Workshop: The Triad Approach to Managing Decision Uncertainty for Better Cleanup Projects

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EPA Optimization Conference, Dallas, TX June 16, 2004

Triad Restructures How Projects Are Done

Triad is a coordinated effort to integrate proven technical strategies into a “new” framework that incorporates 25-30 years of experience + advancing science & technology

Why?

So we can improve the cost-effectiveness and confidence of project outcomes.

What Goes Wrong with Current Practice?

- Little discussion or agreement on project goals and decision points before gathering data. **Easily work at cross-purposes.**
- Data acceptable only if produced by standard fixed lab methods. **Sampling and analytical uncertainties impacting data interpretation are ignored.**
- But budgets limit numbers of lab samples, so data very sparse & CSM is incomplete. **Faulty understanding of contaminant distributions.**
- Incomplete CSM compromises reliability of site decisions and efficiency of remediation. **Resources wasted.**
- This may not happen to every project, but it is much too common

Step-wise field mobilizations best option in 1980s: Working in unknown territory

- Trying to understand the problem one step at a time
- Could not predict…
  - how contaminants behaved in the environment
  - what cleanup levels should be
  - how cleanup would be done
  - land reuse and legal scenarios
  - how data would be used in later stages
- Forced to use simple models to make complex systems more manageable (e.g., assumed homogeneity)

But Programs Have Evolved Since 1980s

- Programs have regulatory benchmarks in place
- More analytical & engineering services
- “Brownfields” make site reuse a key driver
- Insurers have financial incentive to avoid mistakes
- Have years of experience with what works & what doesn’t
- High expectations for projects to be efficient
- Yet, have fewer resources—must do more with less

Science & Technology Have Also Evolved

- **Good News! More & better cleanup technologies**
  - **Bad News:** success requires <u>accurate</u> site characterization
- **Good News! Better understanding of contaminated sites**
  - **Bad News:** cleanup science IS harder than rocket science!

Heterogeneity Rules! Overly simple models give wrong answers and failed projects.

- **Good News! More & better investigation tools**
  - Can deal with heterogeneity to build accurate CSMs
  - **Bad News:** stuck in 1980's mentality using simple models

Programs & capabilities have evolved, but many practices remain in 1980s-mode

In general, we still…

- plan projects as if unable to predict ultimate project goals
- budget and contract as if all projects should cost the same, no matter what the technical issues
- plan for sampling as if we cannot predict contaminant locations, distributions, and behavior (not using a CSM)
- expect simplified models based on assumptions of homogeneity to work:
  - treat analytical method quality as equivalent to data quality
  - use classical statistics w/o knowing contaminant distributions

The Triad Approach Moves Beyond 1980s Thinking

Triad Expects Contaminated Sites to be Heterogeneous

Triad 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

Modern Tools & Work Strategies of The Triad Approach

Systematic Project Planning

Dynamic Work Strategies

Real-time Measurement Technologies

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

Key Triad Concepts Grounded in the Management of Decision Uncertainty

- In-depth, face-to-face systematic planning
  - Know what the project decisions actually are before going to the field!
  - Build "social capital" (trust & common vision)
  - Develop a conceptual site model (CSM)
- When data used to make decisions, manage data uncertainties that impact the decision
  - Manage sampling variables caused by heterogeneity
  - Ground data representativeness in the CSM & the decision

Conceptual Site Model is THE Basis for Confidence in Project Decisions

- Correct decisions require an accurate picture of site contamination
- This picture is called a **Conceptual Site Model (CSM)**
- A **CSM** = any tool to represent site contamination concerns & concentration populations to make predictions about
  nature, extent, exposure, and risk reduction strategies
- Decision-maker's mental picture ("story") of what's happening with contamination in relation to decisions about risk & cleanup

Conceptual Site Model Elements

- Where is the contamination and how is it distributed?
- Contaminant patterns are created by
  - Contaminant **release** mechanism(s)
  - Contaminant **dispersal/migration/fate** mechanisms
- Contaminant patterning creates challenges for data collection
- Defensible & cost-effective decisions require understanding contaminant distributions and spatial patterns

GW CSM from Traditional Sampling Effort (left) vs. CSM from High Density Sampling (right)

same well field…2 different sample collection techniques

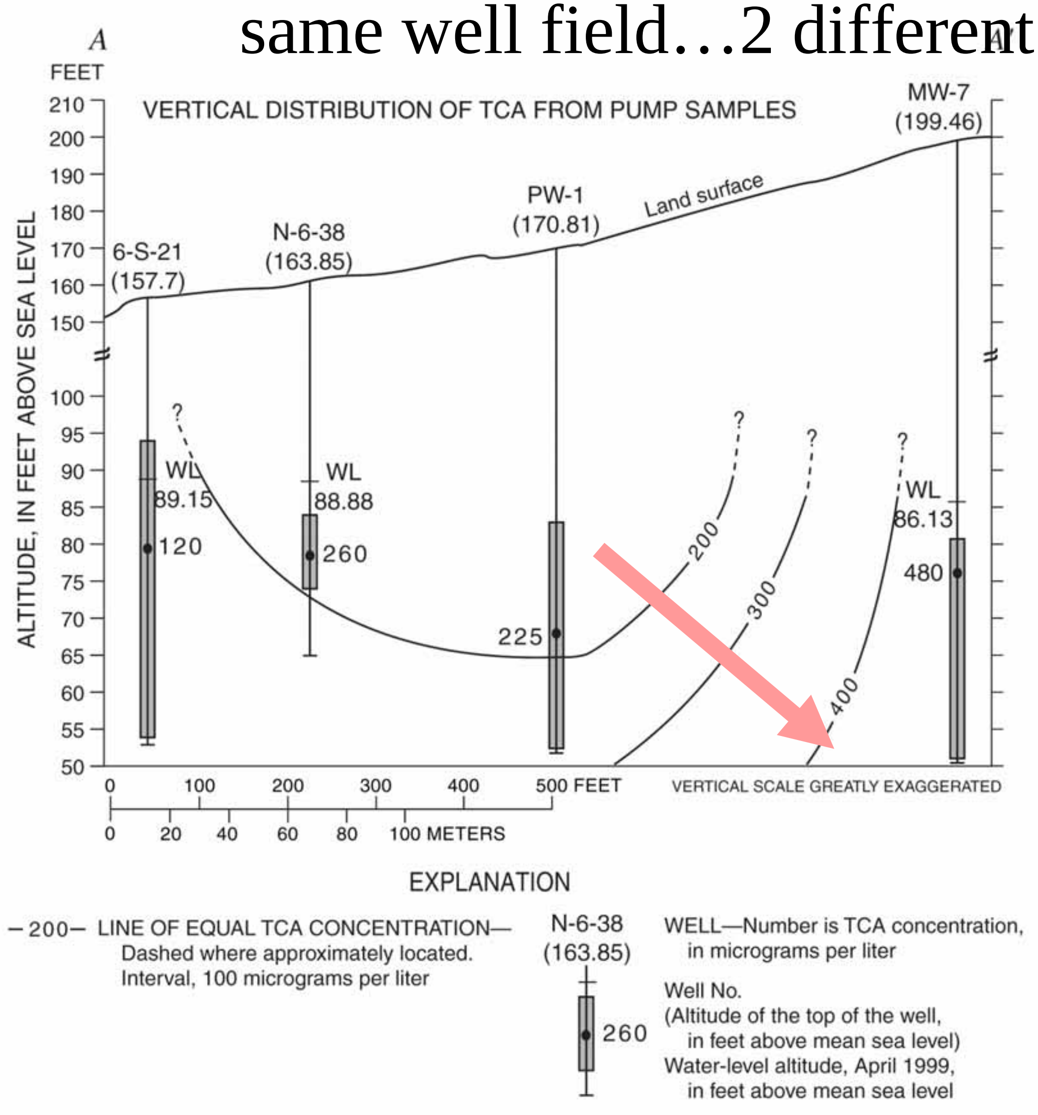


Figure 6. Vertical distribution of TCA concentrations in ground-water samples collected with the diffusion samplers and submersible pump.

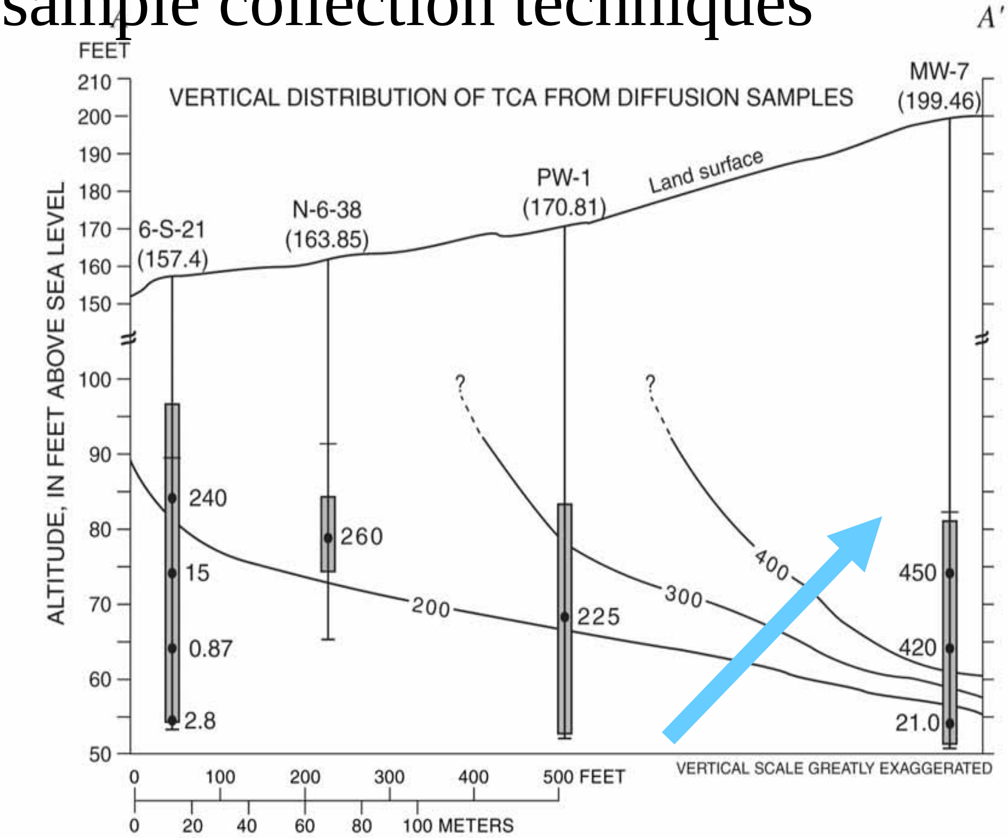


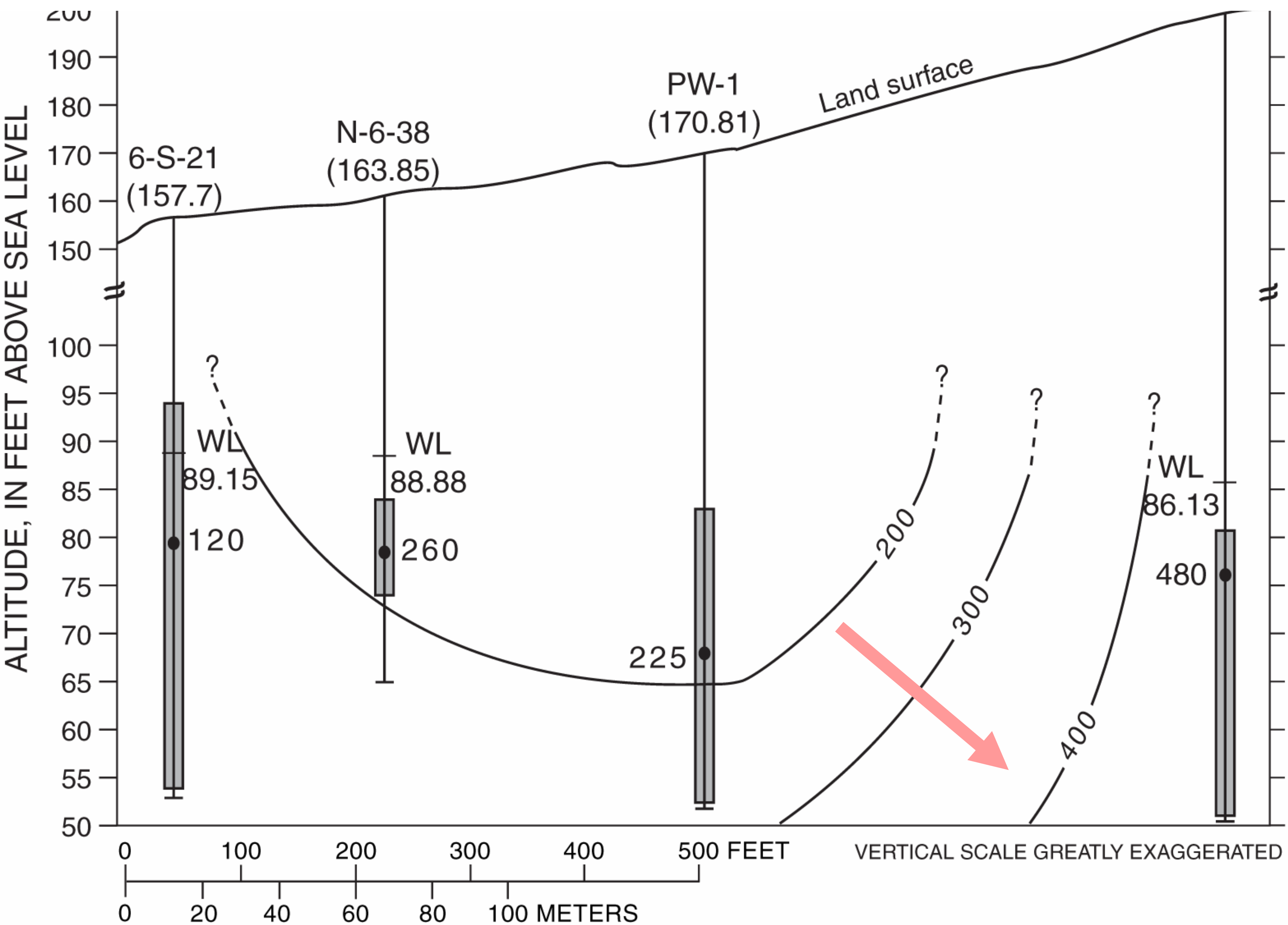
Figure 6.—*Continued.*

From USGS Report 02-4203 (2002)

http://water.usgs.gov/pubs/wri/wri024203/

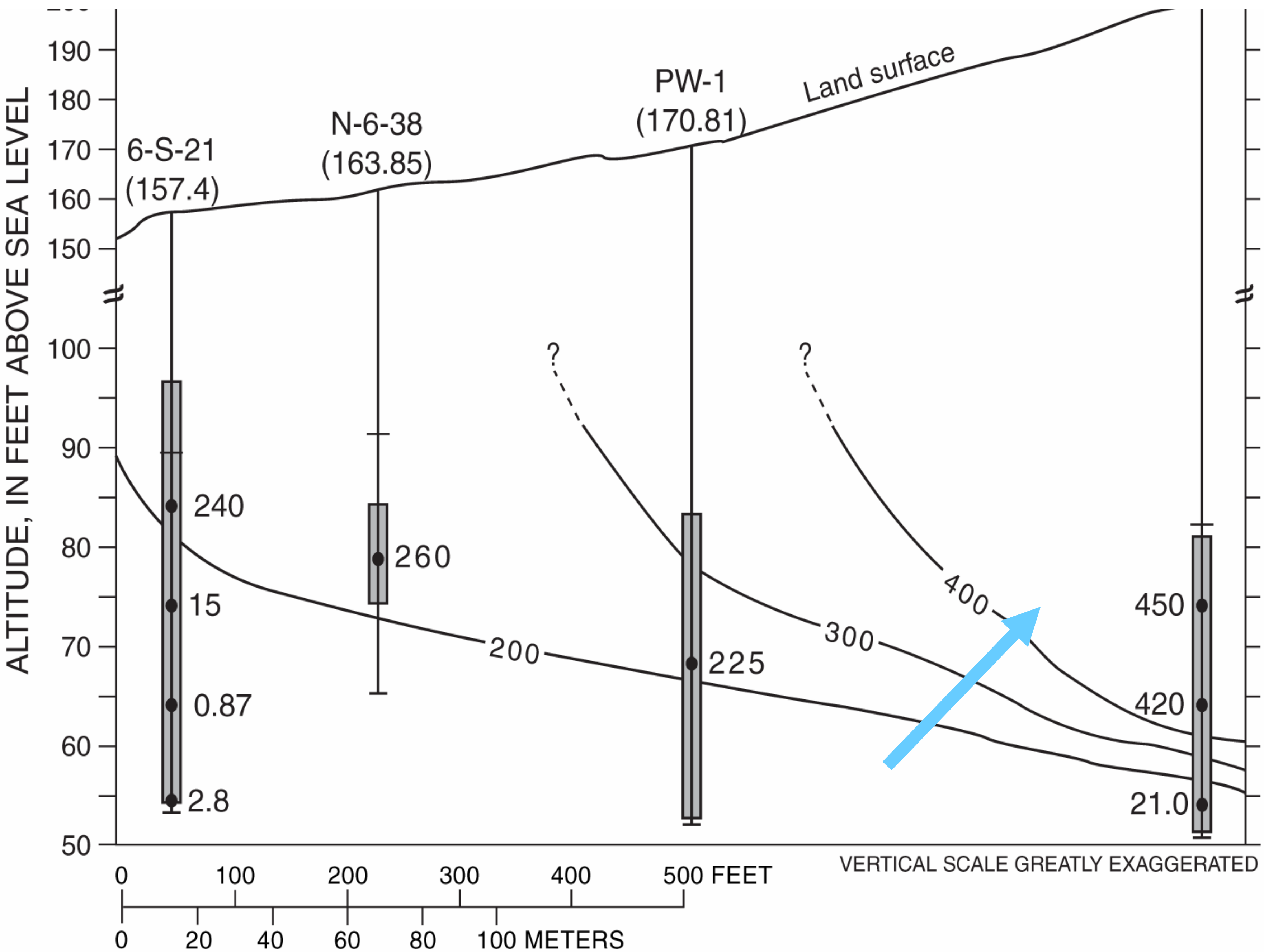
Enlargement of CSM from Purge/Pumped Sample Results

TCA Conc. (ppb)

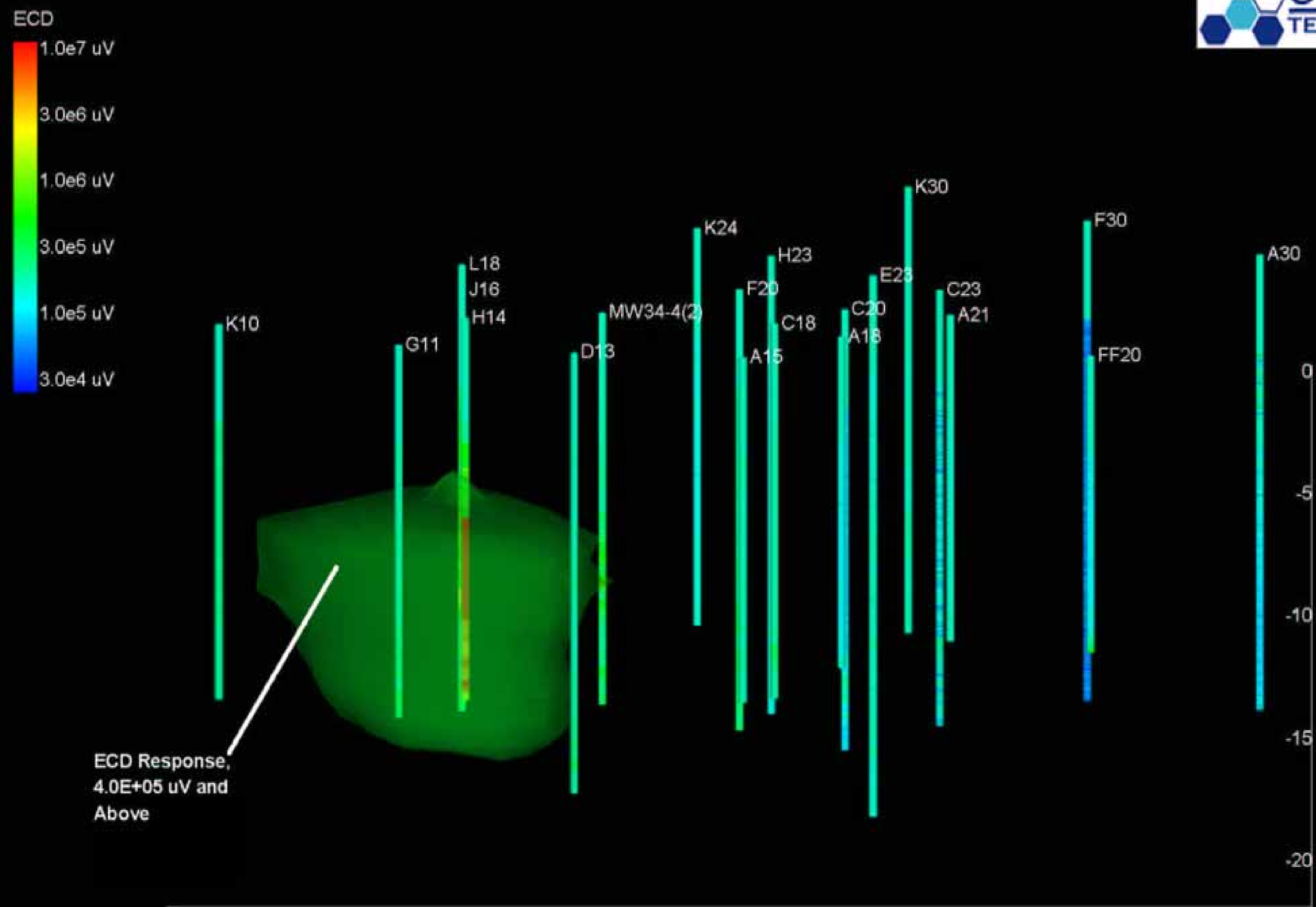


From USGS Report 02-4203 (2002) http://water.usgs.gov/pubs/wri/wri024203/

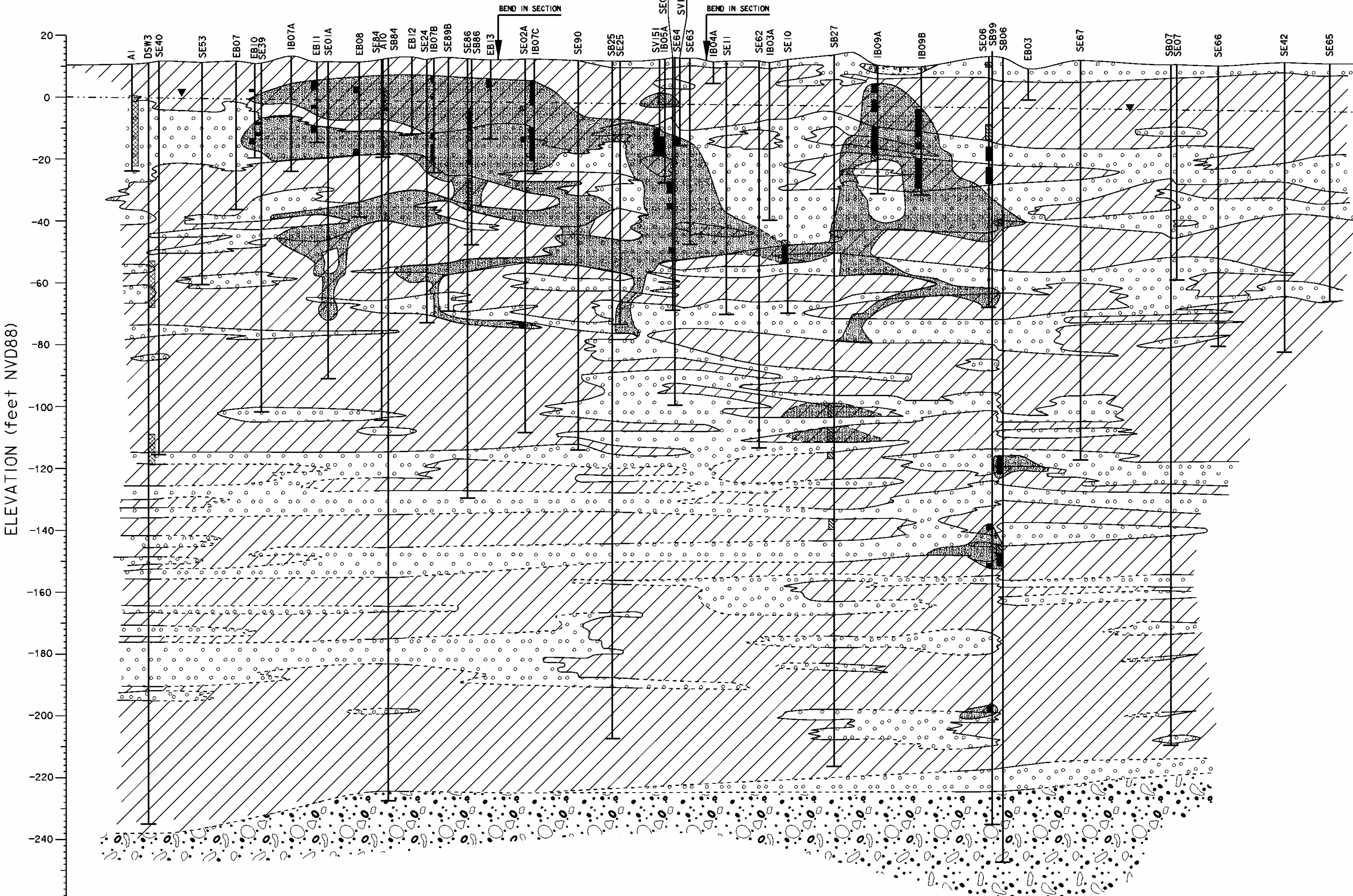
Same Well Field—Passive Diffusion Samplers Preserves Distinct Populations



From USGS Report 02-4203 (2002) http://water.usgs.gov/pubs/wri/wri024203/



CSM of Subsurface PCE source mapped by high density DP-MIP-ECD-DSITMS sensing



CSM of Subsurface Creosote NAPL

Constructing Accurate CSMs Requires a 2nd-Generation Model for Understanding "Data Quality"

Oversimplified 1980s (First-Generation) Data Quality Model

Methods = Data = Decisions

Screening Methods	→	**Screening Data**	→	**Uncertain Decisions**
"Definitive" Methods	→	**"Definitive" Data**	→	**Certain Decisions**

Equating method rigor to data quality made sense for the 1980s, but it has failed to support efficient cleanups. Why?

The Real-World is More Heterogeneous than the Old Data Quality Model Assumes

- Current practices built on assumption that contamination is relatively homogeneous (or is randomly variable)
- Simply not true for most sites
  - Release mechanisms create non-random spatial patterning at macro & micro scales
  - Physical transport may create new spatial patterns, or may reduce patterning through mixing
  - Interaction with matrix components imparts micro particulate-like behavior to many contaminants
  - Degree of patterning depends on mechanism & scale of observation

You can't fool Mother Nature!

In a clash between a model & reality, reality always wins

Building a New Data Quality Model

Data Quality = "a measure of the degree of acceptability or utility of data for a particular purpose." (USEPA QA/G-5, 2002)

- The "purpose" of data: make correct project decisions

- Then, data quality depends on the data providing accurate information about (i.e., representing) the "true state" (of the decision unit) in the context of the decision that the data user wants to make

Data Quality is about More than Just Chemical Analysis

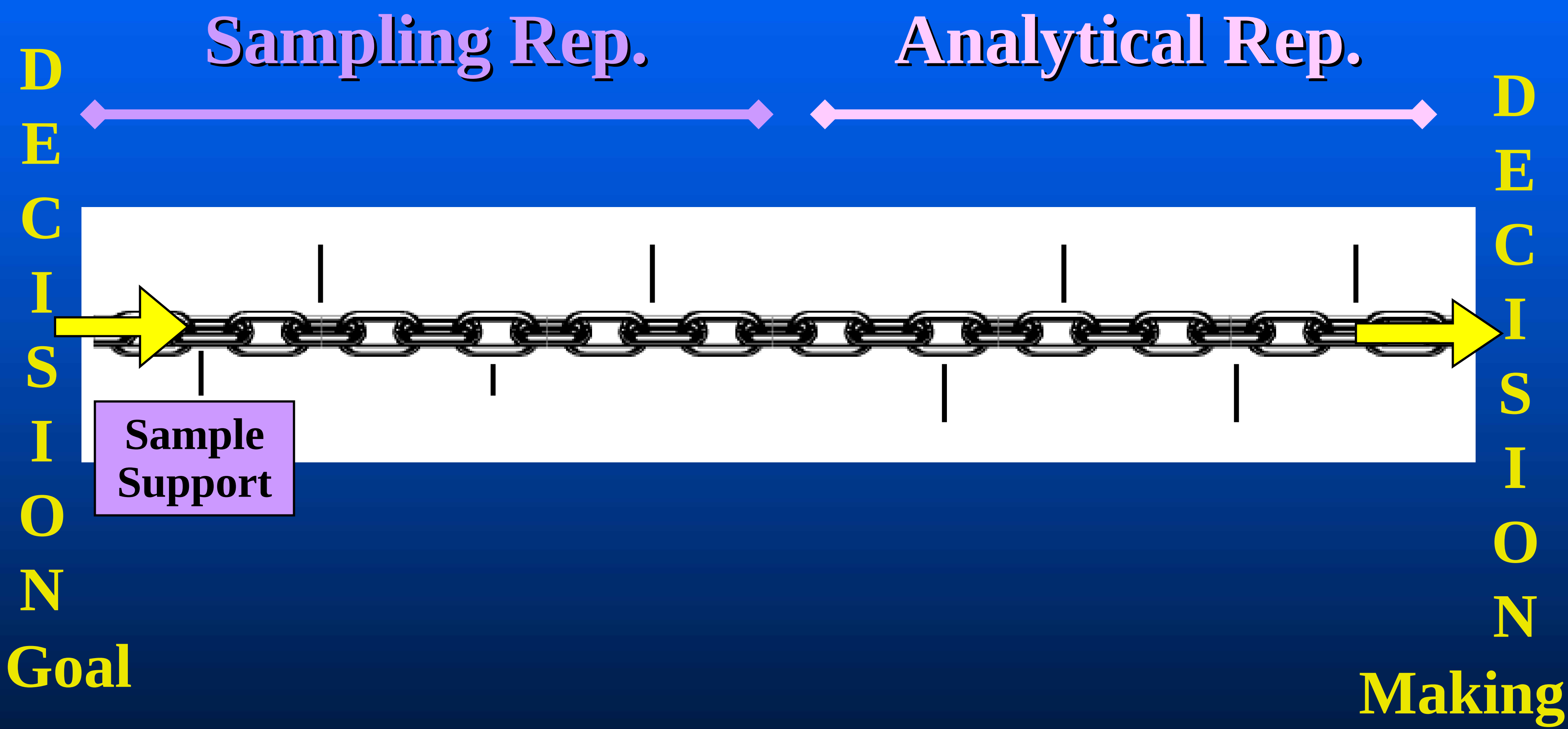
Perfect Analytical Chemistry + **Non-Representative Sample(s)**

Wrong Decision
"BAD" DATA

Data Quality =
Sample Representativeness + Analytical Quality

Need to Distinguish Analytical Quality from Data Quality

A Chain of Variables Controls the Generation of "Representative Data"



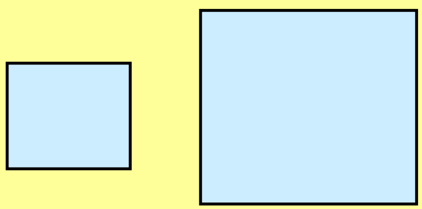
All links in the Data Quality chain must be intact for data to be representative of the decision!

Facets of “Sample Support”

- Physical properties of a sample (or subsample) that help determine what the analytical result will be
- Includes
  - Sample volume
  - Sample orientation
  - Particle size
  - Time

Sample Support: Size Matters!

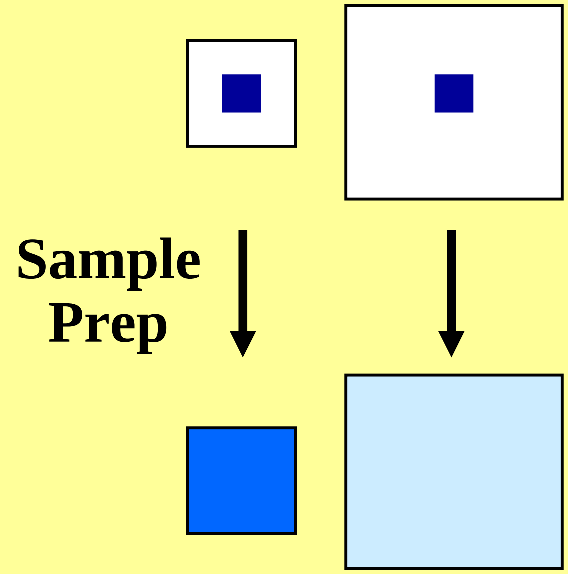
Typical regulatory and field practices assume that the size/volume of a sample has no effect on analytical results for contaminant concentrations.



That assumption doesn't hold true when environmental heterogeneity exists;

sample volume can determine the analytical result!

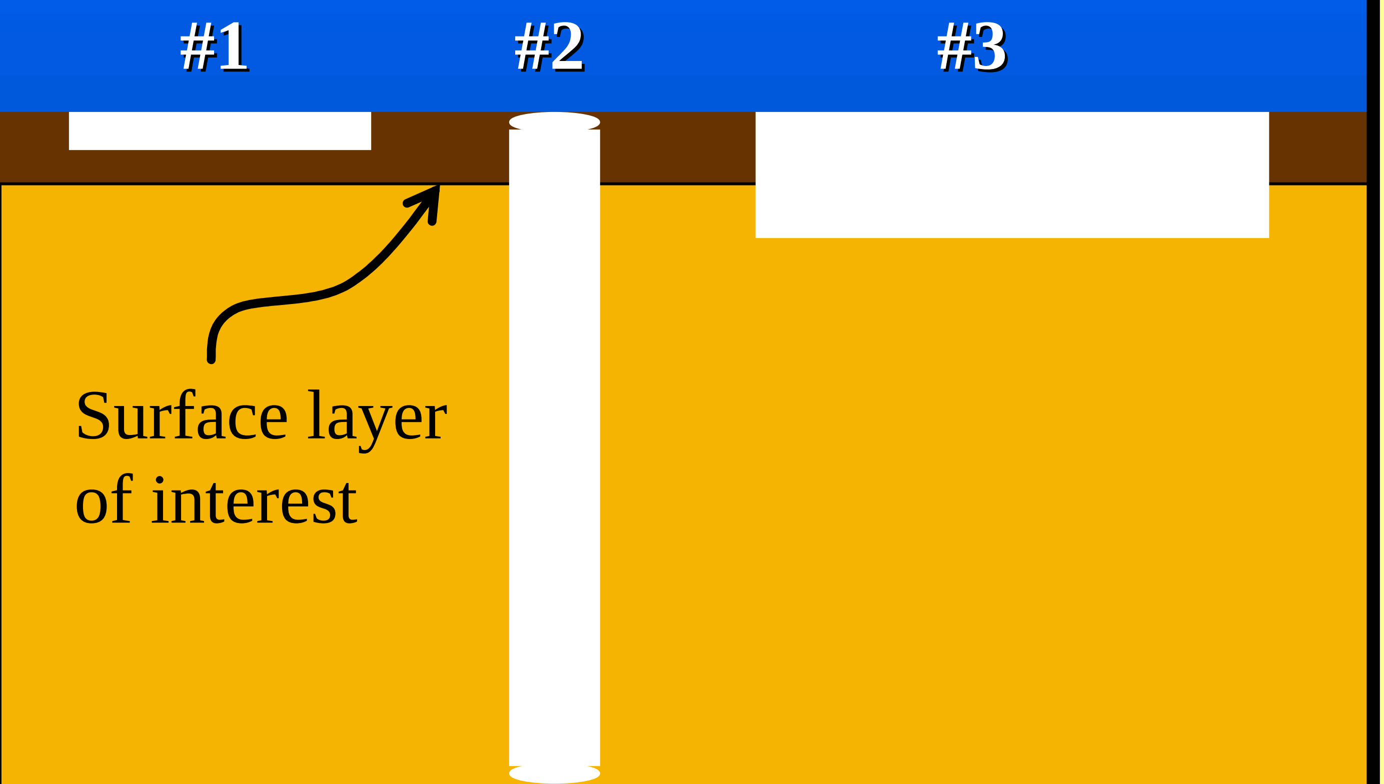
The Nugget Effect



Although there is the same contaminant mass in the captured nuggets, different volumes of cleaner matrix will produce different sample concentrations after sample homogenization.

Sample Support: Includes Spatial Orientation

What sample support is representative of the decision?

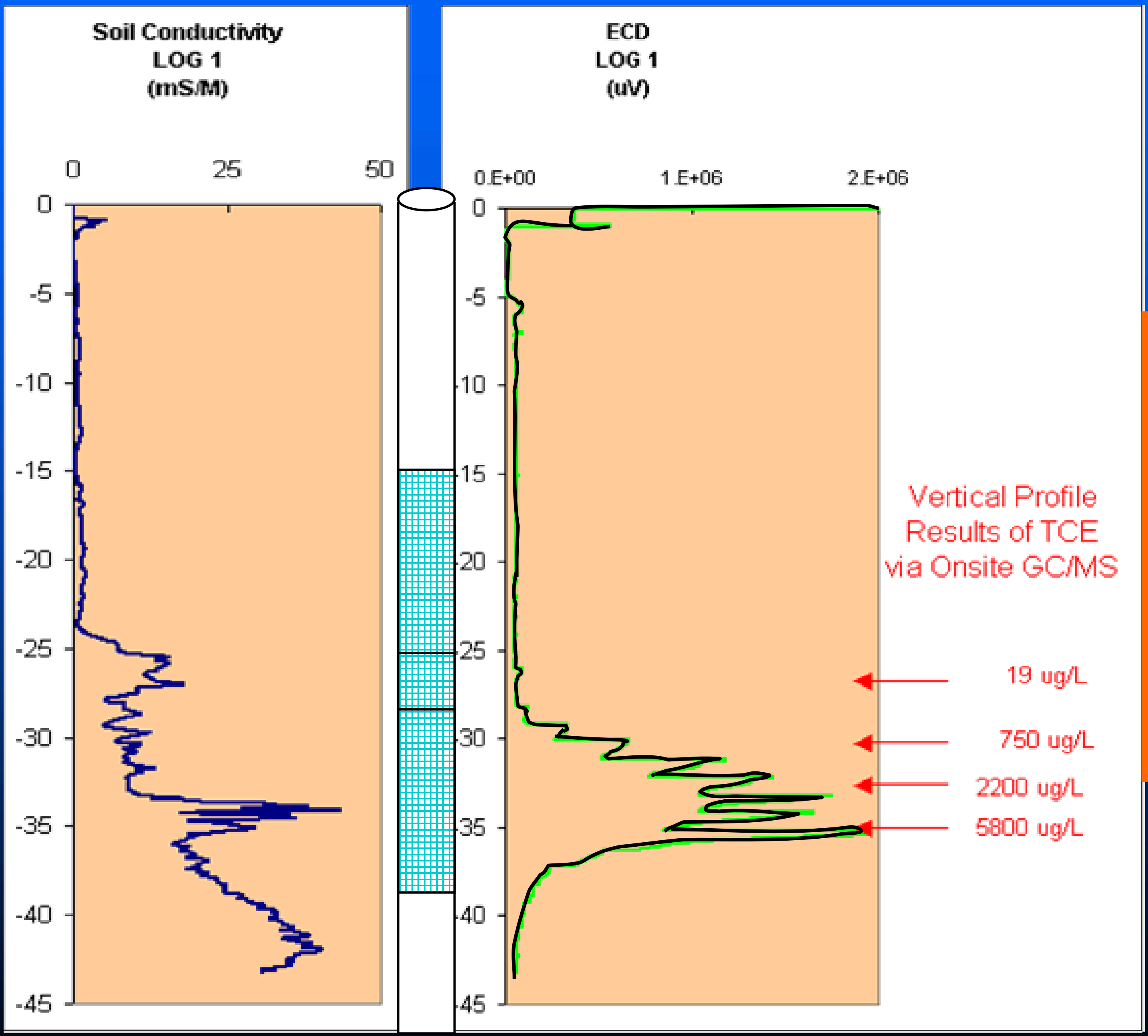


The decision driving sample collection: **Assess contamination resulting from atmospheric deposition**

Given that the dark surface layer is the soil layer impacted by atmospheric deposition relevant to this project:

Which sample support (white areas #1, #2, or #3, each homogenized before analysis) provides a sample that is representative of atmospheric deposition for this site?

Different Sample Support Changes Analytical Results for GW



MIP = membrane-interface probe (w/ ECD detector)

Sample support for MIP on scale of mm to inches

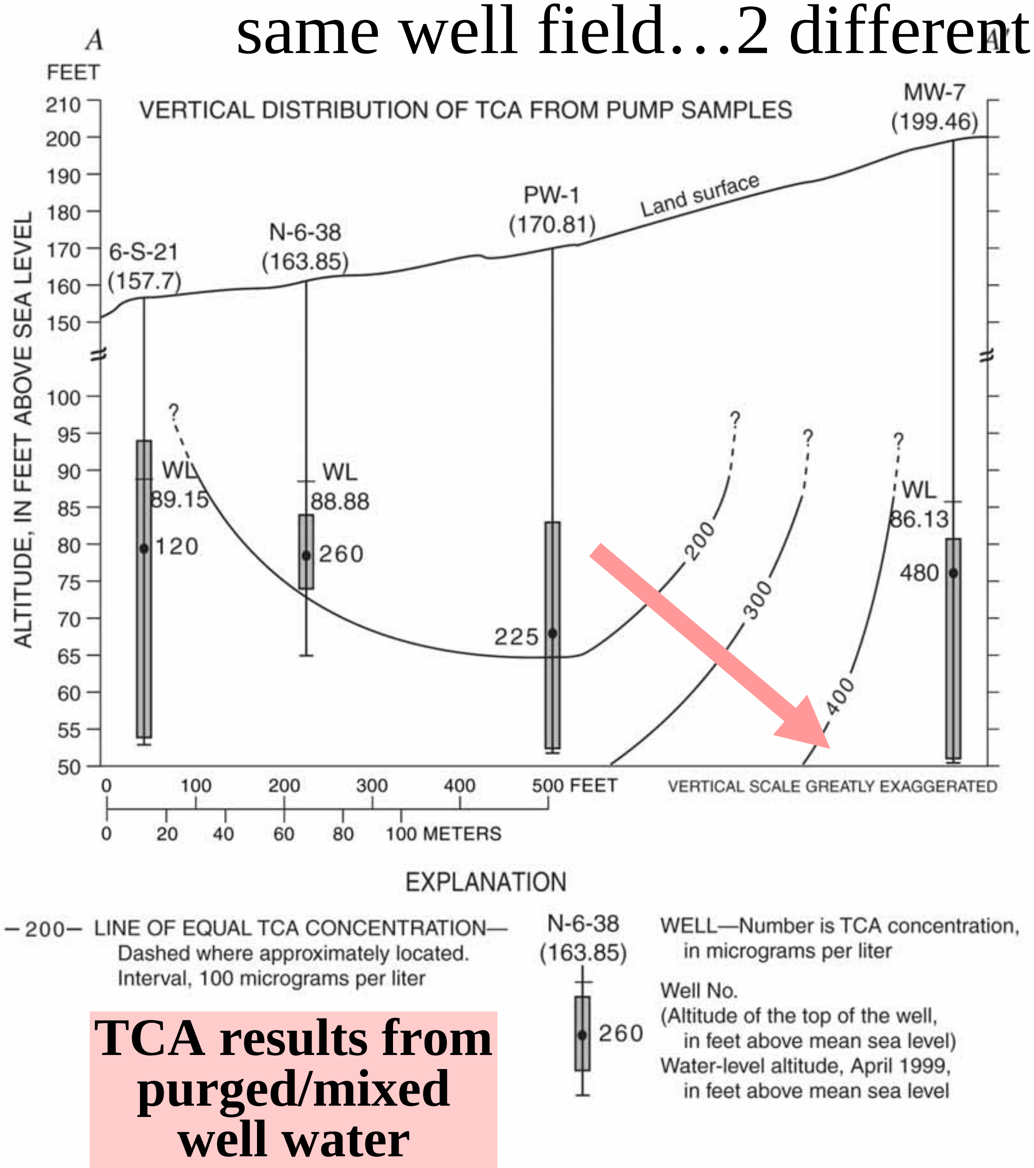
Sample support for discrete-depth GW samples on 6-in scale

Sample support for traditional well sampling on scale of feet

Graphic adapted from Columbia Technologies

Purging Creates a Different Sample Support than a Diffusion Sampler → Different CSMs

same well field…2 different sample collection techniques



TCA results from purged/mixed well water

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

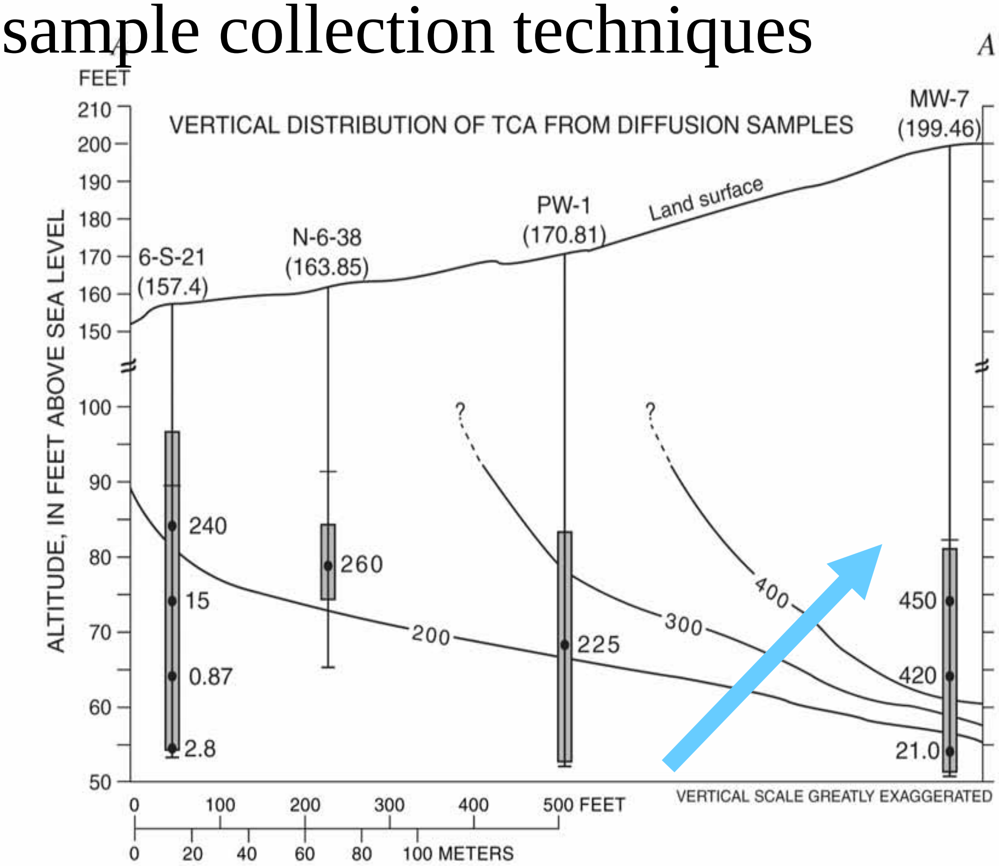


Figure 6.—*Continued.*

TCA results from depth-discrete well water

From USGS Report 02-4203 (2002)

http://water.usgs.gov/pubs/wri/wri024203/

Sample Support Can Spell the Difference Between Hits and NDs in the Same Well

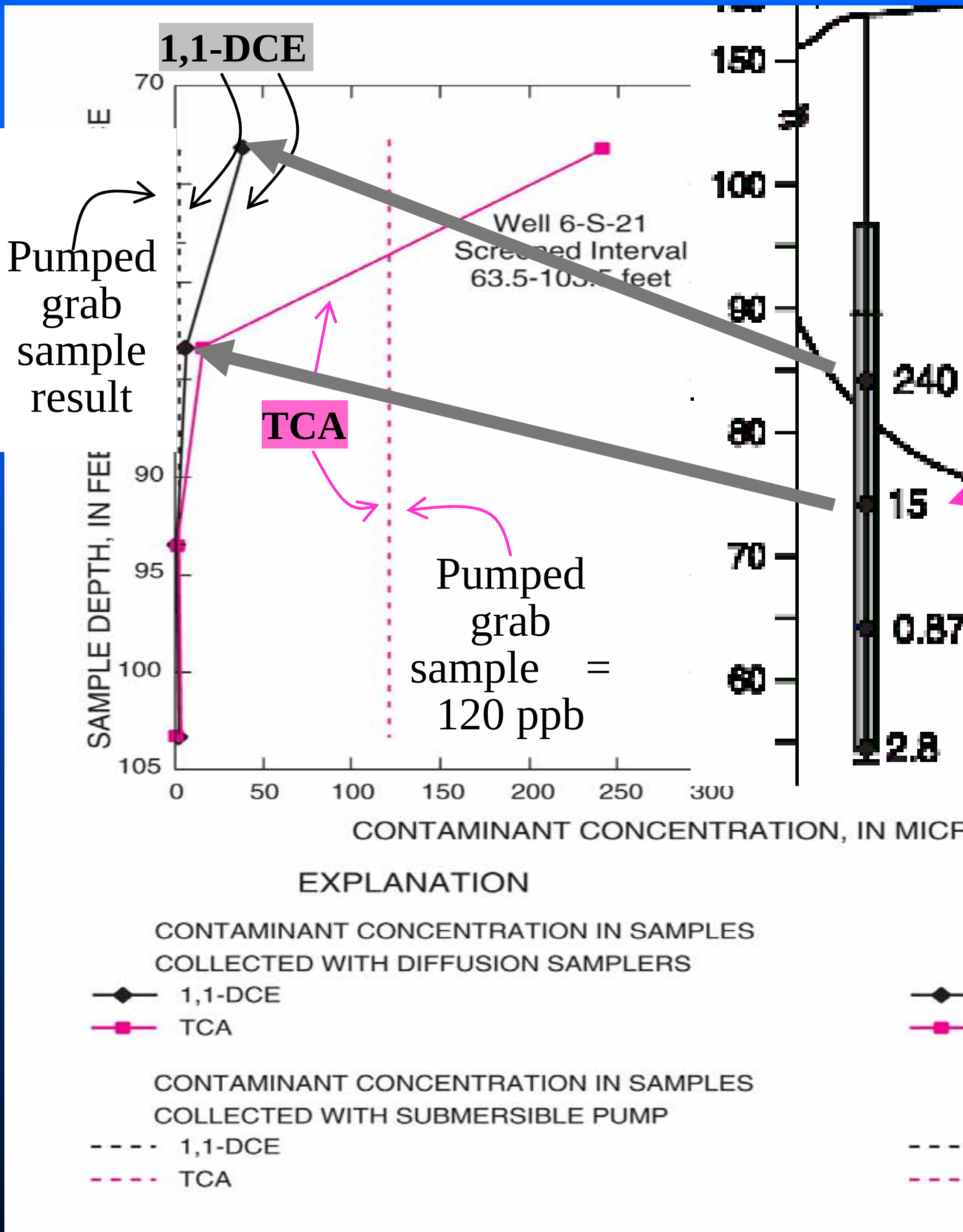


Figure 5. Comparison of selected volatile organic compound concentrations from and a submersible pump for wells with greater than 20-foot screened intervals in A

Zoom to Well 6-S-21

PDS TCA results

Vertical distribution pattern of DCE is same as TCA, but concentrations lower. Purging mixes with cleaner water--could dilute to ND → misleading CSM

From USGS Report 02-4203 (2002); http://water.usgs.gov/pubs/wri/wri024203/

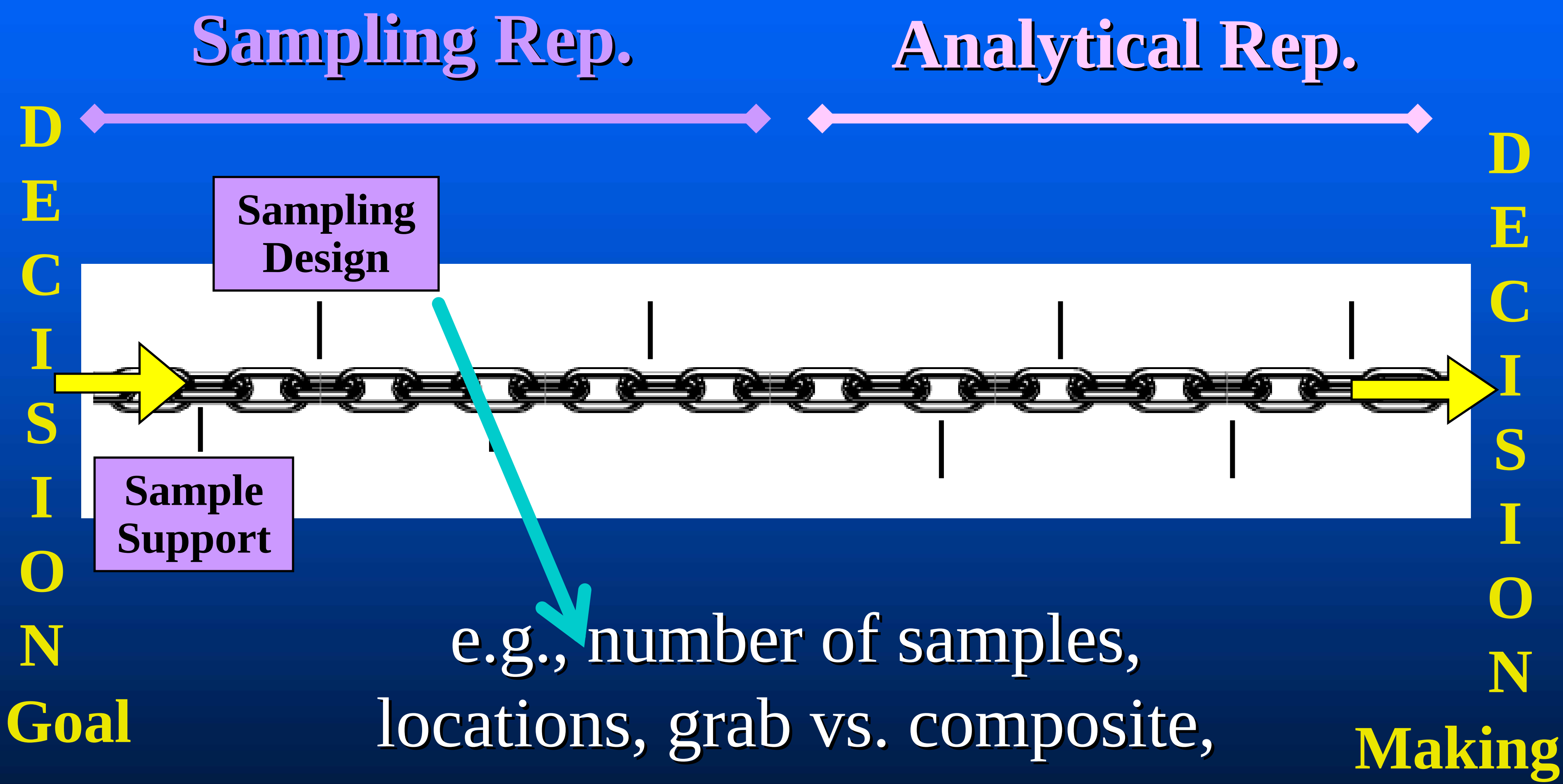
Different Particle Sizes Give Different Results Due to Micro Heterogeneity

Soil Grain Size (Standard Sieve Mesh Size)	Soil Fraction-ization (%)	Pb Conc. in fraction by AA (mg/kg)	Lead Distribution (% of total lead)
Greater than 3/8" (0.375")	18.85	10	0.20
Between 3/8 and 4-mesh"	4.53	50	0.24
Between 4- and 10-mesh	3.65	108	0.43
Between 10- and 50-mesh	11.25	165	2.00
Between 50- and 200-mesh	27.80	836	25.06
Less than 200-mesh	33.92	1,970	72.07
Totals	100%	927 (wt-averaged)	100%

For this matrix, sampling/subsampling that captures larger particles will get lower results than procedures that get the smaller particles!! Cannot assume "average" will be representative of the decision!

Adapted from ITRC (2003); http://www.itrcweb.org/SMART-1.pdf

Macro Heterogeneity Affects Sampling Design



e.g., number of samples, locations, grab vs. composite, etc.

Will Your Sampling Design Avoid Decision Errors from Misleading Grab Sampling?

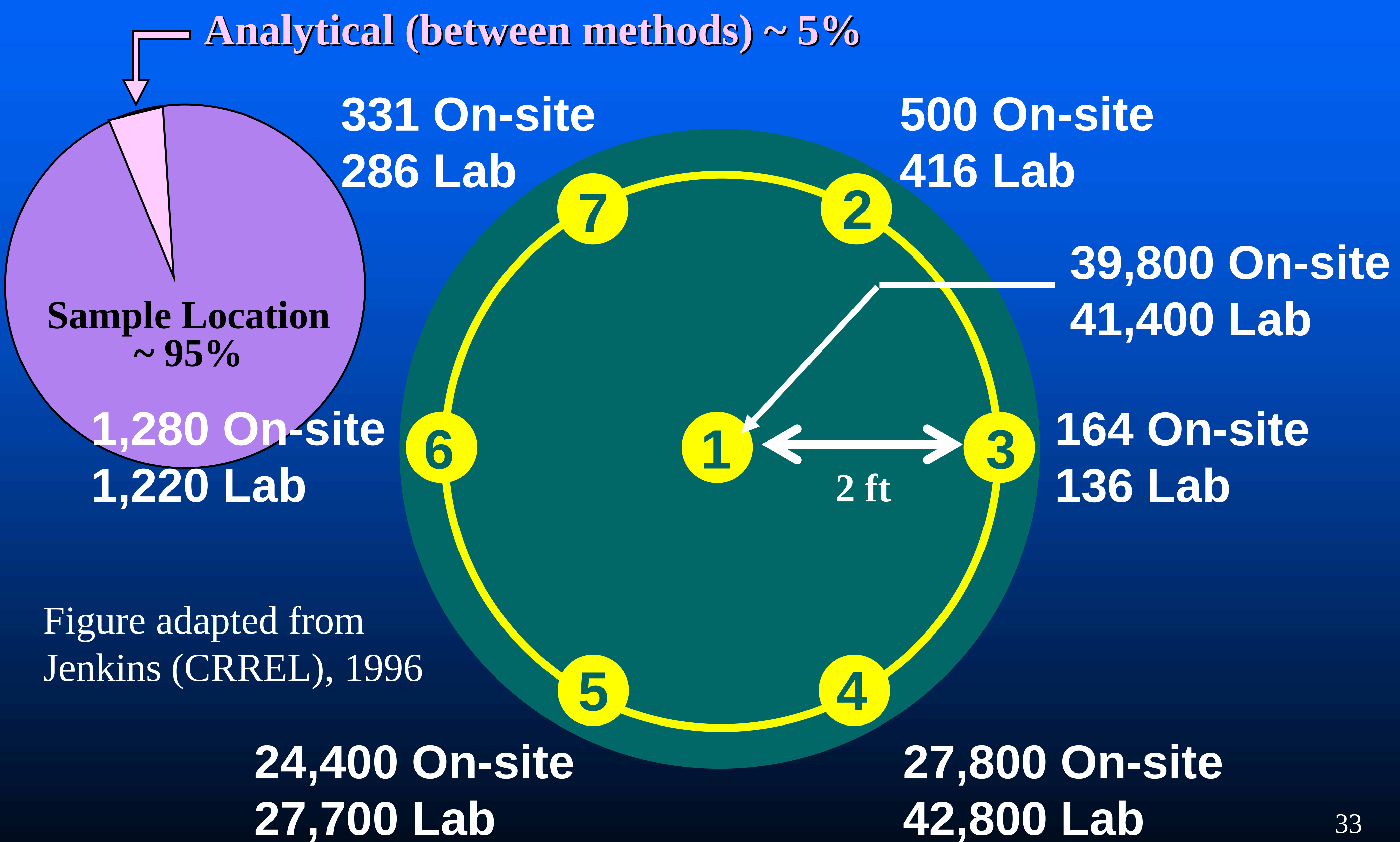
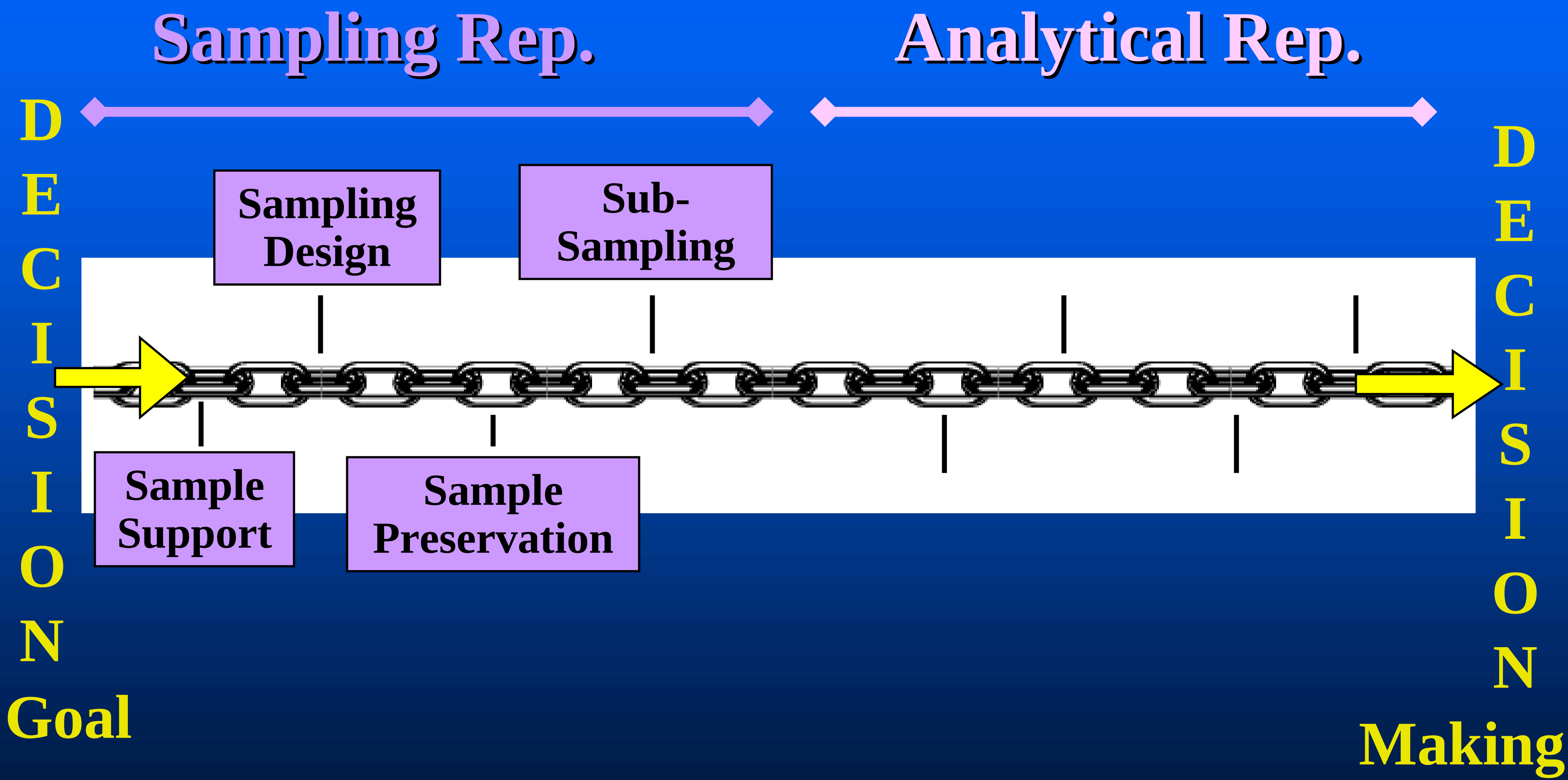


Figure adapted from Jenkins (CRREL), 1996

Micro Heterogeneity Impacts Subsample Support



Smaller Subsamples Are More Variable (^{241}Am in Soil Study)

Subsample Support (after sample was dried, ball-milled, sieved <10-mesh)	Coefficient of Variation	Number of subsamples required to estimate the sample true mean ± 25% *	Number of subsamples required to estimate the sample true mean ± 10% *
1 g	0.79	39	240
10 g	0.27	5	28
25 g	0.30	6	35
50 g	0.12	1	6
100 g	0.09	1	4

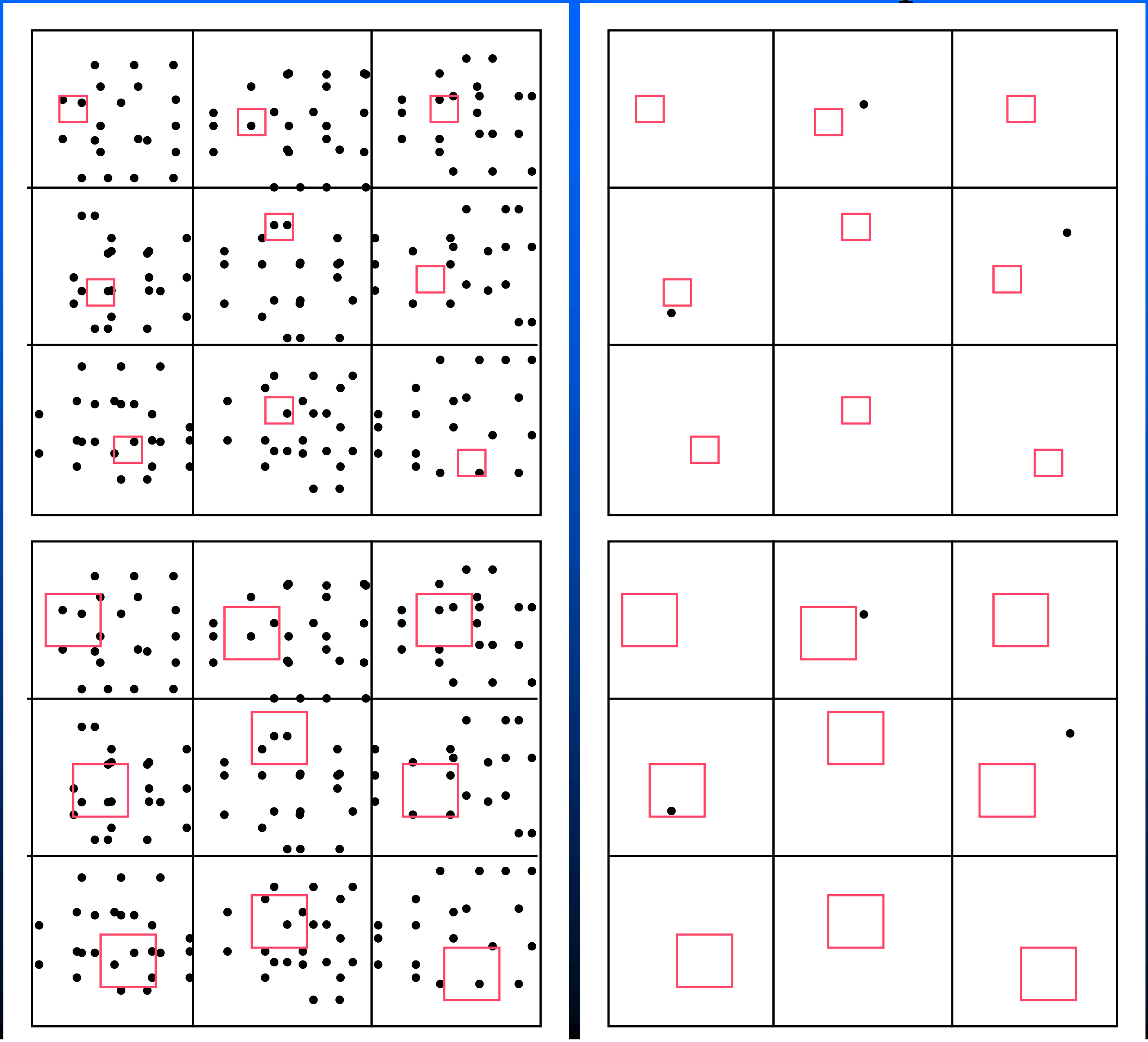
* Using classical parametric statistics at 95% confidence

Adapted from DOE (1978)

Major problem!! Advancing analytical science use smaller and smaller subsamples→ more variable results! Any single subsample result likely not representative of original sample.

Smaller supports are more variable because many contaminants behave like particulates

Figure adapted from Jeff Myers, 2001



Black & Red boxes = different volume samples

Contrast different concentration and sample volume scenarios.

Left panels represent higher concentrations than right panel.

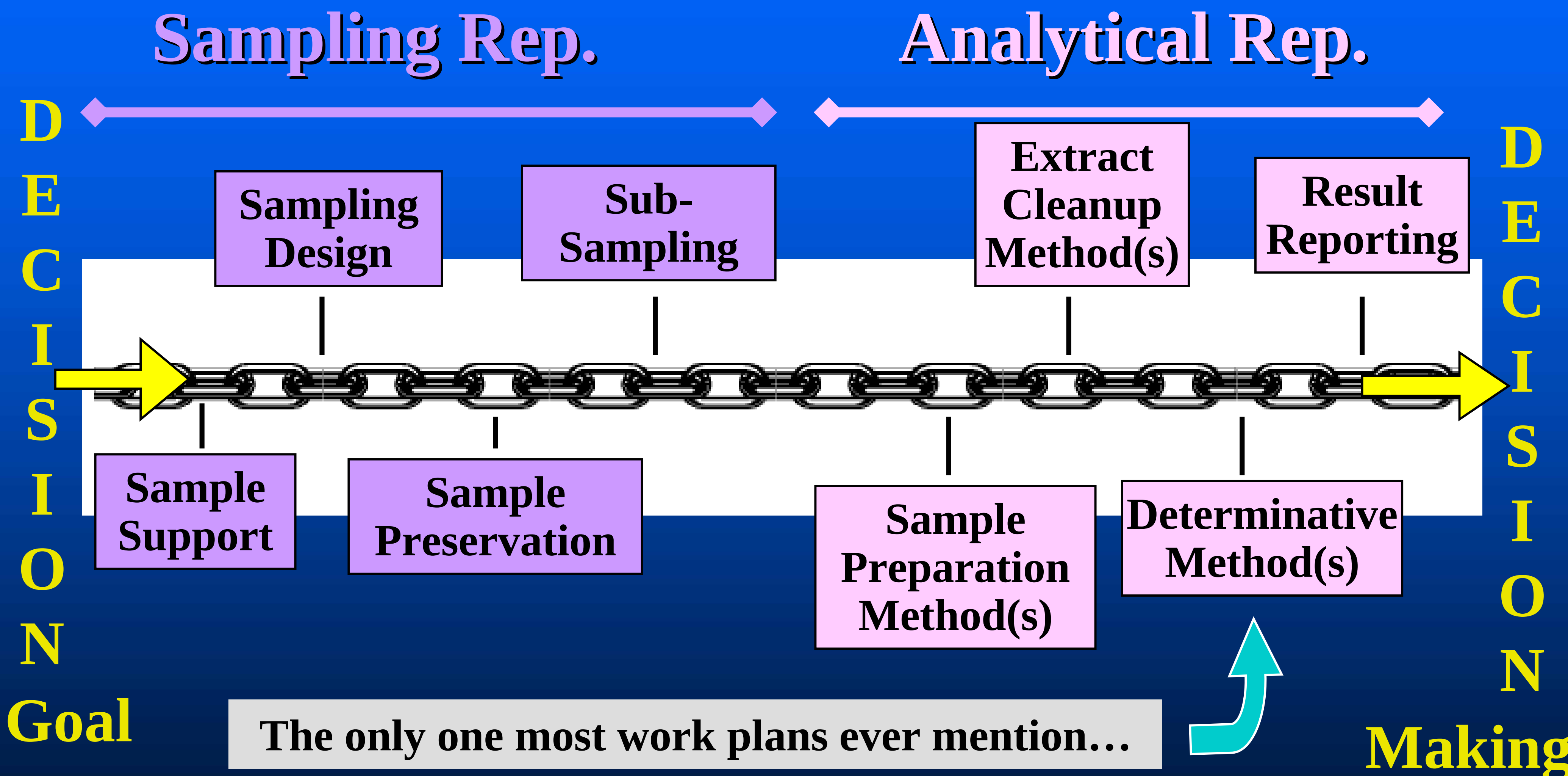
Top panels represent smaller sample supports than bottom panels

What is the Correct Support for Samples and Subsamples?

- Sample support must represent or mirror the decision support for the population of interest
- **Decision/population support** = the physical characteristics of the "decision unit" (i.e., the population of interest).
- Sample collection & processing procedures must mirror these physical properties ("maintain the rep. chain")

If the decision is unknown, then decision support is unknown and it's impossible to plan for representative data collection!

Triad Projects Should Consider the Whole "Chain" of Sampling & Analytical Variables



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

All this attention to detail becomes highly cost-effective when CSMs are built (and remediation is guided)

in

REAL-TIME

Triad's 2nd Leg: Dynamic Work Strategies

- Real-time decision-making "in the field" (often telecommunications assisted)
  - Implement pre-approved decision tree using senior staff to reach project goals in fewest mobilizations
  - Contingency planning: anticipate problems
- Real-time decisions need real-time data
  - Adaptive sampling design; in-field QC
  - Use off-site lab w/ short turnaround?
    - » Screening analytical methods in fixed lab?
  - Use on-site analysis?
    - » Mobile lab with conventional equipment?
    - » Portable kits & instruments?
    - » In situ detectors?

Mix And Match

In all cases, must generate data of known quality

Triad's 3rd Element: "Real-time Measurement Technologies"

- Involves more than just field analytics
- "Real-time Measurements"
  - Data turnaround sufficient to support "real-time decision-making"
    - » Decisions made while the work crew remains in the field
  - Includes rapid data turnaround from fixed lab
- Measurement systems are more than just test kits
  - Rapid sampling platforms
  - Combination sampling-analysis capability of *in situ* technologies
  - Geophysical options
  - IMPORTANT: Software & IT tools to assist data management: data generation, data processing, data review, data interpretation, mapping/visualization, decision-support, & sharing

QC is a Vital Triad Component

- Goal is to match project-specific QA/QC protocols for both field and fixed lab methods to intended data use to manage decision uncertainty.
- Difficult to achieve if based on a rigid checklist.
- Purpose of QC is to evaluate & demonstrate control over all important data generation variables
- Most powerful QC check of all = real-time evaluation of compatibility between data results and the CSM
- Special studies (DMAs) used to select proper tools

Triad Projects Use Demonstrations of Methods Applicability (DMAs)

- A "pilot study" that helps to optimize tool selection and technical operations (both field tools & off-site analytics)
- "Kills many birds with 1 stone" when designed thoughtfully (see handouts). Examples:
  - Modify methods: improve performance/workflow efficiency
  - Understand how to interpret non-specific kit results (e.g. IA)
  - Set decision levels for kit results ("field-based action levels")
  - Prepare SOPs and contingency plans
- Critical if want to make split sample comparisons

Systematic Planning Ties It All Together

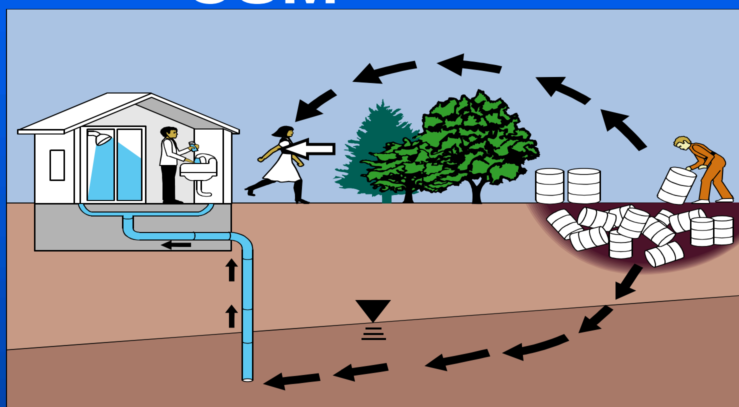
Lack of clarity here

Reuse Plans, Goals, Outcomes

Impact

…means uncertainty here

CSM



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Decisions:

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

…which means no foundation for agreement here

Determine

…or here

Approaches to:

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

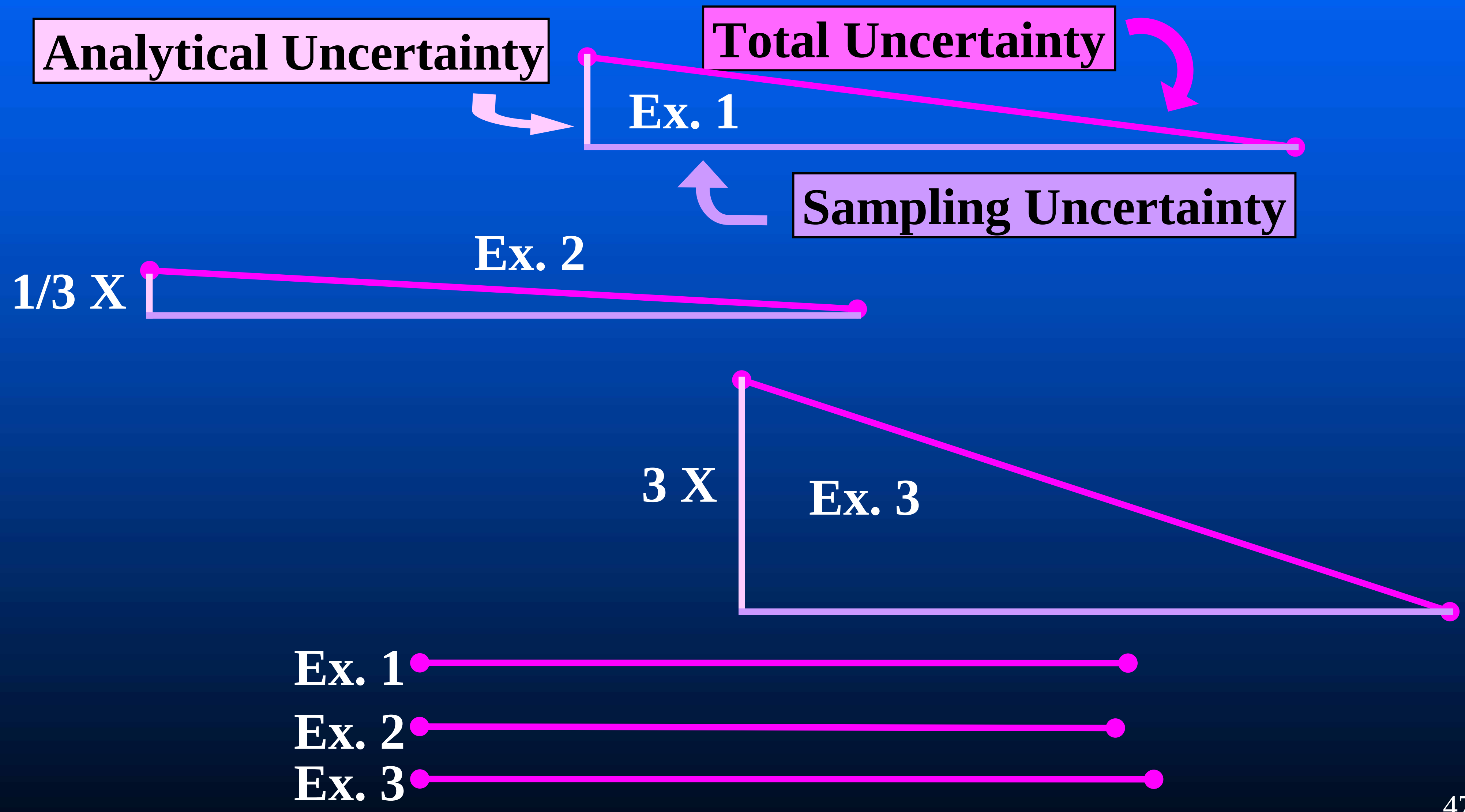
Tools for:

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

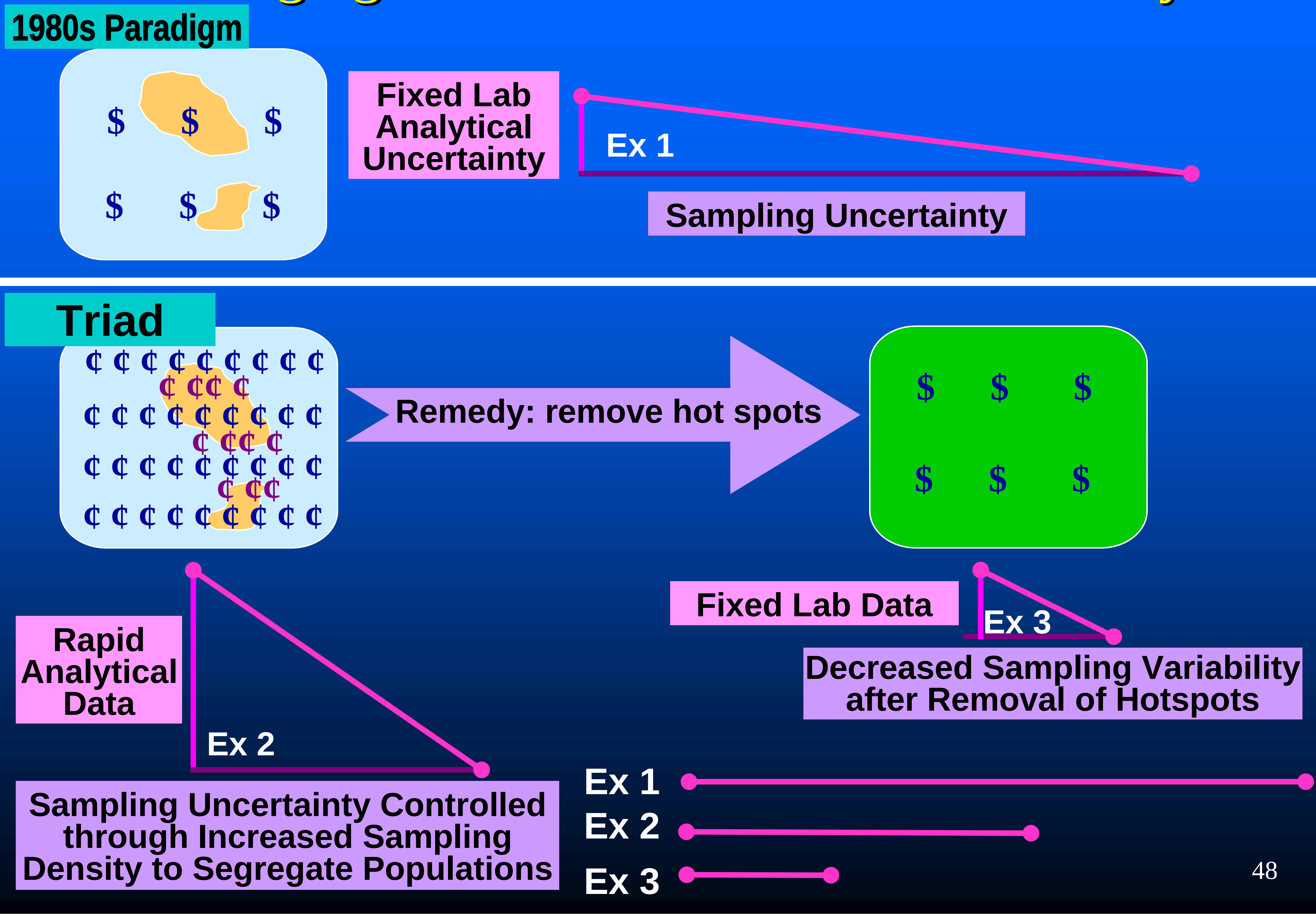
Summary

The Triad approach uses the concept of "managing uncertainty" as a compass that charts a clear course through the complexities of site cleanup science and policy.

Managing Data Uncertainty Means Managing the Components



Managing the CSM & Decision Uncertainty



Triad Recognizes the Strengths & Limitations of Analytical Methods

Costly standard analytical methods

Low DL + analyte specificity

Manages analytical uncertainty (analytical quality)

"Definitive" analytical quality
Screening sampling quality

Screening Quality Data

Cheaper, rapid analytical methods

High spatial density

Manages sampling uncertainty (sampling representativeness)

Builds CSM

"Definitive" sampling quality
Maybe screening analytical quality

Updating the Data Quality Model to Cope with Heterogeneous Matrices

Cheaper, rapid (lab? field? std? non-std?) analytical methods

↓

High density sampling

↓

Costlier rigorous (lab? field? std? non-std?) analytical methods

↓

Low DL + analyte specificity

↓

Manages CSM & sampling uncertainty

Manages analytical uncertainty

Collaborative Data Sets

Collaborative data sets complement each other so that all sources of data uncertainty important to the decision are managed

When is it NOT a Triad Project?

- The value of social capital is ignored
- Sources of decision uncertainty are ignored
  - CSM missing / not project- & site-specific / based on untested assumptions
  - Sampling variability uncontrolled
  - Data quality not tied to data use
- Field data are collected before understanding…

  …how the data will be used

  …what uncertainties could complicate data interpretation

  …what QC is needed to control uncertainties
- When a Triad label is used as a marketing ploy for the same-old-same-old!

Misconceptions Quiz
Explain why these are not true

- Triad requires identifying every molecule of contamination
- Any project using a dynamic work strategy is a Triad project
- Any project using some field analytics is a Triad project
- Real-time technologies = field analytics
- Triad turns governmental functions over to the contractor

www.triadcentral.org

Glossary [Go] Search Site [Go]

Triad Overview | Triad Management | Regulatory Information | Technical Components | User Experiences | Reference/Resources

Privacy/Security

Triad Resource Center

TRIAD: A SMARTER SOLUTION TO SITE CLEANUP

The Triad is an innovative approach to decision-making for hazardous waste site characterization and remediation. The Triad approach proactively exploits new characterization and treatment tools, using work strategies developed by innovative and successful site professionals. The Triad Resource Center provides the information hazardous waste site managers and cleanup practitioners need to implement the Triad effectively.

Triad Overview
Introduction to Triad key concepts, guiding principles, and benefits

Triad Management
Triad vs. traditional, cost estimation, procurement, QA/QC, logistics and implementation, and other management concerns

Regulatory Information
Legal defensibility, relationship to DQO process, QA/QC, and other regulatory issues

Technical Components
Triad and cleanup programs, systematic planning, dynamic work plans, real-time measurements, and other technical information

User Experiences
Triad projects map, case studies, and lessons learned

References/Resources
Triad documents, web links, training classes, and resource providers

Triad — Systematic Planning — Dynamic Work Strategies — Real-Time Measurements

"The NJDEP supports and encourages the use of the Triad for sites undergoing investigation and remediation within the Site Remediation and Waste Management Program where feasible."

Evan Van Hook
New Jersey Department of Environmental Protection
Assistant Commissioner for Site Remediation and Waste Management

Multiagency support for Triad

News
ITRC Releases Triad Guidance Document for State Environmental Protection Agencies

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Frequently Asked Questions

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The Diffusion of Innovation

"At first people refuse to believe that a strange new thing can be done, then they begin to hope it can be done—then it is done and all the world wonders why it was not done centuries ago."

—Francis Hodges Burnett