Overview: Integrated DNAPL Site Characterization and Tools Selection

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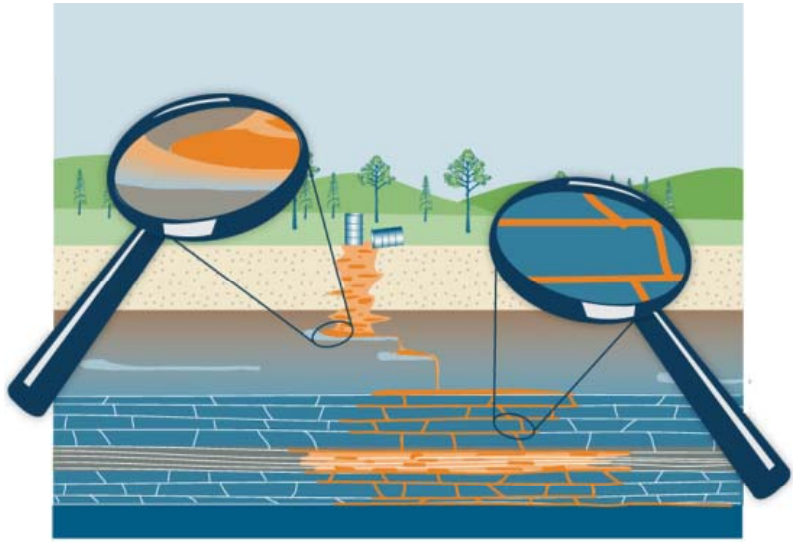


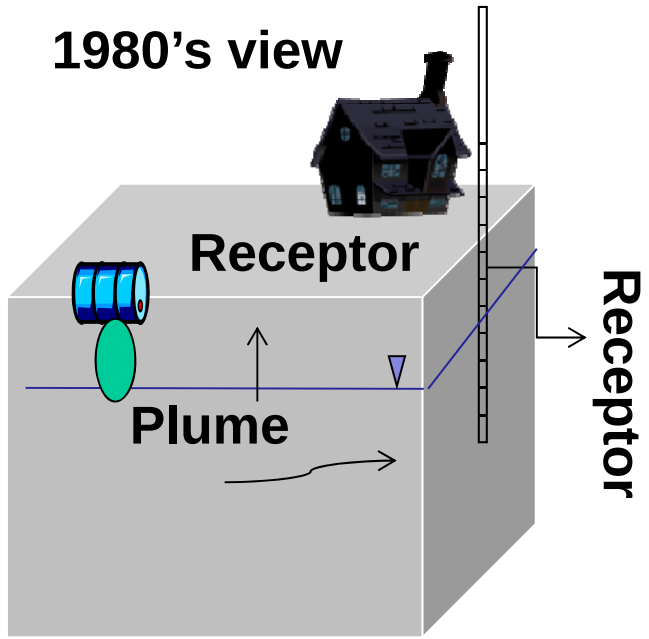
The Problem: Dense Non-Aqueous Phase Liquid (DNAPL) Sites

- 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

The Problem: Outdated DNAPL Site Characterization Concepts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



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

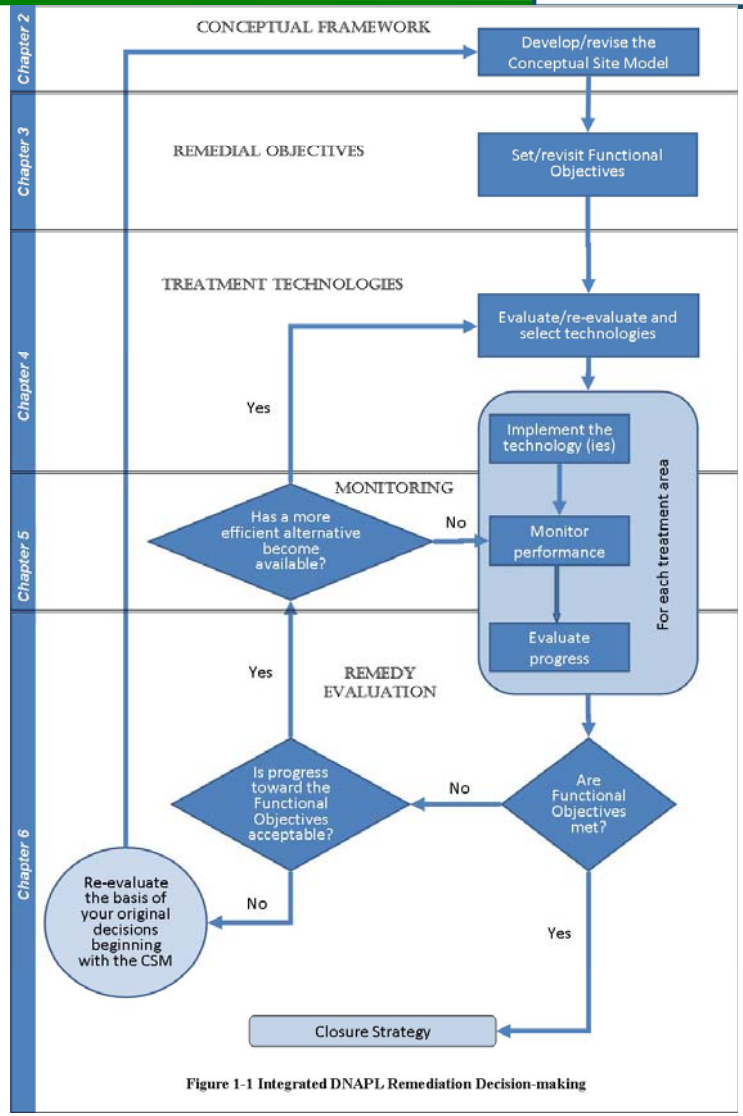


Figure 1-1 Integrated DNAPL Remediation Decision-making

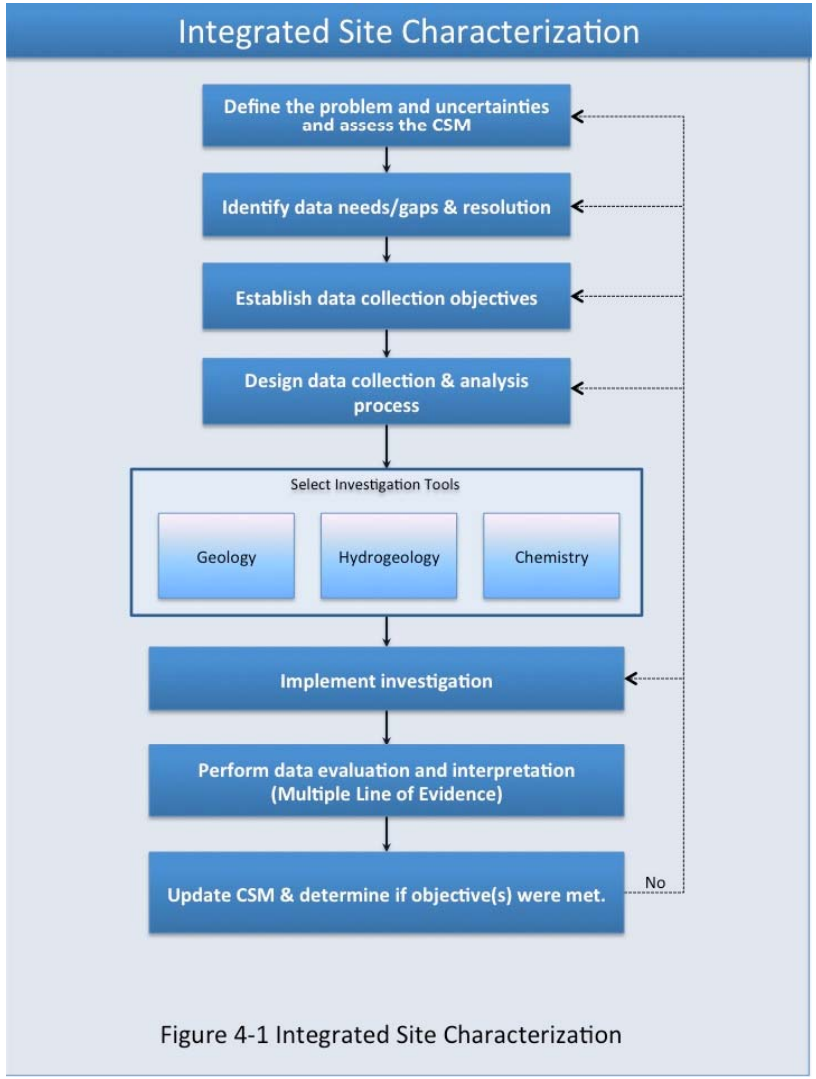
ITRC IDSS-1, Figure 1-2

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



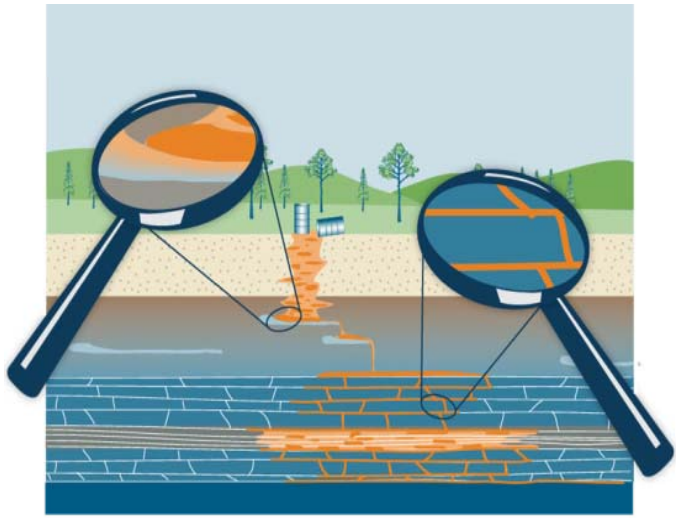
ITRC ISC-1, Figure 4-1

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

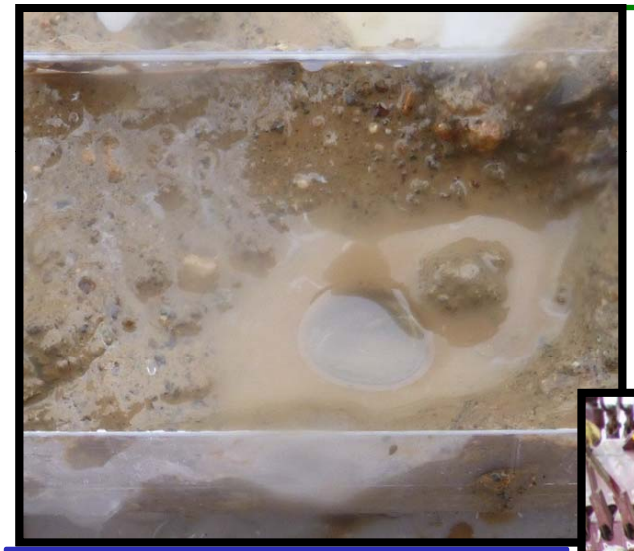
Guidance Overview

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



ISC-1, Chapter 2

DNAPLs – Not Just Chlorinated Solvents!



"Neat" PCE in Soil Core

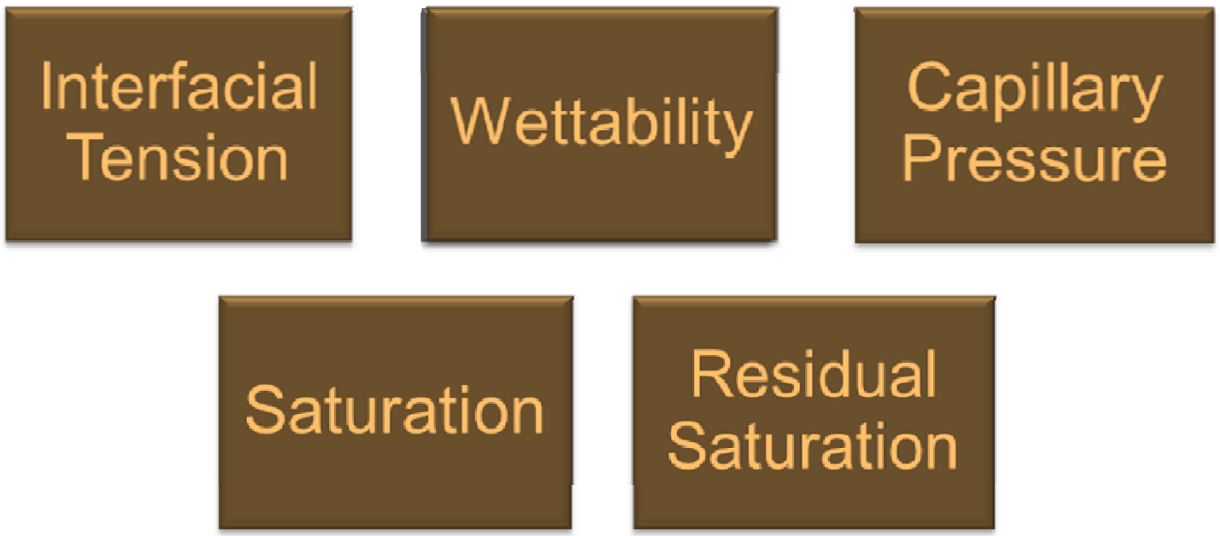
Coal Tar

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

Important DNAPL Properties Affecting Mobility

Modified from
ISC-1, Chapter 2

DNAPL Interactions with the Sub-Surface Media Affecting Mobility



Modified from ISC-1, Chapter 2

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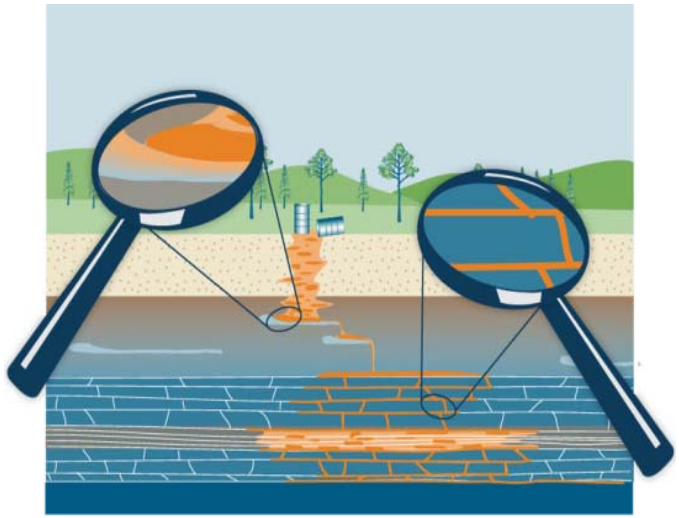


ISC-1, Chapter 3

Controlling Role of Geology in Matrix Diffusion

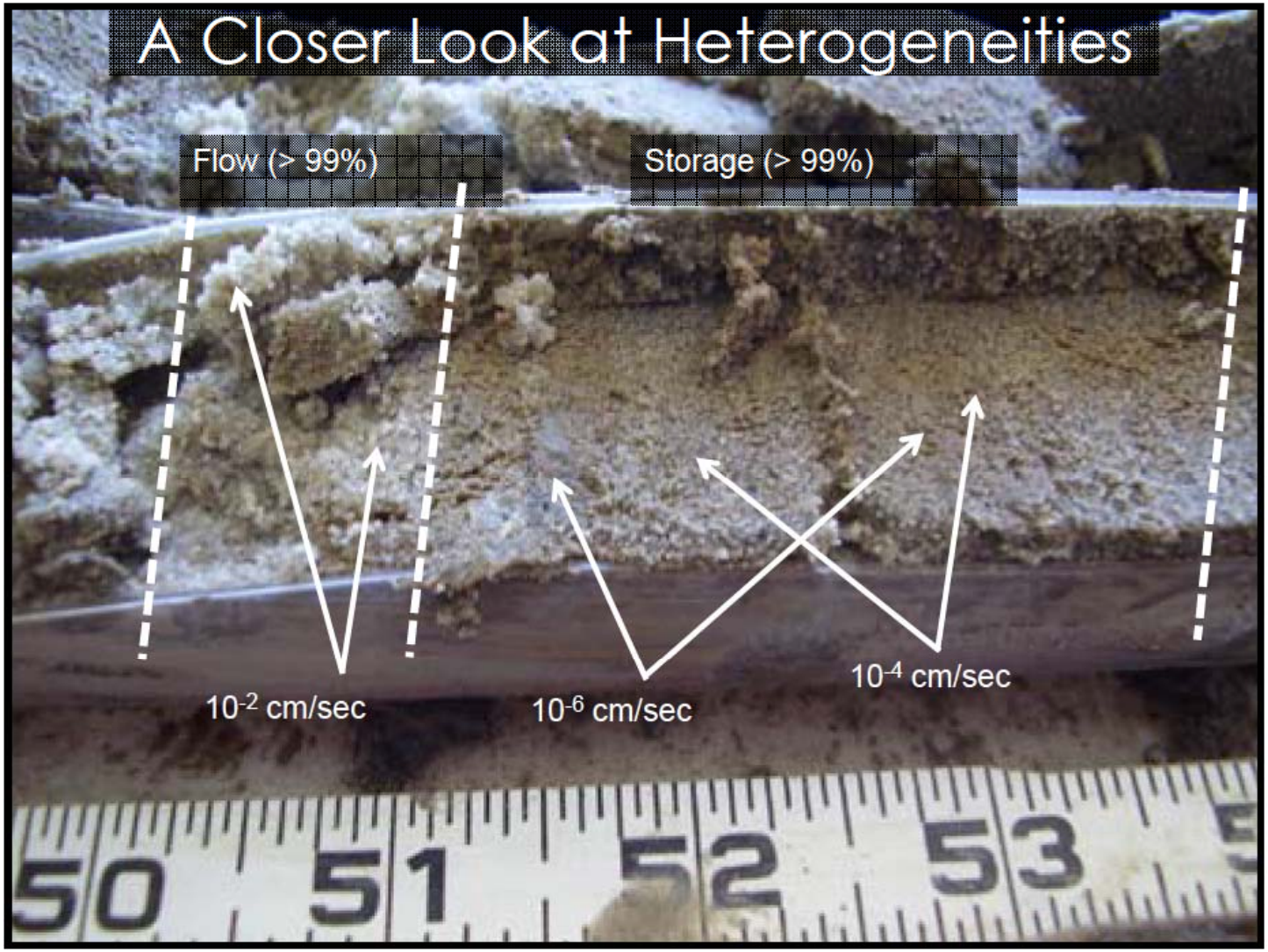
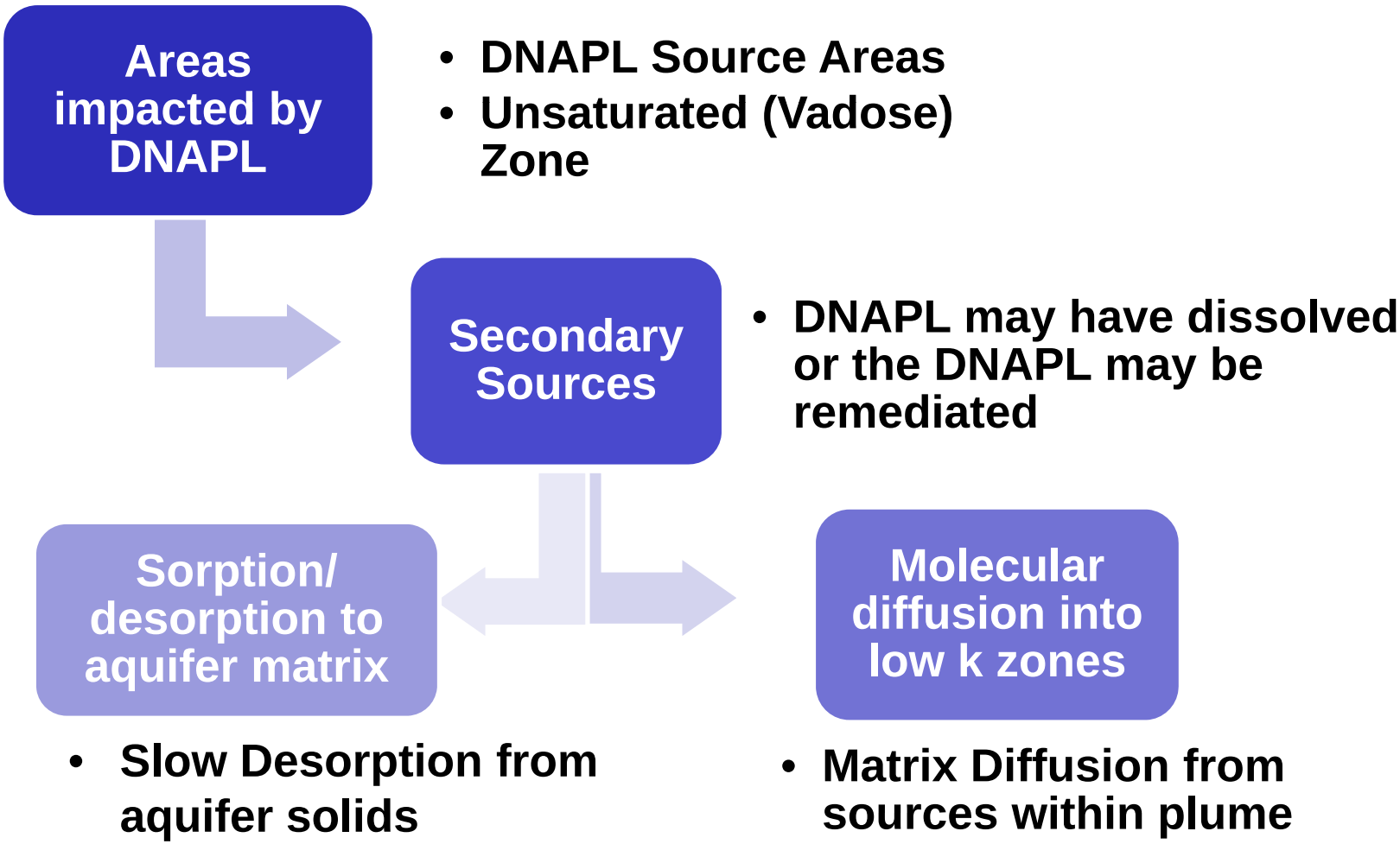


Figure courtesy of Fred Payne, Arcadis

Redefining the DNAPL Source Term: Apparent Secondary Sources



Modified from ISC-1, Chapter 2

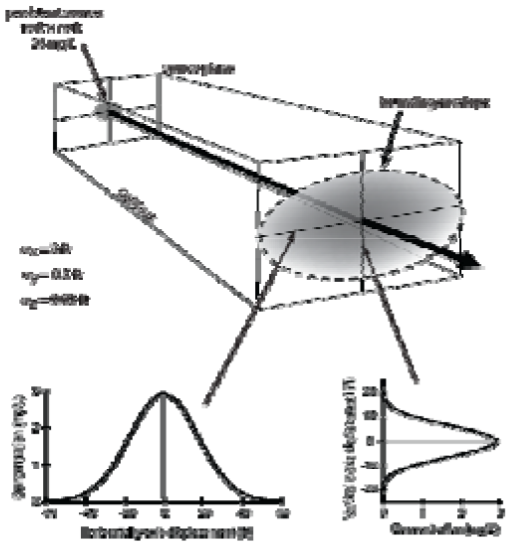
Diffusion Replaces Dispersion in Dissolved Phase Plumes

- 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

The Dispersivity Model:

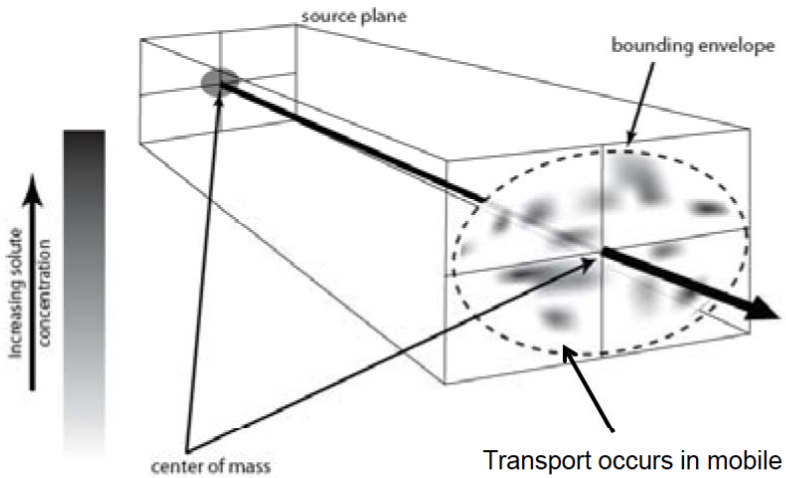
The old view - "Classic" transverse dispersivity

Calculated from mechanical dispersion coefficients (alpha x,y,z) that aren't tied to any site structure or contaminant characteristics



REMTEC09

Without Dispersivity, the Advection-Diffusion Approach Comes of Age



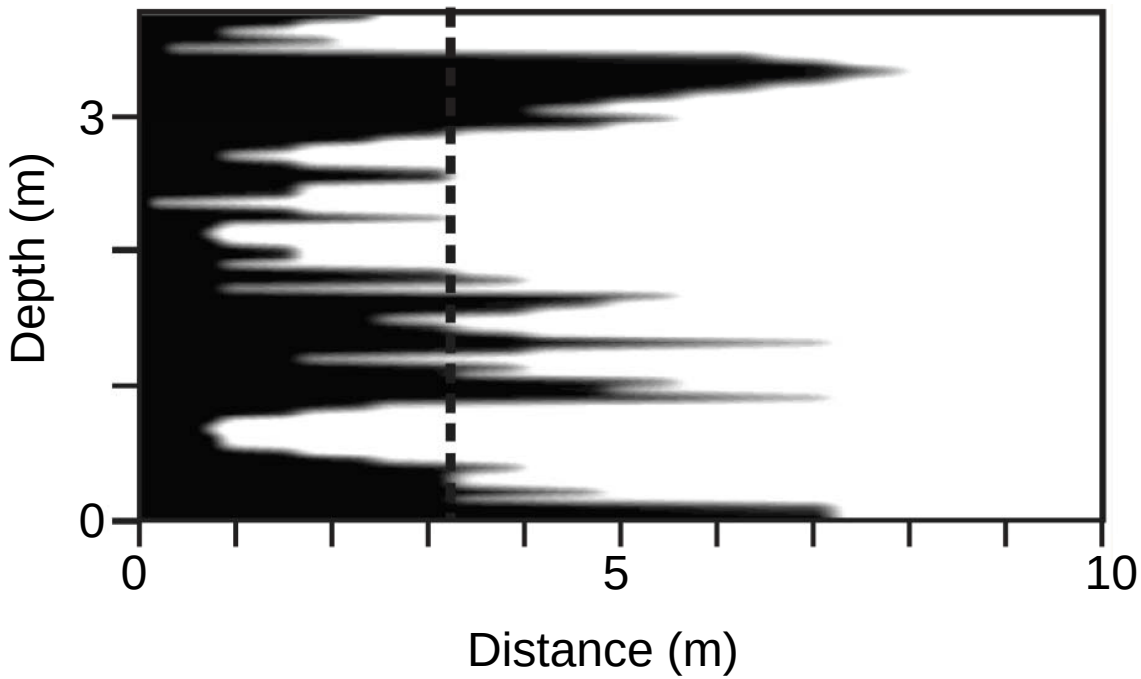
REMTEC09

Figures courtesy of Fred Payne, Arcadis

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

Borden Tracer Simulation – Combined Heterogeneity and Diffusivity Effects



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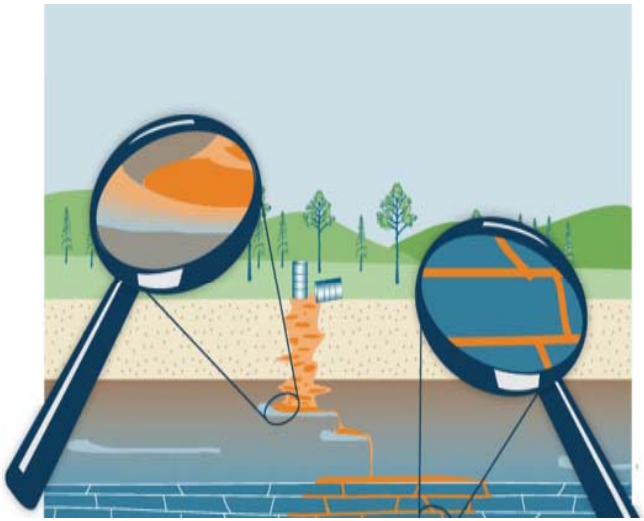


Integrated Site Characterization

- Flexible, iterative 8-step process for CSM refinement

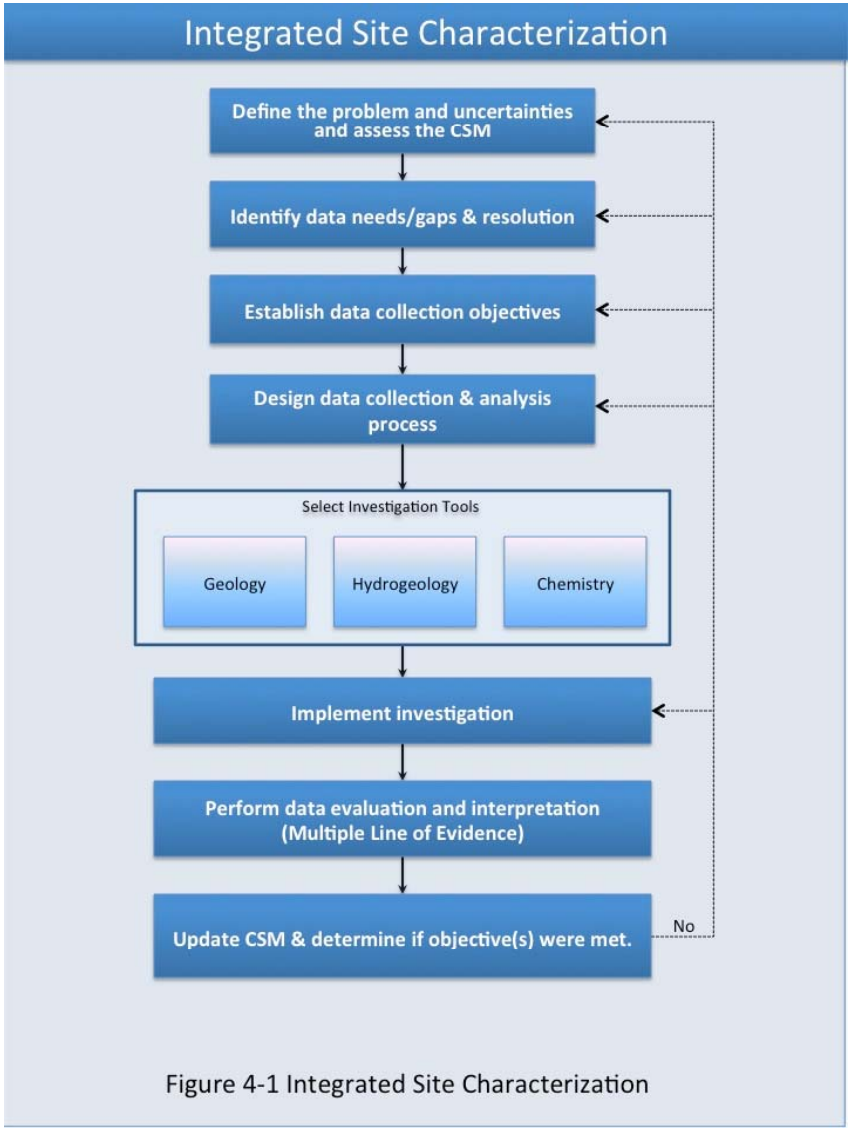


Figure 4-1 Integrated Site Characterization

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

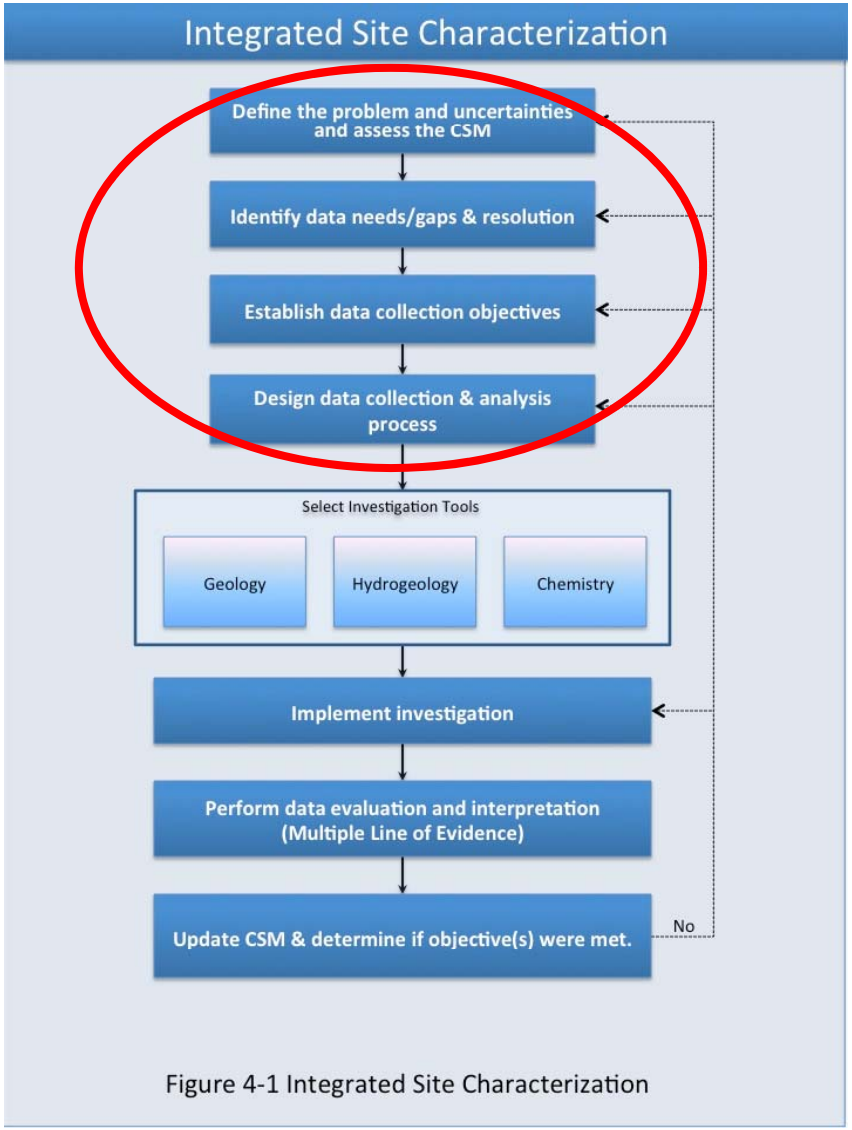
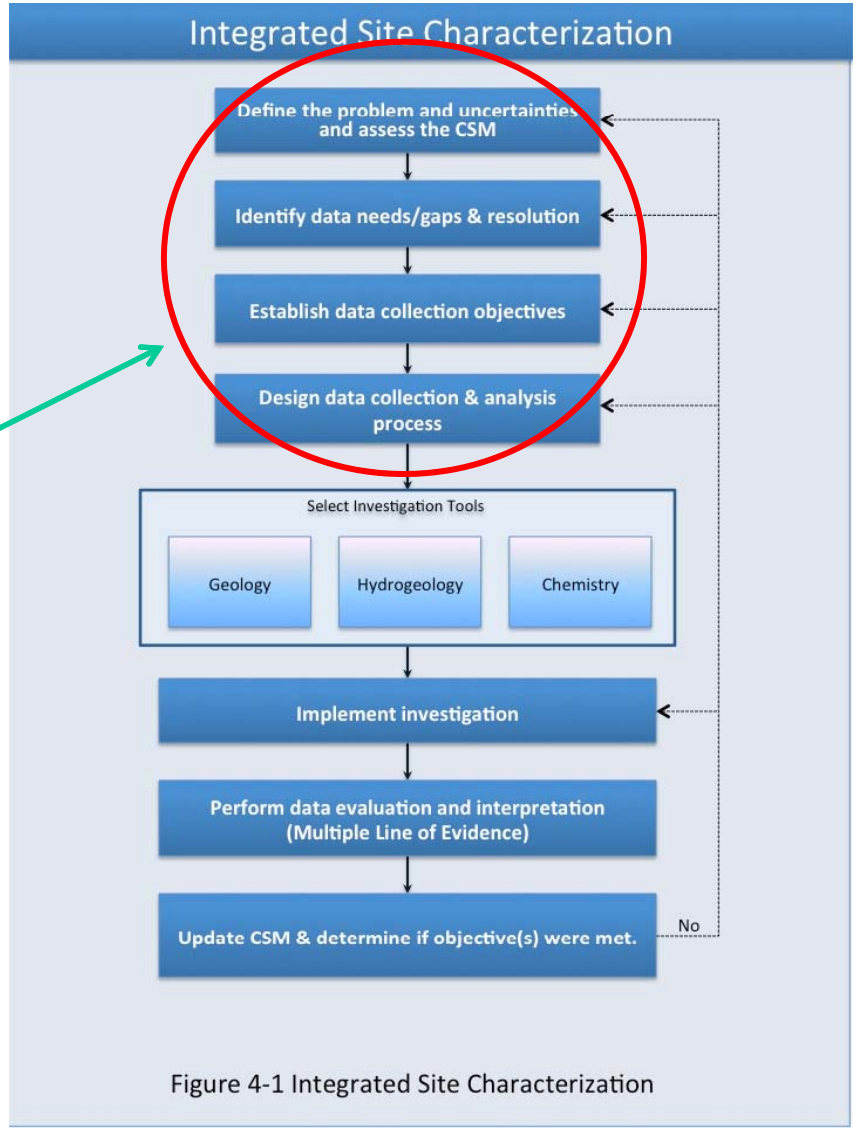


Figure 4-1 Integrated Site Characterization

Data Quality Objectives are "Built in"

USEPA Data Quality Objectives

- Step 1: State Problem
- Step 2: Identity Goal of Study
- Step 3: Identify Information Inputs
- Step 4: Define Boundaries of Study
- Step 5: Develop Analytical Approach
- Step 6: Specify Performance or Acceptance Criteria
- Step 7: Develop Plan for Obtaining Data



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Integrated Site Characterization

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

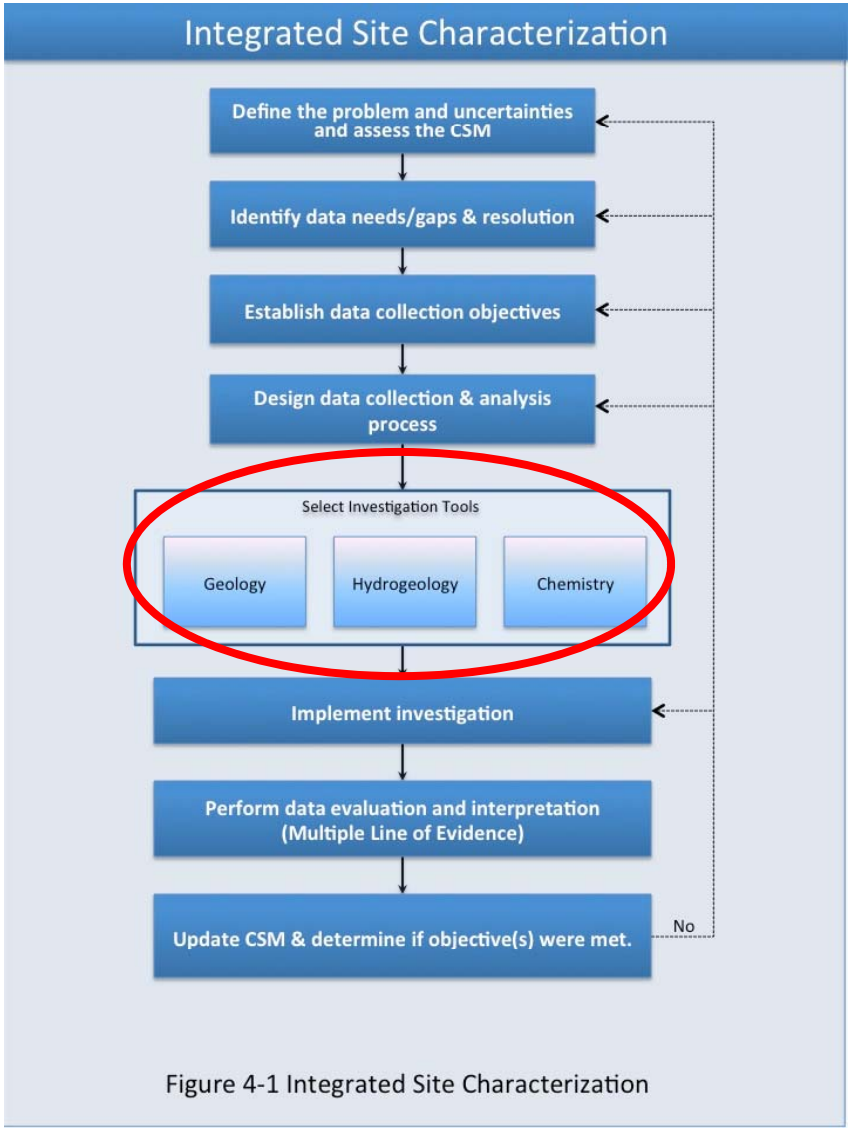
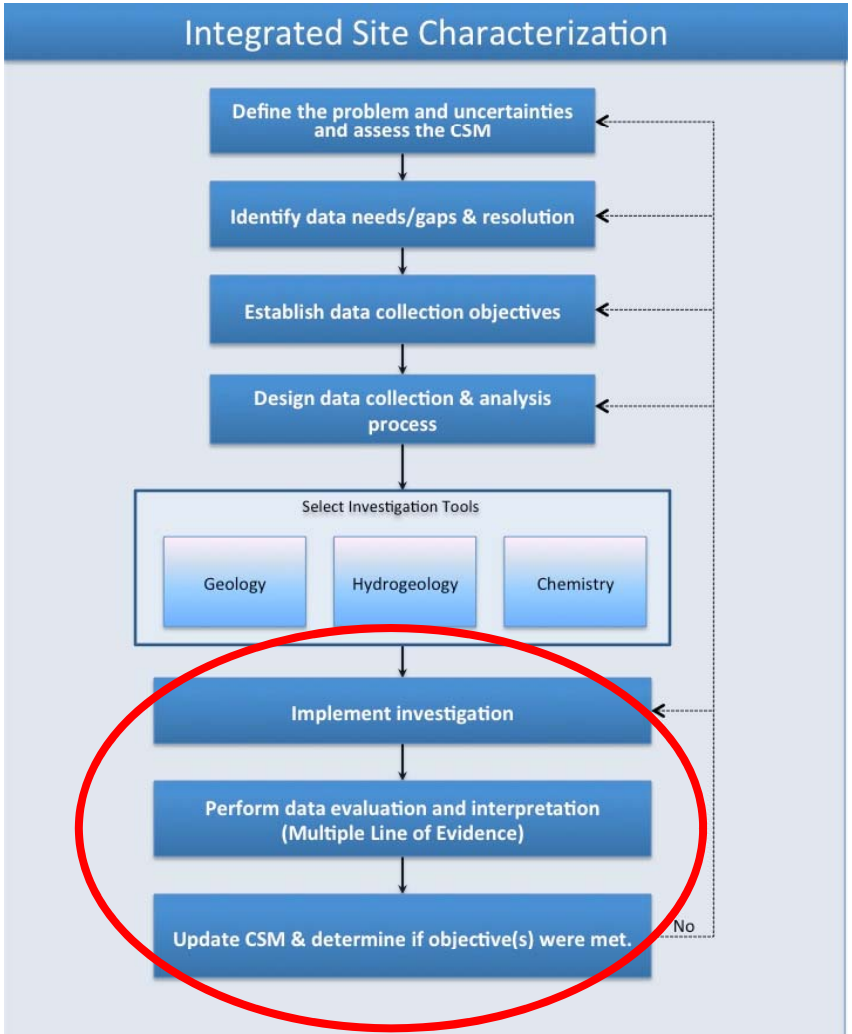


Figure 4-1 Integrated Site Characterization

Integrated Site Characterization

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



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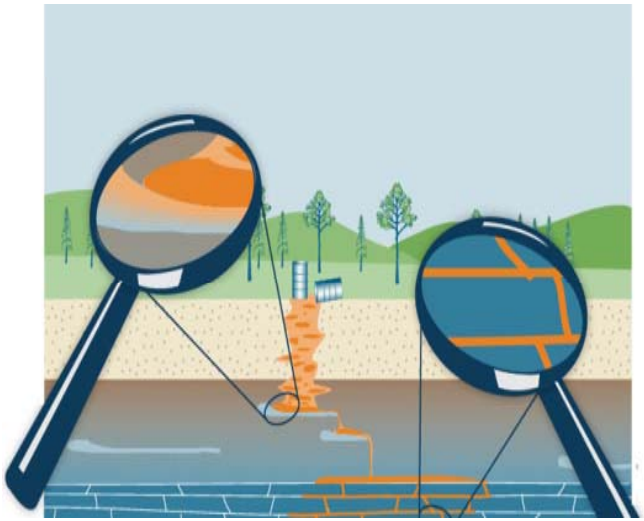


Orientation to the Tools Matrix

- 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

Tool	Data Quality	Sub surface		Zone	
		Bedrock	Unconsolidated	Unsaturated	Saturated
Geophysics					
Surface Geophysics					
Ground Penetrating Radar (GPR)	QL - Q	✓	✓	✓	✓
High Resolution Seismic Reflection (2D or 3D)	QL - Q	✓	✓		✓
Seismic Refraction	QL - Q	✓	✓	✓	✓
Multi-Channel Analyses of Surface Waves (MASW)	QL - Q	✓	✓	✓	✓
Electrical Resistivity Tomography (ERT)	QL - SQ	✓	✓	✓	✓
Very Low Frequency (VLF)	QL	✓	✓	✓	✓
ElectroMagnetic (EM) Conductivity	QL	✓	✓	✓	✓
Downhole Testing					
Magnetometric Resistivity	QL	✓	✓		✓
Induction Resistivity (Conductivity Logging)	QL - Q	✓	✓	✓	✓
Resistivity (Elog)	QL - SQ	✓			✓
GPR Cross-Well Tomography	QL - Q	✓	✓	✓	✓
Optical Televiewer	QL - Q	✓	✓	✓	✓
Acoustic Televiewer	QL - Q	✓			✓
Natural Gamma Log	QL - Q	✓	✓	✓	✓
Neutron (porosity) Logging	QL - Q	✓	✓		✓
Nuclear Magnetic Resonance Logging	QL - Q	✓	✓	✓	✓
Video Log	QL - SQ	✓	✓	✓	✓
Caliper Log	QL - Q	✓	✓	✓	✓
Temperature Profiling	QL - Q	✓	✓		✓
Full Wave Form Seismic	Q - QL	✓			✓

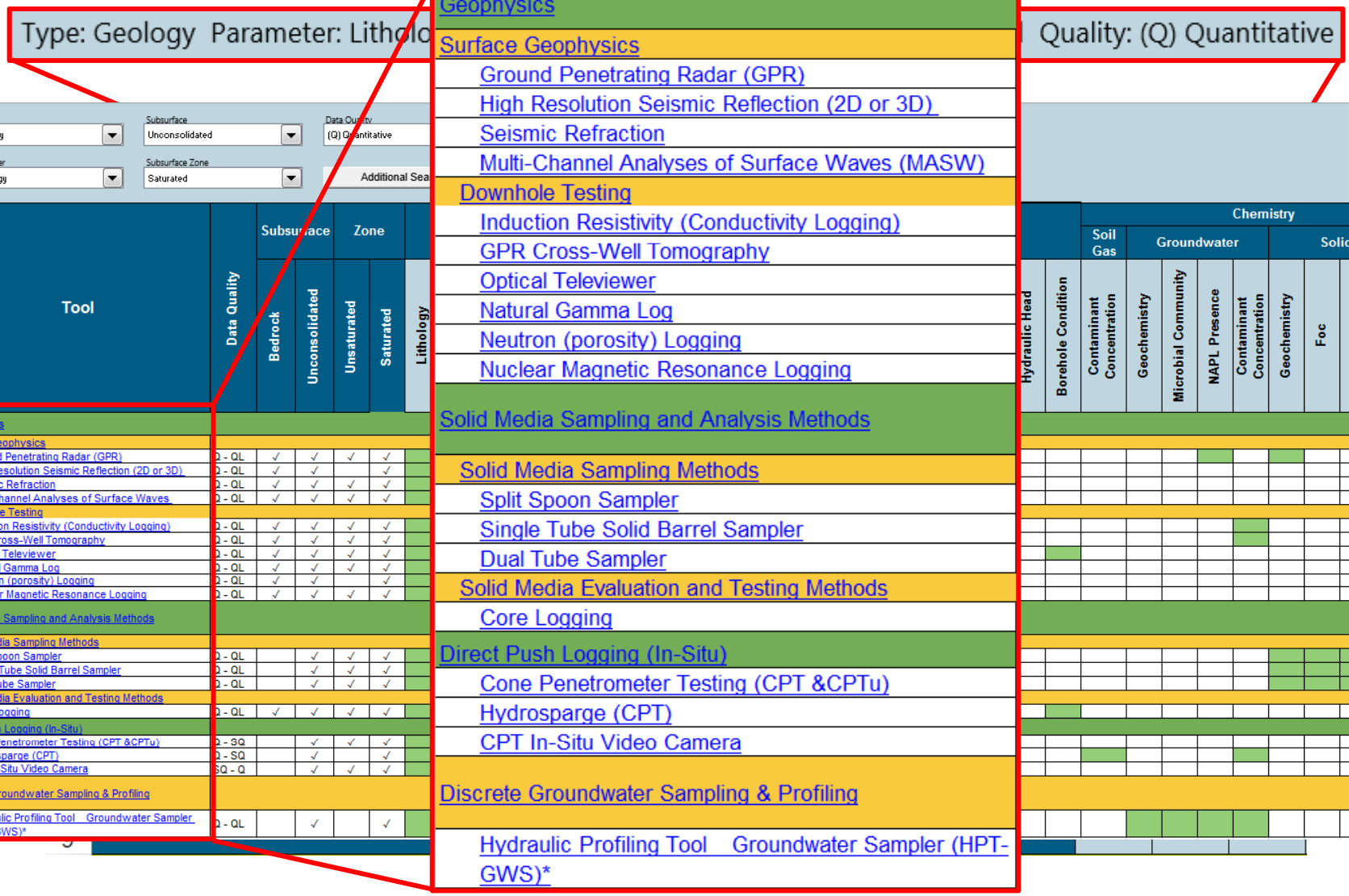
Shaded Boxes Denote Tool Meets Objective

Tools collect these types of information

Tool	Data Quality	Sub surface		Zone		Geology										
		Bedrock	Unconsolidated	Unsaturated	Saturated	Lithology	Lithology Contacts	Porosity	Permeability	Dual Permeability	Faults	Fractures	Fracture Density	Fracture sets	Rock Competence	Mineralogy
Geophysics																
Surface Geophysics																
Ground Penetrating Radar (GPR)	QL - Q	✓	✓	✓	✓											
High Resolution Seismic Reflection (2D or 3D)	QL - Q	✓	✓		✓											
Seismic Refraction	QL - Q	✓	✓	✓	✓											
Multi-Channel Analyses of Surface Waves (MASW)	QL - Q	✓	✓	✓	✓											
Electrical Resistivity Tomography (ERT)	QL - SQ	✓	✓	✓	✓											
Very Low Frequency (VLF)	QL	✓	✓	✓	✓											
ElectroMagnetic (EM) Conductivity	QL	✓	✓	✓	✓											
Downhole Testing																

Green shading indicates that tool is applicable to characterization objective

Apply Filters, Evaluate Tools



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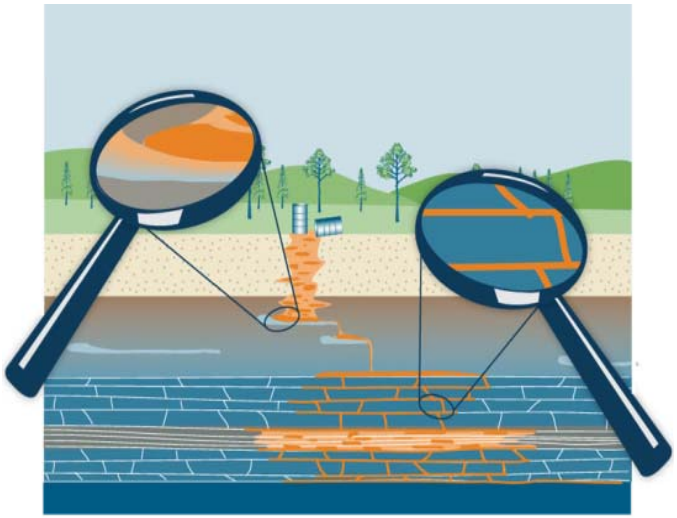

Benefits of Integrated Site Characterization

- 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