Developing a Site Characterization Plan

NEWMOA

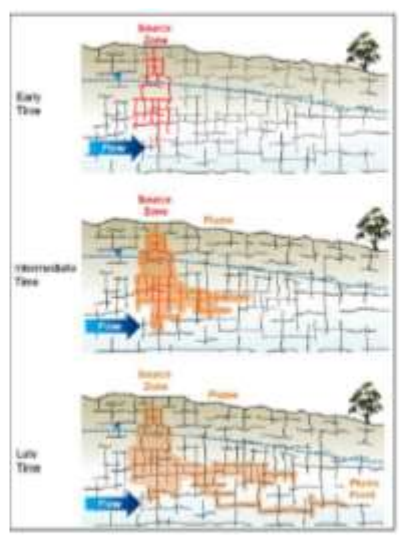
Back to Basics Part 1: Developing the CSM and Site Characterization Plan

Ryan A. Wymore, PE
CDM Smith
Denver, CO

March 27-29, 2018

Introduction

- Initial CSM is already developed
- Data gaps likely exist that need to be filled
- An iterative approach is recommended for filling these data gaps
- **Recommended process is the ITRC Integrated Site Characterization (ISC) Process**



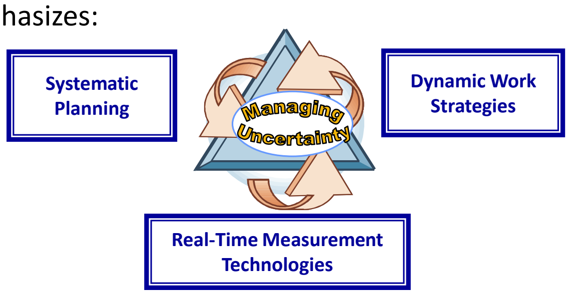
Parker et al. 2012

Integrated Site Characterization

ISC relies on the concept of an *objectives-based site characterization.*

This emphasizes the importance of establishing clear, effective objectives to drive characterization data collection.

It is a systematic, stepwise process that encourages use of a characterization approach which emphasizes:



Integrated Site Characterization

- Integrated Site Characterization flow chart
  - Planning
  - Tool Selection
  - Implementation
- Planning module
  - Step 1: Define problem and uncertainties
  - Step 2: Identify data gaps & resolution
  - Step 3: Develop data collection objectives
  - Step 4: Design data collection & analysis plan
  - Similar to DQO process

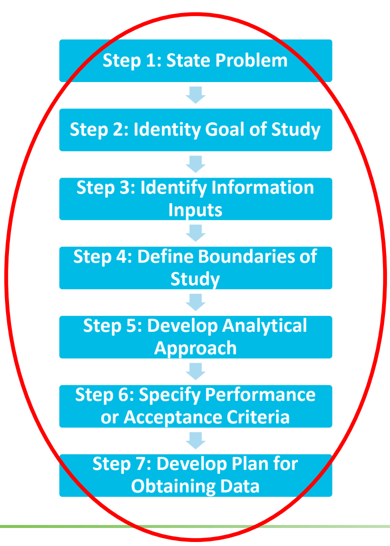
CDM Smith

Integrated Site Characterization

- Plan characterization (1-4)
  - Define the problem
  - Identify data needs and resolution
  - Develop data collection objectives
  - Design data collection and analysis plan
- Select tools (5)
- Implement investigation and update CSM (6-8)

Data Quality Objectives are "Built in"

USEPA Data Quality Objectives



CDM Smith

Step 1: Define Problem and Assess CSM Uncertainties

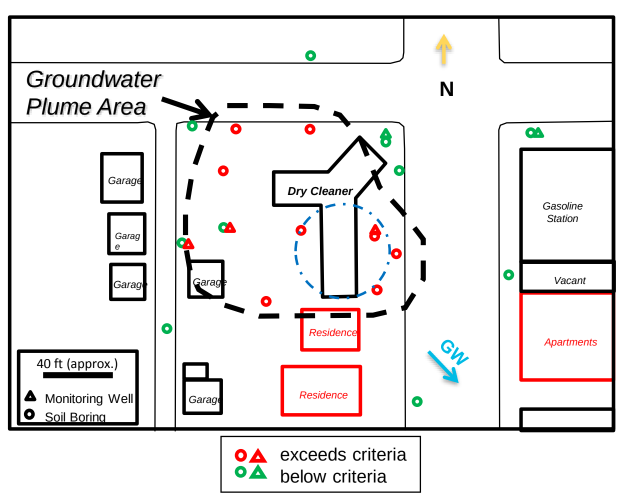
- Assess existing CSM
- Define problem
- Define uncertainties

Figure 4-1 Integrated Site Characterization

Case Example – Dry Cleaner Site

Case Example

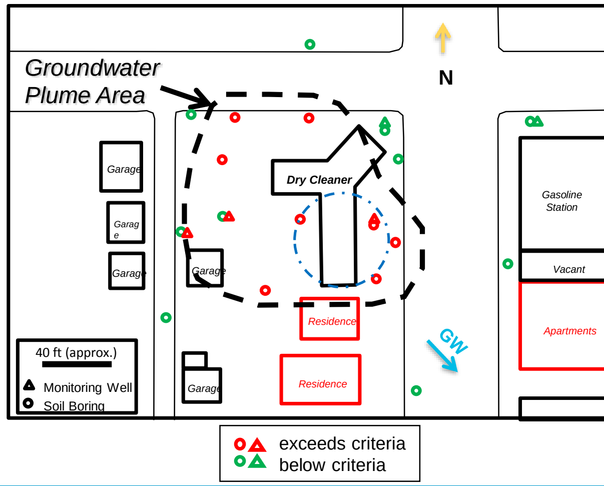
1. Commercial & residential location
2. Shallow groundwater (<20’ bgs)
3. Five MWs; 10-ft screens
4. 18 soil borings; 5-ft samples
5. No soil-gas evaluation
6. In situ chemical oxidation (ISCO) & enhanced in situ bioremediation (EISB) injections in source area & plume



Step 1: Define Problem and Assess Uncertainties

Case Example

1. Uncertain plume delineation; no down-gradient control
2. Source area inferred, not confirmed
3. No remedy evaluation
4. No soil gas or VI assessment



Step 2: Identify Data Needs & Spatial Resolution

- Translate uncertainties into data needs
- Determine resolution needed to assess controlling heterogeneities

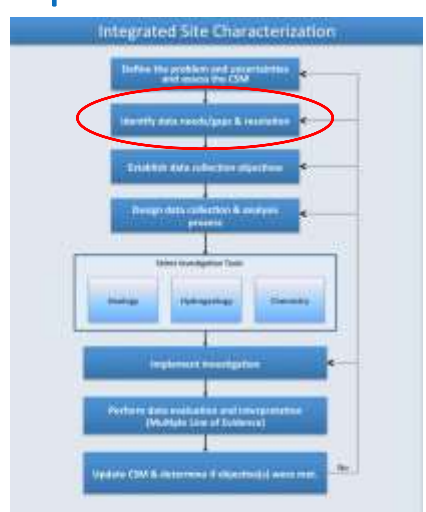
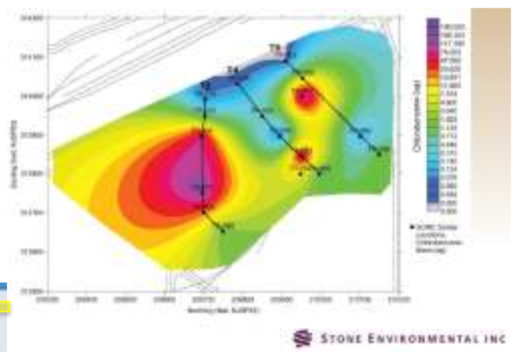


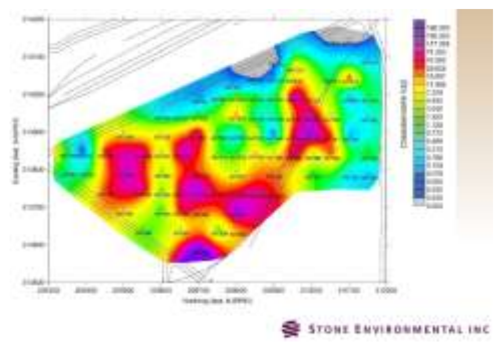
Figure 4-1 Integrated Site Characterization

CDM Smith

2. Identify Data Needs / Gaps and Resolution

- Once the uncertainties in the existing CSM are recognized, specific data needs (e.g., type, location, amount, and quality) as well as data resolution (i.e., spacing or density) can be described. Spatial resolution should be assessed laterally and vertically.





2. Identify Data Needs / Gaps and Resolution

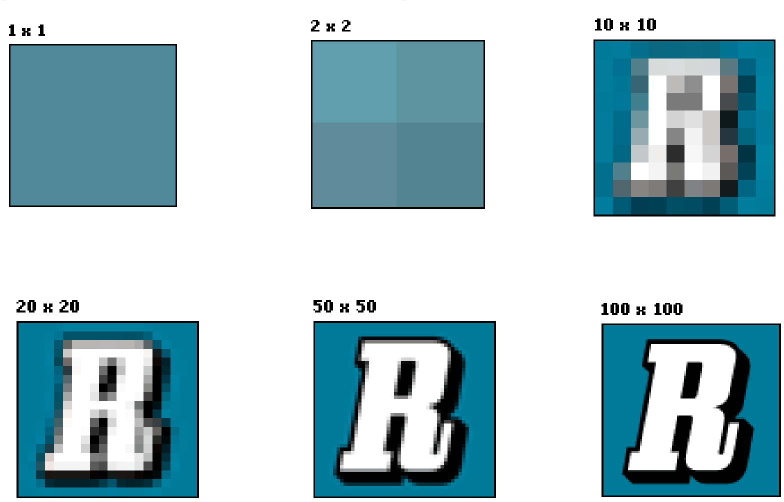
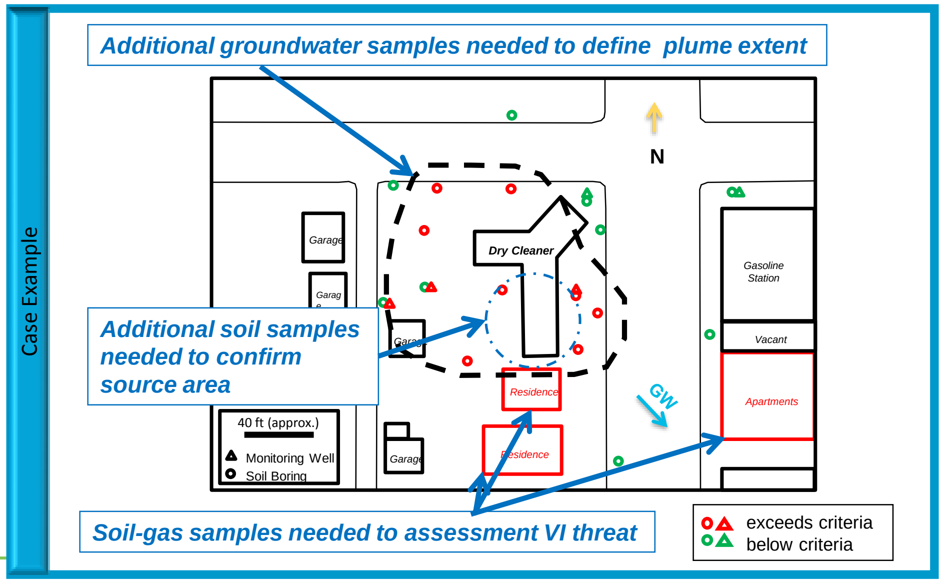
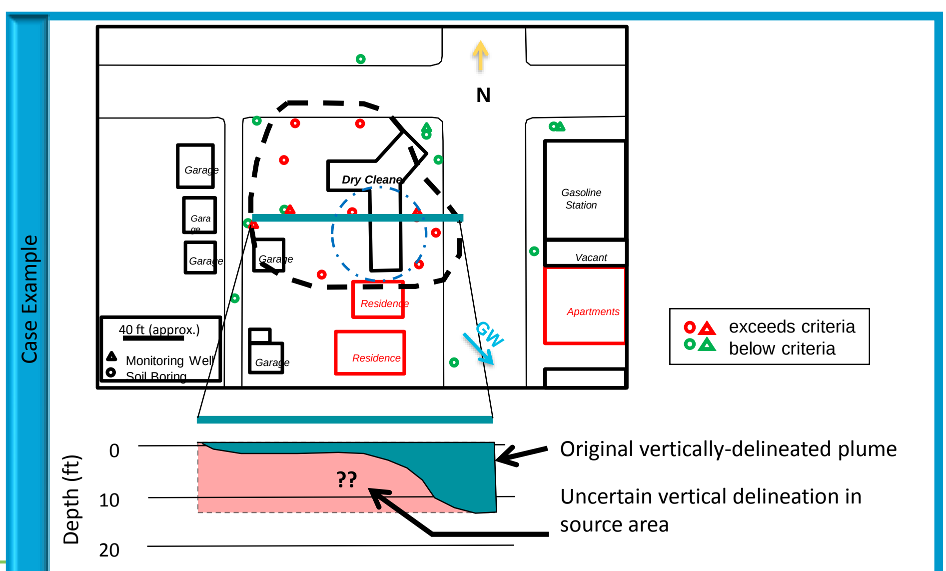


Figure courtesy of Seth Pitkin

Step 2: Identify Data Needs & Spatial Resolution



Step 2: Identify Data Needs & Spatial Resolution



CDM Smith

Identify Significant Data Gaps

- Missing information limits the formulation of a scientifically defensible interpretation of environmental conditions and/or potential risks in a bedrock hydrogeologic system. A data gaps exists when:
  - it is not possible to conclude with confidence whether or not a release has occurred
  - evaluation of all data, in proper context, does not/cannot support the CSM
  - if more than one interpretation of existing data set

- **Fractured rock CSMs will unavoidably have data gaps throughout the process**
  - the lateral and vertical extent of contamination
  - the direction the contamination is moving
  - identification of imperiled receptors
  - the rate at which the contamination is moving
  - what areas should be targeted for sampling.

Each data gap can be transformed into one or more specific characterization objectives

Step 3: Establish Data Collection Objectives

- Specific, Clear, Actionable
- Consider data types, quality, density, and resolution

Figure 4-1 Integrated Site Characterization

Formulate-Revise Characterization and Data Collection Objectives

- Data collection objectives (DQOs)- determine specific data needs and to select tools to be used in the investigation
- DQOs should be clear, focused, specific, & consider:
  - fracture orientation,
  - spacing and aperture,
  - hydraulic head,
  - and flow velocity

- **Characterization Objective:** Determine the lateral and vertical extent of dissolved phase VOCs.
- **Data Gap:** The vertical and lateral extent is unknown.
- **Data Collection Objective**: Gather data on: fracture location, orientation, connectivity and VOC concentration in the source, plume and towards receptors.

Step 3: Example Data Collection Objectives

Delineate extent of dissolved-phase plume; determine stability and attenuation rate

- Grab groundwater samples at X and Y depths
- Soil borings every X feet to capture subsurface variability
- Delineate to drinking water standards
- Install three to five wells; monitor along axis of flow
  - Quarterly for two years
  - Evaluate C vs T and C vs. distance trends
  - Specify COCs and geochemical parameters

CDM Smith

Step 3: Drycleaner Site Data Collection Objectives

Case Example

- Objectives
  - Define plume extent exceeding standards
  - Assess remedy progress – soil and GW samples
  - Assess shallow soil vapor & VI threat
  - Streamline assessment – days not weeks
- Data types & resolution
  - Continuous cores; samples at lithologic boundaries
  - Groundwater samples every 4’
  - Soil gas at 5 and 10 feet

Step 4: Data Collection & Analysis Plan

- Write work plan
  - Recognize data limitations
  - Select data management tool
  - Develop data analysis process
- Consider real-time analysis

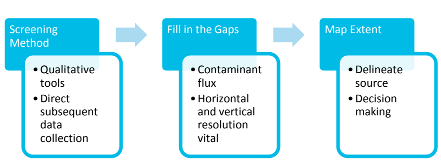
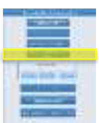


Figure 4-1 Integrated Site Characterization

4. Design Data Collection and Analysis Process

- There are generally three types of data collected:
  - Quantitative:
    - A tool that provides compound-specific values in units of concentration based on traceable standards (e.g., µg/L, ppm, and µg/m^3)
  - Semi-quantitative:
    - A tool that provides compound-specific quantitative measurements based on traceable standards but in units other than concentrations (e.g., ng or ug) or provides measurements within a range.
  - Qualitative
    - A tool that provides an indirect measurement (e.g. LIF and PID measurements provide a relative measure of absence or presence, but are not suitable as stand-alone tools for making remedy decisions.



4. Design Data Collection and Analysis Process

Accuracy:

- How “close” a result comes to the true value?
- Requires careful calibration of analytical methods with standards

Precision:

- The reproducibility of multiple measurements
- Described by a standard deviation, standard error, or confidence interval.

4. Design Data Collection and Analysis Process

Develop Site Investigation Work Plan

- The plan should be Dynamic-Flexible-Adaptable
  - This concept works for large and small sites
- Consider use of field laboratory
- Incorporate real time data collection and analysis to continuously up date CSM
- Continuously adjust work plan to incorporate evolving CSM and to address data gaps as they are understood

Step 4: Drycleaner Site Data Collection & Analysis Plan

Case Example

Soil vapor sampling

Triad ES mobile lab and Geoprobe

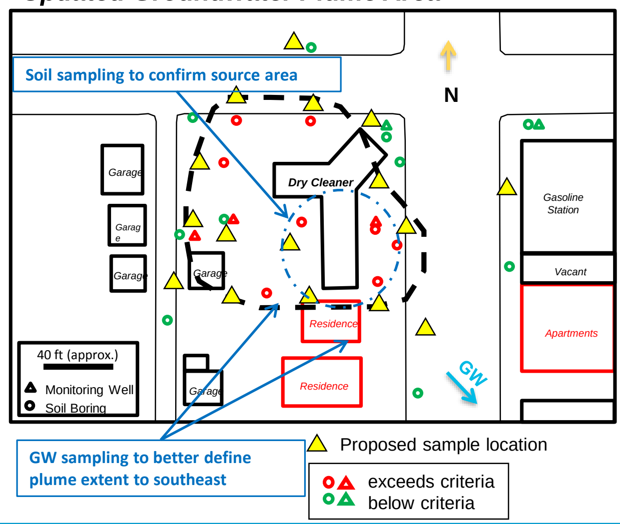
Direct sampling ion trap mass spectrometry (SW846 Method 8265) with mobile lab provides up to 80 soil/groundwater and 60 soil vapor VOC analyses per day

Step 4: Data Collection & Analysis Plan

Case Example

- 16 borings
- 80 soil samples (~5 per boring)
- 48 grab groundwater samples (~3 per boring)

Updated Groundwater Plume Area

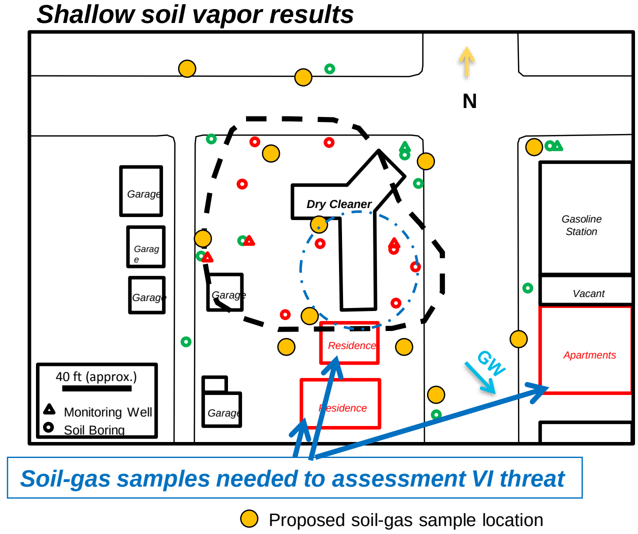


Step 4: Data Collection & Analysis Plan

Case Example

- Soil gas
  - 12 points
  - 24 samples

Shallow soil vapor results



CDM Smith

Tools Matrix Format and Location

- The tools matrix is a downloadable excel spreadsheet located in Section 4.6
- Tools segregated into categories and subcategories, selected by subject matter experts
- A living resource intended to be updated periodically

Tool
Geophysics
Surface Geophysics
Downhole Testing
Hydraulic Testing
Single well tests
Cross Borehole Testing
Vapor and Soil Gas Sampling
Solid Media Sampling and Analysis Methods
Solid Media Sampling Methods
Solid Media Evaluation and Testing Methods
Direct Push Logging (In-Situ)
Discrete Groundwater Sampling & Profiling
Multilevel sampling
DNAPL Presence
Chemical Screening
Environmental Molecular Diagnostics
Microbial Diagnostics
Stable Isotope and Environmental Tracers
On-site Analytical

Excel worksheet available at http://www.itrcweb.org/documents/team_DNAPL/DNAPL.xlsm

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

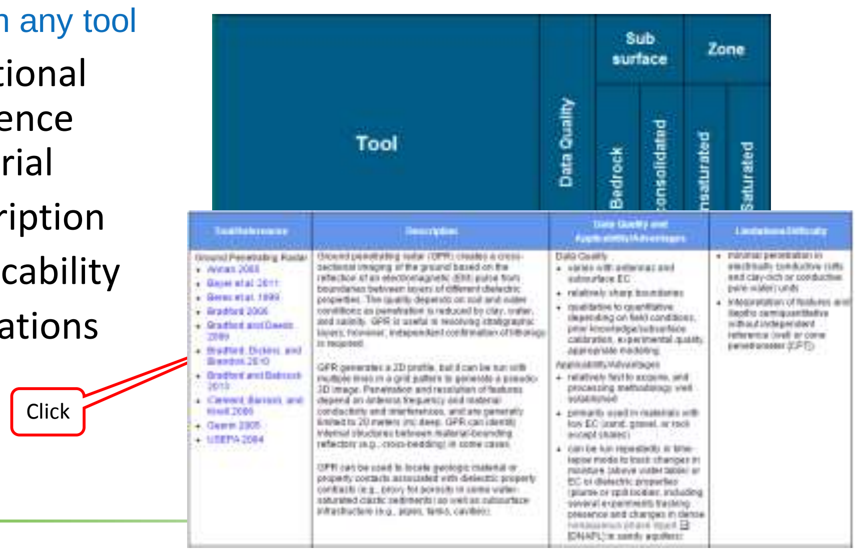
Tools Matrix Functionality

Click any box for a description or definition

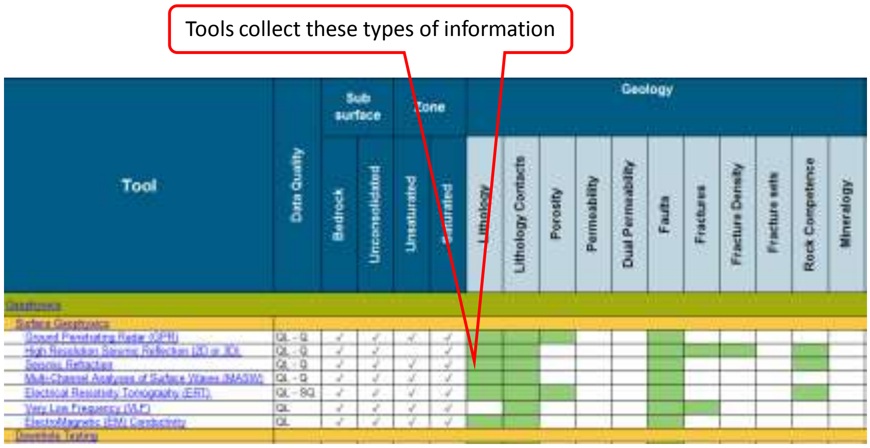
Detailed Tool Descriptions (Appendix D)

Click on any tool

- Additional reference material
- Description
- Applicability
- Limitations



Shaded Boxes Denote Tool Meets Objective



Green shading indicates that tool is applicable to characterization objective

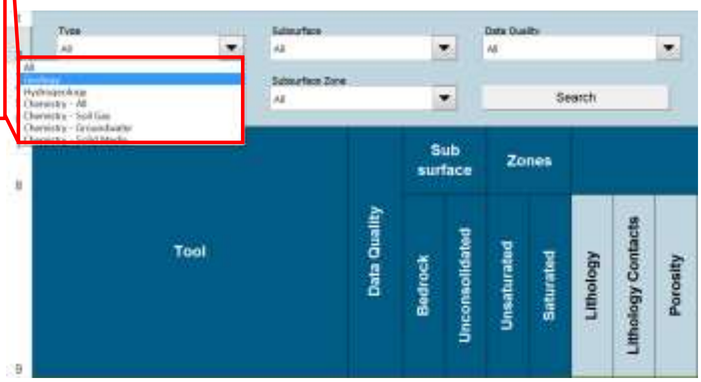
Using the Tools Matrix

- Down-selecting appropriate tools to meet your characterization objectives
- A systematic process
  - Select your categories: geology, hydrogeology, chemistry
  - Select parameters of interest
  - Identify geologic media (e.g., unconsolidated, bedrock)
  - Select saturated or unsaturated zone
  - Choose data quality (quantitative, semi-quantitative, qualitative)
  - Apply filters, evaluate tools for effectiveness, availability, and cost
- Ultimately, final tools selection is site-specific, dependent upon team experience, availability, and cost

CDM Smith

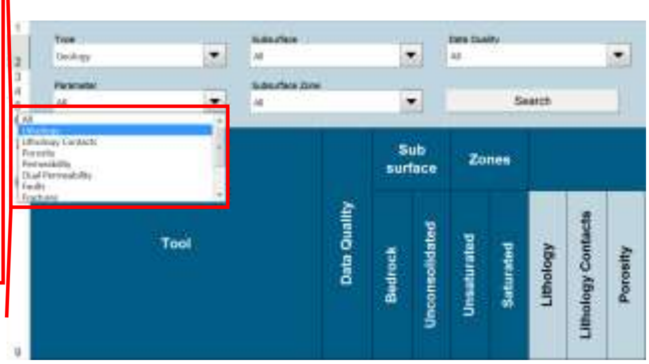
1. Select Category

- All
- Geology
- Hydrogeology
- Chemistry
  - All
  - Soil Gas
  - Groundwater
  - Solid Media



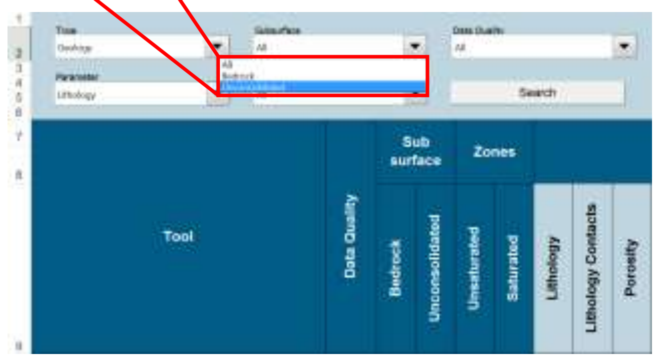
2. Select Parameters of Interest

- All
- Lithology Contacts
- Porosity
- Permeability
- Dual Permeability
- Faults
- Fractures
- Fracture Density
- Fracture Sets
- Rock Competence
- Mineralogy



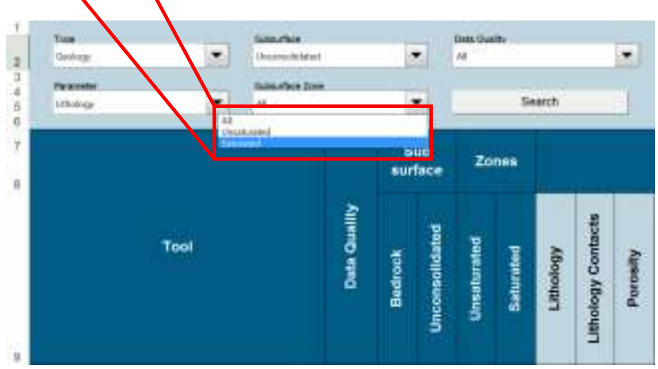
3. Identify Geologic Media

All
Bedrock
Unconsolidated



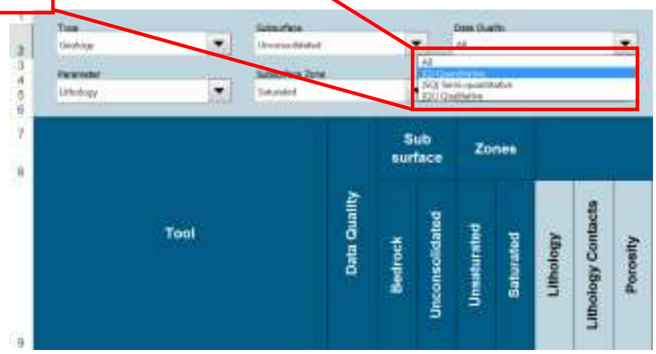
4. Identify Zone

All
Unsaturated
Saturated



5. Choose Data Quality

(Q) quantitative
(SQ) semi-quantitative
(QL) qualitative



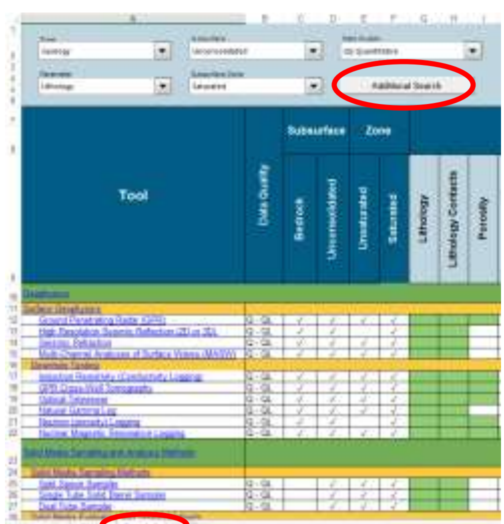
6. Apply Filters, Evaluate Tools

Perform Additional Searches to Find More Tools for Different Objectives

Additional parameters can be added or removed from any given search

Add Parameters to a previous search

Multiple searches can be saved on one matrix



Apply Selected Tool(s)

- Incorporate selected tool(s) into characterization plan
- Implement plan, evaluate data, update CSM, reassess characterization objectives
- Repeat tool selection process as necessary

Case Example – Characterization Objectives

Case Example

Returning to Case Example from prior section

– **Characterization Objective:**

- Delineate lateral and vertical extent of dissolved-phase plume; determine stability and rate of attenuation.

Goal:

- Define boundary exceeding groundwater standards
- Assess remedy progress – soil and groundwater samples
- Assess shallow soil vapor impacts

CDM Smith

Case Example – Select Tools Matrix Filters

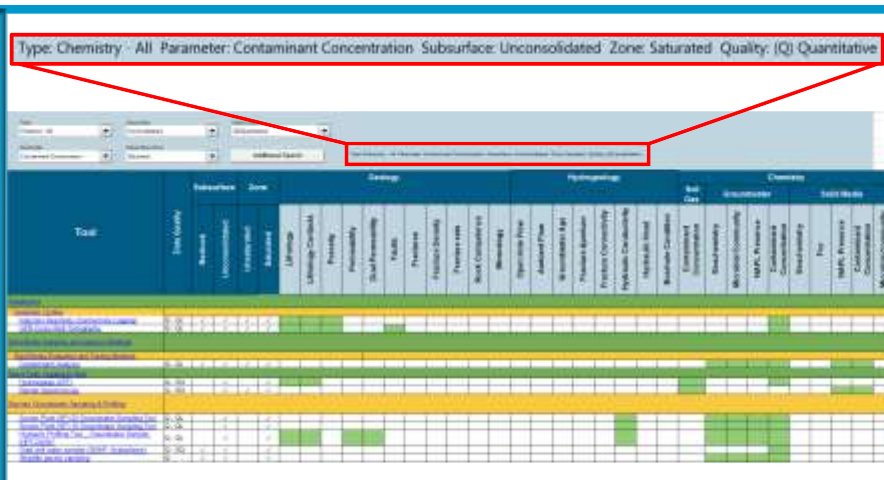
Case Example

Filters

- Type
  - Chemistry
- Parameter
  - Contaminant Concentration
- Subsurface Media
  - Unconsolidated
- Subsurface Zone
  - Saturated
- Data Quality
  - (Q) Quantitative

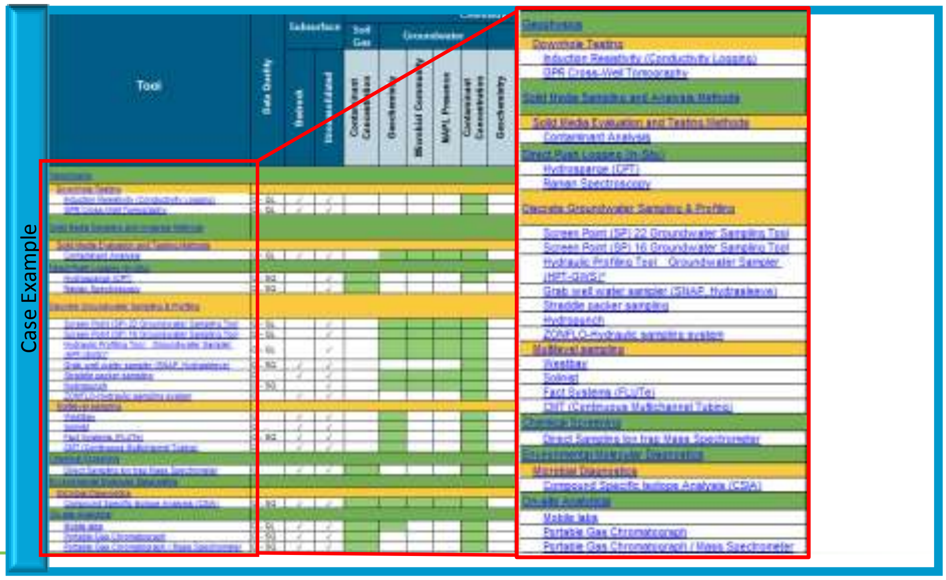
Case Example – Apply Filters

Case Example



Case Example – Applicable Tools

Case Example



Case Example – Tools Selection

Case Example

- Search returns 21 tools
- Considering desire to expedite the assessment, project team selected
  - Direct Push borings with continuous soil sampling and GW grab sampling on 4-foot intervals
  - Active Soil Gas Survey at two depth intervals
  - Direct Sampling Ion Trap Mass Spectrometer (DSITMS) mobile field lab

Active Soil Gas Survey

DSITMS Mobil Lab

ITRC Tools Matrix Summary

- Characterization objectives guide selection of tools
- Interactive tools matrix - over 100 tools with links to detailed descriptions
- A systematic tools selection process
- Select tools, implement work plan, evaluate results
- Align data gaps with characterization objectives, update CSM
- Repeat as necessary until consensus that objectives have been met

Conducting Investigation – Details in Subsequent Workshop!

- Step 6: <u>Implement</u> investigation
- Step 7: <u>Perform</u> data evaluation and interpretation
- Step 8: <u>Update</u> CSM

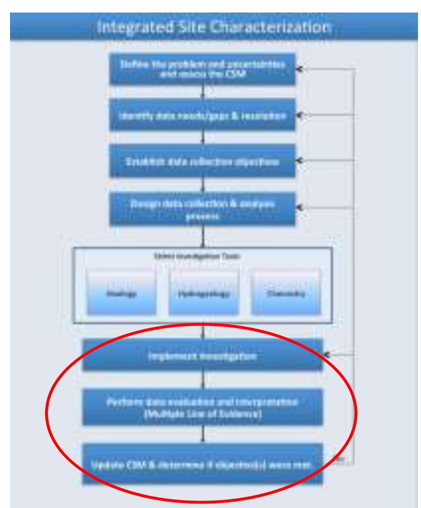


Figure 4-1 Integrated Site Characterization

More on the Content of the Characterization Plan

Develop a Work Plan

A typical characterization work plan should:

- Emphasize characterization and data collection objectives
- Present a data collection process
- Include the tools selected
- Be forward-looking to discuss what procedures/software/models will be used for data evaluation and interpretation
- Include data evaluation process, particularly for fractured rock sites

More on the Content of the Characterization Plan

Develop a Work Plan

Use a dynamic field approach to site characterization to the extent practical, even at fractured rock sites

- The work plan should be flexible to allow changes to the work scope based on real-time results obtained during the investigation activities.
- The work plan should outline the process for documenting field changes or adjustments during implementing the site investigation

More on the Content of the Characterization Plan

Develop a Work Plan

A dynamic work plan can involve

- Real time data assessment
- Frequent (up to daily) calls or data uploads between the field team and project stakeholders to review field activities and data, to make decisions next steps for efficiently completing the characterization.
- Continuously or frequently updating the CSM

Additional Words of Wisdom

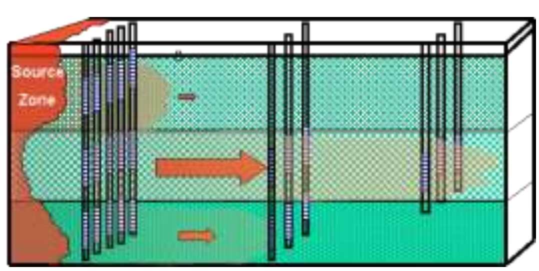
- Understand the difference between characterization and monitoring
  - Don't use monitoring wells for site characterization (fractured rock sites excepted)
- Value quantity of data collected over quality
  - Profiling tools
  - Field laboratories/instrumentation
- Don't wait to deploy innovative tools and technologies
  - Molecular diagnostics
  - In situ microcosms
  - Mass flux/mass discharge evaluations

Molecular Tools

- Don't wait until late stages of project (e.g. pre-design or later) to evaluate microbial community/degradation potential
- Valuable information can be gained from a small number of samples
- One example is QuantArray from Microbial Insights, which can provide data on several key types of microbes and enzyme systems

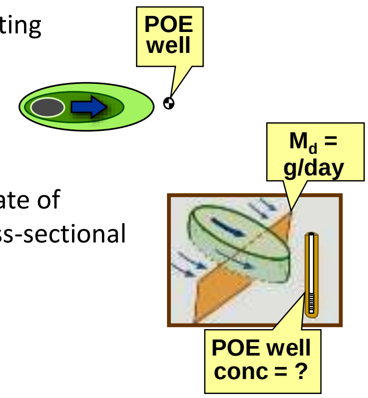
Use and Measurement of Mass Flux and Mass Discharge

An ITRC Technology Overview Document (published 2010)



Mass Discharge vs. Traditional Approach

- ***Traditional Approach:*** Measure existing plume **concentrations** to assess
  - Impact on receptor wells
  - Natural attenuation rates
  - Remedial options
- ***Mass Discharge Approach:*** Define rate of **mass discharge** across specified cross-sectional areas of plume to assess
  - Impact on receptor wells
  - Natural attenuation rates
  - Remedial options

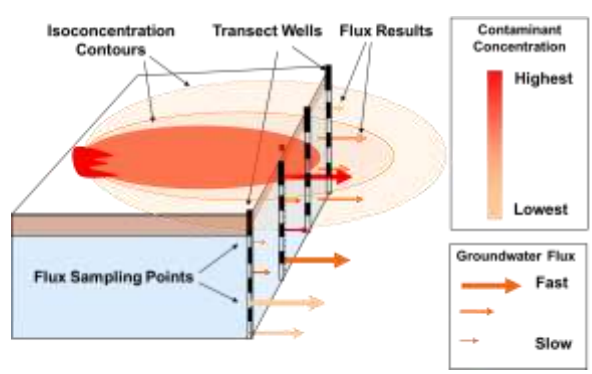


KEY BENEFITS: **Mass discharge approach <u>sometimes</u> offers a better understanding of potential risks and attenuation rates, and can lead to sounder remediation strategies.**

Mass discharge approach based on Einarson and Mackay (2001) ES&T, 35(3): 67A-73A

Mass Flux/Mass Discharge

- ITRC guidance provides thorough discussion of this topic, including measurement methods
- If this is a goal for your site characterization plan, it will impact the data to be collected
  - Mass flux/mass discharge evaluations can be very data intensive
  - Difficult to "retrofit" data into a mass flux/mass discharge evaluation
- Can be very useful to understand your site



Case Study Examples

Commerce Street Plume Superfund Site

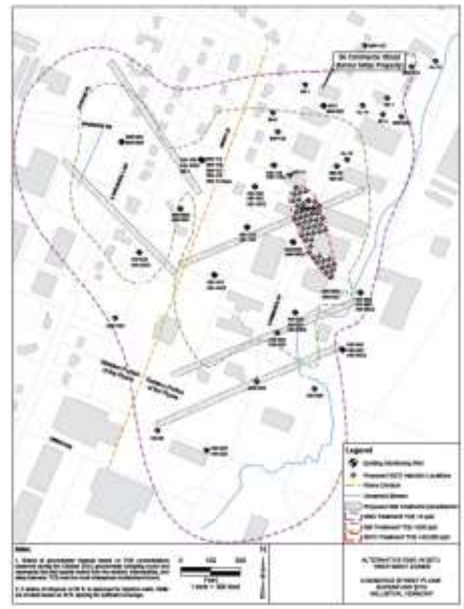
- TCE plume in mixed-use area
- ROD-selected remedy:
  - In situ chemical oxidation (ISCO) for TCE > 50,000 ppb
  - In situ bioremediation (ISB) for TCE > 500 ppb but <50,000 ppb
  - Monitored natural attenuation (MNA) for TCE < 500 ppb
- Follow ISC process to define data gaps, set objectives, and select tools
- Lesson Learned – site conditions can change over relatively short time frames

CDM Smith

High Resolution Site Characterization

Initial CSM

- TCE DNAPL released into sandy aquifer
- Sand unit:
  - Shallow zone 10-20 ft below ground surface (bgs)
  - Intermediate zone 20-30 ft bgs
  - Deep zone 30-40 ft bgs
- Continuous clay unit underlying sand unit (40 ft bgs)



Characterization Activities and Preliminary Results

Characterization program

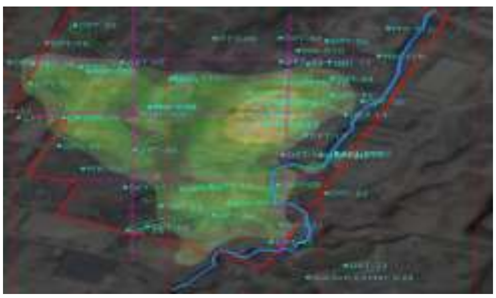
- Membrane interface probe/hydraulic profiling tool (MiHPT)
- Waterloo Advanced Profiling System (APS)
- DPT soil and groundwater sampling
- Onsite VOC analysis

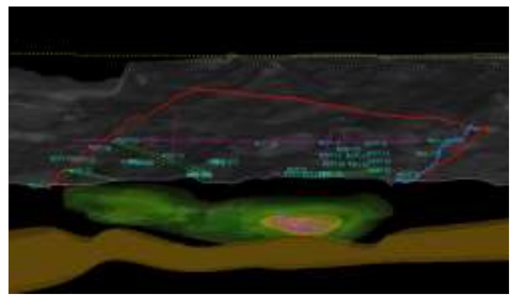
Results Summary

- 50,000 ppb hotspot no longer exists
- In east-central portion of site, TCE is almost completely converted to c-DCE
- Sand unit is hydraulically somewhat variable and not related to previous designations

Path Forward

- ISCO may no longer be needed
- Current nature and extent of contaminants could be treated by ISB and MNA
- Bench and pilot testing approach is being modified
- RD will incorporate new CSM and bench/pilot results





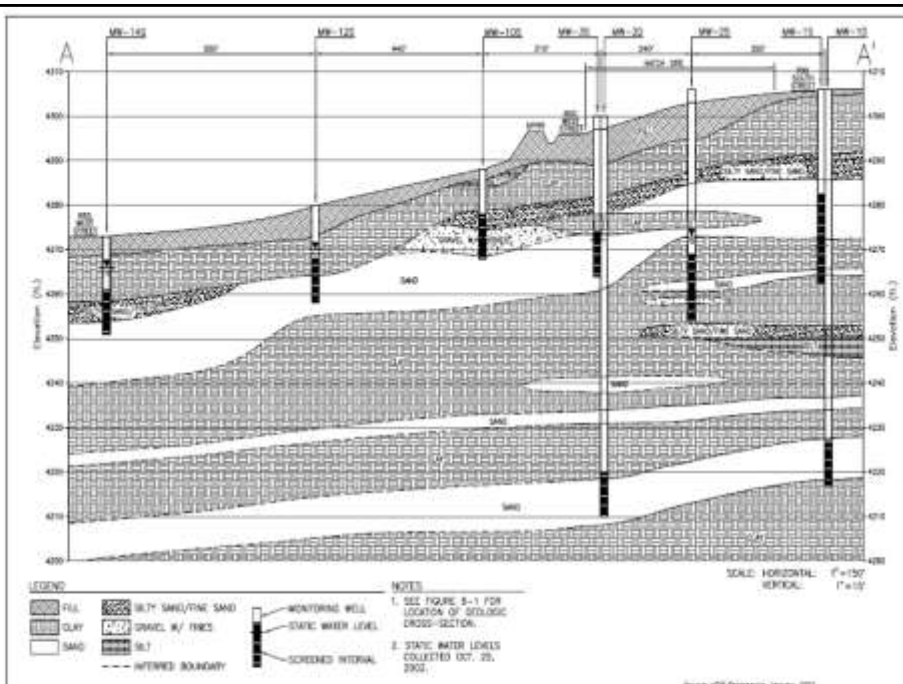
Bountiful OU1 Site

- Lesson Learned: Be willing to challenge the current CSM

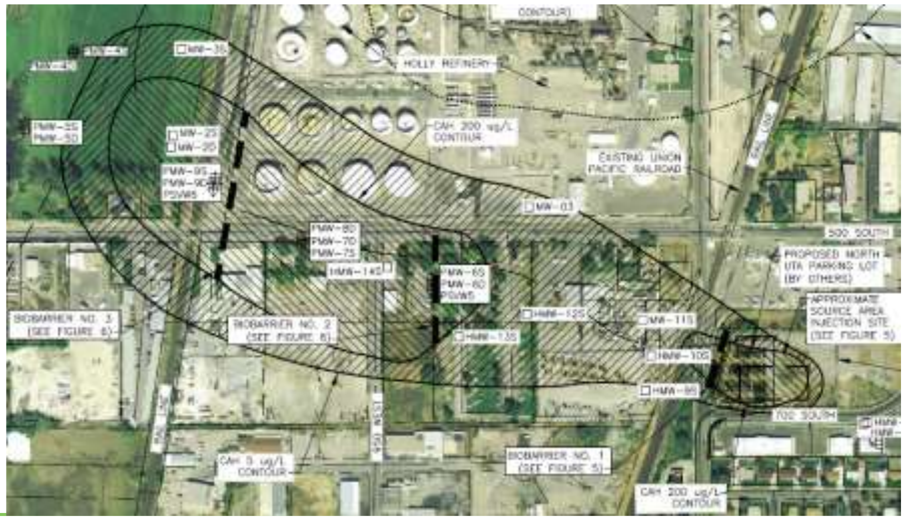
CDM Smith

Site Hydrogeology - RI

- Water table generally at about 25-30 ft. bgs
- Sand and gravel zones present to 35-40 ft. bgs
- Clay aquitard present below sand and gravel unit
- Separate, uncontaminated sand and gravel unit below clay



Full-Scale Design



Pre-RA Characterization (2008-2009)

- Source area & Biobarrier # 1
  - Membrane interface probe (MIP) / Electrical Conductivity (EC) characterization to determine contaminant profile and lithology
  - Direct push technology (DPT) points to confirm MIP/EC results
- Biobarrier # 2 and # 3
  - MIP/EC and DPT along plume axis to look for hotspots > 200 µg/L
  - Additional MIP/EC and DPT at the identified hot spots to define biobarrier locations
- Monitoring well installation and baseline sampling

Pre-RA Characterization Results: Contaminant Distribution

- Membrane-interface probe (MIP) used to determine areas with high concentrations of VOCs
- MIP results showed responses at depths greater than 40 ft. throughout the source area and downgradient plume
- DPT sampling confirmed MIP results as source concentrations greater than 15,000 ppb were found below 40 ft.
- Downgradient concentrations were greater than 3,000 ppb in one location

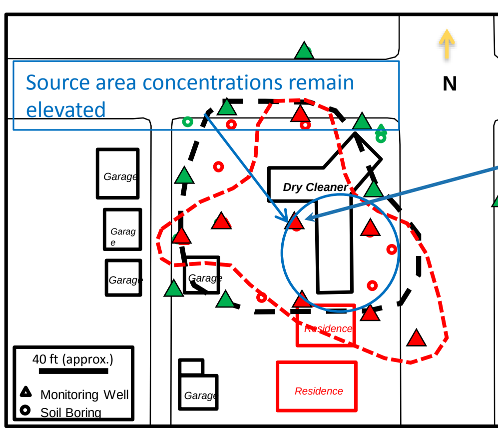
Pre-RA Characterization Results: Hydrogeology

- Clay layer at 35 ft. bgs was found to be laterally discontinuous
- Modified DPT/EC approach was used to investigate hydrogeology below 60 ft.
- Below 35 ft., layers of sand and gravel exist to 80 feet bgs, with intermittent thin clay layers present in some areas
- A several foot thick clay layer was found at depths of approximately 80 ft. throughout the source area
- The deep clay layer was confirmed in the downgradient area during other site drilling activities
- As a result, the remedial design was changed to include injection into deeper zones

Wrapping up the ISC case study

Step 7. Soil and Groundwater Data Evaluation and Interpretation

Case Example



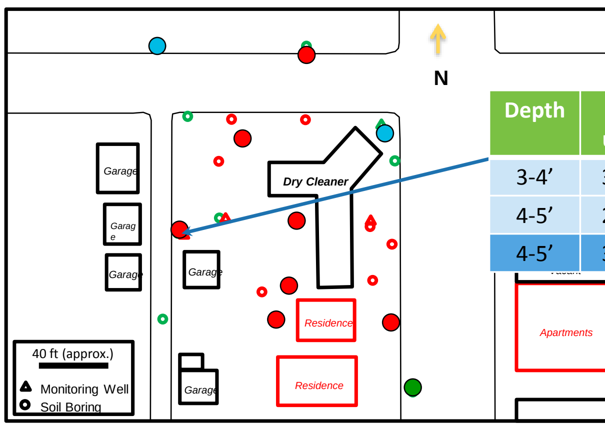
Depth	PCE mg/kg	Lab
0-2	3.25	Mobile
2-4	2.232	Mobile
4-6	<0.37	Mobile
6-8	3.298	Mobile
8-10	11.5	Mobile
10-12	<0.37	Mobile
0-2’	21	Fixed

Result exceeds criteria
Result does not exceed criteria

CDM Smith

Step 7. Soil Vapor Data Evaluation and Interpretation

Case Example



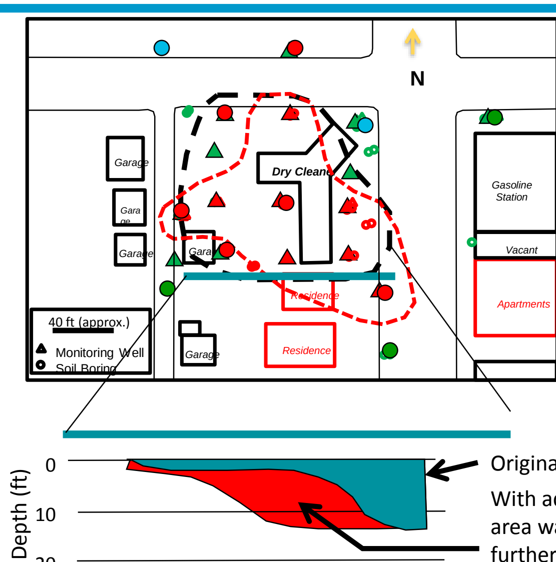
Depth	PCE units	Lab
3-4’	3720	Mobile
4-5’	2398	Mobile
4-5’	3800	Fixed

Shallow soil vapor results

- Result below vapor screening level
- Result exceeds chronic vapor screening level
- Result exceeds sub-chronic vapor screening level

Step 8: Dry Cleaners – CSM Update

Case Example



- < vapor screening level
- > chronic vapor screening level
- > sub-chronic vapor screening level
- > soil/GW criteria
- < soil/GW criteria

Original vertically-delineated plume

With additional data, the source area was found to extend west further than previously delineated

CDM Smith

Integrated Site Characterization Benefits for Dry Cleaners Sites

Case Example

- Confirmed need for residential indoor air evaluation and VI mitigation for commercial buildings
- Optimized data density in specific areas; avoided unnecessary / inconclusive data collection
- Accurately determined source zone and remediation target area
- Completed ahead of schedule; saved $50k of $150k budget (33%)

Summary

- Characterization activities should be driven by objectives (e.g. SMART)
- Characterization plan should facilitate dynamic decision making
- The CSM should be continuously updated during all project phases

Ryan A. Wymore, PE
Technical Strategy Leader for Remediation
CDM Smith
555 17th St Suite 500
Denver, CO 80202
wymorera@cdmsmith.com
(720)-264-1126

CDM Smith