

SHORT COURSES

Short courses will be offered on Sunday, before the Conference begins, and on Wednesday, during the afternoon break in the program. Courses are open to both Conference registrants and nonregistrants. To register, go to www.battelle.org/chlorcon and register on line or use the form on page 72. Note: The maximum discount applies to fees paid by February 26. Prospective course attendees should preregister no later than March 15—classroom space allocations and production of materials will be determined by the number registered for each course by that date. If insufficient registrations are received for a given course by March 15, the course will be canceled, with registrants' fees being transferred to other courses selected by the registrants or refunded. Course registrations will be accepted after March 15 if space is available. Course registration cancellations received by April 1 will be refunded less a \$10 service fee. No refunds will be made after April 1, but paid no-shows will receive all course materials. Substitutions will be accepted at any time, preferably with advance notice.

Handouts for each course will include the instructors' presentation slides and other supporting materials as appropriate to the course, such as references from the literature, reprints, files, or publicly available software.

SUNDAY, MAY 23, 2010

8:00 A.M.–5:00 P.M.

1-hour break at 12:00 for lunch on own

Use of Practical Models to Support Remediation of Chlorinated Solvents

Instructors: Ronald Falta, Ph.D. (Clemson University)
Charles Newell, Ph.D. (GSI Environmental Inc.)
Karen Vangelas (Center for Sustainable Groundwater and Soil Solutions, Savannah River National Laboratory)

Objective: Share knowledge of how publicly available analytical models can be used in combination to address questions site owners and regulators ask about waste sites when making remedy selections and reviewing proposals for remediation. The intended audience includes practicing environmental professionals, regulators, and site owners responsible for closure.

Overview: Used to their fullest, practical tools can provide sound technical answers to common waste site remediation questions and support effective and efficient source and plume remediation. The course will survey a subset of publicly available simulation and data analysis tools that can be used alone or in combination to answer questions such as the following about a waste site. Will source remediation meet site goals? What will happen if no action is taken? Should source and plume remediation be combined? What is the remediation timeframe? What is a reasonable remediation objective? The course will present the unique features of five selected practical models—RemChlor, BIOBALANCE, MAROS, MassFlux Toolkit, and SourceDK—and discuss how those features can support strategy development. During the afternoon session, instruction and hands-on exercises with a subset of the five models will illustrate how to use the tools to answer typical questions everyone asks in regard to cleaning up groundwater units, with emphasis on chlorinated solvent contamination. Course outline:

1. Overview of Groundwater Remediation Approaches and Challenges
2. Survey of Available Tools
3. Discussion of Unique Features of the Five Selected Tools
4. Key Questions and How to Use Analytical Models to Generate Results
5. Hands-On Exercises Using the Tools to Evaluate Site Treatment Options.

Participants are asked to bring laptops and scientific calculators, if possible; the exercises will be worked as teams.

Approaches for the Remediation of DNAPL Sites and Tools for Measuring Mass Flux and Mass Discharge in the Remediation Process (An ITRC Course)

Instructors: Naji Akladiss, PE (Maine Department of Environmental Protection)
Wilson Clayton, Ph.D., P.E., PG. (Aquifer Solutions, Inc.)
David W. Major, Ph.D. (Geosyntec Consultants)
Fred Payne, Ph.D. (ARCADIS)
Grant Carey, M.Eng., P.Eng. (Porewater Solutions)
Alec Naugle (California Regional Water Quality Control Board)
Kimberly Wilson (South Carolina Department of Health and Environmental Control)
Richard Lewis, Ph.D., P.E. (HSA Engineers and Scientists)
Guy Sewell, Ph.D. (East Central University)

Objective: Describe the proper application of new technologies, techniques, and tools able to characterize, monitor, and optimize remediation of sites contaminated with chlorinated solvents (DNAPLs). Developed by the Interstate Technology and Regulatory Council (ITRC), the class is intended for regulators, stakeholders, site owners, and practitioners involved in site remediation.

Overview: This class will cover the important mechanisms affecting in situ bioremediation of DNAPL, collection and use of mass flux and mass discharge information, and optimization of attenuation mechanisms at chlorinated solvent-contaminated sites. The training is based on two Technical and Regulatory

Guidance documents (*In Situ Bioremediation of Chlorinated Ethene: DNAPL Source Zone* [ITRC BioDNAPL-3] and *Enhanced Attenuation of Chlorinated Organics (EACO)* [ITRC EACO-1]) and a special presentation based on *Measurement and Use of Mass Flux and Mass Discharge* (ITRC MassFI-1). Course modules:

1. In Situ Bioremediation (ISB) of Chlorinated Ethenes—*technology background on ISB; requirements that support realistic determination of ISB goals*
2. Tools, Methods and Models for Estimating Mass Flux and Mass Discharge
3. Enhanced Attenuation of Chlorinated Organics: A Site Management Tool—*transition between aggressive remedial actions and MNA; ITRC EACO team decision framework for integrating enhanced attenuation into the remedial decision process*

Participants will not need computers to use during the class.

Phytotechnologies (An ITRC Course)

Instructors: David Tsao, Ph.D. (BP Corporation North America, Inc.)
Eleanor Wehner, P.G. (Texas Commission on Environmental Quality)
Kris Geller (State of New Jersey Department of Environmental Protection)

Objective: Provide an understanding of phytotechnologies and how these green and sustainable technologies can be used to expand site remediation options. The intended audience includes consultants, site owners, regulators, and other environmental professionals searching for proven, yet innovative, methods of dealing with soil and water contaminants.

Overview: Phytotechnologies are a set of technologies that use plants to contain, stabilize, sequester, assimilate, reduce, detoxify, degrade, metabolize and/or mineralize contaminants in soil, groundwater, surface water, or sediments. What has been learned about phytotechnologies in the past few years? Which applications have been successful in remediating contaminated sites and which have not? The Interstate Technology and Regulatory Council (ITRC) asked these questions and determined that a great deal has been learned since the initial publication of documents on this subject in 1999 and 2001. This practical, how-to workshop includes introductory technical information, real-site case study examples, regulatory perspectives, and practice sessions for the participants on using the resources and tools provide in the document. This workshop uses *Phytotechnology Technical and Regulatory Guidance and Decision Trees* (rev. February 2009; ITRC document nbr. PHYTO-3) as a template. The ITRC document is organized along a project lifecycle, making it useful at any stage of a remediation project. This class will provide participants with an understanding of the various mechanisms and applications and the ability to evaluate a particular technology for use at a site. Course outline:

1. Overview of Phytotechnologies
2. Basic Plant Physiology
3. Mechanisms and Applications
4. Phytotechnologies Project Management Requirements—*project structure and organization; site assessment and class exercise; remedy selection and class exercise; design and implementation and class exercise; operation maintenance and monitoring; closure*

Participants will not need computers, but a calculator will be useful during the exercises. Attendees are asked to download the ITRC document before coming to the class; it is available at <http://www.itrcweb.org/guidancedocument.asp?TID=63>.

SUNDAY, MAY 23, 2010
8:00 A.M. –NOON

Building a Better Background Data Set

Instructors: Jonathan Myers, Ph.D., and Karen Thorbjornsen, P.G. (Shaw Environmental, Inc.)

Objective: Provide information about practical approaches for establishing background distributions of constituents in soil, sediment, groundwater, and surface water. The course is recommended for regulatory personnel as well as consultants, site managers, and others with an interest in improving their background studies.

Overview: This course presents practical approaches for establishing background distributions of constituents in soil, sediment, groundwater, and surface water. These methods are applicable to naturally occurring elements and radionuclides, as well as anthropogenic compounds such as polycyclic aromatic hydrocarbons. The course expands on existing regulatory background guidance by including tools for dealing with real-world (nonideal) analytical data: handling nondetects, evaluating outliers, how and when to combine subgroups of data, and extracting background data from existing data sets when the collection of new samples is not an option. The importance of considering geochemistry is emphasized. Incorporating geochemical evaluations of the data, in addition to the purely statistical methods provided in guidance documents, results in more representative background data sets, provides insight into the processes controlling the concentrations, and enhances their utility in site-to-background comparisons. The concepts are illustrated with case studies from the instructors' work on more than 50 background studies across the United States and Puerto Rico. Prior knowledge of statistics is not required. Course outline:

1. Definitions of "Background" and Uses of Background Data
2. Use of Local (Site-Specific) vs. Regional Background Data
3. Background Sampling—*locating background samples; sampling methods*
4. Statistical Data Evaluation—*determining required sample size; statistical characterization of distributions; reporting limits; handling nondetects; outlier tests*
5. Background Screening Values and Site-to-Background Comparisons
6. Geochemical Data Evaluation
7. Comparing Subgroups to Determine the Appropriateness of Combining Their Data—*surface vs. deep soil; different aquifers; different surface-water body types*
8. Evaluating the Effects of Organic Contamination on Natural Metals Concentrations
9. Extracting Background Data from Existing Site Data

Participants will not need computers to use during the class.

Practical Training in the Use of Direct-Push Logging Methods for Site Characterization

Instructors: Thomas M. Christy, P.E.; Wes McCall, P.G.; and Dan Pipp (Geoprobe Systems)

Objective: The purpose of this workshop is to provide training in the use of direct-push logging tools for site investigation. The primary audience for this course will include regulators, project managers, scientists, engineers, and field practitioners who are responsible for effective site characterizations that will be used to define conceptual site models and design remediation programs.

Overview: Direct-push (DP) logging tools are either pushed or driven into the subsurface and are capable of logging some parameters related to soil properties or contaminant distribution. These tools allow the logging of soil behavior type, soil conductivity or resistivity, estimated permeability or hydraulic conductivity, and relative concentration of volatile contaminants with depth. Using various tools, an investigator can develop conceptual site models for lithology, hydrostratigraphy, and VOC distribution that allow for improved design and optimization of subsequent sampling, analysis, and remediation programs. Specific logging methods addressed during this workshop will include electrical conductivity, membrane interface probe (MIP) with heated trunkline, hydraulic profiling (HPT), and cone penetration testing (CPT). This will be a practical workshop with emphasis on the physical tools used to make logs and especially the QA and QC methods that should be specified to control the logging process and ensure quality of the log data. Various probes and associated components will be set up and used for bench demonstration during the workshop. Course participants will learn to identify soil conditions amenable to direct-push logging methods, the information provided by each logging method, and the QA procedures for each tool that should be used prior to logging. The seminar also will review operating procedures for various logging methods, practical field considerations for tool deployment, review of completed logs, and presentation of log data. Course outline:

1. DP logging basics and QA/QC
2. Electrical logs
3. Membrane Interface Probe logs
4. Hydraulic Profiling Tool logs
5. CPT logs
6. Log Interpretation

Participants will not need computers to use during the class.

The SRT™ and SiteWise™ Sustainable Remediation Tools

Instructors: Erica Becvar (U.S. Air Force Center for Engineering and the Environment)
Carol Lee Dona (U.S. Army Corps of Engineers)
Charles Newell (GSI Environmental, Inc.)
Issis Rivadineyra (U.S. Navy)
Russell Sirabian, P.E., PMP, and Mohit Bhargava (Battelle)

Objective: Provide users with the knowledge necessary to apply the tools confidently to site remediation projects, using their understanding of how the tools work and what they calculate. The intended audience includes remedial project managers,

consultants, regulators or anyone interested in either performing sustainability reviews for remediation projects or reviewing sustainability reviews performed by others.

Overview: To support green and sustainable remediation (GSR), the U.S. Department of Defense has developed tools that calculate the environmental footprint of remedial alternatives. One such tool is the Sustainable Remediation Tool (SRT™), developed by the U.S. Air Force Center for Engineering and the Environment (AFCEE) and its partners. Another is the SiteWise™ Tool, developed in a collaborative effort by Battelle, the U.S. Navy, and the U.S. Army Corps of Engineers. These tools, which are free and available to the public, calculate similar metrics, including (1) energy consumption, (2) greenhouse gas (GHG) emissions, (3) air emissions of criteria pollutants, (4) water consumption, and (5) accident risk. Both tools can be used to support decision-making during the remedy selection process as well as to help optimize planned or existing remedies to reduce the overall environmental footprint. The structure and inputs of the two tools are quite different, the SRT™ being technology-based and SiteWise™ being activity-based. Knowledge of both tools allows users to determine which tool best fits their particular situation. Participants will receive detailed training on how to use the tools, the assumptions behind them, and their respective benefits and limitations. Highlights of case studies where the tools were used will be presented along with trends of the findings. Copies of the SRT™ (along with the AFCEE-developed Performance-Tracking Tool and the Uncertainty Analysis Tool) and of the SiteWise™ software will be distributed to participants at the conclusion of the class. Course outline:

1. Description of the tools—*GSR metrics calculated; structure; basis of calculations*
2. Live demonstrations of sustainability evaluations performed with each tool—*description of subject sites; developing inputs; inputting data; discussion of outputs*
3. Case study highlights—*presentation of results; discussion of trends and lessons learned*

Participants will not need computers to use during the class.

Introduction to Groundwater Remediation Geochemistry

Instructor: Bill Deutsch (Geochemistry Services, LLC)

Objective: Enable attendees to better understand subsurface processes that can have a major impact on whether or not remediation is a success. The primary audience is remediation project managers, design engineers, site characterization planners, responsible parties, and regulators.

Overview: Remediation doesn't always proceed as expected—more reagent must be added to reach a desired result; the concentration of an initial contaminant of concern decreases in response to treatment, but the concentration of a new contaminant increases to a level of concern; unanticipated reactions plug the aquifer, reduce the reactivity of a treatment compound, or affect the pH in a detrimental fashion. Remediation may be ineffective because of unforeseen or insufficiently accounted for geochemical processes that occur naturally in the aquifer or are produced by the introduction of treatment chemicals into the aquifer geochemical system. Proper design of a remediation system requires that the basic geochemical processes be understood and taken into account. Site-specific conditions must be determined by an adequate

sampling program. Reactions that treat the contaminant of concern must be evaluated for their individual and interactive impacts on the ambient geochemical system. The anticipated longevity of active remediation and the final environmental condition of the aquifer must also consider the natural system. This course provides an introduction to these topics. Course outline:

1. Information on Geochemical Processes Affecting Remediation—*solution speciation; gas phase exchange; redox; adsorption/desorption; mineral equilibrium; impact of metals on biodegradation*
2. Geochemical Modeling to Simulate Remediation Processes—*conceptual model development; data needs; code types/availability; longevity estimating*
3. Working with Reaction Byproducts That Affect Subsurface Geochemistry—*ZVI; FeS₂ oxidation; CO₂ impact on pH and mineral equilibrium*
4. Advances and Path Forward—*analytical tools; application methods; recalcitrant contaminants*

Participants will not need computers to use during the class.

SUNDAY, MAY 23, 2010
1:00–3:30 P.M.

3-D Visualization of Site Remediation Data: From Site Characterization to Post- Remediation Monitoring

Instructors: Frank Stolfi and Eliot Cooper (Vironex, Inc.)

Objective: Demonstrate how datasets can be integrated into pre- and post-remediation soil and groundwater data, injection performance data, and targeted injection plans. The course is recommended for remediation professionals and regulators who are looking for better ways to present a complex remediation data set to clients and/or stakeholders.

Overview: The Geoprobe Systems® Membrane Interface Probe (MIP) and other subsurface sampling systems are widely known, and many remediation professionals have used it successfully to better define source areas at sites. Because the output is digital, the data can be graphed and presented as 3-D images through software such as Rockworks™ or EVS-Pro. This short course will demonstrate how these datasets can be integrated into pre- and post-remediation soil and groundwater data, injection performance data, and targeted injection plans, and how the result can be used to troubleshoot sites where rebound is occurring. This integration is accomplished by starting with site soil, vapor and groundwater data; overlaying MIP/HPT results; developing a targeted injection plan; storing injection performance and distribution verification data (e.g., EC), and then overlaying post-injection soil and groundwater data and any post-injection MIP troubleshooting data to optimize the next injection event. This model works on mechanical treatment systems as well. Visualization in 3-D is important also for gaining regulatory approval for moving into an MNA program while turning off existing remediation systems (e.g., pump-and-treat) because this requires compelling documentation that source mass has been reduced. Pre- and post-remediation groundwater and soil data, supported by MIP/HPT and presented through

3-D visualization is an excellent approach to support the MNA objective. Course outline:

1. Fundamentals of EVS-Pro software and Explanation of Modeling Assumptions
2. Fundamentals of MIP/HPT Technology
3. Visualization in 3-D of Site Data (Pre- and Post-Injection)—*groundwater, soil, vapor, MIP, EC, HPT, injection logs*
4. Chlorinated Solvent Site Case Study

Participants will not need computers to use during the class.

SUNDAY, MAY 23, 2010
1:00–5:00 P.M.

Geochemical Evaluations of Metals in Environmental Media: How to Distinguish Naturally Elevated Concentrations from Site-Related Contamination

Instructors: Karen Thorbjornsen, P.G., and
Jonathan Myers, Ph.D. (Shaw Environmental, Inc.)

Objective: Provide practical geochemistry-based approaches for identifying metals contamination in soil, sediment, groundwater, and surface water. Course is intended for regulatory personnel, consultants, and site managers.

Overview: Do you really have metals contamination at your site? Metals concentrations in environmental media often exceed screening criteria, but they may be naturally elevated. It is well known that trace elements naturally associate with a limited number of minerals in soil or sediment (or with specific suspended particulates in groundwater and surface water) under a given set of environmental conditions. In most oxic soils, for example, arsenic and vanadium are almost exclusively associated with iron oxide minerals at consistent ratios. These processes result in positive correlations between specific trace vs. major element concentrations, which can be visualized with scatter plots. Contaminated samples are identified by their anomalously high elemental ratios relative to uncontaminated samples. For groundwater and surface water, additional factors considered include pH, redox effects, aqueous complexation, salinity gradients, and (for groundwater) well construction materials. Unlike a purely statistical approach, geochemical evaluation greatly reduces the probability of falsely identifying contamination; does not require a statistically valid background dataset; identifies contaminated locations, thereby focusing remediation; and provides mechanistic explanations for elevated concentrations. During this course you'll learn geochemical evaluation techniques that use existing data to distinguish natural metals concentrations from potential contamination, without performing geochemical modeling or adding significantly to project cost. Insightful case studies are drawn from the instructors' work at hundreds of investigation sites across the U.S. and its territories. The material is presented in an accessible style, and prior knowledge of geochemistry is not required. Course outline:

1. Standard Techniques for Dealing with Inorganics Data: The Limitations of Purely Statistical Approaches
2. Geochemical Mechanisms Controlling Trace Element Concentrations in Solid and Aqueous Media

3. Preparation and Interpretation of Geochemical Correlation Plots and Elemental Ratio Plots
 4. Supporting Lines of Evidence
 5. Case Studies of the Successful Application of Geochemical Evaluations
 6. Worst-Case Scenarios
 7. How and When to Apply Geochemical Evaluations
 8. Successful Presentation of Geochemical Evaluations to Regulatory Agencies and Project Teams.
- Participants will not need computers to use during the class.

Striking a Sustainable Balance: A Practical Guide to Successfully Implementing Greener Remediation Solutions

Instructors: Kurt A. Beil, P.E.; Suthan S. Suthersan, P.E.; Eric M. Nichols, P.E.; and Alexis M. Troschinetz, P.E. (ARCADIS)

Objective: Provide site owners, practitioners, and regulators with a practical understanding of green and sustainable remediation, the regulatory context for applying sustainable solutions, and the framework and challenges to sustainable remediation.

Overview: Methods for implementing greener remediation strategies will be presented, including how to quantify and measure sustainability metrics within environmental solutions. The course will offer guidance on incorporating sustainability analyses into remedy selection, along with more conventional elements, to achieve environmentally, economically, and socially balanced decision-making. The course will begin by defining sustainability and green remediation. Subsequently, the current state of the practice and a detailed look at the overall framework for implementing greener remediation strategies will be presented. Topics will include methodologies for implementing sustainable solutions, regulatory perspectives, and an overview of the challenges that lie ahead within the rapidly evolving practice of greener remediation. Once the principles have been established, the course will transition to guidance on the practice and application of sustainable remediation concepts, including life-cycle considerations for remediation projects; a comprehensive overview of sustainability metrics and criteria; methods for analyzing, calculating, and quantifying sustainability variables; aggregation of the diverse sustainability metrics; weighting of metrics; and incorporation of sustainability analyses into remedy selection, optimization, and environmental portfolio management. Case studies will be used throughout the course to provide real-world, practical examples of applied sustainability analyses. The course will conclude with a demonstration of the **Balance₃**[™] tool, a powerful quantitative model to assess the sustainability of remedial programs and remedial alternatives. Course outline:

1. Overview of Sustainable Remediation—*definitions and variations of green and sustainable remediation; practical application of greener strategies; “The Green Zone” (confluence of environmental, economic, and social sustainability)*
2. State of the Practice of Green and Sustainable Remediation—*methods for evaluating and applying green and sustainable remediation; development of green remediation standards of practice; technical focus and development areas; U.S. EPA, state and regional regulatory overview and context; new frontiers*

3. Implementation of Green and Sustainable Remediation—*application framework for green and sustainable remediation; evaluation criteria and metrics; quantification of sustainability variables; applied sustainable analysis*
4. Balance₃[™]: A Comprehensive Tool for Implementing Greener Remedial Solutions—*overview of quantitative model and tool capabilities; example applications and case studies; remedy selection, optimization, management*

Participants will not need computers to use during the class.

New Tools and New Approaches to Improve the Assessment and Evaluation of Monitored Natural Attenuation (MNA) of Organic Compounds in Groundwater

Instructors: John Wilson, Ph.D. (U.S. EPA)
Barbara Wilson (Consultant)
Todd Wiedemeier (T.H. Wiedemeier & Associates, LLC)

Objective: Provide an overview of appropriate applications and current good practice for MNA. This course is intended for environmental practitioners with limited background in applications of MNA, as well as for experienced engineers and geologists with little background in the new tools that are now available.

Overview: In the more than 10 years since publication of the U.S. Air Force and U.S. EPA technical protocols for evaluating Monitored Natural Attenuation, MNA has found widespread application to organic contaminants in groundwater. However, the science has moved on. This course will review the U.S. EPA's expectations for the appropriate applications of MNA as well as current good practice for the use of geochemical footprints and mathematical modeling to recognize and characterize natural attenuation processes. Then the course will summarize and integrate the new science, including (1) recent discoveries concerning abiotic processes that degrade of chlorinated organic compounds, (2) the application of compound-specific stable isotope analysis to document the degradation of organic contaminants at field scale, (3) the use of stable isotope probes to document the capacity for biodegradation of organic contaminants in groundwater, and (4) the application of molecular biological tools to identify and enumerate organisms in groundwater that can degrade contaminants. The course will introduce a new statistical approach to analyze long-term monitoring data to determine whether a site is on track to meet a cleanup goal. Case studies will be presented to tie it all together and illustrate the path to success and pitfalls to avoid in the implementation of MNA. Course outline:

1. Review of Established Principles and Procedures—*U.S. EPA's expectations for the appropriate applications of MNA; use of geochemical footprints to recognize natural attenuation processes; use of mathematical modeling to recognize (forecast) natural attenuation processes*
2. New Science and New Tools—*abiotic processes that degrade chlorinated organic compounds; use of stable isotope analysis and stable isotope labeling; molecular biological tools to enumerate organisms that can degrade contaminants*
3. New Approaches and Established Good Practice—*statistical approach to determine whether a site is on track to meet a cleanup goal; case studies to illustrate the path to success and pitfalls to avoid.*

Participants will not need computers to use during class.

WEDNESDAY, MAY 26, 2010
1:00–5:00 P.M.

Groundwater Remediation at Complex Sites: Alternative Endpoints and Strategies

Instructors: Rula A. Deeb, Ph.D., BCEEM; Elisabeth Hawley, P.E.; and Michael C. Kavanaugh, Ph.D., P.E. (Malcolm Pirnie, Inc.)
Herb Levine (U.S. EPA, Region IX)
Thomas Sale, Ph.D. (Colorado State University)

Objective: Improve understanding of the underlying limitations and tradeoffs of complete restoration, alternative endpoints and strategies, tools and lines of evidence used to evaluate them, and other related topics. Course would be useful for DoD project managers, DoD contractors, other environmental consultants, and federal and state regulators.

Overview: This course will describe a variety of alternative endpoints and perspectives for groundwater remediation at complex sites. Alternative endpoints include formal designations under CERCLA, RCRA, and state cleanup programs such as technical impracticability waivers and other ARAR waivers, ACLs, and similar approaches used by states. Alternative perspectives include remedial approaches that clearly state non-traditional expectations without changing the long-term remedial endpoint (e.g., approval of MNA over a long timeframe, use of shorter-term technology-specific goals, low-threat or conditional closures). Workshop presentations and group discussion will cover a variety of alternative endpoints and perspectives, situations where they may be applicable to site groundwater, and case studies illustrating how these designations are implemented in practice. For example, at Watervliet Arsenal (WVA), an adaptive site management strategy was used to address chlorinated solvents present in fractured rock. Corrective measures included five years of permanganate injections, post-injection rebound monitoring, long-term monitoring, and pre-determined decision points. WVA is applying for a determination of ACLs. At least 13 states have programs that allow for containment zones, groundwater management zones, and classification exemption areas. Several case studies of groundwater management zones will be presented. Course outline:

1. Overview and Perspectives on Groundwater Restoration
2. Subsurface Transport and Remediation: Emerging Concepts and Implications
3. Group Discussion 1
4. Regulatory Policies and Perspectives on Alternative Endpoints
5. Case Studies
6. Group Discussion 2

Participants will not need computers to use during the class.

High-Resolution Site Characterization

Instructors: Beth L. Parker, Ph.D. and Steven Chapman, P.E. (University of Guelph)
Seth Pitkin and Mike Rossi (Stone Environmental, Inc.)
Joe Fiacco (ERM)

Objective: Provide the foundation for application of successful high-resolution site characterization, from the background and theory, through the tools and techniques required, including application of numerical models, to case studies showing practical applications.

Overview: The successful evaluation of risk and application of remedial technologies and strategies at sites contaminated with chlorinated solvents requires an adequate knowledge of subsurface conditions such as the distribution of contaminant mass, the phases in which the mass is distributed, and the characteristics of the geologic media in which the mass exists. Lack of such knowledge is the largest source of uncertainty in a subsurface investigation and the primary reason why many remedies are unsuccessful. This uncertainty is a direct result of geological heterogeneity and the attendant spatial variability of key variables in the subsurface. An adequate investigation, then, is one that is designed and implemented in accord with the spatial structure of the contaminant mass distribution and the hydrogeological factors that control the fate and transport of that contaminant mass. These factors include hydraulic conductivity, capillary pressure, hydraulic gradients, organic carbon, and geochemical conditions that control degradation, both biotic and abiotic. All of these factors vary over short distances in three dimensions. Most investigations are not designed to assess the degree of spatial variability that is commonly present. Over the past decade, a variety of tools and techniques have been developed that can assist investigators in developing an adequate understanding of the nature of the contaminated subsurface system. Course outline:

1. Introduction and Overview
2. Historical Overview of the Investigation and Remediation of Sites Contaminated with Chlorinated Solvents
3. Mass Distribution, Dual-Porosity Media, and Diffusion
4. Challenges to Remediation
5. What is High-Resolution Site Characterization?
6. The Integrated Toolbox and Collaborative Data—*direct-push tools (direct-sensing, sampling); analytical chemistry; bedrock and the discrete fracture network approach; modeling*
7. Case Studies and Practical Applications
8. Summary and Conclusions

Participants will not need computers to use during the class.

Remediation Optimization: State of the Process (An ITRC Course)

Instructors: Tom O'Neill (New Jersey Department of Environmental Protection)
Ning-Wu Chang, Ph.D. (California Environmental Protection Agency/Department of Toxic Substances Control)
Sriram Madabhushi (Booz Allen Hamilton)
Javier Santillan, Ph.D., and Erica Becvar (U.S. Air Force Center for Engineering and the Environment)

Objective: Introduce two new ITRC initiatives that promote overall optimization of remedial activities—remediation risk

management and green and sustainable remediation. Course will be useful for regulators, site owners, practitioners, and stakeholders.

Overview: Remediation process optimization (RPO) is the systematic evaluation and enhancement of remediation to ensure that human health and the environment are protected over the long term at minimum risk and cost. New advancements and tools improve the RPO process. This class, developed by the Interstate Technology Regulatory Council (ITRC), will detail advancements in RPO and performance-based environmental management and present information about new tools to more effectively achieve optimization at sites. Course outline:

1. Remediation Process Optimization—*site selection criteria, building the team, developing a conceptual site model, exit strategy assessment, evaluating remedial action objectives and remedy performance, monitoring programs, cost-efficiency assessment, schedules, other RPO considerations*
2. Performance-Based Environmental Management—*the strategic, goal-oriented methodology that is implemented through effective planning and decision logic to reach desired end-state of site cleanup*
3. Remediation Process Optimization Tools—*case study examples focusing on comprehensive evaluation of an entire restoration program for optimization, including demonstration of analysis tools*
4. Remediation Risk Management—*managing uncontrollable project activities or circumstances that may result in negative consequences to remediation system performance*
5. Green and Sustainable Remediation—*a holistic approach for protecting human health and the environment during the remedy selection and implementation process by ensuring that overall sustainable and green approaches are considered*

Participants will not need computers to use during the class.

In-Well Stripping/Recirculation and Two-Phase Extraction Methods: Applications and Enhancements for Groundwater and Soil Remediation

Instructors: Mehmet Pehlivan, P.G., CHG (Bays Environmental Remediation Management)
James A. Jacobs, P.G., CHG, REA II (Environmental Bio Systems)
Philip Mihopoulos, Ph.D. (MACTEC Engineering and Consulting)

Objective: Provide an understanding of how two-phase extraction can be applied as an in-well stripping and recirculation method without removing and treating water on site. Such information supports the intelligent evaluation of in-well stripping, two-phase extraction and recirculation systems, design and selection criteria, and the application of these systems in conjunction with other remediation methods. Workshop is intended for project managers, consultants, geologists, hydrogeologists, engineers, and industry, agency, and government representatives who perform or evaluate cleanup techniques.

Overview: The course will begin with a brief discussion of in-well stripping and two-phase extraction; a fundamental description of two-phase flow application in groundwater

remediation; an overview of the differences between two-phase extraction, multiphase extraction, dual-phase extraction, soil vapor extraction, and bioventing. An overview of existing two-phase extraction and in-well stripping/recirculation methods (both proprietary and nonproprietary) will be presented, along with known case studies, literature reviews, and the effectiveness of these methods for varying subsurface conditions and chemical compounds. A display model of a two-phase extraction and in-well stripping method will be shown to attendees, and different flow regimes created under two-phase extraction will be discussed with their significance in stripping efficiency. The course will also provide information on how to design piping to reduce friction losses, how to collect vapor and water samples from a two-phase flow, and how to measure air-to-water ratio to assess stripping efficiency. Design case scenarios will be presented, and attendees will have the opportunity to consider blower sizes, pump sizes, and other factors. Case studies will be presented on several sites contaminated with petroleum hydrocarbons including MTBE, chlorinated hydrocarbons, and/or LNAPL and encompassing a variety of lithological units. A cost discussion of two-phase extraction and in-well stripping methods as a stand-alone remedial technology or as a supplement to chemical oxidation or other in situ methods will be presented. The optimal range for each of those technologies will be discussed in terms of site characteristics, contaminant properties, contaminant concentrations, and clean-up goals. Attendees are encouraged to bring their project information for discussion. Course outline:

1. Course Introduction—*in-well stripping and two-phase extraction; comparisons with other extraction approaches*
2. Overview of Two-Phase Extraction and In-Well Stripping/Recirculation Methods
3. Piping and Sample Collection Design Issues
4. Case Studies
5. Cost Factors
6. Factors in Selection of Technology

Participants will not need computers to use during the class.

Applications of Stable Isotopes in Environmental and Forensic Geochemistry Studies, with Emphasis on Chlorinated and Recalcitrant Compounds

Instructor: Paul Philp, Ph.D. (University of Oklahoma)

Objective: Present an introduction to stable isotope geochemistry and discuss applications of stable isotopes to various environmental problems, with emphasis on chlorinated and recalcitrant compounds. This course is appropriate for chemists, geologists, engineers, and regulators who need information on application and utilization of stable isotopes to environmental problems.

Overview: Stable carbon and hydrogen isotopes have been used for many decades in the petroleum industry, and most applications of stable isotopes to environmental problems have been limited to the use of carbon and, to a lesser extent, hydrogen isotopes. However, the development of combined gas chromatography-isotope ratio mass spectrometry (GCIRMS) has led to a virtual explosion in applications of this technique in the environmental and forensic geochemical fields. Efforts are being made to introduce the use of chlorine isotopes as an additional tool for monitoring chlorinated compounds. The methodology

will be discussed along with problems associated with the use of chlorine isotopes. Topics will include the concept of stable isotopes, particularly those of carbon, hydrogen, and chlorine. Techniques for determining bulk isotope values will be described, along with the advantages and disadvantages of the GCIRMS approach. Examples will be given of the use of bulk isotope data combined with other techniques (e.g., GC or GCMS) for the purpose of determining whether or not contaminants are related to each other. This is particularly important where there might be multiple sources potentially responsible for a particular spill and it is necessary to see whether any of them were actually responsible for the spill. In cases where the contaminant has multiple components, and the GC and GCMS data are not particularly useful for correlation purposes, it may be that the only means of determining relationships between source and product is through the stable isotopes of individual compounds. GCIRMS is also extremely valuable for single-component contaminants, such as PCE, where GC and GCMS will be of no use for correlation. The instructor will provide detailed discussion of published examples of GCIRMS having been used to both differentiate sources of PCE/TCE and to study natural attenuation at the contaminated sites. Recent developments in reactive-transport models incorporating isotope data to model the fate of chlorinated compounds in groundwater plumes will be considered. Stable isotopes have begun to play an important role in vapor intrusion studies, primarily for correlation of indoor-air contaminants with sub-slab sources of contaminants. This correlation is an extremely interesting challenge primarily because of the many household sources for many of the contaminants commonly found subsurface. Preliminary work has shown that some of these household contaminants can be distinguished on the basis of their isotopic compositions. Finally, the combined use of stable isotopes, GC, and GCMS can be extremely valuable for monitoring remediation as well as determination of the onset of natural attenuation. Recent efforts to incorporate stable isotope data into fate-and-transport models to predict extent of natural attenuation will be discussed. Course outline:

1. Concept of Stable Isotopes
2. Techniques for Determining Bulk Isotopic Values
3. Combining Bulk Isotopic Data for Multiple-Component Contaminants with Data Derived from Other Methodologies (e.g., GC, GCMS)
4. Single-Component Contaminants
5. Using Isotopic Data to Model Fate of Chlorinated Compounds in Groundwater Plumes
6. Role of Stable Isotopes in Vapor Intrusion Studies
7. Using Fingerprinting Techniques for Monitoring Remediation and Natural Attenuation

Participants will not need computers to use during the class.

DNAPL Remediation Decision-Making Based on Cost-Risk-Benefit Analysis

Instructors: Grant R. Carey (Porewater Solutions; University of Guelph)
Edward A. McBean, Ph.D. (University of Guelph)

Objective: Provide information on various methods that can be used to compare the cost-risk-benefit of DNAPL source treatment and source containment alternatives. The content will be of interest to consultants, environmental managers,

regulators, and other stakeholders engaged in making decisions on the remediation of DNAPL source zones.

Overview: Deciding how practicable DNAPL source treatment will be is challenging because of the inherent uncertainty in predicting the timeframe and the efficiency of source remediation. This course will provide a decision-support framework that employs methods for quantifying (a) target goals for reduction in mass discharge from the source zone to the downgradient aqueous plume; (b) source mass depletion required to achieve the target reduction in mass discharge; (c) remediation timeframe estimates; (d) range of technology-specific mass discharge reduction that may occur based on site-specific source architecture and geologic heterogeneity; and (e) lifecycle cost analysis for various treatment and containment alternatives. After this seminar, participants will be able to: list the most important site features that should be characterized prior to a DNAPL source remediation cost-risk-benefit analysis; describe how the ganglia-to-pool ratio (GTP), source age, heterogeneity, and back diffusion can influence remedial efficiency and remediation timeframe; list at least three field investigation techniques that can facilitate an evaluation of the source architecture and degree of geologic heterogeneity at a site; calculate the remedial action objective for mass discharge reduction at a site, and estimate the range of source mass depletion required to accomplish this goal; estimate a site-specific range of source mass depletion and mass discharge reduction that can be achieved with various DNAPL remediation technologies; select an appropriate model and qualify the uncertainty in predictions of remediation timeframe for natural gradient dissolution and active remediation based on historical analytical data collected downgradient from the source zone; use the electronic spreadsheet and unit cost summary provided in the course to compare lifecycle costs for various source treatment and containment alternatives; evaluate the quantitative and qualitative benefits associated with site-specific DNAPL remediation and discuss key areas of uncertainty involved with this type of analysis; and make more informed decisions about the potential benefits and limitations involved with DNAPL source remediation. Participants will receive a CD containing some of the analytical tools used for predicting remediation timeframe and lifecycle costs. Course outline:

1. Influence of source architecture and geologic heterogeneity on remediation performance
2. Quantifying the remedial action objective for mass discharge
3. Quantifying the range of mass discharge reduction that can be expected for various technologies and site-specific conditions
4. Overview of Remediation timeframe prediction
5. Overview of lifecycle cost analysis
6. Cost-Risk-Benefit Analysis Exercises for Various Site Scenarios

Participants are asked to bring laptops, if possible; the exercises will be worked in teams.