



## Welcome to ITRC's Internet-based Training – *Surfactant/Cosolvent Flushing Of DNAPL Source Zones*

Thank you for joining us. Today's training focuses on the ITRC Technical and Regulatory Guidance Document entitled:

### **"Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing Of DNAPL Source Zones"**

The training is sponsored by: ITRC EPA Office of Superfund  
Remediation and Technology Innovation

***Creating Tools & Strategies to Reduce  
Technical & Regulatory Barriers for the  
Deployment of Innovative Environmental  
Technologies***

### **Surfactant/Cosolvent Flushing of DNAPL Source Zones**

Surfactant/cosolvent flushing involves the injection and subsequent extraction of chemicals to solubilize and/or mobilize dense, nonaqueous-phase liquids (DNAPLs). The chemical flood and the solubilized or mobilized DNAPL are removed through extraction wells, and the liquids are either disposed or treated on site. This is a mature technology in the petroleum-engineering field, supported by decades of research and field tests.

Environmental applications have become more common in recent years. The technology has been shown effective for several DNAPL types, including spent degreasing solvents (TCE and TCA), dry cleaning solvents (PCE), heavy fuel oils, and coal tar/creosote. Lab work has demonstrated applicability to PCB-containing mineral oils. The primary appeal of the technology is its potential to quickly remove a large fraction of the total DNAPL mass. Technical challenges include locating and delineating the DNAPL source zone, estimating the initial DNAPL mass and spatial distribution, characterizing the hydraulic properties of the aquifer, delivering and distributing the injected chemicals to the targeted zone, and designing the optimum chemical formulation for a given DNAPL composition and soil type. Typical concerns include the cost of disposal of the effluent, regulatory permitting for underground injection of tracers or flushing agents, the overall impact of unremoved DNAPL, and the expertise of the personnel involved in site remediation.


This training familiarizes participants with ITRC's *Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones* (DNAPL-3, 2003), which provides technical and regulatory information to help people understand, evaluate and make informed decisions regarding potential surfactant/cosolvent flushing projects. Included are a description of the technology, system operation, performance assessment, regulatory considerations, stakeholder concerns, case studies, and technical references.

ITRC (Interstate Technology and Regulatory Council) [www.itrcweb.org](http://www.itrcweb.org)

Training Co-Sponsored by: EPA Technology Innovation Program (TIP) [www.clu-in.org](http://www.clu-in.org)


ITRC Course Moderator: Mary Yelken ([myelken@earthlink.net](mailto:myelken@earthlink.net))

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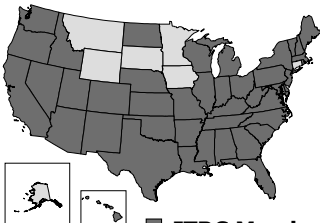


## ITRC – Shaping the Future of Regulatory Acceptance

- Documents
  - Technical and regulatory guidance documents
  - Technology overviews
  - Case studies
- Training
  - Internet-based
  - Classroom
- Network
  - State regulators
  - Federal government
  - Industry
  - Consultants
  - Academia
  - Community stakeholders




Host Organization 

ITRC State Members



■ ITRC Member State

Federal Partners

**DOE      EPA      DOD**

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of more than 40 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network approaching 7,500 people from all aspects of the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at [www.itrcweb.org](http://www.itrcweb.org). Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.



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## ITRC – Course Topics Planned for 2005

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### New in 2005

- Environmental Manag. at Operational Outdoor Small Arms Ranges
- Guidance for Using Direct-Push Wells
- In Situ Chemical Oxidation – Advanced Course
- Mitigation Wetlands
- Permeable Reactive Barriers: Lessons Learn and New Direction
- Radiation Site Cleanup
- Unexploded Ordinance Site Investigation/Site Remediation
- More in development.....

### Popular courses from 2004

- Alternative Landfill Covers
- Characterization and Remediation of Soils at Closed Small Arms Firing Ranges
- Constructed Treatment Wetlands
- Geophysical Prove-Outs
- Performance Assessment of DNAPL Remedies
- Radiation Risk Assessment
- Remediation Process Optimization
- Surfactant/Cosolvent Flushing of DNAPLs
- Triad Approach

Training dates/details at: [www.itrcweb.org](http://www.itrcweb.org)

Training archives at: <http://clu.in.org/live/archive.cfm>

More details and schedules are available from [www.itrcweb.org](http://www.itrcweb.org) under “Internet-based Training.”


## Surfactant/Cosolvent Flushing Of DNAPL Source Zones

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### Presentation Overview

- Introduction
- Description and Overview
- Geological & Chemical Issues
- Questions and answers
- Process Design & Implementation
- Regulatory, Health & Safety, Stakeholder
- Questions and answers
- Links to additional resources
- Your feedback

### Logistical Reminders

- Phone Audience
  - Keep phone on mute
  - \* 6 to mute your phone and \* 7 to un-mute
  - Do NOT put call on hold
- Simulcast Audience
  - Use  at top of each slide to submit questions
- Course Time = 2.25 hours
- 2 Question & Answer Periods
- Links to Additional Resources
- Your Feedback

No associated notes.



## Meet the ITRC Instructors



- Eric Hausamann
- New York State DEC
- Albany, New York
- (518) 402-9759
- eghausam@gw.dec.state.ny.us



- John Londergan
- Intera, Inc.
- Austin, TX
- (512) 425-2028
- jlondergan@intera.com



- Mark Hasegawa
- Hasegawa Engineering
- Alberta, Canada
- (403) 328-2686
- hasmark@telusplanet.net

**Eric Hausamann** is an environmental engineer with the New York State Department of Environmental Conservation (NYSDEC). For the past 5 years, he has worked in the Division of Environmental Remediation advising staff on the selection and implementation of innovative technologies. Prior to working for NYSDEC, Mr. Hausamann worked in the hazardous waste remediation field as a consultant to industry. Eric received a B.S. in Mechanical Engineering from the University at Buffalo and a M.S. in Environmental Engineering from the SUNY College of Environmental Science and Forestry in Syracuse. He has been a member of the ITRC since 1998 and currently leads the DNAPLs Team. Under his leadership, the team has produced four documents on technical and regulatory issues relating to DNAPL site cleanup and continues to serve as a forum for the open exchange of fact and opinion on the topic of DNAPL source remediation.

**John T. Londergan** has 17 years of technical and managerial experience performing environmental investigations and managing regulatory compliance at DOE, DOD, industrial, and commercial facilities. He has served as a senior hydrogeologist with INTERA, Inc. in Austin, Texas since 1993. He has a BS in Geology from the University of Massachusetts at Amherst and an MS in Geophysics from Texas A&M University, with a specialization in Hydrogeology under Dr. Pat Domenico. For the past ten years he has specialized in NAPL source zone characterization, remediation, and remediation performance assessment, and has been involved in the development and deployment of innovative NAPL characterization and remediation technologies.

**Mark A. Hasegawa** is an Associate with Hasegawa Engineering Ltd. in Lethbridge, Alberta. He has a BS in Civil Engineering from Brigham Young University and a MS in Environmental Engineering from the University of Oklahoma, with a specialization in Process Design and Surfactant Chemistry under Dr. David Sabatini. While at the University of Oklahoma, Mark was selected to teach two courses: the introduction to water chemistry and computer assisted engineering analysis. Mark has worked in the environmental remediation field for 10 years and has specialized in NAPL/DNAPL remediation, and process design, and has been involved in the development and deployment Surfactant Enhanced Subsurface Remediation. Mr. Hasegawa has supervised over 10 surfactant enhanced NAPL remediation projects including several DNAPL sites which include: McClellan AFB, Alameda Naval Air Station, a Chemical Plant in Michigan, Dover AFB, and Tinker AFB. Mark was project manager for the aforementioned project and supervised process design for each project. He has extensive experience in performing risk analysis at sites and has supervised the completion of numerous site specific risk assessments. He was also one of three approved trainers utilized by the state of Oklahoma to train consultants on the implementation of Risk Based Corrective Action in the state. Mark is also a registered professional Engineer in several states and provinces. In addition, he has co-authored several peer-reviewed papers and presented on various DNAPL and risk assessment topics at numerous conferences. Mr. Hasegawa currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).



## Technology Description and Overview



Eric Hausamann

**Eric Hausamann** is an environmental engineer with the New York State Department of Environmental Conservation (NYSDEC). For the past 5 years, he has worked in the Division of Environmental Remediation advising staff on the selection and implementation of innovative technologies. Prior to working for NYSDEC, Mr. Hausamann worked in the hazardous waste remediation field as a consultant to industry. Eric received a B.S. in Mechanical Engineering from the University at Buffalo and a M.S. in Environmental Engineering from the SUNY College of Environmental Science and Forestry in Syracuse. He has been a member of the ITRC since 1998 and currently leads the DNAPLs Team. Under his leadership, the team has produced four documents on technical and regulatory issues relating to DNAPL site cleanup and continues to serve as a forum for the open exchange of fact and opinion on the topic of DNAPL source remediation.

## The DNAPL Problem

- Cleaning up contaminated sites with dense-non aqueous-phase liquids (DNAPLs) present one of the biggest challenges in the environmental remediation field.
- There's a presumption, in some situations, that aquifer restoration is not feasible when DNAPLs are present.
- The issue of feasibility and arguments for and against remediating DNAPL source areas are the focus of a recent document entitled *DNAPL Source Reduction: Facing the Challenge* (ITRC, 2002).

**Surfactant/Cosolvent Flushing is one of the technologies that treats DNAPL source zones.**

No Associated Notes



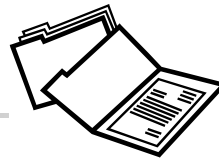
## What will you learn from this course?

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- Basics of surfactant/cosolvent flushing technology
- Applications and limitations of the technology
- Steps that must be taken to delineate DNAPL source zone characterization prior to design, installation, and operation
- Design and operational issues
- Regulatory requirements, health and safety issues, stakeholder issues

No associated notes



- Technology Description and Overview
- Geological Design Considerations and Issues
  - Geosystem Model
  - DNAPL Source Zone Delineation and Characterization
  - Aquifer Properties Characterization
  - Laboratory Studies/Chemical Selection
- Process Design and Implementation
  - Mixing/Injection Issues
  - Extraction System Issues
  - Monitoring and Sampling
- Regulatory Requirements, Health and Safety Issues, Stakeholder Issues

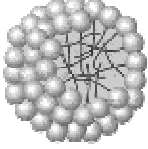
No associated notes

## Key Concepts/Definitions

- DNAPL - dense, non-aqueous phase liquid; DNAPL entry location is where the liquid entered the subsurface
- DNAPL zone - is the volume of pore space in the subsurface contaminated with DNAPL (also called "source" or "source zone")
- saturation - fraction of the soil pore volume that is filled with DNAPL
- capillary barrier - geologic unit that impedes migration of DNAPLs due to the small size of its pore spaces; it should be of substantial thickness and  $k < 10^{-6}$  cm/sec

No associated notes

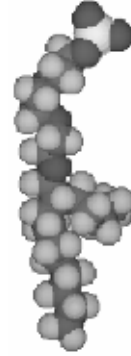
## Key Concepts/Definitions (Cont'd)

- mobility control – the ability to direct fluid flow into less permeable/accessible zones in the subsurface via the use of water-soluble polymers, gels or surfactant-based foams
- wettability - affinity of one immiscible fluid for a solid surface in the presence of a second or third immiscible fluid
- micelle - aggregations of surfactant monomers
 
- microemulsion - thermodynamically stable swollen micellar solution, i.e., contaminant and water molecules partitioned into the center of a micelle.
- SEAR – surfactant-enhanced aquifer remediation.

No associated notes

## What are Surfactants?

- The term “surfactant” is a short way of saying surface active agents.
- A surfactant is a molecule composed of a hydrophilic (water loving) **head with a salt complex** and a hydrophobic (water fearing) **tail with a hydrocarbon chain**.
- Surfactants are compounds that alter the properties of organic-water interfaces.
- Surfactants solubilize and/or mobilize zones containing DNAPL.

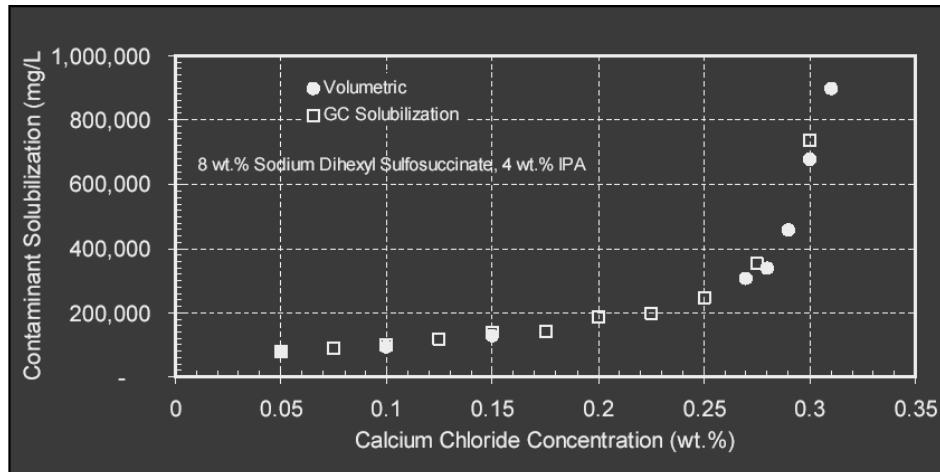


Soap is a common example of a surfactant

Like soaps, surfactants used to mobilize DNAPLs can cause foaming when exposed to surface air

## How Surfactants Work: Solubilization

- Surfactants can enhance contaminant solubilization



No associated notes

## What are Cosolvents?

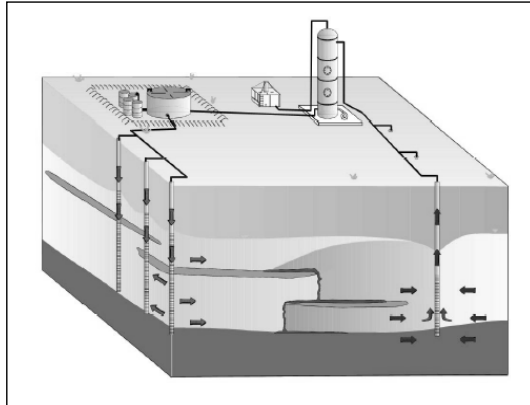
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- Cosolvents are similar to surfactants in that they also alter the properties of solution interfaces.
- Cosolvents are commonly alcohols such as ethanol, methanol, and isopropanol.
- Cosolvents are often combined with surfactants to improve flood performance.

No associated notes

## What is Surfactant/Cosolvent Flushing?

- It is a DNAPL-removal technology that involves the injection and subsequent extraction of chemicals to solubilize and/or mobilize DNAPLs.
- The produced liquids are then either disposed off-site for treatment, or treated on site to remove contaminants and then reinjected to remove additional mass.



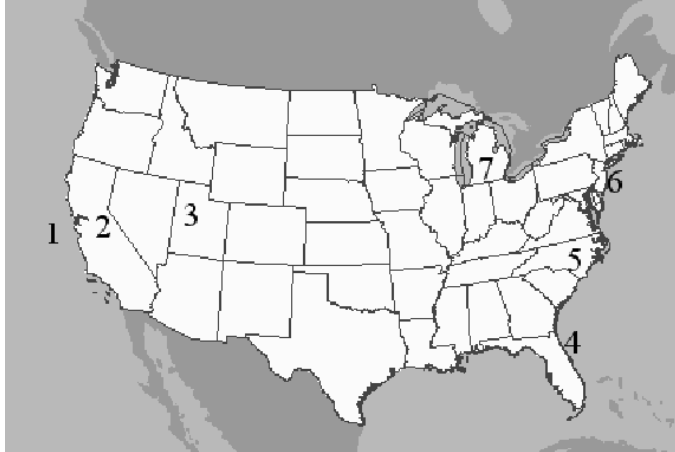
**The appeal of surfactant/cosolvent flushing is its potential to quickly remove a large fraction of the total DNAPL mass.**

No associated notes



## Where Has This Technology Been Implemented?

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1. **Alameda Naval Air Station (NAS)\***
2. **McClellan Air Force Base (AFB)**
3. **Hill AFB\***
4. **Sages Dry Cleaners\***
5. **Marine Corp Base Camp Lejeune\***
6. **Dover AFB**
7. **Spartan Chemical Co.\***

\*Case summaries are provided in the ITRC  
Surfactant/Cosolvent Technical Guidance Document

No associated notes

## Applicability

### Relative Applicability as it Relates to Different Geologic Environments

#### Less Heterogeneous

<b>High Permeability</b> (sand and gravel, $>10^{-3}$ cm/sec)	1
<b>Moderate Permeability</b> (silts, silty sands and clayey sands, $10^{-3}$ to $10^{-4}$ cm/sec)	2
<b>Low Permeability</b> (silty clays and clay, $<10^{-5}$ cm/sec)	4

#### Heterogeneous

<b>Moderate Contrasts</b>	1
<b>Large Contrasts</b>	3

#### Fractured Rock

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Shown to be effective for several DNAPL types, including spent degreasing solvents (TCE and TCA), dry cleaning solvents (PCE), heavy fuel oils and coal tar/creosote.

Surfactant/cosolvent flushing is primarily used to target the removal of DNAPLs and is not well suited for the remediation of dissolved, sorbed, or volatilized plumes.

**Note: 1 is the most favorable**

No associated notes

## Limitations

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- It is a complex technology
- It is limited by aquifer heterogeneities (not yet been proven to be effective in clays or fractured rock)
- A considerable amount of laboratory and modeling work is required prior to implementation
- There is a risk that DNAPL could be mobilized and not recovered with the extraction system
- Uncontrolled mobilization can result in migration of contaminants into previously uncontaminated aquifer regions
- Extracted groundwater with surfactant/cosolvent and DNAPL requires a significant degree of handling

No associated notes

## Key Issues and Concerns

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- Determining extent of DNAPL zone
- Estimating the initial volume of DNAPL mass
- Properly characterizing hydraulic properties of aquifer
- Finding optimum chemical formulation for a given DNAPL composition and soil type
- Successfully delivering and distributing injected chemicals to targeted zone
- Making sure that uncontrolled vertical and horizontal migration is avoided
- Proper handling and treatment of fluids recovered and wastes generated

No associated notes

## Setting Goals for DNAPL Source Remediation

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- DNAPL sites pose special cleanup challenges. Due to their complex nature, a phased approach to characterization is important.
- Remedial goals should be different for DNAPL zone compared to dissolved plume (plume containment and/or aquifer restoration vs. mass reduction to an established level)
- Removing DNAPL mass while managing dissolved-phase plume downgradient of source can significantly shorten the duration of cleanup



No associated notes



## Designing a Chemical Flood

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John Londergan

**John T. Londergan** has 17 years of technical and managerial experience performing environmental investigations and managing regulatory compliance at DOE, DOD, industrial, and commercial facilities. He has served as a senior hydrogeologist with INTERA, Inc. in Austin, Texas since 1993. He has a BS in Geology from the University of Massachusetts at Amherst and an MS in Geophysics from Texas A&M University, with a specialization in Hydrogeology under Dr. Pat Domenico. For the past ten years he has specialized in NAPL source zone characterization, remediation, and remediation performance assessment, and has been involved in the development and deployment of innovative NAPL characterization and remediation technologies.

## Design Components

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- Surface Facilities and Pipeline Completions
- Waste Treatment and Recycling
- Subsurface Design
  - Well Array configuration, locations, screened intervals
  - Chemical ingredients and amounts
  - Flow Rates and Concentrations (influent and effluent)
  - Durations
  - Monitoring locations/frequencies
- Systematic Treatment Concept (integration with other remedial processes)

Discussion of advective processes

## Subsurface Remediation Design Basis

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- Source Zone (Geosystem) Characterization
  - Design Basis
  - Baseline for Performance Assessment
- Laboratory Studies
  - surfactant selection
  - phase behavior
  - bench-scale testing
- Numerical design modeling
- These tasks have to be integrated with the process design

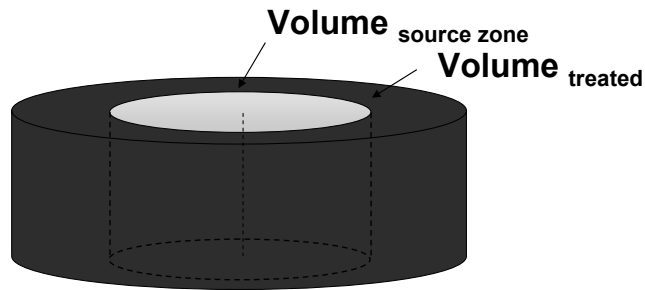
No associated notes



## The Importance of Accurate Source Data

### Cost

- If  $\text{Volume}_{\text{source zone}} = \text{Volume}_{\text{treated}}$ , treatment costs will be minimized.

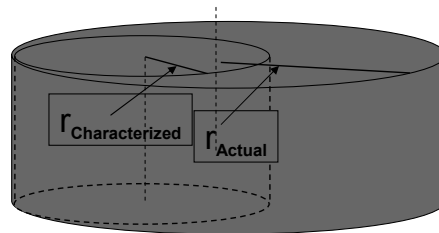


No associated notes

## The Importance of Accurate Source Data

### Performance

- If NAPL volume is missed, then plume concentrations will rebound.



No associated notes

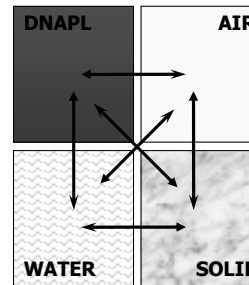
## What is a "Geosystem Model"?

- Comprehensive description of the source zone:
  - Hydrostratigraphy
  - Hydrogeology
  - Geochemistry
  - Physical properties of the DNAPL
  - Multi-phase fluid flow parameters
- Progresses from conceptual to quantitative
- Guides characterization and becomes the remediation design basis

No associated notes

## Using a Geosystem Approach

- Dynamic
- Iterative
- Focused (Data Quality Objectives)
- Funnel
  - rapid screening methods
  - DNAPL specific delineation
  - Becomes design basis

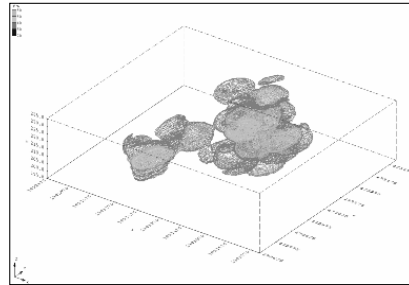
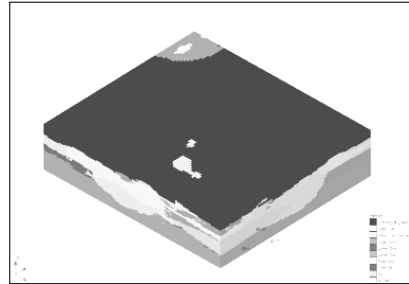


Partitioning Theory

No associated notes

## Source Zone Characterization: Task List

- Define hydrostratigraphy
- Map capillary barriers
- Determine hydrogeologic parameters
- Update geosystem model
- Estimate DNAPL distribution, volume, and extent



Discussion of depositional environment and other factors that influence the DNAPL locations

## Data Types needed for Chemical Flushing

- DNAPL physical properties
- Detailed hydrostratigraphy
  - grain-size distributions
  - capillary barrier properties and structure
  - FOC (fraction organic content)
- Hydraulic testing
  - permeabilities
  - heterogeneity
- $S_n$  - DNAPL saturation distribution and extent

FOC = Fraction Organic Content

## Characterize the DNAPL

- DNAPL-Water Interfacial Tension
- DNAPL-Flushing Agent Interfacial Tension
- Viscosity
- Density
- Wettability of the DNAPL-Aquifer System (Amott and USBM tests)



No associated notes

## Source-Focused Desk Top Review

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- Look for:
  - release point
  - release history and volume (ha!)
  - NAPL properties
  - hydrostratigraphy (where is the NAPL going?)
  - plume attributes
- Assimilate data into Geosystem (scoping calculations)
- Identify data gaps and evaluate data needs
- Plan objectives for investigation

No associated notes



## Conventional Characterization Tools

- Groundwater samples
- Remote sensing (geology/hydrogeology)
  - EM surveys
  - seismic/ground-penetrating radar (GPR)
  - borehole geophysics
- Soil gas surveys (vadose zone)
- Soil Samples (geology/hydrogeology)
  - DPT
  - Drilling

“DPT” refers to “Direct Push Technologies”

## Conventional Characterization Tools (cont.)

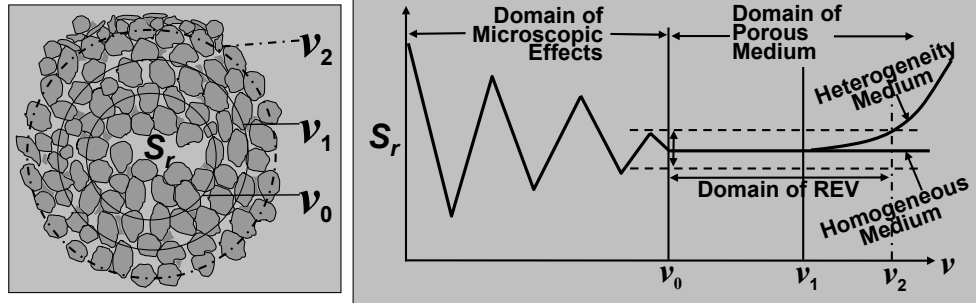
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- Water sampling
  - solubility limitations
  - the use and abuse of the 1% rule
  - degradation products
  - possible NAPL recovery for analysis
- Using a drill rig

No associated notes

## Representative Elementary Volume (REV)



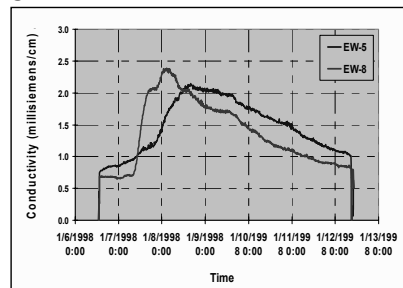
- Est. range of REV for NAPL in soil =  $10\text{-}10^4 \text{ cm}^3$   
= 0.0003 to 0.3  $\text{ft}^3$
- Volume of typical soil sample =  $30\text{-}10^2 \text{ cm}^3$   
= 0.001 to 0.01  $\text{ft}^3$

**Conclusion:** In order to characterize a DNAPL source zone adequately, you need **LARGE NUMBERS** of good soil samples!

A key concept of the EPA TRIAD approach is that you must obtain “Decision-Quality Data.” For a DNAPL source zone, this can mean that a lot of samples may be required to allow you to make the proper remedial design decisions.

## Hydrogeologic Properties

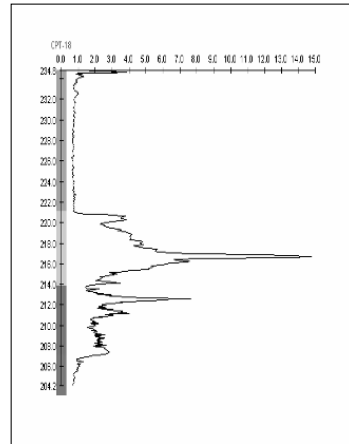
- Grain Size Distributions
- Aquiclude Properties (porosimetry, geochemistry)
- Pumping/Slug Tests
- Conservative Interwell Tracer Tests (CITTs)
  - Extraction and Injection wells
  - Hydraulic Conductivity
  - Dispersivity
  - Transport Properties
  - Swept Pore Volume



No associated notes

## DNAPL Characterization Tools

- Ribbon NAPL Sampler (FLUTe™)
- SUDAN IV Dye
- Radon Flux
- CPT-based NAPL tools
  - permeable membrane (MIP)
  - HydroSparge
  - fluorescence
  - discrete water samplers
  - other sensors (Raman, GeoVis, etc)



CPT/LIF

CPT = cone penetrometer      LIF = laser induced fluorescence

CPT is applicable only in environments that allow for the operation of push tools. Gravels, cobbles, caliche, and rock are examples of geologic environments that are not favorable to CPT.



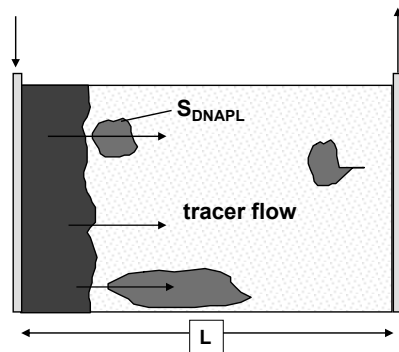
## Partitioning Interwell Tracer Tests (PITTs)

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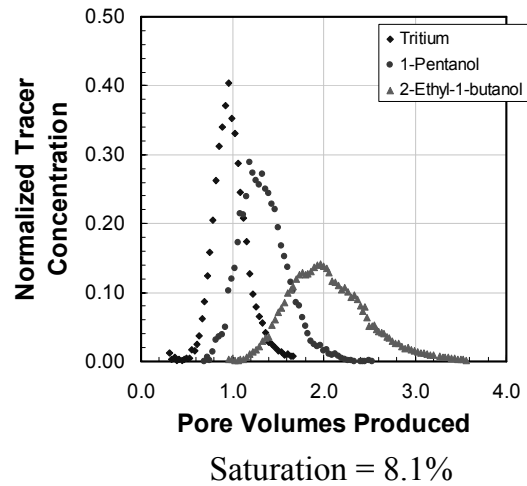
- Developed for NAPL site characterization by DE&S and Dr. Gary Pope at UT Austin
- Adopted by EPA & the USAF for technology performance assessment at Hill, AFB, Utah
- Over 40 conducted since 1994
- U.S. Patent No. 5,905,036

No associated notes

## Partitioning Tracer Test with DNAPL



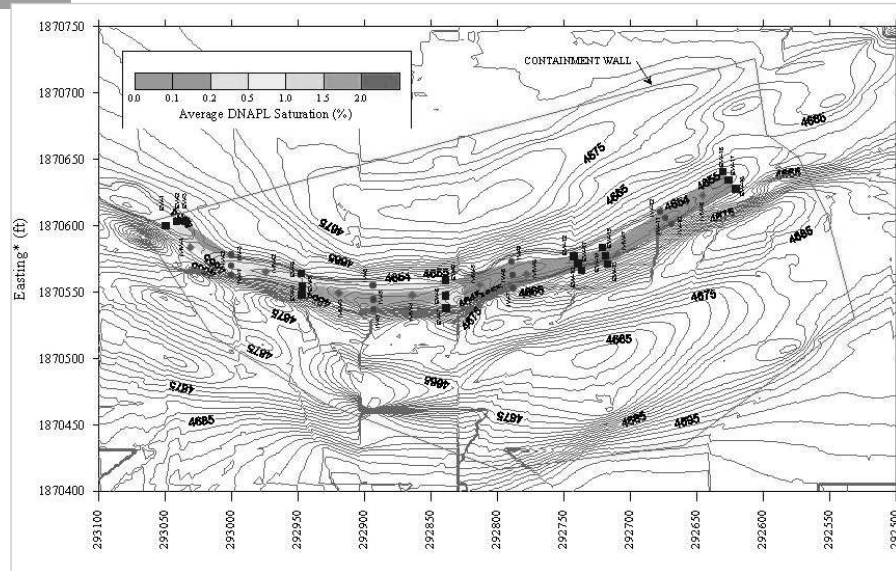
$$R_f = \frac{\dot{t}_p}{\dot{t}_n} = 1 + \frac{K S_N}{1 - S_N}$$



Notes;

This test was performed at Hill AFB near Salt Lake City, Utah

## Remedial Design Basis

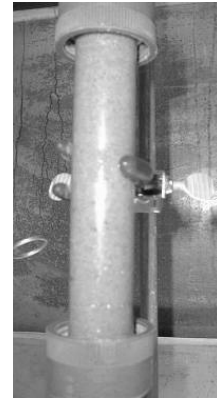
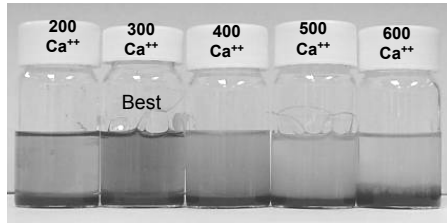


A paleochannel at Hill AFB forms a hydrogeologic trap for DNAPL



## Laboratory Studies

### Phase Behavior



Before

After

Column Tests

No associated notes

## Surfactant Selection

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- Compatibility with site soil and NAPL, may require tailoring NAPL-specific surfactants
  - incompatibility can cause pore plugging
- High NAPL solubilization, IFT reduction
- Biodegradability
- Above-Ground Treatability
- Commercial availability & economics

No associated notes

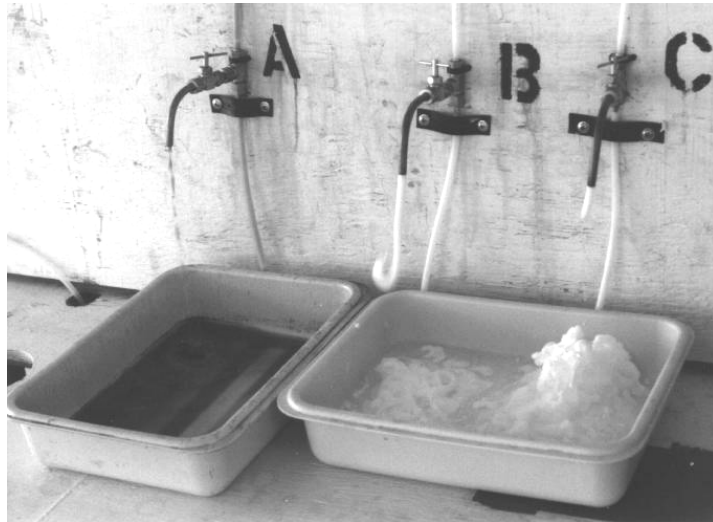
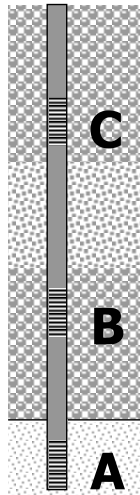
## Mobility Control

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- Goal - improve sweep efficiency
  - mitigate the effect of heterogeneity
  - reduce surfactant mass needed
- Two Types
  - polymer - injectate viscosity
  - foam - gas phase viscosity and mobility
- Pressure Pulsing

Mobility control concepts were developed in the petroleum industry

## Surfactant/Foam Process



Soap is the most common example of a surfactant. When exposed to air, surfactants may foam as does soap.

The foam in units B & C causes the fluid flow to be re-directed to the less permeable zone Unit A.

## Numerical Design Modeling

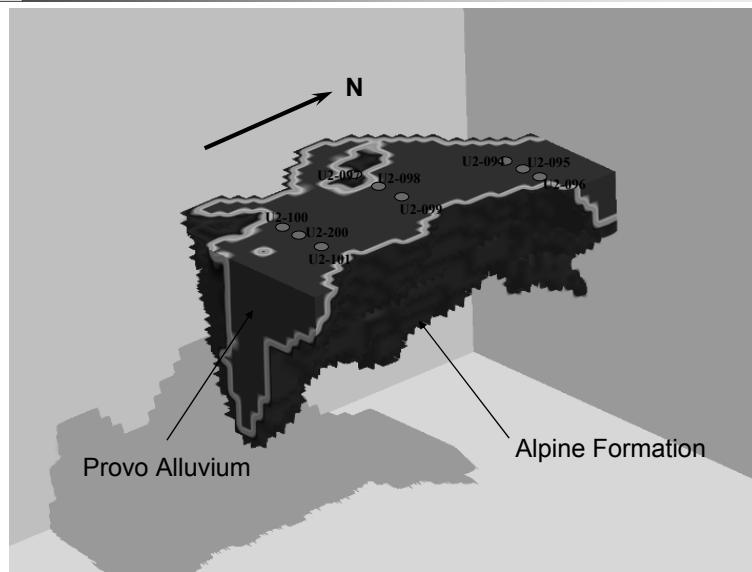
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### UTCHEM

- Chemical flood simulator from the University of Texas
- Multi-phase, multi-dimensional chemical compositional simulator
- Biodegradation, vadose zone capability
- U.S. EPA (1999) approved numerical simulator

No associated notes

## Calibrated UTCHEM Design Model

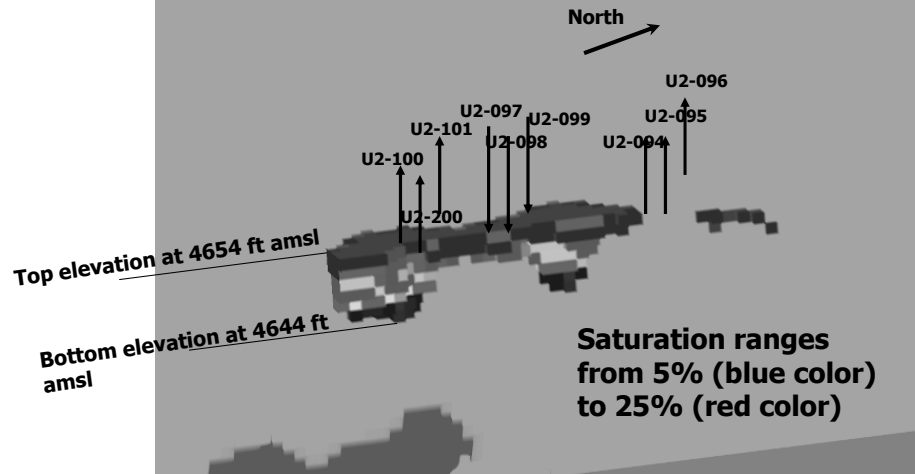


Contaminated Aquifer Permeability Structure

Computer model used to optimize the surfactant flood design

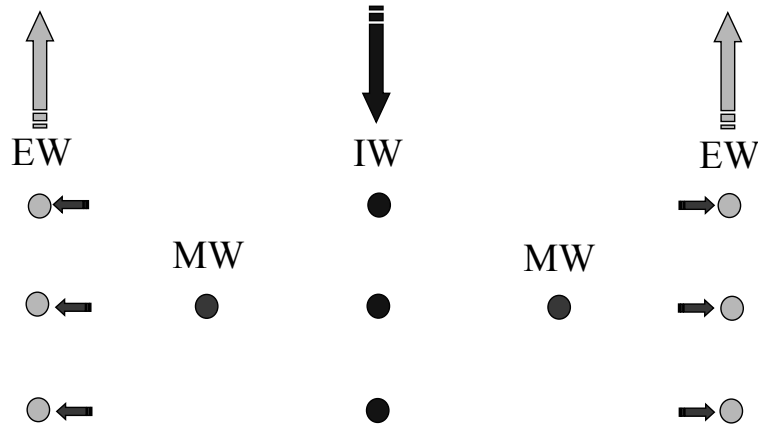


## Pre-SEAR DNAPL Saturations



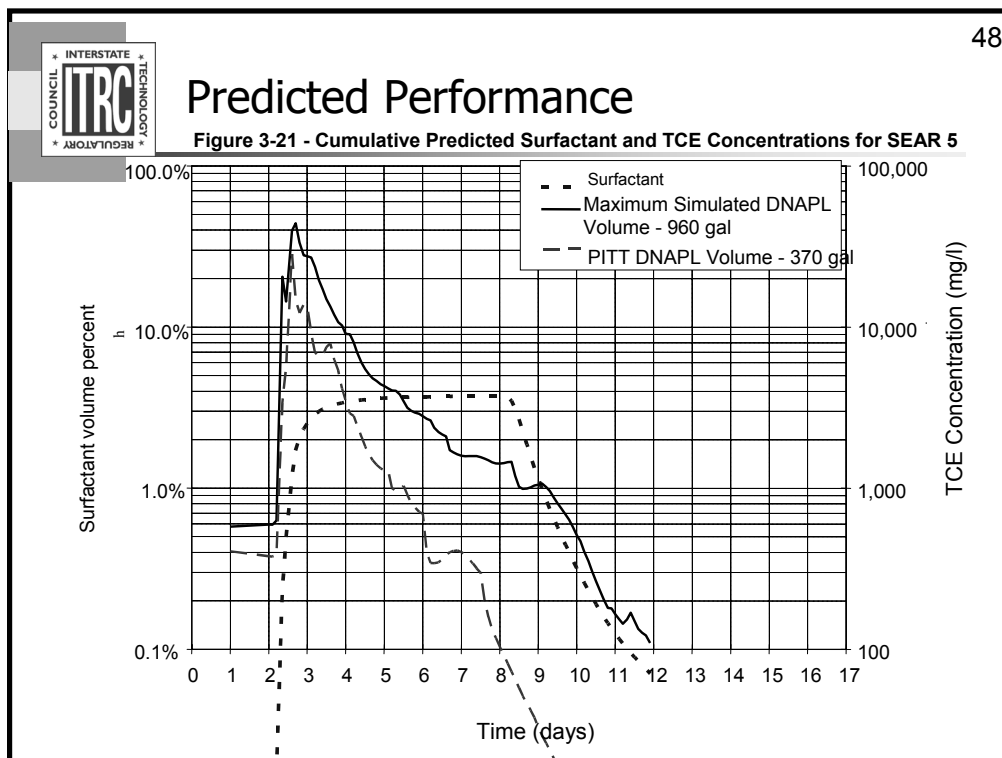
No associated notes

## Divergent Line Drive



IW = Injection Well, and EW = Extraction Well

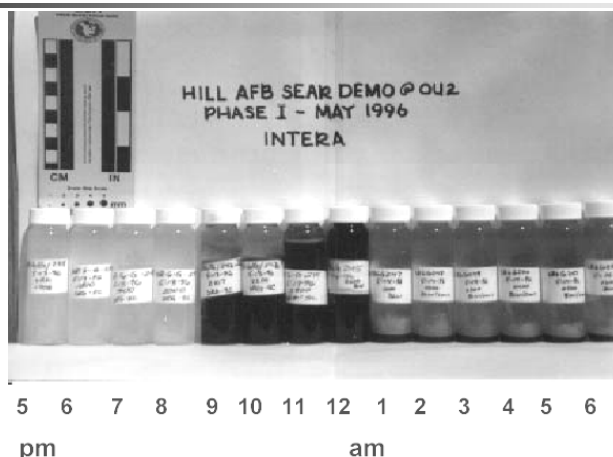




Predicted effluent characteristics during the flood



## Visual Breakthrough Curve



**Before**

**SEAR 900 mg/L**

**After**

**8 mg/L SEAR**

“SEAR” is an acronym for “Surfactant Enhanced Aquifer Remediation”

Note that the recovery wells are recovering only clear water prior to introduction of the surfactant, and then begin to recover the mobilized DNAPL.

## Questions and Answers



No associated notes



## Process Design and Implementation



Mark Hasegawa

**Mark A. Hasegawa** is an Associate with Hasegawa Engineering Ltd. in Lethbridge, Alberta. He has a BS in Civil Engineering from Brigham Young University and a MS in Environmental Engineering from the University of Oklahoma, with a specialization in Process Design and Surfactant Chemistry under Dr. David Sabatini. While at the University of Oklahoma, Mark was selected to teach two courses: the introduction to water chemistry and computer assisted engineering analysis. Mark has worked in the environmental remediation field for 10 years and has specialized in NAPL/DNAPL remediation, and process design, and has been involved in the development and deployment Surfactant Enhanced Subsurface Remediation. Mr. Hasegawa has supervised over 10 surfactant enhanced NAPL remediation projects including several DNAPL sites which include: McClellan AFB, Alameda Naval Air Station, a Chemical Plant in Michigan, Dover AFB, and Tinker AFB. Mark was project manager for the aforementioned project and supervised process design for each project. He has extensive experience in performing risk analysis at sites and has supervised the completion of numerous site specific risk assessments. He was also one of three approved trainers utilized by the state of Oklahoma to train consultants on the implementation of Risk Based Corrective Action in the state. Mark is also a registered professional Engineer in several states and provinces. In addition, he has co-authored several peer-reviewed papers and presented on various DNAPL and risk assessment topics at numerous conferences. Mr. Hasegawa currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).

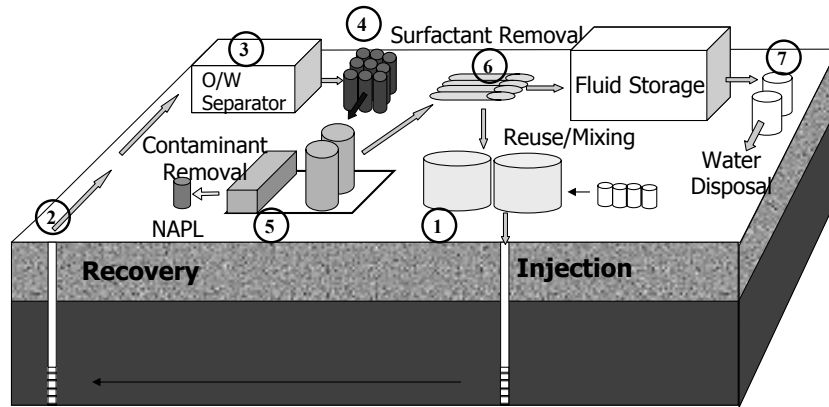
## Integrated Design Process

- When additives are used to increase the solubility or mobility of containments in the groundwater there is a profound effect on subsequent treatment of produced fluids.
- These issues must be considered



Processes that help remove the contaminants in the subsurface make it harder to treat the effluent

## Generic SEAR Process Diagram



“SEAR” is “Surfactant Enhanced Aquifer Remediation”

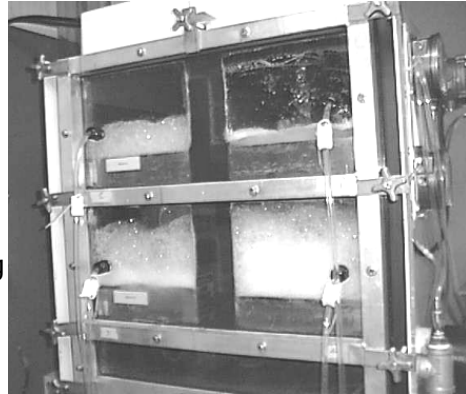
## Key Issues to Consider

- Cost
- Waste disposal and criteria for contaminants and potential additives
  - This can affect chemical formulation
- Chemical recycling and re-injection
- Fluid composition, pressure and flow quantity
- Infrastructure
  - Water, electric, gas, phone
- Footprint
- Temperature
- Process sensitivity and reliability
- Unit processes strengths and weaknesses
- Most of these processes have been used in other industries

Cost is the primary issue that influences the treatment design

## Design Process

- Determine design criteria
  - Influent concentrations
  - Effluent criteria
  - Flow
  - Viscosity
  - Cost limitations
  - Other interferences
- Prepare preliminary process diagram
- Conduct bench/ pilot scale testing if necessary
- Identify limitations in design
- Finalize design



Surfactants can be very sensitive to hard water



## Mixing/Injection System Issues



**20,000 gal Mixing Tanks**

- Reagent transportation
- Reagent receiving and storage
- Make-up water supply
- Staging and mixing process
  - Inline vs. batch
  - Sensitivity of solution



**Control Trailer**

- Injection rate, pressure, and concentration control
- Logging injection parameters
- Sampling for QA/QC and process control
- Contingency planning and spill control
- Logistics (unloading)



**In-Line Mixer  
Inside Trailer**

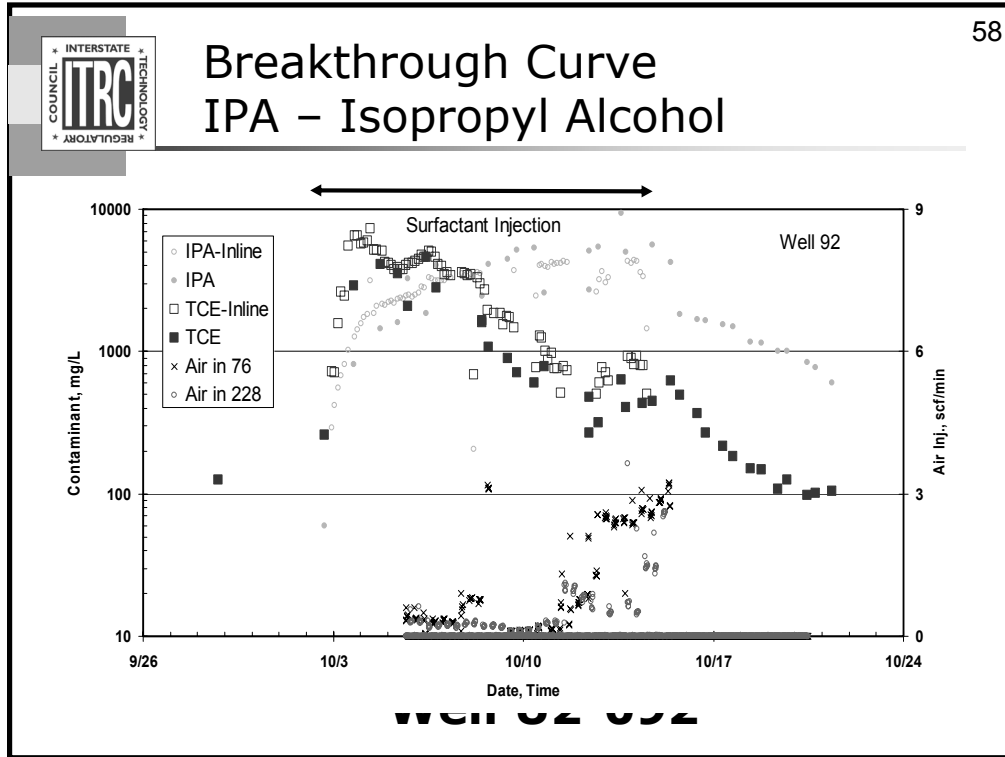
The physical process systems have improved markedly since the technology was first used

## Extraction System Issues



- Pump types (shear) and plumbing
- Water-level monitoring (hydraulic control)
- Rate control and volume logging
- Sampling for Performance Assessment and process control
- Effluent treatment operations
- Contingency planning and spill control

No associated notes



Actual curve from a flushing project. The process equipment must be designed to handle the variations in the extracted fluids.

## Contaminant Removal From Extracted Groundwater

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- Fines removal
  - Filters
  - Sedimentation
- Free Product separation
  - Oil water separation
  - Chemical assisted
- Dissolved chemical removal (up to 40,000 ppm)
  - Stripping technology (Liquid-Liquid, steam, air)
  - Sorption technologies
  - Solubility / volatility
  - Chemical effects (foaming, etc)



Once the contaminated water has been extracted from the ground, the contaminants must be removed prior to re-injection

## Chemical Removal / Recycling

- Highly variable
- Function of cost and treatment objectives
- Stripping technology
  - Steam
  - Air
- Physical Filtration
  - Micellar Enhanced Ultrafiltration (MEUF)
  - Ligand Enhanced Ultrafiltration (LEUF)
- Chemical removal/precipitation
  - Unique to chemical
  - Some surfactants pH and temperature sensitive



MEUF is an acronym for “Micellar-Enhanced UltraFiltration”

LEUF is an acronym for “L -Enhanced UltraFiltration”

## Monitoring and Sampling Issues

- Performance monitoring (Is the process working?)
- Data Objectives
- Sampling/Monitoring Parameters
- Data Quality Objectives
- Sampling/Monitoring Locations
- Purge/Waste Water Handling and Treatment
- Sampling/Monitoring Schedule
- Sample Logging, Control, and Handling
- Sample Analyses



An onsite lab is very beneficial

## Process Control Issues

- Control Parameters and Specifications
- Ranges and Tolerances
- Alarms and Alerts
- Trending and Logging/Reporting Needs
- System Reliability
- System Flexibility



No associated notes





## Design Example

- Surfactant flood which included 8 % IPA
- Influent characteristics
  - PCE concentration from 0 – 6000 ppm
  - IPA 40,000 PPM
  - Flow rate = 50 gpm
- Treatment requirements
  - Discharge to POTW (publicly owned treatment works)
  - 2500 lb/d BOD (biological oxygen demand) limit
  - 5 ppb restriction on PCE
- Other considerations
  - Air emission restrictions for PCE, IPA
  - Ample storage onsite including 700,000 gallon tank
  - Onsite boilers
  - Maximum cost of \$400,000

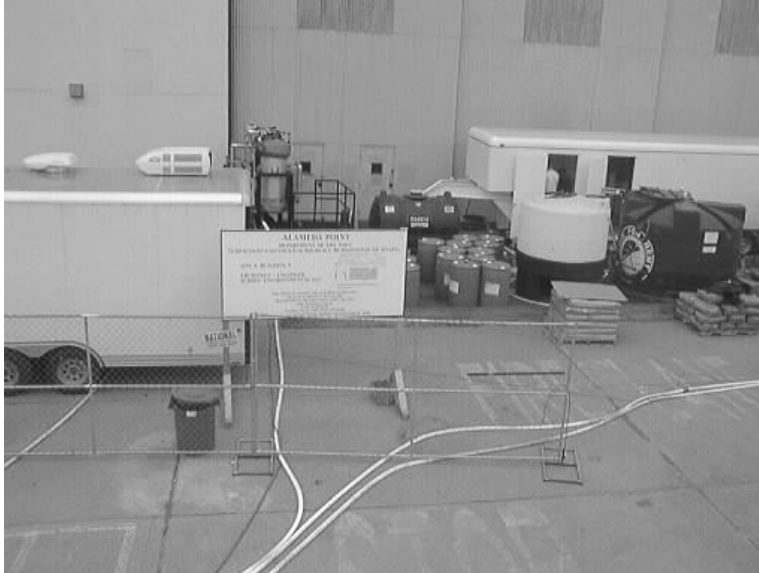
This data is from an actual surfactant flood project

POTW is an acronym for “Privately Owned treatment Works”

BOD is an acronym for “Biological Oxygen Demand”



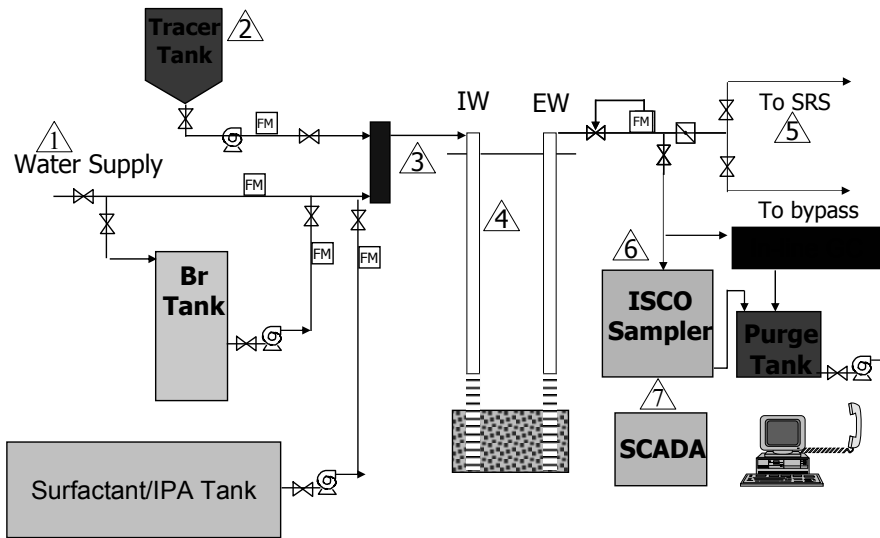
## MPP L-L extraction and MEUF (Alameda)



No associated notes

## PITT/SEAR Process System

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ISCO = in-situ chemical oxidation

## Performance Assessment



- Key Aspect of any Remediation Technology
- Easy to say, hard to do
- Performance criteria needs to be defined prior to starting the project

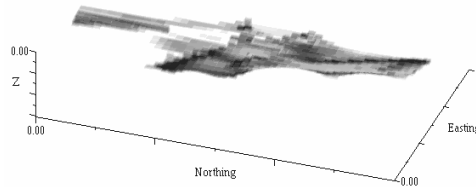
### Methods Include;

- Soil Sampling – before and after
- Mass recovery
- Groundwater Concentrations – before and after
- Mass Flux in Groundwater - before and after
- Partitioning Tracer Tests
- Other Non-intrusive Methods

No associated notes

## Remedial Performance Assessment: Pre-Remediation Baseline

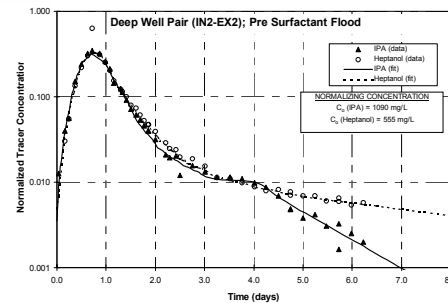
69



**Soil samples:**  
**20 ± 13 gal DNAPL**

227 soil samples

**PITT:**  
**21 ± 7 gal DNAPL**

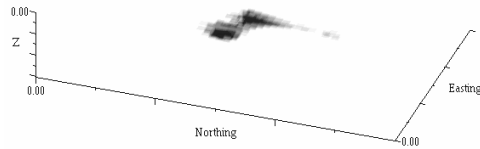


1997 AATDF Surfactant/Foam Flood

Meinardus, H.W., V. Dwarakanath, J. Ewing, G.J. Hirasaki, R.E. Jackson, M. Jin, J.S. Ginn, J.T. Londergan, C.A. Miller, and G.A. Pope. 2002. Performance Assessment of NAPL Remediation in Heterogeneous Alluvium. *Journal of Contaminant Hydrology*, 54(3–4): 173–193.

## Remedial Performance Assessment: Post-Remediation Mass Remaining

70

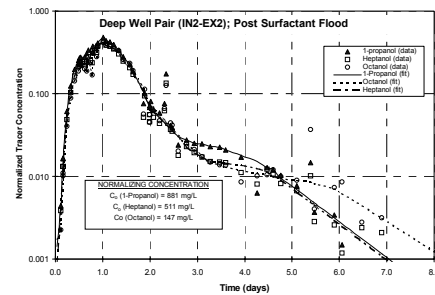


**Soil samples:**  
 **$1.4 \pm 0.9$  gallons**  
**DNAPL**

115 soil samples

**PITT:**  
 **$2.6 \pm 2.0$  gal DNAPL**

1997 AATDF Surfactant/Foam Flood



No associated notes



## Regulatory Requirements, Health and Safety Issues, Stakeholder Issues



Eric Hausamann

**Eric Hausamann** is an environmental engineer with the New York State Department of Environmental Conservation (NYSDEC). For the past 5 years, he has worked in the Division of Environmental Remediation advising staff on the selection and implementation of innovative technologies. Prior to working for NYSDEC, Mr. Hausamann worked in the hazardous waste remediation field as a consultant to industry. Eric received a B.S. in Mechanical Engineering from the University at Buffalo and a M.S. in Environmental Engineering from the SUNY College of Environmental Science and Forestry in Syracuse. He has been a member of the ITRC since 1998 and currently leads the DNAPLs Team. Under his leadership, the team has produced four documents on technical and regulatory issues relating to DNAPL site cleanup and continues to serve as a forum for the open exchange of fact and opinion on the topic of DNAPL source remediation.

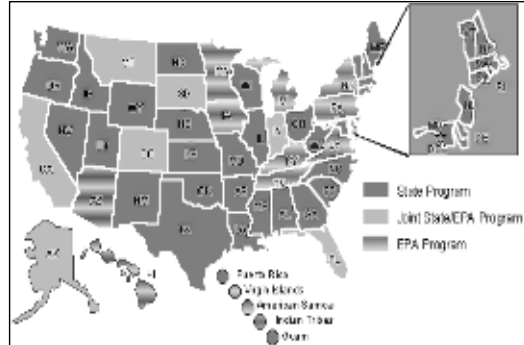


## Regulatory Requirements

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- Underground Injection Control (UIC) Program
- POTW permit for discharge to municipal sewer
- National Pollutant Discharge Elimination System (NPDES) for discharge to surface water
- RCRA LDRs (solid wastes generated during treatment)
- RCRA 3020 (b)
- Air quality permit



Breakdown of Responsibility  
for the UIC Program in the  
United States (June 2001)

Flushing technologies involve the introduction of chemicals into the ground. An NPDES or POTW permit may be required, depending on the method of discharge. An air quality permit may be required depending on the amount discharged to the air.

## Health and Safety Issues

- High concentrations of alcohol can be flammable and explosive.
- Concentrated chemicals should be handled with care to avoid personal injury and damage to the environment during transportation, handling, and injection.
- Drums of flammable liquids and associated equipment should be properly grounded to avoid electrical hazards.
- Secondary containment of chemical storage tanks is necessary.
- A Site Safety Plan prepared in accordance with OSHA 29 CFR 1910.120

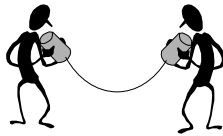


Surfactant flushing requires that workers handle chemicals that may be flammable or explosive. Secondary containment of chemicals must be considered.

## Involving Stakeholders

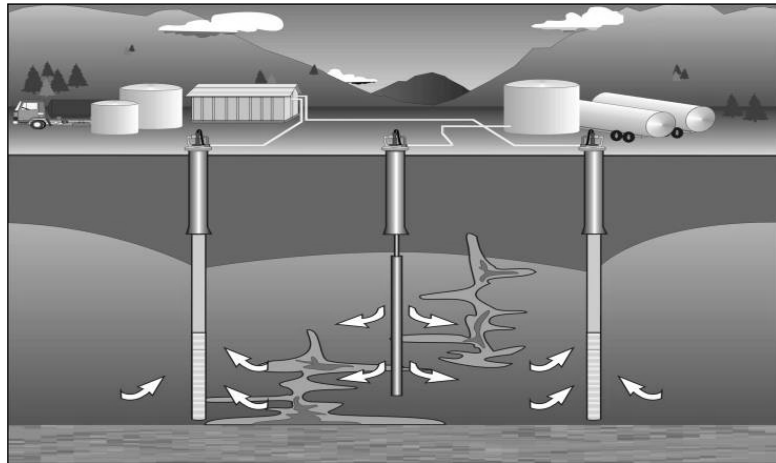
- Stakeholders should be involved at every stage of the evaluation, selection, and permitting (if necessary) of any treatment system
- Since surfactant/cosolvent flushing involves introduction of chemicals into environment, there's the obvious question "Will it do any harm?" This question must be answered carefully and honestly
- Explain the reasons why technology is likely to work and possible failure scenarios

**COMMUNICATE, COMMUNICATE, COMMUNICATE!**



Stakeholders should be involved in the process at an early stage, and must be educated so that they understand the technology.

## Questions and Answers



Thank you for participating in ITRC  
Internet-based Training. To get more  
information on ITRC and provide  
feedback – Go to [www.itrcweb.org](http://www.itrcweb.org)

No associated notes

## Thank you for your participation

To Links  
Resources

Links to additional resources: <http://www.clu-in.org/conf/itrc/flushing/resource.cfm>

Your feedback is important – please fill out the form at: <http://www.clu-in.org/conf/itrc/flushing/feedback.cfm>

### **The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:**

- helping regulators build their knowledge base and raise their confidence about new environmental technologies
- helping regulators save time and money when evaluating environmental technologies
- guiding technology developers in the collection of performance data to satisfy the requirements of multiple states
- helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations
- providing a reliable network among members of the environmental community to focus on innovative environmental technologies

### **•How you can get involved in ITRC:**

- Join a team – with just 10% of your time you can have a positive impact on the regulatory process
- Sponsor ITRC's technical teams and other activities
- Be an official state member by appointing a POC (Point of Contact) to the State Engagement Team
- Use our products and attend our training courses
- Submit proposals for new technical teams and projects
- Be part of our annual conference where you can learn the most up-to-date information about regulatory issues surrounding innovative technologies