Case Study for the Use of a Decision Support Tool: Using Visual Sampling Plan to Optimize Sampling Strategies and Manage Uncertainty at the Ross Metals Site, Rossville, Tennessee

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FOREWORD

This case study is one in a series designed to provide information on use of decision support tools that support the use of data, models, and structured decision processes in decision-making. These case studies include reports on selected tools that have been used to support activities such as site assessment and remediation, data management and visualization, and optimization. They are prepared to offer operational experience and to further disseminate information to project managers, site owners, environmental consultants, and others who wish to screen decision support tools and benefit from their previous use at sites.

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1.0 SITE BACKGROUND

The Ross Metals Site is located at 360 North Railroad Street in Rossville, Tennessee. The site is currently being addressed under the Superfund program and is the location of a former secondary lead smelter that operated from 1978 to 1992. Operation of the lead smelting facility resulted in lead contamination of site soil. Historical activities at the 6-acre site included production of alloyed lead for use in vehicle batteries, lead shot pellets, and sheet lead for radiation shields.

Based on knowledge of the site, lead was identified as the primary driver for remediation early on in the project. A conventional sampling and analysis approach had been applied to one-third of the site (1.86 acres) to characterize the nature and extent of the lead contamination as well as to delineate and remove contaminated materials at concentrations that exceeded cleanup goals. Previous sample results were evaluated to identify areas where lead concentrations exceeded facility cleanup action levels at shallow depth intervals. Under the conventional approach, one composite sample, made up of nine aliquots, was collected to evaluate each 1-foot depth interval for an entire acre. Samples were analyzed at an off-site analytical laboratory using SW-846 method 6010 and results were provided using an accelerated turn around time. In this manner, two separate acres were evaluated in 1-foot intervals, each acre and each 1-foot interval being represented by a single composite sample made up of 9 equal portion aliquots that were homogenized. Sampling to delineate vertical soil contamination ended when the composite sample from a 1-foot interval showed the key contaminant of concern (COC), lead, was below the facility cleanup action level of 400 milligrams per kilogram (mg/kg).

In July 2003, input from the Brownfields Technology Support Center (BTSC) was requested to assist the U.S. Environmental Protection Agency (EPA) Superfund Technical Assessment and Response Team (START) in developing an approach for the remaining portion of the site (3.75 acres) that was consistent with the principles of the Triad approach. The Triad approach is an integrated method to manage decision uncertainty at hazardous waste sites. The Triad approach draws on advancing science, technology and practitioner experience to perfect strategies for making site work more defensible, resource-effective, and more responsive to stakeholder concerns (Crumbling and others, 2004). The term “Triad” refers to the three core elements of the approach: systematic project planning, dynamic work strategies, and real-time measurement technologies, including field-based analyses. Based on discussions between BTSC representatives and the project team, an approach using field-based technologies and systematic planning was recommended to increase the density of data points and minimize required disposal volumes, while explicitly managing decision uncertainty.

Demonstration of Methods Applicability

The BTSC conducted a site-specific demonstration of methods applicability (DMA) study on the behalf of the START program. An x-ray fluorescence (XRF) instrument following SW-846 method 6200 guidelines was proposed to guide excavation and delineate contaminated materials. The DMA was conducted to develop the optimal operating procedures to analyze samples with a field portable XRF. Specifically, the DMA was used to assess the effects of different sampling preparation techniques, sample support techniques (size, shape and orientation of the samples) and instrument count times on field sample results obtained with the XRF. Concentrations of lead from samples analyzed by XRF using various sample preparation techniques and sample support were compared with concentrations of lead from the same (split) samples analyzed by a fixed laboratory using SW-846 method 6010.

The results of the DMA were evaluated through a sequence of statistical analyses (summary statistics, statistical plots and distributional tests), which indicated that neither the various sample preparation techniques nor the instrument operating conditions of the XRF appeared to significantly increase the variance or standard deviation of the analytical results. Therefore, the BTSC recommended operation of the XRF instrument in the in-situ “point and shoot” mode to minimize sampling times and maximize data density. The DMA provided the necessary information to identify the most cost effective and scientifically sound strategy for designing a sampling and analysis approach to characterize the remaining 3.75 acres of the site using XRF.

2.0 USE OF DECISION SUPPORT TOOLS

Because XRF results would be used to delineate areas for excavation and confirm that excavation resulted in removal of lead concentrations above the facility action level, it was important to estimate a “field-based” action level that could account for variability in XRF results and represent, with the desired level of confidence, the facility action level of 400 mg/kg. The historical facility action level (400 mg/kg) developed during discussions with regulatory agencies was based on results from fixed-laboratory analysis using SW-846 method 6010 and did not reflect any inherent bias associated with using XRF.

A decision support tool (DST) called Visual Sample Plan (VSP) was used to develop a “field-based” action level that would confirm that lead contamination in soil at concentrations that exceeded the cleanup goal (400 mg/kg) was removed with a specified level of confidence. The VSP analysis required the following input data: standard deviation of the log-transformed population, a specified level of confidence and a specified power, and an estimate of the total number of samples anticipated to be collected.

The project team developed a null hypothesis that stated "site soil contained lead at a concentration that exceeded the action level of 400 mg/kg." The null hypothesis was developed to represent a grid, the size of which was later optimized based on an analysis of sampling and disposal costs. A statistical "false rejection decision error" (also known as a Type I or alpha error) is rejecting the null hypothesis when it is actually true and a "false acceptance decision error" (also known as a Type II or beta error) is accepting the null hypothesis when it is actually false. The statistical confidence is the probability of accepting the null hypothesis when it is true, whereas the statistical power is the probability of rejecting the null hypothesis when it is false. Thus both statistical confidence and power represent the probability of making the correct decision.

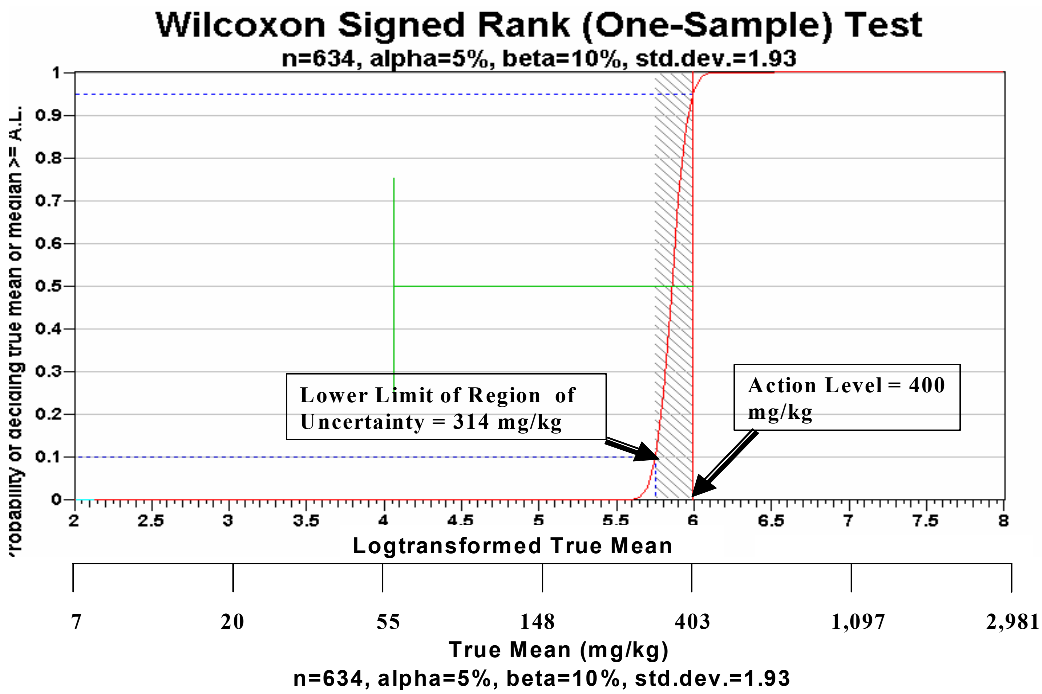
Type I and II errors may result in an adverse consequence for the project team and stakeholders. Decision uncertainties of 5 percent probability for false rejection (rejecting the null hypothesis when it is actually true) and 10 percent for false acceptance (accepting the null hypothesis when it is actually false) were selected. A false rejection decision error, in this case, may result in a decision to leave soil in place when its "true" concentration exceeds the action level for lead (400 mg/kg). Conversely, a false acceptance decision error may result in a decision to excavate and remove soil when its "true" concentration is below the action level. The false rejection decision error was set with a lower threshold (5 percent) because the consequences of making this type of decision error could expose receptors to concentrations of lead above facility cleanup levels. The false acceptance decision error rate was set with a higher threshold (10 percent) because the consequences of making this type of decision error would result in slightly higher disposal costs, but would not expose receptors to elevated concentrations of lead.

Original Data Set

The site action level (400 mg/kg) was log-transformed (natural logarithm of the value), resulting in a value of 5.99. A decision performance goal diagram (DPGD) defining the region of uncertainty was developed (Figure 1) using the nonparametric Wilcoxon Signed Rank Test and entering values for the log-transformed action level (5.99), the total anticipated number of samples be collected (634), the standard deviation of the log-transformed DMA XRF data set (1.93), the false rejection decision error rate (5 percent), and the false acceptance decision error rate (10 percent). The DPGD for the original DMA XRF data set is provided as Figure 1. The shaded area is referred to as the "gray region" or "region of decision uncertainty." This region of statistical decision uncertainty is the range of field analytical results that cannot confidently be determined to be either "definitely clean" or "definitely dirty" based on the specified decision error rates. The value of the lower boundary of the region of uncertainty (5.75) was then back-transformed from the natural logarithm, to yield a field-based action level of 314 mg/kg.

FIGURE 1

VISUAL SAMPLING PLAN OUTPUT FOR INITIAL DATA COLLECTED AT THE ROSS METALS SITE



Notes:
n – Number of samples that wree anticipated to be collected.
alpha – Alpha error rate or acceptable limit on false negative error rate.
beta – Beta error rate or acceptable limit on false positive error rate.

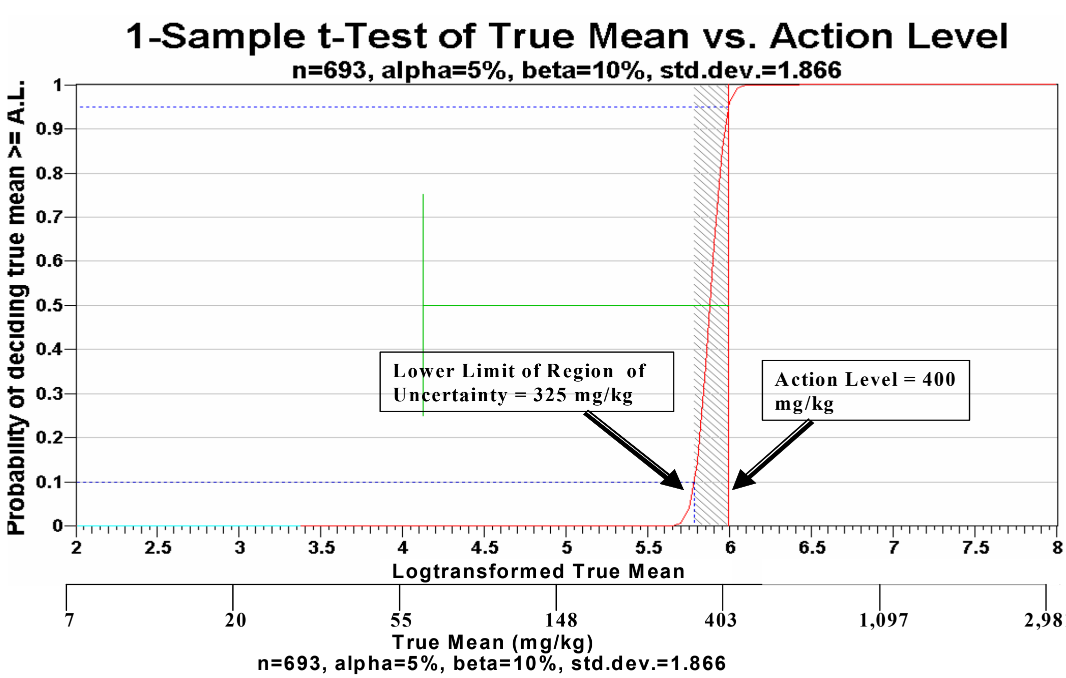
This value is the highest field-measured concentration that can be considered "definitely clean" within the specified confidence intervals. Field-based XRF concentrations for lead greater than 314 mg/kg were defined as lying within the "region of decision uncertainty," where it is unknown if the actual concentration of a volume of soil is greater than or less than the 400 mg/kg action level. The portion of the site where lead concentrations are within the "region of decision uncertainty" would require excavation and disposal, based on the conservative decision logic developed for the project. Field-based XRF results less than 314 mg/kg are below the region of decision uncertainty and thus were considered less than the action level of 400 mg/kg. The portion of the site where lead concentrations are less than the lower bound of the "region of decision uncertainty" (gray region) are assumed to be "clean" and thus do not require excavation.

Supplemental Data Set

After the initial VSP analysis, 74 additional field XRF measurements were collected, resulting in a larger data set with 178 field-based XRF measurements. Summary statistics were compiled for this larger data set, resulting in a slight reduction of the standard deviation from 1.93 to 1.87. Concurrently, resources became available to increase the number of samples that could be collected. VSP provides an interactive method to change these input parameters and recalculate the DPGD. A new proposed number of samples to be analyzed using XRF in the field (693) was entered into VSP, along with the new standard deviation (1.87). A refined DPGD for the log-transformed data (Figure 2) was developed, increasing the lower boundary of the region of uncertainty from 5.75 (corresponding to the initial 314 mg/kg field action level) to 5.78 (corresponding to a revised field based action level of 325 mg/kg). The new action level for field-based XRF analyses was therefore increased from 314 mg/kg to 325 mg/kg based on the lower standard deviation of the new larger data set and a larger proposed sample size of 693 (Figure 2). This type of revision to a field-based action level reduces the amount of potentially clean material that might be excavated unnecessarily, while maintaining the same level of decision certainty.

FIGURE 2

VISUAL SAMPLING PLAN OUTPUT FOR REVISED DATA SET COLLECTED AT THE ROSS METALS SITE



Lower limit of Region of Uncertainty = 325 mg/kg

n – Number of samples that wree anticipated to be collected.
alpha – Alpha error rate or acceptable limit on false negative error rate.
beta – Beta error rate or acceptable limit on false positive error rate.

3.0 LESSONS LEARNED

The DMA provided the information necessary to refine the relationship between XRF results using various sample preparation methods and different analytical methods [SW-846 method 6200 (XRF) and SW-846 method 6010 (ICP)]with the goal of supporting decision certainty at the Ross Metals site. The statistical data analysis of the DMA data and use of VSP allowed development and refinement of a field action level that could be used to make confident decisions on lead contamination using XRF in relation to the facility action level of 400 mg/kg. After the initial analysis using VSP, two developments changed the underlying assumptions of the analysis. Additional data were collected for the DMA; the addition of the new data lowered the standard deviation. A concurrent increase in project resources provided an increased estimate of samples that would be collected. The new parameters were entered to VSP and the field based action level was optimized (raised from 314 mg/kg to 325 mg/kg). This action further minimized the amount of clean material that would potentially be removed without changing the level of confidence (a false rejection decision error rate of 5 percent) and power (a false acceptance decision error rate of 10 percent) used to support decision making.

4.0 POINT OF CONTACT

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5.0 REFERENCES

Crumbling, D.M., and J.S. Hayworth, B.A. Call, W.M. Davis, R. Howe, D.S. Miller, and R. Johnson. 2004. The Maturing of the Triad Approach: Avoiding Misconceptions. *Remediation: The Journal of Environmental Cleanup Costs, Technologies and Techniques*, vol. 14, no. 4, pp. 81-96. September 21, 2004.

U.S. Environmental Protection Agency. Innovations in Site Characterization, Case Study: Expedited Site Characterization and Excavation Of Lead in Soil Using X-Ray Fluorescence at the Ross Metals Site, Rossville, Fayette County, Tennessee (currently under review).