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# Best Practices for Site Characterization

*AquaConSoil 2015*

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# Let's Start With a Few Definitions

Best Practices → A set of methods or techniques found to be the most effective and practical means in achieving an objective while making the optimum use of resources

## Characterization vs. Monitoring

**"the act of characterizing or describing the individual quality of a person or thing." ***

Build Conceptual Site Model- We want to understand and describe site attributes like:
-Contaminant properties and distribution
- Fate and transport
-Geologic setting/site attributes
-Hydrogeologic setting/site attributes
-Risk

**"to watch, observe, listen to, or check (something) for a special purpose over a period of time." ***

Test Conceptual Site Model- We want to observe changes in site attributes like:
-Temporal changes
-Effects from active/passive remediation
-Compliance

*** As defined by Merriam/Webster**

# EPA's Triad Approach-
## *The Source of Many Best Practices*

A process for building a consensus vision for conducting environmental investigation and remediation


A work strategy that incorporates the flexibility to adapt to information generated by real-time measurement technologies

Real-time = within
a timeframe that allows the project team to react to the information while in the field

***Synthesizes practitioner experience, successes, and lessons learned into an institutional framework***

# Common Best Practices Associated with Triad

- Comprehensive team formation
- Adaptive site management
- Project life cycle CSM
- Stakeholder outreach
- Systematic planning
- Dynamic work strategies
- Real-time measurement technologies
- Demonstration of method applicability
- High resolution collaborative data
- 3-D visualization and analysis
- Data management and communication
- Optimization

# Investigate and Characterize with Remediation in Mind

*If you don't know where you're going, any road will take you there.*
*-- George Harrison*

**Superfund Requirements for Action (must have all four)**

- Hazardous substance
- Sufficient quantity
- Migration pathways
- Sensitive receptors

**Four Remedial Options (perform one or more)**

- Treat to non-hazardous
- Remove – excavate/extract
- Immobilize, contain, cut off
- Protect/remove receptors

**<u>The remedial investigation</u>:**

***Superfund Reforms Glossary**

1. Determine the nature and extent of contamination
2. Establish site cleanup criteria
3. ***<u>Identify preliminary alternatives for remedial action</u>***
4. ***<u>Support technical and cost analyses of alternatives</u>***

**<u>All too often</u>: RIs only address nature and extent**

**Field data collection → Lab analysis → Data tabulation → Report prep→ Review/comments → Report edit → Data gap analysis → Back to the field**

**Is there a better way?**

# How Did We Get Here?

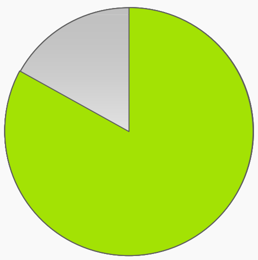
## A Brief History of Optimization

*Optimization 2015*
*"Systematic site review by a team of independent technical experts, at any phase of a cleanup process, to identify opportunities to improve remedy protectiveness, effectiveness and cost efficiency; and to facilitate progress toward site completion."*

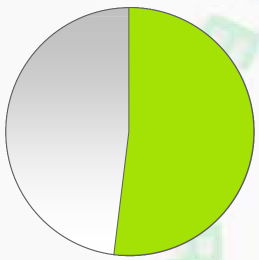
# Optimization Results 2005

Based on an analysis of 52 of 100 optimized sites

- Cost savings

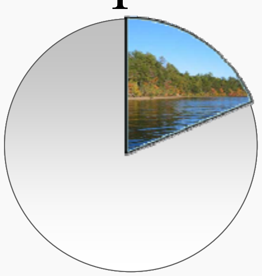


83% cost savings opportunities

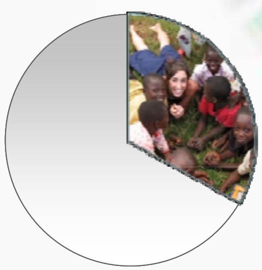


52% cost savings opportunities > $1 million

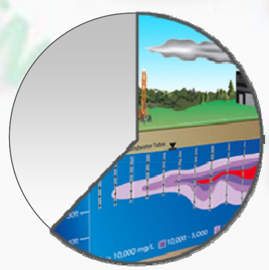
- Improved protectiveness



19% eliminate or confirm no ecological exposures

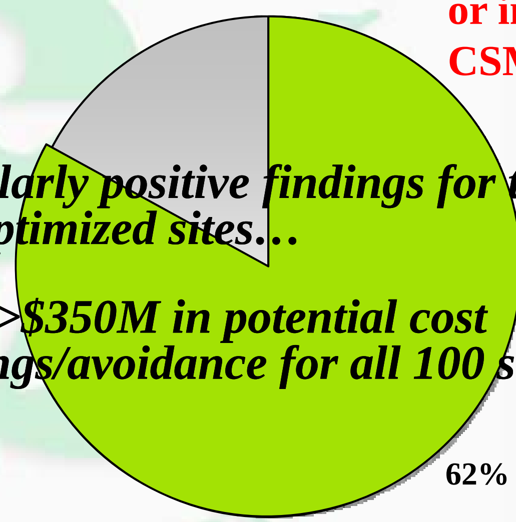


33% eliminate or confirm no human exposures



62% improve or confirm control of plume migration

**>50% of sites had recommendations for additional characterization or improvements to the CSM**



***Similarly positive findings for the other 48 optimized sites…***

***and >$350M in potential cost savings/avoidance for all 100 sites.***

**62% improve or confirm control of plume migration**

**52% cost savings opportunities > $1 million**

**83% of sites cost savings opportunities**

**19% eliminate or confirm no ecological exposures**

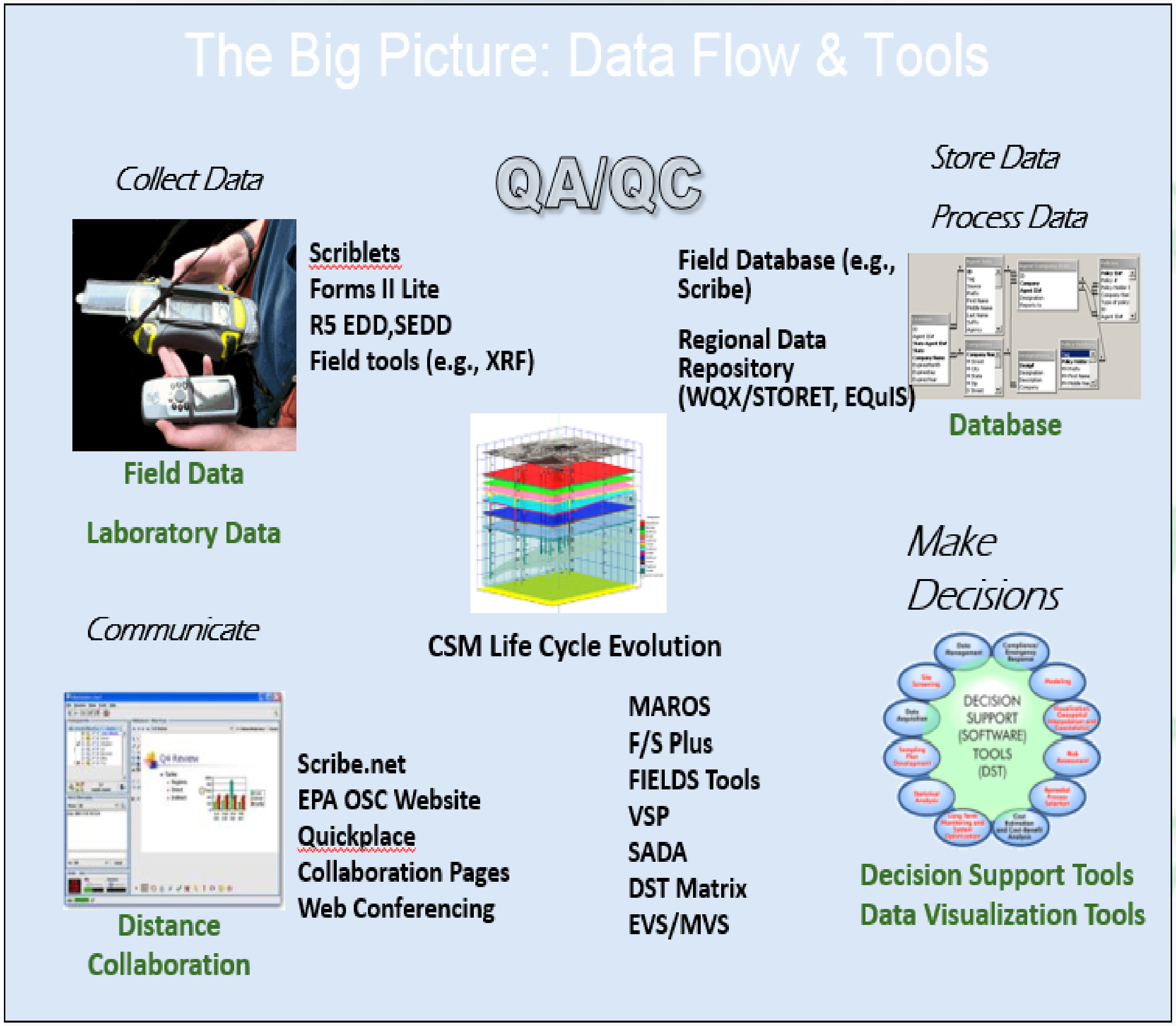
**33% eliminate or confirm no human exposures**

# Where Do We Go From Here?

- **Data management**
  - Historically reports as mechanism to exchange information, now data as  deliverable, active data management
  - Data warehouse, data interoperability, economies of scale
- **High Resolution Site Characterization**
  - Direct sensing tools, scale appropriate measurements
  - Collaborative data approaches
- **Real-time data visualization**
  - Conceptual Site Model (CSM) lifecycle management

# Data Management is Key

*Plans required- Region, Site, Project*



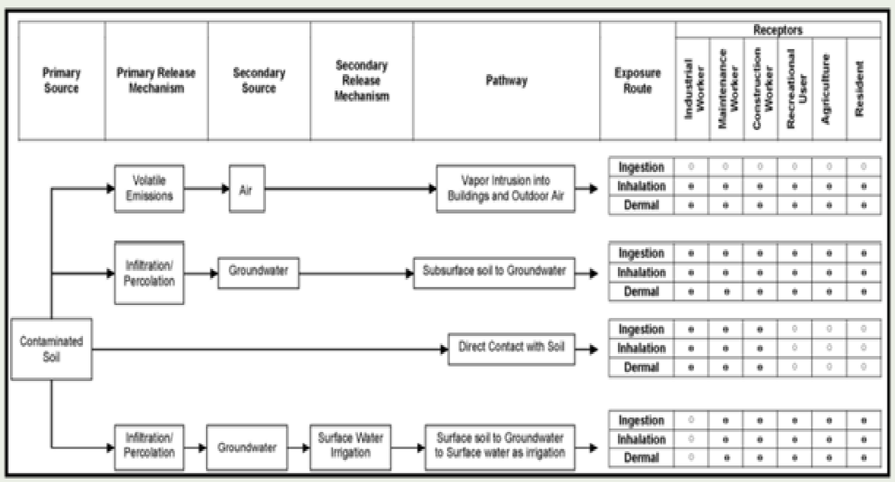

- **Data acquisition**
  - Occurs quickly, involves large amounts of data
  - Data must be integrated into CSM quickly to inform continued data acquisition while mobilized
- **Data input**
  - Automatic/manual systems to QC at point of generation accurately transfer to databases
- **Decision Support**
  - Statistical, visualization, modeling
- **Communicate**
  - Force interpretation, compress timeframes

# Data Management Leads to A Robust Conceptual Site Model

## What is a CSM?

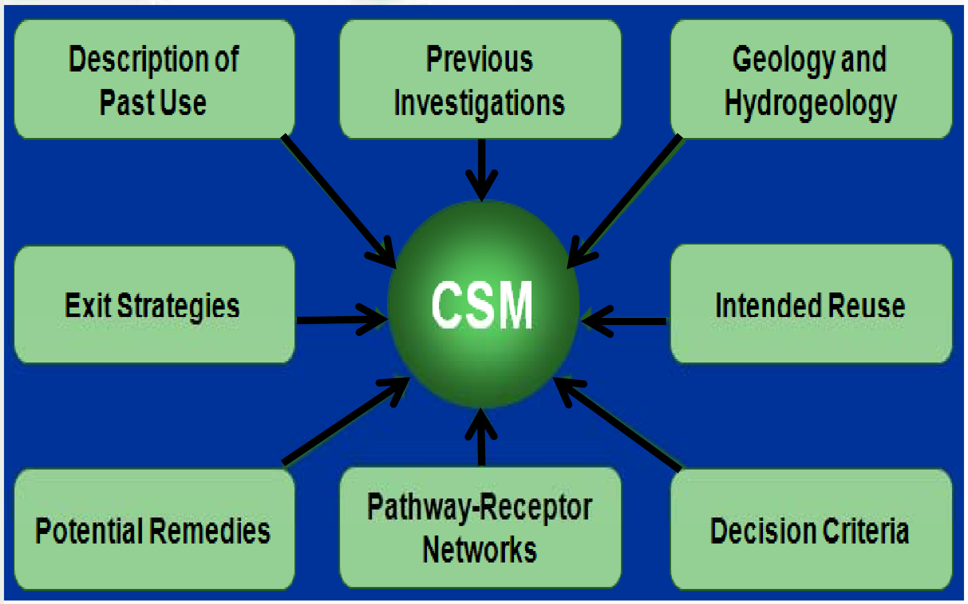
- Written and graphical expression of site knowledge
- Primary basis for project design and execution
- Updated throughout project life cycle
- Essential to successful projects

- P-RN diagrams are NOT FULL CSMs – too simple to serve all CSM functions
- However, they are a critical COMPONENT of CSMs




- CSM should incorporate all actual and potential P-RNs
- Investigation efforts confirm or refute each element of P-RNs

***Primary Anatomy of a CSM***



# Project Life Cycle CSM Supports All Programs and Project Phases

Environmental Cleanup Best Management Practices: Effective Use Of The Project Life Cycle Conceptual Site Model. EPA 542-F-11-011

| General Environmental Cleanup Steps | CSM Life Cycle | Best Management Practices: SPP | Best Management Practices: DWS/RTMT | CERCLA - Superfund | RCRA | Brownfields | UST | VCUP Varies by State | IRP/ERP | MMRP |
|---|---|---|---|---|---|---|---|---|---|---|
| Site Assessment | Conceptual; Preliminary CSM; Baseline CSM | | | Preliminary Assessment (PA); Site Inspection (SI); National Priorities List (NPL); No Further Remedial Action Planned (NFRAP) | Facility Assessment (RFA) | Phase I Environmental Site Assessment (ESA) | Initial Site Characterization; Initial Response | PA; SI | PA; SI | PA; SI; MR Site Prioritization Protocol (MRSPP) |
| Site Investigation and Alternatives Evaluation | Characterization CSM Stage | | | Remedial Investigation/ Feasibility Study (RI/FS); Removal Actions - Emergency/ Time Critical/Non-Time-Critical | Facility Investigation (RFI); Corrective Measures Study (CMS) | Phase II ESA | SI; Corrective Action Plan (CAP) | RI/FS | RI/FS; NFRAP | RI/FS |
| Remedy Selection | Design CSM Stage | | | Proposed Plan; Record of Decision (ROD) | Statement of Basis (SB); Final Decision and Response to Comments | Remedial Action Plan (RAP) | Cleanup Selection | ROD | Proposed Plan; ROD | Remedy Selection |
| Remedy Implementation | Remediation/ Mitigation CSM Stage | | | Remedial Design (RD); Remedial Action (RA) – Interim and Final | Corrective Measure Implementation (CMI) | Cleanup and Development | Corrective Action; - Low-impact site cleanup; - Risk-based remediation; - Generic remedies; - Soil matrix cleanup | RD; RA | RD; RA – Interim and Final; Remedy in Place (RIP) | RD; Time Critical Removal Action (TCRA); RA; RIP |
| Post-Construction Activities | Post-Remedy CSM Stage | | | Operational & Functional Period; Operation & Maintenance (O&M); Long term monitoring (LTM); Optimization; Long Term Response Action (Fund-lead groundwater/surface water restoration) | O&M; On-site inspections and oversight | Property Management; Long-term O&M; Redevelopment Activities (Private- and Public-led) | LTM | O&M; LTM | Shakedown period; Operating Properly and Successfully; O&M; LTM | Shakedown period; Long Term Management |
| Site Completion | Quantitative | | | Construction Complete (CC); Preliminary or Final Close Out Report (PCOR/FCOR); Site Completion - FCOR; Site Deletion; O&M as appropriate | Certification of Completion; Corrective Action Complete with Controls or without Controls | CC; Property Management | No Further Action (NFA) | CC | Response Complete (RC); NFA | RC; NFA |

Abbreviations:

SPP = Systematic Project Planning
DWS = Dynamic Work Strategies
RTMT = Real Time Measurement Technologies

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
RCRA = Resource Conservation and Recovery Act

UST = Underground Storage Tanks
VCUP = Voluntarily Clean Up Programs

IRP/ERP = Installation Restoration Program/ Environmental Restoration Program
MMRP = Military Munitions Response Program

*"As we know, there are known knowns. There are things we know we know. We also know there are known unknowns. That is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know."*

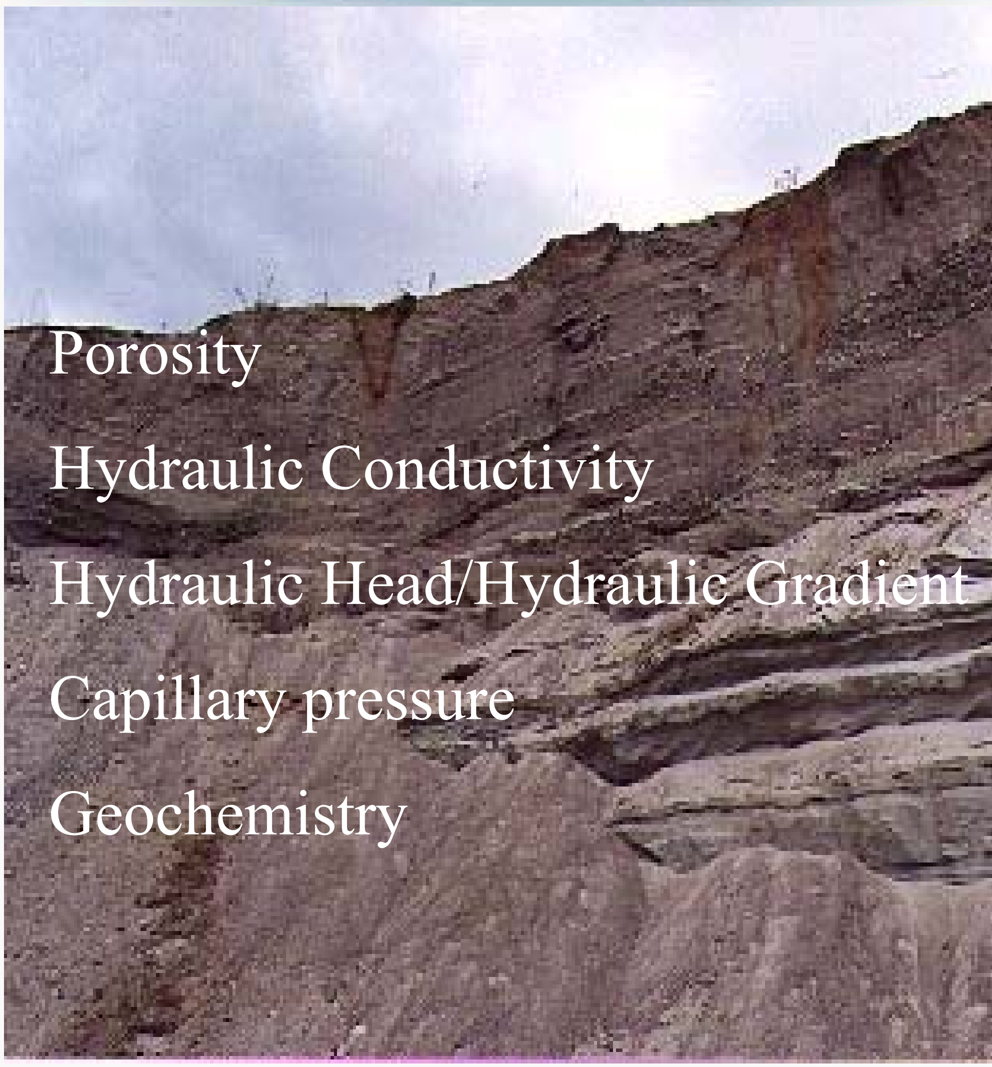
**Donald Rumsfeld,**

**Feb. 12, 2002**
**U.S. Department of Defense**

Newmark PCE plume 25 to 1ppb without WHS.4d

Newmark Geologic_Hydrogeologic Controls on Plume.4d

# Why High Resolution Site Characterization (HRSC)?



Porosity

Hydraulic Conductivity

Hydraulic Head/Hydraulic Gradient

Capillary pressure

Geochemistry

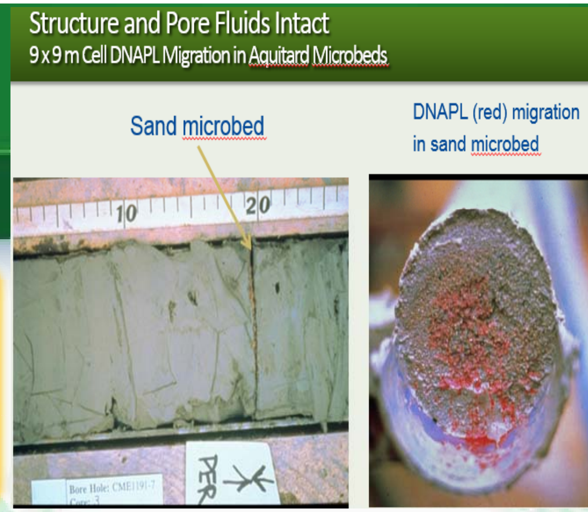
- **Historical perspective**
  - » Soil- EPA Superfund has historically focused on high quality analytical samples collected at discrete soil locations
  - » Groundwater- EPA has historically used monitoring wells, pump tests, etc. to characterize and monitor sites
- **Challenges encountered**
  - » Discrete soil sampling designs do not address matrix variability/heterogeneity- resulting in highly variable or statistically uncertain decision making
  - » Large scale averages of aquifer materials obscure primary contaminant transport and mass storage areas
- **New thinking**
  - » Soil- Incremental and composite techniques that provide large scale averages are better suited to represent exposure scenarios, control matrix variability/ sample heterogeneity, and make statistically confident decisions
  - » Groundwater- large scale averages derived from aquifer materials can be misleading resulting in poorly performing or applied remedies. HRSC techniques provide measurements at scales more appropriate for remedy design.

## Incremental Soil Sampling vs. HRSC in Groundwater

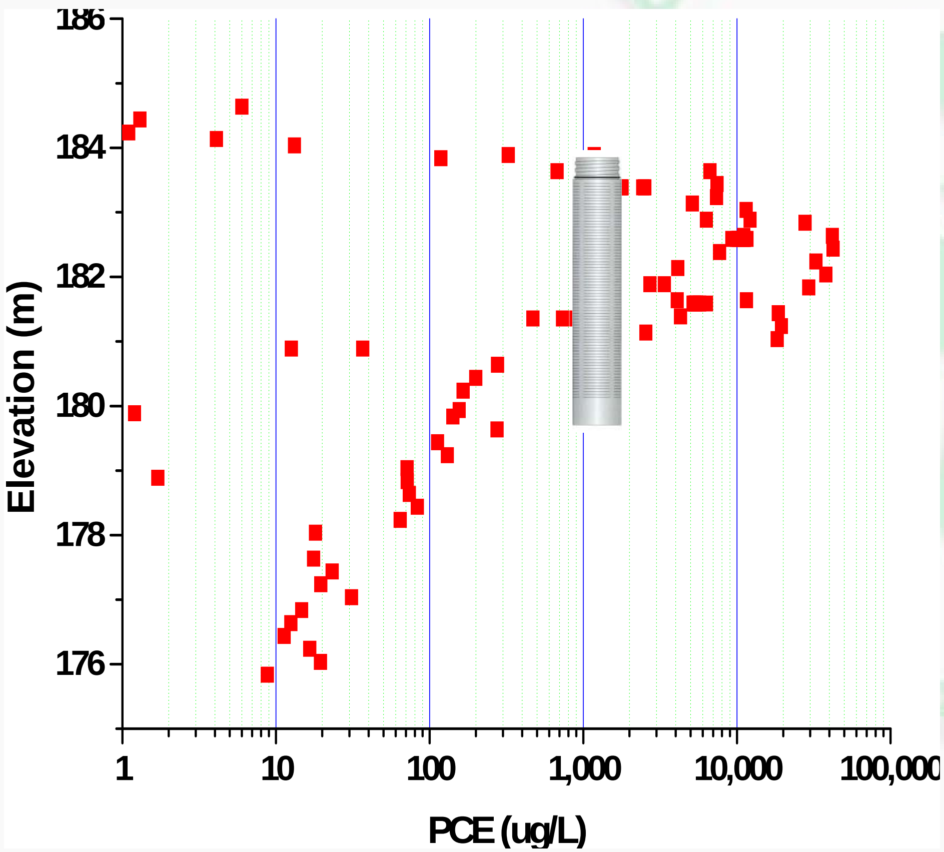
| Soil | Matrix Property | Groundwater |
|---|---|---|
| 1. High | 1. Variability | 1. High |
| 2. Static, Lower spatial correlation | 2. Contamination distribution | 2. Dynamic, higher spatial correlation |
| 3. Low | 3. Mass transfer and storage | 3. High |
| 4. Low | 4. Cost of obtaining samples | 4. High |
| 5. Decision Unit | 5. Typical exposure scenarios | 5. Variable |
| 6. Lower cost/shorter cleanups= blunt force | 6. Remediation applications | 6. High cost/long cleanups= finesse, |

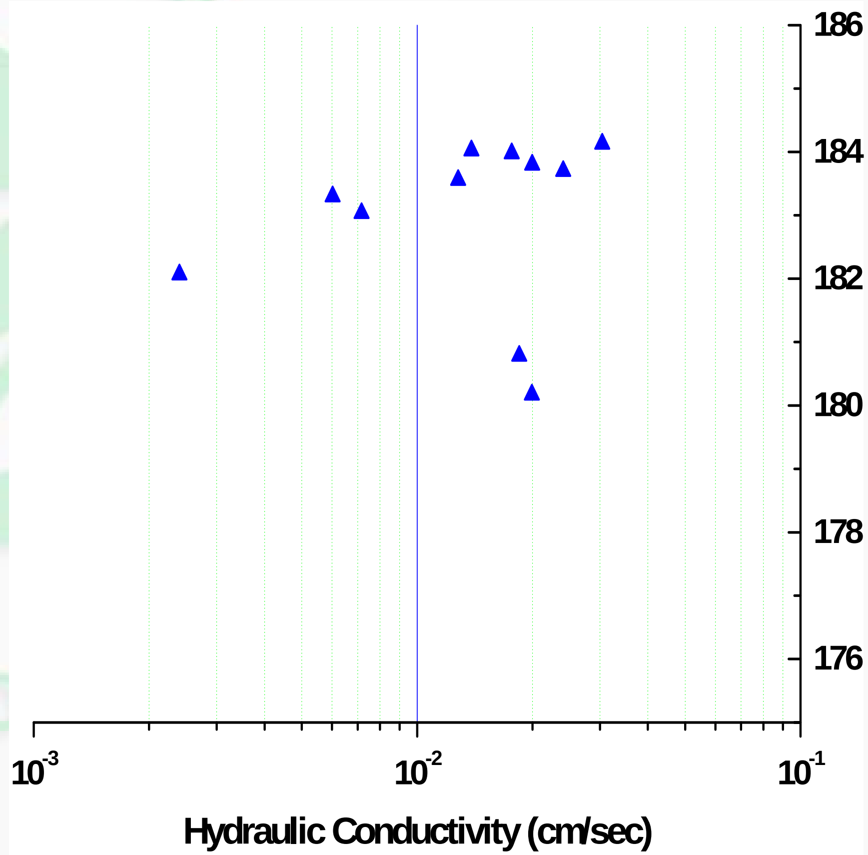
# Sampling Scale and Averaging

Monitoring wells yield a depth integrated flow weighted average

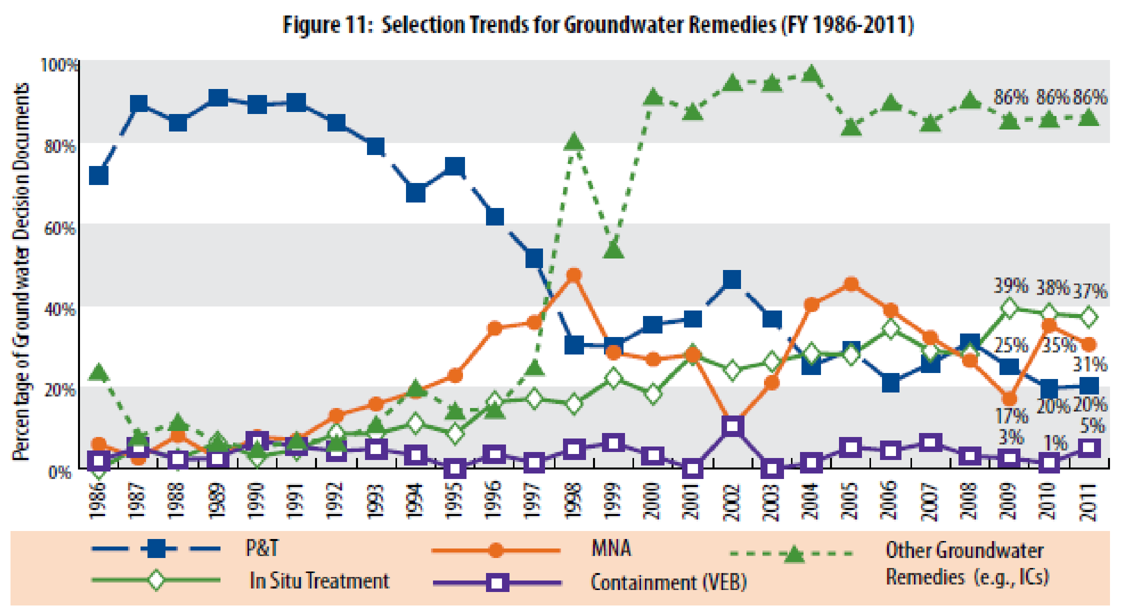






# Mass Flux Distribution-
# *The Rise of In-Situ Remedies*



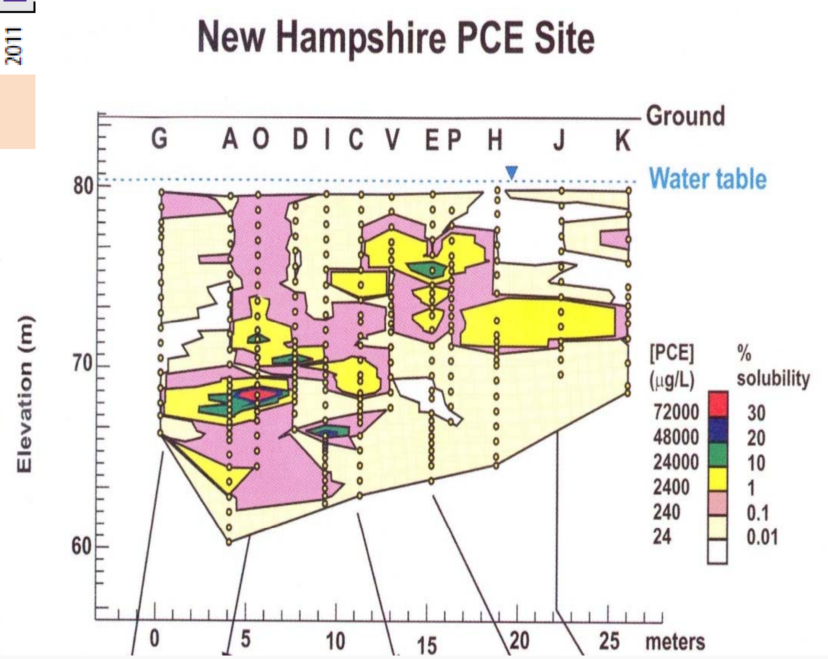

**Superfund Remedy Report 14th edition**

- **1980's- Pump and Treat 90% of GW remedies, no in-situ remedies**
- **2011- Pump and Treat 30%, In-situ almost 40%**

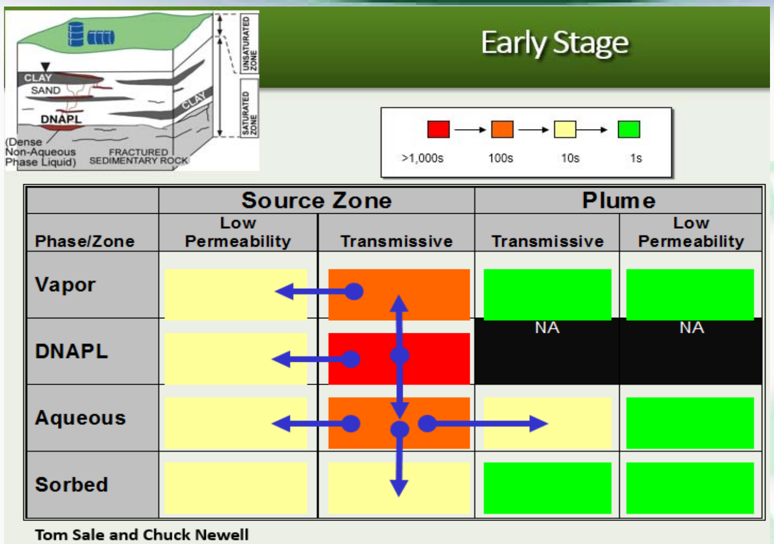
**Guilbeault et al., 2005**

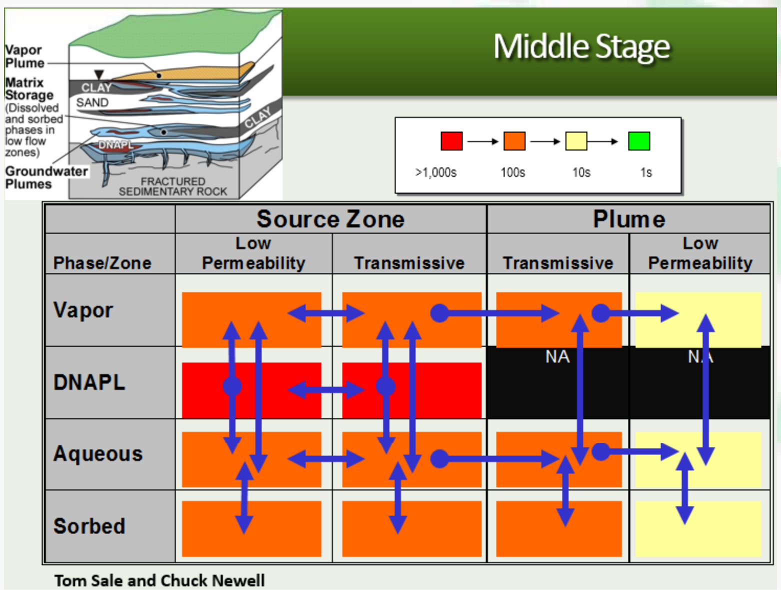
**75% of mass discharge occurs through 5% to 10% of the plume cross sectional area**

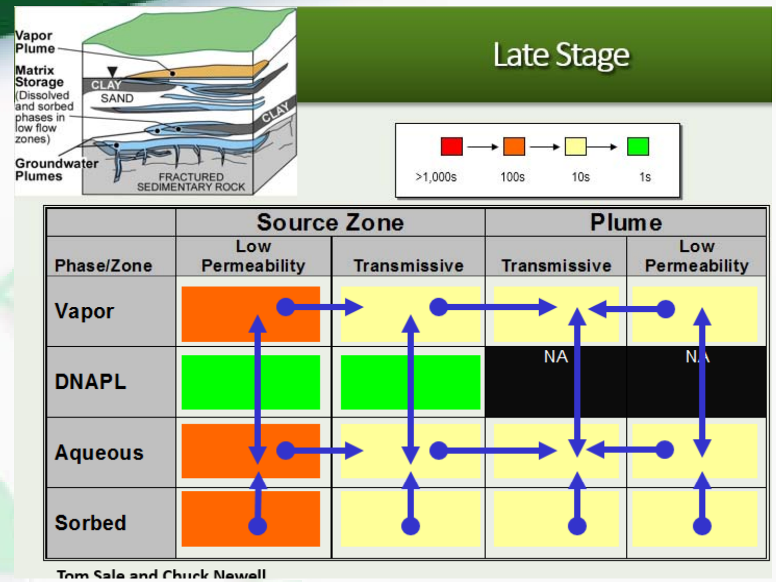
**Optimal Spacing is ~0.5 m**

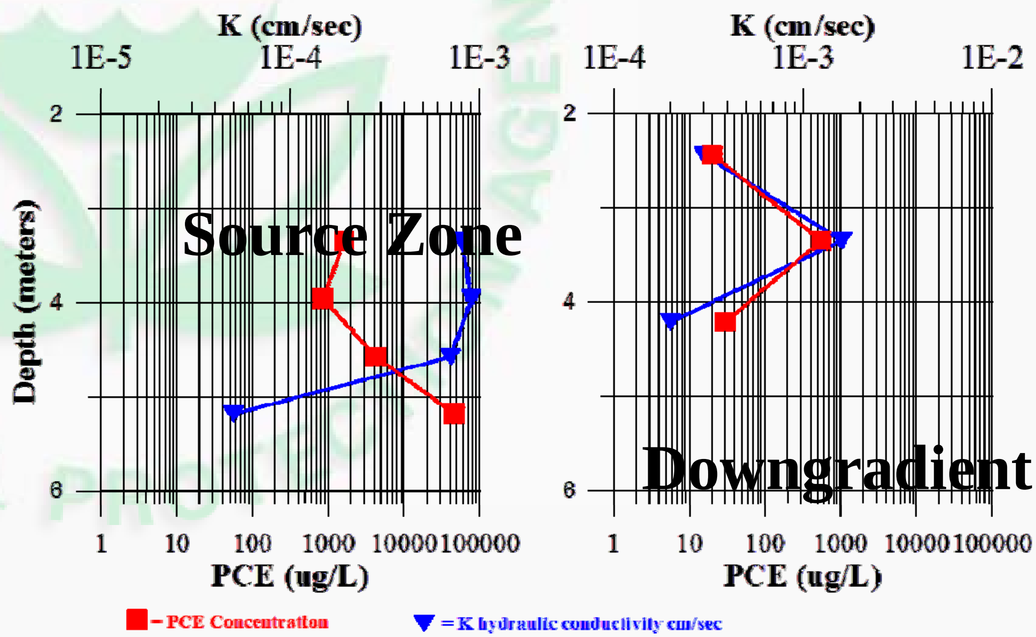


# Spatial Variability In Flux…… But Also Temporal

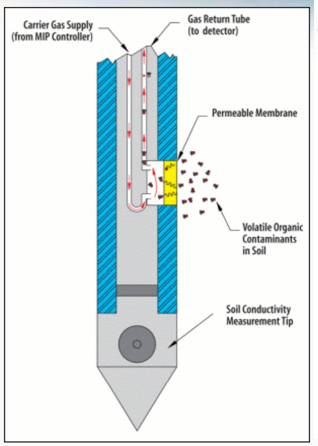


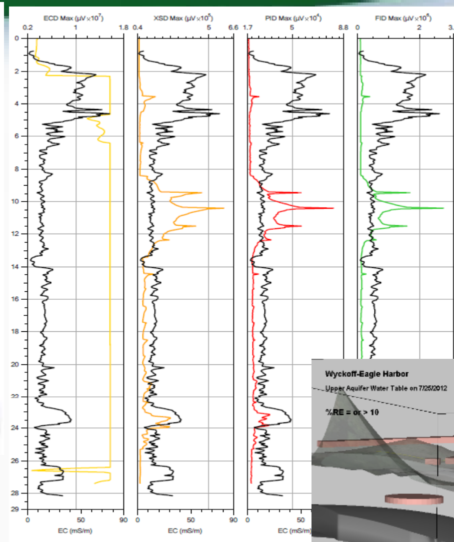



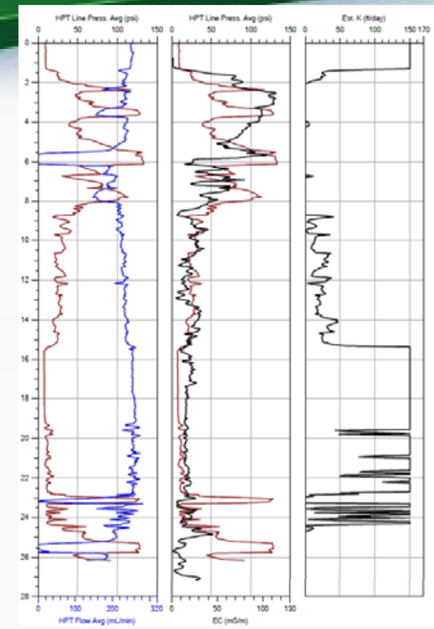



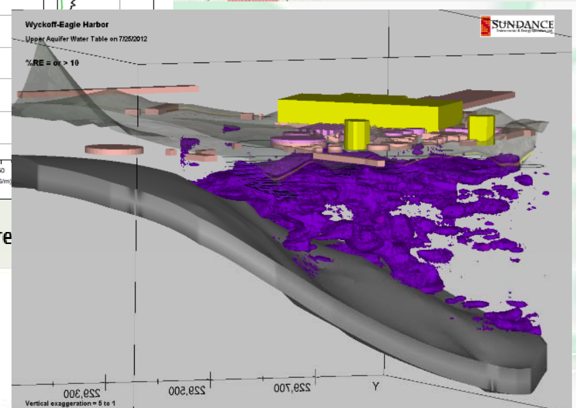



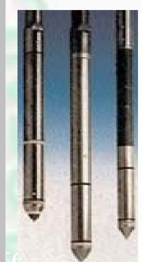
# Hail to the Tools!

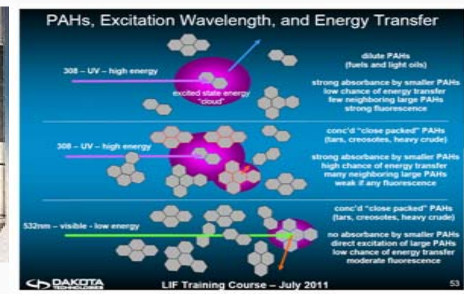


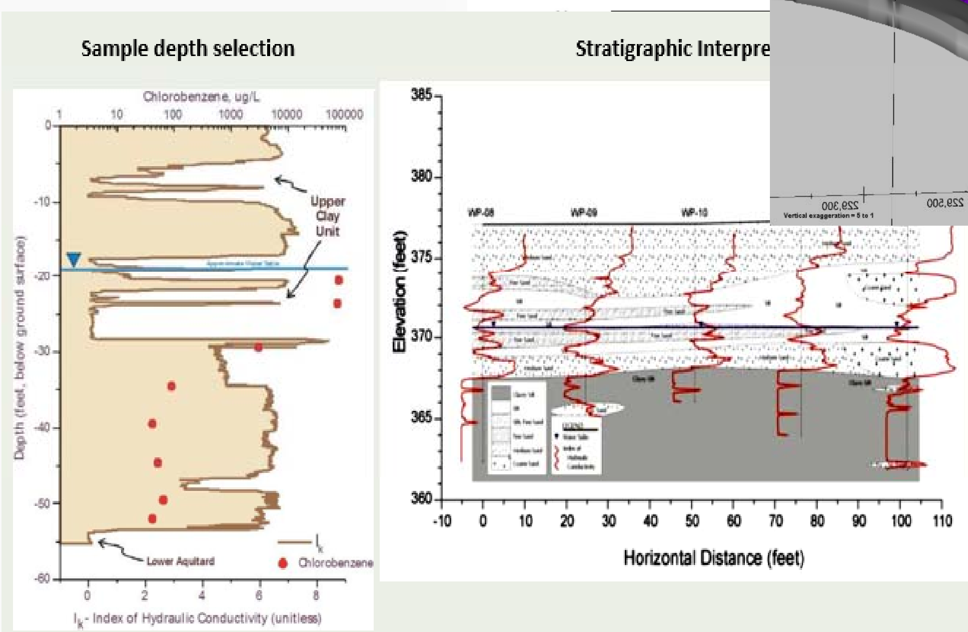



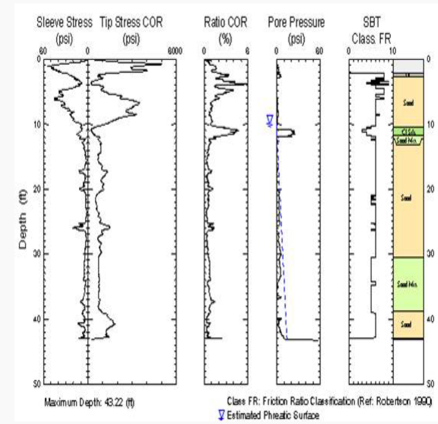


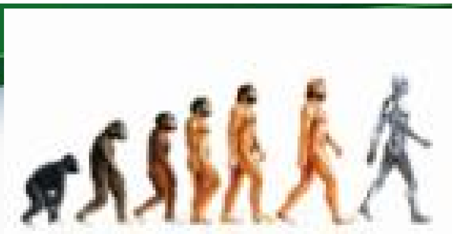











## Addressing Uncertainty and Matrix Heterogeneity

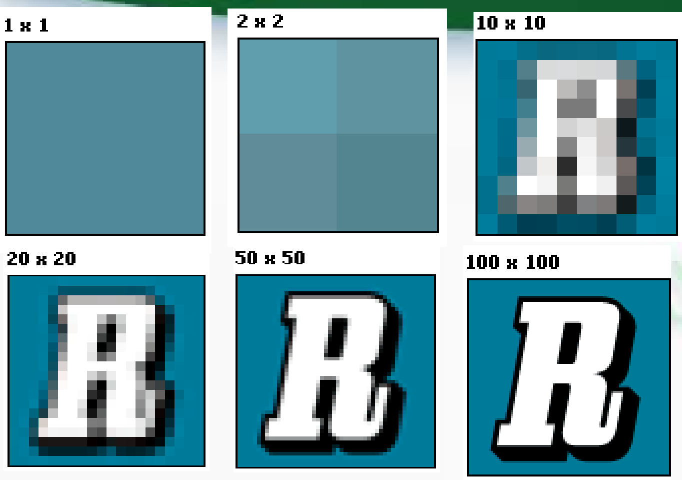
# The Missing Link

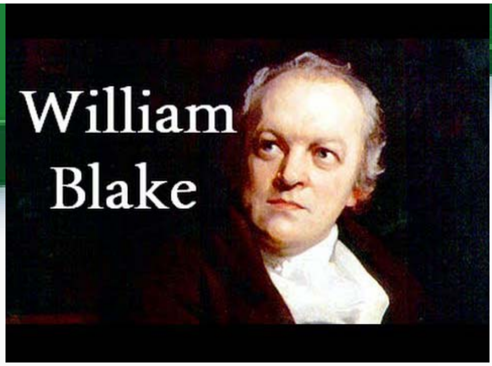
Collaborative data sets and high-resolution also critical for geologic / hydrogeologic information.

- Not just analytical concept.

- In many cases, geologic / hydrogeologic context may be more critical for effective remedy design.

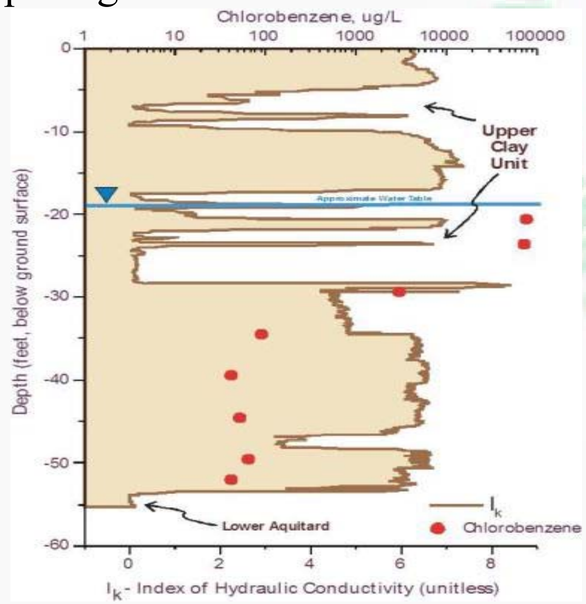
# How Much is Enough?




"You never know what is enough unless you know what is more than enough!"

With real-time or direct sensing spacing can be variable



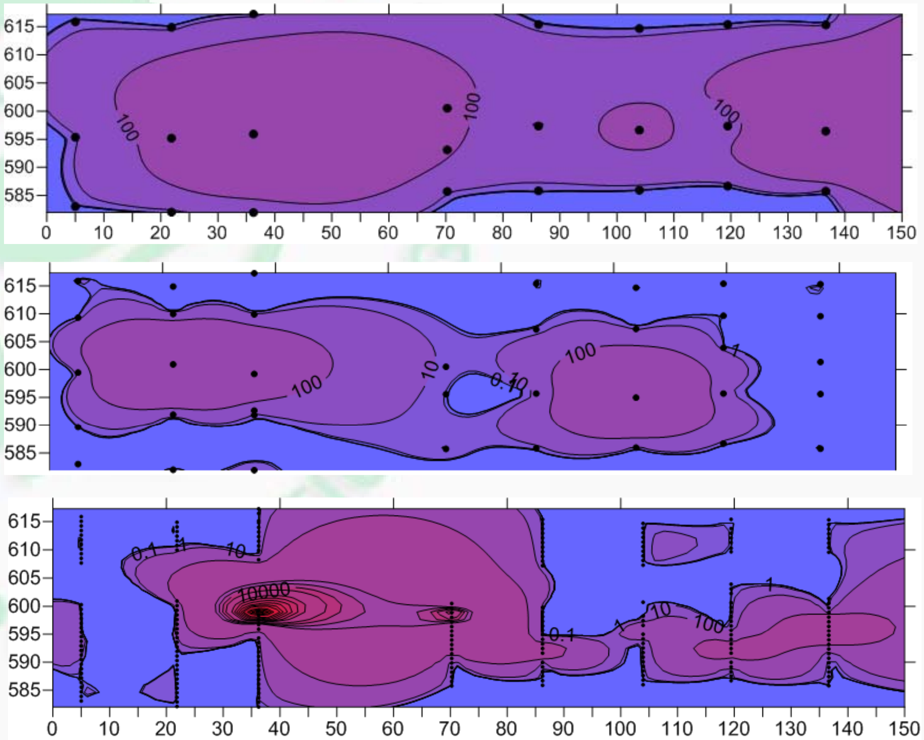

## Multi-Level Sampling Transect

### PCE in a Sandy Aquifer

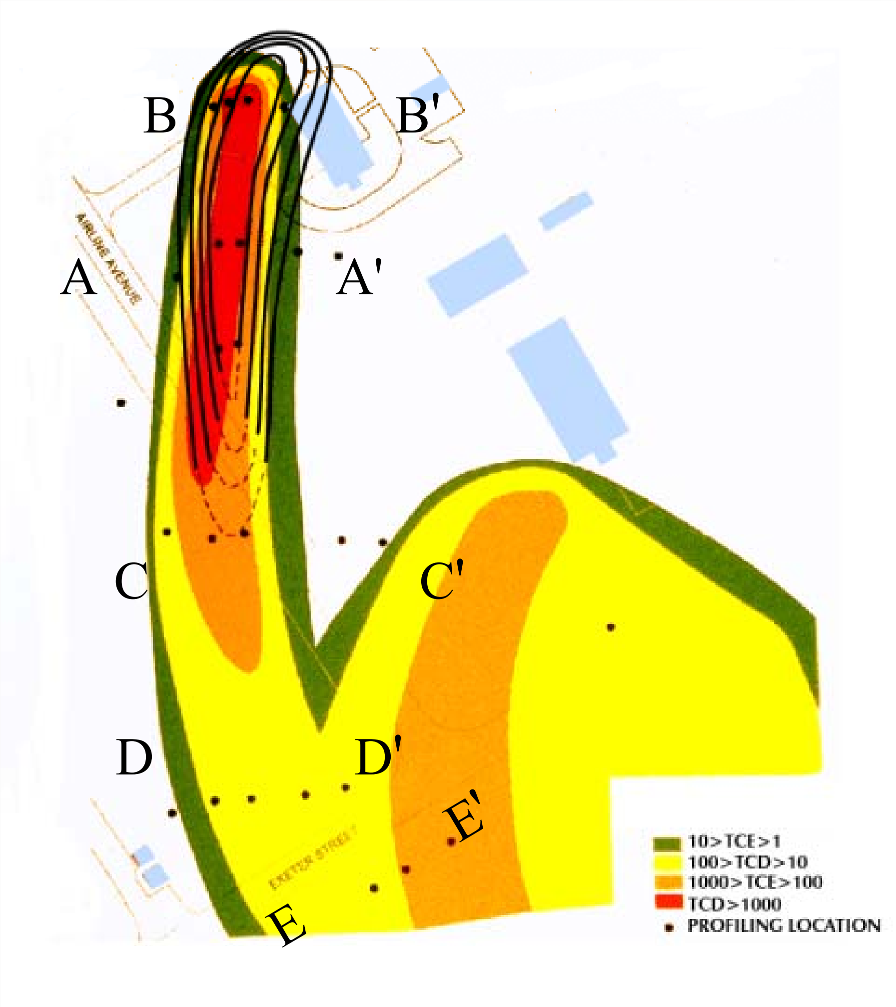
Shallow, medium, deep

10-ft vertical spacing

0.8-ft vertical spacing

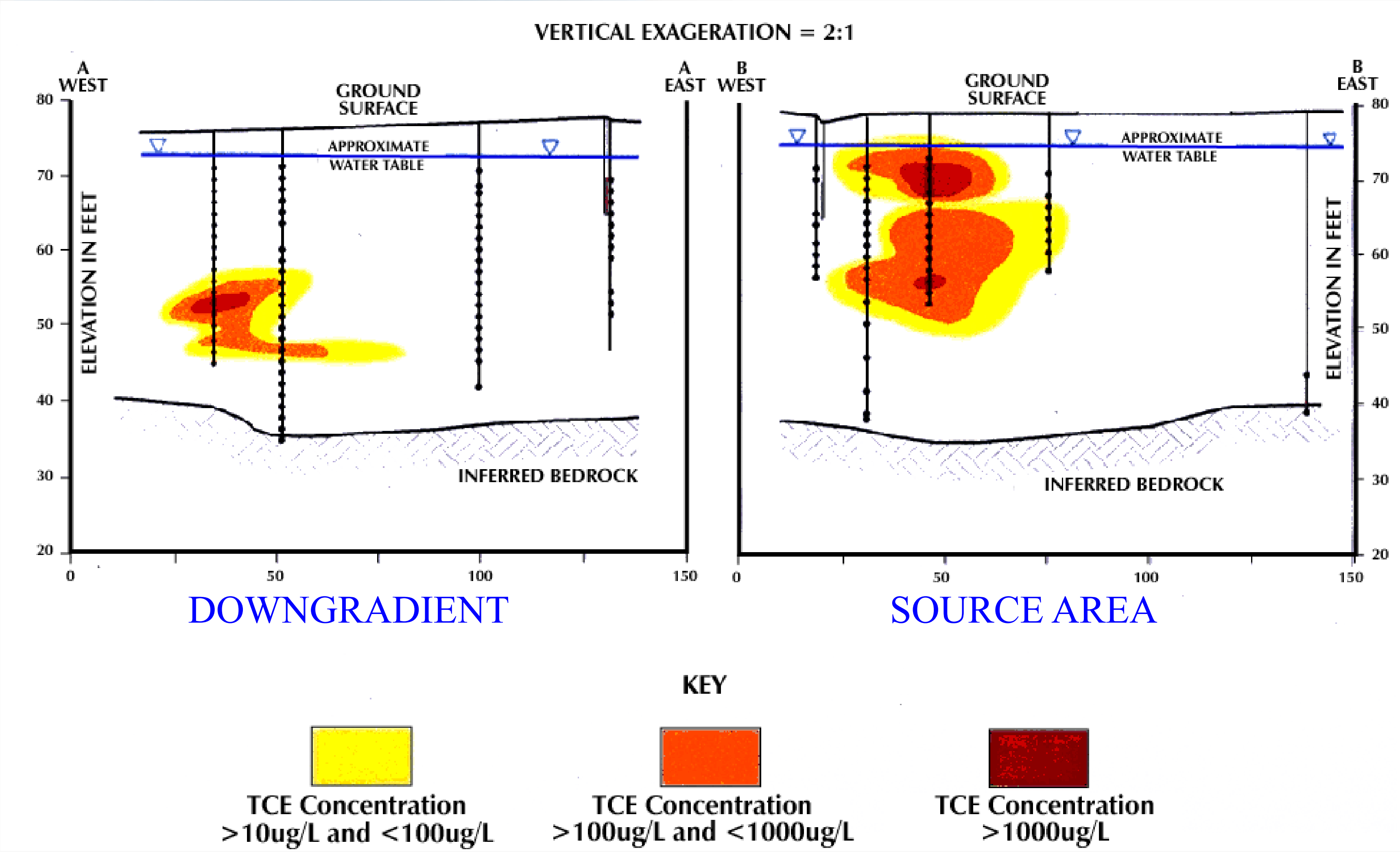


# Transect Case Study: Secondary Groundwater Plume Characterization, Pease AFB, NH

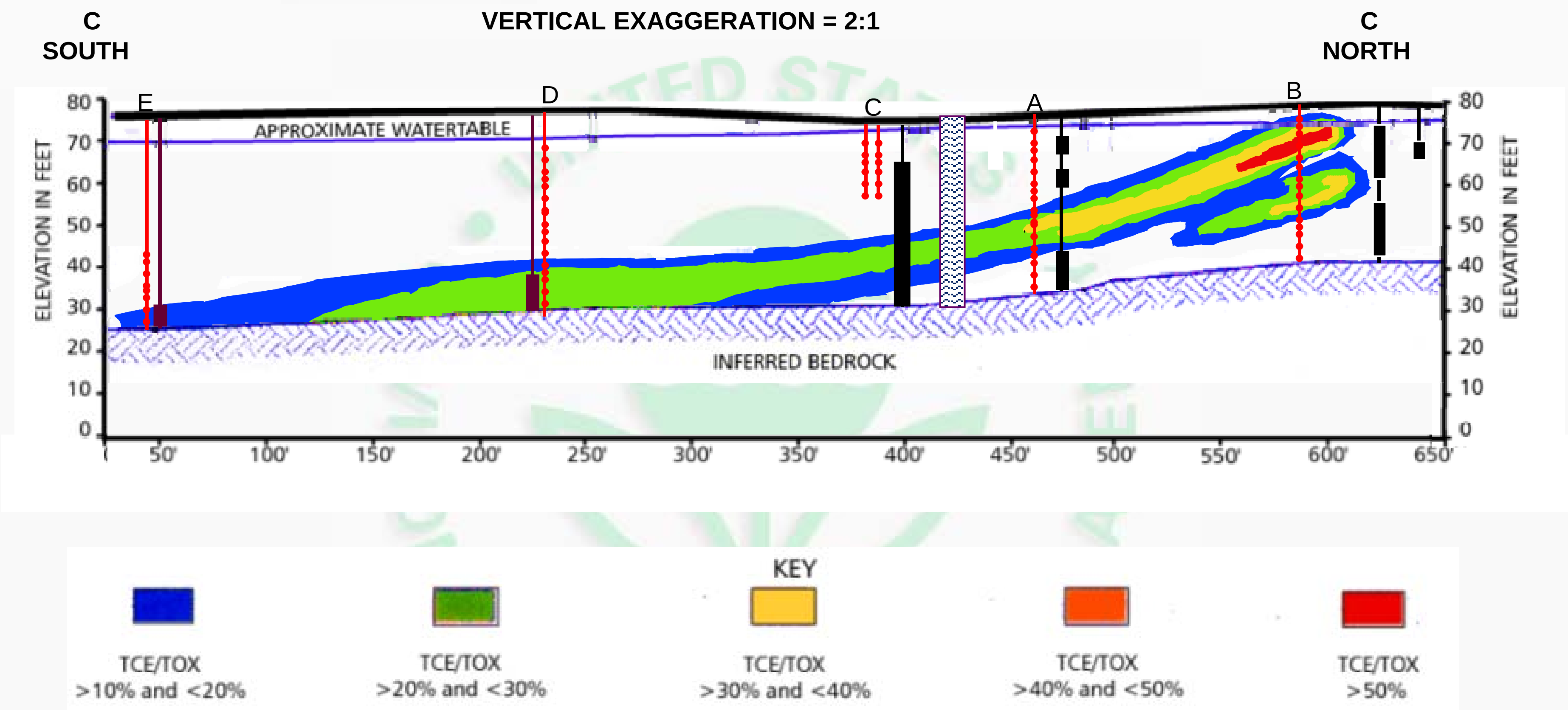



- VOC and POL release site
- VOCs potentially affecting two bedrock supply wells
  - Concern over DNAPL in bedrock
- Prior monitoring well investigation did not accurately characterize the plume
  - Defined as "short plume"
- 5 Modified Waterloo Profiler transects performed normal to plume axis
  - A - A' = Downgradient of source
  - B - B' = Through source area
  - C - C' / D - D' / E - E = Downgradient plume delineation

# Transects/Vertical Profiles Showed TCE Plume was Sinking with Distance from Source



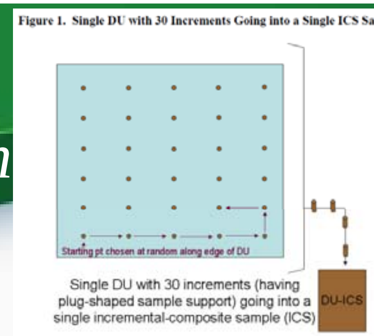
# Vertical Profiling vs. Monitoring Well

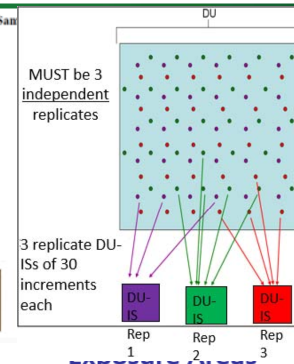



Prior Investigation Monitoring Well  Stone Profile  Stone Monitoring Well

# What About In Soil?

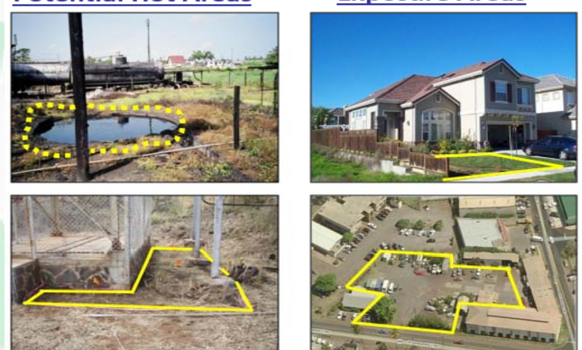
## *High Density, High/Low Resolution*



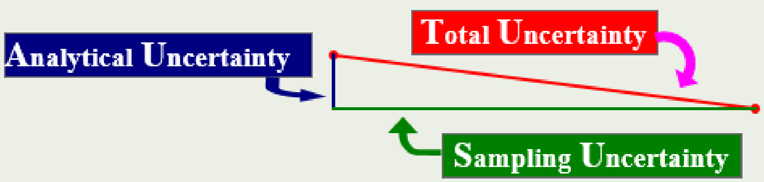


Potential Hot Areas



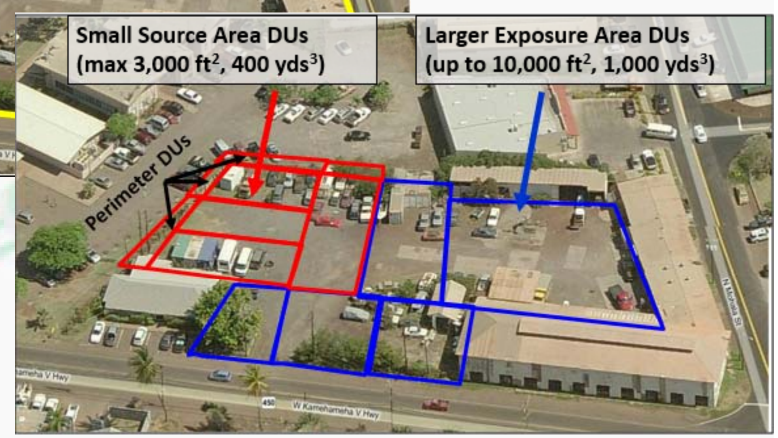
See ITRC, ISM-1 (www.itrcweb.org/ISM-1)
Section 3.3
and
ITRC ISM Internet Training archives: http://www.cluin.org/live/archive/
and
search for "incremental"

**Uncertainties add according to ($a^2 + b^2 = c^2$)**



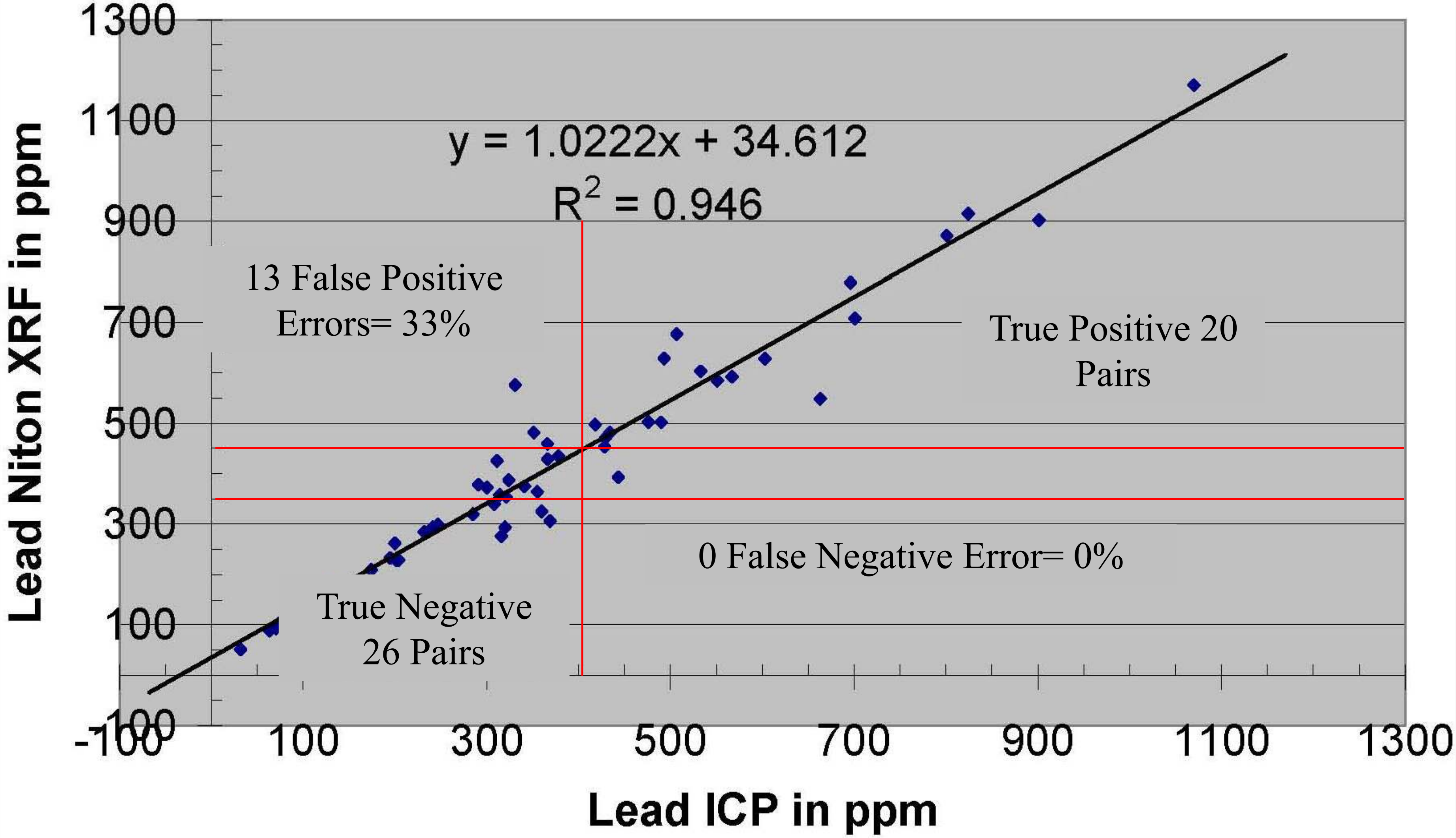

Example:

- AU = 10 ppm, SU = 80 ppm: **TU = 81 ppm**
- AU = 5 ppm, SU = 80 ppm: **TU = 80 ppm**
- AU = 10 ppm, SU = 40 ppm: **TU = 41 ppm**
- AU = 20 ppm, SU = 40 ppm: **TU = 45 ppm**

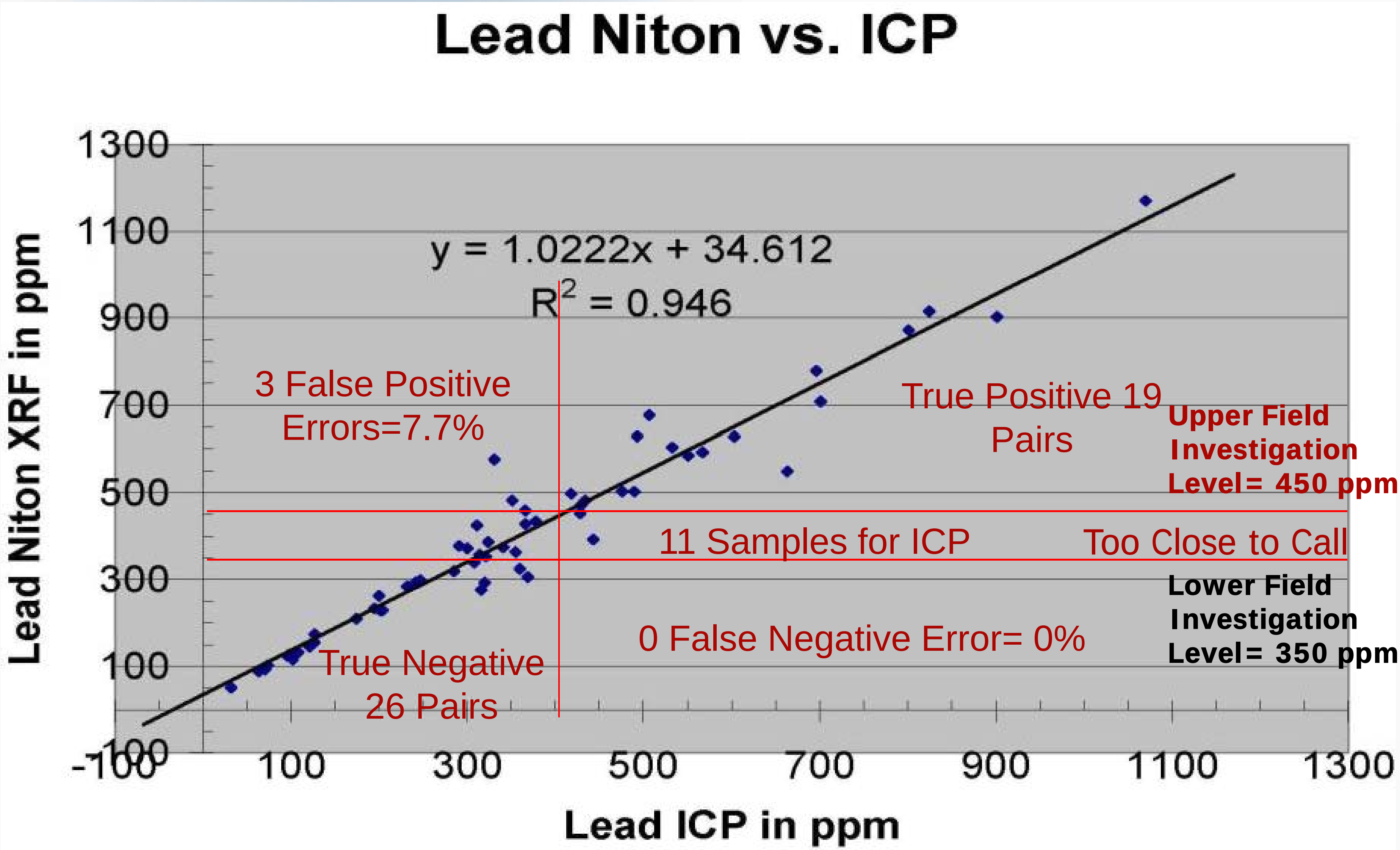



# Lead Niton vs. ICP

59 Total pairs



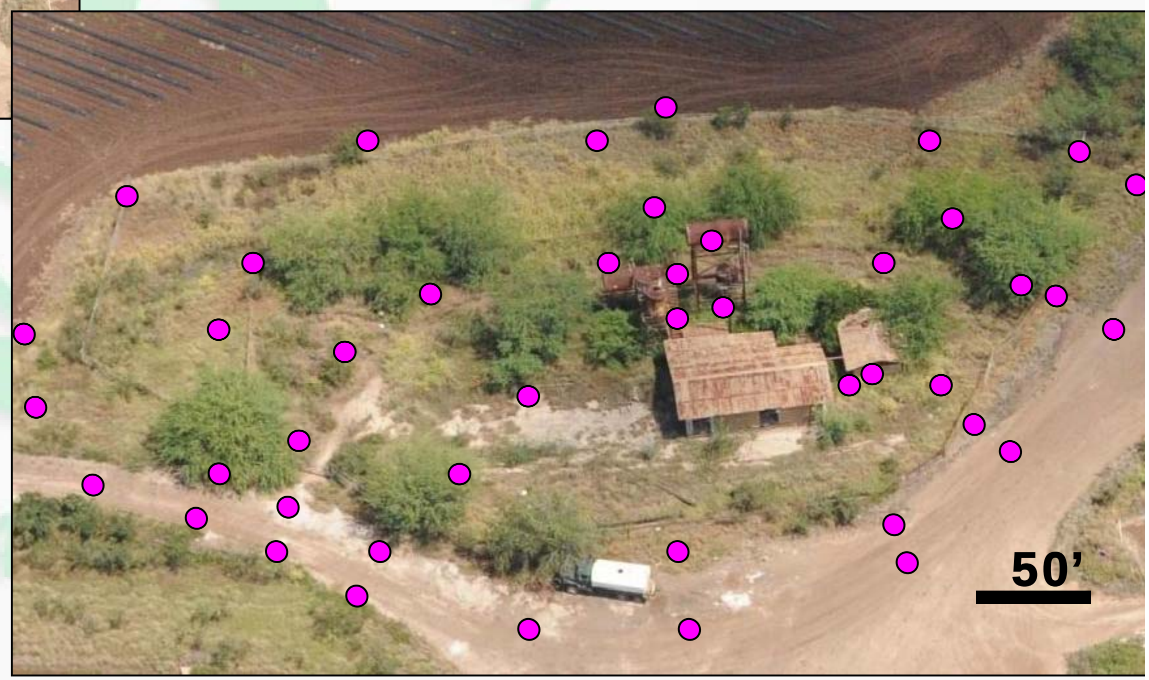
# Three-Way Decision Structure with Region of Uncertainty



# What About In Soil?

*High Density, High/Low Resolution*

- Arsenical pesticide mixing area in Hawaii
- Residential redevelopement
- This parcel is 3 acres
- As cleanup level = 25 ppm




- 44 grab samples (judgemental or random) collected for lab analysis.
- Sampling density of 15 samples per acre.

# Results Mapped

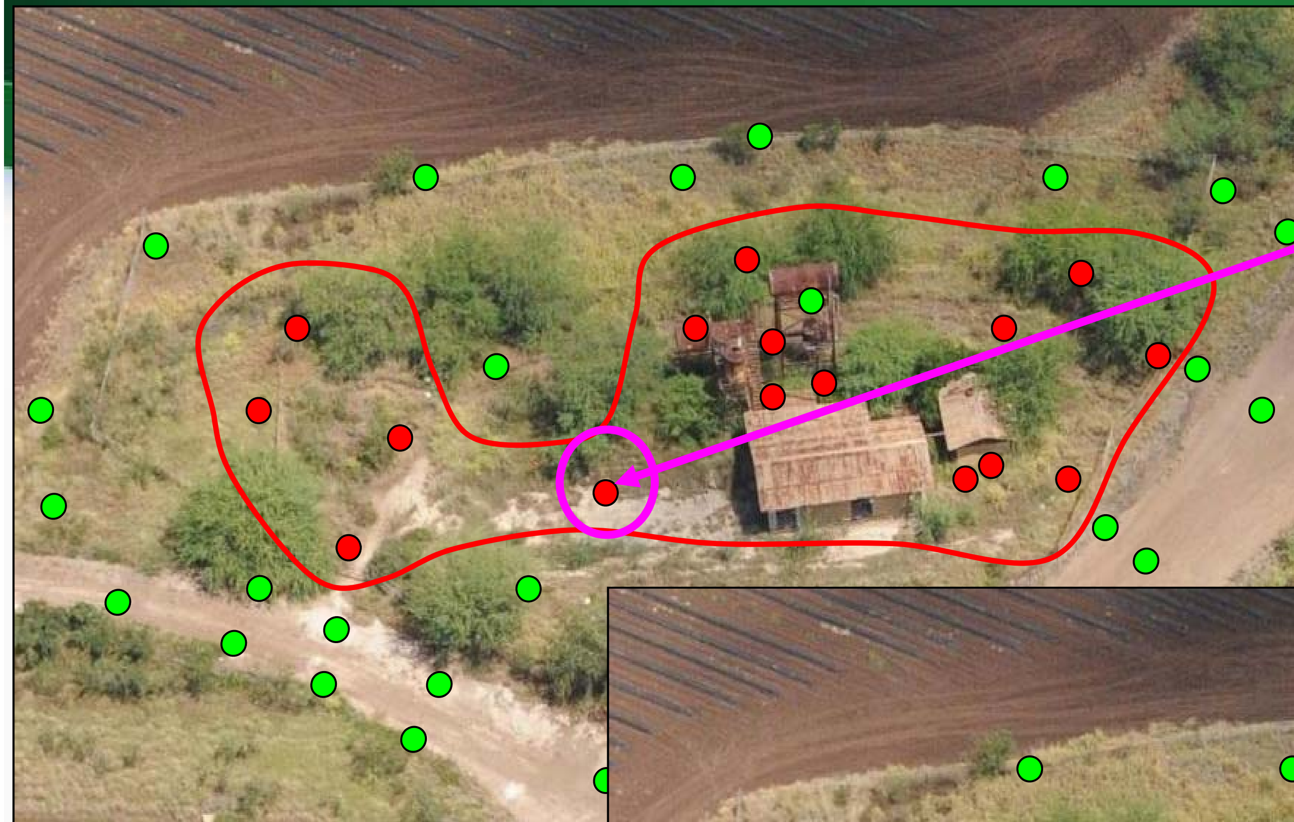
*Red line represents soil to removed 1' deep= 1650 $yd^3$*

Dear Developer,

Please fund the removal and disposal of 1,650 $yd^3$ of arsenic-contaminated soil. Oh, and by the way, there is about a 50:50 chance that this cleanup footprint is incorrect. The actual volume needing removal could be

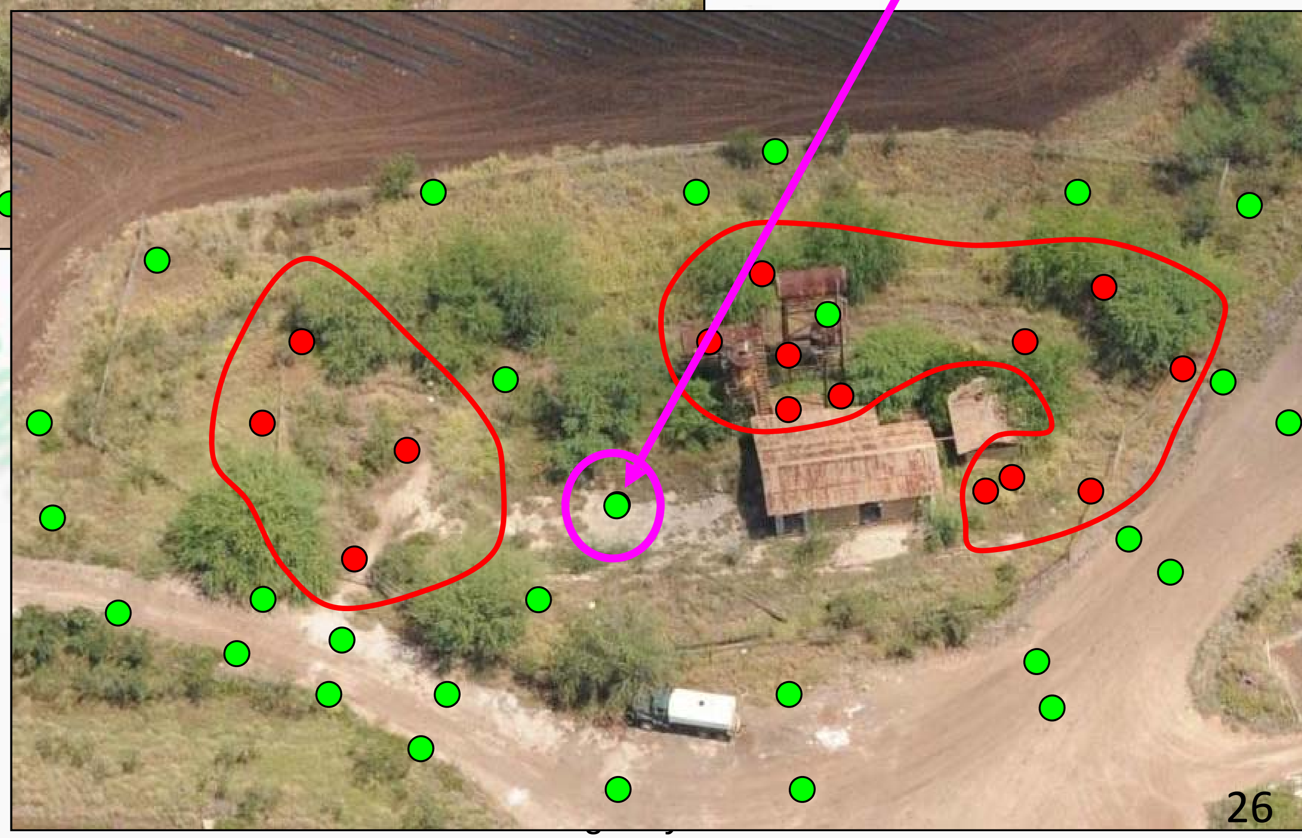
1) more than this;
2) less than this; and/or
3) the footprint could be in the wrong place.

So, after confirmation sampling, I may be asking you for more money to do this all over again. But it will be the data's fault, not mine.

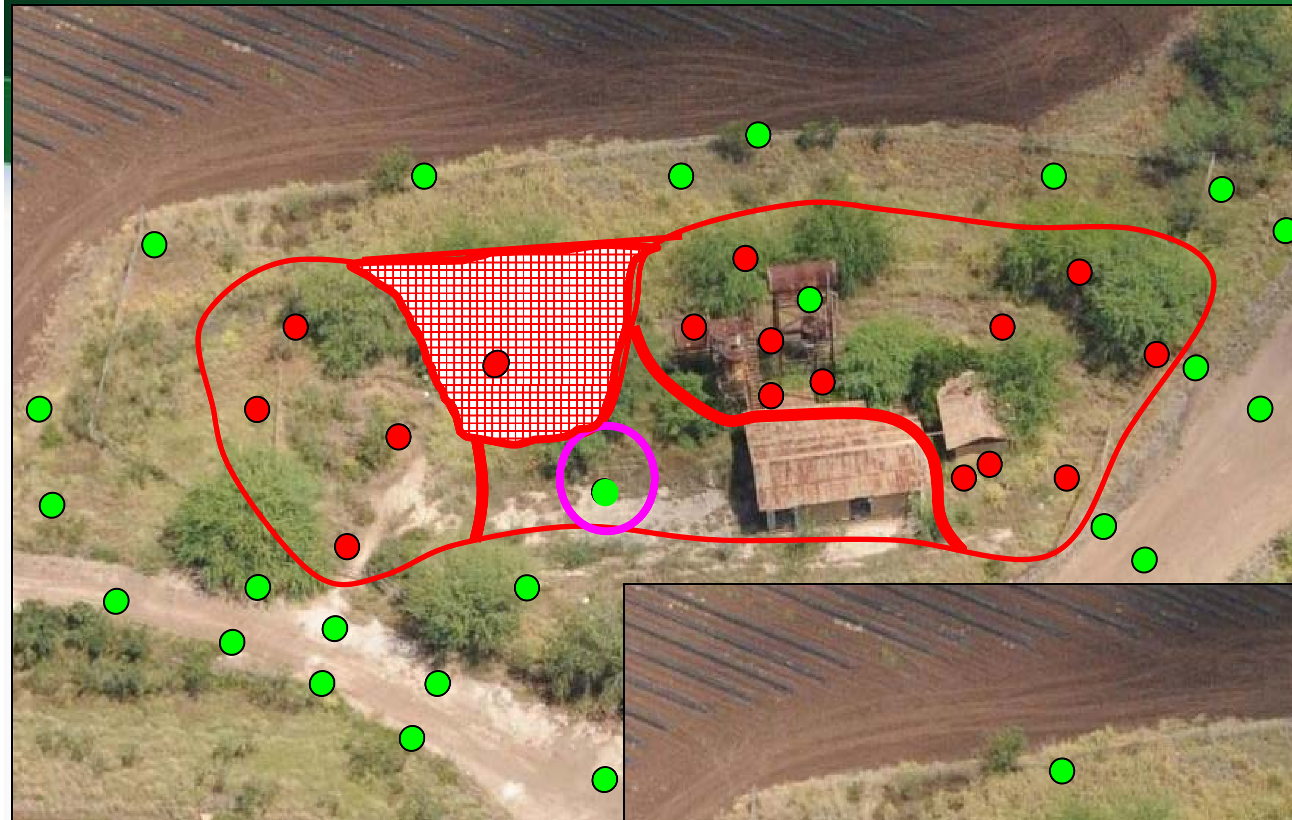


1st result of lab dup pair was 31 ppm

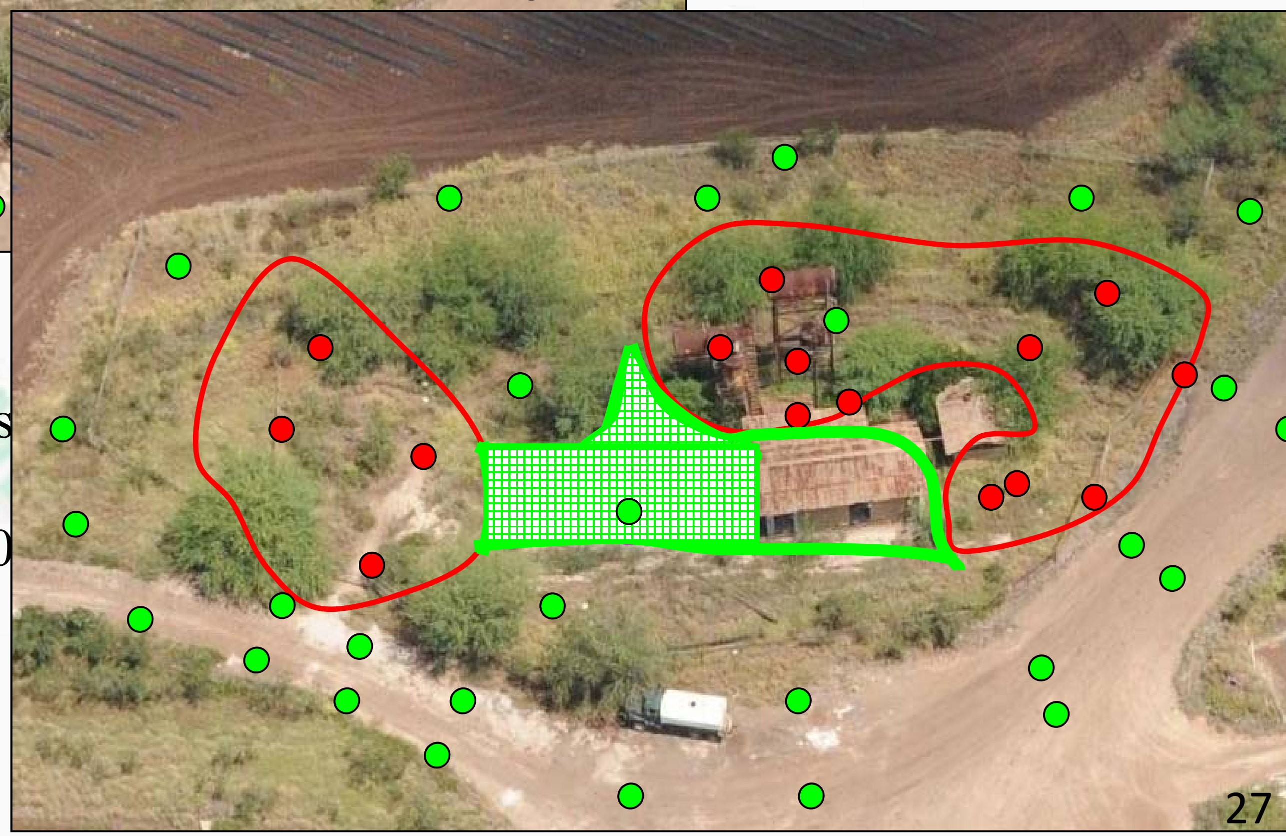
2nd result of lab dup pair was 17 ppm



The sample concentration is assumed to “represent” the concentration of about 4300 sq.ft. of soil



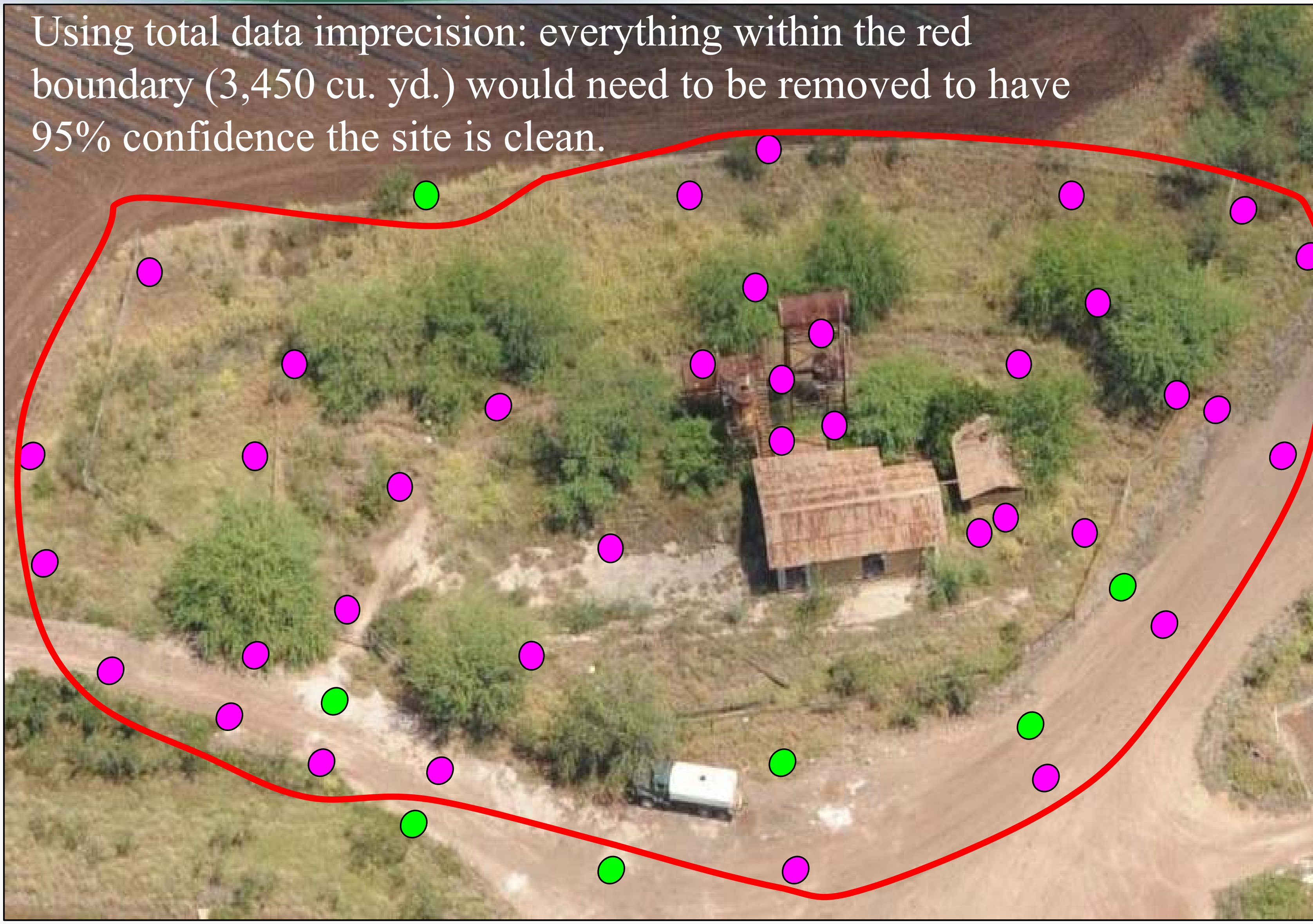
The sample concentration is assumed to “represent” the concentration of about 5800 sq.ft. of soil (green)



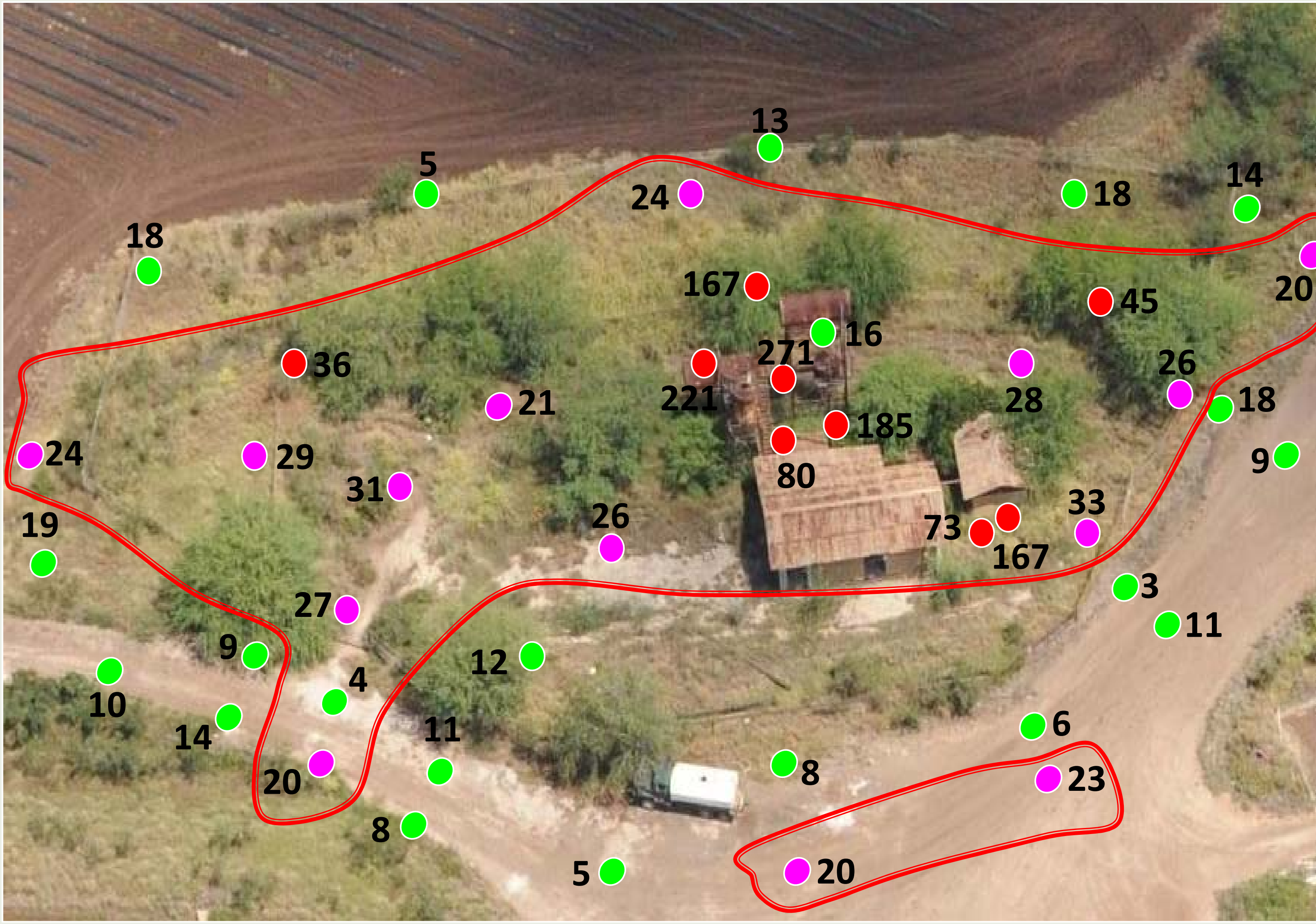
The sample concentration is assumed to “represent” the concentration of about 4300 sq.ft. of soil (green)

# How Much Confidence Do You Need?

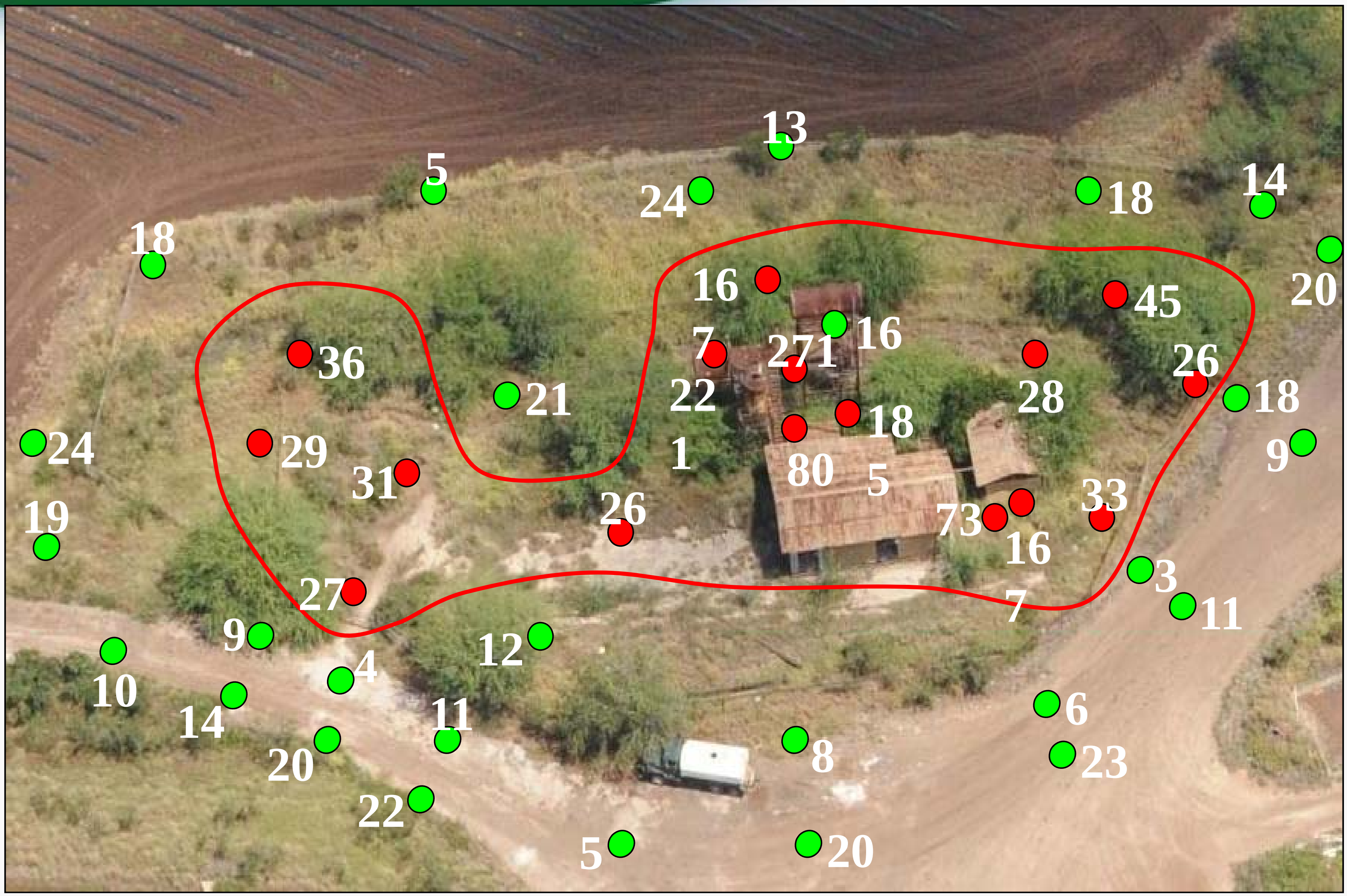
Using total data imprecision: everything within the red boundary (3,450 cu. yd.) would need to be removed to have 95% confidence the site is clean.



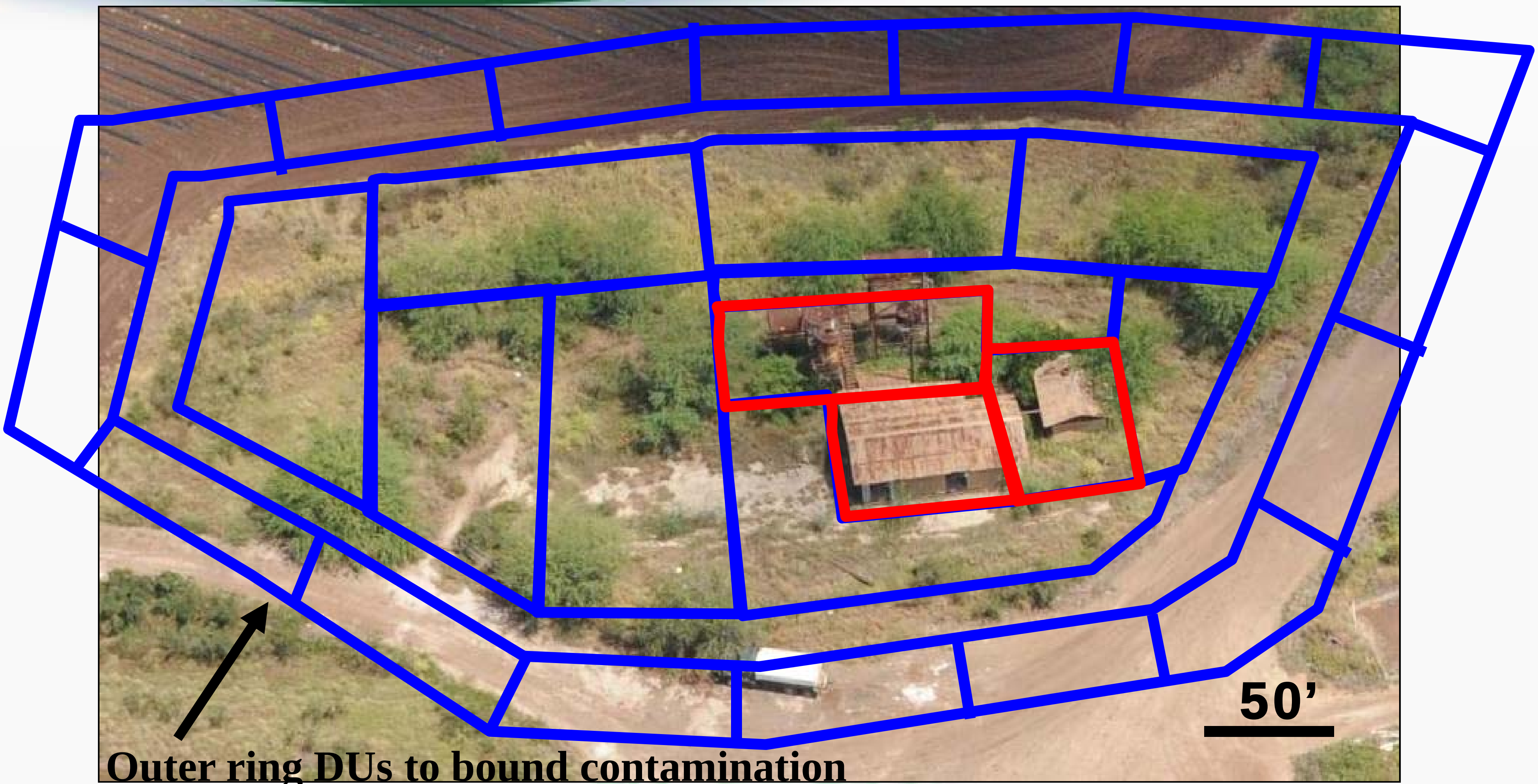
Settling for 75% decision confidence means removing only 2,650 cu. yd.



Or, again, you can flip a coin to decide whether this cleanup footprint (1,650 cu. yd.) is correct.



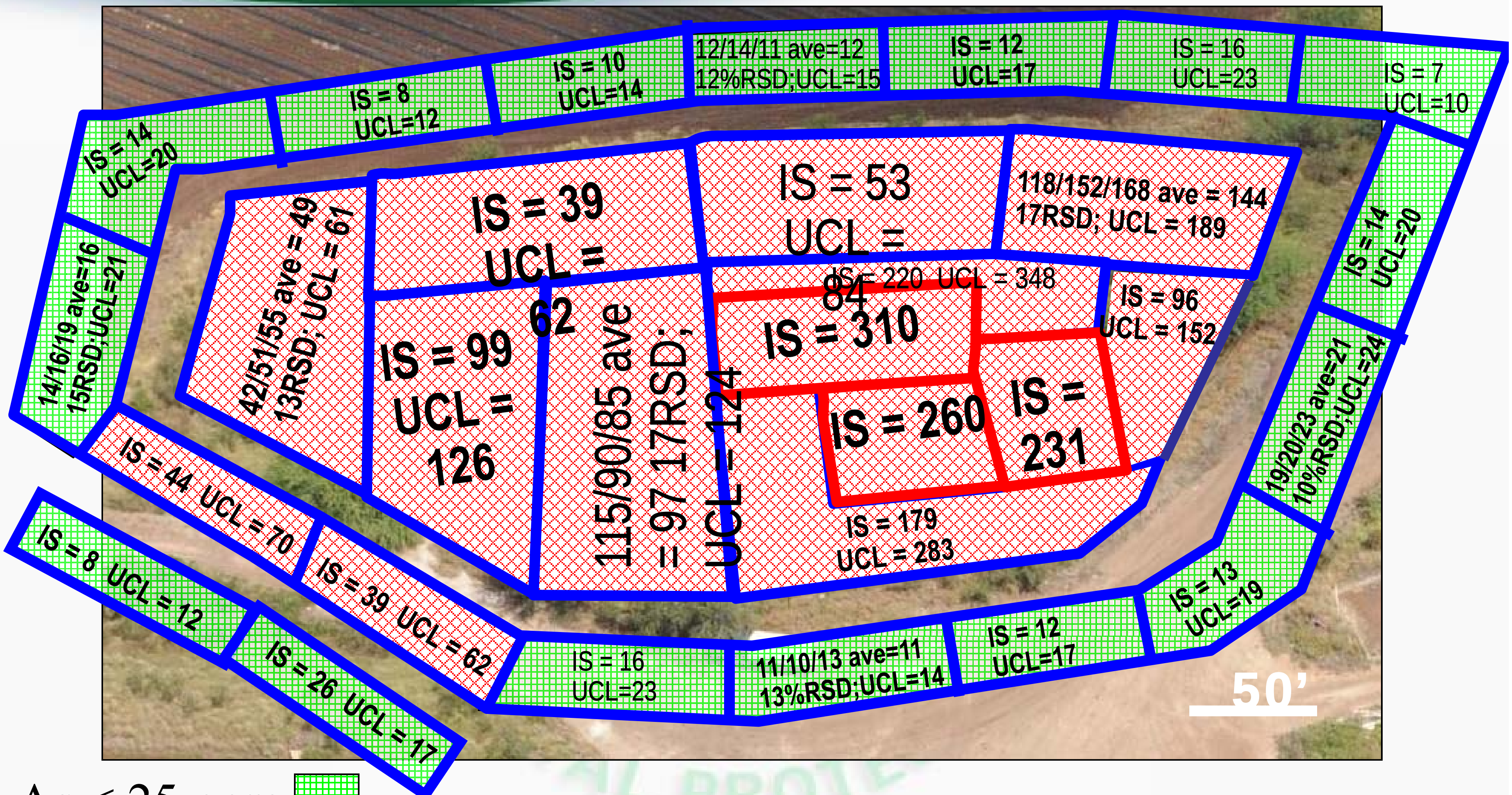
# Decision Unit Designation for Incremental Sampling




Spill Area DUs: Heavy contamination

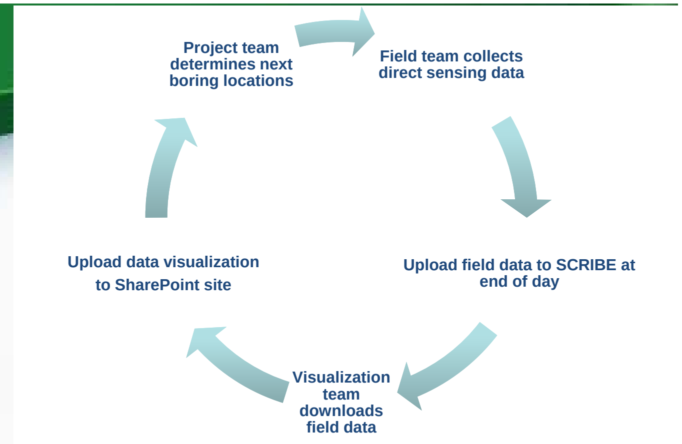
Direct Exposure DUs: Maximum 5,000 $ft^2$

# Results



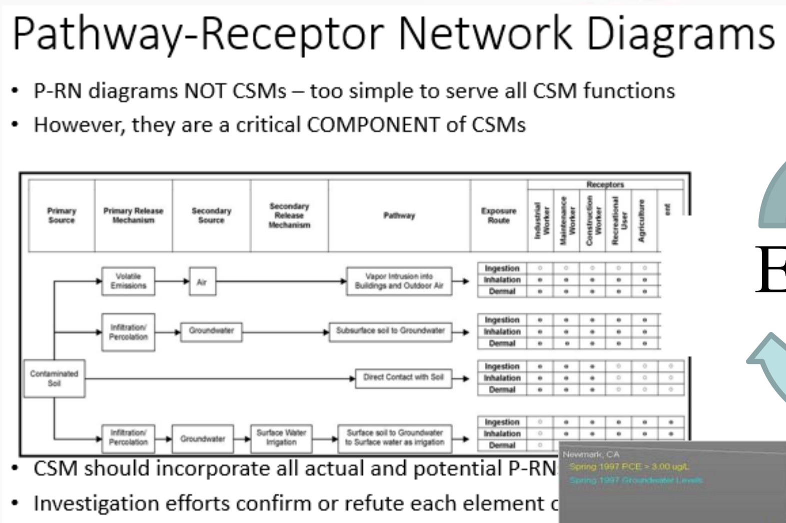

As < 25 ppm
As ≥ 25 ppm

# Real Time CSM Evolution and Data Visualization

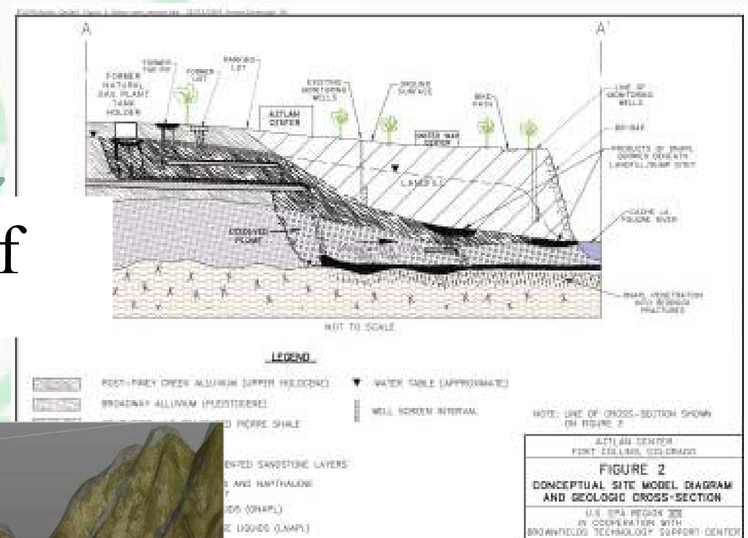



## The Conceptual Site Model Has Evolved as Technology has Advanced

**1980's—1990s**

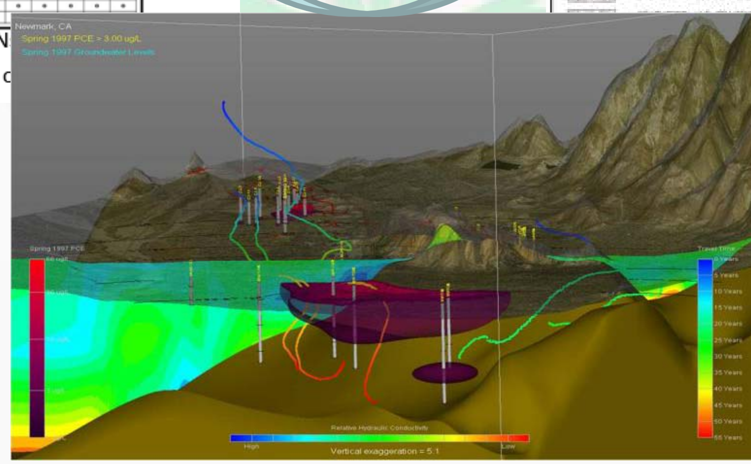



**2000's**



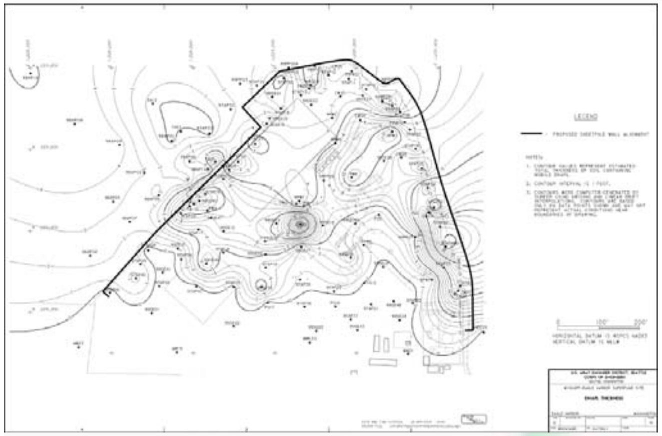

Evolution of CSMs

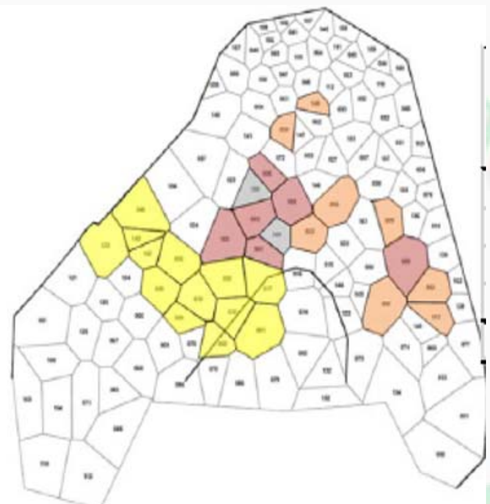
**2010 to present**



# Example 1- Wyckoff Region 10

## Existing Work Products





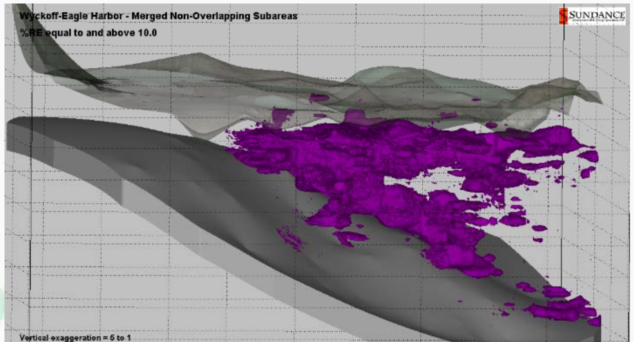
Wyckoff Geology

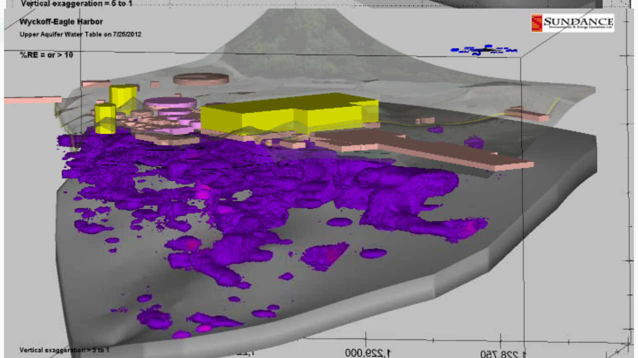
Wyckoff TarGOST

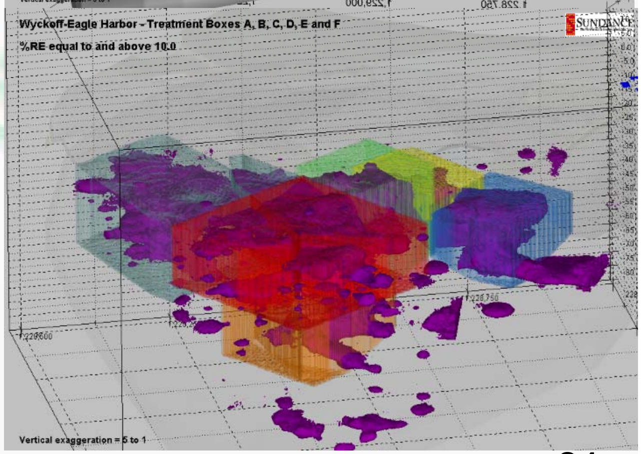
Wyckoff Treatment

| | Y-Length, ft | X-Width, ft | Z-Height, ft | Treatment Box Soil Volume, cu. yds. | TarGOST Impacted Soil Volume @ 10 %RE in Treatment Box, cu. yds. | TarGOST 10 %RE Percent of Treatment Box Volume, cu. yds. | TarGOST 20 %RE Percent of Treatment Box Volume, cu. yds. | TarGOST 50 %RE Percent of Treatment Box Volume, cu. yds. | TarGOST 100 %RE Percent of Treatment Box Volume, cu. yds. |
|---|---|---|---|---|---|---|---|---|---|
| Box A | 160.00 | 170.00 | 45.00 | 33,836 | 12,883 | 38% | 9% | 0% | 0% |
| Box B | 200.00 | 210.00 | 30.00 | 38,538 | 5,524 | 14% | 7% | 1% | 0% |
| Box C | 180.00 | 165.00 | 23.00 | 18,302 | 6,491 | 35% | 19% | 5% | 1% |
| Box D | 180.00 | 132.00 | 10.00 | 5,861 | 2,253 | 38% | 15% | 0% | 0% |
| Box E | 305.00 | 300.00 | 28.00 | 77,146 | 13,371 | 17% | 3% | 0% | 0% |
| Box F | 300.00 | 300.00 | 22.00 | 72,706 | 14,734 | 20% | 7% | 1% | 0% |
| TOTAL | | | | 246,389 | 55,255 | 22% | | | |
| | | | | Total 10 %RE TarGOST Impacted Soil Volume Inside Wall | 59,489 | | | | |
| | | | | % Captured in Boxes | 93% | | | | |

## FFS- TarGOST® and 3D Visualization



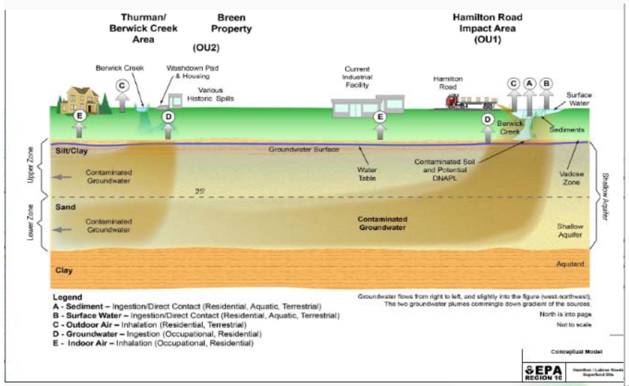



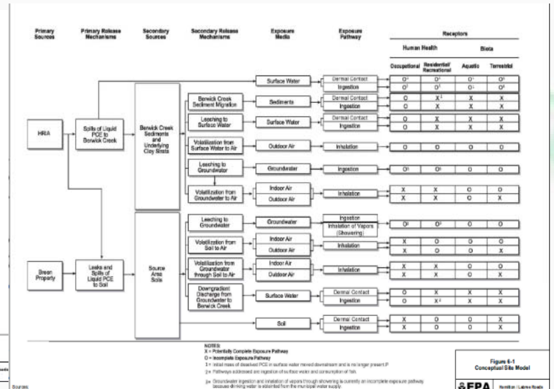



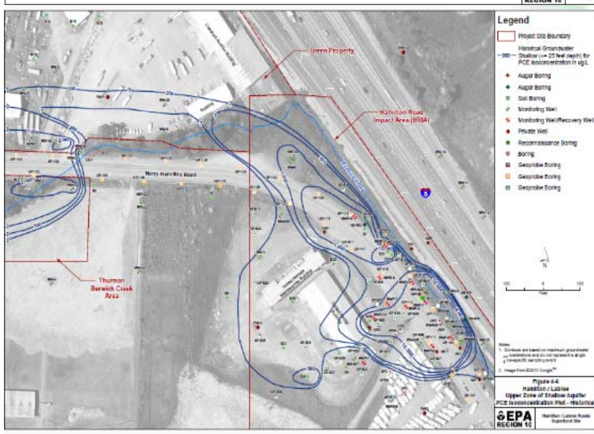
# Example 2- Hamilton Labree Region 10

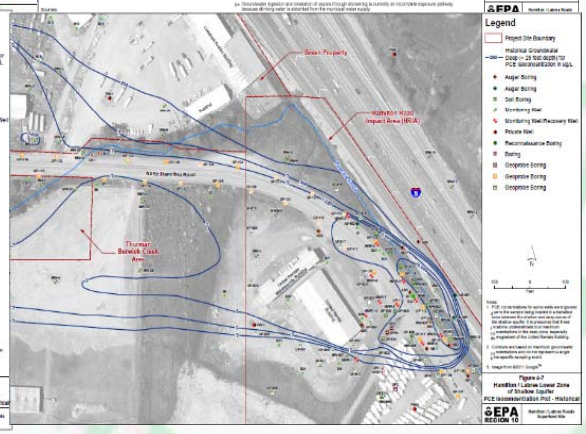
PDI- MIP, HPT, 3D

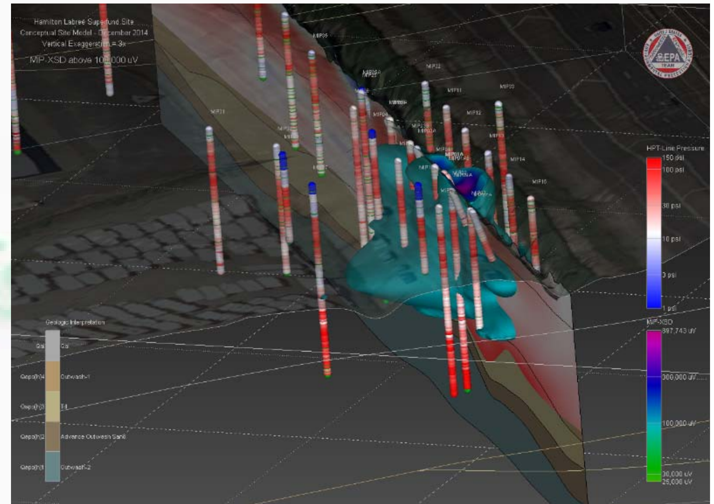
HRIA RI work products

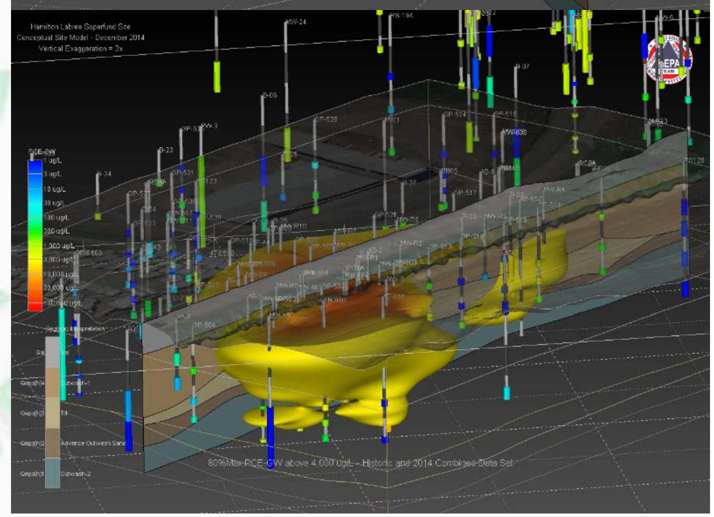










HRIA MIPHPT Geology

HRIA PCE GW

HRIA PCE Soil

# Conclusions

## HRSC and Incremental Sampling Translated for Remedial Designs

- **In Groundwater**
  - Limit large scale averaging, use scale appropriate measurements
  - Use transects and multi-level sampling
  - Use direct sensing and collaborative data sets
- **In Soil**
  - Use incremental and compositing techniques to control matrix variability, reasonably represent exposure and decision units
  - Many increments and replicate samples provide- good estimate of mean, and ability to calculate UCL/LCL and statistical confidence
- **Real-time CSM Updates/Data Visualization**
  - Forces interpretation not just presentation
  - Includes all decision makers in the process- consensus, streamline
  - Save time and money- fewer repeat mobilizations, early ID of data collection errors
  - Keeps focus on root causes not symptoms- High mass footprint (where to remediate), Matrix distribution (how to remediate)

# Q&A / Discussion