Conducting Site Characterization With Incremental Sampling Methodology (ISM): Practical Applications for Representative and Defensible Decision-Making

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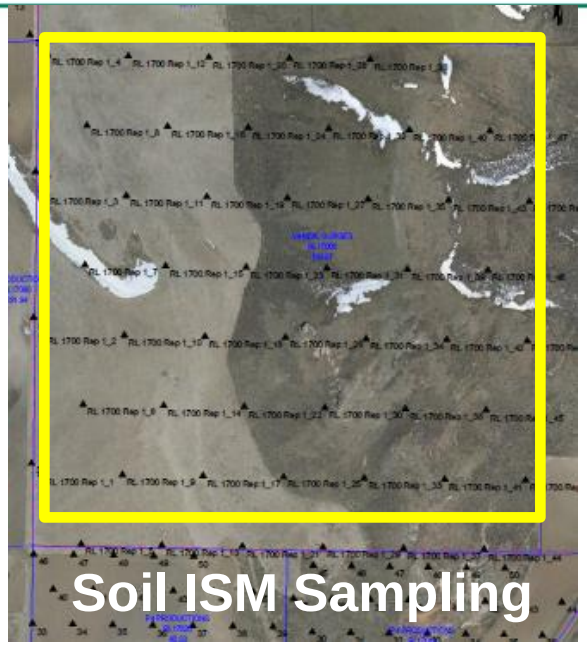
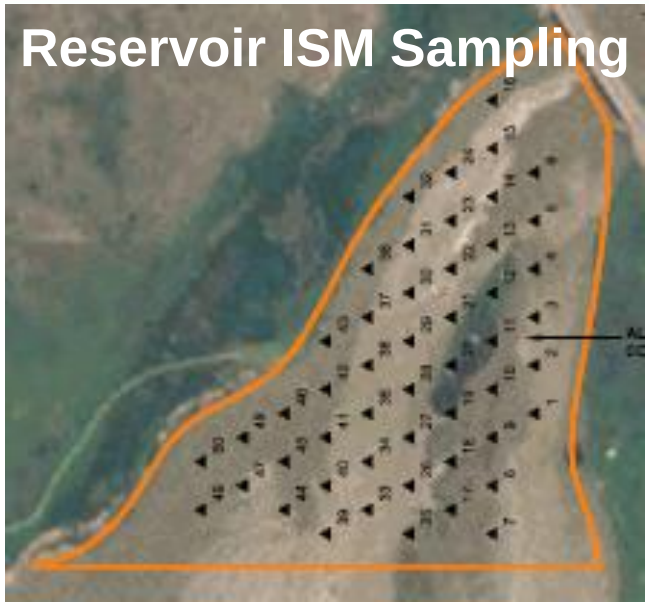
What is Incremental Sampling Methodology (ISM)?

- A structured composite sampling and processing protocol
- Design to address natural heterogeneity in the environmental media
- Every particle within the sample area has an equal probability of being sampled, and of being analyzed
- Reduces sampling and analytical error
- Detailed Guidance available at: www.itrcweb.org



Why Use ISM?

- Provides close to a true mean of a volume of environmental media
- Reduces data variability
- Provides defensible data because it is highly reproducible
- Data Quality Objectives process gets the entire team on board
- The Myth of Maximum Concentrations:
  - **Cannot** be defined unless an infinite number of samples are collected
  - **Does not** reflect the level of potential affects/risk
  - **Does** give a representation of variability



Decision Units

A **Decision Unit (DU)** is the unit of environmental media that requires a decision.

What questions will be answered by the data?

What decisions will be made with the data?

Defined by:

- Area, Depth, Time
- Exposure Areas
- Geology, Geography

Factors that Matter:

Source characterization?

Nature and extent?

Contaminant boundaries?

Stream ISM Sampling

Sampling Theory

- Overall Error (OE) = Total Sampling Error (TE) + Analytical Error (AE)

- TE = FE + GSE + CE2 + CE3 + DE + EE + PE
  - Where:
  - FE = Fundamental error
  - GSE = Grouping and Segregation Error
  - CE2 = Long-range heterogeneity fluctuation error
  - CE3 = Periodic heterogeneity fluctuation error
  - DE = Increment delimitation error
  - EE = Increment extraction error
  - PE = Preparation error

Note: the variance of the errors are the additive values in this equation

Types of Errors

Factor leading to error	Sampling error	Error results from	How to control
Compositional heterogeneity (CH)	Fundamental Error (FE)	Size and compositional distribution of the particles	Increase the sample mass and/or reduce the size of the particles
Distributional heterogeneity (DH)	Grouping and Segregation Error (GSE)	Heterogeneous distribution of particles within the population	Increase the mass of the sample or increase the number of increments
Large-scale heterogeneity	Long-range heterogeneity fluctuation error (CE2)	Changes in concentration across space or over time	Reduce the spatial interval between samples
Periodic heterogeneity	Periodic heterogeneity fluctuation error (CE3)	Periodic changes in concentration over time	Change the spatial and/or temporal interval between samples
Identifying the correct increment geometry	Increment delimitation error (DE)	Incorrect shape (in all three dimensions) of the sample or increment selected for extraction from the population	Use correct sampling plan design and correct sampling equipment that can sample the entire thickness of the population
Shape of the sample extraction device and nature of the soil	Increment extraction error (EE)	Incorrect extraction of the sample or increment because the sampling device is too small	Use correct sampling equipment that does not push larger particles aside, and use correct sampling protocols
Loss or gain of contaminants during sample handling	Preparation error (PE)	Contamination loss or gain due to alteration, evaporation, degradation, cross-contamination, mistake, or fraud	Use appropriate sample handling, preservation, transport, and preparation measures

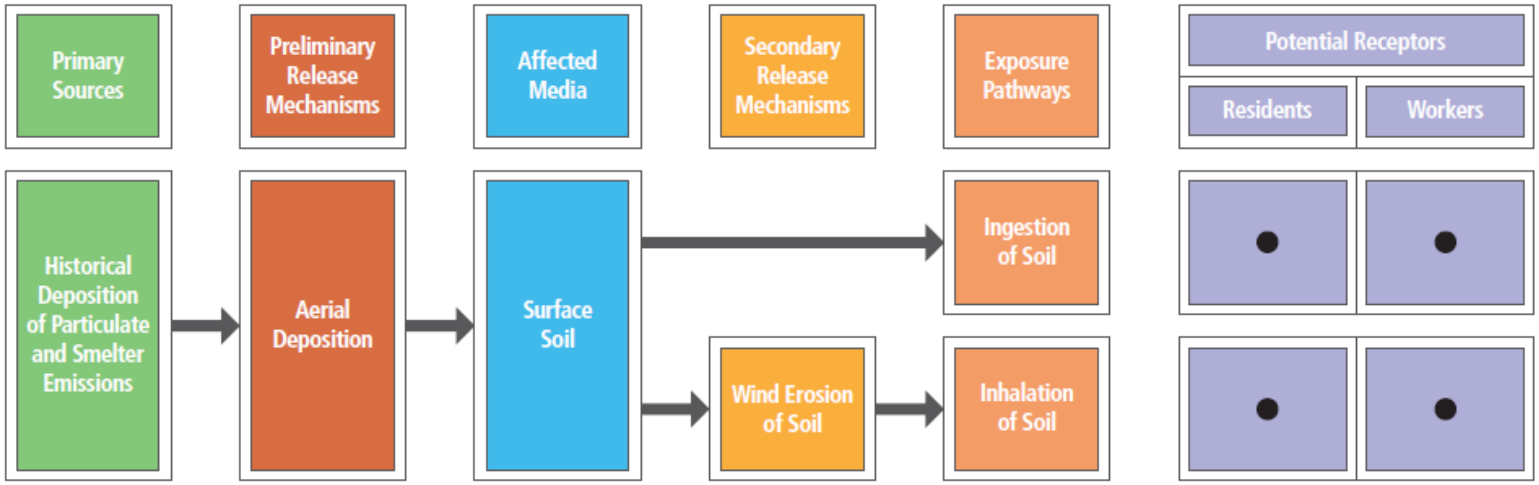
from: www.itrcweb.org

FE and GSE Controls

- FE Can be minimized by collecting a sufficient mass of sample
- GSE can be minimized by collecting numerous increments
- FE = $\sqrt{20(d^3) / m}$
  - Where:
  - FE = Sampling fundamental error (variance)
  - 20 = Sampling Constant
  - d = maximum particle size (cm)
  - m = mass of sample (g)

How to Apply ISM

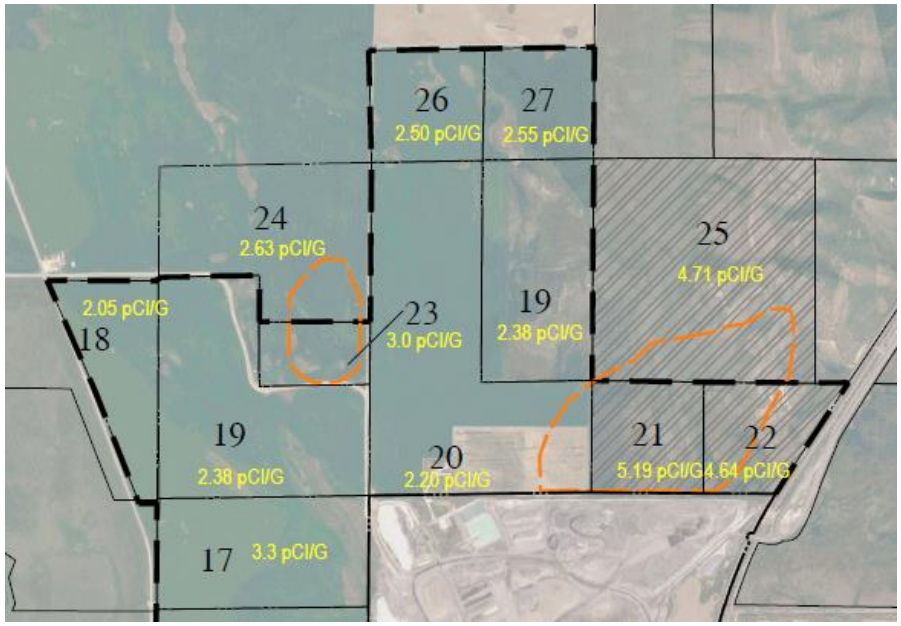
- **Develop Conceptual Site Model**
  - Identify source of contaminants
  - How are they transported?
  - What are the affected media?
  - What re the exposure pathways?
  - Who are the potential receptors?



Decision Unit Example

One DU for each parcel of property surrounding a manufacturing plant

- Why?
  - If the mean concentration is under the Remediation Goal (RG), then no action is required
  - If the mean concentration is over the RG, then the property owner will decide whether they prefer institutional control or remediation
- Would a Bigger DU work? NO
- Would a Smaller DU work? NO



Decision Unit Questions

Great! But I won't be able to see the inherent variability!

- Answer: If the mean is BELOW the RG, you don't need that information
- If the mean is ABOVE the RG, you can choose to investigate further:
  - Stratify the DU and resample
  - Revise boundaries

- **Soil Sampling Example:**
- ONE parcel had a mean result that exceeded the RG
- We went back and looked it over and resampled that parcel

Case Study: Soil Sampling in Idaho

- Collect 30 to 50 increments
- Randomly started systematic grid
- Located by GPS
- All the same volume
- Unbiased at increment location

CRREL Tool

Case Study: Soil Sampling in Idaho

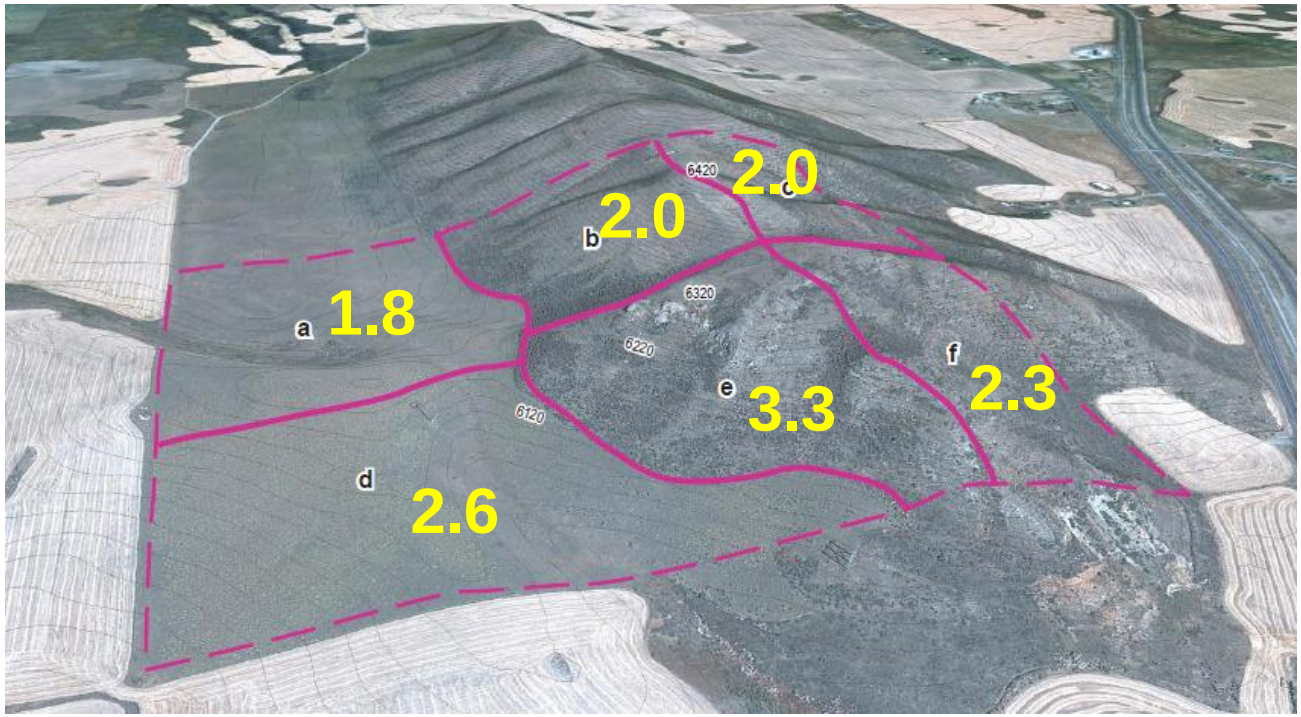
Oblique View

- An oblique look at the parcel shows many potential clues for variations in 226Ra levels

Soil Sample Case Study

Oblique View of Subparcel Results

- Only one Subparcel (Southern West-Facing Slope) had concentrations near the RG (3.7 pCi/G ^{226}Ra)



Case Study: Pile Sampling in Ohio

The Problem:

- Seven piles of material on the site
- Do the piles exhibit the Toxicity Characteristic (40 CFR §261.24)?

The Test:

- Toxicity Characteristic Leaching Procedure (TCLP)

The Decision:

- If a representative sample of the pile passes the TCLP, then the pile is not hazardous material

Decision Units

- Each discrete pile

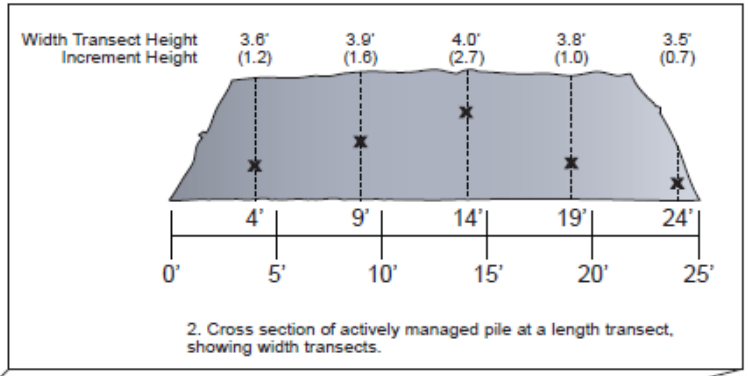
Sampling Approach

- 3-D Sampling systematic grid with randomly generated starts

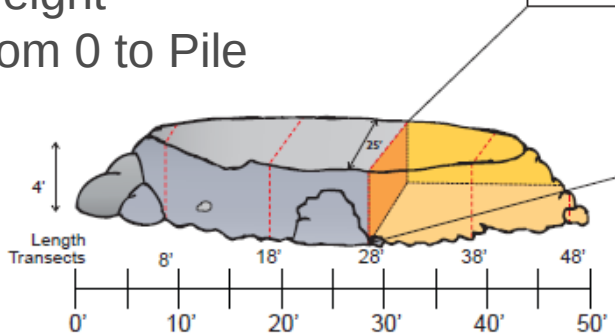
Case Study: Pile Sampling in Ohio

Implementation

- Excavate a series of 5 Length Transects (randomly selected from 0 to transect length)
- Run a series of 6 Width Transects in each Length Transect (randomly selected from 0 to transect length)
- Measure Pile Height each Width Transect
- Identify a Sampling Height (randomly selected from 0 to Pile Height)
- Collect increments



2. Cross section of actively managed pile at a length transect, showing width transects.



1. Actively managed pile regraded to 4' height, showing length transects

Case Study: Pile Sampling in Ohio

Selecting Transects

LENGTH TRANSECTS	
Pile Number	SP-04
Length	177
Length Random Number	96
Length Interval	35
Number of Length Transects	5
Number of Width Transects	6
Number of Increments	30
Length Transect 1	26
Length Transect 2	61
Length Transect 3	96
Length Transect 4	131
Length Transect 5	166

WIDTH TRANSECTS				
Length Transect 2	**61**	**Width Transect**	**Pile Height**	**Increment Height**
Pile Width	**99**	11	15	3
Width Random Number	**62**	28	14	6
Width Interval	**17**	45	17	5
		62	17	5
		79	13	7
		96	14	6

Case Study: Pile Sampling in Ohio

Sample Collection

- All increments collected from unbiased, randomly selected locations
- Every particle in the decision unit had an equal probability of being collected as an increment
- Triplicate samples collected to test variability / representativeness

Results

- All piles passed TCLP
- Relative percent difference for replicates were less than 10%, indicating low variability, highly representative samples *(except cadmium, which had results very close to the reporting limit)*
- The piles are not hazardous waste

Stakeholder Perspective

- What information does a Stakeholder need to determine that ISM is the appropriate method for the task at hand?
  - Site conceptual model
    - Geology
    - Hydrology
  - Processes used at the site
  - Types of contaminants at the site
  - Volume of the material
  - Goals and objectives of the project and the end use of the data
    - Does the upfront cost of the sampling effort exceed the projected outcome?

Stakeholder Perspective

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Stakeholder Perspective

- What ISM approach means to Stakeholders
  - One-time sample event to meet project objectives
  - Data Quality Objectives
    - High data quality
      - Defensible
      - Reproducible
      - Representative
    - Reduced misinterpretation of “chance” variability from grab and conventional composite sampling
      - Heterogeneity
      - Spatial coverage
      - Laboratory aliquots
    - Departure from searching for “Maximum Concentrations”

Stakeholder Perspective

- Ohio pile sampling case perspective
  - Former Ferrochromium Alloy Processing Plant
    - 333 acres
    - Two very large mill building, three bag houses, and other ancillary structures
    - Surrounded by Cross Creek on three sides
    - 1 Million Tons of slag
    - Failing Infrastructure
  - Issue
    - Seven piles of soil that appeared to have been managed/moved
    - Did the piles contain hazardous concentrations of metals, chrome +6 in particular?

Stakeholder Perspective

REMEMBER

- Need a site conceptual model
- Need to understand processes used at the site
- Types of contaminants at the site
- Volume of the material
- Goals and objectives of the project and the end use of the data
  - Does the upfront cost of the sampling effort exceed the projected outcome?

IF YOU CAN ANSWER ALL OF THE ABOVE, THEN

- Clarity in actions resulting from data collection
  - Decisions clear due to up-front agreement between parties
  - Representative and high quality data increases confidence in decisions
  - Cost savings

QUESTIONS?