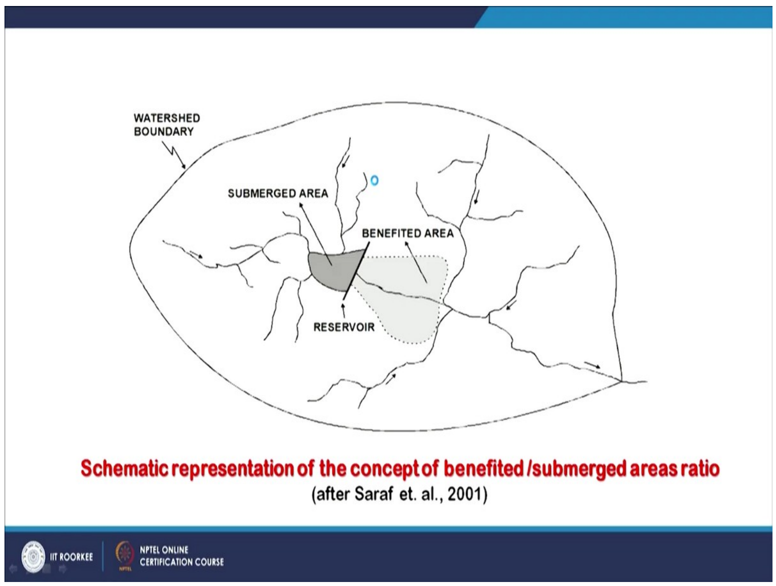

How we can do it? We can quantify things also because many decisions makers, they love the quantities rather than qualitative assessment. So that can also be introduced by taking ratio; that is benefit versus submerged ratio and this index can be used.

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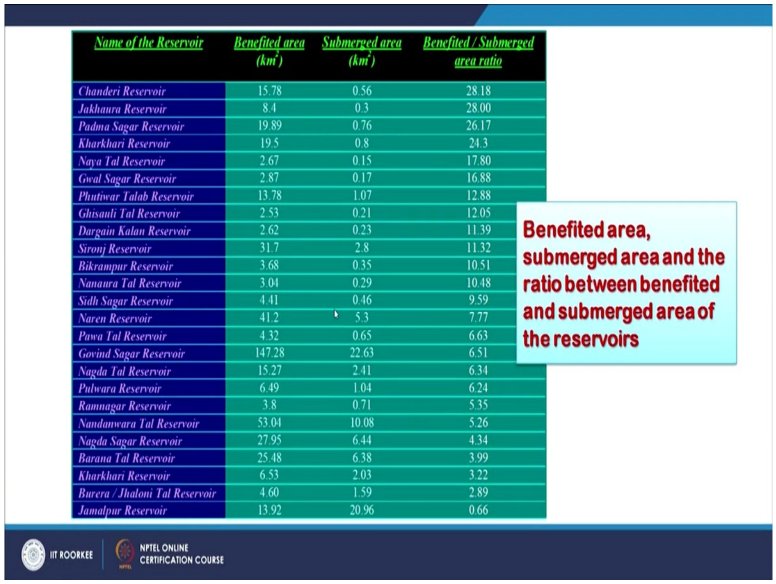

Name of the Reservoir	Benefited area (km^2)	Submerged area (km^2)	Benefited / Submerged area ratio
Chanderi Reservoir	15.78	0.56	28.18
Jakhaura Reservoir	8.4	0.3	28.00
Padma Sagar Reservoir	19.89	0.76	26.17
Kharkhari Reservoir	19.5	0.8	24.3
Naya Tal Reservoir	2.67	0.15	17.80
Gwal Sagar Reservoir	2.87	0.17	16.88
Phutiwar Talab Reservoir	13.78	1.07	12.88
Ghisauli Tal Reservoir	2.53	0.21	12.05
Dargain Kalan Reservoir	2.62	0.23	11.39
Sironj Reservoir	31.7	2.8	11.32
Bikrampur Reservoir	3.68	0.35	10.51
Nanaura Tal Reservoir	3.04	0.29	10.48
Sidh Sagar Reservoir	4.41	0.46	9.59
Naren Reservoir	41.2	5.3	7.77
Pawa Tal Reservoir	4.32	0.65	6.63
Govind Sagar Reservoir	147.28	22.63	6.51
Nagda Tal Reservoir	15.27	2.41	6.34
Pulwara Reservoir	6.49	1.04	6.24
Ramnagar Reservoir	3.8	0.71	5.35
Nandanwara Tal Reservoir	53.04	10.08	5.26
Nagda Sagar Reservoir	27.95	6.44	4.34
Barana Tal Reservoir	25.48	6.38	3.99
Kharkhari Reservoir	6.53	2.03	3.22
Burera / Jhaloni Tal Reservoir	4.60	1.59	2.89
Jamalpur Reservoir	13.92	20.96	0.66

So, what we did? We took 21 reservoirs of that Bundelkhand area and calculated this benefit versus submerged ratio which is on the rightmost column. And ss you can see that sometimes you are getting 28.18 ratio; that means in this particular area, currently this Reservoir is there that Chanderi one. If I submerged 1 square kilometer of area in the vicinity of this reservoir, there are chances that I will get 28 times return in form of benefit area.

It is a wonderful scheme. However, there are locations where this ratio is less than 1; 0.66, that means these are node areas which I should put my investment on land. But if we decide that my threshold is say 10. I need at least 10% return in form of benefit area; that means again, I will repeat that if I submerged 1 square kilometer of land, I should get in return at least 10 square kilometer of benefit area.

That means about more than half of the area can gave us return in terms of groundwater recharge by 10 times. 10 times in terms of land. Important thing is that reservoir or dam access has already been created by the nature in the form of quartz reefs. So, we have to identify only those areas where a stream is breaching the quartz reefs and still unchecked. So, if we block that stream, create a small earthen dam, we will delay the runoff. We will start recharging of groundwater.

And as I have been saying that if we start doing this thing today, in 2 years time in that particular area, this problem can be solved to large extent. And as you know that satellite images provide unbiased recordings of the things.

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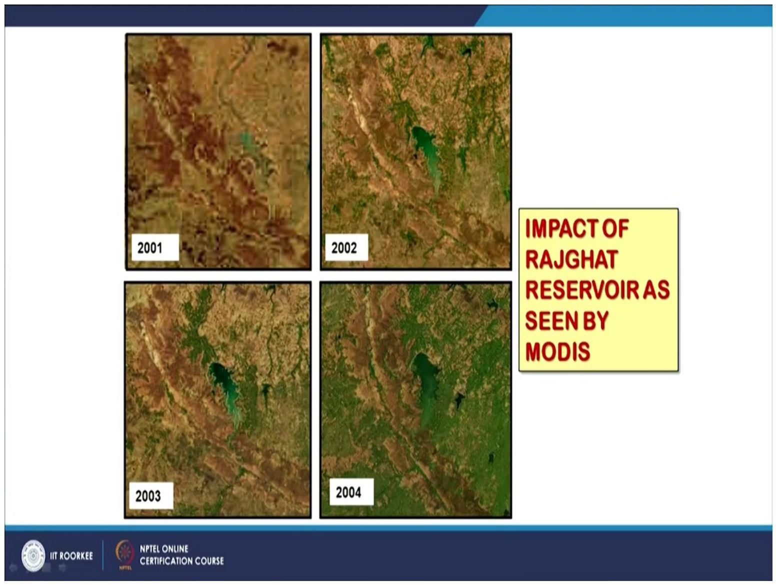

Here in this example what we are seeing? Though it is a larger reservoir which is also called Rani Lakshmibai reservoir, locally it is known as Rajghat. So, this was started just filling in 2001. The entire project was not completed at that time. Next year that is 2002, started to its maximum height. If you notice that these are the true colour images from a MODIS sensor and what you would see that in 2001, hardly there is growth of vegetation.

Here you have started seeing greenery in 2002. Remember just in 1 year. If you go in the 3rd year or 3 years after that, you would realise that the entire area has almost become green. So, compare this 2001 with 2004, you will get the answer that how many years it takes to recharge groundwater regime in hard rock train like Bundelkhand area? Just 2 years. After two years as you can see, a large area is getting benefited because of this reservoir.

So, when I was showing this in a meeting, this particular image or time series images, people said that for 2001, you might have taken a pre monsoon image and for 2004, you have taken a post monsoon image and then you are showing the difference. I said do not worry. As I have said the satellite images records unbiasedly.

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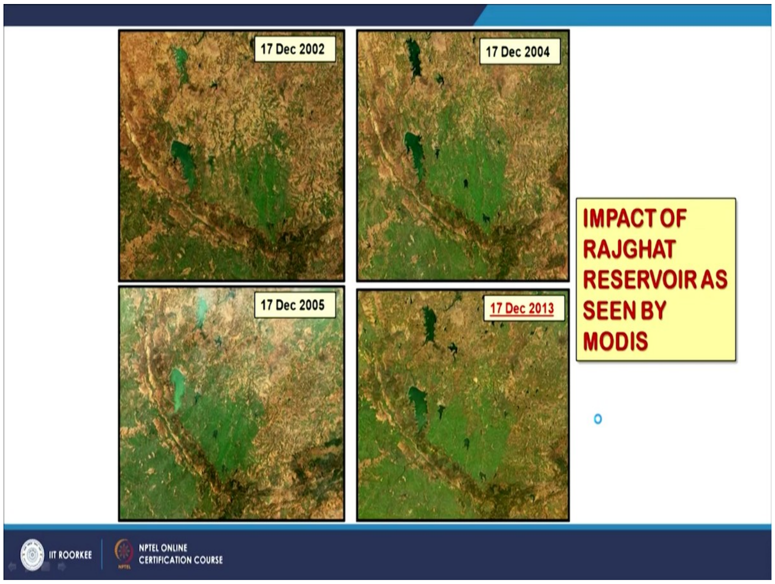

So, this is all 17 December of different years. And as you can realise that this was just 1 year after the reservoir filling, you see the greenery here and, in this part also. And slowly-2 just in 2013, the area has become green. There is another evidence of this that these you know local mandis or local where the farmers bring their grains for selling; wholesale market.

When this reservoir came in existence and started recharging groundwater regime, in the next year, the local Mandis or this wholesale grain market could not handle that kind of output because land was there, soil was there. Only problem was water. As soon as water started coming to the farmer's wells or through canals, crop after crop started coming. That means just if we recharge groundwater regime even for few weeks, it will have affects in the downstream or in the vicinity.

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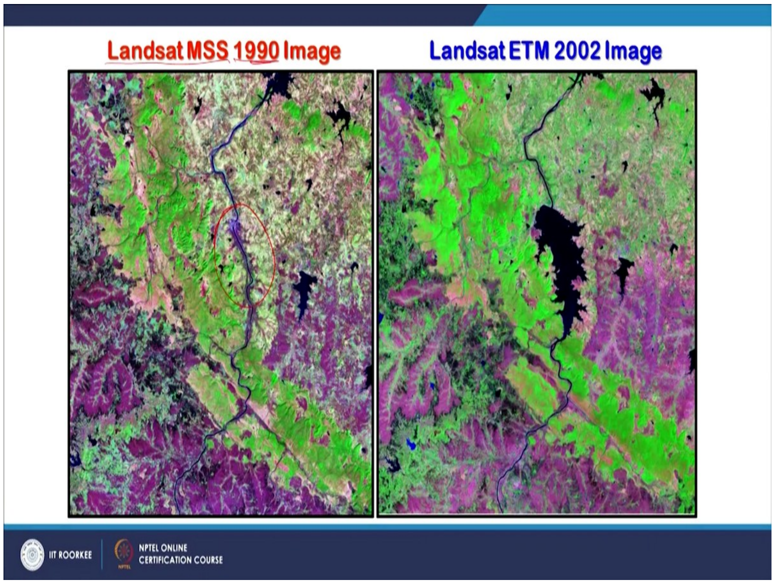

One more example from the same reservoir. This was from the year 1990 from Landsat MSS image. This reservoir was taking shape and see what happens. This is 2002. A large became green, this is again true colour image. So, a reservoir does not matter even it's a small or large, will recharge the groundwater regime particularly in hard rock terrain. And the benefits in the downstream vicinity will start coming in 2- or 3-years' time. And this is the joy of water in the area where these people did not have water and sufficient rain was there.

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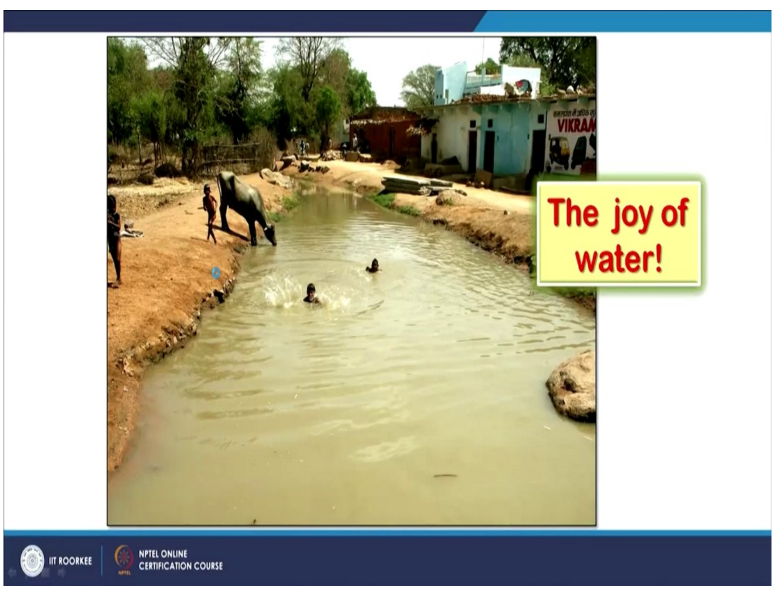

And see these are unlined canals. And what is happening? Because of un-lining of the cannels whenever there is a water, they too recharge the groundwater regime. So. even for 1 month, there is water in these canals. These canals will recharge the groundwater regime.

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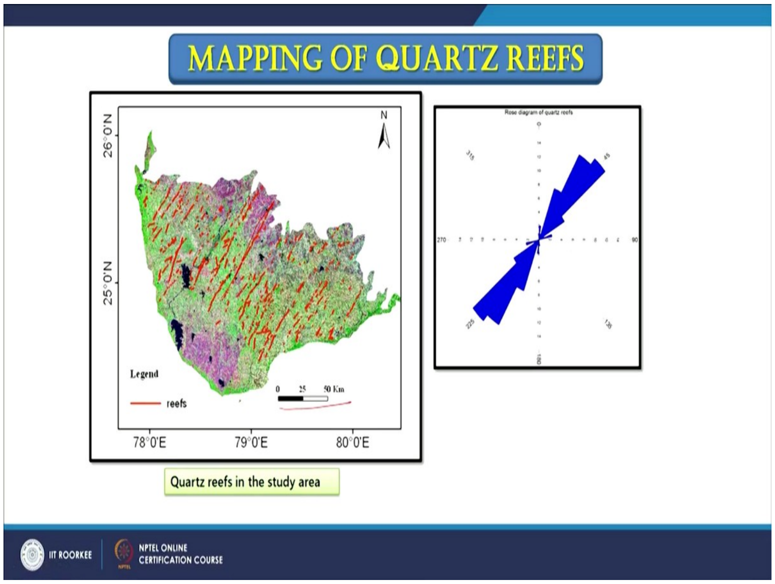

And your groundwater is getting enriched. So, we can solve this problem for a large central part of India just exploiting this quartz reefs which are running northeast southwest and a large area was studied and we delineated these quartz reefs like this red which are marked here. Some of them are running for hundreds of kilometers. See the scale here; 50 kilometers. So, Like this, roughly it is running for 80-90 kilometer. This is the general orientation of all these quartz reefs.

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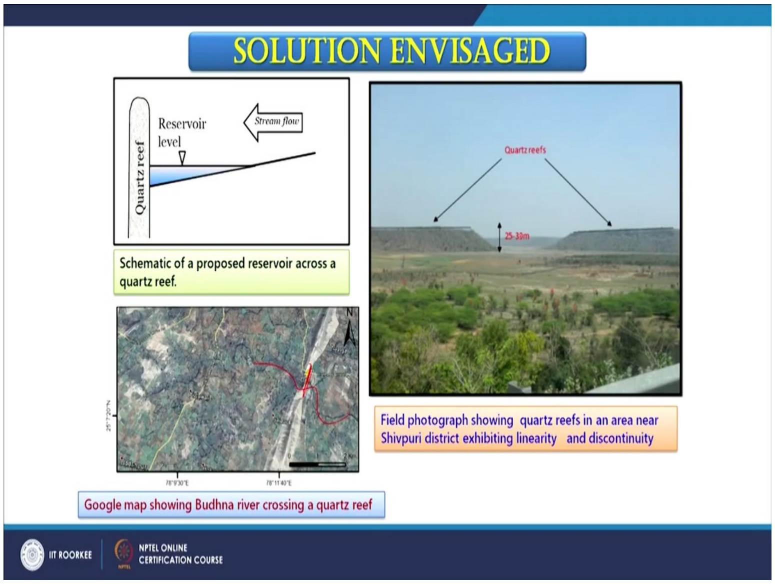

So, this is how in a zoom part in satellite images looks. A stream is going unchecked. So, if we block using local materials, we can create a reservoir. A small reservoir, not multipurpose, not for hydro power, only for the groundwater recharge. And the dam's simulations which we have started can be done here at this stage to convince people that this is what is going to happen.

If you go on the ground, this is how you see these quartz reefs. Having this dam; natural, this is all natural and dam height here is 25-30 meter. So, these abutments can be used to create a reservoir.

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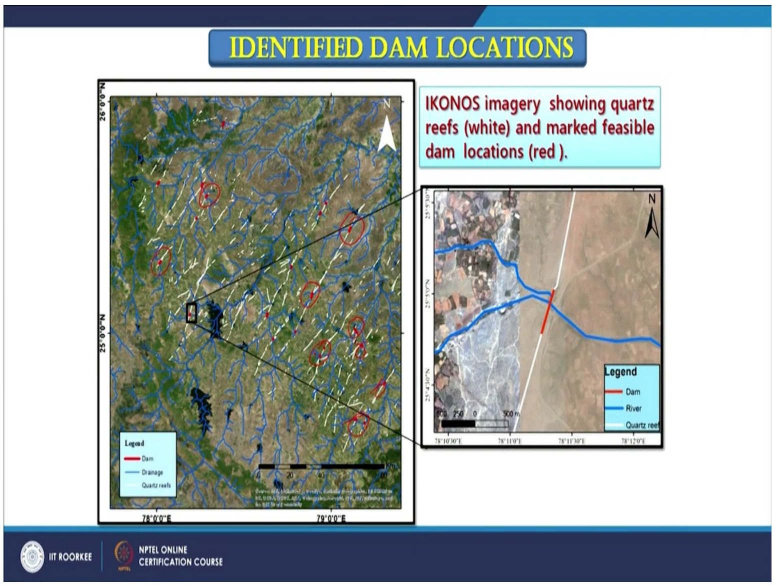

So, this is what we simulated and then predicted that one that these are the areas in that locality, these red one which are marked here, are site for potential reservoir and specially for groundwater recharge. One quartz reef is going like this so if we block this one, a stream is coming like this and it will create a reservoir.

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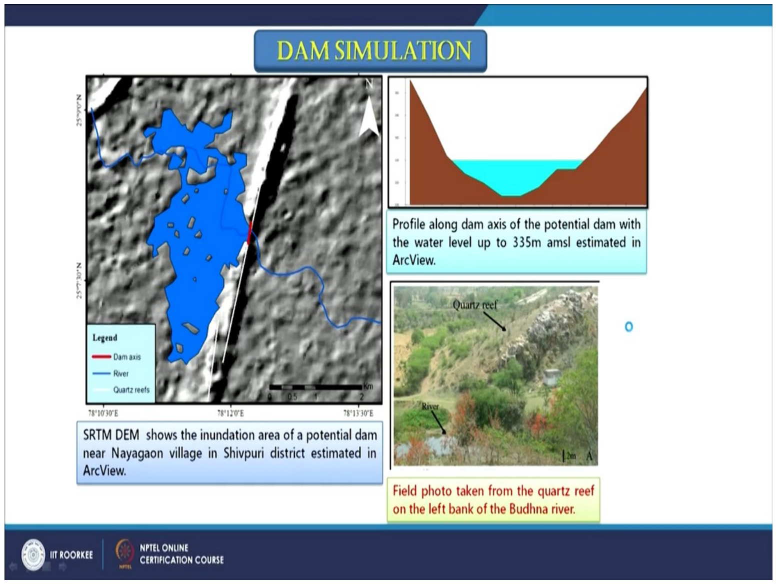

And we can simulate like this which we have done. In the background, it is shaded relief model for the same area and the blue colour is showing the inundated area. Now, there will be other things which we can achieve implying further and do the analysis in GIS. So, we can change the height. Of course, if we want to exploit the quartz reef then we cannot change the location. Only the height we can change. Does not matter but still we would be able to unindentate the area.

This is how it looks more closely on the ground. This is the water which you are seeing here, river and this is how the quartz reefs are looking.

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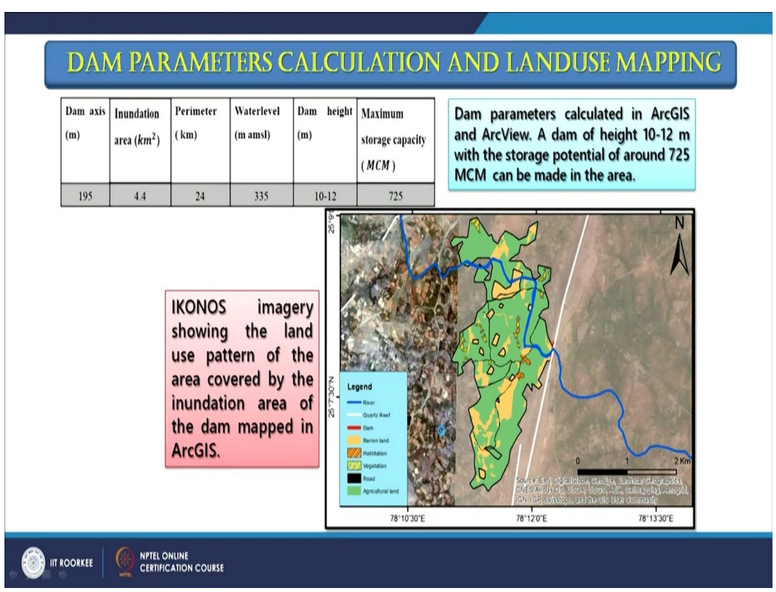

Now, you can also do a land use analysis that which type of lands will get inundated if a reservoir is constructed. All things are modelled. Everything is being simulated before appropriate decisions taken. So immediately implying the satellite images, current land cover land use can also probably assess as has been done for this case. And if you are having revenue record and put this polygon, this is inundated area of the reservoir, immediately you know that whose land will be submerged.

If it is acceptable to local people and decision-makers, a reservoir can come. In two years time, it will start providing benefits.

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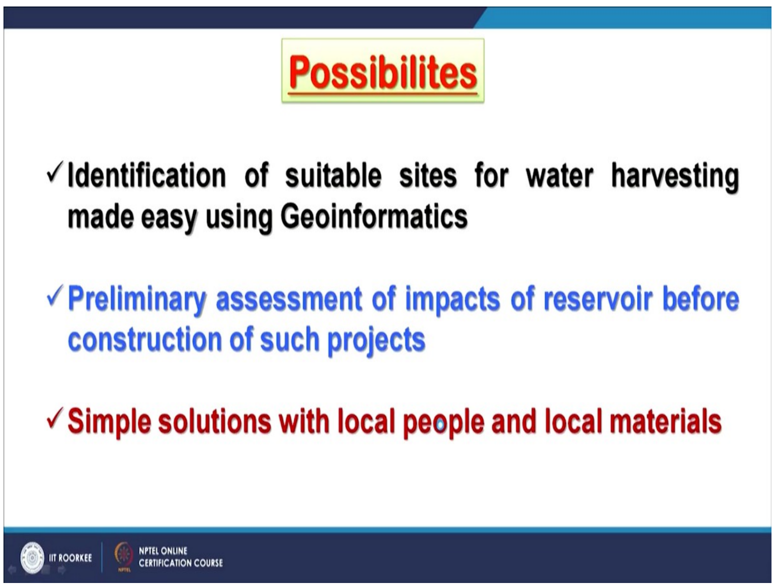

So, whatever the possibilities; that identification of suitable sites for water harvesting has been made very easy using GIS or Geo Informatics Technology. Preliminary assessment can be done. For detailed project report, obviously things have to be checked on the ground but feasibility studies can be done very easily and different scenarios, different options can be created for better decisions. And simple solutions; this is my whole point of discussion.

What solutions which I am providing are very simple and implement with the local people and local material.

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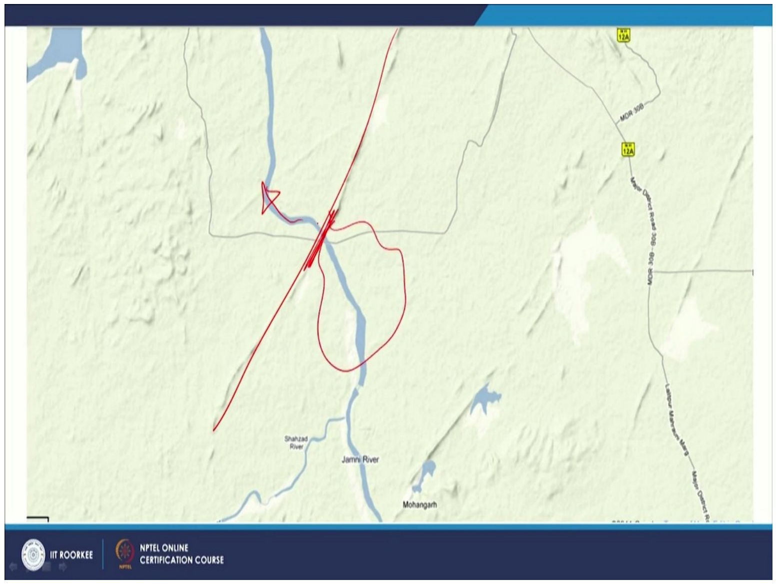

Even if you employ a Google Map image, you can see these quartz reefs very clearly on that because in the Google Map, you are also having digital elevation model and that is in the shaded form; that is hillside. So, these things can be identified. Water bodies are also shown there. So, data is available see here like quartz reefs are running like this. River is you know going like this. Only thing we require to block this one to make reservoir like this.

So, this is one option. Another thing is how to further assess this situation. Remember that we did a hydrologic modelling in GIS and we created drainage network and while discussing this surface hydrologic modelling in the beginning, I said there is an assumption that each drop of water will flow as the surface runoff on the surface. So, that assumption is okay. We can exploit even that assumption and can find out just adding one more layer and can find out which are the areas which will provide better groundwater recharge.

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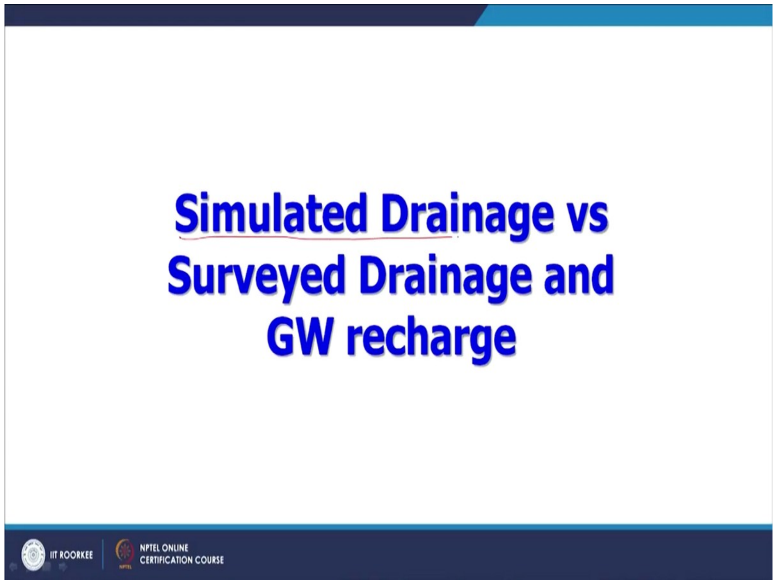

So basically, we have to compare a simulated drainage versus surveyed drainage. Surveyed drainage that is the real one which can come from survey toposheets. And we can get an insight about groundwater recharge.

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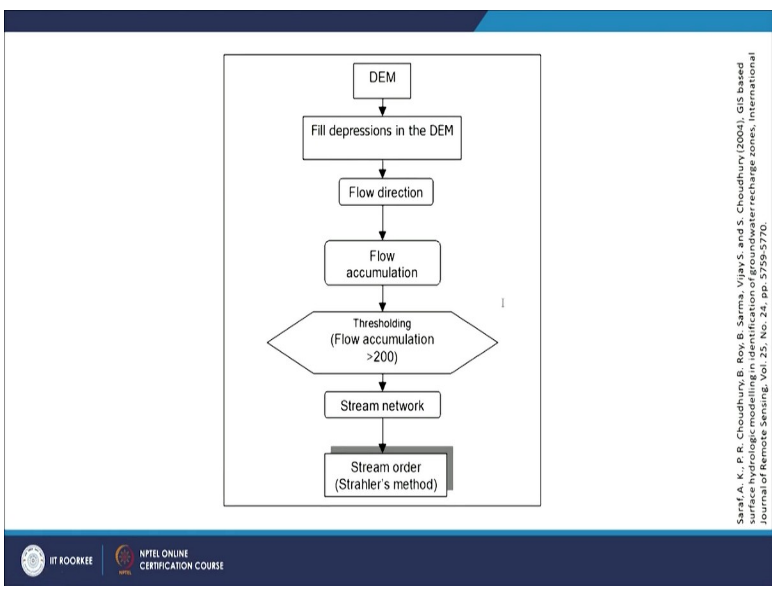

So, this part we have already discussed in surface hydrological modelling that you use a DEM, you fill it flow direction, flow accumulation, thresholding, stream Network and stream ordering. So, once that is you are having in your system, you also require a surveyed drainage network and that means digitizing whatever the best scale toposheets available for a particular area.

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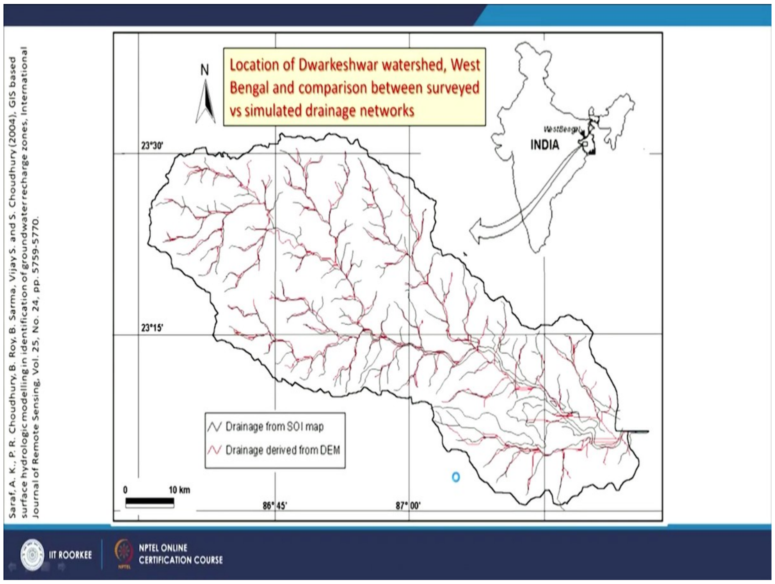

And when you overlay these things, you would notice that in some parts, the surveyed drainage and modelled drainage are almost same. But when you would further observe in some areas like here in this lower part that the surveyed drainage and modelled drainage, there is no match, that means that the model drainage is in the assumption that the water has to flow. So, there is a deviation in the position of the drainage network.

Because natural drainage where whatever the water going towards groundwater regime, that will affect the drainage system. So, this mismatch we can exploit and we can say just comparing these two networks; one is modelled, another one is the real one, that wherever the mismatch we are having high chance of getting groundwater, one and these are the areas where groundwater recharge structures to be reconstructed because surveyed one or real drainage will not be following the modelled drainage concept.

And if it is following that means whenever both are coinciding, that means surveyed drainage and modelled drainage are same. That means there is no loss of water. Assuming that entire watershed is having same evapotranspiration losses. So other losses are to the groundwater. If there is a loss to the groundwater then definitely, the modelled drainage will not follow the surveyed drainage. And this mismatch can also be exploited.

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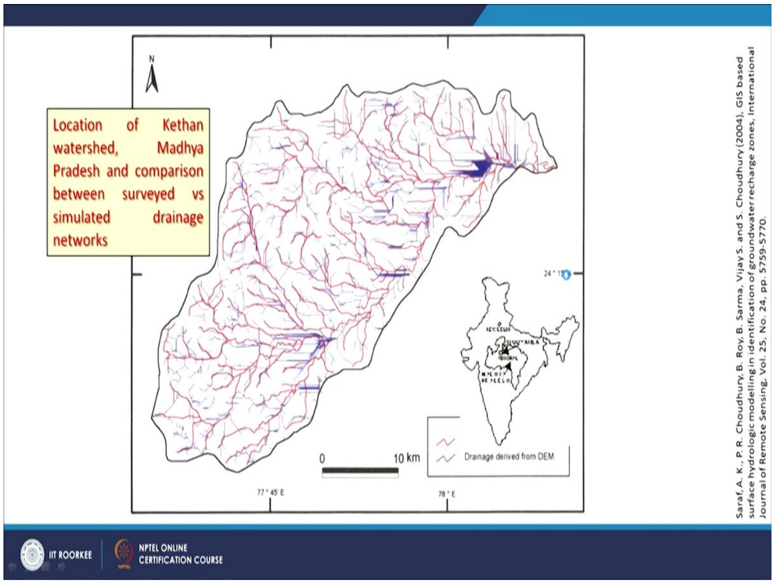

So, very simple technique. One more example of different area. You can see, it works very well.

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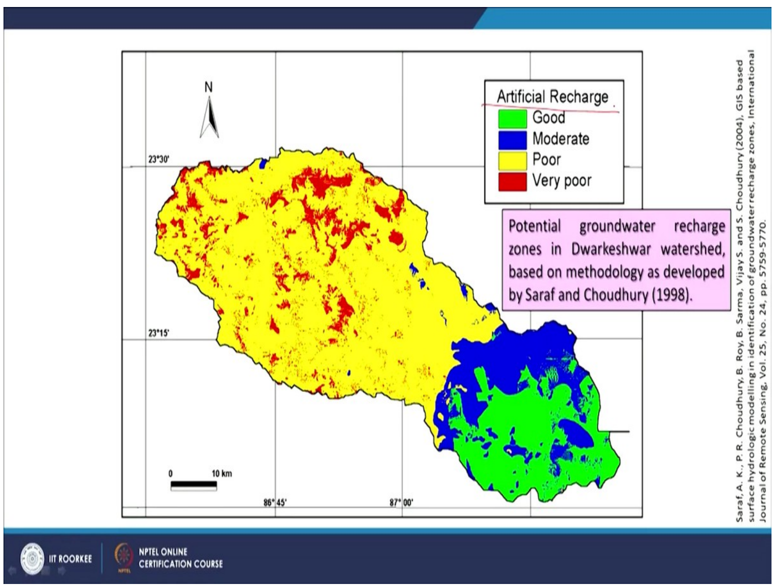

Of course, you can find out the areas which are good for artificial recharge of groundwater regime that you can do it quite easy. Similarly, you can find out the potential groundwater recharge zones for another basin.

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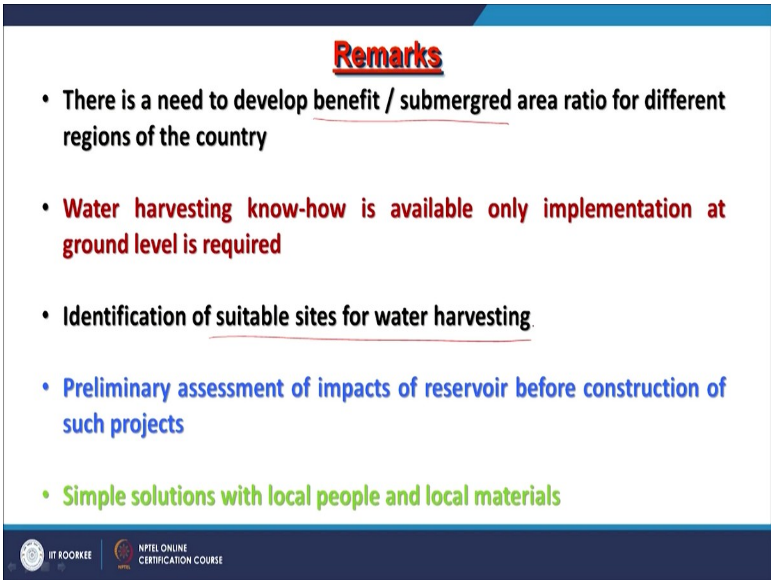

So, what we see that by developing this benefit versus submerged area ratio for the different region of the country if we are having before and we would know that if a structure is created, how much benefits in terms of this benefit area I will going to have? What is the return I am going to get? Because decision-makers would like to know that okay, fine if I construct a reservoir here, how many years it would take?

What the benefits it will provide? All these questions can be answered through such analysis. So, with this basically identification of suitable site for water harvesting, I have already discussed and preliminary assessment can be done. Of course, if before construction, a detailed project report has to be prepared, no matter how small the reservoir is and then construction can be done. And see these are the small check dam's kind of scenario.

So, you do not require many decades to construct a reservoir. Just 1 season or 2 season or 1 year or 6 months, within that employing the local material including employing the local people, one can construct such checks dams and not only one but in cascading if it is possible. On the same stream, multiple. So, tale of one reservoir ends, another should start. Because we want to hold and delay the rain water as much as possible.

So, simple solutions with local people and local material are possible. So, with this, I end this discussion that just recall we started with dam simulations. Just using those damn simulations at least for hard rock terrain, we can find out the best suitable site for groundwater recharge and if those sites are developed in 2- or 3-years' time, we can start seeing benefits. You can verify ground truth or you can verify or validate using satellite images which are having unbiased recordings.

And you can also tell that only it will take 1- or 2-years' time to have or to see the benefits. How much area it will come, that can also be predicted. So, with this, I end this discussion. Thank you very much.