The Triad Approach to Managing Decision Uncertainty for Better Cleanup Projects

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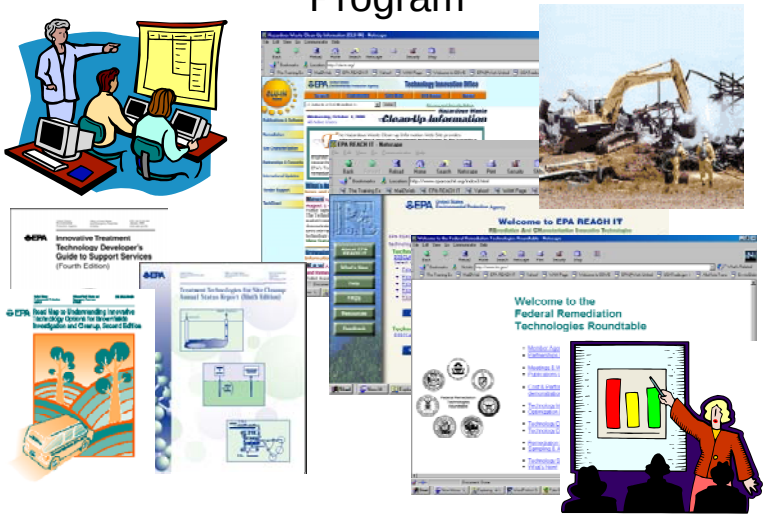
Region 3 RCRA CA Workshop September 14, 2004

Managing Decision Uncertainty Affordably and Transparently

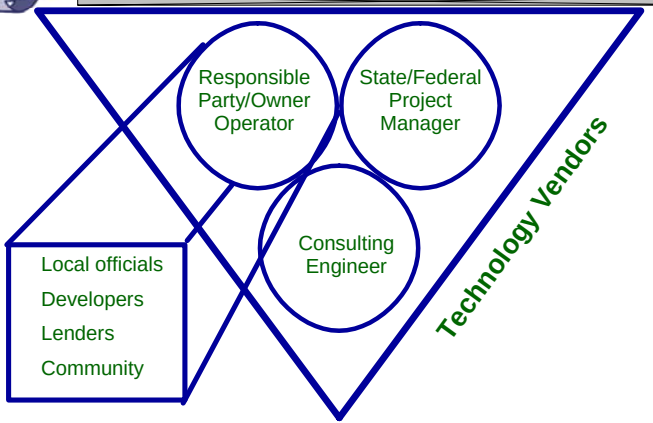
Problem Statement

- Perception: contaminated site cleanups cost too much & take too long
- Unfortunately, that perception has basis in common experiences
- USEPA's Technology Innovation Program (TIP) explores ways to improve the cleanup process by increasing the protectiveness, efficiency, and cost-effectiveness of site investigations and cleanups.
- Started taking a hard look at characterization in 1995

EPA's Technology Innovation Program



Technology Innovation Program: Affecting Site Decisions



What is TIP's Strategy?

- Track status of technologies and markets
- Partner with variety of organizations & agencies, states, and private companies to increase innovative options
  - Influence policy to foster acceptance of promising innovations
- Disseminate information - conferences, direct mail, electronic mail, home pages and bulletin boards

TIP Information Dissemination

- Distribute technology information through many media
  - CLU-IN Home Page (http://cluin.org)
  - Subject-specific Web pages under CLU-IN
  - Direct e-mail: TechDirect (19,500+ subscribers) (see CLU-IN)
  - Coordinate traditional classroom training (trainex.org)
  - Internet seminars (see CLU-IN)
  - Road warrior approach: exhibits to conferences
  - Newsletters – Technology News and Trends & others
  - Paper publications
- No longer a problem of too little information

Complaints about Characterization

- Characterization is THE foundation of all site decisions
- But…
  - Multiple mobilizations required to address knowledge gaps
  - Still, characterization often misses contamination found later
  - Uncertainties stemming from characterization impact every aspect of project management
    - Budget, exposure risk, remediation, & reuse options; real estate transactions & insurance
- Complaints cut across programs: from regulator-led projects to VCPs and BFs

Universality of Complaints Implies a Paradigm Problem

- To rectify problems, need to understand root causes
- To understand root causes, TIP…
  - …studied "successful" vs. "less successful" projects
  - …studied innovative approaches tried by various organizations since the 1980s
    - Summary paper available at: http://www.cluin.org/download/char/whtpaper.pdf

The Triad approach grew out of these studies. It represents a paradigm shift from conventional approaches to project mgt.

What is the Triad Approach?

A technical framework built from practitioner experience that incorporates 25+ years of experience and advancing science & technology

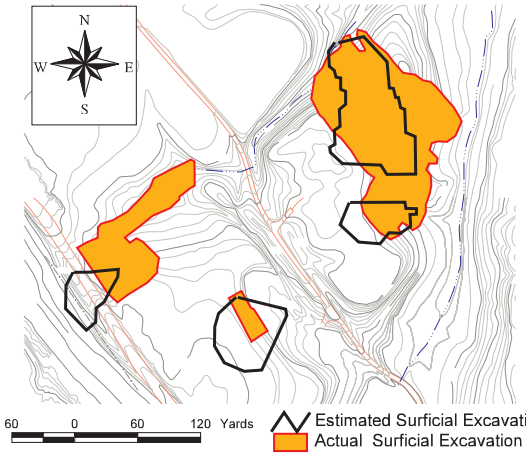
with the intent of

improving confidence in project outcomes & saving money over project lifetimes.

Why Do We Need a Paradigm Shift?

- We've learned that traditional notions of data quality & statistical confidence have not led to efficient projects.
- Conventional characterization routinely produces incomplete or inaccurate pictures of site contamination
- WHY? How can we break this pattern?
- Let's look at a project that did break the pattern…

Ashland 2 DOE FUSRAP (1998)
Tonowanda, NY



Excavation based on RI data would have

- removed ~4,000 c.y. compliant soil
- missed ~8,000 c.y. non-compliant soil
- same issues at depth

Accurate CSM + precise excavation saved ~$10M just by not excavating clean soil.

Adapted from Argonne, 2002 http://cluin.org/download/char/ASAPs_ITSR_DOE-EM-0592.pdf

Ashland 2 Success

Fast: 1.5 yr to closure

- Jul-Dec 1998: 6-mo integrated characterizat'n & removal
- Aug 1999: complete post-remediation testing & documentation.
- Sept 1999: backfill & CERCLA site closure.

Effective

- Proof: 430 post-remedial samples; 99% compliant

Efficient

- Proof: 146 composite samples to characterize the 45,500 cu yd disposed soil; 97% exceeded the clean-up criteria.

Triad Integrates Multiple Innovations

- Ashland 2 project went under name Adaptive Sampling & Analysis Program (ASAP) per Argonne Nat'l Lab
- All innovations of ASAP are incorporated into Triad
- Triad includes innovations from other site mgt approaches (ESC, SACM, SAFER, etc.), EPA recommendations (e.g., 1996 RCRA ANPR), & academic thought
- Given "Triad" name since it generalizes & integrates concepts from multiple sources to apply across programs
- The Triad approach for site investigation & cleanup first introduced by name in October 2001 ES&T article.

1996 RCRA ANPR

- Emphasized results over mechanistic process
- Encouraged public participation
- Set risk goals & clearly defined cleanup standards
  - ID action levels during planning stages of site investigations
- Early discussion about land use & its impact on decisions
- Recommended using CSMs & existing information
- Recommended innovative technologies, including field analytics
- Encouraged tailoring data collection to specific data use
- Encouraged integrating charact'n w/ evaluating remedial options
- "Cost-effective" ≠ □λεαστ χοστλψ□
- http://www.epa.gov:80/fedrgstr/EPA-WASTE/1996/May/Day-01/pr-547.pdf

Characterization Is NOT Independent of Cleanup

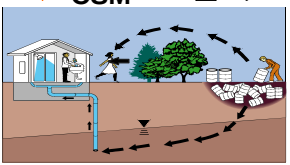
Lack of clarity here

Reuse Plans, Goals, Outcomes

CSM

Impact

…means



Decisions:
- Exposure risk
- Cleanup goals
- Data (type, quality)
- Tolerable errors

…which means

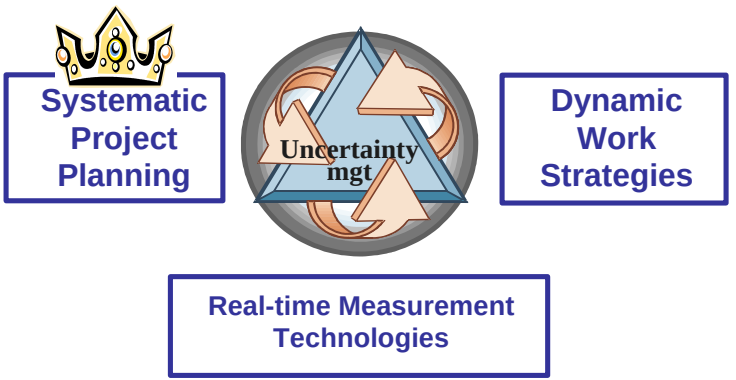
Determine

…or here

Approaches to:
- Assessment
- Investigation
- Cleanup Design, Implementation
- Closeout, Long-Term Operations and Maintenance

Tools for:
- Sampling, Analysis, Interpretation
- Cleanup/Remediation
  - Containment
  - Cleanup
  - Controls
- Monitoring, Maintenance

Successful Strategies Condense into a
Central Theme (“what”) **+ 3 Elements** (“how”)
of the Triad Approach



Triad is Rarely Easy

Triad projects are demonstrably "better, faster, and cheaper" than conventional…

But NO ONE is claiming they are easier!

- Institutional structures often pose barriers
- Extremely difficult to break from traditional thinking

Heterogeneity Rules!

Triad expects heterogeneity: copes by using

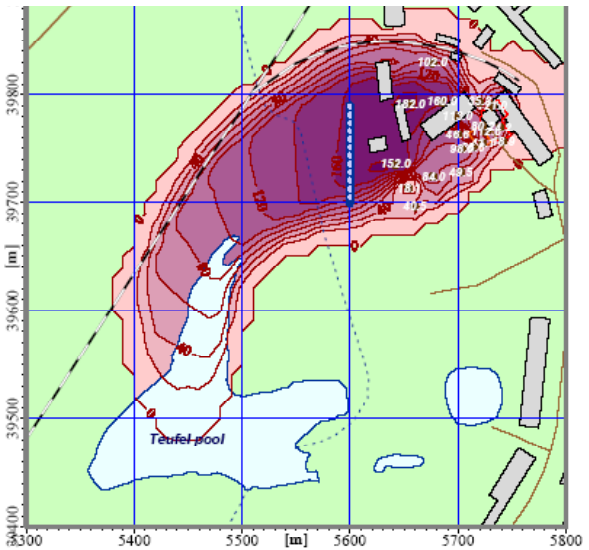
1) "Mgt of decision uncertainty" as the keystone

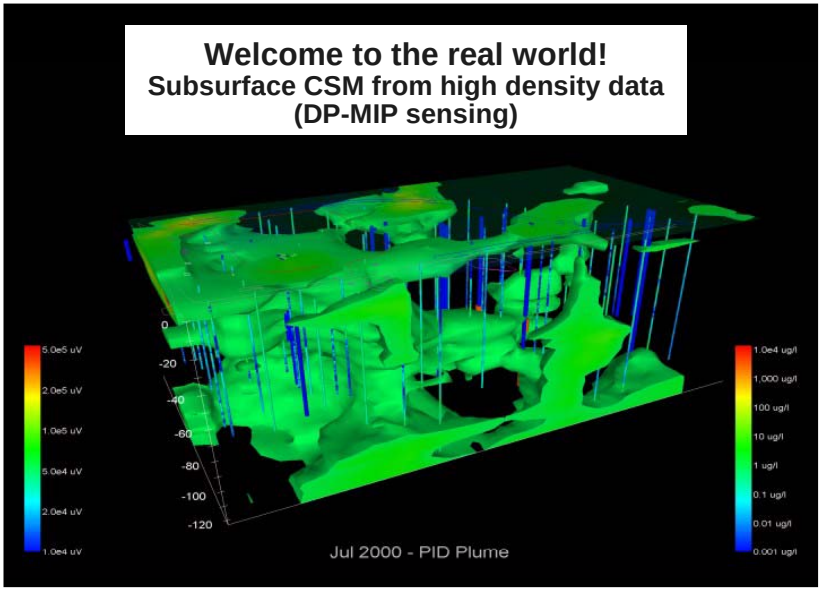
2) Project-specific conceptual site models

3) A 2nd-generation data quality model

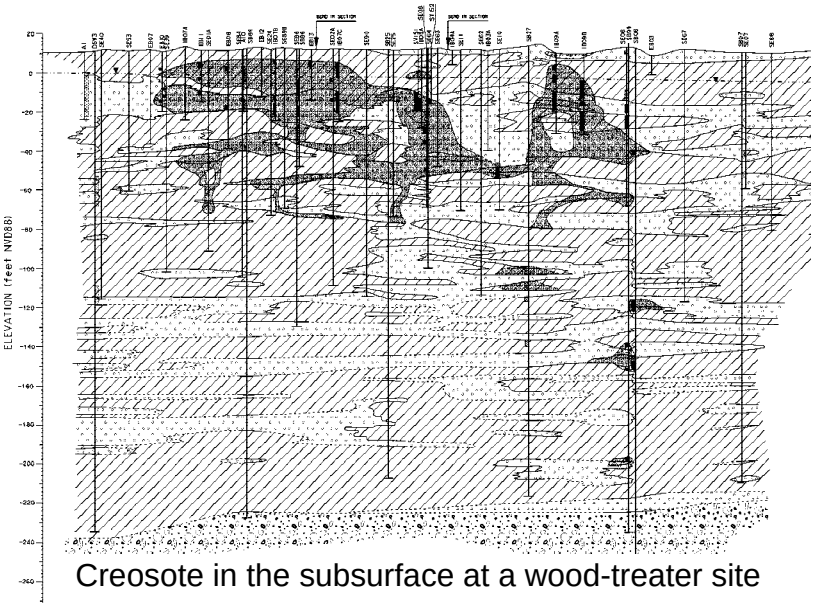
4) Modern tools & work strategies

Idealized models often do not reflect the real world





Slide adapted from Columbia Technologies, Inc., 2003



Creosote in the subsurface at a wood-treater site

The Conceptual Site Model (CSM)

THE Basis for Cost-Effective, Confident Decisions

- A **CSM** is any tool that represents contaminant populations to make predictions about
  - Nature & extent of contamination,
  - Exposure to contamination, and
  - Strategies to reduce risks from contamination
- Decision-maker's mental picture of what's happening in relation to project decisions about risk & cleanup

Spatial Heterogeneity + Grab Samples Can Mislead

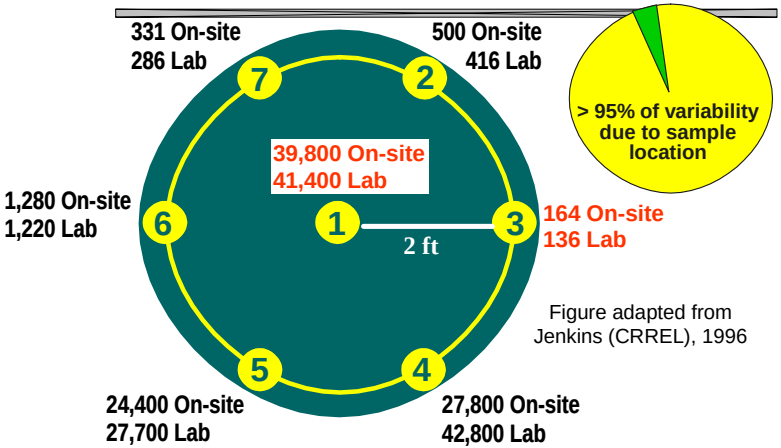
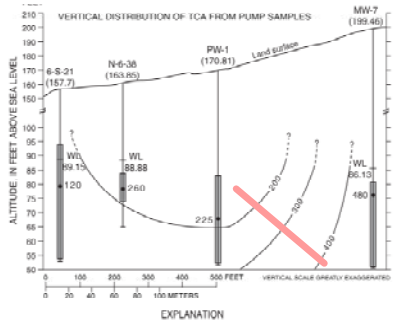


Figure adapted from Jenkins (CRREL), 1996

Traditional GW Sampling Can Mislead

same well field…2 different sample collection techniques



purged well TCA results

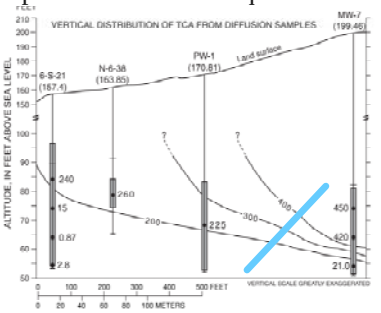
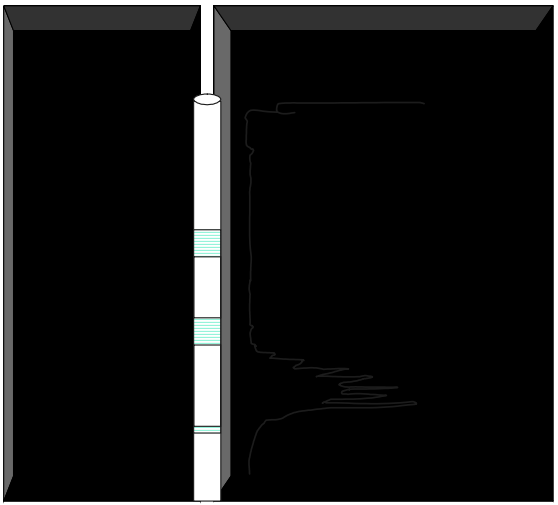


Figure 6. Continued

depth-discrete TCA results

Figure 6. Vertical distribution of TCA concentrations in ground-water samples collected with the diffusion samplers and submersible pump.

Vertical Stratification Changes Lab Results



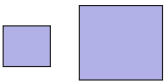
Direct-push deployed membrane-interface probe w/ ECD detector

(DP-MIP-ECD)

Graphic adapted from Columbia Technologies

Causes of Soil Sample Variability

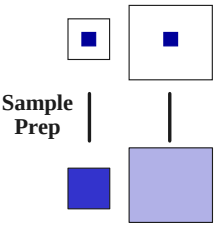
Regulatory and field practice assume the size/volume of a sample has no effect on analytical results.



The assumption doesn't hold under heterogeneity;

sample volume can determine the analytical result!

The Nugget Effect



Same contaminant mass… but different concentration results!!

Smaller Subsamples Have More Variable Results

Am-241: True Mean for Large Soil Sample = 1.92 ppm

Subsample Mass (g) (after sample was dried, ball-milled, sieved <10-mesh)	Range of Results for 20 Individual Subsamples (ppm)	Number of subsamples req'd to estimate the sample true mean ± 25%
1	1.01 to 8.00	39
10	1.36 to 3.43	5
50	1.55 to 2.46	1
100	1.70 to 2.30	1

Adapted from Doctor and Gilbert, 1978

Metal Results Susceptible to Subsampling Bias

Small Arms Firing Range Soil Grain Size (Std Sieve Mesh Size)	Pb Conc. in fraction by AA (mg/kg)
Greater than 3/8" (0.375")	10
Between 3/8 and 4-mesh"	50
Between 4- and 10-mesh	108
Between 10- and 50-mesh	165
Between 50- and 200-mesh	836
Less than 200-mesh	1,970
Totals	927 (wt-averaged)

Adapted from ITRC (2003)

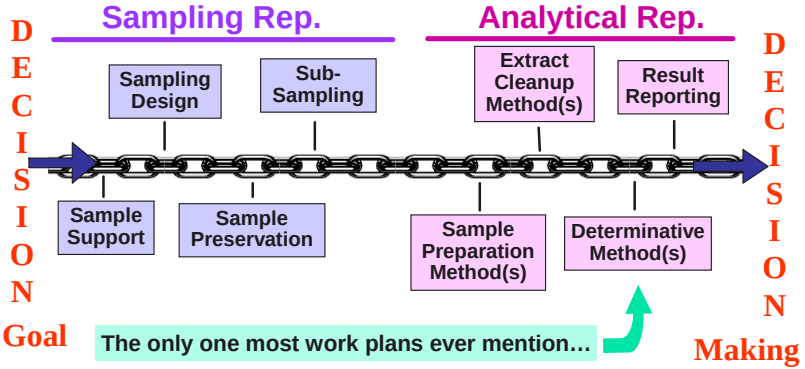
Sampling/subsampling procedures that preferentially capture larger vs. smaller particle sizes will get different results!
Cannot always assume the "average" is representative of the decision.

Data Quality Is Much More than Chemical Analysis

Perfect Analytical Chemistry + **Non-Representative Sample(s)**

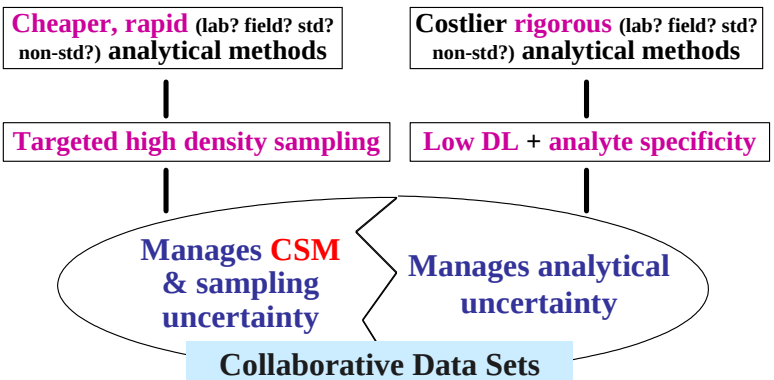
“BAD” DATA

Triad Controls Data Uncertainty



All links in the Data Quality chain must be intact for data to be representative of the decision!

A Second-Generation Data Quality Model (for Heterogeneous Matrices)



Collaborative data sets complement each other so all sources of data uncertainty are managed

Summary: Triad is NOT…

- …written in all caps (not an acronym)
- …just about field analytical (must manage ALL components of data uncertainty)
- …a way to justify using field analysis without using proper QC (must have data of known/documented quality)
- …just about using a dynamic/flexible work plan (must manage decision uncertainty)
- …a license to write vague work plans or escape regulatory oversight or accountability (negotiated & pre-approved decision logic fundamental)

www.triadcentral.org

The Challenge to Change Traditional Thinking

"The difficulty lies, not in the new ideas, but in escaping the old ones…"

John Maynard Keynes
(English economist, 1883-1946)