Application of Soil Sorting for Depleted Uranium Fragments – 14373

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ABSTRACT

The Iowa Army Ammunition Plant FUSRAP site is performing soil remediation for depleted uranium (DU). The primary focus is a Firing Site where the presence of DU fragments have been identified. The selected remedy is physical treatment of the soils for segregation of the DU fragments. This includes an automated soil surveying and sorting system to more efficiently sort the soil excavated in order to significantly reduce the total quantity of DU-contaminated soils that must be sent off-site for disposal. The Orion ScanSort^{SM} system has demonstrated that it can perform this physical treatment of these soils in a cost-effective manner. The overall approach to soil remediation, soil processing/segregation and results for materials processed will be presented.

INTRODUCTION

Prior to soil remediation, a pilot test of the Orion ScanSort^{SM} system was performed to determine if the ScanSort^{SM} system (a conveyor-assisted, automated soil surveying and sorting system) could effectively detect and isolate DU fragments from bulk soil while confidently satisfying the remedial action goals (RGs). An additional objective was to determine the full-scale operational process throughput rate that could reasonably be achieved and to estimate the soil waste volume reduction when operating in a full-scale remedial action mode in support of the RA stipulated in the ROD.

The scope of work for the pilot study test was to calibrate, test, operate, and evaluate Orion *ScanSort*^{SM} screening and sorting system for its ability to detect and isolate fragments of DU distributed in bulk soils within OU-8 such that soil passing through the system as “clean” would have a maximum equivalent diffuse uranium 238 (U-238) activity concentration of less than 5.5 becquerel per gram (Bq/g) (150 picocuries per gram [pCi/g]) averaged over a conservative mass of no more than 453,592 kilograms (kg) (500 tons) (soil survey unit associated mass). The purpose of the pilot test was to design and implement a pilot and demonstration test that would ascertain whether such a system has the necessary sensitivity to screen out DU fragments from surrounding soils with economic feasibility, while at the same time meeting or exceeding the soil RG.

Supplemental tasks integral to meeting the objectives outlined in the pilot test work plan included:

- Testing the variability in detection sensitivity with DU fragments at different soil depths, belt lateral locations, and belt speed;
- Evaluating/calibrating/optimizing system parameters for maximizing system production efficiency; and

- Conducting a short-duration production run using soils from the designated pilot test dig areas to estimate volume reduction and production rates.

Site Description

The IAAAP site, managed by the Department of Defense (DOD), produces and delivers component assembly, and medium and large caliber ammunition items in support of worldwide DOD operations. The site was established in 1940 as the Iowa Ordinance Plant. Portions of the site were managed by the US Atomic Energy Commission (AEC) from 1947 through 1975. During management under the AEC, production of materials and components for atomic weapons and final assembly of atomic weapons was performed. In 1975, control of the entire site reverted back to the US Army.

Portions of the site contain contamination resulting from activities that supported the early atomic weapons and energy programs qualifying those areas as eligible for activities under the Formerly Utilized Sites Remedial Action Program (FUSRAP). This Pilot Study was conducted for the USACE as a component of the FUSRAP remedial activities of area OU-8.

The IAAAP site encompasses approximately 78 square kilometers (30 square miles) in Des Moines County near Middletown in southeast Iowa (Figure 1). Approximately one-third of the IAAAP is involved in loading, assembling, and packing ammunition items including projectiles, mortar rounds, warheads, and other munitions. The remaining two-thirds of the site is either forested or agriculture space.

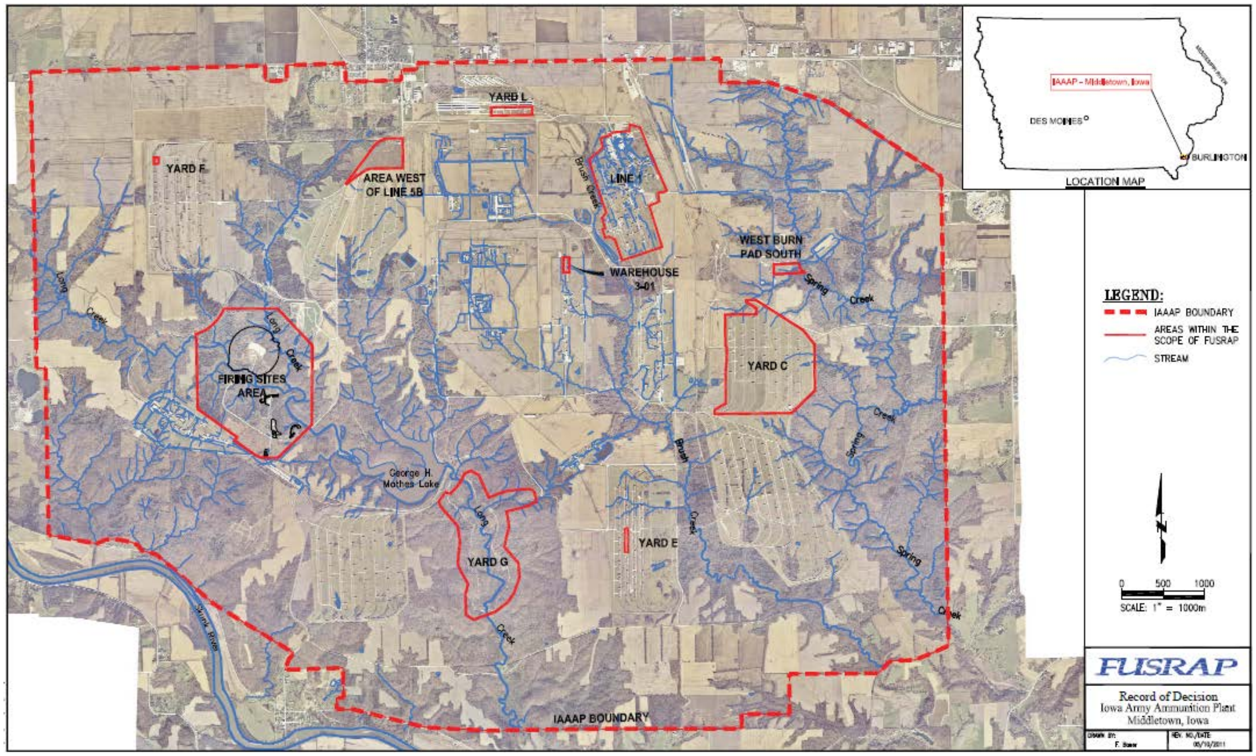

Figure 1 - IAAAP Site, Middletown, Iowa

METHODS

The pilot study was conducted at the IAAAP, FS 12 site using the full-size, production-ready, Orion ScanSort^{SM} soil screening and sorting system. DU contaminated soils at the FS 12 site were used as the testing medium. Site soils were excavated from designated areas within the site, stockpiled, and then processed through the system in a number of varying configurations, allowing system operational variables to be tested.

Soil

Soil material was obtained from different areas of the site for the pilot study. The soil was excavated from the pilot study dig areas, identified, and selected using site characterization data based on the surface radioactivity levels and observed population density of radiological surface measurements for each of the areas. In support of the pilot study objectives, three levels of soil were identified and selected:

1. High DU surface fragment density area,
2. Intermediate DU surface fragment density area, and
3. Low DU surface fragment desnity area.

The areas were excavated in nominal 20 – 25 centimeter (cm) lifts, as shown in Table I. Materials and soil excavated from each of the areas and each lift were kept segregated prior to and during the pilot study operations.

TABLE I Pilot Test Soils

<table>
<tr><th>Area Decsription
(DUFragment Density)</th><th>Area
(m²)</th><th>Lifts</th><th>Approximate Volume
(m³)</th></tr>
<tr><td>Low Area</td><td>216</td><td>2</td><td>100</td></tr>
<tr><td>Intermediate Area</td><td>432</td><td>2</td><td>229</td></tr>
<tr><td>High Area 1</td><td>268</td><td>1</td><td rowspan="2">239</td></tr>
<tr><td>High Area 2</td><td>185</td><td>2</td></tr>
</table>

ScanSort^{SM} System

Components of the *ScanSort*^{SM} include a survey conveyor, sorting conveyor, control and operation station (e.g., mobile command center trailer), power distribution panels, and system electronic panels. Associated conveyor and support equipment, includes a mechanical material screener, feed conveyor, below criteria soil stacking conveyor, and above criteria soil stacking conveyor as shown in Figure 2.

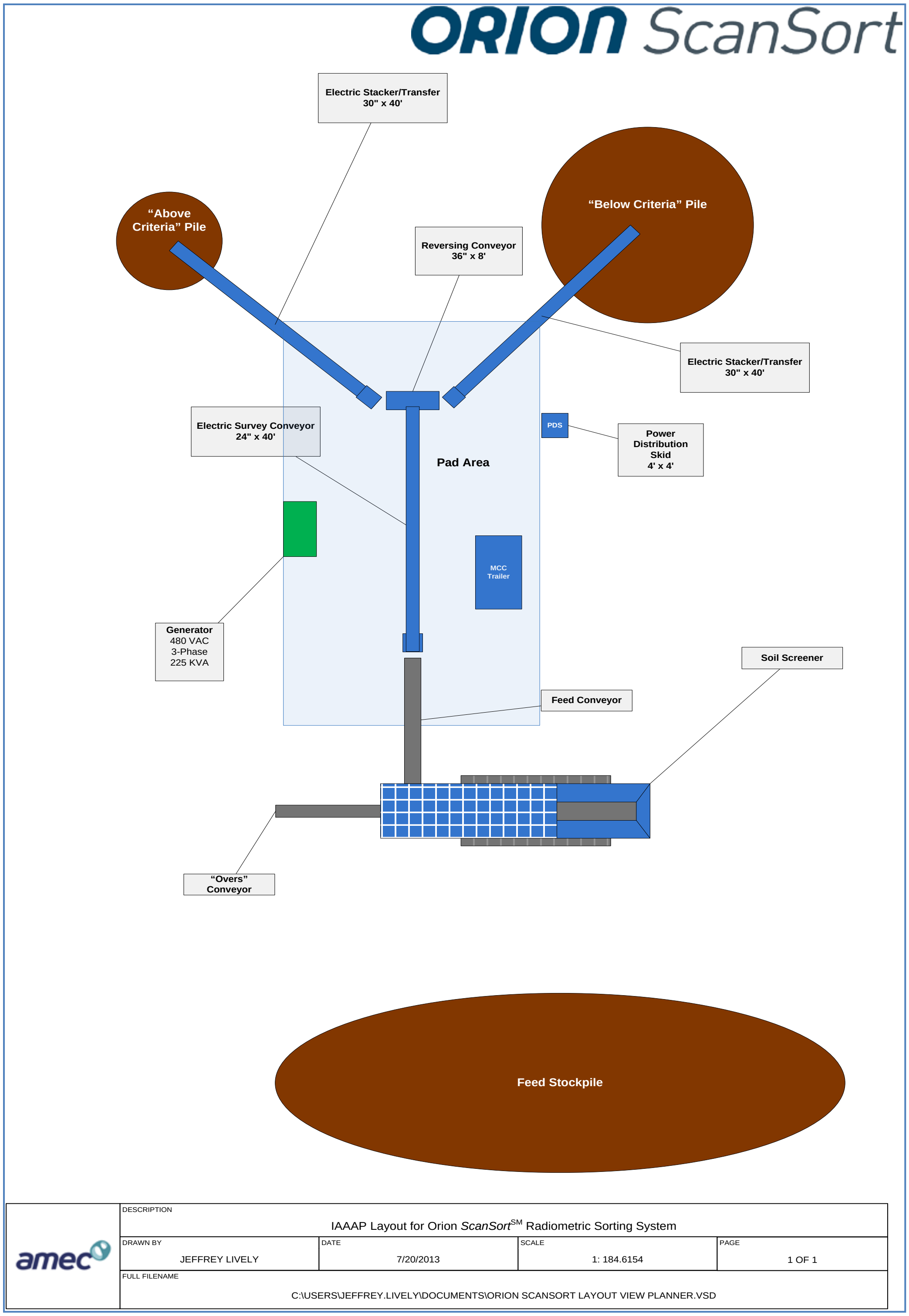

Figure 2 – ScanSort^{SM} Setup

Flow of Soil

The soil material flows through the *ScanSort*^{SM} system as follows:

- Beginning at the trommel drum style material screener, soil is loaded into a large hopper by a front-end loader and conveyed into a rotating trommel drum.
    - The trommel drum is equipped with a 6 cm wire screen designed to break up soil clumps and remove large debris,
    - The trommel produces material that is mechanically screened to 6 cm minus size gradation, and
    - Larger soil clumps and debris that do not pass through the screen are sent out of the system into a discharge pile to be reprocessed or otherwise dispositioned.
- Soil passing through the trommel screen is fed onto the feed conveyor and then into the Orion *ScanSort*^{SM} survey conveyor's feed hopper.
- The Orion *ScanSort*^{SM} survey conveyor's feed hopper is equipped with an adjustable soil leveler gate that controls the flow of soil into the survey conveyor, which is set to regulate the depth of soil on the survey belt.
- The mass of soil on the survey belt is measured with the *ScanSort*^{SM} system's nuclear measurement gauge.
    - The soil is then passed under the *ScanSort*^{SM} system's DU radiation detector array for radiometric assay, which utilized two large volume, 2-liter (5 cm × 10 cm × 41 cm) NaI(Tl) detectors.
    - The detector array was suspended roughly 5 – 10 cm above the soil, depending on the soil thickness being tested.
- Parameters of the soil measured are fed to the *ScanSort*^{SM} system's operating software and compared to established diversion control setpoints (DCSs) to determine which one of two bins a given element of soil under evaluation should be discharged into.
    - An element of soil that is judged to exceed a DCS is diverted to the "above criteria" bin, and
    - An element of soil that is judged to satisfy each DCS is diverted to the "below criteria" bin.
- As an element of soil that is judged to exceed a DCS approaches the end of the survey conveyor belt, the software reverses the sorting conveyor to divert the offending soil.
- A set of two stacking conveyors are positioned at the two discharge points of the sorting conveyor to capture the soils that are diverted into either of the two pathways.
    - The stacking conveyors rapidly move the segregated material from the discharge of the sorting conveyor to form two stockpiles of material (one that is "above criteria" and another that is "below criteria") for subsequent management and disposition.

System Calibration

The calibration of the Orion *ScanSort*^{SM} system involves calibration of the sensors that feed data to the decision logic in the Orion software system (OSS). Each major element of the system calibration is described below, including sensor array alignment, DU region of interest (spectral), bulk soil efficiency, nuclear measurement gauge and survey belt speed-distance.

Sensor Array Alignment

The first alignment consideration is related to the desired size of a single element of soil to be evaluated. Several considerations are taken into account, including the survey/sorting objectives, the anticipated operational belt speed, the anticipated operation soil thickness on the survey belt, and the physical limitations and constraints of the equipment itself. Since it is known that the sorting objective is to detect and divert soils that contain discrete DU fragments above some activity threshold, the decision was made to set the length of a single element of soil equal to 0.5 meters. This is ideal for diverting smaller volumes of soil when a fragment is detected. AMEC's proprietary Orion operating system software (OSS) records spectral data for each soil element in unique "acquisitions," which it then uses to process and analyze the data set and make diversion decisions. An acquisition length of 0.5 meters is the smallest practical acquisition length that can be implemented when singular, discrete, point sources (i.e., with DU fragments) are potentially present in the soil and must be assayed as such. This limitation is due to the large physical size of the spectrometers that *ScanSort*^{SM} uses, which are themselves nearly 0.5 meters long.

Having set the desired acquisition length to 0.5 meters, the AMEC team positioned and aligned the various detectors and sensors of *ScanSort*^{SM} system on the survey conveyor. All positions are identified relative to the end of the survey belt (Figure 3).

After physical placement of the sensors, tests were performed to verify the alignment of the system relative to the alignment settings programmed into the OSS. This alignment test ensures that an acquisition identified as having an elevated signal above a pre-determined alarm point was appropriately timed to be diverted to the "above criteria" bin when a divert signal was initiated by the software. The alignment tests performed confirmed that the *ScanSort*^{SM} system consistently diverted flagged acquisitions accurately. To ensure that an offending acquisition is completely diverted to the above criteria bin and stockpile, a small amount of additional (collateral) soil is also diverted into the "above criteria" pile.

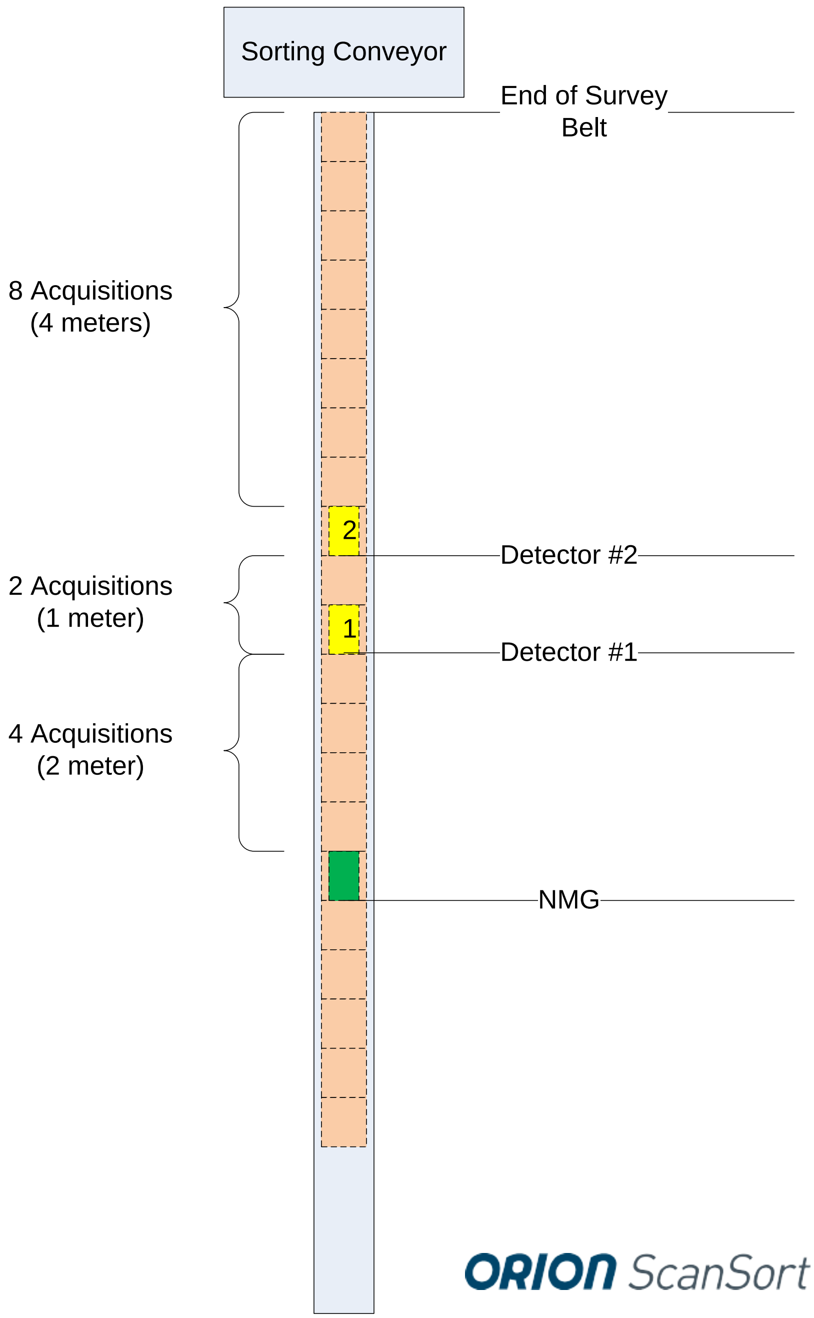

Figure 3 - ScanSort^{SM} System Sensor Array & Alignment

DU Region of Interst

The *ScanSort*^{SM} system is a fully functional and integrated scanning spectroscopy system capable of measuring and distinguishing between a wide range of gamma-emitting isotopes. The operating software makes use of the ability to set regions of interest

(ROIs) within the gamma spectrum to derive meaningful and quantitative information related to the identity and radioactivity of radionuclides of concern. DU is dominated by the radioactivity associated with U-238 (one of the three radionuclides specifically identified in the ROD) and as such, the soil RG specified in the ROD is expressed as an activity concentration of U-238. The soil RG is stated as 5.5 Bq/g (150 pCi/g) U-238 and is derived as an activity concentration limit permissible in a mass of soil associated with a single survey unit of 300 cubic meters (m^3) of soil (conservatively about 453,592 kg).

The relative signal-to-noise ratios of a number of potential spectral regions (various positions and channel widths) were evaluated in efforts to determine the appropriate ROI to be used for identifying and quantifying the radiation signal emitted from DU. Given the natural background levels (signal not attributable to radiation emission from DU) observed while measuring a variety of soils from the site, a number of channels were identified and selected as a ROI that yielded the greatest signal-to-noise ratio for the detection and quantization of DU under a conservatively assumed set of operating and measurement conditions likely to be encountered. The gamma radiation emissions from DU are primarily those associated with U-238 and associated daughter products that can achieve equilibrium with U-238 during the time period since the DU was processed.

These daughter products include thorim 234 (Th-234), protactinium 234m (Pa-234m) and Pa-234. While there are a number of gamma emissions at various energies that could be utililized for quantification of U-238, there are interferences from other naturally occurring radionuclides in soil (e.g., uranium, thorium, and potassium). The selected DU ROI provides a range that includes primary gamma lines (63 keV Th-234, 226/227 keV Pa-234, 258 keV Pa-234m, 293 keV Pa-234, 351 keV Pa-234, and 369 keV Pa-234), uranium K x-rays, and compton scatter generated by the DU gammas as they interact with the surrounding soil. Therefore, the ROI selected is 30 keV to 409 keV.

Bulk Soil Efficiency

To calibrate the *ScanSort*^{SM} system for bulk soil efficiency, a multi-point volumetric calibration method using large volume site soils as “standards” was used. The bulk soil efficiency calibration is necessary to quantify the volumetric soil concentration of U-238 as DU. It is not required to detect and remove discrete DU fragments from the soil; however, it is required to measure and report soil activities in units that the RG is stated. The product of this calibration is an efficiency curve that relates the response of the *ScanSort*^{SM} system in counts per second (cps) within the selected DU ROI to the radioactivity of U-238 in bulk soil. The objective of the multi-point volumetric calibration method is to isolate and blend two to four volumes of soil taken from the site and having a range of activities spanning the activities of interest for the project. It is desirable to have one volume with a very low bulk soil activity concentration (i.e., near background), one at or near the decision threshold (i.e., 5.5 Bq/g U-238), and one somewhat above the decision threshold (e.g., 7-11 Bq/g U-238). A portion of soil from each of the four soil test areas for the pilot study project was evaluated for its potential use as a reference calibration standard.

To prepare the soils for use as bulk soil reference calibration standards, each of the four soil batches were processed through the *ScanSort*^{SM} system to remove discrete DU fragments. The soil was then assayed with the *ScanSort*^{SM} system to yield a measure of the count rate in the DU ROI in cps. This process was repeated for each of the four candidate soil batches. After each batch was assayed by the *ScanSort*^{SM} system, a set of five soil samples was collected from each batch and tested at the the USACE St. Louis District FUSRAP Laboratory in St. Louis, Missouri for U-238 activity.

Likely due to the nature of the contaminant distribution in soil at the FS-12 site, only one of the four candidate soil batches (High Area-1, Lift 1) yielded a mean volumetric U-238 activity that was markedly elevated 0.7 Bq/g (18.63 pCi/g) U-238 relative to background 0.04 Bq/g (1.21 pCi/g) U-238 after having removed the measureable DU fragments. One other batch (Low Area, Lift 1) yielded a small U-238 activity concentration 0.09 Bq/g (2.48 pCi/g) that was measureable, statistically distinguishable from background, and at a relatively low activity concentration and was therefore useful to establish a calibration response curve for bulk soil quantitation. The other batches were not discernable from background. Therefore, two known datapoint pairs were used to establish the bulk soil response curve.

The response of the *ScanSort*^{SM} system within the DU ROI compared to the reported mean activity from soil samples collected from the same soil and measured at the USACE St. Louis District FUSRAP Laboratory provides the necessary relationship to establish the calibration curve and its associated calibration constant in units of cps per pCi/g. The slope of the response curve, which correlates the *ScanSort*^{SM} system's response in the DU ROI to soil sample results collected from the same soil, is the bulk soil efficiency calibration constant. It is used to establish the basis for reporting DU radioactivity in units of pCi/g.

Nuclear Measurement Gauge

The nuclear measurement gauge (NMG) on the *ScanSort*^{SM} system measures the attenuation of a baseline radiation signal caused by the amount of soil mass on the survey conveyor belt. The degree of attenuation measured is sensitive to the variances in the bulk soil density (including the soil moisture content) and the thickness of the soil on the survey belt. The primary function of this gauge is to:

- Provide continuous measurement of the mass of soil that is surveyed by the *ScanSort*^{SM} system.
- Provide correction factors that normalize the *ScanSort*^{SM} system's primary radiometric sensors to their "belt-full" geometry response established at the time of their calibration. In this way, variability in bulk soil density, moisture content, and survey belt fill height are automatically and continuously compensated.

Survey Belt Speed-Distance

The travel distance of the survey belt is an important parameter used in a number of calculations performed by the *ScanSort*^{SM} system's operating and control software. A high resolution, digital encoder device is used to continuously sense the change in position of the survey belt in real time. That signal is fed to the *ScanSort*^{SM} system's digital input/output controller, where it is synthesized with timing circuits and other parameters to initiate control functions (i.e., data-logging and sorting conveyor reversing) and record important operational data for reporting.

The calibration uses a sequence of trials in which the survey belt is moved a known distance (e.g., one complete revolution of the belt). The number of pulses produced by the digital encoder is measured over each trial and a simple ratio of pulses for distance travel is calculated. The average ratio observed over a series of trials is established as the calibration constant for the survey belt speed-distance sensor. This value is entered and set into the *ScanSort*^{SM} system's operating software and provides a precise measure of survey belt travel distance, position of acquisition on the conveyor belt, and belt speed.

Pilot Test

One important objective performed as part of the pilot study's point source efficiency phase was to characterize the system for its response to a discrete (i.e., singular) point source of DU in a variety of configurations that could be anticipated during operations. Several critical variables were tested, including:

- Angular response (lateral [side-to-side]) position of the DU source in relation to the position of the detector),
- Residence time (speed of the survey conveyor),
- Attenuation (thickness of soil covering the source), and
- Activity of the DU fragment.

Before the empirical point source efficiency for a DU fragment could be established, it was necessary to acquire a suite of DU fragments (point sources) of varying size (mass) and activity to be used in the tests. To accomplish this, impacted soils from the site were processed thru the *ScanSort*^{SM} system. Alarms were established in the operating software that would make the system highly sensitive to discrete fragments of depleted uranium. When an alarm signal was generated, indicating the presence of a DU fragment, the survey belt was stopped to identify and retrieve it. A hand-held 5 cm x 5 cm (2-inch × 2-inch) NaI(Tl) detector was used to survey the volume of soil until the DU fragment was identified and retrieved. A total of 13 DU fragments were collected in this manner, eight of which were selected for use during the engineered test runs (TableII).

TABLE II –DU Fragments Retrieved

Assigned Fragment ID	Mass (g)	U-238 Activity (kBq)	Total DU Activity (kBq)
1	186.0	2315	2478
2	22.2	276.4	295.6
3	10.5	130.6	139.9
4	8.0	99.5	106.6
5	2.0	24.8	26.6
6	0.9	11.1	11.8
7	0.7	8.9	9.3
8	0.4	4.8	5.2

The eight DU fragments selected (Table II) were then used to characterize the system's response to fragments in different system configurations. The fragments were manually inserted into clean material being processed by the *ScanSort*^{SM} system. Material was processed at different fill heights (5, 8, 10, 13 and 15 cm) by adjusting the soil leveler gate position on the outlet of the survey conveyor's feed hopper. For each fill height tested, the system was operated at 30, 50, and 70 centimeters per second (cm/s). For each combination of fill height and speed, the identified fragments were inserted into the process material at a variety of locations (i.e., the top of material in the center of the survey belt, the bottom center, and the edge of material). These locations are illustrated in Figure 4.

At each location, the fragments were processed in ascending identification order (fragment 1, 2, 3, etc.) with sufficient physical space between each insertion so that the measured radiation signal from one fragment did not overlap with a subsequent fragment's signal. At each fill height, speed, and location, the eight fragments were processed a total of five times each.

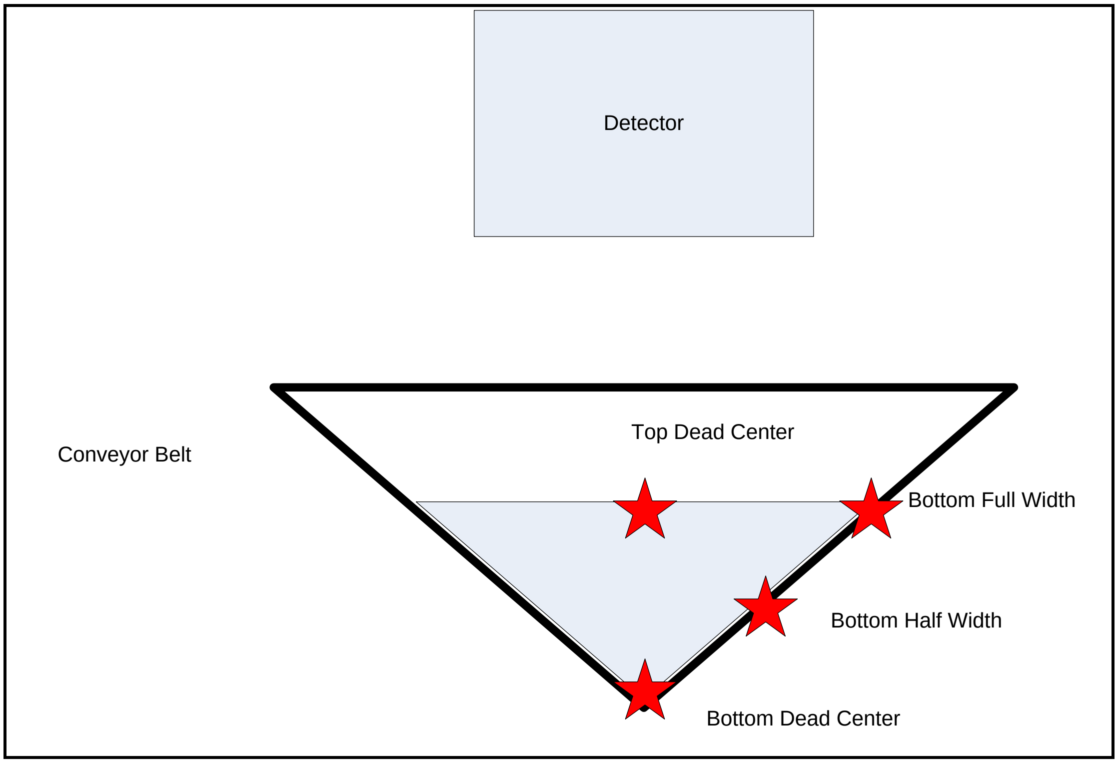

Figure 4 - Source Location on Conveyor Belt

Mock Production Runs

Following the engineered test runs, mock production runs were performed to assess the system's performance in a production environment and to estimate the soil separation efficiency of processing site soils through the *ScanSort*^{SM} system. The *ScanSort*^{SM} system was configured to process soils using the proposed operating conditions based on preliminary pilot study data prior to the mock production runs.

Soils were processed in batches corresponding to the areas from which they were excavated. Acquisitions of soil that generated a signal above the DCS were diverted as "above criteria" material. The total volume of diverted material for each batch was then compared to the total volume of soil that was not diverted during that mock production run. Soils from Intermediate Area, Lift-1; Intermediate Area-1, Lift-2; and High Area-1, Lift-2 were processed in this manner. The data from previous testing for Low Area, Lift-1 and High Area-1, Lift-1 were analyzed to determine the volume of soil that would have been diverted at the proposed operational set points. The percentage of material diverted from each batch is presented in Table III.

Table III Soil Volume Diverted

Batch ID	Proportion of Material Diverted
Low Area, Lift 1 Low Area, Lift-2	2.0%
Intermediate Area, Lift-1	5.3%
Intermediate Area, Lift-2	1.2%
High Area-1, Lift-1	3.1%
High Area-1, Lift 2	3.0%

DISCUSSION

Because no discrete activity remediation guidance existed, the results were examined to qualitatively establish a discrete DU fragment activity that the system could confidently detect under a varity of variable conditions. The data from each of the five engineered test runs for each fragment insertion at each fill height, speed, and location were then analyzed to assess the probability that the *ScanSort*^{SM} system would detect and alarm on the DU fragment as it passed beneath the detector array. The engineering test runs generated a series of datasets that were used to calculate and project the DU fragment detection probabilities over the range of values tested for each variable. These detection probabilities were established by utilizing alarm thresholds that delivered <2% false positive alarm rates.

As expected, the analysis of the engineered test runs shows that the thinner the soil layer thickness used, the higher the likelihood that a DU fragment of diminishing activity would be identified and diverted. While the 5 cm thickness would offer better detection probabilities at very low DU fragment activities, it was confirmed during the pilot study testing that the material flow characteristics of the soil begin to suffer appreciably when the soil thickness was reduced to less than 8 cm. This is related to the 6 cm screen size used in the mechanical screen plant used to precondition the soil and the cross-sectional profile of the survey belt constrained by the soil lever gate.

The probability of detection for a given size or activity of DU fragment continuously improves as the fragment resides closer to the soil surface. It is informative to consider the “best case” scenario detection probability scenario alongside the “worst case” detection probability scenario for a given activity of DU fragment (on top or on bottom). Such a comparison reveals that there is a range of detection probabilities for a given activity of DU fragment dependent upon its position in the soil column and the speed at which the survey belt is operated. When the data are composited to account for the random nature of the position of a fragment within the soil column on the survey belt, the overall projected detection probability is derived for the 8 cm fill height case (Figure 5).

8 cm Fill Height - Random Position						
Source			Speed (cm/second)			
No.:	Mass (g)	U-238 Activity (kBq)	70	50	30	
1	186.0	2315	100%	100%	100%	CONFIDENCE
2	22.2	276.4	100%	100%	100%	
3	10.5	130.6	100%	100%	100%	
4	8.0	99.5	100%	100%	100%	
5	2.0	24.8	83%	92%	93%	
6	0.9	11.1	67%	77%	80%	
7	0.7	8.9	47%	60%	67%	
8	0.4	4.8	27%	40%	50%	

Figure 5 - Projected Detection Confidence, 8 cm Fill Height, Random Position

Soil was excavated from a variety of selected locations and depths at the site and processed through the *ScanSort*^{SM} system in a number of varying configurations along with discrete DU sources of known radioactivity and mass to optimize the operational characteristics of the system. Critical variables evaluated during the pilot study included angular response (i.e., response of the detector in relation to the lateral position of the source), residence time (i.e., speed of the conveyor), and radiation attenuation (i.e., thickness of soil placed on top of the source). Following the evaluation of critical variables, which indicated that the system can be an effective tool to accomplish the RGs for the site, the system was operated in a mock production mode to identify potential issues regarding communications, logistics, maintenance, etc.

Key conclusions derived from the engineered test runs include:

- The ideal fill height thickness for processing soil and detecting small DU fragments is 8 cm.
- As the fill height increases, the probability of detecting increasingly smaller DU fragments goes down.

- As the survey belt speed goes up, the probability of detecting a DU fragment of a given size and activity, assuming a constant false positive rate, goes down.
- DU fragment detection probability is more sensitive to its random position within the soil column than it is to belt speed variance.
- DU fragment detection probability is more sensitive to soil thickness than is it is to belt speed variance.
- Over the range of survey belt speeds tested (30 to 70 cm/sec), the *ScanSort*^{SM} system detected the 99.5 kBq U-238 (8g) DU fragment 100% of the time when placed in the worse case lateral and depth positions in 5, 8 and 10 cm fill heights.
- Over the range of survey belt speeds tested (30 to 70 cm/sec) and using 8 cm fill height, the *ScanSort*^{SM} system detected the 24.8 kBq U-238 (2g) DU fragment between ~80 and 100% of the time depending upon its lateral and depth position within the soil column.
- At a survey belt speed of 30 cm/s, and a fill height of 8 cm the *ScanSort*^{SM} system can be expected to remove a 99.5 kBq (8g) DU fragment ~100% of the time, a 24.8 kBq (2g) DU fragment ~93% of the time, a 11.1 kBq (0.9g) DU fragment ~80% of the time, a 8.9 kBq (0.7g) DU fragment ~67% of the time, and a 4.8 kBq (0.4g) DU fragment ~50% of the time.

Based on this data and assessment, the *ScanSort*^{SM} system can support a diversion control setpoint that identifies and segregates soil that contains a single discrete DU fragment with a U-238 activity of 83 kBq (~6.5g) with at least 95% confidence and/or a DU fragment with a U-238 activity of 25.9 kBq (~2g) with at least 80% confidence.

In addition to the relative significance of the amount of radioactivity associated with a DU fragment, the DCS should be selected in recognition of the waste volume that will be generated at a given DCS. Again, data collected during the pilot/demonstration study and identified as “mock production runs” provide a basis for assessing projected waste volumes that might be expected relative to the magnitude of activity in a DU fragment that is designed to be removed. The “mock production run” data was used to create a composite, projected waste volume estimate (as a percentage of volume processed) curve plotted against potential diversion control set points that might be used to remove DU fragments (Figure 6).

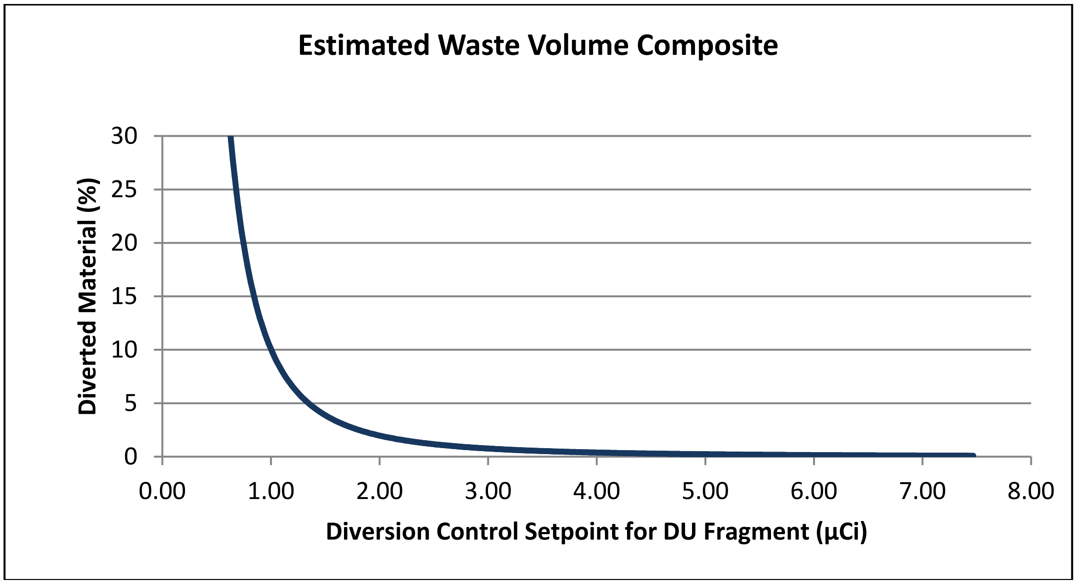

Figure 6 - Waste Volume vs. DU Fragment DCS

This curve predicts that waste volumes (as a percent of total volume assayed) will likely be relatively low (given the DU fragment activities and spatial densities in soils tested during the pilot / demonstration study), likely less than 5% if the criterion for a "significant, measureable fragment of DU" is defined as 83 kBq or more. However, it is noteworthy to consider that the inflection point of this composite, projected waste volume estimate curve occurs between 37 and 74 kBq. Thus, two cost consequences will occur if the criterion for a "significant, measureable fragment of DU" is defined as less than ~83 kBq.

CONCLUSIONS

The pilot study/demonstration project proved to be very successful. AMEC's *ScanSort*^{SM} system demonstrated the ability to consistently detect and isolate discrete, singular DU fragments with activities greater than 83 kBq U-238 (which is equivalent to a fragment that is approximately 6.5g) in producing "below criteria" soil with an average bulk concentration significantly less than the soil RG 5.5 Bq/g (150pCi/g U-238 as DU). There is not a single lateral point in the designed measurement geometry of the system that will limit the capabilities of DU fragment detection beyond that for which it has been calibrated. During a full-scale demonstration run, processing speeds of nearly 45,359 kg (50 tons) per hour were achieved. At this process speed, the system was able to divert less than 50 kg of soil per single DU fragment diversion. Based on the site-specific soils tested during the pilot study, the *ScanSort*^{SM} system is estimated to produce a contaminated soil volume reduction of greater than 90%.

REFERENCES

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3. USACE, 2013b, *Final Status Survey Plan for the FUSRAP Areas at the Iowa Army Ammunition Plan*, Middletown, Iowa, February.