2021 Design and Construction at Hazardous Waste Sites Virtual Symposium

Sponsored by: Society of American Military Engineers (SAME) Philadelphia Post, and US EPA

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Closed Captioning Transcript

Please stand by for realtime captions. While, good morning or good afternoon, depending on your time zone, welcome you should be joining us for today's upcoming 2021 design and construction and hazardous waste site virtual symposium. We have reached our official start time so I will go ahead and officially began today's session and first by starting the recording and then giving each and every one of you might Ernest welcome and greeting as you join us for today's virtual symposium for the design and construction and hazardous waste site. Today's session has been sponsored by the Society of American military engineers. And the USC PA. My name is Jean Balent and I will be serving as the technical moderator for today's session. I will be with you all throughout the virtual symposium helping to provide opening instructions as well as helping to mend questions in the background. In just a moment I will be introducing some of our plenary speakers but before I do that I would like to walk through a series of very important housekeeping and reminder messages so everyone understands how to participate. Each day for the symposium you will check in through the seminar homepage which looks something like this one. That seminar homepage will have a series of tabs located along the top which will give you access to information about our speakers and ways to download their materials and browse through related resources and even share feedback after our like that session. To join us for the live broadcast simply click the join webinar but in each day and you will be brought to the simple check-in page where you can identify yourself by name, let us know if others are joining at your location and then join us for the live session and broadcast through Adobe Connect we do encourage you to disconnect from VPN whenever possible for the most optimal broadcast possible and audio will be available unlike by default payment you should be able to hear us coming through your computer speakers or headphones. You can also opt to listen by phone and know that regardless of how you are listening you are automatically placed in a listen only mode meaning you can hear us but we cannot hear you and we ask you remain muted to minimize any background noises or audio disruptions. Now if you need any assistance with the online audio first take a look at the top of your screen and you should each have a speaker icon that you could click on to adjust the speakers and volumes. If that does not resolve the online audio problems you can absolutely let me know in the Q&A and I will be more than happy to provide a toll-free call and option that you could listen to by phone. For those of you who can hear my voice I will let you know we do have a box located in the lower right corner of your screen called the Q&A. You should already see some welcome messages for me in that space. The

Q&A window will be available throughout our entire broadcast sent you can use that to privately submit comments, questions, report that Google issues and that window again is open throughout our entire broadcast. Just to be sure that everybody understands how to use this space I will ask each of you to look for the Q&A window and click your cursor on the very bottom of the box in the lower right and send in a greeting message and just say hello and let me know how that audio visuals are coming through and let us know how excited you are to be joining us for today's live session. Again anything you type in there is private and we will have moderators moderating that space so that when we get to our designated Q&A break they could read questions and comments out loud on your behalf. The session is also being recorded and when the virtual symposium is over you will be provided a summary email in approximately one week with information on how you can access and replay the sessions on demand and I will ask each of you to please send just a moment with you at the very end of our session because I will provide important reminders including how you can print out certificates for joining us in today's life brought cast. I see so many greeting messages coming in from participants so thank you very, very much for chiming in and confirming the audio and visuals are working for all of you. >> This is a quick screenshot of our Adobe Connect interface so each of you will see different windows and boxes depending on our session in the session today. For the most part you will see a large window where the presentation content is visible and you each have a button in the upper corner of that window and looks like he box of rackets around it and you can use that to go fullscreen at that is better for you. There will be information about the speakers in the upper corner and the Q&A window is available throughout the entire session in the lower right. For those of you who need life closed-captioning we have provided a direct link already in the Q&A window so you could actually play that back in a separate window and adjust the size, color and speed as needed. With those very brief instructions I would like to again welcome you all to the virtual design and construction hazardous waste sites virtual symposium. I would like to review the event goal for this symposium and although there are typically held in person SAME and EPA have held them now virtually and caring that through the series of webinars that will also be hosted in the calendar year. If you are new to the design and construction of hazardous waste sites platform, a primary goal of this event is to facilitate open and frank information exchange amongst professionals in both the private and public sectors. We provide a variety of forms for presentations and describing current practices and approaches in the heirs of hazardous waste design and construction and it also helps enhance communication networks amongst our stakeholders involved in site cleanups. As we get started with our virtual symposium, I went to provide a snapshot of those of you participating. We have over 415 registrations for this event. As you can see a easy community and federal government is highly represented and we have a number of participants from SAME as well as EPA joining us, 89 SAME members and 118 young professionals registered in today's session. I will might everybody that we will ask all participants to keep their telephone lines muted if you choose to call in and I will be working in the background and if you do not mute I will help mute you on the back end so I appreciate everybody compliance with that request.

Again although we are normally doing these things in person we still have a great representation with this virtual option. Geographically, we have a great spread of participants from across the United States as you can see from this map and we have heavy participation from the Northeast but we also have two international attendees joining us in today's virtual broadcast so this helps to ensure that the DC HWS messages reading abroad audience. Let us take a look at our session agenda for day one. We are starting out with our opening remarks and after those remarks we will then move into our first of two panels panel one will focus on Institute remediation by looking at a federal case study. We will then have a short intermission or break. That we will transition to the second panel of the date where topic will be Institute remediation amendment delivery methods. After panel two, then close with her to closing remarks and find reminders for the day. The typical format for our panels will include a special moderator and three panelists now each panelist will be provided a 20 minute winter to offer technical presentation and after those presentations our moderators will help guide us through a facilitated Q&A answer session and that is exactly why we provided the Q&A window on your screen in the lower right so you can send in questions and comments all throughout the presentation and no need to wait and then we will go to the Q&A and get to as many questions and the time allotted today. Again please do not call back on those questions and comments and send them in at any point today.

We did want to extend our deepest appreciation to the symposium committee and again join sponsors EPA office of Superfund remediation and technology innovation and Society of American Military Engineers in the Philadelphia post. We also have a number of event sponsors without their support whom we could not make this session take place. We just want to thank all of our event sponsors, large business sponsors, and our small business sponsors.

With those very brief opening comments, I would like to introduce our first guest speaker, who is Jenny Blake, leading us through the Pledge of Allegiance so I will be shifting things around on the screen and I will remind Jimmy that he is welcome to take himself off mute on his end here and if you could unmute your line, Jimmy, just confirmed that you are available and ready to begin and I will provide a brief introduction to you.

Thank you.

Jimmy break --

[Indiscernible - overlapping speakers]

Thank you.

Jimmy Blake with Rambo with the incoming first vice president of the SAME Philadelphia post and he is a member of the DC HWS planning committee a culture of the small business committee and part of the SAME national leader development program test force and he will be

leaving us today with the Pledge of Allegiance so Jimmy, please take over.

Thank you, please join me in reciting the Pledge of Allegiance.

I Pledge allegiance, to the flag, of the Untied States of America And to the republic, for which it stands, one nation under God Indivisible, with liberty and justice for all . Back to you, Jean.

Thank you so very much, Jimmy. It is now my distinct pleasure to introduce our first plenary speaker. With that I would like to introduce to you to Larry Dishon, director of the EPA office of Superfund remediation and technology innovation in the EPA office of land and emergency management. Appointed in January 2021, he oversees EPA national implementation of remedial cleanup under the circular copperheads of environmental response compensation and liability act in prior to coming to EPA he served from 2006 , 2021 as the assistant commander of environment the programs for the Naval facilities engineering system command. He is also helping position at the U.S. Army Corps of Engineers and he holds a Masters in environmental management and the University of San Francisco and a bachelor nuclear engineer from the University of California at Santa Barbara. Registered professional engineer in the state of Maryland. But that I would like to turn it over to Larry.

Thank you, Jean. Thank you for those kind introductions, good afternoon, on behalf of the you is make it environmental protection agency am very pleased to welcome you to the 2020 with virtual symposium for design and construction issues of hazardous waste sites or more commonly known as DC HWS East and as Jean said in her kind introduction [Inaudible static] tenure of EPA is a little more than two months in today's event is my first opportunity to speak to an external audience at the national director of the Superfund remedial program. And to do so is truly exciting and an honor. While this is my first symposium as director I understand this is the seventh year that EPA and the Society of military American military engineers have formally cosponsored this event. The event history and speaks to both to EPA and SMU commitment to budget public, private partnership. Since this relationship began we have expended DCHWS to include two annual symposium East and West as well as continuing education with online training events. Although these events have typically held in person I welcome how the virtual format creates a greater opportunity for participants from and expanded network of environmental professionals or all over the country. Weather next gathering is in-person or virtual, I look forward to continuing the EPA SAME partnership and I invite you to join me and strengthening further the important bonds between our organization. As you likely know, our new EPA administrative Michael S McGregor was when as EPA 16th administrator just a few weeks ago on March 11th. Administrator Reagan identified several areas where the agency will focus under his leadership. Including a showing that sound science fair is a backbone to policy and decision-making at EPA. Addressing the prevalent and potential risk of P FAS in the climate change crisis and setting up for environmental justice guided by the conviction that all people have the right to breathe clean air entering

clean water and lead a healthy life. All these priorities intersect with the Superfund remedial program. We rely on sound science to develop contaminant specific cleanup standards and we are in the forefront of addressing p FAS in terms of restoring regulatory action and developing guidance to facilitate p FAS disposal and construction. We considered climate change when evaluating and selecting site-specific remedies. And we need the agency and engaging communities and coordinating with other programs on accumulative risk posed beyond Superfund related contaminations. I for one am incredibly excited about these priorities and their implications for the Superfund program. I look forward to working with our EPA is a MD program partners to address these important issues within the context of the Superfund design and construction issues before I close I would like to take a brief moment to highlight an issue of national importance. I want to echo President Biden declaration that the federal government has a responsibility to prevent racism, xenophobia, and intolerance against everyone in America including Asian Americans and Pacific islanders. I joined the President in condemning and announcing acts of racism, xenophobia and intolerance against Asian Americans and Pacific Islander communities. Enclosing, I want to extend a hearty thank you to my chick staff at EPA -- to my staff at EPA and those that SAME for dedicating their time and expertise in planning this event. Thank you also to the sponsors, we truly appreciate your support. Please enjoy the program over the next few days and I challenge you to take full advantage of the engaging agenda. Thank you very much and now back to Jean.

Very much, sir. With those brief opening remarks, let us go ahead and jump right into our first panel for today. At this time I'm going to introduce our panel moderator Dr. Rosa Gwinn with AECOM who is provided technical and project management expertise to private and government clients were nearly 30 years.'s primary focus has been on the characterization and remediation of emerging environmental contaminants including p FAS chlorinated solvents and explosives and metals and executed and managed multi million dollar task orders for p FAS military munitions response and operational range assessments in each phase of circular so with that brief introduction let me go ahead and invite Dr. Rosa Gwinn and introduce her panel.

Yes, thank you, Jean for the introduction and welcome to everyone and here we are at tunnel number 1 and in these studies as a reminder [Indiscernible - low volume] Safe Drinking Water Act originally in the 1970s and then subsequent environmental regulations there have been some types of contaminated groundwater sites that are essentially difficult to remediate and each of our AECOM panelist will share a real-world example of how unique in situ technology has been deployed at some of the more geologically challenging groundwater sites. So join me in welcoming budget panel is introduce our for speaker. Paul Dombrowski, senior radiation engineer at Advanced Technology ink with over 16 years of experience in hazardous waste sites investigation. And remediation. He is a technical leader for design, implementation, and management of a full Suite of remediation technologies, incorporated innovative technologies and approaches to support projects. Mr. Paul Dombrowski part-time lecture at Tufts University received his

bachelors and Masters degree in environmental engineering from Manhattan College in New York and is a registered professional engineer. So without further ado let's listen to Paul provide his presentation and optimizing injection based remediation and bedrock lessons from. Remediation by chemical oxidation.

All right, low, everyone, Rosa, thank you for the introduction. And I'm quite excited to be the first panelist of the first panel. Also to follow Mr. Dishon's opening statements.

Many of us who have been involved or with any contamination in bedrock recognize there is numerous challenges that we face in this environment. First and not least just an incomplete understanding of groundwater flow and then how the contaminant transports that and it is not a porous media and very little primary porosity contaminants in groundwater primarily flowing through fractures, some more than others, and they have different dips and strikes which could allow contaminants to move in the direction of the Oak groundwater flow but also in other directions as well including vertical.

Bedrock poses challenges to site characterization and this can be to make to the depth that some sites require investigations to, or it also can be associated with just getting different tools and the drilling methods required into bedrock compared to overburden environment and this leads to higher cost and investigation in terms of the type of equipment needed as well as just doing remediation and bedrock generally at higher costs than in overburden. And like many sites, bedrock remediation projects can have unrealistic primary objectives as well.

So with any project where there is remedial
characterization and remedial design, there is a number of questions we always need to be asking ourselves, wears a contamination and where is a traveling and how did it get there?

What amendments are being delivered? And ultimately we want to as the question on a higher level, how does the site geology impact the answers to each of these questions? Then as we move forward into our remedial design and recognize that whatever amendments or fluids could be liquidated or air are likely to follow paths of similar to groundwater flow themselves. So the focus of this presentation is a Superfund site and it is a fund lead site located in region two and the site has had over 100 years of various industrial and manufacturing activity. Paper mill, textile manufacturing, commercial dry-cleaning, and primarily due to the dry-cleaning activities the primary contaminant here is PC or but the cousin Epting and prior to any remediation activities castration as high as or more than 120 milligrams per liter have been measured and numerous lines of evidence that likely presence of it being at the site.

There was a record decision which included demolition of site structures and focus oil [Indiscernible - low volume] and groundwater and bedrock groundwater with ultimate target of 50 parts per billion.

And groundwater flow is generally to the south to the river which you can see in this bottom picture here.

At the site, very sand overburden, it is really only for, 5 feet thick and the water table is generally right at the bedrock overburden interface. The bedrock is a limestone and we can see here on this right photo this is at the river which is immediately to the south of the site and it allows an actual visual cross-section of the bedrock that is present below the contaminated area from the former activities. We can see even in this cross-section that there are a number of fractures and breaks and the like. The bedrock is generally divided into upper middle and lower zone.

As part of remedial investigation they were -- there were various investigations and geophysical tools worked at the site which looked at where bedding planes may have been, the direction of vertical strike, and other bedding plane angles. Generally there is not a lot of vertical flow particularly in the upward direction.

Looking at a site map as well as the cross-section this pink dashed line shows the cross-section there on the map and you can see that the primary highest concentration and historic source areas happen in the Western end of the former building which was demolished as specified in the Rod and then areas immediately to the west and southwest of that source area in the building. From the cross-section we can just see that there is a very thin overburden here and then you can see the PCE getting into the bedrock itself. As part of the bedrock remediation program, when entire network of injection wells were installed into the bedrock and there were in total more than 80 injection wells and they were generally installed with 20 foot screens and some of them are nested to have two screens in them in order to apply treatment to both the upper and the middle carbonate zones. As part of that remedial design deselected chemical oxidant for remediation was sodium per sulfate. >> So there have been several injection events and I will discuss each of these in some of the optimizations and modifications that have been made as time has gone on and lessons have been learned and observations made. The first injection event was not performed by ISOTEC so predates our company involvement and like I said sodium per sulfate was oxygen that was used and for this initial injection the base two per sulfate ratio was quite low and generally there was not much alkaline activation that was achieved at the project. There was injection into the overburden and bedrock in the bedrock we are using the injection wells and described on the last slide and overburden were performed with direct push and these were relatively shallow points. During the first injection event relatively high injection rate where used so between five, 10 gallons per minute and ultimately there was significant daylight that occurred with the high-pressure, high injection flowrates. We look here on the bar chart on the right, of the 89 injection wells that were tempted at this project, more than half of them received negligible volumes anywhere between zero, and less than 30 gallons of solution and more than 60% of the overall oxidant volume into the bedrock was injected into only 12 wells and we were very focused on the treatment is based on the wells at that could receive amendment. And in terms of the treatment from the first event it was

mixed and there were some wells that decreased in concentration and many wells that actually increase in the concentration following injection. But there was increases in sulfate, chloride and carbon dioxide in many well so there was indication that there was and Institute chemical oxidation injection and evidence of that in various mining wells across the site.

Injection event two, is when ISOTEC project became involved with the project and starting to plan how event two was going to be implemented and I checked work with the EPA project manager. Really think about the conceptual site model and how the first event went and what we could do to that it deliver oxidants to the environment. And part of the conceptual site model was recognizing that there was d -- DNAPL present either sitting on top of the bedrock or in very shallow fractures as shown in the schematic that was in I TRC document. And a question that was asked then well can the non-busy people be put into the WIC phase more available for treatment? And it was evaluated to incorporate modified Fenton reagent as part of the oxidation approach. Modified Fenton reagent utilizes a chelated iron catalyst, and using that what they stabilize hydrogen peroxide. This was incorporated not so much for treatment but more for soluble icing the scene Apple -- DNAPL through the process I one being bubble agitation of the gases product of hydrogen peroxide reaction, it can help to shake and disturb the to 12. Modified sent region also has the generating of the generous -- free radicals including the sulfate and free Celtic [Indiscernible - low volume] reducing free radical and has surfactant like effects to also help to break up the DNAPL and is also through further globular breakdowns or we could make those globules maulers they will have more surface area for opened ended the solution.

So injection event two, at the site, first by ISOTEC, we also made modifications to the chemical oxidation plan and ISOTEC performed based BPHC laboratory test edit never tried to better dial in a better base to per sulfate metaphor activation. The event included continued base activated in the bedrock and overburden injection points with direct push accommodation of modified Fenton reagent and base activated sodium persulfate. Lower injection rates were used, more pumps and multiple attempts into individual wells were performed. With the slower injection rates, we can see that from comparing event one and event two, the yellow bars, more volume went into more wells so a little bit better distributed, however, still about half of the wells did not receive any solution at all.

One of the key observations after the event was that many wells particularly in the source area saw very large increases in PCE concentration in the bedrock after these intimate which was the desired effect and also I will show this on a template on a later slide.

After event two, it was noted that some of the injection wells where not quite installed as had been hoped and the number of the injection wells had -- were not keyed in properly so some of the wells that were intended for bedrock injection were allowing chemical oxidants to leak into the top of the or the bottom of the overburden. So we wanted to

really better focus and better deliver the chemical oxidants to where the contaminants were in the bedrock. So there were a number of the injection wells that had the casings and the screens removed. The new casings were reinstalled and keyed into the bedrock. And they were left as open boreholes for injection using straddle packers so that we could go in and target discrete vertical intervals.

This event three focus on 39 wells and these were most of the reinstalled wells or wells that were successful at receiving chemical oxidant solution. In the areas of highest concentration of PCE from previous events.

This was primarily at base activated sodium persulfate event but in 13 of the wells as a pilot test we attempted to inject modified Fenton rage and just to see how well the bedrock would react and could we inject the more reactive peroxide oxidant approach into the bedrock?

And we were and that was successful.

The fourth event, some additional modifications were made that mostly included installing new bedrock injection wells that were willing to gaps and it was noted that not all the boreholes oh injection wells monitoring wells were connected in order to get continued treatment or treatment while we were not able to achieve delivery previously, we needed some more delivery..

This event attempted into 62 injection wells and including 24 wells where we use both modified Fenton reagent and base agent content in the bedrock as opposed to -- sodium persulfate in the 50-50 racial one of the upsides of this event was that the total volume of physical solution of 26,000 gallons with the highest oxidant volume installed in any given event so we were getting more solution and more oxidant into the bedrock and always a positive for treatment.

So focusing on the number the modifications that have been made in different events, if you recall the source area was at the Western end the building immediately to the west of that so we have three key source area wells are shown in the map with the blue, orange and purple dots. This plot here shows the overtime temporal trends of these two wells for the PCE. And the first, purple one is more to the east and this had elevated concentrations at the start but less lines of evidence of DNAPL and one of the real take holes as we know from numerous chemical oxidation logics over the years, is that chemical oxidation very effective for various contamination and we see that where we have high concentrations of aqueous PCE, eats excessive event saw additional reduction and starting with a high concentration, with the series of injections, we were able to reduce that concentration over time. And the orange well we see another pattern that we sometimes seat with chemical oxidation projects is decreased following an injection, followed by further, further by rebounds and could be absorption from DNAPL and absorption into other areas. But by incorporating the base activated sodium persulfate particularly in addition to the modified -- modified Fenton reagent, we were hoping to enhance and maybe even accelerate that rebound so that we could come

back in and treat that mass that had been pushed into the aqueous phase and we see that through a series of events and the concentrations in this well went down and up and then after the fourth event, stayed down and remained down.

Looking at the blue well in the source area which is ERT 33 which was one of the main focuses in one of the areas where would you there was significant mass. And we see after the first event maybe actually we had a little bit of an increase and then after the second event was when the modified -- modified Fenton reagent was incorporated right at the bedrock interface and we saw significant absorption and increase in the PCE concentrations in two event several months apart, PC concentrations in excess of 180 milligrams per liter which is right in that zone of aqueous solubility so we are basically collecting samples at the maximum possible solubility of PCE and then when we came in with our third round of injection, right after that, we see that -- how well chemical oxidation is that reducing concentrations and reducing from 180,000, down to the 10,000 after that event . And then the fourth event, we see a continued decrease to the point where this well is now at the lowest concentration it has been -- and it really highlights the point that for DNAPL projects particularly in bedrock we really need to take it longer view remediation and we are not going to get the site cleaned up in a single event or one shot. But it takes a combination of knowing or understanding receptive site model and where is your mess and how to deliver your reagent into that zone.

And then looking at a couple of snapshots at data further to the south and west of the previous injection points and their were less injection points their in the earlier vents and these are some of the areas where the additional wells were installed as part of that fourth event so we can see that some of these wells were actually seeing -- both of these wells are located in the yellow box, increases over time and some of that could've been just from ongoing migration and some of it could've been localized DNAPL and some of it could've been just by us all realizing the Apple -- DNAPL [Indiscernible - low volume] some of that was moving down slowly. But by incorporating more points and I checked perform additional injection, in the very late, 2020, we can see that there are more and tighter grid points in there. Such that as were increasing the aqueous stated concentration, then we could come back in and hit that and get those rapid reductions of PCE and aqueous states that we desire.

So in summary not all projects are going to be successful with a single injection or even the first time you look at it. If it is first you do not succeed, go back, reevaluate your conceptual site model, see how you could optimize your remedial design and how do you improve your delivery of your oxidant or your reagent and then go and try again.

With that I thank you for your time and just acknowledge some of my collaborators on this project, Jeff Kun tonsil Rita of EPA ERT, and the entire ISOTEC team.

Thank you for the honor to present at this conference. >> Fantastic, thank you so much, Paul, for the presentation and the excellent

information. I just want to remind everybody that your questions are welcomed and they will get answer we opted to answer them at the end of the three presentations so what that means is into your questions and they are not being skipped over and we will capture those and our speakers and panelists will take a moment to answer those at the end of the formal presentation. All right, anyway, now let me introduce Dr. ISOTEC, principal scientist at Advanced Environmental technologies which is in Fort Collins, Colorado. He is an adjunct professor at the University of Wyoming as well. He has over 20 years of experience developing and implementing innovative remedial technologies. He is a pioneer and a leading practitioner in the knees world of bio electrochemical lead on techniques for in situ remediation. He received his PhD from the University of Wyoming. Song Jin has published over 180 papers and peer-reviewed journals and he also holds over 30 U.S. and international patents. Prior to AETP worked as a principal scientist and consultant in W agent Western research Institute and try Harjo Corporation so let me turn over the floor to Dr. Song Jin to present utilizing low intensity electrochemical based technology for treating chlorinated compounds in type subsurface matrix.

Thank you for the introduction and can you hear me all right?

Checking audio?

Yes.

Great.

Great.

Good morning or good afternoon everybody. Thank you for attending our to talk and this panel one. I actually -- Paul laid a good foundation on the importance of a correct site conceptual model, and also the strategizing of different or multiple remedial tools or multiple applications of remedial tools for a successful site clean up. I like to take this opportunity to introduce a relatively new tool to address a common issue, come intelligence that a lot of us have experienced which is the tight formation including bedrock and mostly it is clay and silt and I like to use the case study to introduce this electrochemical tool that is not really dependent on the permeable or permeability matrix so kind of counterintuitive and how this tool can be used to address tight formations.

So the tool I will talk about is trademarked as e redux to be a little easier and it was developed by environmental technologies and also I would like to acknowledge my co-author, my close collaborator, profile.

So first of all I would like to go through some mechanisms of this technology of the electrochemical reduction and oxidation and then I will give it to a case study and show the application of this tool and I go through these summary and I will show some limitations of this technology like any other remedial tools and the applicability of that.

The electro chemical E-Redox reaction and now I will mix that term as redux and it involves three main processes in the first one is reduction because now we are feeling the matrix with the electrons and that causes abiotic and biological reduction reactions. And the second processes involve is the desorption of contaminants from solid taste into aqueous phase like Paul just said a lot of remedial technologies are highly effective if we are targeting contaminant in the aqueous phase but when they are absorbed to the solid phase, and that could cause issues like rebalance because they could be solely released into the aqueous phase and it will around the remedial time and that is something or the second process the E-Redox results and the third one a side benefit, because now we are dealing with electrical fields and the negativity of electrons can bring down the redux potential of the Matrox to the low level that would favor and that would sustain the biological coronation and a lot of times we have to rely on injecting a lot of electronic donating compounds and for microbes to take those electrons out of those compounds to lower the redux potential because now we are dealing with abiotic electrical field and then we could drop that redox within a very relatively short amount of time and I will talk about an independent study in a later slide about that.

Because the process is based on the electron transfer, rather than physical substance transfer, so the technology is not limited by the permeable -- the physical permeability of the matrix, it is rather on the electrical conductivity of that so it certainly becomes these clay and silt suddenly becomes infinitely matrix to the technology.

So this plot for the lower left side, it is actually a summary to show that the energy density involved in -- I just listed up to the electrically related technologies in here and if I am using the energy level use for these electricity, I guess that is also related to the sustainability and you could see that of course the thermal would be energy intensive but it is a good technology to treat sources and stuff like that and in the middle we have electrolytic destruction so this would be a radical oxidation and then we have electric can edit kinetics or EK and that's basically a mass of electro forces that we can pool charged species for ionic species in the matrix going to different directions. And then the last one just a tiny tip of that, is where E-Redox would stand and just a very low, intensity electrical field and we did that on purpose because we don't want to cause a more aggressive electrochemical reaction like in the other technologies, but we want to establish what is called micro capacitor kind of scenario in the matrix and I will show you a few slides on that and then to trigger abiotic reductive reactions in the matrix for chlorinated compound treatments and also to trigger like desorption of contaminants and also to lower the redox potential. To make this very simple, if we have different configurations of this tool, but every one of them at least got two electrodes, compote and anodes and then we put the electrical charge and there and then you formed this electrical field and sometimes recalled that static electrical field because of how low the electrical density it is.

In early 2000 when we were still developing this, this technology, you know early times, we started in lab columns and things like that and

also in small field pilot test, researchers -- researcher name whose names is but more rain are from Germany, he published his hypothesized mechanism of what is called a micro conductor mechanism. And basically what it says is if you have a low intensity electrical field in the matrix, and we are turning those -- polarizing -- turning those solids into numerous micro capacitors, so they are charged and now when that capacity is reached, it will discharge. Through that process the electrons would get transferred in the matrix and when the electrons are in contact with contaminated species, they can just start reduction, because these compounds, if they can accept the electrons, they will be reduced. That would include chlorinated compounds and the same process that charged -- charging Andy charging and discharging the electrons also caused the surface, interface charge shifts in the subsurface, in the matrix oh that will change what is called the water cage configuration and that is very important to keep contaminants close to or attached to solids. With that, with that shift, some of these contaminants would be desorb into a space so that is something we always see in the field.

Since that desorption or absorption is closely related to rebalance and if we can kick more absorbed the mass into the aqueous phase, we can enhance remediation efficiency and in the meantime we are eliminating the rebalance. So here is like the electrical field in here between the two electrodes, and usually it is around 25 feet between the two electrodes and then it is going out from either both kinds but for some sites -- sides went to some injections of more conductive species, like the the I, like electro donating compounds, and the carbon materials, that could increase the electro conductivity and that would further extend the that are i of the interlocks of the permutation.

Now we are talking about an electron triggered reduction so talk about that and we have to visit the two main pathways of the chlorination and if I use TC as example here, and the top pathway is pretty familiar to everybody, hydrogen analysis so we are going to if it is PCE then TCE would go through DCE chlorate and then to ethane and then I think so that process is considered manly by microbial -- microbial reactions or it is a biological pathway for the the chlorination. At the bottom part, that is different and it is better elimination abiotic and we know that for like ZBI the first z the I can trigger this reaction so also Eva docs -- E-Redox social triggering this reaction. The high intensity electrons from these technologies, they are actually forming a tight bond in the TC so it is going through a triple bond pathway like floor sibling, and T acetylene and to ethene. Rather than through the top TC, VC pathway that we note that a lot of times they would cumulate if the ORP is not low enough, or the microbes are not sufficient or the electrons donors are insufficient and it could all cost that accumulation of those intermediates, but for the bottom better elimination these intermediates are very stable and usually -- these compounds are hard to detect and so far we have only detected Sakhalin and we have not seen chlorinated ethenes -- that has to be the precursor for acetylene and ethene has the compound could be detected.

This process of abiotic fetid elimination donated reduction is not excluding biological reaction because some of these electrons can be taken, harvested by some optimistic microbes and they can still use the electrons to carry out the reactions of high -- hydrogen analysis to the top, original biological implementation reactions. So that is kind of the side benefit of it and the other benefit, as I mentioned, it is E-Redox color the redox condition to make a parable to redox coronation.

And because of that electrical field, in the matrix, and I am powering this figure and I will show that again from the case study, you are seeing the peaks and valleys in here. Actually these are responding to the desorption of contaminants from solid to the aqueous phase. When we are using E-Redox, we are encompassing the desorption, especially towards the area that is dominated by the anode, another electrodes because that is our observation over there and we are seeing more desorption and also seeing something on the capital site than the majority cases that is on the anode side so we are seeing and we can flip the priority and then we can rotate reduction and desorption, desorption and reduction and causing this but you can see that the peak is getting lower and lower and we are removing more mass with the flip of the priority. To continue that reductive the chlorination.

I just mentioned that the E-Redox could lower the redox potential and this was an independent study by a third party and we just went to the site and set up the E-Redox electrodes and this independent electro chemist he used his equipment to monitor the E-Redox -- redox condition of the matrix and what he saw was and ORP drop of 115 many bullets within 30 minutes of that was a really fast redox potential drop so as soon as the electrical field was established, the ORP started to decrease. Very fast.

It kept decreasing for a couple of hours when we were doing the test and doing the measurement and the other measurement he did was the ORP, reaction radius away from the electrodes and he measured about 26 feet from either electrode backboard and this study was published in peer review Journal, Journal of environmental science and health and just to show the side benefit of electrochemical process, versus redox potential drop.

Now I will go to the case study and I will just use one example and this table listed some of the example field studies we have done. Ranging from chlorinated ethene's to perchlorate's and then hex Chrome. That I will talk about this case in South Carolina. And this is the site and we have c and a here representing capital and anode at the beginning and we flipped the clarity's frequently just to rotate between that desorption reduction desorption reduction, part suppliers, and this is the best make it is PVC conduit and we have the wiring in there and it is very -- about 2 inches below ground because there is lawnmowers operating in here. This is one of the wells and it is showing after the installation and we have more pictures showing the electrodes coming into. This is a electro made from special materials and that would facilitate fast electro transfer and releasing. So power suppliers and just regular DC power suppliers and we operate at very

low power, usually one unit between the two electrodes, talking about maybe 50 watts of energy cost. So very minimum.

This is just a summary of the total site wide chlorinated VOCs and you could see the training here, one point I want to address is you don't see any rebounding here so that is the unique this of this tool. Over here, we are seeing this up-and-down from collective of a couple of wells, --

[Indiscernible - overlapping speakers]

I will help you and you should be able to navigate back to the slides, go right ahead.

Okay. All right. It is showing you that peak and valley again so then we flipped the priority so we could go to the reduction part. This is just -- alternative design that we could use the tool to set up like a virtual barrier. So I will list a couple of limitations in here, Manley it is electrical conductivity. So it does not really work for Beto zone with a lot of porosity's and with very low conductivity. And we need power source, we can use solar panels we can use wind turbine, pass power but if there is absolutely no part, there is no E-Redox.

To summarize that, it can initialize and sustain abiotic and biological reduction. And it works for a tight permission and not limited by matrix visibility permeability. And it can desorb COC's from solid into aqueous phase. And it can drop the redox potential with the ROI of 22 -- 25, 50 feet and last but not least I'd like to say that this to elegy can be used with a lot of other remedial technologies. It works with biological the chlorination, works with DVI injection and chemical oxidation and that is another one so with that I will close my talk and thank you for your time.

Fantastic, super interesting and I see we are receiving questions about -- for each of the panelists and hopefully other folks will continue to add their questions as we go along so I will go ahead and introduce our next panelists Mr. Ben Young and he is with the EPA engineering and is a registered professional engineer and has 35 years of experience performing, managing, multidisciplinary environmental engineering and consulting projects. His technical expertise, he brings to managing a broad range of environmental projects such as assessments, audits, investigation, design, implementation, and so forth. And he also worked in CERCLA, [Indiscernible - low volume] other regulatory program so I will turn the floor over to Mr. Young who will present low-pressure injection of mixture suspension of soil DVI and EPO enter fracture clay so take it away.

A right, thank you, Rosa, you can hear me, right?.

Yes, you are loud and clear.

Just wanted to make sure.

So I am going to talk a little bit about the injections that we performed with ZVI and EPO in fractured play in Niagara Falls and I will actually look at two sites we injected at numerous sites out on base but look at two sites in particular and kind of compare and contrast those sites and overall the objectives were to target the residual source material, primarily chlorinated VOCs, at each of these two sides. And I am going to walk through kind of the process that we went through to develop design and implement the injections. Things we have to look at where the geology and hydrogeology. We had to fill data gaps . As mentioned previously, knowing the conceptual site model and understanding it is very important to these types of projects. We utilized servile iron and EVO mixture so I will talk a little bit about that and then once we got out in the field I will look at pilot tests results in the injections themselves and the success in some cases not as much success as we would have liked but I will present those results at the end.

Over all geology was very similar across the entire base. The overburden was very shallow, again it was mostly clay and silt's, fine-grained materials, fracture, and beneath that was a highly weathered, highly fractured bedrock up to about 30 feet, 35 feet below grade and then below that was bedrock which was -- had very few fractures. And even though the geology and hydrogeology was pretty much the same for both of the sites, the approaches were different and I'm going to talk about that now.

Again conceptual site model understanding, it is key. You want to look at all your historic data and you want to look at the sources of contamination and one of the sites, site 10, was a former fire training pits. The other site was a historic drum storage area. Each site has historic remedial actions that have been performed. You know you want to make sure you understand the contaminant migration, groundwater flow. Gradients, flow directions, whether or not there is preferred pathways, receptors, surface and subsurface structures, which actually in our case we had some physical barriers that we had to try to work around. And then look at where your highest remaining concentrations are. Whether it is in the overburden or in the fractures. >> Okay, I've lost the ability to change the screen.

Problem -- I could step in.

There it goes.

Okay, it worked. So we looked at the different methods and techniques to fill in those data gaps. Like I said even though the two sites were very similar in terms of technology and hydrogeology, we really had to take different approaches to each. For instant site 10 which was the fire training pit area, most of the contamination could be right at that overburden and fractured rock interface. So we were able to utilize a direct push. Very fitted with AMI P which had both FID and PID and we were able to get direct response, okay, so we were able to get direct response, results on site. We also used a hydraulic profile tube to look through the relative permeability of these formations and the tight overburden that we had and then we collected some soil and

groundwater samples to correlate and confirm the field data that we did have. Site five we found that even though we did have some residual source material, absorbed to the fine grain overburden, really we had higher concentrations in the bedrock fractures, the fractured zone and the fractured bedrock area. At that site we ended up installing some core holes down to the bedrock and we were able to isolate -- we did do some downhole geophysics to identify and map fractures and look at fracture patterns and planes and so we were able to isolate some of the fracture zones with downhole packers to sample specific -- specific zones if we felt like we needed to, to identify where the contaminants really were and actually we found that the highest concentrations were in only a couple of fractures. Not through the entire zone.

So some of the challenges and considerations and things we had to take into account, I mean the biggest thing has been mentioned before, and this is -- this is context port, injections, if you cannot get delivery to the contaminants, you cannot really have success. So with our tight materials, ended up using a chordal ZVI which is about three microns in size and I will talk about that a little bit more. One of the other things we had to take into consideration, a lot of our injections were really shallow and maybe 10 feet or less below grade so some of the things we had to look at was daylighting, we did not want to have daylighting occurring. We did not want to have short-circuiting or anything like that so we had to look at the various surface -- we were on pavement, we were in drainage swells, grass, and subsurface structures and in our case at least that site five we had some very large missile, formal missile pads because that was -- this was a former missile site so you had large, six, 7 foot thick concrete pads throughout the site and we had to work around those.

So the ZVI, why did we select that? We know it is very effective on reducing the chlorinated solvents that we had at the site. When we mixed it with the EV open could be provided both fast and slow release electron donors. It not only did the EV oh help with reductive the chlorination, but also as previous speakers have talked about, ZVI, we also got the abiotic or amicable reduction and we were able to get down to ethane and eating -- ethene and the other thing that we found with this product is we were able to get persistent, have that reducing condition for over -- we actually had it for over three years so it was very effective and continuing to reduce the concentrations.

Once we had had all of our data and were able to fill all our data sites and the conceptual model, we performed a pilot test on site. We went to what of the sites on the base and took a well clustered well, both shallow overburden and a deep well, into the fractured walk and did the injections and those. We had direct push points, temporary points, space, seven, 10 and 12 and have feet from this well cluster. And we utilized a very low proximately three PSA injection. At the site. That was primarily like I said to help prevent the daylighting that could occur if we had done some -- had some higher pressures. And that we looked at the temporary points to see whether or not we saw any product. And lo and behold, we actually saw product the EV oh ZVI within minutes in each of these. So we ended up deciding to use a radius of influence of 10 feet for our injection points and we use

that across each of the sites so these kind of are the numbers associated with each of the two injections. Injection sites. And we did end up doing two separate injections for each of these sites. We did use rectangular spacing of approximately 12 feet. We did a grid over all the sites. We were able to connect and process, usually three points at a time. But sometimes it was less or more. We did the actual mixing on site. We brought in all the chemicals on-site in totes and then utilized potable water from the base from fire hydrants to do all the mixing. Before the injections.

At site five, we ended up installing 100 temporary points to inject where site 10 we used -- ended up installing about 33. Like I said mixed the product on site and overall at site five, we ended up putting in over 33,000 gallons into the formation. And at site 10, about 12,000. The other thing I mentioned is for site five, we did put in 600 gallons into the core holes, we were able to pack her off at the two high concentrated fractured zones. We did the injections specifically into those, and that seemed to work very, very well.

Just to give you kind of and over aerial view of the sites, this is site five. The former missile site. The green shaded areas were the first injections that we did in 2015. And followed that with what year of quarterly monitoring for all of our performance wells we had identified a number of performance wells. And then what you are seeing the pink, and the blue, is the second injection that was performed, and the points that we installed at those. One thing I want to have you look at, was the's outlying areas, squares, rectangles, in green, those are actually the missile pads that we had to work around. In particular, here was one of our mod performance wells, monitoring five, five d, does actually one of our wells that we had a lot of trouble with that we did not get the reduction we expected, and we suspect that there is probably some material source material absorbed either into the concrete or beneath the six, 7 foot thick concrete pad that was a low-grade, that we weren't able to get -- again, you have to get content that the contaminant for it to be effective and I don't think we were very successful at doing that.

For the other side, site 10, this was the former fire training pit. Again the shaded green area, it was our first injection, and the second injection we targeted and focused a little more on this eastern section. Of the source area. Even for this site, MW 10, 10 D, that is when will again that we had some trouble with and we do have a number of utilities buried, buried utilities that run kind of North, South, in this area, that we may have had some residual source material in that betting zone or associated with those utilities that still work desorb being. So we are still seeing some concentrations here. That we were effective -- at being able to reduce all of the other wells, all the other areas of both the sites. Let me see if I could [Indiscernible - low volume].

Okay, site five results. Again, this pre-injection was prior to the 2015 injections that we performed. This was our starting concentrations. As you can see, we had pretty good success with the exception of MW 55D. You know that was the one right adjacent to the

missile pad. We actually were able to get reduction of the TCE to assist the TCE and bio chloride. But we were not able to get it down to the concentrations we were expect Dean. Our overall objective was to get 50, 70% reduction in groundwater concentrations during each event. And overall for the site, from an average, we were able to get that, but again we were not able to get the distribution in or under that missile pad. So the results were not quite what we were hoping to get for that well.

For the other sites, site 10, once again we had some fairly high concentrations prior to the first injection event. This was the result after the second injection. And quarterly monitoring. That event. >> And we were able to get good reduction in all of these wells. Again, 10, 10 d, we did not get quite as low and we did reduce TCE but we still had a lot of assists and bio chloride remaining but overall we ended up with an 90 estimate over 90% reduction in concentration.

So in summary, really the key to having a successful injection is to understand the conditions at the site. Use the proper techniques and methodology to fill data gaps. Know your site and know what you have and what you need to put together and design a good injection. Understand the physical features and other challenges for each site. You know knowing the geology and hydrogeology, the site conditions, and use the proper material, the proper amendment to inject. We were able to work with our vendor, Read Genesis, to identify the colloidal ZVI but the three micron and that was successful in getting the distribution even through the tight clay and silt that we had in the overburden. And we were able to get both abiotic and biologic reductive D chlorination. And the reducing conditions were persistent for over three years. We were able to target the source areas for the most part and we were able to successfully get good reduction at each of those sites. With that, I will turn it back over for questions or comments.

Great, fabulous that is a rep from the three panel is, excellent presentations. Now we can start asking some questions and I know some folks have entered question and I am going to try and sift those across through the different presenters because I think I will actually start with Mr. Young who went last and just ask one quick question, even though I think folks have not had a chance to chime in, you know I did want to ask about your overall percent reduction calculation. How did you do that? Did you average every well equally? Did you wait every well reduction equally or did you do it sort of by volume of subsurface treated, does that make sense?

Yes, actually we did average each well and looked at it, you know, as equals for each of the wells. We did other calculations including on a molar or other method and we basically came up with very similar results. Part of what we had proposed again it was a work plan and as part of a performance-based contract, not at Niagara Falls so we had established the overall concentrations in using that average so that was kind of the way we had established our performance objectives and that is what we were being graded on. So that is how we ended up doing it.

Excellent comment, because that is exactly my point and you need to know your performance criteria and often you need to know in advance before you even can start so Mr. Paul Dombrowski, you received a couple of questions that are more practical in nature right at the beginning and some curiosity about how long each injection lasted, what was the duration of injection and also what types of pressures were injection where you evaluating -- performing?

Right, and Rosa, very practical questions but important specially on bedrock. Injection pressures, they ranged. So we were using jeweled diaphragm pumps and the intent is to pump that at a relatively low pressure so we had a lot of wells, wears wells we are accepting solutions would pump it, five to maybe 20 psi, maybe 30, which is right where we want to be for relatively low to the moderate pressure. Other wells where there were very limited or no fractures, with the pressures of 80, to more than 100 psi. But generally bedrock projects like this, we are seeing 100 psi, not a whole lot of flow rate, it is a good indicator that there is no fractures that we can attach to. I know one of the areas related to injection event duration, the events were somewhere between seven and 15 days depending on the number of wells in the overall volume that was targeted but yes, generally a little more than a week to maybe two, two and half weeks as the event and the timing in between they were generally events, generally about a year apart and in the fall of each year. And that is not uncommon in my experience with some of these large Superfund programs, where multiple injection events are anticipated and it allows some time in between to do some sampling, see this rebound so we could plate whack a mole if we have certain areas that can [Indiscernible - low volume] go back and modify the plan or wells that stay don't we don't have to meet to go back and then it allows modification -- sometimes it is on the EPA on the administered side and if there needs to be a new workplan or new permit and yes, about a year in between each event.

Excellent information. Regarding the duration of monitoring after the event being really critical for planning your next event, very good answer and super interesting. He also did receive a question -- first advocate and that was did you have to be concerned about any materials that you injected at your site entering the river? I know you had a graphic at the beginning showing the [Indiscernible - low volume] at the site itself so how do you protect the river system.

Right, it is a super applicable question for any site where chemicals are being injected into the ground to know what receptors may be nearby in this case it was surface water body but it could be a drinking water well and it could be a residence and it could be utility and so incorporating that into your conceptual site model, knowing what is the relative groundwater flow rate, super velocity that you anticipate to go from your injection area to your censored of receptor is a really vertical target of the remedial design and then if there are concerns about that it is also how you seek once your injections. So in the areas where we may be knowing and trying to mobilize the DNAPL to inject a longer-term, or persistent Occident further down gradient, and we did adjust that and we had a surfactant plus his go project and not the sun but that [Indiscernible - low volume] but the

objective was to do most of the down gradient injection points for the [Indiscernible - low volume] first prior to doing any surfactant injection such as if there were any mobilization, it will flow into a network of long persistent Occident. And Sue some of that results in was incorporated to the positive like this.

Yes, most important thing, usually, sounds like -- that was the first starting. We are and information, cool. Yes, so I will shift gears a little bit and share a few questions to Dr. Jim and that was super interesting and what is the question having to do with what is the preferred mythology or maybe another question was are there mythological limitations to where the E-Redox is most beneficial, wears it [Indiscernible - low volume] somebody mentioned Sandy formations [Inaudible static] clay rich formations and so forth.

Great question. Since E-Redox is totally relying on the electrical transfer so electrical conductivity and that is our key parameter here, so it is related to the methodology because usually the clay formation is more conductive because it has though conductive species and there. Including the saturation, you know, the weather and ionic species and transition metals and things -- and micros sometimes they are conductive too. But usually what we use for like the design parameter is on the electrical conductivity and if the site has a conductivity about when Minda Simmons centimeter, that is considered pretty healthy to our technology but we can go down below that and we might have to reduce the space in between the electrodes to make sure -- or increase the current density but we do have a cap in there as a setting up of some of the slides of one system -- we cannot go higher than like 1000 walls, never go that high. But if the conductivity is not high enough, we would have to either reduce the spacing or increase the current density. But most of the plate sites, we were on, they have plenty of conductivity. But for the sand and gravel, for those sites I think there are a lot of other technologies that can be used too because it is relatively easier and at this time we are targeting more challenges type of formation but not to say that we cannot work on the Sandy formations.

Yes, excellent response and basically this is a tool in the toolbox and it is possible the Sandy formations could use other tools [Indiscernible - low volume] con Sapir. We did get a couple of questions and you are asked what the measured ORP on any of your site monitoring wells and I was sort of interested also if you had seen any mobilization of like reduced metals under the application of the E-Redox so that [Indiscernible - low volume] is a concert [Indiscernible - low volume].

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[Indiscernible - overlapping speakers]

Go ahead.

Yes, we have not really monitored for those mental species, because most of the time we're limited by -- we usually work with consultants

and if they are analyzed list -- doesn't really have any metals we would not have it. But for the ORP and that separate study itself, we could see that the ORP dropped really low two minus 300 or even lower mandibles range within the relatively short time so that is always the case, especially in the area closer to the cathodic electrode, sometimes it is not like always a pair. That is a minimum requirement but a lot of the sites depending on the distribution of plume or source area, we can do like one anode, two cathodes or three cathodes or the other way around and we can flip the priorities to adjust them too. For the cathodic part, in that area, usually a very reduced -- your ORP stays pretty low. On the cathode side, if it is very close to the electro, very close, talking about maybe within two, 3 feet, of radius, then that place is relatively oxidize because anode is supposed to do that anyway and the pH [Inaudible - static] but you would not see anything beyond that because the -- for other sites we have worked on, the matrix buffering capacity is just sufficient enough to mask anything the on that, that distance.

So in general between the two electrodes and electrical field has a very low ORP and it stays there as long as the electricity is off yes, on or the system is operating and if we take that off, turn it off, then eventually it will come back to the baseline ORP.

Yes, and that kind of links to another -- super interesting. Also links to another question which has to do with -- so the way you layout your anode, cathodes, creates the best make this characteristic, I just wrote it down, micro capacitor in the subsurface, is there a strategy to combining the presence of these micro capacitors with where you might be injecting materials for oxidation or reduction?

Do you see what I am saying Mech?

Yeah, I think this would be a good tool to use in combination with other technologies like -- like for example if we want to keep the site ORP very low for longer time without operating the E-Redox system all the time we do need enough crown electron donating compounds to sustain that. And also actually we started this whole development, not even for the reduction at the beginning. We were doing this to extend or to rejuvenate the patented aid DDI because he found that we could reduce some of the oxidize newly formed, oxidize a new species and basically killing off these oxidize species for ZVI to recover. I guess you know up to the 50, 60% of reductive activity after it is fully passivated we could E passivated that and so if you use this with the ZVI then it could definitely extend the lifespan of the ZVI. And if it is used with donating compounds, then it works the same way because both of them would provide electrons but just a different electrical density to the matrix. The electron donating yes, the electron donors are mostly trying to feed the microbes, so they could carry out the biological part.

Yes.

And the abiotic part is mostly done by this.

We have got a very intelligent audience and they are asking also -- maybe I will ask Mr. Young to address this, so all the case studies are super interesting, information about about, concentrations when you first treat the site and that was super interesting. And to Paul's.at the beginning, you what those lasting apples to get off of the substrate and off of the lithology. So for Mr. Young, you mentioned that you had gotten the ZVI and EVO distribution in your fine-grained soil or into the interstices, but how did you know that you got good distribution? What was your evidence of that?

Well, during the pilot study, we actually could visually see the product appearing in those temporary points and similarly we saw -- we measured iron, you know, concentrations in adjacent wells and adjacent points. And we saw and increase, almost immediately. And then we also could see the vegetable oil present in the groundwater as you could see the sheen or actually physically see the EVO present in the adjacent or nearby monitoring wells.

So we know we got the distribution to those wells.

Yeah. Another question had to do with your depth of injections, may look like it was about 10 feet, but did you actually see these materials getting into the bedrock, the deeper materials, deeper [Indiscernible - low volume] at the site?

Yes, we would inject right at the interface --

[Indiscernible - overlapping speakers]

I see.

Burden of the actual rock and we actually did get product to the actual fractures in the fractured rock, and actually saw improvement, you know, reducing concentrations in wells that were screened in the fractured rock. So we were able to see good results, even though our injection wasn't into the fractured rock, we did see impact. We did see the compound getting down there. And reducing concentrations.

Excellent, so there are a handful of additional questions about the E-Redox presentation and I know this could be a bit of a conundrum, but one of the questions was, what is the relative cost? I'm sure that is very site-specific, but when you tee up the E-Redox a look at Cisco or other direct injections, what is the magic -- what are the magic characteristics you need for the five to be your first selected alternative?

Yes, [Laughter], that is --

[Indiscernible - overlapping speakers]

That is a hard one.

Yes, it is site-specific. I think either -- well, it is site-specific but it is not really sensitive to the matrix itself. As I said, at this

time we see this as a unique tool for the tight formation, but that doesn't necessarily mean that it is significantly more expensive to the commission or other contemporary technologies. And this is more -- I think the cost of driver in here would be the to cover the area. So that goes back to the electrical conductivity. So if we have the large enough conductivity, and I guess to put it simply, if we want to use ZVI permeability react ability, I would say this virtual reactive barrier is much more cost-effective. Because you don't need to dig a trench. You don't need to change the material, and we can do that like every 20, 30 feet with one electrode to form the large area of reactive [Indiscernible - low volume]. For source treatment, depending on the size of a, if it is very small area, I would say, you know, excavation and chemical oxidation or chemical reduction, this kind of.-- point to the point contact of removal technology would be more efficient than the electrical -- electrochemical technology. But you know, I guess the cost also is related -- associated with -- the main cost here is upfront. It is mostly for the system and the installation. After that, it could go down to almost 0. Because usually sometimes we -- they are site and him and interesting to spend a little time to check the boxes and see the voltage and if there is any disconnections and things like that, because we have not seen any like corrosion of electrodes or things like that to take care of. So the little e m is very minimal and the energy cost as I said one system is like a lightbulb so the electricity is not that -- not a big bill either. And --

[Indiscernible - overlapping speakers]

Yes, that was a question, actually, what kind of power supply are you using? I know you addressed it a little bit, but I'm just going to confess, I'm a geologist, so when you talk about how many watts are being applied to the ground, can you translate that into something that -- I do know, rule of thumb that you might have? Is that a lot of energy? Is it not a lot of energy? What is the duration that you are operating at that rate?

Do you know what I am asking?

Yeah, well one site -- this site is a little different. Another typical site we got in Denver area, that is the site in the middle of the commercial Plaza, and there is a light pole in there so we talked to the city, I guess, just to get a power outlet from that light pole and set up in the shed, and that single outlet was supporting five sets of E-Redox to treat a Street block in that area. And each unit is about 50, 60 watts.

Yeah.

If you have five, that is maybe like depending on how many lights you got in your house, maybe one room or two rooms.

Yes, fabulous explanation and you just said the correct supply [Indiscernible - low volume] [Inaudible static] is a correct.

Yes, --

[Indiscernible - overlapping speakers]

I guess you can flip-flop apples and bananas, right?

Right but not as frequently as AC. AC would not work, too fast.

Would be crazy, when I get any penetration into the formation.

Yeah.

Cool, let's see, there was a question -- I think this is super interesting and the question was can you use E-Redox for other compounds? You mentioned chlorinated solvent and I was thinking things like PCA, their attendee has asked the about things like saline, any comments about the range of reducing targets, targets to be reduced?

The electronegativity of this system is very low, or very high, depending on how you vision it. It can go to very reduce conditions, so that means the majority of the species above that would be able to be reduced. So we noticed that even DESI Amano chloride, they could be used. And that if you go further up to like selenium, I assume it is still in a, that is close to nitrate so it is very -- it is a very easily reducible compound, like Chrome six and uranium and perchlorate nitrate and things like that.

Perfect.

One point I want to add is we did try this on p FAS compounds on PFO SN PFAS for a few species and there, just as a kind of a of concept, we did not really see -- we saw the destruction but we are not sure if it is through the oxidation or reduction of that. We don't know the mechanism. But that desorption part was very similar to chlorinated compounds. We did see some sort of a desorption from solid tracing to [Indiscernible - low volume] initial increased concentration of p FOS and p Flora compounds. And then we got about 20, 30% destruction of that as I said I didn't know about the mechanism but we did see fluoride in the water so it is not vaporization for sure.

Right, it could be of some more easily the fluorinated components that we don't even know what they were. I actually use the pure PFO has, PFO a. This was in reality though and was not in the lab, right?

It was in the lab.

It was in the lab, okay.

Yeah.

Strike my comment [Laughter].

We could go around the horn on this, but there is going to be another question, and I think it applies for each of you, I would like to start with Paul, as a comment, what else, other than the original

chlorinated solvent was being monitored? That everybody look for Dr. products and eventual mineralization and Paul, if I could kick it over to you, if you don't mind?

Sure. I would have to go back to the -- some of the monitoring data. But in this case, it was a relatively aerobic before so to my knowledge it was very little data product starting with -- so we were primarily work with PC and high concentrations and that was a primary contaminant. But I do believe right off the monitoring for metals and if you other sulfate and other electronic receptors.

Right. And Mr. Young, over to,'s in question pane where your performance criteria also including some rectum products or other products?

Yes, we actually did have some reductive the chlorination already happening. We had similar concentrations in most of the wells. Of TCE, cysts, DCE, and then a little bit less vinyl chloride. So we saw -- you know, kind of a combination. They were fairly relatively the same concentrations of TCE and broader compounds. Then I don't know if they were asking the question but we also had v TEC and a lot of other volatiles that were at the sites but at very low concentrations, primary contaminant where the chlorinated VOCs. And we did not have much, if any, PCE. So all of ours was letter TCE and broader products, compounds.

Yeah, exactly the question. And in fact it looks like I missed a question for you about your specific site. That was -- it was typed right in the middle of your presentation so I apologize to the questioner but the question was site five, for that Mager falls example, -- Niagara Falls example, is it embedded in the bedrock matrix as well as a fractures. In other ways do you think the bedrock itself is containing some of your chlorinated solvent problems?

We actually had some bedrock wells, some of the existing wells, and we saw traced -- very low concentrations of chlorinated PLCs. But I mean right at or maybe just above were just below the MCL. So we had what where the bedrock -- in the areas of highest concentration, and we did not really see much, you know, like I said, just a very low level. So it was primarily in the fracture and the fractured rock.

All right, okay, good. But it is a good question and it is excellent that that was studied before the treatment occurred. So that's good. Let's see. I guess we're kind of getting pretty close to the end of our questions from our participants and we have a little bit of smidgen of time left and I'm wondering if around the horn each of you wouldn't mind saying a word or two about how important the site methodology was because I know that our second panel, the comes later today, is really about design construction for Institute amendment delivery. So any site constraints you want to mention or Mr. Paul Dombrowski , your site?

Yes, for this site and particularly bedrock sites, I know just where challenging in terms of developing exceptional psych model and knowing where your contaminants are and where they are traveling. So if you

have the opportunity -- if you find where contamination is, then you want to make every effort to go and deliver to those areas whether it is a fracture or fractures that are connected so yes, being able to -- and I know been praying mention the same thing in terms of delivery has been so important and if we cleared deliver where the contaminants are, that is how you will get your effective reduction and you don't want to be spending money or time or injecting chemicals where the contaminants are not.

Exactly. Any other party remarks from Mr. Young or Dr. Song Jin?

Yes, mythology is also important to us but as I said because we are not delivering a physical substance, we are delivering electrons, so sometimes it is just counterintuitive to other remedies, so the -- like for example, if it is the Sandy site, and if it is freshwater, without a lot of ionic species, connectivity could be relatively low but if it is -- at the coastal area, legacy water invasion or it has a lot of I sulfate and things like that, it to be a better site for us. Even it could be limiting the biological activities, because of the salt concentration.

Very good example of conductivity on that end.

And I will just reiterate the delivery is the most important. And find, great plays and silts, 10 to absorb -- tend to resort -- adsorbed residual material and those are hard to reach but as Paul mentioned, fractured rock really poses a whole different set of challenges and knowing which direction flow is going and knowing where the contaminants might be getting to. So they each have their own challenges and you just have to make sure you know and understand your site and design for it.

Okay, good place to end with a reminder that we have a lot of arrows in the quiver and sometimes you need more than one arrow so Jean, passing it back to you.

All right, thank you so very much, Rosa, appreciate that. We are right on time according to our agenda. So I'm actually going to change the arrangement here on the screen and I wanted to think Rosa and our penalties for sharing their information and expertise and I also want to thank those participants were on the line chiming in with their comments and questions. We are reaching our designated break time and so I will take the time here and edit a few things that we have got about 18 minutes or so for our break. So what I will do is play a few quick words from our sponsors and information about future semi or DCHWS events that are appear on the screen so I encourage you to sit back and listen to a few words from our sponsors while we take a break and again the session will carry on at approximately 3:10 after the brief intermission and if you need to hang up on the phone and call back and you certainly can do so. For those joining us on panel two, if you could stay with me on the line for just a moment so remember you want to keep your phone lines are muted and I will pull my panelist into a special sub conference in just a minute and we will go through a few technical checks in the background so with that anybody enjoy your

break and we will get back to the show shortly. >> [The event is on a recess. The session will reconvene at 3:10 P.M. Eastern time. Captioner on standby.]

[Captioners transitioning]

>>
>> [Captioner on stand by.]

Good afternoon, everyone but we are just gathering back from the end of our break on today's virtual symposium for the design and construction issues. My name is Jean Balent . I will be serving again in the background for today's broadcast . We have resumed a audio stream, so everyone should hear my voice coming through your headphones. I am going to change a few things around on the screen here . I am just going to ask everyone to type a message into the Q&A window and just let me know if you're able to hear my voice. If you are back and you are ready to carry on with our second panel of the day, please go ahead and send that message and with the upcoming panel able to see the so I just wanted to thank you
to I'm chiming back and getting the managers ready to carry on with their virtual symposium . Seeing as though we have raised our official time to resume I will just welcome everyone back to our second panel of the day. To date the session is going to be moderated by Rich Evans who is a senior vice president with overall responsibility for groundwater and environmental services technical practices in air-quality and data management. Rich has optimized injection projects through the eastern United States with remediation experience including biological and stabilization amendment projects for a variety of contaminants . I will it Rich tell you more about himself to introduce you to your panel you should be joining us here for Panel 2 that will look at delivery methods designed and construction consideration . With that introduction to Rich I will turn it over to you and let you begin .

I am here with my final audio check.

You sound great.

I have taken a number of the webinars and I told Jean this. She is the best moderator in our industry are doing this she does a great job coordinating everything and is probably the most professional moderator. Thank you. You really do a wonderful job with all of this, Jean . I had a chance to think about last night through the wind gusts and power going on I was wondering how this is going to go today. Fortunately, we have power. I was thinking about the first set I worked on and it was the phone call I got one day that stuck with me were the bank who from the property said we destroyed all of your wells. Were they important? It is something I was thinking about's my power was going in and out. Today we have a great panel of engineers and geologists bring in 100 years of experience of in-situ remediation and that is pretty grade. It is a good team. Let me jump ahead here and

give me some images of who we have here we have a variety of people with backgrounds and they can introduce themselves further, but we have Jason Ruf who will be providing his experience and expertise on the data visualization and in situ remediation. We also have Glenn Iosue to offer his expertise. We have him speaking in the pilot study section. Chapman Ross is the is going to offer insight on topics today but we also have Mark Strong with Jacobs to lend experience on remediation wells and at the end we have Rick Kramer who is the sequence practice lead who will share his experience today. The way we are going to run this session, it is different than earlier but we will not have 20 minute talks

we will have shorter ones and poll questions so we can get to know about you a little bit . We might use that to adjust what we are talking about and respond to the audience experience and we have dedicated panel sessions where we will turn on our cameras and respond to questions that we have is will is questions and the audience . An some of the other sessions where you're talking about a specific case study, our panelists will present case studies and certain information but you are welcome to ask general questions . I think you will see if you were here for the first session some of what they talked about will also fit into our session as well. >> Jean, do you want historical poll questions ? These are just a couple questions to get to know the audience here to see how people have used institute remedies and also for purposes . It looks like most people who have used this as a primary remedy, in situ, Lewis people use it as a secondary remedy and that is interesting. And mass reduction is really by far and above the number one reason people use that. May be that was the presentation earlier but we certainly see the . Pretty interesting. The second places trying to get that no further action or site closure . This is what people are going for. Thank you for sharing that and hopefully it will fit into our discussion here today. Be panelists will touch on different topics. The tagline we came up with is how to make them succeed in looking for pictures it is a fun failure mode if you were to turn people's water., Which has happened and I like the photo on the right and things are going so well that the operator can sit down and watch what is going on . You are hoping that nothing is happening and that everything is going well. You can just kind of watch things as they get injected down the road. That is the overall goal , to try to talk about what makes them seed or fail. We broke this out into different areas of in-situ projects and the stages they go through. The ones in green are the ones we will focus on more. These are the areas where we have assessment and be designed and amendment selection and the implementation , which a lot of the topics have focused on today. We do not talk much about the monitoring program, but some talked about data and rebounder not having rebound and optimization as well. We are hoping today what we talk about the topics that we are going to weave them into our conversation to talk about pitfalls or costs so that all of our progenitors will have a chance to bring those

into the top box. The way we are going to do this we will go to one speaker at a time . Sometimes we will have one or two speakers and a short panel session you can ask questions throughout and hopefully get to all of the questions by the end. We are going to turn over to Jason .

Thank you, Rich. This is a quick case study where we used 3-D visualizations

and HRSC for optimization of a chance of and . I think based on the first poll question there was the majority of answers that were the primary remedy for the selected choice and 70% said mass reduction . We are going to be talking about mass reduction and the primary remedy was the in-situ injection work. On this I am going to start this video here . It should come up here . As we start the video , this is the output from the terminal event. I just wanted to share a video of the output of the 3-D model showing some of the geology . If you look closely, you'll see 200 injection wells . It was a pretty significant remedial injection at this property with high concentrations of Freon and chloroform and a little bit of everything . I am going to get back to the slideshow now. Let's advance and that we have another poll question to ask. U.S. performed a direct sensing program prior to implementation of the injection and if you have, what tools did you use and as and when ever completed one of these as part of a post remedy ? Will get those communal email. It looks like the majority have not done a high-resolution program prior to injection program . It looks like not many have done one as part of post remedy . Hopefully we can show you the advantages in terms of optimizing your injection programs. Artery optimize site remediation ? I am a geologist, so to me the geology controls everything . Geology controls everything. That was one of the key thing is, what is the geologic matrix and where will the amendment go? At this site what is the mass and how do we evaluate the 3-D? I worked with Mike Hansen with Varina and we were going to use the MIP with the HPT and we wanted to evaluate mass versus geology, look at untreated mass and evaluate the effectiveness of the injection to show where it wasn't effective, and then as part of this we developed a 3-D CSM . At this site we used both the MiHPT data and we also used HRSC data . A little bit about. The strategy was focused treatment, institutional controls, and MNA . This consisted of 70 MIP borings advanced on targeted at injection wells that we went to the locations where we already had an injection well in place . The depth was around 35 or 40 people. We were looking to identify the geologic information and chemical information . This is one of the lawns that we are going to have you should be able to see my mouse now that we have three detector information here. This one only responds and in this case this log is actually showing an indication and that is because we see them all responding at high respond levels pay geologically the green here is giving us HPT pressure data . High pressure is fine-grained material and low pressure the sand and gravel . The light blue it is estimated K values they are basically the inverse of pressure . It is high pressure and it is now estimated K. And grade that is the electrical conductivity . In the site, the injection amendment was for sulfate . This is actually in the ground for the remnant in the ground resulting in high connectivity we can actually see where the injection material went in the subsurface . So this is just a cross-section

and it is four langues taken next to one injection well. They were up gradient, side gradient , and down gradient . This is the injection well screen . The green is our EC. We see the remnants of the injection material , and we see this is the signature and DNAPL. This is below the actual will screen works is the data and this is the case where we are having a XSD response and you can see that in the EC response practices

where we are outside the radius of influence without the high EC Valley and we see some XSD response . The next slide is just showing the pressure data . It is just showing the geology firm pressure the way of high pressure that is low K . If I go back one you are going to see right into this interval here that EC will be high. High EC is where it is preferential to the amendment . We use the MiHPT to develop a 3-D model for the . That is what I showed him the video. I took the existing analytical data so used analytical data from 2012 through 2019. The injection to play starting in 2013. It was done over a number of years to reduce the annual cost so there was not all at once but then over a few years so that we could reduce cost over that time period for for this event eight sampling events have Dana. The site was divided into five injection areas in two geologic units . We can was all of the data very quickly once you have it set up and you can generate grounds like received down here , and we can generate the three-dimensional pictures up here we are going to zoom in closer here. This is a two-dimensional view of the total Freon's and the aerial extent of them looking through the three-dimensional plume to applaud the highest value practices prior to injection, March 2012 . We could look at our data and relationship.

We had to drink monitoring wells but no data below the control . If we step forward in time trimming to February 20 maintain at the time this is the current condition we are looking at . If you pay attention to the color and we went from little bit more rent to quite a bit more yellow. We have a significant decrease in the amount of the plans over 1000 parts per billion in the fence diagram. This data was processed for five individual areas outside. I was initially one of those areas Rainer .

This is Freon greater than 1000 in one area . All of this is all of the calculations that were done with the total volume , average concentration, and then also with differing compounds. Services Freon greater than 10,000, 20,000 , sorry. It skipped back on me. In here were individual lines that showed the contours . Sorry about that. I am having some issues. It is skipping back. So we can look at individual compounds we can look at individual mastery time and we could also look at all of this information with the data. All of the information we have used with HRSC to optimize the future injection strategy. Basically , the product they came up with was additional injection wells at specific intervals to target the most mass. There was additional areas that were identified head to the injection program with different materials that were not identified. That was part of the optimization strategy. Any questions ?

I have some questions but I want to get to Glenn. I think we should just head on over to Glenn because he has some questions on the we will have some questions in the panel after that. Are you ready, Glenn?

Yes. Can you hear me ?

Yes. You are good to go .

There was some actual snapshots and a great presentation. Thank you for attending today's presentation. I just wanted to give you a brief background on myself. I started off in the late 90s with EPA Superfund work . On the left side this is a further me at the EPA environmental response training center in journey in a Level A Suit . the mid-is play football in a Level A Suit, which was interesting. A great sector to be in. With Regenesis and provide remediation solution and 23 years experience.

Here is a polling question for those in the audience to answer who will sell everyone understands these concepts that we are going to be talking about. It looks like right now we see a majority of responses for primary concerns when choosing a in-situ remedy. Impeding cost is the feasibility of the implementation at 62%.

Reporter: To have you have a site where event has occurred following implementation , it is 90% think that a significant. Thank you. I will continue on. Here is an item of interest. As practitioners we have a lot of pitfalls and best management practices we see in our industry. Some of the newer publications that you will see out and published today talk about remedial design characterization and in essence we caught here internally and Regenesis design verification testing with you call it a RDC or a DVT, eserves the same principles. In essence, we are trying to make the remedy more effective at the end of the day . As you can see from this nice illustration, modified

what happens when you implement they were money without doing any characterization for the remedy? You seem to have a longer lifecycle as well as higher cost. If there is additional information relevant to the ground truth, some of the parameters being evaluated as you can see the blue with the RDC . You have obviously last time consumed and the cost savings. It is ultimately similar to optimization where we are basically collecting data that is going to improve and implement a remedy to be a with client collecting the data out front service great value in the long-term . Here are some of the other common pitfalls. The geology, the way it is characterized and high-resolution , which was just discussed earlier . The second central models , role modeling. These are some items of interest. They'll have different class. Mary Nam. Just a quick snapshot of fundamentals of contaminant distribution. We are looking at in-situ below ground surface and that the sun is off we will consider them when you have high transmission zones some of the send you now that we focusing it and then you also parking lot, clay storage units that store mouse

even though it is 10 foot below ground surface, there are certain zones within the you have low or high hydraulic conductivity . Borough switching those two are extremely important and we find every site is unique . As we dive into the data, we can modify the in-situ remedy based on the side characteristics of each aquifer.

>> So why do design verification? There's been a lot of data collected . It is not to disprove or expand upon any site assessment that is already completed. It is all great information that has been done done by consultants with use of programs to characterize the vertical extent of the plume . It is basically to target and identified the target mass . Pretty much trying to understand the principal impacted

elements within the zone and then obviously improve the performance of the remedy at the end of the day . Here are some tools that we deployed to help with characterization of contaminant mass. It is not to characterize the registration but to focus on remedial design. Some of the typical parameters it is extrapolated that the entire site might be sandy silt when you go out you will find that there is a different portion and that makes a big difference when we are plane amendments. This is a great way to further expand upon the contaminant mass word is located and how to target with remediation.

Fiddling tubes there is a picture on the right and it is real simple test that helps to fine-tune injection strategy. I will talk about meters in the next presentation about how to target that. Is a great snapshot on clean water injection touts is a simple test in terms of getting the data to target your treatment zone and the doctor worry about going out waiting on site. You can get this information prior to injection this helps to confirm your radius of influence and helps expand upon some of the pressures and flows should be anticipated prior to application of the remedy in the short term duration in terms of how long it is to complete this period also for you put in expensive injection was using get a hand on if you are targeting the right sounds . If you're in the zone and a lot of pressure build up, you would probably see it is not a great place to put the injection model to target your remedy.

Here is a quick snapshot of passive flux meters. We are deploying these in the field . You can see a nice illustration of the passive flux meters on the right but we do see a difference in terms of groundwater velocity that is captured with this device versus some of the seepage will also be given to us based on the geology known in the region. Here is a quick snapshot of a

passive flux meter getting deployed. It is pretty much nylon mesh filled with absorbent tracer . It is turned into groundwater monitoring well. They passively intercept over time within a week or two you take this ship it out to the lab. These devices

and from 1700 up to 2500 per unit for each can sample between two or five samples and the range of our crisis can vary if you are sampling pupils, which would be more expensive. This is a quick snapshot of this device in the FIFO segments. This is when three of them are strung together before the appointment and then deployment down the well. This is pretty good Irene and what we have seen. Some of the seepage paucity that they are Gavin , you can see that these passive flux meters are shown in orange a much different value in certain cases than the seepage paucity in blue is provided as part of the noon value . As a result of this , this is actually the critical factor when you are designing a remedy with your plan dimensions and such and where you want to target your remediation . There is the great analysis that was done internally. One of the benefits we have within Regenesis as we look at about 150 sites per month which is 1800 that we look at . We basically looked at the design verification process. We see the benefits, the pros and cons, and one half pounds when we analyze these sites but we took a project population but 43 sides. We found we had 33 which were resources areas that were being evaluated. 67% of them were made at distal plumes and this is showing the mix . 50-50 between fine-grained and coarse-grained materials with soil types to what happened

was here shown is some of the blind spots. When we consider doing this after the characterization was completed we have the model and what happens when we zone in on remediation of the benefit of doing a RDC . 46% had been identified conditions, lower injection rates with a short-term ROI. You want the open up the you are hoping for is 21% or one and five that had been identified contaminant transport zones getting back to passive flux meters. Figure contaminant zones here with 18%. If you are targeting the FIFO loan and you have 4 feet of mass it is going to make a bid for when your injection amendments . And then obviously, the higher contaminant concentrations is 18% . One itemize want to mention some of the information provided usually when we are getting data is usually in the source area. A big disconnect in the plume and we are looking at the distal area. There is a lot of good characterization activities that we see mostly in the source area in the midst distal plume data and the extrapolation of the source area not really reflective. That is a good reason to perform 70s design verifications. This is a nice illustration of the design changes and what happened in the analysis. One and three had no changes. The design was right on target . We confirmed the ROI and looked at the velocity. It was within the range and the chemistry was right on target. In terms of analysis, 35% were few changes and then 8% moderate and 8% significant. And then in certain situations the injection was canceled quick that is interesting data . And what is the significant change ? In looking at the significant change it is more like where we modified the mass of the dues they . It was underestimated, the contaminant mass so we had to increase the dose same . It could be point placements changing the vertical intervals or changing the ROI to make them more closely spaced . What was most importantly see these changes is really there is no cost increase. So performing this analysis did not result in any huge cost . What is important is canceling the injections does not mean you proceed with any remediation with another amendment or remedy but in a sense , there is a huge cost savings if this was implemented and shown to be ineffective because of the data collected that it when I worked and we would've had a veiled remedy. At the end of the day , the intent is to get a closure with your remediation objectives . So the design verification test we are finding that it is really to provide additional insight into the great data and the value of doing is almost like an insurance policy with your return on investment from the great work you have done as consultants and then in terms of the improvement , it improves the predictability of your remedy honing in on where the chemistry should go and this is been discussed by others during our presentation today. It helps the implantation time and efficiency with the crew being read can ensure 10 your application or days on side by looking at the simple test. You have identified technical blind spots that I talked about earlier . If you have one or two of those blind spots it could obliterate your memory and proved to be in effect the if too many problems. In terms of design application it is targeting the contact they need and your understanding better and it is a great value at the end of the day . I have heard a lot of people talk over the years about one of the time with the verification test. Typically the cost could vary between 3% and 5% . The return is a more effective remedy and a remedy that is going to cost you less. On a typical site that we have seen that is about $60,000 to go out with the direct push

and collect samples and data and I just want to do a quick wrap-up and toss the torch over to Rich for any questions.

This is our first scheduled panel session here. We are running a little behind schedule here and want to mix together the poll result we got and when the first, and it was like 100% had rebound. And it rebounded back tonight percent and considering it is not often equate to a significant reduction in groundwater impact can you expand on the site closure. We often have mass recovery. And you are nowhere near the MCL. You talk about how you set up your path of closure down the road ? Back in my experience most sites that I have seen have always been going with M&A as the final remedy . It shows that you have service removal. You will not get the MCL because they are so low . When you do the 3-D analysis in looking at the mass reduction it is always much higher. Your average concentration may only go down 20%. The minimum concentration is going to lag even further when you look at the analysis of it , but you still need the target mass. That is where you get the most bang for your buck if you can get rid of the source, you should be able to use other things to reach those goals.

Those numbers a strange. Like if the Postal Service delivers 90% of the mill on time, there is an enormous amount of mail that is not delivered on time, even though 99% sounds good. I will ask you, Chapman . In terms of setting expectations, when you have worked with consultants and clients, how do you do it when you look back at the work that you did that it met the expectation that was reasonable?

A lot of times we have these conversations on the front and where we say what are your goals? What are you trying to achieve here ? A lot of times it really comes down to the level of aggressiveness of the remedy that we propose to meet those goals. That is going to be a close injection point with a higher mass loading of amendments in the subsurface . Those are the kind of questions we have to ask so we understand what we have to achieve here. There are ways that you can come up with calculations,
but a lot of it is based on experience with the remedy you just have to have a good sense for how long you would expect.

It is always the number we multiply everything by . If you look behind the equation somewhere in there is some factor that is been used based on experience and the

Amateur almost always underestimates what you're doing and if you are not looking at your work you are missing a big piece.

Yeah. With the stoichiometric calculation you will easily be 10 or 100 times below we actually need to be and practice . You have to take the experience home.

And you had something interesting, Glenn. I was thinking about the passive flux meters and how they can improve sustainability . I was so overwhelmed by the differences between expectations and what those meters were observing . I you recommending people use a more frequently

on the front and? Of that is a key factor , that is like a disaster waiting to happen if they are that far off on everything.

We are recommending and it just gives a better representation of data and it is how readily chlorinated compounds will absorb . It is a great way for us to validate and what was glaring for us even before was the inaccuracies of some of the book values that were given from the site reports versus what is occurring in the field. If you have a velocity of 1000 feet per year you can pretty much, the travel time . You cannot . up some of the absorption technologies here. That is one of the reasons why we recommend them
at very low cost to do up front . a lot of this site characterization , if you can build this RDC into your site characterization, that is preferential to get the data before you go to implementation of remedy .

I have a lot of other questions here , but I will hold them for a later panel session but what a way go ahead and give Chapman here some opportunities to go into content and I will have Mark and another short panel session . Hugo, Chapman. You should be all set.

Thank you. I appreciate it. Let me talk about some concepts, some treatment concepts and injection concepts. The work that I do is primarily based around using hydraulic fracturing mechanisms to deliver solid amendments to the subsurface. This is a great photo here showing these sheetlike structures that are representative of common forms of the hydraulic fracturing process. This one in particular on a one to start off with a poll question to get a sense for what injection methods folks have used in their site.

I apologize , but it looks like I need to stop this question and make it a multiple answer question. I'm going to be opened up poll. My apologies, ladies and gentlemen.

Select all that apply for we want to see if there is any responses here. If you missed it by getting your initial one in , try to hit it again if you can. It does not look like it is updating on my screen .

It looks like it is frozen.

It is to see the group of what you are saying.
>>

They can always type in letters into the Q&A window . So feel free. A, B, C, or D. All that apply.

All right. Let's go ahead and move forward.

[Captioners Transitioning]

So I want to point out this ITRC document. It is all about optimizing ejection strategies. I encourage you to go check it out. I'm going to highlight a couple of pieces of the document just in the context of the panel today and the first is this delivery technique. This is table 3 out of four of the guidance. What I want to point out here is that it is key for the ejection method for remediation for in-situ remediation but it also matches the jollity geology and a lot of people on the panel talked about this, parking lots and highways in the first panel today we have folks talking a lot about delivery and contact is key. That all speaks to what the table gets out. Now, the work that we do it

F RX -- the key to match the delivery method with the geology just to take on this there. here is another great picture of a hydraulic fracture. This is the boxes you see here and about one centimeter square , just again, sense of what those fractures look like and the subsurface and the planar structure , generally horizontal in attitude and we know this from a lot of work. Excavating fractures and really understanding the mechanics of those forms of subsurface.

Chapman, while you are on the picture, I'm wanting to understand and I see it clearly in that photo.

This is actually not sand.

Yeah? It looks like a quick

I believe this is -- I think it is some sort of graphite-based compound. But now I'm going to have to learn what it is so I don't -- so I can answer that question better in the future.

Who provided the sound quick

We do use sand. We do use sound a lot and the reason we use sand -- and I will talk about this a little more on the amendment slide -- but the reason we use sand is to enhance flow through these fractures. That can be a flow of liquids or gas and use those sand-filled fractures tied into wells to extract basically something like -- extraction or -- abstraction or -- in case of bio -- or -- liquids like electron donors, DEO, sodium lactate and that sort of thing. It is really all about flow enhancer so that is how we talk about it.

Thanks for the question. Appreciate it. So that brings us to amendments which is another great table. I'm only showing a little fracture fraction of the table out of the I QSC document and it talks will all about amendments and the different types of amendments that can be used for different types of treatments and a great resource . But I want to -- the take-home message here I want to pass along his that you have to match your amendments. What your contaminants, obviously, if you don't use them to treat your contaminant, that's a problem but you will have to match it to your delivery and that goes further by saying you need to use an amendment that is going to last for a long time. If the source of it you're trying to treat or the groundwater you're trying to treat

is going to last for a long time. That is another thing to keep in mind as well. Choosing injection measurements and amendments. Some of the amendments we commonly inject into the subsurface Arcand and you can see

the thick, viscous slurry that is created to an that sand. Here you can see potassium Megan Knight and on the right-hand side, ZVI and we have Jean that will bring up a video of some of these flurries. Slurries, can you go ahead and play that, Jean? This is a video showing a potassium Megan Knight slurry right before it gets injected into the ground. -- Potassium manganate slurry just before it gets injected into the ground. You can see that potassium manganate slurry and this is a potassium sulfate and hydrated lime slurry, very high concentration slurry up to 70% by weight to solids and it looks and behaves a lot like toothpaste as a fluid. Thanks, Jean, you can go ahead and put that away. I appreciate it.

So now you are seeing sort of what these slurries look like and what they look like when they are moving around, just to get a sense of kind of how much mass is really encapsulated in a gallon of that slurry. Just to give you a sense of how much we are talking about. A gallon of this ZVI slurry that you see here on the bottom might contain 20 or 25 pounds of ZVI. That is 25 pounds of ZVI per gallon so a very high concentration of slurry and that kind of speaks to the second point here and I am wrapping up now. But basically, you can put a lot of mass of amendments in the subsurface and this speaks to the question that Rich was asking in the panel a. Mass loading is a big part of the design and effective meant remedy and you see there on the bottom, this ZVI mass loading, this 3% -- soil. That is not really achievable using standard methods but that is something we can it achieve using hydraulic fracturing methods and some of that allows you to target some of these really challenging formations and coupled with very high concentrations -- source of the --.

The last piece I will highlight here is the cost. Everyone asks questions about cost so I like to give a sense for what the cost is. Using ZVI as an example, costs using ZVI for treatment of chlorinated solvents, might range from $50-$150 per cubic yard and that is when treating something like a diffuse plume in more of a PRB setting to a high concentration of a DNAPL source zone. With that, I will pass it back to Rich .

Thanks. We will just let Mark go since his slides are all queued up here. Mark, if you are ready?

Okay. Is my audio good, Rich?

Yes, sir.

So I just want to provide a brief overview of horizontal directional drilling and a little bit of history and some challenges and opportunities. The technology has been around, you know, really since the 40s and it is kind of power from the oilfield, more or less

revolutionized the -- gas market. It didn't really get started in environmental applications until the late ' 80s. Jason has installed approximately 80 of these wells in the late 90s and they did not find their environment until the late '90s. That is when it really started to kind of gain steam and optimize the process. There were some technical challenges as far as materials and drilling methods and fluids in the 90s and that had to kind of be worked through the technology had to evolve and gain some theme in the mid 2000s. Anything you can do vertically, you can apply with HDD. I would say the majority of our applications have been in sparging and STD on pumping but what we are so continuing to see is developing liquid injection and ERH, I STD. This has a flow-through technology and Jacobs is working on its own set of sustainable technologies with collection of treatment wells.

Obviously, usually the initial driver to consideration to HDD is plume access. This is a picture of a bulk storage facility in North Carolina where we had to drill at least three of these large tanks. Of course that was the driver but in addition to that, there is always contact efficiency. These plumes tend to be elongated and relatively shallow in most cases so HDD allows you to put more -- in contact with that plumes of that type of geometry side is one advantage. Also the decreased site in the impact of technology tends to be less unobtrusive. You can stage your treatment facilities possibly even off-site or in some location that is not in the immediately immediate vicinity. And cost , a pro and con. It can be more expensive in some cases but when you consider the busy sites when you have a lot of trenching and manifold in, that is on the cost becomes advantageous for HDD. In addition, to a simpler and streamlined
O&M.

This pictorial is from an industrial site in California. Most of these sites are shallow plumes. In this case we drove to 130 feet successfully and saw a couple of blind end wells and achieved 90% plus reduction of a to BOC plume using our sparging. One of the major development I have seen over the years is line end drilling especially incense where you have heaving and collapsing materials. We developed with the drillers a method for installing blind end wells in these type of commission conditions. Also the Gyro steering tools have been developed by companies that enable accuracy usually in the range of plus or minus one foot even as depths of over 100 feet so the depth is not as much of a factor.

Just to jump through a quick case study, this is an industrial site in South Texas. And we faced a number of challenges here. Our plan was underneath this busy intersection and let me see if I can get the pointer to work here. This intersection had a significant number of utilities and of course, the traffic we had to deal with. So once again, the access was a driver to consider HDD here. But then we also did some plume modeling and I will -- captured some plume modeling. I was so in the next slide to show we could generate an expensive capture zone in this layered or stratified lithology and to follow up, we did see in the strata side stratified lithology improved yield and draw down from this target Sandy's own kind of in the center of this material. So we

installed as well and let me go back here for a second. We installed this well that was approximately 1100 feet long with 380 feet of schedule a PVC. And the HDP line at the top was a direct pump that distributes to an IWT P system so fairly straightforward and we were targeting HDD to draw down this system. So the next slide shows the particle track modeling. And kind of a unique factor of horizontal pumping wells is it does take a significant period of time for the capture zone to stabilize. In this case, it took about three weeks. Pumping that at approximately 12 GPM, we did verify we were getting the zone capture we predicted with this model.

As I said before, relatively unobtrusive well vault here. In this case, we were in a flood zone. That is why you see kind of a raised concrete axis fault with pillars behind it. and then the last slide, just because we were at relatively shallow depths, we just used a surface mounted double diaphragm pump. Just Easy Access and reliable, easy to maintain.

So kind of short, back to you, Rich.

Mark, I'm glad you showed the pump because I am sure that was a question as people were sitting in the audience were thinking about putting a graph is pumped donate 400 foot well.

It has been done. It has been done that way but in our case, we liked the ease of maintenance with a surface mount and pump. Obviously our pumping level was
25 feet so it is an optimum solution step but there is no reason you can't use a -- pump if you have a deeper well.

And you mentioned the blind , single entry versus having the dual entry. Is there, you know, I think, initially everybody was dual entry and then there has been a movement to blind where you can't access the other end . What is your experience now on that?

That is dominating the market now because what you said. There are so many sites where you don't have access on the distal end so blind end wells are probably 80% of what we are doing now.

And I am sure everyone wants to know and I have gotten, I have put some of these in my [Indiscernible muffled] but from your experience, what are you seeing in current cost? I know there differences you have size and depth but I have seen anywhere from 150 dollars total $150-$350 per foot.

I was going to get back to that for all in cost was about $300,000. The well range was about $108 a foot and for shower drills that gives you an idea of what you are getting into but once the depths get above, say, 7500 feet, you name or especially navigational technologies. That is when you could see in the range of $250 a foot.

All right. Thanks, Mark. Jean, I think we've got our second panel session here and I will take a few minutes and go through some

questions here. While you do that, Glenn, I have a question here I'm going to throw to you. Which was, is the conclusion that the passive flux meter is more accurate than the groundwater flow velocity you are giving ? It seems the answer is yes. It is surprising as we understand our data is it may be as good as we think? >> Glenn, I think you are muted.

I think you are muted, Glenn.

All right, yeah, sorry about that. Can you hear me now?

Yes, we can hear you. There is a -- certain sites they are close but in certain other of those 11 sites there is a huge difference so we do feel that the passive flux meters do offer additional value especially for velocity.

All right. And Chapman, I know you answered this question. I had this question. I was thinking about this and I wanted to see some of the fracturing and probably the same thing with horizontal directional drilling. Because it is used in other industries like hyper insulation, oil and gas industries which are different applications, nonetheless has had high public awareness and in many cases, frowned upon, has that affected your ability to apply it to remain remediation Providence projects?

I would say five years ago it was much more -- much West much less well understood in terms of technology and the applications of it. it started to sort of become a stigma but lately it hasn't had really come up that often and I would say not really as much of an issue now. Occasionally, we will have someone say, "Oh, well you can't call that hydraulic fracturing in the work plan." But, you know, call it something else. So that is about as far as it goes.

And since we haven't heard from Rick yet, Rick, I'm going to ask this question but anybody else in the panel can chime in afterwards. Looking at the questions from earlier and the ones now, we talk a little bit about optimization but sometimes it looks like the optimization is really just trying again because maybe we didn't have all the data we wanted to up front for whatever reason, the site model wasn't complete, we didn't have that geochemical data we wanted, didn't quite understand the contaminant distribution or something of that nature but Rick, I know we have the site optimization slide. From what you have seen, what are your thoughts on how optimization fits into the data we have up front?

In other words you want me to start my presentation, right?

[Laughter].

Well, I'm helping to cue you up.

Yeah, where I go, where I see it from my perspective, there is a lot that can be done with existing data in order to better understand the framework and it really is , as we will see in a little bit, focusing on the geology. So then you can better apply a lot of these tools and data that you get at anyone boring location so really the optimization is to be able to do a better job predicting away from your data and bringing that into not only understanding processes but then also developing better volumetrics and more quantitative conceptual site model for managing and developing, designing your program.

And Jason I haven't picked on you in a while. So the next question, do you think in some cases we are compensating for data we don't have under the optimization umbrella and doing it on the back end?

I think we definitely see that. I think that, you know, when we get caught double is called out to cite typically a lot of them are Postma remediation or they are doing a free design, predesigned investigation so static mass [Inaudible static] when you have the Hi-Rez data, you may be collecting data that wasn't available. Maybe the first time anyone has used it but I also agree with Rick. There is usually a lot of data that is good that people aren't necessarily looking at so we have been doing more and more of looking at existing data sets as well in terms of building conceptual models up front and then designing maybe an HRC program. It might actually be smaller to collect specific information.

I'm going to do a two part question and Mark and then we will head over to Rick's presentation but Mark, two questions were one is the dynamic diameter of your will and another is offering some disadvantages to the blind distal horizontal wells?

Diameter specifically ranges from 4 to 6 inches
disadvantages to blind, again, the technology has advanced to the point where the risk is lower but depending on the technique you are using, there is always the risk of possible she's your seizure of raw materials especially with flowing sands or gravels, the risk goes up significantly. Again, we develop with drillers these technologies that eliminate that but not all drillers have that technology so just something to keep in mind.

Okay. Well let's go with Rick and then we have one more Q&A panel session at the end so I will get through some more of the audience questions. Rick, we are going to turn it back over to you and ESS.

Thanks, Rich. Okay let me do this. There we go. All right. So yes, as I mentioned, a bit ago, there is a lot of uncertainty with the subsurface and really, what we are talking about here when we talk about optimization, it's about addressing what my colleague, Mike Shildt liked to call the common enemy and that is the heterogeneity of the subsurface. The primary control of subsurface plumbing and the contaminant state in transport is the geology so what we are trying to communicate with this graphic here is the essential role that the

geologic model plays throughout the remediation lifecycle. It is the framework for analyzing and interrogating all of the good subsurface data that we collect, the groundwater data, in order to develop what we call a

process-based conceptual site model. This is the foundation for all of the components of the remediation lifecycle whether we are talking about strategic characterization programs or high-resolution site characterization or our remediation design or focused remediation implementation. But what you need here and what we are talking about today really, I think it is the position of the subject matter in the panel. I usually lead things off promoting how important it is to start with an effective, robust geological focus or CSM but we panel members agreed that the CSM is key throughout the process as a means to optimize in situ program so at with that we put it at the end of the presentation to make this point. All right so a pole question. Have you completed an environmental sequence stratigraphy or

depositional based evaluation of geologic conditions as part of an in-situ design? There we go. >> Okay.

It looks like we are hanging around 70/30, 70/25. That's a pretty good number, Rick. I did not expect it to be so high.

It is. That is true. All right. Okay. Let's move onto the next. So the main challenge for these complex sites is like a mentioned, earlier, the inherit subsurface geologic heterogeneity and that uses a succeeding existing data to address this and we -- wholesale improvements in understanding the subsurface so I can't underemphasized the value of a detailed geologic model because it is the quickest pathway to remediation optimization because it defines the framework and the structure that brings focus and efficiency to our site characterization and our remediation.

Not only that, this also, the geologic model also defines the geologic and G features that have direct relation sit relationship to the subsurface processes that have contamination. For example, the permeability architecture is defined in detail in the geologic model and this is significant for hydraulic processes like defining transport and storage zones and another aspect of the GRG geology has control in the distribution of organic carbon in the surface based on geologic deposition, different geologic deposition systems so defining that in the geologic model again is important for matrix diffusion operators as well as absorption and desorption. >> Okay so getting to now, environmental sequence stratigraphy, that is a great example of a geologic model. -- ESS to sedimentary aqua force because it is the best practice from the petroleum industry. I introduced it to groundwater remediation projects in the 1990s and this approach is totally geology-focused. There are three steps that I show you that are the standard for developing any geologic model. When I talk about geology, again, I am talking about the application of a science, not the geologic data so when we talk about boring log data or data that we get from CBDs are under downhole tools, that is the data. Geology, the geologic model is applying the data in order and the science in order to predict the way from our data points.

So for instance, the main outcome of step one of the processes determining the depositional environment. This establishes the genetic relationships of our boring log that we collect. This is the basis for being able to interpret and predict away from the data to develop a three-dimensional geologic framework.

Step two is about formatting existing mythology data to emphasize that geologic relationships and facilitate our subsurface analysis interpretation. It is about preparing what we call graphic grain size logs that emphasize vertical grain size products and this is like a Rosetta Stone for doing the interpretation. That is where our own old unified USC a script logs just don't do that job of defining grain size patterns that are there but have to be extracted with a reformatting of the data.

The final step is about easing this understanding and mapping out and predicting the three-dimensional geologic framework. Again, between and a way from our data points.

Okay so let's see.

There we go. So this geology focused approach was published in a 2017 U.S. EPA technical issue paper that established ESS as the best practice for conceptual site models and for the paper for those who want to dive in deeper in that same I.T. RC publishing publication is there and you can find it on clue in EPA's website and it was co-authored by EPA's Herb Levine from Region IX as well as man Mike colleagues from Burlington McDonald, Mike Schultz and Howard Planck. Both are -- to trigger first. And this brings up another point and that is the practitioner because a geologist is not a geologist is not a geologist. What I mean by that is the expertise and experience of a strained was trained stratigraphy or is essential for developing an ESS geologic model. So not only the guidance document that shows what you need to do but again having that experience, the old geologic mantra is whomever sees the most rocks wins so it is not having that experience. So to wrap things up and going to show an example here. This is showing like a final product. We are going to start out by looking at before and this is

a conceptual site model for a site that we came into work on.

>> I have trouble advancing. There we go. And so again, using the same data available data that was identified are available at the site, we applied, yeah, the ESS approach , understanding depositional systems, reformatting the data to emphasize vertical grain size patterns and doing three-dimensional correlation and network of geologic cross-section and what we -- the result is a much more detailed understanding of the subsurface , being able to map out the different geologic units first and then, like I say, then bring in debt groundwater data and be able to define what we call hydrostatic graphic units which end up developing primary pathways for groundwater flow and contaminant migration.

Okay. So there we go. Okay. So this is an example, again of having a more detailed understanding. And what I said at the outset, it is really about being able to interpret away from the data by understanding the different depositional systems and the genetic

relationships of the boring logs data, the point data that we have and with that, we can then develop a better understanding of the interpretations of the processes within these -- within the geologic framework and developing more focused remedy that can consist of, in this case, an example was source treatment versus a mid-plume in-situ chemical reduction addressing the HS yous transmitting the -- advanced reductive D coronation which addressed potential receptors and pathways and enhanced natural attenuation so it makes it more of a quantitative exercise rather than just an educated guess about the subsurface. With this ability to map out the subsurface in 3-D, you can do more true volumetrics for your targeted zone and also the detailed geologic framework is critical for developing effective remediation programs. So the point here is that , you know, better understanding is not just a nice thing to have but it is a need to have to understand these complexities of the subsurface and this, again, is when you can do a more quantitative assessment than previous, then than -- versus assuming a more simplified subsurface and not really addressing the heterogeneity head on.

So with that, that completes my presentation. Thank you. >>

I'm just waiting to see if we can get our session moderator back on the line. I believe you are there, Rich.

I am here, sorry. Can you get our errands pole back online? Do you think that would work this time?

Would you like to go back to that pole we did not do earlier?

If you can but if you can't, we can go on.

All right, ladies and gentlemen, I would like to redeem myself if I can.

[Laughter]

I have put up on the screen a pole that we were asking earlier in this chat presentation and I think it is working.

It looks that way.

Rich, I will leave it to you.

All of that anticipation, people are going to be wondering what this pole is all about so I appreciate that.

[Laughter] >> All right. It is working.

Interesting. I certainly expected the traditional and direct push to come in as the top one and we have -- a little higher than what I thought but there is a good mix to be in that 15 to 25% range . All

right, I wanted to, all right, that is good information. Then you can close out --

Yeah --

I want to use the slide that Rick has up and Rick, ask you a couple of questions and then go back to some of our other panelists but so Rick, I'm curious. Could I not get this information by going out in the field and doing more drilling? And how much am I going to pay for this desktop exercise versus going out and doing that fieldwork?

Yeah, that is where the big value added cost-benefit is done is exactly what you are saying. We can use high-resolution site character when you can not do direct push and collect more data but no, the no-brainer is that taking your existing data and first the developing a better model, that is where you can more effectively and cost efficiently target any additional data collection. In fact, you know, because our cost is, you know, the labor charge to desktop and that is part of the process in actually preparing a cost or a proposal is to evaluate the cost benefit so again, it just makes it a no-brainer . Because to take that data, the existing data that you have and that you have already invested in, and put it to use to develop a better model in which to target your additional data collection.

And Rick, I have had the benefit of seeing some longer presentations of this so I don't want to go too far down a technical rabbit hole in ESS but probably one of the questions audience members might have is if you are dealing with well logs going 20 your back or 20 years back or are stratigraphy was able to sort through the different geologists and classifications to do what one person calls silty sand versus sandy silt and colors and come up with a good model?

That is actually one of the biggest advantages of this approach is being able to make use out of what you are talking about. A lot of disparate data because the essence of what a stratigraphy or is looking for when they look at a boring lot, they are looking for a signature, the signature of the energy of the depositional environment, the relative energy of the depositional environment, you know, whether it is just to keep it simple in a stream/River environment, you have high energy, coarse-grained materials deposited in the sand channels and then in the floodplains it is low-energy, well, there are , in different different but depositional symptoms there are distinctive characteristic vertical grain size patterns so getting back to your question, the unified silt classification system is really about the material properties. That is not what a stratigraphy or cares about in that sense. It is so that it is not hung up here on the absolute definition , looking at the relative so that is one thing that all geologists can do well at any one location is defined relative grain size so that is what these graphic grain size logs do and that is what makes all the data, quite frankly even to a certain degree, drillers logs, too when you just map out, produce these
graphic grain size logs and look at relative grain size, those are the kinds of patterns that can be interpreted and correlated. So yeah,

it is all -- through that what we call step two of the process, in developing vertical
grain size, graphic grain size logs, that makes all the data valued.

And there are a couple of very technical questions , Rick and I'm one of the engineers on the call so I will defer back to you but one of them is a question as to is there a recommended guidance document that the protection or practitioner would use quick

Yes, the 2017 EPA technical issue paper. That is the guidance document. That has pretty much all the details you want and that is again, if you are familiar with the I TRC document that was shown earlier, it is a reference to that or you can just either Google it or go on the EPA site and then , also if you are interested in hearing more about it, we did a clue in presentation in 2018 with the co-authors and presented in a lot more detail and that is archived on the EPA site.

And the other highly technical question is a lot of logs don't include pre-positional environment and can cause issues. How do you address that ice placed versus water placed? Is that also in the guidance document?

Let's see. Ask the question again? Did it have to do with like what do you know, what --

It is our last Q&A if you can see it but a lot of logs do not include prepositional environment and can cause issue. How can you address that ice placed versus water placed?

So that is what, that is why the importance, if I understand the question, the importance of the practitioner. So trained stratigraphy is understand -- and they are research scientists, too so the first step is to gather all the regional information that is available for a site so before they even look at any site data, they have already developed an understanding of what the depositional systems are and they can basically draw up a model of sand bodies and clay bodies, generally speaking on the site so those kind of data are always available publicly either at USGS or Masters or PhD thesis or other consultant technical documents that are available so that is where all of that double that that is what we call step one of the three step process is evaluation of regional geology and deposition systems.

Okay and everyone on the panel spoke to a different topic and are all a different maturity in the industry and I don't think any of them are really new to the world but they may still be new in our industry are finally getting applied to projects and probably what we have here is the newest so to the other panelists, have you evaluated this site for your practitioner earlier that included ESS with that data as well?

We have done some deposition review work, not necessarily pool ESS but basically it is typical of that in trying to integrate basic HDP pressure -- and things like that through those models. One of the challenges for me because I do a lot of three-dimensional work is

trying to take, you know, an ESS or depositional base and make it three-dimensional and that is like drawing a cross-section is a little easier but when you start going a third dimension to get an update and that is really challenging. And that is where the more data you have, the better. But certain data, sometimes there is a tremendous amount of data that already exists.

And just a comment on that, too is that
E VF is a powerful tool of their particularly for data interrogation but however it does use creaking methods and I don't recommend that for any detailed geologic evaluation so that is what we would do is bring in our geologic cross-sections and geologic maps. That is basically our three-dimensional depictions or three cross-sections and maps and bring that into EBF to help better define the framework and -- but what is really difficult like you are just mentioning is to try and actually put in Deming points and make the EBS model mimic the geologic interpretation please.

Just with the process you have up here, you look at the channels, the sand channels, you could never, it would be very difficult to get those almost impossible to make those [Inaudible static]

That is a case in point is if you look at the data you say G, how do you know where those sand channels end and begin, right? But again, that is the experience of the stratigraphy or. They know the fabric of the depositional system, the direction. They know generally speaking what the dimensions of different channels, sand bodies are but again, it is an interpretation but now you have something to then go by to start filling in the gaps where it is important and to start directing your Hi-Rez program. -- To try and validate any of this if that is a key question to ask. >> I'm going to ask a similar question to Mark and Chapman. I will start with Mark. Market, if you had an opportunity to conduct a sustainability analysis for a project where horizontal wells were one of the options being pursued what it have clear benefits on the sustainability side?

I would say reduced infrastructure, reduced number of wells and I think there is options to look at using designs with recirculation approaches to possibly even eliminate aboveground infrastructure. So that is how I approach that, sustainability.

And Chapman, basically the same question with fracturing?

Yeah, there was some work done on one of the Denmark projects I was involved in because the Danes are really sensitive about sustainability. Looking at sustainability of [Indiscernible muffled], hydraulic fracturing and it came out quite favorable. I mean, not surprisingly, you are injecting -- injecting the ground one time and it sits there and works for 5 to 10 years so you are not be mobilizing the site, you are not having to reinject. So there are a lot of advantages for -- like that.

And Glenn, I'm going to give you the last question here for a panel because Jean has graciously given a few extra minutes. I know you went through a lot of benefit to doing design verification testing so this might be a reiteration but what are the top pitfalls you think people can avoid if they do that up front, you know, with pilot, design verification, bench testing for in-situ remedies?

Top pitfalls? Well one of the items, I will go back to your question, I know my subject was bench skill treat ability and pilot studies and we talked about design application and one of the benefits of going out there in the field is to further analyze the -- model and target those zones. One of the items of interest that was proposed to us, can we just do a bench scale or treat ability study and usually the -- basically we ask what are the questions you are trying to answer and in most cases, if the technology has been proven, lots of cases, there is no need typically to do a bench scale feasibility unless there is unique interference whether it is high or low pH or something unique about the site to do a bench skill treat ability. What we are trying to answer when we do this is designed the application test really that chemistry to make sure we have contacted so many times we have gone out and seen a lot of contaminant that was not anticipated but why go out there with chemistry in hand to find out that there is a lot more contamination mass than was initially estimated when you can find out all that information up front. And I have been on sites where I have a tanker to track of product and I can't get the injections to go into the ground and now I have a tanker top truck. What am I going to do with a tanker truck? I wish I had done a clean water application test prior to that. There is a lot of evaluation at the end of the day.

And I think we used up our 10 minutes of goodwill. Thanks to all the panelists. This was great. There is just a wealth of information and knowledge with this panel. We could go on all evening but we are not going to. So Jean, I'm going to turn it back over to your.

All right, thank you so very much. So I will take the camera spotlight off of you gentlemen and give, again, a great big thankful thank you to our panelists and a fabulous moderator who just joined us for that second and final . I'm calling up on the screen a few final reminders before we close things out today. While I'm doing that I wanted to remind the audience this is your last chance -- so if you have any burning questions or comments you wanted to share with our presenters or organizers, now is your chance so as I go through some final reminders, please be sure to type your message in. Mike might be able to squeeze it in, in the last couple of minutes but if you don't have any questions or comments you can answer an no questions in the panel and that way I will know we have answered all your questions in our live broadcast today. I want to continue to think our event sponsors who helped provide resources we needed to help author today's session virtually. A number of you have shared comments thanking us for making this session available online and allowing people who have either never been before or would have never had the resources to travel in the current work paradigm. We truly appreciate the opportunity to listen to

these presentations. I also want to thank our large business sponsors as well as small business sponsors for their support in hosting our event today. So this is the first day of the virtual symposium. We will carry on with additional panel sessions later this week so I hope you will be fine coming back Wednesday and Thursday to carry out for day two and day three. But there are other events being hosted through DCHWS and I encourage you to visit the DCHWS website to find out the most up-to-date information on future events, specifically the West symposium has been slated for this fall so fall of 2021 in Denver, Colorado. So you can look for a call for abstracts sometime later this summer. As noted, we will carry on our five monthly webinar series where we will host technical presentations through our partnership with -- on the clue in website so I encourage you to visit us on CLUEIN.ORG and you can visit this as well as others we have done. I want to thank all of the moderators and panelists and support staff in the background as well as they DCHWS planning and committee members. I know the organization and speakers are looking for feedback and input from you so there will be a seminar feedback form that I will push out to you in our Q&A window there in the lower corner. So again, for those of you looking for copies of the presentation materials, we already posted those online so you can download those from the seminar home page and we also have a brief seminar feedback form that I just shared with each of you. It is the link on that same home page to the page he used to check in for today's live class. You can bookmark that website and come back to it because we will post all materials there and you can get that back to the form. I will ask you to fill out that feedback form and let me know both if the tools and materials that were highlighted in the session along with the platform are used for hosting today's session. We are trying a variety of different tools, making these interaction though they are virtual so we love your feedback. One of the most common questions I get for hosting these seminars is if we offer participation certificates. For those of you just looking to get credit for sitting in on today's virtual session as soon as you feedback the feedback form, as long as you check the box to verify you are there for the whole session you will immediately have access to a participation certificate that you can say for your records. For those of you working on PDHs check with the event organizers for details on obtaining credit hours. I will send a reminder email for checking on the virtual symposium and the entire symposium is being recorded so we will send out a final email reminder at the end of the symposium when all three days of recorded panels are available for you to watch on-demand. For those of you that might be lucky enough to replay the recorded version right now, remember, you can still click on those links and share feedback after the replay of the archive content so with that, a few moments early, I will let go ahead and formally conclude day one of the virtual DCHWS symposium. Again, thank you to each and everyone of you for joining us and I look forward to carrying on when we regroup for day two on Wednesday. So with that, I will go ahead and conclude today's live broadcast.

[Event Concluded]