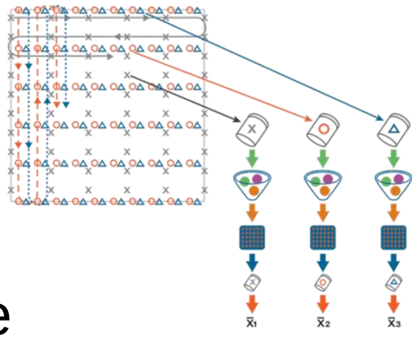
Advancing Environmental Solutions

Incremental Sampling Methodology (ISM) Update (ISM-2, 2020)



Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

ECOS

1

Training Course Overview:
The newly updated **Incremental Sampling Methodology (ISM)** training is a series of six modules providing an overview of ISM and presenting five sections from the ITRC guidance document (ISM-2, 2020):

- Overview (Sect 1)
- Heterogeneity (Sect 2)
- Statistics (Sect 3.2), Data Use Planning (Sect 3.3), and Data Quality Evaluation (Sect 6)
- Field Sampling Collection (Sect 4)
- Lab Preparation (Sect 5)
- Risk Assessment (Sect 8)

After this series, you should understand:

- Incremental Sampling Methodology (ISM) is a statistically supported technique for assessing the unbiased mean contaminant concentration in soil, sediment, and other solid media which can afford an economy of effort and resources in your projects.
- How the ISM structured composite sampling and processing protocol reduces data variability and provides for representative samples of specific soil volumes by

collecting numerous increments of soil (typically, 30 to 100 increments) that are combined, processed, and subsampled according to specific protocols.
- The key principles regarding heterogeneous soil sampling errors and how ISM reduces those errors to have more confidence in sampling results.
- How to use the new ITRC Incremental Sampling Methodology (ISM-2) guidance document to learn the principles and approaches of the methodology to improve representative, reproducible, and defensible data to improve decision-making at your sites

For regulators and other government agency staff, this improved understanding can hopefully be incorporated into your own programs. ISM is finding increased use in the field, as well as acceptance and endorsement by an increasing number of state and federal regulatory organizations. Proponents have found that the sampling density afforded by collecting many increments, together with the disciplined processing and subsampling of the combined increments, in most cases yields more consistent and reproducible results than those obtained by more traditional discrete sampling approaches.

Prior to attending the training class, participants are encouraged to view the associated ITRC guidance, Incremental Sampling Methodology (ISM-2). Additionally, for participants in a more detailed instruction to ISM, please view the ITRC Soil Sampling and Decision Making Using Incremental Sampling Methodology 2-Part Training Series.

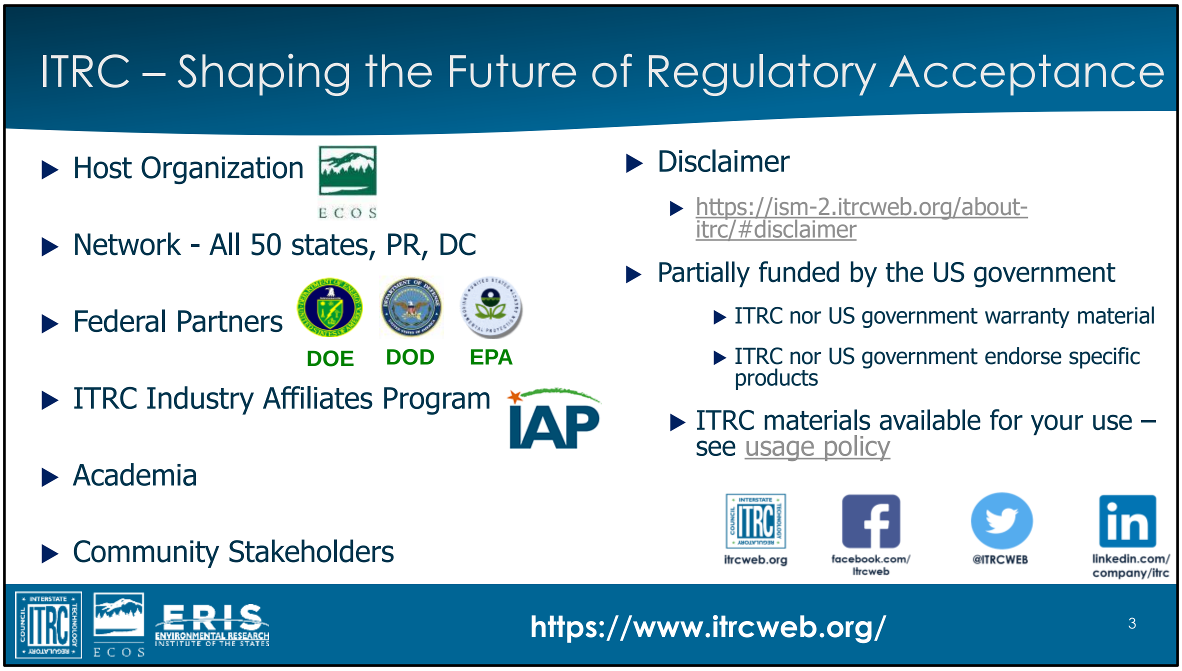
Housekeeping

- This event is being recorded; Modules will be available On Demand after the event at the main training page
- Download slides for today at the CLU-IN training page https://clu-in.org/conf/itrc/ISM2/ Under "Download Training Materials"
- If you have technical difficulties, please use the Q&A Pod to request technical support
- Need confirmation of your participation today?
  - Fill out the online feedback form and check box for confirmation email and certificate

2

Notes:
Use the "Q&A" box to ask questions, make comments, or report technical problems any time. For questions and comments provided out loud, please hold until the designated Q&A breaks.

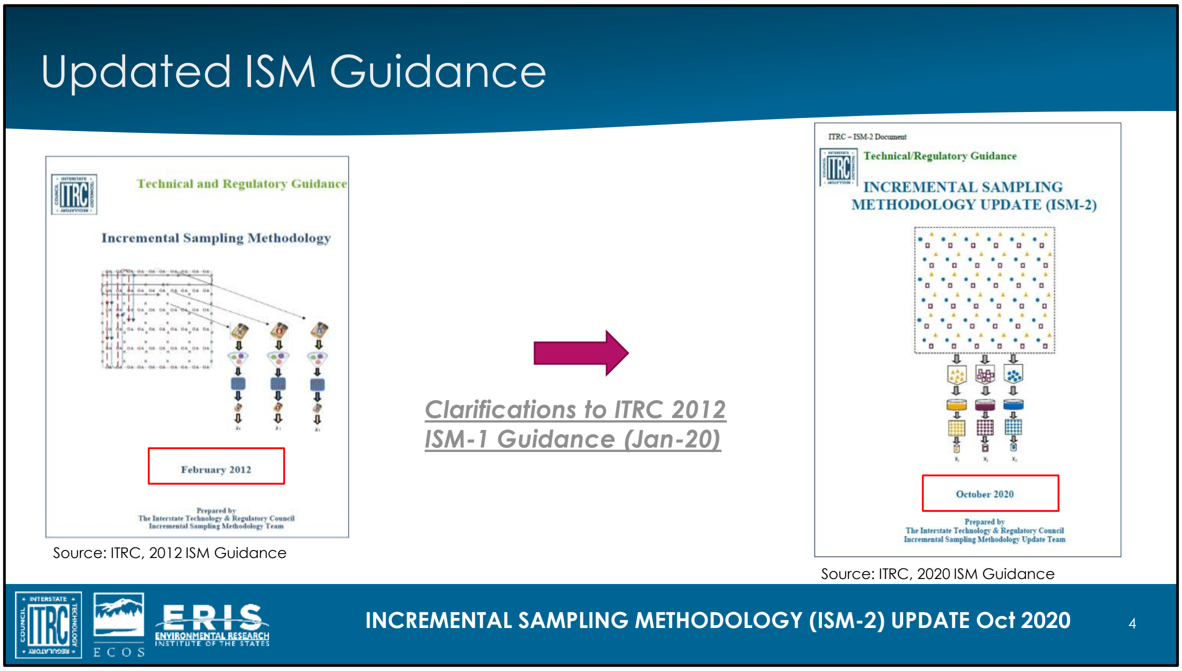
Everyone – please complete the feedback form before you leave the training website. Link to feedback form is available on last slide.



The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

ITRC, ERIS, and ECOS do not endorse or recommend the use of specific technology or technology provider through ITRC Materials. Reference to technologies, products, or services offered by other parties does not constitute a guarantee by ITRC, ERIS, and ECOS of the quality or value of those technologies, products, or services. Information in ITRC Materials is for general reference only; it should not be construed as definitive guidance for any specific site and is not a substitute for consultation with qualified professional advisors.



ITRC issued the Incremental Sampling Methodology Guidance (known as ISM-1) in February 2012. Since that time, many more states and consultants have adopted its use, and we found that it could benefit from an update. But, what started as an update, really turned into a complete overhaul and improvement of the original document, with input from experts and new practitioners from around the world.

The revised and updated ITRC guidance (ISM-2) was developed to build on the 2012 version to reflect advancements in technology and to share case studies that simply were unavailable at the time of ISM-1, and that provide insight into potential applications, benefits, and challenges of the ISM approach. The ISM-2 Update Team also determined that clarification of incorrect, unclear, or inconsistent information in ISM-1 was also necessary. A clarification statement is now appended at the beginning of the ISM-1 document and ISM-1 continues to be a useful and valuable tool for those interested in learning the concepts of ISM.

Meet the ITRC ISM-2 Team Leaders

Caroline Jalanti
New York State DEC
Albany, NY
(518) 402-9621
Caroline.Jalanti@dec.ny.gov

Troy Keith
Tennessee DEC
Chattanooga, TN
423-634-5755
troy.keith@tn.gov

Read trainer bios at https://clu-in.org/conf/itrc/ISM2/

5

Caroline Jalanti received her B.S in Environmental Engineering from Worcester Polytechnic Institute and was recognized within the Environmental Engineering Department for her research into remedial technology advancements for the emerging contaminant 1,4-Dioxane. Caroline has been working as an Environmental Engineer with the New York State Department of Environmental Conservation (NYSDEC) since 2014. During her time with NYSDEC, Caroline has worked on various investigation and remediation projects across multiple state programs including: State Superfund, Brownfield Cleanup Program, and Petroleum Response.

Troy Keith, PG, has been working as a geologist in the environmental industry for thirty years, with the last 20 being with the Tennessee Department of Environment and Conservation, Division of Remediation. Mr. Keith has worked on investigation and remediation of numerous active and inactive DoD sites, NPL sites and State Superfund sites. In addition to traditional CERCLA and RCRA work, Mr. Keith has extensive experience with regional implementation and administration of the DoR's Voluntary Oversight and Assistance Program (Brownfield Program) for the Southeast Tennessee region.

Incremental Sampling Methodology (ISM-2) Update

- Introduction (Sect. 1)
- Nature of Soil Sampling (Sect. 2)
- Systematic Planning & Decision Unit Designation (Sect. 3.1)
- Statistical Concepts & Calculations (Sect. 3.2)
- Planning for the Use of ISM Data (Sect. 3.3)
- Cost-Benefit Analysis (Sect. 3.4)
- Field Implementation, Sample Collection, and Processing (Sect. 4)
- Laboratory Sample Processing and Analysis (Sect. 5)
- Data Quality Evaluation (Sect. 7)
- ISM for Risk Assessment (Sect. 8)
- Stakeholder Input (Sect. 9), Case Studies, and Statistical Simulations

ITRC ECOS ERIS Environmental Research Institute of the States

Incremental Sampling Methodology (ISM) Update (ISM-2, 2020) 6

The updated ITRC Incremental Sampling Methodology guidance document (ISM-2) was developed to build on the 2012 version (ISM-1) and to reflect advancements in technology, incorporate the lessons learned by practitioners over the past eight years, and share case studies that provide insight into the potential applications, benefits, and challenges of the ISM approach.

ISM-2 contains 9 sections and an appendix with case studies as well as an update to the Statistical Simulations contained in ISM-1. The ITRC ISM-2 Training Module will not cover all the sections of the guidance document, so we strongly encourage you to visit the web-based document and explore all the tools and resources available.

ISM-2 Training Modules (6 module series)

Module 1: Introduction (Sect. 1)

Module 2: Heterogeneity (Sect. 2, 3.1)

Module 3: Statistics, Data Use Planning, & Data Quality Evaluation (Sect. 3.2, 3.3, 6)

Module 4: Field Sampling Collection (Sect. 4)

Module 5: Lab Preparation (Sect. 5)

Module 6: Risk Assessment (Sect. 6)

ISM-1 Training: Soil Sampling and Decision Making Using Incremental Sampling Methodology
Two-Part Training On Demand Listening on Clu-In!

7

The ISM-2 Team created this training as a series of six modules. These are designed to be stand-alone modules to help participants understand specific components of ISM. These can be viewed separately and in any order preferred by the participant.

Module 1 provides an overview of ISM to orient participants to the concept of ISM and the Guidance Document.

Module 2 discusses the importance of small-scale and large-scale heterogeneity – how ISM addresses soil contamination in such a challenging environment. Soil and other solid matrices are inherently heterogeneous and, because of that heterogeneity, traditional grab sampling approaches can substantially over or under estimate the true mean concentration of contaminants present. This module shows how ISM reduces the errors inherent in traditional sampling approaches and provides representative samples suitable for accurate decision making.

Module 3 recognizes the common statistical misconceptions and pitfalls in sample planning and analysis, and how to avoid them. Wondering which UCL to choose, and how to calculate it? Learn how to use our UCL calculator in the statistics module.

Module 4 provides a variety of examples and techniques to help you understand the field sampling methods used for ISM. This module goes over a comprehensive field planning checklist, and covers how to locate and collect your increments.

Module 5 provides a comprehensive review of the laboratory and analytical side of ISM and how it impacts the quality of your results. This module will help project planners select sample processing options to manage microscale heterogeneity and to preserve representativeness. It will explain the most common processing options and has video examples of milling and 2D slabcake subsampling.

And Module 6 is your go-to resource for what you need to know about using ISM data in risk assessment and risk-based decision making. You can use ISM data for risk assessment for providing an accurate estimate of the true mean for a scientifically defensible risk assessment and risk-based decision making. Module 6 covers designing DUs for risk assessment, including 95%UCLs. This module also touches upon use of ISM for establishing background concentrations, post-remediation confirmation sampling, and risk communication.

Also, don’t forget that ISM-1 has a two-part training available on Clu-In. This training is still relevant and current.

Incremental Sampling Methodology (ISM) Update
Module 1: Overview (Sect 1)

Meet the ITRC Trainers

Jason Brodersen, PG
Tetra Tech, Inc
Oakland, CA
415-497-9060
jason.brodersen@tetratech.com

Chris Christensen
Michigan Dept. of Environment, Great Lakes and Energy
Grand Rapids, MI
616-446-7582
christensenc@Michigan.gov

Read trainer bios at https://clu-in.org/conf/itrc/ISM2/

Incremental Sampling Methodology (ISM) Update (ISM-2, 2020) 1

Module 1 will discuss

Clarifying misconceptions
Expanded understanding of ISM applications through case studies
the benefits of using ISM at various sites (Confidence in data)

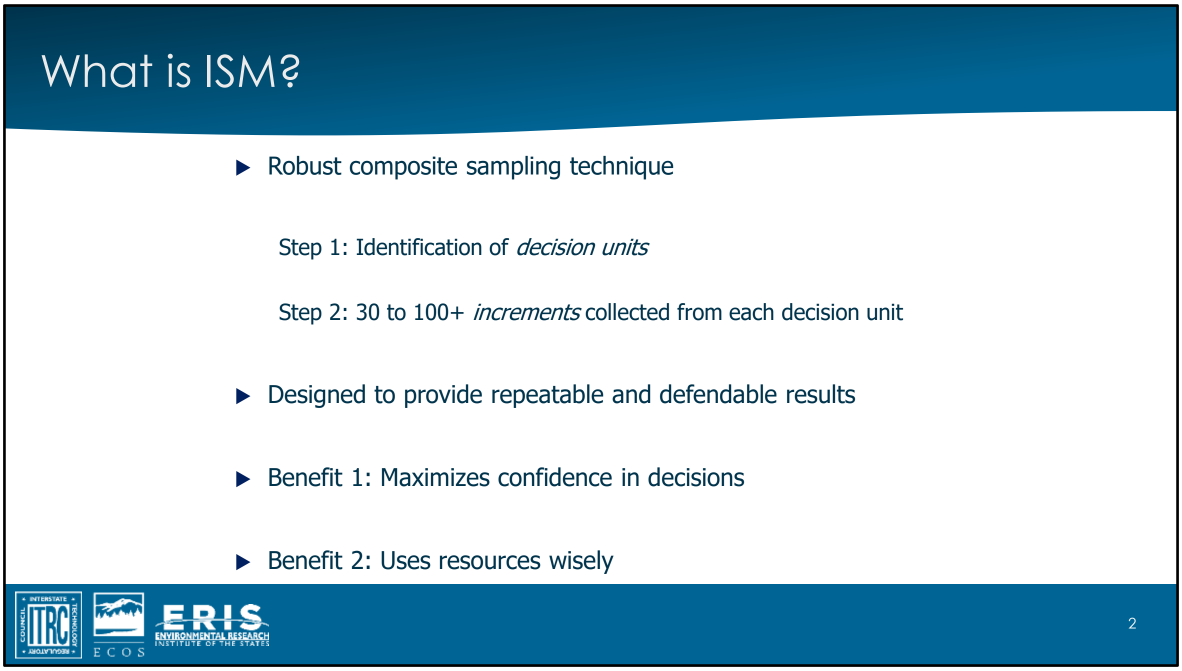
- Thanks for the intro
- Welcome to the intro module
- Nicole can you start our poll question to help give us an idea of everyone's familiarity with ISM. Thanks.
- Overview including applications and benefits. Specifically, I will be discussing the big picture of ISM and some of its benefits, along with many examples
- Chris will dive a little deeper into the nitty gritty of implementing it.
- First of 6 training modules for this updated guidance manual – at the conclusion Chris will summarize the following 5 modules

****

<u>TRAINER BIOS</u>

Chris Christensen is an Environmental Hydrogeologist with the Michigan Department of Environment, Great Lakes and Energy (EGLE), Remediation and Redevelopment Division (RRD), in Grand Rapids since 1992. Chris works on both leaking underground storage tank sites as well as chlorinated solvent and surficial soil contamination sites. He is on RRD Technical Teams related to Incremental Sampling, Non-Aqueous Phase Liquids, Risk-based Corrective Action and Groundwater Modeling. He has advocated for Incremental Sampling use in Michigan since 2011; and contributed as a member of the ITRC ISM-2 team. Chris has a B.S. in Geology from Michigan State University, and an M.S. in Hydrogeology from Western Michigan University.

Jason Brodersen, PG, is a Geophysicist and California Professional Geologist with over 32 years of professional environmental consulting experience, including 30 years with Tetra Tech. He has been a Project and Program Manager for complex environmental investigation and cleanup projects, due diligence, guaranteed fixed price remediation, and Phase I and II environmental assessment projects. Mr. Brodersen has managed over 150 environmental projects with a combined value of more than $50 million. Mr. Brodersen also provides technical and contract quality assurance and quality control review for projects nationwide within Tetra Tech. Over the past 16 years, Mr. Brodersen has emerged as a nationwide expert in the development, training, and implementation of Incremental Sampling Methodology (ISM) at hundreds of projects throughout the US. Mr. Brodersen was heavily involved in development of the State of Hawaii ISM technical guidance and oversaw some of the first ISM investigations in that state. He has provided trainings and workshops in California to EPA, CalEPA, DTSC, RWQCB, California Department of Health Services, and other regulators and stakeholders as the method gains acceptance with regulators.



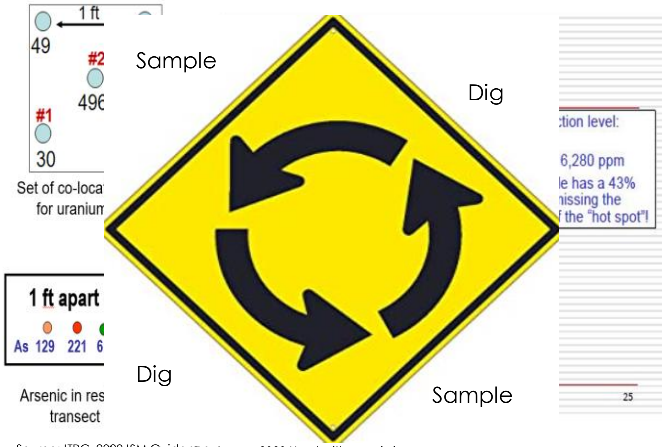
So what is ISM exactly?

- So what is ISM exactly?
- It is a robust planning and systematic sampling methodology based on a two-step process:
  - Determining your *decision units* (define)
  - Collecting 30 to 100 increments from a DU
- Small soil volumes – 10 to 30 grams per increment are combined in 1kg sample
- Combined increments for single concentration for DU.
- Note there is also an improved laboratory processing protocol associated with ISM.
- Emphasis on coverage and replicate samples designed to provide repeatable and defendable soil concentrations – generally at much lower costs than traditional sampling.
  - Results? Increased coverage and replicates enables us to maximize our confidence in decisions
  - Result? Confidence in decisions means we use resources more wisely
  - Bottom line: Resources to focus on areas that are contaminated or

providing supporting information for those areas which are not.

Why is this Critical?

- Need high confidence in decisions
- Known challenges to soil characterization
- Must avoid unnecessary resources spent on areas which do not need cleanup and focus on those which do!



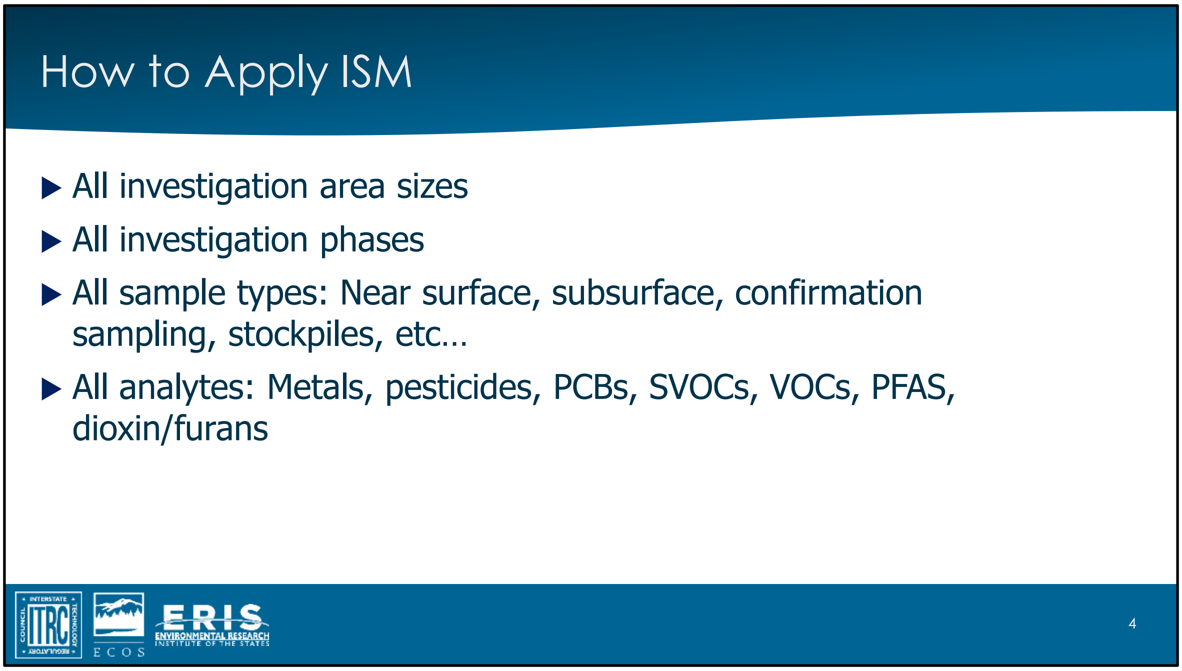
Source: ITRC, 2020 ISM Guidance
Source: Jason Brodersen, 2020 Used with permission.

So, why is ISM critical?

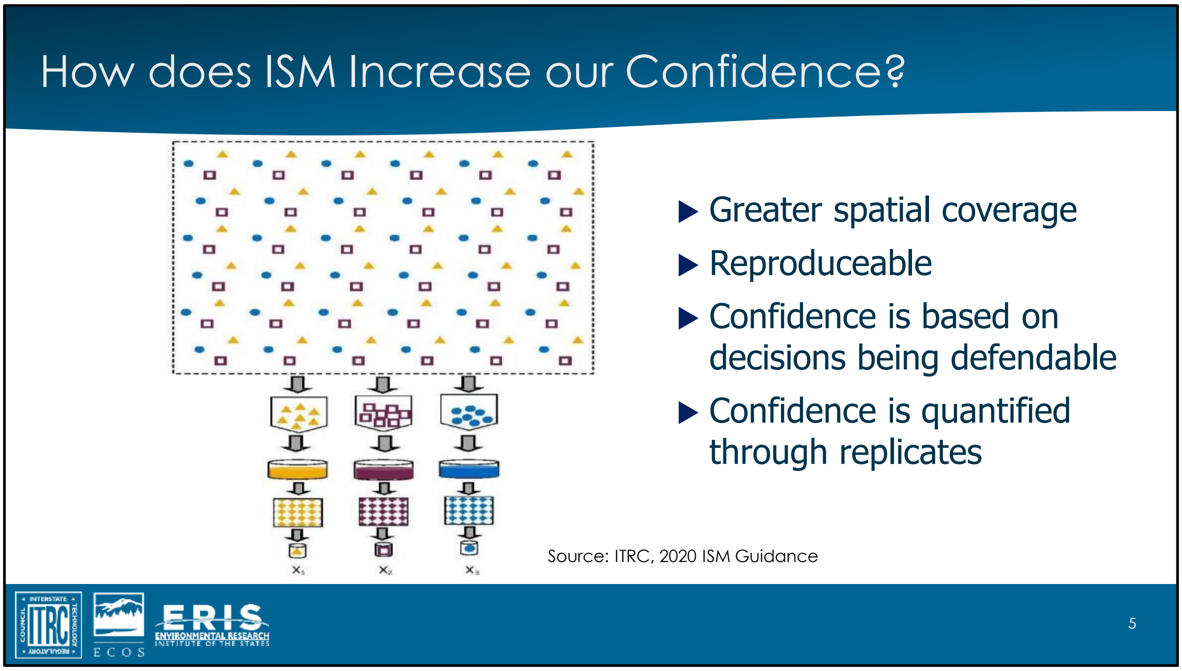
- Everyone knows we need to have high confidence in our decisions – we are after all scientists, engineers, and professionals working a challenging field. Our decisions must hold up to client, stakeholders, agencies, and community scrutiny.
- I'm a consultant – I need to make sure I am spending my client's money in an efficient and effective manner – not something I have historically felt comfortable about with discrete sampling.
- Why didn't I have that confidence? Inherent challenges in (1) soil heterogeneity, (2) contaminant distribution and heterogeneity, and (3) unknown nature of site histories.
- Yet we need high confidence in every step of decision making
- The last 30 years have shown us the high variability in traditional discrete results
- Orders of magnitude changes

- So what does that mean? Even small changes in sample locations might alter results – that results poor repeatability and low confidence.

- What else does it result in? Sample-dig-sample-dig endless do loop.
- That wastes time and money, and exposes low confidence in more traditional discrete sampling.
- We can’t afford to make low-confidence decisions re cleanup or leaving cont in place. Repercussions just too large and important



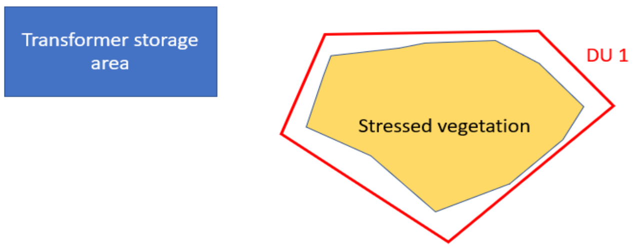
- Variety of sizes, depend on what your project needs
- Single play area, then ISM can provide your results there.
- Soil in a 1-acre commercial lot
- I am going to run through a variety of examples – which should help everyone visualize how it can be applied
- Any phase of investigation
- Scoping, source, nature and extent, risk assessment, waste profile, confirmation sampling, et cetera.
- Surface or subsurface, although subsurface sampling can provide its own challenges. But - if defendable data is the goal, then those challenges are worth overcoming.
- All analytes, including VOCs.
- ISM is a compositing technique, it can be used for VOCs
- Planning and coordination with your laboratory – and it does not impact the quality or integrity of your VOC sample.



How does ISM increase our confidence?

- 30 to 100 soil increments within the decision unit provides orders of magnitude of coverage over traditional sampling
- Replicates enable us to evaluate and quantify reproducibility
- So even with a defendable single sample, reps enable us to quantify and add statistical confidence intervals if necessary.
- Bottom line: Repeatability is the cornerstone to the scientific method, and the emphasis on replicate samples give ISM a foundation in solid science.
- Reminds me of my then 7th grade daughter…
- And again – this is all accomplished at generally lower costs and vastly improved schedules than traditional discrete sampling
- This is because of much reduced lab costs – which can sometimes be up to 30% of your traditional budget – but mostly because of getting high quality and representative results the FIRST time, minimizing or eliminating the need for step outs or further investigations.

Practical ISM Uses

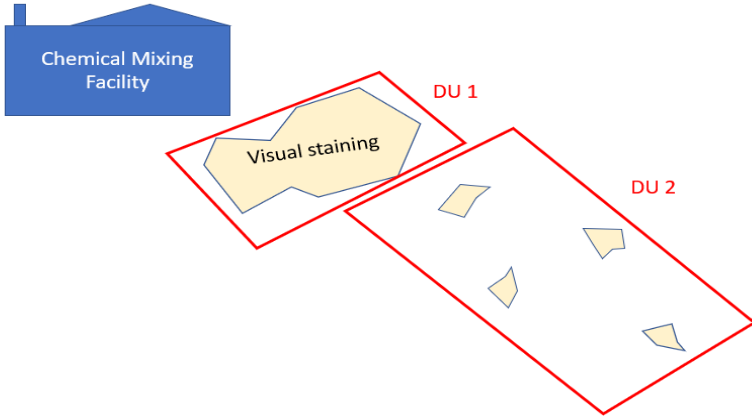


Source: ITRC, 2020 ISM Guidance, 1.3 Figure 1.1

At this point I'd like to run through a number of examples of how you might apply ISM at your site

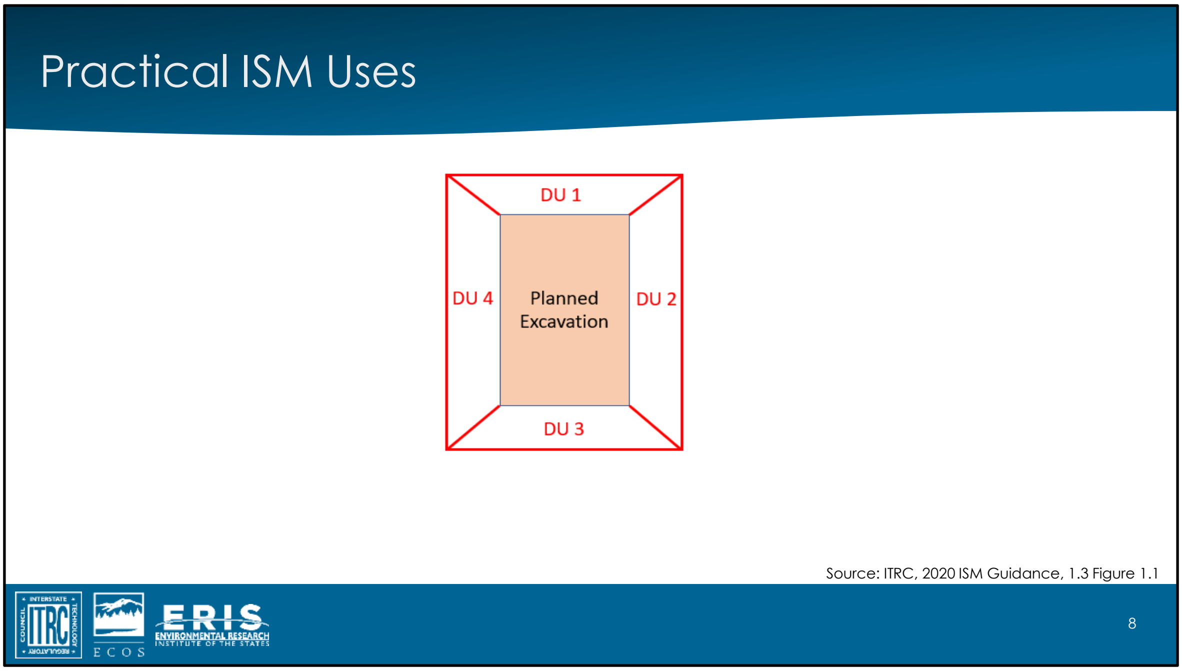
Start with the simplest of scenarios

Practical ISM Uses



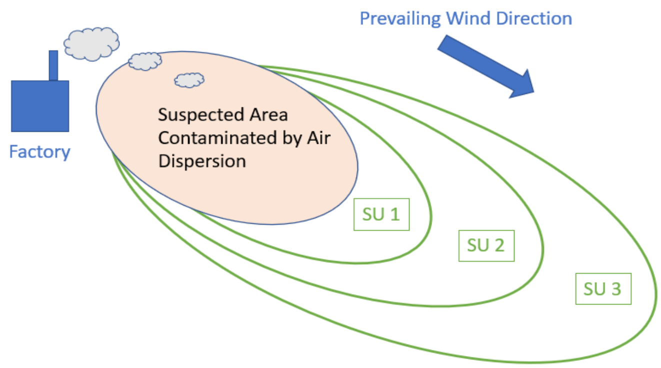
Source: ITRC, 2020 ISM Guidance, 1.3 Figure 1.1

Add two areas of interest



How about you are planning an excavation and would like to confirm the concentrations around the excavation before you start digging

Practical ISM Uses



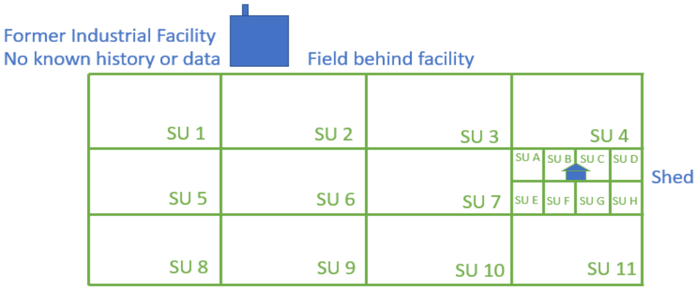
Source: ITRC, 2020 ISM Guidance, 1.3 Figure 1.1

Can be used to characterize contaminant distribution over space, such as this example with air dispersion.

Notice the use of SU instead of DU. As the guidance document notes, there is a bit of overlap and possibly ambiguity of the uses in the industry of SU vs DU. Some practitioners use the term SU if multiple ISM samples are collected in order to support a larger site decision – others just use DU to represent an ISM sample, regardless of the type of decision being made.

No need to get hung up on it – it is really just a nomenclature issue. For example, you could just call it a cell represented by ISM sampling.

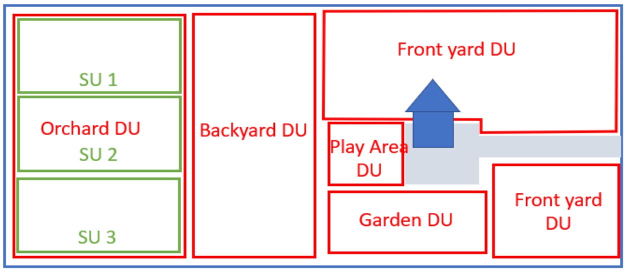
Practical ISM Uses



Source: ITRC, 2020 ISM Guidance, 1.3 Figure 1.1

Focusing on an individual area within a larger area

Practical ISM Uses

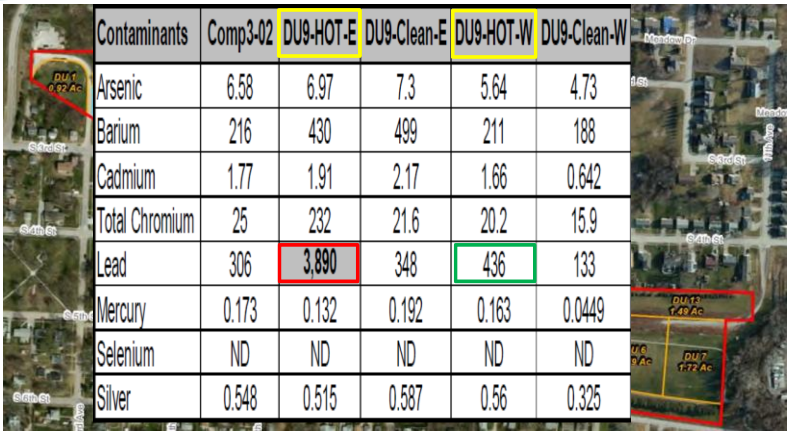


Source: ITRC, 2020 ISM Guidance, 1.3 Figure 1.1

And different size DUs or SUs based on risk assessment or exposure areas.

Rhylander Park
Nebraska

- Exposure-specific sampling
- Sample depths:
  - 0-2 inches
  - 2-12 inches
- Conclusive results
- Public acceptance



Contaminants	Comp3-02	DU9-HOT-E	DU9-Clean-E	DU9-HOT-W	DU9-Clean-W
Arsenic	6.58	6.97	7.3	5.64	4.73
Barium	216	430	499	211	188
Cadmium	1.77	1.91	2.17	1.66	0.642
Total Chromium	25	232	21.6	20.2	15.9
Lead	306	3,890	348	436	133
Mercury	0.173	0.132	0.192	0.163	0.0449
Selenium	ND	ND	ND	ND	ND
Silver	0.548	0.515	0.587	0.56	0.325

Source: Nebraska DEQ, 2013. Used with permission

Now lets look at a real example:

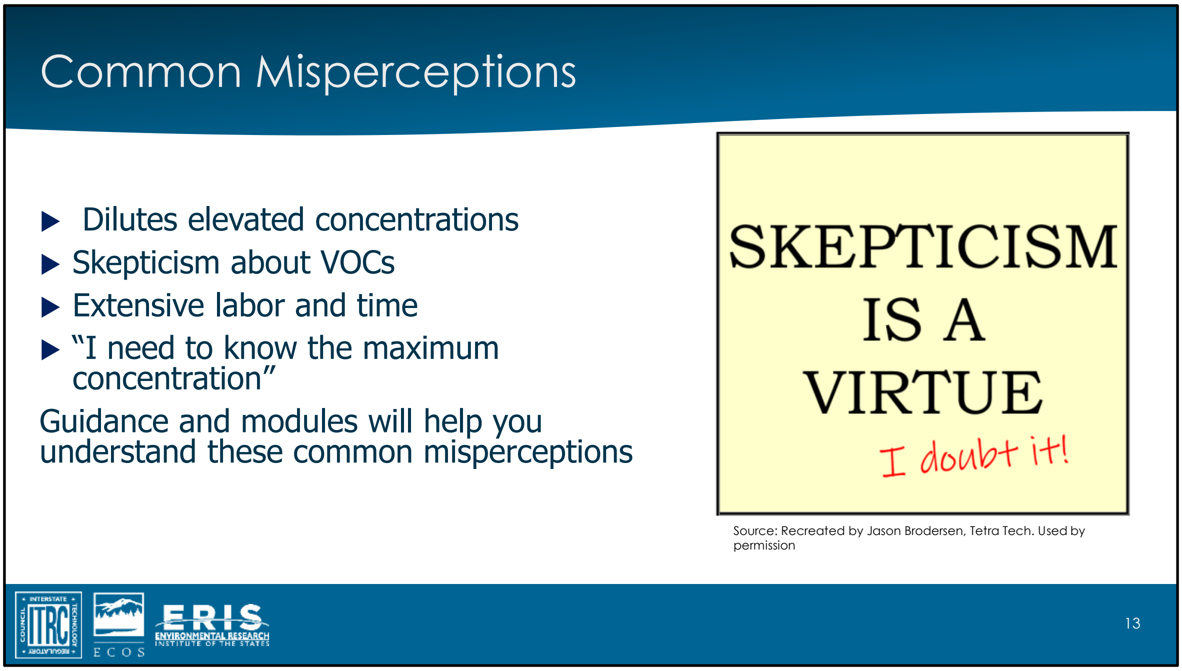
ISM was implemented at Rhylander Park in Nebraska adjacent to a legacy railway and machine shops which were abandoned in the 1980s.

Specific current activities and elevated contamination from previous investigations.

ID DUs

- Metal COCs – specifically lead
- The single DU with elevated lead REALLY stands out as contaminated – a good example that if elevated contaminants are present, they will be reported.

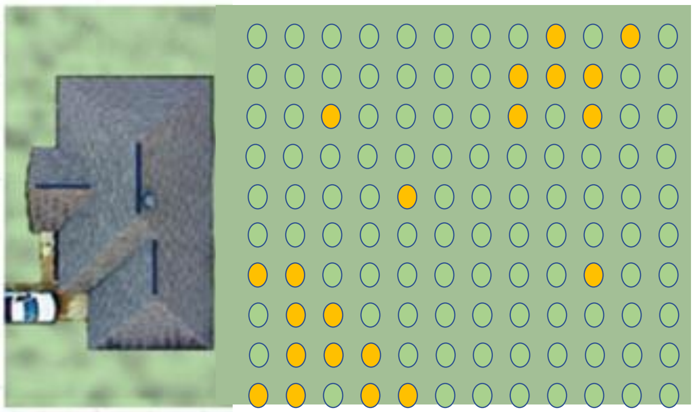
- Resulted in a cleanup of the elevated areas, remaining park area safe for use.
- Area this large completed in single mobilization! ISM resulted in resources being spent in the right places.
- The data was presented at a community meeting and the public supported the recommendations.



- I've given enough trainings to know that many of you have already been jumping ahead about some concerns regarding ISM, like:
- It dilutes elevated concentrations, "hot spots" One of the original uses of ISM was by miners to find - not dilute – precious metals during prospecting. That should give you an idea of the confidence they had in finding small elevated concentrations with this method.
- How can you analyze for VOCs if it is a composite? – as mentioned previously, this is easily overcome by working with your lab
- Sounds like a huge amount of labor involved – not really! Shallow sampling is very easy and effective – and huge cost savings are realized by fewer mobilizations and removal of uncertainties.
- "But I need to know the maximum concentration!" How convinced are you that traditional sampling gets you the maximum concentration? If you are interested in contaminant variability, you can get that too.

Takes more time than we have, but check out each of the other 5 modules and the guidance doc to answer these.

Selecting the Decision/Sampling Units



Residential Backyard Exposure Area

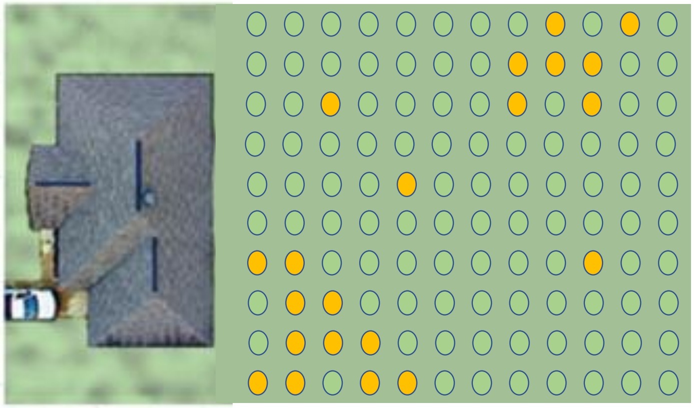
Decision will be made for entire area

Site conceptual model predicts that there could be small pockets of elevated contaminants

Source: ITRC, 2020 ISM Guidance, 1.3 Figure 2.17

At this point I'd like to take you through an example demonstrating how different project objectives at the same site would result in different ISM designs.

Selecting the Decision/Sampling Units

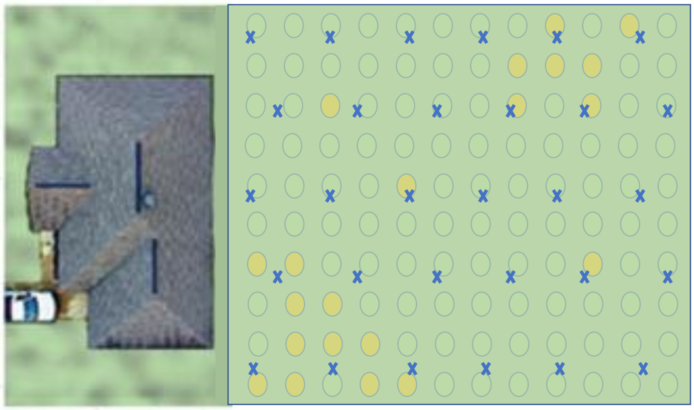


Two Scenarios:

1. Only interested in exposure across entire area
2. Concerned about possible small areas with elevated concentrations

Source: ITRC, 2020 ISM Guidance, 1.3 Figure 2.17

Selecting the Decision/Sampling Units



Scenario 1:

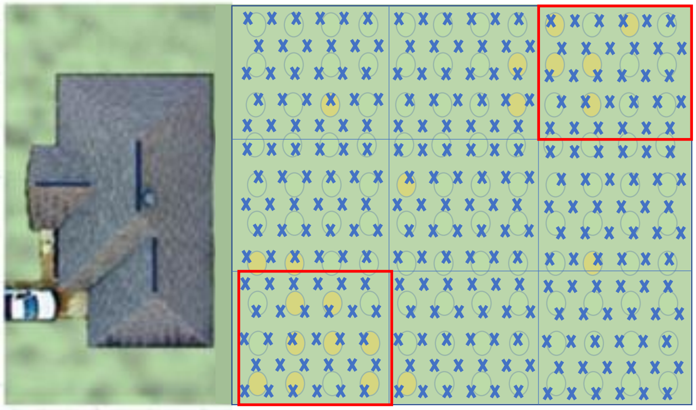
Design decision unit to capture total exposure

- 1 decision unit
- 30 total increments

Result: average concentration over entire area

Source: ITRC, 2020 ISM Guidance, 1.3 Figure 2.17

Selecting the Decision/Sampling Units



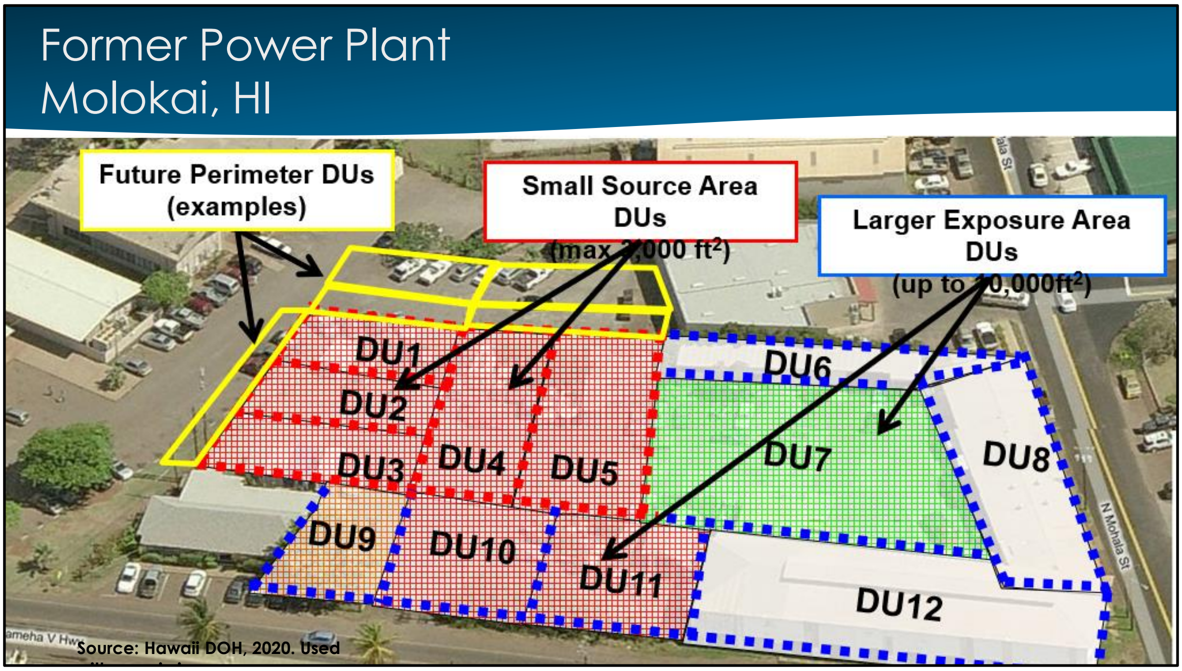
Scenario 2:

Design sampling units small enough to capture variability within decision unit

- 9 sampling units
- 30 increments each

Result: Higher resolution allows for cleanup of specific areas

Source: ITRC, 2020 ISM Guidance, 1.3 Figure 2.17



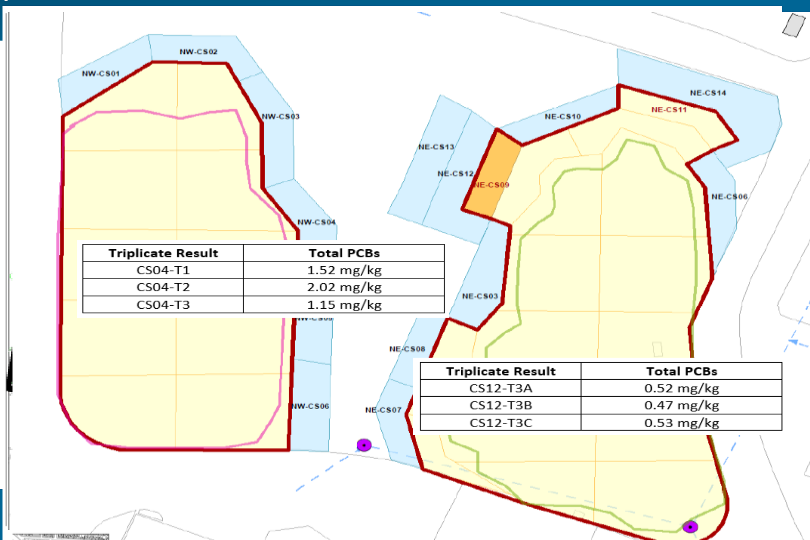
I'd like to give one more real example:

- Power plant in Molokai, Hawaii,
- Proposed as a new community center.
- The primary chemical of concern at the site was PCBs, with an action level of 1 mg/kg,
- Results from traditional
- New ISM
- Discuss different DU types
- Reminder about pre results

Results

- Again – all results and site conclusions were completed in a single mobilization – so lower cost and faster schedule
- Most importantly – cleanup resources spent in the right places. Prev results would have resulted in comm members exposed.

Example Triplicate Results



Triplicate Result	Total PCBs
CS04-T1	1.52 mg/kg
CS04-T2	2.02 mg/kg
CS04-T3	1.15 mg/kg

Triplicate Result	Total PCBs
CS12-T3A	0.52 mg/kg
CS12-T3B	0.47 mg/kg
CS12-T3C	0.53 mg/kg

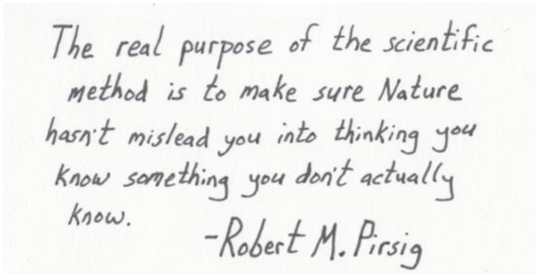
Back in the early 90s, EPA protocols had us collecting duplicate discrete soil samples.

…

We instead embrace it – here are just a few examples.

ISM Advantages and Benefits

- ▶ Efficient and effective
- ▶ Highly versatile
- ▶ High confidence



Robert M. Pirsig, Author of Zen and the Art of Motorcycle Maintenance

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES 20

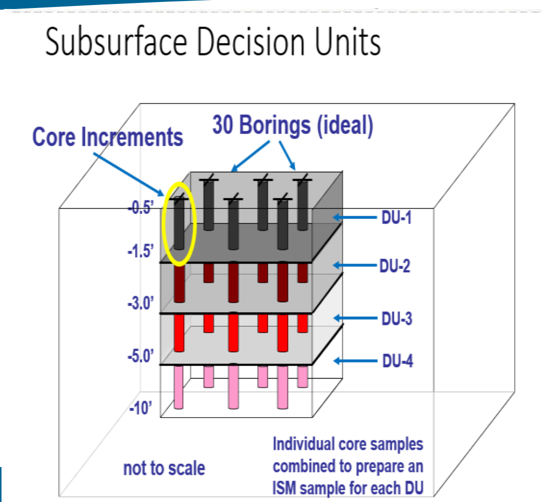
- To close my portion of the presentation:
  ISM is designed to be efficient and effective use of your resources.
- Lower lab costs and you get high quality and defendable results the first time – often minimizing or even eliminating further investigations
- Highly versatile: can be used at any time, any site, and for any objective
- Sample coverage and replicates help capture and quantify soil heterogeneity, resulting in high confidence in your decisions.
- Enables you to feel really great about how you've spent your resources on your project.

ISM Logistics

- Establishing the decision unit
- Collecting the ISM sample
- Replicate samples
- Subsurface decision units

Left: Video by: Troy Keith, TDEC
Sample collection by:
Leslie Shaver and Jerica Korak, Tetra Tech
Roderick Jones, CERM

Right: ITRC, 2020 ISM Guidance, Figure 3-8.



So how do you go about collecting your ISM sample?

It all starts with establishing your decision unit – the volume of soil you are interested in. In ISM, there is a very heavy emphasis on systematic planning and how you are going to use the data – that is the fundamental basis for how decision units are established.

The goal of ISM is to obtain and analyze a sample that contains mass (and therefore analytes) in the same proportions as the soil throughout the decision unit. As discussed previously, this can be small or large or anything in between – it is ALWAYs a project-specific decision based on your data quality objectives.

Collecting the ISM sampling increments involves the systematic sampling of small soil samples from throughout the decision unit. The are most often collected in a random systematic grid to help ensure representative coverage.

Here is a video demonstrating the ease in which surface increments can be collected

[Start video]

[After video, advance]

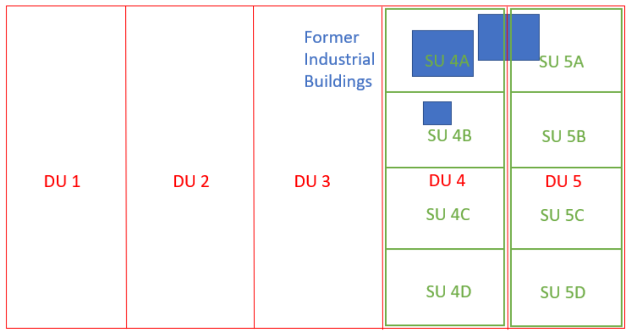
Another key element of the sampling approach is the collection of resamples, typically three replicates. These replicates are collected with consistent coverage, but the increments are located at different locations within the decision unit. The replicate results enable you to understand the heterogeneity of your decision unit, as well as understand how well the number of increments capture the concentrations within the decision unit. Significant differences between replicates may trigger you to collect more increments, or make the decision units smaller.

[advance]

Subsurface increments, as mentioned before, can be more challenging as they require drilling techniques and collection of increments from cores.

Using ISM Results

- Single results
- Multiple results
- Confidence intervals



Decision units to investigate area for commercial exposure scenario.
DU 4 and DU 5 split into smaller SU sampling units

Sources: ITRC, 2020 ISM Guidance

Each ISM project will generate its own unique set of results and uses of those results.

ISM projects may use single results

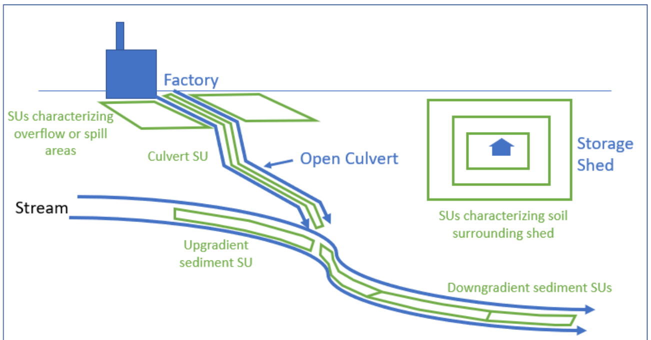
[advance]

multiple ISM results, or the use of confidence intervals through the collection of replicates.

Ideally the initial results will provide all the data necessary for your decisions, if the sample design is correct. Regardless of planning, there can be unforeseen or unexpected concentrations, which should not be surprising since often we don't *really* know where contamination exists - because let's face it, if we did, we would only sample there! And so it is not uncommon to reevaluate the data to determine if additional decision units or changes in the sampling method are needed.

Using ISM Results (continued)

- Due diligence/property acquisition
- Risk assessment
- Fate and Transport
- Sediment loading modeling
- Engineering parameters



Sample units to define nature and extent, and refine site conceptual model

Sources: ITRC, 2020 ISM Guidance. 1.3 Figure 1-1.

In terms of types of uses, ISM can be used for any project needing soil concentrations, including property transfer and acquisitions, site characterization, risk assessment, sediment model loading, fate and transport studies.

For example, it can be used to test engineering parameters like concentrations of soil through a treatment train, and any other use where you want to know the average concentration of any volume of soil. Let me repeat that, ISM can be used anywhere where you need to know the average concentration in any volume of soil.

The bottom line is you can use the results to get you to the next step, whether it be cleanup, no action, or anything in between.

Benefits

- Representative and defendable
- Neutralizes the inherent uncertainty in soil sampling
- High confidence in decision making

24

To summarize, ISM is a cost-effective and scientifically defensible sampling technique designed to provide you with results to support highly-confident decisions.

It provides incredible sample coverage and use of replicates enables you to quantify your confidence in the results. Larger coverage and increased confidence results in fewer phases or mobilizations, elimination of traditional “step outs”, or sample-dig-sample routines, and therefore faster and more effective decisions. Most ISM projects derive their final conclusions in a single mobilization.

The ISM method is designed to ensure that existing contaminant levels are captured, or to justify no contamination present, if that is the case.

Continued Training Modules

Module 1: Introduction (Section 1)
Module 2: Heterogeneity (Section 2)
Module 3: Statistics and Data Quality Evaluation (Sections 3 and 6)
Module 4: Field Sampling Collection (Section 4)
Module 5: Lab Preparation (Section 5)
Module 6: Risk Assessment (Section 8)

25

Thank you for participating in this introductory training module. This was one of six modules - there are five upcoming modules, consisting of:

Module 2 discusses the importance of small-scale and large-scale heterogeneity – how ISM addresses soil contamination in such a challenging environment. Soil and other solid matrices are inherently heterogeneous and, because of that heterogeneity, traditional grab sampling approaches can substantially over or under estimate the true mean concentration of contaminants present. This module shows how ISM reduces the errors inherent in traditional sampling approaches and provides representative samples suitable for accurate decision making.

Module 3 recognizes the common statistical misconceptions and pitfalls in sample planning and analysis, and how to avoid them. Wondering which UCL to choose, and how to calculate it? Learn how to use our UCL calculator in the statistics module.

Module 4 provides a variety of examples and techniques to help you understand the field sampling methods used for ISM. This module goes over a comprehensive field planning checklist, and covers how to locate and collect your increments.

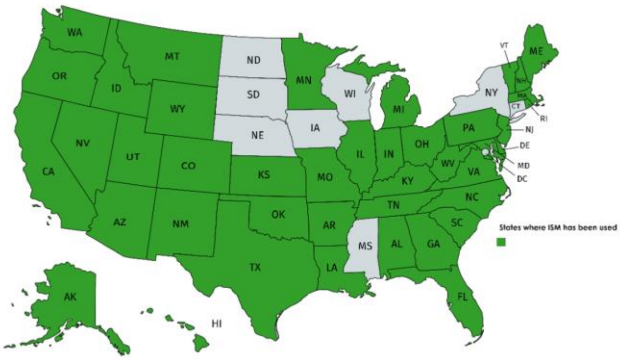
Module 5 provides a comprehensive review of the laboratory and analytical side of ISM and how it impacts the quality of your results. This module will help project planners select sample processing options to manage microscale heterogeneity and to preserve representativeness. It will explain the most common processing options and has video examples of milling and 2D slabcake subsampling.

And Module 6 is your go-to resource for what you need to know about using ISM data in risk assessment and risk-based decision making. You can use ISM data for risk assessment for providing an accurate estimate of the true mean for a scientifically defensible risk assessment and risk-based decision making. Module 6 covers designing DUs for risk assessment, including 95%UCLs. This module also touches upon use of ISM for establishing background concentrations, post-remediation confirmation sampling, and risk communication.

Thank you – and we will now open the floor to questions.

Proven

- Increase in State acceptance
- Effective use of resources
- High quality data stakeholders can count on



Sources: ITRC, 2020 ISM Guidance Figure 7.1.

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

26

These benefits have born out in a significant increase in use across the nation since our first ISM tech reg. The number of states where ISM has been done increased from 30% in 2012 to 85% currently.

Sites finish faster with fewer mobilizations.

Honestly, I’ve never run into a team who has implemented ISM who hasn’t embraced it for its effectiveness, cost-conscious approach, and higher quality data.

ISM results, with their high degree of confidence, are critical when presenting data to the public, other regulatory agencies, management, or any other stakeholders where you need to quantify the degree of confidence and certainty that resources have been, and will be, responsibly allocated.

Thank you for attending! Questions & Answers?

- Email further questions on today's session to: training@itrcweb.org
- Feedback Form & Certificate of Completion: https://clu-in.org/conf/itrc/ism2/feedback.cfm
- ISM Training Modules will be hosted for separate viewing On Demand
- Want more? Visit https://clu-in.org/conf/itrc/ism/ for more in-depth training modules on ISM

ISM Update Modules

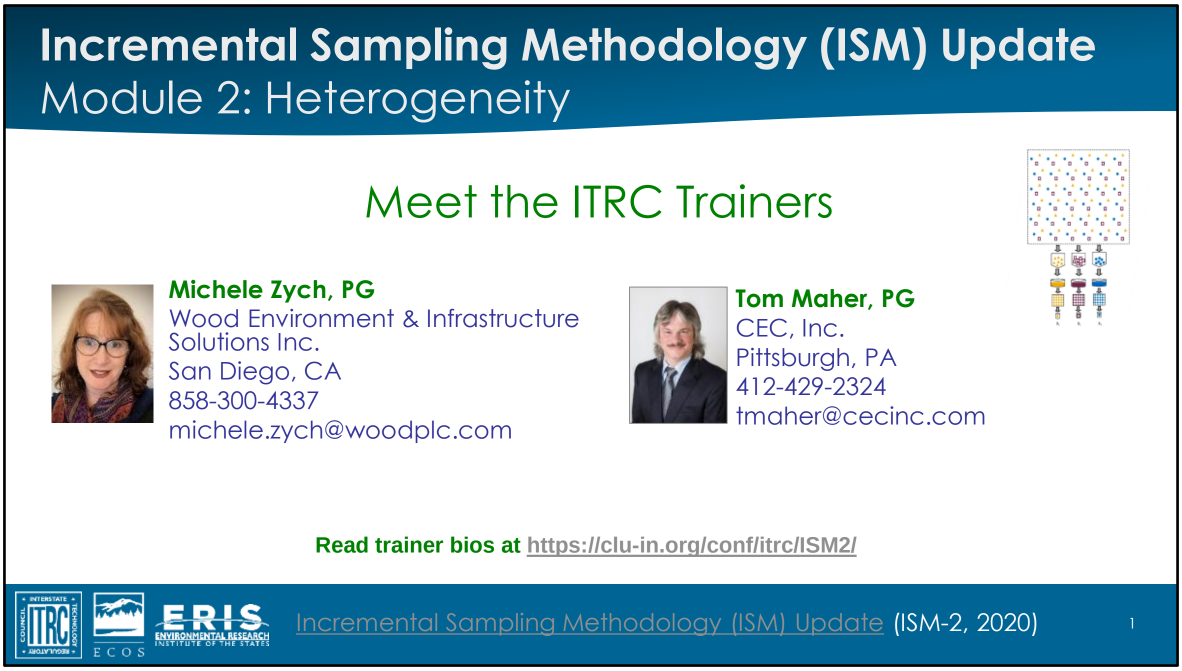
Module 1: Overview (Sect 1)
Module 2: Heterogeneity (Sect 2)
Module 3: Statistics (Sect 3.2), Data Use Planning (Sect 3.3), and Data Quality Evaluation (Sect 6)
Module 4: Field Sampling Collection (Sect 4)
Module 5: Lab Preparation (Sect 5)
Module 6: Risk Assessment (Sect 8)

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

27

We would like to hear back from you today so please be sure to fill out the online feedback form that's linked on this last slide. You can also access the feedback form by clicking Feedback in the related links section and then clicking browse to. Filling out the feedback form and certifying that you participated will allow you to receive a certificate of completion by email.

ITRC archives all its training classes, so if you find that you have additional time or looking for additional training opportunities, please visit Clu-In and the archived trainings to see if there are other courses that might interest you.



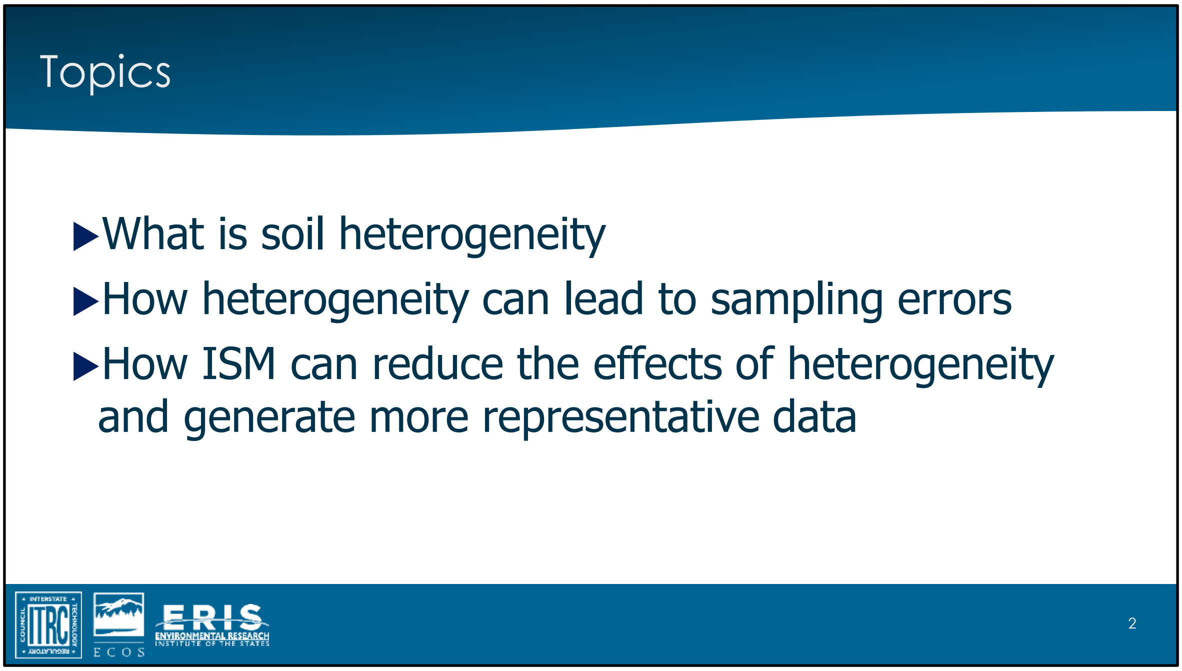
Module 2 will discuss …

Introduce and explain the importance of understanding soil heterogeneity
Introduce Gy Theory (developed in mining applications)
Sampling design based on heterogeneity
The impact of heterogeneity/representativeness of decision errors, soil sampling processes, decision making

TRAINER BIOS

Ms. Michele Zych, P.G., has worked for the environmental consulting industry in southern California since 1992. She is currently with Wood Environment & Infrastructure Solutions, Inc. (Wood) in San Diego, California as an Associate Project Manager managing and providing technical oversight for environmental restoration projects in California and Arizona under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA) and Cleanup and Abatement Orders issued by the California Regional Water Quality Control Boards. She has directed investigations at former range sites, industrial and manufacturing facilities, former aerospace testing facilities, Superfund sites, and brownfields for both the Department of Defense, private sector companies and real estate developers. She has managed multi-phase long term projects from site inspections, preliminary assessments, remedial investigations and risk assessments, feasibility studies, and remedial design and implementation working with various agencies including Region 9 US EPA, California Department of Toxic Substances Control, California Regional Water Quality Control Boards, United States Fish and Wildlife Services and California Department of Fish and Wildlife for the protection of human health and the environment. Ms. Zych has been working with the ITRC on the incremental sampling methodology update since 2018 and has executed several ISM sampling designs at former range sites and facilities with historical use of arsenic-based herbicides. Michele earned a bachelor's degree in geology from the California State Polytechnic University, Pomona in 1992 and is a registered Professional Geologist in the State of California.

Thomas L. Maher, Jr., P.G., has worked for Civil & Environmental Consultants, Inc. (CEC) in Pittsburgh, Pennsylvania, since September 1991. He is a Vice President with CEC and serves as the company's Corporate Environmental Practice Lead. Tom is also a co-founder of CEC's Technical Advisory Group, which was created to keep CEC at the forefront of technology issues important to clients. He has more than 35 years of diverse environmental compliance, investigation, and remediation experience and has worked on a wide variety of sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), and various state-led programs. He has successfully completed projects across the country and in Canada, leading teams of engineers, geologists, ecologists, and risk assessors. He has direct experience working with small to very large companies ranging from routine environmental compliance to complex, legacy industrial sites requiring in-depth knowledge of state and federal regulations and detailed negotiations with regulators and various outside stakeholders. Tom earned a bachelor's degree in geology from the University of Pittsburgh in 1985 and is a registered Professional Geologist in the Commonwealth of Pennsylvania and the State of Arkansas.



This module will look at…

Heterogeneity in soil
How heterogeneity can lead to sampling errors and
Show how ISM can reduce the effects of heterogeneity and ultimately generate more representative data

This module covers information provided in Sections 2 and 3.1 of the ISM Guidance update

Purpose of Soil Sampling

- Collect data to make key decisions
  - Decisions rely on representative data
  - Soil heterogeneity complicates sampling
- Errors in sampling can impact decisions and outcomes

3

As practitioners of environmental assessment and remediation, sampling is performed to collect representative data to make a decision.

In our industry this decision is typically about the condition of a property, and whether it is safe for redevelopment, occupancy, and is not a hazard to the environment.

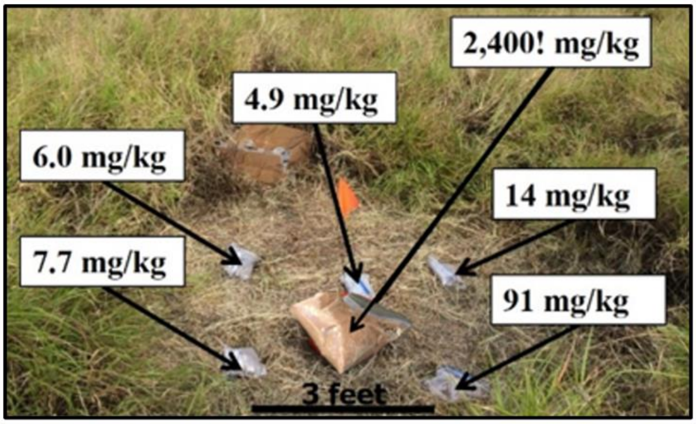
Decisions require representative data and soil heterogeneity makes it difficult to collect reproducible and representative data.

Errors in sampling can impact decisions and outcomes of an assessment.

Improper decisions can lead to wasting time and money for additional assessment.

Or a bad decision can be made to remediate clean soil or leave dirty soils in place, risking the health of the site occupants.

What is Soil Heterogeneity?



Source: Developed from data by HDOH, 2005. Used with permission

As those who have conducted soil sampling know, it is really hard to get reproducible results in soil because it is not uniform.

Heterogeneity is the term we use to describe soil that is not uniform.

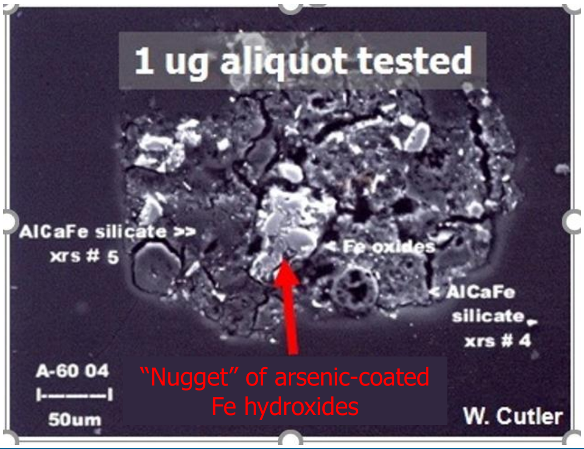
The term relates to the variability of its physical and/or chemical properties.

These properties are not equally distributed within the soil and this is the reason for the variability.

Here is an example of sample variability in the field.

- The samples were all collected within three feet of each other and in some cases as you can see, the analytical results varied as much as three orders of magnitude.
- In this case, which of these results are representative of the chemical concentrations at the site?
- If only one sample were collected, the data would not be representative of actual soil conditions and could ultimately lead to the wrong action.

Small-scale Heterogeneity and Data Variability



Source: Roger Brewer, HDOH, 2012. Used with permission.

Soil heterogeneity is observed on the large and small scales.

This slide shows magnified soil particles of iron hydroxide and silicate minerals.

Here arsenic coats the iron hydroxide particles and not the silicate minerals.

The arsenic more readily adheres to iron hydroxide because of its chemical properties.

Small scale heterogeneity is the result of dissimilar and diverse particle constituents in soil.

It is also dependent on the physical attributes of the soil including composition particle shape, size and density.

Large-scale Heterogeneity and Data Variability

Source: Modified after Deana Crumbling from HDOH, 2005. Used with permission.

Large-scale distributional heterogeneity occurs across a site.

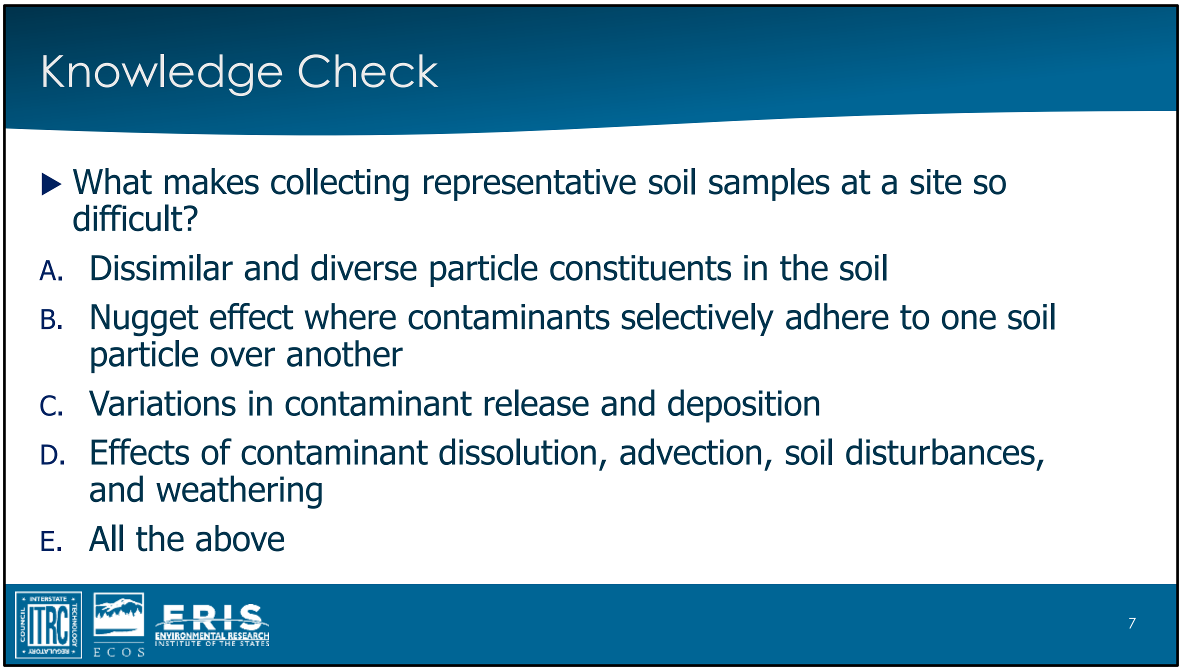
It is when two or more samples collected adjacent to each other have very different concentrations.

It is the result contaminant release and depositional mechanisms, such as dissolution, advection, soil disturbances, and weathering.

In this example, a tractor trailer carrying a white liquid chemical, overturns and spills its contents. The liquid follows the topography.

More liquid will flow around the bumps and into tiny swales. If sampling is performed years later when the spill is no longer visible, and the bumps and swales have eroded.

Low to non-detect concentrations maybe immediately adjacent to much higher concentrations and neither sample is representative of the site.



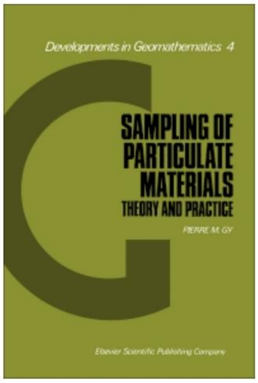
What makes collecting representative soil samples at a site so difficult?

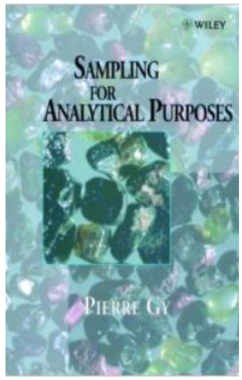
A. Dissimilar and diverse particle constituents in the soil
B. Nugget effect where contaminants stick more to one soil particle over another
C. Variations in contaminant release and deposition
D. Effects of contaminant dissolution, advection, soil disturbances, and weathering
E. All the above

There are many reasons that inhibit collection of truly representative samples in soil.

Sources of Sampling Error

Pierre Gy's sampling theory



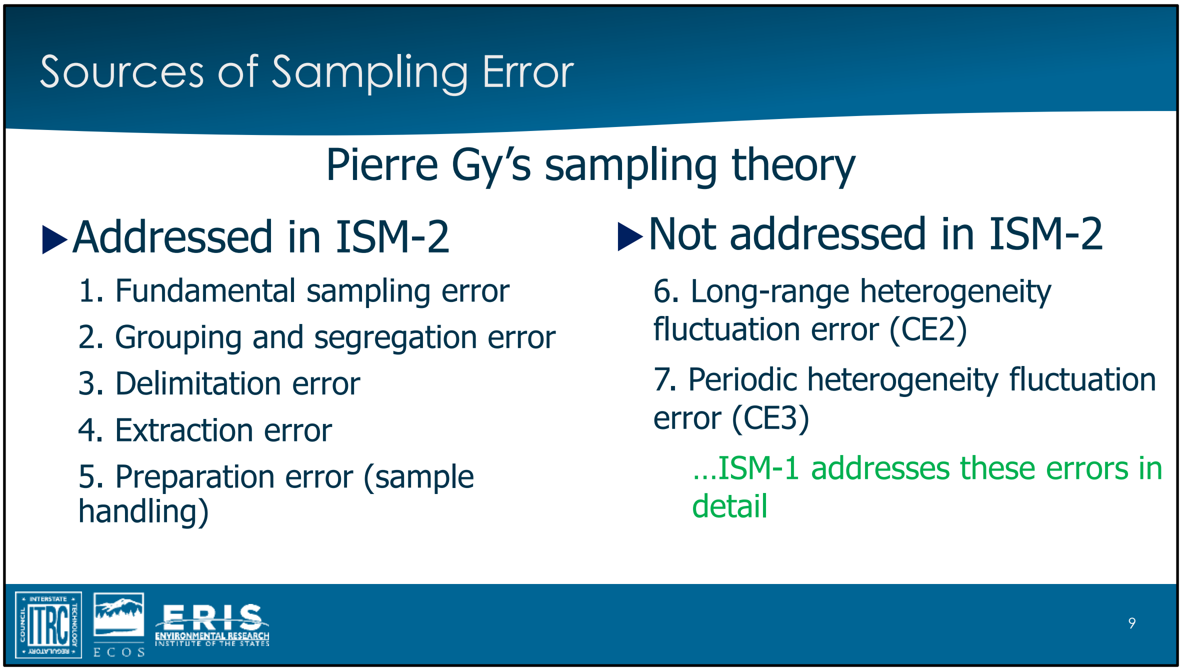


Pierre Gy Cover images, 1979 & 1998.

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

8

Dr. Pierre Gy was a leading thinker in the field of particulate matter sampling. Gy spent 25 years developing procedures for taking representative samples from particulate materials such as ores and cereal grains. Obtaining representative samples was vital to the mining industry because non-representative data could lead mining companies to either spend significant amounts of money trying to extract mineral ore of insufficient quality or to overlook valuable ore deposits. For that reason, Gy's theory and its techniques are recommended in sampling guidance documents issued by USEPA and others.



Gy identified seven principal errors that negatively impact the ability to collect representative samples. Five of these errors are addressed in ISM-2.

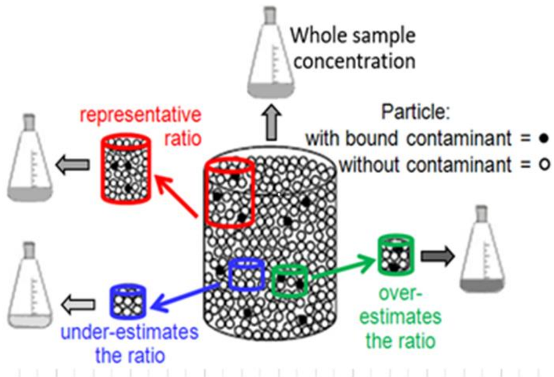
The other two types of errors are discussed in detail in ISM-1.

The five sampling errors addressed in ISM-2 are fundamental error caused by the characteristics of soil (and other solids), and the errors brought about by sample collection and preparation techniques in the field and laboratory including grouping and segregation, delimitation, extraction and preparation errors.

Each of these errors and methods to reduce the magnitude of each error are described on the following slides.

Source 1: Fundamental Sampling Error

- The result of sample particles of different size and composition
- ISM reduces error by
  - Increasing sample mass/volume
  - Sieving samples to a small particle size and/or milling/crushing



Source: Adapted by Deana Crumbling from EPA 2002a, p. 92. Used with permission

10

Fundamental Sampling Error is a result of the nature of the different particles comprising the material to be sampled, known as compositional or micro-scale heterogeneity. Fundamental sampling error cannot be reduced by any degree of blending or mixing because mixing the particles around does not alter the nature of the particles.

Gy's theory accurately predicts that fundamental sampling error increases as the particle sizes get larger or as the range of particle sizes increases.

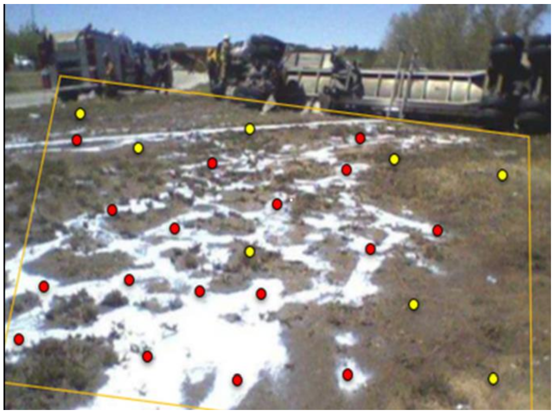
ISM reduces the compositional heterogeneity aspect of fundamental sampling error by increasing sample mass by collecting more increments and/or by increasing the mass of each increment.

ISM reduces the range of particle size aspect of fundamental sampling error either by sieving samples to retain and analyze a small particle size or by milling or crushing particles to a fine powder prior to subsampling.

It is important to note that fundamental sampling error is never eliminated, just managed.

Source 2: Grouping and Segregation Error

- The result of contaminants not uniformly dispersed **in the field**
- ISM reduces this error by combining increments of equal mass into one sample



Source: Developed by Deana Crumbling from HDOH, 2015. Used with permission.

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

11

Grouping and segregation error occurs when the sampling procedures are not adjusted for contaminant heterogeneity and it is assumed the contaminant is uniform throughout a specific area.

For example, grouping error can occur in the field if collection staff gravitate to where the soil is “softer” and it is easier to sample. What if those “softer” locations preferentially accumulate contaminants?

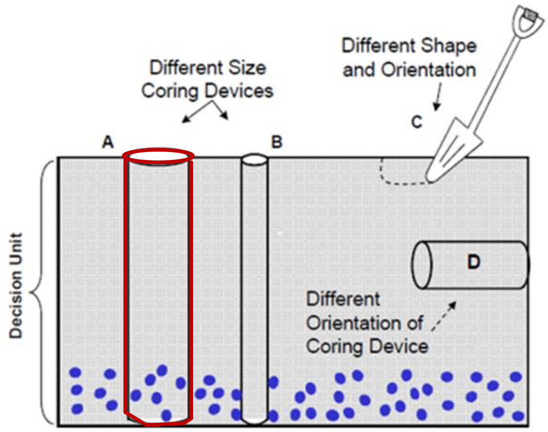
The example photograph shows spilled white chemical and the contaminant heterogeneity is visually obvious at the time of the spill. However, heterogeneous contaminant distribution is not normally visually obvious. Grouping error would occur if samples were collected at either all the red or all the yellow dots whereas grouping error would be reduced if sample increments were collected at both the red and yellow dots.

Note that if a discrete sample was collected at any one of the red or yellow dots, the reported concentration would not be representative of the overall spill area.

ISM field procedures reduce grouping and segregation error by using a systematic random sampling approach and by increasing the number of increments. At least 30 increments are recommended to reduce grouping and segregation error.

Source 3: Delimitation Error

- The result of using inappropriate tools for sample collection
- ISM reduces the error by specifying appropriate field and laboratory sampling tools



Source: USEPA, 2002b.

Delimitation error is closely connected to the field sample collection tool shape, orientation, and mass.

In the illustration above, Corer A correctly picks up blue particles in the proper ratio.

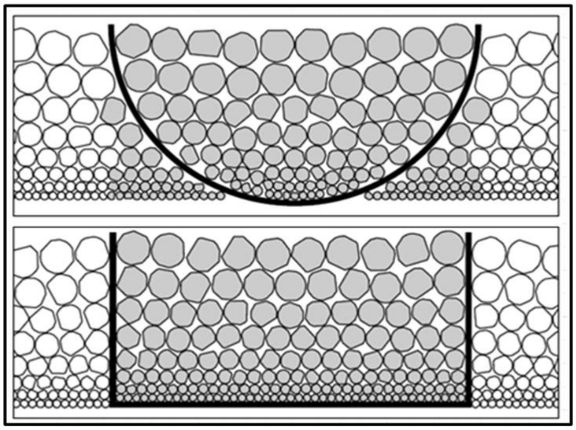
Corer B is too small: it pushes aside the blue particles, so samples collected will be non-detect or biased low for blue particles.

The shovel shown as Device C is the wrong shape because it cannot sample through the full thickness of the Decision Unit.

Corer D is the correct width, but its orientation is wrong. Coring horizontally from the side of the pile will not obtain a sample representative of the full Decision Unit thickness.

ISM controls delimitation error by specifying the appropriate field sampling methods and tools.

Source 3: Delimitation Error



Source: USEPA Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP), 2004.

13

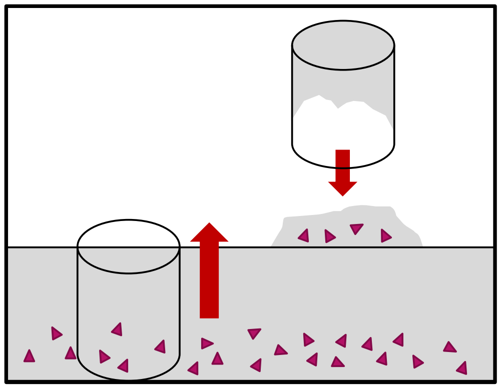
This diagram illustrates how a scoop with a round bottom discriminates against the fine particles settled at the bottom of the pile, in contrast to a scoop with a rectangular shape.

Delimitation error can occur with both field and laboratory sampling equipment.

Delimitation error can be avoided by obtaining the different particle sizes in the same proportions as present in the material being sampled.

Source 4: Extraction Error

- The result of faulty or ineffective sampling techniques
- ISM specifies the appropriate field sampling tools



Source: ITRC ISM Team, 2020

Extraction error is caused by faulty sampling techniques that fail to extract the entire increment.

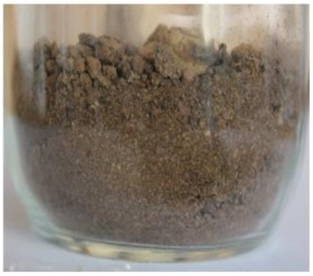
Extraction error is exemplified by sampling dry, sandy soils with an open-bottom corer. As the corer is withdrawn from the ground, the loose material in the bottom part of the sample can fall out. The increment would then over-represent the upper part of the sample because the lower part of the sample has been lost.

ISM reduces sampling error by specifying appropriate field sampling tools.

Source 5: Preparation Error

- The result of improper laboratory preparation

Ineffective blending



Particle segregation

Improper subsampling

- ISM specifies the appropriate laboratory sampling tools

Source: Deana Crumbling, 2013. Used with permission.

15

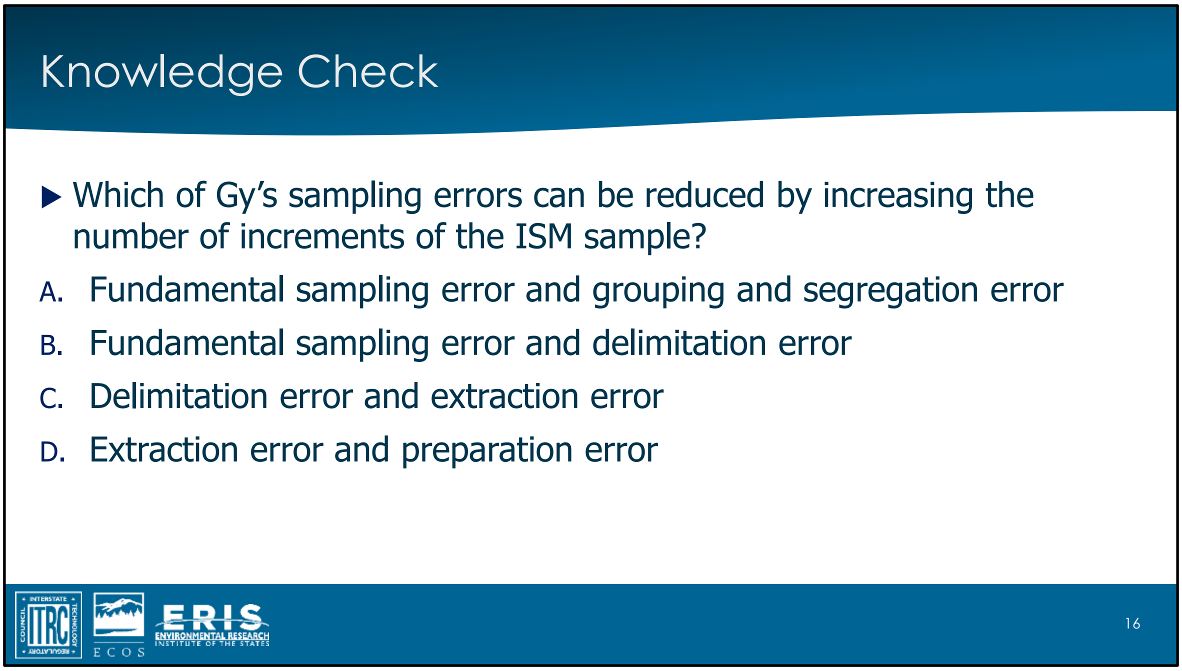
Preparation error is a term that incorporates various errors that can occur during laboratory preparation of soil samples. Many of these preparation errors have equivalent field sources of potential errors.

Causes of preparation error include:

- Blending or stirring cohesive soil without breaking up strongly aggregated clumps will result in the sample not being homogenized before subsampling.
- Particle segregation of non-cohesive field samples can occur during sample handling and shipping where smaller or denser particles work their way to the bottom, leaving larger particles on top.
- Improper subsampling such as scooping the subsample off the top of the field sample, which unlikely to result in a subsample representative of the entire sample.

ISM reduces preparation errors by having the laboratory prepare the subsamples for analysis using specified processes and special tools under controlled conditions.

More information on laboratory procedures and tools for ISM is provided in Module 5 of this series.



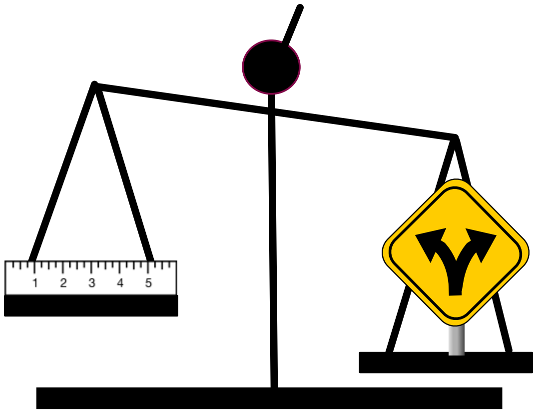
Which of Gy's sampling errors can be reduced by increasing the number of increments of the ISM sample? Take a few seconds and select your answer…

A. fundamental sampling error and grouping and segregation error
B. fundamental sampling error and delimitation error
C. Delimitation error and extraction error
D. Extraction error and preparation error

Fundamental sampling error and grouping and segregation error can be reduced by increasing the number of increments in the ISM sample.

Delimitation error, extraction error, and preparation error cannot be reduced by increasing the number of increments.

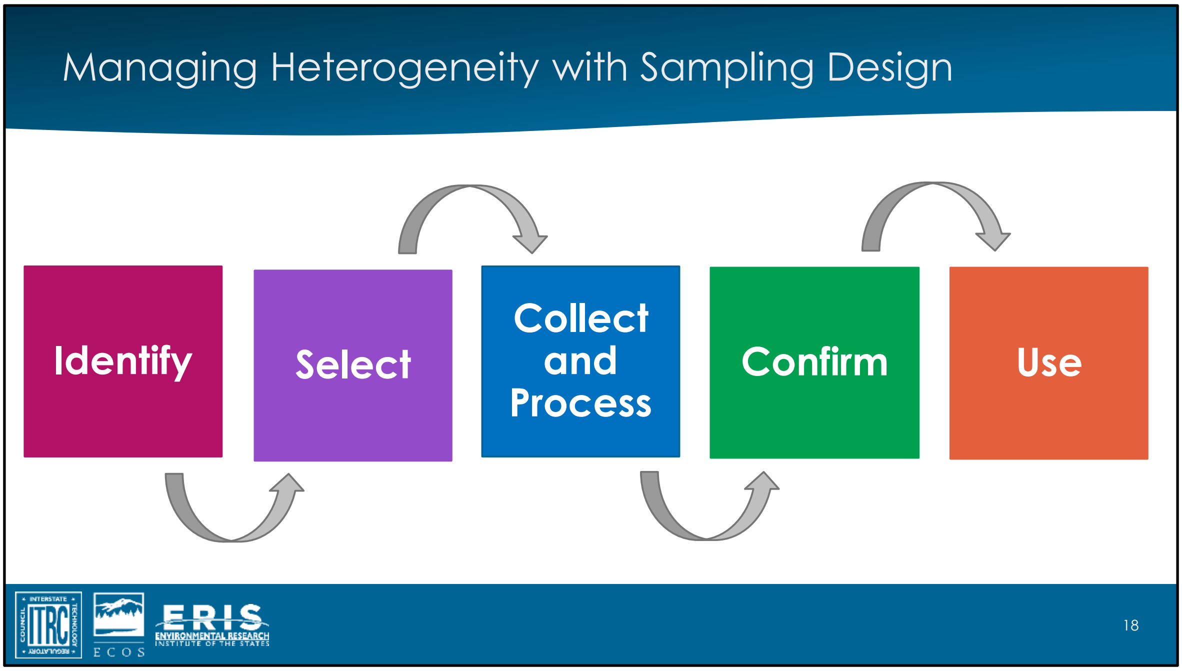
Importance of Sampling Design



Effects of sampling error can be mitigated with proper sampling design

17

Frequently there is a mismatch between the scale of observation and the scale of decision-making. This means if we collect samples at a single point or several single points, we have data that is representative of just those points. We frequently make decisions about an entire site using such data and the scale of observation does not match the scale of decision. ISM increases the number of sample points and combines them into a single sample for analysis. Therefore, data from the ISM sample is representative of a much larger area, much closer to the size of the area to which a decision is to be made.



So how can we manage heterogeneity with sampling design?

The first step is to identify the area or areas to be evaluated.

The design should then select a method to collect representative data based on the soil characteristics and likely mode of contaminant distribution.

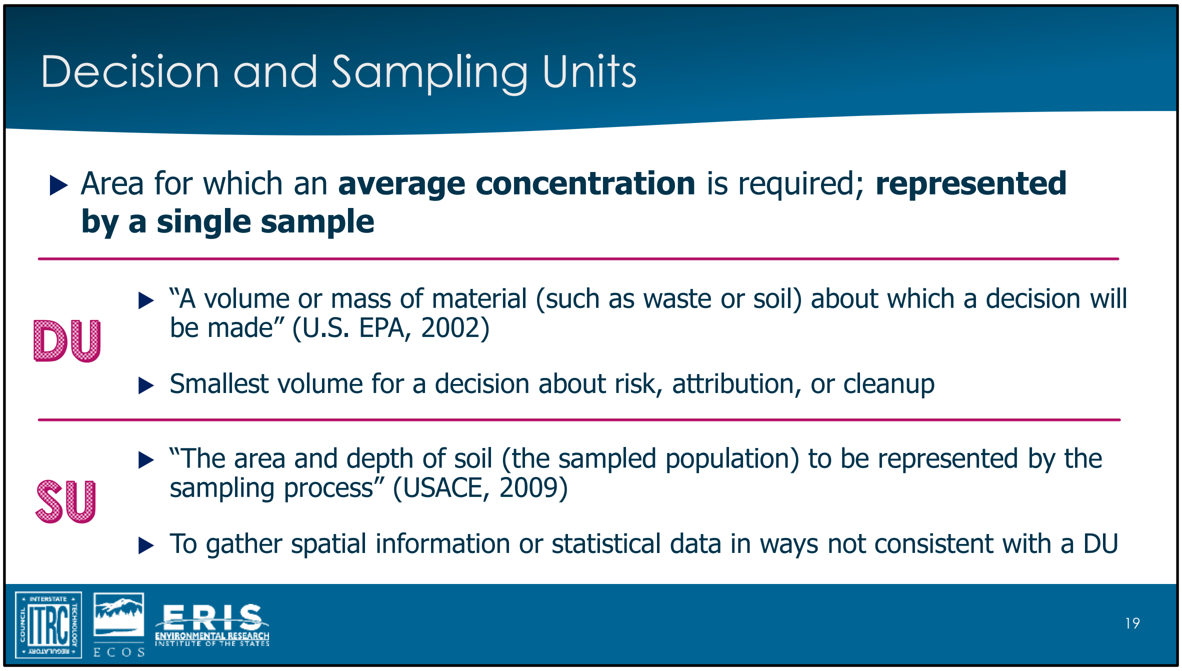
These two items are typically identified in the conceptional site models.

The selected method should collect sufficient sample volume at a statistically defendable number of locations. Those locations should be distributed without bias and using proper tools and procedures.

The data should be confirmed that the data are representative and reproducible by the collection and analysis of replicates

If this process is followed, the data can be used with confidence and there is a reduced potential for decision error

ISM includes these steps and is therefore a better method to manage heterogeneity by sample collection, processing, and confirmation.



The main elements to sampling design with ISM are decision units and sampling units

Both DUs and SUs are areas for which an average concentration is required, and they are areas to be represented by a single sample.

DUs are different from SUs by how the data will be used.

By definition, a decision unit is a volume or mass of material about which a decision will be made.

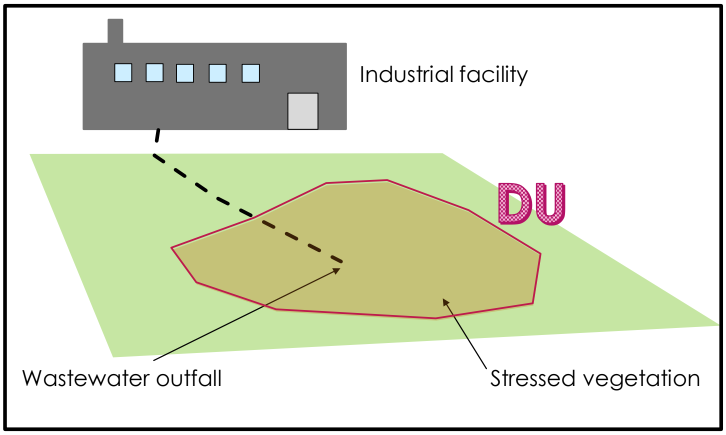
Specifically, it is the smallest volume of soil for which a decision about risk, attribution, or cleanup.

Exposure Unit (EU) is a decision unit selected for the evaluation of risk

A Sampling Unit is "the area and depth of soil to be represented by the sampling process." Basically any defined volume of soil intended to be represented by a sample or samples.

The SU does not need to be dependent on the intended purpose of the data. SUs can also support other kinds of sampling objectives such as nature and extent or the collection data in ways that do not fit neatly into the definition of a DU.

Decision Units and Sampling Units - Example

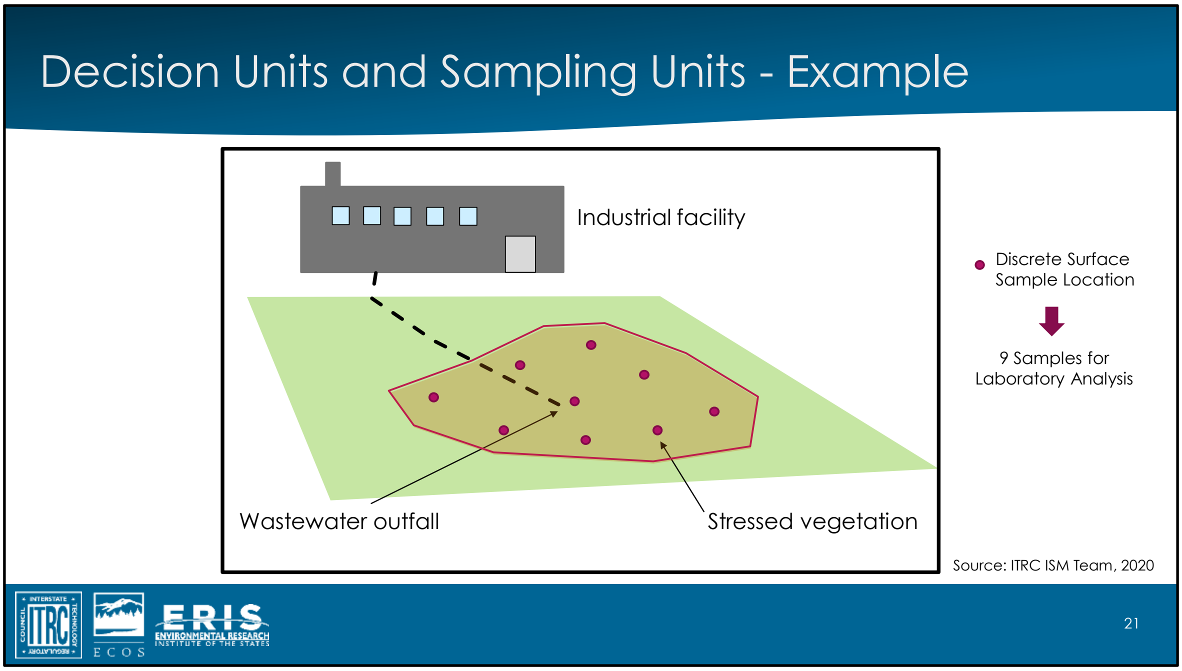


Source: ITRC ISM Team, 2020

20

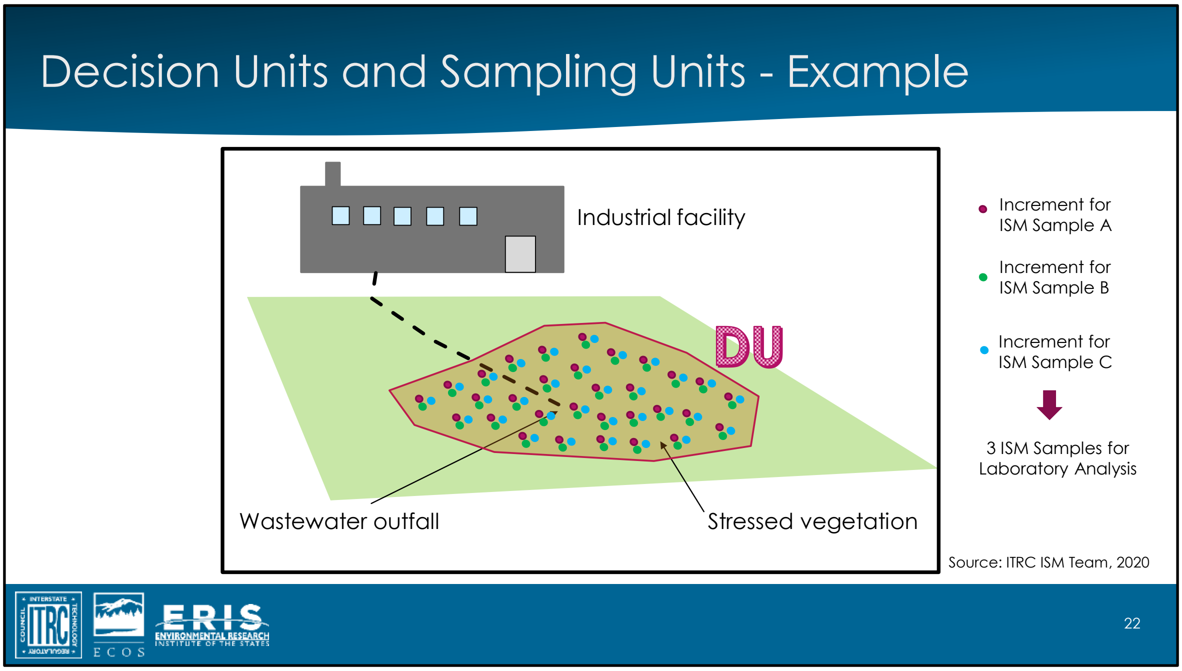
Example of a sampling design where the objective is to assess the nature and extent of impacted soil resulting from the activities at a manufacturing facility that uses chlorinated solvents to clean equipment. In this case, the investigation was prompted by the observations of stressed vegetation near the facilities' wastewater outfall. "Impacted soil" is defined to contain chemical concentrations exceeding state and federal soil screening levels for protection of human health and the environment.

The DU was selected to determine the average concentration of the area of stressed vegetation to compare to these regulatory standards.



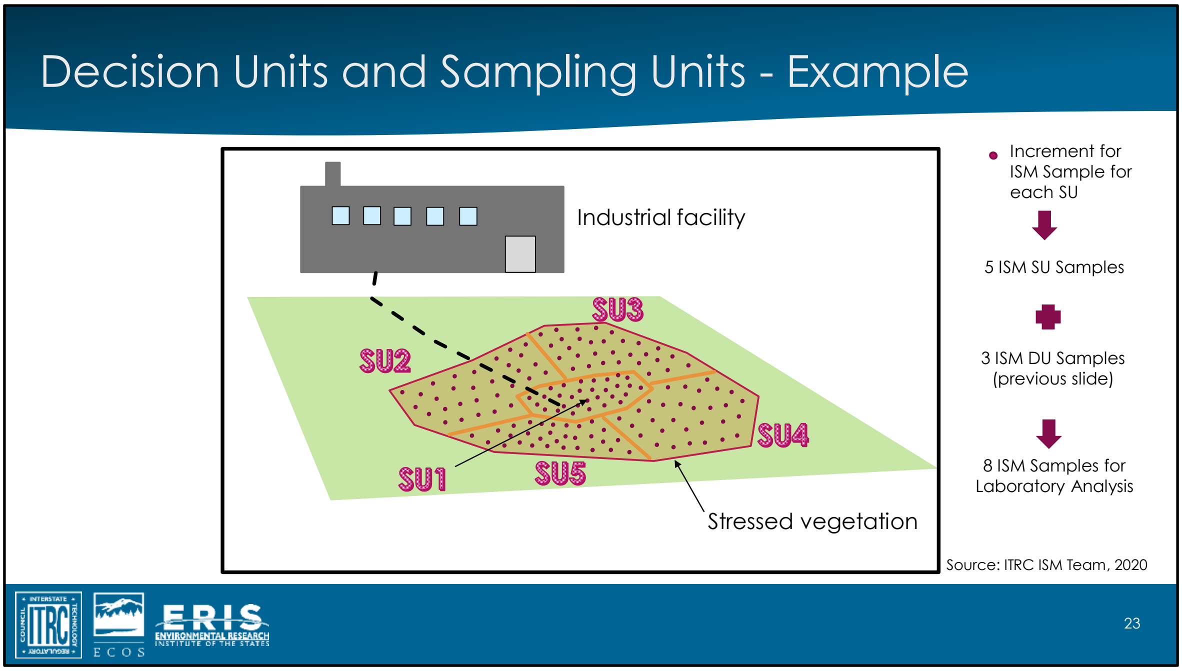
One sampling design consists of a handful of discrete samples set on a grid spaced throughout the DU. One location would target the discharge point of the wastewater outfall and the other locations placed at varying distance from the outfall. In order to provide an average concentration, a minimum of 8 to 9 samples are needed.

From what we learned about soil heterogeneity, these samples are likely to have very different concentrations, potentially orders of magnitude from each other. We also know from experience that analytical results from the same soil sample are typically not reproducible. While one sample at the discharge point from the outfall was strategically selected, the remaining locations do not consider the past surface topography, variations in soil types and moisture content, and preferential contaminant distribution. It is unlikely that the nine samples will contain concentrations representative of the entire area.



Another sampling design consists of an ISM sample made of 30 increments collected at systematically random locations throughout the DU. In this example, the ISM sample would be collected in triplicate to confirm reproducibility, and three ISM samples are submitted for laboratory analysis. The increased number of sample locations, the increased soil volume for each sample, and the sampling collection and processing techniques reduces the effects of heterogeneity. If only the average concentrations is required for this DU, this sampling design would provide more technically-defendable and representative data than the data collected with the discrete samples.

The disadvantage of this sampling design is that the resulting ISM sample would not tell us if there are areas in the DU that are more contaminated than others; it would not tell us the extent of contamination and if there are variations within the DU.

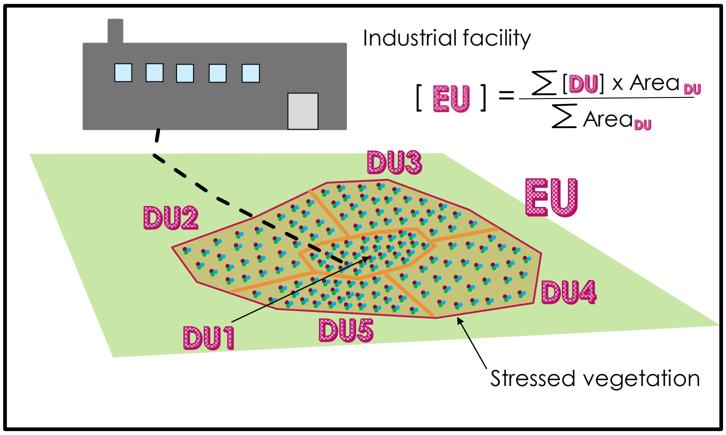


In order to determine variations in contaminant concentrations at the wastewater outlet and four directions from that outlet, you could divide up the DU into separate SUs. An ISM sample would be collected for each SU. One SU will assess if the wastewater outfall contains higher concentrations. The other SUs will assess which direction from the potential source that contamination may have migrated. These data will also narrow down the area for which remedial action is necessary should some of the SUs contain higher concentrations than others. This sampling design includes 5 additional ISM samples being submitted to the laboratory for analysis.

For this sampling design, there are a total of 8 ISM samples submitted to the laboratory. This is one less than the discrete sampling design. the representativeness of the resulting data is well beyond that of the sampling design using discrete samples. The resulting data takes into account the soil and contaminant heterogeneity by reducing the sampling errors.

Notice here, I didn't run triplicates on the SUs. Because I wasn't making a decision about how to handle the soil in each of the SUs, and the data were used solely to delineate the lateral extent of impacted soil away from the outfall, I didn't need the triplicate samples for the SUs. The DU sample results collected over the entire area in triplicate were sufficient to meet the assessment objectives and data quality goals for this project.

Decision Units and Sampling Units - Example



- Increments in triplicate for each DU

3 Samples for each DU x 5 DUs

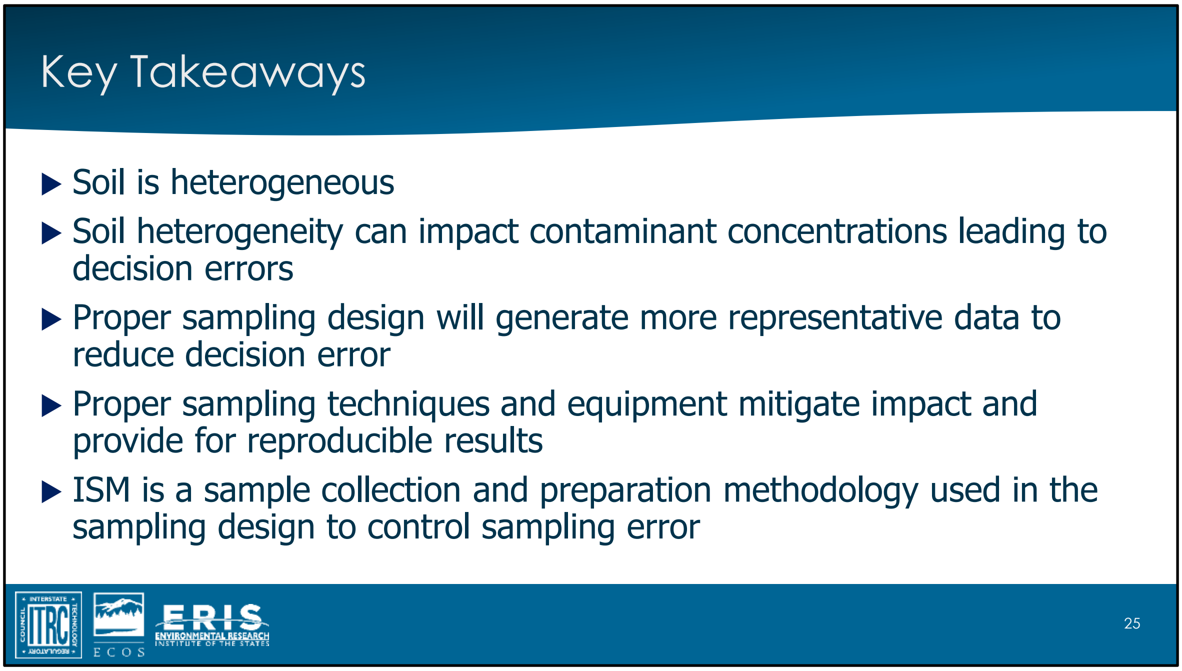
15 ISM Samples Total for Laboratory Analysis

Source: ITRC ISM Team, 2020

One additional option for a sampling design at this site. This design would designate the 5 areas shown in the last sampling design but here I am calling them DUs. The DUs in this example will all be collected in triplicate to provide the desired confidence and demonstrate reproducibility in these smaller areas. This design would allow me to make specific decisions regarding the volume of soil which remedial action is necessary should some of the DUs contain higher concentrations than others. Please also note I changed the designation of the entire area to an exposure unit or EU to convey that the entire area is being evaluated for risk to human health and the environment. In this example, there are no samples representative of the entire EU. The concentration of the EU can be calculated as a weighted overage, as the sum of the average concentration for each DU times the DU area divided over the sum of the area for all DUs (or in this case the area of the EU.

This sampling design with replicates for each DU includes 15 samples being submitted to the laboratory for analysis. While the number of samples submitted to the laboratory have increased by 7 samples, the representativeness, reproducibility, and thus dependability of the resulting data is well beyond that of other sampling designs. In this example the 7 additional samples provide defendable conclusions on how to manage the soil in a potentially more cost-effective manner in one mobilization.

If you are interested in reviewing many more examples of sampling design, they are provided in Section 3 of the ISM update. The statistical methods for evaluating ISM results is discussed in Module 3 and Section 8 of the ISM update.



<u>Before we go, let's review the key takeaways you should understand from this discussion of Section 2:</u>

Soil is inherently heterogeneous on both small and large scales.

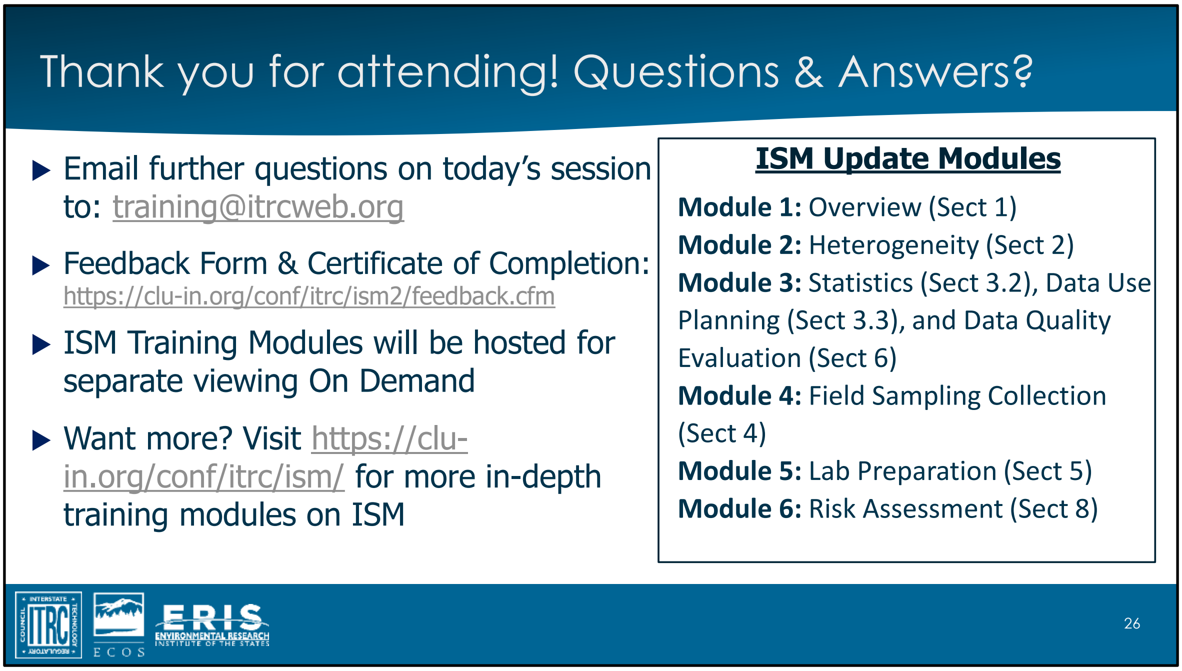
Soil heterogeneity reduces sample representativeness, which can lead to a range of decisions errors. Incorrect decisions have the potential to impact project costs, project schedule, and result in negative effects to human health and the environment.

Proper sampling design will generate more representative data and reduce decision errors.

Proper sampling techniques and equipment mitigate the impact of potential sampling errors and provide more reproducible results. Gy's sampling theory Identified sources of sampling error and most can be addressed by ISM

ISM is a sample collection and preparation methodology used in developing the sampling design to control sampling error.

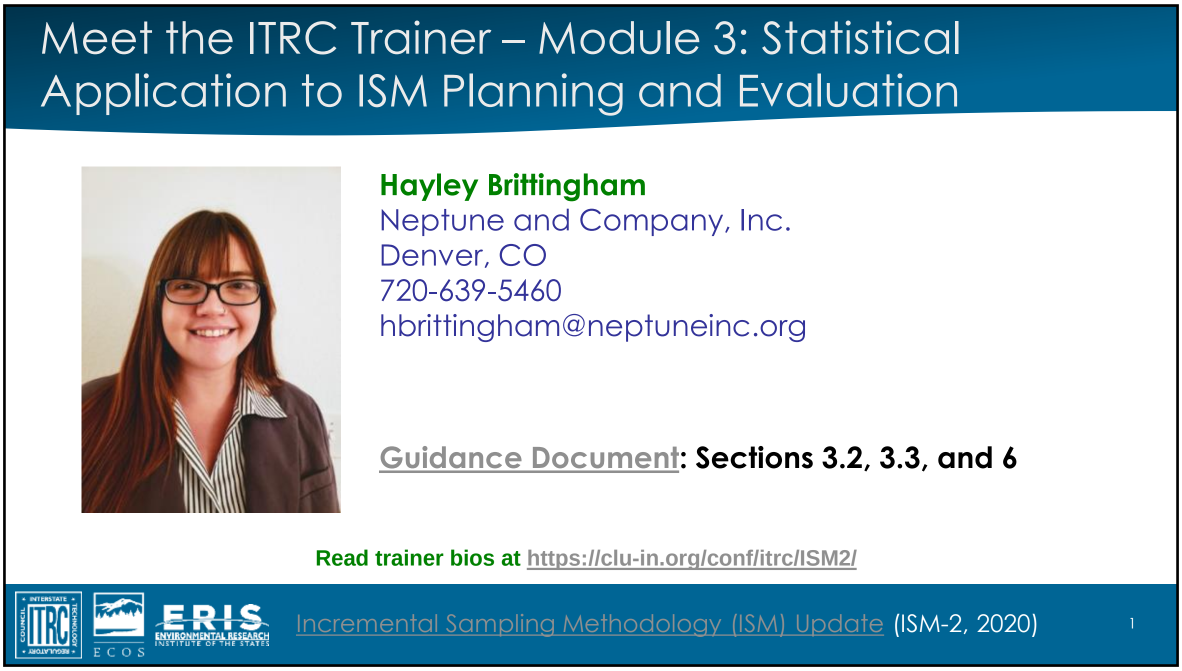
ISM is a way to generate soil data that is representative of the scale of the decision, unlike discrete sampling, which generates data that is more representative of the scale of observation. Soil data collected by ISM helps is make more informed and more accurate decisions.



If you need further clarification on the answers or would like to ask more questions, feel free to email us at training@itrcweb.org and we will follow up with our trainers to get your questions answered.

We would like to hear back from you today so please be sure to fill out the online feedback form that's linked on this last slide. You can also access the feedback form by clicking Feedback in the related links section and then clicking browse to. Filling out the feedback form and certifying that you participated will allow you to receive a certificate of completion by email.

ITRC archives all its training classes, so if you find that you have additional time or looking for additional training opportunities, please visit Clu-In and the archived trainings to see if there are other courses that might interest you.



We will now begin Module 3, which will go over the main statistical concepts necessary to understand ISM design and is covered in more detail in Section 3.2 of ISM 2. We will also discuss how to handle statistical analysis once the data are collected, which is the focus of Section 6 of ISM 2. This module also addresses some statistical considerations in planning for data collection and is covered in Section 3.3 of the guidance document.

Specifically, Module 3 will discuss …

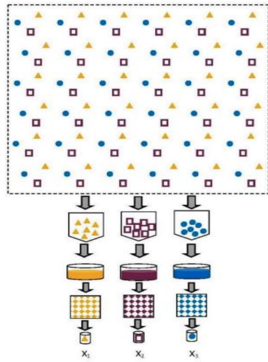
The importance of statistical considerations in project planning phases
Discuss Upper Confidence Limits developed with ISM data
How to use statistics in determining data quality
And Appropriate statistical methods to use in data evaluation

TRAINER BIO

Hayley Brittingham is an Environmental Statistician with Neptune and Company, Inc. in Denver, Colorado and has worked for the company since 2017. She is experienced in both fundamental statistical principles and their practical implications, and has contributed to the ITRC Incremental Sampling Team since 2018. She designs and reviews sampling plans using a variety of sampling techniques and analyzes both discrete and ISM data sets for use in transparent and defensible decision making. She has experience in statistical theory, ecological research, and programming, including multivariate statistical methods for both continuous and categorical data, and geostatistical methods for evaluation of spatial trends. In addition, she provides statistical support for probabilistic performance assessments of radioactive waste disposal sites by developing distributions that consider the spatial and temporal complexities of the model and by performing sensitivity analyses to inform model implementation. She earned a Master's of Science in Applied Statistics from Pennsylvania State University in 2017 and a Bachelor's of Science in Ecology and Evolution from the University of Pittsburgh in 2016.

Learning Objectives

- Why use statistics?
- Data verification, validation, and usability
- Why ISM works
- Comparison to action levels and UCLs
- Multiple sampling units
- Background comparisons



2

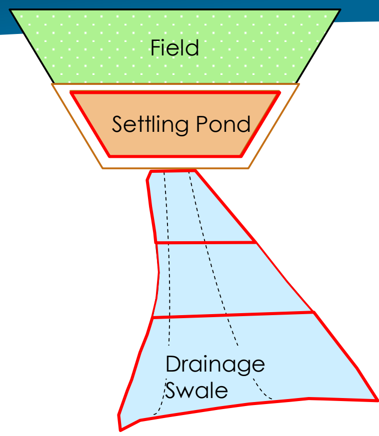
Statistics is used in order to facilitate defensible and transparent decisions, which can be made in an objective way. We can use statistics to be cost effective, but at the same time still be protective of human health and the environment.

I'll review data verification, validation, and usability for incremental sampling. Then, I'll talk about why ISM works from a statistical perspective. I'll also cover various decision rules including the comparison to action levels through the calculation of upper confidence limits, as well as background comparisons. And, I'll show how statistics can be used to handle the problem of multiple sampling units within a decision unit.

Keep in mind that this module is not meant to be a crash course in statistics, but we are going to go into detail on these topics so that you can be ready to perform defensible analysis for your project. For some of you with some statistical background already, this module can serve as a review for you and an introduction to what is different about ISM. For others, this module is designed to serve as an introduction to what you may need additional clarification on, either by reading the guidance document or by contacting a statistician.

Data Verification

- Data are complete
- Sampling plan properly designed and carried out
- Correct number of increments were collected
- Correct number of replicates were collected



3.1.6.1. Figure 3-7. Source: ITRC ISM Update Team, 2020.

3

Similar to other sampling techniques, data verification for incremental sampling designs involves making sure the data are complete and that the sampling plan is properly designed and carried out. For ISM, this means ensuring that the correct number of increments were collected, and that the correct number of replicates were collected (6.1.1).

This schematic is an example of a study design with four total decision units, each collected in triplicate. So data verification in this case includes ensuring that we have 3 ISM samples each from 4 different decision units, for a total of 12, and that the specified number of increments were collected from each.

Data Validation

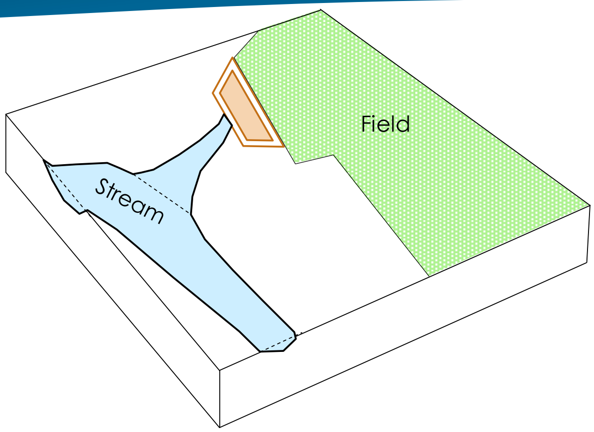
- Conformance to SOPs
- Confirmation of qualifiers (6.1.2)
- Evaluation of performance criteria

The next step in the process, data validation, is also similar to data validation for discrete sampling. It involves ensuring the standard operating procedures, for example the laboratory SOPs, were properly followed, and confirming the proper qualifiers, such as identification of non-detects, were assigned (6.1.2).

This step also includes the evaluation of performance criteria. For example, were any data rejected due to not meeting the quality control criteria?

Data Usability

- Review project objective and sampling design
- Evaluate conformance to performance criteria
- Document data usability
- Document lessons learned



3.1.6.1. Figure 3-6. Source: ITRC ISM Update Team, 2020.

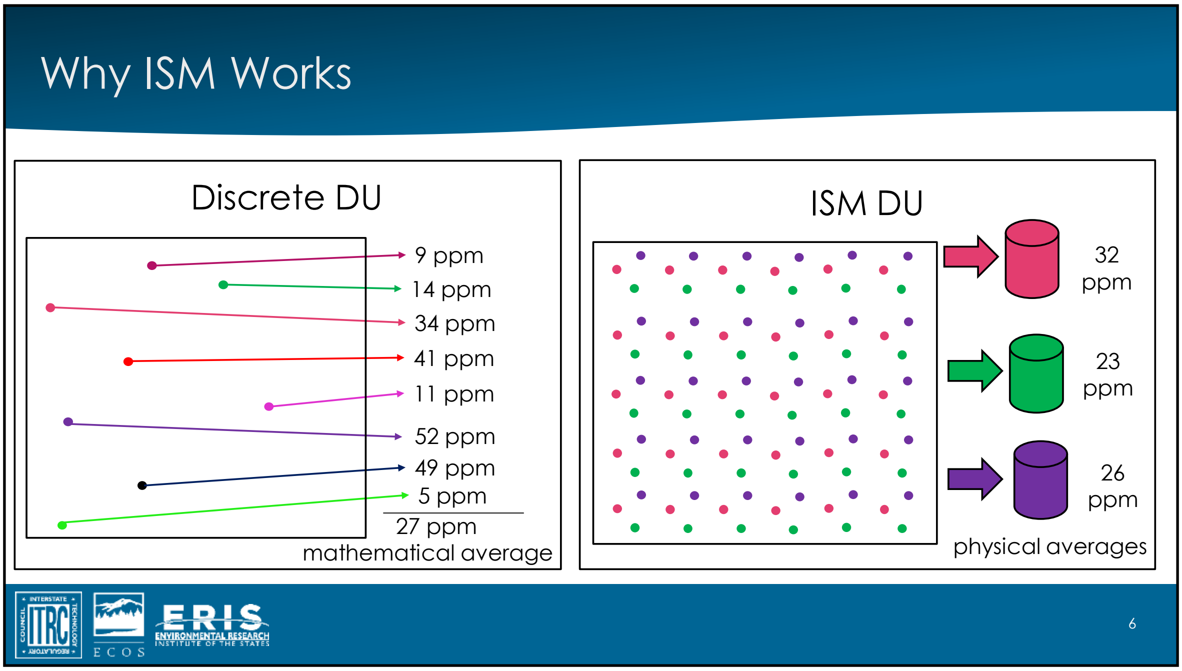
5

Finally, data usability is a retrospective look at the project objectives and sampling design, and is also similar to data usability for discrete data collection (6.1.3).

As a continuation of data verification and validation, the outputs from those steps must be reviewed to evaluate the conformance to performance criteria and the implications of unacceptable results.

For example, did the laboratory detection limits meet the sensitivity needs documented in the data quality objectives process? Next, document data usability and update the conceptual site model (CSM) if necessary. Apply the decision rules and draw conclusions.

Finally, what new information was learned during sampling? Use this information to modify the study design or make final conclusions about the site.



As many practitioners have experienced, discrete samples are sensitive to anomalies that might be present at the site.
The image on the left shows the variation in concentrations that might be expected for a collection of discrete samples.

Because ISM designs combine material from across the decision unit in a single sample, the sample result is an estimate of the average concentration of the decision unit.
So in this way, the sampling process does the averaging for us.

The image on the right shows the physical averaging process in ISM designs. Each of the three different colors represent a single ISM sample. This image is an example where we are taking three replicate ISM samples.

Notice that for the ISM design, we have many more locations and information going into a single sample. That's why a single ISM sample is much more valuable than a single discrete sample, and possibly even more valuable than several discrete samples.

Why ISM Works

- Key advantages of ISM
  - Increased mass for a single sample
  - Better spatial coverage across the DU
- Better precision compared with discrete sampling

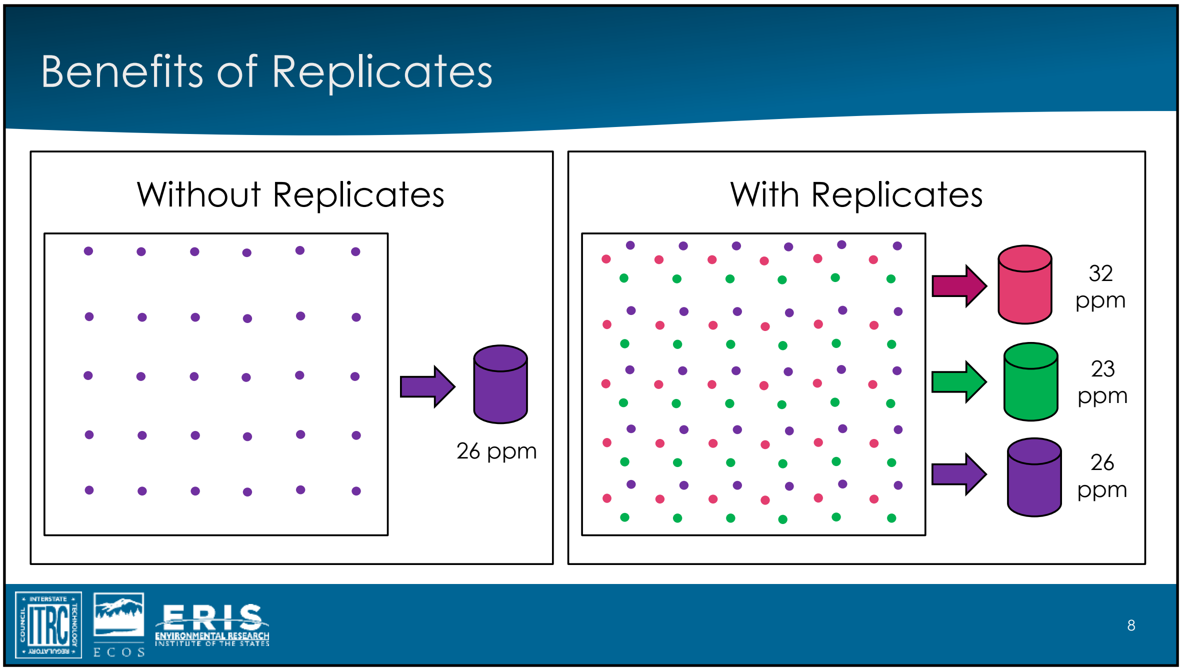
ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

7

Key advantages of ISM designs are the increased mass present for an individual sample, allowing more information for characterization, and better spatial coverage across the decision unit.

These two advantages combined ultimately result in better precision compared with discrete sampling, because the design captures both low concentrations and anomalies that may be present in a highly heterogeneous environment.

For more details on heterogeneity and sampling theory as well as various type of errors, refer to module 2, Heterogeneity.



For some projects, a single ISM result might meet project objectives because of the increased precision we can achieve.
This single ISM result can be directly compared to an action level to make a decision about the site.

However, with a single ISM result, it is not possible to determine the likelihood of exceeding the action level because there is no measure of precision or uncertainty. If we need to quantify or evaluate precision, we need to collect replicates. Note that 95% confidence is a common requirement for environmental projects, which can only be achieved by collecting three or more replicates.

Benefits of Replicates

$$CV = \frac{SD}{Mean}$$

$$RSD = \frac{SD}{Mean} * 100\%$$

9

Collecting duplicates or triplicates from a decision unit and calculating performance metrics is a good way to evaluate whether the precision achieved meets the project objectives.

The coefficient of variation (CV) is the standard deviation of the replicates divided by the mean of the replicates.

The relative standard deviation (RSD) is the coefficient of variation multiplied by 100 and expressed as a percentage.

If the relative standard deviation or coefficient of variation will be used to evaluate precision, a goal for the parameter should be specified in project planning (3.3.2.1). Typically, goals for the relative standard deviation are around 20 or 30%. The precision metric used should be considered along with other site information to determine action at the site.

Knowledge Check

Which of the following factors allows incremental sampling to achieve better precision compared with discrete sampling?

a) More locations within the DU are sampled.

b) Increased mass per sample and better spatial coverage.

c) Composite sampling always increases precision.

d) None of the above. ISM does not achieve better precision.

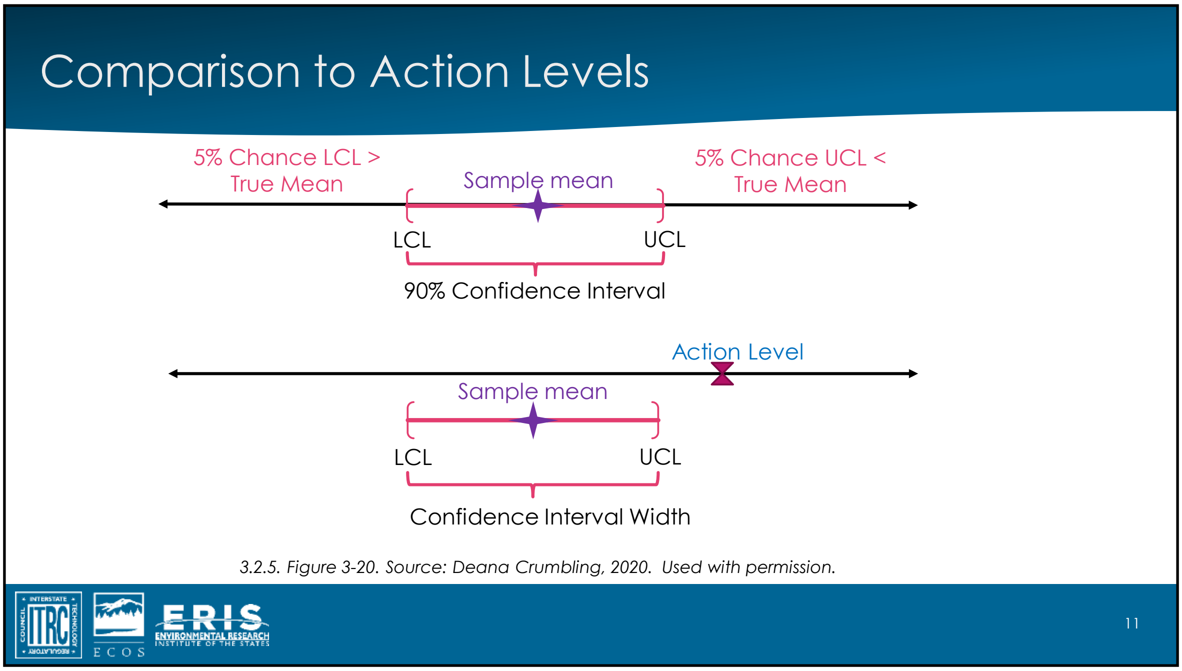
ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

10

Correct answer is B.

For A: it is important to note that spatial coverage alone will not necessarily increase precision of the results if the mass collected is similar to that of a discrete sample.

For C: note that the specific recommendations covered in the training modules and the guidance document are what makes ISM a more disciplined and precise approach compared with other composite methods.

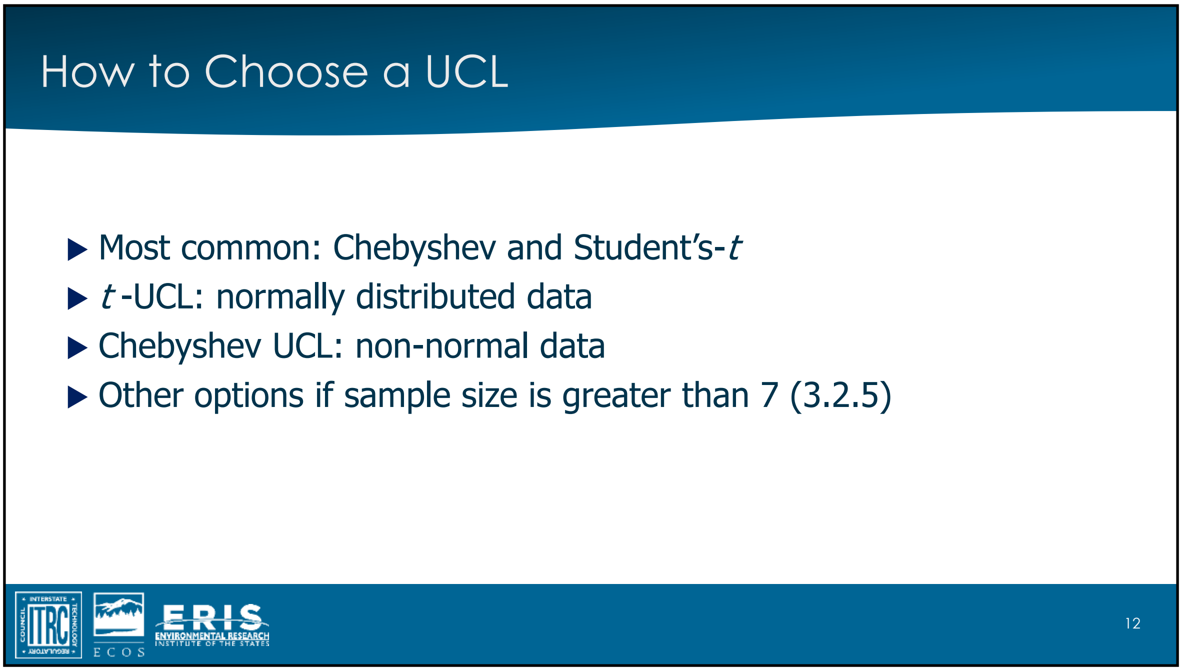


Another advantage of replicates is that a confidence interval can be calculated with three or more ISM samples.

The confidence interval quantifies the uncertainty around the estimate of the mean, and is often required in order to be protective of human health and the environment. A confidence interval specifies the probable range of the mean, usually with 90 or 95% confidence.

With a 90% confidence interval, there is a 5% chance that the true mean is above the upper confidence limit, and a 5% chance that the true mean is below the lower confidence limit. The upper confidence limit of a 90% confidence interval corresponds to a 95% UCL because there is a 5% chance the true mean is above the 95 UCL.

Typically, the UCL is compared with an action level. If the UCL is less than the action level, we are at least 95% confident that the true mean is less than the action level.



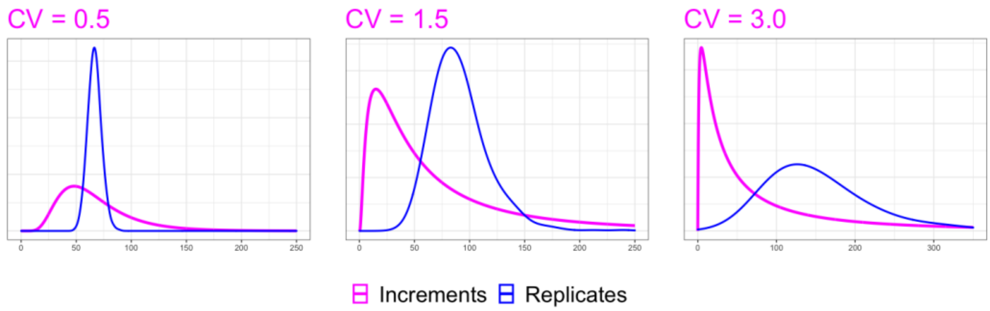
The most common upper confidence limits for ISM data are the Chebyshev UCL and the Student's-t UCL.

The t-UCL is the most reliable choice for normally distributed data. For approximately normal data, the Chebyshev UCL is biased high, meaning it is overly conservative. In other words, the 95 Chebyshev UCL is larger than it really needs to be to achieve 95% confidence if the data are normal.

However, for non-normal data, the student's-t UCL is biased low, meaning the desired 95% confidence is not achieved. The choice of UCL must be made considering the nature of the data collected.

The Chebyshev and the t-UCLs are the only available UCLs for very small sample sizes that are typical in ISM designs. If you collected more than seven replicates for a decision unit, you may have other options available to you (3.2.5).

How to Choose a UCL



3.2.4. Figure 3-17. Source: ITRC, 2017, ITRC Webinar: Soil Sampling and Decision Making Using Incremental Sampling Methodology -Part 1, Module 4 (Statistics).

Student's-*t* UCL best for data with a CV < 1.5 (increments)

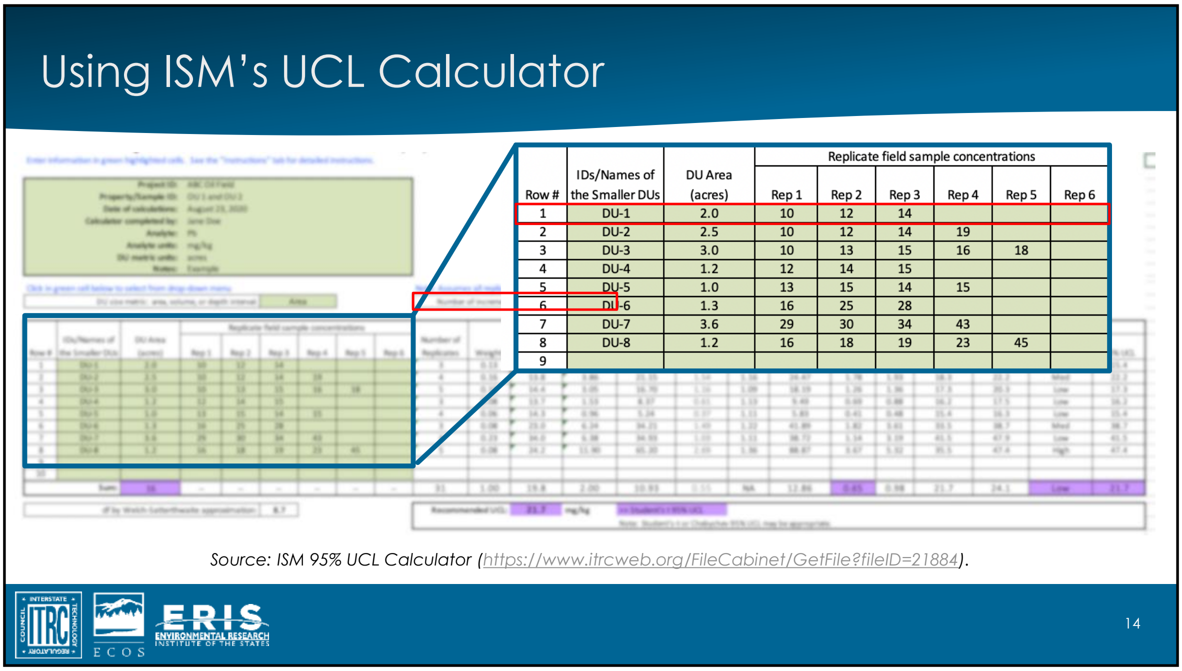
13

Due to the composite nature of ISM, the distribution of the sample results will appear more normal compared with the distribution of discrete samples.

The pink curve in this figure is the distribution we'd expect if we analyzed individual increments, and it's also the distribution we would expect from discrete data collection.

The blue curve is the distribution of ISM samples we would expect if we collected 30 increments.
Notice that the blue curve appears more normal, but may still be skewed, depending on the distribution of the increments. When distribution of the increments is highly skewed, may not be able to overcome this by compositing – i.e., can't assume normality

It is important to note that the CVs displayed here describe the variation of the increments (in pink), not the variation of the replicates for which we have data. We recommend using the t-UCL when the coefficient of variation of the increments is less than 1.5. Where the data are more skewed, an alternative method such as the Chebyshev UCL may need to be used.

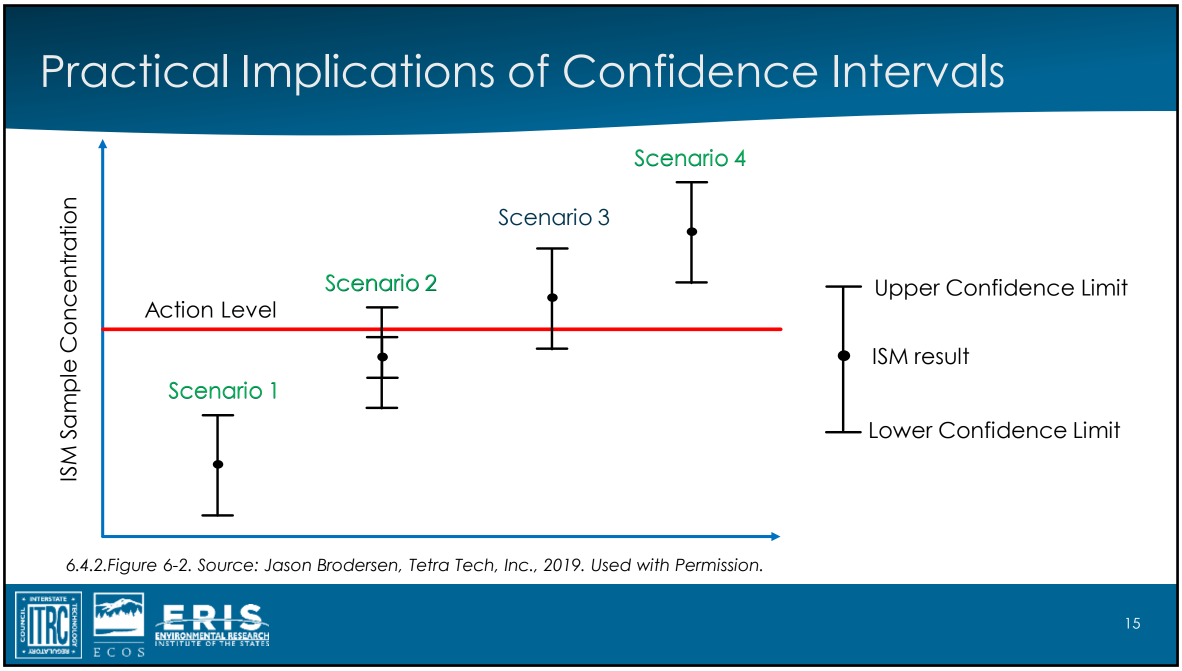


If you're having trouble deciding which UCL is best, refer to our ISM UCL calculator, which is in the form of an excel spreadsheet, pictured in this slide. The point here is not to be able to read and understand each individual column shown here, but just to show you what the calculator looks like. The calculator uses the number of increments in each ISM sample, so be sure to fill this in at the top of the sheet.

You can simply enter the sample results in these green cells for each of your decision units. Let's take a closer look at that field. For a given decision unit, fill in the area of the decision unit and the sample results for between 3 and 6 replicates.

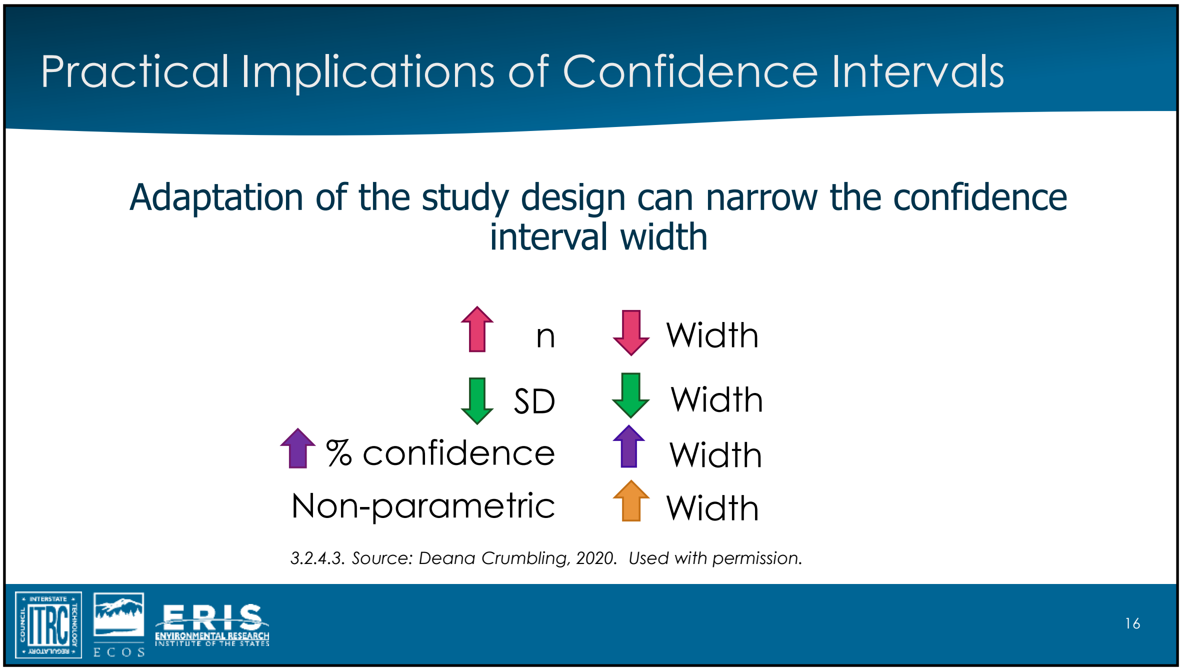
The calculator is designed to compute summary statistics for you and classify whether the CV is low, medium, or high. The calculator computes both the Chebyshev UCL and the t-UCL, and gives a recommendation on which is more appropriate based on the guidelines. The calculator makes an adjustment to estimate the CV of the increments to recommend the appropriate UCL.

This calculator can be a useful tool, but it is important to also consider information available related to the site, like the CSM and the expected variation.



The location of the UCL and the mean can help determine alternative actions for the site. For example, if both the UCL and the mean are below or above the action level, indicated by Scenarios 1 or 4 in this figure, the existing data are sufficient to make a decision about the site because we are confident that the mean really does fall below or above the action level.

If the action level falls within the confidence interval, additional data may be needed to make a confident decision. In the case of Scenario 2, the mean is below the action level but the UCL is above.
For the decision rule comparing the UCL to the action level, this site may require remediation. However, it is possible to conclude the site is “clean” if additional data are collected such that the UCL drops below the action level.
Modifications of the study design could be considered, such as increasing the number of increments or replicates.



Adaptation of the study design can narrow the confidence interval width.

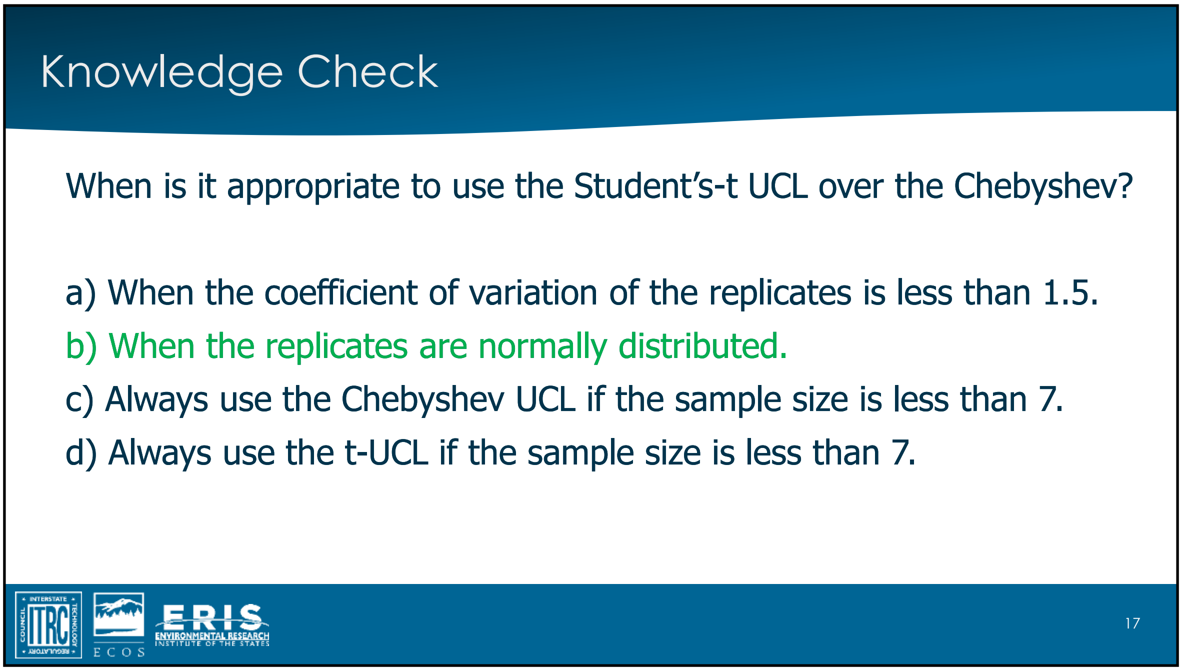
Most commonly, the number of observations could be increased – increments or replicates. Recall that one of the key advantages of ISM is the increased mass for a single sample. So, if the number of increments are increased in order to improve the width of the confidence interval, the mass of an ISM sample should also increase to maximize this benefit.

Lower variability in the data also causes the width to be smaller, but this is not something that can be controlled by the study design.
Stated another way, we may have to increase the number of observations to compensate for data that are expected to be highly variable, or redesign the placement of decision units to reduce SD

Another factor we might be able to control is the statistical confidence. For example a 90% UCL would result in a narrower confidence interval compared with a 95 UCL. If we can be satisfied with only 90% confidence, this adjustment may be a valid way to achieve a narrower confidence interval width in the case of Scenario 2. However, 95% confidence is often a requirement for environmental projects.

The last factor that affects the width of the confidence interval is the distribution of the data. The true shape of the distribution is not known, especially with the few samples taken for ISM designs. Recall that the Chebyshev UCL is typically more conservative than the t-UCL, meaning it gives a wider confidence interval width. This is because the Chebyshev UCL is a non-parametric approach which does not require assuming a particular data distribution.

With the t-UCL, because we assume the data are normally distributed, we can apply that information to achieve a narrower and more precise confidence interval. However, this is not a factor that we are able to control. Similar to variability, we may need to increase the number of observations to compensate for this in the study design.

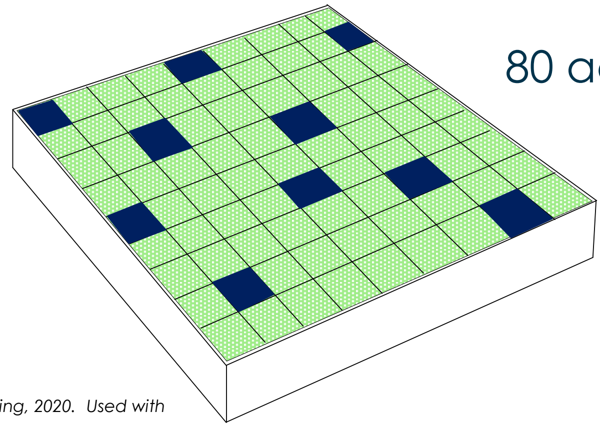


The correct answer is B.

For A: remember that this rule of thumb applies to the coefficient of variation of the increments, not the CV of the replicates. if you're having trouble with that distinction, I recommend looking at the example in the UCL calculator, and you can actually see the formulas that show the adjusted CV of the increments that's used to recommend a UCL. The t-UCL should be used when the data are normally distributed.

For C or D: note that either the t-UCL or the Chebyshev UCL can be used for small sample sizes.

Multiple Sampling Units: Large Areas



3.2.8.1. Figure 3-25. Source: Deana Crumbling, 2020. Used with permission.

For some study designs, you may have multiple sampling units within a decision unit. This is especially common with very large decision units.

In this example, we have an 80 acre field that is represented by a single decision unit. We could divide this into grids and take increments from each grid as we normally would for a smaller decision unit. But, those increments would be very far apart.

In order to better account for heterogeneity, we could select a subset of these grids as sampling units, and collect an entire ISM sample from within the grid. The increments would be closer together and more likely to achieve the desired precision.

We recommend selecting at least 10 sampling units. The 10 ISM samples can then be used to compute a UCL as you would for 10 discrete samples (3.2.8.1).

You may also find it useful to collect triplicates for one or more of the sampling units, depending on the requirements for your project and the information you already have about the level of heterogeneity. You can use one of the metrics we talked about – the CV or RSD -- to evaluate if the desired precision was achieved. Ideally this should be done on the first SU before the other data are collected, because if the desired precision is not achieved, the number of increments should be increased.

Note that this technique should only be used if the concentration is not expected to vary spatially on a large scale across the DU. Typically, this is a case where the entire area is an exposure unit. Check out the risk assessment section of the document, or the upcoming risk assessment training module for more details on exposure units.

Other Approaches for Large Areas

- CSM-equivalent DUs
  - Compare variances of DUs
- Proportion of the large study area that exceeds a threshold
  - Study area exceeds the size of regulatory interest
  - Many samples required

19

A similar approach relates to CSM-equivalent decision units. This is also common for large areas where the concentration is not expected to vary much across the area, but in this case the scale of the decision is much smaller. Instead of dividing a very large DU into several sampling units, we might divide the area into several DUs, with the intention of making a decision for each individual unit. These individual units are called CSM-equivalent DUs (3.2.6.2).

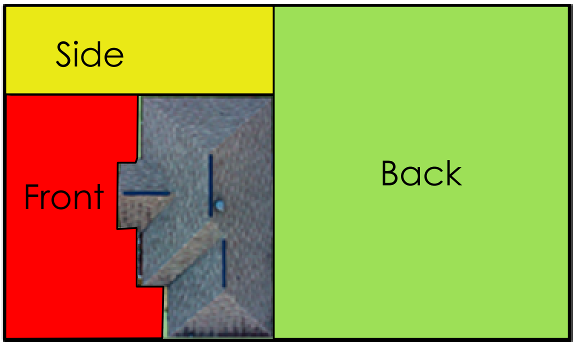
In this case, replicates are typically collected from only a subset of DUs. The variances from the replicate DUs should be compared statistically. If they are not significantly different, the pooled variance across DUs can be used to compute a confidence interval.

Depending on the project, it may be necessary to determine whether a proportion of the study area exceeds a threshold. This not-to-exceed determination is very different from concluding the mean of the area is below the threshold, but it might be of interest if the area exceeds the size that could potentially be of interest from a regulatory perspective.
For example, we might be interested in whether the mean concentration across a 100-acre area exceeds an action level, but we might also be interested in the

proportion of the study area that exceeds a much larger threshold. This decision rule is much more conservative and many more samples are required to support this objective (3.2.8.2).

Refer to guidance document for info on how a larger area would be properly split up into decision units or exposure units.

Multiple Sampling Units: Spatial Differences



2.5.3.1. Figure 2-16. Source: ITRC ISM Update Team, 2020.

- If concentrations differ within the DU, must account for this in the study design
- Divide into multiple SUs
- Weighted average

20

On the previous slides we saw examples of a very large decision unit where the concentration was expected to be similar across the DU. If there are differences in concentrations over space, this should be accounted for in the study design.

The decision unit can be divided into sampling units according to the concentrations expected by the CSM, which ensures each individual area will be adequately characterized during sampling.

Refer to module 2, heterogeneity and Section 3.1 of the document for details on how to properly divide a DU into sampling units for this purpose.

With multiple ISM sample results for each sampling unit, a weighted average and UCL for the entire DU could be calculated (6.2.2). The UCL calculator I discussed previously is also able to handle this situation.

Background Comparisons

- Common in risk assessment
- Different statistical methods – background concentrations vary
- Comparison of mean concentration
- Other objectives possible
- See Soil Background Guidance by ITRC (upcoming)

ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

21

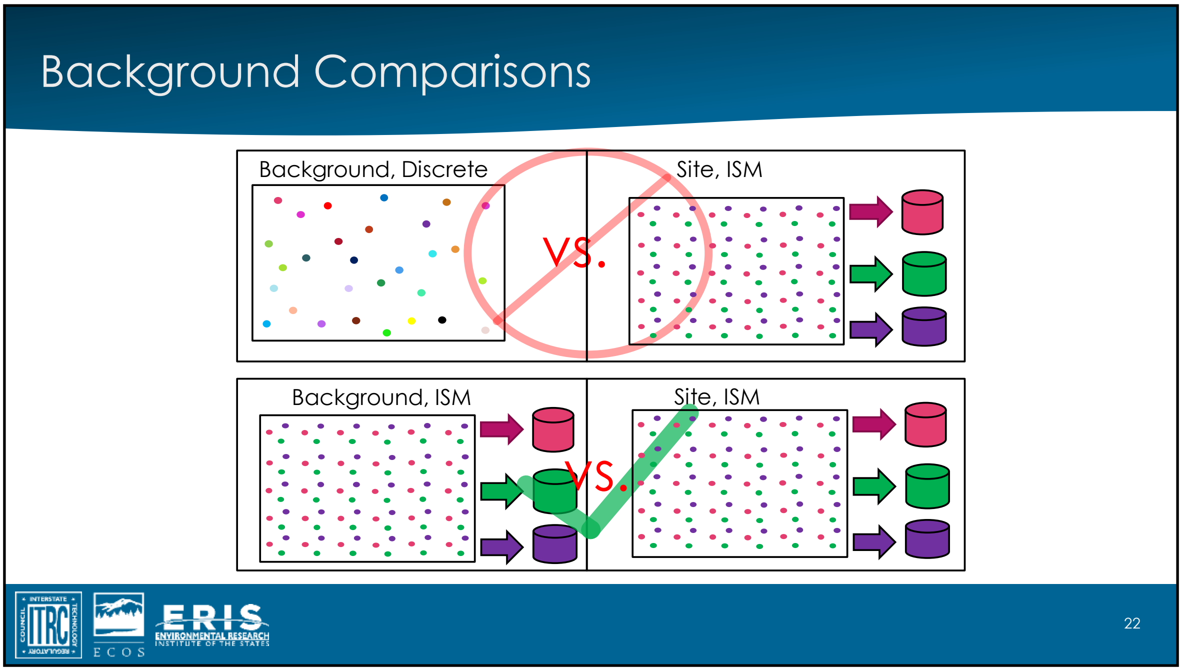
Background comparisons are another objective that is particularly common in risk assessment.

The statistical methods for this type of comparison are different than comparisons to cleanup levels. This is because while cleanup levels are known constants, background concentrations have variation. The true mean and maximum background concentrations are unknown just as the true mean and maximum site concentrations are unknown. In addition, the shape of each distribution is also unknown (3.3.4.1).

Most commonly, the project objective includes comparing the means of site and background concentrations. Appropriate statistical tests for this objective include the two-sample t-test or non parametric alternatives, depending on the resulting shape of the distributions. ANOVA could also be used to compare more than two group, for example comparing two decision units to background concentrations (3.3.4). Less commonly, comparing the upper quantiles of the distributions may be of interest (see Section 3.3.4.2)

We recommend comparing the site and background distributions through valid statistical tests rather than relying on point estimate comparisons.

The ITRC Soil Background Guidance document will give more details on this topic, which is estimated to be released sometime in 2021



One of the most important considerations for background comparisons is the collection method of the background data set.
Existing background data may be available for the site, but if those data are discrete then they cannot simply be compared with ISM site data. We recommend comparing ISM site data with background data that is also collected using ISM.
If discrete background data are used, a statistician must be consulted for proper comparisons.

Site and Background Sampling Designs

Must Be Equivalent	Ideally Should Be Equivalent
Volume of soil per increment	Range of sample depths
Number of increments per replicate	SU size and volume
Soil type	Number of replicates
Field and analytical methods	

ITRC ECOS ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

23

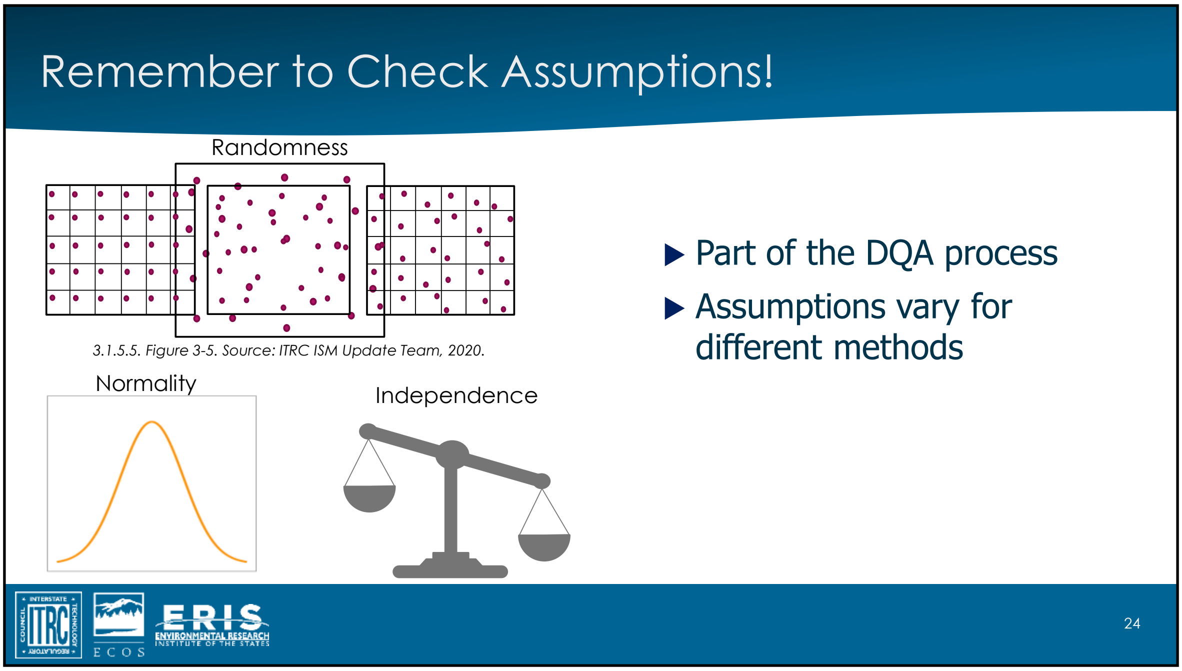
In addition to the sampling methodology, there are several other similarities to consider between site and background sampling designs.

It is important that the volume of soil per increment and the number of increments per replicate be equivalent for the site and background data sets.

Both data sets should ideally employ the same sampling unit size and volume, and range of sample depths. Equal SU size and number of increments means equal density of increments, which controls heterogeneity and affects precision. If it is not feasible to collect background data using the same SU size as the site data, the expected scale of heterogeneity should be evaluated with respect to SU size to ensure the data will be comparable.

Additionally, background comparisons work best when the sample sizes are equal, so the number of replicates for each DU should also be approximately equal. If the sample sizes are not equal, check with a statistician for guidance on how the comparison may be affected.

As with discrete sampling for background comparisons, both data sets should be taken from the same soil type, and the same field and analytical methods should be used.



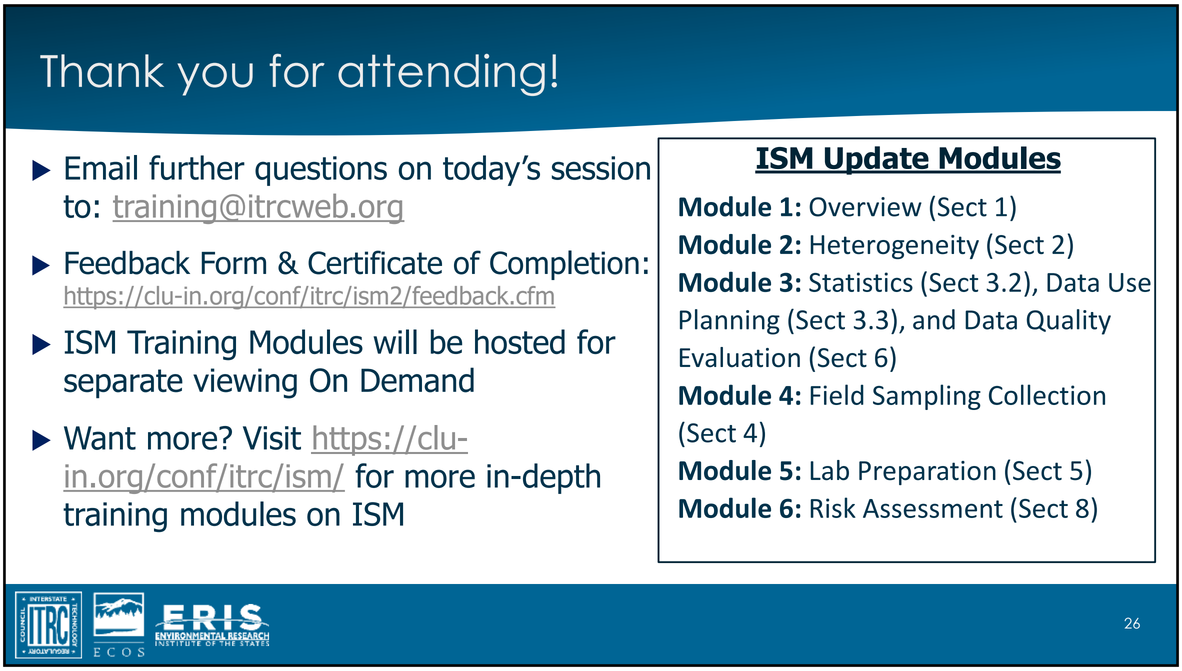
Whatever statistical method is used, the assumptions of the method should be checked as part of the data quality assessment process. Assumptions vary for different statistical methods.

Randomness is a common assumption of nearly all statistical methods and should be a key element of all sampling designs.
There are different ways to incorporate randomness in ISM designs. Refer to Section 3.1, Section 4, and module 4, field sampling for more details on how to incorporate randomness in your design.

Other common assumptions, depending on the statistical method, are that the data are normally distributed, and that they are independent (6.3). Note that depending on the sampling design, some assumptions may not be able to be checked, but you should be aware of them and use information about the site to evaluate whether they are likely to be violated.

Learning Objectives Review

- Data verification, validation, and usability
- ISM works due to physical averaging over many increments
- Comparison to action levels and UCLs
- Multiple sampling units
- Background comparisons



If you need further clarification on the answers or would like to ask more questions, feel free to email us at training@itrcweb.org and we will follow up with our trainers to get your questions answered.

We would like to hear back from you today so please be sure to fill out the online feedback form that's linked on this last slide. You can also access the feedback form by clicking Feedback in the related links section and then clicking browse to. Filling out the feedback form and certifying that you participated will allow you to receive a certificate of completion by email.

ITRC archives all its training classes, so if you find that you have additional time or looking for additional training opportunities, please visit Clu-In and the archived trainings to see if there are other courses that might interest you.