Engineering Geology

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Lecture - 1

Introduction

Hello everyone, I want to begin by welcoming you all to the video course on engineering geology. My name is Debasis Roy, I can be or I am, I teach in the department of civil engineering of Indian Institute of Technology Kharagpur. My contact address is on the screen there, I can also be contacted by email at this address that it is - debasis at civil dot iitkgp dot ornet ernet dot in.

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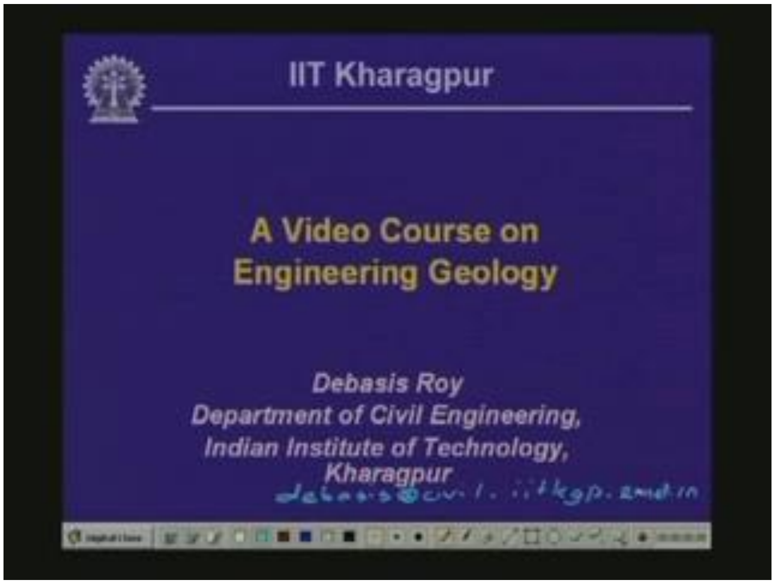

This course actually is going to be comprised of about 40 sessions, 40 - 1 hour sessions out of which there will be about 35 or 36 sessions of instructions in the class room and the rest 3 or 4 sessions will be laboratory based instructions. So, we will visit lab, we will try to identify some rock samples or try to identify different features on a geology map; those things will be taken care of in the laboratory, rest of it for that matter, most of the things are going to be taken care of in the class room.

In the first session of this video course, we are going to cover some introductory topics that are of general interest in order to give you a flavor about what to expect out of this course. So, what we are going to try to learn in this first lesson?

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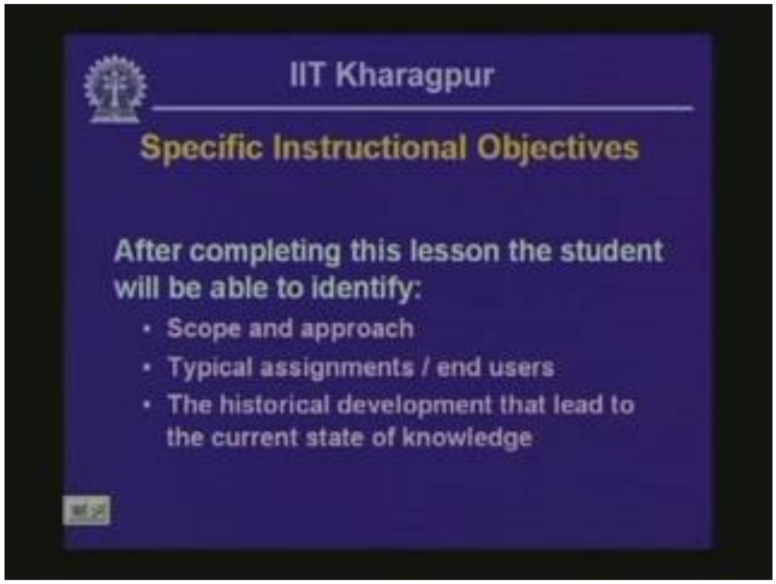

We are going to try to learn what are the general scope and approach used in engineering geology, then what are the typical assignments that one might expect while working as a an engineering geologist, who might have to be interacted with when you work as an engineering geologist, who are the end users of this knowledge, of this field of a knowledge and then finally we are going to actually talk about a summary of the historical developments that has led to the current state of knowledge in this field.

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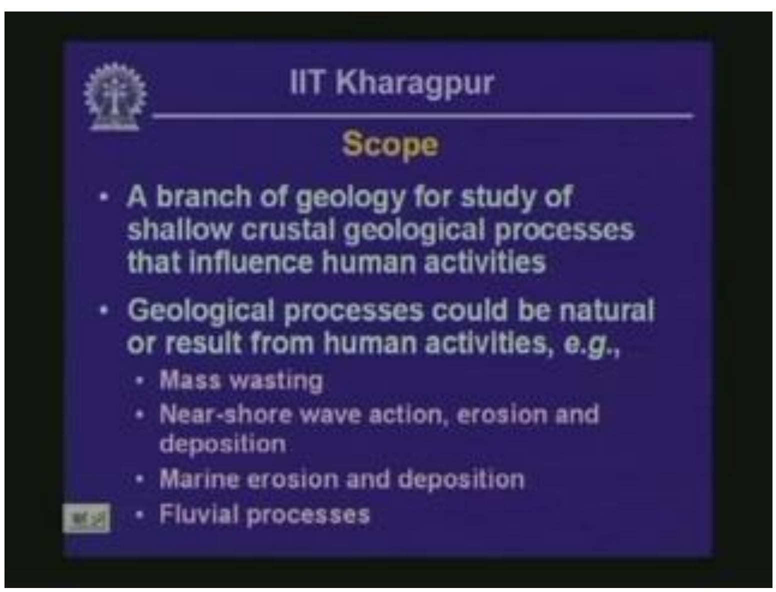

So, to begin with we want to, we want to understand; what is actually engineering geology?

What are the definitions? What are the essential aspects considered in engineering geology? Now, as the name suggests, the field of engineering geology is actually a sup-topic or a sub branch of the field of geology. Now, geology essentially involves studying of different aspects of or different processes involving different parts of the earth.

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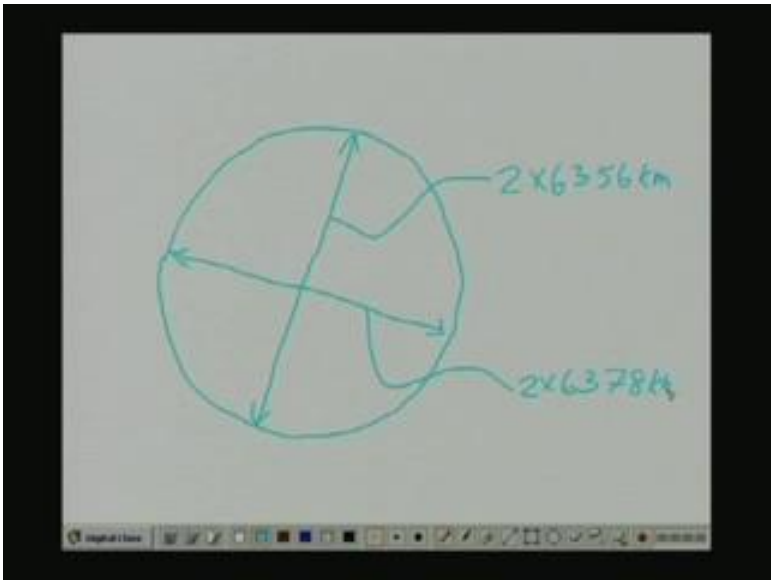

Now, in order to understand what we learn, what we cover generally in geology, we try to understand first of all, what is the structure of earth? Now, you all know that earth is essentially a spherical body, the diameter or the radius of the earth; it is actually a little bit of omelet, so the polar radius is a little bit smaller. This is the polar radius that is a little bit smaller than the radius or the diameter at the equator. So, the polar radius actually or polar diameter for that matter is about 2 times 6356 kilometers and the diameter at the equator is about 2 times 6378 kilometers. So, there is the difference of about 22 kilometers when you consider the, consider the diameter at the pole or that across the equator.

Now, geologists concern themselves with the process that actually covers the entire earth actually. So, this entire sphere actually that is shown on the screen is what is dealt with by geologists and you can understand that this is not a homogeneous structure and the sphere the oblate spheroid actually can be sub-divided into several different shell like zones.

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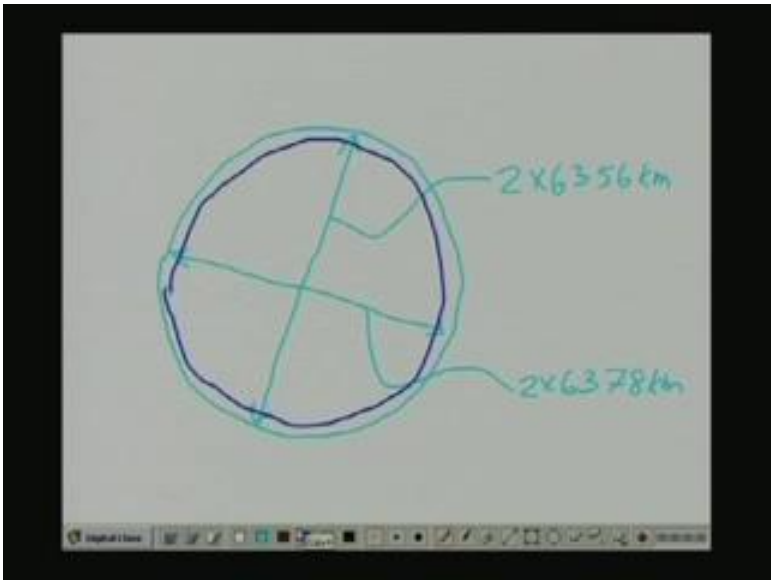

For instance there is a zone which has got a thickness of between 5 kilometer and about 100 kilometer at the surface of the sphere that is called the lithosphere. Now, this one has got a thickness of about 5 kilometer underneath oceans and the thickness can go up to about a 100 kilometers underneath where there are major mountains chains and underneath the continents, the thickness of this lithosphere is only about 35 kilometers.

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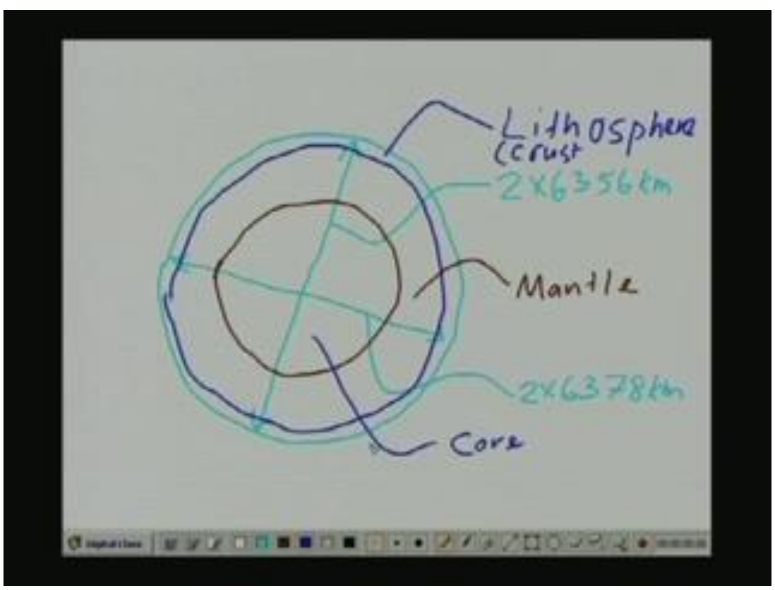

Now, underneath the lithosphere, there is another shell thicker shell actually, that is called the mantle. So, the one we talked about earlier was the lithosphere are the crust and underneath the crust, there is mantle that goes upto about 2500 to 3000 kilometers measured from the surface and below the mantle is the other unit that is called the core; all these different parts of the sphere of the spherical structure are different in terms of their properties or in terms of their density or in terms of the chemistry. So, the processes that are there in the lithosphere are not essentially the same as those one encounters in the mantle or those that take place in the core.

Now, you all know that the construction, human activity or the construction, I mean all the human engineering projects; they are confined within the top few tens of meters or at the most top few hundreds of meters from the surface. So, these are the particular things that are considered by all, that are considered by engineering geologists. So, engineering geologists deal with all processes that affect human activity or human habitat or human environment.

So, what we are going to be concerned with? We are going to be concerned with the processes that take place over the top at the most hundred meters from the surface of the earth. So, we look at shallow crustal processes in engineering geology, shallow crustal geologic processes in this subject. What are those shallow crustal geology processes?

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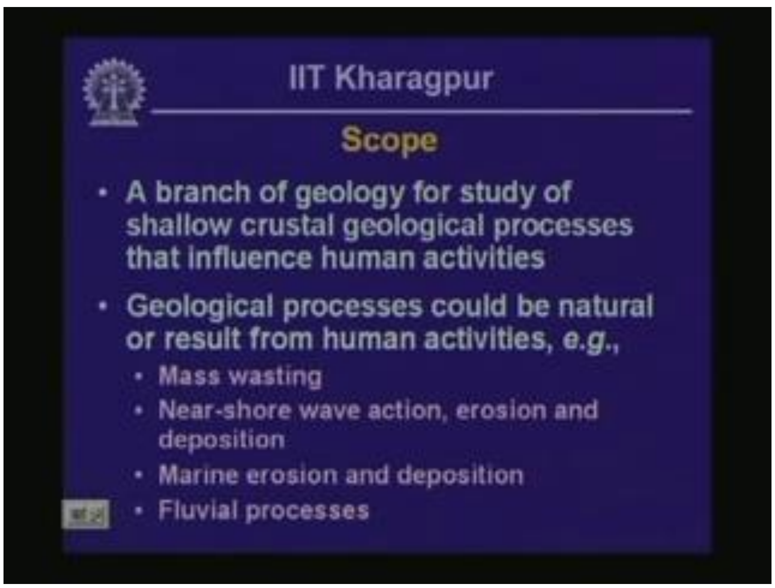

They could be mass wasting, something to do with the slope failure or landslides, then they could be near shore processes like erosion of the or erosion due to the action of sea waves or waves generated on the river bodies or on the other water bodies, there are could be deposition due to these wave action or a fluvial processes that is also taken care of by engineering geologists in the near shore area, then marine erosion and deposition; another topic of interest of the subject and then fluvial processes, deposition erosion flooding, these kind of processes also are studied in the subject of engineering geology.

Now, we need to understand the essentials of the approach taken of the problem solving approach normally adopted in engineering geology. Now, it needs to be highlighted that engineering geologists are essentially geologist, they are not engineers but they are geologist. So, they concern themselves only with engineering aspects.

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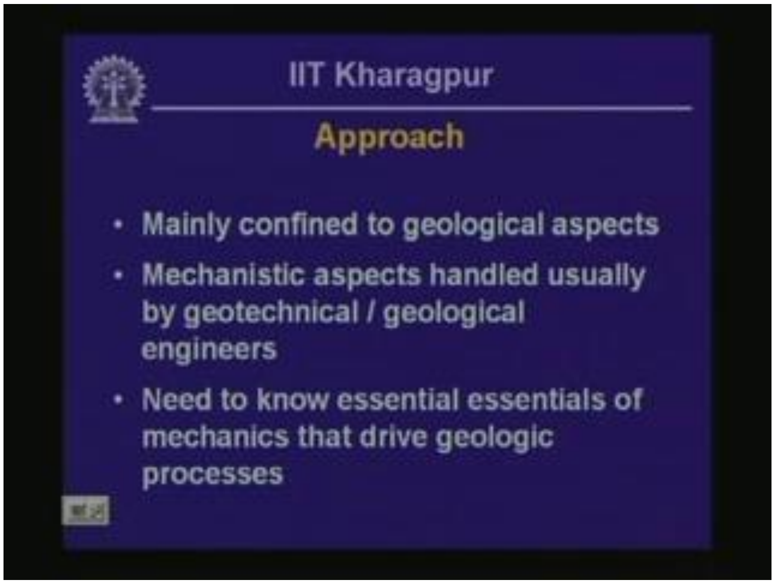

Now, you all know that mechanistic aspects are normally handled by engineers and here we are looking at geotechnical or geological engineers who are mainly concerned with the mechanistic aspects of the geological processes. Now, that does not say that engineering geologist should not have a good understanding of the mechanistic aspect that drives this shallow crustal geologic processes because if they do not understand the mechanistic aspects, then they cannot interact effectively with the engineers, geotechnical or geological engineers who are ultimately going to be responsible for the construction processes of different projects.

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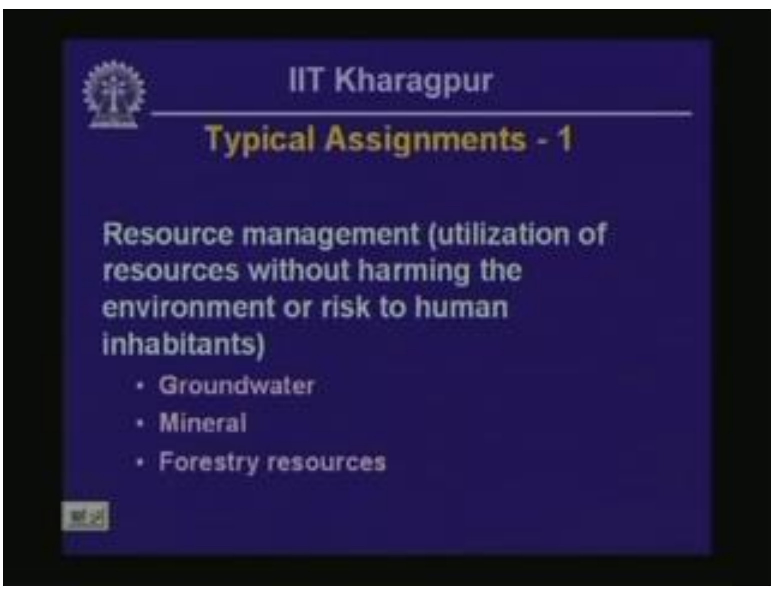

Now, we look at typical assignments that one might encounter while working as an engineering geologist. First class of assignment that one needs to handle as an engineering geologist is in resource management. What do you mean by resource management? Resource management essentially means that utilization of natural resources without harming the environment. Now, what are the resources that we need to worry about? We need to worry about ground water resources, mineral resources and forestry resources to name a few.

For instance we need to exploit, I mean if we need to exploit the ground water resource, then we need to be very judicious about the use of ground water. If the ground water use is too much compared to the local geology or local meteorology, then that could cost undue harm to the environment. We will look at an example problem in this regard later on in this lesson.

Then we need to also look at how to exploit minerals resources without judicious of course to the maximum benefit of the construction activities or for the human livelihood. Now, mineral resources, you all know that mining activities, they actually are concerned with the exploitations of minerals resources. We also should look at how to exploit other types of resources to extract construction materials for a particular type of construction project. And finally, forestry resources also is a very major part that engineering geologists deal with. We need to, for instance, when we are harvesting timber, then if there is an over harvesting or clear cut operations, I mean clear cutting of huge areas huge swats of forest, then that could lead to disastrous consequences like that could lead to enormous amount of erosion which can have or that can have a chain reaction to all aspects of human habitat, locally as well as on a regional scale.

The second aspect, the second type of assignment that we are going to deal with as engineering geologists is natural hazard assessment and risk management of course. What do we do in that? We actually try to quantify the hazard involved in a particular area because of geologic processes. To give you a few examples, engineering geologists sometimes have got the responsibility of dealing with the hazards arising as a result of terrain stability. Out of terrain stability, we can or by terrain stability what we mean is that landslide, mudslide, rockslide, debris flow all these events are actually lumped together in this sub-topic.

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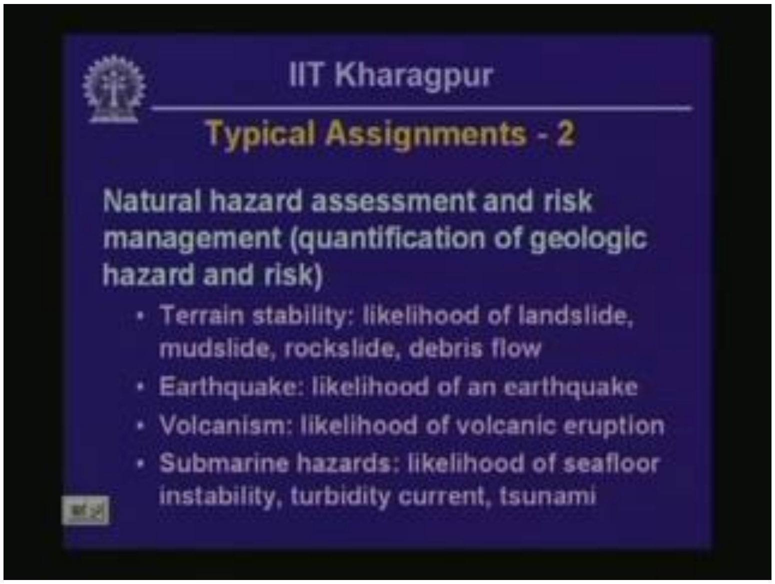

So, engineering geologists need to identify the hazards of terrain stability, terrain stability related hazards and they need to quantify those hazards. So, for instance, if they find, if an engineering geologist finds that in a certain area there is an undue hazard of land slide; then land use planners, they may decide that the particular project or settlement cannot be located in that particular situation.

Earthquake hazard is another topic of interest in this regard. What do we do in that? We try to find out what is the likelihood of an earthquake to occur in a certain area. Engineering geologists are mainly interested in this regard to find out if there is a seismogenic source in the vicinity of a particular type of development, whether there is any active fault or volcano that could cause that could actually pose earthquake hazard to a particular development in the vicinity of those features. The quantification of the hazards is normally done by seismologists and that is we are going to deal with that a little bit in the later part of this course.

But in general, the details of those things are within the scope of other branches of engineering and science. So, in regards to earthquake hazard identification, engineering geologists are entrusted mainly with trying to identify whether there is any earthquake source nearby. The other thing is of course as I mentioned just a little bit ago that volcanism is another aspect that one need or engineering geologists look at whether, by that what I mean is that whether there is a volcano that is active or dormant which might actually become active during the life time of a project or the settlement that is going to be constructed nearby. So, these things are done by engineering geologists.

Then, they also deal with submarine hazards like likelihood of seafloor movement; whether there is any likelihood of turbidity current or tsunami caused by seafloor instability or earthquake taking place very near the seafloor. So, these are the assignments typically are entrusted to engineering geologists which involves assessment of natural hazards and risk management.

The other class of problems that engineering geologists deal with is assessment of geologic hazards and risks that arises because of human activities. So far, we were taking about geologic risk or geologic hazards because of natural processes. Now, because of human activity also, we could actually complicate or worsen the likelihood of a geologic hazard. Now, we will consider a few examples in this regard, this kind of problems may be posed because of any big construction project like constriction of dams, construction of railways or construction of highways. We are going to take an example like by considering a dam project.

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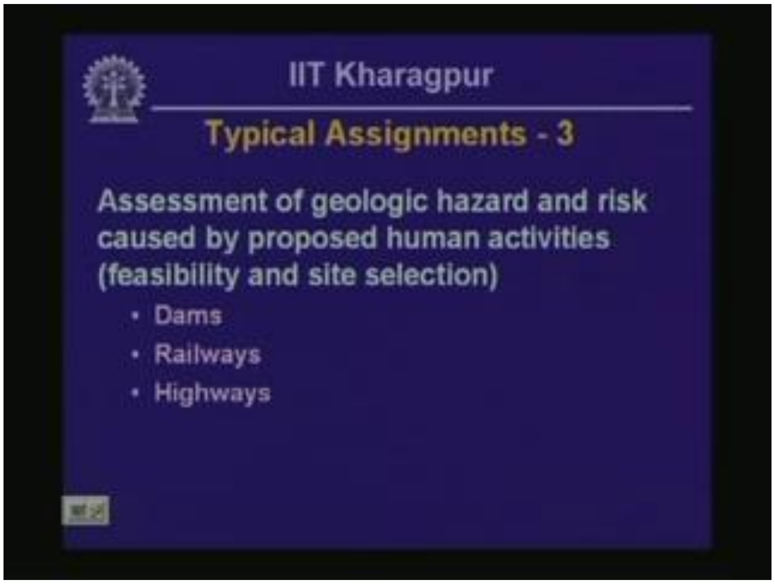

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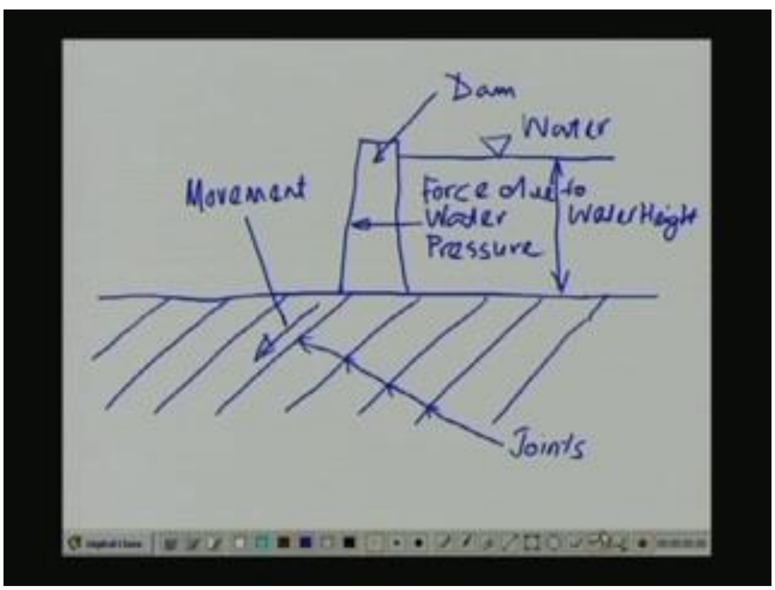

We all know that rock masses are comprised of joint sets. Now, let us consider a dam to be constructed on top on the rock mass that has got a joint set identified to be aligned like that is shown on the sketch there. So, these are the joints in between relatively intact rock masses. Now say, we want to construct a dam, a gravity dam which is going to the resist the pressure due to water primarily by its self-weight. So, this is the dam and it is going to actually retain water of that much of height. This could be depending on the dam height; the height of reservoir would be several hundred feet.

Now, this type of alignment, it is this type of alignment is not really preferred by engineering geologists because the pressure of water which is going to act in that direction that has got a component which is going to cause which is going to or which might actually trigger instability in the rock joints in that which are aligned as shown in this sketch. So, this kind of movement might be triggered if a dam is constructed as shown on this sketch.

Now, if the dam on the other hand was to be located such that the water was on the other side of the dam like let us modify this sketch to show what I mean. So, we just modified the sketch.

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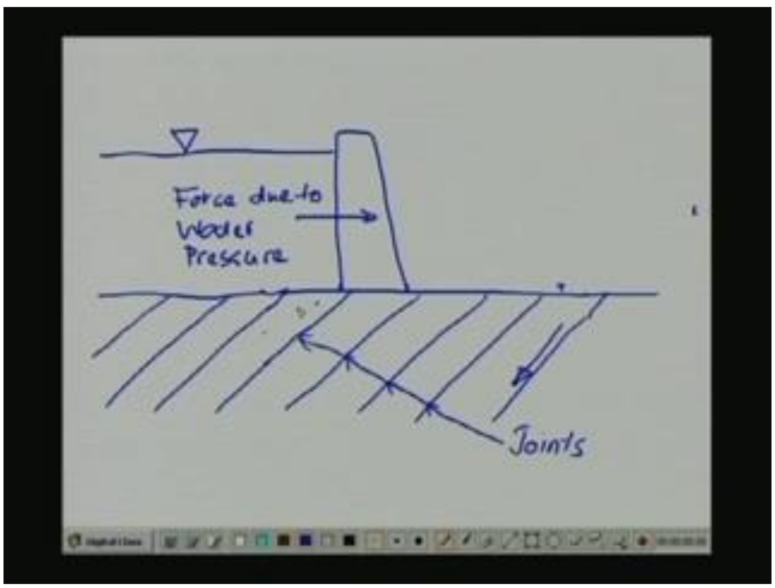

We kept the joint set intact but here we are going to construct the dam in such a manner that the water is on the other side with respect to the orientation of the joint set. Now, in this case, the pressure due to water is going to be aligned in the other direction and the force aligned like this is unlikely to trigger any instability along the joint sets oriented dipping in that manner. So, this is a preferred orientation of the dam.

So, if an engineering geologist is entrusted with a site selection for a dam site, he is going to he or she is going to look at these aspects of rock characteristics of course. I mean these are not the only aspects; you should realize that in this introductory topic, we are just trying to get a flavor of what is going to be generally expected in this field in the subject of engineering geology. So, we are not covering all the different aspects that are going to be considered while selecting a dam site. We are going to do that thing later on when we take these subjects up in more detail in due course of time.

So secondly, let us consider a railway project or for that matter, a highway project. These things are called liner developments because they have got a long, they are relatively long corresponding to the lateral extent of the right of way. Now, let us consider a typical linear development, it could be railway or it could be a highway or it could be a pipeline for that matter. Now, what are the considerations that come in selection of a route for a railway or a highway or a pipe line? Now, what has been known for a long time is that clayey sub-grade situation poses a lot of problem in this kind of development because clays tend to settle or they tend to behave in a problematic manner, they tend to develop uneven deflections or deformations under load over the course of the project life.

So, what is normally done is that if there are clay pockets, they are generally avoided while deciding a route for the highway or a railway or any other type of linear development. What I mean by that? Say, you want to go from point A or you want to construct a highway from point A to point B. Now, there is a clay pocket; we are actually looking at a map area in this sketch. So, what we are looking at? We are looking at a plan view. As I was mentioning, we are trying to construct a highway for point A to point B and in between point A and point B, there is a clay pocket which is as shown on this sketch.

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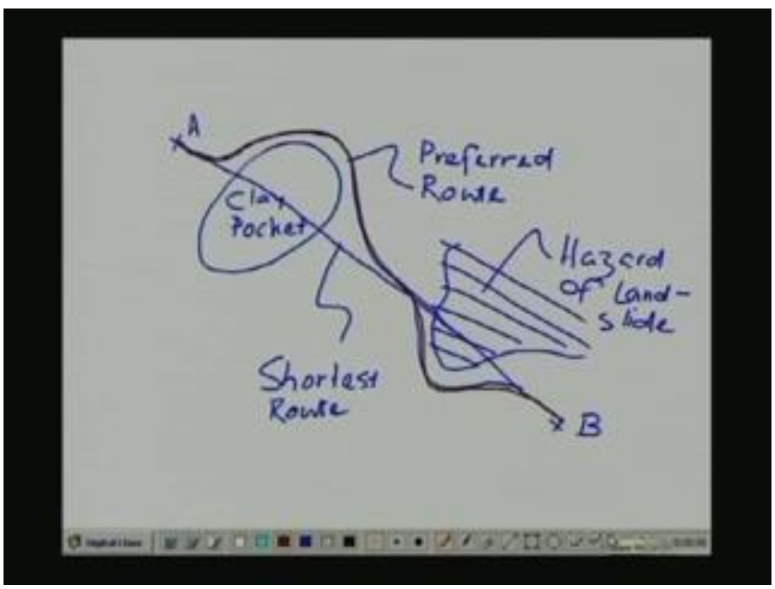

Now, the shortest route from A, point A to point B is going to cut across the clay pockets. Now, as I was mentioning, the clay pockets are normally notorious in terms of posing maintenance problem over the course of the project life. So, these things are normally avoided and a route that might be selected may be like this. So, this is a preferred route perhaps whereas this was the shortest route. Again, there may be other considerations depending on a local terrain or topography that may come up in this regard like may be, over in this portion of the alignment, there is an excessive hazard of landslide. So again, the engineering geologist may actually recommend that the route of the linear development from A to B follow the outer periphery just outside of the land slide hazard zone.

So finally, what we end up with? We end up with a route which is perhaps going to be like this; this is not the shortest route and how the route is going to be aligned; it is going to be decided in a close consultation with the engineering geologist. So, that kind of gives a general idea about what kind of assignment that you might expect while working as an engineering geologist. Now, who are the end users of the expertise?

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End users as was very clear from the discussion that we had so far; the end users include mining and forestry industry, they are very heavily reliant on the knowledge of engineering of geologist, then regulators and developers, they are also heavily tapped into the expertise of engineering geologists. Land use planners, linear facility developers, project engineers and designers; they are actually some of the beneficiaries of the knowledge of the engineering geologist.

Now, we are at a stage when we can take up a couple of example problems that you might actually have to deal with if you work, if you decide to take a career of engineering geologist. One of those concerns is mass wasting.

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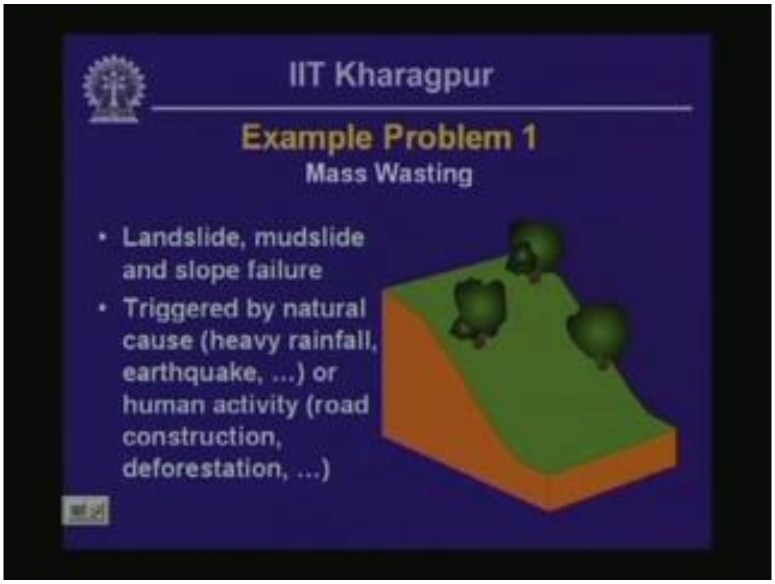

What do you mean by mass wasting? Mass wasting includes landslide, mudslide or any other kind of slope failure like rock slide or debris flow, rock avalanche; any of those type of problems that is dealt will classify as mass wasting. Now, mass wasting can be triggered by natural cause like heavy rainfall or earthquake or it can be caused because of human activity like road construction or deforestation. What do you mean by that is for example if we actually, if there is a hill slope which looks like that which is originally stable and we are looking at section here and then we decided to cut steepen the hill slope so as to accommodate a road way and this type of steepening of the hill slope may actually trigger, may actually trigger a landslide like in this, like this manner.

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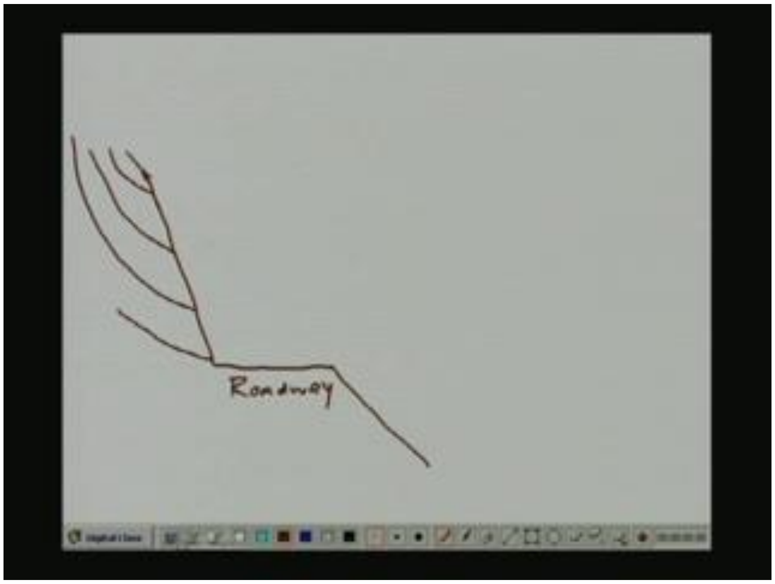

So, over steepening of slope because of any construction activity may actually make an area susceptible to landslide or slope failure. Similarly, if the hill side is afforested and we actually indiscriminately cut down the trees, that is also going to increase the chances of slope instability.

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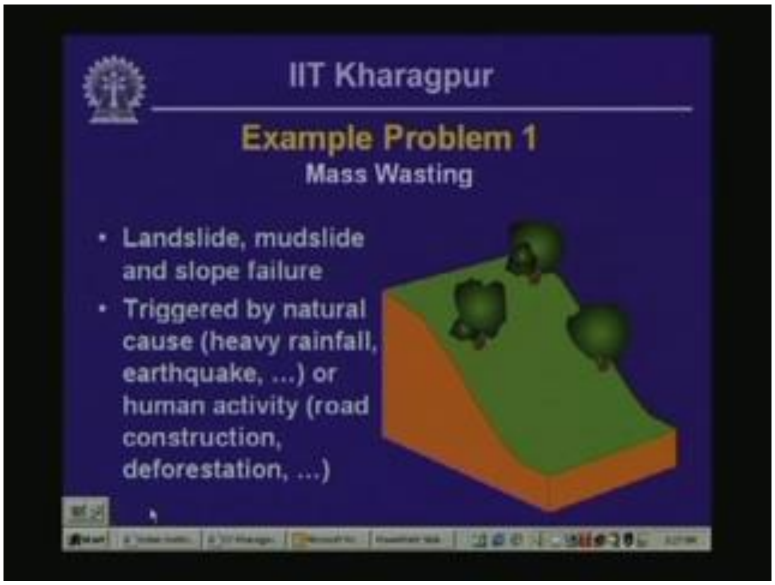

Now, in order to illustrate what we mean, we actually consider a configuration of slope which is shown, which is shown on the sketch there and what I actually … at the, before the slope failure and the alignment of the trees and other things. So, you just have a close look at the sketch that is shown on the right-hand side of the slide there. So, all the trees are upright and we do not have any indication of slope failure as yet.

Now, we move on to the next slide in which we are going to see an animation of slope failure. I again, I want to you to see what happens to the orientation or to the uprightness of the individual trees and you just take a close look about what are the other features that you can identify during the mass wasting process.

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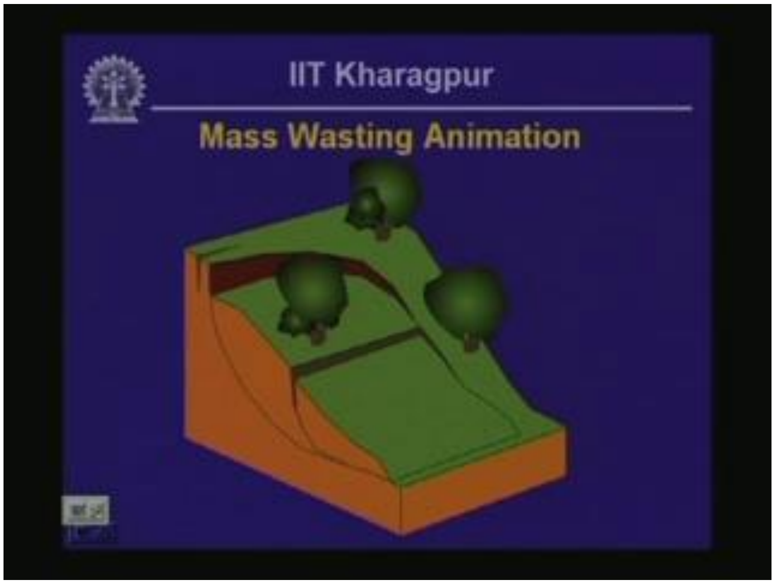

Now, what we see here? First of all, we saw that there was a crack that developed near the top of the slope. That was kind of a precursor in the problem of impending slope failure. So, there was a development of crack near the top of the slope and then what we saw is that a crack that actually opened up again near the top of slope from where the sliding mass actually came tumbling down. So, this is called the main scarp and then there were other scarps that developed in the process of slope failure. We saw that this tree which was originally upright got titled in the process of slope failure. We also saw that there was a bulge that appeared near the bottom of the slope which is also called the toe of the slope. So, this thing is called, we could call it toe bulge.

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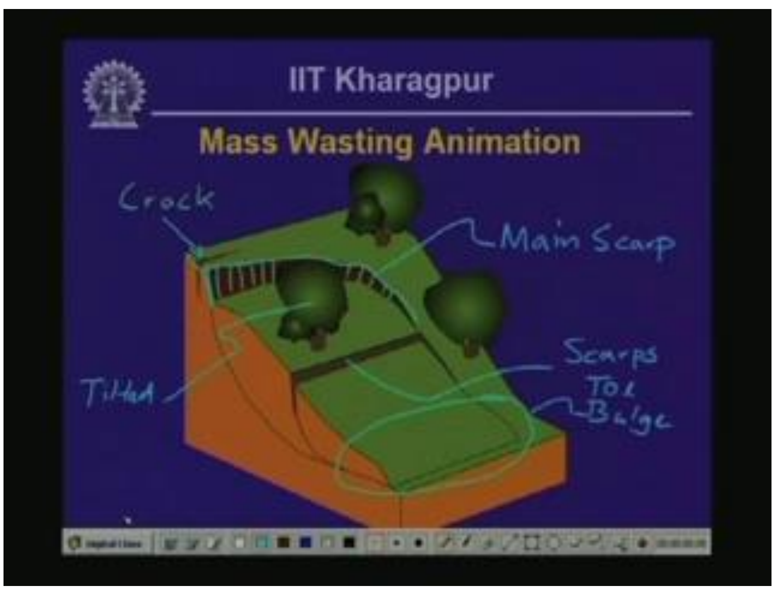

So, what is the precursor then of the slope failure? If you see that a crack is starting to appear near the top of a relatively steep slope, then that that is considered sometimes as a precursor to an impending slope failure. What is actually an indication of ongoing slope instability? All the other features that I actually marked here like presence of a main scarp which is on one side is a relatively flat slope in the other side the slope is relatively steep and more steep compared to any other portion of slope; that is an indicator of ongoing slope failure or a process that has been there that develop developed over the recent past.

Now, if this feature is very old, then what is going to happen of course because of erosion is; the steep portion, the steep portion of the main scarp is going to flatten out and the area is going to be again vegetated. So these things, this feature is going to vanish, this is going to be erased, erased by you know as the time progresses. If you see toe bulge near the bottom of the slope; not one bulge actually, there could be hummocky topography comprised of several different bulges, that is also indicative of an impending or ongoing or earlier slope instability.

So, these are the things that geologists are going to look for to find out whether a slope is going to be stable or it has got some likelihood of getting mobilized by I mean, there is the possibility of slope instability.

Now, this is what we discussed just a little bit back; the precursors to slope instability is that if there is appearance of crack or if there is a seepage coming out near the bottom of slope, that is an indicator of the impending slope instability. Then other indicators of ongoing or slope instability in the recent past includes uneven ground surface near the bottom slope, then there are scarp like features along the slope face or tilted tree or tilted telegraph poles or any other type of man-made thing that got tilted that was constructed originally in an upright geometry which is now tilted; so these all things are considered as indicators of slope instability or mass wastage.

Now, the other problem, another example problem that we are going to consider here is ingress of salinity.

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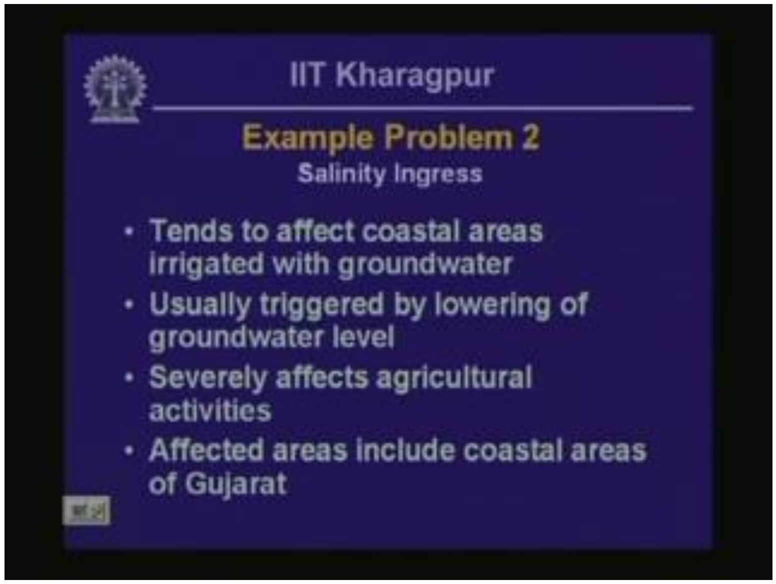

What actually causes ingress of salinity? Ingress of salinity is caused in the coastal area because of heavy tapping of ground water resources. If ground water is tapped more than the replenishment of ground water because of rainfall or other types of precipitation that causes a draw down in the ground water and when the ground water gets drawn down, then in the coastal area, saline water gets into the I mean, it gets further inland and that actually makes the ground water wells and other things, brackish; I mean, all the ground water resources that can be tapped become brackish. So, we are going to look at how these things develop over the next couple of slides.

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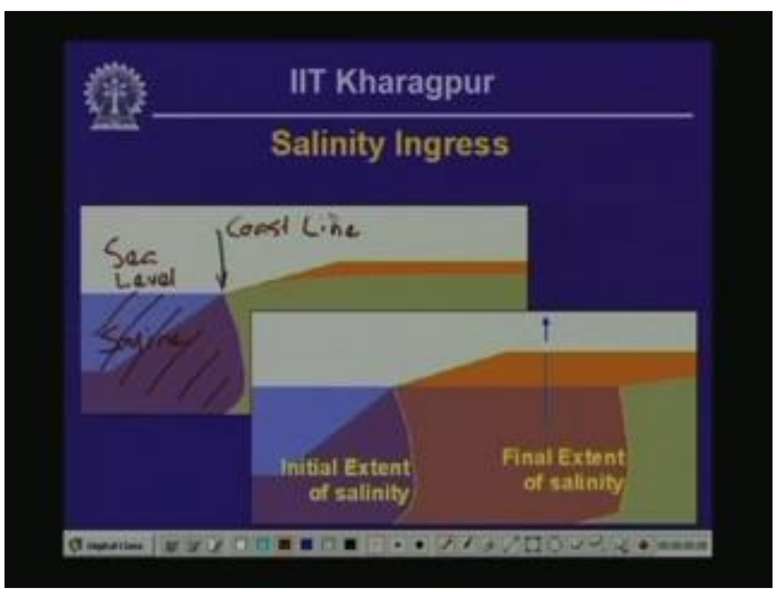

So, what we begin with? We begin with geometry like that, again we looking at section here where we have got a coast line; this is the coast line and that is the sea level. So, this water here, this one, this is actually saline water and the water on the right hand side is fresh water. So, what we consider here? We consider that a well, water well, irrigation well is installed at that location and in the next slide we will try to see, how the initial extent of salinity progresses to a location which is farther, quite a ways on the inland.

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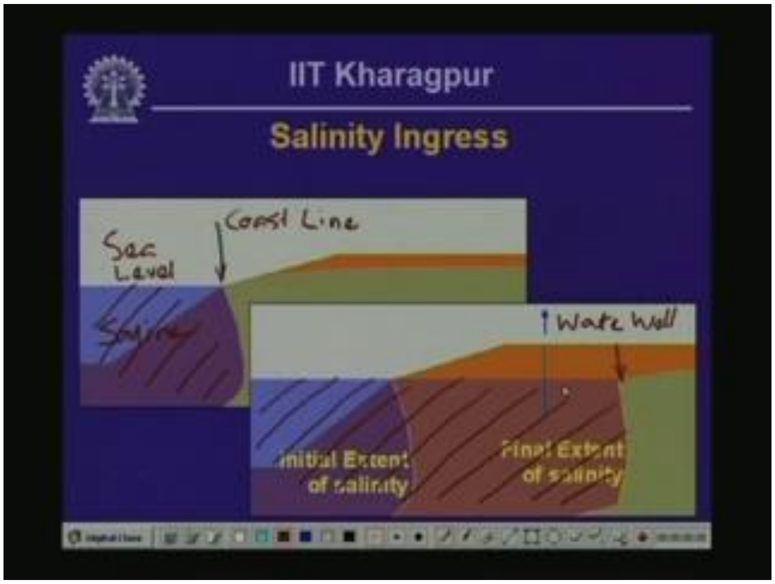

So, you can see what happens actually? What is the outcome of this is that the water well is going to actually start taping brackish water in this kind of situation because the entire water from the sea coast to this much far inland has become saline. How does it happen?

This actually shows an animation which will let you see how saline water which was initially at that location there, it progresses in land. Now, water table has drawn down upto that level because of ground water taping. Now, what happens actually? Let us start it again. What happens actually? Because of the draw down, the slope of the top of the ground water actually pulls the saline water further inland and because of the fact that brackish water is heavier than fresh water, the water that gets on top of the fresh water that actually pushes the fresh water out and in that process, the brackish water is going to make an advance upto the extent that is shown on this particular slide.

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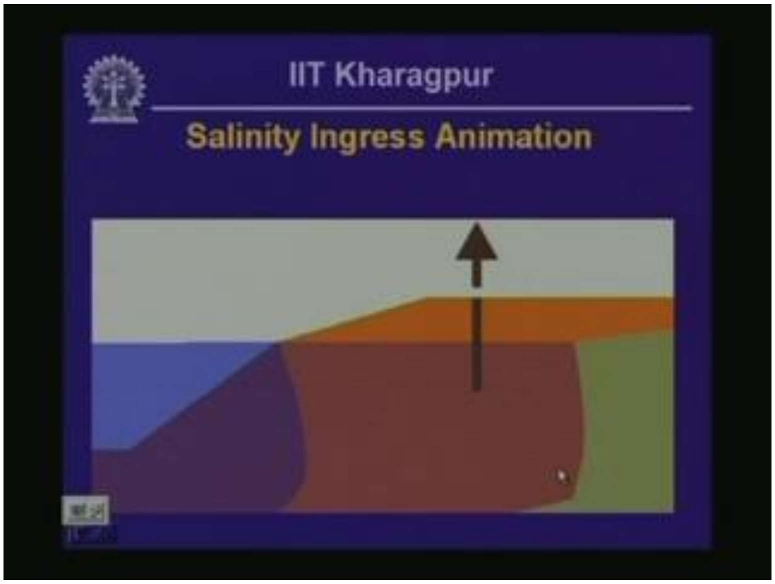

Let us look at it again; pay a careful attention to the sequence of events. So, this was the original configuration.

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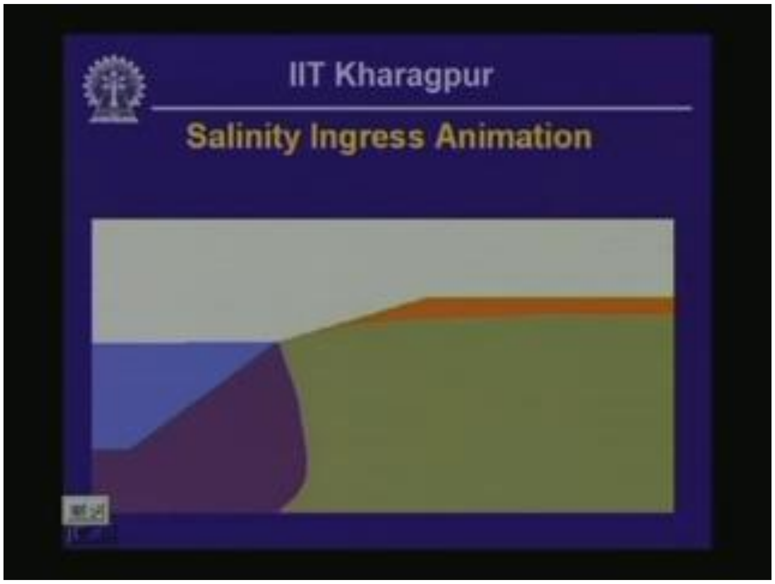

This is when the water was pushed on top of the original refresh water.

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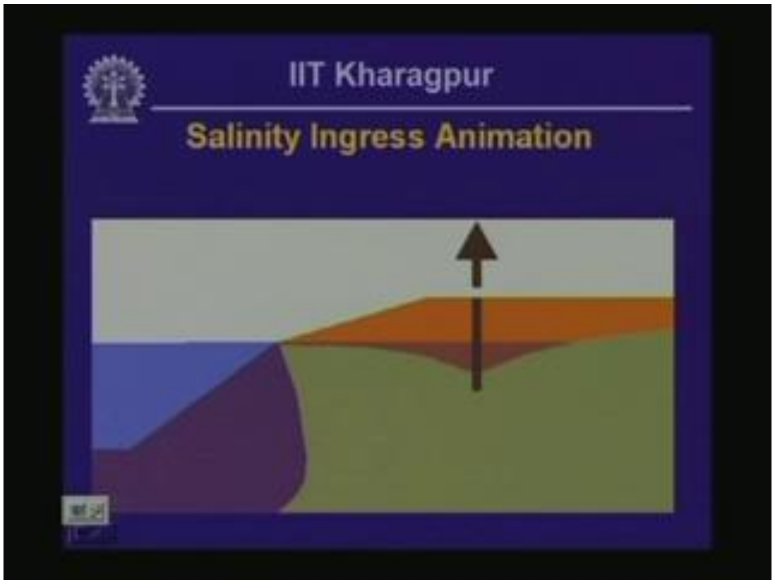

And now, it is going to push everything down because of gravitation, because of gravity.

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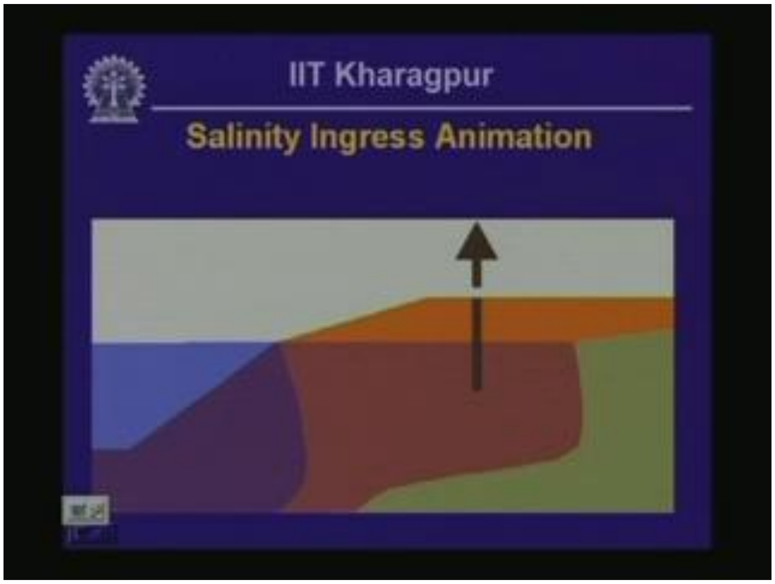

And finally, we end up with brackish water upto that location. So initially, so this is the final extent, if you recall, this is final extent of salinity and as I mentioned earlier, this was the initial extent of salinity. Once again the water that is being tapped by this water well is tapping into brackish water only. So, whatever area this water well is going to start irrigating that is going to be affected by salinity.

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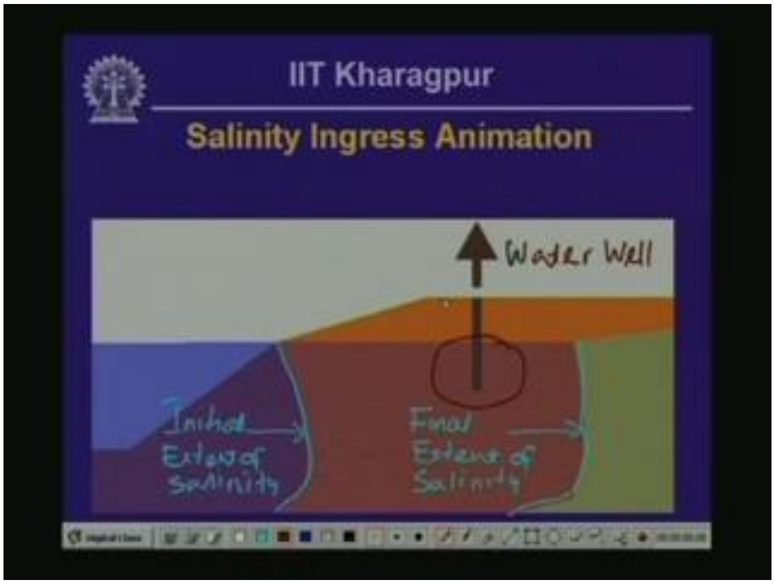

So, salinity ingress; what the precursors? A precursor is that if you have got seasonal or temporary salinity showing up in irrigation water that could be considered as a precursor of salinity ingress. Now, what are the fixes? The fixes are restricted groundwater use of course and facilitation of recharge. Now, how much groundwater one could safely tap in this kind of situation is often quantified by engineering geologists. In the final segment of this particular lesson, we are going to look at what are the historical developments that have led to the current state of understanding of the subject of engineering geology.

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Now, use of geological resources and heavy construction actually dates back to several thousand years. One could, for example, given is example of mining and metallurgy, then religious or ritualistic facilities, ports, lighthouse and bridges construction. Occasional knowledge of what works and what does not works was there for development of this particular heavy construction. But what was not there is a scientific understanding of why a certain thing works and why some other things do not work.

So, what I want to highlight here is that there has been history which dates back several thousand years of heavy construction, I mean extremely large civil engineering project we can think about; like for example pyramids of Egypt or Taj Mahal I mean, we can take about several different heavy construction activities over the history of human kind. But most of the time, these things relied on the knowledge on rules of thumb that told the construction people whether something is going to work or something is not going to work.

So, what I mean by that is that say, you have got a, in several different occasions what was found that mid ways into the construction project, one had to actually change the entire sequence or entire drawing, entire details of project in order to make the project a success. This was quite primarily because of the fact that there was no knowledge, no scientific knowledge that from which one could predict, the engineers could predict whether a certain type of construction can be successfully implemented or not.

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Now, other thing is the next bit of development took place after the eighteen hundreds and this is when the transition from the approach based on the rule of thumb to the scientific approach began and this was primarily pushed by the advancement I mean by the advancement of the human civilization into areas which was not inhabited for the most part. So, what happen because of those spreading of human settlement is one of which was railway construction. Railways, railway construction was a prime investigation of the developments of that we get to see today about of many different aspects of engineering geology. Then this happened, actually this thing actually happened between eighteen hundreds to early ninety hundreds. Then early nineteen hundreds to mid nineteen hundreds, what happened actually were development of several analytical techniques and emergence of geotechnical and geological engineering in the process. Scientific knowledge, quantified I mean, calculative approaches to implement different scientific knowledge was actually started to develop in this particular time frame.

Now, after mid nineteen hundreds to present, the development is mainly in the area of instrumentation or different ways of investigation process and remote sensing; these are the different types of, different areas that actually developing since the mid nineteen hundred and in this process, the sensitivity of human kind towards environmental protection also increased. So, another branch of engineering that actually bifurcated from the general area and that was geo-environmental engineering. So, that was, in a nut shell was the historical development that led to the current state of the practice in engineering geology.

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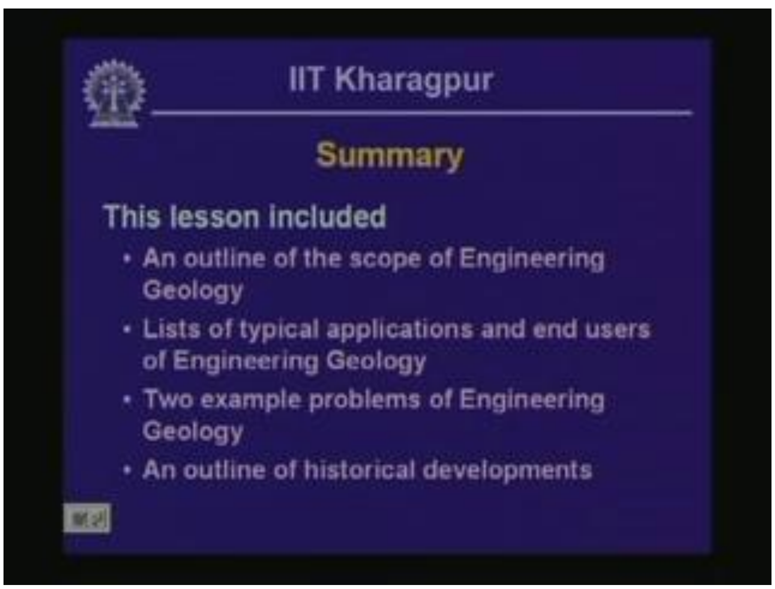

So, now we try to summarize actually, what was discussed in this lesson. So, we actually presented an outline of the scope of engineering geology; what is the definition and what are the different types of problems that we consider in engineering geology, what is the approach typical approach and end users that we encounter while working as an engineering geologist, then we actually considered two problems of engineering geology to give a flavor really about the general nature of problem that you might actually come up with or you might actually encounter during this of course and finally we considered a very brief point form summary of the historical developments that actually let to the present state of practice in engineering geology.

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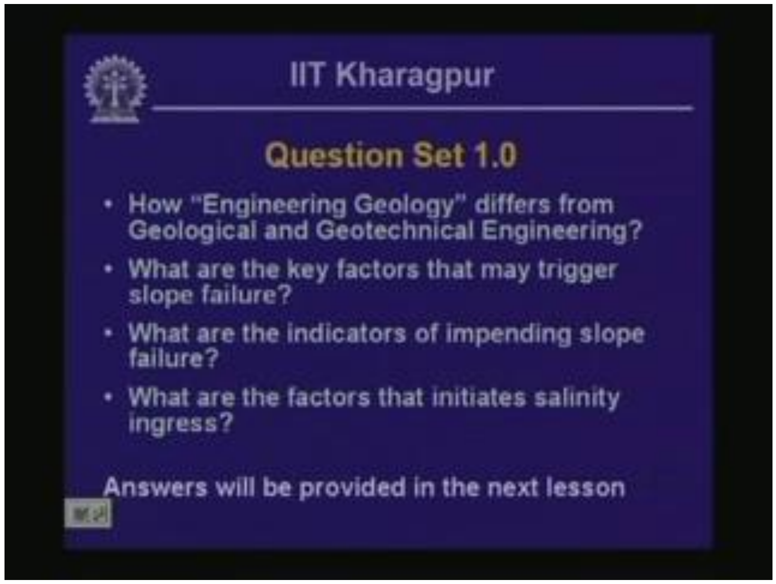

And to conclude, we actually leave you with a question set and just note down these questions and try to answer these questions in your leisure. Some of the answers were very obvious from what was presented in this lesson and some of which you have to think a little bit. Try to develop all the answers yourselves and we are going to actually give you brief answers when we meet in the next class of this series of lectures.

Thank you very much.

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Hello everyone, welcome to session 2 of the series of presentations on engineering geology. In this session, we are going to talk about geologic structures; different types of land forms and will try to recognize what are the various land forms that one might have to encounter while working as an engineering geologist.

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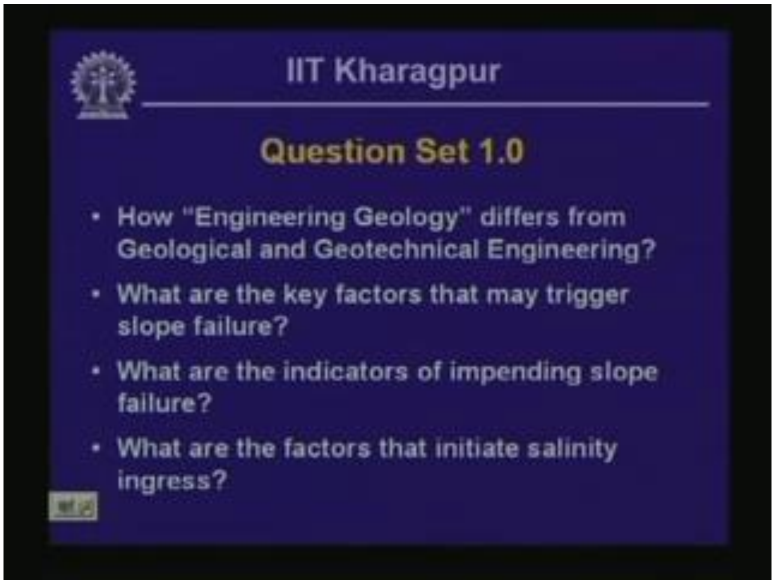

But before we get into the subject matter of today's presentation; I am going to take up the question set that I gave in the first of this series of lectures and I am going to try to provide you the answers of the question set.

The first question that we had in the last presentation was; how engineering geology differs from geotechnical and geological engineering? Now, the difference is essentially very tenuous. Only thing that I can think about is engineering geology is more inclined towards the geologic maters; while, geotechnical and geological engineering deals primarily with the mechanical aspects of the different problems that are encountered in engineering geology.

Then the second problem, the second question that I asked was that what are the key factors that may trigger slope failure? Two of the major factors that cause slope failure are loss of strength, loss of shear strength of the material of which this slope is comprised. The major reason for the loss of shear strength is basically … ((55:35))

We now try to understand try to get an idea about different types of lands forms that one might have to have encounter in a fluvial …. ((55:51))

Set of questions that you should try in your leisure and again as we did in the last presentation; I am going to provide brief answers when we meet for the next lesson. You should try to explain the dip, strike, anticline and trust fault and loess and you should explain …. ((56:24))

Whereas dunes are generally underlain by sand grain deposits; we could also have glacial deposits.

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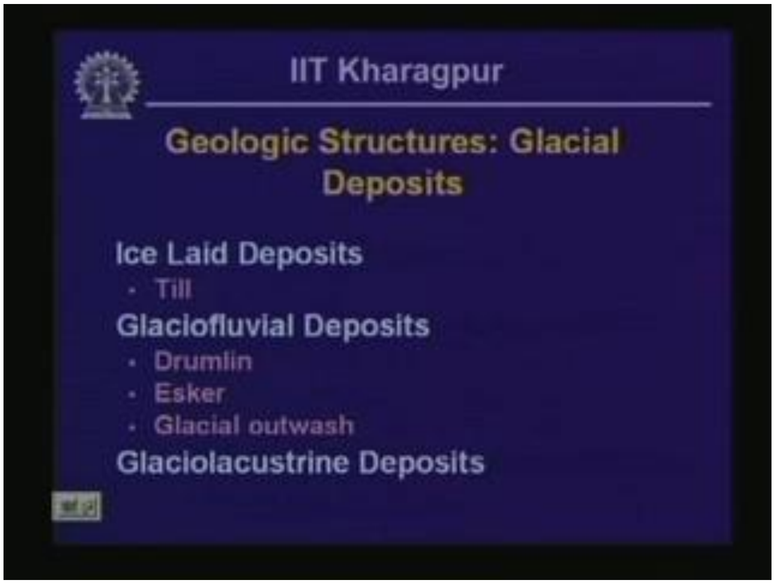

Glacial deposits are listed here and they are generally laid by ice. So, if they are directly laid underneath ice, they are called till. There could be glacial fluvial deposits, melt water that originates from melting of glaciers like drumlin, esker or glacial out wash. Now these things, typically are elongated in the direction of the ice flow with their slope in the direction of ice flow; in the up ice direction is generally gentler compared to or generally steeper is comparison with the down ice direction.

There could be glacial outwash deposit that are comprised of basically sand and gravel deposits or there could be glaciolacustrine deposits that are find grained deposits underneath glacial lakes. That in a nut shell summarizes different types of land forms.

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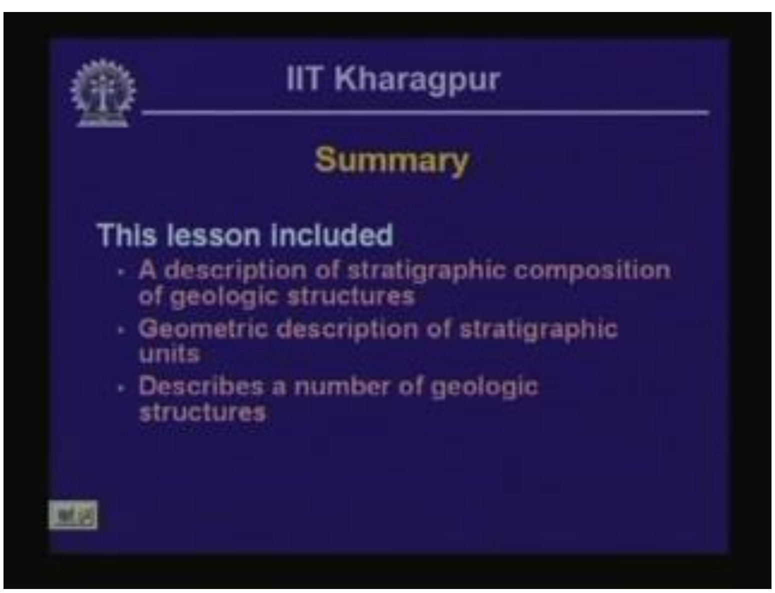

We looked at descriptions of different stratigraphic units, we looked at how to define them geometrically and we looked at, we tried to list a number of landforms that are encountered often in the branch of engineering geology.

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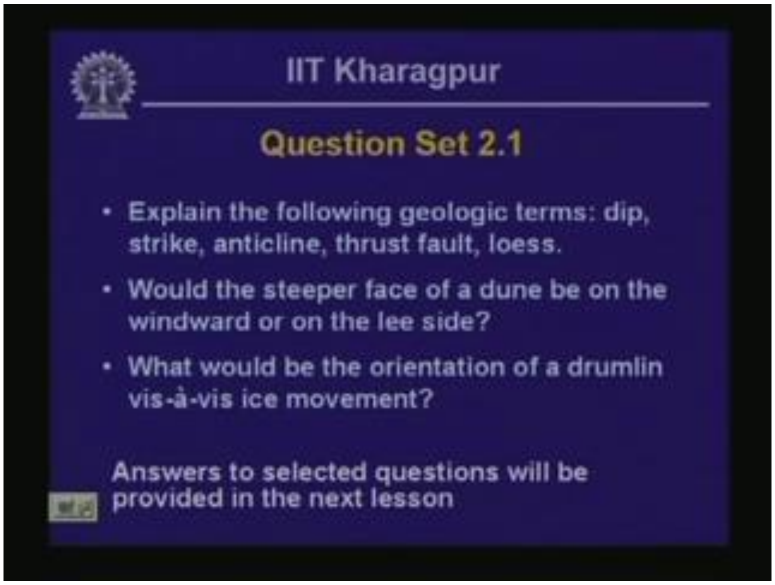

We finally end the session with the set of questions that you should try in your leisure and again as we did in the last presentation, I am going to provide brief answers when we meet for the next lesson. You should try to explain the dip, strike, anticline and trust fault and loess; you should explain the slope on the windward and the lee side whether the slope of the dune is likely to be steep on the windward or on the downwind directions that is the lee side and you should also try to say, try to answer whether a drumlin, what is going to be an orientation of a drumlin visa ice movement.

So, you try to answer those questions and I am going to provide the solutions when I meet you again for the third of the series of presentations.

Thank you very much.