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PRECISION EXCAVATION APPROACHES TO REMEDIATING SOILS CONTAMINATED WITH RADIONUCLIDES

D. Conboy, U.S. Army Corps of Engineers
L. Durham, Argonne National Laboratory (USA)

ABSTRACT

The U.S. Army Corps of Engineers (USACE), Buffalo District, is responsible for remediating Formerly Utilized Sites Remedial Action Program (FUSRAP) sites within its jurisdiction. The largest cost element for most of these sites is the excavation and disposal of contaminated soils. A cost-effective approach is to use "precise excavation," which reduces the amount of unnecessary excavation. Precise excavation involves identifying an initial excavation footprint and redefining the footprint for subsequent lifts until the entire site has attained predetermined remediation levels. Precise excavation employs a combination of field radiological screening techniques, discrete sample data, and spatial decision support tools.

During the course of soil excavation, thousands of measurements are made each day to guide excavation decision making. These data must be made available in a timely fashion to on-site contractors, Buffalo District program management staff, technical team members who are off site, and regulators. The Buffalo District is using secure web sites especially designed for this purpose. These web sites offer several advantages to the Buffalo District. Web-site users require nothing more than Internet access and a Java-enabled browser to access the information. Because data are centrally located, the USACE can be confident that all who use the web sites are viewing the same data sets at any given point in time. Site data are immediately available to anyone who has Internet access, the correct login and password, thus allowing the Buffalo District to inform regulators and provide technical assistance to support the remedial activities without requiring management and technical experts to be present at the excavation site.

INTRODUCTION

In an effort to ensure a complete remediation and to control costs, the Buffalo District of the U.S. Army Corps of Engineers (USACE) implemented an Internet-based approach for coordinating the precise excavation and off-site disposal of soils contaminated with low levels of residual radioactivity. This method has been applied at the Formerly Utilized Sites Remedial Action Program (FUSRAP) Ashland 1 and Ashland 2 sites.

During precise excavation, the soil at a site is "peeled" back in layers, and each layer of exposed surface soil is characterized by using real-time data collection techniques. Thus, the contamination footprint is redefined before the next layer of soil is excavated. The goal is to ensure that only soils that truly exceed cleanup goals are identified for off-site disposal. During the course of a precise excavation, thousands of measurements are made each day to guide excavation decision-making. Precise excavations at Buffalo District FUSRAP sites impose significant data management, integration and dissemination demands. These data sets must be made available in a timely fashion to on-site contractor teams, Buffalo District program management staff members at their offices, technical team members who are not on site, and regulators involved with the remediation activities. The Buffalo District used secure web sites especially designed for this purpose. An independent evaluation of the efficiency of the precise excavation approach indicated minimum savings of 30 times the cost of implementation.

PRECISE EXCAVATION MEHODOLOGY

The first step in implementing a precise excavation is to define the potential extent of contamination by using existing data. For this purpose, a combination of indicator geostatistics and Bayesian analysis is used. Geostatistic techniques make use of the spatial autocorrelation structure present in data to interpolate from locations where samples have been collected to areas where samples are not available. Indicator geostatistics is a more specialized form that focuses on the presence or absence of contamination above cleanup guidelines rather than on the actual concentration values themselves. Indicator geostatistics mirror the actual decisions that have to be made (e.g., does a particular area have to be excavated or can it remain?). The results tend to be more robust and less sensitive to wide ranges in contaminant concentrations. Bayesian techniques are used to blend information about the presence or absence of contamination that comes from sources other than discrete sampling into the analysis. This information may be derived from aerial photographs, evidence of soil staining or stressed vegetation, the location of infrastructure related to the original contamination, terrain, etc. Although this type of information is not definitive, it can be extremely useful, particularly for cases in which soil sample data are scarce. A complete description of the estimation process can be found in (1).

The product of this analysis is a 2- or 3-dimensional probability map that shows the likelihood of any particular location exceeding cleanup guidelines. These probabilities can range from 0, which indicates that sample concentrations are consistently below cleanup goals, to 1, which indicates that sample concentrations are consistently above cleanup goals. By picking appropriate probability levels, one can divide a site into three regions. The first region is where the probability of contamination above cleanup goals is sufficiently low that no excavation is considered necessary. The second region is where the probability of contamination above cleanup goals is so great that excavation is almost certainly required. The volume associated with this region represents the minimum amount of soil that will likely need to be excavated. The third region is where the probability of contamination above goals is neither very low nor high; in this region, on the basis of existing data, the presence or absence of contamination above cleanup goals is uncertain. The volume associated with this region combined with the volume of the second region represents an estimate of the maximum amount of soil that will likely need to be excavated.

The second step in a precise excavation process is to select the most appropriate mix of data collection technologies for delineating excavation footprints as the excavation work proceeds. In the case of radionuclide-contaminated sites, the selection typically includes some combination of 100 % scan coverage made with a mobile gross activity sensor combined with a global positioning system (GPS) and direct measurements and/or mobile laboratory analyses using gamma spectroscopy techniques. The advantage of 100% mobile gross activity scans is that they provide a complete surficial picture of gross activity distribution at low cost. Another advantage of a walkover measurement program is that it is conducted in "real time," so decisions can be made quickly. The disadvantage is that these data are qualitative, and, particularly for sites with multiple isotopes of concern, the data may only be weakly linked to the actual concentration-based cleanup criteria. The advantage of both direct measurements and discrete sampling is that the concentration values obtained are directly comparable to cleanup guidelines. The disadvantages are that the data are relatively more expensive to obtain, the data provide information on only the specific locations where they were collected, and there is a time lag before data are available.

The challenge for a precise excavation in radionuclide-contaminated soil is to develop a relationship between abundant screening data and cleanup goals by using direct measurements and/or discrete sampling techniques. Figure 1 provides an example of this kind of relationship as developed from the Ashland 2 Site. In Figure 1, gross activity is along the x-axis, while the probability of samples encountering contamination above cleanup goals is shown on the y-axis. Discrete sampling was used to derive this relationship. On the basis of this relationship, two gross activity trigger levels were selected. The first represents a level below which soil could be left; the second represents a level above which soil needs to be excavated. As shown in Figure 1, for the Ashland 2 Site, the lower trigger level was initially set at 16,000 (16K) counts per second (cps), while the higher trigger level was 20K cps.

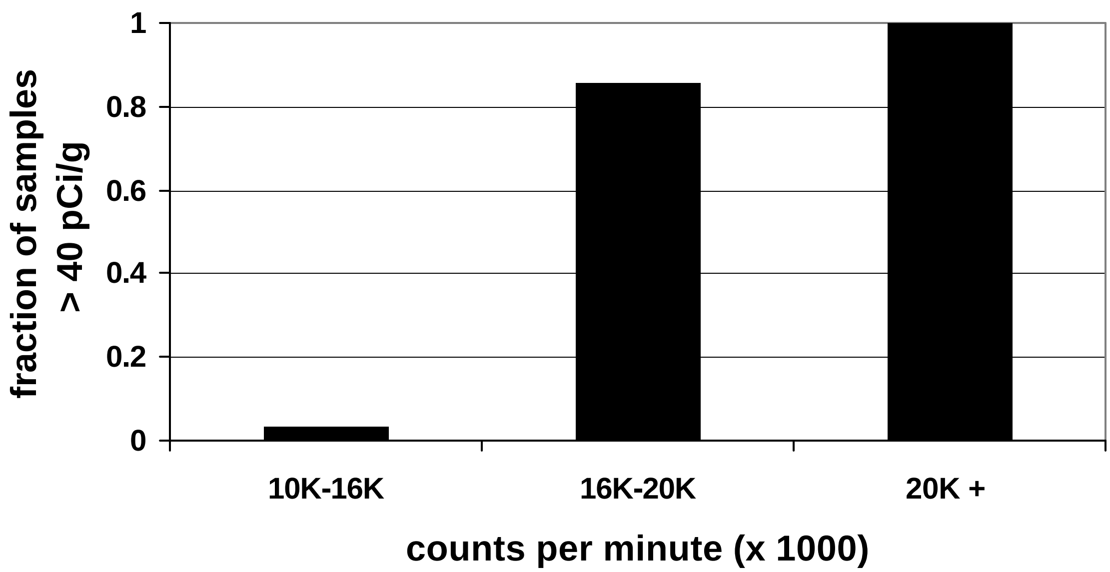

Fig. 1. Relationship Between Gamma Walkover Data and > 40 pCi/g Thorium-230 Cleanup Guideline

The last step in the precise excavation process is to actually proceed with the excavation. These excavations typically proceed in lifts, where lift sizes may range from a few inches to several feet.

Before each lift is taken out, the exposed surface is scanned. On the basis of the scan and a relationship such as that depicted in Figure 1, the exposed surface is divided into (1) areas that are clean and, if excavated, can be stockpiled for backfill; (2) areas that are contaminated and so must be excavated and disposed; and (3) areas where the gross activity numbers are inconclusive. In these third areas, additional samples might be collected to determine if the areas should be considered clean or contaminated. Whether additional samples are collected is a cost/benefit judgment, with the cost of additional sampling (and an outcome of perhaps being able to label the soil as clean) balanced against the cost of simply lumping the soil with the rest of the contaminated material. If disposal costs are low, additional discrete sampling may never be warranted. If disposal costs are high, additional discrete sampling may always be beneficial.

THE INTERNET PROVIDES DECISION SUPPORT

Dedicated project web sites are a particularly effective means for enabling precise excavation. The web sites are secure, with access being limited to users with the appropriate login and password. Through direct connections to databases and maps, web sites provide easy access to the data being generated to support the excavation. Because access to Internet-based data management requires only the availability of an Internet link and browser information is available to any authorized user, any place, any time.

In the context of precise excavation, a dedicated project web site provides several key benefits beyond ready access to information:

- The combination of processing, integrating, and posting data to such a web site provides an additional measure of quality assurance. Potential data problems such as data gaps, outlier values, wrong locations, or unexpected results become more readily apparent.
- The organization responsible for the site can be sure that all users of the data are working with the current information at any given time, because all data are stored on a central server associated with the web site. This feature is important for precise excavation sites where data are being updated daily.
- By making information readily available, the project managers can involve technical support staff and stakeholders in decision making and problem solving without requiring their presence on site.
- Since regulators and stakeholders can be provided access to data that support and drive the entire remedial action, the process of gaining concurrence for final site closure can be expedited.

PRECISE EXCAVATION AT THE ASHLAND SITES

The principal sources of real-time data at the Ashland FUSRAP sites are gamma walkover surveys, coupled with GPS data-logging systems and soil sample results from an on-site gamma spectroscopy laboratory. Gamma walkover surveys are conducted with detectors that measure gross gamma radiation. Gamma walkover surveys can provide complete coverage of an exposed surface.

To be useful for excavation-control purposes, these data must be integrated, mapped, analyzed, and redistributed back to field staff in a timely manner.

Dedicated web sites were established for both the Ashland 1 and Ashland 2 projects. The sites were developed by using Microsoft Access™ as the database, Allaire's ColdFusion™ as the interface between web pages and Access, and the Maps and Data (MaD) browser from Argonne National Laboratory (Argonne) for serving dynamic maps.

The MaD browser is a Java applet that provides basic geographic information system (GIS) capabilities for vector-drawn maps that can be downloaded over the Internet. These vector-drawn maps are linked back to underlying databases, allowing users to select objects from specific locations on the maps and retrieve the results associated with those locations.

On-site contractors had a local Internet Service Provider (ISP) connection to transfer data electronically to Argonne. At Argonne, the information was loaded into databases, mapped, analyzed, and posted on the web for review by the USACE team. Turnaround time for the gamma walkover data from the point of collection to dissemination on the web was typically less than 24 hours, although, in some cases, the data and maps were available on the web almost immediately after collection; consequently, the data analysis and decision support process never delayed site remediation efforts.

After the gamma walkover data indicated that the sites were sufficiently remediated, additional samples were collected for off-site laboratory analysis, as part of the final status survey process to confirm that the remediation was complete. The off-site laboratory data, along with other information such as the on-site gamma spectroscopy results, air-quality sampling results, waste characterization data for off-site soil shipments, electronic documentation, and digital photos of work, were posted on the web sites.

BENEFITS

The Buffalo District used a "virtual team" approach to accomplish the remediation. The team included experts from several USACE organizations, such as the Hazardous, Toxic and Radiological Waste (HTRW) Center of Expertise. Internet-based data management enhanced the ability of the USACE team to monitor and document the progress of the remediation. This approach ensured the identification and removal of contaminated soil that was not previously identified during the remedial investigation. Additionally, the high cost of off-site disposal was avoided in some cases, because soil originally identified as contaminated was proven to be below the cleanup criteria. In addition to cost savings, precise excavation also provided additional data during the excavation to confirm that the remediation was being implemented correctly.

When suitable "real-time" data collection technologies exist, precision excavation is a very attractive alternative to traditional methods for designing and implementing soil remedial actions. A cost analysis that compared the precise excavation work conducted at the Ashland 2 site with a more traditional soil removal process estimated a minimum cost savings of $6 million. The additional expense of implementing the precise excavation approach and its associated internet-based data management infrastructure was approximately $200,000.

The New York State Department of Environmental Conservation staff members were able to review data throughout the remedial process, which raised their level of confidence with the overall remediation and expedited the final site closure process. The web site provided a mechanism for immediate, comprehensive data review and analysis, which enhanced the overall quality of the work. Issues such as inadequate data coverage, suspect results, and missing information were identified quickly, and the underlying problems were addressed.

LESSONS LEARNED

The following is a list of the lessons learned from the Ashland 1 and Ashland 2 remediation activities:

- Precise excavation relies on field analytical methods and their ability to produce numerical results in real time. The field analytical method selected must be appropriate for the needs of the excavation program. A correlation between the activity concentrations of the contaminant(s) of concern and the count rates from the field instrument should be developed prior to the start of the excavation and monitored and updated, as necessary, throughout the excavation process.
- Sample production rates must be closely matched with field laboratory analysis capabilities. If the sample production rate is significantly greater than the rate at which the laboratory can analyze, there will be significant pressure to continue excavating without the benefit of results from the previous round of sampling, and the value of adaptive sampling will be lost. If the laboratory can analyze significantly more samples than field crews can produce, then per-sample analytical costs will be driven up, since field laboratories are typically billed on a daily basis.
- The coordination of data, including information on sample locations, sample results, and subsequent analyses, can be more challenging for precise excavation then for traditional, preplanned excavation. . However, if the logistics of precise excavation data management have been laid out and tested beforehand, problems can be significantly reduced. The use of web sites for data integration and dissemination have proven to be a particularly effective enabler of the precise excavation approach to soil remediation.
- Precise excavation requires a higher degree of coordination and control of field-level decision making than traditional programs for which the excavation area is predetermined. The ability to make decisions in the field in response to sampling results is what makes the approach efficient. If timely decisions cannot be made, the value of precise excavation is lost. The inclusion of practice sessions involving sample collection teams, field crews, and key decision-makers before the actual work begins is helpful in identifying potential problems.
- A careful, spatially correct initial model enhances the efficiency of precise excavation. While the ability to visually identify contaminated soils is peculiar to certain types of contamination, every contaminated site includes information that – if explicitly included in an initial

conceptual model – leads to a better excavation plan. The information may come from aerial photographs, stressed vegetation, the physical layout of facilities, results from contaminant fate and transport modeling, data from nonintrusive geophysical work, or past experience with similar sites.

- Precise excavation imposes contractual requirements different from those imposed by standard preplanned excavations. Precise excavation projects are particularly well suited to cost-reimbursable-type contracts that provide for general performance on the basis of the scope of work without specifying in detail the way the work will be performed. Since there is a large amount of uncertainty involved in these types of projects, a cost-reimbursable contract allows a contractor to develop a more reasonable cost proposal without including a large contingency. In addition, if the work is done for less than the cost estimate, the government shares in the cost savings.

CONCLUSION

The ability to collect and utilize information rapidly is beneficial for environmental settings as diverse as site remediation, site characterization, long-term monitoring, and emergency spill response. For all of these applications, efficient and cost-effective data management and dissemination are key components critical for informed decision making. As the work at the Ashland 1 and Ashland 2 FUSRAP sites has demonstrated, Internet-based data management can help to ensure successful remediation projects that are protective and cost effective.

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