Indian Institute of Technology Madras

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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

NUCLEAR REACTOR AND SAFETY

AN INTRODUCTORY COURSE

Module 10 Lecture 01

Siting of Nuclear Power Plants

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Good afternoon. So in this afternoon lecture I plan to take you through a these different steps based on which the site for a nuclear power plant is chosen. It is not a simple affair as you think. Now in a nuclear power plant what are the different stages. Siting, siting is the first stage. Then design, construction or manufacturing, operation, commissioning, and decommissioning of course the last stage.

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INTRODUCTION

Siting, design, construction, operation, and de-commissioning are the five major stages during the life time of a nuclear power plant. Site selection forms an important aspect in the approach to the safety of the plant personnel, public and the environment from radiological hazard. Important factors affecting selection of site for nuclear power plants (NPPs) include availability of required infrastructure, economics, sociological aspects, impact on the public and environment, technical feasibility and engineer-ability of the site. Like any other facility, nuclear power plants are also designed to withstand the loading effects due to hazards from external events.

Now this site selection is one of the most important things which are important for the before we go into the design. Why? That is what we'll be seeing in the lectures. For example, if I want to have a nuclear power plant first I must have the necessary infrastructure there for with which I can see. Then what about the economics and most important what is going to be the impact on the public or the environment so because very important. We do not want any radioactivity to be released. So whether it is going to be whether I need to dislocate people, how many people will get dislocated if I had to put that plant but one thing I can tell you for that matter whether you construct a coal-fire power plant or hydro-power plant or anything there will be a displacement of people. Some site you have require some site but only thing is it should not displace a large number of people. So this is like any other facility all the different loads for example you have a wind load, coastal places wind is high. You must consider your wind load. You must see what about the flood, or if it is very close to the sea what is the tsunami level. All these things so it encompasses a lot of things before we choose a site.

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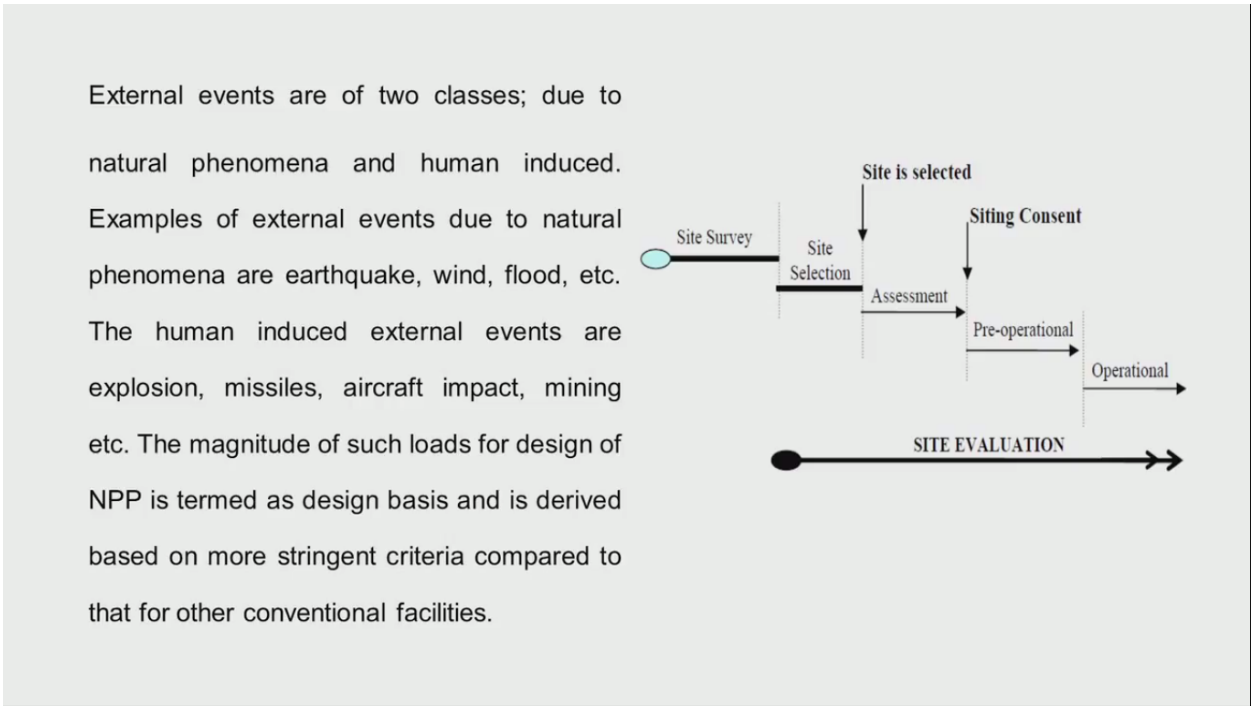

That means let us look at, now let us look at the events which can be external to the plant to due to natural phenomena like tsunami, or a cyclone, or a tornado for that matter. We do not hear of tornadoes in India. We do aware of of tornadoes in the North America. Then human-induced you take your terrorist taking a flight and trying to crash on your plant. So it could be human induced. The Earthquake is one. Then missiles. Then explosion let us say my nuclear plant is operating and maybe adjacent few miles or within a mile or two I have a chemical plant which is producing some chemicals. It could explode and that could have an effect on my nuclear power plant operation and safety. So we need to find determine all this before we select a site. So that is what the site survey does. We do all the surveys. We have to see whether the site is good enough. We will see how we look at that, and so in the site evaluation comprises after the site survey is done you select the site, you assess the site whether it is okay.

Then you go to the regulatory authorities with the data, get the consent for siting then of course you do the pre-operational things and all. So site evaluation encompasses all these.

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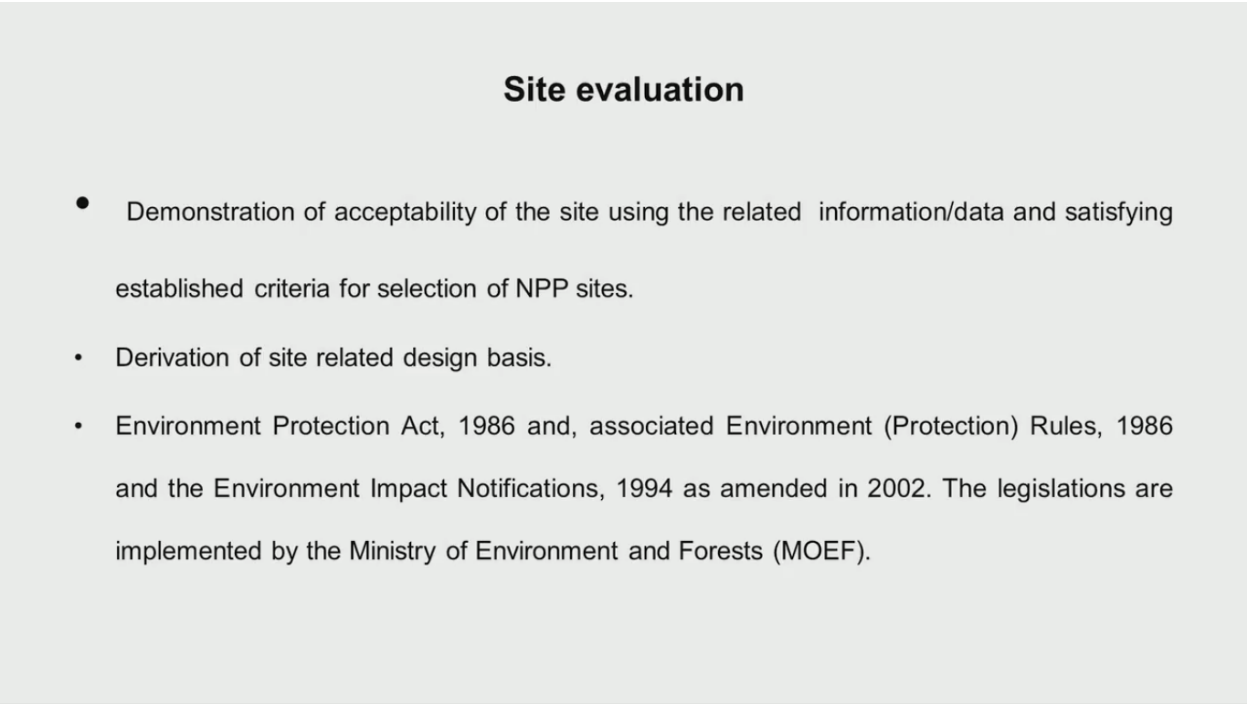

So what we do in site evaluation? We need to demonstrate to the regulatory authority that this site I have all the information. I have what is the wind load. I have know what is the flood data. I have what are all the factories and layout nearby. I have what is the population strength around. Everything I have. So then i satisfy what are all the criterion which has laid down by the regulatory authority so then only I am at the regulatory authority can give a clearance. Then also what is the design basis on which I am choosing this site. May be there is – there is there are some deviations why I am accepting. Not only that we need to follow or satisfy the Environment Protection Act. They have been laid by the Ministry of Environment and Forests and this need to be considered. One of the examples of the environment I can tell you whether it is a coal-fired plant or a nuclear power plant other than hydro, you require cooling of the condenser and the water is taken from a river or sea. So this water picks up the heat from the condenser and comes back to the sea, river, or water. This temperature at which it is coming out will be at a higher temperature. Now there is a stipulation that this should be within 7 to 10 degree centigrade. The difference in temperature should not be more than that. The idea is that the marine organisms like fishes and other things can still survive under that condition and this is common. There is nothing unique to a nuclear power plant. It is similar to a coal-fired power plant also. So all these environmental things so this need to be respected before while evaluating the site.

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- Public consultation is an essential pre-requisite for obtaining clearance of an NPP project. The State pollution control board (SPCB) conducts the public hearing. After completion of the public hearing, the project proponent addresses the environmental concerns expressed during public hearing and makes appropriate changes in the draft environment impact assessment and environment management plans. The MOEF clearance is given after the study of the environmental impact assessment (EIA) report and the documents on outcome of the public consultations. This lecture brings out the regulatory procedures followed by AERB to evaluate the site of nuclear power plant.

Not only that in the last few years it has become mandatory that you get a sort of public consultation. We call it as a public hearing wherein all the stakeholders, the people around take part. They are briefed about the project; what they are going to do and in which way it will benefit them and what are all the issues which is it will happen and how it is being taken care of. And here the State Pollution Control Board I mean the state in which your plant is going to be situated they will conduct this public hearing and they will record the views of the public and the answers which are being given by the nuclear authorities and then compile them and then forward it to the government. So this is mandatory for not earlier days it was not mandatory. Now it is very much mandatory. In fact in India if I recall the prototype fast breeder reactor at Kalpakkam when we built that we went for a public hearing. The fast breeder test reactor when we built we did not have a public hearing or we didn't have a public hearing when the two heavy water reactors were constructed. So this is mandatory because we have to take the people into confidence because they are the stakeholders. Now after the hearing is over if the concerns basically on the environment whatever is voiced the authorities have to look into and if they feel that some changes we can do and satisfy they do that, and then after that they go to the Ministry of Environment and Forest and this not only takes this report, it also gets the environmental impact assessment report which is carried out by an independent agency appointed by the nuclear authorities. Normally these are people consultants who independently do the job and submit the report. In this lecture I will bring out what are all the procedures which are followed in evaluation of a site for a nuclear power plant. Now site. What is the site? It includes the area surrounding the plant which is under the management's control.

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Basic Requirements

- The ‘site’ includes the area surrounding the plant enclosed by a boundary, which is under effective control of the plant management. Current mandatory requirement of AERB siting code is that an exclusion zone of at least 1.5km radius around the plant is to be established and this area should be under the exclusive control of the station wherein public habitation is prohibited.
- The Exclusion Zone's purpose is to restrict access to radioactive areas, reduce the spread of radiological contamination and conduct radiological and ecological monitoring activities. It also helps in establishing the security of the power plant through minimization of entry of normal public.

Management means the nuclear authority management control. Now we have specified a circle of about 1.5 kilometer radius around the plant which is totally under the control of the plant authorities. So in this exclusive area no other establishment can be there. So there will be no houses nothing. Nothing will be there. Only the plant and its associated requirements or establishments related to the nuclear power plant only will be there. This is called as an excuse zone, that is public is excluded you can say. Now what is the purpose of this? The idea is two fold, one is security for the nuclear power plant. Other one is to restrict the amount of radioactivity which a person can receive should there be any even a minor release of radioactivity. And also the fact that in case there is an emergency and we want to evacuate we may need to ever get to larger number of people who are very close close in the five kilometers area. So in this exclusion zone in fact you can say we do not have anybody from the security of the plant.

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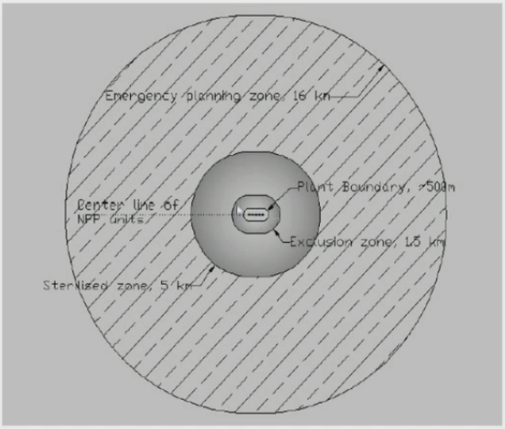
- In addition, a sterilized zone around the exclusion zone covering an area up to 5km radius around the plant is also established. Only the natural growth of population is permitted in the sterilized zone, but planned expansion of activities leading to enhanced population is regulated.



Here is a figure. So this is the plant and you can say the plant boundary so this is your exclusion zone which is about 1.5 kilometers. Then you have the another zone up to about 5 kilometers wherein nobody can, that is there but a very scant population. So 1.5 kilometers nobody, 5 kilometers very this is actually called as a sterilized zone but no further activity or is allowed in this area subsequent to the startup of the deciding to construct this plant. After that no further only very scanty things are allowed.

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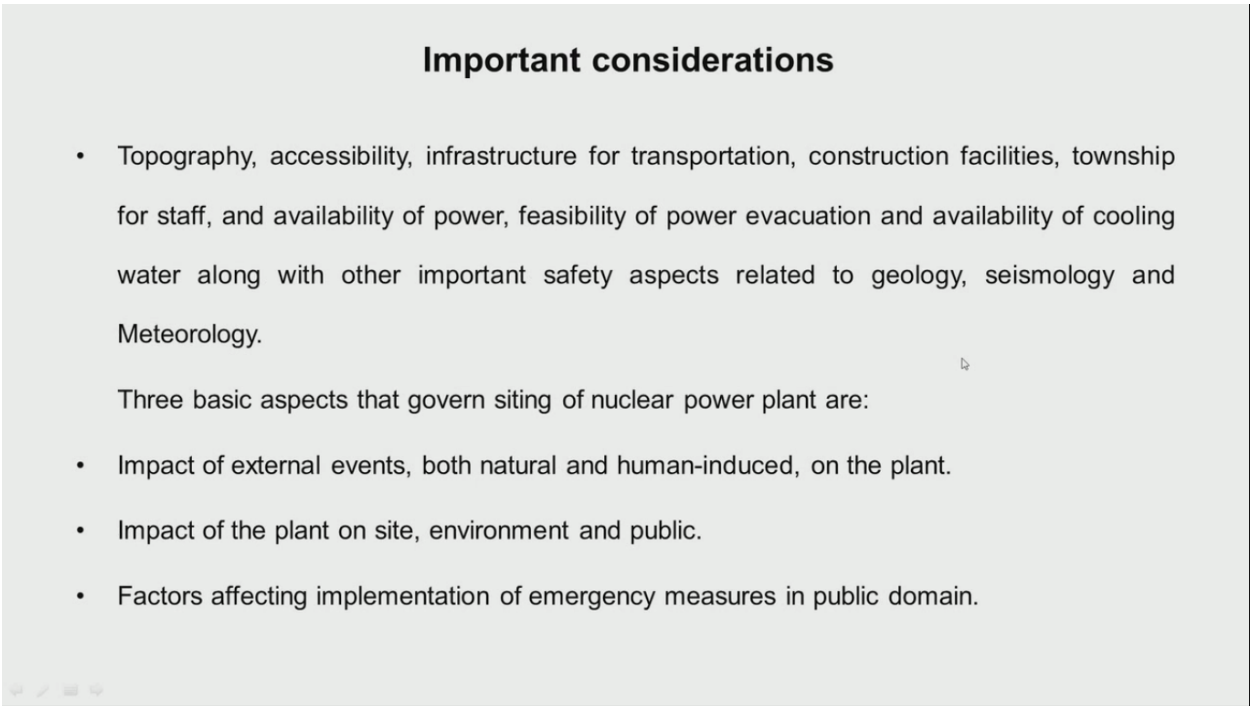

Now how do we do the siting? We look at the topography of the place, rocky, whether that place side is accessible, whether it is accessible from in all directions or accessible only in a particular direction. This is very important like in case of a fire you want many escape routes. Similarly for a plant should there be a problem with one route we should we have another route not only from an emergency even in a normal way normal fire anything we should be able to move out in different ways. So we see the accessibility. Then infrastructure for transportation. See we must be able to transport that component to the site for example you have to cross some bridges. Those bridges must have adequate strength that they can withstand the load of the component. So whether and whether the roads are good enough there are no very steep bends wherein a trailer of about let us say 24 meters long trailer should be able to turn. Mind you when we get components from the Larsen and Toubro factories in Bombay to Kalpakkam the equipment will go to Hyderabad, then to Bangalore and then from Bangalore it will come to Chennai. They have established this route is strong, good enough and come. So this need to be established before a site is chosen.

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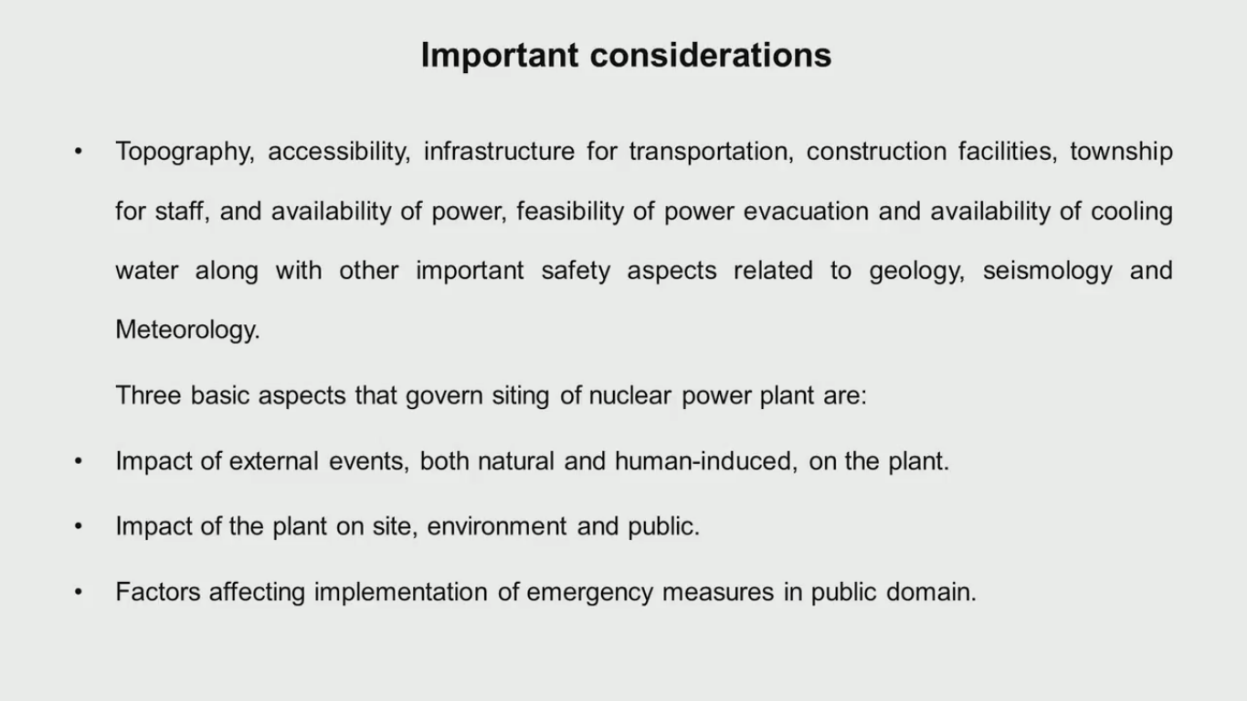

Then construction facilities how whether the constructability is there at that site, what sort of facilities are available, whether I have a good place for a township for the staff because normally in a nuclear power plant you always have a township so that the plants crew can come in different shapes and work. Then availability of the electrical power. Whether that place because when I start construction I require power. I must know how much load I require and whether I can get power in that place. Then suppose I am going to build a plant whether there are enough transmission lines through which I can transmit the power. In fact, this very important that this transmission line should be completed before the construction of the plant is completed because then only the moment the plant starts you can export the power to the grid and not only transmission to one direction it must be two, three different routes. For example, your Kalpakkam atomic plant is connected to the Tamil Nadu grid at one at [Indiscernible] [00:16:17]other at to the Neyveli, another at Arni. Three different directions. In case there is a problem in this line I can export the power through another line. So all these considerations need to be put. Then availability of cooling water. As I mentioned it needs cooling whatever condenser. So it needs so we must have a good source of water. If it is away from, if a river is there like Rajasthan we have the Rana Pratap Sagar dam we have water. If it is Kalpakkam we have seawater. If it is an inland site we have to look whether there is enough water available and then whether cooling towers how I can place them. All these need to be looked into. Of course, we cannot forget the seismological aspects whether the place is the earthquake prone, what is the earthquakes which are expected in that, how many have occurred. Then the weather conditions as I said should not be a place where cyclones come very frequently. So what are the basic aspects which govern the sighting. One is the impact of external events. Then impact of plant on the environment and public, and third last but not the least that in case of an emergency I must be able to implement my emergency measures of evacuation and other things also. These are the three considerations; basic aspects.

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REJECTION CRITERIA

- A large region is investigated to select one or more candidate sites on the basis of safety and other considerations. Rejection criteria, generally given in terms of screening distance values (SDV), are applied at site selection stage to shortlist the candidate sites. For many hazards like toxic gas release, explosion, etc., the hazardous effect diminishes as we move away from the origin of the event, and beyond a particular distance the event will be of no concern. SDV reflects this distance.

Now so in a negative sense we say what are the rejection criteria. Normally we call the selection criteria. Here we call rejection criteria. That means if certain criterias are not followed we reject them. We reject that site. So we generally give that in terms of distance values, screening distance values. For example I have a chemical plant and any toxic release from that plant might affect my nuclear power plant. I say if a chemical plant is situated at this much distance it should be more than that only I will accept. So like that. So if you move away from the plant your hazard is going to be less.

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Sl. No	Hazard	Rejection criteria and SDV, if applicable
1.	Earthquake	Site falling in seismic zone V as per BIS 1893
2.	Earthquake	Distance from capable fault < 5km
3.	Earthquake	Potential for soil liquefaction
4.	Earthquake/ Geological	Potential for slope instability which cannot be mitigated by engineering measures
5.	Earthquake/ Geological	Potential for ground collapse/subsidence/uplift which cannot be mitigated by engineering measures
6.	Geological	Possibility of formation of sand dunes
7.	Aircraft impact	Distance from small air fields < 5km
8.	Aircraft impact	Distance from major air ports < 8km
9.	Aircraft impact	Distance from military air fields < 15km
10.	Explosion	Distance from military installations storing ammunitions < 10km

The existence of places like historical monuments, pilgrimage centers, or tourist interest within 5 km calls for rejection of site. Environmentally sensitive locations like national parks, sensitive marine environment or biota may also impose rejection of candidate site.

So basically the screening distance value gives this idea. Now let us look at some of the criterias which are being followed. Now seismic conditions we different them by different zones and depending on the seismic nature or the earthquakes which have happened we do not want to put a nuclear plant in a place where the earthquakes are very frequent. So first is whether the site falls if it is zone 5 then from the fault of the earthquake if it is less than five kilometers where has happened we reject that site. Then potential for soil liquefaction which can happen. I will talk about this later. Then formation of sand dunes is another suddenly let us say if it is a sea coastal thing and sand dunes are developed. So I would not accept. Then distance from an airfield. If it is less than five kilometers I would reject that site because my aircraft taking of itself it can crash. If it is a major airport surely 8 kilometers must. If it's a military airfield still more because you have fighter planes which very high large energy level, 15 kilometers and in addition to all this we do keep in mind social responsibility that any pilgrimage centers of historical monuments should not lie within five kilometers. We in fact when we sighted the [Indiscernible] [00:20:32] plant our site choice was dictated to some extent by the nearness to Mamallapuram which has got a old Shore temple and old Pallava architecture. So that we kept in mind. These are also then since marine environment these things also can pose, you know, rejection to a site. So we need to satisfy all this.

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	Safety Series No	Title
1	AERB/SG/S-1	Atmospheric Dispersion and modeling
2	AERB/SG/S-2	Hydrological dispersion of Radioactive Materials in relation to NPP Siting
3	AERB/SG/S-3	Extreme Values of Meteorological parameters
4	AERB/SG/S-4	Hydro-geological aspects of siting of NPP
5	AERB/SG/S-5	Models for Radioactive Dose Computation Methodologies
6	AERB/SG/S-6A	Design Basis Floods For NPP Inland sites
7	AERB/SG/S-6B	Design Basis Floods For NPP coastal sites
8	AERB/SG/S-7	Man induced events and Establishment of design Basis Events
9	AERB/SG/S-8	Influence of site Parameters on Emergency preparedness
10	AERB/SG/S-9	Population Distribution and its analysis in relation to siting NPPs
11	AERB/SG/S-10	Quality assurance in siting
12	AERB/SG/S-11	Seismic Studies and design basis ground motion for NPP Sites

Now AERB, the Atomic Energy Regulatory Board in India looking at all this it has drawn up a large number of guides, and I am just giving you a glimpse of about 12 guides which talk about the different aspects of siting. See atmospheric dispersion and modeling. Hydrological dispersion of radioactive materials in relation to NPP siting. Extreme values of meteorological parameters. Hydro-geological aspects of siting. Models for radioactive dose computation. See everything is clearly documented. How you have to go about it. Design basis floods for inland sites. Design basis floods for coastal sites means very close to the sea. Man induced events and establishment of

design basis events. Influence of site parameters on emergency preparedness. Quality assurance in siting. Seismic studies and design basis ground motion. See all aspects have been well thought of and guides are made and these guides if followed will assure that siting is done properly.

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AERB SITING CODE

- Mandatory requirements: These requirements are related to those phenomena whose effects shall be considered in the design of NPP and evaluated during the siting process; e.g. wind, rainfall/flood, vibratory motion due to earthquake, etc. Usually, suitable measures can be adopted to take care of these phenomena in the engineering of the plant.
- Desirable requirements: Non fulfillment of these requirements does not affect the plant attributes related to radiological safety e.g. distance to facilities handling inflammable/ toxic/explosive substances, population around site, etc. The design basis parameters of the plant are altered at the cost of economic penalty, e.g. evacuation of population during an off- site emergency.

Now in all these guides there are requirements one which are mandatory. mandatory means these shall be considered there is no going this where. They are mandatory like wind, flood, earthquake. So these things have to be considered and in the design of the plant you have to design for that much seismic condition, that much wind loading you have to design. If there is a flood you have to take that consideration and you have to see that your plant does not get damaged or your safety is not jeopardized.

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AERB SITING CODE

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Then there are some desirable requirements like distance from a chemical factory. Maybe it is not that much. So let us say we have put some five kilometers. Let us say that is about 4.5 kilometers we think twice whether it is really and what sort of a factory is this, weather really it can cause. So here based on the what you call local situation, local conditions we can do some adjustments. So these are all designed but they if at all they are altered they there will be a means there should not be an economic penalty.

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- The criteria to derive design basis parameters of external natural hazards like earthquakes, floods, cyclone, and wind are based on the concept of mean recurrence interval (MRI). Mean recurrence interval is defined as the mean time between the occurrences of two successive events of a given type averaged over a large number of occurrences, that are equal to or greater than a given magnitude.
- The site is also evaluated with respect to safety aspects of storage and transportation of input and output materials, for example, new fuel and spent fuel as well as radioactive wastes including possible combined effect of nuclear and non-nuclear effluents.

Now the design basis parameters normally which we get like floods, earthquakes and all, they are all have a concept of mean recurrence interval. This mean recurrence interval is what? It is the mean time between two consecutive occurrences of that event. An earthquake has happened now, after how much time it again happens. So it – what is the magnitude, what is the average over the different earthquakes. So all these data we get based on the seismological observations which have been done and records kept. Now as I mentioned you have to evaluate the site with reference to storage aspect, safety aspects, storage of fuel, in fact storage of material for the plant later for the fuel not only the fresh fuel, the spent fuel. Spent fuel would need cooling. There could be radioactive waste which are generated, how you are going to handle; all these aspects so when you say nuclear power plant it does not mean the plant alone all this waste handling facility, the spent fuel be everything needs to be considered we had to evaluate the site whether all these things can be there. So it is not the nuclear plant alone.

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- The preferred means of ensuring that the risks associated with the plant are within prescribed limits are engineering of the site and appropriate design features of the plant. If evaluation indicates that the overall risk cannot be kept within the acceptable limit by means of design of the plant, engineering of the site or administrative procedures, the site is deemed unsuitable. A site is re-evaluated if a new plant or other nuclear facilities are proposed to be built adjacent to the existing ones.

Now how do you ensure is by engineering the site. We can alter the some of the features of the site and evaluate the site to satisfy the different conditions. Again I repeat the mandatory conditions cannot be violated. The desirable conditions can be adjusted here again looking at a local condition. If we are not able to satisfy the mandatory condition surely we either go to a different site. We do not consider that site.

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Earthquakes and surface faulting

- Earthquakes are low probability events capable of producing severe consequences. Shaking (vibration) and ground failure/rupture are the main effects created by earthquakes that cause damage. The earth's crust comprises of different sets of plates and these plates move slowly relative to each other from <1 to about 16 centimeters per year. The movement causes plates to converge/diverge in contact regions between the plate boundaries. The difference in speed of movement between the plates causes stress buildup and, in turn, increases potential energy in the plate. When the built-up stress exceeds plate's capacity, it ruptures leading to release of the energy stored. The faces of ruptured area also move with respect to each other so as to achieve the total displacement that was restrained in the past. All these, ultimately, result in earthquake. The plate boundaries are located both under the sea as well as on the land.

Now let us come to the individual aspects. Earthquakes. Now in our country unlike Japan this is not a very frequent event. It is a low probability event. But of course earthquake can cause severe consequences. Now how does a earthquake happen? The Earth's crust composes of different strata or different plates and normally they move slowly related to each other depending on the pressures which are there, stresses which are within the core of the Earth. Now the moment happens at different speeds somewhere like 1 to 16 centimeters per year. When the moment is high of the plates this they can converge or they can diverge and this happens because they move at different speeds. All the layers do not move at the same speed. They are at different speeds. So when this happens there is a stress built up.

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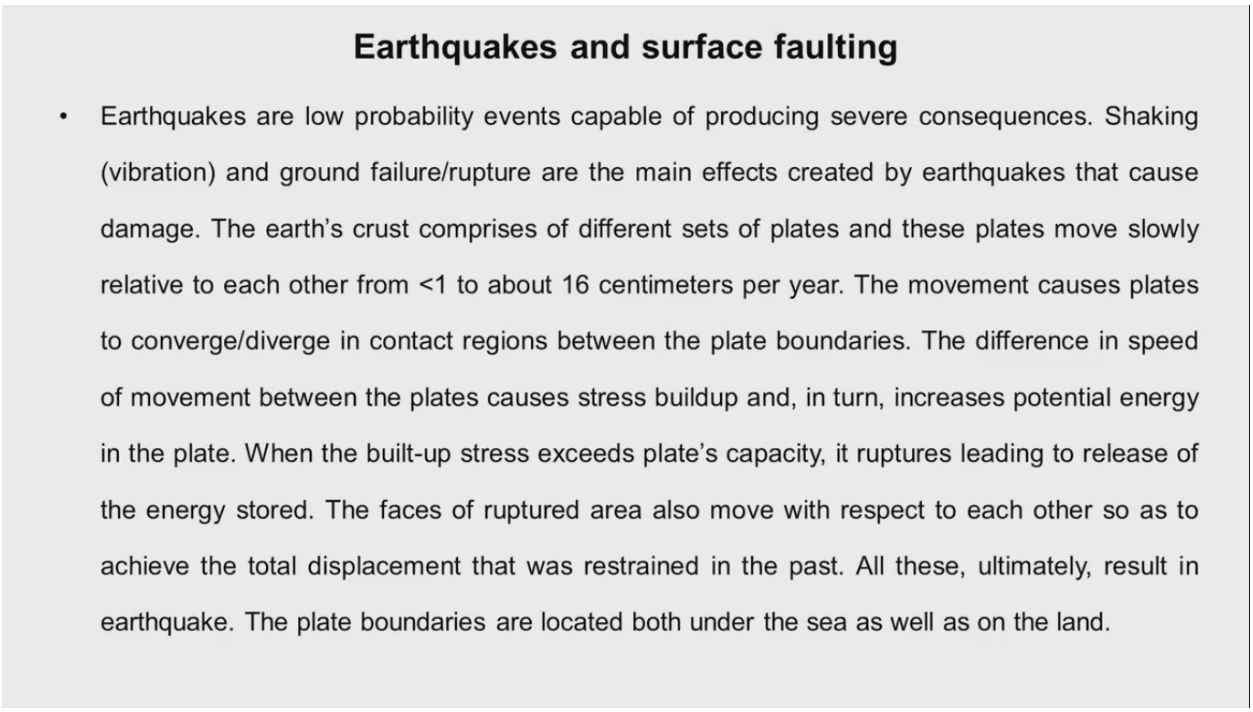

Potential energy is built up in the plate and this exceeds that capacity of that plate stress which it can withstand. It ruptures. The plate ruptures and the ruptures leads to the release of the energy and the ruptured portions they move with respect to each other and displace and this displacement finally is what you call as earthquakes and these plate boundaries could be either on the land or could be under the sea.

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- The location inside the earth where the rupture of plate starts causing earthquake is known as hypocenter or focus, and the corresponding point located above on the surface of the earth is known as epicenter. The ruptured area along which the displacements have occurred is termed as a fault. Ground rupture occurs when the ruptured fault, which caused the earthquake, intersects the ground surface and the fault displacement could be observed with naked eye. The severity of the earthquake at a site depends on the complex combination of the energy released during the earthquake (measure of which is magnitude), its distance from epicenter/hypocenter, and the local geological, geo-morphological geophysical conditions as well as seismological status.

Normally tsunamis happen when they are under the sea. Now you must have heard the word epicenter. Suppose when it's happening on the land of course it is happening below the ground and the corresponding point on the land is what we call as a epicenter but suppose there was this – this was happening in the sea the point corresponding to that is called as hypocenter or focus. Then the rupture area is called as a fault area or fault line. We say where is the fault line from Kalpakkam, where is the fault line from Koodankulam like that we ask ourselves. So the severity of the earthquake again is a this how much it is away from the epicenter or hypocenter. So you need to locate it away because from the history of earthquakes we do have where is epicenter and where is the hypocenter.

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Safe Shutdown Earthquake (SSE)

The design basis vibratory ground motion is derived for two levels of earthquakes,

- S1 or Operating Basis Earthquake (OBE) level and S2 or Safe Shutdown Earthquake (SSE) level. SSE represents the maximum potential vibratory ground motion that can be expected for the region (with MRI ≥ 10,000 years). In the event of this level of earthquake, the only consideration is to keep the radiological risk to the public below the acceptable level. Hence only those safety systems, which are needed to meet this requirement, are designed for this high level of earthquake.

Now in this earthquakes for the design purposes we consider two types of earthquakes. One is called as a Safe Shutdown Earthquake, and other is called as an operating base earthquake. These are called as OBE Operation Base Earthquake, Safe Shutdown Earthquake is SSE. Now the Safe Shutdown Earthquake are those earthquakes which have got a large return period something like once in some 10,000 years. So they are very rare. That means they can happen so for that condition of what we call ground motion which we represented as the G acceleration of gravity in point where 1 G, 2 G. So we design all the components which are involved in the safe shutdown of the plant should operate under that condition of a Safe Shutdown Earthquake. So the idea is under this condition which can happen very rarely our radiological risk is to be brought to the public should be kept below the acceptable level. So only safety systems are designed for this sort of an earthquake.

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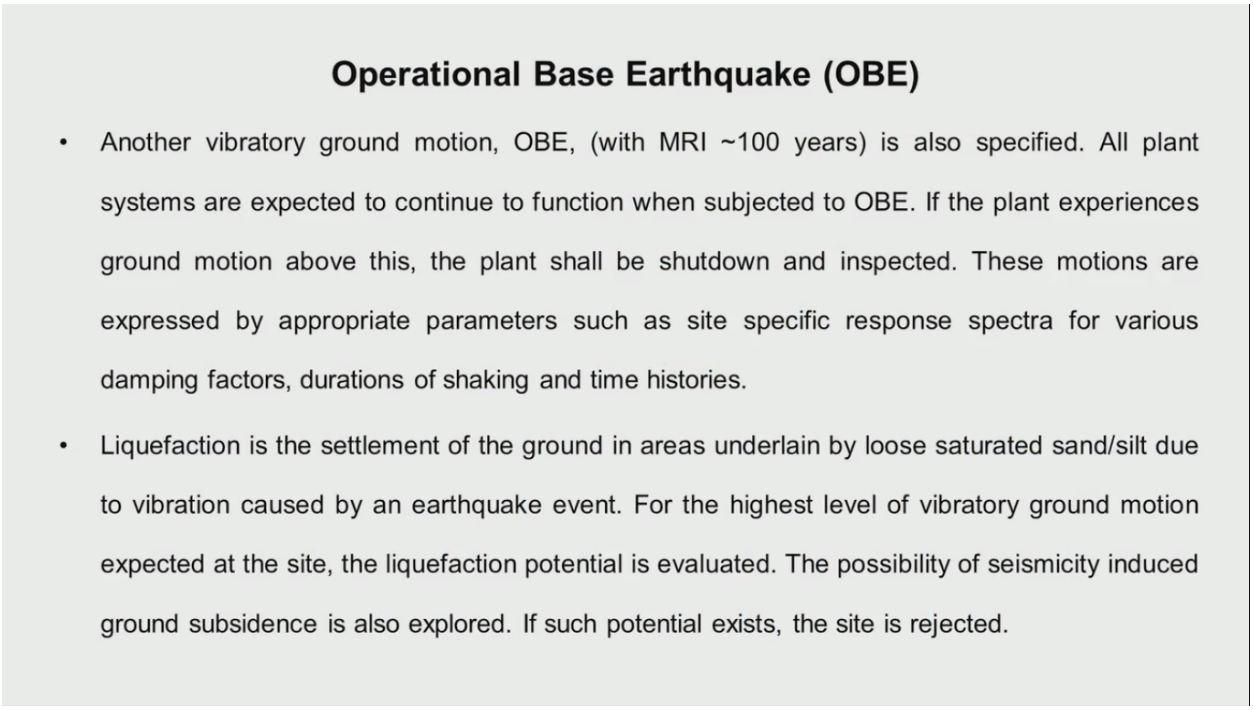

The other one which I called as OBE or Operational Base Earthquake with a return interval of about 100 years all plant components are designed to function when subjected to OBE. So every site specific response spectra we derive based on the measurements at that site and we have the time history, all these things we use. Now I mentioned something about called liquefaction. What is this liquefaction? See it is the settlement of the ground in areas where your loose sand or silt which because of -- happens because of an earthquake and it can settle down. So the liquefaction potential of different sites is evaluated, should earthquake thing happen whether the soil conditions are such, whether it can liquefy. So liquefaction can occur or not this is done and in case liquefaction occurs we reject the site.

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Geological hazards

- Geological hazards are the types of adverse geologic conditions that are capable of causing damage or loss of property and life. These hazards include landslides (lateral displacement of earth materials on a slope or hillside), rock falls, rock avalanche and debris flows, sand dune migration, etc. Potentials for slope instability (land/rock slides, land erosion, snow avalanches) as well as collapse, subsidence or uplift of the site surface are assessed during site evaluation. Effects of related hazards are assessed using reliable methods of investigation and appropriate analyses are carried out for safe engineering of the plant. The susceptibility of the site/region for the formation of sand dunes is studied. If the location is found to be vulnerable, the site is rejected.

Then the geological hazards. Basically geological hazards are those which can cause you know damage to life and property, landslides, which are very common in the himalayas. Then rocks rolling down the hills, rock falls. Then avalanche. Then sand dune migration, all these things happen. Again based on the geology of the place. Then we have to look whether there is something called as slope instability, like land rock slides, land erosion or snow avalanche due to snow not only a rock avalanche, but the snow avalanche. So these things whether can happen at that site, and we have to assess these effects using very reliable methods of investigation and we have to come see the analysis of the plant whether the plant can withstand this.

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- The site is also investigated for subsidence of ground due to occurrence of geological feature called 'Karst', mining activity and oil extraction. Karst is a special type of landscape that is formed by the dissolution of soluble rocks. During rainfall, water seeps into the soil. The water becomes weakly acidic when it reacts chemically with carbon dioxide in the atmosphere and the soil to form carbonic acid. This acidic water passes through the bedrock, dissolves the rock material and eventually forms into cave passages and caverns, which is termed as Karst. Incase potential of such geological hazards exist and no practical engineering solutions are available to mitigate their effects, the site is deemed unsuitable.

Then we also have to investigate the site for subsidence due to what is called a geological feature called Karst. What is Karst? It is a type of landscape that is formed by dissolution of soluble rocks. All rocks are not solid. Some rocks would be real solid. Some rocks can in case of water seeps it can become acidic, and it reacts and forms Carbonic acid with the water and it can maybe the rock can be soluble. Now once it is rock is soluble it forms a cave in that area, and so if it forms a cave you can have the ground can subset. It can push coming down. so his is need to be checked very much for the geological condition. So you see how of site investigations we need to do before we finalize the plant, nuclear power plant. We follow this thoroughly through the thick and thin. It is a very important. It takes some time but we do that.

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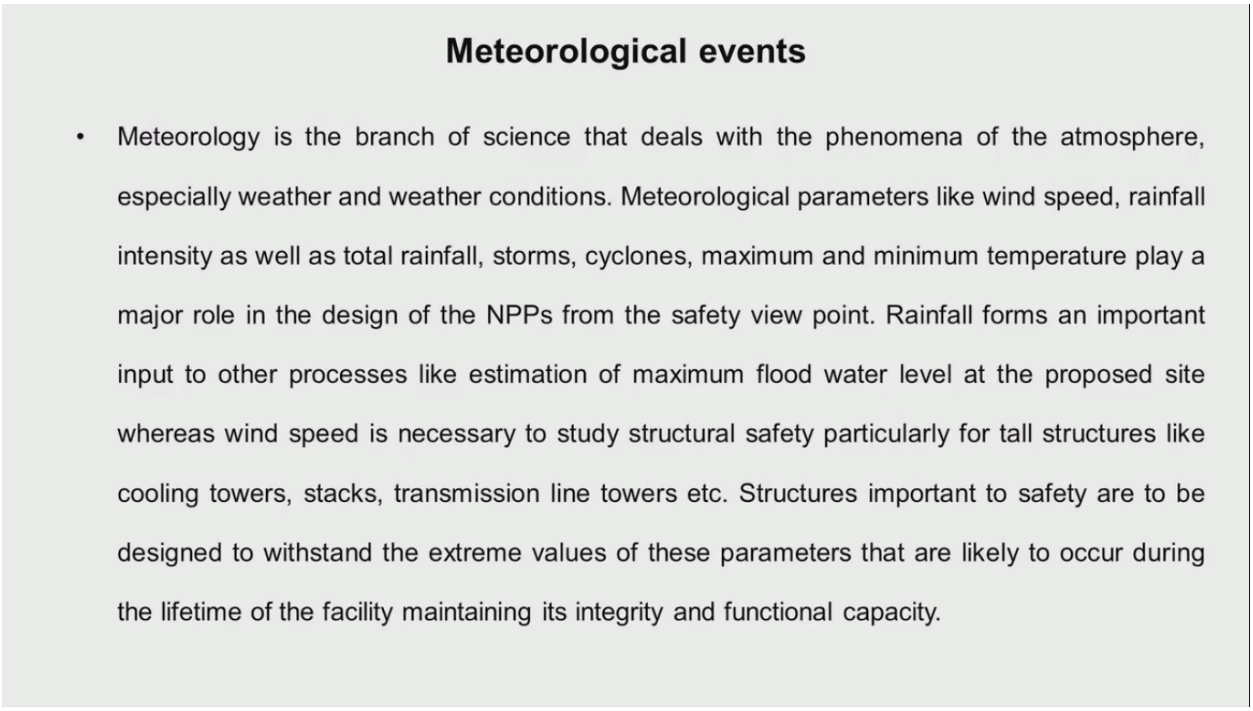

Then meteorology. Of course meteorology deals to the weather, the weather conditions, the climatic conditions throughout the year, how the wind speed, the wind direction, the rainfall, any storms, any cyclones and how what is the maximum temperature, what is the minimum temperature; all these data for quite a large number of years we have and we see whether the maximum flood level that can happen at the site whether I can engineer my plant. Normally we try to find out what is the maximum design basis flood at a place, maximum wind loading at a place, and without much economic investment I can design the plant, economic penalty I can design the plant I will design the plant. Engineering is not difficult, but if it is going to be highly costly I would not like to do it.

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- The site is also investigated for subsidence of ground due to occurrence of geological feature called 'Karst', mining activity and oil extraction. Karst is a special type of landscape that is formed by the dissolution of soluble rocks. During rainfall, water seeps into the soil. The water becomes weakly acidic when it reacts chemically with carbon dioxide in the atmosphere and the soil to form carbonic acid. This acidic water passes through the bedrock, dissolves the rock material and eventually forms into cave passages and caverns, which is termed as Karst. Incase potential of such geological hazards exist and no practical engineering solutions are available to mitigate their effects, the site is deemed unsuitable.

So all the structures which are important to safety ought to be designed to withstand the extreme value; there is no what you call margin in that. It has to be totally met. We can have an upper margin but not a anything to the lesser one.

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- The meteorological and climatological characteristics of site region are investigated to derive extreme values of the meteorological variables such as wind, precipitation, snow, temperature, storm surges, and rare meteorological phenomena such as tornadoes, tropical cyclones. Under the influence of high wind velocities, the materials on the ground (e.g. wooden poles, vehicles etc.) could be lifted into air and could form a projectile which can impact the plant structures in the form of a missile. Potential missile hazard associated with tornadoes and tropical cyclones is also considered and adequate design measures are incorporated if necessary.

So these all these conditions even snow it can be snow. If it is going to be located in a place very close to the hills or the northern side snow can settle on the what you call dome of the reactor that it can – the dome can fail. The snow will add loading to the plant. So it is very important and not only that if you have a high wind and you have some steel yard near by the very large amount of wind can lift the steel plates they can missiles, the projectiles could be happening. So the missile hazard and the potential hazard because of this flying objects in case of a very large wind needs to be kept in mind while choosing the site.

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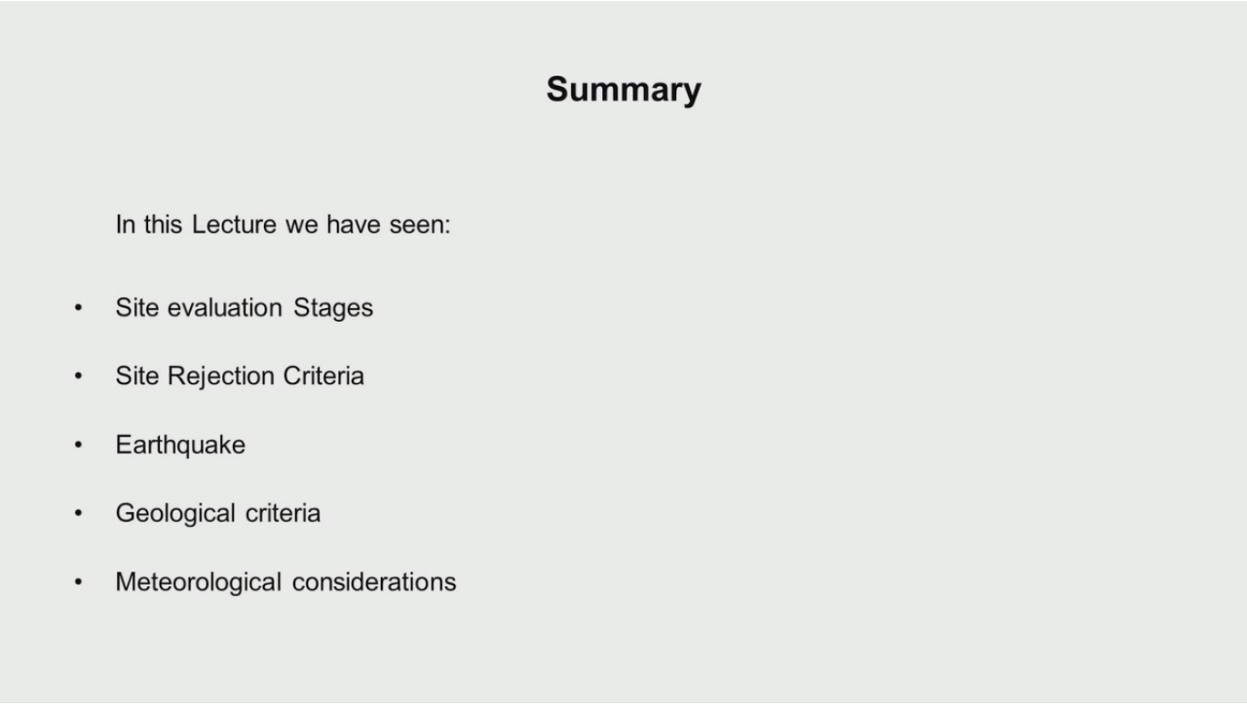

In summary what we have seen in this talk is the different stages of site evaluation. We also had a look at what sort of criteria are applied like from the fault, earthquake fault center how minimum distance it should be, how much it should be distant, minimum distance from a let us say a toxic chemical factory. Not only that, how much distance it should be from an airfield. For example, now you take our Kalpakkam site. After the establishment once the site of Kalpakkam was decided, now in the air routes normal flights no flight is allowed in the direction of Kalpakkam. The aerial routes are away from Kalpakkam. So air corridor is not anywhere above Kalpakkam. Of course during surveillance as a part of the our security, we do surveillance in helicopters above the plant, we go round, see activities going on. All that we do but that is only a planned even but normally we do not have any normal flights going about the Kalpakkam plant. So we have all these rejection criterias but we also look at the social aspect like pilgrimage center and our monuments which should be preserved. We do not do. So we look at the different rejection criterias. Then we looked at the earthquake. The earthquake how an earthquake is caused, how the energy is built up, and how it can cause failure, damage to property. Then we had a look at the geological criterias which or

the geological conditions which need to be looked into from the idea of sliding rocks, avalanche, etc. Then the meteorological considerations; the wind, the flood, etcetera. So we saw all this.

So with this I conclude my talk on these siting aspects. Thank you.

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