Earth Sciences for Civil Engineering Part-2
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Introduction to Geological Hazards and Environmental Impact (Part-2)
Module 1
Lecture No 2

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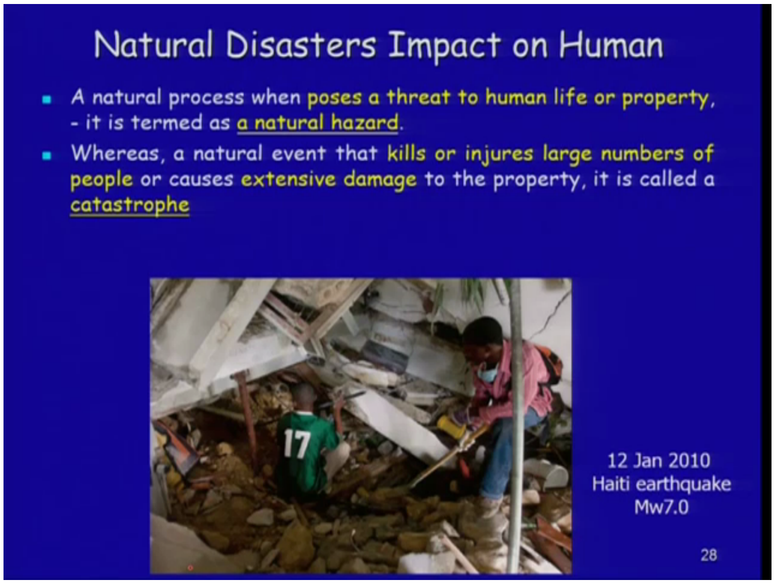

So let us talk in few slides about the natural disaster impact on human okay so a natural process when causes a threat to human life or property, it is termed as natural hazard whereas a natural event that kills or injures large number of people or causes extensive damage to the property, it is called catastrophe. Many geological processes are potentially hazardous for example floods, earthquakes, Tsunamis, cyclones etc.

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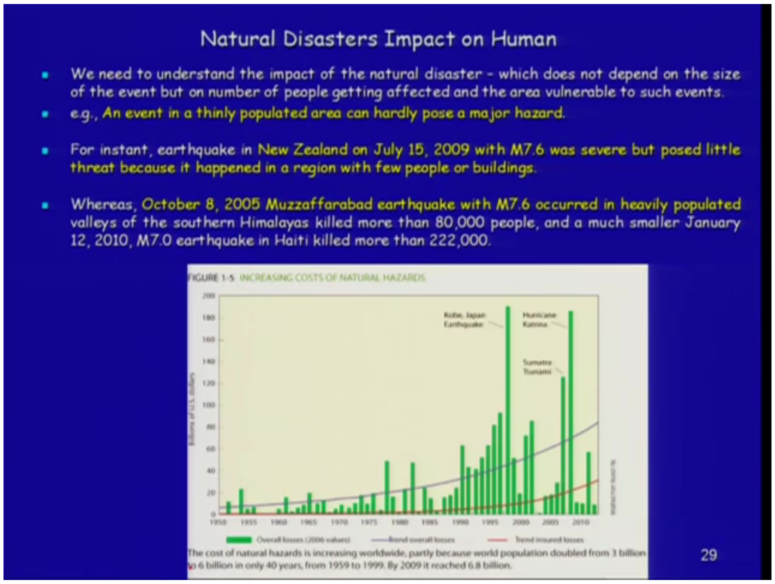

Now we need to understand the impact of natural disaster which does not depend on the size of the event but on number of people getting affected and the area vulnerable to such events okay. So if less number of people are affected, it is not, these processes are not hazardous at all okay so example, an event in thinly populated area can hardly pose any major hazard so hence those events are not hazardous to us okay but if you have more people which are exposed to such hazards, definitely that events are hazardous to us okay.

Now, there is an example from the earthquake which occurred in on on 15th July 2009 with the magnitude of 7.6, the (magn) magnitude, according to the magnitude, it was a severe event but posed little threat because it happened in a region with few people or buildings okay so it was not very hazardous for that particular region okay but other case if you take that this 2005 Muzzaffarabad earthquake with similar magnitude of 7.6 occurred in heavily populated region in Himalayas killed around 80000 people.

And a much smaller earthquake with magnitude 7 in 2010 in Haiti, it killed almost like people more than 2 lacs okay so this is one of the the reason that we need to understand that where the event will occur and how many people are going to be affected by that okay and accordingly things have to be taken into consideration in terms of the mitigation and all that so this is to show that over the time the loss of, that is the (com) the property and all that okay population has doubled almost and the the the loss is becoming higher and higher day by day. This is 1995 Kobe and this is Tsunami and you are having the hurricane here okay.

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Now this the again the similar case if we take, on 2008 cyclone in Myanmar killed around 1.3 lac people okay and mostly in the rural areas because they were absolutely not prepared and no proper evacuation was been taken into consideration okay. Whereas if you take in terms of the the was Super typhoon which was categorized as category 5 storm okay passed directly over the northern islands south of Japan but it resulted no deaths okay because very few people live in that area.

Whereas in terms of here Myanmar, it was so severe cyclone or the storm which can be categorized as 5, under the category of 5, it killed many people. Again example from US, the eruption of volcanic eruption which took place on Mount St. Helens in 1980 caused very few fatalities because many ub the population was very sparse in that area but it in case of Italy, this was a very major even which took place okay. The volcanic eruption of Vesuvius, it resulted into killing of hundreds of thousands of people okay so natural processes become hazardous only if they are going to affect more number of people.

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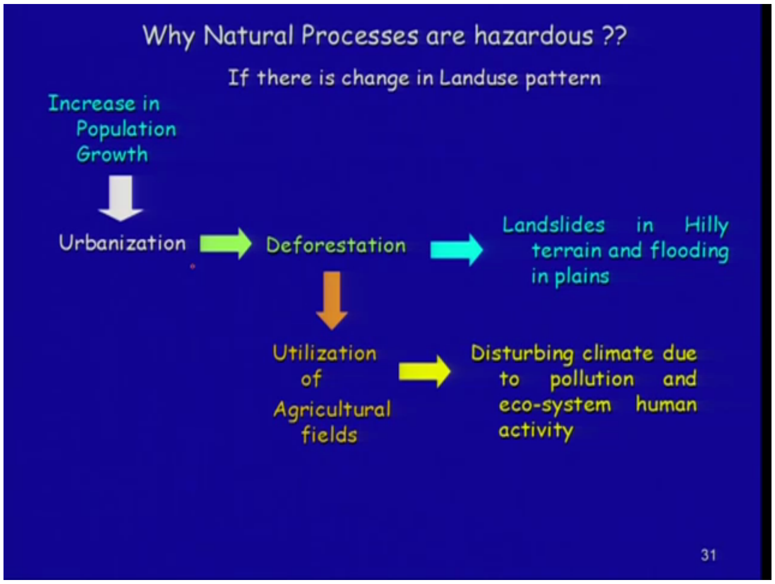

So natural processes are hazardous if there is a change in the land used pattern so in the initial slides we were talking about that increase in population is one of the major factor why these processes are becoming hazardous okay because increase in population has exposed more number of people to such natural processes and mostly in terms of we are moving at more and more people are moving towards urban settlements okay.

So organization has also affected the climate to some of some part and we have degraded the environment also okay because we are removing more and more number of trees and that is what we are doing deforestation okay which eventually can result into landslides in the hilly terrain and flooding in the plain areas okay. These plains are we are talking about the Alluvial plain very much similar to what we have the Indo Gangetic Plains okay and of course the deforestification, what we are doing, utilization of agricultural field and this will result into the the flooding, more flooding in the the urban cities okay because we are we lack in preparedness, we lack in planning also.

And then disturbing the climate due to pollution and eco system so by because of the human activities so these are the major reasons which are affecting the the natural processes also okay mostly the climate but the internal processes, you cannot disturb it all okay but more and more number of people are exposed to such hazards and we are we are having these problems increasing day by day.

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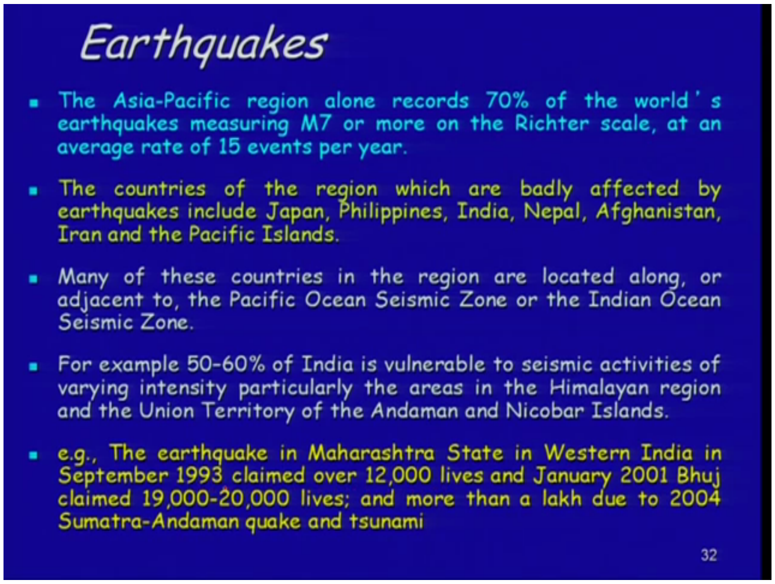

Now, coming to the earthquake part so in particularly Asia pacific region alone if you take, we have almost like 70% of the world's earthquake measuring 7 magnitude or more on the Richter scale at an average of 15 events per year. So this is absolutely very large number of this region okay. Then countries like Japan, Philippines, India, Nepal, Afghanistan, Iran and the Pacific islands okay these are the countries which are badly affected by earthquakes.

Then as we have discussed couple of them, of course they they are mega earthquakes from this region and many of these countries in the region are located or are adjacent to the subduction zones okay or we can say the pacific ocean seismic zone or the Indian ocean seismic zone and both of them have triggered like this one triggered 2011 Tohoku earthquake and this one triggered 2004.

So we have these are the regions which are affected or vulnerable to the the earthquakes, mega earthquakes okay and for example 50% to 60% of India is vulnerable to seismic activity of varying intensity particularly the areas in Himalayas and along the Andaman regions Okay. For example, if we consider the the Indian subcontinent, we had earthquakes within the plate and this is example from Maharashtra 1993 Killari earthquake and we had 2001 Bhuj earthquake.

Killari claimed almost like 12000 people whereas Bhuj killed around 19000 to 20000 people okay and Andaman, it was more than a 1 lac people were been killed so you can imagine that not a single area is been left out okay so we have Himalaya in the north, we have subduction zone in the east and we have couple of events which are taking place within the plate okay so we have like 2001 and 1993.

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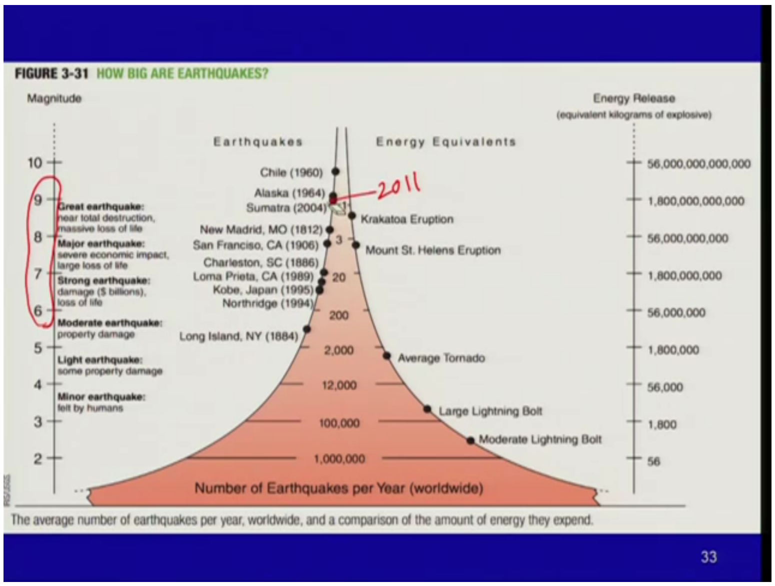

Now if you look at this information it says the average number of earthquakes per year worldwide and a comparison of amount of energy they expand okay, so you only if you look at the the magnitude which will be bothering us in terms of the damage, it will be above 5 okay so these are the magnitudes if such events occur, they bother us actually okay so it says that around the world between 5 to 6 almost like 2000 or around 6, 200 events will occur every year okay and if you go further up, 8 magnitude event will be around 3 of such type occurring around the world and between 8 and 9 or above 9, you will have the probability of occurrence of less than one events okay. So we had like this is Sumatra and then we had again another one over here, we can put okay, that was 2011 Tohoku earthquake so ub this will keep on occurring okay.

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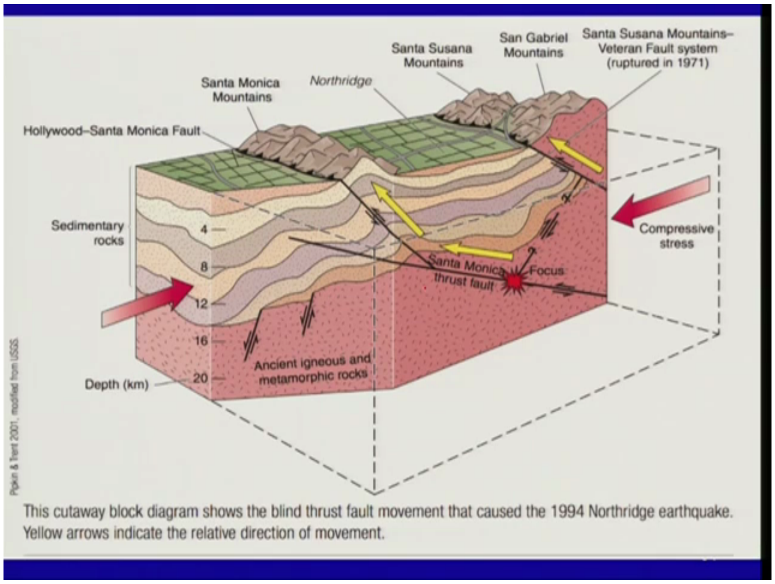

And I just want to mention a little bit here that with the advancement of the science and the the understanding of the hazard or people have done to save the property and life also okay so whenever there is an earthquake, there will be displacement which is coming right above the surface okay. So if you are going to put any lifeline structure on this part okay, you have to be extremely careful in having understanding that what will be the amount of displacement and what type of displacement will take place along this fault whether it is a thrust fault or it is a normal fault or it is seismic fault so this is extremely important. Along with that of course, we are bothered about that what will be the magnitude and how deep the earthquake will occur okay.

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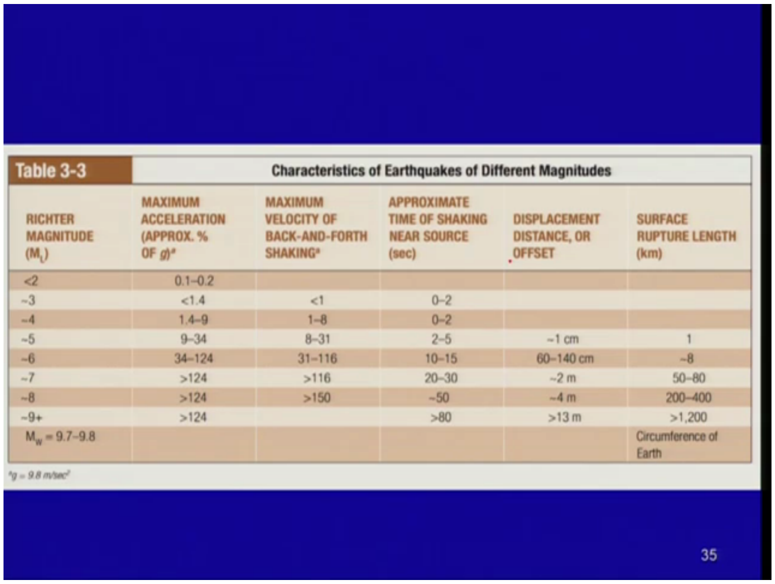

Table 3-3	Characteristics of Earthquakes of Different Magnitudes				
RICHTER MAGNITUDE (M_L)	MAXIMUM ACCELERATION (APPROX. % OF g)[a]	MAXIMUM VELOCITY OF BACK-AND-FORTH SHAKING[a]	APPROXIMATE TIME OF SHAKING NEAR SOURCE (sec)	DISPLACEMENT DISTANCE, OR OFFSET	SURFACE RUPTURE LENGTH (km)
<2	0.1–0.2				
~3	<1.4	<1	0–2		
~4	1.4–9	1–8	0–2		
~5	9–34	8–31	2–5	~1 cm	1
~6	34–124	31–116	10–15	60–140 cm	~8
~7	>124	>116	20–30	~2 m	50–80
~8	>124	>150	~50	~4 m	200–400
~9+	>124		>80	>13 m	>1,200
M_W = 9.7–9.8					Circumference of Earth

[a] $g = 9.8\ m/sec^2$

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So because along with the magnitude, the rupture areas will also vary okay. Of course the peak ground acceleration will also vary depending on different magnitudes.

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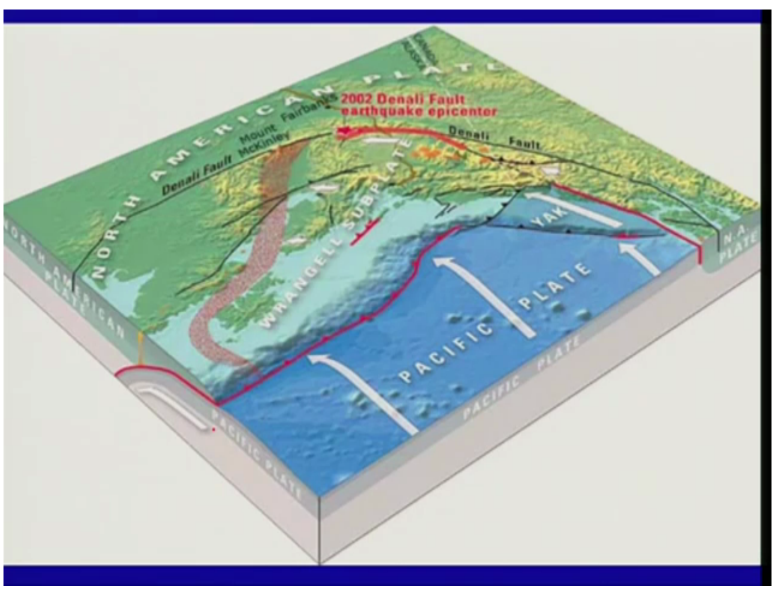

So this is an example which is which I I feel is one of the best to understand and to know that how they were able to save the structure which was crossing the the Danali fault. Now this is an example from US where pacific plate is subducting below the north American plate and it that has resulted into the formation of several active faults and one of the active fault which they mapped and they knew was Danali active fault okay on which they studied and they carried out the detailed study before putting an oil pipeline Okay.

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Taking it all in Slide —
How the Trans-Alaska Pipeline Survived a Big One

So let I will I will show what they did okay so this is what they they found okay so how the trans Alaskan pipeline survived the big one. The big one they are talking about the event okay so this even was it took place on in 2002 November 3 with the magnitude of 7.9 on Danali fault.

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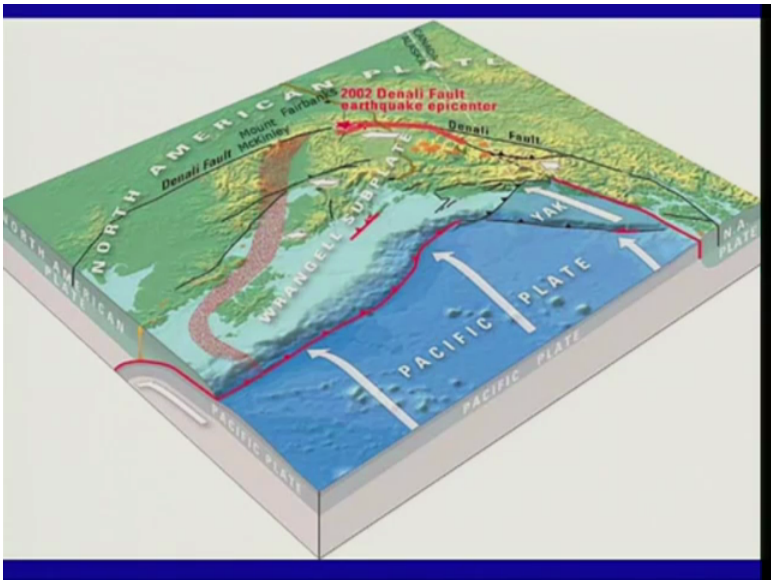

So this is in Danali fault and the proposal was that they wanted to put the the pipeline, oil pipeline and the pipeline was crossing this faults so initial plans were that the pipeline will go underground but later on when they knew of course that there is a fault here so they had detailed discussions and then the geologists, they took over the studies and they completed the detailed investigation and they identified that this fault, if it ruptures in future, it will have the displacement of almost like 20 feet okay.

And then it will move right laterally so they had the motion that in which direction it will move and what will be the pattern of the movement so they finally planned that let us put the pipeline over the surface so they brought on the surface and with an understanding that how much movement it will this fault will result when there is an big earthquake, they constructed or they designed the pipeline accordingly.

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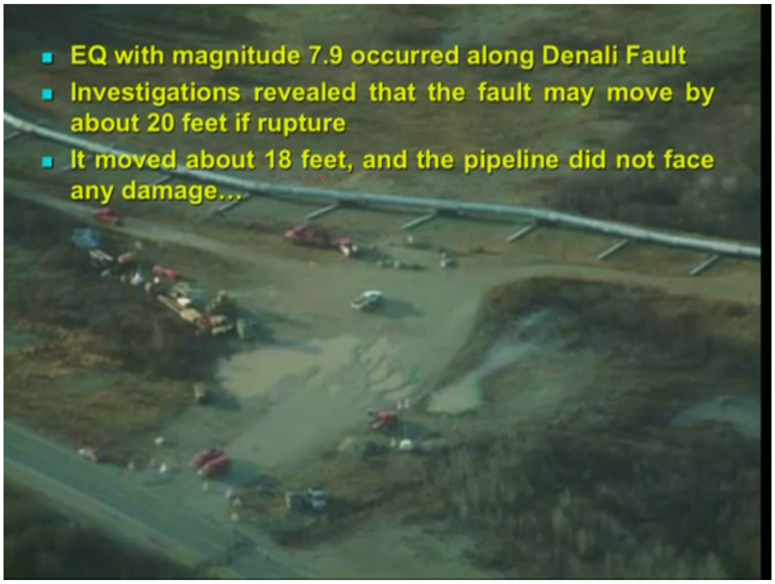

So what they did was they put the pipeline on surface and made it flexible in such a way that it can move on these are roller coaster on which they have put so so this and then the pipeline was quite flexible in that sense okay. So earthquake occurred with magnitude 7.9 and investigation that revealed that the movement will be of around 20 feets okay so the the pipelines are sitting on the roller coaster and then you are having this flexibility which accommodate the displacement and then it moved in 2002, the displacement was 18 feets okay and the pipeline did not face any problem.

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What happened was something like this okay so it was so flexible that it accommodated the displacement so Danali fault is over here Okay.

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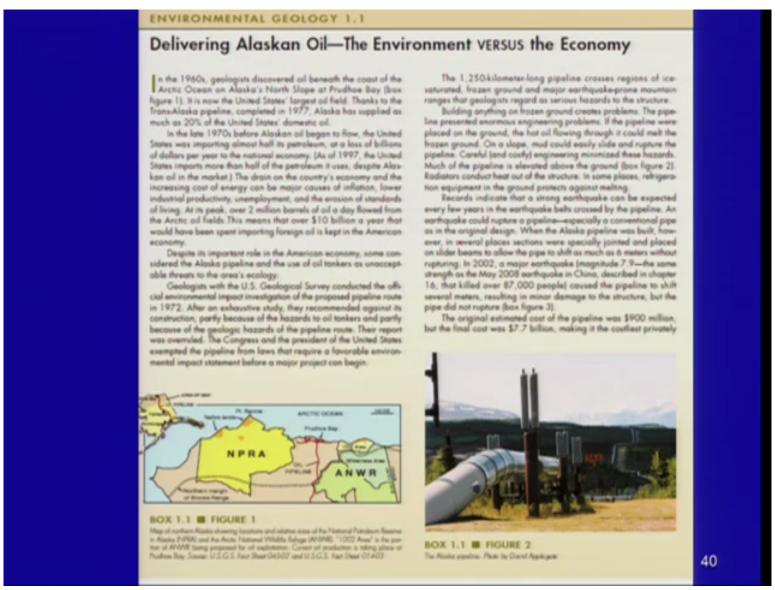
ENVIRONMENTAL GEOLOGY 1.1

Delivering Alaskan Oil—The Environment VERSUS the Economy

In the 1960s, geologists discovered oil beneath the coast of the Arctic Ocean on Alaska's North Slope at Prudhoe Bay (box figure 1). It is now the United States' largest oil field. Thanks to the Trans-Alaska pipeline, completed in 1977, Alaska has supplied as much as 20% of the United States' domestic oil.

In the late 1970s before Alaskan oil began to flow, the United States was importing almost half its petroleum, at a loss of billions of dollars per year to the national economy. (As of 1997, the United States imports more than half of the petroleum it uses, despite Alaskan oil in the market.) The drain on the country's economy and the increasing cost of energy can be major causes of inflation, lower industrial productivity, unemployment, and the erosion of standards of living. At its peak, over 2 million barrels of oil a day flowed from the Arctic oil fields. This means that over $10 billion a year that would have been spent importing foreign oil is kept in the American economy.

Despite its important role in the American economy, some considered the Alaska pipeline and the use of oil tankers as unacceptable threats to the area's ecology.

Geologists with the U.S. Geological Survey conducted the official environmental impact investigation of the proposed pipeline route in 1972. After an exhaustive study, they recommended against its construction, partly because of the hazards to oil tankers and partly because of the geologic hazards of the pipeline route. Their report was overruled. The Congress and the president of the United States exempted the pipeline from laws that require a favorable environmental impact statement before a major project can begin.

The 1,250-kilometer-long pipeline crosses regions of ice-saturated, frozen ground and major earthquake-prone mountain ranges that geologists regard as serious hazards to the structure.

Building anything on frozen ground creates problems. The pipeline presented enormous engineering problems. If the pipeline were placed on the ground, the hot oil flowing through it could melt the frozen ground. On a slope, mud could easily slide and rupture the pipeline. Careful (and costly) engineering minimized these hazards. Much of the pipeline is elevated above the ground (box figure 2). Radiators conduct heat out of the structure. In some places, refrigeration equipment in the ground protects against melting.

Records indicate that a strong earthquake can be expected every few years in the earthquake belts crossed by the pipeline. An earthquake could rupture a pipeline—especially a conventional pipe as in the original design. When the Alaska pipeline was built, however, in several places sections were specially jointed and placed on slider beams to allow the pipe to shift as much as 6 meters without rupturing. In 2002, a major earthquake (magnitude 7.9—the same strength as the May 2008 earthquake in China, described in chapter 16, that killed over 87,000 people) caused the pipeline to shift several meters, resulting in minor damage to the structure, but the pipe did not rupture (box figure 3).

The original estimated cost of the pipeline was $900 million, but the final cost was $7.7 billion, making it the costliest privately

BOX 1.1 ■ FIGURE 1

BOX 1.1 ■ FIGURE 2
The Alaska pipeline. Photo by David Applegate

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So in that case, that is what the example I was talking about that if you understand the hazard and where it will occur and what will be the magnitude of that hazard, whether it will be severe or it will be less severe or it will be extremely severe then you can plan the things accordingly okay.

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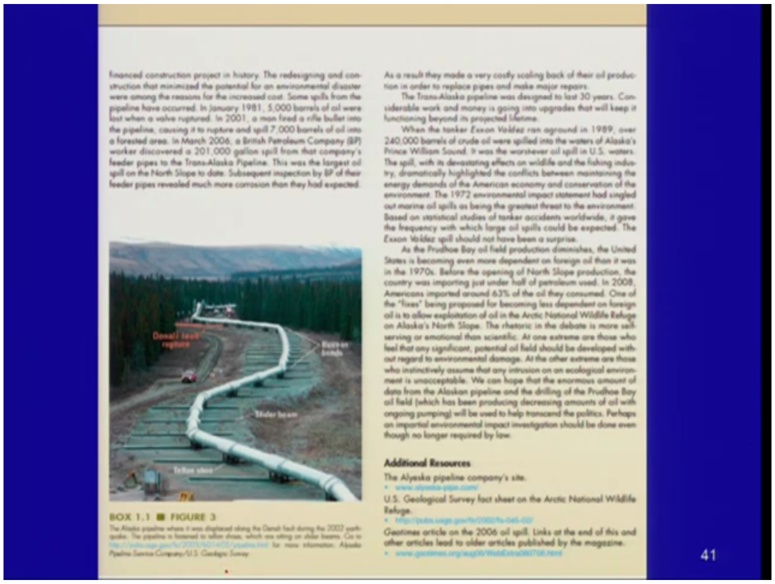

So this is one the best example which we have which saved the the pipeline okay. Similarly you can do about the structures and all that.

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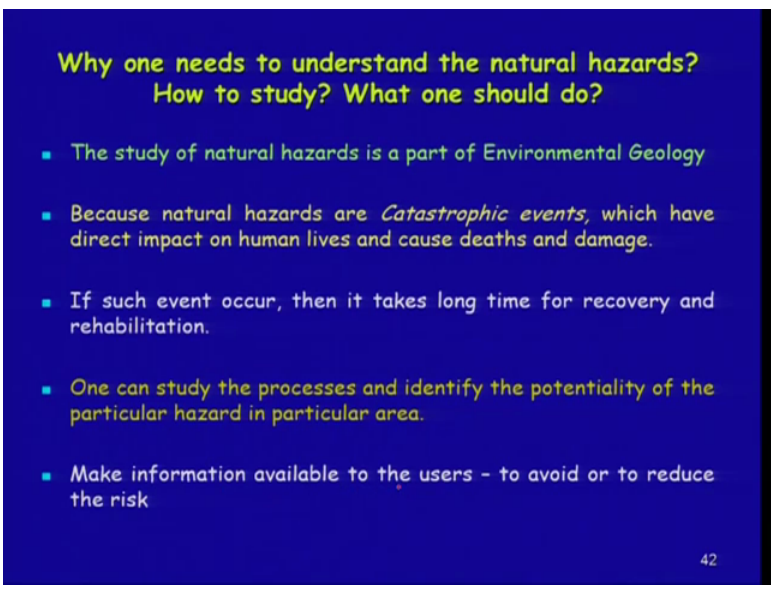

So why one needs to understand the natural hazard, how to study, what one should do? The study of national hazard is a part of environmental geology okay so in a broader sense, you can classify or categorize this and as an as environmental geology part okay because natural hazards are catastrophic events which have direct impact on human lives and causes deaths and damage so if event occurs then it takes long time for recovery and rehabilitation okay. One can study the processes and identify the potentiality of a particular hazard in particular area.

So for example, we were talking about Danali fault so knew the location okay and we knew about the particular hazard okay and the potentiality also so accordingly we design the the structure. So the another part and then this information is made available to the people then you can avoid and reduce the risk factor.

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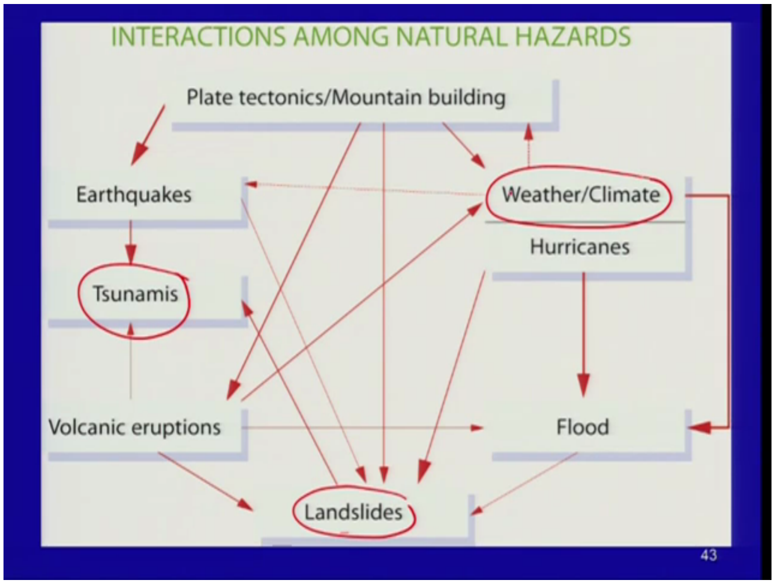

Now there is one a very nice correlation which has been done okay between the plate tectonics and earthquakes and other hazards okay. If you consider the the plate motions which discussed in the previous course okay, plate tectonics or mountain building activity will cause earthquakes, will cause Tsunamis also along the subduction zones and even it can result into the volcanic eruption okay. As well as the volcanic eruptions can also trigger Tsunamis and volcanic eruptions can also result landslides.

So if the volcanic eruption is taking place closed to the the ocean okay then it can result into the landslide and another part which I would mention here there is one more slide which we will be talking about the type of landslide or mud flow which can be resulted because of the volcanic eruption. Suppose a volcanic cone is been covered by snow here okay and if the eruption takes place okay then it will result into the snowmelt and that snowmelt will cause the mud flow and that is the the type of mass movement okay.

And further there is mountain building activity because of the ongoing deformation in the hilly areas will result into landslide. Earthquakes can result into landslides okay because strong round shaking will result into the loss of shear strength of the slope material which can trigger the landslide. Then landslide can trigger Tsunami so in ocean if you are having submarine landslide, large chunk of mass is been moved into the ocean and it the the the ocean water, the water column will be disturbed so this can also trigger Tsunami here.

Then mountain building activity will also affect the weather and climate so best example is that we had the plate (tecton) because of the plate tectonic movements and the the collision, the Himalayas were formed, that is mountains were formed and we had different weathers in the region okay so this is also interconnected or interrelated okay and then volcanic eruptions can also cause the change in the climate and weather because if we are having continuous volcanic eruption, lot of ash and carbon dioxide will be put in the the air and which can result or affect the weather and climate okay and weather and climate in turn will result into hurricanes or you can say storms or cyclones and then can result also into the flooding events okay.

And if you are having flooding it can result into landslides and also the weather, if you are having stream weathers you will have to face the landslide so please carefully goes through this chart which explains the interaction amongst the natural hazards okay. So in short I would say that these all processes are interconnected okay and will affect one another if there are slight changes taking place okay.

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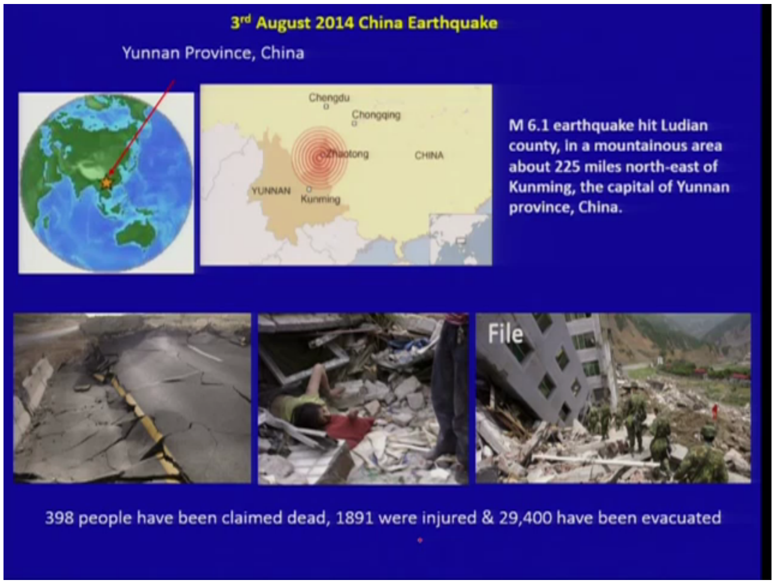

So there is an example of 2014 earthquake in China, the magnitude was not very um large, that was a moderate magnitude earthquake of 6.1 but resulted into severe damage but not many people were been killed. Around 398 people were been killed here.

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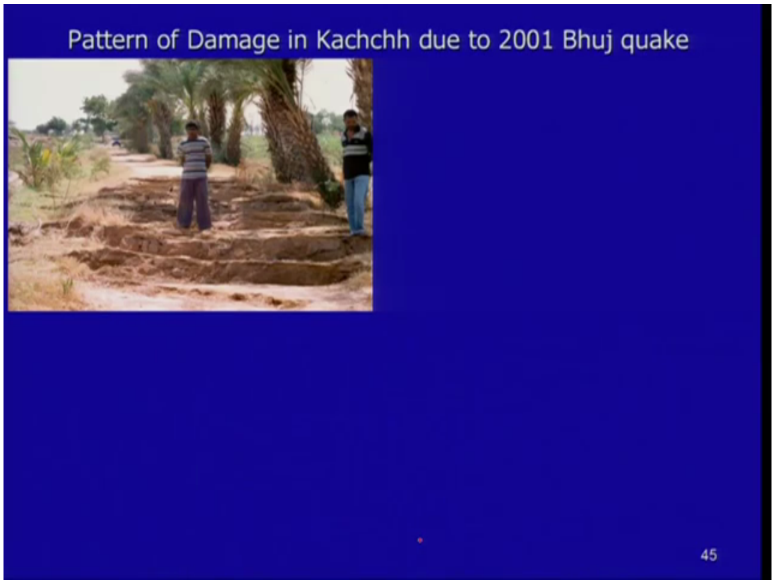

And then this is a pattern of damage which was experienced in Bhuj. We had lateral spread, this been typical of lateral spread we are having and can be categorized at so we can say this is a lateral spread. Now this took place on a very gentle sloping surface and the land slipped in this direction so this is a part of we can categorize it a landslide or landslip okay.

Then we are having the liquefaction, this is what I was talking about and this is very typical of of the the liquefied sand coming onto the surface through this ventair and this this had been poured on this side okay. Very much similar to the the volcanic eruption okay but this is what we call as sand blows okay and this phenomena is is related to liquefaction caused by strong seismic shaking.

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Then we have this example again is from the area closed to the coastal zones and from Gandhidham in Kutch where you can see this black spots, these are all the sand blows which are which came which resulted into the the pouring out of liquefied sand and of course along with that, we faced damage in Bhuj area an around then Bhuj. Severe damage was been experienced.

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There is an example 1964 Niigata earthquake. The building were toppled down because of the loss of shear strength of the underground material so this is again an example of liquefaction okay. So if the land lost the shear strength or the surface lost the shear strength because of strong seismic shaking which was resulted by liquefaction.

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There is a liquefaction from New Zealand, okay, Christchurch earthquake. Lot of sand came on the surface and along with the the water okay.

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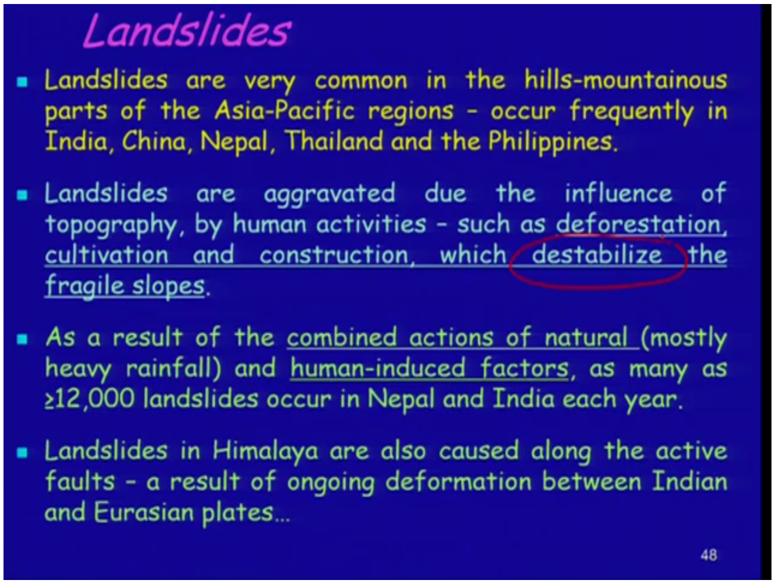

Then coming to another part, the landslides are very common in hilly and mountainous part of the Asia pacific region occur frequently in India, China, Nepal, Thailand and Philippines. Now landslides are aggravated due to the influence of tomography okay, or we can also say that to some extent, by human activities such deforestation, cultivation and construction which destabilizes the fragile slope.

Then as a result if you take the combined effect or the action of natural and human induced factor as many as greater than 12000 landslides occur in India and Nepal every year okay so landslide in Himalaya are also caused along the active faults okay because active faults are the areas where you will have the recent deformation or ongoing deformation because of the ongoing plate movements okay and this portion or the region will have more fragile material or sheared material in the which can result into the liquefaction if they are subjected to heavy rains okay.

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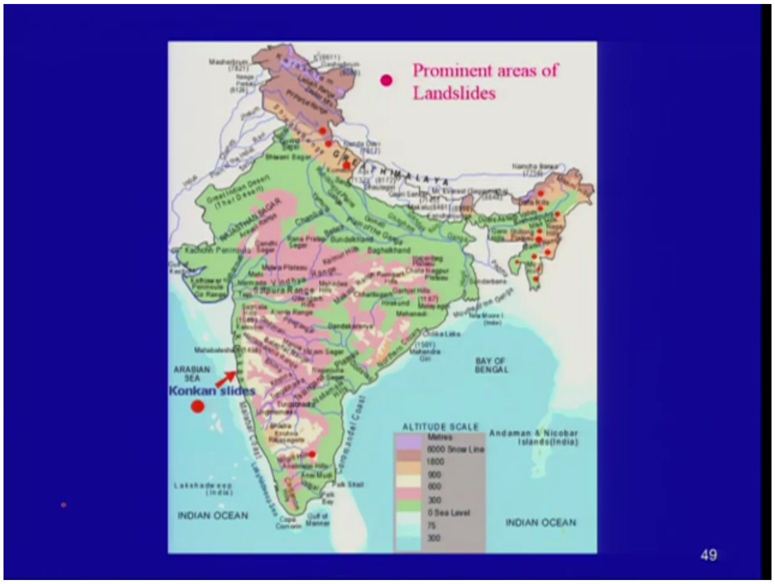

These are the areas which shows the prominent regions of the landslides so mostly we face the landslide in the hilly terrain, apart from this of course we also have the regions which are facing the landslides in this area because of the heavy rain and all that.

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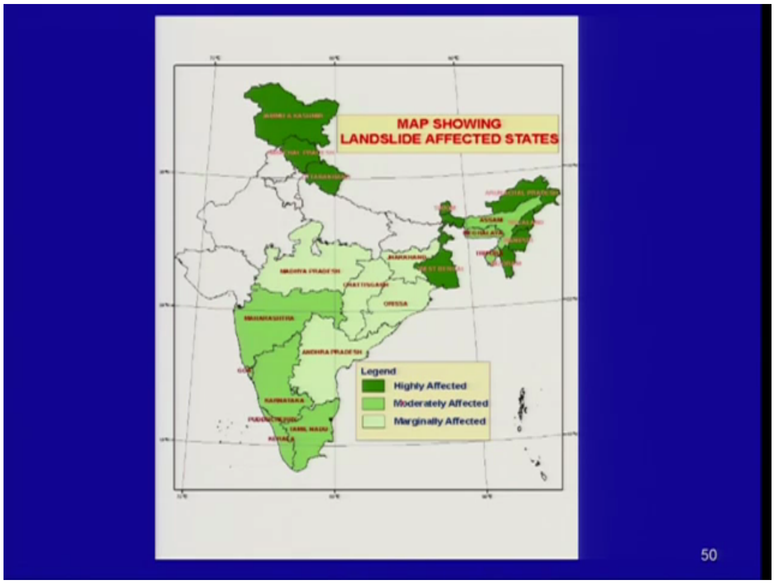

So highly affected areas are being shown with the darker green colors and marginally affected areas by this one. So mostly if you consider this, we have the hilly terrain in this region.

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Date/year	Location	Damage
Sep-68	Himachal Pradesh	Active Maling slide: 1km of road and a bridge washed out
Jul-68	Garhwal Himalaya	Active Kaliasaur slide: continuous damage to road
Dec-82	Himachal Pradesh	Near Sotding nallah 3 bridges & 1.5km length of road washed away
Jan-82	Nashri, Jammu & Kashmir	Active slide from 1953. Every year road and communication network is damaged.
Mar-89	Himachal Pradesh	Nathpa, 500m road section is frequently damaged during successive year
Oct-90	Nilgiris	36 people killed and several injured. Several buildings and communication network damaged
Jul-91	Assam	300 people killed, road and buildings damaged, Millions of rupees
Nov-92	Nilgiris	Road network and buildings damaged, Rs.5 million damage estimate
Jun-93	Aizawal	Four persons were buried
Jul-93	Itanagar Arunachal Pradesh	25 people buried alive 2 km road damaged
Aug-93	Kalimpong, West Bengal	40 people killed, heavy loss of property
Aug-93	Kohima, Nagaland	200 houses destroyed, 500 people died, about5km road stretch was damaged
Nov-93	Nilgiris	40 people killed, property worth several lakhs damaged
Jan-94	Kashmir	National Highway 1A severely damaged
Jun-94	Varundh ghat, Konkan Coast	20 people killed, breaching of ghat road damaged to the extent of 1km. At several places
May-95	Aizwal Mizoram	25 people killed road severely damaged
Jun-95	Malori Jammu	6 persons killed, NH 1A damaged
Sep-95	Kullu, HP	22 people killed and several injured about 1 km road destroyed
9, Jun-97	Gangktok, Sikkim	20 people were killed
14,August -98	Okhimath	69 people killed
18,August - 98	Malpa,Kali river	205 people killed road network to Mansarovar disrupted
Nov-01	Amboori, Kerala	More than 40 people were killed
26-Jul-05	Sakinaka Mumbai	More than 74 people were killed
27-Jul-07	Dasalgaon Maharashtra	50 people were killed
16-Jun-13	Kedarnath	5700 people killed, multi day cloud burst
30,July-13	Malin	150 people died and 100 went missing
20,Sep-14	Northern Sikkim	24 people died
22,April-16	Arunachal Pradesh	16 people died

And of course along with that, we have the rain fall is also more in that area so these are few of landslides which have been listed here which occurred in recent years so disastrous landslide in India.

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This is from Nepal.

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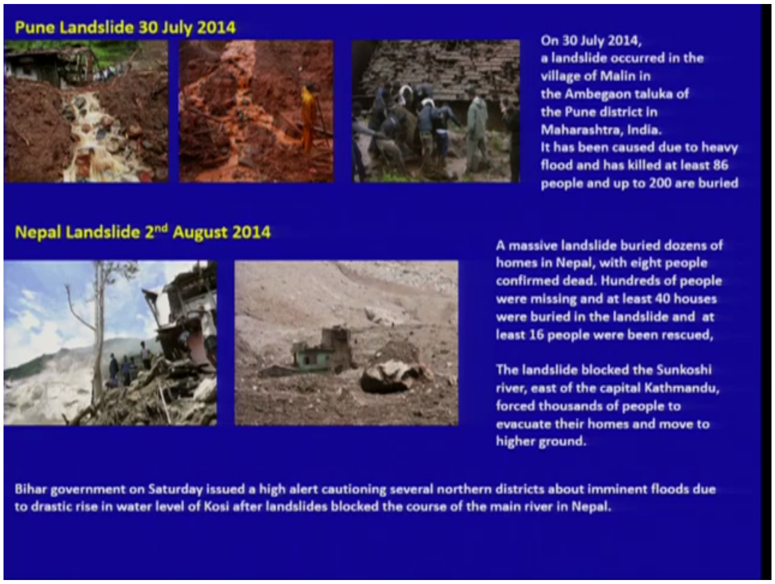

This is from Pune in 2014 and another again from Nepal in 2014.

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This is what I was talking about that if you are having in volcanic cone covered by snow so during an eruption, it may result into the mud flow and this mud flow type has been termed as Lahars flows okay so this is an example from Columbia where the snowmelt because of the volcanic eruption resulted into mud flow, Lahars flows in 1985.

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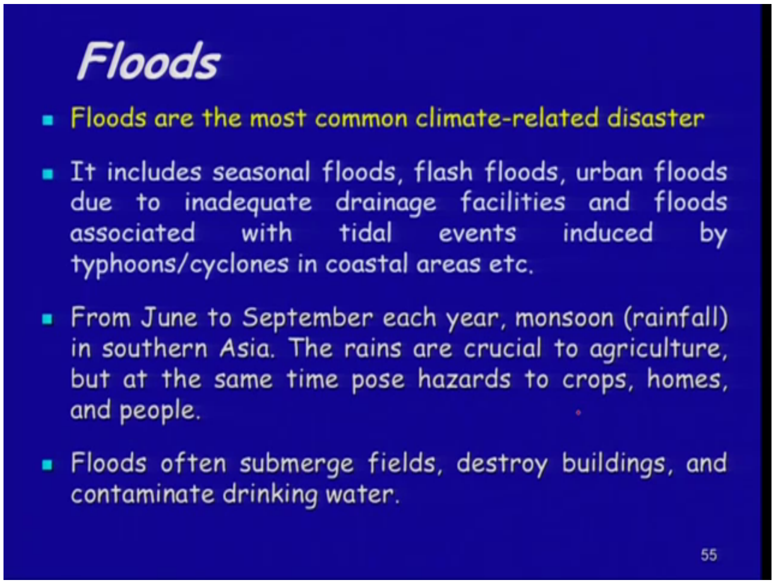

Then coming to the floods are most common and more frequent okay because these are again seasonal and we have every season in most of the areas where we have inadequate drainage facilities and more and more number of people have occupied the floodplain areas have experienced the floods okay so includes seasonal floods, flash floods, urban floods due to inadequate drainage facilities and floods associated with tidal events induced typhoon, cyclones in the coastal areas okay.

Mostly in the when we have the monsoon, extreme monsoons, we have this problems okay so from June to September each year, monsoon in southern Asia will result into most of the areas are flooded because of the inadequate drainage okay. If you are having a proper drainage and facilities and all that, you may have less problems in terms of that so rains are crucial of course for the agricultural but at the same time they pose hazard to the crops, homes and the people okay.

So flood often submerge the fields, destroy building and contaminate drinking water so not only it will it will result into the submergence of the field but in in another terms it will also contaminate the drinking water also so groundwater is also getting contaminated.

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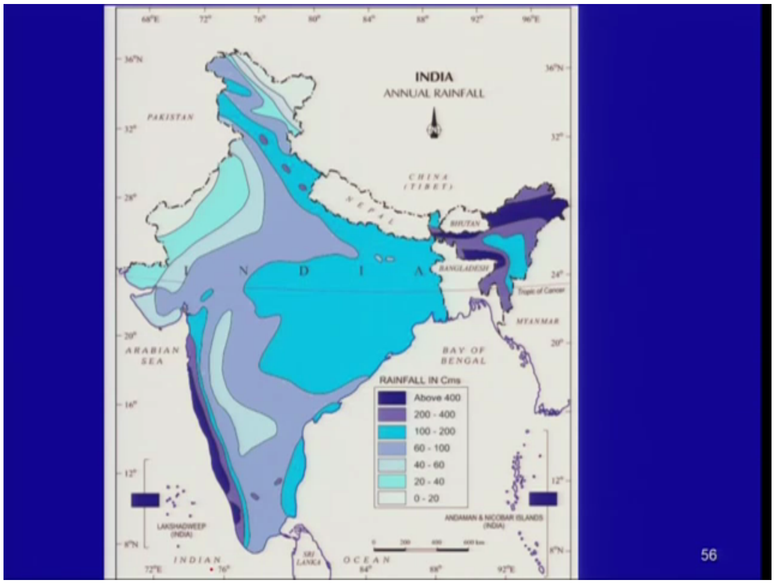

This is just to show that what is the pattern of rainfall we received or we keep receiving every year in different part of India so the the dark blue color which shows that these regions are receiving um rainfall like around 400 centimeter per year so you are having this this regions okay whereas very scanty rainfall is somewhere over there.

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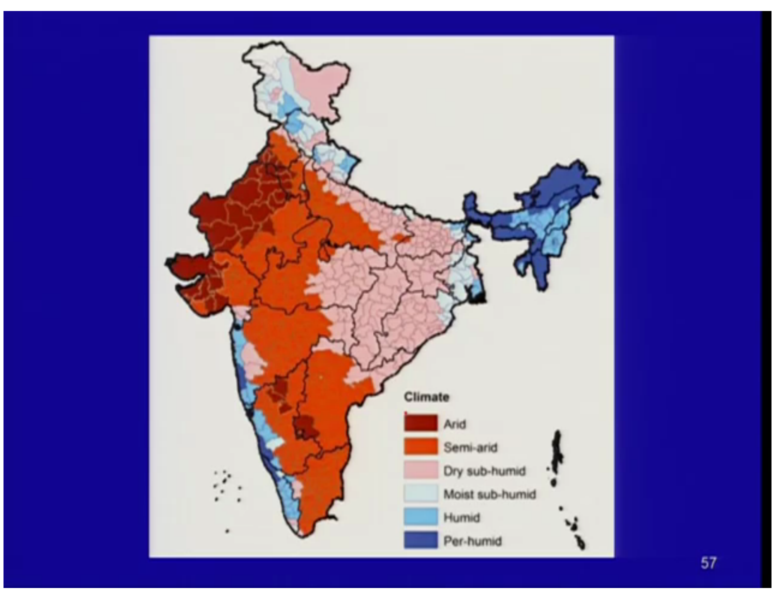

Now based on this, these regions have been classified into different climatic zones okay so these are what they have done this as arid so arid is this one here. We have this area arid, to semi arid we are having okay and these regions are the areas where we have very large amount of rainfall so you humid to sub humid or so.

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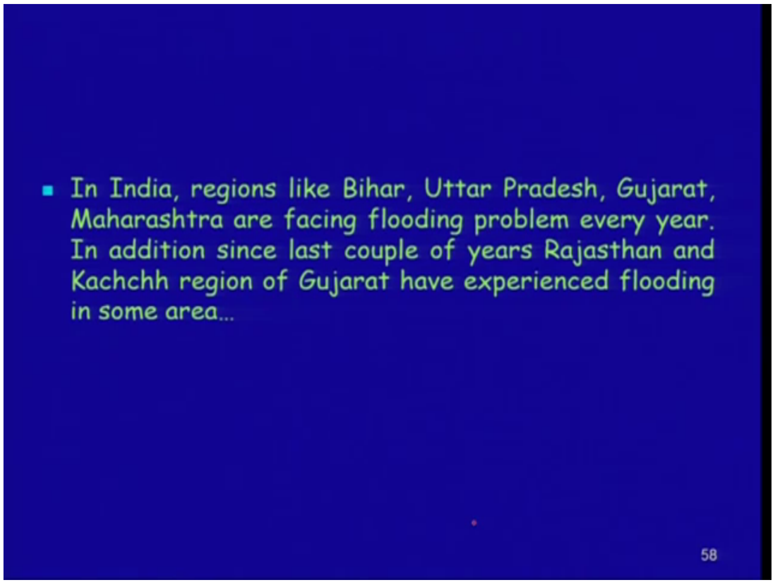

So nowadays we are even facing the the areas which are (con) considered to be arid and semi arid like Rajasthan and (Guj) Kachchh regions, they have also experienced floods in recent years okay. Other than that these regions are always experiencing floods like Bihar and Uttar Pradesh.

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There is an example from 2006 flood in Tapti but the the the most important part which we learned from this area was this is from Gujarat, this is the city of Surat which was affected by severe flood in 2006 and then flood was related to the heavy rainfall in the upstream of Tapti river but this area that is Surat city did not have much of rainfall okay.

So this was because of the heavy rain in the upstream and and opening up of the the tidal opening up of the the the dam reservoir okay resulted in the flooding in the downstream region okay so this is another whether this is should be called as in manmade hazard of this should be termed as an natural hazard, there is another question here so I will stop here, thank you so much.