Environmental Remediation of Contaminated Sites
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Lecture – 44
Case Study: In-situ Chemical Oxidation: Part - I

Hello everyone, so again welcome back to the latest lecture session, so the last session we have been looking at or we looked at rather various redox process or non-redox process in the context of chemical methods, right as in what are the various chemical methods that we can use to remediate a particular containment site and in that context obviously, we looked at a few examples but one of the aspect upon which we spent more time let us say was in situ chemical oxidation, right, ISCO, I guess, right.

So, in that context we are going to or you know, we are going to have a particular case study you know that is going to look at the applications of these in situ chemical oxidation methods let us say and I chose this particular case study because it had what do we say, constable data available as in obviously there are many such what do we say applications of or you know cases where in situ chemical oxidation was carried out.

But you know, when I try to find the relevant data, I could not find what do we say, sufficient data or satisfactory amount of data if I can say so, right, so in that is the reason we are going to choose those.

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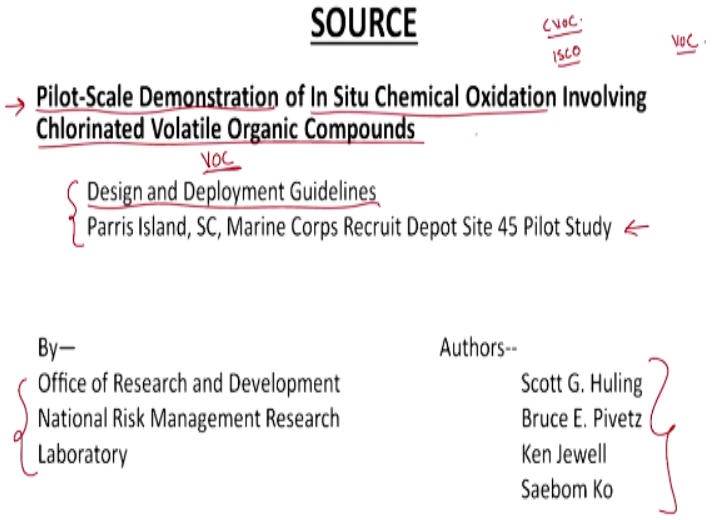

So, what is the topic or you know what is the document that I chose more or less, so it is the pilot scale development or demonstration, pardon me, though I say that its pilot scale demonstration keep in mind that in situ chemical oxidation is widely used and widely practised let us say right but for that particular site for some unique cases, they were looking at pilot scale demonstration let us say, right.

And based on that they were planning to or use it in other location let us say, right, again though we are looking at pilot scale here, it does not mean that in situ chemical oxidation is at its initial or nascent stages let us say of development or usage, right that something to keep in mind, so we have this ISCO and what is this, we are trying to remediate let us say, it seems chlorinated, volatile organic compounds.

So, we have volatile organic compounds let us say, right, so what is the particular document that I am looked at or you know I came up with or looked up rather design and deployment guidelines, you know for this particular pilot study let us say, right and then developed by the national risk management research laboratory let us say, right and then we have the relevant authors.

So, you can obviously, if you want to let us say, gather more information, look up the source document that is available online, so the data that I am going to present over the next two

sessions let us say is going to be from this particular publicly available document out there, right, again this is the source and you can look at the or refer to these particular source if you want more information now, right.

So, let us move on obviously, what are we looking at; we have a site contaminated with CVOC's and we are looking in situ chemical oxidation let us say to be able to remediate this particular site, first aspect let us say, what are some of the issues that you would face now, if it is volatile, organic carbon let us say, right, firstly it is volatile but I guess in this particular site, they have not really looked at let us say remediating that particular gaseous phase let us say, right.

Typically, they looked at remediating that particular VOC which would be absorbed onto the soil now, right and again when I say adsorbed on the soil with what part of soil, let us say or you know what caused this particular sorption of the volatile organic compound and soil, you have this organic matter let us say, or organic fraction of the soil and that adds as source let us say or media for adsorbing these particular volatile organic carbon.

Again that is what we are going to look at, so we have this VOC's and by you know applying an oxidant, we are going to try to remediate the particular site let us say, right.

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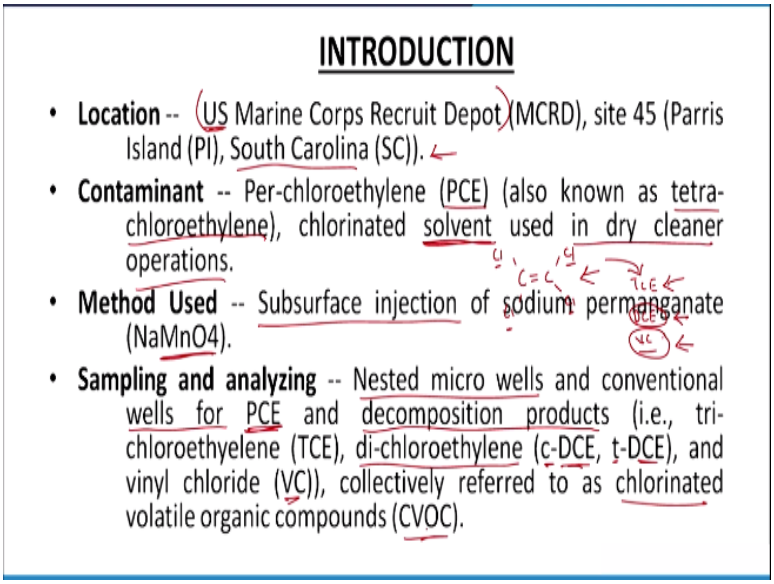

So, let us look at that particular case, so location is again in South Carolina, right and keep in mind that we are talking about US Marine Corps Recruit Depot let us say as and when people let us say in the US let us say, again this is obviously from a site in the US let us say, right and here again as I mentioned it is in South Carolina let us say, right and here I guess this location serves as a base let us say for new recruits let us say to be trained and so on and so forth let us say.

And that is what we have out here and what are the contaminants; its per chloro ethylene or tetra chloroethylene, so it has 4 Cl-, let us say right and that is something we are going to look at again, also called as tetra chloroethylene and typically, as we mentioned earlier I believe we did look at this particular compound earlier too, I believe in the context of permeable reactive barriers, right.

I think we did not start with perchloro or tetra chloro but we started with trichloro, the compound which had 3 Cl- let us say, right, again here we are starting with the one that has 4 Cl – let us say, right as in carbon and then Cl Cl, this is the structure, again typically, toxicity, due to these particular Cl, let us say right and typically, if there are reducing conditions due to different pathways either hydrogenolyses or cleavage of this particular Cl- let us say, right, you are going to have different pathways.

And you can how what do we say, TCE, DCE, vinyl chloride, again vinyl chloride is pretty toxic, DCE is also toxic, so some of these byproducts which are formed when this particular PCE or tetra chloro ethylene is degraded are also toxic that something I believe we looked at in the context of PRB's right or the permeable reactive barriers, again what is the typical use of these particular what do we say a chlorinated organics?

They obviously solvents or you know solvents let us say, right, they are obviously serve as solvents, pardon me, right, so typically here, they have a huge dry cleaning unit obviously, right, you have a huge base and you have need to dry clean let us say or clean vast amounts of soiled clothes, right, so they have a huge dry cleaning unit, there obviously, you are going to use chlorinated solvents, right.

And I believe, they were using tetra chloro ethylene let us say or PCE let us say, right, so in that context again, they were using this particular compound in dry cleaning operations, right, so let us look at what else we have; so here we are going to look at remediation by a subsurface injection of permanganate let us say, right, I believe we looked at permanganate let us say in the context of the in situ chemical oxidation let us say, right, different oxidants.

We looked at ozone and so on and so forth, in that context we also looked at permanganate let us say, right, a strong chemical oxidant now, right, so and that is what they are trying to do and we look at that obviously, so some of the relevant aspects are that they looked at nested micro wells also conventional wells and what did they monitor let us say, obviously for per chloro or tetra chloro ethylene, this particular compound.

And also for the by-products as in the decomposition products as in TCE, the tri chloro ethylene, di chloro ethylene, both the 2 isomers I guess, right; DCE and TCE, pardon me, this is I believe right, DCE; di chloro ethylene and also vinyl chloride, right as we talked about and how are they form? Again, if you have reducing conditions let us say and you have an electron donor let us say, this is the particular what do we say pathway let us say.

I believe you have the pathway but you know that is something easy to deduce let us say and here we are collectively referring to all these compounds as the chlorinated VOCs let us say or the chlorinated volatile organic compound, the reason being that you know most of these are toxics, so you can obviously, look at you know all these compounds or you could typically look at that compound which is more toxic let us say, typically vinyl chloride.

But here the way they have gone about is that they looked at total CVOC's; total would obviously take into account, all these relevant compounds here, right, so that is what they have looked at.

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So, let us look at or understand the site location, again it is out here, along the coast more or less right, again in since to location or since to zone if I may say so, right. So, again along the coast of South Carolina and keep in mind that it is 1 miles South of the city of Port Royal, right that is a major city, yes and what does this particular location serve as let us say, you need some background.

It serves reception and recruit training facility as in you have new or you know you have recruits let us say to the US army I guess or US Marine Corps, pardon me, right and you know these recruits are typically hosted here and they are talking about a particular states that are East of the Mississippi river all those particular states that are east of the Mississippi river, all the relevant recruits from those regions, let us say are sent to this particular base, right.

So that is the considerable or you know you can understand the size of the base and obviously, all the women that enlist nationwide let us say, right, again why are we choose this data; not because it is in the US or such though but because you know this; for this particular site, I had or was able to find relevant data on line let us say, right, so that is one thing to keep in mind.

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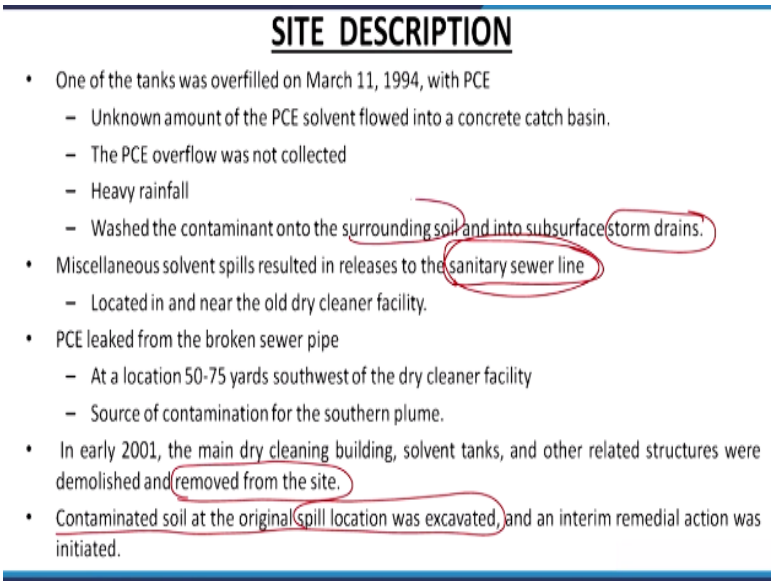

And let us move on, so we are now going to look at let us say, how this particular contamination occur, right and what is the background again, why is that because there are obviously lessons to be learned in this context let us say or in this aspect in the Indian context let us say as in we have a lot of dry cleaning units out there either you know in the unorganised sector or in the organised sector but to my knowledge, you know there is remarkably toxic compounds let us say are rarely or not rarely, at to my knowledge, they are not treated.

Or you know no enforcement too I guess and you know, you have more or less this particular chlorinated solvent being dumped into the relevant soil or the drains let us say and the drains you know the status of a drains let us say or even the end product let us say, again these are CVOC's, there also volatile, so typically, they can seep into the soil again, I am talking about the Indian context here or you know they can volatise too depending upon the relevant temperature and the relevant conditions let us say, right.

Again that is something to keep in mind and now keep that in mind and let us see what we have out here, so looks like they were storing this TCE or PCE in one of the tanks that was overfilled, right and thus you know, there was spill obviously, so unknown amount of PCE flowed into concrete catch basin as in they had what do we say it is all built up area, right and they had the dry cleaning unit there.

And one of these holding tanks for these what do we say, compound as toxic let us say to humans again, right but again as you use here it as an industrial solvent too, right, you know that is filled over, right and obviously, then they also had again, due to various reasons, the what do we say, PCE let us say, that overflowed was not collected or was not treated let us say, right, it was not one of their priorities.

And obviously, you know, worst case scenario you had heavy rainfall and once you have heavy rainfall, you are going to have run off and this washed the contaminant into the surrounding soil, so keep in mind that it contaminate the surrounding soil and also you know obviously, you know travel along with or was transported by this run-off from the rainfall into the strong water drains, right.

So, two key aspects, right, one was that at spill over into the surrounding area and contaminate the soil, right and also because of its transport into the storm water drains let us say, it was and now the drain; storm water drain obviously is carried over to different locations let us say and they analyse related that some of the storm water drains had considerable leaks, let us say and also they were going beneath the water table at some locations.

So, this led to considerable contamination, again we are going to look at those aspects, right, one as we can see is that soil is contaminated and again as you know hydrophobic compounds, we looked at it in the context of pump and treat and so on and so forth, pumping them out and treating is not feasible because the compound is adsorbed on soil that again acts as the reservoir of this particular compound, right.

So, we know that just pumping and treating it out is not feasible though, right, again one particular aspect was the tanks being overfilled and then spill and then heavy rainfall leading to relevant contamination, right, so let us move on so, again obviously during operation and this is something as I mentioned you know, we need to keep in mind in our Indian context let us say, so different you know, during different times or during operation let us say, miscellaneous spills let us say also in resulted in release of this particular what do we say now, compound into the sewer; sanitary sewer let us say not the storm water sewer.

But the general sanitary sewer, right, while operation let us say, you are going to have some minor spills but that particular spills or those spills should be mopped up and clean because again these are remarkably toxic compounds let us say, right but what happen here is that they did not do that but for this level of large scale facility, the considerable amounts of PCE were generated and this also I guess, considerable amounts of spills, I guess this is the conclusion that I am drawing or assumption that I am making, right.

But in the Indian context keep in mind that you know we because of the amount of load that come in you know, this is something that you would presumably happens as in spills occurring or even the PCE being dumped depending on the relevant conditions let us say, so one aspect as we looked at was spill and other aspect was that you know, a miscellaneous or minor spills during operation.

So, obviously now, it is located in and near the old dry cleaner facility as in they learn the lessons and then demolish this; and demolish this old dry cleaning facility later and constitute a new facility later but obviously, you know thus we have an old dry cleaning facility here and as I mentioned earlier, the PCE leak from the broken sewer pipe let us say as in here, you have the PCE going into the sanitary sewer and this is broken, right.

So, now you have contamination of that particular soil and maybe groundwater, right, so at location of; what is the location; 50 to 75 yards let us say may be 50 metres, let us say, right, around 50 meters, source of contamination for southern plume as in there are 2 plumes as we are going to understand let us say. So, we can visualise a 2 plumes; one due to the contamination from this sewer line as in one plume is due to let us say the compound or contaminant being transported by the sewer line.

And the other one due to storm water drains let us say, right, so 2 plumes; 2 more or less correspond to these 2 sources, let us say, right and in early 2001, let us say, once they notice that you know there is contamination and so on, so what did they do; the main dry cleaning building solvent tanks and other related structures were demolished and removed from the site, so keep in

mind that at least once they knew of those particular contamination of the soil or such reach the relevant higher authorities, you know they did start taking remedial steps or remedial action let us say.

And the contaminated soil at the original spill location was excavated, so what happens now; at the original spill when let us say, they had this heavy rainfall, let us say some of this particular contaminant flowed into the surrounding soil let us say, right, so this soil they excavated let us say and treated let us say and then interim remedial action was initiated let us say, I mean minor corps and so on.

But keep in mind that though they removed a particular fraction of the soil let us say or you know, volume of the soil, pardon me, right, you still have or you will have what do we say, seepage of this particular or transport of this particular compound into the subsurface and then along with groundwater, it will be transported, right and again keep in mind some of the compound was also transported by the storm water drains and also the sewage drains or so on, right.

So that different aspects; so one aspect at least what they try to address was the immediately any way was the source location, the contaminated soil that was excavated and I guess taken off site for treatment, right.

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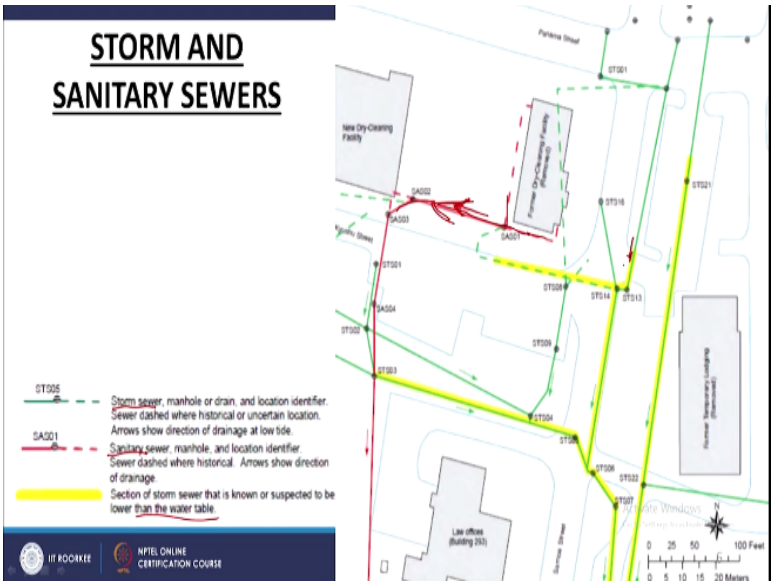

So, here let us look at the location of these storm and sanitary sewers, right and this is the dry cleaning facility that we are referring to let us say, yes and these red dots or the red coloured lines represent the sanitary sewers, okay and the storm sewers by these green dotted lines or the solid lines let us say, right, so I believe, you look at the ligand again or you know ligand in a few minutes but these yellow colour parts of the storm water drain.

Again, keep in mind this is the storm water drain, the one in the green colour but you have some parts of it, you know coloured in yellow, so these particular parts or in this particular parts, the storm water drain is below the groundwater level that is something to keep in mind, right, we will look at that later, so here is the ligand, so storm water, manhole or drain that is the green colour let us say, right.

And again, sanitary sewer is red coloured one, so the key is to understand the flow of this particular sanitary sewer, so any contaminant from this particular location let us say that is collected out here, well be taken in this direction let us say, right, so if there are leaks in this direction obviously, you will have relevant contamination at that particular location and this is the section of the storm water sewer that is known to be or suspected to be below the water table, let us say, again 2, 3 different aspects.

So, the other aspect is to understand the; what do we say, direction of the storm water drains too or the flow of the water in the storm water drains, again keep this in mind because you are going to come back to this later.

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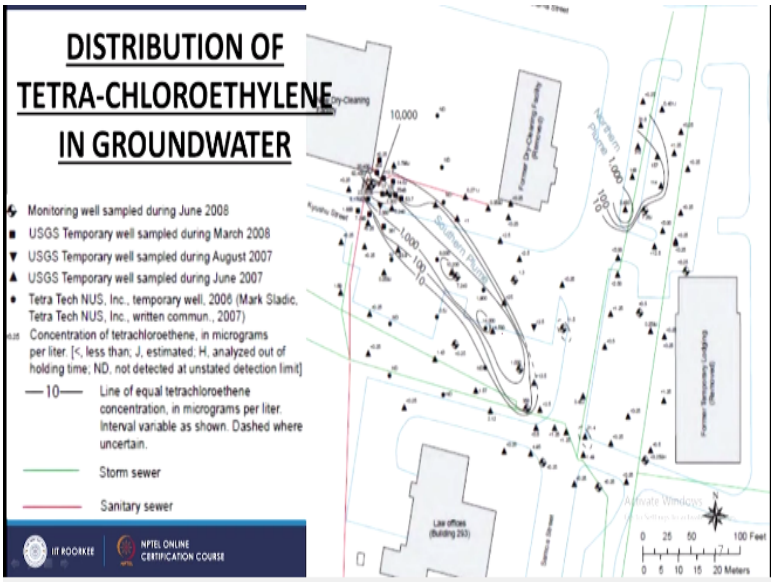

So, now we are going to look at the distribution of PCE, let us say in groundwater, they started taking samples, so obviously as you can see, once you contaminate the relevant site let us say, are lead to obviously understand the site and the extent of contamination, so from this particular set of data as you can see considerable, what do we say, number of locations were monitor let us say, right.

So, here we have temporary wells in March 2008, June 2008, August 2007, June 2007 and so on, so over a period of year let us say, they looked at different aspects, right and again, what are; varies are dry cleaning unit that is out here, yes. If you look at the plumes let us say, as in this is the; these are contours more or less, right, so what are this solid line indicate now; line of equal tetra chloro 3 in concentration in microgram per litre, let us say, right.

So, for example, all along this particular line, the concentration of the relevant contaminant is 10 ppb let us say microgram litre and along this it is 100 and so on, so it gives you an idea about the source of your particular contaminant and the direction in which the contaminant is being

transported, so here as you see is one source of location and as you can see that is on one of these relevant storm water drains, right.

So, this particular one source let us say, the northern plume is along the storm water drains, again keep in mind that these green colour lines are the storm water drains, so you can now presume that you know or may be, yeah presume that I guess, right, the initial spill that occur when there is a rainfall let us say and the spill was transported through storm water drains, so end it up leaking into the relevant soil out here too, right.

So that is one particular case let us say, looks like the source is somewhere out here and as we looked at a continuous what do we say or miscellaneous spills, minor spills during the daily operation let us say, thy were going into the sanitary sewer which is this particular red line let us say, right and that is being transported out and looks like here at this particular band let us say or that particular join, there seems to be a leakage.

And as you can see here, you have a source of almost 10,000 ppb and then you see the different contours; 1000, 100 and 10, right, so now you understand that the contaminant is being transported in this particular direction obviously, we also need to look at it, this particular data in the context of the groundwater data, right as in the groundwater table and understand in which direction the groundwater is moving.

But looking at these contour lines, right or understanding from these contour lines, you can see that you can just guess the direction of movement of the relevant contaminant plume let us say, right, so that is something to keep in mind.

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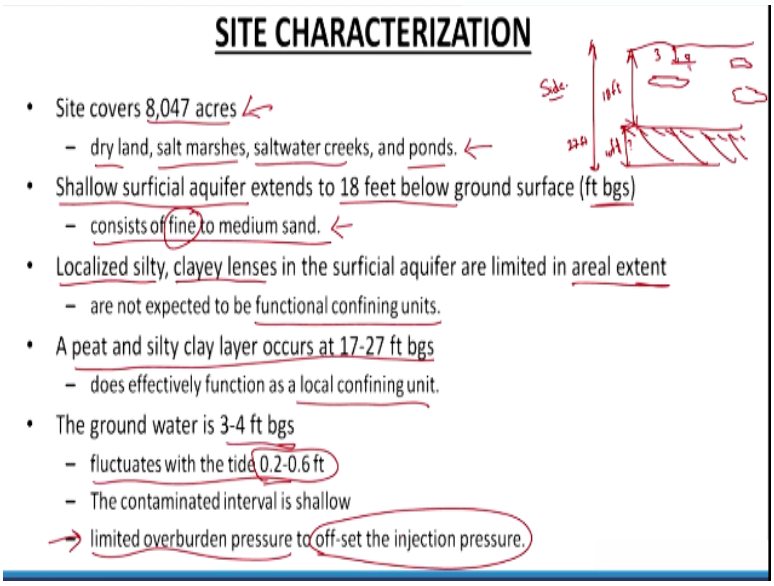

So, site characterisation; guess a huge site that something to keep in mind yes but the major aspect is that if you remember let us say it was along the coast or near the coast, pardon me, right, so you have dry land, salt marshes, saltwater creeks and ponds, so it is an ecologically sensitive area, right, so obviously you know its what do we say, something that is a priority, again as we know once or if let us say this particular VOC or in NAPL let us say you know is transportable over wider area let us say.

It obviously gets more difficult to remediate and especially let us say in these ecologically sensitive areas let us say where you have different or you know thriving ecosystems let us say, the adverse effect or you know the potential end points let us say are going to be numerous now, right, so that is one particular aspect to keep in mind, so what is the feature that we have here; we have a shallow surficial aquifer which is or which extends to up to 15 feet below the ground surface let us say, right.

So, if this your subsurface, you have a shallow aquifer let us say that extends to 18 feet part; is around 18 feet let us say, right, that extends till 18 feet and that I guess means we have an impermeable layer at around 18 feet from the surface let us say, right, so let us look at what else we have and this consists of fine to medium sand; so what is the key aspect here, typically medium sand I guess, we do not at know how fine the sand is.

But again, typically let us say you would expect the permeability or the hydraulic conductivity to be high, right, so the relevant transport of the contaminant if any will be you know considerably high let us say and also because it is sand, it will typically not have a lot of organic fraction let us say organic content, pardon me, and thus let us say this particular VOC let us say could have permeated through let us say or been transported to through to the greater depths let us say that something to keep in mind.

One that permeability is typically, high for you know, sand let us say, you know those kinds of layers and also let us say the because of typically, lower organic fraction of carbon let us say, the relevant contaminant would have not been adsorbed on to sand but would have transported through it or most of it, right, so let us look at the other aspects. So, there are some obviously localised silty and clayey let us say, right.

But they are limited in their relevant area let us say or the coverage, so as in may be out here, this is the side view obviously, so let us say you have some minor clay layers and so on out here, right within this 18 feet but you know they are limited in area, right and thus they are not expected to be a functional confining units, they will not act as confining the either the aquifer or the relevant NAPL let us say, right.

So, as we mentioned or you suspected earlier, a peat and silty clay layer occurs from 17 to 27 feet below the ground surface, so from here to around 27 feet wide, right, so maybe 10 more feet out here, right. What do you have; you have clay layer let us say, so this serves as more or less what is its; clay layer, right, so it is going to have relatively less hydraulic conductivity let us say, right.

And thus let us say that is going to act as a confining layer let us say, right, so that is something to keep in mind, right and what else; effectively function as a local confining unit both for the water and for the NAPL and the ground water is 3 to 4 feet below the ground surface that is a key aspect as in the groundwater table is just or very high because it is obviously near the coast, the ground water table is just 3 feet below the ground surface let us say, right or 1 meter deep right that something to keep in mind.

So, again keep in mind that this particular site was on the coast, so you are going to have tides, right; tide coming in and going out, so because of that particular tide, the groundwater what do we say level fluctuates by 0.2 to 0.6 feet let us say that is something to keep in mind, contaminated interval is shallow let us say, okay. So, one advantage that they had at this particular site is that the contamination was typically or at that particular point in time was limited to the shallow regions.

As in why is that advantage let us say because then limited over burden pressure, right leads to requirement for less injection pressure, as in here, you need to inject your relevant compound, right, I believe they are looking at manganese, right, permanganate and now, let us say, if you need to inject into greater depths and there will be a greater over burden pressure and if you want to let it transport let us say, laterally, you will obviously need to what do we say, inject it higher pressure.

But obviously, you looks like it is shallow and thus the over burden pressure is not the high thus requiring less injection pressure let us say that is one particular aspect to keep in mind, right.

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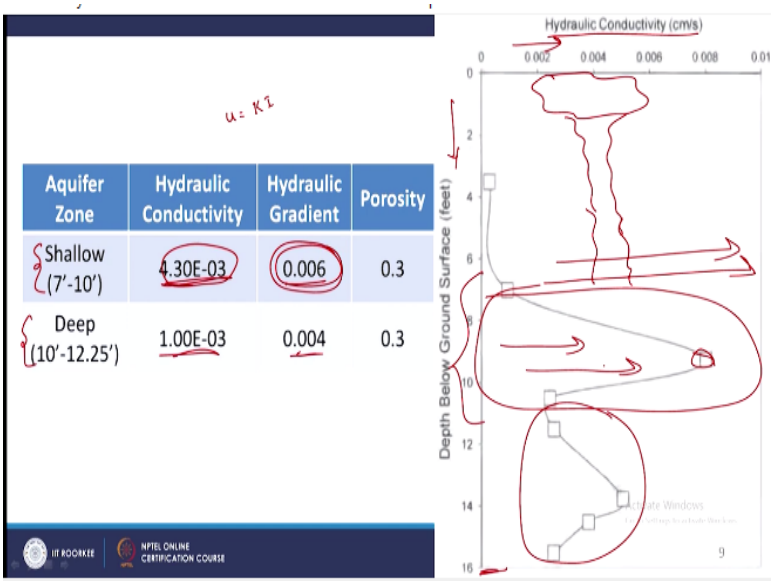

So, let us look at the hydraulic conductivity here, right this is on the x-axis and this is the depth below the ground surface let us say, so as you see they had particular I mean, initially for some

reason, you know the hydraulic conductivity is less let us say and this particular region of around 1 meter if I may say so but in this particular region from 6 or 7 to 10 metres, the hydraulic conductivity is remarkably high.

So, any contaminated let us say that is transported from to this region let us say, my contamination occur out here and over time let us say it has this particular region let us say, what will happen? Now this contaminant is going to be transported over a wider area let us say or wider extent let us say, why is that? Obviously, as you can see hydraulic conductivity is remarkably high at this particular depth.

So, it is again decreases slightly let us say, right at the deeper locations maybe but again it is still relatively high though, right and at 16 or below 16 feet as we looked at earlier, we have this impermeable layer, right, so that something to keep in mind and let us look at it, so they have 2 aquifer zones, they are classifying them as shallow and deep. Shallow as we saw let us say, hydraulic conductivity was typically high, almost 4 times higher than the one in the deep, occasion let us say, right.

So, hydraulic gradient is also given here, again hydraulic gradient is also high, so how do you calculate the Darcy's velocity now; Darcy's velocity gives you an idea about the groundwater flow velocity, right, so it is KI, right, so as you can see K is high and also the hydraulic gradient is also high, right, so typically as we can see in this region, the contaminant will be transported over considerable or relatively greater distances let us say, right that is something to keep in mind.

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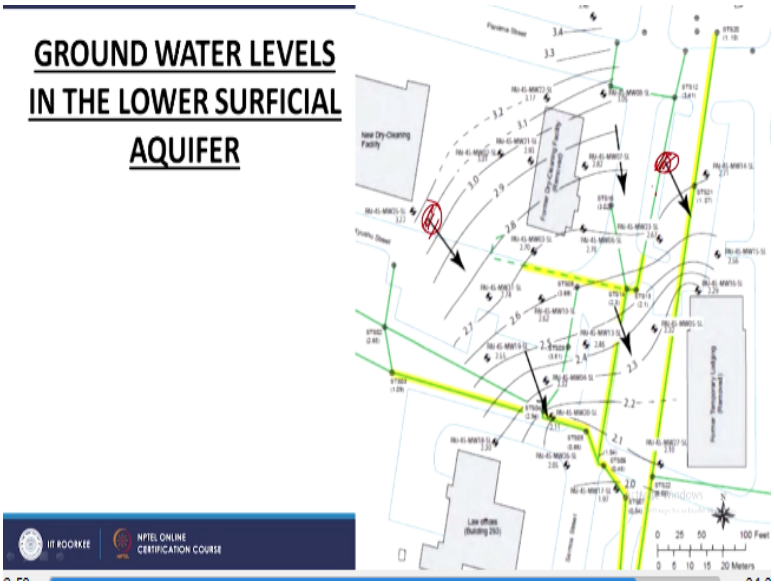

So, we also have now, groundwater levels, why do we need to understand this let us say, right, we want to be able to understand let us say the groundwater levels because we want to see in which direction is the groundwater flowing let us say or travelling let us say, right. So, let us try to understand it, so here is are particular dry cleaning unit and here we have 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2. 8 so on and so forth.

So, if you look at this particular level, you see the gradient and now you will obviously, you can deduce that the groundwater flow is in this particular direction let us say, right, so that is what we have out here, right, ground water flow direction and again, you have some localised patterns here, right, you have some localised patterns here and that is what we have them represented here, right.

So, why is this important; again if you keep in mind earlier, we had this particular sanitary sewer somewhere out here and going out this way, right? The green one is the storm sewer, this particular red coloured line is for the sanitary sewer let us say and if you remember there was a spill somewhere out here or not spill let us say, leak from this particular sanitary sewer and you saw that this particular plume was in this particular direction or the contaminant was being transported in this particular direction, right.

So that is something to keep in mind and also in the northern area too, there was some particular contamination here and as you can see the contaminant is again being transported in this direction why is that; because it follows the path of the groundwater flow, right, so that is something to keep in mind as in we have 2 plumes, added to 2 sources; one somewhere out here and one somewhere out here let us say, right.

One due to the sanitary sewer and one due to the storm water sewer, right that is something to keep in mind.

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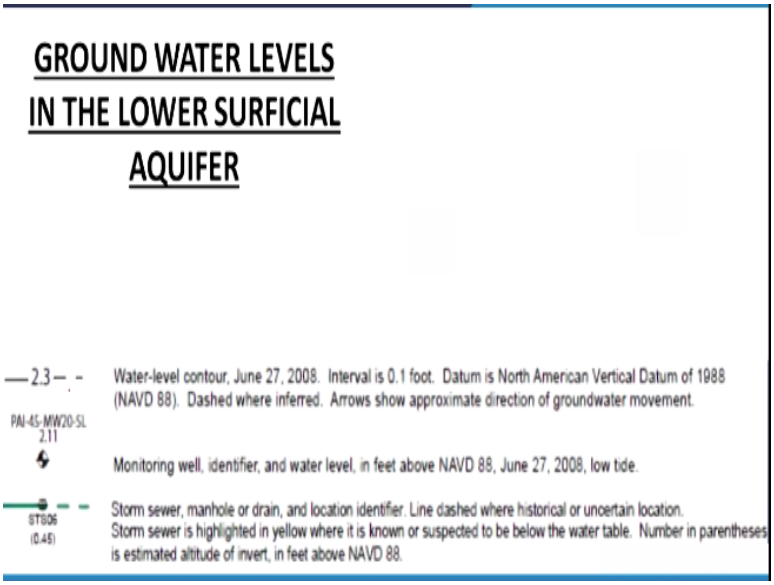

And what have we looked at more or less the ground water levels and so on, they looked at monitoring wells and so on, so I will skip this.

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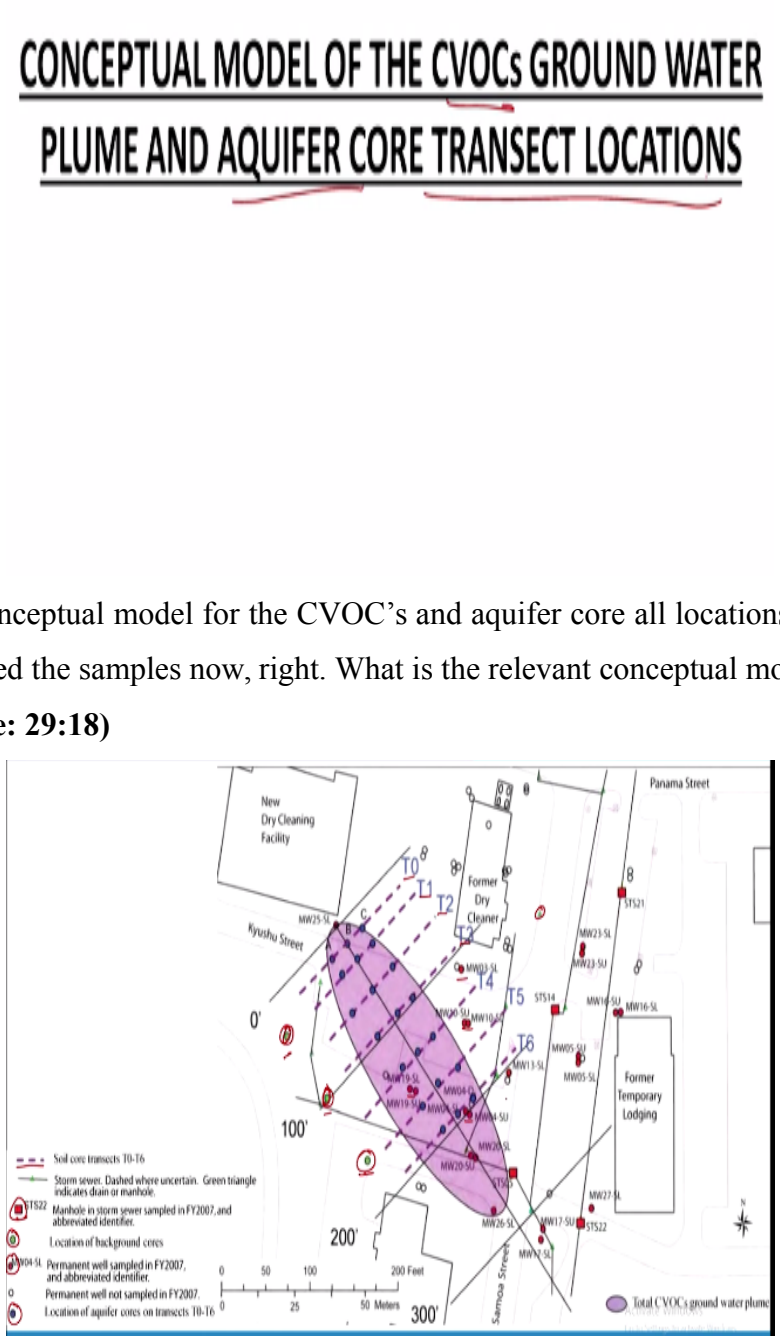

So, what is the conceptual model for the CVOC's and aquifer core all locations where they what do we say, collected the samples now, right. What is the relevant conceptual model now?

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So, let us look at that particular aspect, so initially, they looked at this particular model, right and keep in mind this is the dry cleaning unit begin, so they looked at the relevant measurements and saw that the major source is not only from that one time spill though it was considerable, they were obviously able to excavate some of the soil and such and though it was transported by storm water drains to may be a particular location out here, right.

They saw that the major source was this particular point in the sanitary sewer, when how did that particular contamination occur, right and why is that relevant to the Indian context, as I mentioned multiple times earlier, right it is because of the daily spills let us say, it is not the one time spill that affected or matter a lot, it is that there would spills daily and all this particular spills that occur daily were washed through the sanitary sewers and which leak let us say at this location.

And this is the plume that they assumed I guess, right and you know that the groundwater was flowing in this particular direction and they looked at these transit locations where they took both the soil and ground; mostly the soil, samples T0 to T6 and as you can see to understand the relevant aspects they have samples along the longitudinal direction and also in the lateral direction as in A, B and C.

So, B is along the centreline of the plume as you can see more or less, right and A and C on either sides, so you can get the relevant idea about the diffusion or such too, right, so here typically you have both advection and diffusion in this direction, right in this direction and typically, I guess, dispersion or diffusion in this particular direction let us say, right. So, let us move on and what else do we have here?

I guess, we have some control wells out here, right, let us look at the ligand, so soil core transects, obviously, the soil samples were taken at T0 1, 2, ,3 along these particular transects and storm water sewer that is something that we looked at so, different manholes, so here they also looked at manholes and use them as sampling ports let us say right, location of background course let us say, obviously outside this particular contaminant plume as in why do we need to obviously look at these background course let us say?

As in you want to understand this soil characteristics before it was contaminated because once it is contaminated, you are going to have different chemical reactions, chemical and may be biological process too that change the characteristics of the soil let us say right, so you want to understand the background or initial characteristics and thus obviously, you need that particular data and that is what you have here.

So, they have different permanent wells let us say and also location of the aquifer course out here, they also have some permanent wells that they have drill into let us say, right. So, I guess you now get an idea about or you know picture of the contamination and its relevant transport let us say and I guess I am running out of time, so I will end this session today let us say or end this session for now.

And then in the next session, we are going to look at the relevant aspects let us say, right as in manganese let us say or permanganate if I added, what are the relevant by products is the relevant contamination and also remediation occurring both at the shallow and the deep locations and so on and what are the relevant hurdles, let us say right, I guess with that I will end today's session and thank you.