HAWAII STATE DEPARTMENT OF HEALTH

The **Hawai'i Department of Health (HDOH), Hazard Evaluation and Emergency Response Office (HEER Office)** is a state environmental health division whose mission is to protect human health and the environment. The HEER Office provides leadership, support, and partnership in preventing, planning for, responding to, and enforcing environmental laws relating to releases or threats of releases of hazardous substances.

Use of DU-MIS Sampling Methods for Risk-Based Investigation of Contaminated Soil and Sediment

This fact sheet provides government regulators, consultants, property owners and other interested parties with a brief overview of Decision Unit and Multi Increment® Sample (DU-MIS) investigation methods for contaminated soil. (Multi Increment® is registered trademarked of EnviroStat, Inc.) The Fact Sheet focuses on soil, but similar approaches are applied to testing of sediment.

What is DU-MIS?

"Decision Unit" and "Multi Increment Sample" (DU-MIS) investigation methods are a risk-based strategy to test soil and determine if contamination poses a potential threat to human health and the environment. The methods were specifically designed to address concerns related to the unreliability of traditional, discrete sample data. The approach can require additional time and effort at the beginning of a project but will ultimately help to:

- Reduce total project duration and cost;
- Ensure sample data collected are reliable and reproducible;
- Provide a higher degree of confidence that potential risks have been identified and addressed;
- Provide confidence that cleanup actions are only conducted where warranted; and
- Avoid unanticipated delays or even abandonment of projects due to time and cost overruns and lack of a clear endpoint.

DU-MIS investigation methods provide greater confidence in decision making and help to complete environmental projects in a reliable time- and cost-effective manner.

The methods apply to both nonvolatile and volatile contaminants as well as surface and subsurface soils. Similar sampling methods have been used for decades by the mineral exploration and agriculture industries but are relatively new to the environmental industry, where the effects of erroneous data are less evident. Hawai'i first published guidance in 2009.

How is DU-MIS Implemented in the Field?

DU-MIS investigation methods are carried out in a very methodical, step-by-step manner to ensure that the resulting sample data directly answer the questions being asked and are reliably representative of site

conditions. The science behind DU-MIS methods might seem very complex, but implementation in the field is relatively straightforward with some experience.

Step 1: Review the Site History

The first step in "risk-based" investigation is to gain a thorough understanding of the site before samples are collected. This step-by-step process, which includes inspecting the site, talking to people familiar with the site history and compiling existing data, is referred to as "Systematic Planning." The information is summarized in a preliminary "Conceptual Site Model" or "CSM." The CSM is used to design the site investigation.

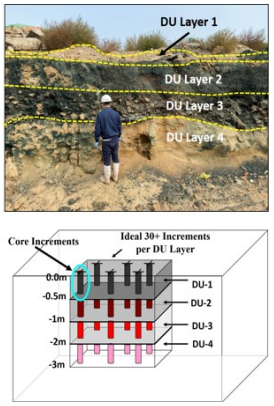
Step 2: Select Areas for Individual Testing

The second step is to designate well-thought-out areas of the site to be individually tested for contamination, referred to as "Decision Units." A DU can be thought of as an area *and volume* of soil that would ideally be sent to a laboratory for testing as a single sample. Each DU is designated to address a specific site investigation question regarding risk assessment or optimization of potential remedial actions. The objective of sample collection is always to determine the mean or "true" concentration of the contaminant for the DU volume of soil *as a whole*.

DUs are designated to answer specific risk or remediation questions. The entire property is often tested.

Risk-based DUs should be selected based on site history and current potential exposure pathways. "Exposure Area" DUs include unpaved areas where children and adults frequently play or work, such as playgrounds, schoolyards, gardens, open areas of commercial and industrial sites and exposed soil at construction sites. These are a very common component of human health risk assessments. The exact size of an Exposure Area DU is necessarily site-specific but normally ranges from a few hundred to a few thousand square meters in area and one hundred to several hundred cubic meters of soil in volume. Assessment of current exposure risk typically focuses on establishing the mean concentration of a contaminant in the upper 10 to 20 centimeters of soil (i.e., surface soil). Assessment of future risk might include the designation and testing of subsurface soil DUs of similar size, assuming the soil could be excavated and spread out at the surface or encountered by workers during construction or utility activities.

Areas of known or suspected, heavily contaminated soil that are almost certain to pose a risk if exposed at the surface should be isolated for separate testing. These are referred to as "Source Area" or "Spill Area" DUs. Source Area DUs are surrounded by anticipated clean, "Boundary DUs" in order to isolate areas of relatively higher contamination and optimize remediation efforts. Successful remediation of contamination can be verified by designation and testing of Exposure Areas DUs in the same locations.



DU Layers are also designated to test subsurface soils.

DUs are designated to characterize both surface soil and, as needed, subsurface soil. Subsurface soil is characterized in terms of stacked, DU Layers. Suspect layers of subsurface soil, identified by site history, initial surface soil data or other observations, should be designated for separate testing in order to bound the vertical extent of the contamination.

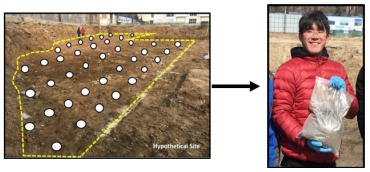
The size and number of DUs designated to characterize a site reflects the "resolution" of the investigation necessary to answer the questions being asked, much like the pixels of a digital photograph.

Five to ten DUs are normally adequate to characterize a simple site. Twenty or more DUs might be required to characterize a complex site.

A very specific, "Decision Statement" that explains the action to be taken when sample data are received is prepared in advance for each DU. This provides a clear pathway forward for subsequent stages of the investigation and helps to expedite overall completion of the project.

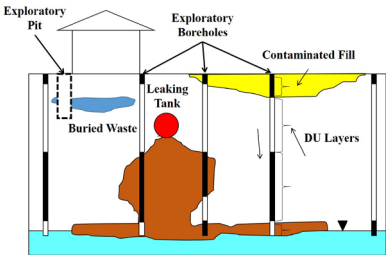
Step 3: Collect a Representative Sample from Each DU Area

Because the collection of the entire volume of soil from a DU and submittal to a laboratory is rarely possible, a representative sample of the soil must instead be collected. The science and statistics behind the collection of a representative sample of soil is complex and involves the need to address both variability between individual particles ("compositional heterogeneity") and variability within the targeted DU ("distributional heterogeneity"). The procedure to collect a sample in the field is, however, relatively straightforward.



A single sample is prepared for each DU by combining small amounts of soil from a large number of points.

A single sample is prepared for each designated DU by collecting and combining small, core-shaped masses of soil from a large number of points within the targeted area. The soil from each point is referred to as an "increment" and the combined increments are referred to as a "Multi Increment (MI)" sample. The sample should be collected from 30 to 75+ points in a systematic, random fashion within the DU area, depending on the nature of the contamination. A default of 50 increments per sample is recommended. Fewer increments might be acceptable for testing of liquid releases (e.g., pesticides). A larger number of increments is required for contaminants present in the soil as clumps or chips (e.g., lead or PCBs). The final mass of the sample must be at least 1 to 3 kilograms or around one liter. Increments are combined in a bottle containing a pre-measured volume of methanol if the sample is to be tested for volatile chemicals.



MI samples can be collected from targeted, DU layers in single, Exploratory Borings for initial investigation of subsurface conditions.

This sample collection method provides a high degree of confidence that that the resulting data will be representative of the targeted area of soil and pertinent to the investigation questions being asked. Just to be certain, however, two additional, independent samples are collected from at least one of the DU areas. These are referred to as "replicate" samples and are used to evaluate the overall precision of the sampling method and reproducibility of the sample data.

Direct-push rigs or excavators can be used to collect increments and prepare MI samples from subsurface DU Layers. If the collection of 50-increment MI samples is not possible due to drilling obstructions or other challenges, then this should be discussed with the overseeing, regulatory agency and the limitations of the resulting data noted. MI sample testing of targeted, DU Layers in individual, "Exploratory Borings" can be useful for very general estimation of the extent and magnitude of subsurface contamination, especially in the case of subsurface petroleum and solvent releases. Be aware, however, that there is a risk of "false negative" results when using this approach and underestimation of contamination and risk. Full, DU-MIS testing of the soil is required for confirmation.

Step 4: Sample Processing and Analysis

Contact the laboratory during the planning phase to ensure the correct sample containers are used and that the laboratory can achieve desired reporting limits and data quality objectives. Select analysis that achieve the desired risk concerns and goals. Avoid testing for unneeded unknowns to keep costs in control. Lead, arsenic, petroleum, PCBs and pesticides like Technical Chlordane and DDT are common contaminants of potential concern.

MI samples to be tested for nonvolatile chemicals are dried, sieved and then carefully subsampled.

Once collected, the sample is sent to a laboratory for processing and testing. The laboratory will not be able to test the entire, 1-2 kg sample. Strict protocols must be followed in order to collect a representative subsample for testing. The sample is normally air dried for 24 to 48 hours and then passed through a sieve to remove large rocks and other debris. A sectoral splitter is then used to collect a representative subsample (third photo in figure). Although more prone to error, the sample can also be spread into a thin layer and a subsample manually collected from a large number of points, similar to how the original sample was collected in the field.

These steps help to ensure that the laboratory data are representative of the sample submitted and that the sample submitted is representative of the targeted DU area. The laboratory is also instructed to collect and test independent, triplicate subsamples from 10% of the samples submitted in order to verify that the subsampling method utilized is reliable and the data generated are reproducible. (Note that this is not necessary for samples preserved in methanol for VOC analysis.)

Step 5: Data Review and Decision Making

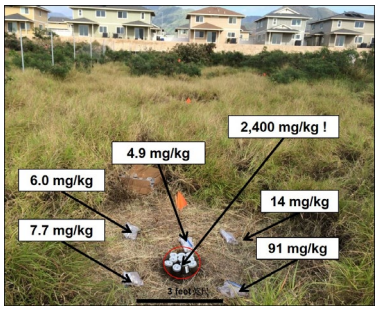
When the laboratory data are received, a review of the overall reliability of the data is made based on field and laboratory replicate samples and other quality control measures. If the replicate data are very different and the problem is determined to be at the laboratory, then determination of the source of error and retesting of the samples might be required. If the problem is determined to be related to the method used to collect the samples in the field, then the sampling process will be reviewed and the collection of new samples might be required. Error associated with sample collection and laboratory testing decreases as experience is gained.

Once the data are determined to be usable, then data for each DU can be directly compared to risk-based screening levels and decisions can be made on the need for cleanup or other soil management actions. The need to collect additional samples should be minimal, assuming that DUs were properly designated at the beginning of the project and DU questions and decision statements were properly prepared ahead of time.

Why are DU-MIS Sampling Methods Necessary?

Guidance for the investigation of contaminated sites published by the USEPA in the 1980s focused on the collection and testing of individual, small masses of soil from single points referred to as “discrete” samples. The authors noted that this method would only be reliable if the concentration of a contaminant in soil was very uniform both within a sample and between closely spaced samples.

Scientists and field workers began to warn in the early 1990s that this was not the case. Data for co-located samples often varied widely and randomly, as did data for duplicate subsamples tested by the laboratory. This caused confusion in the field regarding the extent of contamination above levels of potential concern and in the assessment of risk. The need to repeatedly remobilize field teams for sample collection and the discovery of additional contamination after remediation was thought to be completed caused some projects to drag on for years and in some cases to be abandoned due to the lack of a clear endpoint.



Contaminant concentrations can vary dramatically between co-located, discrete samples and even within the same sample.

A thorough field study of the reliability of discrete sample data for testing of environmental sites was, surprisingly, not carried out until 2015 – thirty years after the first USEPA site investigation guidance was published (Brewer et al. 2017). The field study verified contaminant concentrations can vary dramatically and randomly between samples collected just a few centimeters from each other and even within an individual sample. Statistical analysis of replicate sets of discrete samples can predict very different risks associated with mean contaminant concentrations for targeted exposure areas.

These factors are the primary cause of failed remediation attempts, project delays and cost overruns, and the later discovery of significant contamination in areas earlier declared to be "clean." The mineral exploration and agricultural industries recognized the same problems many years ago. Gold exploration companies often went bankrupt when the amount of gold present in a discovery turned out to be far less than predicted by the samples collected or more commonly when large accumulations of gold were overlooked due to erroneous sample data. Farmers realized the unreliability of discrete sample data very quickly, as crop yields failed to meet expectations or large sums of money were unnecessarily spent on fertilizer or other field amendments.

The result was the development in the 1950s of the Theory of Sampling by Pierre Gy, which serves as the basis of the DU-MIS methods described in this fact sheet. Errors in sample data and decision making are less obvious in the environmental industry, but DU-MIS methods are being continually improved in order to make the investigation, assessment and remediation of contaminated soil as efficient and reliable as possible.

Where can I get more information on DU-MIS methods and Gy's Theory of Sampling?

Refer to the HEER Office website and *Technical Guidance Manual* (https://health.hawaii.gov/heer/) for further information about this fact sheet and the basis and implementation of Decision Unit and Multi Increment Sample investigation methods or contact:

Hawai'i Department of Health, Hazard Evaluation and Emergency Response Office
2385 Waimano Home Road, Pearl City, HI 96782
Telephone: (808) 586-4249

Field study of the nature and reliability of discrete sample data:

Brewer, R., Peard, J. and M. Heskett. 2017a. A critical review of discrete soil sample reliability, Part 1 – Field study results: Soil and Sediment Contamination, Vol. 26 (1).

Brewer, R., Peard, J. and M. Heskett. 2017b. A critical review of discrete soil sample reliability, Part 2 – Implications: Soil and Sediment Contamination, Vol. 26 (1).