Contaminated Soil Volume Estimation at the Maywood Site - 12292

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ABSTRACT

As part of the ongoing remediation process at the Maywood Formerly Utilized Sites Remedial Action Program properties, Argonne National Laboratory assisted the U.S. Army Corps of Engineers (USACE) New York District in revising contaminated soil volume estimates for the remaining areas of the Stepan/Sears properties that require soil remediation. As part of the volume estimation process, an initial conceptual site model (ICSM) was prepared for the entire site that captured existing information (with the exception of soil sampling results) pertinent to the possible location of surface and subsurface contamination above cleanup requirements. This ICSM was based on historical anecdotal information, aerial photographs, and the logs from several hundred soil cores that identified the depth of fill material and the depth to bedrock under the site. Specialized geostatistical software developed by Argonne was used to update the ICSM with historical sampling results and down-hole gamma survey information for hundreds of soil core locations; both sampling results and down-hole gamma data were coded to identify whether the results indicated the presence of contamination above site cleanup requirements. Significant effort was invested in developing complete electronic data sets for the site by incorporating data contained in various scanned documents, maps, etc. The updating process yielded both a best guess estimate of contamination volumes and upper and lower bounds on the volume estimate that reflected the estimate's uncertainty. The site-wide contaminated volume estimate (with associated uncertainty) was adjusted to reflect areas where remediation was complete; the result was a revised estimate of the remaining soil volumes requiring remediation that the USACE could use for planning. Other environmental projects may benefit from this process for estimating the volume of contaminated soil.

INTRODUCTION

The Maywood Formerly Utilized Sites Remedial Action Program (FUSRAP) site is in a developed area of northeastern New Jersey, in the boroughs of Maywood, Rochelle Park, and Lodi. Contamination at the affected properties results from rare earth and thorium processing activities conducted from the early 1900s through 1959. The United States Army Corps of Engineers (USACE) New York District is currently responsible for remediating soil contamination associated with the Maywood site through FUSRAP. Soil is remediated by excavation and shipment to an off-site disposal facility. Remediation at a significant portion of the Maywood properties has already been completed. However, some of the most significant amounts of contamination — from a soil volume perspective — remain to be addressed. Figure 1 shows the location of the Maywood properties addressed by this study (highlighted in red).

The primary purpose of the volume estimation analysis was to estimate the remaining in situ volume of accessible Th-232 contaminated soils. Argonne's Bayesian Approaches to Adaptive Spatial Sampling (BAASS) software was used to prepare the volume estimate. A secondary objective of the analysis was to prepare retrospective volume estimates for areas that have already been remediated, to indicate the likely accuracy of the estimate of remaining contaminated soil volume.

METHOD

The BAASS contaminated soil volume estimation process involves a series of steps that include the following:

- Assembling and evaluating all existing soft information (other than soil sampling and measurement results) pertinent to the potential contamination status of soils at the Maywood site. This includes descriptions of what occurred historically at the site, historical aerial photographs, maps, etc. The product of this evaluation is an initial conceptual site model (ICSM) that captures the probability of contamination being present above release criteria at various locations of the site.

- Reviewing existing soil sample and measurement information and codifying it as indicating that
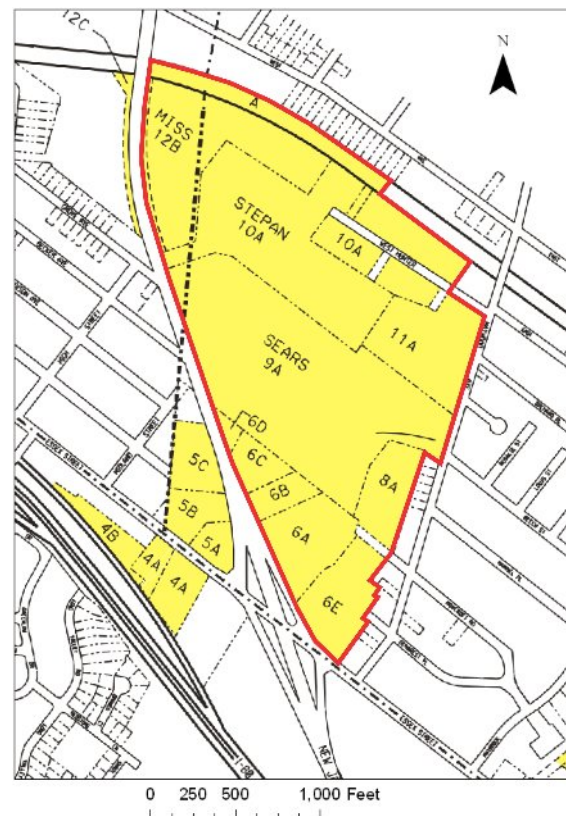

Fig. 1. Location of Maywood Properties.

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contamination is either above or below release levels. The available information for Maywood included soil sample results from soil cores and down-hole gross gamma measurements.

- Updating the ICSM by using BAASS and the sample/measurement data to produce a final conceptual site model (CSM). This final CSM is used to develop volume estimates that are tied to levels of certainty. Typically, a BAASS analysis will provide at least two points of information: the "most likely" volume estimate and a more conservative volume estimate that bounds the quantity of contamination present. The difference between the two volume estimates reflects uncertainty in the true volume of contaminated soil present at the site. In general, the more sample/measurement data available to support the volume estimate, the closer the upper bound will be to the most likely volume estimate.

RESULTS

Initial Conceptual Site Model

In the case of Maywood, three primary sources of information were available for constructing the ICSM. The first source was anecdotal information captured and described in various historical reports prepared for the site (see, for example, [1]). This reporting was particularly useful for identifying the potential presence of burial pits across the site. The second source was a series of historical aerial photographs that depicted site conditions from 1931 (the earliest photo available) to the present. Use of geographical information system (GIS) software for geo-referencing air photos allowed disturbed areas that indicated the presence of pits/lagoons or backfill activity to be identified and delineated. The third source was information from site bore logs that indicated the depth of fill and the depth to bedrock — critical pieces of information for volume estimation. Because the majority of the soil contamination at the site resulted from fill activities, the depth of fill provides an indication of the possible depth of contamination at locations where bore logs are available. Depth to bedrock provides a maximum estimate of vertical contamination extent.

Maywood Chemical Works (MCW) was constructed in 1895. In 1916, the plant began extracting thorium and rare earths from monazite sand for use in manufacturing industrial products such as mantles for gas lanterns. Thorium extraction ceased in 1956, but thorium processing of stockpiled material continued until 1959, when the property was sold to the Stepan Company. The Stepan Company never processed radioactive material. The primary radioactive contaminant at the Maywood site is Th-232 and its associated daughter products, with lesser amounts of radionuclides in the U-238 decay chain. Recoverable wastes from thorium processing operations were stored in an unsheltered phosphate pile between buildings in the main yard. Unrecoverable wastes from thorium processing operations (i.e., residues and tailings) were piped to a large pile on the perimeter of the MCW property. The pile, containing several tons of waste slurry, was surrounded by earthen dikes but remained exposed to weather.

In 1932, the disposal areas were separated from the plant and partially covered by the construction of New Jersey State Highway 17 (Route 17). Additional waste migrated off the property via natural drainage associated with the former Lodi Brook. Historical photographs and maps indicate that the former course of the brook, which originated on the MCW property, generally coincides with the distribution of contaminated properties in Lodi. Most of the open stream channel in Lodi has been replaced by a subsurface storm drain system. Thorium extraction ended in 1956, and MCW stopped processing thorium from stockpiled material in 1959; the property was sold to the Stepan Company that same year.

Stepan began to clean up residual thorium wastes in 1963, partially stabilizing residues and tailings in place by covering them with clean soil. In 1966, 6,400 cubic meters (m^3) (8,400 cubic yards [yd^3]) of contaminated material was removed from the property west of Route 17, returned to the Stepan property, and buried in an area now covered with grass. In 1967, an additional 1,600 m^3 (2,100 yd^3) of material was removed from the same general area and buried on the Stepan property at another burial pit that is now a parking lot. In 1968, an additional 6,600 m^3 (8,600 yd^3) of waste from the area west of Route 17 was transferred and buried in a third burial pit in an area where a warehouse was later constructed.

Seventeen aerial photographs spanning an 80-year period were available for the area of interest. Once geo-referenced, these photographs were invaluable for identifying and delineating the locations of burial pits and areas of significant fill activities. On the basis of anecdotal information and the aerial photographs, a probability map was constructed representing the ICSM (Figure 2), color-coded by the likelihood that contamination might be present above release criteria. Because of the long duration of site activities and the degree of surface reworking over the years, almost the entire area of interest was identified as possibly having contamination present. The areas of highest likelihood corresponded to locations where burial pits were known to exist or significant fill activity took place. Because of the surface reworking, contamination overlain by relatively clean surface backfill or building footprints was assumed to occur in many instances across the site.

In addition to the ICSM presented in Figure 2, more than 500 soil core locations were scattered across the site, with core log information that could be potentially used to determine the depth of fill. Of these, more than 400 were completed to bedrock and so provided depth to bedrock data. By combining data gleaned from these soil core locations with the ICSM, preliminary contaminated soil volume estimates were calculated, assuming that contamination could extend either to the depth of fill or, most conservatively, to bedrock.

Soil Sample and Down-Hole Gamma Data

Historical data for the site consisted of soil samples retrieved from various depths and locations and analyzed in a laboratory for Th-232 activity, plus down-hole gamma

(DHG) activity measurements performed for a subset of the available sampling stations and at independent stations.

Analyzing the Maywood historical data was challenging. Some data existed in spreadsheet format, but much was only available as scanned reports. Location information existed as State Plane coordinates in some cases, while in other cases local coordinate systems were used, with location information only as demarcations on a scanned map. Significant effort was invested in developing data sets suitable for volume estimation, based on available historical data. This effort included capturing data contained in scanned reports in a suitable electronic format, as well as rectifying coordinate information for locations where data had been collected. In the latter case, GIS software was used to geo-reference scanned report figures so that approximate State Plane coordinates could be determined for each station.

Fig. 2. ICSM for Maywood.

Sample analytical results and the DHG data were contained in separate files. As part of the data evaluation process, where possible, the laboratory data and DHG data for the same station location were merged to provide the most accurate understanding possible regarding the presence and vertical depth of contamination. In some cases this was straightforward (e.g., both laboratory data and DHG data shared the same station name and mapped to approximately the same location). However, in many other instances station names were absent, and slight spatial errors were associated with geo-referencing. In general, when a sampled location mapped to within 3.05 meter (m) (10 feet [ft]) of a location with DHG information, the presumption was that the two together reflected the contamination status at that spot.

Overall data quantities assembled for this study included 2,360 laboratory results for Th-232 at 1,023 stations and 13,338 DHG measurements at 724 stations. Through the data evaluation process, this set was reduced to 733 stations with only laboratory sample results, 434 stations with only DHG results, and 290 stations with a combination of the two.

Sample/DHG results for individual locations were compared with the ICSM predictions, providing one measure of the quality of the ICSM (Figure 3). In general, the agreement

between the ICSM and laboratory result/DHG data was good. Only 4% of stations within the area considered unlikely to be contaminated on the basis of the ICSM encountered contamination; 58% of those in the ICSM area deemed to have a 50% chance of being contaminated were contaminated; and 68% of those in the areas considered likely to be contaminated were contaminated.

BAASS Volume Estimation

The BAASS software uses sample and DHG results to update the ICSM and refine estimates of contaminated soil volume. BAASS requires that soil sample laboratory results and DHG measurements be converted to indicator form (i.e., results either indicate the presence of contamination at levels of concern or they do not). For laboratory data, any Th-232 result less than 5 pCi/g was considered clean and assigned a "0" value, samples with results between 5 and 15 pCi/g showed some impact and were assigned a "0.5" value, and results greater than 15 pCi/g were assigned a "1" value, indicating contamination at levels of concern. In the case of DHG measurements, any result less than 23,000 counts per minute (cpm) was considered not impacted at levels of concern and was assigned a 0 value, any result between 23,000 and 33,000 cpm was assigned a 0.5 value, and any result greater than 33,000 cpm was considered indicative of contamination at levels of concern and was assigned a 1 value.

Each station was then assigned a 0, 0.5, or 1 depending on the maximum indicator value observed from its DHG/lab sample results. For each station, the maximum depth at which either a 0.5 or 1 value was observed was noted as well. By using the station data and assuming an exponential variogram with a range of 15.24 m (50 ft) and a search neighborhood of 15.24 m (50 ft), a BAASS update was performed on the ICSM. The BAASS grid resolution was set to 3.05 m (10 ft), resulting in approximately 45,000 BAASS grid nodes for the study area.

The results were updated probabilities that contamination was present at each of the grid nodes. The depth of contamination at each grid node was estimated by using nearest-neighbor interpolation and the maximum depth of contamination observed for each station location. Previous information supplied by the USACE [2] divided the study area into parcels: "remediated" versus "remaining" areas, and "accessible" versus "inaccessible" areas. By using GIS, in situ contaminated soil volumes were estimated for each of the area types by parcel, including a "best guess" soil volume corresponding to all grid nodes that had a 50% or greater probability of contamination at levels of concern, as well as a conservative bounding volume corresponding to all grid nodes that had a 20% or greater probability of contamination. In the case of the best guess, the average maximum depth of contamination observed for that area across grid nodes was used for the volume calculation. In the case of the conservative bounding volume estimate, the 80th percentile of the depth of contamination observed for that area across grid nodes was used in the calculation.
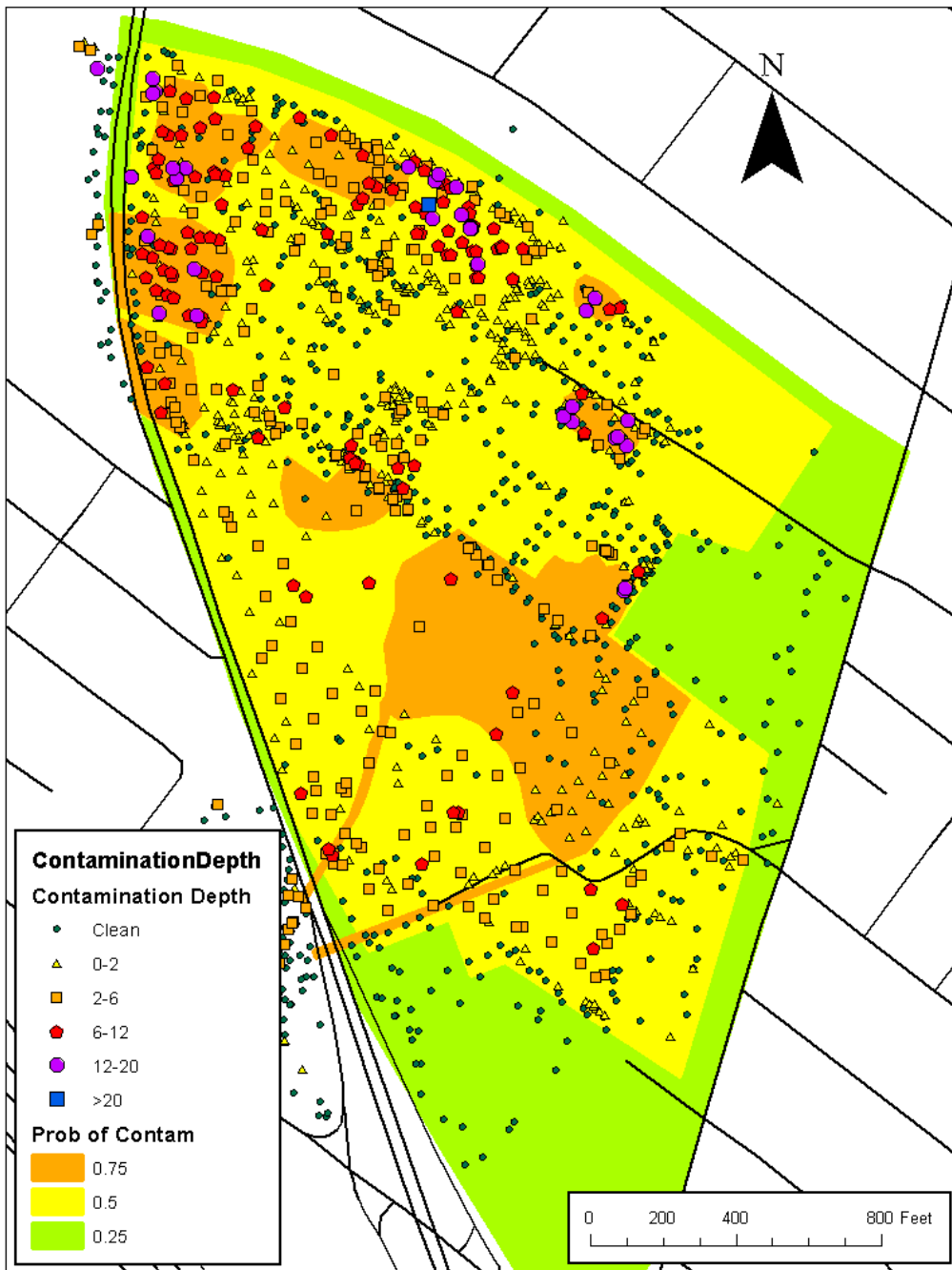
Fig. 3. Sample and DHG Results Color-Coded by Depth of Contamination Encountered, Overlain on the ICSM.

Table I summarizes the overall volume estimation results. Table I does not account for potential layback/constructability soil removal requirements or ex situ bulking.

Table I. Maywood Contaminated Soil Volume Estimate Summary.

	Best Guess	Conservative
Already Remediated	47,000 m^3 (61,000 yd^3)	89,000 m^3 (117,000 yd^3)
Remaining Accessible	70,000 m^3 (92,000 yd^3)	141,000 m^3 (185,000 yd^3)
Remaining Inaccessible	42,000 m^3 (55,000 yd^3)	75,000 m^3 (98,000 yd^3)
Total	**159,000 m^3 (208,000 yd^3)**	**306,000 m^3 (400,000 yd^3)**

DISCUSSION

A comparison of sample and DHG results for various stations with the site ICSM provides one measure of the quality of site understanding relative to the presence of contamination and its likely extent. A second measure of the quality of a contaminated soil volume estimate, in the case of BAASS, is a comparison of the best guess volume estimate with the conservative volume estimate. For Maywood, the conservative volume estimate is more than double the best guess. The data available for the site indicate that the preponderance of this difference is attributable to uncertainty about the exact depth of known contamination. The observed depth of contamination based on sample results and DHG data often varied significantly among adjacent soil cores.

In the case of Maywood, where a significant amount of remediation has already taken place, a third measure of the quality of the volume estimates is the retrospective estimate of contaminated soil volumes for areas that have already been remediated [2]. The USACE is currently comparing the latest BAASS volume estimates for those areas with records indicating what was actually removed.

REFERENCES

1. Bechtel National, Inc. (1992). Remedial Investigation Report for the Maywood Site New Jersey, Volume I, December.

2. United States Army Corps of Engineers (2011). Triangle Properties Maywood, NJ, Remedial Excavations Status, computer file TRIANGLE_FEB 9, 2011.dwg, February 9.

ACKNOWLEDGMENTS