Remaining Simulcast Questions and Answers from January 7, 2016

**Question 1:** The reason for selection of a model of 14 compartment, not 16?

- *Wilson Clayton:* Two of the compartments for DNAPL in the plume area can be excluded, because DNAPL would only be in the source area. So, we are left with only 14 compartments out of the 4x4 matrix.

**Question 2:** You indicating reducing the Source? is by containment?

- *Wilson Clayton:* For the purposes of the presentation, conceptually source reduction could be by any technology. Containment could also apply, conceptually.

Remaining Simulcast Questions and Answers from July 16, 2015

**Question 1:** back to slide 15: why can't the blogs/ganglia of DNAPL migrate? And how do you know when/whether you are dealing with residual or mobile DNAPL?

- *Wilson Clayton:* If they meet the "residual" definition, blobs and ganglia of DNAPL cannot migrate because they are held by capillary forces. In other words, the capillary force resisting movement is greater than whatever force might make it move. If conditions change and capillary forces are modified (such as by a surfactant, heat, etc.), then what was formerly immobile can become mobile. This can also happen if hydraulic gradients or other factors change.

**Question 2:** What is the consideration for the cost on the "Achievable" criteria?

- *Trainer Name:* (response)

**Question 3:** Can you elaborate on how vadose zone vapor phase contamination can recontaminate groundwater?

- *Wilson Clayton:* That is a slightly hypothetical concept, but if you have high concentrations in the vadose zone and clean up the groundwater it would be possible that some diffusion-limited mass transfer or infiltration might occur back into the groundwater. I am not sure, off hand, if this might be significant or not. I think it would be very site specific.

Remaining Simulcast Questions and Answers from March 17, 2015

**Question 1:** Can you recommend any good resources for good DNAPL characterization approaches?

- *Wilson Clayton:* The ITRC DNAPL characterization document is a good place to start.
Question 2: could you elaborate on the calculation and use of equivalent aqueous concentrations in the 14-box table?

- Wilson Clayton: If you have soil concentrations and want to compare this to groundwater, this can be done by making an equilibrium calculation using a tool such as soilmod.

Question 3: Orders of magnitude are very useful for characterization but evaluating remedies that way seems based on some large and potentially false assumptions. Generally, remedies are designed to reduce contamination to whatever degree is needed—therefore the OoM will be based on whatever your starting concentration is.

- Trainer Name: (response)

Remaining Simulcast Questions and Answers from December 2, 2014

Question 1: In the comparison of treatment technologies, the slide for Technology Category 1, Physical Removal, did not list median removal effectiveness for Multiphase Extraction. Has anyone looked at typical Order of Magnitude (OoM) removal for multiphase extraction?

- Wilson Clayton, Trihydro Corporation: Multiphase extraction will have widely varying OoM removal, since it will not achieve any contaminant destruction (except through fortuitous biodegradation). The concept of percent removal may not be applicable to multiphase extraction in the same way it would be for a destructive technology such as bioremediation or chemical treatment.

Question 2: At creosote release sites where the plume and source zones are in complex geologies and the DNAPL is a heterogeneous material (likely containing some LNAPL and DNAPL component) and they may continually evolve over a greater length of time, do you find that the frequency of the CSM updates and evaluation and reevaluation process should increase. Also, looking for creosote specific information for site strategy scenarios

- Wilson Clayton, Trihydro Corporation: More viscous and less soluble NAPLs, such as creosote, will take longer to reach middle or late stage, on the order of decades or more. The frequency of CSM updates is probably more dictated by shorter-term milestones such as getting new information from characterization or O&M, preparing a CERCLA 5 year review, preparing a new baseline project cost estimate, etc. So, in the end the frequency of reevaluating your CSM is probably not linked to the time frame for source/plume evolution because that takes so long.

Question 3: With respect to selecting the appropriate technology or combination of technologies for a DNAPL site, are there technology or combination of technologies is/are appropriate for a site with chlorinated solvents as well as 1,4-dioxane?

- (trainer name): (response)

Remaining Simulcast Questions and Answers from June 12, 2014

Question 1: With respect to the 14 Compartment figure. TCE in vapor is single phase, also single phase in DNAPL, and water. However CVOC in sorbed phase is to multiple minerals and organic compounds. Since we are in the Late stage, (which is a 20-200 year phase) can you discuss your philosophy on sorbed CVOC to clays or zeolites, bitumes etc. CVOC are frequently discussed as sorbed to generic matrix

- (trainer name): (response)

Question 2: Can you identify the 14 compartment Model?

- (trainer name): (response)

Remaining Simulcast Questions and Answers from July 18, 2013

Question 1: Is this presentation recorded and available for later viewing? - Environmental Consultant; Gardner, MA, United States
**ITRC Training Program:** Archives of over 50 previous ITRC Internet-based training events are available anytime you want to view and hear a previous offering of the ITRC course. The training courses are listed at [http://cluin.org/live/archive.cfm?sort=title#itrc](http://cluin.org/live/archive.cfm?sort=title#itrc)

**Question 2:** If you only have minor amounts of fine-grained material mixed in with sand and gravel (glacial till). Can that result in back diffusion at a late stage site? Back diffusion trends based on precipitation or what other influence? - Environmental Consultant; Cincinnati, OH, United States

Wilson Clayton: Back-diffusion is a relative process between relatively less permeable and relatively more permeable materials. So, yes you can still have it in overall permeable materials, but it may be a lot less significant.

- Trainer Name: (to be added)

**Question 3:** Where on the website can we find the document? - US Army participant; Sam Houston, TX, United States


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**Remaining Simulcast Questions and Answers from April 25, 2013**

**Question 1:** what about free product metrics? transmissivity or something of that nature to determine if the plume is stable or migrating? How do you study the actual plume to determine if containment or MNA is an appropriate action? - Environmental Consultant; Novi, MI, United States

- Trainer Name: (to be added)

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**Remaining Simulcast Questions and Answers from July 24, 2012**

**Question 1:** Please address how these DNAPL concepts are different when there is a 400 foot thick vadose zone. Most of the work seems to have been conducted where groundwater is

- Trainer Name: (to be added)

**Question 2:** Any experience or data to share using trap and treat methods? - Environmental Consultant; Louisville, KY, United States

- Trainer Name: (to be added)

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**Remaining Simulcast Questions and Answers from April 5, 2012**

**Question 1:** With respect to DNAPL in the wells question - Is it safe to say that the various zones shown in slide 26 are defined more by how they function with respect to gradients and mass contribution rather than where they actually exist in the system? I.e. DNAPL in distal portions of the plume (in a well) can be treated as "source" - Environmental Consultant, New Jersey

- Charles Newell: The 14-compartment model is shown on slide 26, and is based on the following definition of a source from the National Research Council's 2005 book "Contaminants in the Subsurface": a subsurface reservoir that a) initially contains DNAPL and b) sustains plumes (primarily dissolved groundwater plumes. In other words, any part of the site that contains or contained DNAPL, and is still sustaining a plume via any mechanism (DNAPL dissolution or matrix diffusion once the DNAPL is gone) would be defined as a "source." That being said, most of the applications of the 14-compartment are geographic based, and don't necessarily limit themselves to just the source and plume. One application developed by Tom Sale at CSU divides the site into a Source, On-Site Plume, and Off-Site Plume. Back to your specific case, DNAPL at the distal end of the plume, it seems you would have to define the entire site where DNAPL is (or was) as a "Source" in the 14-compartment model, so function (presence of DNAPL) trumps geography.
Question 2: What functional objective would be reasonable for an old DNAPL source in fractured bedrock where no biodegradation is occurring, only dilution? - State Regulator, North Carolina

- Charles Newell: Without knowing specifics, here are a wide range of possible function objectives: 1) delineate the plume if not already delineated within 5 years; 2) put point-of-use treatment on wells drawing water from the plume within 1 year; 3) stop any further migration of the plume within 10 years; 4) within 20 years limit the mass discharge of the plume to a nearby river to less than 10 grams of TCE per day; 5) reduce concentrations in a small area hot spot by a factor of 10. Some of these example functional objectives may not be feasible for some sites or regulatory environments, but are examples of SMART objectives that might be goals that would manage the impacts of such a plume.

- Trevor King: The Integrated DNAPL Site Strategy team recommends that a functional objective must satisfy five attributes: (1) Specific, (2) Measurable, (3) Attainable, (4) Realistic, and (5) Time-bound (SMART). In your scenario, the assumption is that your functional objectives were SMART but unattainable using bioremediation (active and or passive treatments). Irrespective of these bioremediation treatments, if progress was not made toward meeting the five SMART attributes, I recommend identifying which of the five attributes were not met. In the Integrated DNAPL Site Strategy document, a text box with several diagnostic questions is provided to assist you in identifying the unmet attributes (i.e., Text Box 3-3. Diagnostic Questions to Ensure Compliance with Smart Attributes. (pg 31). If you identify any unmet SMART attributes in your scenario, you should revisit the functional objectives for the old DNAPL source with all stakeholders and refine or replace those unmet attributes to satisfy SMART. This process also provides you with an opportunity to revisit the conceptual site model to ensure that both absolute and functional objectives are appropriate.

Question 3: In your "plumathon" literature search, many times the easiest geology is used to demonstrate or to illustrate success. Failures and difficult geology (eg clays and silts) are seldom used as examples and papers. - State Regulator, California

- Dan Bryant: This actually raises an interesting point about plumathons that perhaps we have not considered. Plumathons are dependent upon the case study literature. From an anecdotal perspective, I suspect that case studies are probably biased towards successful treatment programs, and that relatively few unsuccessful treatments are published compared to the total number. However I do not know if that has been considered or if this perception is quantified.

- Charles Newell: In the McGuire et al. (2006) 59-site plume-a-thon study, each site was classified as fine-grained, coarse-grained, or fractured rock, with 75% of the projects analyzed in "fine-grained" settings. There were not enough data to discern any difference in remediation performance between these different classes. However, the authors noted that rebound at chemical oxidation sites was observed in both fine-grain and coarse-grained settings. The McGuire study also made an effort to reduce ?cherry picking? easiest sites by obtaining data directly from regulatory agencies. Approximately 40% of the sites were obtained from a regulatory agency, with the remaining 60% obtained from the literature, technology vendors, or consultants. In the Krembs et al. (2010) chemox study, the authors wrote: "No significant differences were noted with respect to percent reductions in maximum groundwater concentration between the various geology groups." Similarly, the Kingston et al. (2010) thermal study showed data from 14 sites and did classify the setting at each site. However, most were type "C" sites (primarily permeable materials with finer grained lenses) so there were not detailed correlations between performance and hydrogeologic setting. Overall each of these plume-a-thons showed projects with less than 50% reduction in concentrations, indicating that they captured at least some projects that might be classified by some as "failures."

Question 4: With respect to microbe population recovery following thermal treatment: What has been the generally observed recovery time of a healthy effective microbial population? Any literature references on this topic? - U.S. Navy, California

- Dan Bryant: It is very dependent upon the temperature decay after the heat is turned off, and also variability among different organisms. There is a logarithmic increase in microbial activity up to about 30 to 40 degrees C for many species. After that, the activity for many species will decrease. However, there are not very many detailed studies that I am aware of that have tracked this closely. Here is one recent reference: ENHANCED BIOREMEDIATION AS A COST EFFECTIVE APPROACH FOLLOWING THERMALLY ENHANCED SOIL VAPOUR EXTRACTION FOR SITES REQUIRING REMEDIATION OF CHLORINATED SOLVENTS (available at: http://provectusgroup.com/downloads/icem2009.pdf.

Question 5: slide 58 is not representative. We usually do excavations based on a statistical goal of 90% of confirmation below our statistical standard. Although most of the contamination is removed, we usually leave some level of contamination below a health based standard or statistical or upgradient background. - State Regulator, California
Charles Newell: In slide 58, the unsaturated soil concentration in low permeability zones was assumed to be equivalent to 1000 ug/L in the water in the pore space. An excavation project was assumed to reduce this by 3 OoMs (orders of magnitude), or to an ending concentration of about 1 ug/L. This slide doesn't directly address what the standard is, or how many confirmation samples it would take to close the site. If the soil standard were 5 ug/L equivalent concentration in pore, then this planning-type model on slide 58 would say you (on a very rough planning level basis) would say you could achieve this, because the particularly excavation project would give you 3 OoMs (99.9%) reduction in the treatment zone. But the key thing is the 14-compartment model is a planning level model, where you match observed concentrations and expected performance to estimate where you might be if you implemented a certain technology.

Question 6: On slide 79 it is sometimes the case that the technologies agressive and passive plume technologies are not as successful as planned. Why not have a “fall back” remediation technologies in case the initial technology does not perform as planned? - State Regulator, California

Alex Macdonald: That would be a perfectly sound application of the site strategy. If there is sufficient information available at the time of selection of remedies, establishing a decision point and rationale for transfer to a different technology can be placed into the strategy.

Question 7: For In-Situ chemical oxidant treatment, how can the application model be optimized to access contaminants which are isolated in low permeability soils below high permeability soils saturated in water, when most chemical oxidants are soluble and will be diluted and rendered inoperable by the naturally flowing aquifer? - Environmental Consultant; Canada

Dan Bryant: This is a challenge for any technology, not just ISCO. However for ISCO in particular, we have had success with permanganate, using either relatively high concentrations emplaced at the base (permanganate is dense and sinks, and can chemically diffuse into the lower permeability zone), and by fracture emplacing solid permanganate directly into the low-permeability zone.

Question 8: Could you speak to the available literature or case studies which focus on Enhancing In Situ Bioremediation post Surfactant Flood at a DNAPL site? Thanks for this great work.- Environmental Consultant; Michigan

Dan Bryant: Perhaps the best studied example is the Bachman Road site in Michigan. If you do an internet search with the terms "Bachman Road" "bioremediation" and "surfactant" you will find a number of references.


Remaining Simulcast Questions and Answers from January 10, 2012

Question 1: In reference to plume evolution and in situ source treatment, slides 21 through 24; my question is what kind of integrated policy you follow with a site has considerable residual DNAPL remain after treatment in the lower permeability zone of the site conceptual model subsurface compositional details? Do you continue looking to apply different treatment technology or just leave it for monitoring natural attenuation? In terms of the site hydrodynamic and mechanical properties, there may be some zones contains DNAPL that can never be recoverable? Thank you - State Regulator; Atlanta, GA, United States

Alex Macdonald: This is not an unusual case in remediation of sites with DNAPL. There are two main potential courses of action. One is to evaluate alternate remedies as the process is described in Chapter 6 of the document. Chapter 4 discusses the remedial technologies and potential coupling and sequencing of technologies. Taking a look at the initial remedial efforts to see why that technology did not work - which could have been caused by insufficient site characterization or improper application techniques. The second option could be applying a containment remedy - containing the contaminant flux coming off of the DNAPL area so that a remedy can be applied to the downgradient dissolved plume - thus giving it a greater chance for success in a reasonable period of time while helping to protect downgradient water supplies. Using the second alternative could provide time to allow evaluation and application of remedies that will sufficiently reduce the residual mass of DNAPL. The process may or may not lead to a final cleanup of the site in time frame that is desired.

Question 2: Referring to functional objectives section: We have used the concept discussed on a number of projects. It is very important to educate the regulators the difference between RAO (remedial action objective) and functional objectives. They are not the same. - Environmental Consultant; Pittsburgh, PA, United States
• **Alexander Macdonald**: You can actually craft RAOs to also be equivalent to functional objectives. It may be that the remedial objective becomes much more descriptive with multiple parts to it. As an example, instead of the remedial objective being restoring the groundwater to drinking water standards. A second part to the objective can be written to state that the restoration to drinking water standards will be achieved within 25 years by reducing the concentration of TCE to 5 ppb or less at the points of compliance listed in Table B and depicted on Figure 3. In some instances the RAO could have several functional and interim functional objectives assigned to it to specifically demonstrate how the generic part of the RAO is achieved. The RAO is thus composed of both the generic RAO and the specific function objectives associated with it.

**Question 3**: Advice on creating concise functional objectives when dealing with multiple stakeholders (PRPs)?

- Participant

• **Alexander Macdonald**: In our development of Chapter 3 of the document and the examples found in the section, we found it best to have a small group of 1-3 people work on drafting the objectives and refining them as much as possible before providing them to the remainder of the group for editing. The most difficult of the SMART criteria to apply usually was time-bound as there was the greatest uncertainty in the time needed and other factors that affect the ability to achieve a goal in a specified period of time. Fortunately (or unfortunately) it usually the case with DNAPL sites the time element is the one that has the most flexibility. It is usually easy to provide the attributes of specificity, measurability and appropriate. Achievability, on the other hand, is open for much more interpretation.

**Question 4**: Question re Slide 46 (59-Site study)--- What are the COCs at these sites? Are the contaminant classes (COCs) at most of the sites chlorinated solvents or something else? Is there a difference in achieving OoM's based on the contaminant chemical class/group? - State Regulator; Twinsburg, OH, United States

• **Charles Newell**: The COCs at the sites in the 59-site study were all chlorinated solvents. The performance studies that we cited on slide 45 were all chlorinated solvents. You can get different performance for different COCs; for example, in the Krembs et al. study (slide 45) only say about 0.3 OoM's for chemox projects (slide 49) but more like 1 OoM for Benzene and TPH (see Figure 2 of the Krembs et al. paper).

**Question 5**: I'm interested to know what successes members of the panel may have had in using OoM's for CVOC source reduction to document "infeasibility" for remediation during the feasibility assessment process and development of functional objectives? For example, if groundwater concentrations in deep overburden is 300,000 ug/l, a OoM of approximately 5 would be required to remediate to regulatory endpoints. Based on the information presented, this would appear to be potentially "infeasible", especially if excavation is not an option for source control? - Environmental Consultant; Groton, MA, United States

• **Charles Newell**: Although a site might be infeasible for reaching a particular environmental endpoint, there might be other benefits from performing remediation (reducing risk, reducing the plume footprint, etc). But in other cases even a 1 OoM reduction in concentration may be perceived as insignificant compared with how far one has to go at a site. In the IDSS document we recommend stakeholders develop SMART functional goals, one of which is that the functional objective must be Attainable. In response to your first question, I don't have any good examples where the multiple site study data and OoM's changed site management strategy from a planned active remediation project to a no-active remediation site.

**Question 6**: Functional objectives can be achieved through an IROD but can you sign a ROD for a functional objective knowing the absolute objective is many (1000) years away. - State Regulator; Montgomery, AL, United States

• **Alex Macdonald**: Yes you can. If a functional objective is not be achievable for a 1000 years, then interim functional objectives need to be established. These interim functional objectives would then be used as milestones that demonstrate acceptable progress towards meeting the final functional objective. As an example, the functional objective could be to achieve MCLs throughout the aquifer by the year 3000. An initial functional objective could be to reduce the concentrations at a point of compliance by 15% by the 2032 (20 years is generally the maximum length of time we want to use for these interim objectives as modeling can only reliably project a fairly short time in the future, there is uncertainty in concentration data that makes projecting values in the future more difficult, technology improvements can come along and change potential outcomes and there needs to be some accountability). When the interim functional objective comes up for review down the road, the next set of functional objectives can be established or ones already established can be modified if necessary.

**Question 7**: On slide 24, could you provide some guidance for typical 'early stage', 'middle stage', and 'late stage' for source-plume evolution. Thought I heard Wilson Clayton partially address this in Q&A by saying a 20
year old plume could still be 'middle stage', but for very large sites, the time frame could be much longer. While it may take decades for a very large plume to stabilise, would the source area itself, where the DNAPL is present, be expected to generally reach 'late stage' within say 20-40 years? For example, I think Beth Parker has indicated that in sedimentary rock, DNAPL is likely to have diffused within the primary rock porosity within 40 years. It may be useful to provide separate guidance on timeframes for the source area and the plume, where this can be done, for different geologic settings. - Site Owner; Australia

- **Charles Newell**: There is some great discussion and debate in the groundwater community about how to distinguish between middle stage (source zone sustained primarily by DNAPL) and late stage (source zone sustained primarily by matrix diffusion). Opinions range from "there are no late stage sites; DNAPL is always the key factor" to "it doesn't matter; a source is a source". My thinking is there are a number of late stage sites, and at those sites some technologies are going to be less successful (surfactants would be less successful if there is no DNAPL) and other technologies may be more successful (thermal is theoretically better at treating clays). More importantly, I have a conceptual model that if we could demonstrate that the DNAPL was gone, then many of those sites could be treated as "low risk" sites where there is a weaker, diffuse, almost non-point type source in the subsurface. It will be interesting to see where this goes.