CONTAMINATED SOIL VOLUME ESTIMATE TRACKING METHODOLOGY

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ABSTRACT

The U.S. Army Corps of Engineers (USACE) is conducting a cleanup of radiologically contaminated properties under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The largest cost element for most of the FUSRAP sites is the transportation and disposal of contaminated soil. Project managers and engineers need an estimate of the volume of contaminated soil to determine project costs and schedule. Once excavation activities begin and additional remedial action data are collected, the actual quantity of contaminated soil often deviates from the original estimate, resulting in cost and schedule impacts to the project. The project costs and schedule need to be frequently updated by tracking the actual quantities of excavated soil and contaminated soil remaining during the life of a remedial action project. A soil volume estimate tracking methodology was developed to provide a mechanism for project managers and engineers to create better project controls of costs and schedule. For the FUSRAP Linde site, an estimate of the initial volume of in situ soil above the specified cleanup guidelines was calculated on the basis of discrete soil sample data and other relevant data using indicator geostatistical techniques combined with Bayesian analysis. During the remedial action, updated volume estimates of remaining in situ soils requiring excavation were calculated on a periodic basis. In addition to taking into account the volume of soil that had been excavated, the updated volume estimates incorporated both new gamma walkover surveys and discrete sample data collected as part of the remedial action. A civil survey company provided periodic estimates of actual in situ excavated soil volumes. By using the results from the civil survey of actual in situ volumes excavated and the updated estimate of the remaining volume of contaminated soil requiring excavation, the USACE Buffalo District was able to forecast and update project costs and schedule. The soil volume tracking methodology helped the USACE Buffalo District track soil quantity changes from projected excavation work over time and across space, providing the basis for an explanation of some of the project cost and schedule variances.
INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is conducting a cleanup of radiologically contaminated properties under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The largest cost element for most of the FUSRAP sites is the excavation and disposal of contaminated soil. Project managers and engineers need an estimate of the contaminated soil to determine project costs and schedule. Contaminated soil volume estimates are developed for sites using existing characterization information. While characterization data sets are often adequate for their original purpose (e.g., identifying the presence and levels of contamination for feasibility study evaluations), they often prove to be inadequate for accurately estimating contaminated soil volumes, particularly when significant volumes of subsurface contamination are involved. Once excavation activities begin and additional remedial action data are collected, the actual quantity of contaminated soil often deviates from the original estimate. For example, in the case of the Ashland 2 FUSRAP site, the original estimated contaminated soil volume was 21,000 m$^3$ (28,000 yd$^3$); however, when excavation was complete, approximately 34,000 m$^3$ (45,000 yd$^3$) of soil was removed for disposal.

Deviations in the actual excavated contaminated soil volumes from original estimates can result in significant cost and schedule impacts to a project. Excavated soil volumes that exceed original estimates may also be indicative of problems with the remediation process. For these reasons, the actual quantities of excavated soil and remaining contaminated soil needs to be tracked during the life of a project. Tracking results serve as the basis for project budget and schedule modifications and also assist in identifying issues with the remediation process. A soil volume estimate tracking methodology was developed and deployed to support FUSRAP remediation activities at the Linde site.

THE LINDE SITE

The Linde site is located in the Town of Tonawanda, near Buffalo, New York. The site comprises about 55 hectares (ha) (135 acres) and consists of various office buildings, fabrication facilities, warehouse storage areas, material laydown areas, and parking lots. The Linde site is currently owned by Praxair, Inc. As a result of Manhattan Engineer District (MED) ore-processing activities onsite, soils and some of the buildings are contaminated with radionuclides. The principal radionuclides of concern include radium-226 ($^{226}$Ra), thorium-230 ($^{230}$Th), and total uranium.

The Linde Record of Decision (ROD) (USACE 2000) was based on an Applicable or Relevant and Appropriate Requirements (ARAR) analysis and a radiological dose assessment for the radionuclides of concern (i.e., total uranium, $^{226}$Ra, and $^{230}$Th). On the basis of this analysis, the Linde ROD contained two requirements. The first requirement was removal of contaminated soils with residual radionuclide concentrations averaged over a 100-m$^2$ area exceeding unity for the sum of ratios (SOR). The SOR calculation was based on the ratio of the total uranium, $^{226}$Ra, and $^{230}$Th concentrations to their associated concentration limits. These concentration limits, as measured above background, are 554 pCi/g of total uranium, 5 pCi/g of $^{226}$Ra, and 14 pCi/g of $^{230}$Th for
surface cleanups, and 3,021 pCi/g of total uranium, 15 pCi/g of $^{226}$Ra, and 44 pCi/g of $^{230}$Th for subsurface cleanups. The second requirement was that USACE remediate the Linde site to ensure that no concentration of total uranium exceeding 600 pCi/g above background would remain in site soils.

While much of the MED residues were probably deposited on or near the soil surface, subsequent earthmoving activities associated with building construction and landscaping resulted in subsurface contamination overlain by clean backfill throughout the site. Traditional mobile gamma scans are relatively ineffective in identifying areas of potential concern, because of the known covering of the MED residues resulting from building construction and landscaping activities.

The original contaminated soil volume estimate was based on limited data sets. The remedial investigation/feasibility study (RI/FS) for Linde yielded 1,074 samples from 328 soils bores. The bulk of this characterization activity, however, was concentrated in relatively few locations across the site and within areas of the potentially highest contamination. Thus, large portions of the facility had not been characterized. Additionally, of the 1074 samples, 932 had $^{238}$U results and only 315 had $^{230}$Th results. (All the samples were analyzed for $^{226}$Ra.) An initial pre-remedial in situ contaminated soil volume of 14,000 m$^3$ (18,000 yd$^3$) was estimated on the basis of a limited RI/FS data set, and anticipated cleanup criteria prior to the establishment of the final cleanup criteria. Pre-excavation exploration activities conducted by the USACE Buffalo District identified contaminated areas previously unknown. In addition, as excavation work began, excavation footprints grew in pursuit of buried contamination whose lateral extent had been hidden by clean backfill.

Excavation work at the Linde site began in August of 2000, and remediation is slated for completion in 2004. All excavated wastes are shipped off-site for disposal.

**METHODOLOGY**

The USACE Buffalo District implemented a soil volume estimate tracking system for Linde to support project quality assurance/quality control (QA/QC) and planning as remediation got underway. The methodology behind this system has several components, including:

- Joint Bayesian/geostatistical techniques for initial volume estimation based on RI/FS data. The purpose of these techniques was to provide an indication of the range of contaminated soil volumes that might be encountered, along with a best estimate based on available information.

- Logged, systematic gross gamma activity walkovers of excavated surfaces as excavation proceeded. The purpose of the walkovers was to document the status of soils slated for excavation (e.g., above or below ROD requirements) and compare actual footprints with planned.
• Discretionary, biased sampling of dig areas. The purpose of this sampling was to confirm the status of soil surfaces when gamma walkover data were inconclusive, and to provide information about the status of subsurface soils adjacent to active or planned excavations.

• Periodic excavation-support civil surveys. These surveys provided definitive estimates of soil volumes removed by excavation work.

• On-going revisions of remaining contaminated soil volume estimates and future excavation footprints. The purpose of this analysis was to provide a continual update of total contaminated soil volumes, remaining contaminated soil volumes slated for excavation, and deviations from previous estimates.

Joint Bayesian/Geostatistical Techniques for Soil Volume Estimation

Joint Bayesian/geostatistical techniques were used to generate the initial contaminated soil volume estimates based on existing historical information. The methodology is described in Johnson (1996). Indicator geostatistics, using the ROD requirements for defining indicator values, allow the interpolation of results from sample locations to areas where no samples exist. Bayesian techniques provide a means of combining other sources of information quantitatively with sample results when deriving volume estimates. These techniques provide both a “best guess” value for contaminated soil volumes as well as an estimate of the error associated with the estimate. Using these techniques, along with the final cleanup criteria established in the ROD, the existing RI/FS information, and some pre-remedial characterization data (i.e., geoprobe samples) a pre-remedial in situ contaminated soil volume estimate of 36,000 m³ (47,000 yd³) was derived for the site. The analysis determined that the actual volume, however, could plausibly exceed 76,000 m³ (100,000 yd³). Figure 1 shows the Linde site indicating the sample locations and pre-remediation excavation footprints.
Logged, Systematic Gamma Walkovers of Excavated Surfaces

The excavation at the Linde site is guided by a technician with a gross gamma detector and is proceeding in “lifts.” As specified in the Sampling and Analysis Plan, at the end of each day, a logged gamma walkover survey is to be conducted of the exposed excavation surface. Gamma walkover surveys using a 2 x 2 sodium iodide (NaI) detector were combined with a global positioning system (GPS) to provide locational control and log the data produced by the survey. Analyses conducted prior to the onset of remediation identified gross activity and were used to develop trigger or investigation threshold levels. These were gross activity levels below which field staff could be confident that there was a low probability of encountering contamination above the ROD cleanup criteria. Gross gamma surveys allowed remediation field staff to make in-field decisions about the course of excavation work.

Logged systematic gamma walkover data sets were used in several ways to support soil volume estimation tracking. The gamma walkover data sets were brought into a Geographical Information System (GIS) and combined with other existing mapping...
information (e.g., discrete sample results) for the site. Gamma walkover surveys corresponded to excavated areas. Consequently, the footprints of gamma walkover surveys in the GIS could be used to determine the lateral extent of contaminated soil excavation for any given day. This, in turn, could be compared with the pre-remedial design excavation footprints. Deviations from the pre-remedial footprints indicated either potential problems with the excavation process, or the fact that actual contaminated footprints differed from the original estimates. When the actual excavation footprints deviated from the pre-remedial design footprints, the gamma walkover data provided the documentation required to show that, in fact, the deviations were justified on the basis of contamination levels encountered during the excavation process.

Discretionary, Biased Sampling of Dig Areas

Gamma walkover data were not always sufficient for assisting in reviewing what had been excavated or in planning for the next round of excavation. For example, gamma walkover data provided no information about the potential for buried contamination adjacent to an active or planned excavation footprint. This was of particular concern at the Linde site because it was known that historical landscaping and construction activities resulted in the placement of clean backfill over contaminated soils in some areas. Discretionary, biased sampling in and around dig areas provided additional data for determining whether, in fact, buried contamination was present.

Discretionary biased samples were obtained using a GeoProbe and were submitted to an on-site gamma spectroscopy laboratory for quick turnaround. GeoProbe work focused on undisturbed areas immediately adjacent to active excavations where there was evidence that contaminated lenses continued into dig face walls beyond the planned excavation footprint. As these areas were encountered, additional subsurface soil sample results obtained via the GeoProbe were pooled with the historical sample results and existing excavation footprints to update the contaminated soil volume and the expected excavation areas.

Periodic Excavation-Support Civil Surveys

The differentially corrected GPS used to log gamma walkover data did not provide sufficient depth accuracy to directly estimate the volume of soil removed during the excavation. Consequently, periodic excavation-support civil surveys were conducted to more precisely estimate actual volumes of soil removed from specific areas. These volumes, in turn, were compared with the planned excavation volume for the area to determine the extent of the deviations. Where significant deviations were identified, the gamma walkover surveys conducted during the excavation provided a means for documenting the deviations. For example, if the depth of contamination was expected to be 1 m (3 ft) in an excavation area and the actual depth of contamination extended to a depth of 2 m (6 ft), the daily gamma walkover surveys provided evidence that the soil between 1 and 2 m (3 and 6 ft) was above the cleanup criteria and required excavation.
RESULTS

In the case of the Linde site, the excavation process has deviated significantly from the original planned excavation footprints and removal volumes. This deviation was based on the discovery of new subsurface contamination lenses during additional remedial characterization work. In addition, contamination in many of the known contamination zones extended beyond the original estimated footprint. Figure 2 is a map of the Linde site with excavation footprints, as they existed as of October 2002 superimposed on the original remedial design footprints.

As of October 2002 approximately 41,000 m$^3$ (54,000 yd$^3$) of in situ contaminated material (i.e., concrete and soil) has been removed, compared with 36,000 m$^3$ (47,000 yd$^3$) in situ contaminated soil volume that was expected to have been removed on the basis of an original estimate. The estimated remaining volume of contaminated soil is 8400 m$^3$ (11,000 yd$^3$) in situ. Figure 3 shows a bar graph that plots volumes of contaminated soil removed along with the estimated remaining volume of contaminated soil from May 2001 through October 2002.
By May, 2001, with approximately 40% of contaminated soil removed, the total contaminated soil volume estimate had stabilized at around 49,000 m$^3$ (65,000 yd$^3$). Over the subsequent 16 months, as excavation work proceeded, the estimated total volume fluctuated based on available data, but remained close to this figure. As one would expect, the estimated total volume estimates exhibited less fluctuation as excavation work proceeded.

Reviews of existing logged gamma walkover data and waste profile sampling results indicated that the excavation work was focused on contaminated soils, and that increases in contaminated soil volume removal as compared with what was expected were not due to overexcavation. Figure 4 is a photo of an area of the site after excavation and provides evidence of how carefully the contractor involved with the excavation work attempted to limit excavation only to those contaminated soils actually requiring removal.
The fact that actual excavated soil volumes have significantly exceeded those originally expected for the site is not surprising given the limited RI/FS data set available for producing the original volume estimates. The soil volume tracking system that was in place for the Linde site allowed ongoing adjustments to be made to estimates of the remaining contaminated soil volumes. This, in turn, provided the opportunity to revisit budget and schedule assumptions, providing support for overall project management.

CONCLUSIONS

For sites with subsurface contamination, it is usually extremely difficult to produce accurate assessments of contaminated soil volumes based on RI/FS data alone. This has been the experience of the USACE Buffalo FUSRAP program. Consequently, project managers should recognize that deviations from planned excavation soil volumes and schedules are to be expected, and that a process should be in place in the project plans for identifying, justifying, and accommodating those deviations as they occur. Drawing upon its experience with the Ashland sites, the USACE Buffalo District implemented a soil volume estimation tracking system for the Linde site. This system rolled original soil volume estimates, excavation-support logged gamma walkover survey data, biased
subsurface soil sampling, and periodic civil surveys into a methodology for tracking deviations from the original excavation plans. This allowed deviations to be quickly identified and investigated to ensure that they were in response to unexpected contamination encountered during excavation, and not due to problems with the excavation process itself. Quantifying these deviations and generating new estimates of remaining soil volumes provided project managers with needed information for budget and schedule modifications.

REFERENCES
