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Triad Case Study: Former Small Arms Training Range

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ABSTRACT

The U.S. Army Corps of Engineers (USACE) used the Triad approach to expedite site characterization of contaminated soil at the Former Small Arms 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. Concurrent analysis of soil samples during the 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 berm was delineated by collecting both FPXRF data and fixed-laboratory confirmation samples. The combined data set provided analytical results that allowed for revisions to the conceptual site model for the range and directed additional sample collection activities to more clearly determine the extent and distribution of soil contamination.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) used the Triad approach to expedite site characterization of contaminated soil at the Former Small Arms Evergreen Infiltration Training Range in Fort Lewis, Washington. The investigation was conducted at the request of the Fort Lewis Public Works (PW) to fulfill a portion of the requirements of an agreed order (AO) between the military base and the Washington State Department of Ecology (Ecology). In the AO, Fort Lewis agreed to conduct a Remedial Investigation/Feasibility Study (RI/FS) that covered several small arms ranges and other areas of concern on the military reservation (USACE 2004).

The Triad approach was used at the site to actively identify and manage both decision and data uncertainties. The Triad approach consists of three major elements: systematic project planning; dynamic (flexible) work strategies to allow flexibility in the field; and real-time measurement systems. The primary technology tool used to accomplish real time data collection for this project was field portable X-ray Fluorescence (FPXRF). By involving all stakeholders in the development of data quality objectives, support was obtained for the Triad approach that clearly identified project goals and ensured high decision confidence. A multi-disciplinary team was then assembled to develop and translate project goals into realistic technical objectives.

The dynamic work strategy guided the project team in real-time decision-making that allowed the team to adapt field activities to new information as soon as it became available. Real-time measurement systems using innovation technology tools such as the FPXRF and computerized data management/visualization tools, allowed data to be gathered, interpreted, and shared fast enough to support real-time decisions. This resulted in a more seamless flow of site activities and fewer mobilizations.

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FORMER SMALL ARMS EVERGREEN INFILTRATION TRAINING RANGE BACKGROUND

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 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 (U.S. Army 1992). 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 (USACE 2003).

Exhibit 1. Evergreen Infiltration Range Impact Berm

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A multi-disciplinary team was assembled to work on the former ranges site characterization project. Additional support was obtained from the U.S. Environmental Protection Agency (EPA) and the USACE Engineer Research & Development Center (ERDC). Deana M. Crumbling (U.S. EPA Technology Innovation Office) provided review and provided comments on the dynamic sampling and analysis plans. Steven Larson and Victor Medina of ERDC were simultaneously researching treatment options based on lead separation from the bulk soil, and, if required, stabilization of lead in fine soil material using Fort Lewis range soils as the basis for their research. The sample design incorporated the needs of future construction projects and was coordinated with USACE MILCON and the Fort Lewis Public Works Planning Department.

The primary objective of this project was to obtain sufficient data in one mobilization to make remedial decisions. Statistically valid conclusions require both sampling and analytical uncertainties to be managed to proceed with reliable contaminated soil estimates. From the onset, the project team supported the Triad approach as previously conducted site investigations at other ranges using a traditional site characterization approach resulted in data gaps. There was initial resistance to the use of the FPXRF as a field analytical tool by the regulator at Ecology. However the concerns expressed by Ecology were eventually alleviated by the demonstration of method applicability. This allowed for regulatory acceptance for the use of the FPXRF.

A communication strategy was developed during the planning stages of the project that allowed all members of the multi-disciplinary team (including those team members who were not in the field) to participate in the real-time decision-making process. This communication strategy included; daily meetings with field team; weekly update meetings to include project support team; data and activity summary reports posted daily to a website for stakeholder and regulator viewing; written documentation and meetings with regulators at major milestones and decision points (i.e., after the demonstration of method applicability study).

TRIAD STRATEGY

The Triad approach encourages participation in project planning among all team members, including regulators. The objectives of project planning included:

- Focusing on desired site outcome; a good understanding of the extent of contamination was critical to the evaluation of potential remediation techniques.
- Identifying decisions, developing decision logic, and managing decision uncertainties
- Creating opportunities for real-time decision making (dynamic work plans using a decision logic) to save time and money.

The primary challenge during the planning phase of the project was overcoming regulator concerns with the implementation of the Triad approach and field-based analytical capabilities. One of the methods for overcoming these concerns was the development of site-specific data quality objectives (DQOs) (EPA 1998). The DQOs provided a wide variety of information, including:

- Description of the project goals and objectives;
- Identification of the type of data needed;
- Identification of any constraints to data collection;
- Determination of the quality and quantity of data needed;
- A summary of salient data and information from historical document reviews which became the framework for the development/refinement of the conceptual site model (CSM);
- Identification of decisions;
- A listing of data gaps based on a preliminary CSM;

- A review of selected data collection tools, and their strengths/weaknesses; and
- Methods to resolve uncertainty of field analytical tools.

The CSM was used as a key tool for generating accurate remedial action decision-making. The preliminary CSM was described as:

- Contaminated soil was most likely to occur around fixed or stationed targets areas and impact berms;
- No lead contamination in the infiltration area since range rules would not allow direct firing into areas where troops were moving;
- Lead contamination in front side of the impact berm only;
- Lead was expected to be the primary contaminate of concern (COC);
- Potential of explosive residues in the demolition pits;
- Potential of lead at firing points limited to spent shells;
- Potentially complete pathways for exposure to soil contamination exist for human and ecological receptors;
- Bullet impacts result in significant fragmentation and ricochet so lead distribution is likely heterogeneous;
- Soil as the primary matrix of concern and COCs not expected to have impacted groundwater based on age of site and information from other sites on Fort Lewis.

Development of the DQOs was an iterative process, and all team members provided input. The DQOs provided a broad view of all potential data gaps based on the preliminary CSM as well as possible investigative tools to fill the data gaps. The team agreed upon the final list of data gaps that needed to be addressed in order to establish a remedy, as well as the tools required to fill these data gaps. Once the data gaps were agreed upon, the project objectives were established to fill the data gaps quickly, efficiently, and cost effectively. The following data gaps became the focus of the Triad field investigation:

- Confirm the presence of lead contamination in site soils;
- Sampling objectives included delineation of the vertical and horizontal extent of lead contamination above 50 mg/kg and managing uncertainty around contaminant volume estimates greater than 250 mg/kg and 1000 mg/kg;
- Confirm that lead, of all potential metals at the site, can be used a the driver to define extent at the ranges; and
- Determine appropriate application of field-based technologies during a DMA study.

A major factor in filling the data gaps of the CSM were the uncertainty intervals where soils would be declared clean, dirty or ambiguous (i.e., more data required) and confidence in the decision that the true concentration is greater than or less than the action level (TIO 2003). To address this issue, an uncertainty management plan was developed consisting of:

- Collection of collaborative samples at the region of decision uncertainty around action levels. The collaborative samples were analyzed by fixed laboratory methods to provide definitive measurements of contamination levels in the sample;
- Increased data density using FPXRF field analysis (an added bonus: reduced analytical per sample costs);

- Measurement of precision samples for FPXRF to determine within sample heterogeneity. Multiple measurements on the same sample to determine the impact of the “nugget effect” on sample variability and decisions based FPXRF results;
- Co-located field duplicates to assess site heterogeneity; and
- Collection of additional samples by immediate step-out.

To address large-scale variability at the site, the software program Spatial Analysis and Decision Assistance (SADA) provided a number of tools for the visualization of data, geospatial analysis, statistical analysis, sampling design and decision analysis (TIEM 2003). Secondary sampling design applications assisted in determining additional sample locations. New sample locations were placed in areas where there was the greatest uncertainty about exceeding the action level(s) and delineating the boundaries of the area of concern. Data visualization using SADA was used to maintain close communication with team members as work progressed, and evaluate statistical uncertainty.

DYNAMIC SAMPLING STRATEGY

The core technical team developed the project work plan based on the project objectives and data gaps identified by the team. 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 action level. Sample location density was initially determined using process knowledge of site usage and was modified as real-time data was collected. For example, if results from several grids indicated lead contamination greater than the action level, no additional information was required; however, refinement of the CSM was required where uncertainty regarding boundaries existed. Additional depths were considered, however the instability of the berm soil did not allow the collection of samples below two feet using hand tools. Samples were collected from both the 0 to12 inch and 12 to 24 inch depth intervals.

For the first phase of work, a DMA was conducted on the impact berm, in order to determine the usability of the FPXRF for lead soil sampling and to assure that a reasonable correlation could be substantiated between the proposed field-based sampling method and fixed lab analysis. Both the DMA and the sampling for the front face of the berm occurred during the same mobilization. During the DMA, collaborative samples were submitted to the fixed laboratory for analysis of total metals. The information obtained from the collaborative sample collection in the DMA was used to determine the frequency and types of collaborative samples for the remainder of the FPXRF sampling. The metals other than lead that were analyzed include antimony, arsenic, copper, tin, zinc, and iron. This information was used to establish that lead was the driver. The number of collaborative samples was guided by the need to manage decision uncertainty in defining the extent of contamination at the FPXRF detection limit of 45 mg/kg and the potential project action levels of 50, 250, 400, and 1000 mg/kg.

As data were made available, the CSM was updated and the sampling strategy adapted to address unexpected conditions. For example, lead contamination on the backside of the impact berm was not identified as a potential area of concern in the original CSM. However, when one exploratory sample was collected, it exhibited lead contamination greater than 1000 mg/kg. Therefore, potential contamination of the back face of the berm was considered due to potential lead contamination from either the ricochet effect of high velocity bullets flipping over the top of the berm or the possibility that the berm was constructed with contaminated materials. In order to establish the extent of contamination on the back face of the berm, additional samples were collected from this side of the berm. Additional sample areas were located at the toe of the berm, at the same height of the impact zone and a trench area, located approximately 75 feet from the berm. Initially, six samples were collected from each of these additional areas (approximately 50 ft. apart), with additional

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locations chosen as necessary to minimize uncertainty in defining the extent of contamination at the FPXRF detection limit of 45 mg/kg and the project action levels of 250 and 1000 mg/kg.

RESULTS

The real time measurement tool, FPXRF, was used in combination with conventional soil sample collection and analysis techniques to build a strong collaborative data set to refine the CSM. Initial sampling confirmed releases of lead and demonstrated FPXRF appropriateness. The following observations regarding the lead contamination at the impact berm resulted in revisions to the CSM:

- Soil concentrations greater than 250 mg/kg are present across the front face of the berm with 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 at least 2 feet depth 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 1-foot depth interval with significant decrease of lead concentration in the 2-foot depth interval. Some limited lead contamination was encountered in samples collected within a trench approximately 75 feet SE from the backside of the berm; the source of the contamination is not definite.

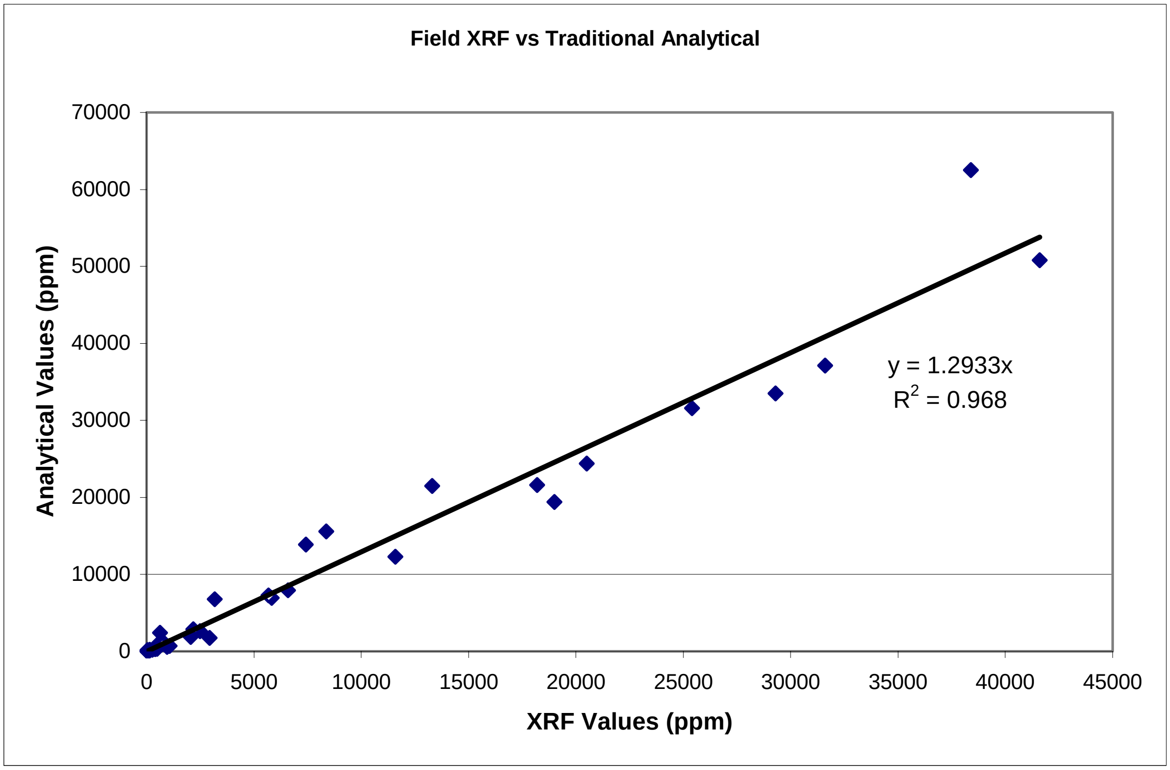

Exhibit 2. Relationship between XRF and Traditional Analytical Values

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- Toxicity Characteristic Leaching Procedure (TCLP) analysis was conducted on five samples from the front side of the berm with soil lead concentrations ranging from 37.5 to 62,500 mg/kg. Samples with soil lead concentrations above 250 mg/kg exceeded the maximum concentration of contaminants for the Resource Conservation and Recovery Act Toxicity Characteristic of 5 mg/L.

- Results from the demonstration of method applicability study indicated that FPXRF field technology was adequate and appropriate for this site investigation. The linear regression correlation coefficient factor (r^2) for the data set was 0.96 (Exhibit 2).

- The resulting collaborative data set from the Triad field investigation confirmed that the FPXRF detected lead contamination to 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 regulatory levels when lead was not above criteria.

- Based on the refined conceptual site model, lead concentrations in soils pose a risk to potential human health and ecological receptors by direct contact, ingestion, root contact, or inhalation of dust.

The successful delineation of the site will allow timely implementation of the selected remedy, which will include excavation of metals contaminated soil followed by separation and recycling of lead bullet fragments. Once the bullet fragments are removed, the excavated soil will be used as backfill material on active ranges at the base.

CONCLUSIONS

The use of the Triad approach was successful as it achieved the project objectives efficiently, expeditiously, and cost effectively. The high-density sampling and resulting collaborative data set generated during the Triad field investigation refined the CSM with a high degree of confidence. In addition, the Triad field investigation identified the highest level of contamination and defined the extent of contamination. The most significant difference between the traditional and the Triad approach is that enough data was collected in one investigation to enable movement forward to the feasibility and remedial action phases without additional investigations, thereby providing significant cost savings.

It is important that a mutually agreed upon CSM exists to support a dynamic site investigation that is constantly adapting. It is also important that sufficient data is collected to allow revision to the original CSM. Often, debate surrounding the definition of what data is “sufficient” to support project decisions is the central issue in conflicts between project stakeholders. However, in this case, the primary point of contention was the appropriateness of the field-based FPXRF. Meetings that included Fort Lewis Public Works, the state regulators, and the Corps technical team during the project-planning phase were instrumental in resolving this issue. Detailed discussion at important project milestones including presentation of DQOs before the development of the dynamic work plan, after development of the work plan, and again after the demonstration of method applicability allowed all parties to voice and address concerns. This process ensured agreement on the preliminary CSM, the appropriateness of the use of FPXRF technologies, and the objectives for the field investigation. Participation of team members in the decision-making process assured satisfactory collection of all necessary data prior to field mobilization.

Other learning experiences that occurred during the project include:

- Involve regulators early in the planning process. This allows any potential concerns to be voiced and allows the sample design to incorporate regulatory concerns early in the process.

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- Ensure both customers and regulators are part of the field decision process by planning meetings and regular communication during the investigation.
- The field team needs to be clear on objectives to perform dynamic sampling and empowered to make decisions in the field based on the real time field measurements.
- Efficiency is improved by focusing on the CSM and the data gaps that are lacking to prove/disprove the CSM and by coupling the investigation efforts with potential remedies in mind.

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