Module 5

Triad Toolbox

"All truths are easy to understand once they are discovered; the point is to discover them."

Galileo

Triad Data Collection Design and Analysis Built On:

- **Planning systematically** (CSM)
- **Improving representativeness**
- **Increasing information** available for decision-making via field methods
- **Addressing the unknown** with dynamic work strategies and real-time data

Planning Systematically

Systematic Planning and Data Collection Design

- Systematic planning defines decisions, decision units, and sample support requirements
- Systematic planning identifies sources of decision uncertainty and strategies for uncertainty management
- Clearly defined cleanup standards are critical to the systematic planning process
- Conceptual Site Models (CSMs) play a foundational role

Example of Systematic Planning

- Introduction and consensus on primary project goals, authority, and lines of communication
- Identify key site decisions and decision-making processes, decision logics, rules, etc.
- Create the Baseline CSM based on refinement of Preliminary CSM
- Identify key data gaps and areas of uncertainty
- Identify real-time technologies to collect data
- Develop detailed outline for DWS
- Evaluate exit strategies, contingencies, and performance metrics

Planning Systematically

The Conceptual Site Model (CSM) is Key to Successful Projects

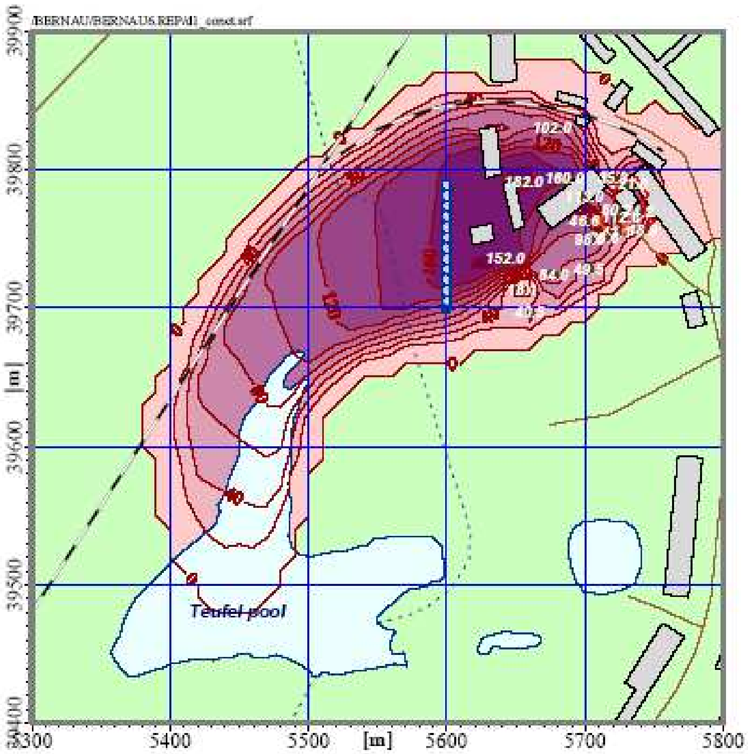
Not to be confused with a fate/transport or exposure scenario model (although these may be components).

THE basis for cost-effective, confident decisions

- Decision-maker's mental picture of site characteristics pertinent to risk & cleanup
- A **CSM** can include any component that represents contaminant populations to make predictions about
  - Nature, extent, and fate of contamination,
  - Exposure to contamination, and
  - Strategies to reduce risks from contamination

How well does the idealized mental model match reality?

Planning Systematically



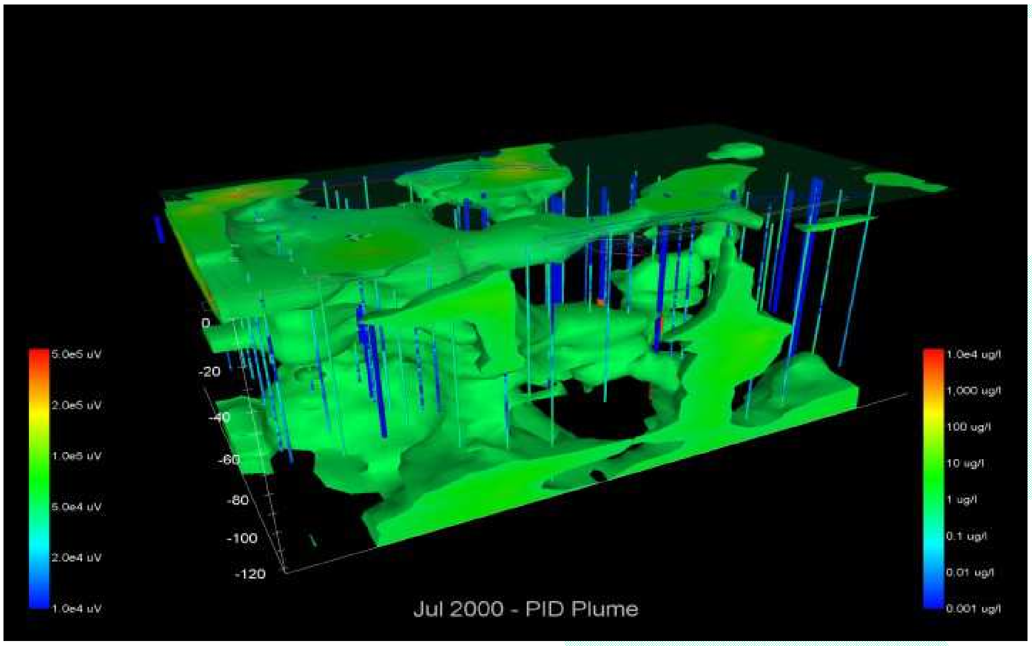
September

7

Planning Systematically

The real world is usually a lot messier than models portray

(Subsurface CSM from high density data using DP-MIP sensing)



Slide adapted from Columbia Technologies, Inc., 2003

CSMs Are Critical!!

Planning Systematically

- Whether or not openly articulated, the CSM is the basis of all site decisions about risk, remediation, & reuse. Unarticulated CSMs create conflict, are often based on untested assumptions, & lead to faulty projects designs.

Preliminary CSM predicts contaminant distributions → **Prediction guides development of SAP** / **Data confirms or modifies predictions as CSM gradually matures** → **Mature CSM is the basis for decisions & all subsequent activities**

- The CSM is the working hypothesis about the site's physical reality, so working without a CSM is like working blind-folded!

CSMs Articulate Decision Uncertainty

Planning Systematically

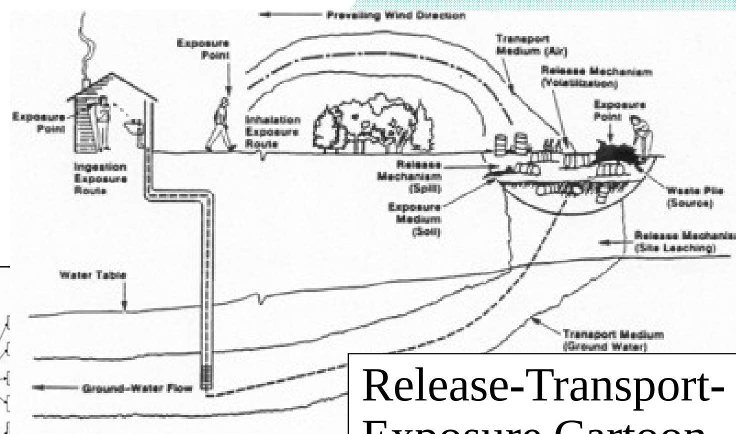
- CSM captures understanding about site conditions
- CSM identifies uncertainty that prevents confident decision-making
- A well-articulated CSM serves as the point of consensus about uncertainty sources
- Data collection needs and design flow from the CSM:
  - Data collection to reduce CSM uncertainties
  - Data collection to test CSM assumptions
- The CSM is living…as new data become available, it is incorporated & the CSM matures

A CSM Organizes Information

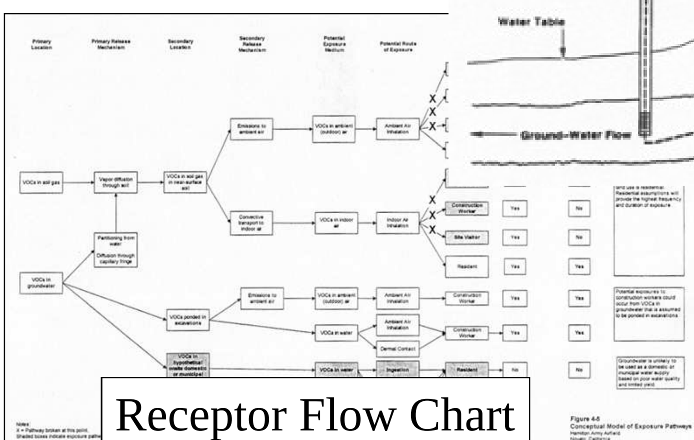
Planning Systematically

Text
(simple scenarios)

Computer Model



Release-Transport-
Exposure Cartoon

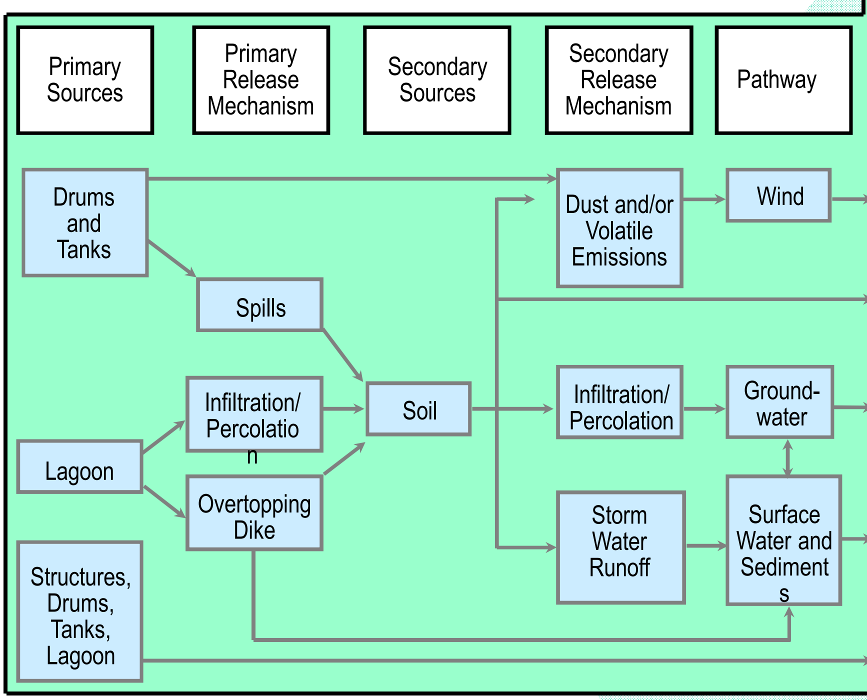


Receptor Flow Chart

2-D Cross Section

Tabular Presentation of a Pathway-Exposure CSM

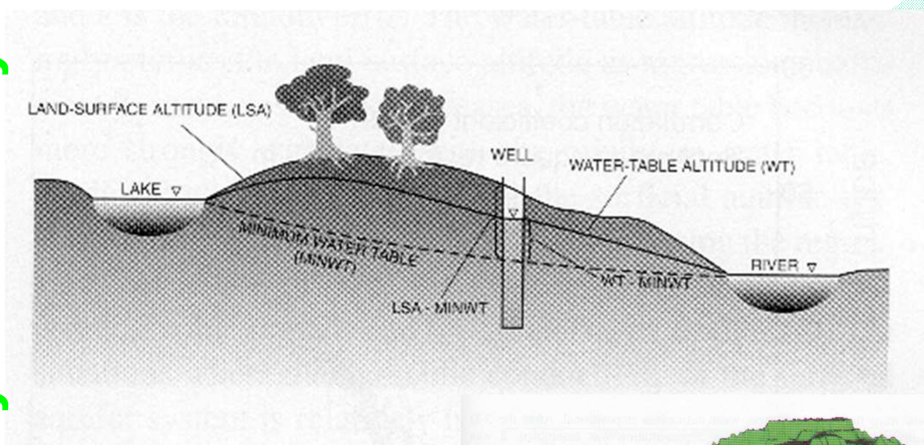
Planning Systematically



	Receptor			
	Human		Biota	
Exposure Route	Area Residents	Site Visitors	Terrestrial	Aquatic
Ingestion				
Inhalation	●	●	●	
Dermal Contact				
Ingestion	●	●	●	
Dermal Contact	●	●	●	
Ingestion	●	●		
Inhalation	●			
Dermal Contact	●	●		
Ingestion	●	●	●	●
Inhalation				
Dermal Contact	●	●	●	●
Dermal Contact		●	●	

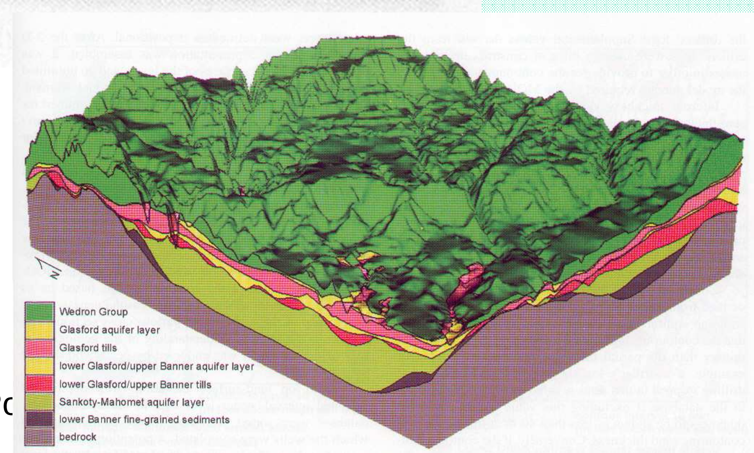
Other CSM Representations

Planning Systematically



2-D Hydrology Model

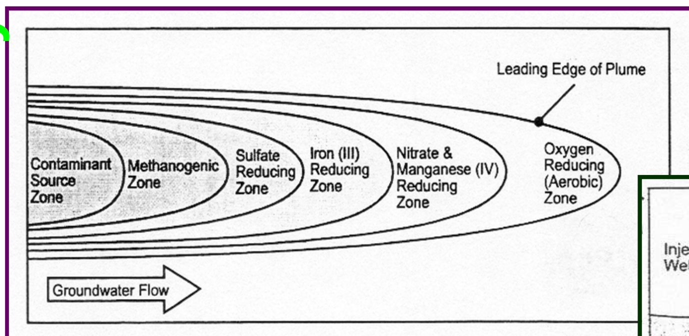
3-D Geology Model



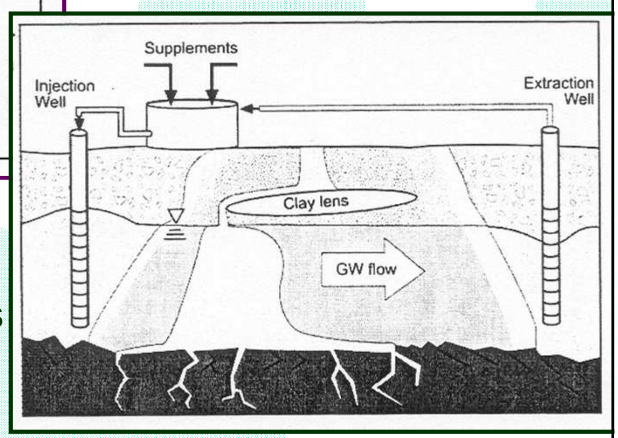
September 11, 2012 Po

CSMs Should Encompass All Activities

Planning Systematically



Simple representation of anaerobic degradation



Augmenting bioremediation with supplemental nutrients

It usually takes more than 1 format to organize & display different types of site information

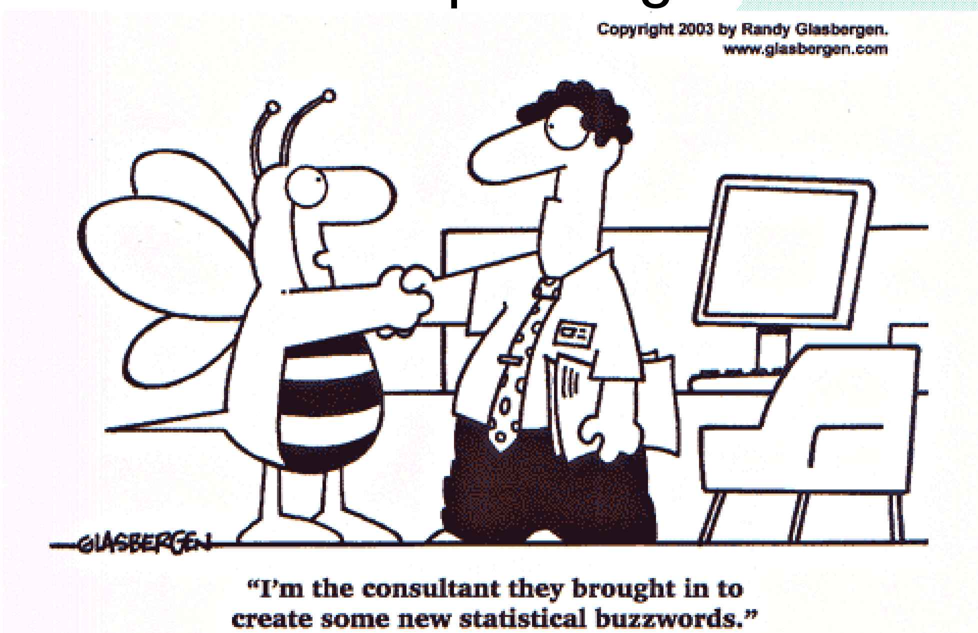
Improving Representativeness

Improving Data Representativeness

- Sample support
  - matching sample support with decision needs
  - field of view for in situ analyses
- Controlling within-sample heterogeneity
  - Appropriate sample preparation important (see EPA EPA/600/R-03/027 for additional detail)
  - Uncertainty effects quantified by appropriate sub-sample replicate analyses
- ***Controlling short-scale heterogeneity***
  - multi-increment sampling
  - aggregating in situ measurements

Improving Representativeness

Multi-Increment Sampling?
Incremental Sampling
Compositing?



September 11, 2012 Portsmouth Training 16

Improving Representativeness

Compositing Strategies to Improve Representativeness

- Samples are assumed “representative” of the location from which they are taken
- Past experience has demonstrated that discrete grab samples are not necessarily “representative” of their decision unit or even their immediate vicinity
- Compositing strategies, if done correctly, can greatly improve representativeness without significantly increasing costs for surface soils

Increasing Information via Field-Deployable Methods

Increasing Information

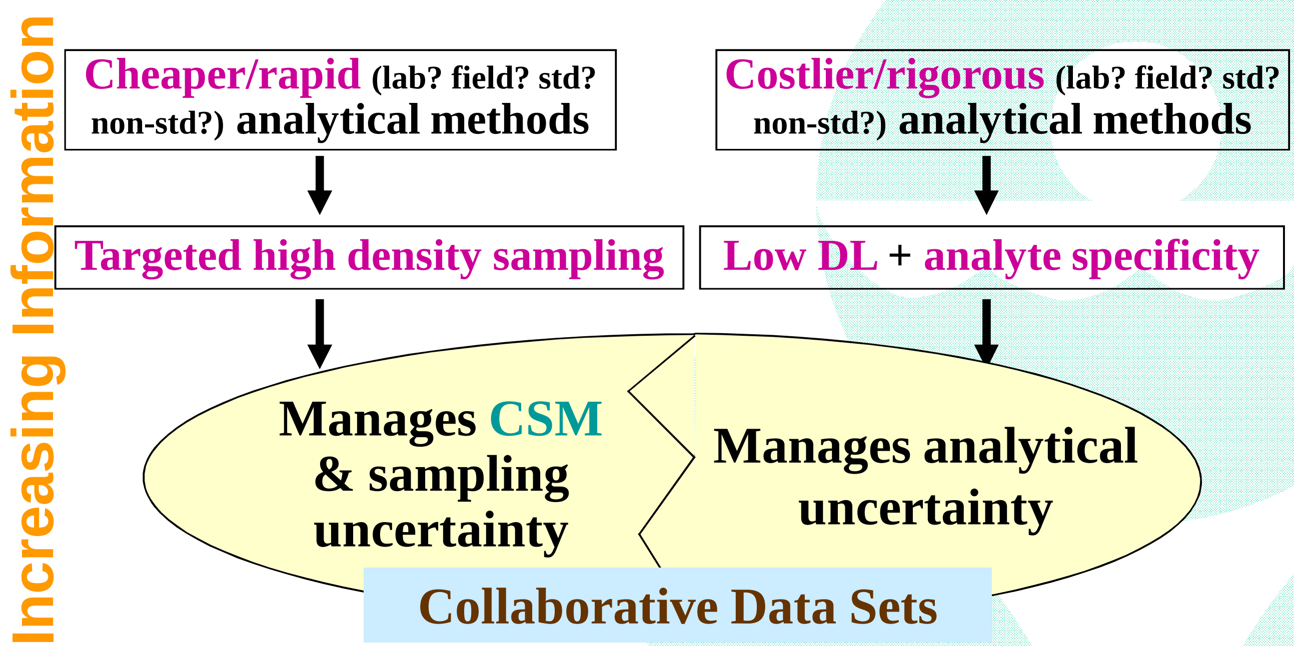
- Field-based methods are usually cheaper and faster
  - Allow increased data densities
  - Allow real-time decision-making and optimization of the sampling approach
  - Typically higher detection limits, or greater analytical error, or less specificity, or more limited range of analytes
- Typically produce "collaborative data sets"
  - Collaborative data sets are powerful!!
  - Multiple lines of evidence = "weight of evidence"
  - Control multiple error sources
  - Result: increased confidence in the CSM, better decisions

Examples of Common Field-Based Methods

Increasing Information

Technology	Matrix	Data Provided
X-ray fluorescence (XRF)	Soil	Metals
Immunoassay test kits	Water, Soil	SVOCs (PAH, pest., PCB)
UV methods (UVF, UV lamp)	Water, Soil	TPH, PAH, DNAPL
Misc. colorimetric kits	Water, Air	Water Quality, Toxic Gas
Direct push sensors (MIP, DSITMS, LIF)	Water, Soil	VOCs, TPH, DNAPL
Geophysical tools	Soil	Sources, Pathways
Gamma scans	Soil	Radionuclides
In situ HPGe	Soil	Radionuclides
Field GC and GC/MS	Water, Soil	VOCs

Collaborative Data Sets Address Analytical and Sampling Uncertainties



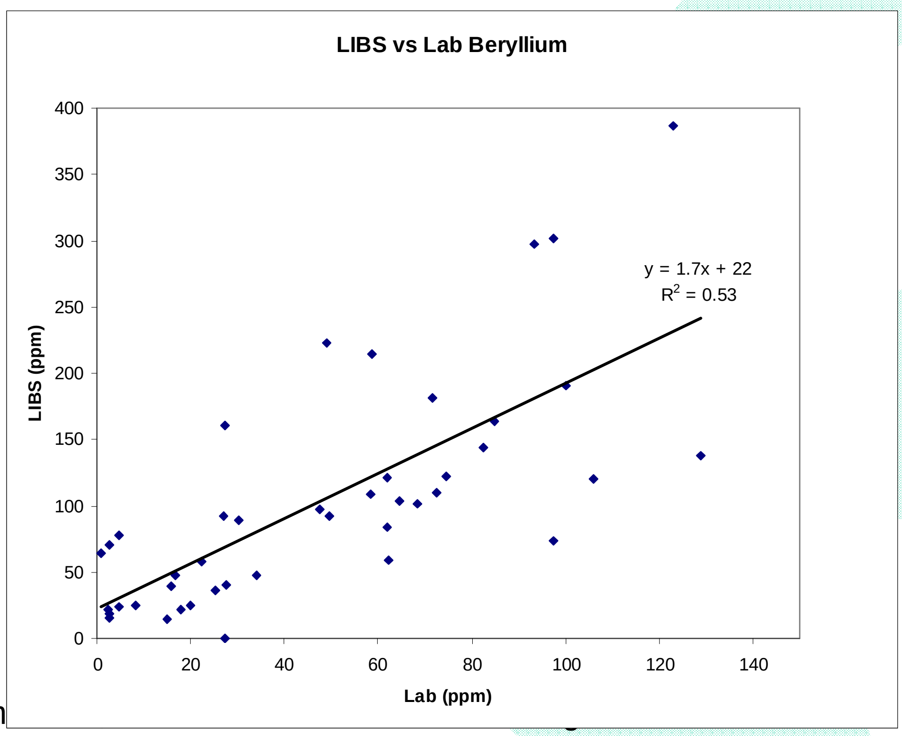
Regression Analysis is Not Always Appropriate for Collaborative Data Sets

Increasing Information

- Beryllium/LIBS (laser-induced breakdown spectroscopy) example illustrates:
  - Site with surficial beryllium contamination
  - Experimental backpack LIBS system used to generate a lot of characterization data
  - Much smaller set of laboratory analysis for a subset of LIBS locations also available
  - Question: Where's the contamination?

At First Glance, LIBS Data Appear of Little Value…

Increasing Information

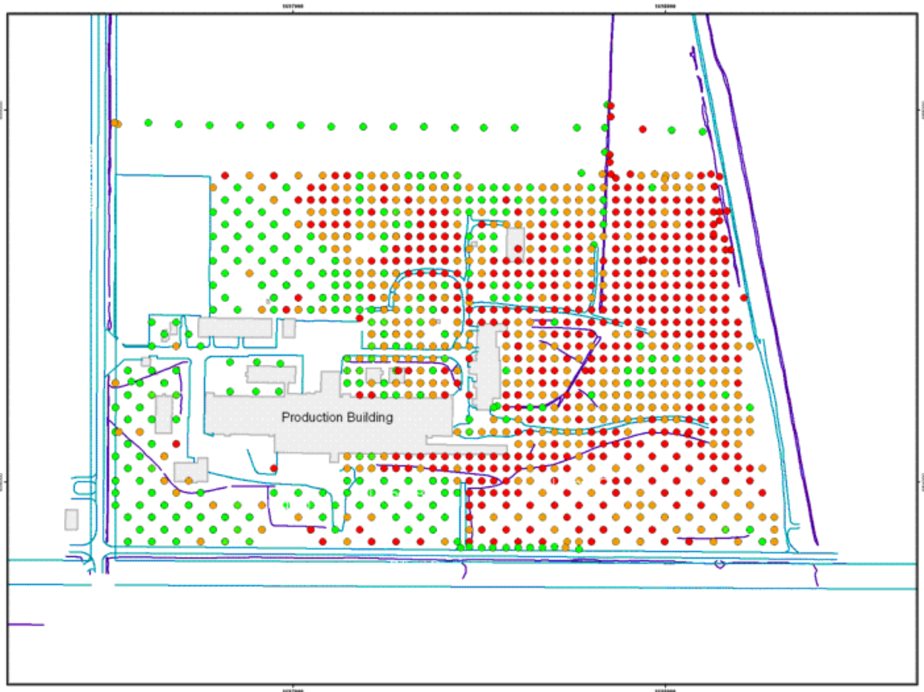


Septem

22

But Mapping Suggests a Different Conclusion…

Increasing Information



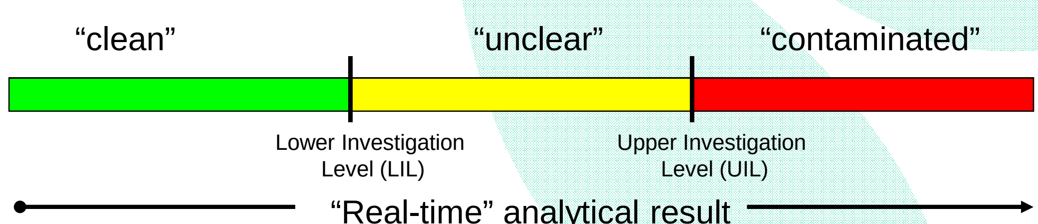
Septer

23

Non-Parametric Analysis Can Be a Useful Alternative to Regressions

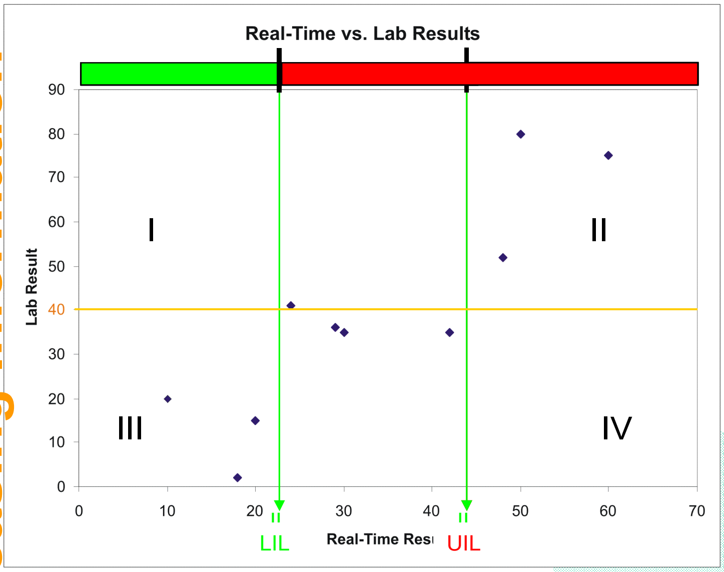
Increasing Information

- Decision focus is often yes/no
  - Is contamination present at levels of concern?
  - Should a sample be sent off-site for more definitive analysis?
- Goal is to identify investigation levels for a real-time method that will guide decision-making
  - Lower investigation level (LIL) for real-time result below which we are confident contamination is not present
  - Upper investigation level (UIL) above which we are confident contamination is present



Hypothetical Example

Increasing Information



- I: False Clean
- II: Correctly Identified Contaminated
- III: Correctly Identified Clean
- IV: False Contaminated

- I/(I+II)*100: % of contaminated samples missed by LIL (false clean rate)
- I/(I+III)*100: % of "clean" samples that are contaminated
- IV/(II+IV)*100: % of "contaminated" samples that are clean
- IV/(III+IV)*100: % of clean samples above the LIL (false contaminated rate)

False Clean Rate: 0% **False Contaminated Rate: 0%**

September 11, 2012 Portsmouth Training

Addressing the Unknown

Dynamic Work Strategies: a Product of Systematic Planning

- Cost effective means for addressing unacceptable decision uncertainty
- Recognize that we don't know enough to support "fixed" work strategies at the outset
- Require a clear articulation of
  - Project goals/decisions
  - Sources of uncertainty
  - Acceptable levels of uncertainty
- Grounded in Conceptual Site Model

DWS Cut Across Cleanup Activities

Addressing the Unknown

Increasing DWS Sophistication

- Selecting analytical options
- Determining sampling strategies, numbers, and locations
- Form and intensity of QC
- Course of remediation activities
- Overall characterization and remediation strategies

Addressing the Unknown

Successful DWS Affect Field-Work Planning and Implementation

- Strategies employed
- Regulatory approval
- Cost estimation
- Contracting
- Logistics
- Collaborative data usage
- Decision-making framework
- Data management

Addressing the Unknown

Things to Avoid

- Not involving stakeholders
- Shortcutting the QAPP and HASP
- Using untested field-based methods without demonstrating applicability or contingencies
- Sole use of prescribed sample locations
- Determine QC samples prior to field activities
- Using generic or incomplete SOPs
- Inadequate planning for real-time data collection, management, assessment, and communication

Addressing the Unknown

DWS, Data Collection, and Real-Time Measurements

- Optimizing data collection design
  - Strategies for testing CSM assumptions and obtaining data collection design parameters on-the-fly
- Adaptive analytics
  - Strategies for producing effective collaborative data sets
- Adaptive compositing strategies
  - Efficient strategies for searching for contamination
- Dynamic stratification strategies
  - Strategies for estimating mean concentrations
- Adaptive sampling strategies
  - Strategies for estimating mean concentrations
  - Strategies for delineating contamination

Addressing the Unknown

Optimizing Data Collection Design

- How many increments should contribute to composite samples?
- What levels of contamination should one expect?
- How much contaminant concentration variability is present across decision units?
- What kinds of performance can be expected from field methods?

Much of this falls under the category of "Demonstration of Methods Applicability"

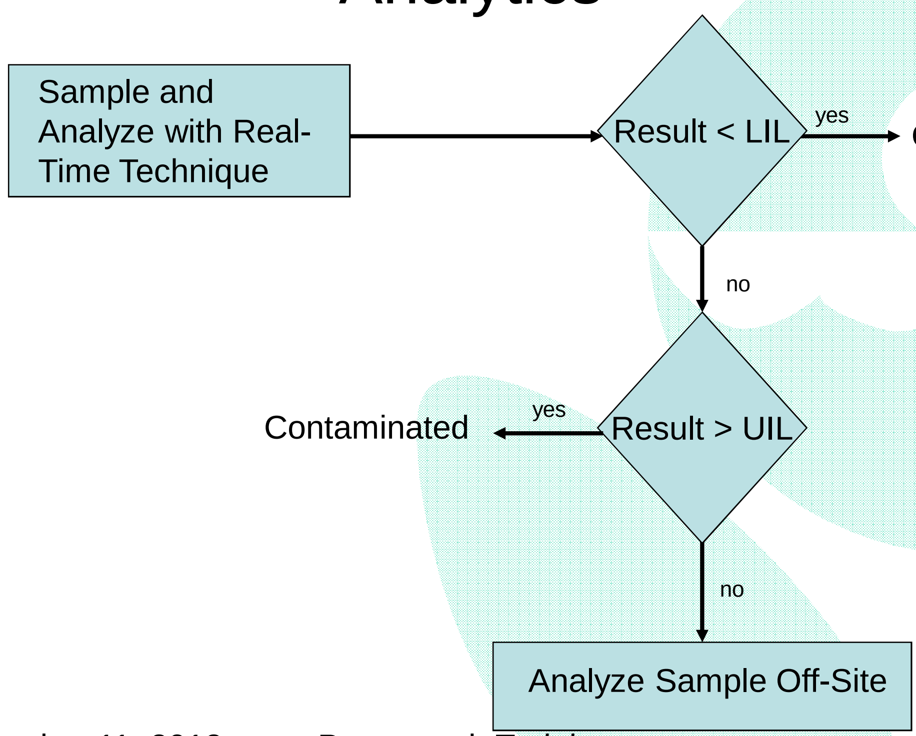
Addressing the Unknown

Adaptive Analytics

- Goal is to identify elevated areas or delineate contamination
- Assumptions:
  - Two methods, one cheap/less accurate, one expensive/“definitive”
  - Investigation levels (i.e., LIL and UIL) can be derived for cheaper, real-time data
- High density real-time data used to screen out areas that are obviously contaminated, or obviously clean
- Fixed laboratory analyses target locations where real-time results were ambiguous
- Design requires determining appropriate real-time investigation levels (e.g., LIL and UIL)

Typical Decision Logic Adaptive Analytics

Addressing the Unknown



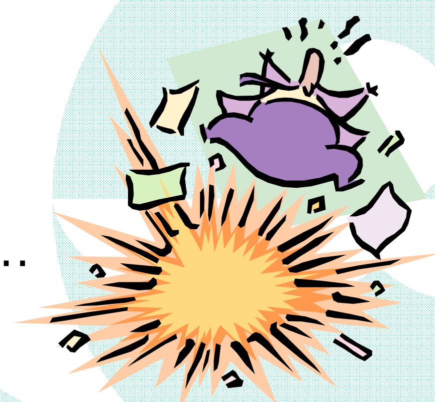
September 11, 2012 Portsmouth Training 33

Addressing the Unknown

Contamination Delineation: Simple Decision Rules

- Simple if/then statements that guide the placement of samples in a dynamic program
  - If bottom of core has contamination above some threshold, go deeper x feet
  - If contamination present in location above some threshold, step out another y feet and re-sample/re-measure

The Biggest Bang Comes from Combining…



- CSM knowledge, with…
- Incremental sampling, with…
- Collaborative data sets, with…
- Adaptive analytics, with…
- Adaptive QC & data uncertainty reduction, with…
- Adaptive compositing, with…
- Adaptive sample location selection.

Any Questions?