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Use of Field Portable X-Ray Fluorescence (FPXRF) and the Triad Approach To Investigate the Extent of Lead Contamination at a Small Arms Training Range, Fort Lewis, WA

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At-a-Glance

- Application of an adaptive sampling strategy to minimize the mobilizations needed to completely characterize the site
- Performance of a demonstration of method applicability (DMA) study at the beginning of the field investigation to ensure that FPXRF could meet data quality and decision objectives for the project
- Use of FPXRF along with collaborative laboratory data to assess risk associated with lead and other metals

Summary

In 2003 the U.S. Army Corps of Engineers (USACE) used the Triad approach to expedite site characterization of contaminated soil at the Former Evergreen Infiltration Training Range in Fort Lewis, Washington. The characterization was

designed to determine if surface soils contain significant concentrations of metals, with the focus on collecting sufficient data for determining appropriate future actions (i.e., risk analysis or soil remediation). A dynamic sampling and analytical strategy based on rapid field based analytical methods was created in order to streamline site activities and save resources while increasing confidence in remediation decisions. At the beginning of the field investigation, concurrent analysis of soil samples during a Demonstration of Method Applicability (DMA) used both field portable X-ray Fluorescence (FPXRF) and laboratory methodologies to establish a correlation between FPXRF and laboratory data. Immediately following the DMA, contaminated soil from the impact beam was delineated by collecting both FPXRF data and fixed laboratory confirmation samples. The combined data set provided analytical results that refined the conceptual site model (CSM) for the range and directed additional sample collection activities to more clearly determine the extent and distribution of soil contamination.

1. Site Information

Site Name	Evergreen Former Infiltration Range
Location	Fort Lewis, WA
Site Type	Small Arms Firing Range
Project Lead Organization	Fort Lewis Public Works
Project Lead Type	U.S. Army Lead
Regulatory Lead Program	State Remedial
Triad Project Status	Field Program Completed
Reuse Objective Identified	Yes **Proposed Reuse:** Military Barracks

Background Information About Site

Fort Lewis is a major military facility located approximately six miles south of Tacoma, Washington. The facility consists of approximately 34,875 hectares of cantonment areas, natural prairies, lakes, wetlands, and forests. Weapons qualifications and field training has occurred at Fort Lewis ranges since around the time the Fort was established in 1917.The former Evergreen Infiltration Range was initially identified from a 1951 aerial photograph. There are no records to confirm how long the range was active, however, based upon growth of vegetation observed during site visits, and a historical analysis of aerial photography, indications are that activity at this range was decreasing between 1955 and 1957. Subsequent photographs from 1965 to the present indicate that the range had not been used since that year. Infiltration ranges provided training opportunities for soldiers to move under live fire and under combat type situations. Fixed-position machine guns placed on concrete footings provided the live fire training. The ammunition associated with infiltration range training during this era was the 30-caliber cartridge. The primary constituents in the bullet slugs consist of 97 percent lead and 2 percent antimony with trace amounts of copper. Potential contaminants of concern are lead, antimony, arsenic, copper, tin, and zinc. As an infiltration range, the impact berm was set back approximately 300 feet from the firing discharge area. The impact berm is a constructed earthen bank approximately 40 feet high. Bullet slugs and fragments are evident at the impact berm. Trees, grasses, and shrubs currently cover a large portion of the area since active use for training has not occurred on the site for several decades.

Contaminant(s) of Concern

- Antimony
- Arsenic
- Copper
- Iron
- Lead
- Tin
- Zinc

Contaminated Media

- Soil

Project Results and Outcomes

Soil concentrations greater than 250 milligrams per kilogram (mg/kg) (the State of Washington clean-up level for unrestricted use) were found across the front face of the berm with the highest concentrations located at the impact zone. Lead concentrations greater than 250 mg/kg are present down slope along the toe of the berm in the 0 to 12 inch depth interval. Concentrations remain significantly higher in the middle of the impact zone in the 12 to 24 inch depth interval, with decreasing lead concentrations encountered moving away from the impact zone. Bullet fragments were present to a depth of at least 2 feet within the impact zone. Soil lead concentrations greater than 250 mg/kg are present in the 0 to 12 inch depth interval across the back face of the impact berm. Since no bullets were found, the origin of the contamination is unclear. Lead contamination is highly heterogeneous due to the nature of the contamination source. However, highest concentrations are primarily in the one-foot depth interval with significant decrease of lead concentration in the two-foot depth interval. Some limited lead contamination was encountered in samples collected within a trench approximately 75 feet southeast from the backside of the berm; the source of the contamination is not definite. Results from the DMA study indicated that FPXRF field technology was appropriate for this site investigation. The linear regression correlation coefficient factor (r^2) for the DMA data set was 0.96 between the FPXRF and comparative laboratory data for lead. The resulting collaborative data set from the Triad field investigation confirmed that the FPXRF reliably quantitated lead contamination down to a concentration of 45 mg/kg in soils. The FPXRF was not only effective in identifying contaminated areas, but was also able to clearly locate "clean" areas. Laboratory analysis of collaborative soil samples confirmed that lead is the primary driver to define the remedial action, since other metals were not above Washington State clean-up levels when lead was not above criteria. Based on the refined CSM, lead concentrations in soils pose a risk to potential human health and ecological receptors by direct contact, ingestion, root contact, or inhalation of dust.

2. Project Information

Project Objectives/Decisions

The objective was to determine the environmental condition of the property to support the development of a cost-efficient strategy for assessing the extent of lead contamination at the former range and remedial alternatives.

Remedial Phase

Site Investigation (Includes RI/FS or Similar Detailed Investigation Work)

Triad Project Benefits

The Triad offered a cost effective approach to gather the information necessary to ensure that confident decisions could be made in an efficient and timely manner. Investigation costs and mobilizations were minimized.

Cost and Time Savings

No formal cost comparison was performed. Because the Triad minimized the number of mobilizations necessary to characterize the site, it is estimated that months of time and thousands of dollars were saved.

3. Triad Approach Information

Systematic Project Planning

Systematic project planning began with team formation. Coordination was accomplished with meetings, telephone conferences and e-mail. After initial project team discussions, the USACE prepared a systematic project planning memorandum and data quality objectives to guide Triad implementation. These materials included a preliminary CSM that was based on information gleaned from existing reports from similar sites in the area. Uncertainty regarding the presence of hot spots and volumes of soil exceeding regulatory criteria was managed with a strategy of progressive sample evaluation based on the preliminary CSM. Field techniques were used to reduce sampling uncertainty, while laboratory analysis was used manage field analytical uncertainty for lead by providing a collaborative data set for comparison to the FPXRF data. Additionally, the laboratory methods were used to determine analyte presence other than lead, and for field data interpretation.

Project Team Description

- Fort Lewis Public Works: Project lead
- Washington Department of Ecology: Lead regulatory agency
- US Army Corps of Engineers: Triad project facilitation, project technical team (including field sampling and analysis personnel), and off-site laboratory services
- Field chemists, geochemist, geologists, environmental scientist

Dynamic Work Strategies

Decision logic grew out of the project objective of delineating the nature and extent of metals contamination in soil at the site. A systematic grid was used to delineate the vertical and horizontal extent of contamination, if present. Starting with the areas most likely to be contaminated (e.g., impact berm), sample locations were stepped out laterally until lead FPXRF values were detected below the clean-up level. Samples were collected from both the 0 to 12 inch and 12 to 24 inch depth intervals. Sample location density was initially determined using process knowledge of site usage and was modified as real-time data was collected. The Sampling and Analysis Plan (SAP) allowed for the collection of additional samples to define the extent of contamination. Once real-time data were obtained from the FPXRF, the sampling density was evaluated and increased in certain areas based on the decision logic as the investigation progressed.

Decision Logic

The potential need for additional sample collection was to be determined after evaluating the FPXRF data obtained from the initial sampling grid. For example, if results from several grids indicated lead contamination greater than the clean-up level, no additional information was required; however, refinement of the CSM was required where uncertainty regarding boundaries of lead-contaminated soil existed. The project decision logic was incorporated into the SAP. The logic began with the premise, based on the CSM that lead contamination if present would be at the highest concentrations in the impact berm. The initial sampling grid was designed to ensure detection of potential contamination. The logic included provisions to delineate the vertical and horizontal extent of any contamination discovered. FPXRF was the primary analytical method used to address sampling uncertainty and to determine the pattern of contaminant distribution. Laboratory analysis was used to obtain results for metals other than lead, to aid interpretation of the data, to confirm the FPXRF data, and to gather data below the FPXRF detection limits.

Real-Time Measurement Technologies

Following approval of the SAP, soil samples were collected from a pre-established grid. The initial sample collection was performed at both the 0 to 12 inch and 12 to 24 inch depth intervals. Additional depths were considered, however the instability of the berm soil did not allow the collection of samples below two feet using hand tools. Starting with the areas most likely to be contaminated, sample locations were stepped out laterally until lead FPXRF values were detected below the clean-up level. Additional soil samples would have been collected if it were found necessary to delineate the extent of contamination. The soil samples were analyzed using FPXRF with collaborative samples sent for laboratory analysis. The FPXRF analysis was performed both in the field and in the controlled conditions of the Seattle District soils laboratory. The laboratory method was EPA 6010/6020 for metals of interest with method 3050B for predigestion.

During the DMA 40 samples were collected from various areas of the berm in order to obtain a potential range of concentrations. All were measured by both FPXRF and fixed lab analyses to determine the correlation between measurement methods.

All samples were sieved through a #10 sieve and homogenized in a stainless steel bowl before being placed in a gallon-sized plastic baggie.

Technology Category(s) for Sampling and Analysis

- Inductively Coupled Plasma Spectrometry (ICP)
- Mass Spectrometry
- X-Ray Fluorescence

Specific Technology(s)/Model Used (e.g., SCAPs)

- Inductively Coupled Plasma Spectrometry (ICP): No information available
- Mass Spectrometry: No information available
- X-Ray Fluorescence: NITON 300 Series XRF

Technology Vendor(s)

- Niton LLC

Attached Technology Quick Reference Sheet (TQRS) Form

TQRS pending

Data Quality Assessment

Quality control measures included careful sampling procedures as well as collection of collaborative samples, co-located field duplicates and precision samples. Collection of collaborative samples was greatest in the region of decision uncertainty around the clean-up levels; the collaborative samples were analyzed by fixed laboratory methods to provide definitive measurements of contamination levels in the sample. The linear regression correlation coefficient factor (r^2) for the FPXRF and the collaborative sample data was 0.96. The collaborative samples showed good agreement at the action levels. The co-located field duplicates were collected to assess site heterogeneity and the precision samples were measured to determine within-sample heterogeneity. Both the co-located and the precision sample results indicated heterogeneity, the results of which provided information on sample variability and guidance for decisions based upon sample results.

Data Management Approach and Tools

SADA, Spreadsheets. Data visualization using SADA was used to maintain close communication with team members as work progressed and to evaluate statistical uncertainty.

4. Supporting Information

Key Triad Project Milestones

- **March 2003**: Initial systematic project planning memorandum (DQOs) completed
- **August 2003**: Draft Sampling and Analysis Plan completed
- **September 2003**: Field work conducted (5 weeks)
- **December 2003**: Field work conducted (3 days)
- **March 2004**: Draft investigation reports prepared by USACE

Dates of Operation - Field Work

September 2 - October 3, 2003
December 2 - 4, 2003

Source(s) of Information

- U.S. Army Corps of Engineers (USACE). 2002. Evergreen Former Small Arms Range DQO Memorandum. PW, Fort Lewis, WA, December 2002
- U.S. Army Corps of Engineers (USACE). 2002. Evergreen Former Small Arms Range Historical Research Memorandum. PW, Fort Lewis, WA, December 2002
- U.S. Army Corps of Engineers (USACE). 2002. Project Planning Memorandum Fort Lewis Agreed Order Former Small Arms Ranges. PW, Fort Lewis, WA, August 2002
- U.S. Army Corps of Engineers (USACE). 2003. Demonstration of Method Applicability Memorandum Former Small Arms Ranges. PW, Fort Lewis, WA, October 2003
- U.S. Army Corps of Engineers (USACE). 2003. Path Forward Memorandum Former Small Arms Ranges. PW, Fort Lewis, WA, October 2003
- U.S. Army Corps of Engineers (USACE). 2003. Sampling and Analysis Plan Addendum, Former Small Arms Ranges Miller Hill Pistol Range and Evergreen Infiltration Range (AOC 4-2.2 and 4-6.3), PW, Fort Lewis, WA, August 2003
- U.S. Army Corps of Engineers (USACE). 2004. Draft Site Investigation Report, Remedial Investigation Phase Former Small Arms Ranges (AOC 4-2.2, 4-3 and 4-6). PW, Fort Lewis, WA, March 2004

Electronic Documentation of Supporting/Related Information

- DMA Memorandum (*1.2 MB*)
- DQO Memorandum (*68 KB*)
- Draft Site Investigation Report (*45 MB*)
- Fort Lewis Evergreen Plans-Final (*1.3 MB*)
- Fort Lewis Final Workplan (*4.7 MB*)
- Fort Lewis Interim Cleanup Action Plan (*4.6 MB*)
- Path Forward Memorandum (*3.7 MB*)
- Project Planning Memorandum (*67 KB*)

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