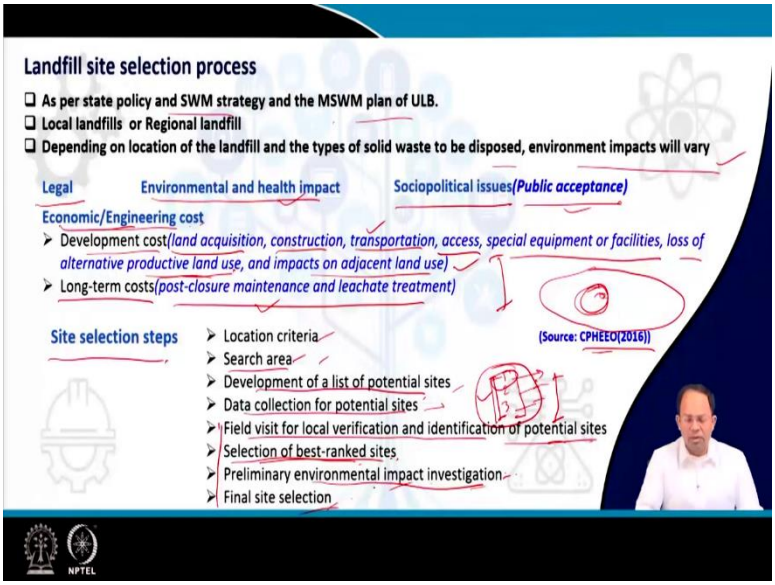
Urban Services Planning
Professor Debapratim Pandit
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur
Lecture 32
Site Selection for Sanitary Landfills

(Refer Slide Time: 00:29)

Welcome back in lecture 32, we will talk about Site Selection for Sanitary Landfills. The different concepts that we will cover are the landfill site selection process, location criteria, search area, field visit and potential sites, ranking and selection of site as per CPCB guidelines. Then we will do a case study of calculation of site sensitivity index of two sites in Varanasi, then final site collection and case study and then we will do another case study on ranking and selection of sites from international case study. And finally, we will look into data collection and site investigation that is required for selection for gathering the data that is required for the site selection process.

(Refer Slide Time: 01:13)



So, the landfill site selection process as in the last lecture, we have discussed a sub certain criteria for that as specified in the solid waste management rules 2016. But, at the end of the day, it is as per state policy and solid waste management strategy and the municipal solid waste management plan of the ULB which is taking into consideration that is every state has its own set of rules and strategies that they formulate following the MSWM rules of course, but at the same time every ULB have their own specific plan.

So, the final landfill site selection is done according to that, and sometimes local landfills are not possible that is there is not adequate space to for creation of a local landfill site. So, in that case a regional facility is required, and a regional landfill is decided for you know, for adjacent ULB's of a particular area, depending on the location of the landfill, and the types of solid waste to be disposed the environmental impact will also vary.

So, that means, the environmental impact for each site is different. And what kind of environmental effects impact should be investigated in detail depends on what sort of waste is coming to the landfill as well as in which area we are present. So, if it is a rainy area, we will go for certain kinds of parameters that we should check if it is a dry area, we will look for other parameters. So, that determines in how the analysis should be done.

Now, fundamentally, there are a few things that we have to follow one is the legal aspects, what are the laws, what are the rules of the land. So, of course, we have to follow the state policy and strategy and the MSWM plan and MSWM rules. So, these are the legal aspects

that we have to follow. The environmental and health impacts we have to understand what would be the max the environmental and health impacts of a particular offer choice to develop a landfill it at a particular site.

Socio political issues, maybe we will find a site very suitable in every measure, but people in that area may not be accepting it. So, public acceptance is a key. So that again becomes we have discussed this earlier right. So, this kind of protest can actually stop a project halfway after construction, it may get stop with waste of time, money and all and finally, the economic and the engineering cost.

Now, a basic cost is obviously there that means whenever we have to create an engineered facility or sanitary landfill, there will be obvious engineering costs, but depending on which site we choose, this cost will vary. Because what happens in each site that impact is different. Now, if it is within the limits, that means then I have to say that okay, in both cases, there are some impacts, but it is within out the limits that is allowed by as per rules. So now, how should I compare which one should we should select, which site should we select? The one where the impact is less, or how we can make the impact less, we can make the impact less by investment in liners, we are more better quality covers and so on.

So that means every site we can improve it by investing some amount of money in the different kinds of equipment or technologies that we use to design that particular site. So, in that case, this cost will also change for each site. So, engineering and economic costs, plays a big role in selection of a particular site. So, and it is not only the cost of actual construction, but also cost a mitigation of the environmental impacts and all. So, all this overall needs to be considered.

So, what is the cost? So, there are two parts to it, one is the development cost that is the cost during the development phase of the landfill and the long-term cost for the landfill as well. So, it includes cost of land, construction cost of the landfill, transportation costs, that means, how far away is the landfill is, if it is far away every day, I will spend money to transport waste over there as we have discussed this is the most costly as part of solid waste management. Access cost that is within the site also access or maybe the site is far away from the highway. So, they have to construct a road for that.

Specialty equipment or facilities as per that particular site, loss of alternative productive land use. Now, one landfill could be constructed at a barren site, whereas another landfill could be

constructed in an agricultural land and maybe it is three crop agriculture land. So, obviously, even though the land price maybe not that different, but in future productive use of the land, that means we are not getting to create grow crops in this particular land for the three crops every year for the you know, for the next 15, 20, 30 years. So, in that case, it is a loss as well.

So, that was an issue we considered an impacts on adjacent land, because if we construct the landfill, automatically the surrounding landfills will be impacted, some maybe because of the environmental pollution, but primarily the overall cost of land in that area goes down overall you know, because of litter because of odour, the overall quality of life in that area goes down and that impacts everything, nobody would like to come over there and so on. So, that really brings the overall cost of land and the quality of life in that area. So, all this should be considered at the cost.

Long term cost is post closure, maintenance and leachate treatment. So, this is what during after the operation is over, we have to keep on monitoring the landfill post closure operations are there. So that will also involve that in cost. So, all this cost has to be considered when right choose a particular site. Now, CPHEEO has given us some stages in which we can go ahead with the site selection process again, this is not mandatory, but this is a process which is suggested by CPHEEP, obviously other agencies or other bodies will suggest other ways also, but more or less, the basic process is same for everybody.

So, first of all, we have to decide on the location criteria, that means which are the aspects that will decide on the choice of a landfill site as per rules as per environmental impacts and so on. Then search area, now in which areas suppose I have got a ULB over here. So, till what distance I will search for a landfill site or because the ULB has its jurisdiction only over till this. So, should I search a landfill area within this area itself. So, all these things plays a role. So, search area is determined based on jurisdiction legal, administrative, as well as you know, consideration of the surrounding habitations and so on.

Then, the development of a list of potential sites. So, this is the first stage selection criteria that means, we can based on land availability, based on government land availability, based on cost of land we can create based on the initial location criteria and search area, we can create a list of potential sites. Now, we have to determine within this particular list of sites or this maybe 10, 15 areas that we have found out, we have to find out which ones is the most

suitable. And for that, we have to do a ranking procedure for these sites. And here again, we use several criteria to generate the ranks.

Now, because we are generally using several criteria to generate the ranks we require data. So that is why data collection is required and field visit for local verification because some data we can get from Maps secondary sources and so on. But appeal verification is required for you know, verification of those particular maps and all if the current situation is same as what is depicted in the map. We can do some investigations locally like groundwater level and soil type all this we can do some tests over there and finally, searching identification of the potential sites.

So, once we create this ranks and all then we can say that out of 15 sites, the top we take the top 1, the 3 sites or maybe out of top 10 sites, I take the top 3 sites based on this ranking, then I do further detail analysis, which should probably look into the environmental impact of this particular three sites. Now environmentally impact analysis we have learned earlier. So over there, we do detailed analysis of impact on air impact on water, impact on all the other, you know, the surrounding habitat, and so on. So, this requires lots and lots of detailed data. And also, it is difficult to do this exercise, but all the 10 sites.

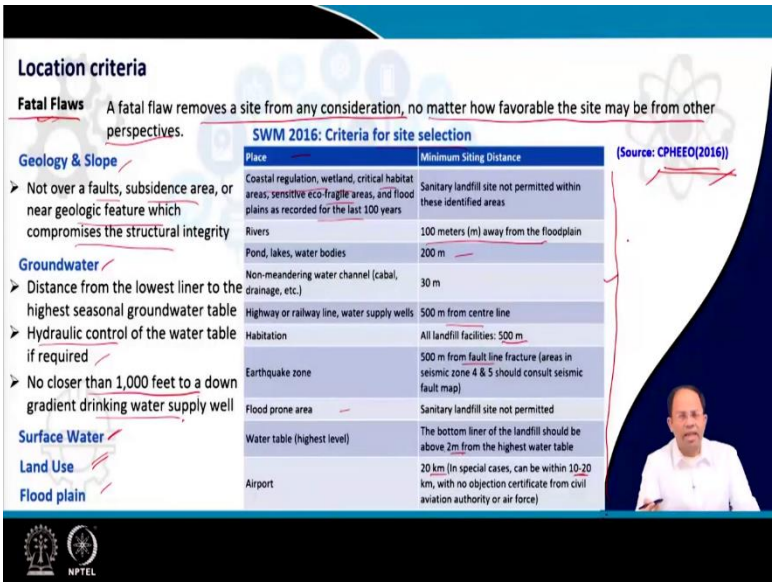
So, we can use a preliminary ranking procedure for this sites to reach at a consensus that these are the top 3 or 4 sites, and then we can do a detailed study of the environmental impact of this particular site. And the final site selection procedure not only considers environmental impact, but other factors like cost, the distances, which are you know, very pertinent in terms of the amount of money that we will invest in this particular area. So, this is the procedure selected, as you know, proposed by CPHEEO, but obviously, you can see that I can reduce all these in all this into only one stage as well.

That means, I go and collect data from all the potential sites, I can do a detailed evaluation, using this ranking method and say whichever is number one, like that, but in that case, the ranking has to be very, very detailed, or the criteria that is utilized will include the cost of land, the transportation cost, land availability, environmental impacts, different kinds, everything has to be considered in the ranking procedure.

So, if I do not want to do it in multiple stages, we can do it in one stage as well. But in that case, the amount of effort that report is quite large, because you have to collect detailed data from all these sites. Otherwise, we can do our initial ranking based on some criteria. And then

we can do a detailed environmental impact analysis assessment analysis on a few sites and then finally, based on environmental impact, and maybe some other parameters, we can do a final selection of that.

(Refer Slide Time: 11:53)



So, talking about location criteria, what are the aspects that should be covered? Now, the first thing that I will talk about is called a Fatal law. Now, what is the fatal flaws? A fatal flaw removes aside from any consideration no matter how favourable the site may be from other prospects. The site may be absolutely good in terms of transportation costs, cost of land and all but maybe one factor is such that it cannot be allowed to be a landfill site.

And usually, these factors are related with geology and slope, groundwater, surface water, land use and flood plain, if the site is within 100-year floodplain, obviously, we cannot have it because it has been the chance of flooding, if it is in over a fault area or a subsequence area or near a geologic picture which compromises the structural integrity of that site, we cannot have it there.

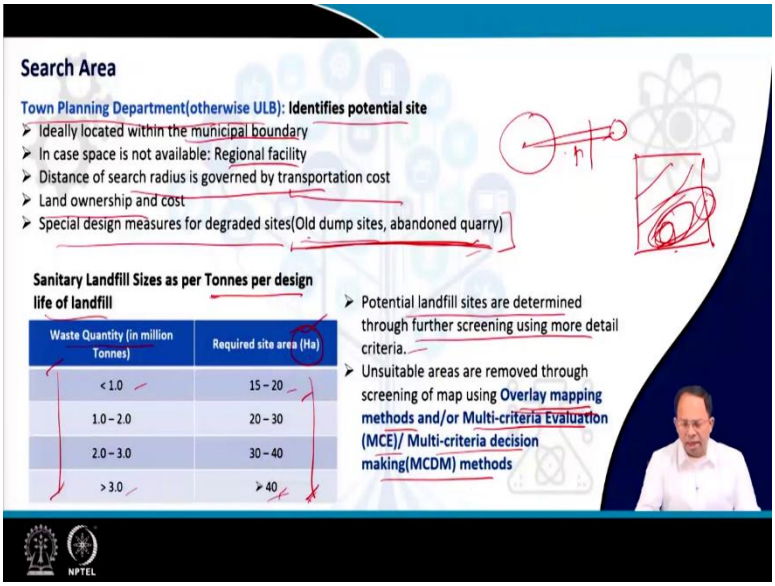
Groundwater if we have no adequate depth the groundwater table is available very near to the surface in that case, we cannot have it, whatever you do like hydraulic control, like we use pumps to lower the groundwater table, that means we create that cone of depression and we lower the groundwater table. So, in that case, also, you know, we can go for sites with a higher groundwater table, but still there is a basic limit of 2 meters as we have discussed in the previous lecture, no closer than 1000 feet to a downloaded drinking water well.

So, this is one where different city may have their own set of rules like then surface water, land use in the surrounding area, all these are considered. So, some of these may become a fatal flaw which will avoid us to have a landfill site over there. But every site is does not have a fatal flaw, we can do some other comparisons or do some ranking and other use criteria to determine its rank or weight or we can give it a score and using that we can deselect or setup you know sites which are potential suitable sites. Now, here I have listed the SWM 2016 and CPHEEO these are some of the factors which you can consider as an absolute must or you can see even a fatal flaw while selection of landfill site.

What are this? Like sanitary landfill site is not permitted within Costal regulatory zones, wetlands, critical habitats areas, 100-year floodplain, eco-fragile areas and son on. It should be 100 meters away from the rivers, 200 meters away from freshwater bodies, 30 meter away from non-meandering water channels, highway or 500 meters away from a highway minimum or a railway line, 500 meters away from settlements human habitations, 500 meter from fault line fractures.

Then Sanitary Landfill is not pumped in flood plain. So, these are the ever 2 meter from a water table. Here put 20 kilometre but 10 to 20 kilometre as we have discussed in certain special permission can be obtained, then the site could be with 10 to 20 kilometres. So, as per MSWM rules sorry, solid waste management rules 2016 and some other criteria CPHEEO has given a CHPEEO, they have given this set of criteria, which will be utilized for pre-selection of sites that we should consider. So, that means, if any of this is violated, we have to immediately you know, lead that site out of our contention.

(Refer Slide Time: 15:29)



So, then come the search area, to understand to determine search area first we should understand how much area is required. So, for that CPHEEO gives a table where give certain specifications for example, if the total quantity of waste which is measured in million tonnes per design life of landfill that is total quantity of waste that will come to this landfill site, if it is less than 1 million, the total site is 15 to 20 hectare. Similarly, if it is more than 3 million tons, then it is more than 40 hectares.

So, first criteria is this that means, if I know that to this value, we will know because I know per capita wealth generation and other waste generation and we can project that for our 50 year sorry 25 years, the total waste that is generated based on that we can have a rough estimate of what kind of area is required. So, this is that rough estimate which is given over here. Now, using this rough estimate we can do preselection of sites, that is at least this material has to be available over there, if the area is like you know 10 hectares then obviously there is no point of considering it as a landfill site.

So, all this has to be considered. So, ideally the town planning department or in case there is the town planning department is not there that particular ULB identifies the potential site. So, each if it is available within the municipal boundary fine, if there is adequate land there, but if not been a digital facility maybe considered. And they can do this initial selection based on a search radius, which is why because then it will be within transportation cost will be within a certain limit.

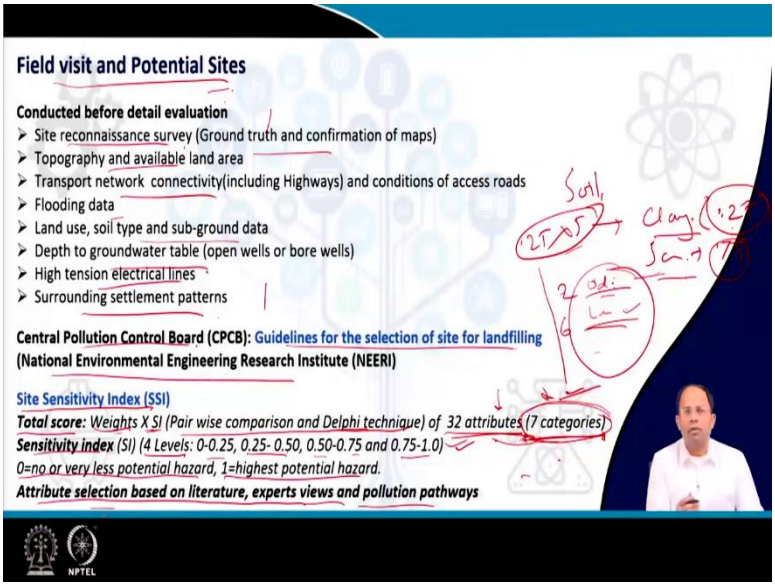
So, usually the search radius is like for example, I have a ULB usually we take it from the centre and we find the distance of that potential landfill site. So, from this calculation, I can easily make out that what sort of cost will be there, and we have to do it for every day for so much quantity of so, many lorries are so many vehicles and so on. So, from that I can make an estimate and I considered okay I should not go beyond 15 kilometres or beyond 20 kilometres something like that.

So, that then land ownership and cost who owns the land does government have land over there or do you have to buy that land in that case, what is the cost of land and then special design measures could be also adapted like for example, if there is no land available, sometimes we have to use the old dump sites or amended queries and other kinds of areas, degraded areas in that particular locality. And then there has to be some special measures or special investment or engineering design that has to go to use these kinds of sites as a landfill site. So, absolutely, there is no land available, then we have to this is the second layer options, second set of options that we have to consider.

So, the first once this search area is determined, then potential landfill sites are determined using further screening using more detailed criteria and that is where the ranking and all this thing comes in. Now, there are two ways to do that, we can either do it through the overlay mapping method, overlay mapping method is I have a map for slope, I have a map for soil type. So, slope wise I say this area is suitable they based on soil type, I will see this area is suitable the other soil type is not suitable, then we can have further criteria in that way we can find that only a certain portion is suitable for setting up a site.

So, we can use this overlay mapping method and or multi criteria evaluation or multi criteria decision making. So, I will show you examples of that. And that means we use several criteria. And we give some weightage to each of these criteria. And we will measure the value of this particular aspect for each of this landfill site and then we can arrive at an overall score using all these criteria. That is why it is called a multi criteria analysis. And we can select which site is better.

(Refer Slide Time: 19:50)



So, before we start this detail analysis or ranking procedure, we have to go for field visit and we have to determine you know, we have to do some basic evaluation. For example, we do site reconnaissance survey, we ground truth and contamination of the maps from that we have opt in from secondary sources, topographic, transport network connectivity, flooding, land use soil types, sub ground data, what kind of you know, underground you know, this base we have got like for example, what kind of what kind of rocks are available below and all this which may decide on what sort of measures we have to protect the depth of groundwater table, high tension electrical line within the site surrounding settlement patterns.

So, all these three basic data has to be collected, even before we go for detailed data collection. And again, as I told you that, here we are talking about a much larger number of sites. So, we cannot do very detailed investigation or detailed data collection for each of these sites, but at least some amount like we have to do this basic investigation, we have to go to the site surface, we have to do this kind of investigation or this kind of data collection. Now, central pollution control board along with NEERI National Environmental Engineering Research Institute has given guidelines for selection of site.

Now, what they propose this, they have also proposed a ranking procedure, where they have asked us to where they have given a method to create a total or compute a total score based on weight of different criteria that are used for your selection, multiplied by a site sensitivity index. So, sensitivity index that means, the value of that particular criteria for that particular site. Now, this overall this is known as the site's sensitivity index or landfill sites.

Now, usually the weightage are determined via pair wise comparison between that different criteria. That means, we can ask experts for their opinions on if I have got two criteria, that is one is odour from the landfill site and we have got leachate production, which one is higher in their priority list, which one is more harmful to the environment, they will say leachate is more often. So, obviously, leachate is more important than odour.

Similarly, there are other criteria that we can do pairwise comparison and using the pairwise comparison there are certain techniques called the analytical hierarchy process. Using that we can determine the weight of each of these criteria. There are other methods also like we can also use other techniques like we ask people about what is the importance they think and from there, we also can compute the weights and all, but usually this pairwise comparison is more robust. But, in case there are lots and lots of criteria, then the pairwise comparison is difficult to create, and we will go with importance rating and so on.

So, then we can use the Delphi technique that we multiply the weights of importance of each of these criteria multiplied by the actual value of that criteria. This actual value is the sensitivity index for that particular criteria. So, it is a relative measure. So, there are four levels are created 0 to 0.25, 0.25, 0.25 to 0.50 to 0.50 to 0.75 to 1. So, this is a relative value, it is an index sort of thing that we are creating that means for each criteria, there is a weight and then there is the value of that particular you know, condition for example, soil type.

So, order leachate soil type maybe the weight of the soil type is 5, whereas order is 2, leachate is 6, these are the weights and soil type now over here is clay soil. So, clay soil I will give a figure out there is maybe sandy soil, sandy soil probably gets a value which is pretty low, that is 0.75, whereas clay soil which is good, it may get values such as 0.25.

So, 0 is given no or very less potential hazards, and 1 is the highest potential. So, that means if there is sandy soil, there is more chance of leachate going down. So that is why I have given a score of 0.75, whereas in clay soil there is this chance of digit popularity, so I have given a value of 0.2.

So, we multiply weights with the actual value of soil for that particular site, maybe this is clay one. So, we will multiply by 5 into 0.25. And we get a score. And when we add up all the scores for all that criteria, we are now doing a multi criteria analysis we get an overall score and using that score, I can compare between different sites. But as you understand these are related criteria measures to determine what is the impact of this particular site.

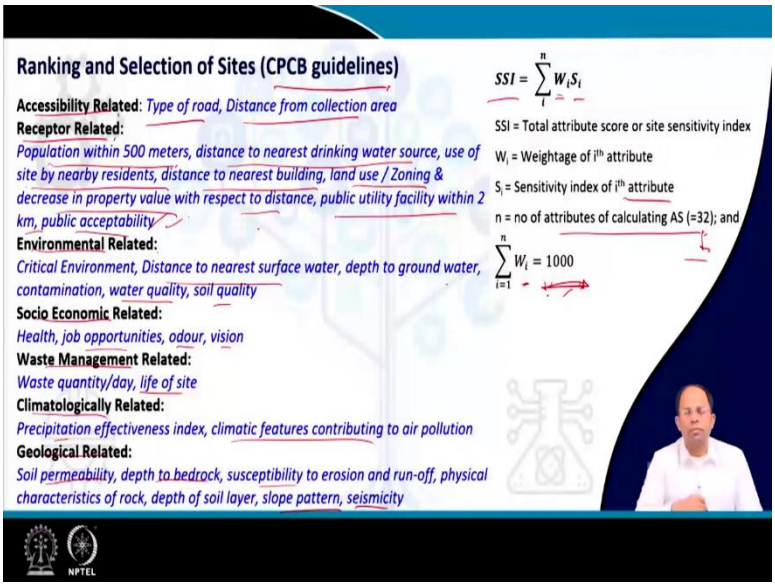
Now, environmental impact has spent there we have to actually find out the detail your measures of how harmful that particular site is to the surrounding environment by you know, either by monitoring the particular location in regard to quality of water or air or by doing some sort of calculations to project what will be the impact for that particular area.

So, the all this requires certain attributes to be construct and selected. So, in this case, you know this guidelines CPCB if considered 32 attributes and this are over 7 categories that is their sub categorizes them into seven categories and then the in each category there are several attributes and overall there are 32 attributes.

Now, there is one benefit of doing this categorization, when you do pairwise comparison, we this categorization helps you to reduce the total number of pairwise comparisons that you can do. So, you do pairwise comparisons between the categories between the general this attribute which are within the category and then between the categories, we can do another layer of you know, this comparison.

So, attribute selection is based on literature, expert views and the pollution partners that is what impacts what So, that is the pollution pathway. So, based on all this we have, that this attribute will be selected based on which the criteria for selecting a landfill site can be determined.

(Refer Slide Time: 26:32)



So, this is the CPCB guidelines. So, they have made seven criteria categories accessibility related category, receptor related category, environmental related categories, socio economic,

waste management related, climatological integrated and finally, geologically related. Now, let us look at the criteria some of them accessibility related this type of road and distance from collection area.

So, these are two parameters two attributes popular receptor related means, you know the effect who will be affected by pollution in our population within 500 meters distance to nearest drinking water source use of sight by nearby residents, distance to nearby building, land use zoning, decrease in property value with respect to distance, public utility facility within 2 kilometres public accessibility, all these are factors which can be considered and we can do relative comparisons between two sites to see which one is better and accordingly we can give scores to it.

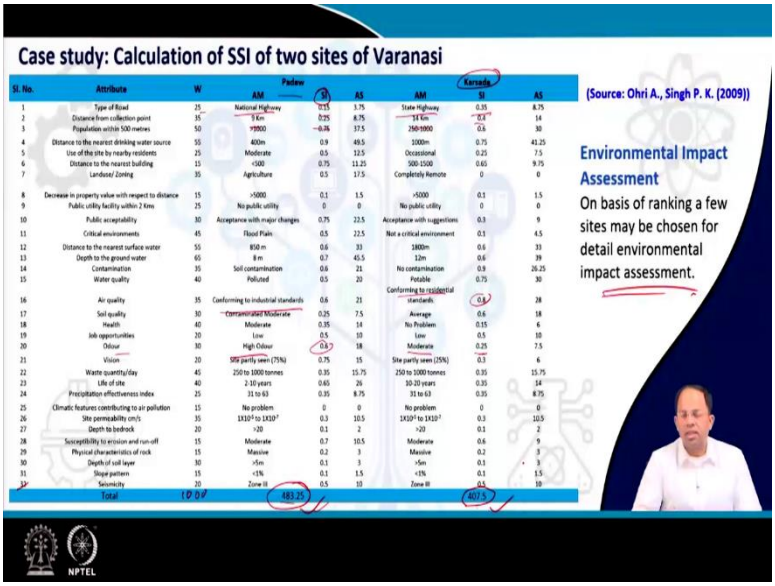
So, again like public acceptability, so, is there any compensation so, to make this site actually happen, then we may have to compensate the people. So, that involves actual costs or decrease in property value there is actual cost involved. So, these detailed calculations are done later, what we are doing now is just a relative measure between the two sites, which one is more or less.

So, that is so, this kind of evaluation helps in the ranking of the sites that solve, but for actual environmental impact actual cost considerations, we have to do further detailed calculations. And as I told you, this cannot be done for all sites, it could be only done but few sites, that is why we do initial screening, why this ranking procedure then we can do those particular calculations.

Then coming to environment related, critical environment distance to near a surface water depth to groundwater contamination, water quality, soil quality, socio economic job opportunities, order, vision, waste management, life of site that is possible based on area if the area is less the life of site will be lower, precipitation under climatic features. Then the soil permeability depth of bedrock, these are the other parameters or other criteria slope pattern, seismicity the method that are also considered.

The method there CPCB we have suggested is to create SSI is to multiply weights with each of this you know sensitivity index of each attribute and we get a total score, and total number of attributes is 32 and overall, the summation of all the weights comes to around 1000. So, that means some weights like within this 32 some has got higher weight, some has got lower weight. So, overall, when you add them up the measured the total weight is very powerful.

(Refer Slide Time: 29:33)



So, this is the example a case study from where two sites in Varanasi have been constructed has been evaluated. As you can see that all these 32 attributes are being considered and like type of road, the weightages given it is 25, this is a specificity guideline. So, when you add all these weightages for each of these 32 it comes to 1000.

Now, we can multiply this with the A Si that is the sensitivity index of that site. So, here the National Highway is present here the state highways is present. So, obviously, here the score is higher. So, it is a national highway gives you more access. So, that is why the score is lower, because lower score means lower impact, then distance from collection point this is 9 kilometres, this is 14 kilometres.

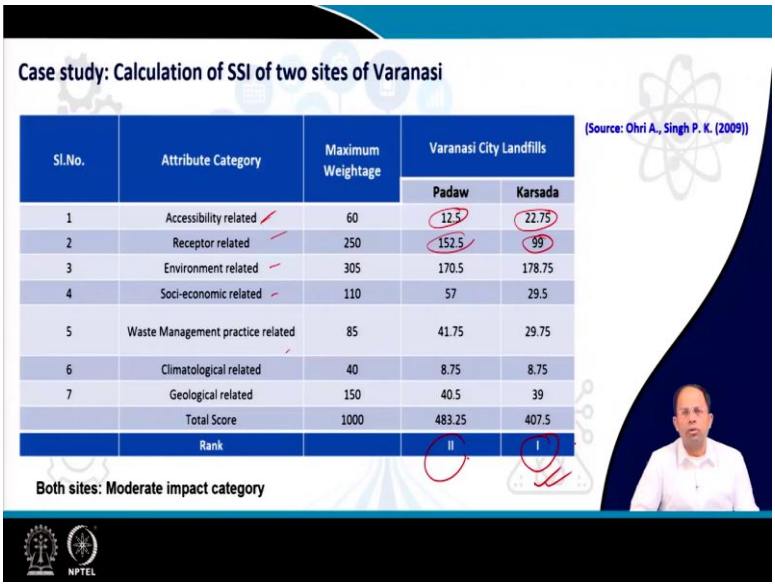
So, obviously, this is lower impact. So, this is 0.25 and this is 0.4 and in such a way air quality conforming to industrial standards, conforming to residential standards. So, this is you know, 0.6 and this is point 8 job opportunity, because here maybe industries are only there, here there is only residences in the surrounding area.

So, we have to conform to residential standards, which are more higher compared to industry standards. So, that is why the score is higher. Then, so, that is why the score is you know, more or more hazard is there, then order this is high order, where this is moderate ordered accordingly the score over here is lower and this one is higher, and in such a way all this value relative value is there.

And once this is done, then this has been added up and the total score for the site number one comes to 483 which is pado and this 407.7, this is for kharsada, this is the score that has come. So, obviously this score is so, environmental, based on this ranking a few sites may be chosen for detailed environmental impact assessment over here only two sites are there.

So, maybe both could be even considered part environmental impact assessment or we can choose the one which is better and we can consider environmental impact assessment. So that that means where scores are less the value is more, so it is a better site. So, obviously, this site will consider for further environmental impactness.

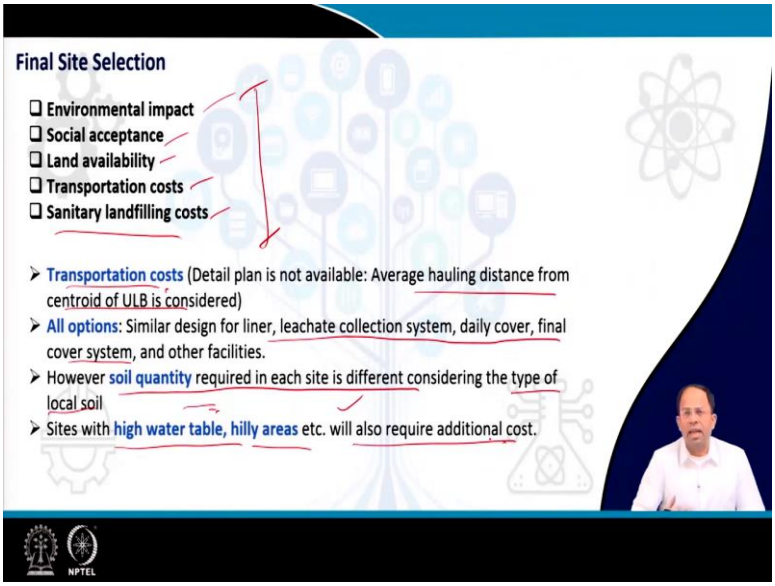
(Refer Slide Time: 32:01)



Sl.No.	Attribute Category	Maximum Weightage	Varanasi City Landfills	
			Padaw	Karsada
1	Accessibility related	60	12.5	22.75
2	Receptor related	250	152.5	99
3	Environment related	305	170.5	178.75
4	Soci-economic related	110	57	29.5
5	Waste Management practice related	85	41.75	29.75
6	Climatological related	40	8.75	8.75
7	Geological related	150	40.5	39
	Total Score	1000	483.25	407.5
	Rank		II	I

This is a summary of these two sites as you can see that this is rank one and this is rank two and here attribute instead of the 32 categories, we have now combined them into accessibility receptor, we have divided into those seven categories and these are the values for each one of them for some site for both of these sites, some value is high, where here the value is low, this is higher, whereas over here, the value is actually higher and this one is lower. So, for each aspect, we are considering what is good or bad. And then based on multi criteria, we are evaluating which site is most suitable. So, we are here this site is to sure.

(Refer Slide Time: 32:44)



So, the final site selection as we have discussed based on is based on environment detail, environmental impact analysis, social acceptance, land availability, transportation costs, and the actual cost of creating that sanitary landfilling facility. And we have determined what sort of cost goes into that. So, this is the final selection criteria, maybe we will consider a couple of sites and then we can do a little analysis to select a final site.

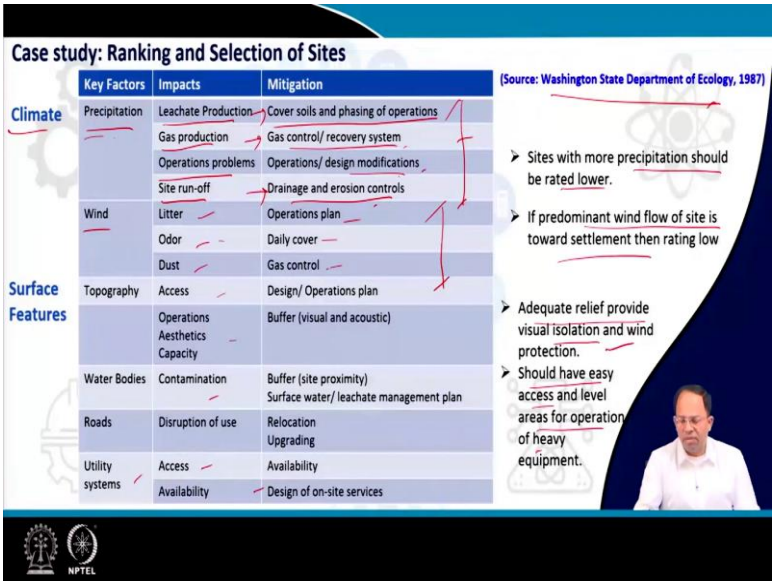
Then of course, transportation cost is a big deal and we have already discussed is the average hauling distance from centroid of ULB is considered like for example, as one important thing is, for example, in both the site so suppose I am comparing three or four sites, the liner, liquid system, daily cover, final cover more or less the designs are thin, it is not that difficult different until unless there is not a change in the geology or in the soil type and so on, but otherwise, these are more or less same.

So, what is different is, the soil quantity required in each site may be different, why because once area may have got you know this sandy soil in the other area, there is clay soil in the area where they said we do not have to import oil from other places, where in our area which is what sandy soil after input soil from other places, soil is one of the most important determining criteria for selecting a location of a site or to determine the cost of particulate engineered landfill facility.

So, we have to be very, very careful about how much soil has to be important because it involves a lot of cost and the quantity of soil required is pretty high for a landfill site. Sites with high water table areas may be chosen, but in that case, there has to be additional

investment for the engineering design. So specific engineering device that has to be adapted for this kind of site.

(Refer Slide Time: 34:42)



This is another case study where you can see that not the this is the international case study from Washington State Department of Ecology. This is their guidelines actually. And you can see that the here they have considered a more detailed number of criteria and what they have considered like under climate they have considered proceed with this is more like an environmental impact different types of impact they have considered.

So, precipitation and wind they have considered and they have determined the impact for precipitation happens, it will create more leachate it will create more gas, it will affect the gas operations it will create operational problems because as we said that, if there is a lot of rainfall, then we cannot use heavy equipment, then there is the site run up that is generated and to handle all this there is also mitigation measures that means, I have to invest more in a drainage and erosion control plan for leachate if it is generated more than more amount of cover soil and more smaller faces has to be caught up.

For gas production if I want to control it the gas control recovery system has been stale installed or we have to design a more sophisticated one. And similarly, operational problems and design has to be taken care of, which also will require more investment. So, this actually gives us an idea about how much investment would be required, and we can do this comparison for different sites and we can put some score for it. For wind litter order does litter means that was sprayed of garbage all around in the surrounding area. So, the operation

plan needs to be modified if there is more windy area, then odour daily cover has to be more thicker.

So, to prevent odour to spread, because of wind, dust, dust will also spread. So, gas control has to be done because most of our gas contains a lot of dust, which actually spread in the surrounding areas. So, all this will require further mitigation measures and further investment and actually that makes the site more costly or the score of that site will obviously be lower.

Typography these are some of the characteristics access operation aesthetics capacity water body, we will look into contamination of the surrounding water and all roads surrounding roads, there will be disruption because of continuous movement of waste vehicles, then access utility systems with availability of water availability of electricity.

So, this kind of thing there. So, sites with more precipitation should be rated lower, obviously, if predominant wind flow of a site is towards settlement, then rating of that site is also low. So that is what we are evaluating and give ratings as per that. Then adequate really provide means really means the change in the height within the site, adequate really provide visual isolation and wind protection.

So, if it is a little bit lower and all it is protected from wind, but it should not create problems for access and because level areas are good for operating heavy equipment and so on. So, if too much of relief that will have some negative effects. So, some same thing can have a positive effect and a negative effect both has to be considered as well.

(Refer Slide Time: 38:00)

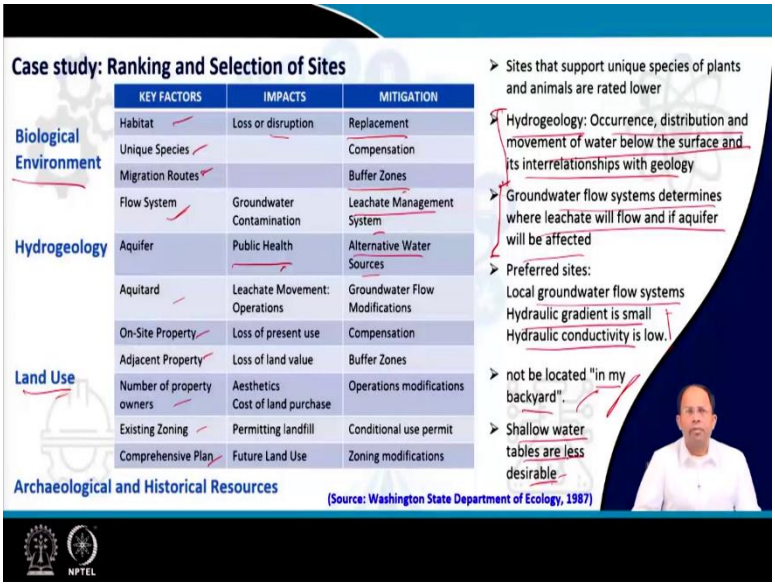
Similarly, for soil types geology, these are the criteria soil impacts or groundwater contamination construction you know, like for example, if adding the thickness is not adequate, then groundwater will be contaminated. So, we require a secondary bottom liner the construction of that site will be affected. So, excavation plan has to be changed operations or site operation plan needs to be changed, then the physical and chemical characteristics of the site like depending on that leachate movement will be different the leachate attenuation will be different operational usage will be different.

So actually, for leachate to prevent leachate movement we have to import for the soil maybe leachate attenuation or spread of leachate we have to do add cement into the soil. So, soil amendments have to be mixed and so on. So, similarly geology considering this bedrock and what kind of environmental hazards are there all these things also you should consider.

So, bottom line is and final cover requests silt and clay types of soil while gas venting and backfill for leachate collection system required sand and gravel type of soil. So, both type of soil are required, it is not like we will just request silt or clay soil but you know for determining the drainage collection layer or the gas collection layer, we require also sandy and gravel type of soil.

So, we have to find out that what sort of soil is available in the site and what is not and accordingly we have to take a decision. Soil for road construction and topsoil and sites. We also request soils for this and usually sites with silt and clay soils rated high and sand and gravel soils require extensive engineering to liner. So, we have to do a lot of mixing of other material and so on. So otherwise, if nothing is possible, then soil has to be imported, which is also much higher. So based on this we can give ratings to different sites.

(Refer Slide Time: 40:00)



Similarly, other parameters are biological environment, what sort of habitats unique species migration routes up some animals flow systems or migration routes are there, for hydrologic we have to consider the flow system of the groundwater aquifer, the spread of the aquifer, the aquitard, then for land use on site properties which are there, what are the adjacent properties, number of property owners existing zoning comprehensive plan for that area all these things that are there and there and each one of them will impact different aspects like you have, if the contamination spreads, it will affect public health. So, we have to also consider mitigation measures for all this.

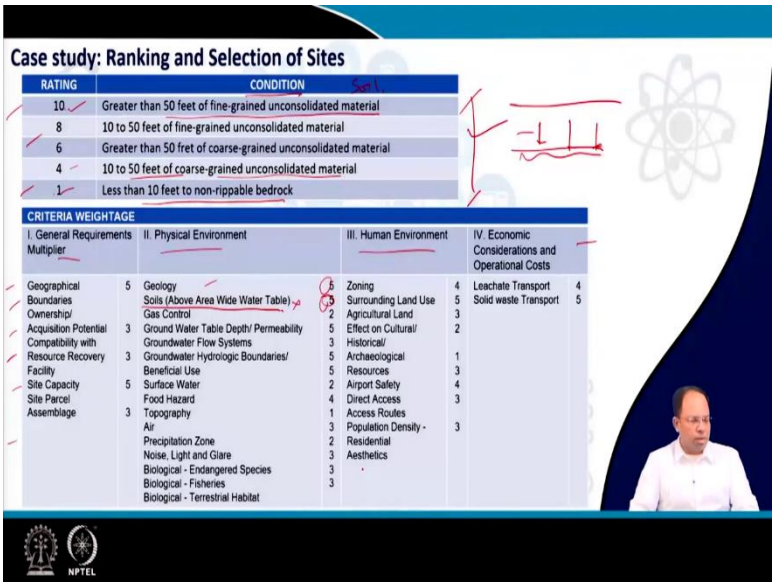
So, these are some of the mitigation measures listed, for habitat we have to do certain replacement of that habitat, migration routes we have to create certain buffer zones for aquifer alternative water sources has to be found for that habitation because you cannot draw water from the aquifer because of contamination. So, for flows for controlling groundwater contamination, the leachate management system has to be designed or augmented. So, this determines the cost of operation for that particular site as well as that will result in a lower or a higher rating for that site.

So, hydrogeology is very, very important, which is occurrence distribution and movement of water below the surface, and it is intense relationship with geology like rock features, soil features and so on. So, this is very, very important for landfill site design and groundwater flow system determines where leachate will flow and that aquifer will be affected. So, these two things are very, very important that should be investigated in detail for each landfill sites.

And so, preference would be sites which have a local groundwater flow system that is it does not stretch too far away, the hydraulic gradient of that particular soil is low or that area is low and hydraulic conductivity of that soil is actually low.

So, when these features are you know, lower, you can give it a better score and always, you know, for land use and all this acceptance, NIMBI that is not in not in my backyard, this kind of you know, protest always happens. So, we have to give adequate compensation, we have to build consensus, that will also require different amounts of effort in different areas, accordingly, we can give some rating to those particular areas, shallow water tables are less desirable compared to deep water table, because if it is shallow, then there is more chance of contamination. So, these are some of the things that we should consider, when we give ranks or for selection of sites.

(Refer Slide Time: 42:48)



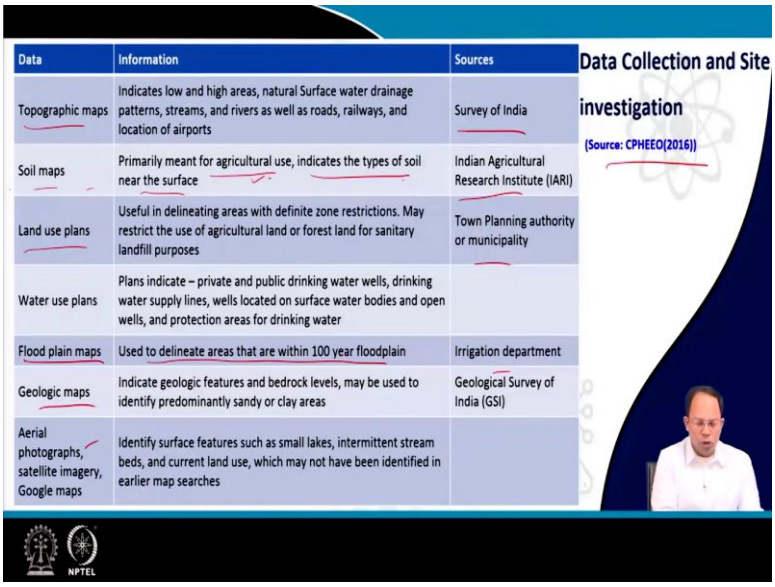
So, for this particular case study, you can see, these are the criteria which requires the which considers the human environment, the physical environment, some generic requirements, and also the economic considerations. So, all that criteria that is considering the cost of operation, the transportation cost, then the cost of land all these things are considered within the same analysis framework.

And this is the weightage given for each of these criteria, which could be generated via some ratings by given by experts or doing HP based on experts opinion. And for each of these criteria, we can create this kind of a scoring pattern where in this particular case study they have used a score of 1 to 10 and this is again a relative score between the sites as you can see

that based and they updated this, here like this is for soil when greater than 50 feet of fine grain unconsolidated materials, the rating is whereas, less than 10 feet of non-repairable bedrock, the rating is lowest which is 1.

So, that means, this is depth of the bed of what kind of soil is there. So, 10 to 50 feet of course, drain unconsolidated material, then the rating is 4. So, this is coarse drained materials. So, that means it allows pass passing up, this will allow passing up leachate pillar. So, based on the soil type that is available, we can give some score for different kinds of soil characteristics in that particular landfill site. We multiply the score with that as the soil and then we get a value for these particular criteria. Now, once we add up all this for all criteria, we get our overall score for this site, and we can do it for multiple sites and see which one is the best same as we have done with the CPCB in that CPC in the study of Varanasi.

(Refer Slide Time: 44:47)



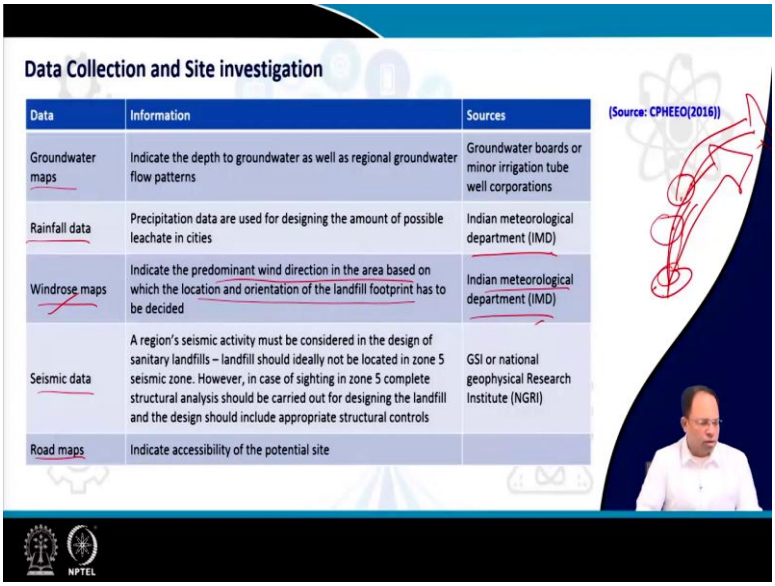
Data	Information	Sources
Topographic maps	Indicates low and high areas, natural Surface water drainage patterns, streams, and rivers as well as roads, railways, and location of airports	Survey of India
Soil maps	Primarily meant for agricultural use, indicates the types of soil near the surface	Indian Agricultural Research Institute (IARI)
Land use plans	Useful in delineating areas with definite zone restrictions. May restrict the use of agricultural land or forest land for sanitary landfill purposes	Town Planning authority or municipality
Water use plans	Plans indicate – private and public drinking water wells, drinking water supply lines, wells located on surface water bodies and open wells, and protection areas for drinking water	
Flood plain maps	Used to delineate areas that are within 100 year floodplain	Irrigation department
Geologic maps	Indicate geologic features and bedrock levels, may be used to identify predominantly sandy or clay areas	Geological Survey of India (GSI)
Aerial photographs, satellite imagery, Google maps	Identify surface features such as small lakes, intermittent stream beds, and current land use, which may not have been identified in earlier map searches	

So, obviously, all these steps require us to collect a lot of data, even though we can do it there or the analysis altogether or we can do it in stages, as given in CPHEEO guidelines, but all this will require a lots and lots of data. So, for example, you will require topographic maps, you will require soil maps, you will require liquid land use plans, water use plans and these are some of the sources from where you can opt in this kind of maps, then floodplain maps, geologic maps, aerial photographs, and this is what they are used for.

So, this table is taken from CPHEEO guidelines. And this will this basically we have discussed soil maps are made, we have to find out that what sort of agriculture used was there or is there and this will help us to determine what is the loss or productive loss in future years

indicates the type of soil near the surface all these things information is gathered from here. Then similarly, if I use a get the floodplain maps, we can use it to delineate areas which are within 100 years of planning and that means, within these areas we cannot have any kind of landfill site. Same goes for geologic maps and other kinds of maps.

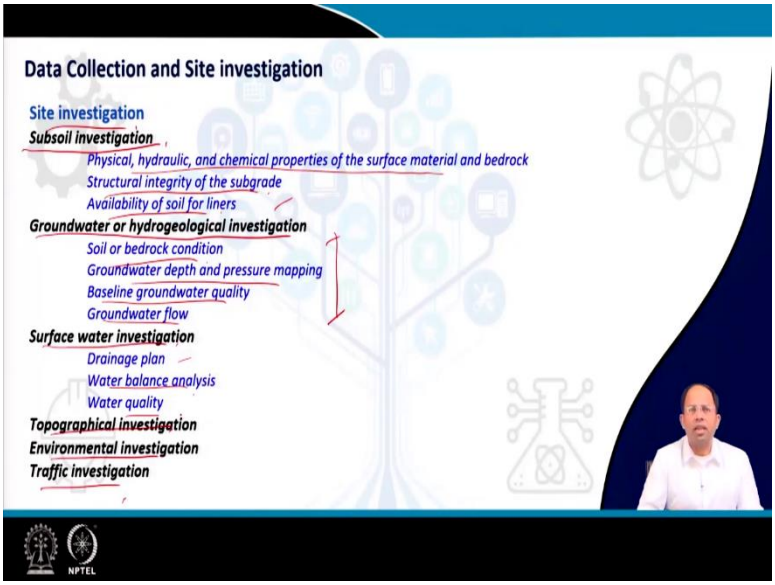
(Refer Slide Time: 46:05)



So, these are other data, seismic data roadmaps, Windrose, maps, rainfall data, groundwater maps and so, on. Windrose maps indicate predominant wind direction in the area based on which location and orientation of the landfill footprint has to be determined. So, if I have our habitation over there, and I have got the landfill site over here, the predominant wind pattern of course, predominant wind pattern is considered because wind flows in every direction all throughout the year, but the main predominant wind direction maybe like this.

So, that means a lot of this order a lot of dust will go into this habitation. So, I will not select this particular site, but if a site is located over here, the predominant wind direction is like this, it will not affect that particular area. So, I can choose that. So, these windrows map actually help us to determine this and we will get the data from the Indian metrological department and for different areas they have this Windrose maps, similar rainfall data is required to determine what sort of infiltration what sort of rainfall will happen in that site. And that from there we can do infiltration analysis, we can do a total water balance analysis of that site and then again, this data from IMD and so on, we can collect our data.

(Refer Slide Time: 47:24)



Now, all data is not available. So, in that case, we have to do some site investigation ourselves, maybe we have to do a subsoil investigation if the data is not there. So, all we have to do our groundwater or hydrological investigation, surface water investigation, topographical investigation, environmental investigation and traffic investigation. So, if data or maps are readily available, we can go and check it at a potential site. But if these are not available, then we have to do the investigation ourselves.

Now, subsoil investigation requests physical hydraulic and chemical properties of the surface material and the bedrock for that particular area we need to analyse those, structural integrity of the sublet, so that we can see if it will be able to take care of that additional weight coming from landfill or there will be subsequent.

Availability of soil for liners. So, these are the things that we need to investigate or to check with different methods and test methods. Groundwater hydrological investigation incorporates soil or bedrock condition, groundwater depth and pressure mapping, baseline groundwater quality groundwater flow direction.

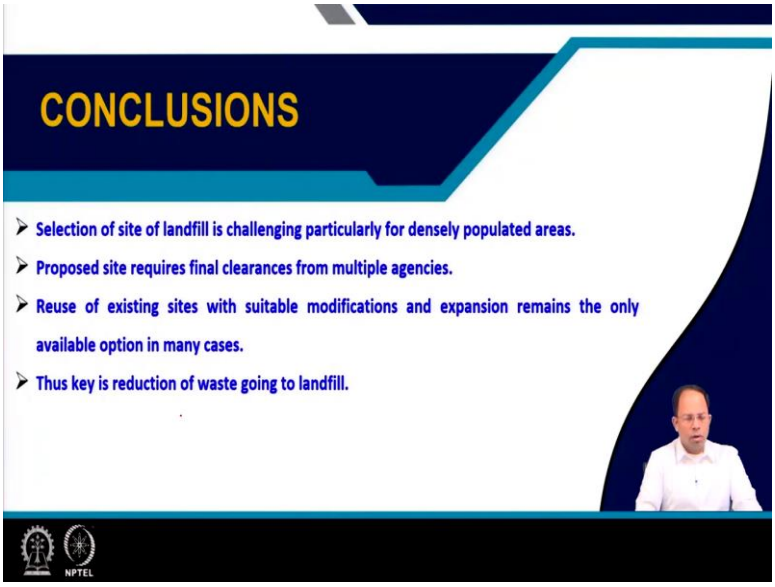
So, we need to create contour maps of our groundwater are based on the piezometric surface. So, all these things will be taken up by measure the groundwater height at the different wells which are located over there, or we can take some measures using some equipment also for that particular area and find determined what is that groundwater table for that particular area and also the direction of flow and so on.

Similarly, surface water investigation is done, we need to look at the detailed drainage plan, the water balance analysis for the site and the water quality analysis for the site and so on. So, this is the kind of data that is has to be collected and the detailed site investigation that has to be done.

(Refer Slide Time: 49:20)

So, these are some of the references that you can study.

(Refer Slide Time: 49:28)



And to conclude, selection of site of landfills is challenging particularly for densely populated areas. And proposed site requires final clearance from multiple agencies and a reuse of existing sites with suitable modifications and expansion remains the only available option in

many cases because land is very you know, in our country we there is not too much land available because there is a lot of settlement the population density is high. So, key is reduction of waste going to landfill. So, we should reduce as much of it that should go into the land. Thank you.