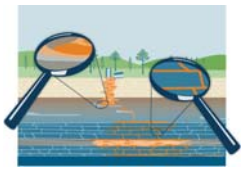
1

Overview: Integrated DNAPL Site Characterization and Tools Selection

Naji Akladiss, Team Lead
Michael Smith, Team Lead
Heather Rectanus, Team Trainer



2

The Problem: Dense Non-Aqueous Phase Liquid (DNAPL) Sites

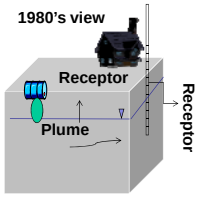
- Not achieving cleanup goals
- Spending time and money, but substantial risk remains
- Common site challenges
  - Incomplete understanding of DNAPL sites
  - Complex matrix – manmade and natural
  - Unrealistic remedial objectives
  - Selected remedy is not satisfactory

Coal Tar

3

The Problem: Outdated DNAPL Site Characterization Concepts

- Considered contaminant flow was similar to groundwater flow
- Simplifying assumptions in equations based on Darcy flow led to inadequate characterization of
  - Site geologic heterogeneity
  - Contaminant
    - Distribution
    - Characteristics
    - Behavior
- This approach limited success of site remediation activities



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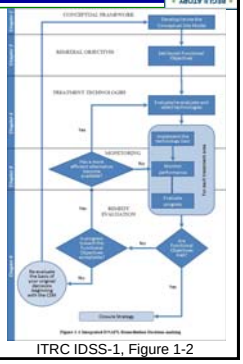
The Solution: An Integrated DNAPL Site Strategy

ITRC Technical and Regulatory Guidance Document: **Integrated DNAPL Site Strategy (IDSS-1, 2011)**

- Comprehensive site management
- Use at any point in site lifecycle
- Key topics
  - Conceptual site model (CSM)
  - Remedial objectives
  - Remedial approach
  - Monitoring approach
  - Evaluating your remedy
- Associated Internet-based training



ITRC IDSS-1, Figure 1-2

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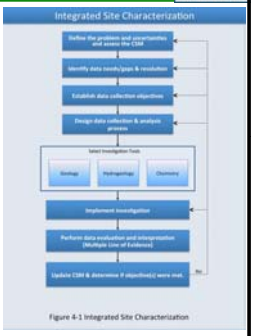
Adding to the Solution: Integrated DNAPL Site *Characterization*

ITRC Technical and Regulatory Guidance Document: **Integrated DNAPL Site Characterization (ISC-1, 2015)**

Benefits

- More accurate conceptual site models (CSMs)
- Improved predictability of plume behavior and risks
- More defensible knowledge of contaminant distribution
- Facilitates communication
- Reduced uncertainty
- Better performing remedies



ITRC ISC-1, Figure 4-1

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Incorporated into the Solution: New DNAPL Site Characterization Approaches

- Heterogeneity replaces homogeneity
- Anisotropy replaces isotropy
- Diffusion replaces dispersion
- Back-diffusion is a significant source of contamination and plume growth
- Non-Gaussian distribution
- Transient replaces steady-state conditions
- Nonlinear replaces linear sorption
- Non-ideal sorption replaces ideal sorption

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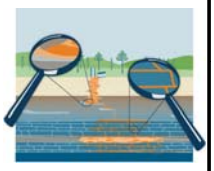
Guidance Overview

- DNAPL Characteristics
  - Life Cycle of a DNAPL Site
  - Integrated Site Characterization
  - Tool Matrix
  - Summary



ISC-1, Chapter 2

8

DNAPLs – Not Just Chlorinated Solvents!

"Neat" PCE in Soil Core

Coal Tar

Mixed Aged Motor Oil/Bunker, Aryl Phosphate and PCB in Soil Core

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Important DNAPL Properties Affecting Mobility

- Density
- Solubility
- Viscosity
- Volatility
- Composition
- Sorption

Modified from ISC-1, Chapter 2

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DNAPL Interactions with the Sub-Surface Media Affecting Mobility

- Interfacial Tension
- Wettability
- Capillary Pressure
- Saturation
- Residual Saturation

Modified from ISC-1, Chapter 2

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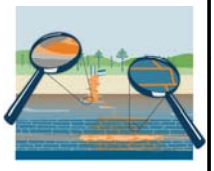

ISC-1, Chapter 3

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Controlling Role of Geology in Matrix Diffusion

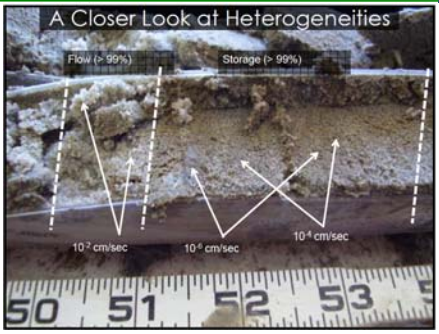

Figure courtesy of Fred Payne, Arcadis

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Redefining the DNAPL Source Term: Apparent Secondary Sources

Areas impacted by DNAPL

- **DNAPL Source Areas**
- **Unsaturated (Vadose) Zone**

Secondary Sources

- **DNAPL may have dissolved or the DNAPL may be remediated**

Sorption/ desorption to aquifer matrix

- **Slow Desorption from aquifer solids**

Molecular diffusion into low k zones

- **Matrix Diffusion from sources within plume**

Modified from ISC-1, Chapter 2

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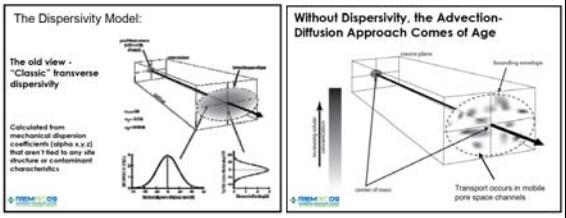
Diffusion Replaces Dispersion in Dissolved Phase Plumes

- As the length scale of interest decreases Diffusion replaces Dispersion in plume behavior
- Geologic heterogeneity and anisotropy also lead to numerous small plumes within each groundwater plume



Figures courtesy of Fred Payne, Arcadis

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Heterogeneity Replaces Homogeneity

- Simplifying the subsurface as homogeneous & isotropic has not worked well for remediation-scale plume geometry
- **Anisotropy replaces isotropy**
- Non-ideal behavior is as pronounced in the vertical

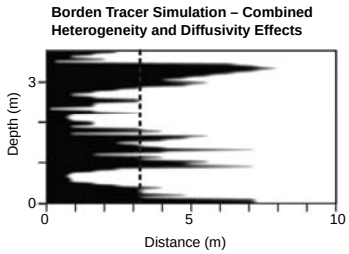

Figure courtesy of Fred Payne, Arcadis

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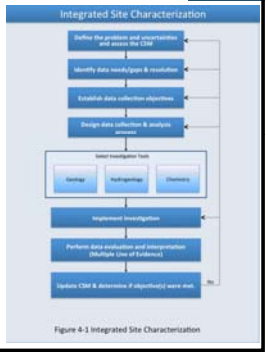
Integrated Site Characterization

- Flexible, iterative 8-step process for CSM refinement



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Integrated Site Characterization

- Plan characterization (1-4)
  1. Define the problem
  2. Identify data needs and resolution
  3. Develop data collection objectives
  4. Design data collection and analysis plan

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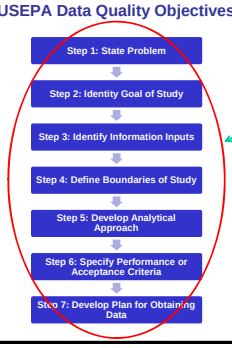
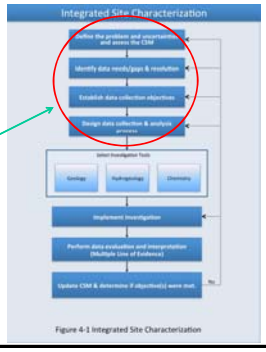
Data Quality Objectives are "Built in"

USEPA Data Quality Objectives





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Integrated Site Characterization

- Plan characterization (1-4)
- Select tools (5)

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Integrated Site Characterization

- Plan characterization (1-4)
- Select tools (5)
- Implement investigation and update CSM (6-8)

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Orientation to the Tools Matrix

- Contains over **100** tools
- Sorted by:
  - Characterization objective
    - Geology
    - Hydrogeology
    - Chemistry
  - Effectiveness in media
    - Unconsolidated/Bedrock
    - Unsaturated/Saturated
- Ranked by data quality
  - Quantitative
  - Semi-quantitative
  - Qualitative

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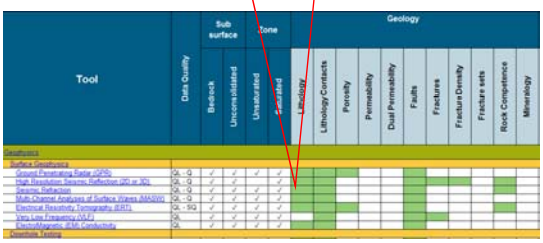
Shaded Boxes Denote Tool Meets Objective

Tools collect these types of information



Green shading indicates that tool is applicable to characterization objective

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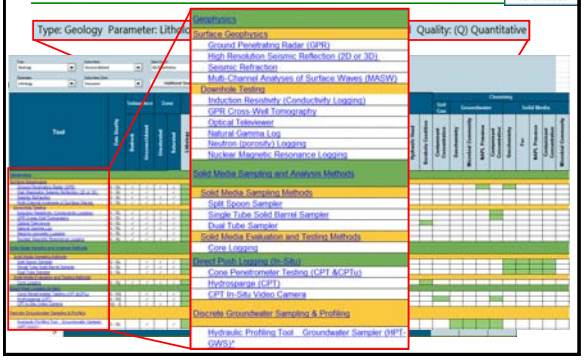
Apply Filters, Evaluate Tools



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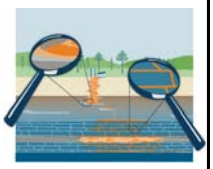

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Benefits of Integrated Site Characterization

- Reduces uncertainties to Improve CSM
- Enables more efficient remedies
- Integrated DNAPL Site Strategy (2012) itrcweb.org/guidance
- Avoids costly do-overs
- Supports stakeholder needs and confidence