ACTION ITEMS

- The FRTR Steering Committee will decide on the topic for the next FRTR meeting, which will be held on November 6, 2014 at NRC Headquarters in Rockville, Maryland.
- Sam Brock (AFCEC) and Jim Cummings (EPA) will touch base to discuss development of adaptive and flexible RODs.
- Marc Ferries (G2 Partners, LLC) and Beth Moore (DOE) will touch base regarding software that can be used for decision tree modeling.

WELCOME/INTRODUCTION/ADMINISTRATIVE BUSINESS

Carol Dona, U.S. Army Corps of Engineers (USACE), welcomed participants to the 47th meeting of the Federal Remediation Technologies Roundtable (FRTR). The theme of this meeting was Remediation Management of Complex Sites: Tools and Approaches to Address Uncertainty. Carol acknowledged Bill Lodder, Department of Interior (DOI), for his chairmanship of the FRTR Steering Committee over the past year, as well as the contributions of the committee members.

Carol announced that the next FRTR meeting has been scheduled for November 6, 2014. The meeting will be held at the U.S. Nuclear Regulatory Commission (NRC) Headquarters, located in Rockville, Maryland. She asked meeting participants to complete the survey that was distributed earlier and select their topic preferences for the next meeting. Carol also asked participants to indicate on the survey whether they were interested in helping organize the meeting, present a topic, and whether they had suggestions for topics that were not on the list.

FRTR Agency Member Announcements

Karla Harre, Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) reported that NAVFAC recently released new lead-based paint guidance. The guidance, along with many other documents and additional information, can be found at www.navfac.navy.mil/go/erb. The website now also has a new area dedicated to vapor intrusion (VI), which contains fact sheets, videos, information on VI mitigation in existing buildings, and VI considerations in the construction of new buildings.

Linda Fiedler, U.S. Environmental Protection Agency's (EPA) Technology Innovation and Field Services Division (TIFSD), said that EPA is working to complete a report on 50 Superfund remedies across the nation. Most of the groundwater remedies included in the report had contaminants in excess of 100 parts per billion (ppb) and contained large plumes in subsurface areas with varying hydrogeologic complexity. Several also had DNAPLs. Many achieved groundwater remedial action objectives. The report is expected to be published soon.

Tom Nicholson, NRC, reported that an annual NRC Regulatory Information Conference was held on March 11-13, 2014. One of the technical sessions at the conference focused on remediation, particularly pertaining to radionuclide releases from nuclear facilities. A presentation on the Fukushima Daiichi Nuclear Power Station was given during the session, where presenters explained the different remediation options being explored at the site. Options include ground freezing, as well as robotics and other innovative technologies. The latter technologies may be of interest to FRTR participants. Presentations are available through the conference website at http://www.nrc.gov/public-involve/conference-symposia/ric/.

Tom Nicholson also mentioned that John Simon, editor of the journal *Remediation,* provided an interesting editorial perspective on hydrofracking and groundwater contamination in the spring 2014 issue. Tom suggested that hydrofracking be explored as a topic for a future meeting, since it is a priority issue for EPA, the U.S. Geological Survey, and potentially DOE.

Paul Beam, Department of Energy (DOE), reported that DOE recently funded a study conducted by the National Academy of Science (NAS). Those interested in seeing the final study report, *Best Practices for Risk-Informed Remedy Selection, Closure, and Post-Closure Control of Contaminated Sites*, which can be sent out as soon as it is published, should send an email to paul.beam@em.doe.gov.

FRTR SUBGROUP REPORTS

FRTR Web Subgroup

Greg Gervais, EPA TIFSD, explained to meeting participants that the FRTR.gov website, which was created around 1997, was historically hosted by the U.S. Army Corps of Engineers (USACE). Over the past year, there has been a migration of site hosting responsibilities from USACE to EPA, in part due to new IT requirements at the Department of Defense (DoD). As part of the migration process, the FRTR Web Subgroup has been examining content to ensure that information on remediation and characterization technologies and approaches is relevant and up-to-date. The subgroup is also focusing on fixing broken links, as well as on the content and functionality of the widely-used Technology Screening Matrix. In the future, the subgroup is looking to have more active content management and ownership. FRTR members are welcome to provide comments on the content by visiting FRTR.gov and clicking on “Comments” in the left-hand menu or at the bottom of the screen.

FRTR Complex Site Closure Subgroup

Skip Chamberlain, DOE, reported that DOE recently sponsored an NAS workshop that resulted in a report, *Best Practices for Risk-Informed Remedy Selection, Closure, and Post-Closure Control of Contaminated Sites*, which is due to be published soon. He also recommended the in-production NAS report, *Subsurface Characterization, Modeling, Monitoring, and Remediation of Fractured Rocks*, as a good resource. Once these reports are completed, information will be disseminated to FRTR members.

A panel on complex sites will convene at the Battelle Ninth International Conference on Remediation of Chlorinated and Recalcitrant Compounds on May 19-22, 2014 in Monterey, California. In addition, ITRC recently held its annual meeting in Garden Grove, California and included project team meetings on the remediation and management of complex sites. Finally, the Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) at a meeting in August 2013 discussed how social scientists can be integrated to identify ways to engage the public and help explain the work being conducted by federal partners. Modeling, visualization, and other methods are currently being explored for better public involvement.

FRTR Optimization and Green Remediation Subgroup

Carol Dona acknowledged the efforts of the FRTR Optimization and Green Remediation Subgroup. She reported that the subgroup is looking at ways to expand optimization across the whole remediation lifecycle and integrate green and sustainable remediation practices. The subgroup also is examining how climate change will impact the process. Carol suggested that the topics the subgroup currently is exploring be considered as topics for the fall FRTR meeting.

INTRODUCTION TO THE MEETING AND MEETING FACILITATORS

Carol Dona introduced Paul Beam and Tom Nicholson, and announced that they will be facilitating the FRTR meeting today.

TECHNICAL SESSIONS

Synopsis of Uncertainties Associated with Complex Sites, Challenges, and Overview of National Efforts on the Topic

Rula Deeb, Geosyntec Consultants, provided an overview of the attributes and technical challenges that lend complexity to soil and groundwater sites, as well as the recent and ongoing national efforts to address technical challenges for completing restoration at highly complex sites.

Significant uncertainty around the definition of a "complex site" exists. The term has neither a formal nor a generally accepted definition, and there is little agreement in the industry on the attributes of a complex site and the percentage of sites that are complex. ITRC recently conducted a survey of 116 individuals in academia; federal, state, and local governments; public and tribal stakeholders; and the private sector, with specific questions on the attributes of a complex site and the percentage of sites that are complex. The survey had mixed responses, even when results were isolated by organization type. These survey results further suggested that little agreement on the definition of a complex site exists among and within stakeholder groups.

In 2012, a National Research Council committee found that at least 126,000 sites have residual contamination at levels inhibiting site closure, with over 12,000 of those sites likely being complex. The National Research Council proposes the following attributes of complex sites: large releases of contaminants over long timeframes (e.g., mining sites with acid mine drainage, low pH and high metal content); highly heterogeneous subsurface geologic environments; recalcitrant and persistent contaminants; contaminants with several levels of magnitude above Maximum Contaminant Levels (MCLs); likelihood of several years of remediation efforts with asymptotic performance (e.g., the Middlefield-Ellis-Whisman site, where trichloroethene (TCE) concentrations have decreased only one order of magnitude after 17 years of pump-and-treat); and lifecycle costs to achieve restoration that exceed $20-50 million. Presence of dense non-aqueous phase liquids (DNAPL) poses technical challenges at complex sites.

An example of a complex site is the Watervliet Arsenal Resource Conservation and Recovery Act (RCRA) site in New York, which has been used for manufacturing of small arms and ammunition since the late 1800s. Site geology is characterized as fractured black medium-hard laminated shale to 150 feet below ground surface (bgs). Site contaminants are chlorinated solvents, which are suspected to have originated from degreasing operations, and include up to 170 milligrams per liter (mg/L) tetrachloroethene (PCE) in DNAPL form.

The long-term cleanup objective for the site was attainment of MCLs. The cleanup approach consisted of five years of permanganate injection, with initial use of potassium permanganate ($KMnO_4$) and later, sodium permanganate, once it became evident that $KMnO_4$ was not lasting long enough to spread through the rock matrix. To determine whether the permanganate was effectively oxidizing rather than displacing PCE, carbon isotope ratios of rock core samples were analyzed throughout the remedial process.

Results indicated that concentrations of PCE and other chlorinated solvents did not substantially decrease after five years of treatment. Mass removal was attempted to the extent practicable, but it was later determined that MCLs were not achievable at the site within a reasonable timeframe. Monitored Natural Attenuation (MNA) was initially considered as the alternative remedy, but based on post-injection monitoring data and analysis, Alternative Concentration Limits are now being considered for the site.

There are numerous national efforts to develop strategies for managing complex sites. The Interstate Technology and Regulatory Council (ITRC) funded a study several years ago that resulted in two documents – *Project Risk Management* for *Site Remediation* (2011) and Using Remediation Risk Management *to* Address Groundwater Cleanup *Challenges at Complex Sites* (2012) – and has a study underway on remediation management of complex sites. SERDP and ESTCP also have funded work on the topic and have several program focus areas relevant to complex sites. EPA published a *Groundwater Road Map* (OSWER 9283.1.34) and a draft groundwater remedy completion strategy. States also have numerous guidance documents on managing complex sites, including Washington, which has 1,671 sites currently listed on the state's Hazardous Sites List.

Question: I have heard that MNA is the default remedy at sites where a Technical Impracticability (TI) waiver cannot be obtained. MNA is also often used where cleanup cannot be achieved within a reasonable timeframe.

Answer(s): There is some resistance to TI waivers, since they are often perceived by stakeholders as walk-away solutions. A lot of stakeholders are not aware that sites have to be revisited after five years and so are more comfortable with remedies such as MNA.

Overview of ITRC's Remediation Risk Management, Using the Remediation Risk Management Framework at Complex Sites, and Overview of ITRC's New Project on Remediation Management of Complex Sites

Anna Willett provided ITRC's perspective on complex sites and how the topic has evolved over time. ITRC is a state-led coalition working to advance the use of innovative environmental technologies and approaches, and works to translate good science into better decision-making.

In 2011, ITRC published a guidance document on Remediation Risk Management (RRM) - *Project Risk Management for Site Remediation* or "RRM-1" (http://www.itrcweb.org/GuidanceDocuments/RRM-1.pdf) – and offered an associated internet-based training course. RRM is a forward-looking management approach that considers all risks related to the lifecycle of the remediation process. Using this approach, risks are addressed holistically with consideration of the factors and parameters to minimize decision uncertainties during the cleanup. According to the approach, a project may include environmental and ecological risks, human health risks, economic risks, regulatory risks, technology performance risks, project management risks, and others such as legal, political, and social risks. To mitigate risks, they are analyzed and prioritized by combining probability and severity to determine which risks are high, medium, or low, creating a watch list based on those priorities, and defining risk metrics.

The RRM-1 document also contains the results of a 2008-2009 survey conducted by ITRC to identify how state environmental agencies address the instances where remedial objectives are not achieved within the designated timeframe. The responses to the survey were: institutional controls (17 responses), long-term monitoring (17 responses), MNA (17 responses), alternative cleanup limits (9 responses), additional modeling (9 responses), TI waivers (9 responses), and other options (8 responses). The results of the survey inspired the publication of *Using Remediation Risk Management to Address Groundwater Cleanup Challenges at Complex Sites* or "RRM-2" in January 2012 (http://www.itrcweb.org/GuidanceDocuments/RRM2.pdf), which applies the framework of project risk management for site remediation to identify and manage challenges in remediating groundwater to final goals and objectives at highly complex sites.

In addition, ITRC formed a new Remediation Management of Complex Sites Team in January 2014 to address the topic of complex site cleanup, which will work to better define a complex site and provide agreement upon approaches for management. The team is large and diverse (approximately 180 members), consisting of representatives from the private sector (52.3%), state and local government (26.6%), DoD (8.3%), as well as DOE, public/tribal stakeholders, academia, and EPA.

Question: There does not appear to be a high percentage of state and federal regulators on the Complex Sites Team. Will you get a sufficient number of regulatory opinions?

Answer: The composition of the Complex Sites Team is comparable to most other ITRC teams. In addition, there will be other contributors to the document in addition to the team. I think we will have enough regulatory representation.

Question: Can you comment on ITRC's training courses and the types of strategies and tools you are exploring?

Answer: Our training courses are designed to make documents more accessible. Every document we produce has its own training course offered free through CLU-IN (www.clu-in.org).

Question: I would propose that it is not necessary to define a complex site in order to develop a methodology. I think we should just focus on approaches to address the issues at a given site.

Answer: Good point. Our teams do get hung up on definitions, although sometimes it is necessary to narrow in on a definition to narrow down a focus.

Question: The survey results for the question "What options are considered if the selected remedy is not on track to meet remedial objectives?" are not what I expected. I'm surprised to see that some of the work that many people in this room have been champions of, such as application of the scientific method and conceptual site models (CSMs), is not listed in the responses.

Answer: I have noted that as well and do not know whether the responses were a result of the way the question was posed. The Complex Site Team will hopefully look at state protocols and case studies of work that has been done at complex sites in more detail.

Question: Can you provide information on how many consensus technical documents have been cited or incorporated into regulation?

Answer: Identifying this information is an ongoing process. Some material is not state guidance-appropriate or applicable, and is much more likely to be used at a site. ITRC's vapor intrusion documents, on the other hand, have been used by states in their guidance documents several dozen times. ITRC's 2011 document on incremental sampling methodology has been documented to have been used by nine states and three more states are in the process of incorporating it. These are lengthy processes and we are tracking the information over time.

Comment: ITRC has historically done a great job at publishing remedial optimization guidance, which embraces the scientific method of reevaluating CSMs and remedy effectiveness, revisiting the remedy, and addressing the changing state of remediation at a site. The optimization document, ASTM standard, and two new ASTM guidance documents on green and sustainable remediation can hopefully be addressed during the fall FRTR meeting.

Key Findings of the NRC Committee on "Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites" with a Focus on "Transition Assessments"

Michael Kavanaugh, Geosyntec Consultants, discussed the key findings of the National Research Council Committee on Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites.

The main issue is the complexity of the site, rather than the definition of a complex site. Examples of complex sites include the Wyckoff Superfund Site on Bainbridge Island, WA, where costs exceeded $100 million have been expended to implement a remedy, and where annual costs for containment are roughly $1 million annually; the Stringfellow Superfund Site, which has a 450-year estimated remediation timeframe and currently is under consideration for a TI waiver in two of the five zones of the site; and the San Fernando Valley, which has four Superfund sites in the vicinity and supplies about fifteen percent of the drinking water for Los Angeles.

Many sites with groundwater contamination remain open and the possibility of restoration to unlimited use/unrestricted exposure, as well as final site closure, remains uncertain within a reasonable timeframe. There are many factors that need to be balanced. In addition, long-term management of orphan CERCLA sites is transitioned to state responsibility after 10 years of remedy operation. However, today, states are financially constrained.

The number of sites that have not reached closure (126,000) is likely an underestimate. The key finding of 2012 NRC report is that there are some sites that are going to require a different strategy. EPA's 2011 *Groundwater Road Map* recognizes that there are sites where restoration is unlikely and suggests exploring the possibility of using a TI waiver or implementing an additional remedy. However, TI waivers have limitations.

The National Research Council developed a diagram that suggests the need for developing a transition plan once a point of diminishing returns is reached with the site remedy, even if the remedy has been optimized the CSM is accurate, and the best diagnostic tools have been applied. There are metrics to support the "diminishing returns" hypothesis, which include LNAPL recovery (asymptotic performance), mass flux (statistical confirmation of target reduction of mass flux), a risk reduction matrix, statistical methods confirming a declining trend in concentrations, elimination of exposure pathways, and sustainability metrics (for example, greenhouse gas emissions per unit mass removed).

According to the 2012 NRC report, there are several factors to be considered in transition assessment. These include an expanded analysis of costs and risk reduction for viable alternatives, including containment; sustainability assessments of options; additional site characterization with advanced diagnostic tools, if justified; risk assessment and risk analysis of post-remedy conditions; a risk-based or risk-informed decision process; and expanded community outreach and education. Empirical safety factors to consider in decision-making include EPA human health risk assessments; establishing MCLs; and the Food Quality Protection Act, which describes factors to protect infants.

Overall, the central theme of the 2012 NRC report is how the nation should deal with residual contamination post-remedy at a large number of sites, and the idea that transition guidance is needed. Complex sites present a persistent tradeoff problem requiring leadership and effective communication. From a sustainability perspective, there are ultimate limits to resource diversion for pursuing restoration. A pragmatic approach to the issue is the embedding of regulatory flexibility in all environmental regulations, which would allow for creative solutions. Finally, research efforts are needed to ensure that long-term management infrastructure meets acceptable residual risk levels and that residual risk is allocated equitably.

Question: One of the issues the Nuclear Regulatory Commission faces is residual radioactivity. How do you go about making determination that you can't release a site to unrestricted use? What are your thoughts with regard to innovative tools or strategies that are coming out?

Answer: Balancing risk analysis with the use of such tools is essential. Radioactivity is a difficult problem to address because of the public perception of radiation. Opening sites with radiation to unrestricted radiation is problematic. Risk analysis and risk communication are key in the radiation field.

Question: There seems to be a lot in common between the NRC study and the Superfund perspective. I think this is something we can talk about to see what can be done with regard to policy and regulatory flexibility. You also mentioned you recently joined a sustainability committee at EPA. Where is that?

Answer: The committee is organized under the National Research Council, Board on Environmental Studies and Toxicology and is funded by the Office of Research and Development. I am chairing the committee.

Question: One of the things you mentioned is using a sustainability assessment to modify Applicable or Relevant and Appropriate Requirements (ARARs). Can you expand on that? From my experience, once a remedy identifies an ARAR, obtaining a waiver or remediating are the two options.

Answer: What I intended to say is that one should look at sustainability factors in comparing different alternatives and assessing the impacts of trying to meet ARARS. Sustainability is another dimension of an analysis that determines whether it's practicable to achieve an ARAR.

Comment: Most people seem to agree that sustainability is secondary to statutory criteria.

Combined Remedies Featuring a Case Study Example of a Creosote Wood Treater Site

Jim Cummings, EPA TIFSD, discussed complex site management using the Wyckoff/Eagle Harbor Superfund Site on Bainbridge Island, Washington, as an example. The Wyckoff site had been one of the largest wood treating facilities in the United States. The site was added to the National Priorities List in 1987, after over 80 years of wood treating operations (1904 to 1988) with creosote, as well as bunker oil and pentachlorophenol in later years. The site is complex in part because it is subject to tidal influence.

The remedy selected in the Record of Decision (ROD) for the site was steam-enhanced extraction, which was contingent upon the results of a pilot study. However, the pilot study did not go well due to design flaws that resulted in crystallization of naphthalene in the piping and heat exchangers. EPA Region 10 subsequently proposed a containment remedy, but the state did not concur with the approach. As a result, a three-part strategy was developed, consisting of the following steps: (1) revision of the CSM; (2) change in the timeframe (reasonable timeframe vs. generational remedy); and (3) expansion of the focused feasibility study scope to include flexible and adaptive use of a combination of aggressive source zone technologies with subsequent polishing steps.

Revision of the CSM using the TarGOST™ Laser-Induced Fluorescence tool, which can distinguish between free product and dissolved-phase contamination, resulted in the reduction of the site footprint from 8.5 to less than 5 acres. The site was compartmentalized into three areas: core, peripheral and dissolved-phase. Two- and three-dimensional hot-spot maps were also developed based on the different levels of response to the TarGOST™ tool.

The following considerations were included in the engineering design: intended use (recreational area), the state's preference to discontinue pump-and-treat operations within 10 years, restoration of the resource within a reasonable timeframe, culmination of remedial activities in the upland area in a timeframe consistent with the life expectancy of the sheet pile wall, and protection of the lower aquifer.

The focused feasibility study is currently underway and expands remedial options beyond thermal to include in situ solidification, in situ chemical oxidation, bioremediation, and 'STAR,' which is an innovative smoldering technology. In addition, promising developments have recently been made in the use of biosparging to address aerobically biodegradable polycyclic aromatic hydrocarbons (PAHs). For instance, there has been great success in the bioremediation of PAHs at the Bay Shore former manufactured gas plant site in New York, where ozone treatment, oxygen injection, and injection of slurry that slowly dissolves and releases oxygen over several months, are being used. The idea of converting the sheet pile wall to a permeable reactive barrier also is being considered for the Wyckoff site.

Challenges for remediating the site include the need for requisite resolution regarding NAPL architecture, better insights and indices for spatial and temporal transition between technologies, better tools for predicting resource restoration timeframes, and low-maintenance long-term technologies to address residual contamination.

Overview of the Air Force Complex Sites Initiative

Sam Brock, Air Force Civil Engineering Center (AFCEC), discussed the Air Force Complex Sites Initiative. The initiative targets high-cost complex sites where technical analysis is required to determine whether site completion is possible or whether alternative strategies or endpoints are warranted. Approximately 1,000 Air Force sites are expected to not close by 2020, at which point they will be considered complex. One of the goals for the initiative is to identify sites that can be closed by 2041 and managed differently. The initiative emphasizes innovation and leverages technology, and considers lifecycle costs.

As part of the initiative, Air Force professionals will identify and assemble critical information for each site and perform multi-day critical review of site data to identify requirements, utilizing EPA's Data Quality Objectives process. The outcome of the critical review will be identification of appropriate goals, establishment of a technical path forward, and identification of appropriate technologies for targeted sites. The Air Force may hire contractors to conduct fieldwork to fill any data gaps. A path forward and a suitable contract mechanism will then be determined by the Air Force to achieve appropriate endpoints for complex sites. Other elements of the Complex Sites Initiative include development of a base-wide CSM, an evaluation of chemistry performance as part of the Air Force's performance-based remediation, a ROD review, and integration of surveillance with legacy guidance and tools. The initiative provides the Air Force with a standardized approach and an opportunity to obtain better performance on contracts that it buys in the future. The Air Force plans to begin thinking about follow-on contract support around 2017, since the current contract ends in 2020. The initiative will allow the Air Force to target the expertise and skills necessary for implementing the appropriate remedy for a given site.

The Air Force also conducts a Critical Process Analysis that validates the remedy to ensure it meets the performance model and determines a contingency response. The Critical Process Analysis is an extensive technical evaluation of an active environmental remediation system at sites with high cost, complexity, and risk to validate technology and design specifications; verify construction and operation according to design requirements; and validate whether the system is on track to meet performance objectives.

To implement the Complex Sites Initiative, the Air Force anticipates needing guidance on several fronts: guidance or criteria on procedures to determine whether progress is likely to achieve Remedial Action Objectives; guidance describing procedures to determine progress and triggering criteria to change remedial alternatives; guidance or criteria to determine whether restoration is achievable at a reasonable cost and within a reasonable timeframe, such as 20-30 years; and guidance on development and streamlining of RODs that accommodate adaptive site management and implementation of sequential technologies without requiring a ROD amendment.

Question: The Air Force has performance-based contracts, which are much shorter than the life of a remedial process. How do you set intermediate goals to ensure the contractor is performing as required?

Answer: That is the thrust of this initiative. The first step is an optimized exit strategy, the second step is obtaining a contract to implement that scenario, and the third is acquisition of monitoring tools that allow us to track the effectiveness of the work.

Question: Who is doing this—the Air Force or contractors? It looks like the Air Force has stopped its optimization program.

Answer: We were directed to pause the optimization program in its present form. We have attempted to look at it in terms of performance models. The follow-on contract would need to keep us on that path. We receive monitoring reports that go into a database, and we are determining whether we can use that data to provide a backup on compliance. Then we can identify locations where we need to send a team.

Question: So you are saying that you are trying to get information more efficiently so that you can do your own analysis.

Answer: Yes.

Comment: (Jim Cummings) We have written a few RODs anticipating the need to be adaptive so that they are flexible. If it is something you are working on, we would like to work with you.

Response: We would like to pursue that opportunity. We have had some personnel changes, which raises some issues with continuity of knowledge and standardization in writing reports, RODs, and other documents.

Question: How many sites do you expect to be in the "closed" category in the first cycle of the contract period?

Answer: 7000 out of 8000.

Question: What you are doing is similar to what the Navy is doing in terms of optimization. At what point do you conduct a Critical Process Analysis? Is it after you select remedy?

Answer: The Critical Process Analysis is an initiative that came about within the past year. It is conducted when the performance-based contractor changes or implements a new remedy and the Air Force would like performance data to determine if the remedy is working. The process is conducted at least six months after the remedy is implemented.

The Complex Site Initiative is independent of the Critical Process Analysis, and deals with how we are going to address open sites in the follow-on contract.

Overview of Modeling to Evaluate Risk and Maximize Predictability of Complex Sites
Mark Freshley, Pacific Northwest National Laboratory (PNNL), discussed several examples where modeling has been used as an integrative tool to help with assessment, address the long-term behavior of contaminants, and evaluate remedial alternatives.

The Hanford Site 300 Area has an issue with persistent uranium contamination in groundwater. When the site was operational, it was used for fuel fabrication for power reactors, as well as for research and development. Liquid wastes that included uranium were discharged into process ponds and trenches. During the remediation process, waste sites were excavated down to 15 feet and backfilled. MNA was selected in the interim ROD for the uranium plume.

A number of modeling studies on the site have been conducted since the late 1970s, increasing in sophistication with time. For instance, a 1994 DOE model looked at three-dimensional flow and transport supporting the Phase I Remedial Investigation and the interim ROD. The model was used to determine cleanup levels in the vadose zone, estimating that the plume would be attenuated within 10-25 years. However, the model did not account for stage variation (both daily and seasonal) of the Columbia River, which impacts the water table.

A 2007 study by Meyer et al. (NUREG/CR-6940, sponsored by the NRC Office of Nuclear Regulatory Research) documented a methodology for assessing hydrogeological uncertainties in performance and dose assessment. The target of the study was to provide a more realistic representation of prediction uncertainty in order to provide a technical basis for assessments and identify gaps in site characterization. The study used multiple models to represent major conceptual uncertainties at the site.

The conceptual-mathematical uncertainty modeling work under the study looked at combinations of conceptualizations of the system, including treating just the Hanford formation either in zones or as one homogenous unit, treating the river boundary as a uniform boundary or incorporating boundary variability, and treating K_d uniformly or allowing it to vary along the model domain to capture impacts of river water intrusion. The methodology developed in this work allowed researchers to assess the likelihood of a CSM, go through a calibration process, and adjust the probability of those CSMs before moving forward with predictions. Predictive results that included model and parameter uncertainties led to the conclusion that it was important to include alternatives and lower probability models in the uncertainty analysis to be able to help identify areas that need additional characterization.

Several additional investigations also have been completed at the site. The Integrated Field Research Challenge Project funded by the DOE Office of Science Subsurface Biogeochemical Research Program, for example, updated the Hanford 300 Area CSM. The work included laboratory and field investigations using a tracer to help explain the persistence of the uranium plume. The project was under review last week and was successfully renewed for continuing investigations.

Remediation Simulations also have been completed at the Hanford 300 Area, modeling polyphosphate infiltration over a uranium hot spot. The simulation indicated that after four days, the infiltration would proceed at a rate of 10 cm/hour. DOE/PNNL is currently working with the site remedial contractor to help them design an infiltration system to properly address contaminants.

Several conclusions have been derived from the modeling work conducted so far. Overall, the modeling conducted at the Hanford 300 Area has been useful for remediation decision support and uncertainty evaluation. Site work also has shown that system scale-models can be used to synthesize and integrate historical characterization and monitoring data to provide decision support for remediation endpoints and final site disposition. However, parallel computing is critical for effective application of system-scale models. The complexity of the models, and concurrently, the complexity of understanding of the site have increased with time, but modeling assumptions need to be documented and revised.

Question: The value of this kind of sophisticated modeling is better understanding of the system in order to evaluate remediation options. Can you comment on some of the unknowns that you are concerned about, such as microbial activity, and how important they are?

Answer: Microbial impacts are important to the site and have been examined as part of the DOE Office of Science Subsurface Biogeochemical Research Program Study. The study is now looking into future scenarios that take into account carbon cycling and river infiltration into groundwater. We have not incorporated the data at this time but we are looking into it, which is expected to have a profound effect on the results.

Question: Are the relative costs of modeling at the site rather than attempting to look at different remediation options worthwhile? Do you recommend exercising modeling before looking at different remediation options?

Answer: Yes, and we have been working with the site contractor responsible for the remedial approach to help them better design the infiltration system.

Question: How did you transfer the model into the right approach?

Answer: The model for which I showed results is for the entire Hanford 300 Area. We are working with the contractor so that they are able to tweak the parameters that cannot be changed, to help them design the right approach to application.

Comment: The long-term performance of the remedial strategy will change as the geochemistry of the site changes after injection of phosphates. It also will depend on the oxidation state.

Response: Part of what we can do with the modeling is predicting how long a remedial approach will be effective. Both oxidation state and microbiology will impact how long the uranium can be immobilized. Modeling allows you to look at the evolution of the chemistry of the system over time.

Advanced Simulation Capabilities for Environmental Management (ASCEM) Overview and Example Application

Mark Freshley, PNNL, discussed the development of the Advanced Simulation Capability for Environmental Management (ASCEM) to support modeling analyses at complex legacy waste sites. He provided a brief overview of ASCEM and its capabilities, as well as an example of how it was applied at the Hanford 300 site.

ASCEM, currently under development, is a modeling toolset for understanding and predicting subsurface contaminant fate and transport. It is an investment by the DOE Office of Environmental Management. The investement also includes the development of an open-source user environment called Akuna that manages subsurface simulation workflows and a high-performance computational simulator called Amanzi. Additional toolsets are used to launch Amanzi, manage simulation data, and visualize both model input and results. The user environment includes the capability for model setup, visualization through the toolset, and launching of jobs for conducting a single simulation run, sensitivity analyses, model calibration, and uncertainty.

An initial release of ASCEM to a select group of users was completed to help DOE better understand the system and control the source of user feedback. DOE is targeting to conduct a broader release at the end of the calendar year. The use of the toolset is being demonstrated at a number of different DOE sites. Several DOE laboratories participate in the effort, including PPNL, Savannah River, and Oak Ridge.

The demonstration at the Hanford Site focused on six cribs in the central plateau that were used for waste disposal from 1956 to 1958. The primary contaminant of concern is ^{99}Tc, which was found at a concentration of about 10^6 picocuries per liter (pCi/L) at the source. The area is characterized by a thick (>100 m) vadose zone. The initial one-dimensional model for the area predicted that all the ^{99}Tc should have migrated through the vadose zone into groundwater, resulting in a ^{99}Tc plume. That was not the case, however, so DOE and its contractor drilled several characterization boreholes. Data collected from the boreholes indicated that ^{99}Tc was still within the vadose zone, close to the water table.

ASCEM generated one hundred different realizations of three-dimensional lithofacies distributions were generated using the geostatistical model. DOE selected 10 realizations for the demonstration and executed a simulation from year zero to 1956 (the year that crib discharge began) and a forward simulation from 1956 to 2008. Though the model did not predict all situations observed through sampling, the trend lines were of the appropriate shape.

The simulation of the Hanford Site cribs provides insight on controlling processes and properties for ^{99}Tc transport in the subsurface. Overall, high-performance computing enables multiple realizations of complex models through reduction in computational time. Examining the uncertainty associated with both net infiltration and detailed heterogeneity represented in multiple realizations of the Hanford Site conceptual model allows for the exploration of impacts of remedial alternatives to address the deep ^{99}Tc contamination.

Question: Some sites have residual radioactivity. Given that there could be stresses on the system, such as changes in rainfall or land use, could you analyze them and build them into your system of analysis?

Answer: Yes. For example, one can look at how climate impacts the recharge rate. We have codes that help us take those factors into account and estimate the recharge rate. I view modeling as a tool for helping people integrate understand everything they know about a system and then test that understanding and make projections.

Comment: (Patricia Lee, DOE) I work on an ASCEM project at the DOE Office of Environmental Management. One of the things that stand out about ASCEM, when compared to other modeling tools, is that ASCEM allows you to put several aspects of modeling, such as uncertainty, transport, and visualizations, under one roof. Visualization has been attractive to stakeholders and regulators because it allows them to see how you are managing uncertainties and making decisions. Overall, ASCEM has a strong data management capability.

FACILITATED BRAINSTORMING SESSION: POTENTIAL MEETING TOPICS FOR FALL 2014

Carol Dona asked FRTR meeting participants whether they had suggestions for potential Fall 2014 topics that were not on the survey distributed at the beginning of the meeting. Additional suggestions included:

- Hydrofracking.
- Monitoring, performance and optimization of in situ technologies.
- Metagenomics and natural attenuation of organic contaminants.
- Climate change adaptation of remedies.

Carol reported that the FRTR Steering Committee will meet the next day to discuss the results of the survey, as well as the additional topics suggested by participants, and decide on the next meeting topic. FRTR members will be informed of the Fall 2014 meeting topic in the coming months.

Lessons Learned from Using Mass Discharge as a Regulatory Compliance Goal

Tamzen Macbeth, CDM Smith, discussed the lessons learned from using mass discharge as a regulatory compliance goal at the Well 12A Superfund Site in Tacoma, Washington. In the early 1908s, the city of Tacoma discovered TCE in a municipal groundwater well (Well 12A). Subsequent sampling and investigation work implicated a former oil recycling facility as the source of contamination. The six primary contaminants in site soil and groundwater are TCE, PCE, *cis*- and *trans*-1,2- dichloroethene (DCE), vinyl chloride, 1,1,2,2-tetrachloroethane, as well as petroleum hydrocarbons, NAPL, lead, and PCBs. In addition, the Time Oil building contains hazardous building materials including asbestos, PCBs, lead, and mercury.

Several treatment systems have been in operation at the site since the 1980s. In 2008, a Five-Year Review indicated that the groundwater extraction and treatment system was not reducing contaminant concentrations and not limiting the migration of contamination as expected, and therefore would not meet Tacoma's ultimate goal of unrestricted site use. A Focused Feasibility Study evaluation was conducted analyzing potential source treatment options. Modeling work conducted as part of the study indicated that source mass could be reduced because it would attenuate before reaching the receptor. As a result, a ROD amendment was issued in 2009, indicating a goal of reducing source strength mass discharge by at least 90%. To achieve that goal, the remedy selected in the amendment consisted of multiple technologies: excavation, in situ thermal remediation, enhanced anaerobic bioremedation, and groundwater extraction and treatment (the existing pump-and-treat system). One unique aspect of the amendment was that while it provided the remedial framework, it was not very prescriptive. The project was implemented using an adaptive strategy.

ITRC's *Use and Measurement of Mass Flux and Mass Discharge* (2010, http://www.itrcweb.org/Guidance/GetDocument?documentID=49) lays out three direct and two indirect methods for measuring mass discharge: transect methods, well capture/pump test methods, passive flux meters, transects based on isocontours, and solute transport models. This project focused on the first two direct methods: the transect method and the well capture/pumping methods. To decide on the method to be used, a robust CSM was needed to: delineate soil contamination extent in the vicinity of the Time Oil building to reduce uncertainty; evaluate distribution relative to site stratigraphy, evaluate transport pathways and mass flux discharge; target treatment areas based on maximizing mass removal and mass discharge; and evaluate hydraulics of the groundwater system.

The study first considered calculating mass discharge with the transect method, which consists of installing wells perpendicular to groundwater flow and collecting the appropriate parameters needed to calculate mass flux. Characterization was conducted with 34 soil borings to reduce uncertainty and delineate sources. Twelve locations were chosen for vertical profiling. Soil at the site is characterized by glacial till and has numerous very conductive zones.

Results indicated the presence of a thin soil 'pancake layer' that contributed half the mass discharge collected by the treatment system. It was observed that 96% of mass discharge was occurring in about 10% of the transect zone characterized by silty soil. Creation of a groundwater cross-section and examination of site gradients indicated a significant shift in gradient, depending on the season, recharge, and whether Tacoma as operating its municipal well field. These factors influenced the ability of the site team to use transect method. Another issue with the transect method was the lack of a plume or source at equilibrium due to the operation of the pump-and-treat system. Sonic drilling rather than direct push technology was employed to accommodate the fact that site soil was composed of glacial till.

The second approach used for calculating mass discharge at the site was using a groundwater extraction and treatment system pumping test. One of the goals for using this approach was to determine when adequate data has been collected to support a conclusion that mass discharge is stable and a baseline measurement can be agreed upon. The second goal was to propose a baseline mass discharge measurement and appropriate uncertainty boundary for consideration and approval by the team, once baseline conditions were stable within an acceptable degree of uncertainty.

A rigorous evaluation was conducted for determining when the groundwater extraction treatment system would be stable. It was necessary to define analytical variability in the measurements, define variability in the sampling and analysis, determine tolerance levels for variability in the data, and define when the data values have reached a point where the mass discharge measurements are stable. The metric used to determine the attainment of steady-state conditions was the relative percent difference analysis or "RPD" ($RPD = (a - b)/((a + b)/2) \times 100$, which is the relative percent difference between successive measurements (a, b). A statistical analysis of the data indicated that analytical variability in the measurements was about 10%. The second step after determining the RPD was to determine the variability in sampling of the groundwater extraction and treatment system. Statistical uncertainty for these measurements ranged from 12 to 20%. The third step was to determine the tolerance for variability in the data. It was then necessary to determine when mass discharge under the current pumping rates reached equilibrium (pumping rates ranged between seven and 80 gallons per minute in different wells). Data reached stability within the acceptable range of variability after three months of pumping.

The benefits of using the pump test method to determine mass discharge included the fact that infrastructure was already in place. This method also provided a better measure of mass discharge that accounts for a larger portion of the source treatment area, required minimal costs for measurement, was less affected by seasonal changes and pumping of the municipal well field. In addition, measurements could be taken during or nearly immediately after treatment. The drawbacks of the method included inherent variability in measurements and significant changes in flow that required an equilibration period.

Using the transect method provided for a relatively easy way to collect measurements, but it also had numerous drawbacks. For example, when using this method, significant site heterogeneity required more intensive transect and sample density to represent mass discharge, significant variability in the vertical stratification of contaminants required evaluation at multiple depths, and rendered variability in the results due to shifting gradients difficult to capture and precisely quantify over time. Overall, the pump test method was determined as the best process to use for compliance.

Question: What happens if you do not reduce source strength by 90%?

Answer: We are just completing our full-scale set of bio-injections now. If we are not close to our mass discharge reduction goal within 180 months, we will be looking to optimize the technology.

Question: Can you explain why Darcy rather than seepage velocity is used in calculating mass discharge using the transect method?

Answer: It has to do with the metric being measured. With mass flux, we are mainly interested in volumetric rates rather than how fast a particle moves from point A to point B.

Question: Can you talk a little about the cost of using each methodology?

Answer: The cost depends on the site. In this case, using the transect method cost $250,000 to obtain all the data that was needed. The method is very intensive in terms of characterization, but it is important to attain greater certainty. If you are already operating and maintaining a pump-and-treat system, the additional costs for the pump test method would be minimal unless the system needs to be modified.

Question: You mentioned that sonic drilling, rather than direct push was used at the site. How much did it increase cost?

Answer: A lot. Only one boring per day was possible to create with sonic drilling, while direct push allows creation of 3-4 borings per day. Overall we created 34 soil borings to delineate primary and secondary sources. Twelve additional vertical profile borings were crated where we laid out transects and collected discrete groundwater data.

Bethpage/Northrup Grumman Airfield Remediation and Stewardship on Long Island

Richard Mach Jr., U.S. Navy, discussed the Navy's overall policies and guidance with regard to remedy selection and provided site-specific examples where risk-informed remedy selection was applied.

The Department of the Navy has been involved in optimization and risk-based decision-making for several decades. Many different guidance and reference documents have been developed over the years. The key reference documents include the:

- *Groundwater Risk Management Handbook*, NAVFAC, 2008 (available at http://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/wg/artt.html)
- *DON Guidance for Optimizing Remedy Evaluation, Selections, and Design*, NAVFAC, 2010 (available at https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/wg/opt.html)
- *NAVFAC Guidance for Optimizing Remedial Action Operation*, 2012 (available at https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/wg/opt.html)

The Navy's toolbox approach to making smart site decisions including conducing a site evaluation or developing a CSM, with a focus on groundwater usability and complete exposure pathways; managing risk with consideration for plume management zones and points of compliance; developing remediation strategies with the recognition that there is no 'one size fits all' approach and consideration of treatment trains, active vs. passive remediation, containment, and MNA as a polishing technology; always considering optimization and sustainability; and considering new tools such as plume stability/MNA software.

Typical approaches to groundwater remediation used by the Navy include groundwater plume management and treatment along with MNA over long time frames. Other passive remediation technologies in addition to or instead of MNA also could be used. Regardless of the technology chosen, particularly with treatment trains, it is important to set performance objectives and develop an exit strategy. Performance objectives should be clearly defined and functional (specific, measurable, relevant, and time-bound). Exit strategies identify when it is time to stop, modify, or change a technology, or the appropriate time to transition to other components of the treatment train.

The Navy applied risk-based decision-making and optimization strategies in the remediation of the Naval Weapons Industrial Reserve Plant and Northrop Grumman Corporation Site in Bethpage, New York. The site is a government-owned contractor-operated facility established in the 1940s to build Naval aircraft (originally 109 acres). Northrop Grumman operated the site as a contractor, but also owned and operated its own facility adjacent to the site (about 500 acres). Releases occurred over 50 years and the site is complicated by a number of other potentially responsible parties (PRPs). The contaminant plume is well-defined, concentrated, and continuous near the site and the Northrop Grumman facility, but becomes discontinuous and move as separate fingers in downgradient areas. The overall plume length is three miles, with a depth of 750 feet and a width of 1.5 miles. The Atlantic Ocean is the ultimate receptor and the plume now has reached the halfway point. There are a lot of public water systems in the area that pump at different rates. The Navy does not believe the plume can be stopped.

The New York State Department of Environmental Conservation is lead regulator and issued several RODs for the site, including a groundwater ROD in 2001. The Navy also prepared RODs for the purpose of implementing the state's RODs, though no final agreement between the Navy and Northrop Grumman regarding the specific responsibility of each party has been reached. Remedial actions at the site have consisted of early concentrated in situ source area treatment and early containment of the plume at the facility boundary. Currently, there is an off-property hotspot system for mass removal where volatile organic compound (VOC) concentrations exceed one part per million (ppm), extensive monitoring, and provisions for wellhead treatment at impacted public water supply systems. Both the state and the Navy agree with this strategy.

The hotspot treatment system is constructed at an offsite residential area. Design, easements, and construction required six years and $14 million. The system began operating in 2009, with an expected 5 to 10 year lifespan. So far, the system has removed 3.5 tons of VOCs. Operation and maintenance costs have increased between 2010 and 2013 from $230 per pound of VOCs removed to $460 per pound of VOCs removed. An optimization study was conducted in 2013 to improve performance and reliability, reduce operating costs, and define metrics for system shutdown.

The offsite groundwater monitoring program consists of plume monitoring and public well supply sentry wells. The offsite plume is very complex, with multiple semi-confining units and fragmented sections as a result of multiple releases over 50 years and seasonal pumping of the public water supply. The delineation of the plume is also complicated by several non-Navy sources in the area and similarity of VOCs. The current goal is to continue monitoring the plume and to have sentry wells monitor in front of each of the public water supply system wells. The design was set up to allow for a five-year window before the plume went into public water supply, though it did not work in all places due to the plume splitting numerous times.

Public water supply wellhead treatment is major component of the remedy. Only public water suppliers can install wellhead treatment, so they must file a claim against the Navy to receive funding. The claim goes through the Department of Justice and fund money is placed into a judgment fund. The Navy is negotiating and/or has implemented wellhead treatment for three public water suppliers. The state is pleased with the outcome, though not with how long judgments sometimes take. Public water suppliers further downgradient would like the plume to be contained before it reaches their areas, but the Navy does not believe that would be possible. Senator Charles Schumer has asked EPA to become more involved with the (non-NPL) site, which has been providing some support.

In 2011, the Navy assembled team of third-party experts to evaluate the effectiveness of the offsite groundwater remedy. An Optimization Report was published in June 2011, recommending in one of the findings to evaluate alternatives for managing impacted groundwater. An Alternatives Report was subsequently completed in January 2012 and underwent an independent review by Battelle, the USGS, and USACE, which all determined that the report was technically sound. Based on these evaluations, the Navy concluded that the overall approach presented in the offsite groundwater remedy (OU2 ROD) was protective of human health and the environment through monitoring and wellhead treatment, complied with federal and state regulations, was cost-effective among the options available, used permanent solutions to the maximum extent practicable, and utilized treatment to the maximum extent practicable.

As a result of the evaluations and based on ten years of implementation experience, specific technical details of the program were modified to optimize performance, including increased plume monitoring to better develop the CSM and allow accurate predictions of potential plume migration; an enhanced sentry well network around potentially impacted public water supplies; use of existing infrastructure, where reasonable, to achieve mass removal and thereby reduce or delay potential impacts to public water supplies; and use of MNA for portions of the plume that will bypass the public water supply.

Question: How are you handling the PRP aspect with Northrop Grumman? Do you have a retroactive agreement for moving forward once you determine the liability?
Answer: Northrop Grumman operates the pump-and-treat system outside their facility. They also conduct some groundwater monitoring and installed additional borings. The Navy operates a hotspot treatment system and also installed additional borings for characterization. The Navy also is monitoring and installing more sentry wells. We are trying to obtain a settlement agreement with Northrop Grumman and are working through the Department of Justice.

Question: You did not have to wait to get that agreement?
Answer: No, we did not wait. Northrop Grumman also emplaced the original wellhead treatment system when concentrations increased from 0.5 ppm to 1 ppm. The Navy agreed to pay for the system and will be taking it into account when we reach a final agreement.

Question: Are the contaminants of concern volatile?
Answer: Yes. They include TCE, PCE and other VOCs.

Question: Are there any concerns for vapor intrusion?
Answer: Yes. However, vapor intrusion has only been an issue at one hotspot. We immediately placed filters and venting systems into and underneath the impacted homes and installed a soil vapor extraction system to pull the plume back. The majority of the plume that has moved offsite has had no vapor intrusion impacts.

Question: Given the number of sentry wells you have out there, have you looked at automated sensor networks?

Answer: No, but I have heard about some research on the technology.

Closing Rocky Flats: Balancing Complex Issues

Carl Spreng, Colorado Department of Public Health and Environment, discussed the complex issues involved with closing the Rocky Flats Plant site. Rocky Flats is a 6,240-acre facility located approximately 16 miles northwest of Denver, Colorado that was used for manufacturing of trigger mechanisms for nuclear weapons from various radioactive and hazardous materials. Operations began in 1952 and ceased in 1989, when the site was listed on the NPL.

Radionuclides were found in building materials and environmental media. About 650,000 cubic meters of radioactive waste was present on the site, along with 21 tons of weapon- grade plutonium and 100 tons of plutonium residues with no disposal path. Nearly 400 potentially contaminated areas existed around the site that needed examination, review, and remediation. There was much community distrust and a culture of strained relationships.

In the early 1990s, site cleanup was estimated to cost $37 billion and last 65 years. A new contractor hired in 1996 estimated the closure date to be 2010. By 2001, the schedule was further compressed, with a new closure date of 2006. That closure date was exceeded when construction was completed toward the end of 2005 under budget at $30 billion. A major part of the cleanup involved decommissioning and demolition of over 800 structures, some of which were highly contaminated. Most of the technologies involved were off-the-shelf, but some innovative technologies were used as well. In September of 2006, a ROD closed the Rocky Flats site after a 10-year cleanup. The majority of the site was delisted from the NPL in 2007 and was turned over to the U.S. Fish and Wildlife Service to create a new National Wildlife Refuge.

Many elements contributed to the success at the site, including a vision for closure with upfront land use assumptions, a single-site mission, steady and reliable funding with a supportive Congressional delegation, community and worker acceptance of site closure, significant public involvement, an appropriately-scoped performance-based contract, a flexible cleanup agreement with accelerated decision-making, technological innovations, and a collaborative process among DOE, contractors, and regulators.

Waste acceptance for variety of waste streams also contributed to the project’s success. Waste shipping was a potential major bottleneck for site cleanup due to limitations in acceptance facilities. A waste processing plant opened just in time and received a steady stream of trucks with waste from the site. Other states (WA, NV, SC, NM, and others) also received site waste, with most waste being deposited in landfills.

The site fell under an extensive set of regulatory framework that included both state and federal regulations. The Rocky Flats Cleanup Agreement reached between DOE, EPA, and the state of Colorado in 1996 (applicable 1996 to 2007) streamlined the regulatory approach and institutionalized the consultative approach to cleanup decisions among the parties involved. It also established an agreement on end state conditions and formally recognized state authority. A modified CERCLA process was followed for site cleanup, which accelerated the cleanup timeframe. Each of the nine criteria under CERCLA was applied to each of the decisions made under the accelerated action process at the site. A "no further action" decision was reached in all areas of the site except the center. That area is currently under long-term monitoring and institutional controls.

Today, the average residual plutonium contamination at the center of the site is 2.3 pCi/g at the central DOE operable unit and 1.1 pCi/g on National Wildlife Refuge property. The lessons learned from the site cleanup process have the potential for broader use, and could serve as a model for how regulators and regulated parties can collaborate to resolve difficult technical and policy issues.

Performance Management of Large Complex Mining Sites

Marc Ferries, BP Atlantic Richfield, discussed strategic management of complex sites, particularly mining sites, and provided several examples. Complex mining sites have characteristics such as large areal extent of impacts and naturally occurring contaminants. There is an uncertainty of remedial standards for complex sites sites and the primary remedy is keeping the waste in place. The ultimate cleanup requires management in perpetuity, while solutions require an integrated remedy.

Several NPL sites exist in Montana: Clark Fork River Basin, Anaconda Co. Smelter, Montana Pole and Treating, and the Berkeley Pit in Butte. BP Atlantic Ridgefield bought out of the Clark Fork River Basin site, but is still working on the Anaconda Co. Smelter and Berkeley Pit sites. Water pH at the Berkeley Pit site ranges from 2 to 2.5 and though a water treatment system is already in place at the site, it will need to be upgraded to deal with the ultimate discharge standards. There is a concern that once water levels reach a critical depth, it will start seeping back into the municipal water supply. BP is now looking at different alternatives for addressing the issue, with a year 2023 deadline for implementation.

These complex sites require an extensive commitment to endure through the extensive data collection, negotiations and establishment of trust with the stakeholders. Development of an advocacy and community engagement plan is critical to the achieving site objectives. The critical elements are engagement with key stakeholders, informing the public on environmental progress using strategic venues on a continuing basis, advocating for legislative and regulatory initiatives that promote reasonable standards, delivering messages through various outlets, and participating in programs that support or align with business objectives. In addition, many of these large sites have multiple sites within them and it is important to develop a holistic site model.

Developing a strategic plan is the first key step to addressing large complex sites. A contingency plan is important to the strategy so that options within the plan are available. The plan should be a living document and written such that if the original team leaves the site, a new team could easily begin where the last team left off and continue implementing the solution.

The next key step is to measure progress. Impacted sites require reduction of risks, which can be defined as uncertainties. Risk reduction needs to be measured to understand progress. Risks are based on site conditions, and can be characterized as technical (for example, site geology, potential receptors, acute and chronic water quality standards) or non-technical (for example, regulations, property value, public perception). A risk profile helps understand the resources that can be applied to mitigate the different risks.

In implementing the program, it is important to proceed through the regulatory steps with a plan, allow sound science to drive protectiveness decisions, implement interim remedies, negotiate through open dialogues, and promote risk-based standards (including TI waivers) that can be demonstrated through scientific studies. The ultimate decision should include achievable protective terms. Complex sites have no endpoints but progression to end states also is important. End states mean that minimal active remediation or reclamation activities are occurring and allow for the development of achievable standards and repeatable operation and maintenance programs. Once the programs are repeatable, they can be monetized. Some industries are moving in the direction of developing community programs that can provide the services that ensure the remedy is compliant and protective.

If acid mine drainage is a component of closure, the best option is to consider obtaining a TI waiver. It would not be possible to meet compliance standards with acid mine drainage present. In those cases, it would be necessary to conduct the appropriate investigations, gain a better understanding of the issue, and implement adaptive management strategies to come to a reasonable protective standard.

Comment: Under "Develop a Strategic Plan" on slide 10, you mention an exit strategy. I recommend that you also look at alternatives.

Response: Exit strategy development usually yields 3-4 different options. The process then involves implementing one of those strategies until another one of those options becomes viable.

Question: When you go back and evaluate whether remedial objectives have been met in terms of costs, how do you determine the amount for indemnity funds?

Answer: You need to develop a plan that looks at various options. I do not know the details of how that is ultimately valued, but you can look at the funds available and the liabilities that need to be funded. You can then try to start developing a plan for each of these and try to gain understanding of how the solution can work to the community's favor, be protective, and be more cost-effective.

PANEL DISCUSSION – REMEDIATION MANAGEMENT OF COMPLEX SITES: CHALLENGES AND OPPORTUNITIES

A Federal Perspective: Myth Busting TI Waivers

Dave Bartenfelder, EPA, discussed TI waivers in the context of groundwater remediation completion strategies. Protection of water, including groundwater, is one of EPA Administrator McCarthy's seven priorities. Ninety percent of current Superfund NPL sites include a groundwater remedy and $30-50 million per year is spent by EPA on the operation of long-term response actions for the first 10 years of restoration actions.

Cleanup expectations for groundwater in the Superfund program involve defining and containing the plume, taking early actions as soon as possible, and restoring the site to beneficial use when practicable. There are two remedial endpoints: restoration and non-restoration. Non-restoration, or if restoration is not technically practicable, a TI waiver can be issued.

EPA has made progress in cleaning up and restoring contaminated groundwater over the three decades of Superfund cleanups. Many groundwater remedies have met remedial action objectives, and where they have not, significant progress has been made to reduce contaminant concentrations. In addition, technologies and cleanup strategies have evolved over time. For example, 75% of groundwater remedies involved pump and treat in 1986 compared to 31% in 2011.

Some of the challenges to groundwater cleanups include the timeline to completion (cleanups can take many decades to complete despite progress) and cost, since remediation systems are costly to build and operate. Technical challenges, such as presence of fractured bedrock and DNAPL, as well as matrix diffusion, can arise as well. These technical challenges present the need for alternative remedial strategies, such as TI waivers.

A TI waiver is one of six types of ARAR waivers. Most TI waivers are issued for groundwater, though some can be issued for surface water as well. Over 100 TI waivers have been granted to date. Waivers are based on the chemical and physical properties of the contaminant, the remedial technology, the subsurface technology, time, and cost. However, there are misconceptions surrounding TI waivers. For example, using MNA should not be a default strategy. Rather, it needs to be supported as a viable response action.

EPA has recently developed a new suite of guidance documents that provide a path to complete sites. The EPA documents include:

- *Groundwater Road Map Recommended Process for Restoring Contaminated Groundwater at Superfund Sites*, 2011, OSWER 9283.1-34 (http://www.epa.gov/superfund/health/conmedia/gwdocs/pdfs/gwroadmapfinal.pdf)
- *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*, 2013, OSWER 9355.0-129 (http://epa.gov/oerrpage/superfund/health/conmedia/gwdocs/pdfs/GroundwaterAttainmentPolicy-finalsigned-11%2025%202013.pdf)
- *Groundwater Remedy Completion Strategy*, 2014, OSWER 9200.2-144 (http://www.epa.gov/superfund/health/conmedia/gwdocs/pdfs/EPA_Groundwater_Remedy_Completion.pdf)

A few additional guidance documents are expected to be published in May or June 2014. The *Groundwater Remedy Completion Strategy* helps focus limited resources toward efficient and effective completion of groundwater remedies; recommends including site decision points along the process and encourages site-specific decision making; encourages re-evaluation of remedial strategy if not making reasonable progress; and promotes stakeholder consensus. The strategy does not, however, alter the Agency approach for setting remedial objectives or cleanup levels; change existing regulations, guidance or policy including remedy selection; address groundwater classifications or groundwater use designations; or request that states and tribes alter existing groundwater classification or use designation.

For more information or questions, participants can contact Anne Dailey (703-347-0373; dailey.anne@epa.gov), Kate Garufi (703-603-8827; garufi.katherine@epa.gov), or Dave Bartenfelder (703-603-9047; bartenfelder.david@epa.gov).

Question: Will we get a chance to see responses to our comments on the *Groundwater Remedy Completion Strategy*?

Answer: We have a meeting arranged between DoD and DOE after the document's publication to discuss the comments internally within the federal government. No comments matrix is being provided to the public.

Question: Will the guidance documents EPA is publishing provide specific technical guidance, or are the documents more policy-oriented?

Answer: They are a combination of both.

Question: Is there anything equivalent to a TI waiver for RCRA sites?

Answer: Yes, but I am not sure about how TI waivers are issued for RCRA sites since RCRA is a state deferred program. Superfund does occasionally review RCRA TI waivers, but they are reviewed for technical rather than policy aspects. In the Superfund program, a TI waiver is granted by the region.

Comment: EPA's TI guidance issued in 1993 applies both RCRA corrective actions and Superfund.

A State Perspective: Overview of Colorado's Policy for Low Threat Closure

Carl Spreng, Colorado DPHE, provided a state perspective on the challenges and opportunities in the remediation management of complex sites. He reported that one of the tools used at the Rocky Flats site was an adaptive management plan that was put into place to address surface water management and monitoring (mostly to include the interested public in the process). The plan was used to address potential options for adjusting implementation of the remedial strategy. The adaptive management process allowed for the flexibility to respond to changing conditions without requiring new or supplemental National Environmental Policy Act analysis. An adaptive management process also can inform the public about site conditions. It is a flexible tool that has been working well in Rocky Flats.

Carl then discussed the issue from the perspective of ITRC, since he has been the co-leader of ITRC Radionuclides Team since 1999. Some of the ITRC team's early objectives were to determine which states have innovative initiatives in addressing some of the attributes of complex sites. A few states with interesting scenarios were identified. Colorado, for example, was dealing with residual groundwater contaminant levels that were asymptotically close to the state groundwater standard. However, some sites continued to incur costs for remediation though there was no longer a threat to human health or the environment. At other sites, the source area needed to be remediated to extent practicable, but the plume was stable or decreasing, and concentrations were decreasing or predicted to decrease.

Groundwater contaminant concentrations have to meet state standards within a reasonable time period. There is no precise definition of "reasonable" but a few ITRC documents do try to provide some parameters that define a reasonable timeframe. In addition, contaminant concentration trends must not be dependent on active remediation systems, no exposures must occur above standards through cross-media transfer, groundwater uses that would be threatened by the plume should not occur downgradient of the site, no discharge to surface water must occur in excess of surface water standards, and groundwater must meet standards in an adjacent aquifer. The Environment Hazardous Materials and Waste Management Division in the Colorado Department of Public Health also requires the implementation of institutional controls (covenants) or establishment of alternative concentration limits. Most cities in Colorado have ordinances that control groundwater use within city limits. At one site, the state of Colorado reached a governmental control agreement with the city where the site was located in lieu of a covenant. The agreement allowed the state to have enforcement over the city ordinance. Along with these conditions, the state of Colorado looks for supporting lines of evidence to support conditions.

Question: What is the process that Colorado used to close the Rocky Flats site? It sounds like the state has a risk-based closure process that could accept an alternative. Is there flexibility in terms of your own state regulations and processes?

Answer: We did not follow the traditional CERCLA process in closing the Rocky Flats site – we used a modified process. We were able to compress the cleanup schedule without diminishing the protectiveness of the remedy.

A DoD Perspective: Overview of Army Challenges at Complex Active IRP Sites and Tool/Studies to Support Path Forward

Laurie Haines-Eklund, U.S. Army Environmental Command (USAEC), discussed DoD's goals for its Installation Restoration Program (IRP). One of the goals includes achievement of Remedy in Place at 100% of IRP sites by the end of FY 2014. Remedy in Place is a remedy that has been constructed, is functional, and operating as planned in the Remedial Design that in the future, will meet the remedial action objectives specified in the decision document. The second goal of DoD's IRP is to achieve the Response Complete (Remedial Action Objectives in the decision document met) milestone at 90% of all IRP sites by the end of FY 2018 and at 95% of all sites by the end of FY 2021.

As of September 2012, the 'active' IRP inventory contained 12,249 sites. The Army's active sites cleanup program has met the majority of the goals, as 10,218 active IRP sites have now attained the Remedy in Place or Remedy Complete status. As of FY 2013, the monetary liability at the remaining sites is around $1.9 billion. A subset of the remaining sites is considered complex due to conditions such as complex hydrogeology (for example, karst, fractured rock, and heterogeneous environments), and presence of recalcitrant compounds. At these sites, there is general agreement among practicing remediation professionals, that due to inherent geologic complexities, restoration within the next 50-100 years is likely not achievable.

The USAEC preferred goals for all sites is cleanup to unlimited use and unrestricted exposure, and removal of all risks. At complex sites, however, the USAEC aims to set realistic (specific, measurable, and functional) Remedial Action Objectives in decision documents, transition from active remediation to passive remediation and long term management as quickly as possible and when reasonable, optimize lifecycle costs, reduce liabilities, and reduce long-term management obligations where possible. At all sites, regardless of complexity, the USAEC manages risk through various methods (for example, land use controls).

The USAEC faces numerous challenges at complex sites. Decision documents often do not include achievable and realistic Remedial Action Objectives (for example, a lot of pushback is received on TI waivers), and lack specific, measureable, functional remedy performance metrics. Even if Remedy in Place is achieved, decisions must be reevaluated every five years and because progress toward the Remedial Action Objective is uncertain, difficult to measure, or difficult to predict.

Comment: The FY 2014 goal mentioned on Slide 2 has changed. The goal is no longer achievement of Remedy in Place at 100% of IRP sites, but rather at 95% at all sites in the program (IRP and non-IRP sites) by the end of FY 2014.

Comment: Flexibility in the decision document to change the remedy with changing conditions is one of the tenets of green and sustainable remediation and optimization.

Question: Can you provide specific examples of transition assessments?
Answer: We wanted to write a proposed plan that acknowledged the difficulty in achieving MCLs in groundwater throughout the plume. We were willing to use an active source area remedy, but wanted to add general language about transitioning to a passive remedy or an alternative remedial strategy when asymptotic levels of various parameters were reached. There was a lot of pushback from both EPA and the state, who indicated that the remedial design document was the more appropriate place for that language. Consequently, we developed a ROD that indicates a goal of reaching certain MCLs when there is no intention of achieving that goal.

Comment: (Greg Gervais) I would imagine that if those alternatives were articulated and assessed in the Feasibility Study, there would be enough documentation in the Administrative Record to support that kind of language.

Comment: (Dave Bartenfelder) I think that there is a general feeling that you need to have confidence in where you are going to be. You either go in with confidence that you can restore a site and issue a ROD, or go in with a confidence that you cannot restore and issue a ROD with a TI waiver. If you are not yet sure, either option might be premature.

Comment: (Richard Mach) I disagree with the notion that a TI waiver is needed if you are not going to be able to restore a site. For example, landfill sites cannot be restored but a TI waiver is not necessary in those cases. We do not have a TI waiver at the Bethpage site and just applied ARARs where they were appropriate.

Comment: (Dave Bartenfelder) I agree. There are certain instances where a TI waiver is not needed. However, if you are dealing with an NPL site or a site with no contamination in a waste management area, you need a TI waiver.

Comment: (Sam Brock) It is clear from these comments that we need to discuss how we can accomplish a meaningful conversation about the standard of practice needed to develop a reasonable characterization of a site, as well as RODs that provide achievable Remedial Action Objectives. As PRPs, we do not want open-ended RODs. We need to learn how to write conditional RODs, whether we want them or not, because we are going to have to be able to make conditional progress on sites.

Comment: (Dave Bartenfelder) These are good points. I can think of several options: (1) Preparing an interim ROD; and (2) Having a lot of meaningful dialogue to come to an agreement and understanding with all stakeholders regarding the appropriate amount of information needed for making a decision.

Comment: (Sam Brock) I do not disagree, but not all individuals within organizations have the capability to set up a platform for a dialogue with the stakeholders and navigate regulations. I think we should focus the discussion on how to write guidance that focuses on making progress across the inventory of sites. We can then come to these discussions with better data, a better understanding of what we think we need to do, and achievable objectives. I am hearing a lot of agreement, but also a lot of reluctance in writing such guidance. It is more an issue of understanding rather than disagreement. For example, TI waivers are very specific and mean something different for Superfund than for other programs or agencies.

Comment: (Dave Bartenfelder) You raise a good point. For example, selecting MNA as a remedy, whether as the primary remedy or as a polishing step, requires multiple lines of evidence in place. However, site teams sometimes choose MNA to see how it works. That is not the way the policy was set up. I am not sure how we can address your paradigm. I think we need a discussion on paradigm shifts.

A Private Sector Perspective: Tools and Approaches Utilized by the Private Sector to Address Uncertainty

Mark Ferries provided a private sector perspective on the challenges and opportunities in the remediation management of complex sites.

Mark stated that more corporations seem to be trying to move away from the face of their projects. They understand that they cannot absolve themselves of the liability for the site, and as long as the corporate logo is on the letterhead, they are able to maintain themselves at the front and center from the public, legal community, and regulatory perspective. Corporations are trying to take a step back from the project by obtaining contracts for the site work, with the aim of guaranteed fixed-price contracts. Considering these factors, Mark emphasized the importance of providing incentives for contractors to improve accountability and the alignment of the project team toward the best solution. Corporations are not changing the type of work being conducted, but they are more focused on the endpoint. They are looking for remedial actions and similarities to try to find the strongest resources associated with certain areas.

Question: In your earlier presentation, you mentioned developing a strategic plan for each site and decision tree modeling as an option within the plan. Is it more quantitative or qualitative?

Answer: The decision tree is both quantitative and qualitative. You have to look at different options, but also apply probability and financial impacts and losses. All three are needed for the decision tree. The tree is constructed together with a group and consensus needs to be obtained before moving forward. We try to look at how much it would cost to do what the agencies are asking, and then look at what our options would cost. Finally, we analyze the hybrid. When we go to the negotiation table, we have all the financial facts.

Question: (Laurie Haines) Is there a software program you use?

Answer: We can talk about that later one-on-one.

Question: (Greg Gervais) Acid mine drainage management is very expensive for both regulators and PRPs. Are there some key thoughts you have on how one might strategically deal with acid mine drainage issues?

Answer: Dealing with acid mine drainage issues is site-specific. We have tackled the issue from a lot of different angles. For example, at a site in Colorado, we visited the mountain that contained the source and tried to segregate the areas where the acid mine drainage was forming so we could limit acid generation. We also looked at potentially injecting different types of amendments into the mountain. However, implementing these strategies is difficult from a safety perspective. Lime slurry is widely used for actual acid mind treatment, but it requires a lot of manual labor. At the Colorado site, the ultimate receptor of the acid mine drainage is a set of wetlands. We tried bioremediation in a few areas of the wetlands, but may be ineffective there because of the high altitude. We set up a pilot test of wetlands bioremediation at a mine site located at a lower altitude, and it was more successful. There will still be manual management of the wetlands, but we are moving more toward passive treatment rather than active remediation.

Comment: (Carol Dona) I have seen complex sites where regulators are conducting minimal remediation or saying they are doing something at the site for the sake of public perception, even if they do not plan on cleaning up the site.

Comment: (Dave Bartenfelder) The notion of telling the public that something is being done when it is not is just going to cause more problems.

Comment: (Jim Cummings) I know of no cases in the Superfund program where that is happening.

Comment: (Carol Dona) There are some sites where trying to change the remedy is an arduous process. For example, obtaining a ROD amendment or TI waiver takes a lot of effort. People are finding diverted ways to minimize effort and cost.

Comment: (Mark Ferries) I think it is important to engage with the right level of community leaders regarding remedy changes or transitions. The community needs to understand what is occurring on their site. The site team is not doing 'nothing,' but rather is going through the regulatory process, which can take a lot of time and effort. Trouble arises when you do not take time to educate your stakeholders, particularly community leaders, since they are the first party the community will go to with concerns. If the leaders do not have the accurate information, they may convey incorrect details to the public and that usually does not have a positive outcome.

At our sites, we have gone as far as developing a vision panel and under confidentially agreements, have included business leaders that have an understanding of community's perspective on the site. This allows us to sit down and have frank discussions on what is occurring at the site and receive input on how those activities are being perceived by the community. We then use that information as needed.

Comment: (Greg Gervais) My sense is that there is a lot of inertia when it comes to projects at complex sites, once interventions have reached a certain point. There is a perception that once the site has gone through the regulatory process for implementing the remedy, the cost of making a change in the remedy is not necessarily worth the effort. There are some complex sites where it can be extremely difficult to achieve Remedial Action Objectives, but there is guidance available for the sites where achieving those objectives is not practicable. It is fine to have spirited discussions during direct communication between federal facilities, PRPs, states, and EPA regarding why something needs to change at a site. There are opportunities to raise the bar within the practice. Maybe that is when we get to the point of having a common understanding.

Question: (Richard Mach) As a follow-on question to Greg's comment and Sam Brock's questions on 'smart' RODs with contingencies, how does this work in the Superfund program? Specifically, how does it work in the program when it comes to giving the site to the state after 10 years of remediation?

Answer: (Dave Bartenfelder) A lot of states have come up with the idea of revisiting the remedy, and this is often done in the ninth year. In the last few years, we issued a memo on restarting the clock. When it comes time over the site, some states step back because they then would be responsible for the restoration goal and costs associated with the site. States are financially constrained, so there are sites EPA still pays for that are beyond the 10-year remediation mark.

Comment/ (Beth Moore, DOE) It would be interesting to go back to communities where

Question: Remedial Action Objectives cannot be reached at a complex site. The land and water impacted by the site are resources the community is really concerned about. One could do a quantitative analysis on cleanup costs per gallon of water or pound of soil, and then use those figures as a weighted percentile in the decision-making process. This would really bring the community in as part of the dialogue in making decisions on recalcitrant sites. Have any FRTR participants who have been working on complex sites had to invoke that kind of analysis? If so, where has it been used in the process?

Response: (Dave Bartenfelder) To my knowledge, EPA has not done this type of analysis for groundwater. Vapor intrusion, on the other hand, is a different issue. However, the challenge with vapor intrusion is that while one homeowner may want a mitigation system for their how, another owner or the overall community may not want the federal government on their property.

Question: (Beth Moore) Wasn’t this done for BRAC sites?

Response: (Richard Mach) Every community is different. At active installations, the community less concerned about the cleanup and more concerned about the operations on the base. At BRAC sites, the community is more concerned about the cleanup. At Navy sites near water bodies or resources, people become very concerned. At Army sites that are not near water, there is less concern.

CONCLUSION

Carol Dona concluded the meeting by thanking the meeting organizers and asking FRTR participants to vote on future FRTR meeting topics. The next FRTR meeting will be held on November 6, 2014 at NRC Headquarters in Rockville, Maryland. Carol announced that the FRTR Steering Committee will meet at 8:00am on May 15, 2014 at Potomac Yards and will choose the topic for the next meeting based on participants’ preferences on their voting ballot.