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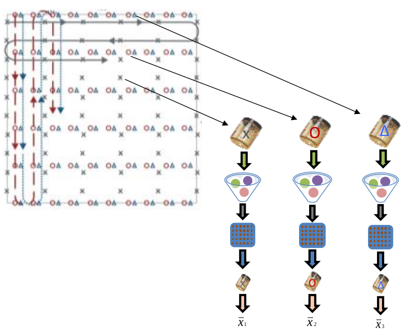
Soil Sampling and Decision Making Using Incremental Sampling Methodology (ISM)



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Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)

Overview

- What is the ITRC?
- Introduction to Incremental Sampling Methodology (ISM)
  - Systematic planning
  - Field sample collection
  - Laboratory processing and analysis
- Where to get more information

What is ITRC?

ITRC is a state-led coalition working to advance the use of innovative environmental technologies and approaches.

ITRC translates good science into better decision making

ITRC Purpose & Mission

- **ITRC Purpose**

  To advance innovative environmental decision making

- **ITRC Mission**

  Develop information resources and help break down barriers to the acceptance and use of technically sound innovative solutions to environmental challenges through an active network of diverse professionals

ITRC Role in the Environmental Community

Reduce barriers → To the use of innovative environmental technologies

Improve cleanup → By educating on innovative environmental technologies

Provide a national consensus → On approaches to implementing innovative environmental technologies

What ITRC Does



ITRC uses a proven, cost-effective approach to develop **guidance documents** and **training courses**

Select Projects

Form Teams

Develop Documents and Training

Conduct Training

Implement Solutions

Since 1995:
114 documents
80 training courses

www.itrcweb.org

Power of ITRC's Unique Network

- Environmental Council of the States (ECOS)
- Federal Government
- State Government
- Public/Tribal Stakeholders
- Industry
- Academia

ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners

    DOE **DOD** **EPA**

  - ITRC Industrv Affiliates Program
  - Academia
  - Community stakeholders
- Follow ITRC

- Disclaimer
  - Partially funded by the U.S. government
    - ITRC nor US government warranty material
    - ITRC nor US government endorse specific products
  - ITRC materials copyrighted – see usage policy
- Available from www.itrcweb.org
  - Technical and regulatory guidance documents
  - Internet-based and classroom training schedule
  - More…

Resources

- **Link to ITRC Document on Incremental Sampling:**

  http://www.itrcweb.org/ism-1/

- **Next Internet Course on ISM:**

September 20, 2016 (Tuesday) 1:00 PM - 3:15 PM EASTERN TIME

www.itrcweb.org/Training

Soil Samples – Desirable Properties?

Representative Data:

- Accurate
- Reproducible
- Defensible

….but how do we get it?

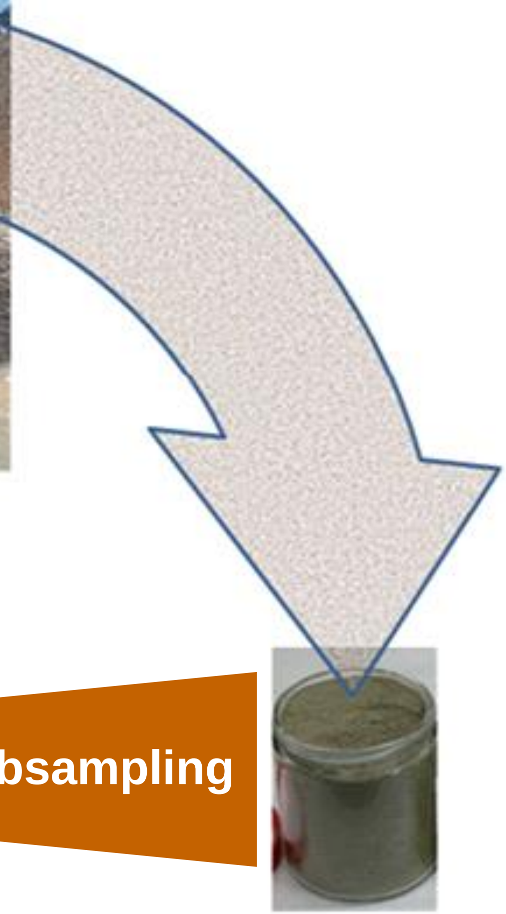
Incremental Sampling Methodology (ISM)

…..might be the answer…..

Are Your Samples Representative?

- How fully do you plan your sampling event?
- Are you confident in your sample results?
- How representative are your samples?
- Do you understand the distribution?
- How reproducible are your data?

What Does the Sample Represent?



Representative subsampling

What Do These Environmental Criteria Have In Common?

- Most risk-based environmental criteria based on estimate of mean
  - Soil screening levels
  - Regional screening levels
  - Site-specific cleanup levels
  - Exposure point concentrations

Uncertainty Sources

- Instrument analysis
- Sample preparation
- Laboratory sub-sampling
- Field sample collection

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- Instrument analysis
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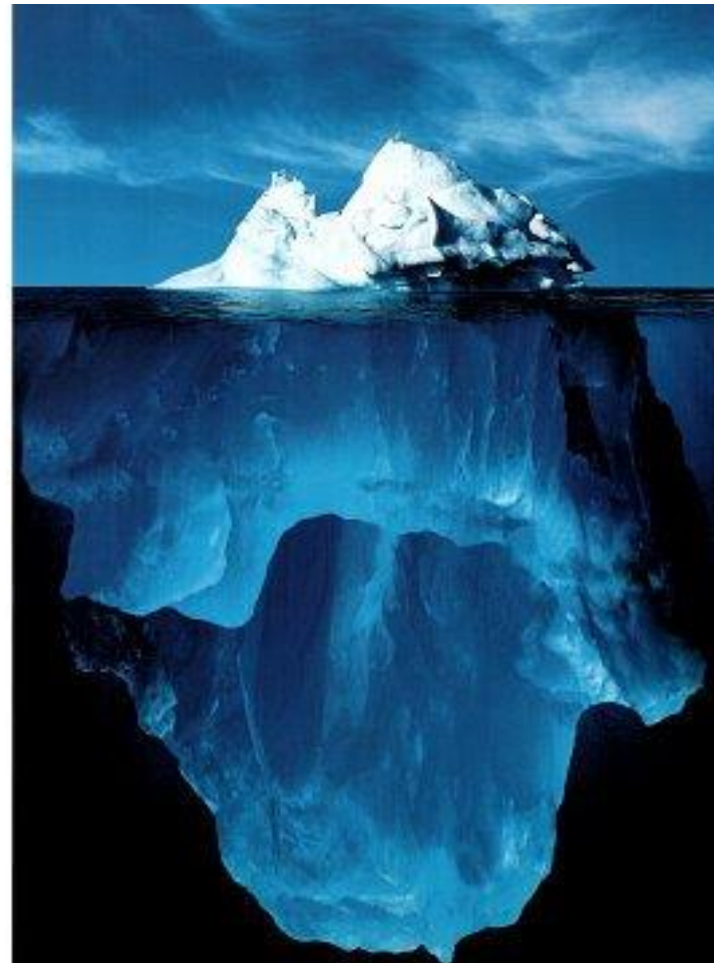


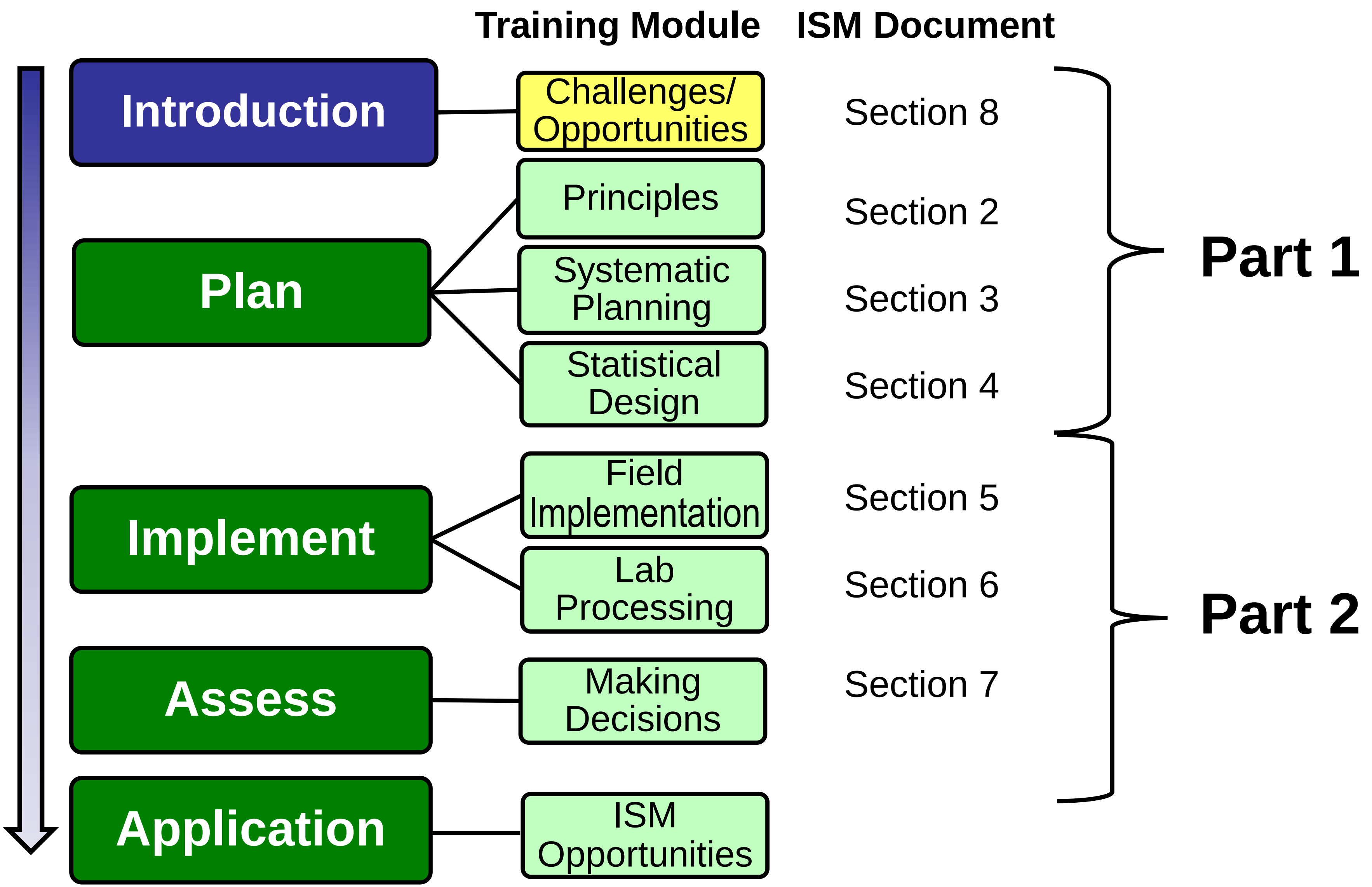
What is Incremental Sampling Methodology (ISM)?

ISM Objective: To obtain a single sample for analysis that has the mean analyte concentration representative of the decision unit

- Structured composite sampling and processing protocol
- Reduces data variability
- Provides a reasonably unbiased estimate of mean contaminant concentrations in a volume of soil targeted for sampling

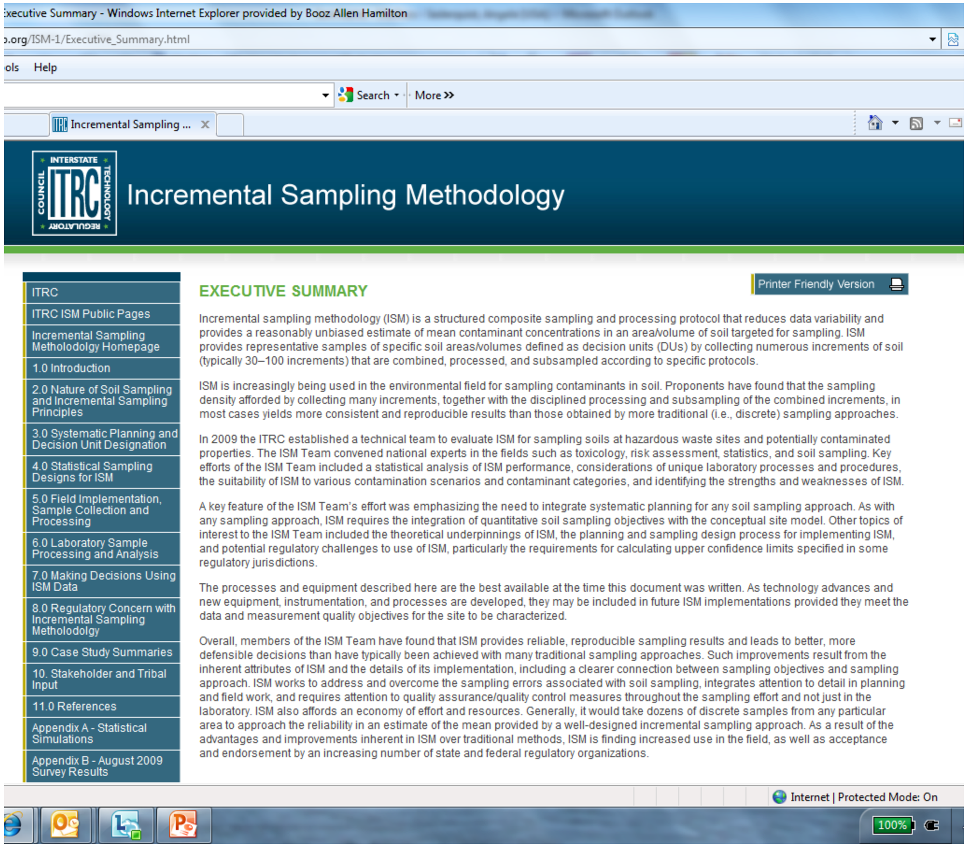
Decision Unit (DU): the smallest volume of soil (or other media) for which a decision will be made based upon ISM sampling

ISM Document and Training Roadmap

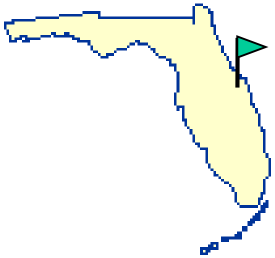


Our ITRC Solution: *ITRC ISM-1 Technical and Regulatory Guidance Document*

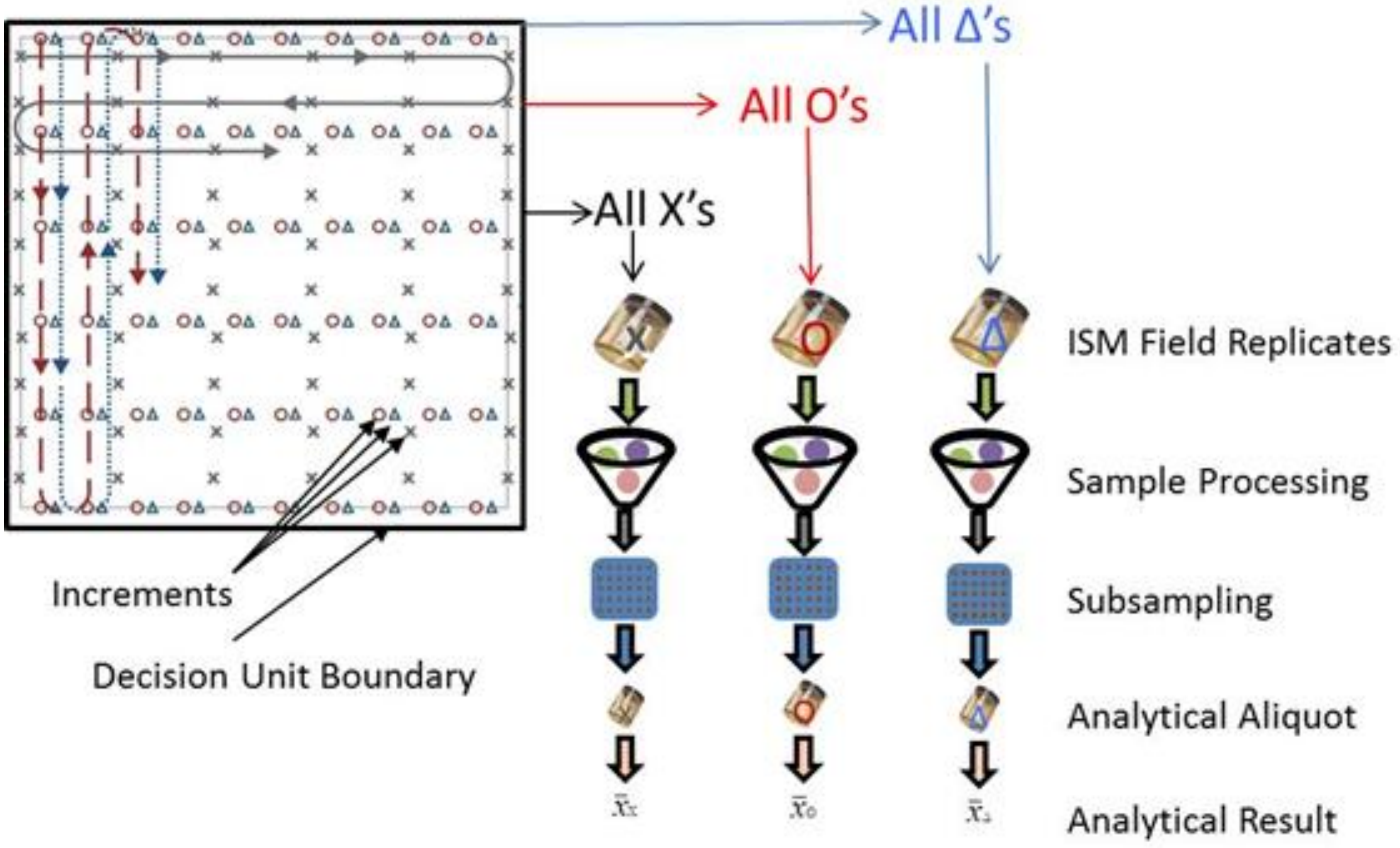
Web-Based Document at:
http://www.itrcweb.org/ISM-1/



- Fundamental understanding of how and why ISM works
- Detailed instructions for design and implementation
- Addresses potential regulatory concerns
- Provides case studies and simulations



What is Incremental Sampling Methodology (ISM)?



Advantages and Limitations of ISM

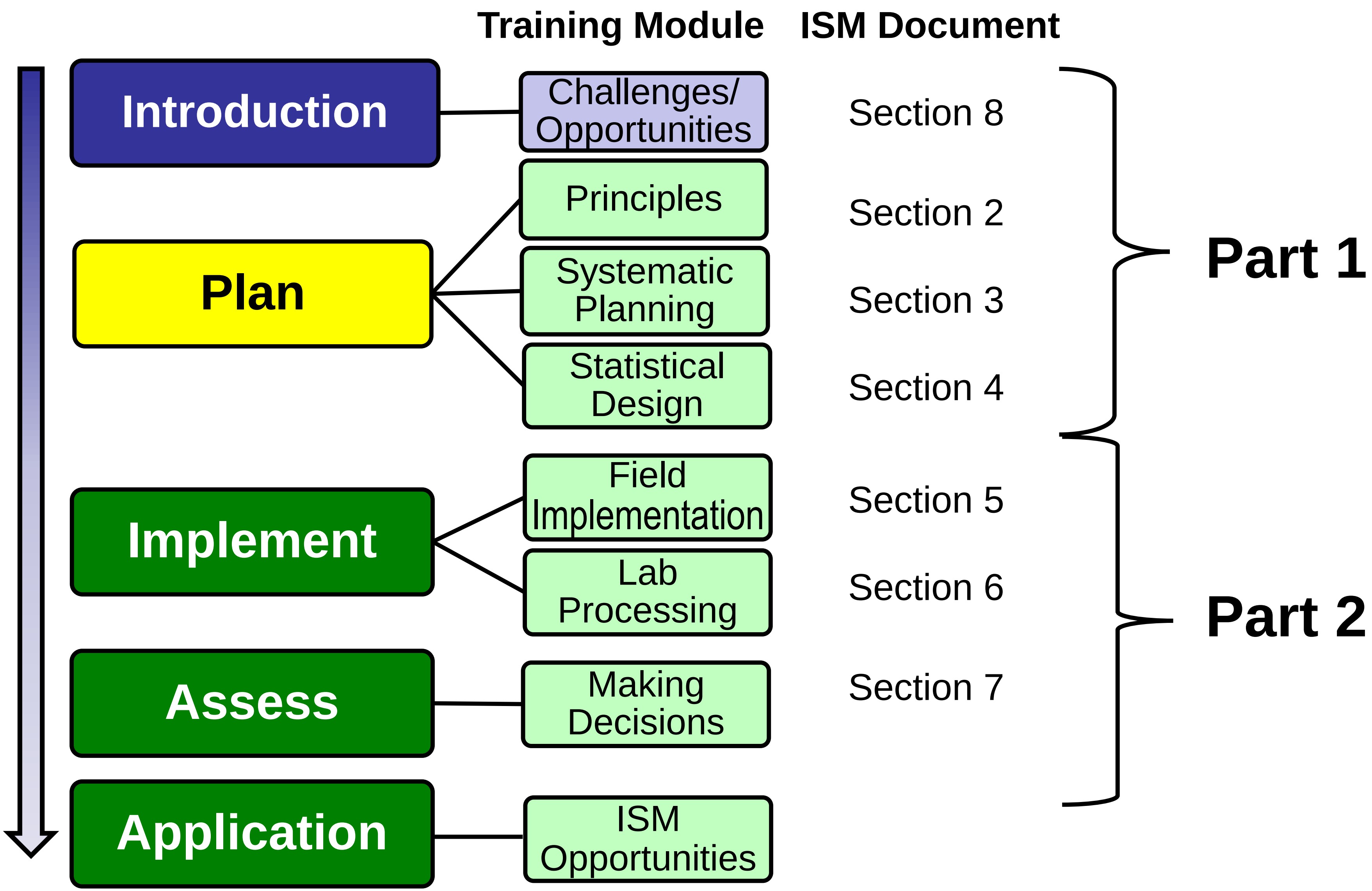
Advantages of ISM	Effect
Improved spatial coverage (increments x replicates)	• Sample includes high and low concentrations in proper proportions
Higher Sample Mass	• Reduces errors associated with sample processing and analysis
Optimized processing	• Representative subsamples for analysis
Fewer non-detects	• Simplifies statistical analysis
More consistent data	• More confident decision

Limitations of ISM	Effect
Small number of replicates	• Limits Upper Confidence Limit calculation methods
No spatial resolution within Decision Unit	• Limits remediation options within Decision Unit • Limits multivariate comparisons
Assessing Acute Toxicity	• Decision Unit has to be very small

ISM – What's In It For YOU?

- Fewer analyses but a more representative sample
- High quality data leads to a more confident decision
- Potential for cost savings

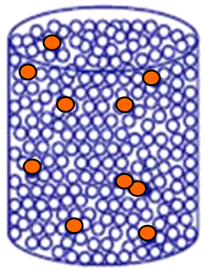
ISM Document and Training Roadmap



ISM Part 1 – Principles, Systematic Planning, and Statistical Design

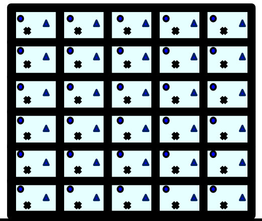
Plan

Principles



Systematic Planning

Statistical Design



- Sampling error
  - Heterogeneity is a big deal so your sampling approach needs to address it
- Requires the entire team and site specific information
  - Conceptual Site Model (CSM)
  - Sampling objectives
  - Develop Decision Units (DUs)
- Provides the statistical foundation for ISM
  - Reasonable estimate of mean
  - Sampling design

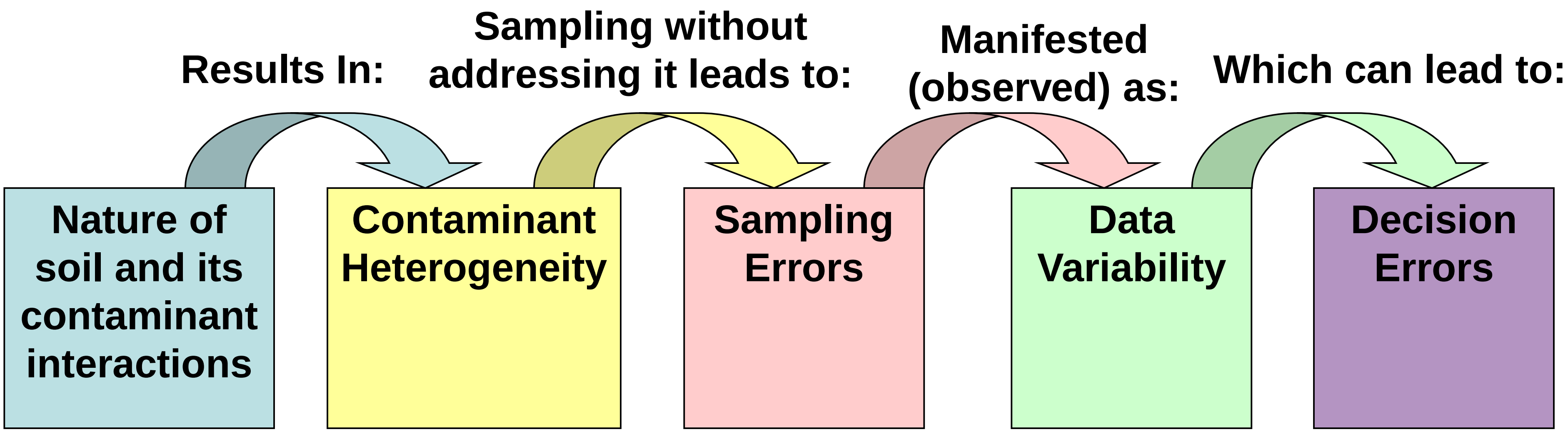
Principles
Learning Objectives

Learn how to use basic principles to improve planning, implementation and decision-making:

- Soil heterogeneity at 2 spatial scales makes it difficult to correctly interpret data results
  - Those spatial scales are micro-scale and short-scale
  - Heterogeneity at these scales can cause data variability → costly decision errors
- Micro-scale heterogeneity is managed by increasing sample mass and *improving lab sample processing (required by ISM)*
- Short-scale spatial heterogeneity is managed by the *field incremental sampling of ISM*

ITRC, ISM-1, Sections 2 and 5.3.1

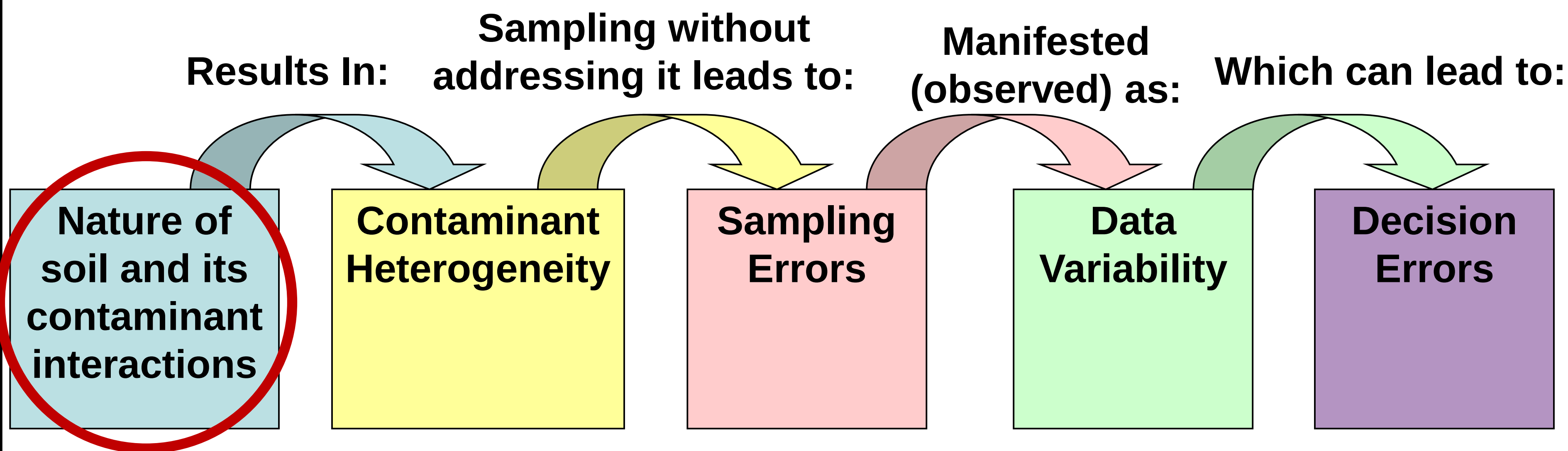
How Soil Heterogeneity Can Cause Decision Errors: Navigation Pane



- Heterogeneity: the condition of being non-uniform
- The heterogeneous nature of contaminants in soils increases the chances of decision error

ITRC, ISM-1, Section 2.1

Soil is a Complex Particulate Material



- All soil is heterogeneous in composition
- Typical mixing/stirring cannot make soil uniform

ITRC, ISM-1, Section 2.2

Micro-Scale Variation in a Homogeneous-Looking Soil

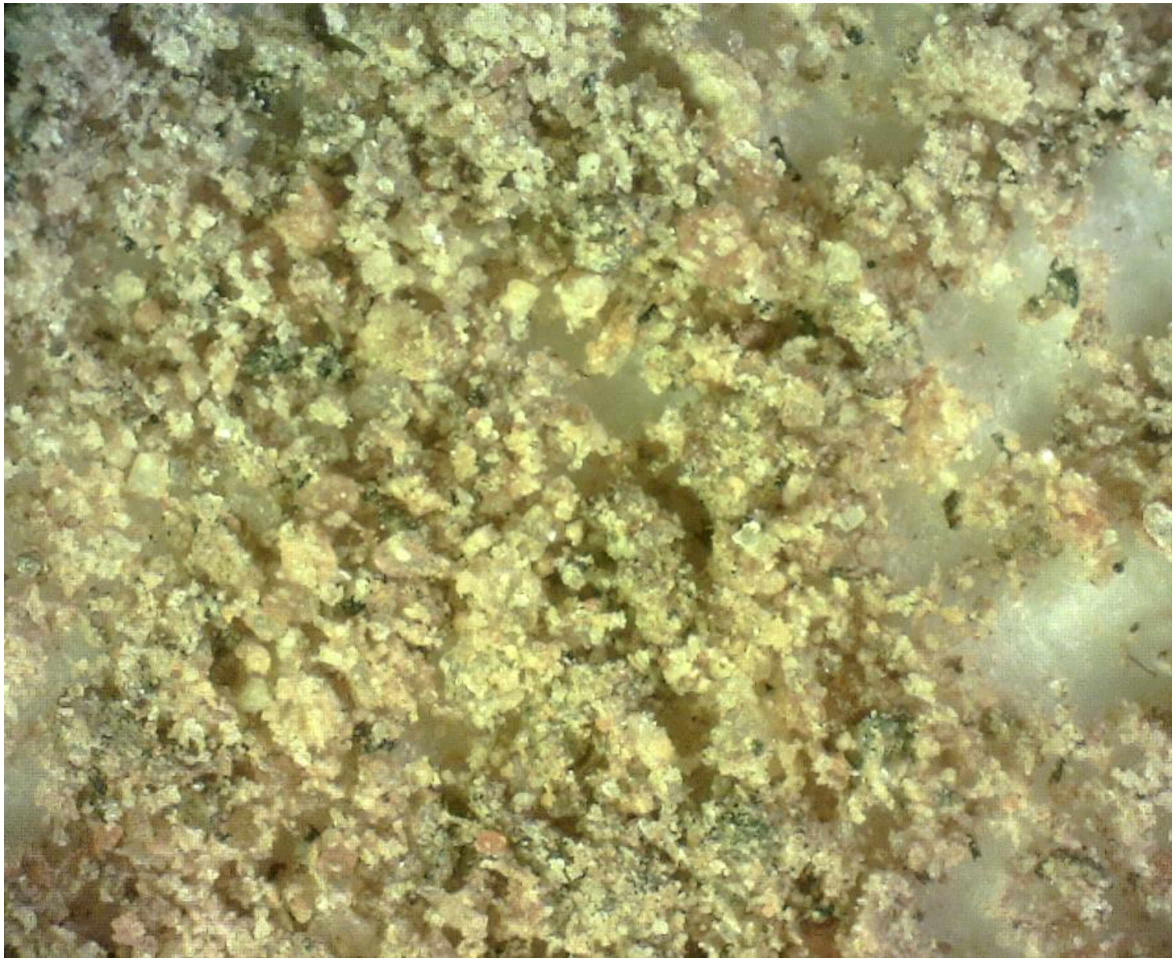


Photo credit: Deana Crumbling

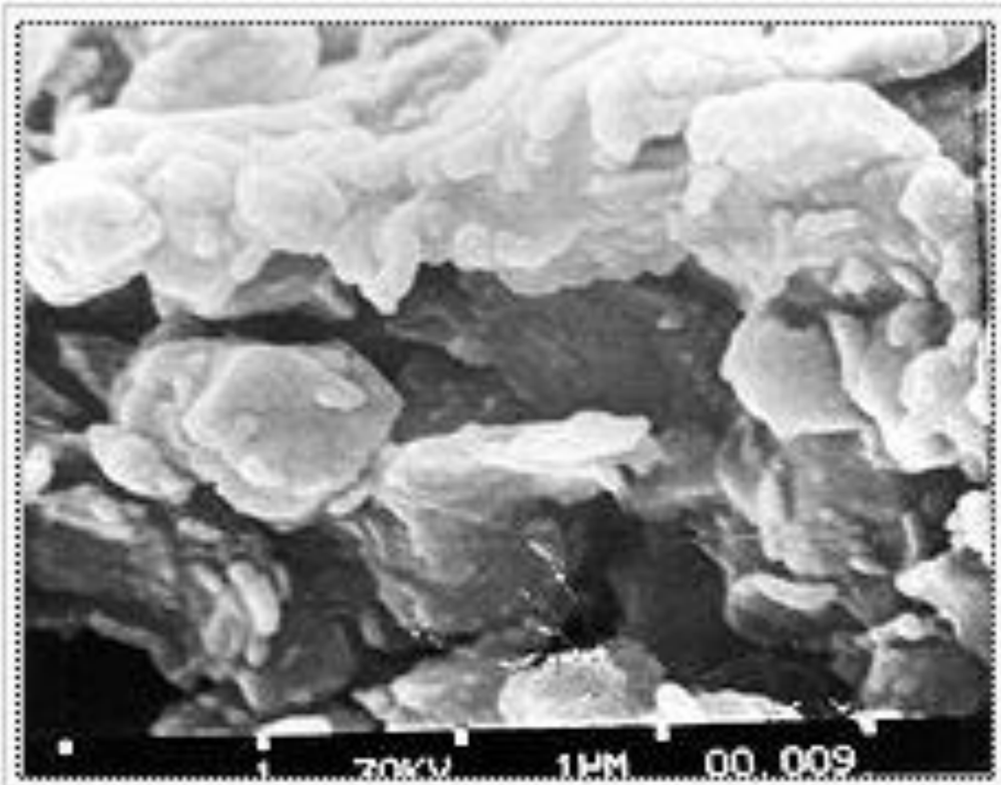
A sandy soil, showing variation in particulate size and mineral content (10X magnification)

Soil Particle Composition

Individual soil particles are inorganic mineral or some form of organic carbon.

- Many contaminants adhere to the surfaces of certain minerals
- Organic carbon is composed of complex molecules that act as molecular sponges

“Sticky” Minerals



Electron microscope photograph of smectite clay – magnification 23,500

- Contaminant molecules/atoms “stick” well to certain particles
- Smallest particles usually the stickiest
  - Clays (see photo)
  - Iron (hydr)oxides
- Stickiness mechanisms
  - (-) and (+) charges
  - Surface area

Photo credit: USGS, 2006

Particles with High Loadings are Called "Nuggets"

- Contaminants adsorbed to distinct particles form "nuggets" of high concentration

"the iron in a cubic yard of soil [1-1.5 tons] is capable of adsorbing 0.5 to 5 lbs of soluble metals …or organics" (Vance 1994).

Arsenic (whitish color) sorbed to iron hydroxide particles

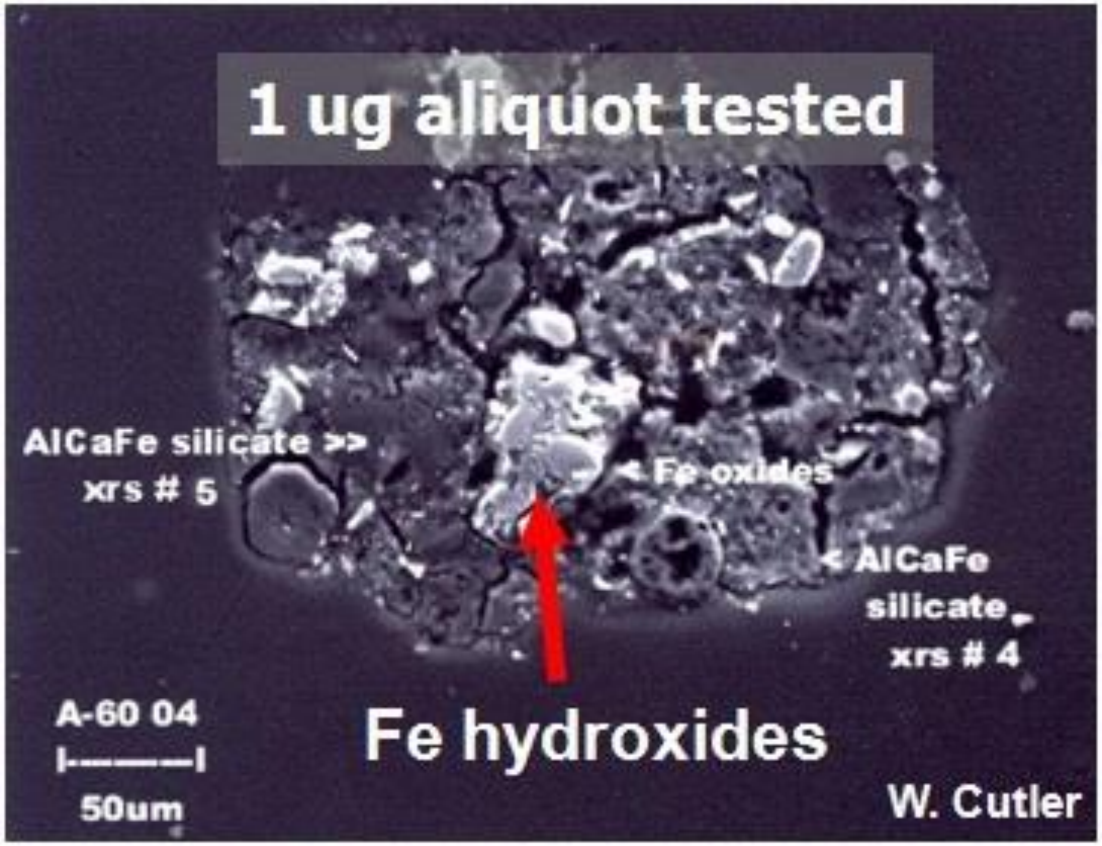


Photo courtesy of Roger Brewer, HDOH

ITRC, ISM-1, Section 2.2 hyperlinks

Key Point: Contaminants Often Exist or Behave as Particles

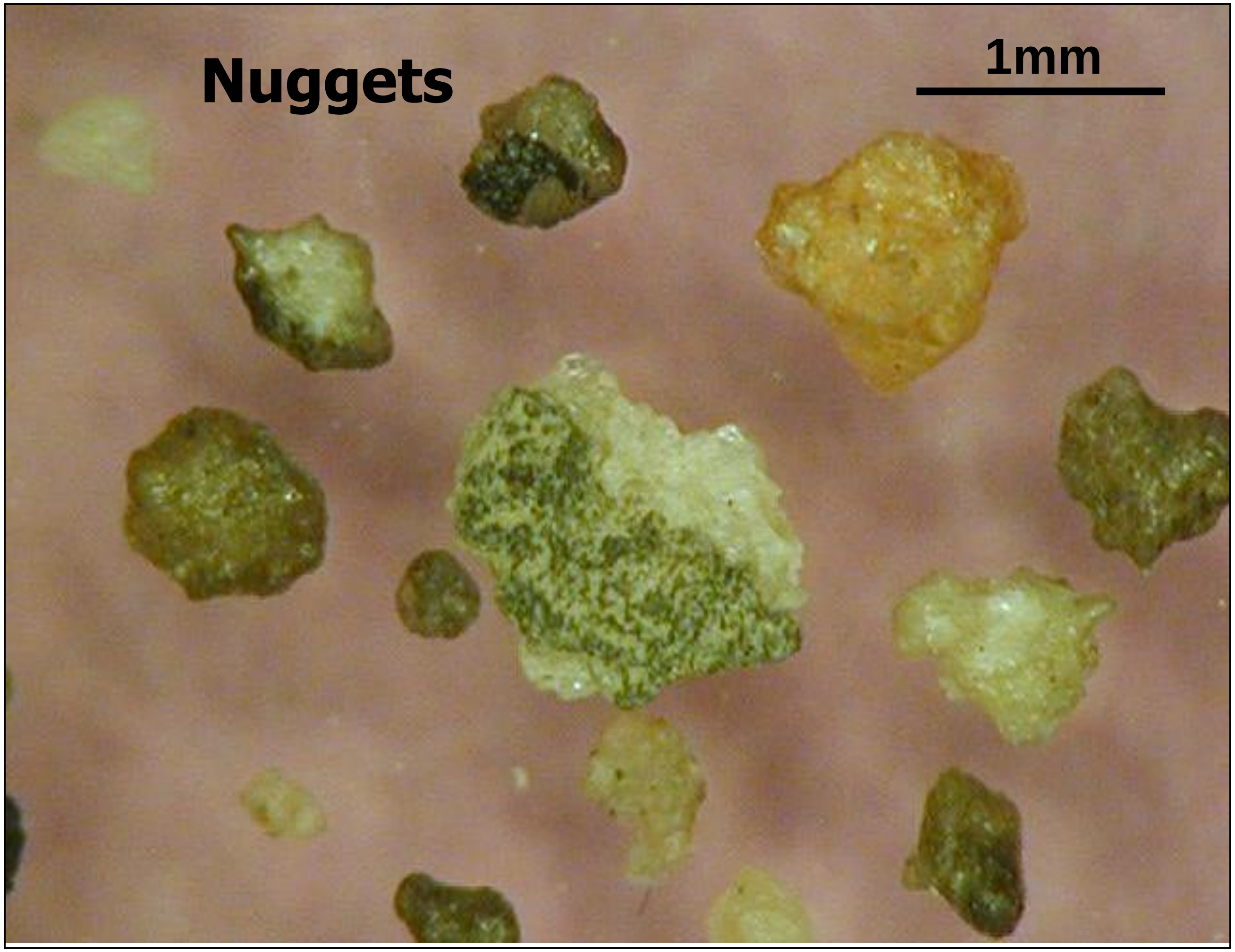
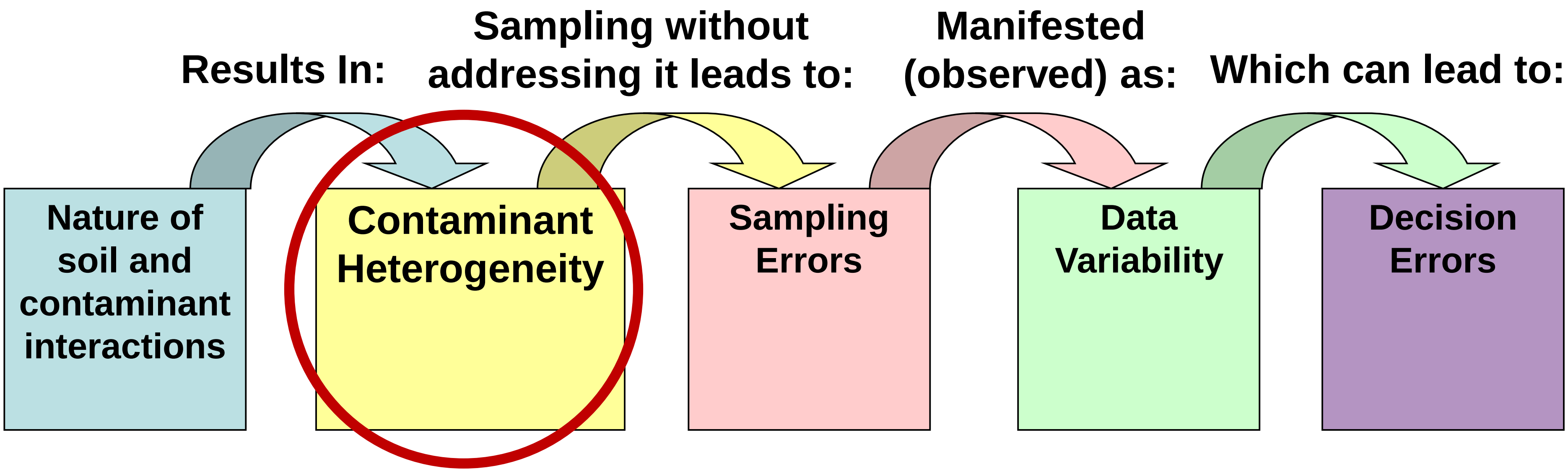


Photo courtesy of Alan Hewitt (USACE)

Tiny chunks of pure TNT-based explosive compound isolated from a soil sample

Particulates in Solid Matrices Create "Micro-Heterogeneity"



- "Micro-heterogeneity" is non-uniformity within the sample jar
- Important because contamination is heterogeneous **at the same spatial scale as sample analysis**

ITRC, ISM-1, Section 2.5.2

Micro-Heterogeneity Makes Contamination Hard to "Read"

- Micro-heterogeneity interferes with interpreting analytical results
- If contaminant distribution is not uniform in the sample jar, how sure that analytical data represent the contents of the jar, much less the field?
  - Huge mismatch between scale of decision-making and scale of sample analysis

ITRC, ISM-1, Section 2.4

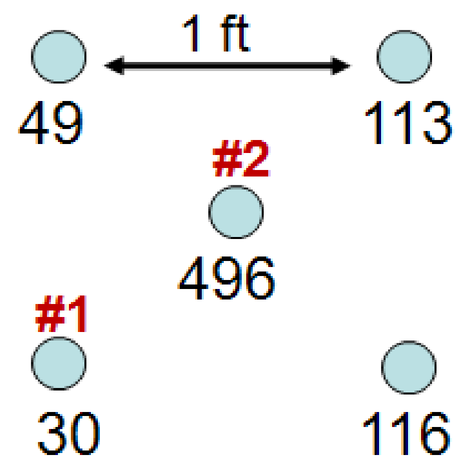
Metals Analysis on 1 Gram of Soil Guides Decisions on Tons

vs.

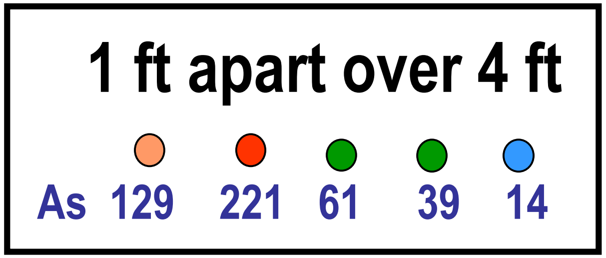
Photo credits:
Roger Brewer, HDOH

Short-Scale Field Heterogeneity: Co-located Samples

- Shortest spatial scale in the field measured by “co-located samples” (inches to a few feet apart)
- Samples anticipated to be “equivalent,” but often give very different results
- Chance governs exact location where soil is scooped
    - Therefore, ***chance*** can determine decision outcome!
- *ISM addresses the problems of both micro- and short-scale heterogeneity*



Set of co-located samples for uranium (mg/kg)



Arsenic in residential yard transect (mg/kg)

ITRC, ISM-1, Section 2.2.2

Long-Scale Heterogeneity is Generally at the Scale of Decision-Making

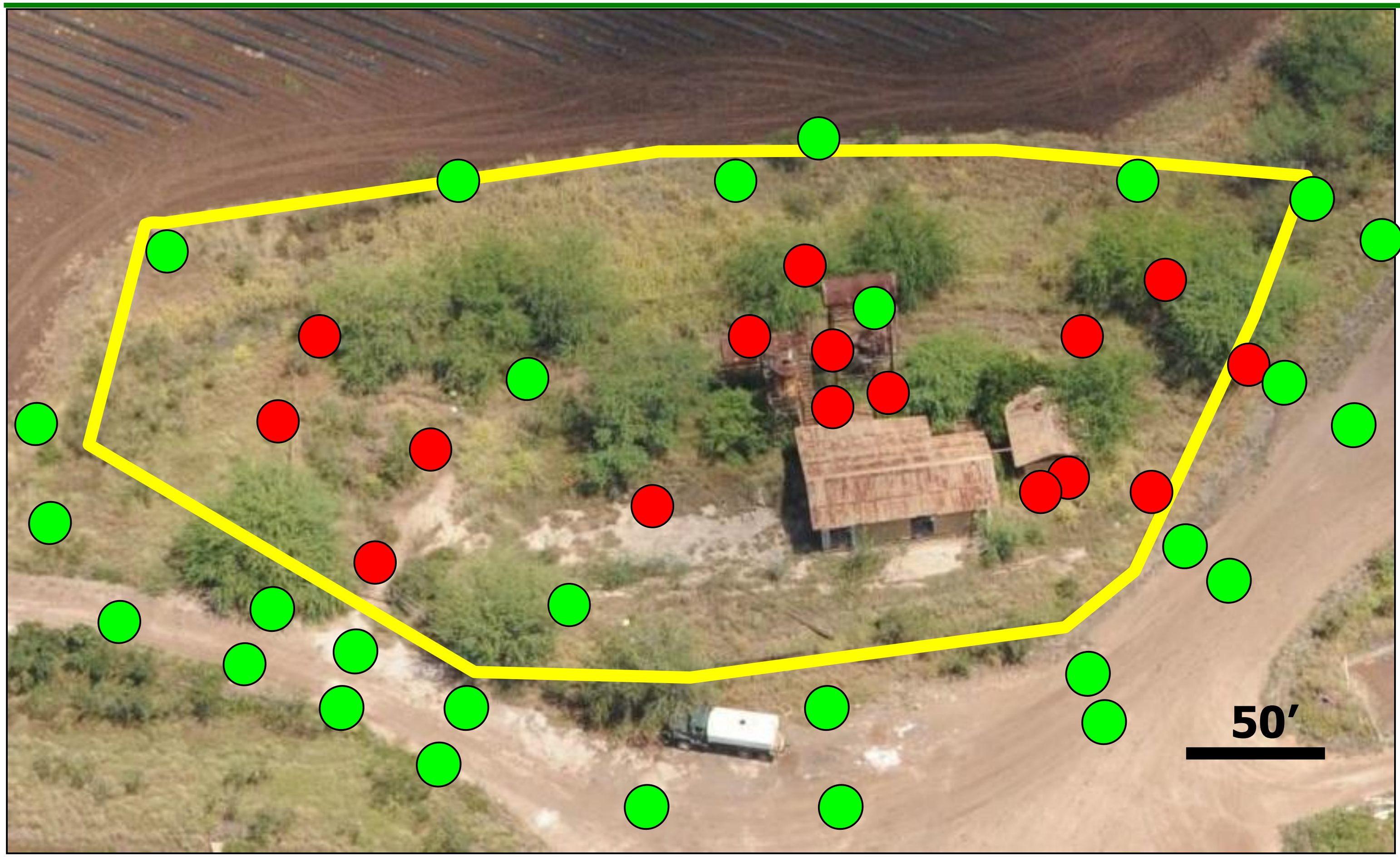
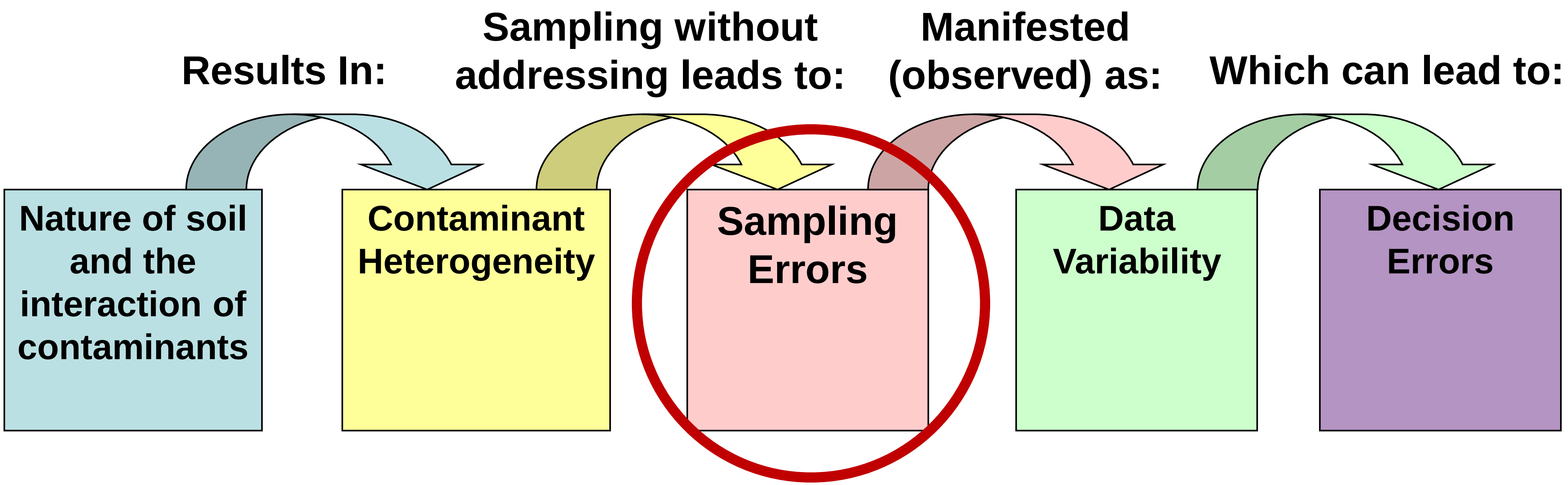


Figure credit: Roger Brewer, HDOH

Results for an actual sampled property. Green circles denote concentrations below the action level; red circles are above the action level.

Heterogeneity Causes Sampling Errors



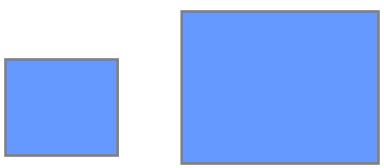
- Sampling error occurs when samples fail to mirror (represent) the original targeted population
- Need the concept of “sample support” (the physical dimensions and mass of the sample)

ITRC, ISM-1, Section 2.3.2, 2.4.1.1 and 2.2 hyperlinks

Concentration is a Function of Sample Support and Nugget Mass

Common assumption

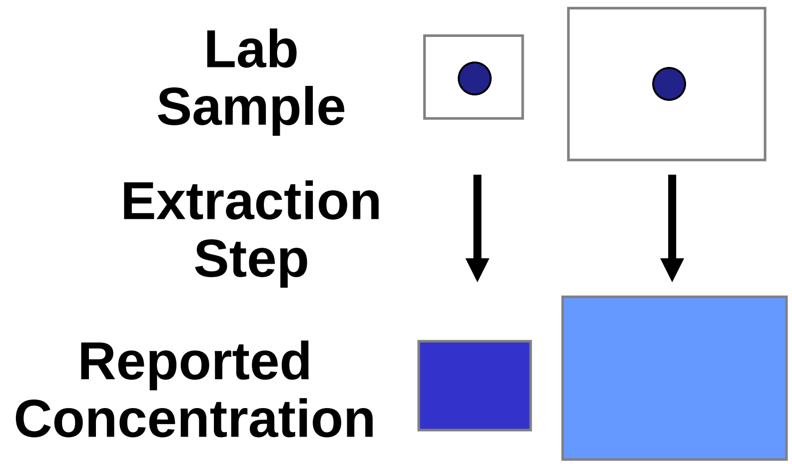
The amount of soil analyzed makes no difference to what results are obtained.



Concentration (mg/kg) = contaminant mass (mg) **/** the soil mass (kg)

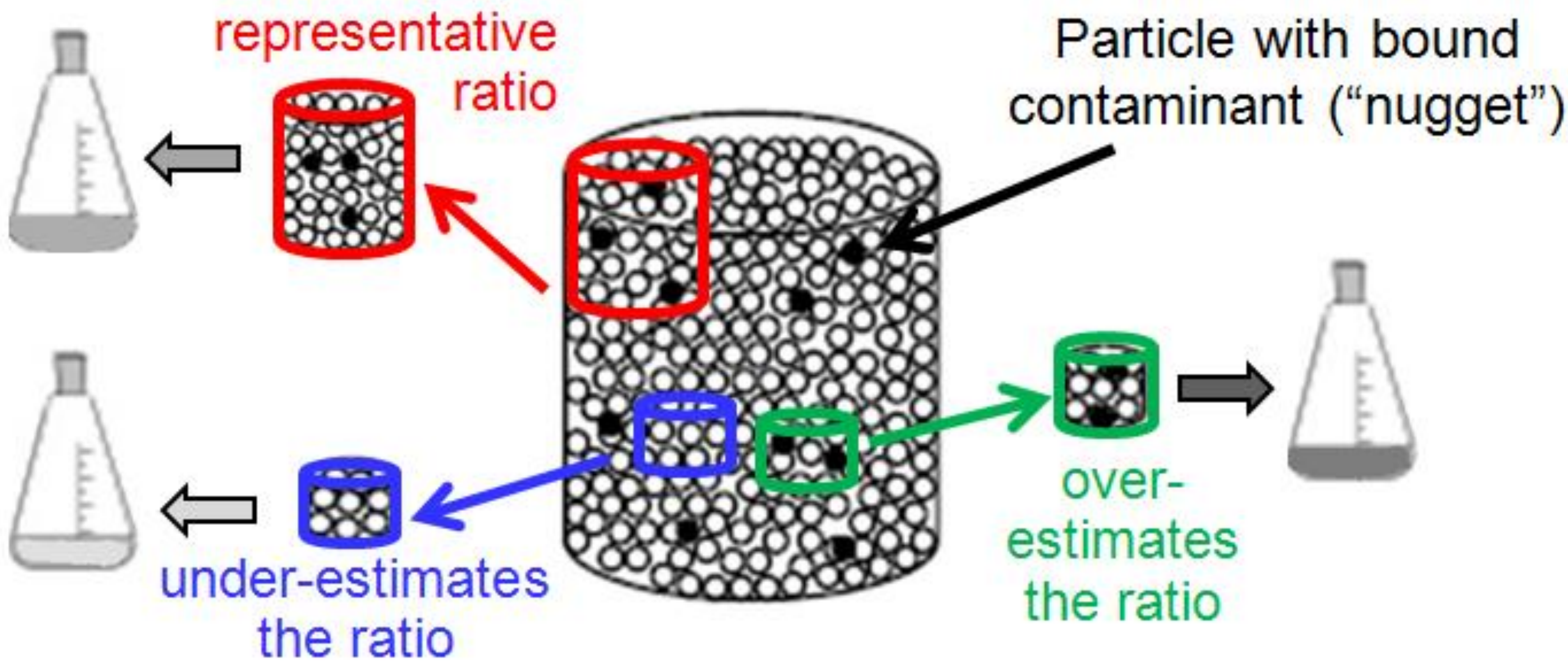
Assumption wrong for solids

Can have the **same** contaminant nugget mass (blue), BUT in different **sample** masses (white)…



…get **different** concentration results

Smaller Sample Supports More Prone to Sampling Error than Larger Ones



- Illustration of sampling error: For the blue and green samples, the proportion of nuggets in the samples do not represent the nugget proportion of the population (the large container)

Change the Sample Support and Change the Concentration

Concentration (mg/kg) = contaminant mass (mg) **/** the soil mass (kg)

Arsenic mass of 5 ng in a sample support of 1 µg of other soil minerals: arsenic conc = 5000 mg/kg

Analyze an As-Fe-OH grain by itself and arsenic conc might be 100,000 mg/kg (10%) or more.

Arsenic (As) sorbed to iron hydroxide (Fe-OH) mineral grains

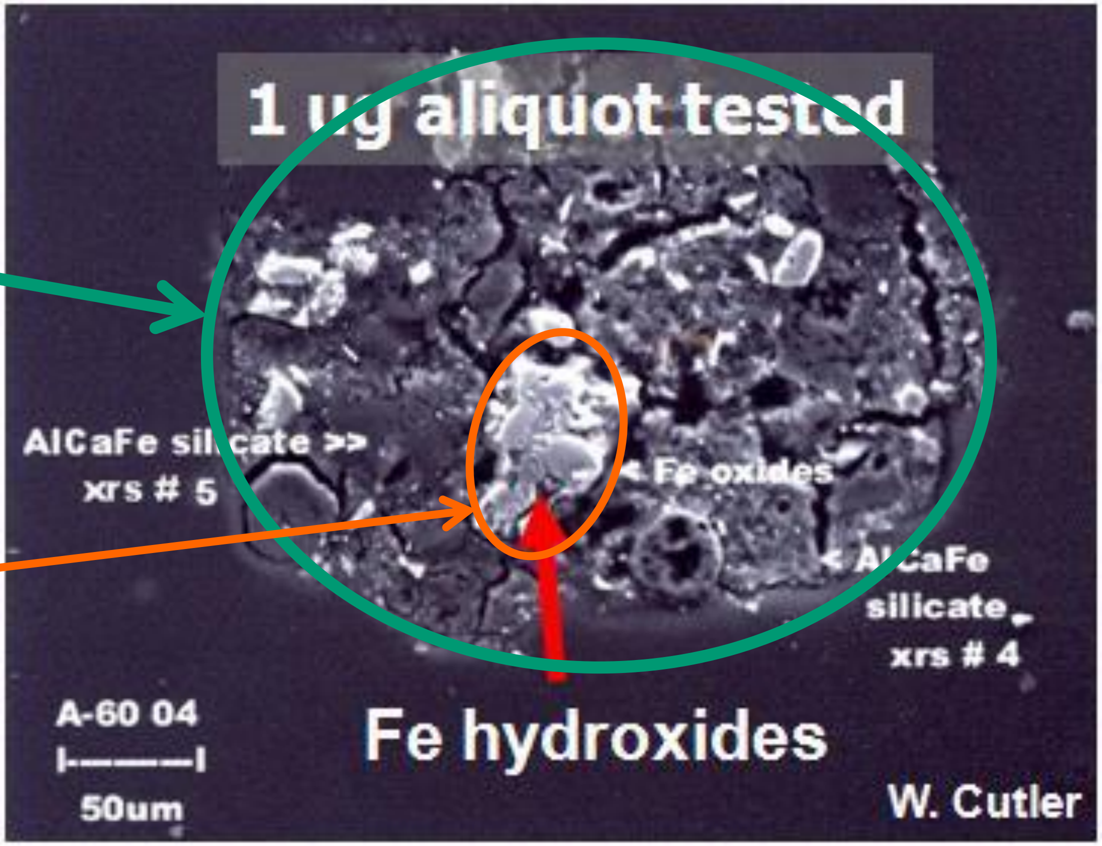


Figure courtesy of Roger Brewer

ISM Addresses Sample Support

Same As-Fe-OH grains in 1 gram of other minerals: arsenic conc = 0.005 mg/kg

Photo credit: Deana Crumbling

A lack of control over sample support during lab subsampling and in the field is a primary cause of sampling error and data variability.

ISM explicitly manages sample support!

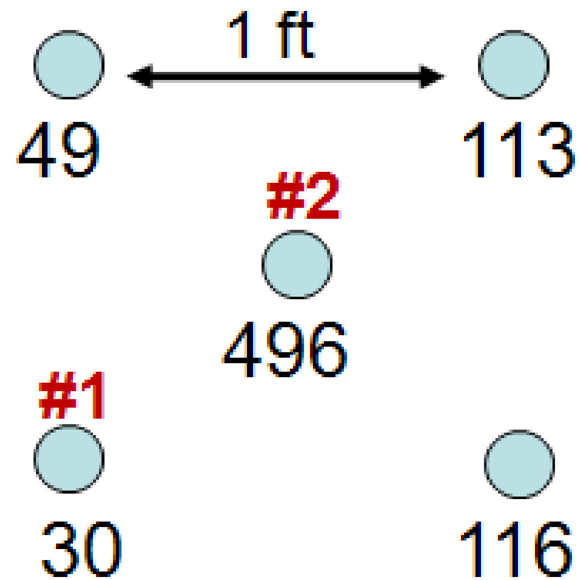
Ways to Reduce Sampling Error When Sampling a Jar

- ISM stresses the importance of sample support and techniques to reduce sampling error
  - Reduce particle size (grinding)
  - Increase sample support (i.e., extract a larger analytical sample mass)
  - Take many increments to make up the analytical subsample ("incremental subsampling")
  - Use equipment like rotary splitters →

ITRC, ISM-1, Table 3-1 and 6.2.2.5 to 6.2.2.7

Reducing Short-scale Sampling Error

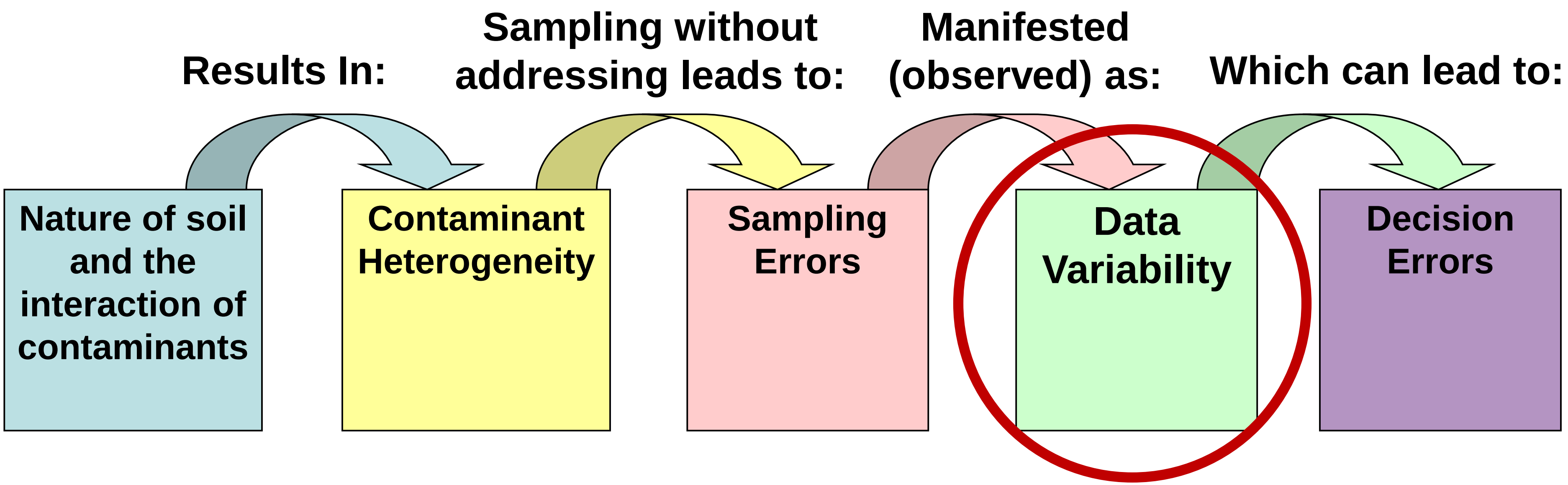
- Goal is to get THE concentration for a target soil volume, so…
  - IDEAL: analyze whole volume as a single sample
  - PRACTICAL: Increase sample support and sampling coverage by taking many small increments across the area and pooling them
- *This is what ISM does*



Set of co-located samples for uranium

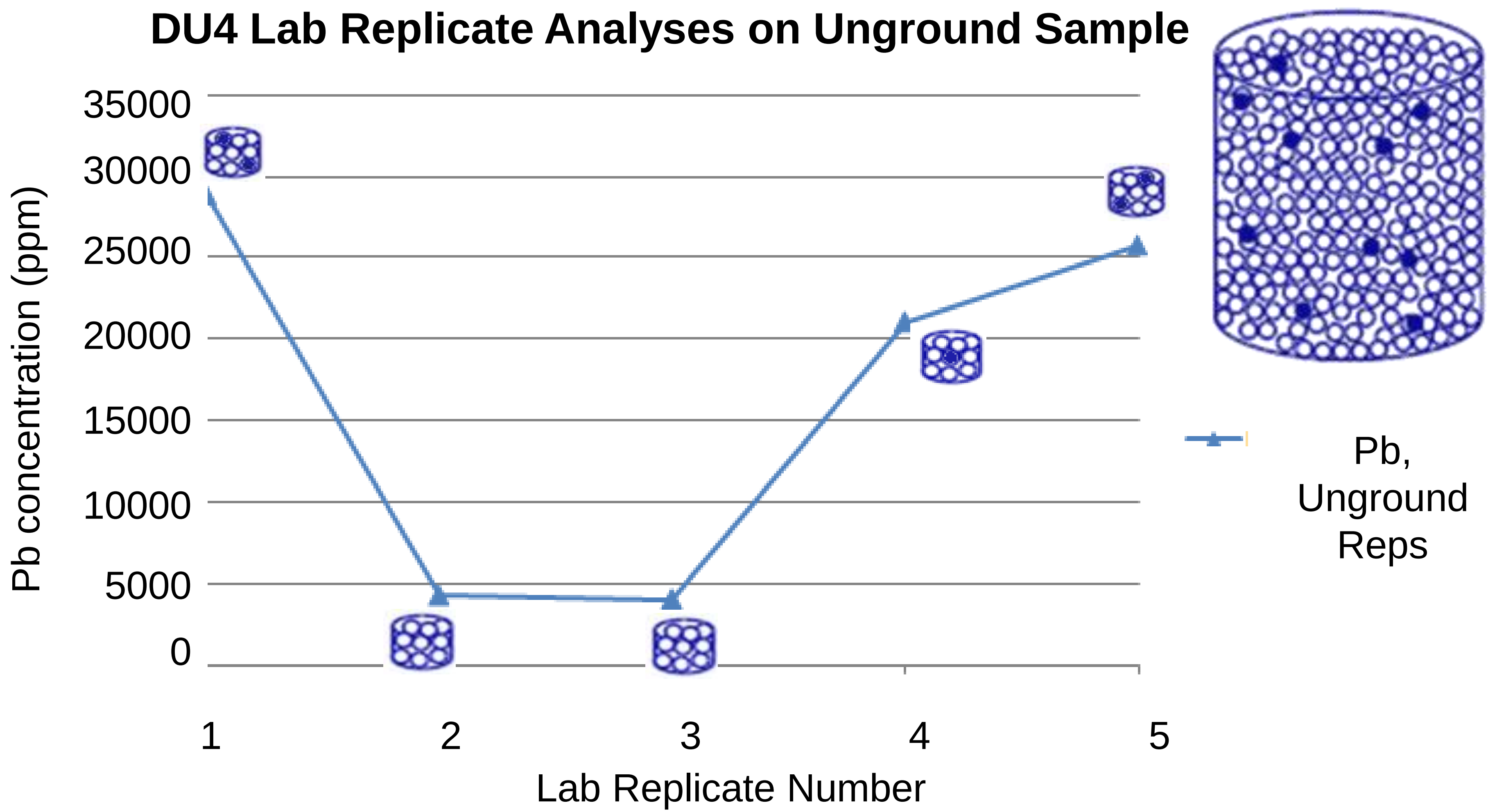
ITRC, ISM-1, Section 2.6.2.1

Sampling Error Causes Data Variability



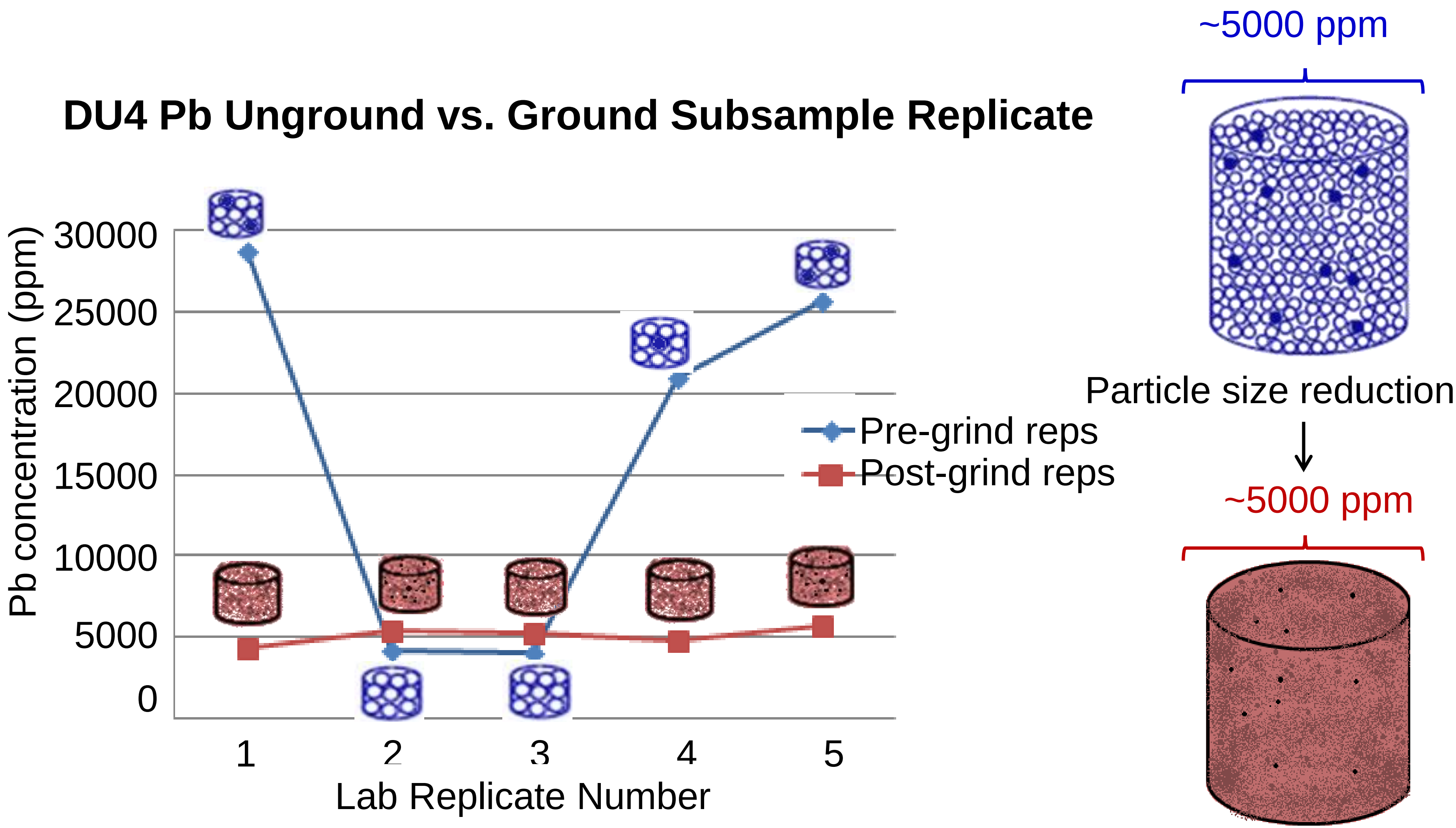
- Sampling errors contribute to data variability

Study Data for Pb: 5 Laboratory Replicate Subsamples from Same Jar



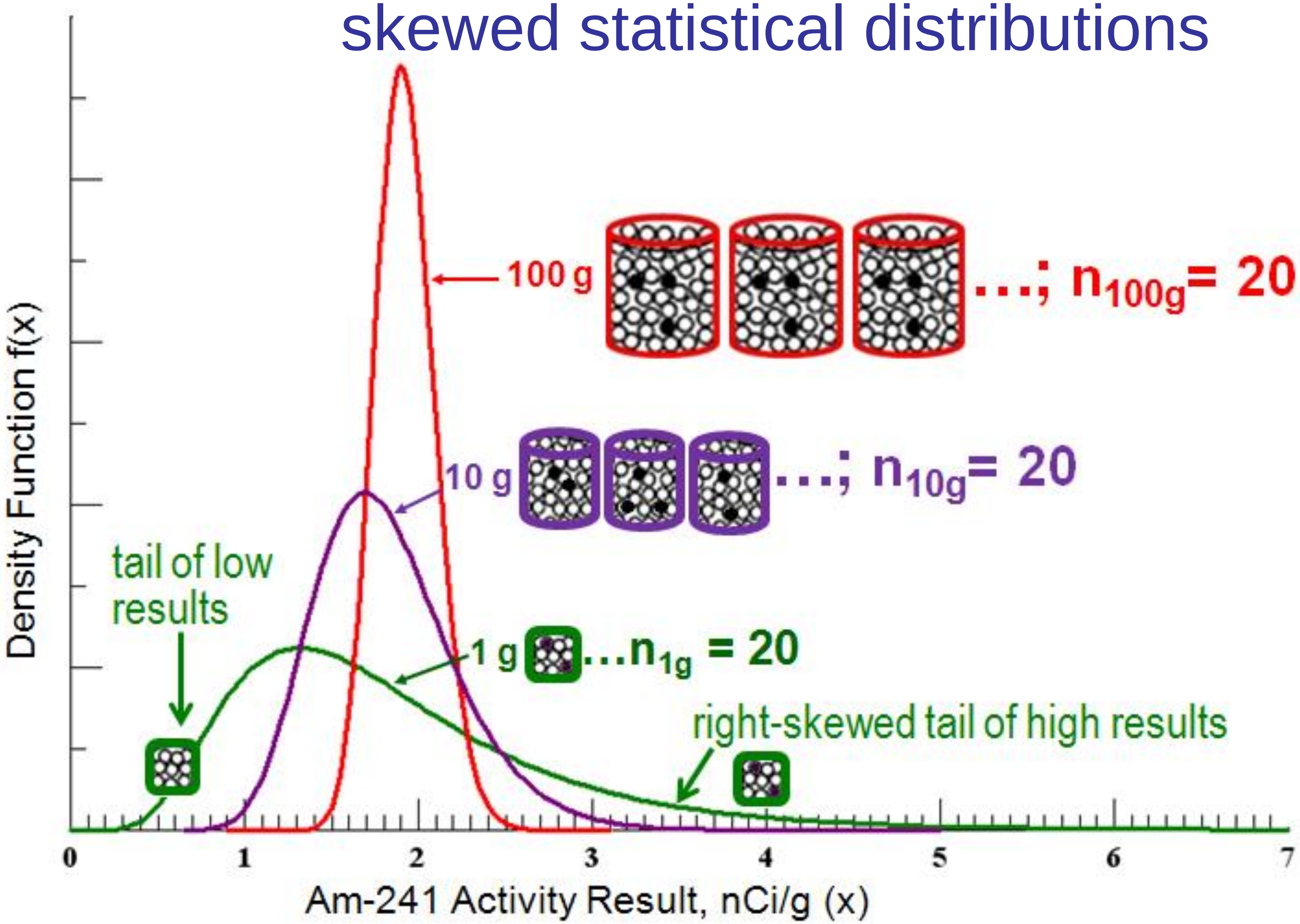
Same Soil Sample After Grinding

Pre-grind range: Pb 4000-29000 Post-grind range: Pb 4360-5660



Sample Support Influences Statistical Distributions

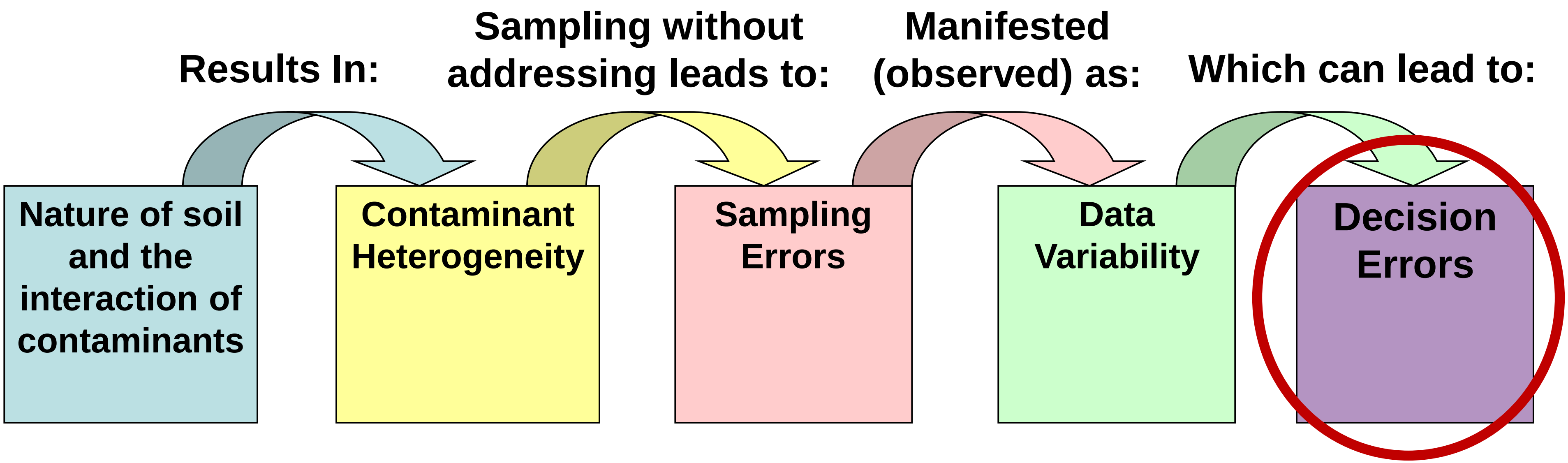
Small sample supports contribute to skewed statistical distributions



ITRC, ISM-1, Section 2.4.1.3

Adapted from DOE study (Gilbert, 1978)

Concepts Underlying ISM: Avoiding Decision Error

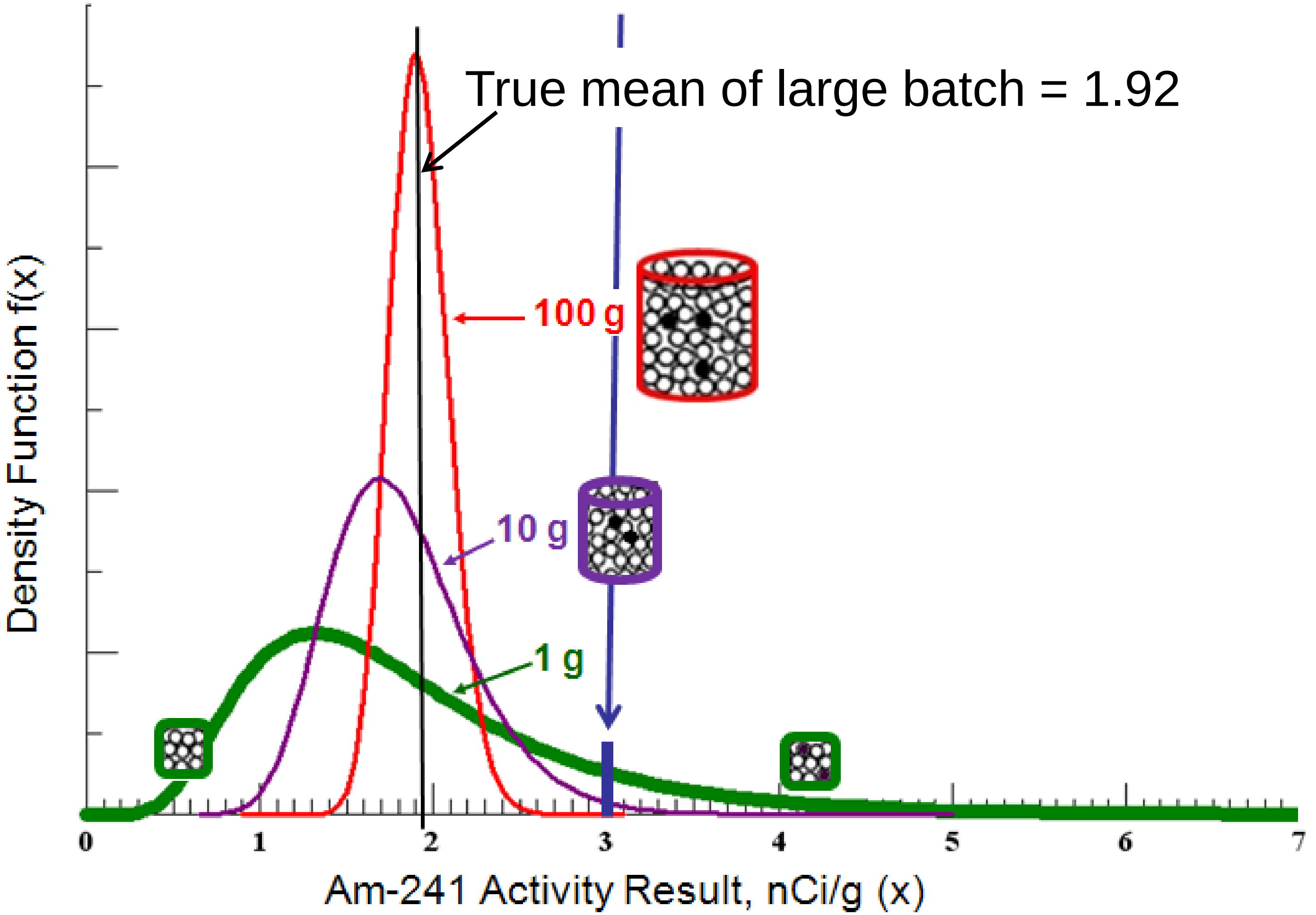


- Decision Error: a decision that would have been made differently if the true condition were known
- Can occur when conclusions are based on data that were significantly influenced by heterogeneity

ITRC, ISM-1, Section 2.4.1.3 and 2.4.2

Skewed Data Distributions Promote Decision Errors

Suppose 3 is an action level. The likelihood of single data points exceeding 3 depends on the sample support.



Avoiding Decision Errors

- Pay attention to QC results in the data package!
  - Suspect sampling error due to micro-scale within-sample heterogeneity when
    - Lab duplicates do not “match”
    - Matrix spikes/matrix spike duplicates do not “match”
  - Suspect sampling error due to short-scale between-sample heterogeneity when
    - Co-located samples do not “match”

Avoiding Decision Errors (continued)

- Be wary of making decisions based on a single data point
  - Especially when traditional sample collection and handling is used
- Use ISM in field and lab!
- Ensure ISM work plans spell out procedures to detect and control sampling error

Summary: Principles

- Inadequate management of soil heterogeneity produces highly variable data sets
- The “maximum concentration” notion is meaningless
- Chance data variability can be misinterpreted to represent the “true” condition for large soil volumes
- Misinterpreting data, especially single data points, can lead to costly decision errors
- The “nuts and bolts” of managing sampling error in the field and lab will be presented in Part 2

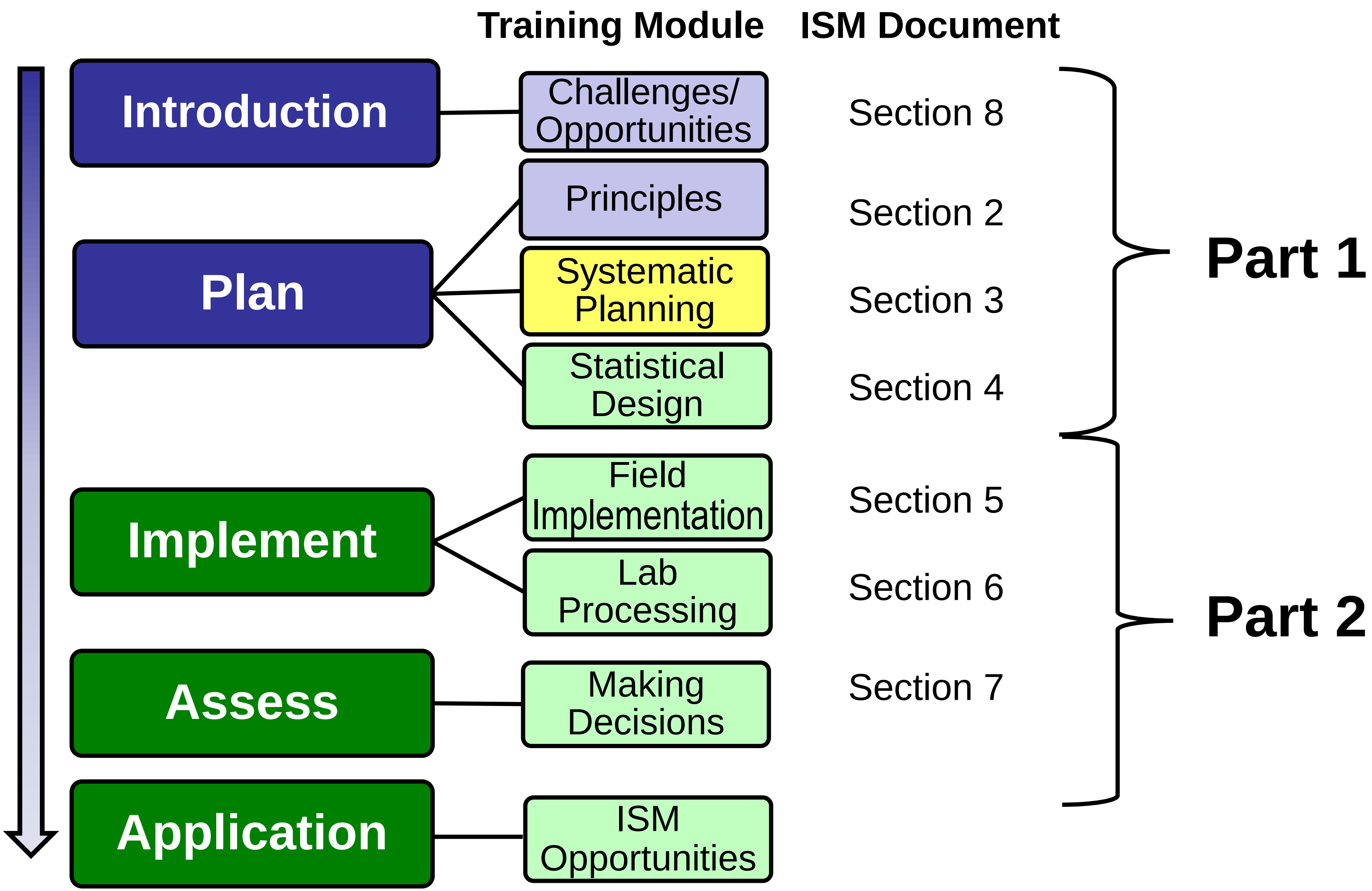
ITRC, ISM-1, Sections 5, 6, and 7

Heterogeneity Rules!

You Can't Fool Mother Nature

Acknowledge her or be hobbled by the consequences

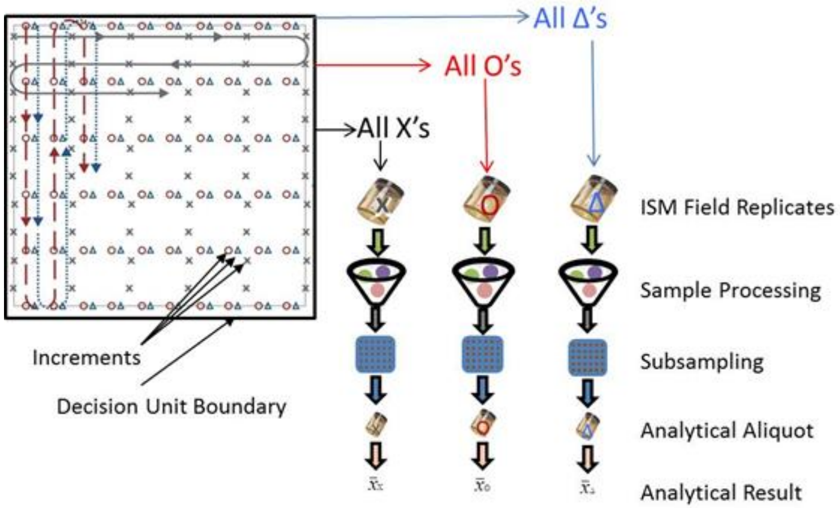
ISM Document and Training Roadmap



Systematic Planning Learning Objectives

Learn how to:

- Conduct systematic planning steps important to ISM
    - Conceptual Site Model (CSM)
    - Risk pathways and contaminants of concern
    - Project objectives (Sampling and Data Quality Objectives (DQOs))
- Determine Decision Units (DUs)
    - Information used to develop DUs
    - Why DUs are important
    - Types of DUs
    - Real world examples (i.e., case studies)



No Data Quality Objective (DQO)/Decision Units? Bad Data!

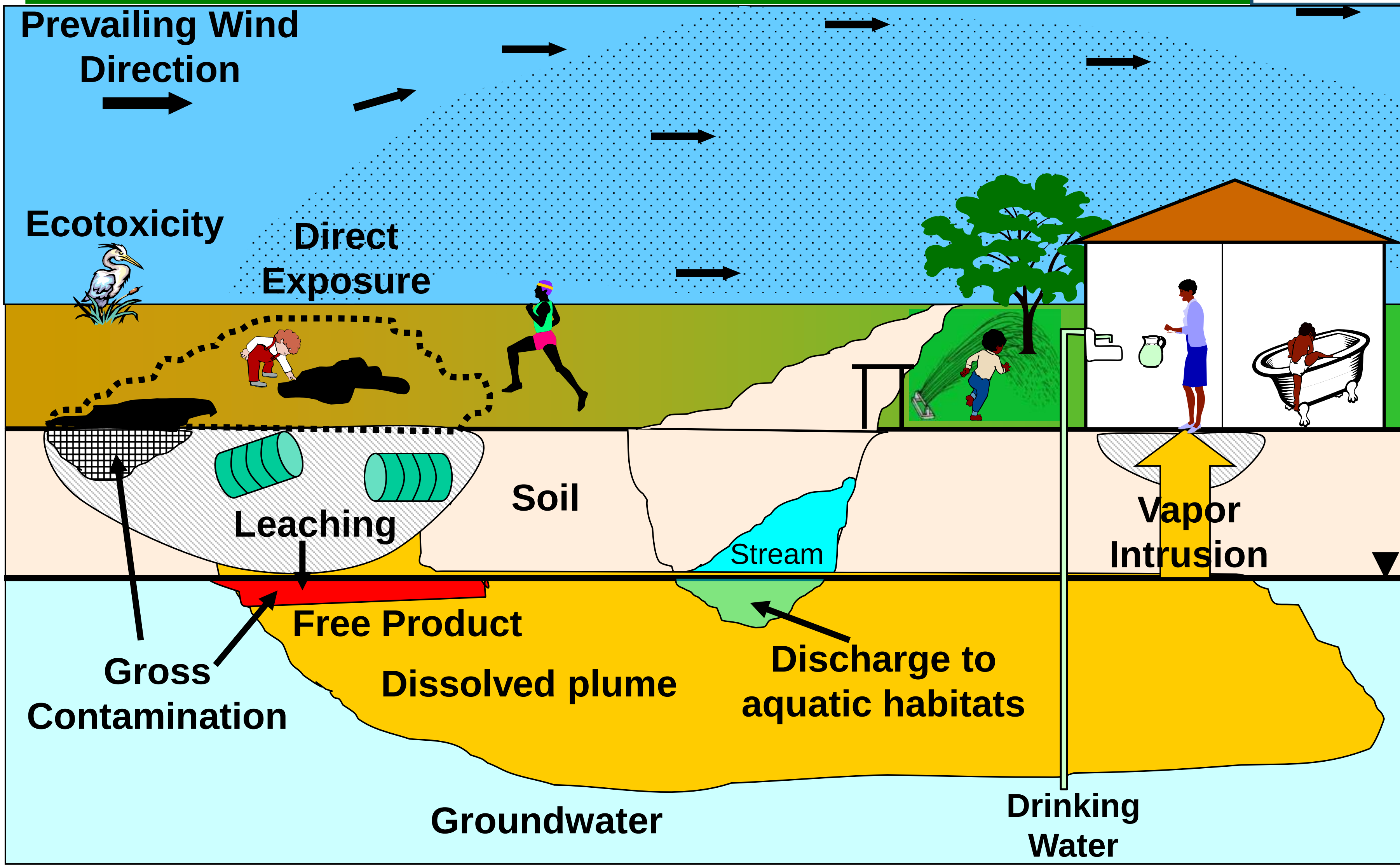
- Decision Units (DUs) – The smallest volume of soil for which a decision will be made based on ISM sampling
- Designating DUs – arguably most important aspect of ISM from a regulatory perspective
  - Selection of DUs determines
    - Where samples are being collected
    - How many
  - DU selection determines whether the data are able to satisfy the project objectives, both sampling objectives and data quality objectives

Systematic Planning and Implementation

- Develop Conceptual Site Model (CSM)
- Identify contaminants and project objectives
- Identify data needed and how it will be used
- **Define Decision Units (DUs)** **Key Step of ISM**
- Develop decision statements
- Collect samples to characterize DUs
- Evaluate data

ITRC, ISM-1, Table 3-1

Conceptual Site Model (CSM)



ITRC, ISM-1, Figure 3-2

Data/Information Needs

- What receptors and pathways are being evaluated?
- What are your sampling objectives?
- Are there multiple sampling objectives that must be met?
- What is the scale of decision making?
- What population parameter is of interest?

The key is the volume over which the mean should be estimated.

Example Sampling Objectives

- Estimate the mean concentration of contaminants in a pre-determined volume of soil (i.e., DU)
- Delineate the extent of contamination above screening levels
- Estimate the potential risk to receptors posed by the soil contamination
- Evaluate background metals concentrations in soil
- Confirmation sampling following remediation

Designating Decision Units (DUs)

- Information used to develop DUs
- Why DUs are so important
- Types of DUs
- Examples

Stakeholder Agreement

Decision Units (DUs)

The volume of soil where samples are to be collected and decisions made based on the resulting data.

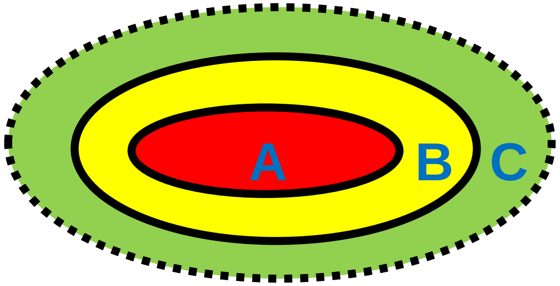
Source Areas

Exposure Areas

Size, shape and type of DU are an outcome of systematic planning and depend on site specific data quality objectives.

ITRC, ISM-1, Section 3.3

Why ISM Is Important



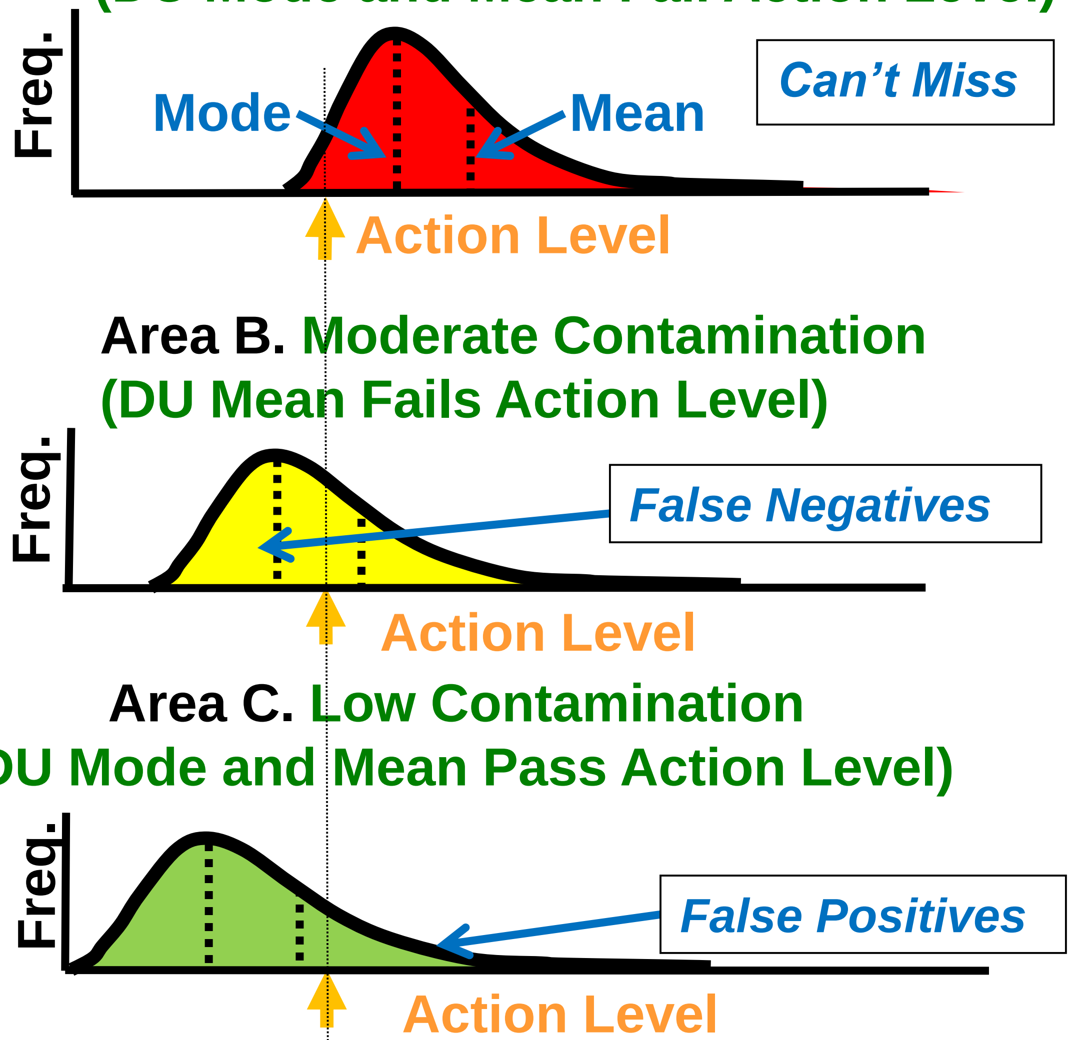
Example Soil Plume Map

Concentrations can vary several orders of magnitude within a DU at the scale of a discrete sample

Area A. Heavy Contamination (DU Mode and Mean Fail Action Level)

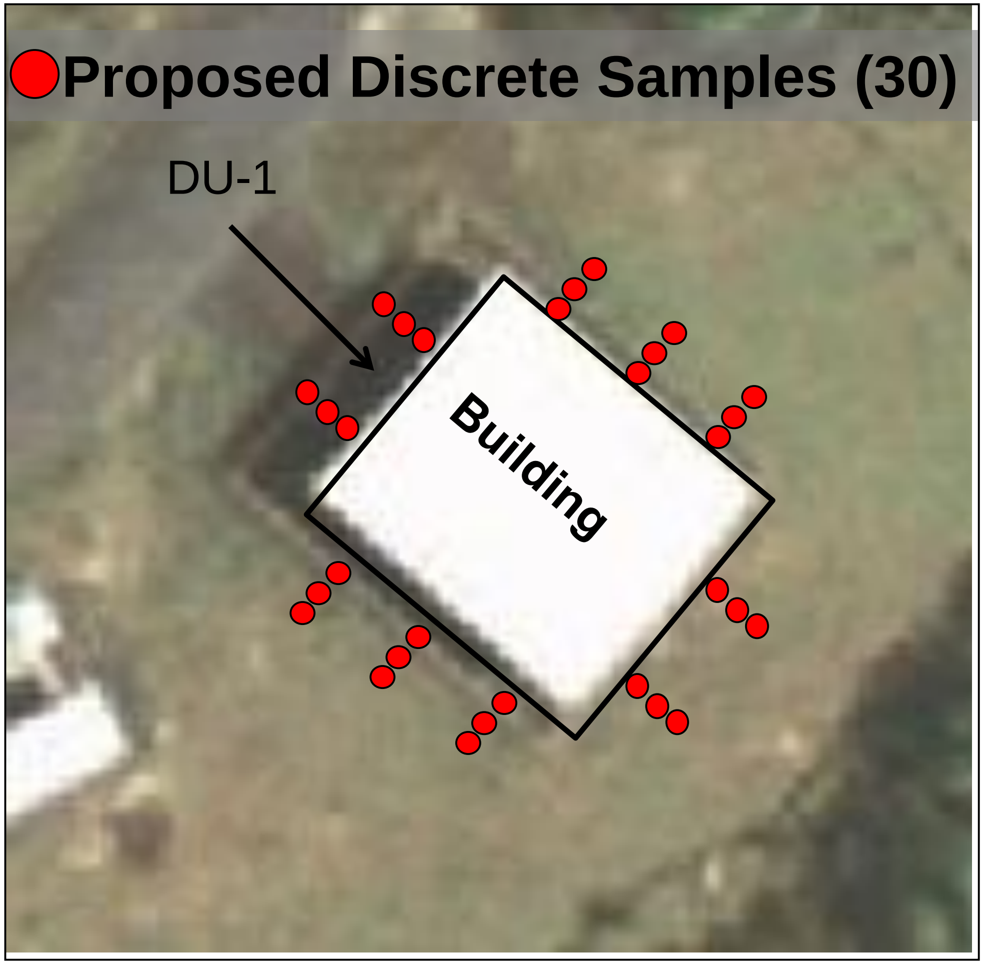
Area B. Moderate Contamination (DU Mean Fails Action Level)

Area C. Low Contamination (DU Mode and Mean Pass Action Level)



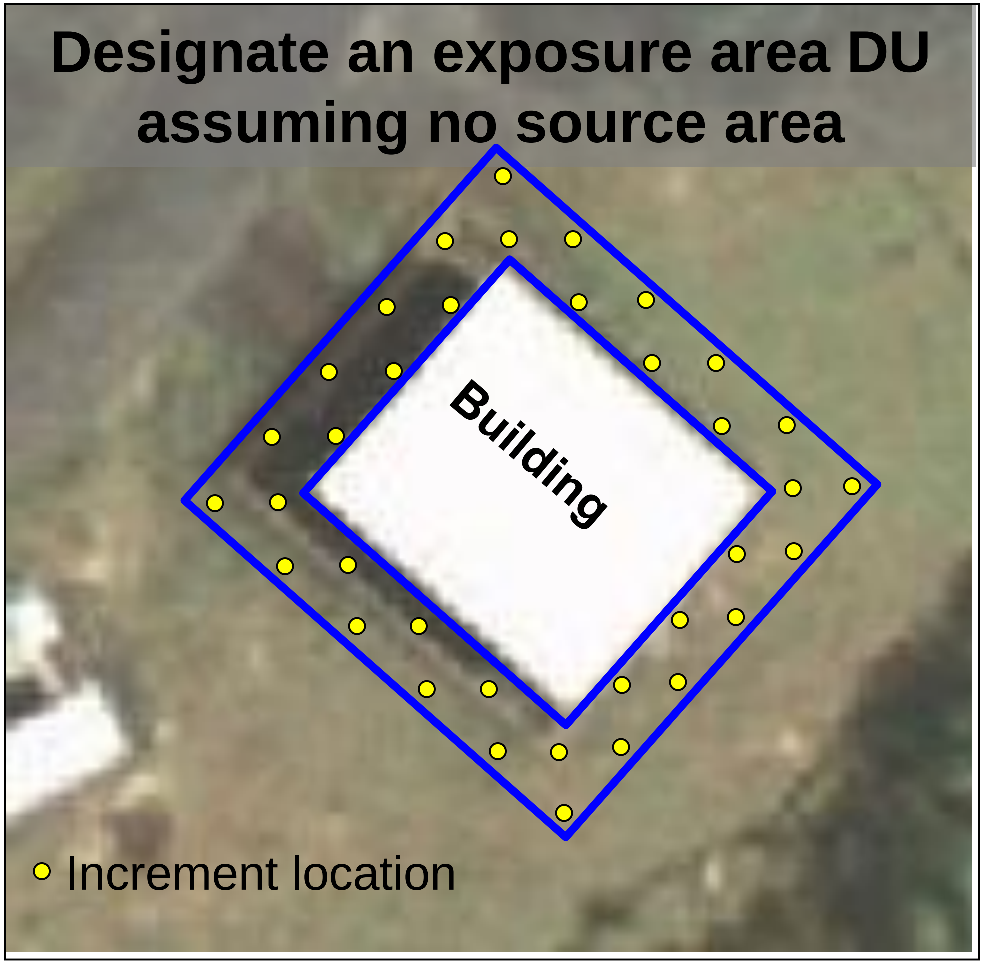
ITRC, ISM-1, Figure 2-15

Traditional Site Investigation Approach



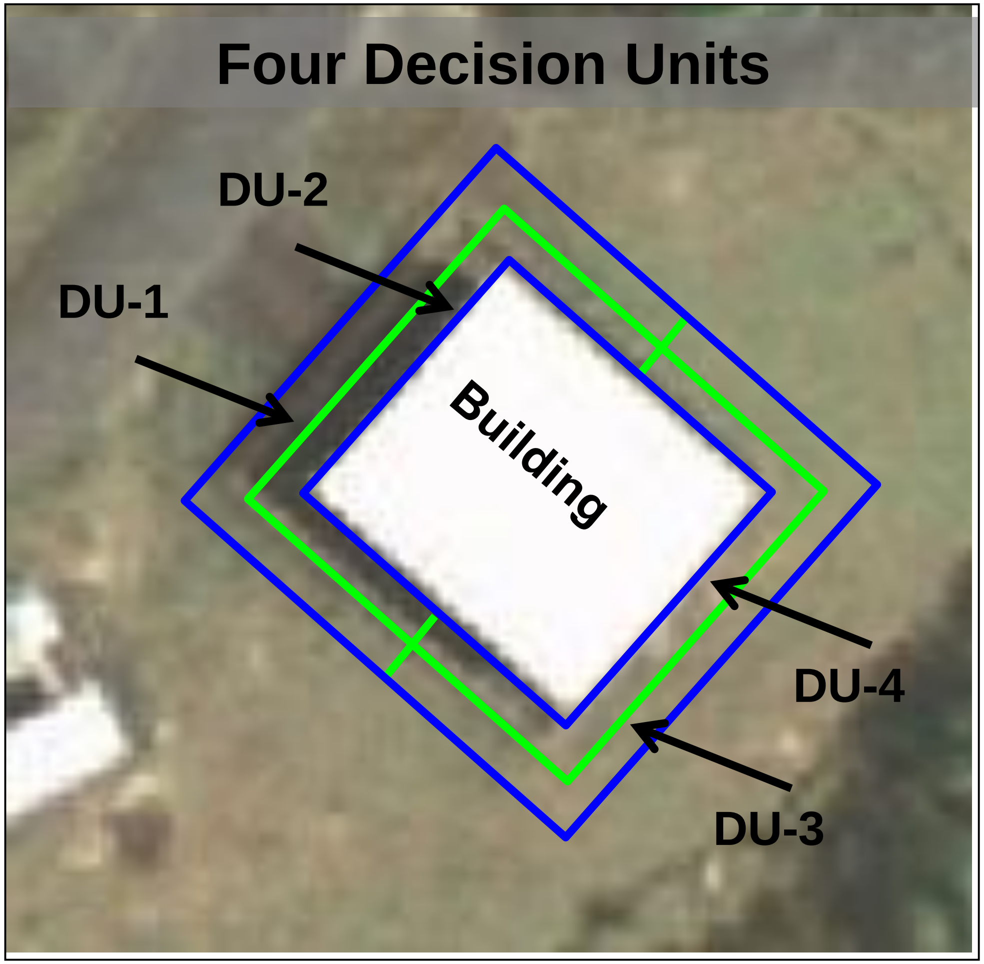
- Potential Concerns
  - Inadequate number of sample points to define outward boundaries
  - High risk of False Negatives and False Positives
  - Confusion over single point “hot spots”
  - Cost of 30 analyses
  - Sample points should be randomly located for estimation of exposure point concentration (EPC)

ISM Approach (Option 1)



- **Advantages**
  - More representative
  - Risk evaluation objective identified up front
  - Increments randomly and evenly spaced to minimize size of hot spot missed
  - Quick and cheap if minimal contamination suspected
- **Disadvantages**
  - Additional sampling required if DU fails

ISM Approach (Option 2)



Advantages

- Addresses both source area and perimeter as well as directional variability if an exceedance is found
- Best approach to minimize additional sampling
- Will minimize remediation volumes if DU exceeds screening level
- If increments are collected using cores, vertical delineation is easily done with stacked DUs

Suspected Lead Paint and Pesticides Around House and in Yard

Source Area DU: perimeter of house

Exposure Area DU: remainder of the yard

Do lead or pesticides exceed action levels around the house or in the yard?

Former Pesticide Mixing Area (0.5 acres)

Suspected heavy contamination with arsenic, dioxins (from PCP) and leachable pesticides

Source Area and Exposure Area DU Designation

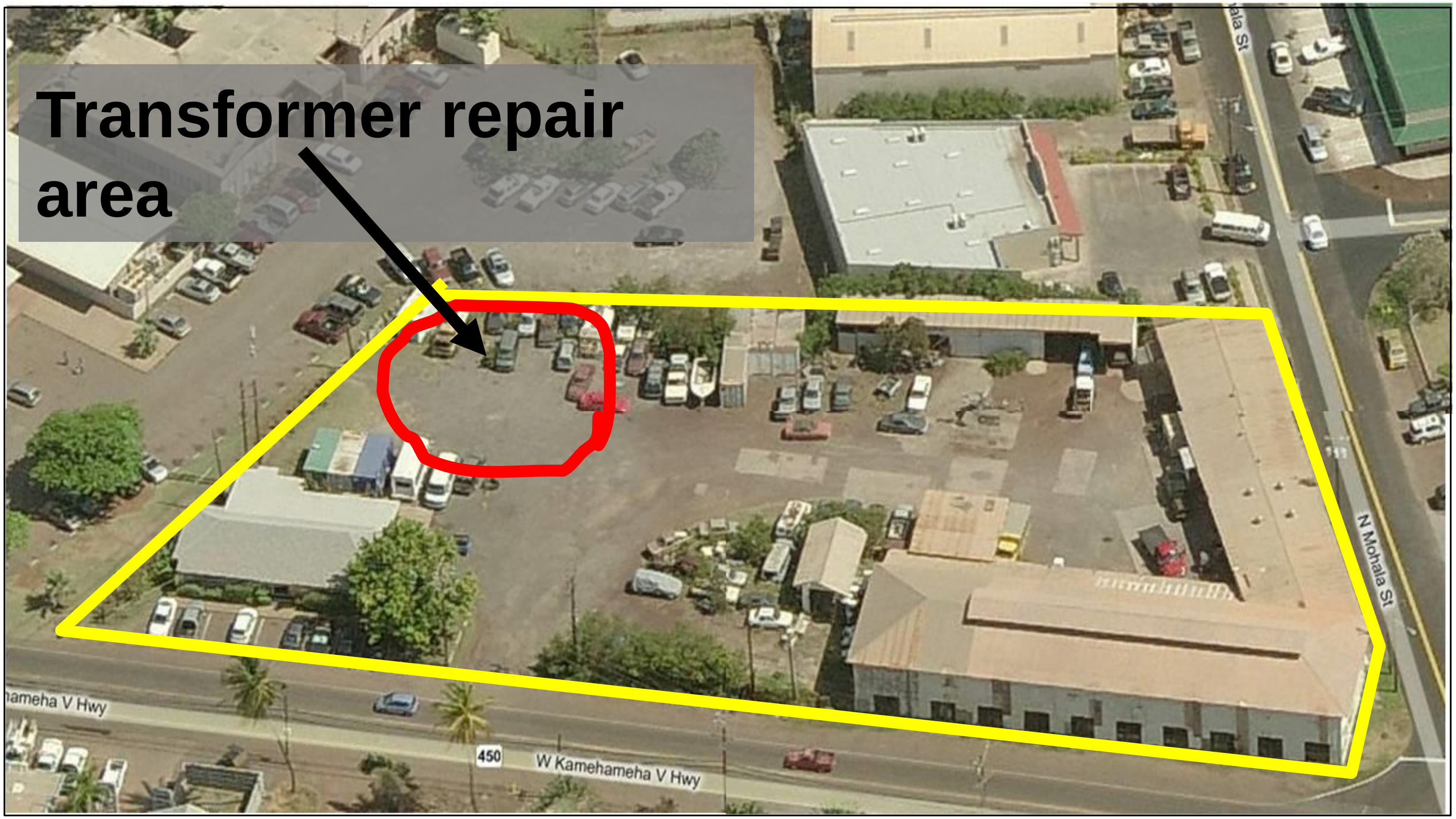
Primary objective is to delineate the source area and the extent of contamination.

Former Pesticide Mixing Area

Source Area DUs: Heavy contamination + leaching

Exposure Area DUs: Maximum 5,000 ft^2

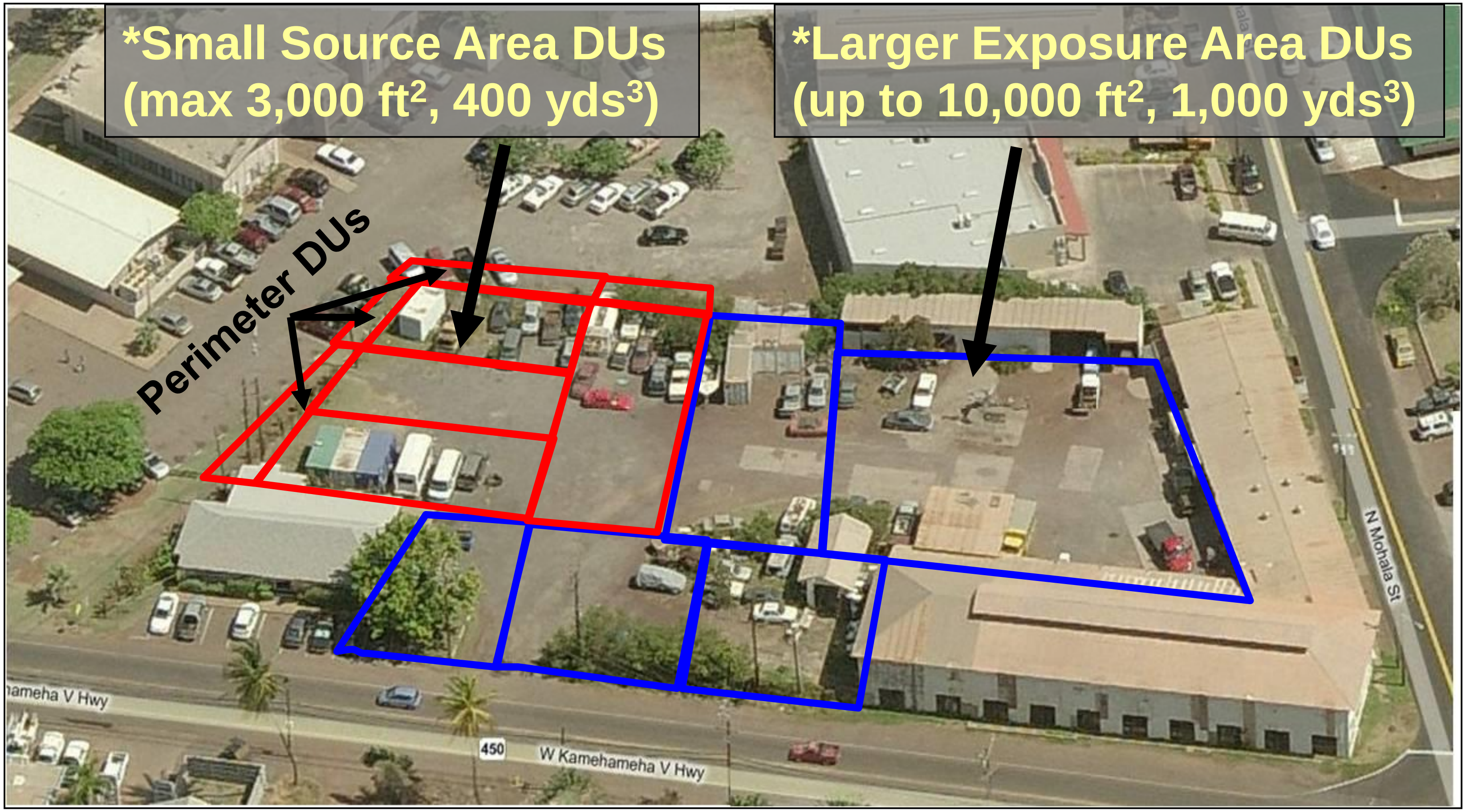
Former Power Plant
Proposed Community Center



100′

Primary objective is to identify and delineate source area and extent of contamination that exceeds action levels.

Former Power Plant Decision Unit Designation



***Assuming 3’ depth**

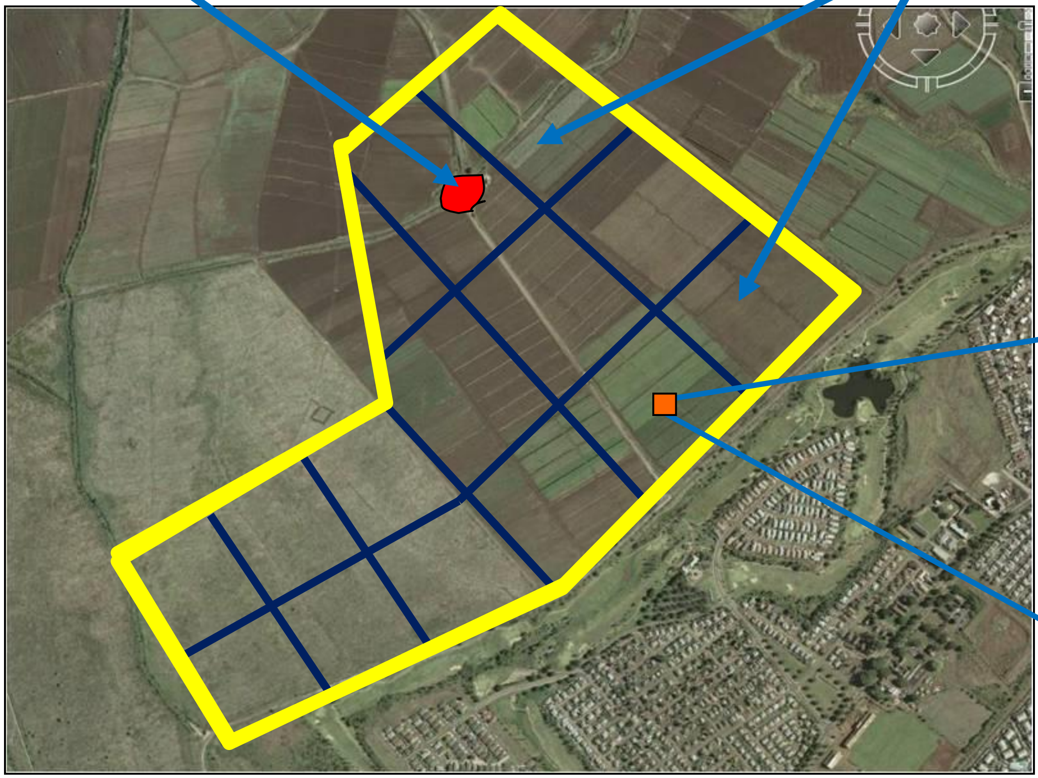
100′

Really Big Decision Units (DU)! (400-acre former sugarcane field)

Source Area DU (investigated separately)

Initial Screening DU
- **Residual pesticide levels?**
- **OK for residential development?**

Lot-Scale Resolution
- **Hypothetical lots**
- **5,000 ft^2 Exposure Area**
- **May also be required**



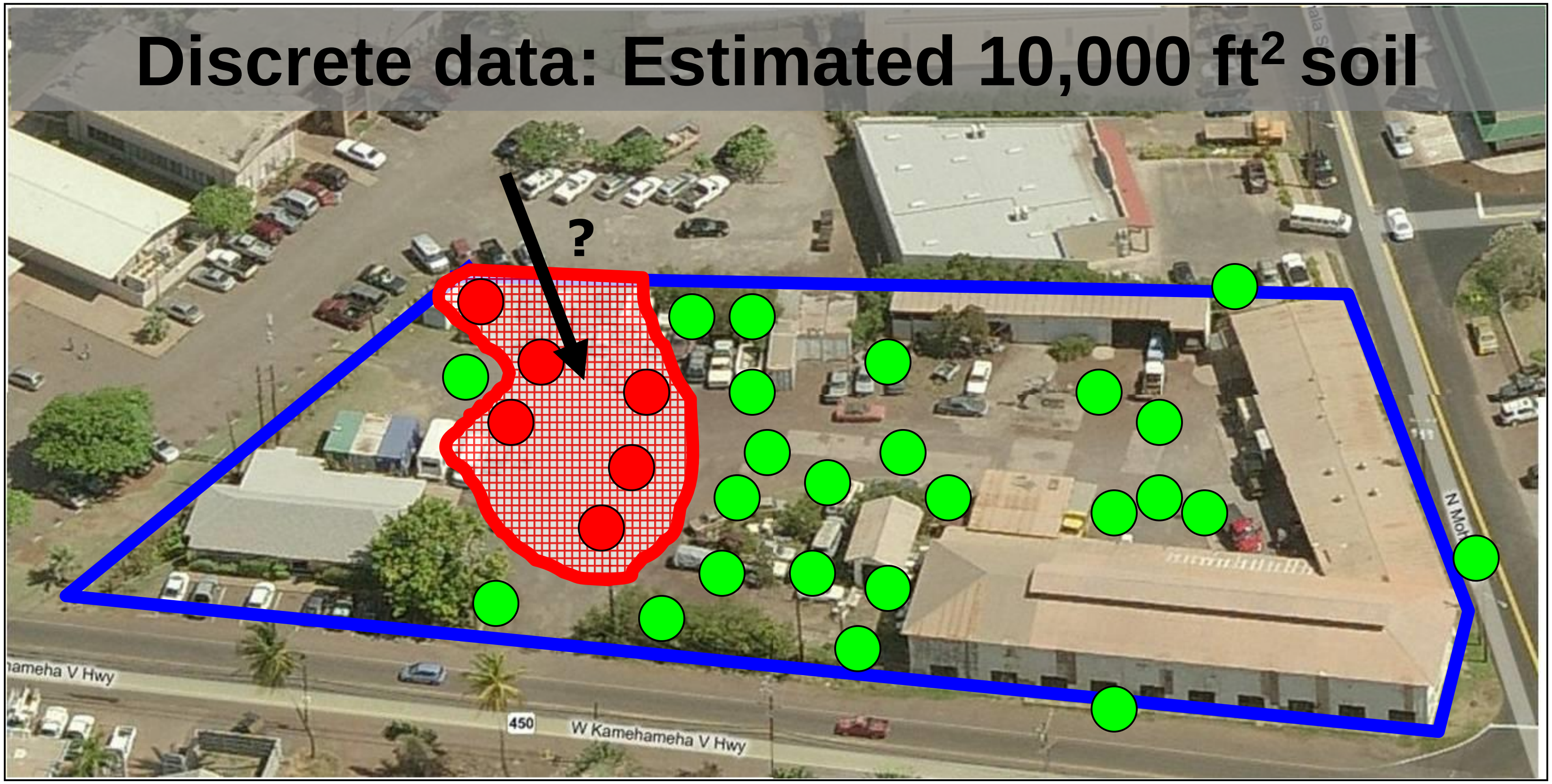
Primary objective is to determine if property can be developed for residential use.

Really Small Decision Units???
What about the Sandbox!?

- Yard-size DUs are most often appropriate
- If acute hazards or intense exposure are being evaluated, smaller DUs may be necessary
  - Not typical
- Investigate known or suspected source areas separately
  - Remember: As sampling objectives change, so must the sampling design

Why DUs (and ISM) are Important (Discrete Sample Data)

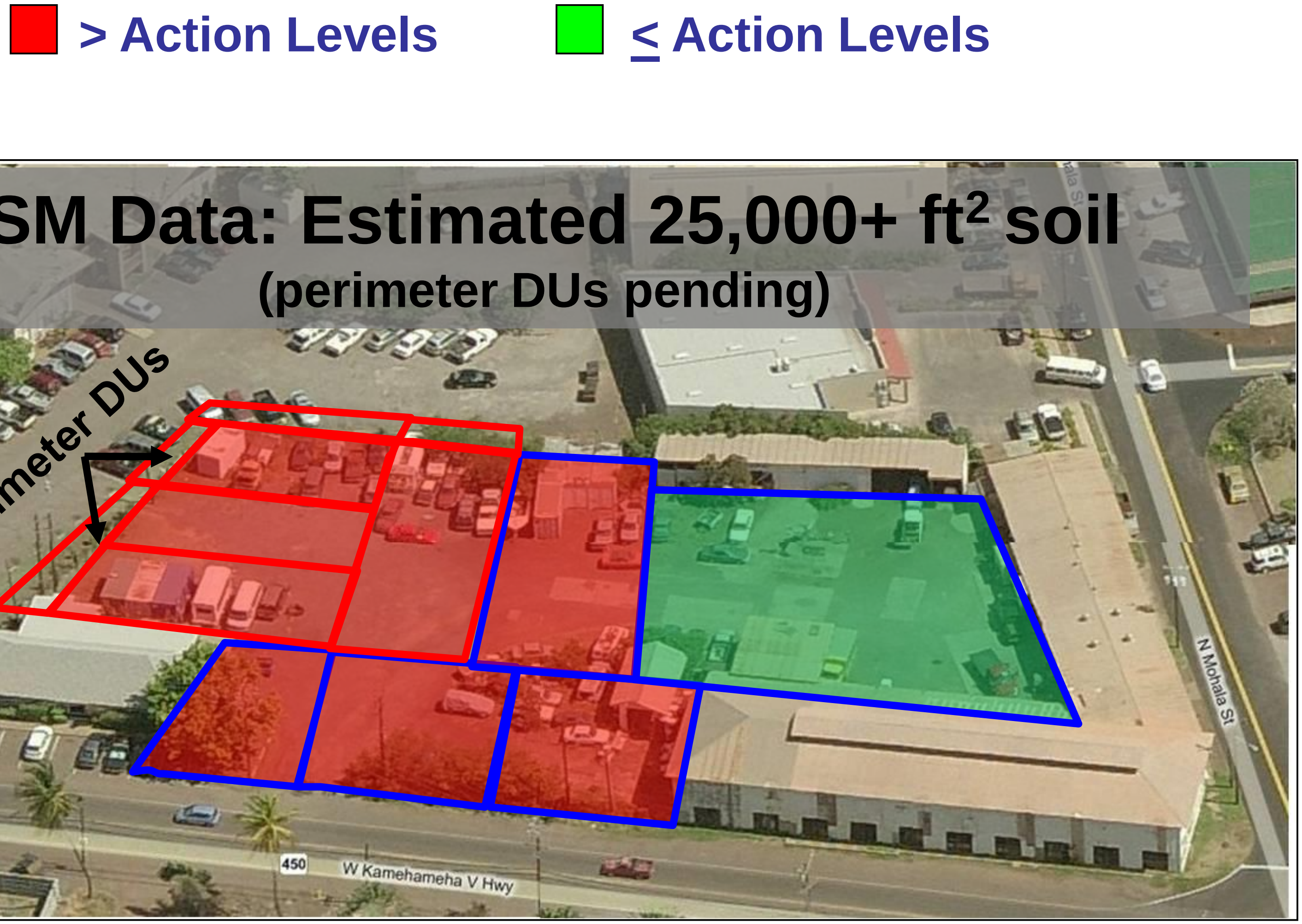
>Action Level ≤Action Level



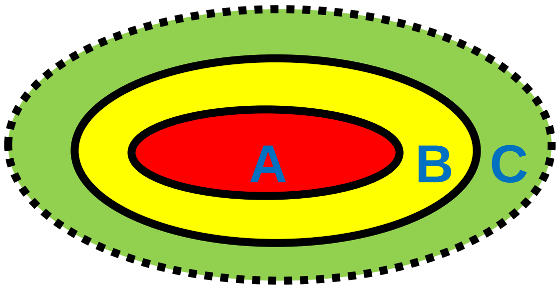
PCB sample aliquot = 30 grams (one spoonful of soil)

100′

Why DUs (and ISM) are Important (ISM Sample Data)



Why ISM Is Important



Example Soil Plume Map

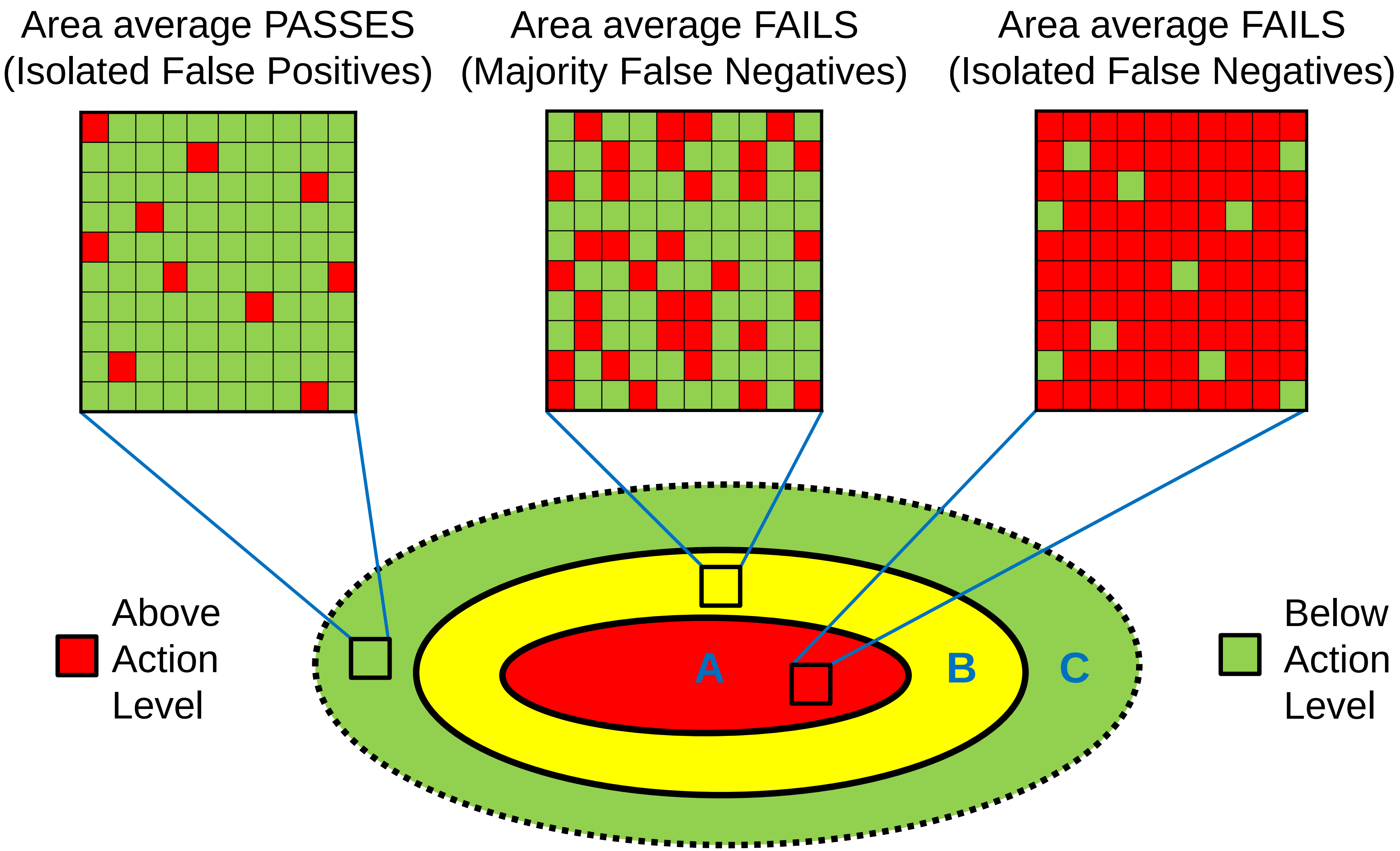
Concentrations can vary several orders of magnitude within a DU at the scale of a discrete sample

Area A. Heavy Contamination
(DU Mode and Mean Fail Action Level)

Area B. Moderate Contamination
(DU Mean Fails Action Level)

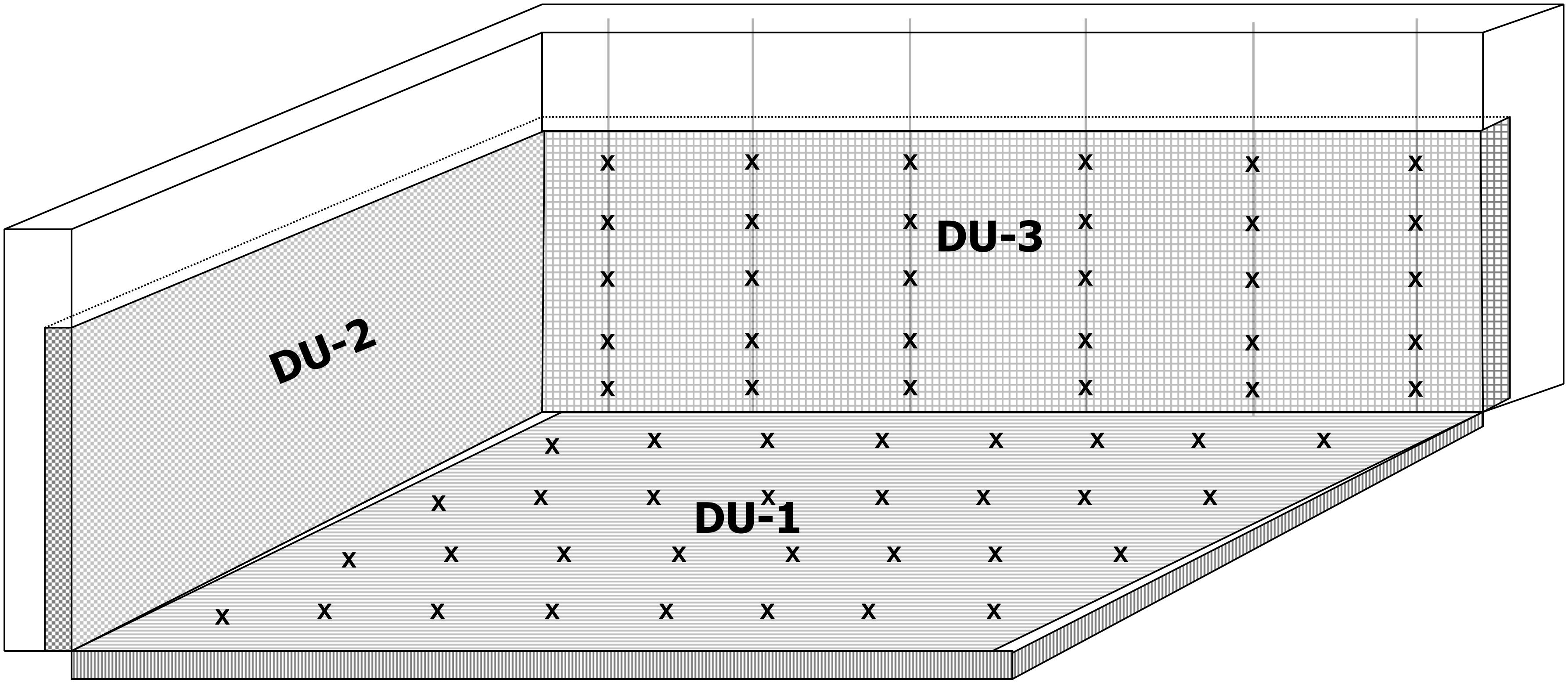
Area C. Low Contamination
(DU Mode and Mean Pass Action Level)

Why Discrete Samples Miss Contamination in the Field



Excavation Decision Units

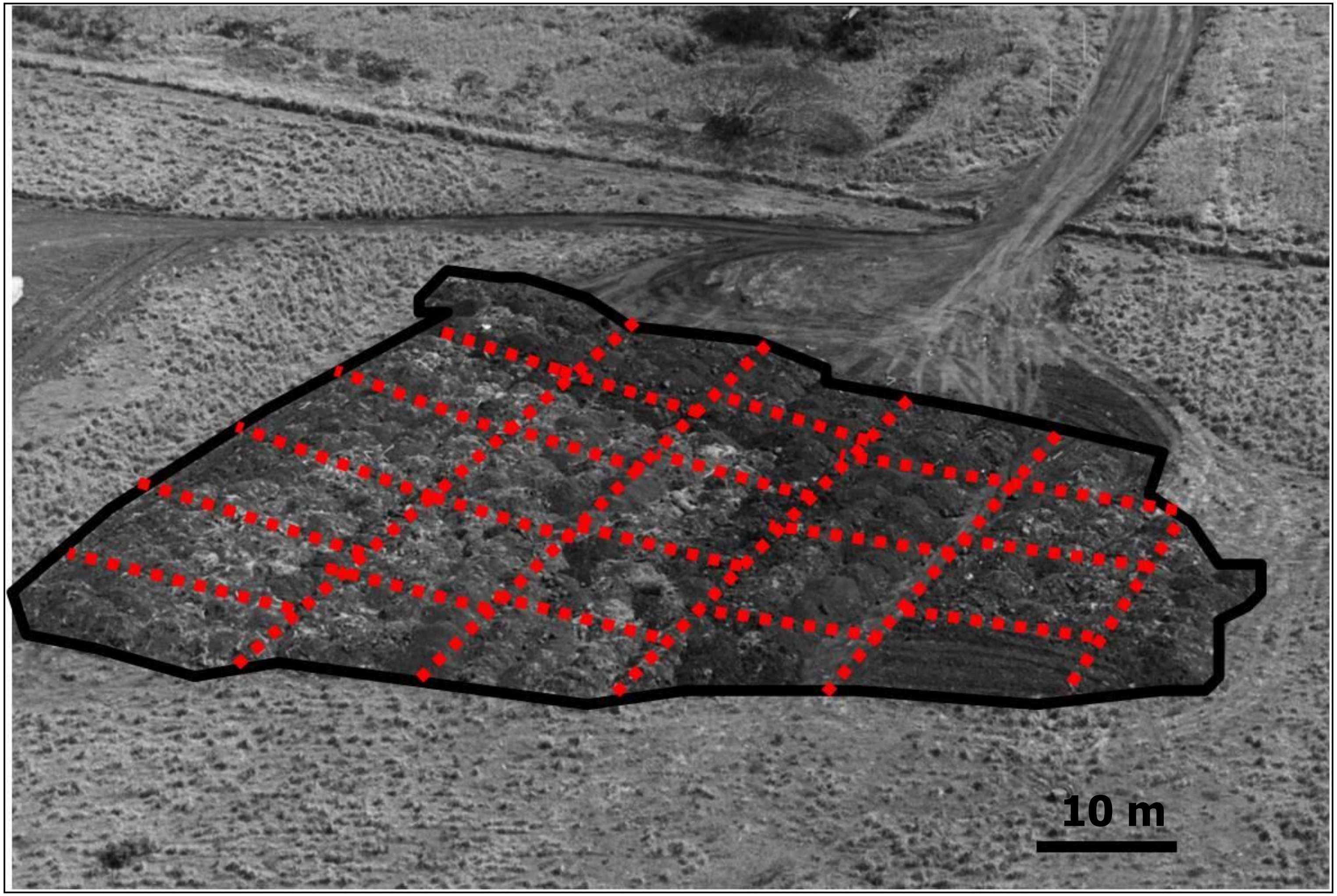
Floor and sides tested as separate DUs



X - Increment Sampling Locations

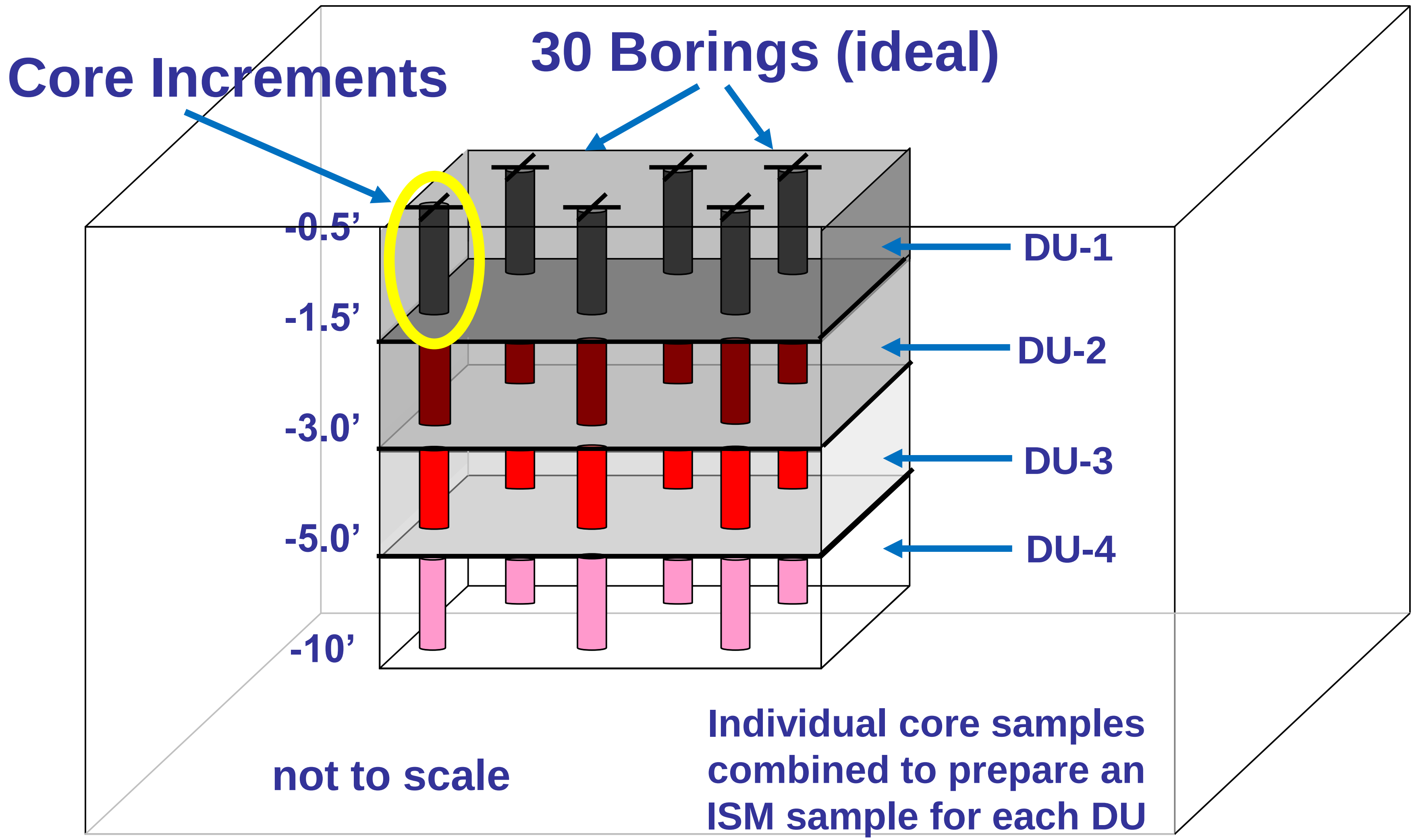
ITRC, ISM-1, Section 3.3.6 and Figure 3-11

Stockpile Decision Units



ITRC, ISM-1, Section 3.3.5 and Figure 3-10

Subsurface Decision Units



ITRC, ISM-1, Section 3.3.4 and Figure 3-8

ISM Case Study – Florida Golf Course

Decision Unit (DU) Highlights

- Determining DU size and location
  - Use all available information
  - Determine Data Quality Objectives
- Establish DUs with risk assessment and remedial goals in mind from the start
- Many random increments required (30 to 50+)
  - Capture the effects of heterogeneity
  - Characterize a DU

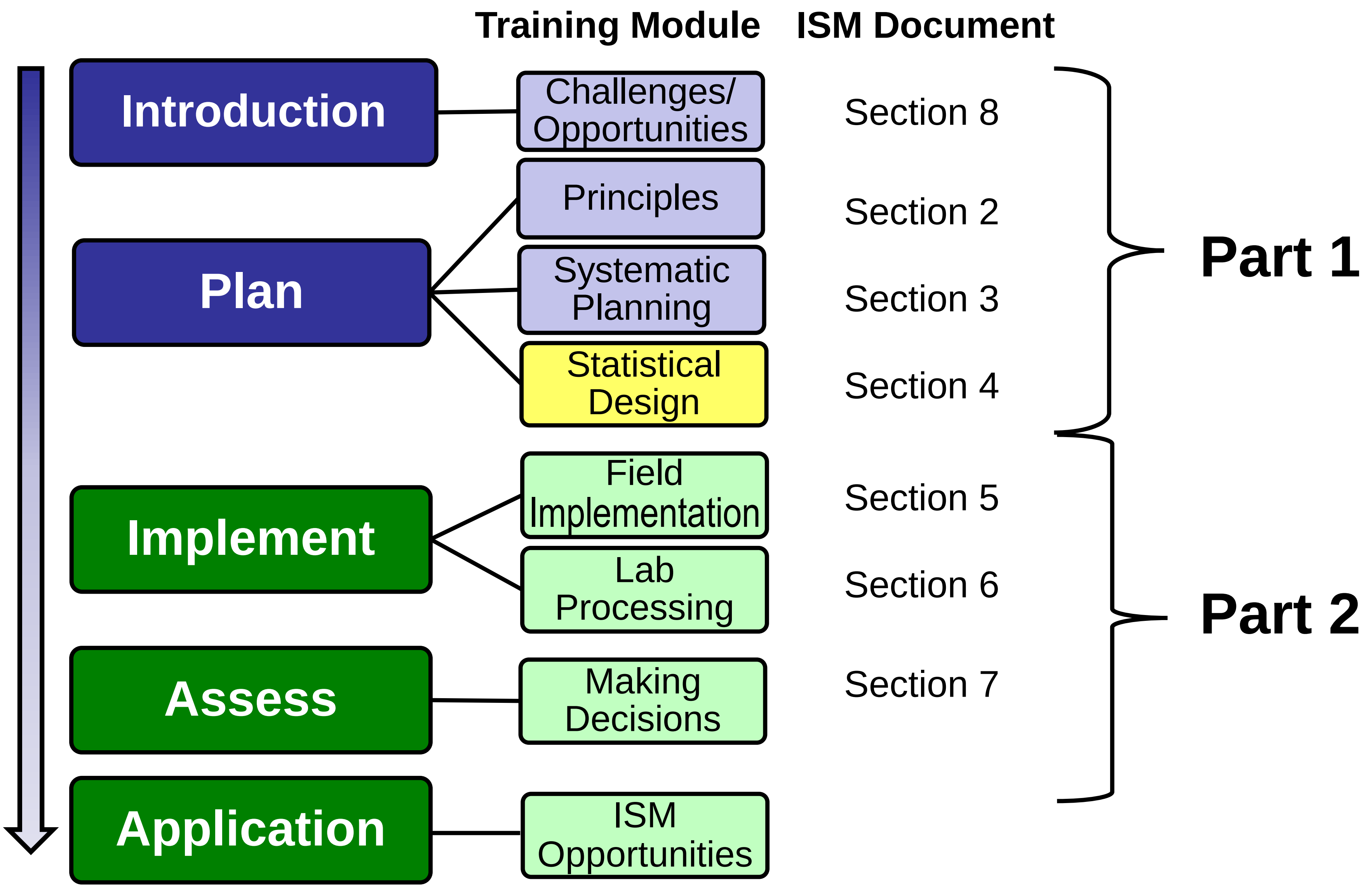
Decision Unit Highlights (continued)

- ISM samples
  - More efficient and cost effective method
  - Minimize the chance of missing hot spots in the DU
  - Represent larger volumes, i.e., DUs
- Tight grids of screening data can be useful to locate suspected source areas for better DU designation, if needed

Summary: Systematic Planning

- Conduct Systematic Planning
  - It's important to develop a CSM before beginning a sampling design
  - Be sure that your sampling design will achieve your sampling objectives
  - Be certain that your sampling design will provide the kind of data necessary to fulfill the sampling objectives
- Decision Unit designation
  - Make sure that all site information has been used to develop your DUs
  - Be sure that your scale of decision making aligns with your sampling objectives

ISM Document and Training Roadmap



Statistical Design
Learning Objectives

Learn how to

- Answer common questions about ISM related to
  - Sampling design
  - Data analysis

- Expand your understanding of
  - Statistical theory
  - Simulation studies conducted by the ITRC ISM Team

Questions – Data Analysis

1. Does a single ISM sample provide a *reasonable* estimate of the mean?

   Section 4.2.1

2. Can a 95UCL be calculated with ISM data?

   Section 4.2.2

What is the statistical foundation for ISM?

95UCL = 95% Upper Confidence Limit of the mean

Questions – Sampling Design

3. What sampling design should I use?

Section 4.3.4.2

4. Is it reasonable to assume that concentrations are similar across DUs?

Section 4.4.2

5. Can background and site data be compared using ISM?

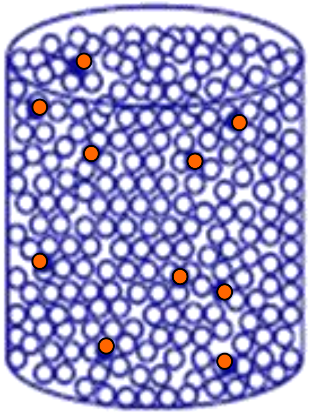
Sections 4.4.3.3 and 7.2.4

1. Does a single ISM provide a reasonable estimate of the mean?

Answer:

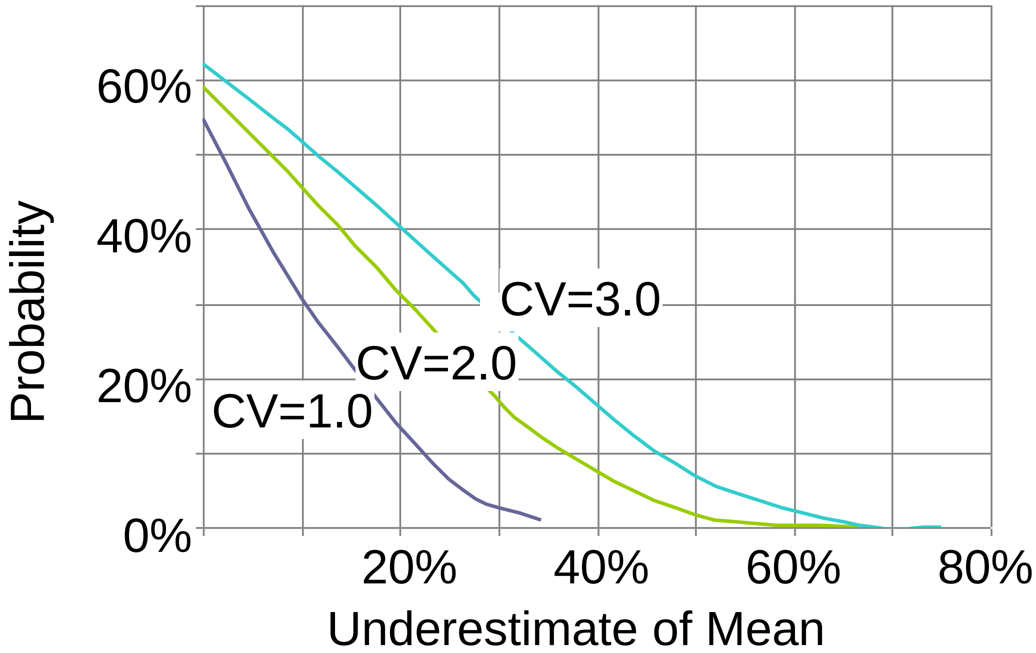
- It depends how much error we are willing to accept. Under some circumstances, one ISM sample can substantially underestimate the actual mean concentration.

- Why would someone collect just 1 ISM?
  - UCL not required by regulator
  - Save time and expense
  - Assumption that more sampling wouldn't change the decision. For example
    - Variance among individual increments is low
    - Mean of DU is far above or below an action level



ITRC, ISM-1, Section 4.2.1

1(b). How "badly" might I underestimate the mean?



CV	Frequency	Magnitude	True Mean	Estimate
1	33%	10%	400 ppm	≤ 360 ppm
2	33%	20%	400 ppm	≤ 320 ppm
3	25%	30 - 60%	400 ppm	160 - 280 ppm

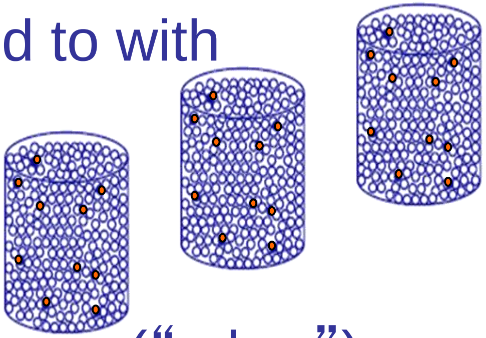
***Coefficient of variation (CV) = St Dev / mean**

ITRC, ISM-1, Section 4.2.1, Figure 4-2

2. Can a 95UCL be calculated?

Answer:
- Yes, even with as few as 3 ISM samples (replicates).

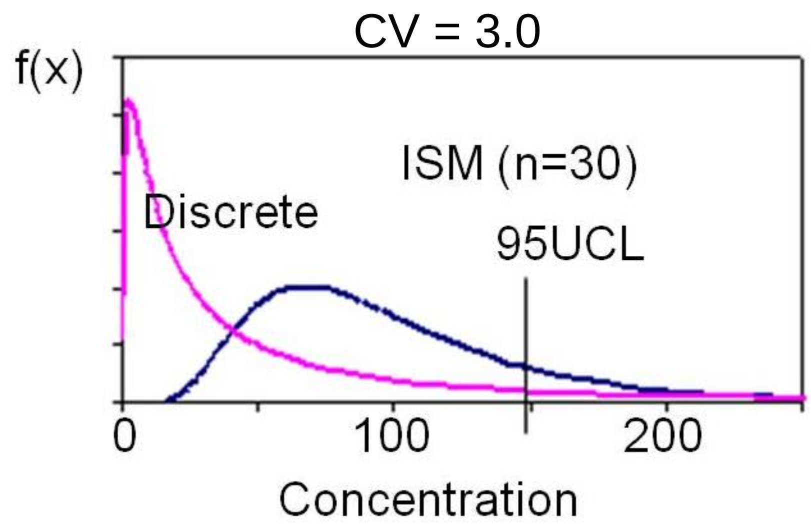
- Need at least 3 replicates (r ≥ 3)
- Supported by theory and statistical simulations
- Fewer methods are available than we are used to with discrete sampling:
  - Chebyshev
  - Student's-*t*



- Each ISM result provides an estimate of the mean ("x-bar")
- Parameter estimates are calculated directly from ISM data

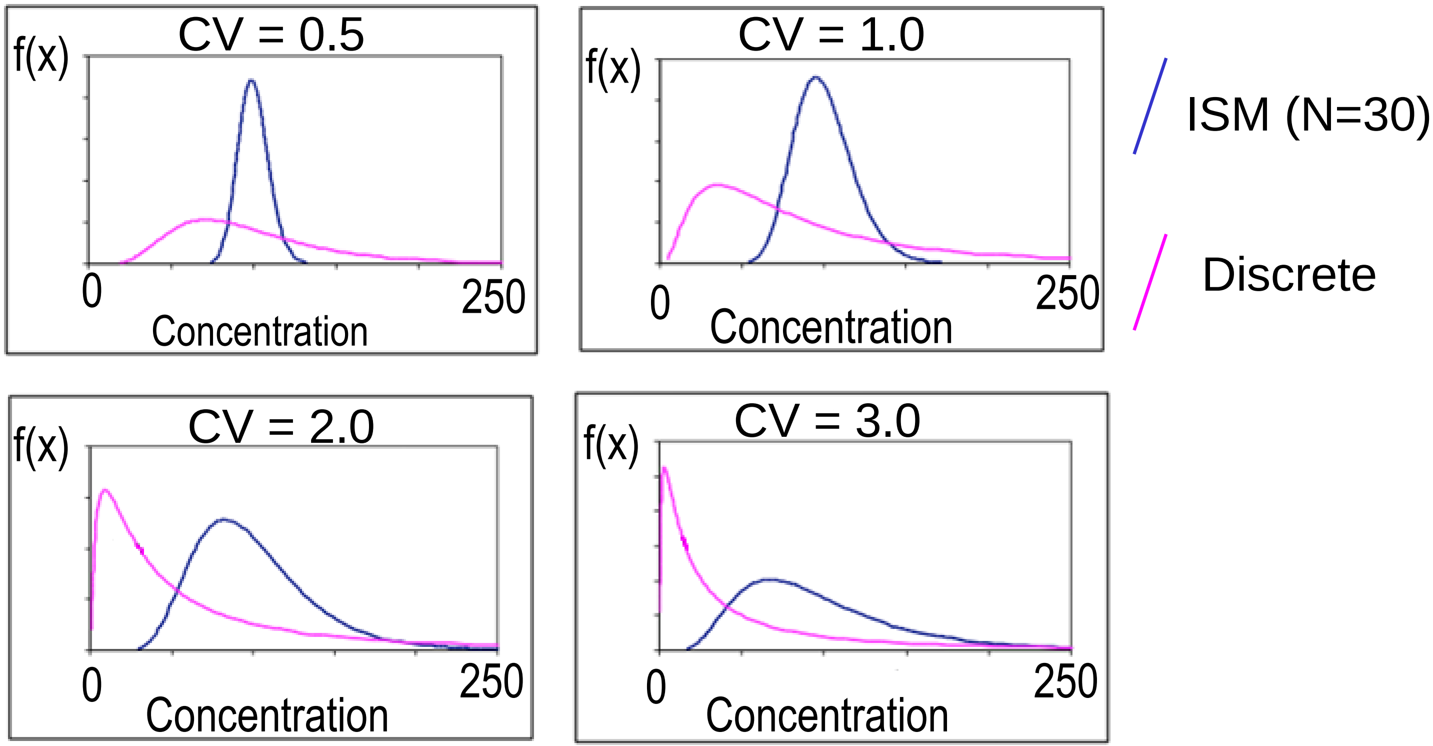
2(b). How do I choose a UCL method?

- Consider performance measures (informed by simulation study)
  - Coverage (probability UCL > mean)
  - Magnitude of difference between UCL and mean



- Recognize the key to performance is <u>variability</u>
  - Distribution of discretes ≠ Distribution of ISM results
  - CV = standard deviation / mean = 3.0 refers to distribution of discretes
  - With only ISM results, assumptions about variability are very uncertain

Distribution of Means (ISM Replicates)



- ISM distribution variance is smaller
- ISM distribution shape becomes more non-normal with increasing CV of discrete distribution

ITRC, ISM-1, Figure 4-3

Coverage Probabilities

UCL Method	Dispersion Among Individual Increments		
	Low (CV <1.5 or GSD <3)	Medium (1.5 < CV < 3 or 3 < GSD < 4.5)	High (CV >3 or GSD >4.5)
Student's-*t*	Yes	No	No
Chebyshev	Yes	Yes	Maybe

CV based on underlying distribution of increments

- Both methods provide desired 95% coverage when variability is low
- Chebyshev has more consistent 95% coverage for medium and high variability
- Increasing *r* (>3) and n (>30) provides marginal improvement in coverage for Chebyshev, but no improvement for Student's-*t*

ITRC, ISM-1, Table 4-4, Sections 4.3; Appendix A

How much higher is Chebyshev?

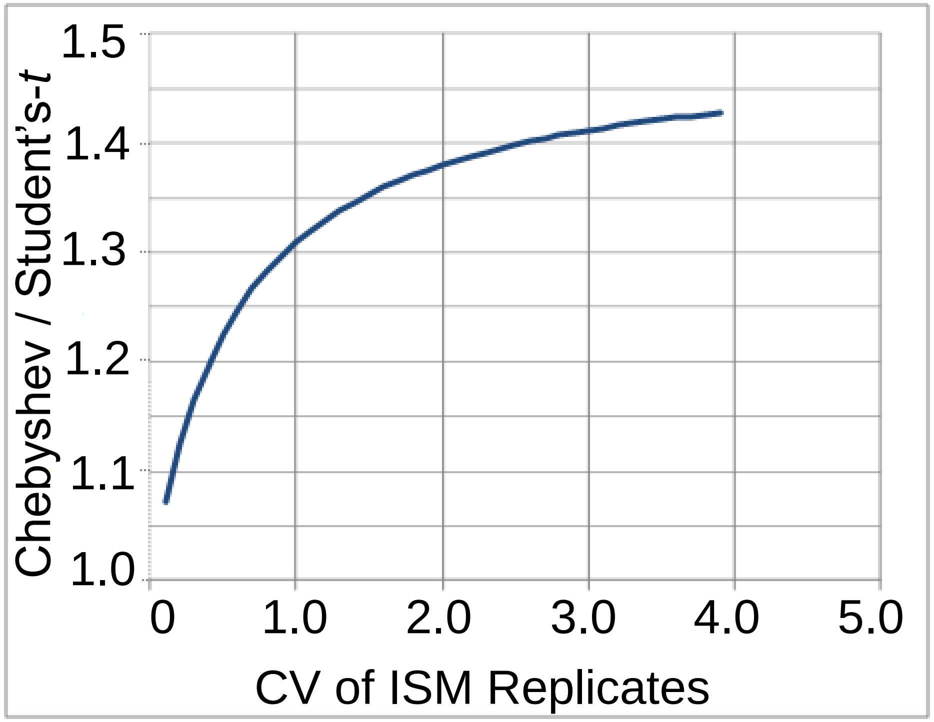
- Chebyshev will tend to yield 10-45% higher UCLs than Student's-*t* depending on the CV of 3 replicates
- Example: Student's-*t* = 100 ppm, Chebyshev = 110 -145 ppm

Chebyshev

$$UCL = \overline{X} + \left(\sqrt{\frac{1}{\alpha} - 1}\right)\frac{s_{\overline{x}}}{\sqrt{r}}$$

Student's-*t*

$$UCL = \overline{X} + t_{1-\alpha, r-1} \times \frac{s_{\overline{x}}}{\sqrt{r}}$$



ITRC, ISM-1, Section 4.3.1.1

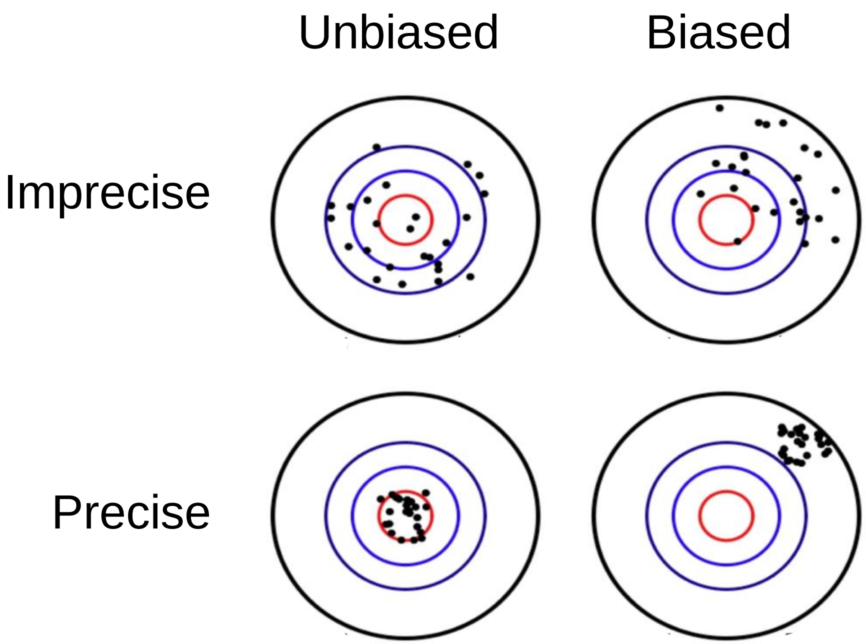
2(c). Can I use ProUCL to calculate the 95UCL?

Answer:

- EPA is updating ProUCL to include an ISM module. Visit the ITRC website for additional tools.

- ProUCL was originally designed to work with discrete sample data, but is being updated to include an ISM module.
- Only Chebyshev and Student's-t UCLs are implemented for ISM datasets.
- ITRC guidance has calculator tools that work for ISM data (see ISM-1, Sections 4.2.2 at http://www.itrcweb.org/ism-1/4_2_2_UCL_Calculation_Method.html).

Bias and Precision



- Accuracy reflects both bias and precision (reproducibility)
- These are metrics of the performance *on average*. They can only be assessed through simulation of many hypothetical sampling events – not by the results of any single ISM sampling event

ITRC, ISM-1, Section 4.3.1, Figure 4-6 and Appendix E

Components of the RSD

Field

- Number of increments
- Increment collection
- Field processing
- Field splitting
- DU size and shape

Laboratory

- Lab processing
- Subsampling
- Extraction
- Digestion
- Analysis

- Simulations used to explore alternative sampling designs did not attempt to isolate sources of error
- In Day 2 of ISM training, methods will be presented for quantifying and reducing relative errors associated with field and lab practices that contribute to RSD

2(d). What can we infer from the RSD?

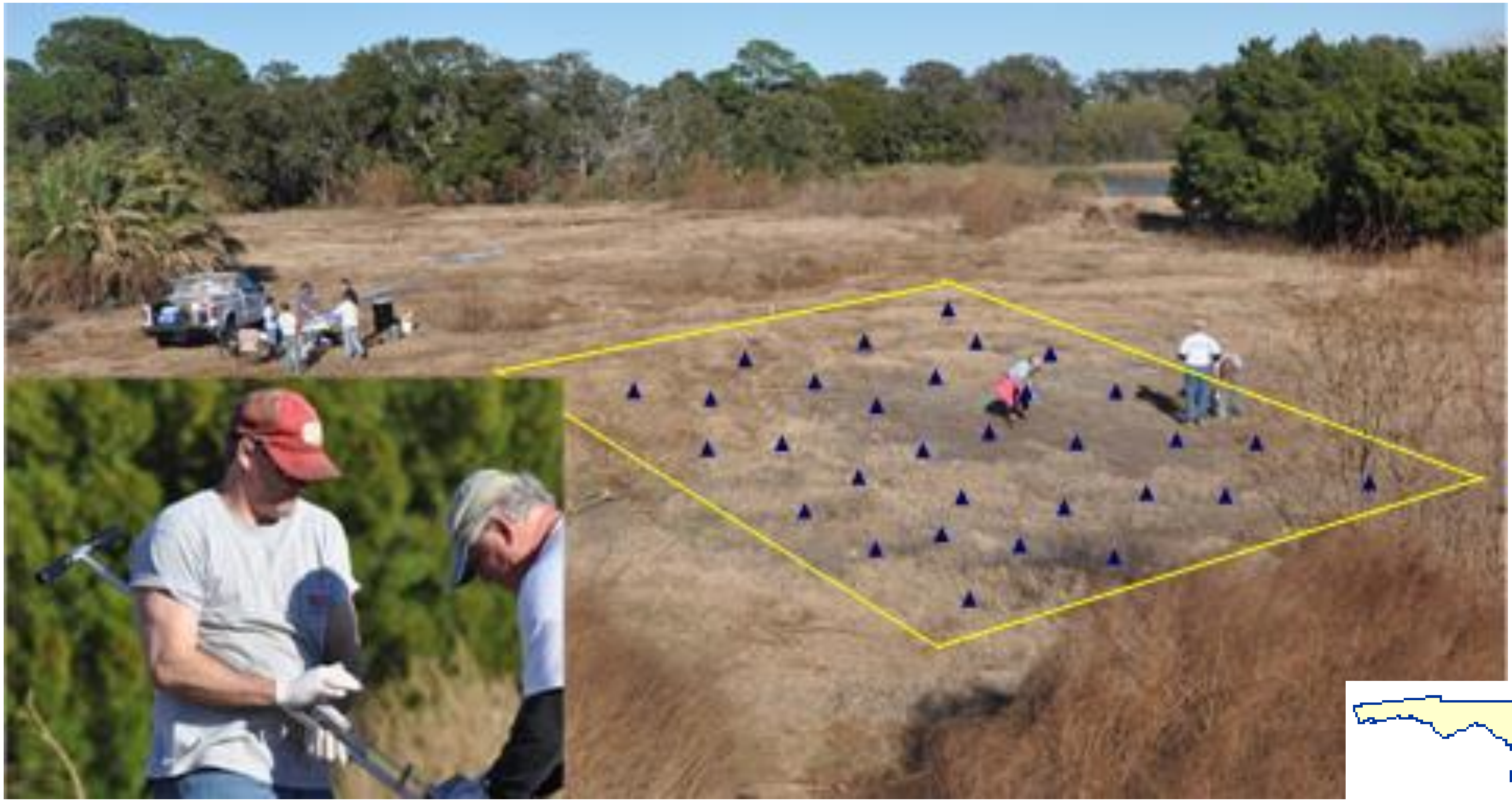
Answer:

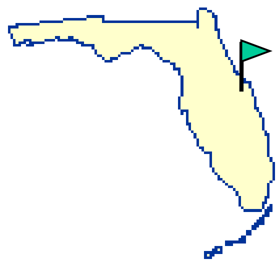
- Without data to quantify sources of lab and field error that contribute to RSD, it is difficult to be conclusive. We expect that low RSD is an indication that steps to reduce error are successful. The 95UCL coverage does not depend on the RSD.

- RSD is the ratio of statistics calculated from ISM replicates
  - RSD = SD / mean
- If the goal is to make sure that the mean is not underestimated, a 95UCL should be calculated regardless of whether the RSD is high or low

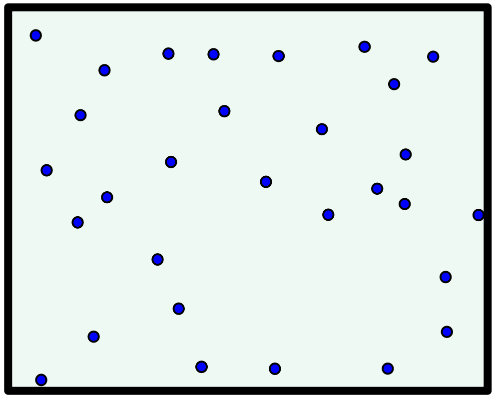
ITRC, ISM-1, Section 4.3.4.4

3. Is there a preferred ISM sampling design?

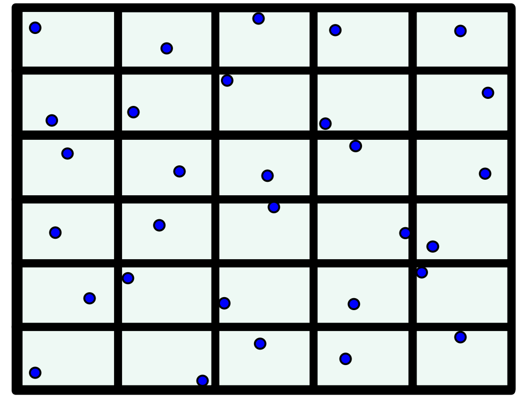




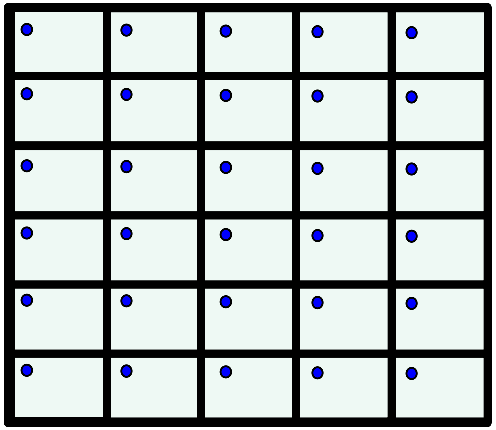
3. Is there a preferred ISM sampling design?



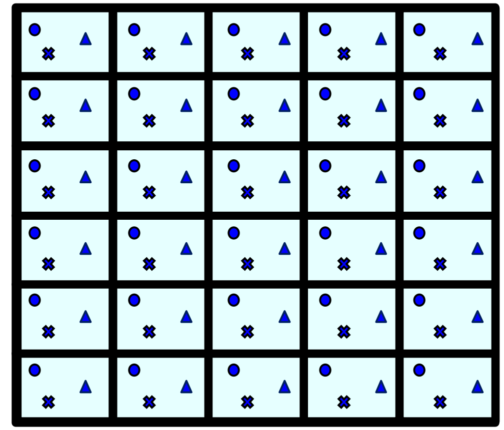
Simple Random



Random within Grid



Systematic



Systematic (3 replicates)

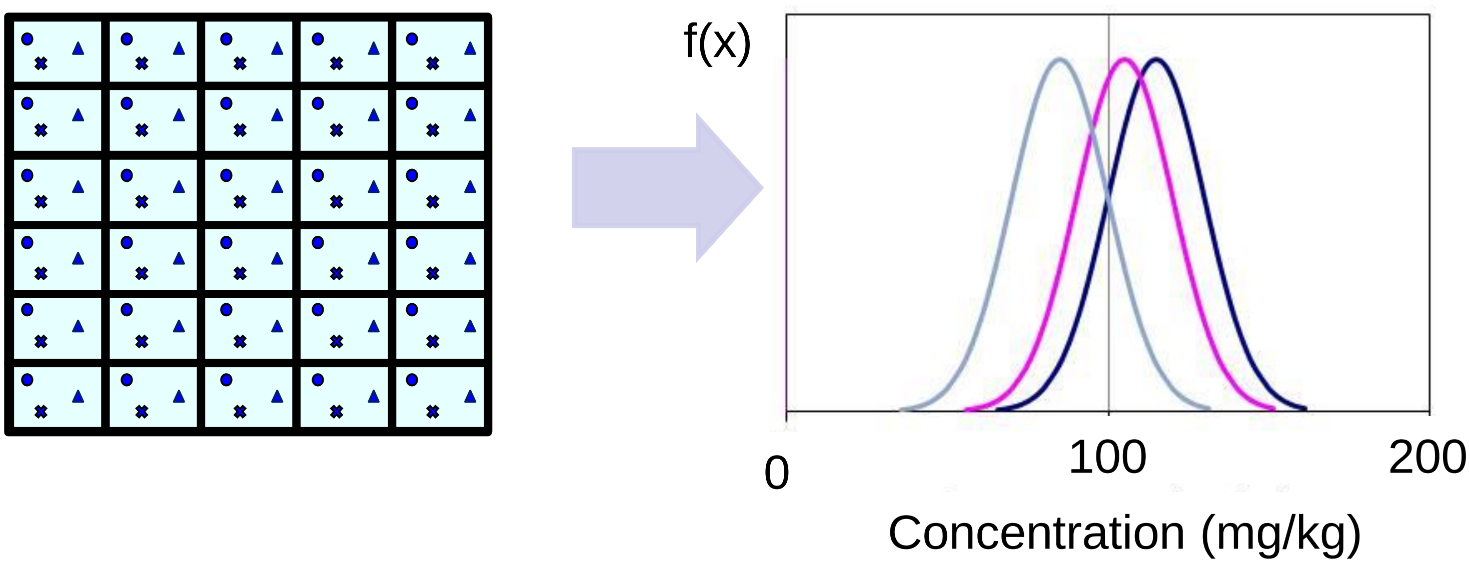
ITRC, ISM-1, Section 4.3.4.2

3. Is there a preferred ISM sampling design (continued)?

Answer:

- Each random sampling design yields unbiased estimates of the mean and is an acceptable approach in most situations.

- Systematic random sampling is most often used because it is the easiest to implement



ITRC, ISM-1, Section 4.3.4.2

3(b). How many increments?

Answer:

- n = 30: generally, 30 increments per ISM sample provide good results. Lower numbers are discouraged and higher numbers provide diminishing improvement in statistics.

- As the number of increments increases:
  - spatial coverage improves (greater sample density)
  - lower variability in ISM results (smaller standard deviation)
  - 95UCL will tend to be closer to the mean
- Size of DU can be a consideration – large DUs may require more increments

10 20 **30** 40 50 60 70 80 90 100

ITRC, ISM-1, Sections 4.3.4.1 and 5.3.1

3(c). How many replicates?

Answer:

- r =3 : for most DUs, three replicates is sufficient.

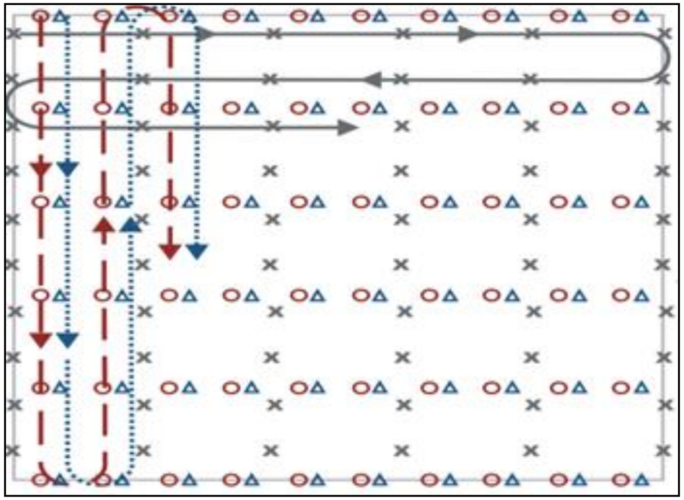
- Minimum number to calculate standard deviation (and 95UCL) of ISM results
- More replicates will produce a 95UCL closer to the actual mean, but may not be cost-effective unless the result is near the action level

Which Would You Choose and Why?

A. n = 30, r = 1

B. n = 90, r = 1

C. n = 30, r = 3 (so 30 x 3 = 90)



Scenario	Spatial Coverage	Analysis Cost	Estimate of Mean	Estimate of Variance
A	Low	Low	Yes	No
B	3 x A	A	Yes	No
C	3 x A	3 x A	Yes	Yes

4. Can I extrapolate results across DUs?

- Unsampled DU – extrapolate estimate of mean
- DU with 1 ISM – extrapolate estimate of variability
  - Standard deviation (SD)
  - Coefficient of variation (CV)

DU-1 $\stackrel{?}{=}$ DU-2

ITRC, ISM-1, Section 4.4.2

4(b). Extrapolation of the Mean

Answer:

- You are assuming that the mean concentration in the unsampled DU(s) is the same as in the sampled DU.

DU-1 =? DU-2

- DU-1:
  - Mean = 100
  - SD = ?
- DU-2:
  - Extrapolation: Mean = 100

4(c). Extrapolation of the Variance

Answer:

- You are assuming that the heterogeneity in contaminant concentrations is similar in all of the DUs.

DU-1 $\stackrel{?}{=}$ DU-2

- DU-1:
  - Mean = 100
  - SD = 50
  - CV = SD/mean = 50/100 = 0.5

- DU-2:
  - Mean = 400
  - Extrapolation:

    CV = 0.5 = x / 400

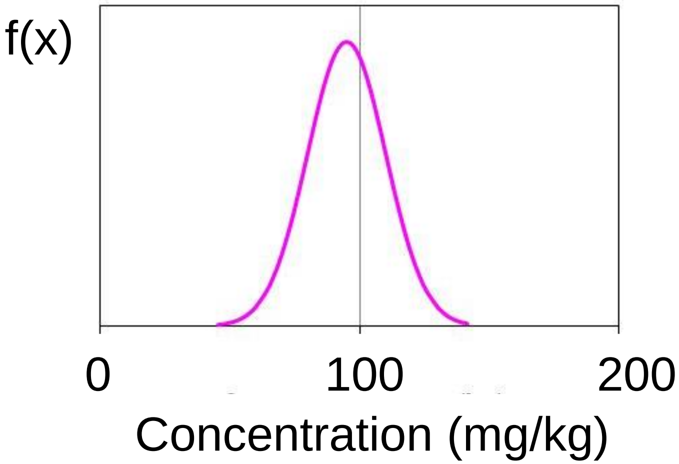
    therefore

    SD = x = 200

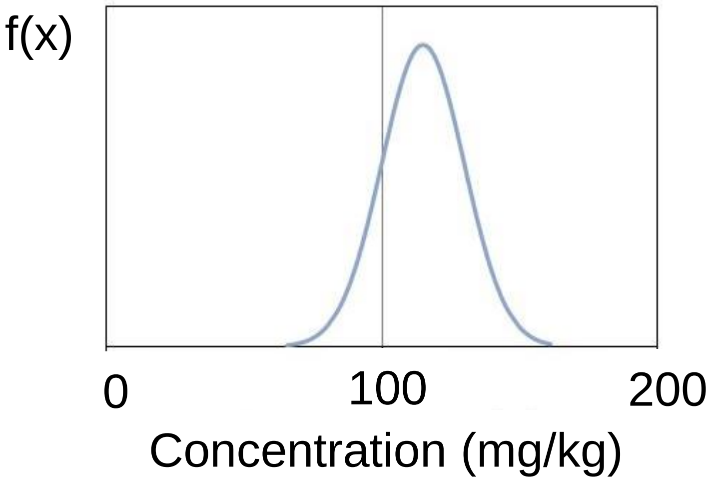
5. Can background and site ISM data be compared?

Answer:

- Yes, but statistical tools for comparison are limited.



Background



DU-1

- Each data sets consists of ISM samples, preferably generated with similar sampling designs

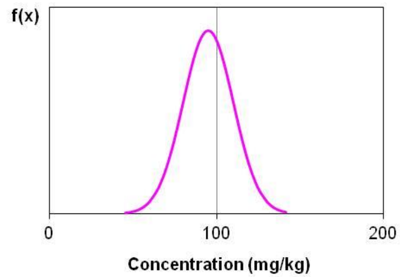
ITRC, ISM-1, Section 4.4.3.3

5. Can background and site ISM data be compared?

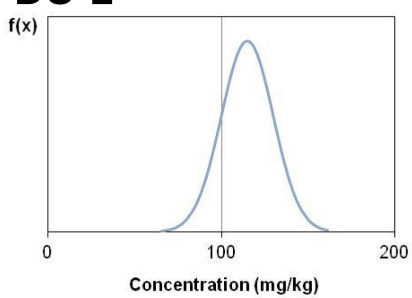
Answer:

- Yes, but statistical tools for comparison are limited.

Background



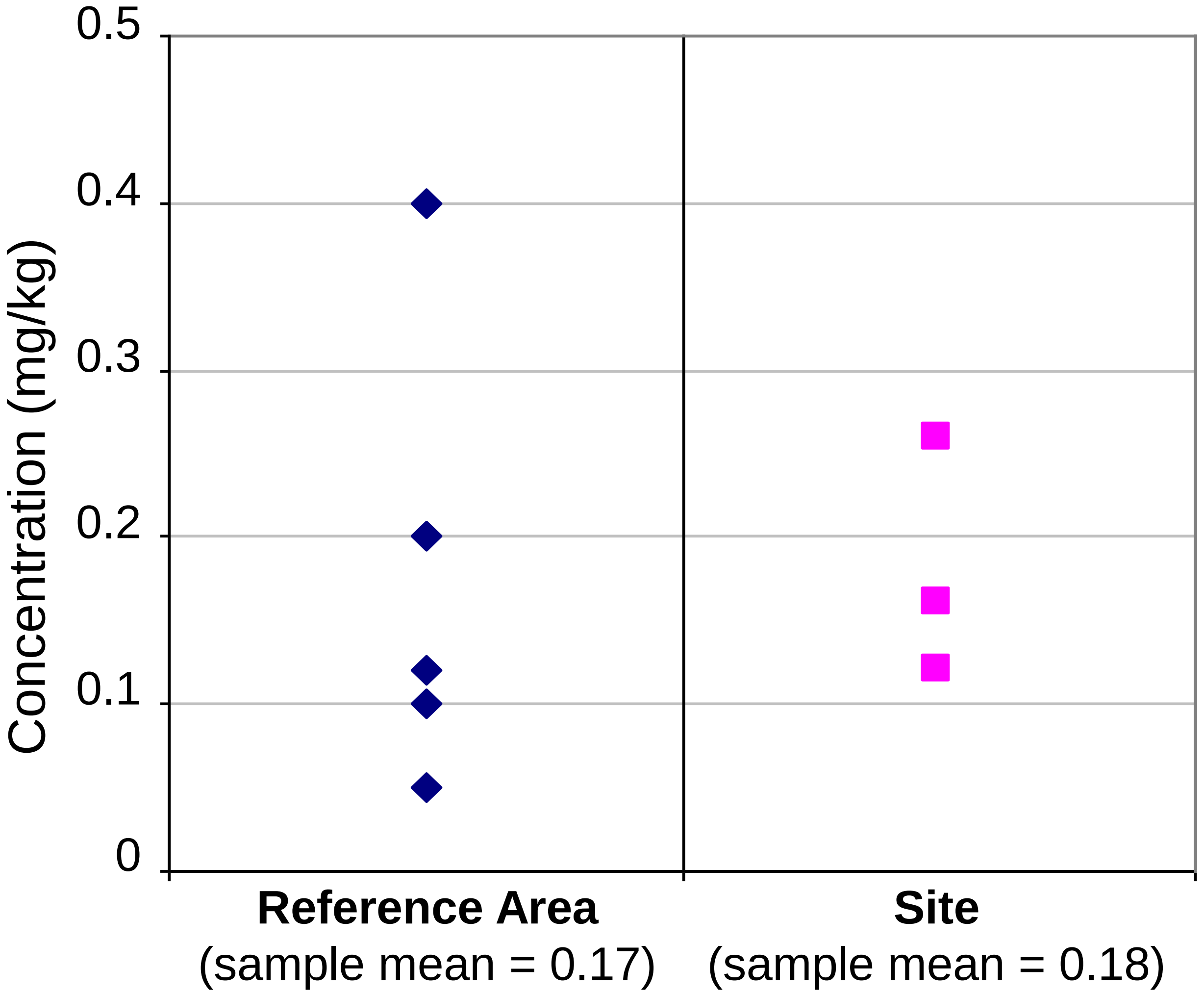
DU-1



- Equal central tendency (mean, median) ?
- Equal upper tails ?
- Hypothesis testing is limited to parametric tests of the mean:
  - Assume distribution shape
  - Use estimates of mean, SD, and number of replicates
- Cannot test upper tails with ISM data

ITRC, ISM-1, Section 4.4.3.3

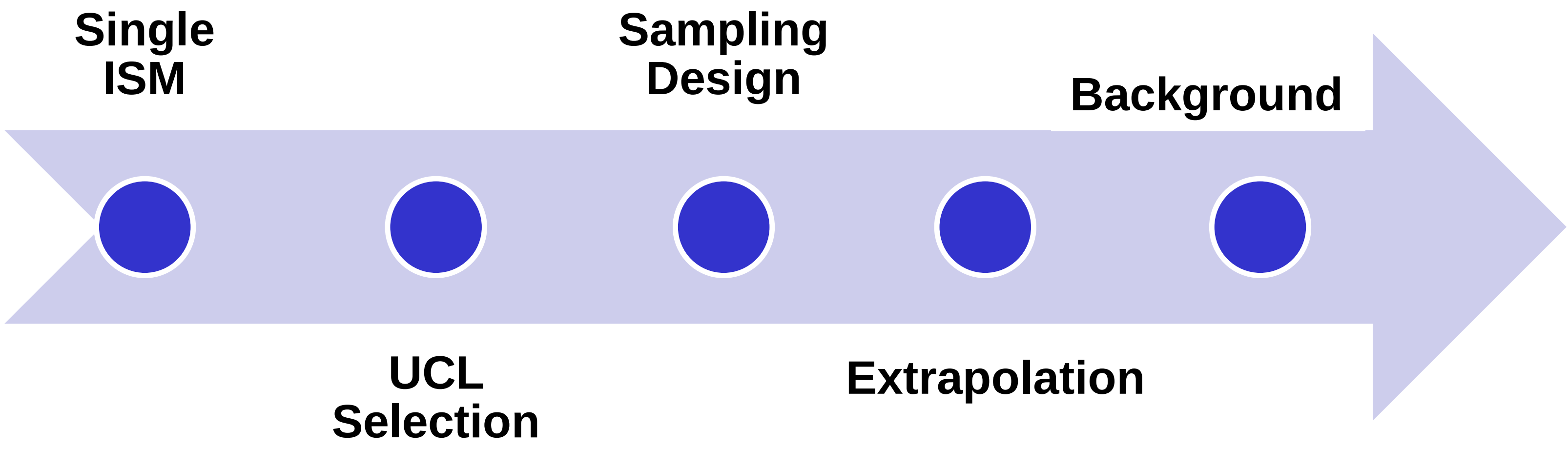
5. Example Background Comparison



ITRC, ISM-1, Section 7.2.4, Figure 7-1

Recap of Learning Objectives

See: Section 4 and Appendix A



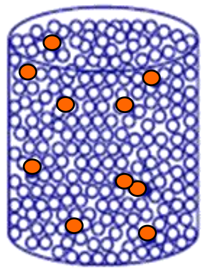
Summary: Statistical Design

- Mean or 95UCL from ISM data may be used to make decisions about a site
- 3 replicate samples provide adequate information to calculate a 95UCL
- Systematic random sampling is most commonly used
- About 30 increments per ISM sample is usually sufficient
- Extrapolation of the mean or variance can be very uncertain
- Comparisons between ISM data (e.g., site vs. background) are possible, with caution

ISM Part 1 – Summary
Principles, Systematic Planning, and Statistical Design

Plan

Principles

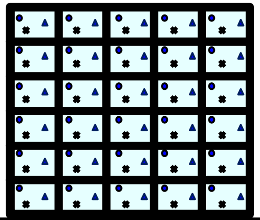


Reduce Sampling Errors
- Heterogeneity Rules!

Systematic Planning

Plan, Plan, Plan
- Involve the entire team
- Know your site
- Know your objectives
- Focus your decisions

Statistical Design



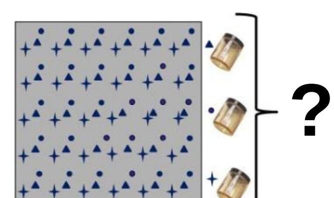
Design for Confidence
- The mean is the goal!
- Collect replicates to calculate UCL

ISM Part 2 Preview
Implement, Assess, and Apply

Implement
- Field Implementation
  - Collect an ISM Sample

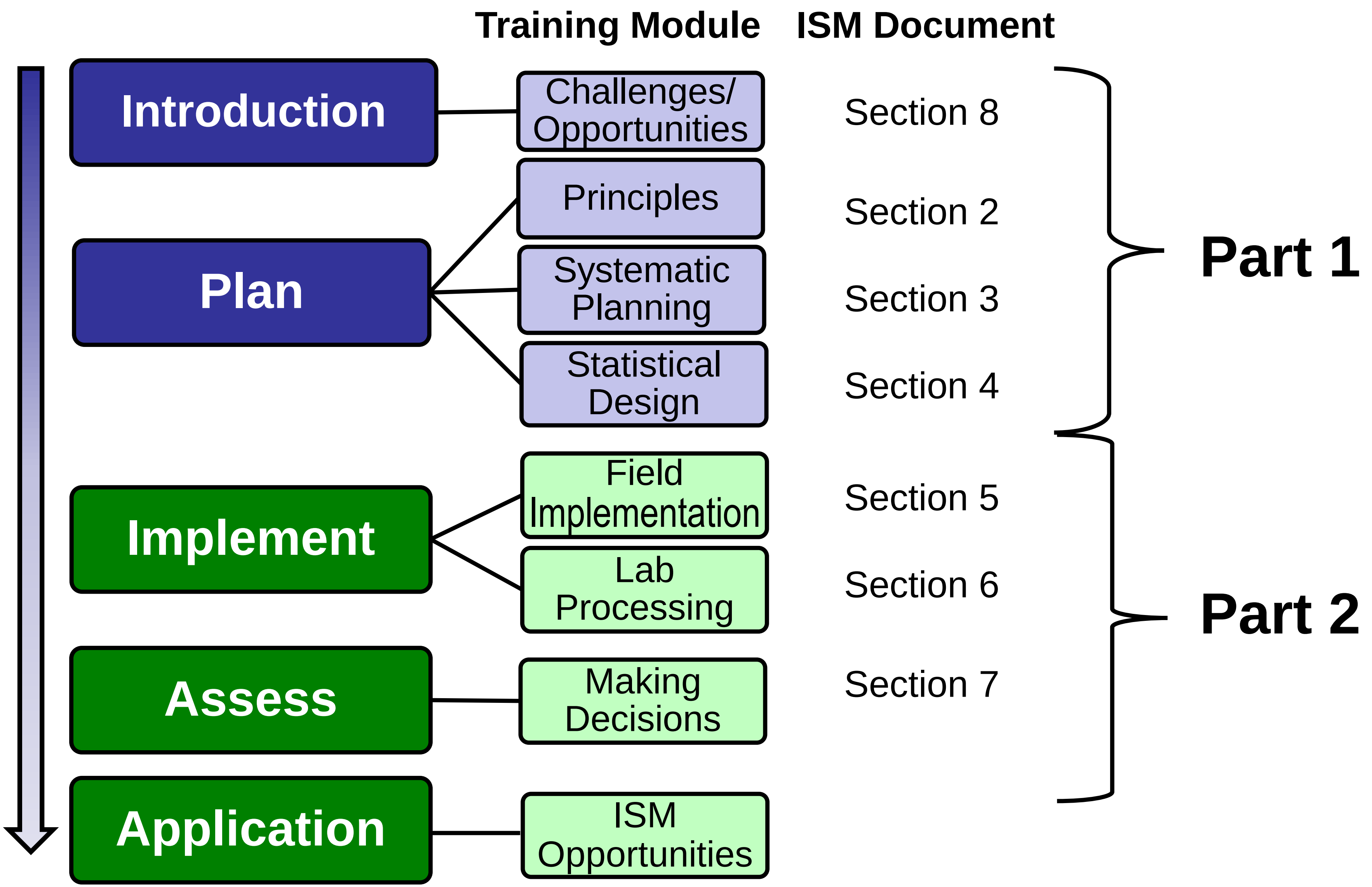
- Lab Processing
  - Match Lab Process to Analytes and Objectives

Assess
- Making Decisions
  - Decision Mechanisms and Data Evaluation



Application
- ISM Opportunities
  - Where to Apply ISM

ISM Part 1 Summary and Part 2 Preview

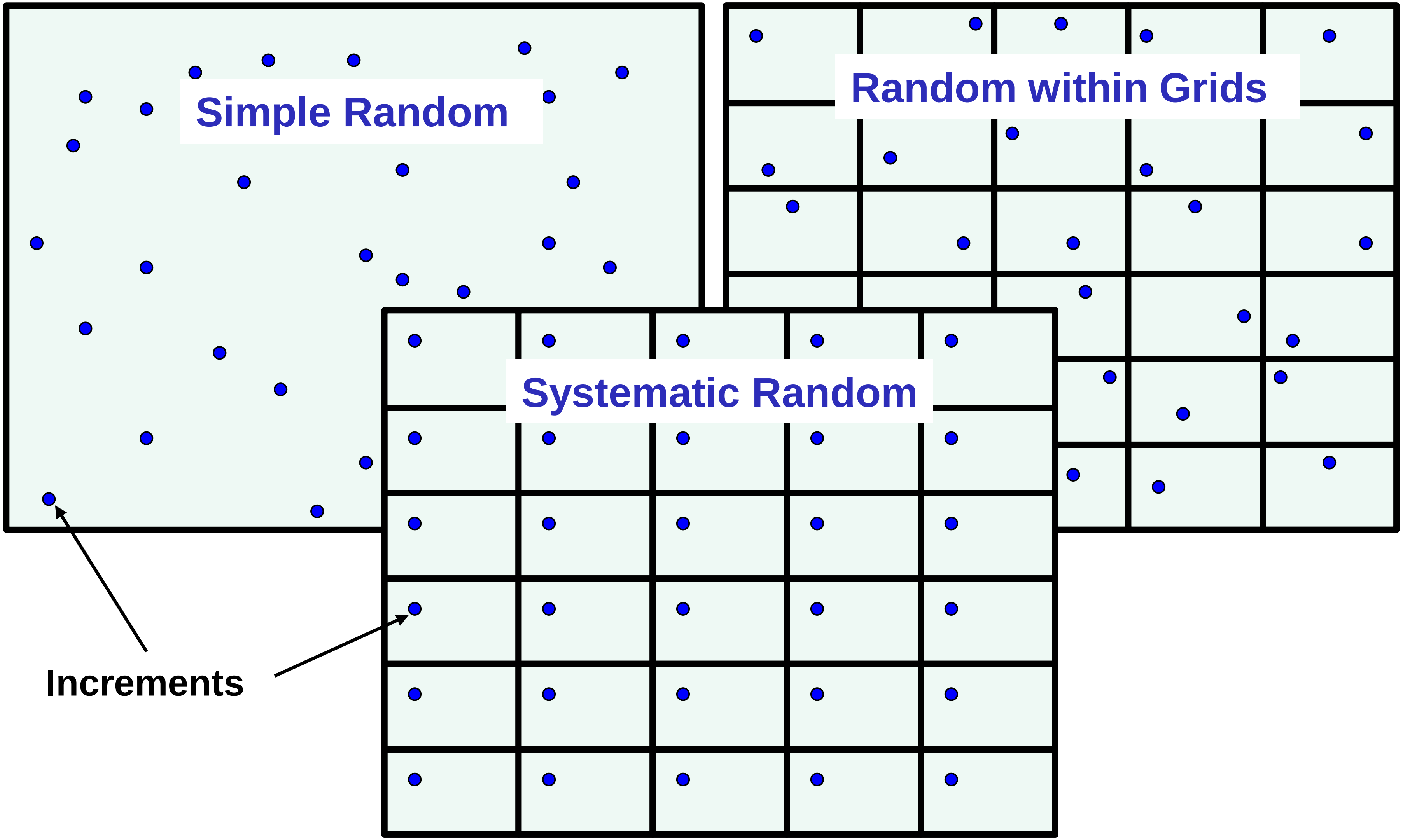


Sample Collection Components

- Decision Unit (DU) sampling design
  - Simple random sampling
  - Random sampling within a grid
  - Systematic random sampling
- Sampling tools
  - Core shaped
  - Adequate diameter
- Mass
  - Increment mass
  - Sample mass

ITRC, ISM-1, Section 4.3.4.2

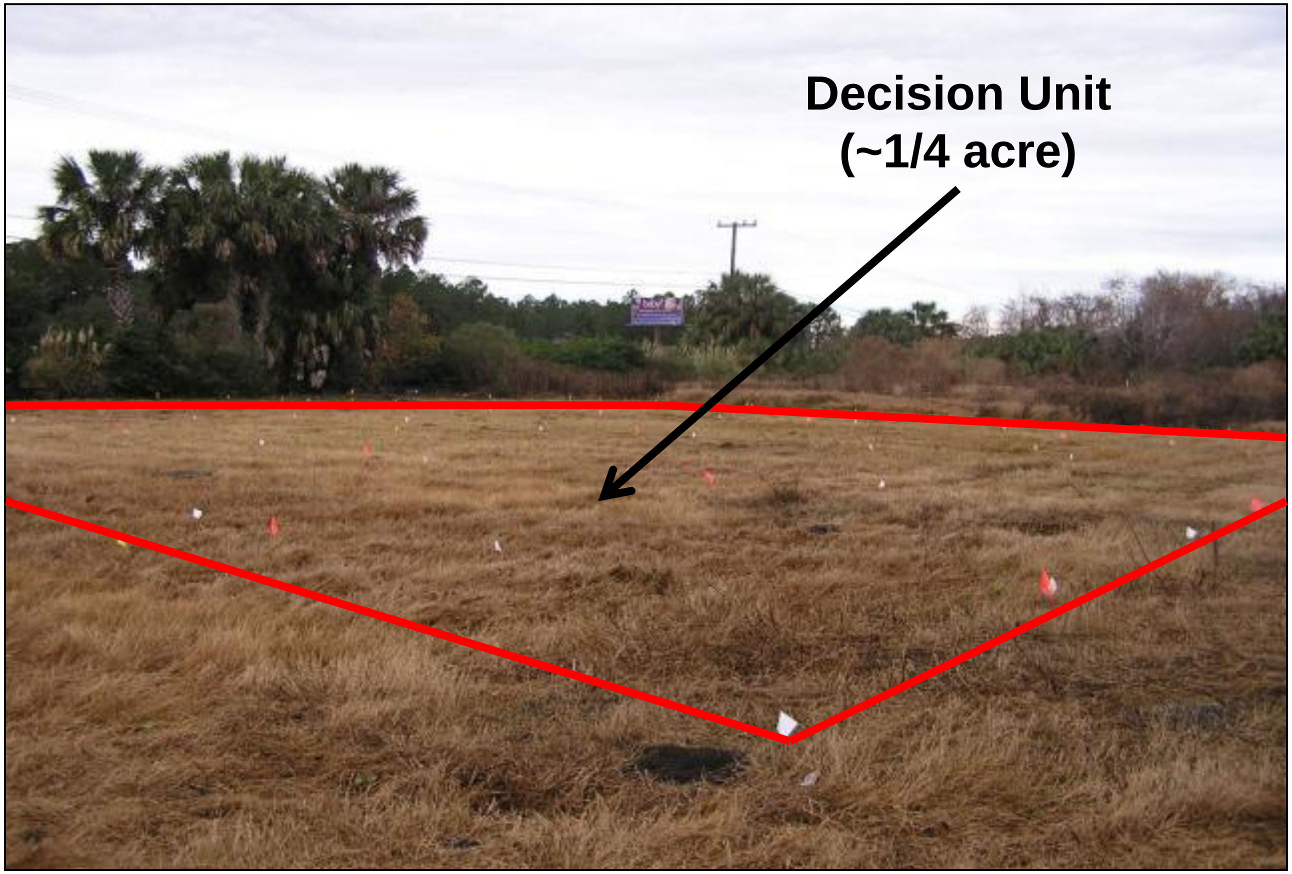
Sampling Designs

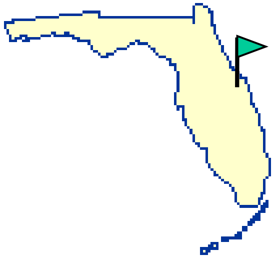


ITRC, ISM-1, Section 4.3.4.2 & Section 5.3.1, Appendix A1

Florida Case Study: Decision Unit (DU) Identification

- Identify DU in the field
  - Use typical environmental site investigation procedures
  - Examples
    - Survey
    - GPS
    - Swing ties



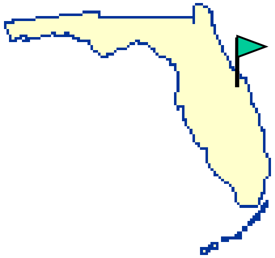


Increment Locations

- Identify increment locations in field
  - Utilize similar site investigation tools

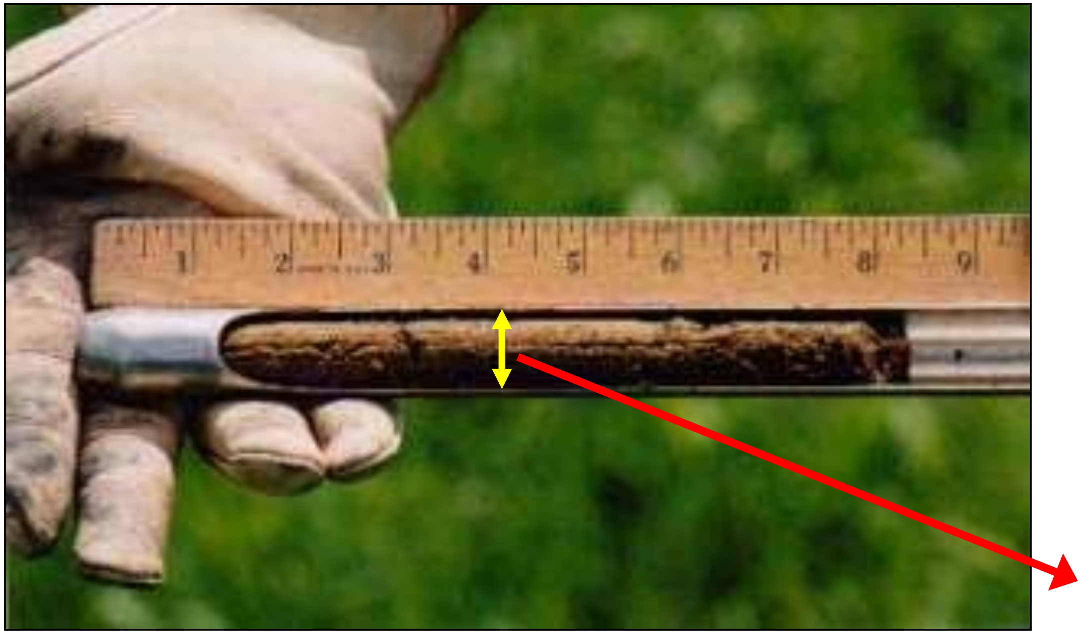
ITRC, ISM-1, Section 5.3.1

Florida Case Study:
Increment Field Determination



Sampling Tool Considerations

- Criteria - shape
  - Cylindrical or core shaped increments
  - Minimum diameter required – based on particle size (soil fraction) of interest



e.g., core diameter >16 mm

Additional Considerations

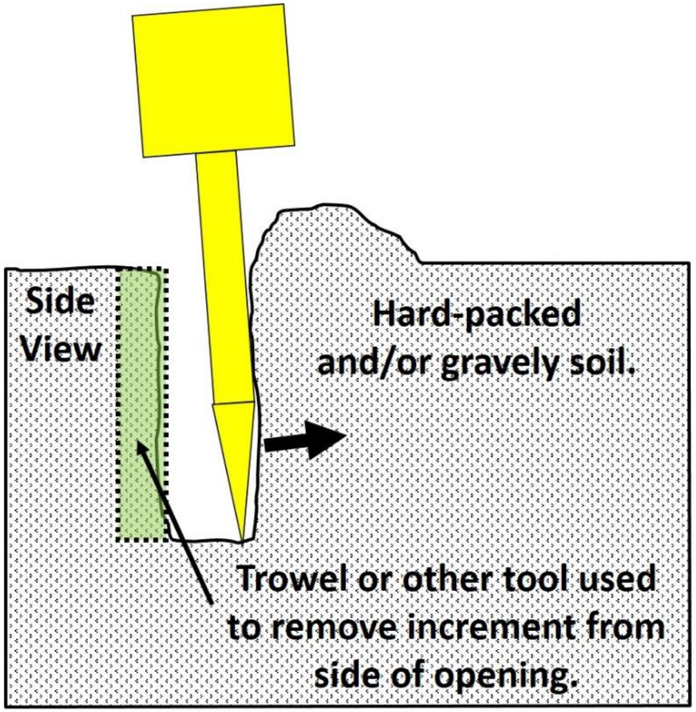
- Decontamination
  - Not necessary within DU (including replicates)
- Sampling tool
  - Appropriate for matrix and contaminant of interest

Sampling Tool Examples

Soft Surface Soil

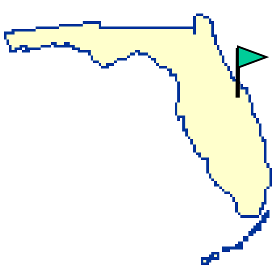
Source: Courtesy http://www.jmcsoil.com/index.html
http://fieldenvironmental.com/evc-incremental-sampler.php

Alternate Sampling Tools

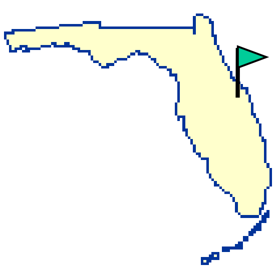


Hard-Packed or Gravelly Soil

Florida Case Study: Field Sampling



Florida Case Study:
"Low Tech" Sampling Tools



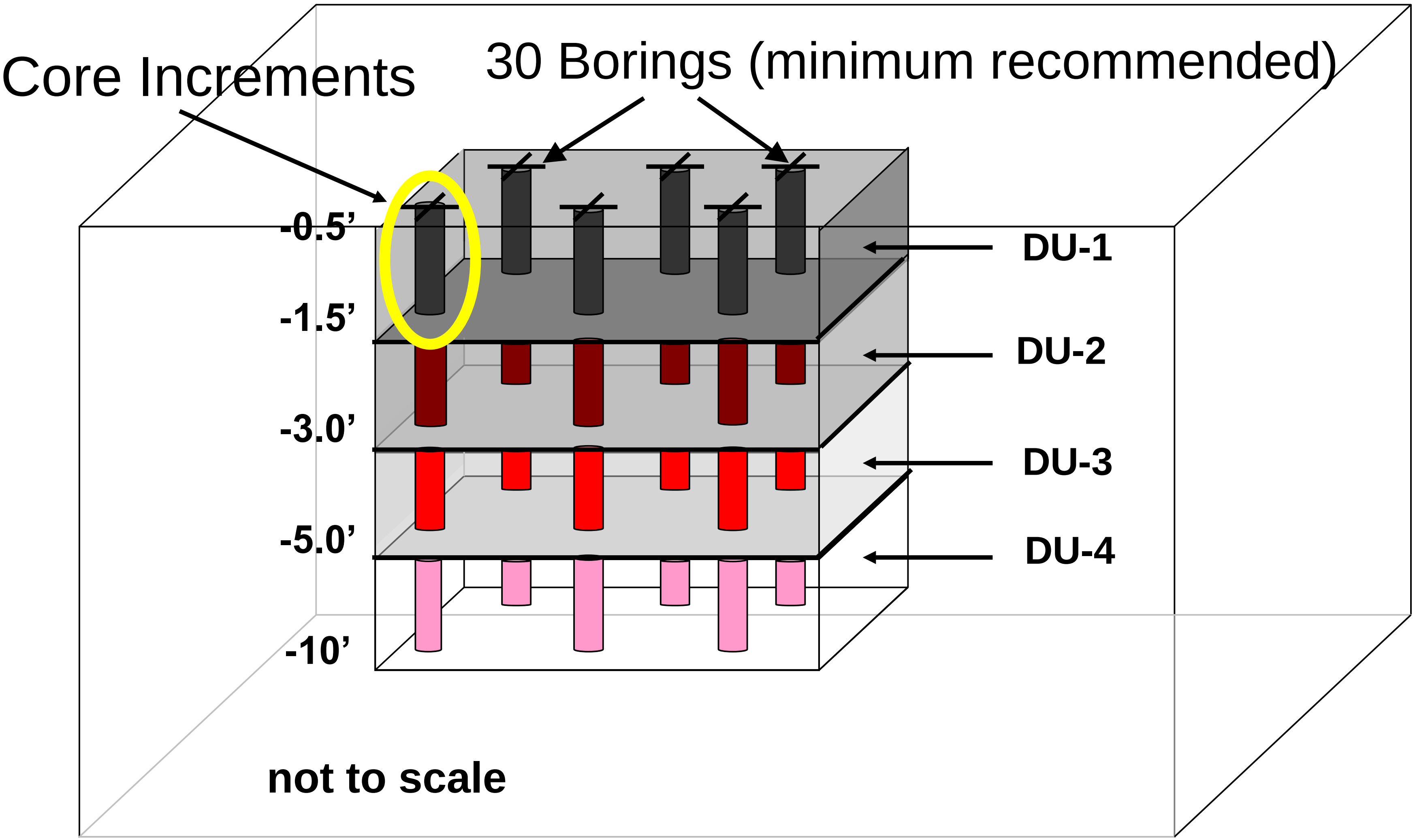
Adequate Sample Mass

- Criteria – mass (non-volatile)
  - Recommended mass per increment: 20-60 grams
  - Final ISM samples: generally 600-2,500 grams

$M_s = \rho \cdot n \cdot D_s \cdot \pi \cdot (q / 2)^2$
M_s – targeted mass of sample (g)
D_s – increment length (cm)
n – number of increments
ρ - soil or sediment density (g/cm^3)
q - diameter of sample core (cm)

ITRC, ISM-1, Section 5.3.1

Subsurface Decision Units (DU)



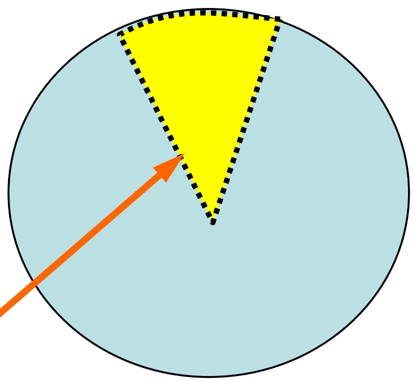
Individual core samples *combined* to prepare an ISM sample for each DU

Subsurface Sampling Considerations

- **Preferred increment – entire core interval**
- Core subsampling alternatives
  1. Core wedge
  2. Core slice

ITRC, ISM-1, Section 5.3.2

Core Wedge



e.g., wedge width >16 mm

Continuous wedge removed from entire length of targeted DU interval for 100% coverage

Core Slice

Core Slice removed from randomly selected interval length of targeted DU depth

ITRC, ISM-1, Section 5.3.2.1

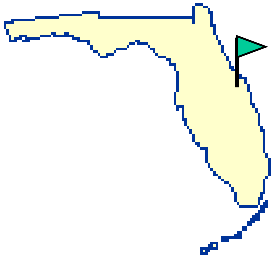
Field Processing for Non-Volatiles

- ISM sample processing in a controlled laboratory environment is recommended to reduce error
- Field processing may be applicable if project specific DQOs can be met

ITRC, ISM-1, Section 5.4.1

Florida Case Study:
Non-Volatile ISM Sample Logistics

- Final ISM samples: typically 600-2,500 grams or more
  - Containers, storage, shipping
- Laboratory
  - Facilities and equipment for correct processing and subsampling



ISM Volatile Sampling Tools

- Core type sampler
- Typical for VOC soil sampling per SW846 5035A

ITRC, ISM-1, Section 5.4.2

Source: Courtesy www.ennovativetech.com

ISM Volatile Samples – Subsurface

- Each core represents an *increment* from the DU Layer
- Subsamples of increment collected from each core to prepare bulk sample (e.g., 5g plug every 5cm, total subsample mass 20-60g to produce bulk ISM sample)



ISM Volatile Sample Logistics

- VOC preservation and analysis
  - Increments are extruded from sampler directly into volume of appropriate container with predetermined methanol
  - Methanol preserved sample submitted to laboratory
  - Note shipping restrictions/ requirements

ITRC, ISM-1, Section 5.4.2, Figure 5-11

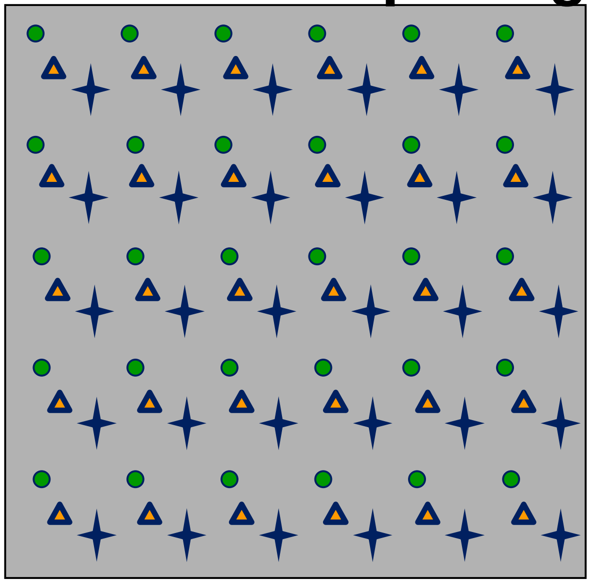
Replicates Recommended

- Increments collected from alternate random locations
  - Independent samples, not “splits”
- Minimum 3 replicate set for statistical evaluations
- Additional replicates may be necessary depending on contaminant heterogeneity and project specific DQOs

ITRC, ISM-1, Section 5.3.5

Replicate Spacing and Collection

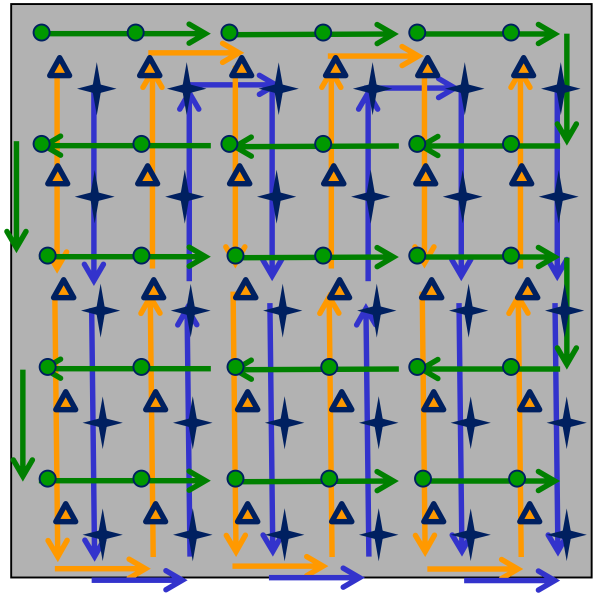
Replicate Increment Spacing



Decision Unit

R1 R2 R3

Sample Collection



Decision Unit

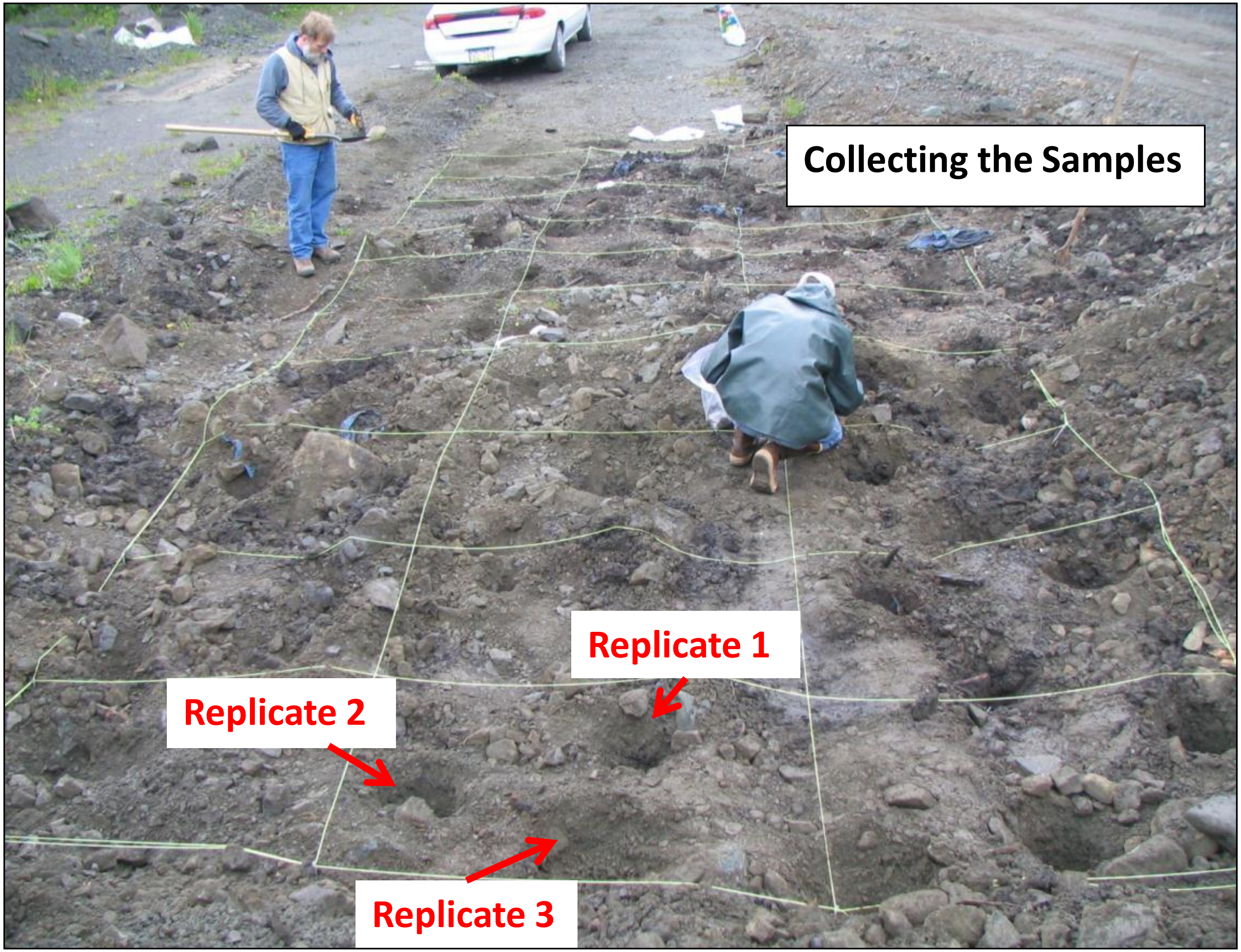
Replicate 1

Replicate 2

Replicate 3

ITRC, ISM-1, Section 5.3.5

Field Replicates – Simple Example



Replicate/Sampling Reminders

- Replicates
  - What type
  - How many
  - Where/when will they be collected
  - How will they be evaluated
- "Homogenizing" or mixing not necessary
  - Laboratory processing and subsampling (following module) designed to attain representative analytical sample

Field Implementation Summary

- Determined during Systematic Planning
  - Sampling design
  - Adequate sampling tools
  - ISM surface/subsurface sampling logistics
    - Subsurface cores and subsampling
  - Specific contaminant of concern (COC) considerations
    - Non-volatile and volatile
  - ISM replicates

Laboratory Processing Learning Objectives

Learn how to:

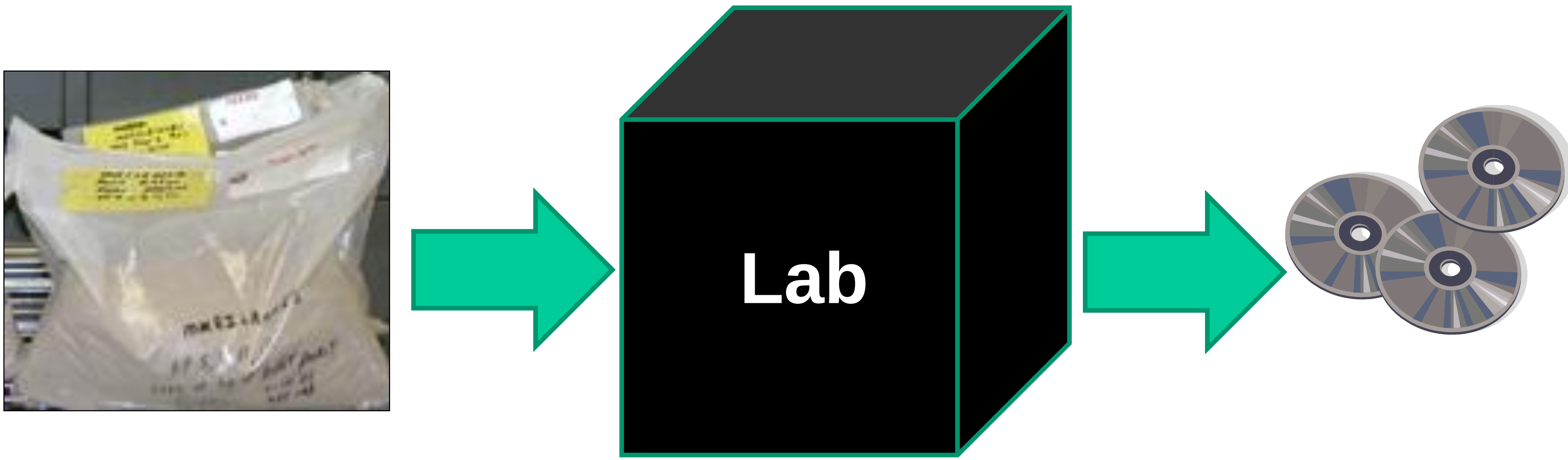
- Match process options to analytes and data objectives
- Manage sample moisture
- Select/reduce particle size
- Collect subsamples for analysis
- Apply Quality Assurance
- Examine options for lab certification

Analyte-Matrix Driven Options

- Pick the right option
  - More representative subsamples
  - Better precision

- Pick the wrong option
  - Poor and unknown bias

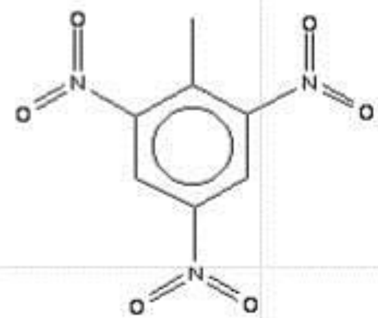
Include Lab Processing in Project Planning

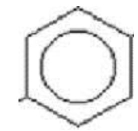


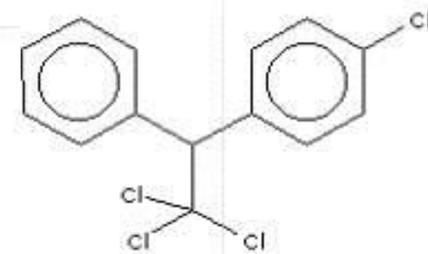
ITRC, ISM-1, Section 6.1.1

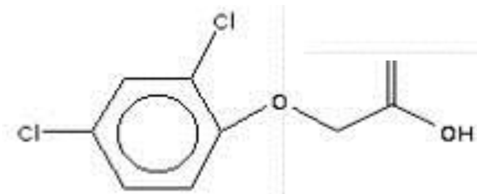
Define the Analytes

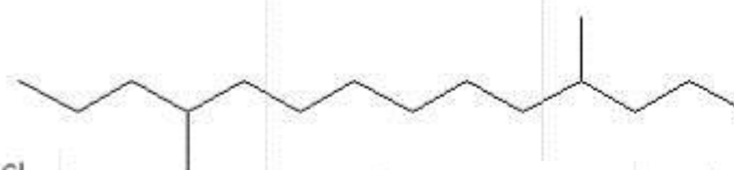
- Volatile organics
- Energetics
- Metals, Hg
- PCBs
- Organochlorine pesticides
- Phenoxy acid herbicides
- Petroleum hydrocarbons
- Semivolatile organics
- Other

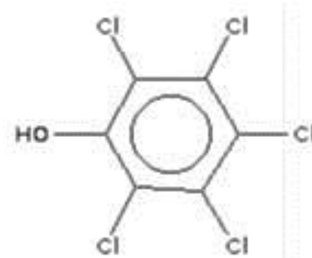


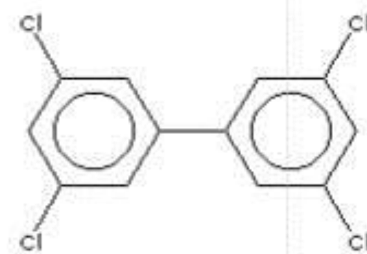












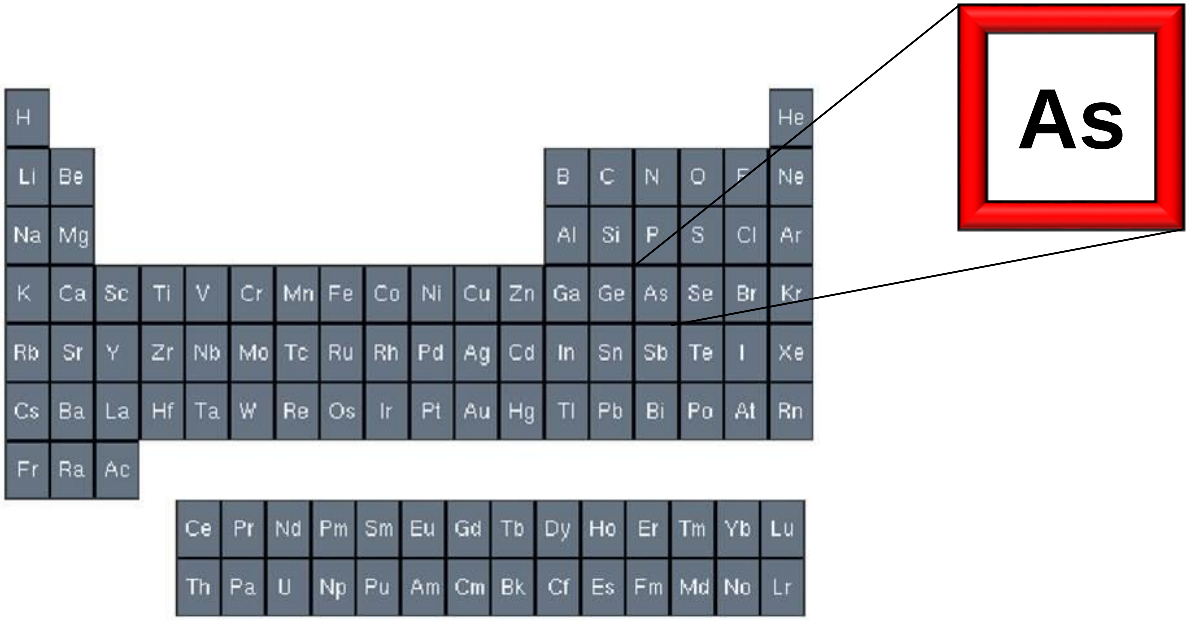
Coordinate VOC Sampling & Analysis

- Use methanol preservation
  - Methanol transport
  - Bottle sizes (large, medium, small)
- Analytical sensitivity limitations
  - Higher reporting limits
  - Selected Ion Monitoring GC-MS
    - Short analyte lists

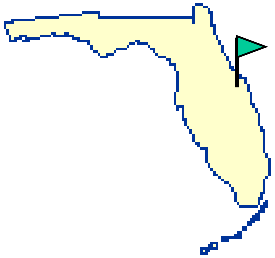
ITRC, ISM-1, Section 6.2.1

Florida Case Study: Contaminant of Concern

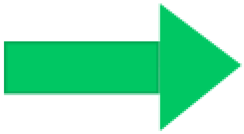
- Arsenic
  - From liquid applied pesticides



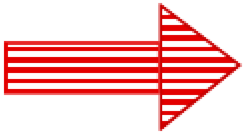
Periodic Table of Elements



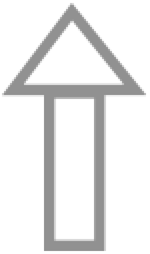
Symbol Key



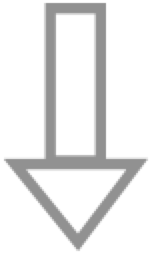
- Good effect



- Bad effect

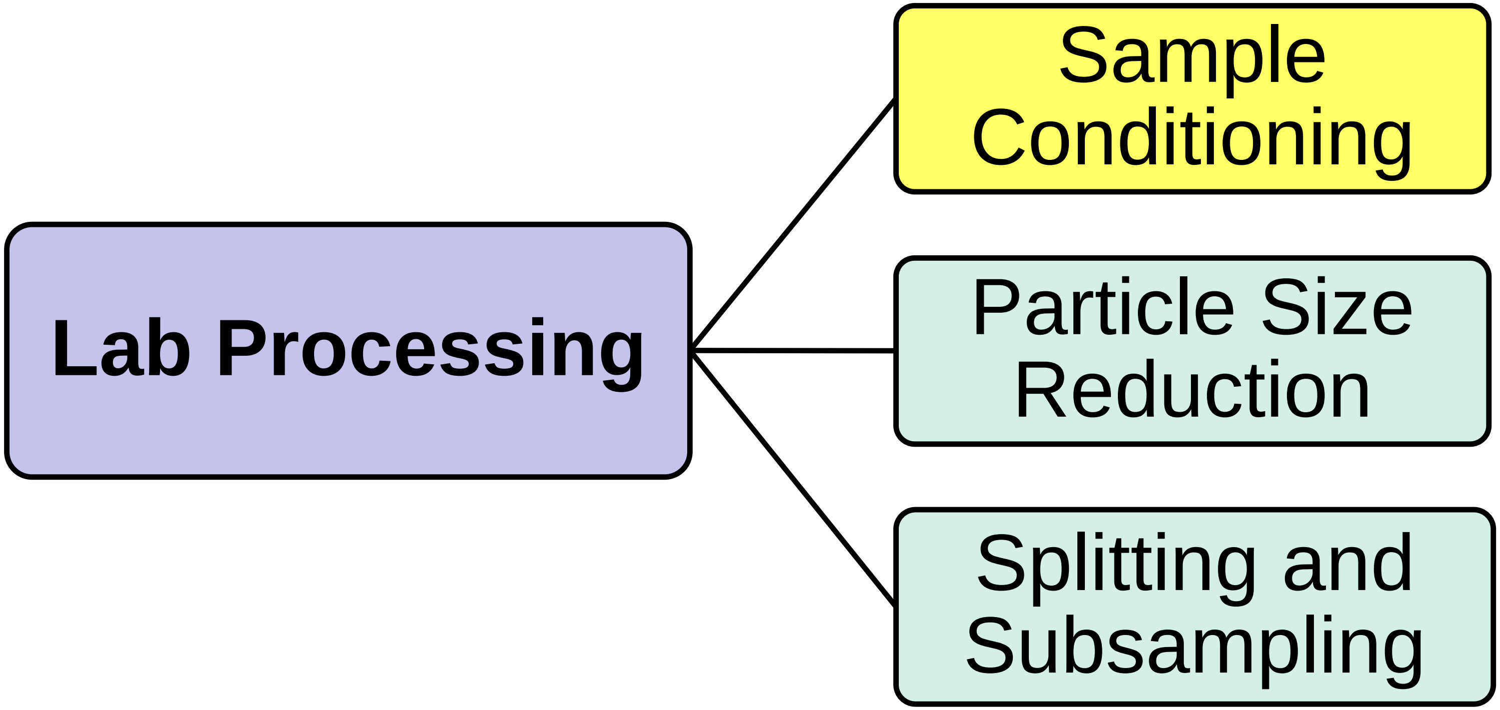


- Result or statistic gets larger in value



- Result or statistic gets smaller in value

Lab Processing Roadmap



Condition the Sample

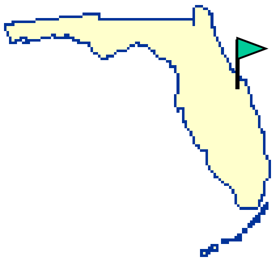
- Air drying
  - Room temperature – most common
  - Ventilation hood
  - Goal: Crushable agglomerates
  - Consider volatilization losses
    - Boiling point
    - Binding to soil particles
    - Potential for Loss Table
      - Naphthalene
      - Acenaphthene
      - Benzo[a]pyrene

- Use other options when drying not appropriate

ITRC, ISM-1, Section 6.2.2.3

Florida Case Study: Air Drying Samples

- Arsenic
  - High boiling arsenic species
  - Volatilization loss not expected



ITRC, ISM-1, Section 9, Appendix C

Define Terms: Grinding

- Generic term for soil disaggregation or milling
- The grinding type or equipment must be specified to select a particular laboratory process

Define Terms: Disaggregating

- Breaking all the soil clumps into individual small particles, but keeping the small pebbles and hard crystalline particles intact

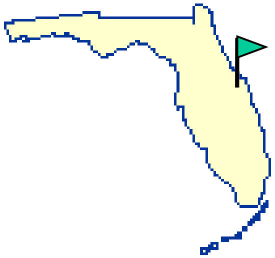
Define Terms: Milling

- Complete particle size reduction of all soil components including hard crystalline materials to a defined maximum particle size (e.g. < 75 µm)

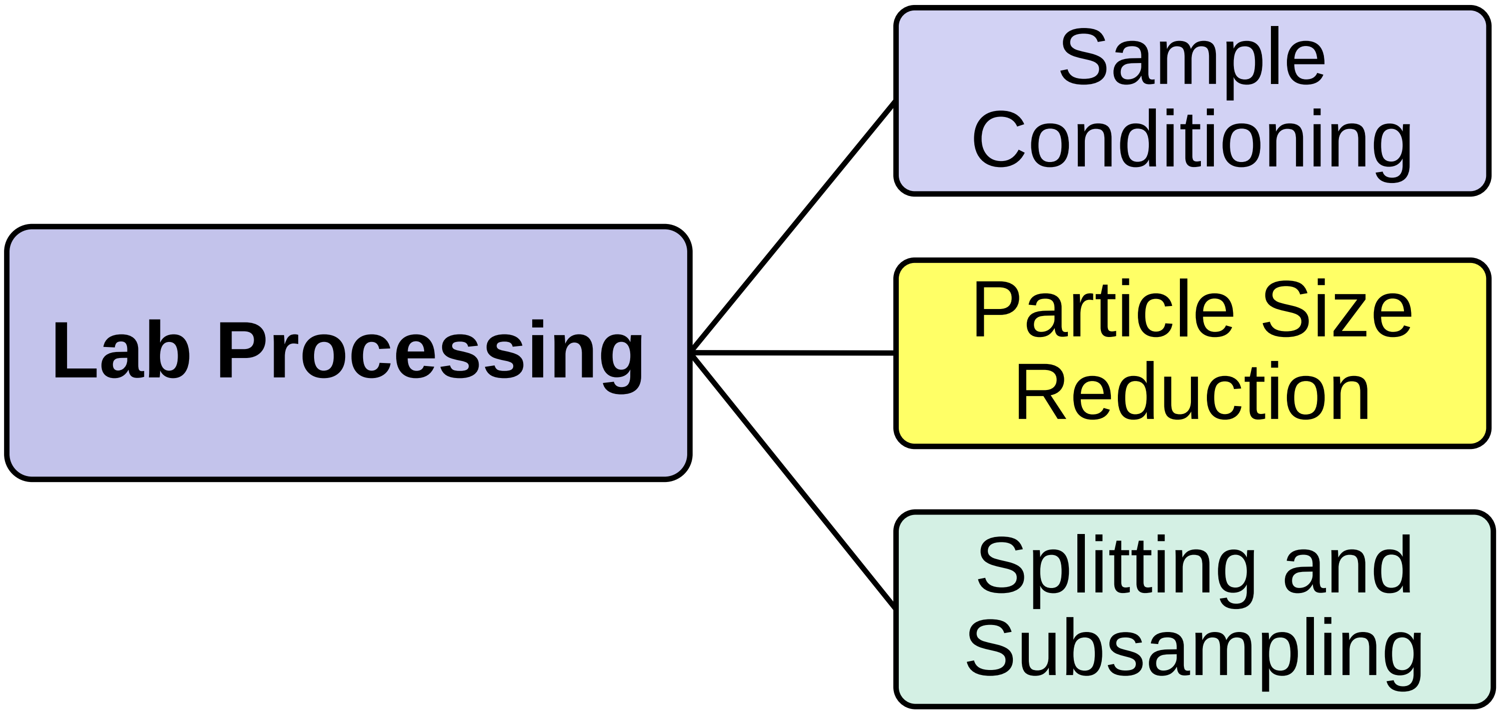
Picture from USACE-Alan Hewitt

Florida Case Study: Particle Size Reduction

- Disaggregation and sieving
  - Nugget effect expected to be small
    - Contaminant exposure sprayed as a liquid
- Mill
  - Puck mill
- Comparison study planned



Lab Processing Roadmap



To Mill or Not to Mill? (Particle Size Reduction)

- Recommended
  - Crystalline particles, fibrous threads, paint chips
  - Energetics, metals
- Strengths
  - Reduces variability
  - Reduces subsampling error
  - Facilitates mixing
  - Improves precision

Picture from USACE-Alan Hewitt

To Mill or Not to Mill

- Not recommended
  - Volatile, thermally labile, increased “availability”
  - Examples
    - Monochloro PCBs, reactive SVOCs, decane, elemental mercury
  - Limitations
    - Analyte losses
    - Metals contamination
    - Potential high bias to metals risk assessment (pebbles)

If uncertain, do milled & unmilled

ITRC, ISM-1, Section 6.2.2.5

How Best to Mill

- Puck mill or ring and puck mill
  - "Stable" energetics
- Ball mill
- Mortar and pestle
- Consider
  - Analytes
  - Concentration of interest
  - Mill materials
  - Particle size needed

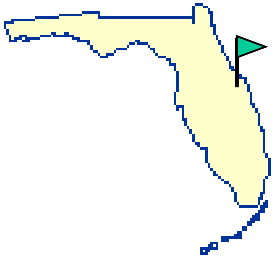
Picture from USACE-Alan Hewitt

Example mills, other types are possible as well

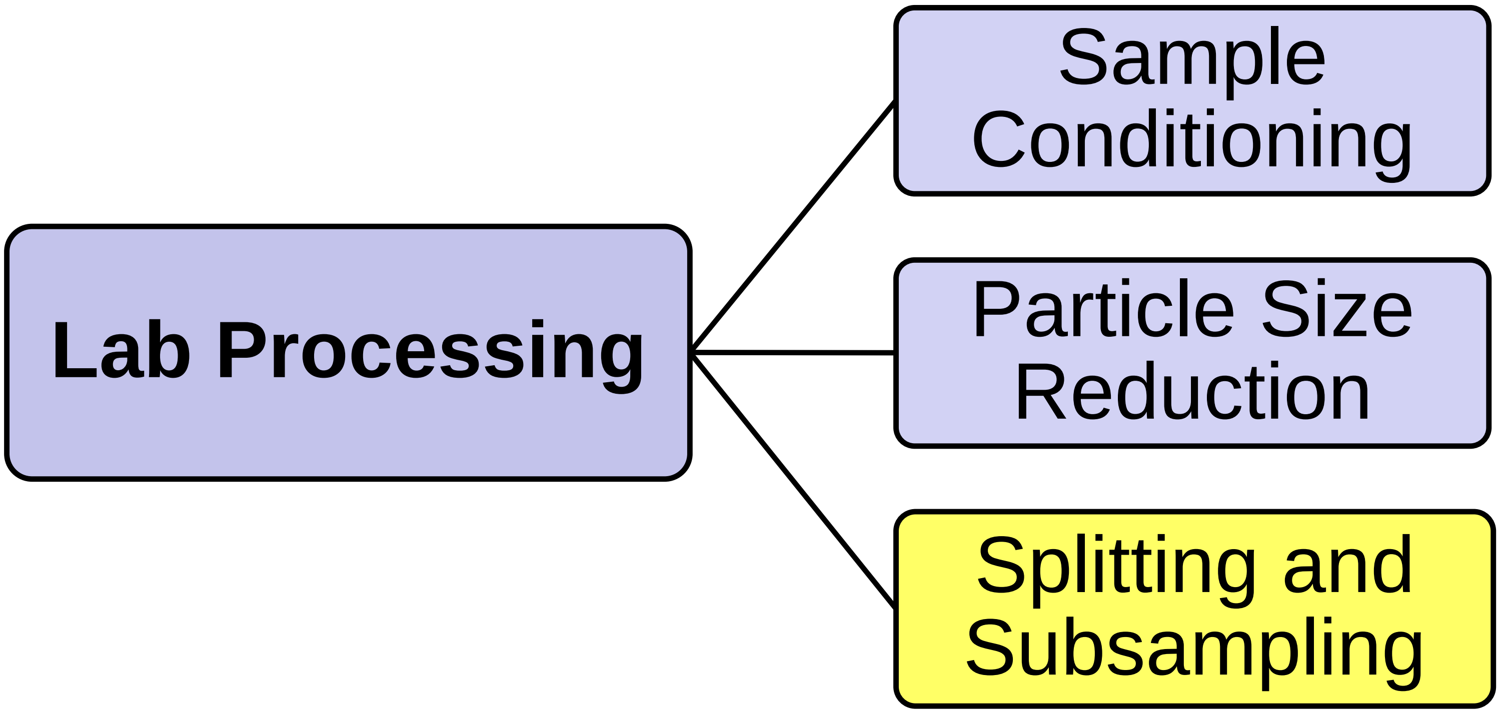
ITRC, ISM-1, Section 6.2.2.5

Florida Case Study: Results Confirm Milling Not Needed

- Disaggregation and sieving
  - Nugget effect expected to be small
    - Contaminant exposure sprayed as a liquid
- Mill
  - Puck mill
- Results confirm milling not needed for this part of site
  - Small precision improvement with milling
  - No change in mean concentration



Lab Processing Roadmap



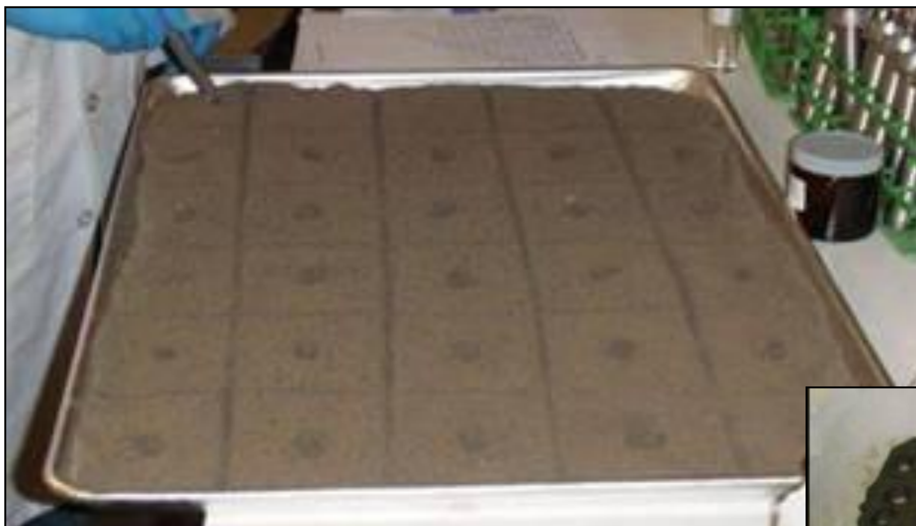
Dry Splitting Options

- Rotary sectorial splitter

ITRC, ISM-1, Section 6.2.2.7

Subsampling Options

- 2-Dimensional Japanese Slabcake

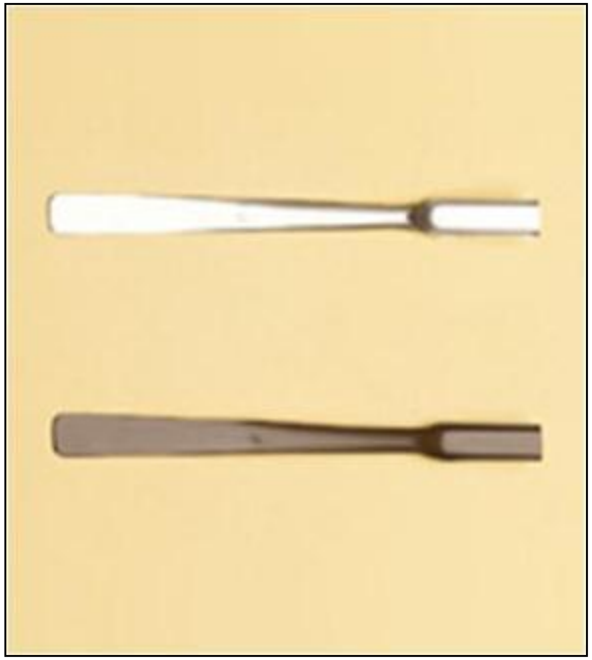


Dry

Wet

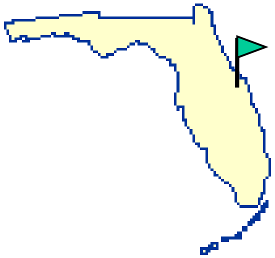
Subsampling Tools

- Square straight-sided scoops for dry non-cohesive soil



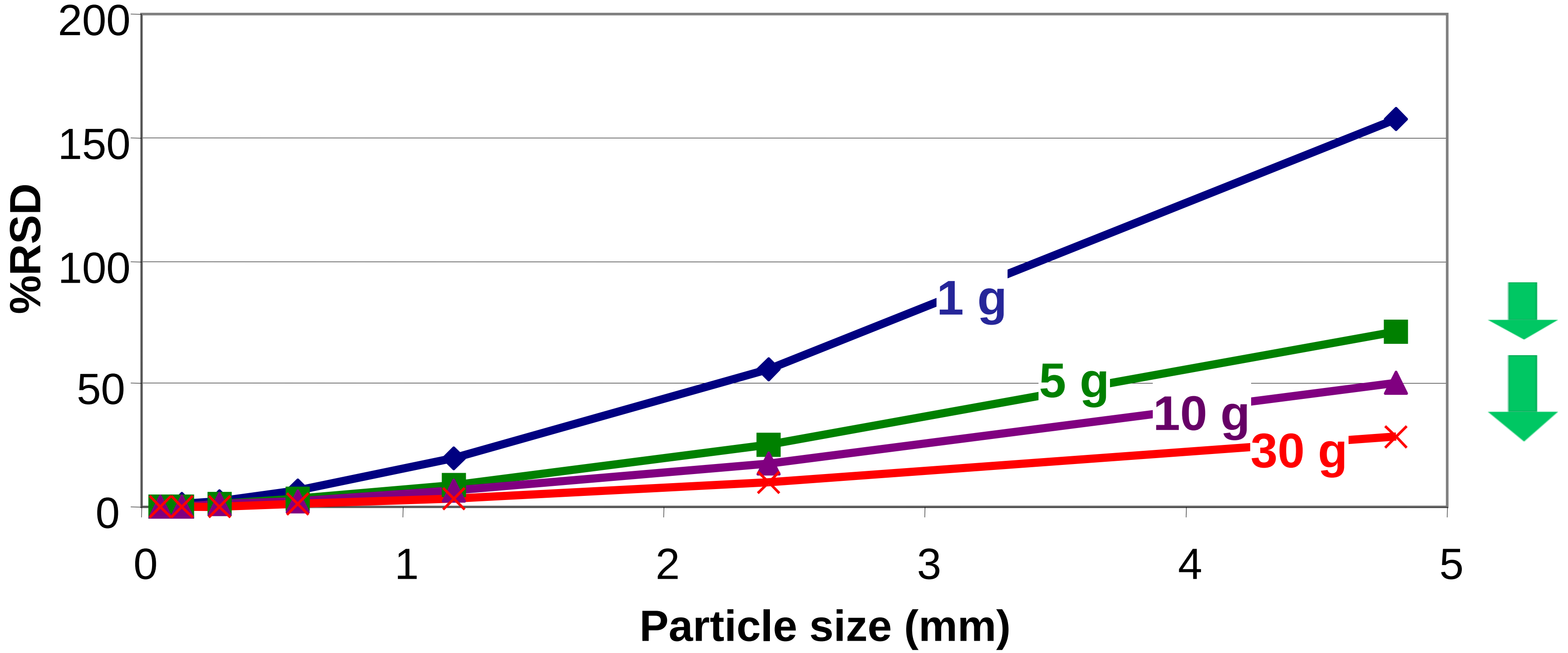
Florida Case Study:
Choose Subsampling Process

- 2-D Slabcake Subsampling
  - Lower cost than sectorial splitter
  - More representative than “dig a spot”



Why Use Large Subsamples?

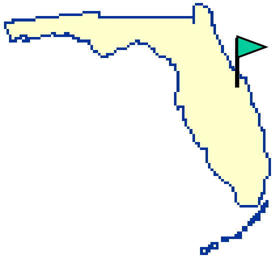
- Larger particles
  - Produce larger errors or require larger subsamples



Florida Case Study: Nugget Effect Minimal

- 2 g subsamples on disaggregated aliquots
- 2 g subsamples on milled aliquots

- Low heterogeneity expected
  - Confirmed through replicates

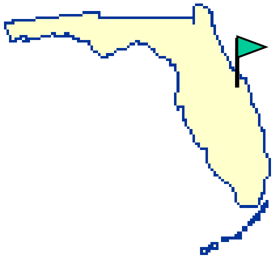


Laboratory Quality Control Measures

- Laboratory equipment blanks
  - Limited clean matrices
- Laboratory control samples (LCS) and matrix spikes
  - Practicality of large scale spiking in kg samples
    - High cost
    - Limited availability
  - Introduced post ISM processing into subsample
- Subsampling replicates

Florida Case Study:
Challenges with “Blank” Samples

- Ottawa sand method blank attempted for milling
  - Metals content of the sand was too variable
- Standard preparation batch QC
  - No laboratory control sample or matrix spike through ISM processes



Verify Laboratory Certification

- National Environmental Laboratory Accreditation Program (NELAP)
- Non-NELAP state accreditation
- Agency-specific accreditation
  - DoD Environmental Laboratory Approval Program

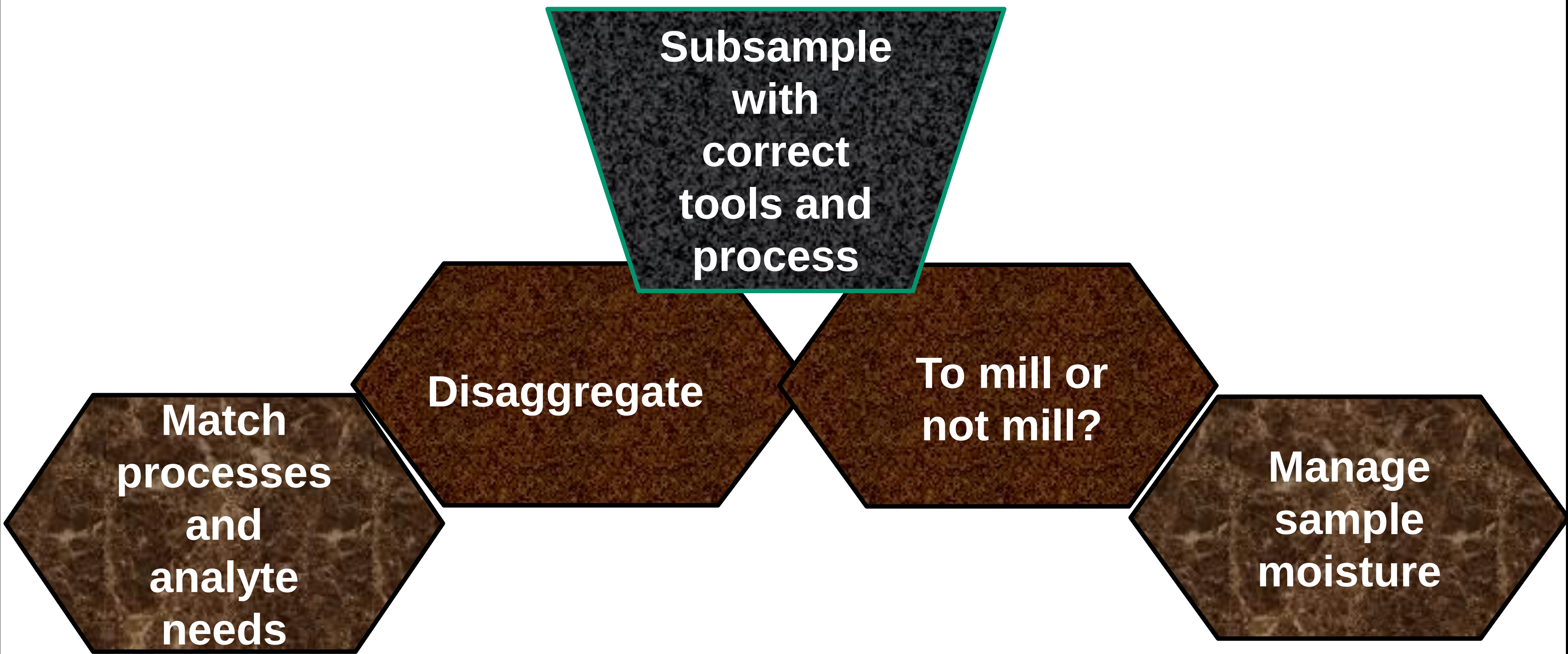
Cite Reference Methods

- Collecting and Processing of Representative Samples For Energetic Residues in Solid Matrices from Military Training Ranges
  - USEPA SW-846 Method 8330B, Appendix A
    http://www.epa.gov/osw/hazard/testmethods/pdfs/8330b.pdf
- Metals in Solid Matrices
  - USACE research effort
  - Planned SW-846 Method 3050 - Update V?

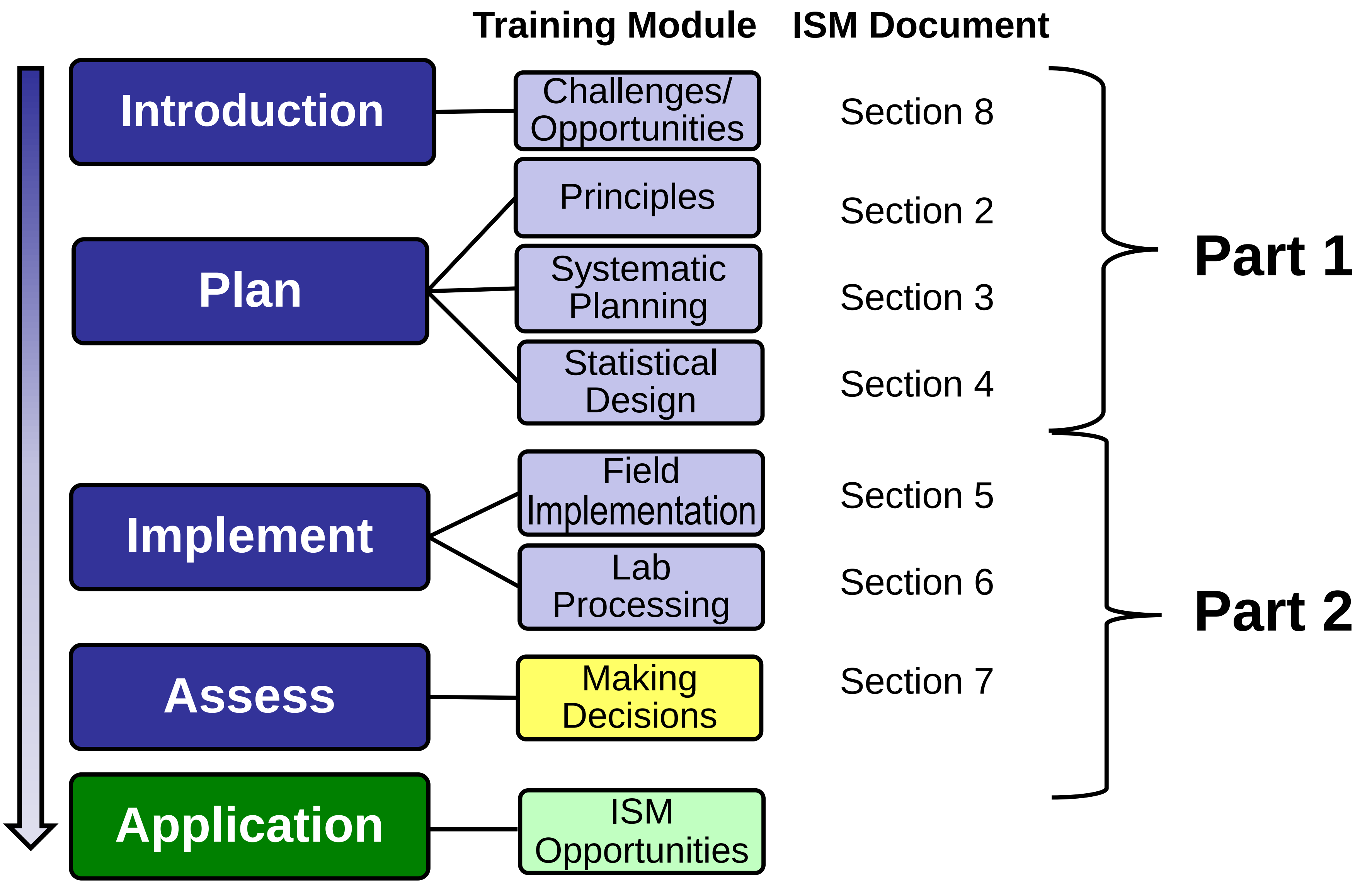
Use Alternate References

- ASTM D6323 Standard Guide for Laboratory Subsampling of Media Related to Waste Management Activities
  - ASTM 2003
- Guidance for Obtaining Representative Laboratory Analytical Subsamples from Particulate Laboratory Samples
  - Gerlach 2003
- Laboratory Standard Operating Procedure

Lab Process "Big Rocks"



ISM Document and Training Roadmap

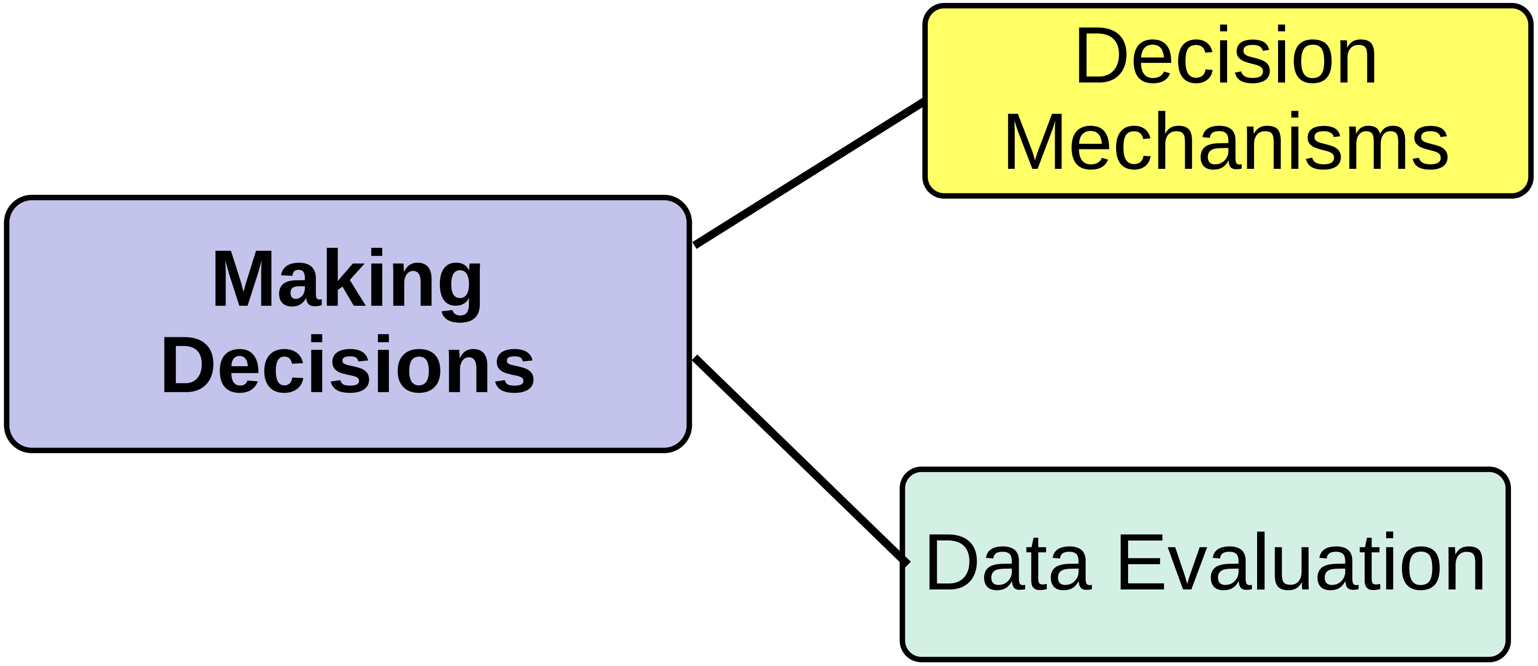


Making Decisions: Learning Objectives

Learn how to:

- Use ISM data to make decisions
- Evaluate data
  - Identifying sources of error
  - Quantify error
  - Interpret error
  - Isolate sources of error

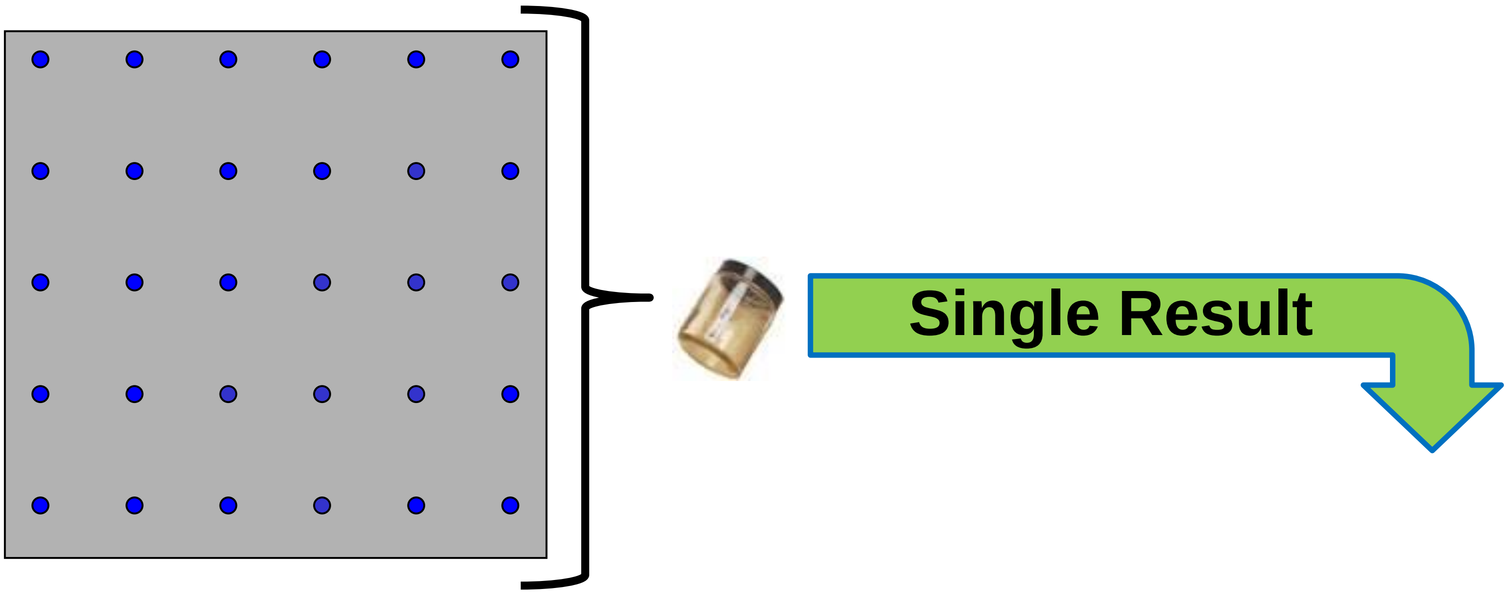
Making Decisions Using ISM Data



Making Decisions

- Decision Mechanism (DM)
  - Structured approach to making decisions
  - Identified and agreed upon during Data Quality Objective (DQO) process
  - 6 common types of DM

DM 1: Compare One ISM Result to Action Level

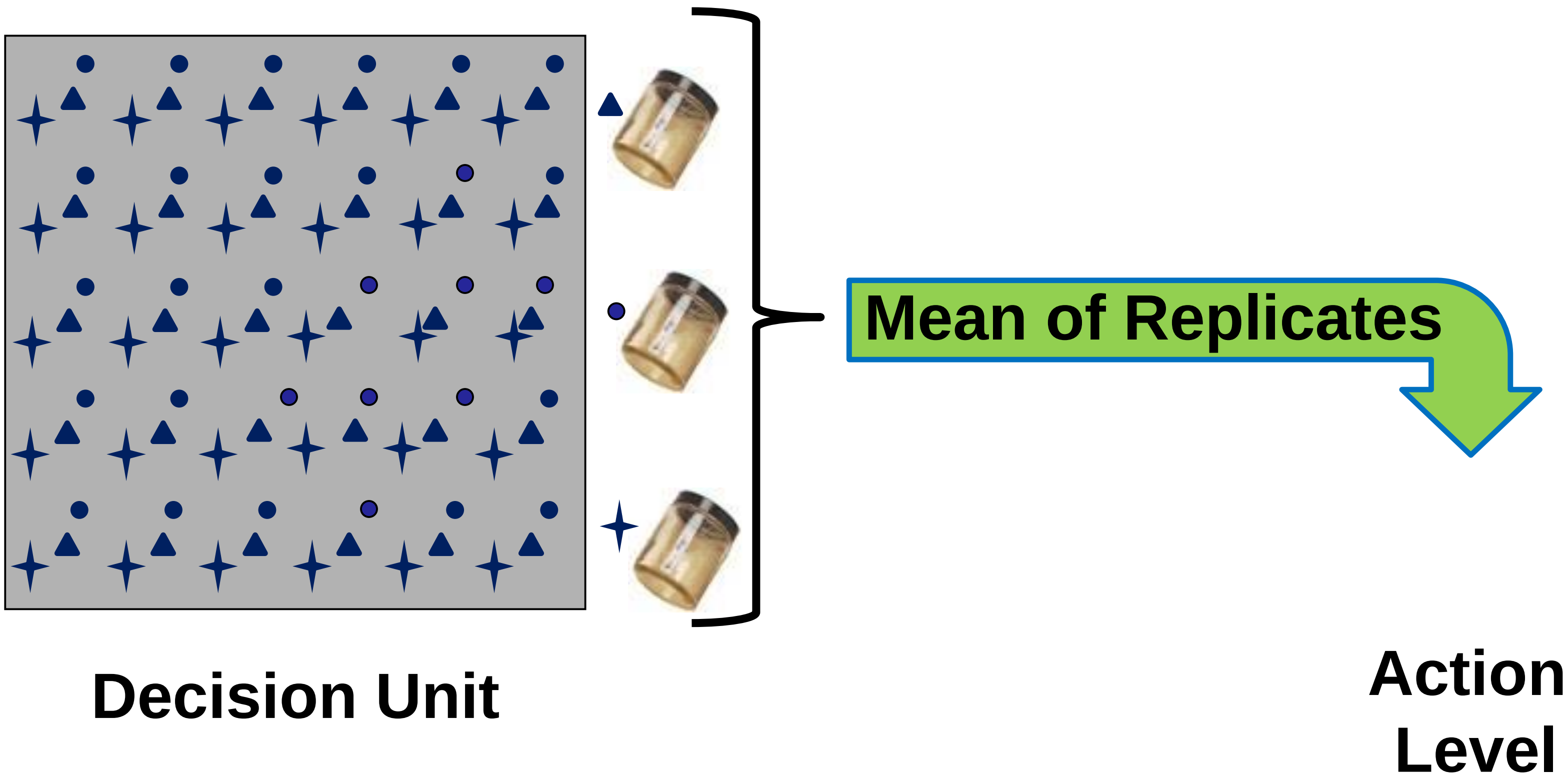


Decision Unit

Action Level

ITRC, ISM-1, Section 4.2.1 and Section 7.2.1

DM 2: Compare Average ISM Result to Action Level

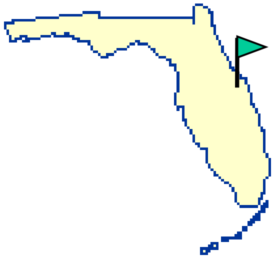


ITRC, ISM-1, Section 7.2.2

Florida Case Study:
Decision Mechanism (DM) 2

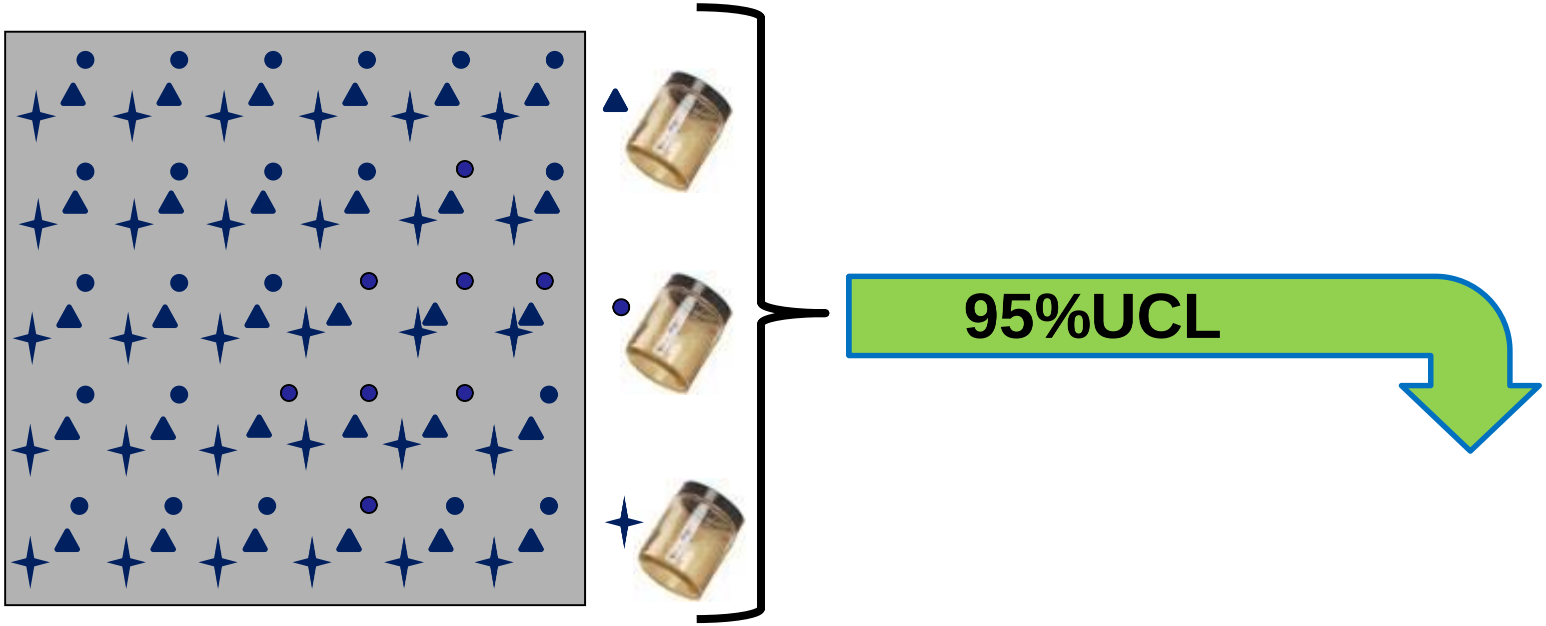
Mean arsenic concentrations (mg/kg)

	Discrete *n* = 30	Incr-30 *n* = 3	Incr-100 *n* = 3
DU 2	4.2	5	5.2
DU 3	7.5	10.5	9.5



DM 3: Calculate 95%UCL then Compare to Action Level or Use for Risk Assessment

Decision Unit



Action level
or risk assessment

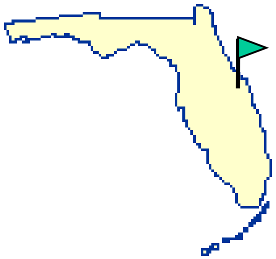
ITRC, ISM-1, Section 4.2.2 and Section 7.2.3

Florida Case Study:
Decision Mechanism 3: (DU 1)

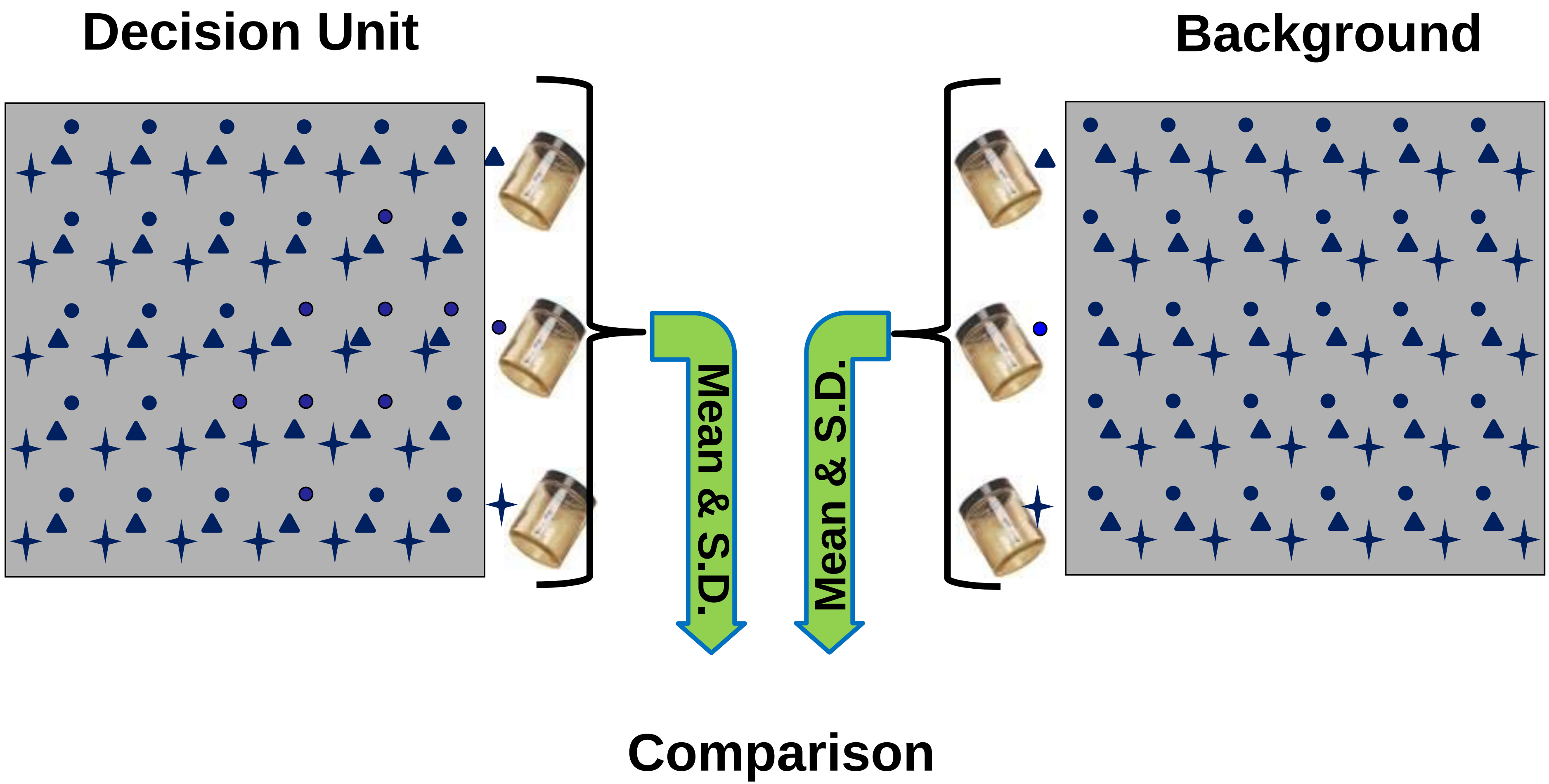
Arsenic Data (mg/kg)

	Discrete n = 10 (mg/kg)	Incr-30 n = 3 (mg/kg)	Incr-100 n = 3 (mg/kg)
Mean	2	1.8	1.7
Std Dev	1.4	0.08	0.03
95UCL	**3.0**	**2.0**	**1.8**

Florida Action Level: 2.1 mg/kg

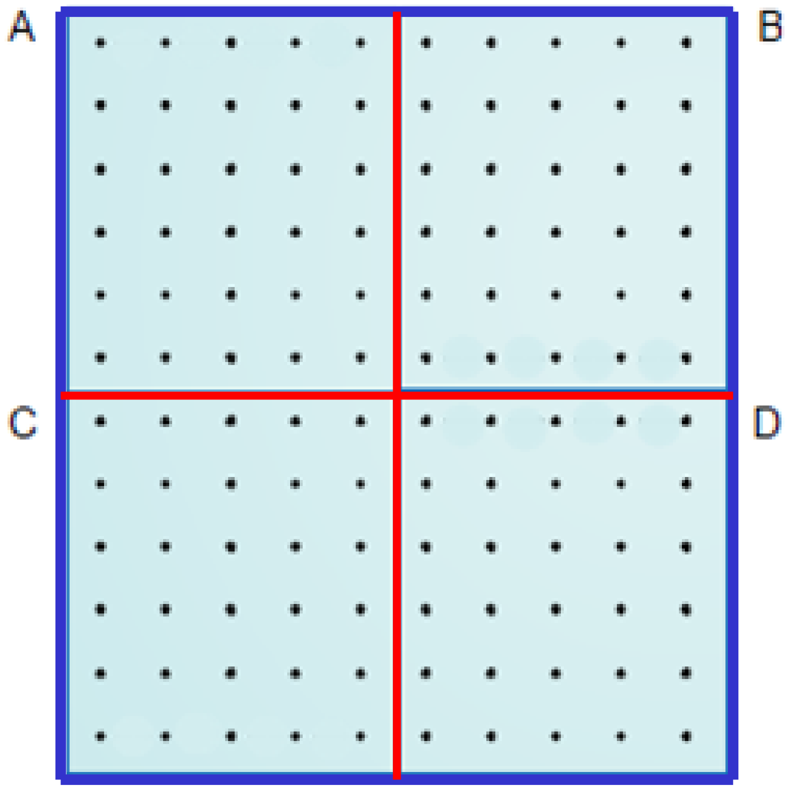


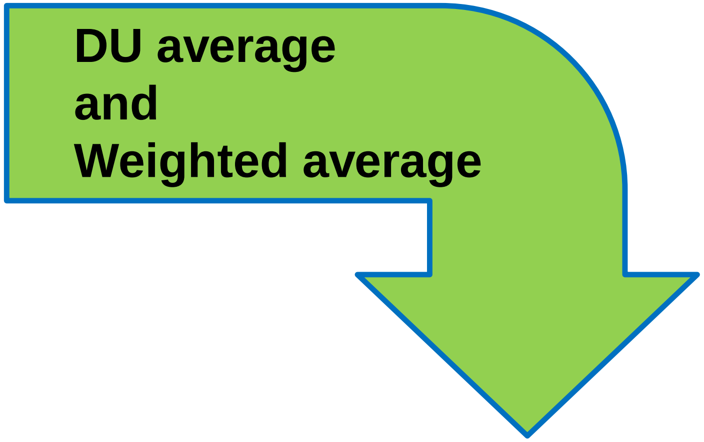
DM 4: Compare to Background



ITRC, ISM-1, Section 4.4.3.3 and Section 7.2.4

DM 5: Combining Decision Units

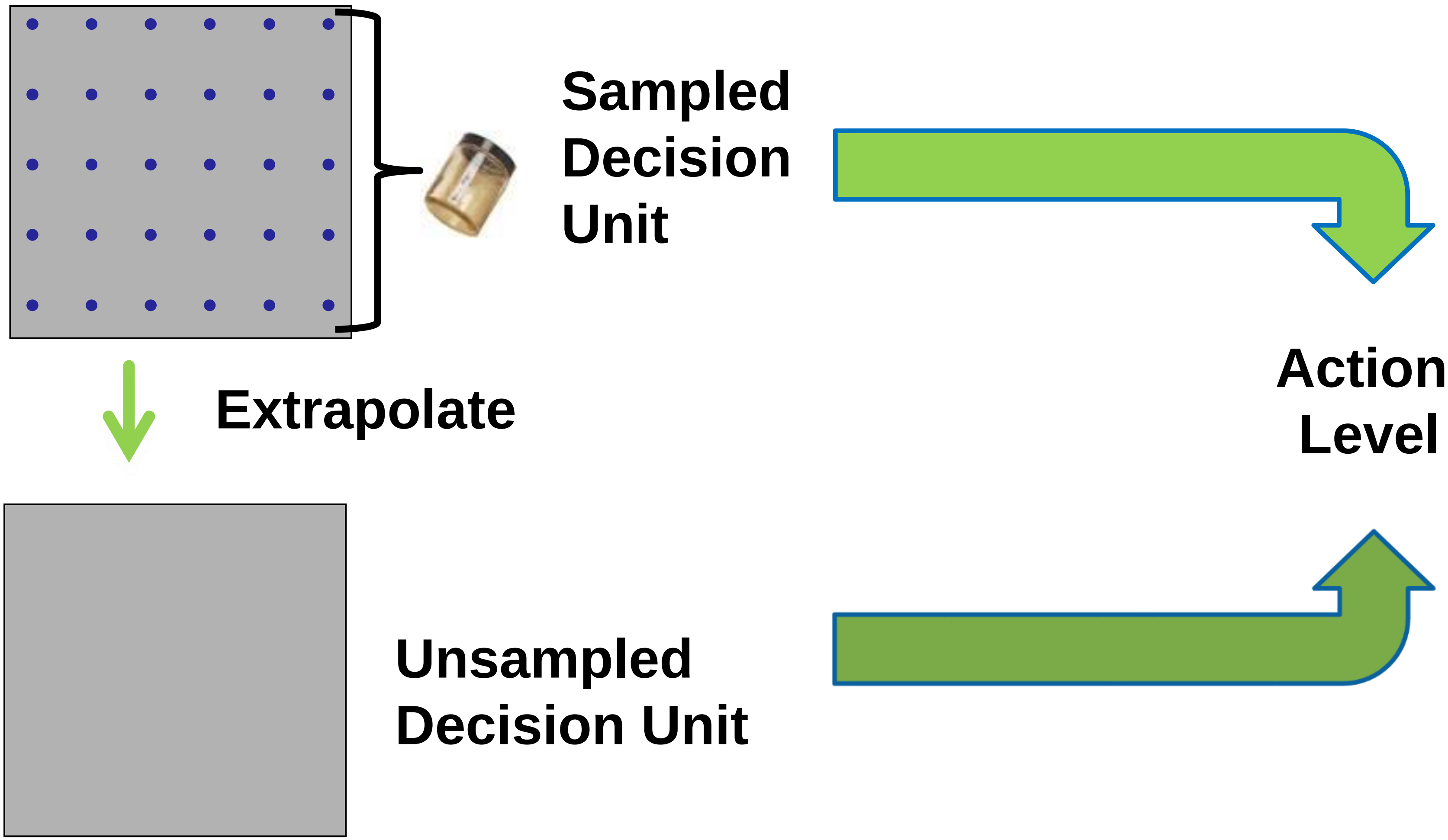




Action Level

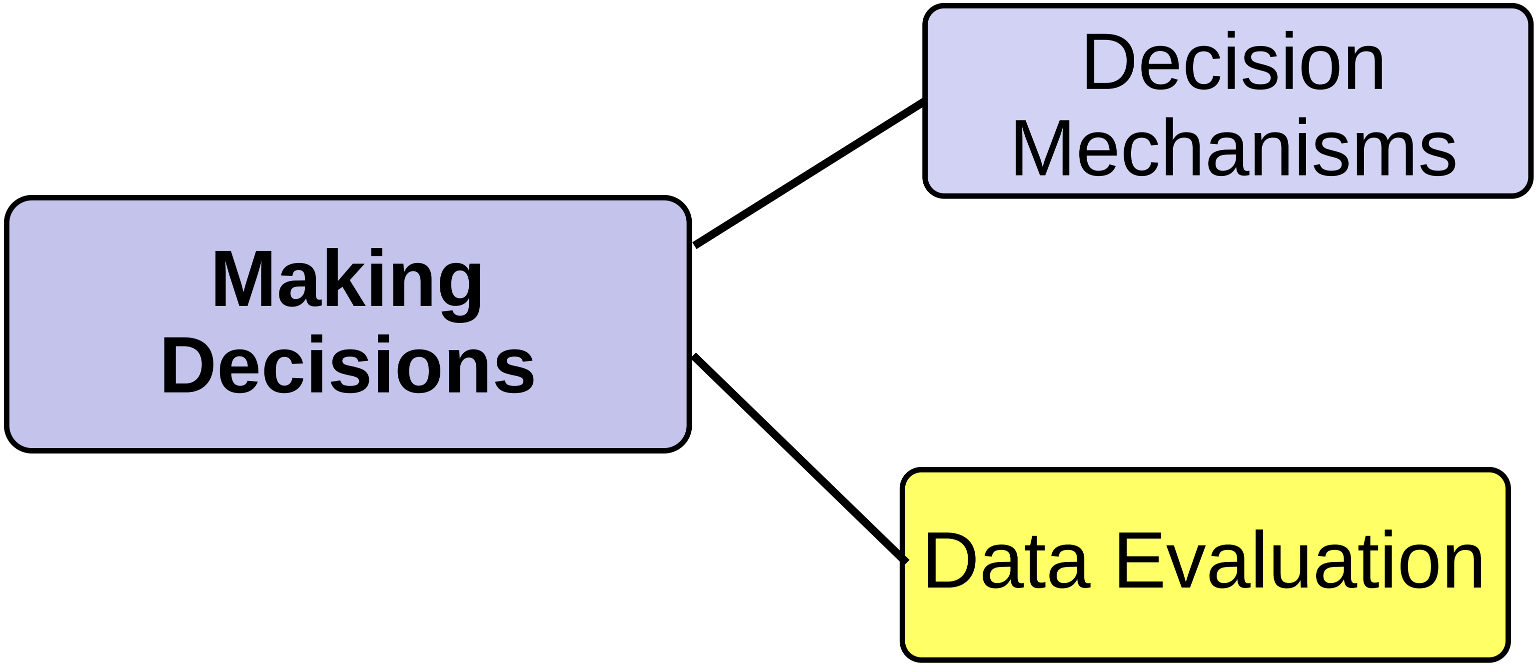
ITRC, ISM-1, Section 4.4.1 and Section 7.2.5

DM 6: Extrapolation to Unsampled Areas

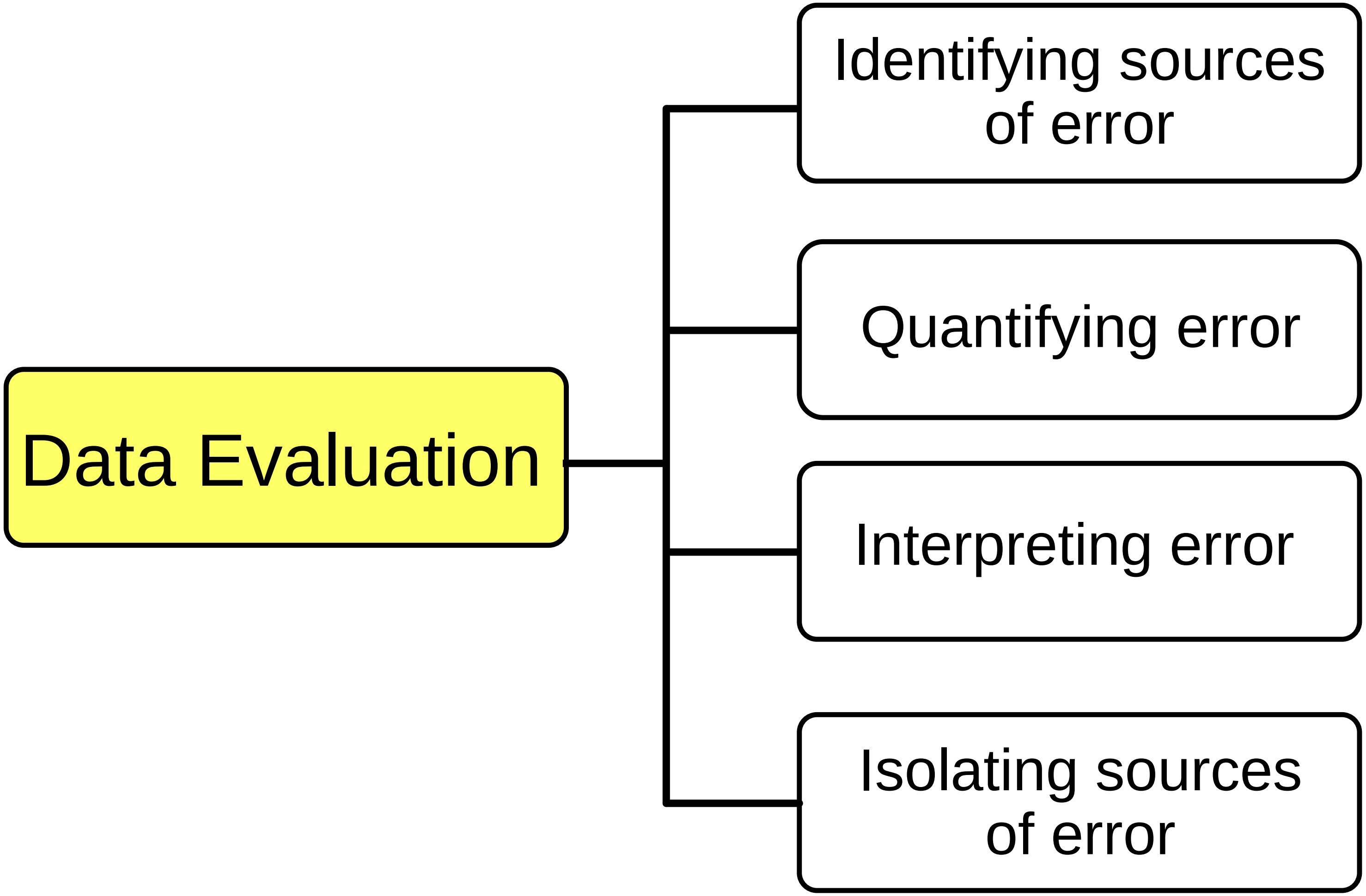


ITRC, ISM-1, Section 4.4.4.2 and Section 7.2.6

Making Decisions Using ISM Data



Data Evaluation Components



Identifying Sources of Error

Field

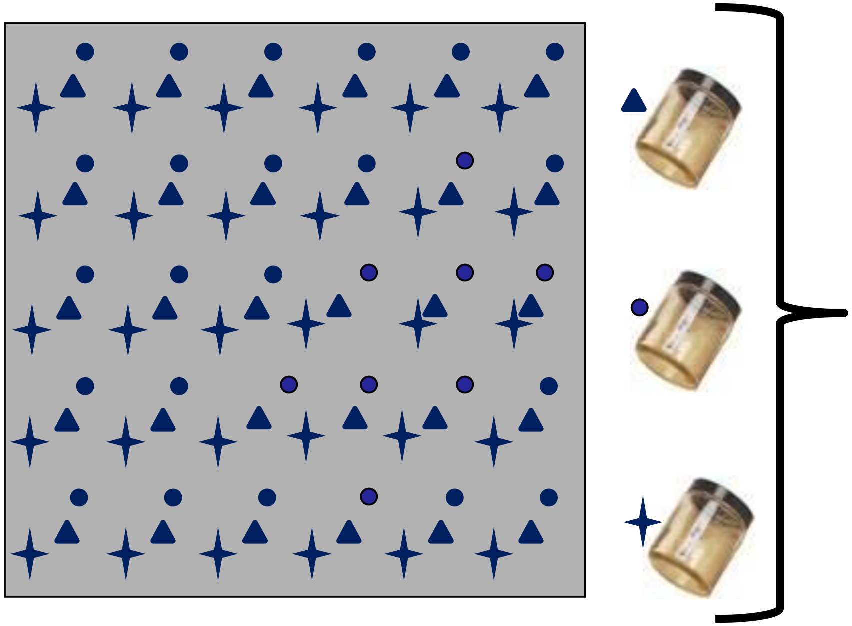
- Number of increments
- Increment collection
- Field processing
- Field splitting
- DU size and shape

Laboratory

- Lab processing
- Subsampling
- Extraction
- Digestion
- Analysis

Quantifying Error

RSD = CV = standard deviation / arithmetic mean



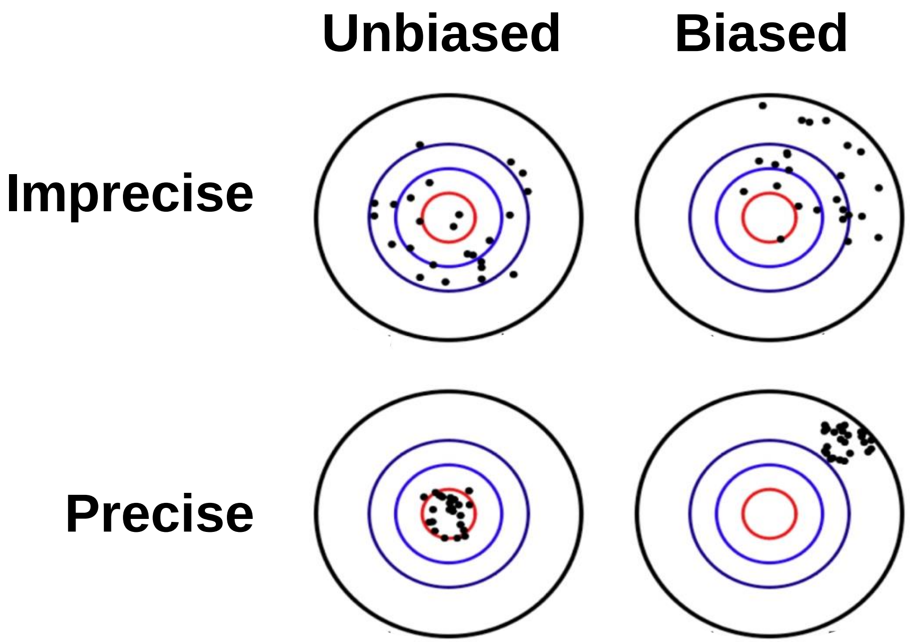
Data includes all sources of error

Decision Unit

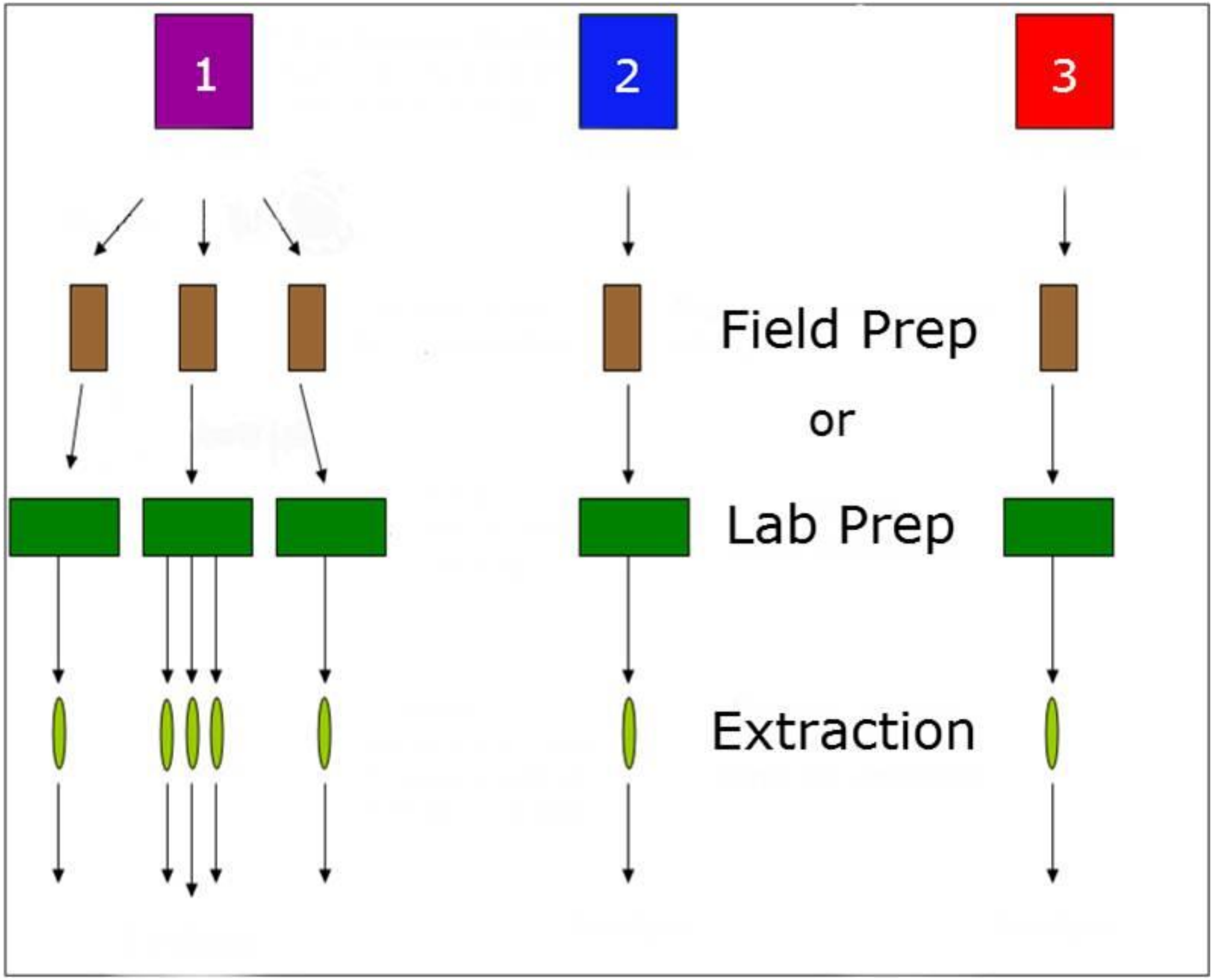
ITRC, ISM-1, Section 4.3.1.3 and Section 7.3

Interpreting Error

- "Unacceptable" RSD
- Low RSD
- High RSD



Isolating Sources of Error



Adapted from EPA 2011, page 38: http://go.usa.gov/EAE

How Does ISM Cost Compare?

Elements

- Planning
- Field Collection
- QA/QC Samples
- Sample Transport
- Sample Processing/Conditioning
- Lab Analysis
- Overall *Sampling/Analysis Portion* of Project

A Cost Comparison Example

US Army Corps of Engineers Study

Metals in Soil

Activity	Per Sample Cost ($)		Total Project Sampling/Analysis Cost ($)		
	ISM	Discrete	ISM[1]	Discrete[2]	Discrete[3]
Field Sampling	35-50	10-15	105-150	70-105	150-225
Lab Prep	40-60	0-10	120-180	0-70	0-150
Analysis	225-275	125-135	675-825	875-945	1,875-2,025
Total	**300-385**	**135-160**	**945-1,155**	**945-1,120**	**2,025-2,400**

[1] Based on 3 replicate 100-increment ISM/DU

[2] Based on collection of 7 discrete samples/DU

[3] Based on collection of 15 grab samples/DU

Source: US Army Corps, Cost and Performance Report of Incremental Sampling Methodology for Soil Containing Metallic Residues, ERDC TR-13-10, September 2013

Bottom Line on Cost Comparisons

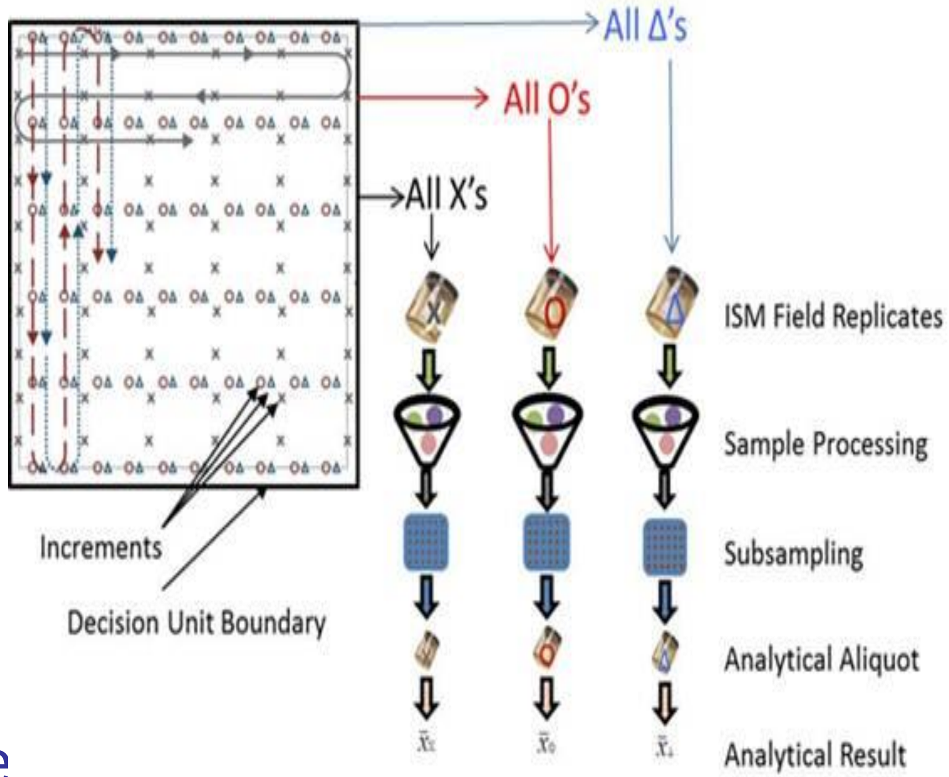
Measuring the cost difference between ISM and discrete sampling.

Measuring the cost of making a wrong decision.

Overview & Wrap-up

ISM:

- Specifically designed to address short comings of discrete sampling methods
- Provides a systematic, science-based approach to site investigation
- Increases data representativeness
- Provides greater confidence in decision making



Follow ITRC

Niaweh! (Thank you)

- Links to additional resources
  - http://www.clu-in.org/conf/itrc/ISM/resource.cfm
- **Link to ITRC Document on Incremental Sampling:**

http://www.itrcweb.org/ism-1/

- **Next Internet Course on ISM:**

September 20, 2016 (Tuesday) 1:00 PM - 3:15 PM EASTERN TIME