Appendix A.Case Study Summaries

Summaries of case studies are provided in this guidance document to provide information with regard to ISM design, implementation, and assessment methodologies. The case studies presented were selected based on their relevance to the use and application of ISM, but the methodologies and conclusions of the case studies provided were not independently verified by the ISM Team.

Each summary provides a description of the case study including its key concepts, COCs, media, geographic area, regulatory agency, owner/responsible party, site complexities, field sampling, statistical sampling design, laboratory processing, data quality summary, level of effort, and outcome/lessons learned where available.

The amount of information provided in each published case study varies based in part on the focus, purpose, and/or goals of each. Consequently, the level of detail provided in each summary presented in this guidance generally reflects the amount of information that was available for review. Links to the actual case studies are provided in each summary to enable the reader to review and gather additional details.

Table A-1 lists the 10 case studies summarized in this document followed by the individual case study summaries.

Table A-1. Case study summary table.

Source: ITRC ISM 2020 Team.

Study #	Author	Title
1	J.L. Clausen, T. Georgian, A. Bedna, et al	Demonstration of Incremental Sampling Methodology for Soil Containing Metallic Residues
2	J.L. Clausen, T. Georgian, K.H. Gardner, T.A. Douglas, et al	Applying Incremental Sampling Methodology to Soils Containing Heterogeneously Distributed Metallic Residues to Improve Risk Analysis
3	D. Crumbling	Advanced ISM QC Field Three Replicates Strategy for Managing Hundreds of DUs
4	B. Bachmann, St. Germain	Confirmation Soil Sampling: Remedial Action Report, FairPoint Communications, Utility Pole Storage Area, 11 Mallet Park Road, Brunswick, Maine
5	R. Brewer	Evaluation of Green Island Landfill and Reburial Pit, Former U.S. Coast Guard LORAN Station Kure
6	(1) TetraTech report to HDOH (2) Enviroservices & Training Center, LLC to DHHL	East Kapolei Final Site Assessment and Site Investigation Reports, Kapolei, Oahu, Hawaii
7	K. Hyde, W. Ma, T. Obal, et al	Incremental Sampling Methodology for Petroleum Hydrocarbon Contaminated Soils: Volume Estimates and Remediation Strategies
8	B. Bachmann, St. Germain	Confirmation Soil Sampling: Pole Storage Area Remediation Report, FairPoint Communications Facility, 104-106 Fairbanks Road, Farmington, Maine
9	L. Stuchal	Anclote Key Lighthouse Assessment, Pinellas County, Florida
10	D.B. Stephens & Associates, Inc.	The Mineral Wool Site

Case Study #1: Metallic Residues at Shooting Range, ISM versus Discrete

ISM Concept Demonstrated: Cost savings and ISM sampling performance

Case Study Name: *Demonstration of Incremental Sampling Methodology for Soil Containing Metallic Residues*

Author(s): Jay L. Clausen, Thomas Georgian, Anthony Bednar, Nancy Perron, Andrew Bray, Patricia Tuminello, Gordon Gooch, Nathan Mulherin, Arthur Gelvin, Marc Beede, Stephanie Saari, William Jones, and Shawna Tazik

Date: September 2013

COCs: Metallic residues

Media of Concern: Surface soils at small-arms ranges

Case Study Link: Demonstration of Incremental Sampling Methodology for Soil Containing Metallic Residues

Background

Metal constituents are introduced into the environment as metal residues from small-arms and pyrotechnic military training areas. The U.S. Army Engineer Research and Development Center created this report for a project that was conducted at two inactive small-arms ranges at Fort Eustis, Virginia, and at the Kimama Training Site in Idaho (both Military Munitions Response Program, or MMRP, sites), as well as at one active small-arms range at Fort Wainwright, Alaska. These locations were selected for the sampling and sample processing of soil samples obtained from the ranges, with the three sites selected to provide a variety of soil types. The project had the objectives of demonstrating improved sampling data quality for metal constituents in surface soils on military training ranges and developing a methodology that would result in the same or lower cost as conventional grab/discrete sampling. This report summarizes the demonstration, which included comparing ISM to conventional grab/discrete sampling through assessing performance and cost.

Site Summary

Regulatory Agency/Program	This report was completed by the Engineer Research and Development Center of the USACE as a partial fulfillment of the obligations for Environmental Science Technology Certification Program (ESTCP) Demonstration Project ER-0918.
Description	Three small-arms ranges located at Fort Eustis, Virginia; Kimama Training Site, Idaho; and Fort Wainwright, Alaska.
Owner/Responsible Party	U.S. Department of Defense
Other Stakeholders	None

Site Complexities

Risks	NA
Characteristics	Three small-arms ranges evaluated, two were inactive MMRP sites and one was active
Other	NA

Planning and Implementation

Field Sampling Conducted	Fort Wainwright: 63 ISM and 50 grab samples Kimama Training Site: 18 ISM and 30 grab samples Fort Stewart: 27 ISM and 33 grab samples
DUs	Fort Wainwright: background, firing point, and berm face Kimama Training Site: background and berm face Fort Stewart: background and berm face
Statistical Sampling Design	Statistical comparisons and summaries were completed for each of the three sites.

Laboratory Processing and Analysis Summary	Laboratory processing included machining or grinding the soil, increasing the digested mass and the digestion interval, improving the digestion efficiency by increasing the acid to sol ratio, and subsampling to build the digestate sample. The following methods were used for analysis: 6010B/3050B for metals, 8330B for explosives, Walkley-Black Method for total organic carbon (TOC), SW-846 9045D for soil pH, ASTM D7503-10 for Cation Exchange Capacity (CEC), ASTM D421/ASTM D422 for grain size, and ASTM D2216 for moisture content.
Data Quality Summary	Acceptable; data were collected to compare ISM to discrete sampling in terms of performance and cost.
Level of Effort (Cost/Benefit, Effectiveness or ROI)	ISM requires additional costs for handling and processing of samples, but this was offset by the need to collect fewer samples using ISM. For each site, the study compared field labor and laboratory analyses costs for ISM and grab sampling. The cost comparisons assumed that three replicate ISM samples were collected for each DU and that grab samples included two scenarios (7 and 15 grab samples). Total costs are compared in Table 37 of the report. For the Fort Wainwright site, total project costs for sampling and analysis using ISM were lower than using grab samples. For the Fort Eustis site, total project costs were virtually identical for both ISM and grab sampling techniques. Total project costs for ISM were slightly higher than total project costs associated with grab sampling for the Kimama site. Overall, the study concluded that total project costs were 5% to 50% lower using ISM: grab sampling would require more samples to be collected.

Decision-making

Outcome and Lessons Learned	This report compared ISM to conventional grab/discrete sampling by assessing performance and cost. The study determined that, at all sites, ISM yielded reproducible and more representative metals soil concentrations than the conventional grab sampling methods. With respect to cost, it was demonstrated that using ISM creates a potential cost savings of 30 to 60% as compared to conventional sampling approaches.
Complicating Factor(s)	The authors of this report are currently working with USEPA to modify Method 3050B and incorporate the recommended changes identified from this project into a Method 3050C. Implementation issues are discussed in section 8 of the report.

Case Study Conclusions

This study was completed by USACE's Engineer Research and Development Center. The report summarizes a project that compares ISM to conventional grab/discrete sampling by assessing performance and cost at three small-arms ranges with metal residues.

Case Study #2: Metallic Residues at Shooting Range

ISM Concept Demonstrated: 100 increments per DU needed for metals at shooting ranges

Case Study Name: *Applying Incremental Sampling Methodology to Soils Containing Heterogeneously Distributed Metallic Residues to Improve Risk Analysis*

Author(s): J.L. Clausen, T. Georgian, K.H Gardner, and T.A. Douglas

Date: January, 2018

COCs: Lead and antimony

Media of Concern: Surface soils

Case Study Link: [Applying Incremental Sampling Methodology to Soils Containing Heterogeneously Distributed Metallic]

Residues to Improve Risk Analysis

Background

This published study was designed to compare grab soil sampling techniques to ISM to characterize the impacts from metals at a small-arms range. Grab and ISM sampling were used to estimate mean metals concentrations in surface soils, particularly for Pb and antimony (Sb), to compare to a background sample previously collected using ISM. The ISM samples were collected within the DU by using a range of increments from 5 to 200 to determine how the number of increments affect data quality. The data were ultimately used to calculate a 95% UCL and then compare it to USEPA residential screening levels.

Site Summary

Regulatory Agency/Program	NA; not discussed in the research paper
Description:	Camp Ethan Allen, Vermont
Owner/Responsible Party:	U.S. Department of Defense, U.S. Army
Other Stakeholders	NA

Site Complexities

Risks	Metals impacts on surface soils
Characteristics	Small-arms shooting range berm (approximately 300 m^2) with metallic and explosive residues
Other	NA

Planning and Implementation

Field Sampling Conducted	For grab samples, 30 grab samples were collected using a steel scoop (or equivalent) and placed in 4-oz glass containers. Grab sample locations were selected using systematic random sampling. For ISM samples, samples were collected to a total depth of 5 cm using a 2-cm diameter corer. Seven replicate samples consisting of 5, 10, 20, 30, 50, and 100 increments each were collected, as was one ISM sample consisting of 200 increments.
DUs	Entire face of the berm
Statistical Sampling Design	Site-specific descriptive statistics (max, min, mean, median) were calculated, as well as SD, percent relative SD, and RPD for the grab and ISM datasets. Additionally, USEPA ProUCL software was used to calculate the UCLs, Student's-*t* tests, and data distributions.
Laboratory Processing and Analysis Summary	Sample processing used a modified method: samples were air-dried, passed through a 10-mesh sieve prior to milling, milled, and then subsampled. Milling involved grinding the sample to <2 mm using a steel ring mill grinder. The milled soil was spread over a sheet of aluminum foil (1- to 2-cm thick layer), and 20 increments were collected using a flat spatula. Increments were combined to yield a 2-g digestion aliquot. Samples were analyzed in accordance with USEPA Method 6010C.

Data Quality Summary	ISM data were acceptable, with higher increment samples providing a better estimate of the mean concentrations.
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	The study concluded that ISM sampling with a minimum of 30 increments and three to five replicates would provide a better estimate of the mean concentration for a DU than collecting a large number (>30) of grab samples, thus reducing the total cost of sample collection and analysis.

Decision-making

Outcome and Lessons Learned	ISM results had much higher precision compared to grab samples (the percent RSD was much smaller for ISM compared to grab), providing a better representation of the DU's mean concentration for Pb and Sb. Grab samples yielded a negative bias when estimating the mean. Ultimately, the ISM datasets indicated that the mean concentration for the DU exceeded the USEPA residential screening level.
Complicating Factor(s)	Elevated chromium concentrations were observed in the ISM samples, the source most likely the milling equipment, which contains chrome-steel grinding surfaces.

Case Study Conclusions

The ISM datasets for Pb and Sb provided much more precise data, with less difference between the mean and median concentrations compared to grab samples and a tighter range between the minimum and maximum concentrations. The study concluded that ISM samples with 100 increments would be appropriate for sampling small-arms ranges for metals, and that ISM samples with a smaller number of increments tended to underestimate the mean concentration.

Case Study #3: Hundreds of DUs, Very Large Sites, Residential, and Landfill

ISM Concepts Demonstrated: Advanced ISM QC field three replicates strategy for managing hundreds of DUs, evaluation of BaP, particle effects caused by data variability

Case Study Name: *Advanced ISM QC Field Three Replicates Strategy for Managing Hundreds of DUs*

Author(s): Deana Crumbling

Date: January 28, 2019

COCs: BaP

Media of Concern: Soil

Background

This technical memorandum serves as a description of ISM techniques used to evaluate DU compliance with a site-specific cleanup level of BaP and assess neighborhood residential properties impacted by a landfill. After a single sample was collected from each DU, a decision tree strategy was used to determine if the DU would automatically qualify for cleanup, if the DU was compliant with the site-specific cleanup level, or if additional sampling would be necessary to provide a three replicate DU. This project involved applications of statistical principles to derive an adaptive strategy to speed cleanups and reduce costs while still maintaining full protectiveness and transparency.

Site Summary

Regulatory Agency/Program	EPA Region 3 Superfund Division and Office of Superfund Remediation and Technology Innovation – Technology Integration and Information Branch
Description	A site located in USEPA Region 3; specific location details kept anonymous
Owner/Responsible Party	NA; specific site details are anonymous

Other Stakeholders	NA; specific site details are anonymous

Site Complexities

Risks	Impact to neighborhood residential properties
Characteristics	Residential properties affected by a landfill
Other	Comparisons made to a site-specific cleanup level of BaP to evaluate DU compliance

Planning and Implementation

Field Sampling Conducted	Incremental soil sampling was used to collect DU samples from two depth intervals (0 to 1 ft and 1 to 2 ft bgs). Each incremental sample was composed of 50 1-in diameter increments collected by auger-drill lift into a bucket through a hole in the bottom of the bucket. Because the mass of each incremental sample collected this way usually exceeded 2 kg, the sample was split in the field using incremental procedures to create a representative subsample mass between 1 and 2 kg, which was sent to the laboratory.
DUs	DUs consisted of residential yards
Statistical Sampling Design	Site-specific statistics collected to assess the degree of data variability prior to sampling
Laboratory Processing and Analysis Summary	The samples were processed and analyzed for PAHs, PCBs, and Pb. However, in the technical memorandum, only BaP was considered of the PAH analytes. Sample processing in the laboratory consisted of air-drying, disaggregation, passing the disaggregated material through a 10-mesh sieve to remove non-soil objects, milling of the <10-mesh material, then incremental subsampling of a 2D slabcake using 30 increments to form a 30-g analytical subsample mass.
Data Quality Summary	Acceptable
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	The goal of sampling and analysis was to obtain an estimate of a DU’s true BaP concentration for comparison to the site-specific cleanup level.

Decision-making

Outcome and Lessons Learned	The technical memorandum serves as a description of ISM techniques used to evaluate DU compliance with a site-specific cleanup of BaP used to assess neighborhood residential properties impacted by a landfill.
Complicating Factor(s)	Despite laboratory processing activities, considerable variability was observed for BaP results in subsampling replicates. Efforts were made early in the project to troubleshoot the problem, but no procedural modifications were found that consistently controlled subsampling variability. The weight of evidence in the data collected suggested that the problem may be caused by irreducible particle effects. The full discussion of the evidence for particle effects causing data variability was deleted to shorten the case study.

Case Study Conclusions

This unpublished technical memorandum serves as a description of ISM techniques used to evaluate DU compliance with a site-specific cleanup level of BaP and assess neighborhood residential properties impacted by a landfill.

Case Study #4: Confirmation Sampling from Utility Pole Storage

ISM Concept Demonstrated: Decision matrix for using DU mean, DU 95% UCL, and CV

Case Study Name: *Confirmation Soil Sampling: Remedial Action Report, FairPoint Communications, Utility Pole Storage Area, 11 Mallet Park Road, Brunswick, Maine*

Author(s): St. Germain Collins

Date: February 9, 2017

Contaminant(s) of Concern: PCPs, dioxin, metals, and PAHs

Media of Concern: Soil (excavation surface)

Case Study Link: Confirmation Soil Sampling: Remedial Action Report, FairPoint Communications, Utility Pole Storage Area, 11 Mallet Park Road, Brunswick, Maine

Background

ISM was used to confirm that remedial actions (such as excavation) removed impacted soils in a utility pole laydown yard. ISM was used to first establish background concentrations for chromium, copper, arsenic (CCA), and PAHs. Excavation of impacted soils was then conducted, removing approximately 3,047 tons of soil in an area approximately 345 ft x 30 ft. The excavation was split into six DUs, and ISM was used to collect confirmation samples from each DU. Those results were then compared to either background and/or Residential Remedial Action Guidelines (RAGs) for COCs.

Site Summary

Regulatory Agency/Program	Maine Department of Environmental Protection (MEDEP)
Description	Utility Pole Storage Area, Brunswick, Maine
Owner/Responsible Party	FairPoint Communications
Other Stakeholders	NA

Site Complexities

Risks	Surface soil exposure (dermal, ingestion, inhalation of particles)
Characteristics	Laydown area for utility poles
Other	The MEDEP approved the response action plan, which proposed the use of ISM for confirmation soil sampling and included a layout of SUs and DUs.

Planning and Implementation

Field Sampling Conducted	ISM was used to collect three background samples (3 DUs) for CCA and PAHs. The excavation boundaries were divided into nine SUs (floor of the excavation had three SUs and sidewalls had 6 SUs). For two specific areas of the excavation, several of the SUs were combined and a total of six DUs to further evaluate the data. Confirmation samples were collected using the USACE multi-increment sampling tool (CMIST) for analysis of dioxins, PCP, and CCA. Each SU sample consisted of 30 increments and collected in three replicates.

DUs	Three DUs for background samples Six DUs for confirmation (two excavation floor samples; four sidewall samples)
Statistical Sampling Design	Comparison of average of three replicates for each SU to remediation goal (either background or RAG). For DUs, 95% UCL of mean concentration for dioxin and CCA for comparison in a pre-approved decision matrix.
Laboratory Processing and Analysis Summary	Nothing reported on laboratory processing. Dioxins analyzed in accordance with USEPA Method 8290. PCP analyzed in accordance with USEPA Method 8270. CCA analyzed in accordance with USEPA Method 6010.
Data Quality Summary	Standard laboratory QA/QC for analyses; data were acceptable for intended use.
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	NA

Decision-making

Outcome and Lessons Learned	Excavation successfully removed impacted soils, and ISM provided more accurate confirmation sampling results. No further remediation was necessary.
Complicating Factor(s)	NA

Case Study Conclusions

The Remedial Action Report documented successful remediation activities to remove surface soils impacted from utility pole laydown operations. Soils were excavated and confirmation soil samples were collected using ISM, with results demonstrating that concentrations were either at below background or RAGs.

Case Study #5: Investigation of a Former Dump Area on an Inaccessible Island

ISM Concept Demonstrated: Incremental sampling conducted successfully at multiple depth intervals. Statistical analyses that determined standard sample collection methodology would have provided unreliable results.

Case Study Name: *Evaluation of Green Island Landfill and Reburial Pit, Former U.S. Coast Guard LORAN Station Kure*

Author(s): Element Environmental, LLC, Haleiwa, HI; prepared for U.S. Coast Guard (USCG)

Date: June 2009

Contaminant(s) of Concern: PCBs and metals (arsenic, cadmium, chromium, lead, and mercury)

Media of Concern: Surface and subsurface soil and sediment

Case Study Link: Evaluation of Green Island Landfill and Reburial Pit, Former U.S. Coast Guard LORAN Station Kure

Background

Kure Atoll includes one vegetated island (Green Island) that is approximately 1.5 miles long and 0.35 miles wide. The USCG operated a LORAN station on Green Island from 1960 to 1992, and waste generated during operations were buried at the southwest end of the island in a scrap metal dump (SMD). It is assumed that scrap metal and electrical components containing hazardous materials such as PCBs (capacitors, batteries, and transformers) were disposed at this location from the early 1960s to the late 1970s. Investigations predating this case study were conducted from 1991 through 1994, and a response action ordered the excavation of approximately 800 yds of soil from the SMD in 1993. The excavated soil was placed in a reburial pit near the center of the island with the exception of off-site disposal of 36 yds^3 of soil.

This report summarizes a follow-on investigation conducted in 2008 that included incremental sampling conducted in and surrounding the SMD.

Site Summary

Regulatory Agency/Program	NA
Description	Kure Atoll, Green Island
Owner/Responsible Party	USCG
Other Stakeholders	None

Site Complexities

Risks	Isolated location, no permanent residents or workers
Characteristics	Predominately water deposited coral sands, so Green Island is subject to drastic changes in sand deposits depending on wave action.
Other	A PCB hotspot identified in the SMD from immunoassay field testing of discrete samples resulted in the addition of a DU.

Planning and Implementation

Field Sampling Conducted	Near surface samples collected with trowel. Below near surface to 36 in collected by digging with a shovel to depth and collection of samples with trowel. Samples below 36 in collected with slide hammer-driven soil probe with acetate liner.
DUs	Eighteen total DUs: Ten located outside of SMD DU-1 through DU-8 had a sample depth of 4 inDU-9 and DU-10 were duplicates of DU-8Five located across entire SMDDU-11 sample depth of 4 inDU-12 sample depth of 36 inDU-13 sample depth of 60 inDU-14 and DU-15 were duplicates of DU-13Two located in SMD hotspot with samples from each analyzed for four separate grain sizesDU-17 sample depth of 36 inDU-18 sample depth of 60 in
Statistical Sampling Design	NA
Laboratory Processing and Analysis Summary	Laboratory analytical methods followed USEPA Publication SW-846
Data Quality Summary	Acceptable
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	None provided

Decision-making

Outcome and Lessons Learned	ISM was useful for determining a representative mean level of contamination within a DU. Additional homogenization of samples in laboratory prior to selection and extraction of samples for analysis was critical to obtain representative results due to some isolated hot spots or nuggets of contamination in SMD.
Complicating Factor(s)	None

Case Study Conclusions

A draft unpublished summary report specific to an investigation scale evaluation of the incremental sampling conducted for this investigation is provided as Appendix C of the report. Statistical analyses determined traditional sampling would have resulted in incorrect conclusions versus the incremental sampling that was conducted.

Analysis of four separate grain sizes collected from the two hotspot DUs indicated that the most elevated PCB concentrations were associated with finer grained fractions.

Case Study #6: Pesticide Mixing and Loading Site

ISM Concept Demonstrated: Creation and sampling of 59 DUs in a 400+-acre residential development area with an additional 12 DUs focused on a chemical handling and spill area

Case Study Name: East Kapolei Final Site Assessment and Site Investigation Reports, Kapolei, Oahu, Hawaii

Reports:

1. *East Kapolei Affordable Housing Project, Final Site Assessment Report*, prepared by Tetra Tech EM, Inc., for Hawaii State Department of Health (HDOH), December 12, 2007.
2. *East Kapolei Pesticide and Mixing and Loading Site, Site Investigation Report and Environmental Hazard Assessment,* prepared by EnviroServices & Training Center, LLC, for Hawaii State Department of Hawaiian Home Lands (DHLL), March 2010.

Author(s): Tetra Tech EM Inc.; prepared for Hawaii State Department of Health (HDOH).

EnviroServices & Training Center, LLC; prepared for DHLL.

Contaminant(s) of Concern: Agricultural property – arsenic, dioxin, herbicides, and pesticides; pesticide mixing and loading area (PML) – arsenic, dioxin, and pesticides.

Media of Concern: Surface and subsurface soil

Case Study Links:
East Kapolei Affordable Housing Project, Final Site Assessment Report
East Kapolei Pesticide and Mixing and Loading Site, Site Investigation Report and Environmental Hazard Assessment

Background

Investigations of former sugarcane fields and a separate PML area were conducted to identify COCs prior to potential residential and commercial development. The site was used for sugarcane cultivation from approximately 1890 to 1994, with the PML area used for the storage, mixing, and loading of agricultural chemicals for approximately 40 years until sugarcane operations ceased while the remaining field were subject to the general usage of these chemicals. It was suspected that occasional spills of products within the PML area may have resulted in localized contamination of soils. The reports summarize the investigation and assessment of the sugarcane fields and of the PML area, respectively.

Site Summary

Regulatory Agency/Program	Results compared to HDOH health environmental ALs
Description	East Kapolei, agricultural property, 413 acres East Kapolei, PML, 0.63 acres
Owner/Responsible Party	State of Hawaii
Other Stakeholders	NA

Site Complexities

Risks	Area to be redeveloped for residential purposes.

Characteristics	Clay alluvium derived from igneous rocks.
Other	Stand-alone PML area was within overall site boundaries.

Planning and Implementation

Field Sampling Conducted	Surface soil samples (0 to 0.5 ft) collected with a trowel. Subsurface samples in PML spill area DUs were collected using direct push drilling equipment. Subsurface samples in PML non-spill area DUs were gathered by trenching with a backhoe and collecting samples with a trowel.
DUs	Agricultural fields: Fifty-nine total DUs randomly were selected in each of the 7-acre grids, representing the approximate full extent of the agricultural fields. Each DU was a 5,000-ft^2 area in order to represent a typical residential lot. A total of 40 increments were collected from within each DU. PML area: Twelve surface DUs ranging in area from 1,000 to 5,000 ft^2 were selected, with three DUs representing likely spill areas. A total of 50 increments were collected in each DU.Three spill area DUs also included sampling of subsurface soil from the following three layers: 0.5 to 2 ft, 2 to 5 ft, and 5 to 10 ft. A total of 20 increments were collected from each layer.Five of the general surface DUs were randomly selected to also include subsurface soil from the following two layers: 0.5 to 2 ft and 2 to 3 ft. A total of 50 increments were collected from each layer.
Statistical Sampling Design	NA
Laboratory Processing and Analysis Summary	Laboratory analytical methods followed USEPA Publication SW-846
Data Quality Summary	Acceptable
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	None provided

Decision-making

Outcome and Lessons Learned	None noted
Complicating Factor(s)	None noted

Case Study Conclusions

The investigations confirmed that ISM identified small hot spots as well as overall contaminant heterogeneity within the areas investigated. There were no concentrations of COCs in the soil that indicated conditions were not suitable for residential reuse. Additional sampling and evaluation did not appear necessary.

Case Study #7: ISM for Petroleum Hydrocarbons

ISM Concepts Demonstrated: ISM does not underestimate plume extents or magnitude of contamination and is a better predictor of contaminant mass and exposure for risk assessment. For sampling from boring cores, 30 plugs for ISM performed better than wedge sampling.

Case Study Name: Incremental Sampling Methodology for Petroleum Hydrocarbon Contaminated Soils: Volume Estimates and Remediation Strategies

Author(s): Kathlyne Hyde, Wai Ma, Terry Obal, Kris Bradshaw, Trevor Carlson, Steven Mamet, and Steven D. Siciliano

Date: October 10, 2018

Contaminant(s) of Concern: PHCs

Media of Concern: Surface/subsurface soil

Case Study Link: Incremental Sampling Methodology for Petroleum Hydrocarbon Contaminated Soils: Volume Estimates and Remediation Strategies

Background

This study was conducted to investigate and compare both traditional discrete sampling through a Phase II ESA and ISM for estimating contaminated soil volume and developing management strategies at two sites. Two legacy gasoline and diesel bulk transfer stations located in Saskatoon and Raymore, Saskatchewan, Canada, with known spill and leak histories were selected for sampling. The objectives included estimating the lateral and vertical extent of PHC concentrations, quantifying and determining the causes for the differences in contaminated soil volumes estimated by each method, evaluating and comparing the precision of each method, and determining how to use the information gathered from both methods to manage the two contaminated sites.

Site Summary

Regulatory Agency/Program	NA; analytical data were compared to Saskatchewan Tier I guidance from the Saskatchewan Ministry of the Environment
Description	Two legacy gasoline and diesel bulk transfer stations located in Saskatoon and Raymore, Saskatchewan, Canada, with known spill and leak histories
Owner/Responsible Party	Not provided
Other Stakeholders	Department of Soil Science, University of Saskatchewan, Saskatoon, SK; Department of Scientific Services and Development, Maxxam Analytics, Mississauga, ON; Department of Sustainability, Federated Cooperatives Limited, Saskatoon, SK

Site Complexities

Risks	Potential exposure pathways not yet identified by a risk assessment
Characteristics	Highly heterogenous soils in western Canada formed from glacial till and freeze thaw conditions, which make estimating the average concentration of concern for a site difficult and unreliable.
Other	Supplementary material also available

Planning and Implementation

Field Sampling Conducted	The site areas were conceptually divided into four IAs encompassing the source, plume, plume delineation, and clean areas. Each IA contained three single borehole DUs in unbiased locations from which soil cores up to 7.5 m in depth were taken using direct push core drilling with a Geoprobe® 7822DT. Single borehole DUs had two co-located boreholes within 0.5 m of each other, one for the Phase II ESA based on discrete sampling methods and one for ISM analysis. Traditional discrete samples were collected on site at depth increments of 0.5 m (for up to 6 or 7.5 m) from each initial borehole for the Phase II ESA. A single sample was submitted for analysis for each single borehole DU. The single or additional bias samples were taken based on visual contamination and odor, and whether there were high VOC readings on a photo-ionization detector (PID). Samples for volatiles analysis were collected with a 5-g Terra Core™ sampler and placed into a 40-mL VOC vial pre-charged with HPLC grade methanol. Approximately 200 g of soil was packed into 250-mL jars, from which a 5-g subsample was used for semi-volatiles analysis. From the co-located borehole, the 1.5-m acrylic tube segments were collected and sealed with paraffin wax on site. Cores were stored at -20°C prior to further subsampling in a laboratory setting.
DUs	Each IA contained three single borehole DUs in unbiased locations from which soil cores up to 7.5 m in depth were taken using direct push core drilling. Single borehole DUs had two co-located boreholes within 0.5 m of each other, one for the Phase II ESA based on discrete sampling methods and one for the ISM analysis. Discrete samples were collected at depth increments of 0.5 m (for up to 6 or 7.5 m), and each single borehole DU was divided into three DU layers: (1) surface zone at 0 to 1.5 m, (2) estimated contaminated zone at 1.5 to 4.5 m, and (3) depth delineation zone at 4.5 to 6.0, or 7.5 m depending on the site. From each DU layer, the samples collected included (1) 30 plug increments to combine for one ISM sample, (2) a wedge sample collecting surface soil from the entire length of the core, and (3) a discrete sample from a biased hot spot.
Statistical Sampling Design	The study describes that ISM holds greater statistical power by overcoming the fundamental and distributional error associated with spatial soil heterogeneity and contaminant distribution. Statistical sampling design included false positive and false negative data analysis and 95% UCL calculations using the ITRC UCL calculator.
Laboratory Processing and Analysis Summary	The analytical data for both the Phase II ESA and ISM work were provided by Maxxam Analytics. Stored, frozen soil cores were used for analysis; the cores were thawed for sampling. From each DU, the team collected (1) 30 plug increments to combine for one ISM sample, (2) a wedge sample collecting surface soil from the entire length of the core, and (3) a discrete sample from a biased hot spot. The top layers of the cores were shaved off to expose fresh soil for sampling, and soils were sampled for C6-C10 hydrocarbons, BTEX (benzene, toluene, ethylbenzene, and xylenes), VOC analysis, and SVOC analysis.
Data Quality Summary	ISM holds greater statistical power by overcoming the fundamental and distributional error associated with spatial soil heterogeneity and contaminant distribution. In comparison to ISM, discrete sample data under- and overestimated contaminants.
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	This study was conducted to investigate and compare both traditional discrete sampling through a Phase II ESA and ISM. Incremental samples identify a greater extent of contamination than discrete samples and reduced the occurrence of false positives, which reduced the quantity of mapped contamination. This would in turn reduce remediation costs.

Decision-making

Outcome and Lessons Learned	The results from both methods indicated that the sites were impacted with petroleum hydrocarbons above Saskatchewan Tier I guidance. The study showed that ISM does not underestimate the plume extent or underestimate the magnitude of contamination, and that current Phase II ESA methods are effective in identifying areas of potential concern, but they cannot provide robust estimates of contaminant mass. The study recommended that ISM be used as a remediation planning tool and that following a traditional Phase II ESA with an ISM-directed sampling approach would provide a statistically robust estimate of contaminant mass and exposure for risk assessment.
Complicating Factor(s)	None

Case Study Conclusions

This study was conducted to investigate and compare both traditional discrete sampling through a Phase II ESA and ISM for estimating contaminated soil volume and developing management strategies at two legacy gasoline and diesel bulk transfer stations. The study recommended that ISM be used as a remediation planning tool and that following a traditional Phase II ESA with an ISM-directed sampling approach would provide a statistically robust estimate of contaminant mass and exposure for risk assessment. Supplementary material is also available for review in addition to the published article.

Case Study #8: Remedial Action Report, Utility Pole Storage Area

ISM Concept Demonstrated: Figures with site plan development, grids, and locations of samples within grids.

Case Study Name: Confirmation Soil Sampling: Pole Storage Area Remediation Report, FairPoint Communications Facility, 104-106 Fairbanks Road, Farmington, Maine

Author(s): St. Germain Collins, Keith R. Taylor, and a Certified Geologist (C.G.)

Date: December 10, 2015

Contaminant(s) of Concern: PCPs, dioxin, and PAHs originating from utility pole preservatives

Media of Concern: Surface/subsurface soil

Case Study Link: Confirmation Soil Sampling: Pole Storage Area Remediation Report, FairPoint Communications Facility, 104-106 Fairbanks Road, Farmington, Maine

Background

The FairPoint Communications (FairPoint) facility in Farmington, Maine, included a utility pole storage area, and preservatives from the utility poles had contaminated surface and subsurface soils with PCPs, dioxin, and PAHs. Since FairPoint planned to end its lease and use of the site, a remedial action was put in place, the goal of which was to remove the soils exceeding MEDEP RAGs. Approximately 312 tons of soil were removed during excavation, and ISM was used during confirmation sampling to ensure that the remedial action had removed the soils exceeding MEDEP RAGs.

Site Summary

Regulatory Agency/Program	MEDEP
Description	Utility Pole Storage Area, Farmington, Maine
Owner/Responsible Party	FairPoint Communications
Other Stakeholders	NA

Site Complexities

Risks	Surface soil exposure (dermal, ingestion, inhalation of particles)
Characteristics	Laydown area for utility poles
Other	MEDEP approved the remedial action plan at the site, and confirmation sampling collection and analysis was completed in accordance with ITRC ISM guidance.

Planning and Implementation

Field Sampling Conducted	Upon completion of soil excavation, 10-ft x 10-ft sampling grids were established over the entire excavated area (sidewalls and floor), and three discrete soil samples were collected from each excavation bottom grid cell. Nine sidewall discrete samples were collected from each sidewall grid cell, as necessary. The discrete samples were combined to create three composite samples, which were then submitted for further processing. The final composite samples represented four DUs, and three replicate results were used to provide the mean concentration for the DU.
DUs	Four DUs: DU-1 (crib excavation bottom), DU-2 (crib excavation sidewalls), DU-3 (debris pile excavation bottom), and DU-4 (debris pile excavation sidewalls)
Statistical Sampling Design	RPD were compared to measure precision, and the three replicate sample results were used to calculate the 95% UCL of the mean concentration of the contaminants. A total of 30 increments were collected per DU and in three replicates.
Laboratory Processing and Analysis Summary	Nothing specifically stated for laboratory processing. Dioxin screening used USEPA Method 4025M.
Data Quality Summary	Standard laboratory QA/QC was utilized for the analyses. Based on the RPD and the 95% UCL calculations, the data were suitable to conclude no further remediation was necessary.
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	NA

Decision-making

Outcome and Lessons Learned	Excavation successfully removed impacted soils below accepted RAGs or below accepted statewide MEDEP background levels, MEDEP urban developed background, or MEDEP urban fill values.
Complicating Factor(s)	NA

Case Study Conclusions

The Remedial Action Report documented successful remediation activities to remove surface and subsurface soils impacted from utility pole laydown operations. Soils were excavated and confirmation soil samples collected using ISM. The results demonstrated that concentrations were below MEDEP RAGs, below detection limits, below MEDEP urban developed background levels, or MEDEP urban fill values. The report concluded that no further remediation was necessary.

Case Study #9: State Park Incorporating Decommissioned Lighthouse and Residential Dwelling

ISM Concept Demonstrated: Example of an ISM WP and method for determining random increments

Case Study Name: *Anclote Key Lighthouse Assessment, Pinellas County, Florida*

Reports:

1. *Workplan for Characterization of Soil Lead and Mercury Levels in Support of Risk Assessment*, Anclote Key Lighthouse, prepared by the Florida Department of Environmental Protection, January 18, 2013.

  - *Incremental Sampling Case Study Power Point Presentation*, Anclote Key Lighthouse, prepared by Florida Department of Environmental Protection, March 2013 (Draft).

Contaminant(s) of Concern: Lead and mercury

Media of Concern: Surface soil

Case Study Links:

Workplan for Characterization of Soil Lead and Mercury Levels in Support of Risk Assessment

Incremental Sampling Case Study Power Point Presentation

Background

The Anclote Lighthouse was constructed in 1887, decommissioned in 1985, and currently sits within a state park. The paint used on the cast-iron lighthouse was lead-based, and over time, it was subject to erosion and chipping. In the 1960s the lighthouse was converted to battery power and casings from used batteries were discarded or stored in buildings near the lighthouse. More than 100 batteries were removed in 1994, and subsequent discrete sampling identified lead and mercury in surface soil above cleanup target levels. Areas to the east and south of the lighthouse will be subject to remediation based on discrete sampling results with additional assessment to be conducted on the remaining areas of concern, primarily north and west of the lighthouse.

Site Summary

Regulatory Agency/Program	Results compared to Florida Department of Environmental Protection cleanup target levels
Description	Decommissioned lighthouse, surrounding landscaped area, and an adjacent state park ranger residential dwelling
Owner/Responsible Party	State of Florida
Other Stakeholders	None

Site Complexities

Risks	Lighthouse area to be open to public visitors and also single residential dwelling for park ranger
Characteristics	Landscaped
Other	Multiple short-term visitors and a single dwelling for residents

Planning and Implementation

Field Sampling Conducted	ISM surface soil samples (0 to 0.5 ft) were collected following FDEP SOPs using PVC tubes or trowels. In addition to ISM: Discrete surface soil samples were collected for comparison of results to ISM surface soil results. Limited discrete subsurface samples were additionally collected for general characterization purposes only.

DUs	Two DUs based in part on data obtained from previous discrete sampling and site layout characteristics: DU1 – Northwest of lighthouse, 0.18 acres, divided into 32 16-ft x 16-ft cells. Three replicate samples were collected from within each cell, locations determined by systematic random selection. Each of the three replicates combined into three separate samples (32 combined subsamples each).DU2 – Area around park ranger residence, 0.5 acres, divided into 30 28-ft x 28-ft cells. Three replicate samples were collected from within each cell, locations determined by systematic random selection. Each of the three replicates combined into three separate samples (30 combined subsamples each). Discrete surface soil samples were collected from each DU cell for comparison to ISM results, and ISM processing was completed by the analytical laboratory of the submitted replicate samples following internal SOPs.
Statistical Sampling Design	95% UCL for comparison of discrete and ISM mercury results and grand mean for comparison of discrete and ISM lead results in each DU. ISM results were provided for both milled and un-milled samples.
Laboratory Processing and Analysis Summary	Laboratory analytical methods followed USEPA Publication SW-846
Data Quality Summary	Acceptable
Level of Effort (Cost/Benefit, Effectiveness, or ROI)	None provided

Decision-making

Outcome and Lessons Learned	Noted below
Complicating Factor(s)	None noted

Case Study Conclusions

ISM results indicated relative variability, most significantly for lead, in measured concentrations between replicates. This was noted in both milled and un-milled sample replicate sets, so milling of samples did not significantly influence the noted variability. The ISM samples that were milled resulted in generally higher measured concentrations of lead with less significant variation in measured concentrations of mercury. Discrete grand mean lead concentrations specific to each DU were higher than both milled and un-milled ISM grand mean results. Discrete 95% UCL mercury concentration in DU1 was higher than both milled and un-milled ISM results, while the discrete 95% UCL mercury concentration in DU2 was lower than both milled and un-milled ISM results.

Case Study #10: Metals in Soils, Discrete versus ISM Costs Comparison

ISM Concept Demonstrated: A larger number of increments (30 versus 50) did not improve data quality. ISM sampling costs were less than collecting a large number of grab samples.

Case Study Name: *The Mineral Wool Site*

Author(s): Daniel B. Stephens & Associates, Inc.

Date: May 2015

Contaminant(s) of Concern: Antimony, copper, and lead

Media of Concern: Surface and subsurface soils

Case Study Link: The Mineral Wool Site

Background

This study was designed to compare ISM results to conventional investigation sampling results for metals concentrations in soils. Additionally, the study compared ISM results based on the number of increments collected within a DU. The study also compared costs from ISM versus standard sampling techniques. In general, the ISM samples were used to determine representative metal concentrations in each DU, and for the background DU, to develop site-specific background metals concentrations.

Site Summary

Regulatory Agency/Program	Texas Commission on Environmental Quality (TCEQ) – State Superfund
Description	Bell County, Texas
Owner/Responsible Party	NA
Other Stakeholders	NA

Site Complexities

Risks	NA
Characteristics	Former blow wool and batt wool manufacturing facility where aerial deposition, wastewater, and surface water runoff caused impacts to surface and subsurface soils.
Other	An initial investigation of the site had already been completed and identified impacted soils.

Planning and Implementation

Field Sampling Conducted	Both ISM and grab sampling were conducted, with grab samples collected from two of the six DUs. Boundaries were outlined in the field, and the DU was divided into evenly spaced grids with increment samples collected from the center of each grid. For the two DUs where grab samples were collected (DU-3 and DU-6), grab samples were collected in the center of the grids as well. For DU-3, 30 grab samples were collected, and for DU-6, 16 grab samples were collected.
DUs	Six DUs were established: DU-1 and DU-2 were for wastes, DU-3 through DU-5 were for impacted soils, and DU-6 was for background soils. For each DU sample, three replicate samples were collected with each sample having 30 increments. For DU-4, three replicate samples with 50 increments were also collected.
Statistical Sampling Design	For individual DUs, comparison was based on RPD, with an RPD <25% as the goal. For previously collected background data (grab samples), a UCL was calculated to compare to ISM results.
Laboratory Processing and Analysis Summary	Field sieving was conducted.
Data Quality Summary	NA

Level of Effort (Cost/Benefit, Effectiveness, or ROI)	A cost comparison matrix was developed to compare labor and analysis costs for ISM sampling to grab sampling. Grab sampling costs included costs to collect 1, 15, or 30 grab samples per DU compared to three replicate ISM samples with 30 increments per ISM sample. The ISM sampling costs were approximately three to five times less than collecting 15 or 30 grab samples per DU. ISM sampling costs were approximately four times higher than collecting one grab sample per DU.

Decision-making

Outcome and Lessons Learned	ISM did a better job addressing variance than the 16 background grab samples. For the 30 versus 50 increment ISM samples, the RPDs were compared and found to be similar. There does not appear to be a benefit for collecting additional increments for these samples.
Complicating Factor(s)	NA

Case Study Conclusions

For the cost evaluation, labor costs were higher for ISM sampling, but the labor costs for grab sampling begin to converge with ISM labor costs as the number of grab samples per DU increased. ISM sampling costs are lower mainly as a result of reduced laboratory costs.

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