Earth Sciences for Civil Engineering Part-2
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Landslide and subsidence (Part-3)
Module 4
Lecture No 17

Welcome back.

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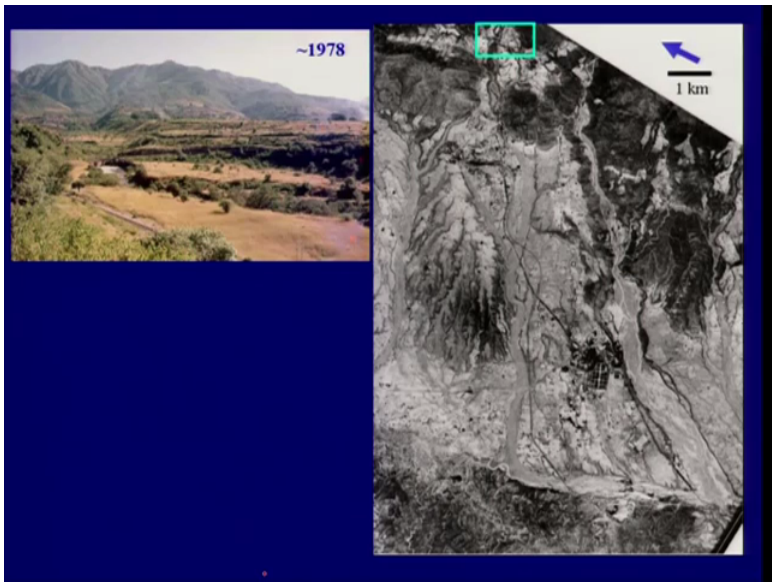

Now coming to the the one of the another Indian example from Himalayas and this satellite photo is from 20 kilometers from Chandigarh and here what we found was quite interesting along this river valley and this river is named as Jhajara river and now here if you see this (rai) this is the rail track which goes to Shimla. Now, let's see over here what happened and what we were able to mark this.

Now this is the area where we were looking at for the signatures of the active faults but we found something else okay here. It was quite interesting. Now this photograph was taken in 1978, now I am of course I was interested in mapping the active fault here but I found something very interesting here. Please note down, try to remember what I am showing in the this photograph which was taken 1978. There is a rail track here that is what which the rail track which I was talking about.

This takes you to Shimla and then this portion here is the fall scarp here and you see the river valley, this stream which is coming up, there is a Jhajra river and you are having the beautiful lesser Himalayas which are sitting at the back. we have terraces, these are the terrace, these are all terraces. These are all terraces. Now it's a if you remember carefully, we were talking about that we in the beginning of the lectures okay. I showed some example of what happened in Uttarkashi floods okay.

That people like to construct their houses on the the flat surfaces and then then close to the river and all that and those are your river terraces.

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Now this photograph was clicked in 2000 okay and you can match a little bit but not exactly because I was unable to take the photograph on the exact location but you can see the rail track. There is a same rail track. Some trees have grown here and few of the trees have come here on this area and then this peak here is this one, the same peak but you can see the terraces here. There are lot of houses you can see on the here. Lot of construction.

Another photograph I will show. You can see from here okay. Same hill tops, same hill top here and same hill top here but you see in the riverbeds, you are having lot of construction which came up and this is hardly 20 to 30 years okay. So this is what we call the improper construction

okay without having understanding that what will happen if you are having have the cloud burst in this region or you are having the flooding in this region okay.

These all houses which are sitting on the terraces okay and and the town planners, they allowed them to construct these houses very close to the riverbeds okay will face problems, severe problem during the the major floods okay. Though they have not experienced until now but the floods or the events which we have, unusual events we have experienced in recent past okay like Uttarkashi, we can have the similar one here also okay.

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If you see one photograph here, what you can, this is again you can see the valley, whole valley is been filled up with the the construction okay. Now this is the the part which I was bit worried about that if you are having the erosion from the base here okay, this house which is sitting on the top here at the corner will come up okay. It will like these boulders will come out and then these and definitely the house will collapse okay and that what similar thing happened in the Uttarkashi flood. So this is an unproper practice of construction.

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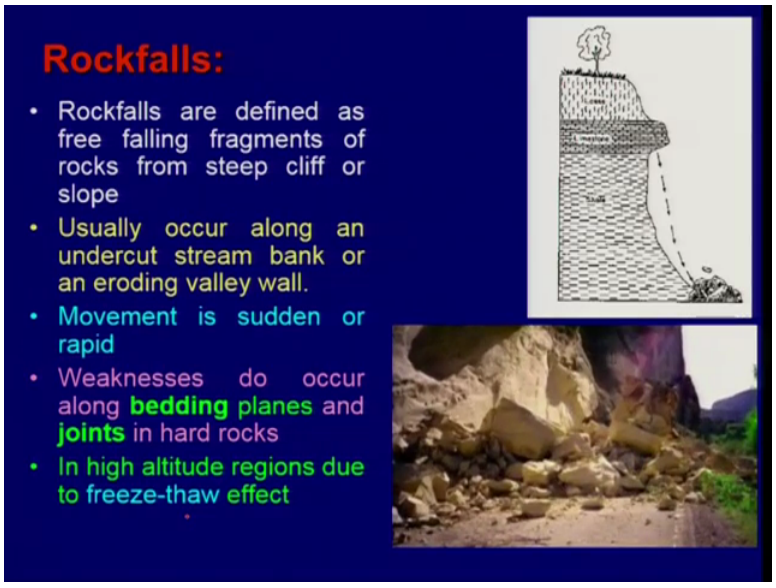

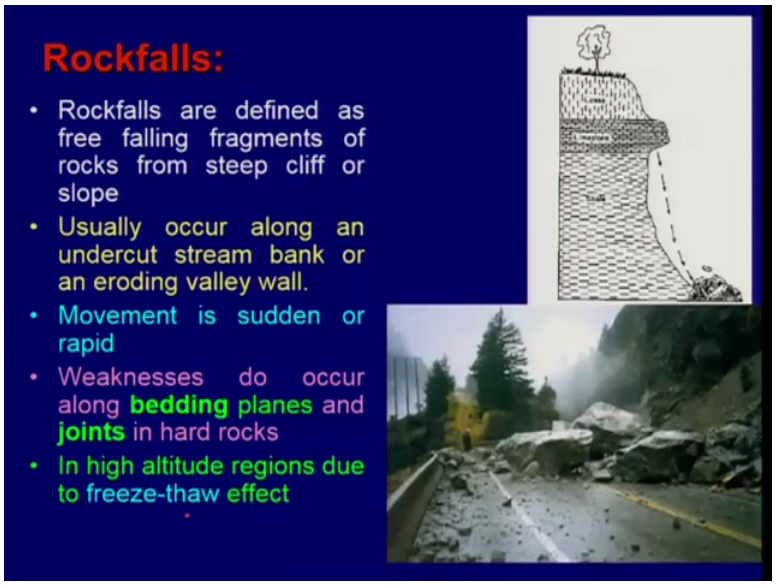

Coming to another type of landslide or the mass movement is your fall okay and these are mainly related to the coarser material which we call the rock falls okay. So these are again the movement is very sudden because it will just the the fractured rocks will fall down from the cliff okay. So mainly it occurs where you are having most of the weak plains and you are having the the jointed hard rocks and in high altitude regions where you are problems with an freezing and thawing effect, you may face this type of landslip very frequently.

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Example of the rock block from US okay which rolled down and mashed up the the whole house okay.

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But this is an example from India close to Nainital so the huge rock block which came down and which destroyed the house okay so we have to be extremely careful where we are locating our houses or or the settlements okay.

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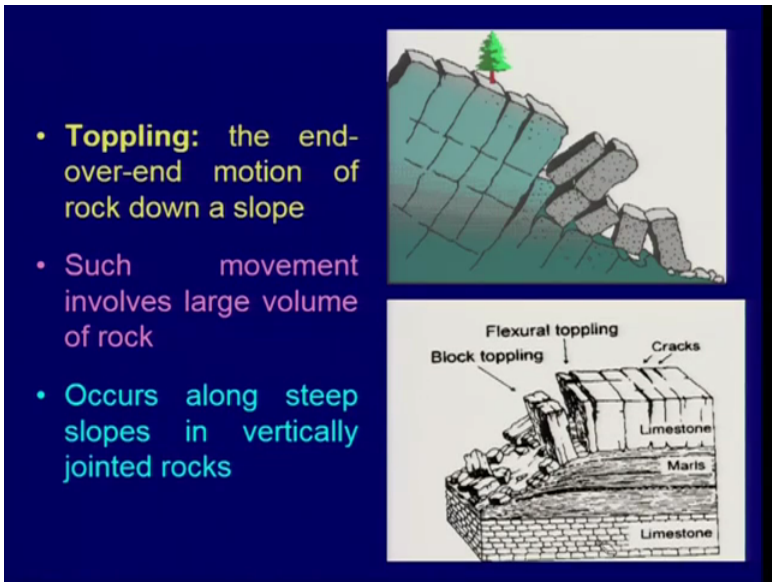

Then toppling is another phenomena which is associated with the mass movement and this will happen where you are having mostly the jointed rocks okay. And that will facilitate the toppling of the material and the movement will be from like end over end motion okay so end over end motion will be something like this okay so this will topple down and so if you are having the fractured material, you may face this type of landslide or the mass movement even though the rocks are massive in nature okay. So occurs along the steep slopes with vertically jointed okay and the the the another one which we looked at was if you are having the bedding planes which are dipping towards the slope okay. So these are the vertical joints and those are the bedding plains which are we talking about.

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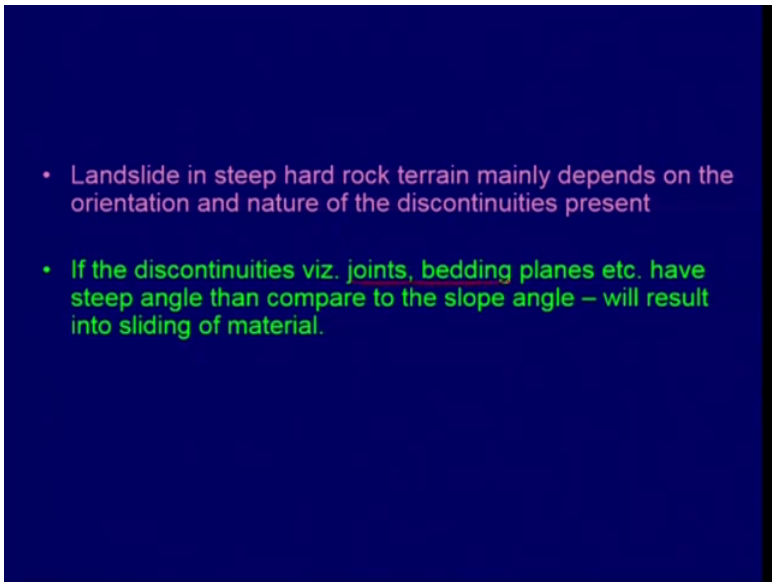

So landslide and steep hard rock terrain mainly depends on the orientation of nature of discontinuities. Now discontinuities are mainly the joints, bedding plains etc okay.

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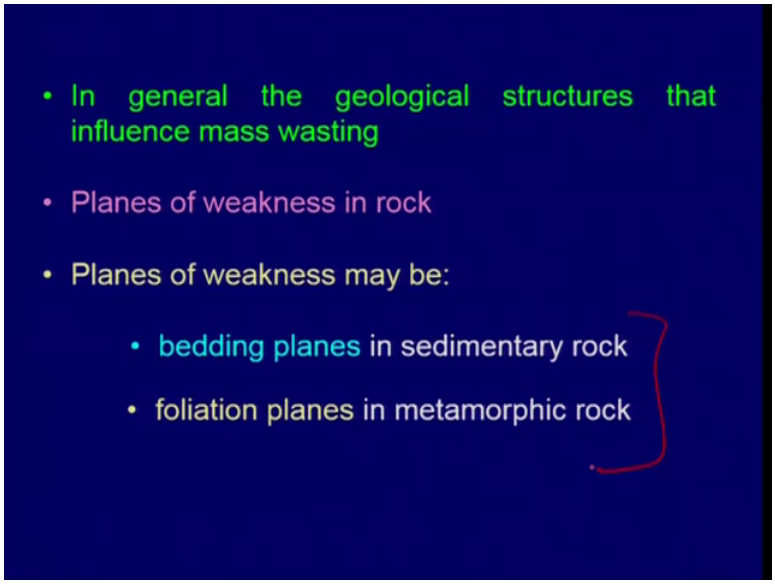

Now in general, the geological structure that influence the mass wasting are the planes of weakness in rocks. Planes of weakness may be bedding planes in sedimentary rocks or foliation

plains in metamorphic rocks so these or or if these rocks are jointed okay then you may the problems of the landslides okay.

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Now flow, it will be sudden okay.

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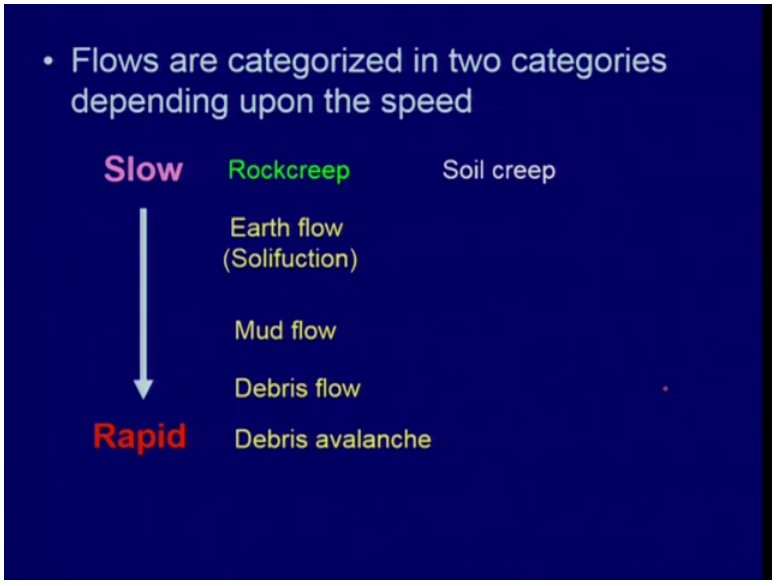

But flow further can be categorized into 2 depending on the speed okay. One is slow, one is rapid so rock creep is a very slow movement okay, soil creep is again a slow movement okay and the

earth flow, solifluction is relatively faster. Mud flows are faster and towards rapid, debris flows are extremely fast and debris avalanches okay so fall category can have depend on on the speed okay, how fast they are going to slip okay.

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Now we will see couple of examples, solifluction mainly will be seen the higher altitude area. Solifluction is a downward movement of wet soil along the slope under the influence of gravity and most commonly in glacial terrains during summer so this will happen because what happens the uppermost part will melt whereas the lower part remains frozen and that will result into the increase in pore water pressure again due to melting and gradual slip of the ground which is melted okay on the top top of the and this mostly it moves like in the form of lobes okay so this here the example which you can see, the uppermost portion of the soil which melted and the subsurface remain frozen. The uppermost will slide down along the slopes okay and it will move very much in the form of the lobes okay but the movement is very slow.

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This is an example of the solifluction.

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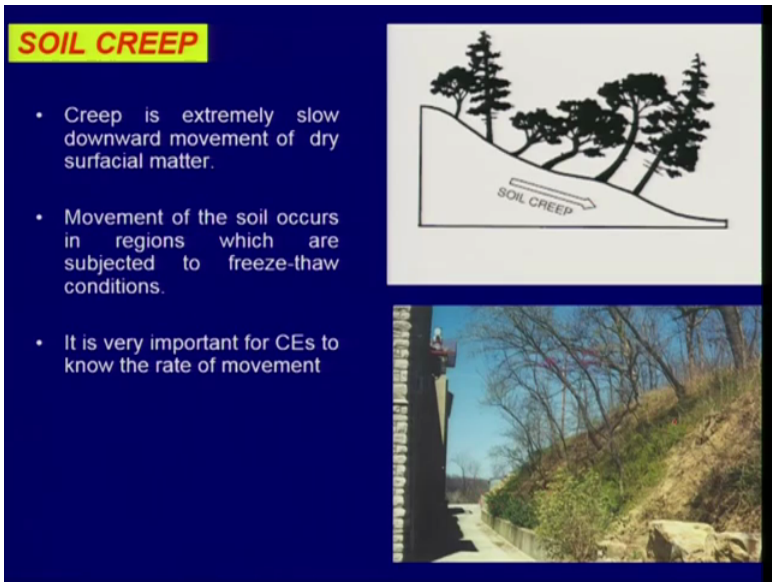

Then another example is the soil creep okay. This is an extremely slow downward movement and it will take time to be seen or observed on surface but in some locations, we can easily make out, if you are having to get, we are getting some cracks which are coming up or there are tilting of

the the lamp post or the trees also that are the indicators of the creep going in the areas okay and this is extremely important for the civil engineers to notice okay.

So this is an example of the soil creep over here and this is again is showing that bending of the tree trunks okay so this can help us in identifying that this area is slowly creeping okay.

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Then example of the the rock creep. Very slow creeping is taking place.

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Now mudflows, we have talked about this so I will move (fo) ahead. So this occurs when slope material becomes so saturated that the cohesion bond between the particle is lost okay. So this is an example again. We had talked about the mud flows, the Lahar flows. They are very rapid type down slope movements that involves mud flows from volcanic ash okay. So mud flows can occur on surface with very gentle slope okay because the internal particle friction resistance and the cohesion is negligible on that slope okay so this may occur or even an very gently slopping surface okay so occurs with the fine texture sediments and soil mixed with water to create a liquid flow. Okay if you are having excess amount of water coming up because of the percolation or because of some other reasons and you may experience the mud flow in that region okay.

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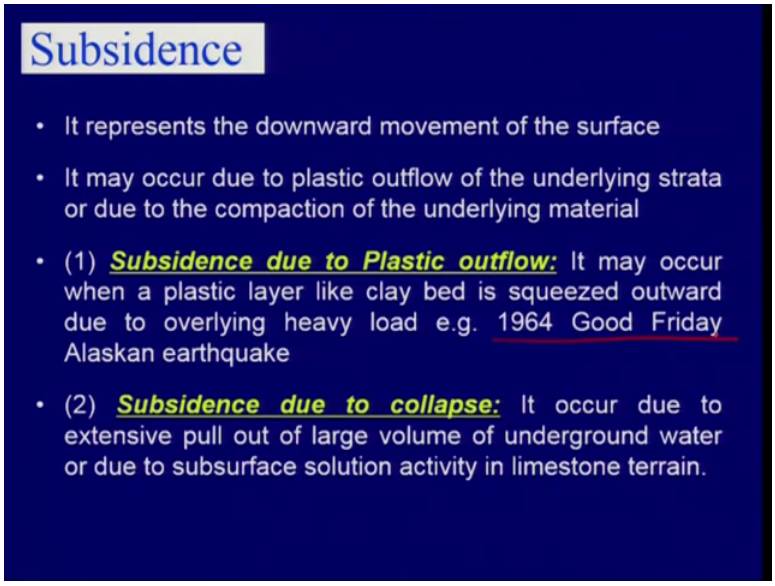

Then coming to the subsidence, it represents the downward movement of the surface okay. It may occur due to plastic outflow as we have the example of Good Friday earthquake 1964 Alaska. Subsidence due to plastic outflow. This is the same example of the Good Friday earthquake or you are having subsidence due to collapse. It occurs due to extensive pullout of large volume of underground water okay so you are extracting groundwater at very high rate okay. That can also result into into the subsidence or due to the subsurface solution activity in the limestone terrains okay so one is large removal of groundwater. Another is (la) dissolution activity because of the in the limestone terrain okay.

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This is typical topography which one can see in the limestone terrain which we call the Karst topography and you can you you have this this subdued one okay. These are all, you may have potholes here which is due to the the subsurface solution activity.

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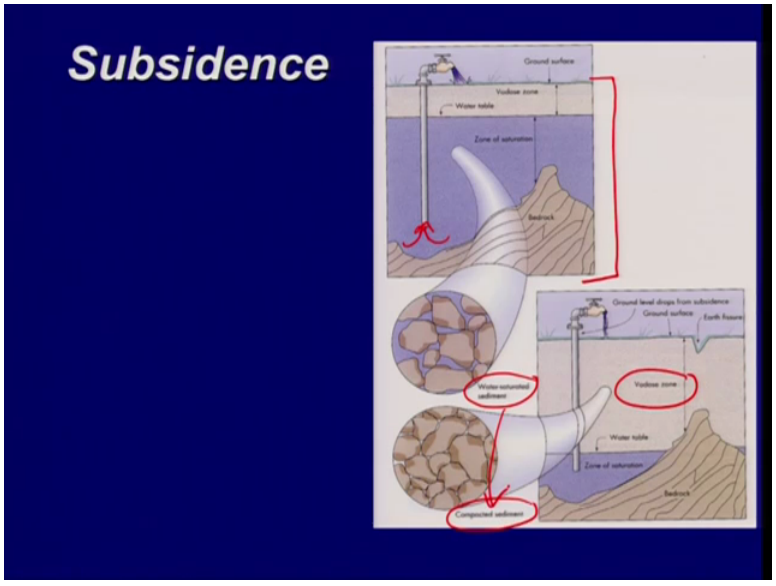

Subsidence, this is what happens when you keep on extracting the water, extensive water so if you look at the profile of the soil and and the groundwater, you what you will see is that you

have a vedose zone and you have a zone of saturation okay where you will have the the pores and the pores are occupied with the water okay and this is what the area you can say. The aquifer from where you will pump up the water okay. Now if you keep on pumping the water and the recharge is very low here, eventually what will happen that this (vesod) vedose zone will have no water left out okay and this will result into the compaction because this is the space which is available between each grains which are still like are occupied by the water but if you have removed this, this will result into the, that is the (wat) water saturated sediments will be compacted okay. So this will happen because of the excess removal of groundwater and this can result into the collapse of the area.

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Best example, this is of the karst topography okay and you can see the the huge, these are the small potholes okay. Small potholes in the limestone terrain.

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This one is the huge one and you can make out the size of this pothole. This is from US based on the size of this truck here okay, a car here so huge pothole which came up okay because of the subsurface solution activity.

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And this is one of the famous example because of the excess extraction of the groundwater okay. This is leaning tower of Pisa in Italy and this was because of the groundwater withdrawn okay so

we need water for the growing cities but we may experience or we may result into the associated hazard because of this.

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Now control and stabilization so very simple methods have been adopted over the past and still we are doing.

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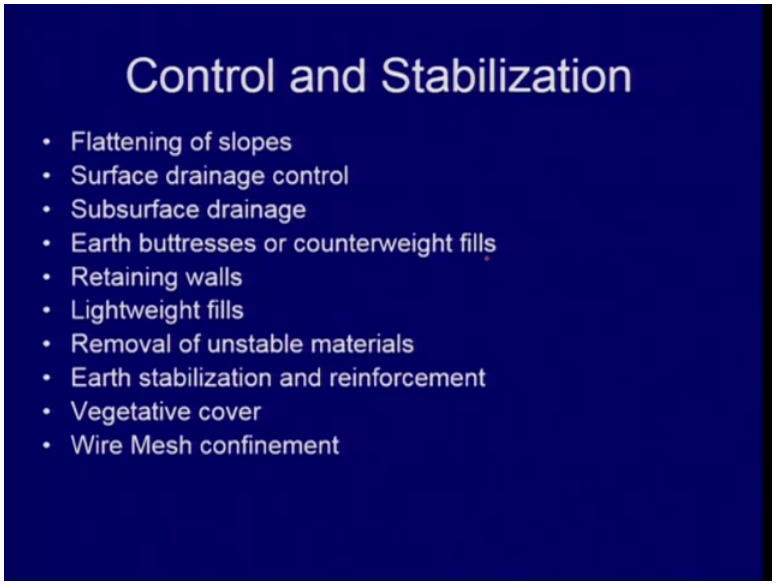

The most important is that the slope factor okay so you reduce the slope, okay. Flattening of slope, surface drainage control. Try to remove water as fast as possible from the surface. Subsurface drainage also, you can apply okay. Earth, buttress and counterweight fills to block the the slip of the material on the surface, construction of retaining walls, light weighted fills. You should not back the area that what we are do in the counterweight fills with an heavier material okay. Then removal of the unstable material, if you understand that this area is having the material which is unstable, try to remove it and fix it up using the counterweight fills okay. Then earth stabilization and reinforcement, you can do vegetation cover, okay, wire mesh confined.

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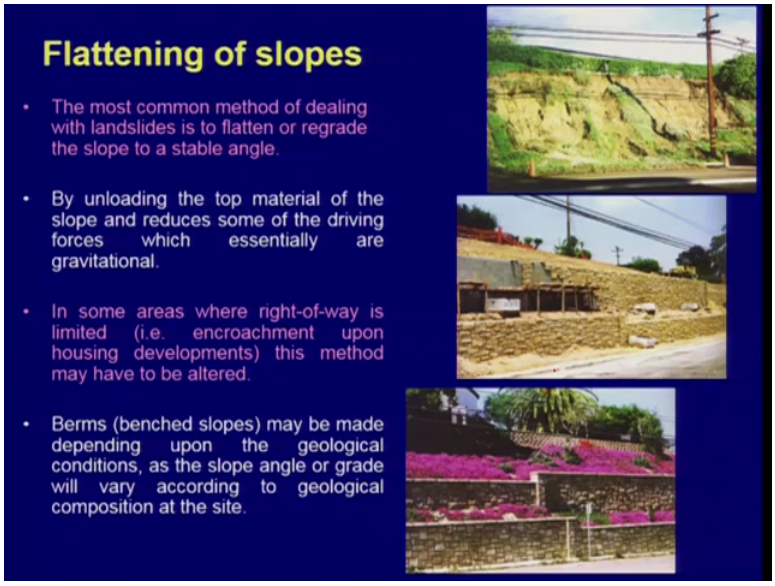

This confinement can be used when you are having major rock falls in the areas. You can use that and in combination of both okay. You can have the wire mesh and then you can also put the the you can do the reinforcement of the areas okay. So flattening of slope, this one of the most commonly seen method. If you go into the hilly terrain, you will find small small terraces along the hill slope okay so if suppose you are having the the slope like this, you will find that you have the small farms like this okay constructed.

Now this is basically very old practice so you will have the agriculture here and here but what eventually they have done is they have reduced the slope. Okay they have reduced the slope so this you will find very common in the hilly terrain okay. That the agricultural practices, the

people have used to do this for cultivation and they have eventually reduced the the slope okay. So most common method dealing with the landslides is to flatten or recreate the slope to a stable angle okay. By unloading the top material of the slope and reduce some of the driving forces which essentially are (grati) gravitational okay. In some areas where right of way is limited or that is an encroachment upon housing development, these methods have been altered okay, so what people have done is the, they have created the bench slopes okay.

For example, in some residential areas, it was difficult to do that sort of slope reduction so over the time what they did is that they constructed the benches here okay what we call the the bromes okay and finally they came up with this okay so you have beatified area and you have retained the slope also okay so this is what the one of the best method can be done okay in the residential areas.

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There is again a photograph which we are showing on the way to Nainital.

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So massive landslides, you will be, you will across in the areas so this is what they have done. They have constructed the retaining walls and they have tried to reduce the the slope here because this is the massive landslide which has been seen on the way.

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There is a close up of that.

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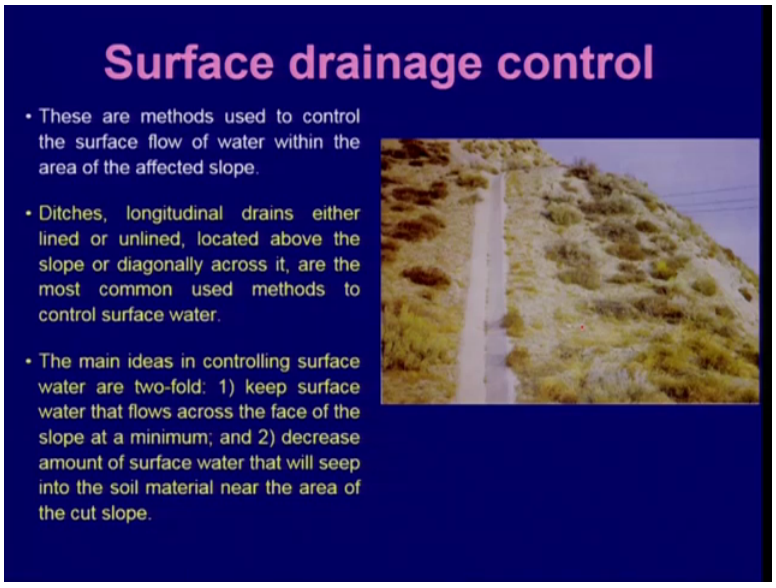

Now surface drainage you can try to construct the drainage on the surface and try to remove or the water as fast as possible because you are not allowing the water to percolate down into the ground okay or on on the slope okay. And that will reduce the the area from having chances of landslides okay.

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There is an example from Japan where you can see the, I may be having better photograph or not, may be this one okay so you have the drain which is coming up down here okay and then you have, they have cut the slope in different benches so they have reduced the slope here and they have tried to stabilize and in some places, they have also put the fences here okay or the the wire mesh too. If if something happens and if some block roll downs, it will be blocked here okay.

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So again this is the example of the drainage which is coming up and they have reinforced, they have put concrete on the surface to protect that and at various locations where they have cut and reduce the slope, they have put such wire meshes.

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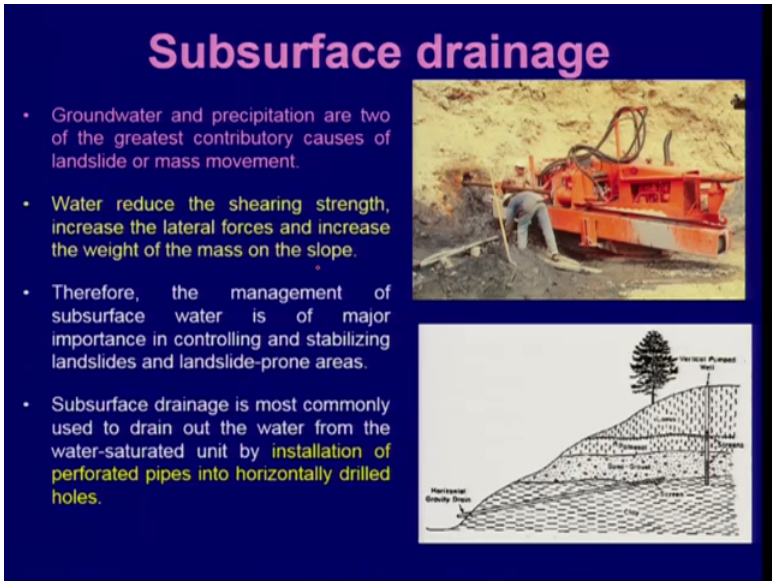

Now subsurface is again, people have been doing that. Suppose you are having the porous material sitting here okay and this material will have is having the capability of absorbing or occupying more water when it is it's coming or percolating down. This may slip okay so as soon as what people have done that they have put artificial horizontal drain pipes okay which can remove the water, percolating water which is and doesn't allow it to collect in this layer okay so that can also reduce the chances of slope failure because water reduces the shear strength and increases the lateral forces and increase the weight of the mass on the slope okay.

So during heavy rain, you may face these problems okay and such areas may have the chances of the landslip. So these pipes are purported pipes which will keep on accumulating the water which is getting percolated down here and will be poured out directly along the slope okay.

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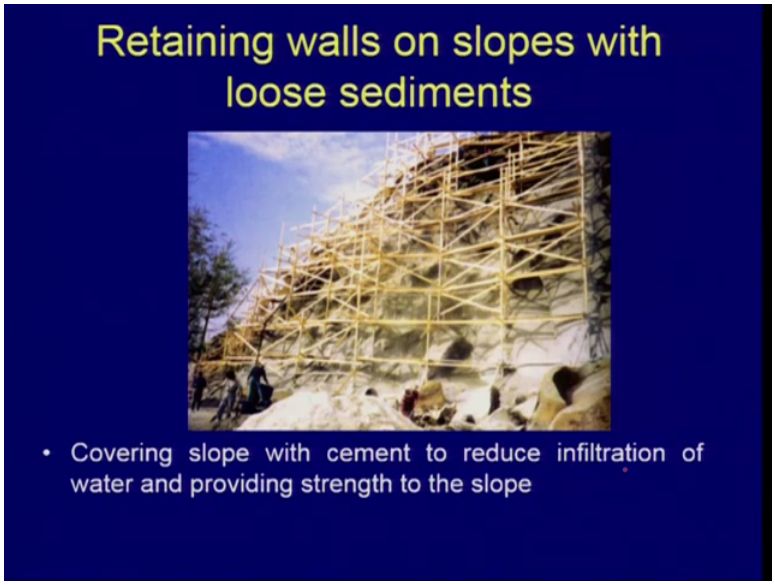

Then our example of retaining walls, you can do and cover the slope with cement and reduce the infiltration and also strengthen the the slope.

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So various methods are employed to stabilize or strengthen the internal shear strength of the soil and the and to achieve the reinforcement. This includes cement grouting, chemical injection or lime stability etc. So using different materials, people have used different methods.

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Wire meshes are confined where you are having the chances of rock falls okay so commonly used on rock fall areas to protect the boulders moving down onto the surface or along the roads and all that okay. Other part is that people have also tried to put the wire mesh into the area of loose material okay. So one is you are putting the wire mesh here to protect the boulders rolling down and another is you are putting the wire mesh and covering it with the cement so that you strengthen this slope which is occupied by the loose material.

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This is the example again from Japan where they have constructed the drains okay.

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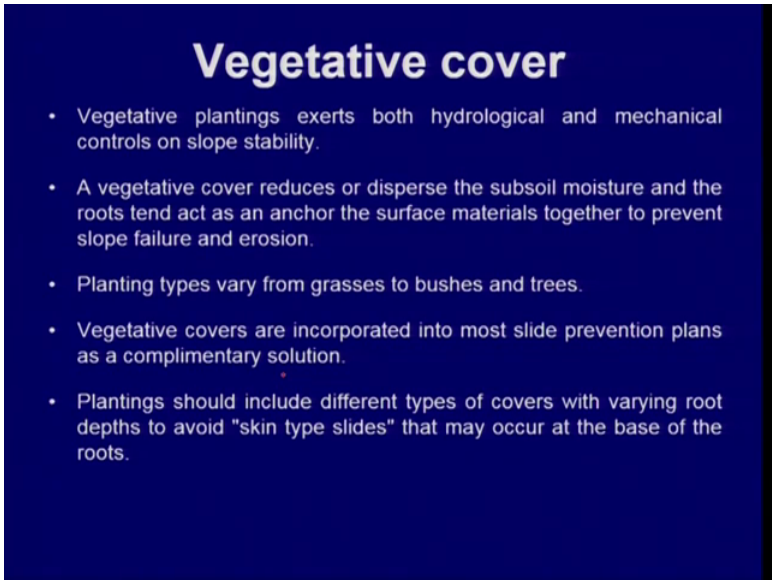

Vegetation cover is another way of protecting the slope. So planting exert both hydrological mechanical control on the slope stability okay. Vegetation cover reduces or disperse the subsoil moisture and the root tends to act as an anchor okay. This is an important okay. The subsurface, the anchor to the subsurface material together to prevent the slope failure. Planting types varies from grass to bushes and trees but as I told that you should not put very heavy vegetation on the slope which will increase the overburden so vegetation covers are incorporated in most of the, most life prevention plants as the complimentary solutions okay.

So along with what you are doing, the benching part and all that, you can add the vegetation as an complimentary solution okay. Planting should include different type of covers which varies root depth to avoid skin type slides that may occur at the base of the roots okay so this is again the botanical people can help in choosing the plant type and all that okay.

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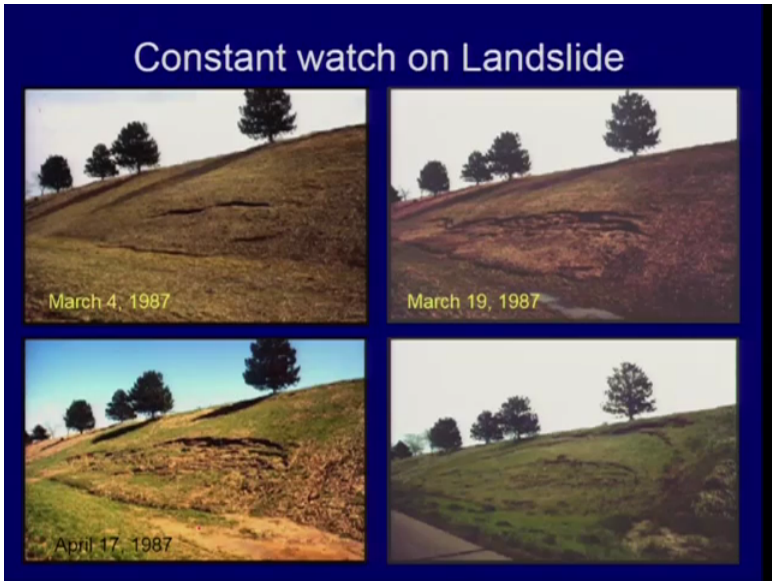

Constant watch of landslide is again an (imp) important part okay. This is in March 1987. This is again in March on 19th, this was on 4th, this was on 19th and this one is on 17th April okay on the same year but slipped okay and finally you have the major one which is coming on March 1990. You can see the more slip has developed here okay so one can also have the constant watch on this okay. And nowadays with the the advancement of science, people are using GPS okay to watch such types of slips okay or taking multiple aerial photographs to see that whether the area is slipping or not and how much it is creeping or sleeping over the time.

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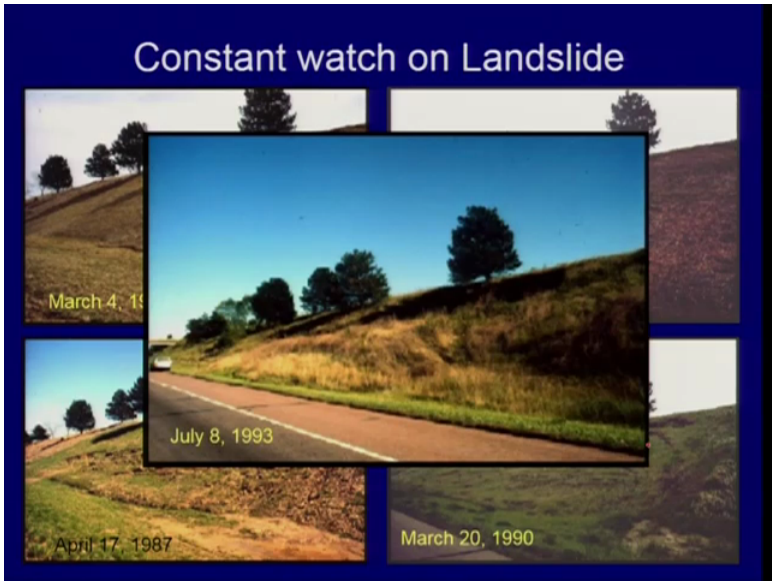

And finally this was the the thing which happened in 93, this whole area slipped out okay but this was very small one but this is one of the good example to understand that how we can constantly watch and monitor the landslides and landslips.

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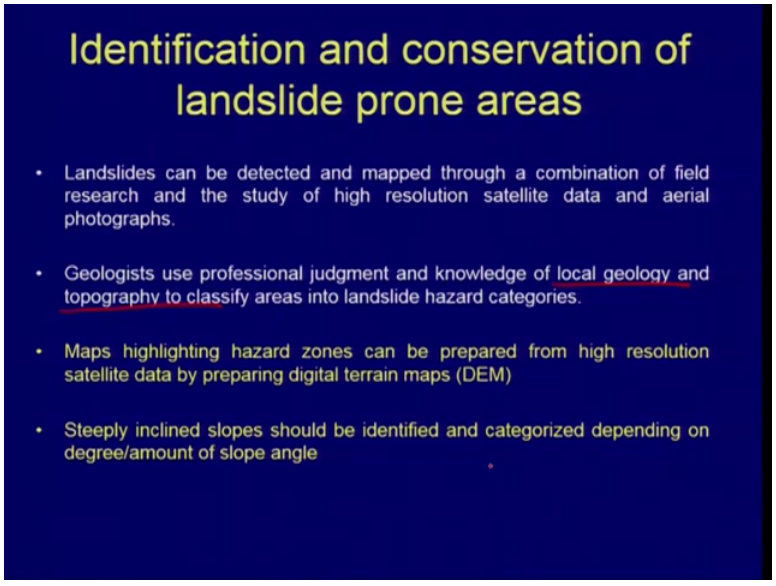

So identification and conservation of landslide prone areas okay. Now landslides can be detected in a map through a combination of field recharge and the study of high resolution data as well as

aerial photographs okay. Geologists use professional judgments and knowledge of local geology and topography to classify area into landslide hazard categories okay. Maps, highlighting hazard zones can be prepared from high resolution satellite data by preparing digital terrain models or digital terrain maps. This can help and as I told that the one can also use the GPS to monitor the landslip okay. Steeply inclined slope should be identified then categorize depending on the degree or an amount of slope angle okay. So here the most important part which we can talk about is the one is the local geology, okay, the topography, that is the slope okay and then based on that, you can categorize your areas in the hazard zone.

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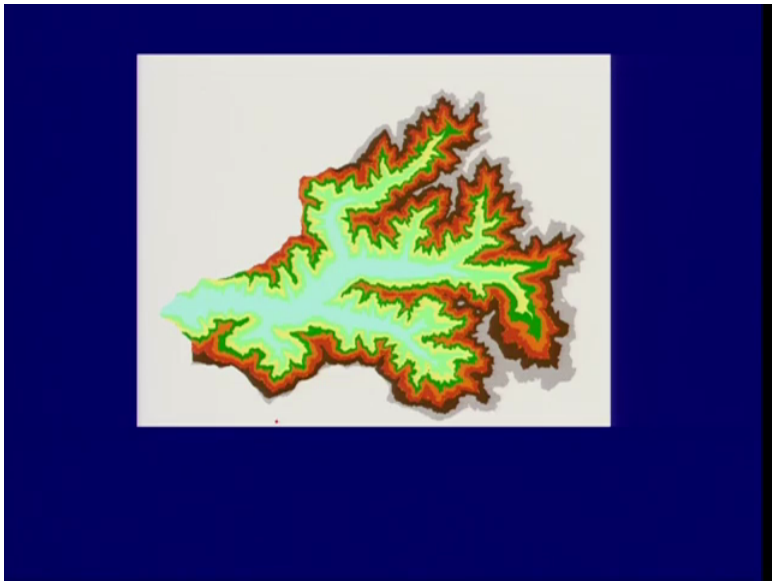

So there is a map which shows prepared based on the digital elevation model which indicates the high slopes areas and these are different colors which shows the height of the region okay.

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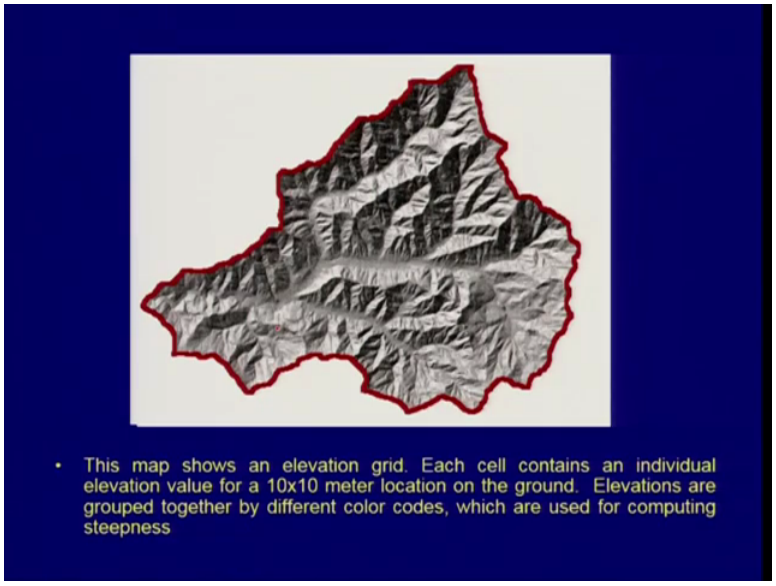

So this is the DM which has been prepared.

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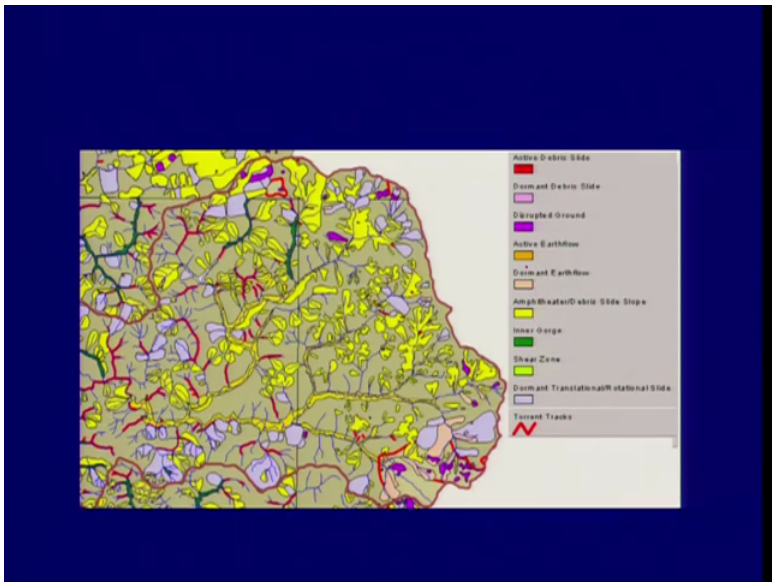

And based on this one can also classify which areas are having which type of material and which type of slide can be dominated there. Whether the some of the slides are dormant and some of them are active.

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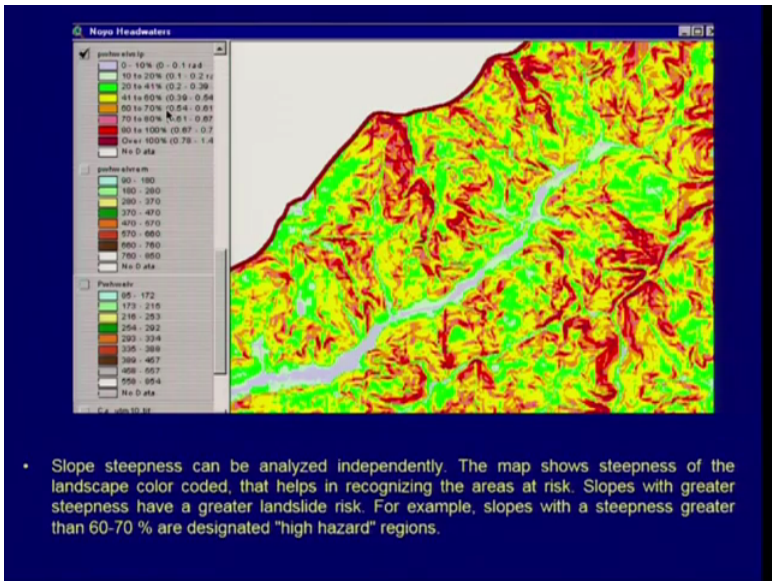

And further you can have classification based on the elevation so this type of classification can be done, here is in satellite data. But nevertheless one should go to field and try to understand that what is the geology in that part.

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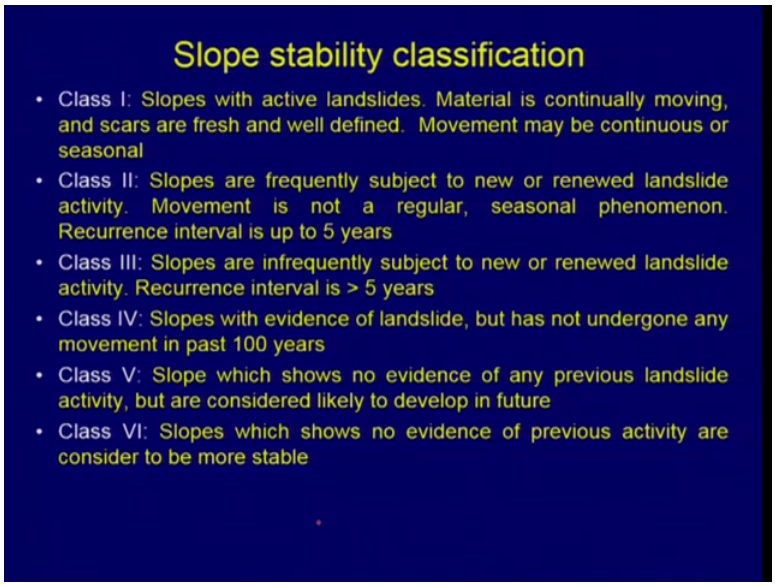

Slope stability if you take, class 1, this may vary from place to place again but in general you can say that slopes with active landslides okay. This is class one where material is continuously

moving and scars are fresh and we defined. Movement may be continues or seasonal. And class 2, slopes are frequently subjected to new or renew landslides, movement is not regular, seasonal phenomena, recurrence interval is up to 5 years or so but this can happen only if you are having constant watch on that area. Third category, you can say class 3, slopes are infrequent. It is subjected to new or renewed landslides or recurrence interval is greater than 5 years okay and class 4 slopes with the evidence of landslides or the historical landslides or the past landslides we can see but it has not undergone any movement in past 100 years.

Okay. Class 5, slope which shows no evidence of any previous landslide activities but are considered likely to develop in future and this will happen because if you have a slope and you have geology which could favor the landslide in future okay and then class 6, you have slopes which shows no evidence of previous activity are considered to be more stable okay so I end here, thank you so much. We will continue in the next class okay.