TECHNICAL EVALUATION REPORT
U.S. NRC Staff Evaluation of the U.S. Army's Plant Sampling Plan for Depleted Uranium from the M101 Spotting Round

License No. SUC-1593
Docket No. 040-09083
U.S. Army Installation Management Command

U.S. Nuclear Regulatory Commission

Office of Federal and State Materials and Environmental Management Programs

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1.0 Introduction

On October 23, 2013, the U.S. Nuclear Regulatory Commission (NRC) issued source material license SUC-1593 to the U.S. Army Installation Management Command (Army) to allow the possession of depleted uranium (DU) from the Davy Crockett M101 spotting round (Agency Document Access and Management System (ADAMS) Accession No. ML13259A062). License Condition 23 of SUC-1593 states: "The licensee shall provide a plant sampling plan to the NRC within 90 days of [effective date of this license] for review and approval. Until the plant sampling results are approved by NRC, the licensee will conduct activities on the ranges in accordance with previously approved restrictions and provisions." On January 15, 2014, the Army submitted a plant sampling plan in accordance with License Condition 23 (ML14027A075 and ML14027A076) of source material license SUC-1593. This Technical Evaluation Report (TER) summarizes the NRC staff's review of the Army's plant sampling plan and assesses the Army's compliance with the applicable requirements of 10 CFR Part 40 "Domestic Licensing of Source Material" and 10 CFR Part 20, "Standards for Protection Against Radiation."

2.0 Summary and Conclusions

The NRC staff has reviewed the Army's plant sampling plan, and finds that the plan is adequate to determine if DU contamination in soil has bio-accumulated in vegetation or settled on the surfaces of the vegetation in the Radiation Control Area (RCA) at Schofield Barracks. In the staff's view, provisions in the current plan for the additional collection of washed and unwashed plant samples at Schofield Barracks will provide the data that is needed to demonstrate that residual DU from the M101 Davy Crockett spotting rounds is not hazardous to the personnel at the Pohakuloa Training Area (PTA) or Schofield Barracks or the public. The NRC staff accepts the vegetation sampling plan, with noted comments, contingent on Army's ability to adequately address the NRC staff comments with regards to the methodology for determining sample locations and approach to sample preparation in the documentation of sampling results.

3.0 Background

During the 1960s, the Army manufactured spotting rounds for the Davy Crockett Weapon System at the Frankford Arsenal in Philadelphia, Pennsylvania under license SUB-307 issued by the Atomic Energy Commission (AEC), the NRC's predecessor agency, and AEC/NRC License SUB-459. These licenses allowed the Frankford Arsenal to produce the spotting rounds and distribute them to various Army installations for testing, training and deployment. The spotting round was fired from a small rifle attached to the underside of the main recoilless rifle and was used to simulate the flight path of the main munition of the Davy Crockett Weapon, which was a low-yield battlefield nuclear device. It is important to note that the spotting round was not an atomic explosive. Rather it consisted of a nosecone, a DU body (containing about 6.2 ounces of depleted uranium), and an aluminum tail assembly. The nosecone of the M101 version of the spotting round contained a small amount of explosive that produced a "puff" of smoke to allow the solider to locate the impact point of the spotting round. Other versions, such as the XM106, did not have an exploding nosecone. M101 rounds were distributed to various Army installations for training purposes. At the request of the Army, License SUB-459 was allowed to expire in April 1978 (ML111080529).

Between 1962 and 1968, the Army received and used DU (which the NRC licenses as source material) in spotting rounds, at firing ranges at various installations, including Forts Benning and Gordon (Georgia), Forts Campbell and Knox (Kentucky), Fort Carson (Colorado), Fort Hood (Texas), Fort Lewis (currently called Joint Base Lewis-McChord) and the Yakima Training Center (Washington), Fort Bragg (North Carolina), Fort Polk (Louisiana), Fort Sill (Oklahoma), Fort Jackson (South Carolina), Fort Hunter Liggett (California), Fort Greeley (Alaska), Fort Dix (New Jersey) and Fort Riley (Kansas). As a result, DU was scattered throughout a limited number of ranges used for Davy Crockett Weapon system practice/qualification. According to information provided by the U.S. Army, the Army discontinued firing these spotting rounds in Hawaii in 1968 (ML13259A081).

In August 2005, the Army identified the remnants of a DU round at the Schofield Barracks, HI installation (ML070650224). During a controlled grass burn of the range in the summer of 2006 the Army discovered several additional DU fragments. In November 2006, the Army notified the NRC that it had discovered the DU fragments at the Army's Schofield Barracks, HI installation (ML070650224). From November 2006 through February 2007, the NRC and Army staff discussed the presence of the DU at the Schofield Barracks (ML070650224). In February 2007, the Army sent a letter to the NRC outlining its investigation of the DU and stated that it may need a license to possess the DU (ML070650679). The Army also suggested that, before submitting a license application, it determine the total number of installations that might contain DU from the Davy Crockett weapons system. In March 2007, the NRC staff sent a letter to the Army stating that the Army's approach was reasonable (ML070710239).

On November 6, 2008, the Army submitted a license application to the NRC for a possession only license for DU (ML090070095). Between November 2008 and October 2013, the Army and NRC staff discussed numerous technical issues associated with the licensing of DU from the M101 spotting round. The Army provided additional information regarding the environment at the Army's Hawaiian installations and submitted revisions to the radiation safety plan for the installations (see the Safety Evaluation Report at ML13259A081). Based on the additional information, and discussions between the NRC and Army staffs, the NRC issued a license to the Army for the possession of DU from the M101 spotting round at the Army's Hawaiian installations on October 23, 2013 (ML13259A062). To support the NRC staff's evaluation of the Army application, and the additional information submitted by the Army to support the application, the NRC staff documented its review in a Safety Evaluation Report (SER) (ML13259A081). Section 3 of the SER discusses the NRC staff's evaluation of the Army's environmental monitoring program. Section 3.4.2 of the SER provides the NRC staff's assessment of the Army sites with respect to biota monitoring and states: "The NRC staff has concluded the Army has not presented sufficient justification for not performing vegetation sampling at the sites."

Section 3.4.2 of the SER further states:

> The NRC staff finds that the lack of vegetation at PTA, the limited amount of M101 Davey Crockett munitions artifacts observed annually, and the hazardous terrain within the PTA impact area is sufficient justification for the Army not to sample vegetation at PTA. However, the staff review of the Army's contractor prescribed burn study at Schofield Barracks finds that the contractor incorrectly concluded that the

vegetation ash samples from the DU contaminated area on the range was incorrect. The contractor collected vegetation ash samples after the burn of the vegetation growing in soils containing visible DU oxidation products (US ARMY, 2008). The contractor intended to collect the vegetation ash separated from the contaminated soils in aluminum pans, but was unable to collect the vegetation ash samples separately from the contaminated soils. The contractor concluded that the DU measured in one of the vegetation ash samples from the contaminated area resulted from uptake (US ARMY, 2008). The NRC finds that the DU measured was probably from the DU oxidation products that were present in the soil before the burn. Additionally, vegetation samples should be split into washed and unwashed partitions before analysis to determine if any DU present is a result of uptake, adsorption, or deposition from wind or surface waters.

In the SER, the NRC staff concluded that the Army should collect additional plant samples to demonstrate that residual DU from the M101 Davy Crockett spotting rounds is not hazardous to the personnel at PTA or Schofield Barracks or to the public.

This requirement was included as License Condition 23 in source material license SUC-1593.

4.0 Staff Evaluation

4.1 Regulatory Requirements:

The following regulations apply to the Army's vegetation sampling plan:

10 CFR Section 20.1101(b) and (d) establishes as low as is reasonably achievable (ALARA) requirements and limits the annual dose to the public from air emissions;

10 CFR Sections 20.1501 and 20.1502 provide survey and monitoring requirements and details on conditions requiring individual monitoring of external and internal occupational dose;

10 CFR Sections 20.1801 and 20.1802 establish requirements to maintain security and control of licensed material;

10 CFR Sections 20.2201- 20.2207 provide reporting requirements related to incidents, exposure monitoring, and theft/loss of materials and transactions involving nationally tracked sources; and

10 CFR Section 40.41 establishes the Commission's authority to incorporate conditions in source material licenses issued by the Commission.

4.2 Regulatory Acceptance Criteria:

The application was reviewed for compliance with the applicable requirements of 10 CFR Part 20 and 10 CFR Part 40.

4.3 Staff Review and Analysis:

Section 1 of the vegetation sampling plan states that the purpose of the plan is to determine if vegetation has DU bioaccumulation and/or surface contamination from DU in contaminated soils in the radiation controlled areas (RCA) at Schofield Barracks. The plan states that the licensee's contractor will collect samples of roots, leaves, and rinsate from leaves and analyze the samples using alpha spectroscopy by an accredited laboratory.

Section 2 of the plan provides the Data Quality Objectives (DQOs) for the vegetation-sampling plan and establishes the following technical parameters for the DQOs:

- The principal question is whether DU is present in or on vegetation at Schofield Barracks; and

- The licensee will analyze vegetation samples for isotopic uranium using alpha spectroscopy, results with the ratio of uranium 238 (U-238) to uranium 234 (U-234) exceeding three will be used to identify the presence of DU.

Section 2.3.1 states that there is limited potential for uranium uptake by plants. Uranium is a heavy metal that is toxic to many organisms and that uranium in its metal form would not be available for uptake by plants.

Section 2.3.2 identifies DU that may be present in vegetation as the radionuclides of concern and states that results of monitoring conducted during the previous controlled burns were used to develop the vegetation-sampling plan. Vegetation at the site is primarily grass and brush and that DU in vegetation can only be present in roots, stems, or leaves and in soil particles attached to plant roots or as particulates deposited on leaves. Section 2.3.3 establishes the action levels for the vegetation-sampling plan at uranium activity results that exceed the critical value based on instrument background and count time. The a priori laboratory alpha spectroscopy detection limit for DU is 0.1 pCi/g (0.0037 Bq/g) of ash (g_{ash}) and a ratio of U-238 to U-234 greater than three indicates the presence of DU.

Section 2.4 describes the study areas as Area 6 within the Schofield Barracks RCA as well as a reference area used in the 2007 effluent sampling event. Samples will be collected from areas that are 10 m^2 within the RCA that indicate elevated gamma radiation as measured with a Field Instrument for the Detection of Low Energy Radiation (FIDLER) probe. An area outside the RCA will be surveyed using the same instrument to establish that the reference area outside the RCA is free of DU contamination.

Table 2-2 in Section 2.5 describes the decision rules for evaluating the gamma survey data to decide whether or not to collect samples. For Area 6, if the average reading exceeds 12,000 cpm, or if the average readings are less than 12,000 cpm but greater than three standard deviations above background, samples are collected from that area. Soils are expected to contain significant concentrations of DU where readings exceed 12,000 cpm and to likely contain DU with readings less than 12,000 cpm, but greater than three standard deviations above background measurements. The reference area samples are collected from 10 m^2 areas where average readings are below 12,000 cpm. FIDLER readings below 12,000 cpm in the reference area are expected to not contain DU activity in soil.

Section 3 of the plan describes the survey design, which consists of collection and analysis of vegetation samples from areas where the licensee would expect DU contamination and a contamination free sampling location within an identified reference area. Sampling locations have been identified within Area 6 of the RCA from previous FIDLER survey results and the licensee will collect one additional sample from the reference area used in the 2007 effluent monitoring event. The licensee will identify the northing and easting coordinates with a Global Positioning System (GPS).

Section 3.4.1 states that the licensee will collect four types of samples from each 10-square meter area sample location. The four samples will consist of a washed root sample, washed and unwashed leaf samples, and a washed leaf rinsate sample. The licensee will collect one-gallon (3.78 L) samples of vegetation and roots from each 10-square meter area using a trowel or similar equipment to collect as much of the root system as possible. The licensee will wash and drain the root system prior to placement in sample bags. The licensee will split the leaf samples such that it bags one-half as is and washes the other half with distilled water collecting the rinsate in a separate sample. The licensee will collect a minimum of approximately one liter of rinsate in containers provided by the analytical laboratory.

Section 3.4.3 describes the sampling and analyses quality control and states that the licensee will collect plant samples from a non-impacted background reference area to confirm the quality of sampling and analysis techniques. The licensee will also collect a duplicate sample from at least one of the impacted sample locations that will include all four of the sample types and a field blank consisting of the distilled water used in the rinsate. The licensee will provide these samples to the analytical laboratory for alpha spectroscopy analysis and will maintain quality control by not identifying the duplicate and field blank samples to the analytical laboratory.

Figure 3-1 of the plan illustrates the survey and vegetation sampling locations.

Section 4 describes sample preparation and analysis. The licensee will have the samples analyzed for isotopic uranium using alpha spectroscopy. The licensee will use an analytical laboratory certified by the Department of Defense Environmental Laboratory Accreditation Program. The licensee will maintain chain of custody for the samples. The analytical laboratory will weigh the samples, ash the samples to remove organics, and re-weigh the samples. The samples will be dissolved and an aliquot of the sample will be analyzed. The laboratory will analyze the rinsate samples without filtering the samples. The laboratory will purify the sample, recover the uranium from other elements in the sample, and analyze the sample by alpha spectroscopy.

Section 5 describes the recordkeeping and reporting for the vegetation-sampling plan and the quality control procedures that the Army will use during the vegetation sample collection and analysis. It states that the licensee will record visual observations in field logbooks and document photographs in a logbook or electronic photo log. The licensee will electronically store location-coordinated gamma radiation measurements made with the FIDLER. The licensee will include the easting and northing coordinates in feet, the count per minute (cpm) FIDLER readings, the date, and the time of the measurement in the electronic file. The licensee will fill out chain of custody forms for each day samples are collected.

Section 6 describes the quality control requirements of the sampling plan. Visual observations will be documented to describe the sample location and vegetation collected along with the date and initials of the person recording the information in the logbook. The licensee will use instruments calibrated within the past year to collect field measurements and maintain copies of the calibration documentation onsite. The licensee will perform instrument calibration checks at the beginning and end of each day the instrument is used, and background checks to ensure that the instrument is not broken or contaminated. The licensee will maintain calibration documentation in electronic logs. The licensee will document the results of the operational checks in an electronic file with the instrument reading, date, and time. The licensee will maintain a time-series plot of the measurement results to visually compare the operational checks with established warning and control limits. The licensee will investigate results that are outside the control limits by repeating the measurement and will remove the instrument from use if results continue outside the control limits until the licensee determines and resolves the problem.

The analytical laboratory will not split samples to obtain duplicates in order to ensure that the laboratory obtains the maximum analytical sensitivity.

4.4 Evaluation Findings:

The NRC staff reviewed the purpose in Section 1 of the vegetation-sampling plan. The NRC staff determined that it addresses the NRC staff condition that additional collection of washed and unwashed plant samples at the Schofield Barracks be conducted in order to provide the data needed to demonstrate that residual DU from the M101 Davy Crockett spotting rounds is not hazardous to the personnel at PTA or Schofield Barracks or the public.

The NRC staff reviewed the DQOs for the vegetation-sampling plan and the technical parameters in Section 2 of the plan. The question posed by the plan is consistent with the concern raised by the NRC staff in the SER developed to support the issuance of source material license SUC 1593 (NRC, 2013). In the SER, the NRC staff found that the Army provided insufficient justification for not performing vegetation sampling at the sites and cited a study conducted by Los Alamos National Laboratory (LANL) using environmental data collected from Aberdeen and Yuma Proving Grounds (APG, YPG) that appeared to contradict the Army's assertion that there is no chance of bioaccumulation of DU in plants (Ebinger, 1996). LANL detected DU in vegetation, such as cattail, milfoil, and pickerel weed in shallow ponds and catchment basins at APG. LANL concluded that DU uptake, attachment, or adsorption in the plants occurred from dissolution of DU from DU fragments in the surface water sediments rather than from transport of DU deposited in the soils (Ebinger, 1996).

The NRC staff found that the lack of vegetation at PTA, the limited amount of M101 Davey Crockett munition artifacts observed aerially, and the hazardous terrain within the PTA impact area is sufficient justification for the Army not to sample vegetation at PTA. However, the NRC staff's review of the Army's contractor prescribed burn study at Schofield Barracks (Cabrera Services, 2008) found that the contractor incorrectly concluded that the vegetation ash samples contained DU from the plant. In this study, the contractor collected vegetation ash samples after the burn of vegetation growing in soils containing visible DU oxidation products. The contractor was unable to collect the vegetation ash separately from the contaminated soils and concluded that the DU measured in one of the vegetation ash samples from the contaminated

area resulted from uptake (Cabrera Services, 2008). The NRC staff hypothesized that the DU measured was more likely from the DU oxidation products that were present in the soil before the burn and that the vegetation samples should be split into washed and unwashed partitions before analysis to determine if any DU present is a result of uptake, adsorption, or deposition from wind or surface waters. Therefore, based on the staff's evaluation of the 2007 burn study, the staff determined that the Army must demonstrate whether or not there is DU uptake in plants and that the limited amount of DU in the PTA and Schofield ranges is insufficient to cause adverse impacts.

Establishing action levels at uranium activity results that exceed the critical value based on instrument background and count time is an appropriate approach because review of the LANL data leads one to expect that any uranium concentrations measured will be near background concentrations. The analytical technique, alpha spectroscopy, is an appropriate method for the analysis of uranium isotopes. The Army correctly characterized the radionuclides of concern as depleted uranium and the study area described in the plan, Area 6 within the RCA, is appropriate to determine if DU oxidation products in soils are available for uptake or deposition on plants.

The activity ratios cited in the plan are consistent with those established in License Condition 24 of SUC-1593. The Measurement Quality Objectives (MQOs) established in the plan are consistent with typical MQOs for analyses using alpha spectroscopy and the quality assurance objectives are appropriate and typical of those established for environmental surveys.

However, the staff notes that it finds that the Army's description of previously found artifacts at Schofield Barracks in the plan's Section 2.3.1 may be somewhat inconsistent with previous reports submitted by the Army. Although the Army described fragments as being relatively intact in Section 2.3.1 of the vegetation-sampling plan, the Army previously had submitted a Technical Memorandum prepared by Cabrera Services that reported that in the scoping investigation conducted at Schofield Barracks it found oxidized DU fragments and observed small oxidation products in soils at Schofield Barracks (Cabrera Services, 2008).

According to this Cabrera Services' report describing the scoping survey conducted in 2007, the survey team observed yellow metal fragments less than one square centimeter (cm^2) and bright yellow soil that measured elevated gamma radiation with the Ludlum Model 2221 scaler/rate meter with a FIDLER probe at the Schofield Barracks. Isotopic analysis of bright yellow colored soil indicated the presence of DU and showed that U-234 concentrations were significantly less than U-238 concentrations. As described in the LANL study at APG and YPG, dissolution of DU oxidation products in soils by surface runoff can result in DU uptake, attachment, or adsorption in the plants (Ebinger, 1996). Because DU was only detected in plants at APG that were collected in shallow ponds and catchment basins containing DU oxidation products rather than soils within the impact area, LANL concluded that the DU measured in plants resulted from dissolution of DU from DU fragments in the surface water sediments rather than from transport of DU deposited in the soils.

The Army states that its objective in monitoring vegetation is to determine if vegetation has DU bioaccumulation and/or surface contamination from DU in contaminated soils in the RCA at Schofield Barracks. Table 3-1 and Figure 3-1 in the plan illustrate the potential sampling locations. These potential sampling locations were identified using results from a previous

gamma survey. The Army identifies two primary sample locations, each with two alternate locations. The Army plans to resurvey areas that previously indicated elevated gamma radiation readings in Area 6 within the Schofield Barracks RCA to select final sampling locations. It is unclear if the Army's gamma survey associated with this sampling plan will be limited to the six total potential sample locations (two Primary and four Alternate locations). The Army expects areas with average FIDLER readings exceeding 12,000 cpm to contain significant concentrations of DU in soil while areas with average FIDLER readings exceeding background by more than three standard deviations are likely to contain soil with DU concentrations above background. It is unclear if the Army will sample from both the Primary and Alternate locations if elevated gamma readings are found in all locations. The Army plans to select the reference sampling area with an average FIDLER reading less than three standard deviations above background. However, Table 2-2 of the plan allows the Army to collect vegetation from a reference area as long as the average survey reading is less than 12,000 cpm. Given the ambiguities present in Table 2-2, the staff finds that the Army should include in the documentation of the sampling results a clear description of the methodology used for determining the final sample locations.

At each final sampling location selected (10 m^2 area), the Army plans to collect four sample types: a washed root sample, washed and unwashed leaf samples, and the washed leaf rinsate. The Army plans to collect one-gallon (3.78 L) samples of vegetation and roots using a trowel or similar equipment to collect as much of the root system as possible. The Army plans to collect the rinsate in one-liter containers provided by the analytical laboratory. The NRC staff finds the survey method of choosing the sampling locations, sample collection, and sample size sound because: (i) previous and planned FIDLER surveys help to identify soils potentially containing DU oxidation products, (ii) analysis of washed and unwashed samples will differentiate between uptake and surface deposition in samples measuring DU, and (iii) the sample should be as large as practicable to obtain low detection limits. Factors that affect the detection limits are the counting efficiency, the quantity of sample, the counting time associated with the standard error of the net count rate, and the background (IAEA, 1989). In order to obtain low detection limits, the analytical efficiency should be high, the sample should be as large as possible, the counting time should be as long as feasible, and the background should be as low as attainable.

The NRC staff reviewed the Army's plans for sample preparation. The Army will be storing the vegetation and root samples in one-gallon plastic ziplock bags. The Army will remove the air from the bag before sealing, and the Army states the bags will be put on ice prior to transport to the laboratory. However, the Army is not specific as to the amount of time that may lapse between the samples being placed in bags, and when they will be stored on ice. Given the hot climate in the area, the NRC staff is concerned about the potential for sample degradation prior to shipment. Therefore, in the documentation of the results, the Army should clarify the sample preparation and explain any potential impacts resulting from sample preparation.

The NRC staff finds the Army's plans for sample analysis consistent with industry best practices. The Army states that it will ship samples collected using chain of custody forms to a laboratory accredited by the Department of Defense Environmental Laboratory Accreditation Program for isotopic uranium analysis using alpha spectroscopy. The laboratory will check the samples received against the chain of custody for accuracy of information and any discrepancies will be resolved prior to reporting the results to the Army. The Army states that

the laboratory will weigh, ash, and reweigh vegetation samples upon receipt and analyze rinsate as received. The laboratory will dissolve samples, excluding the rinsate, and purify the samples and separate uranium from other elements in the samples. The laboratory will conduct isotopic analysis by alpha spectroscopy. The laboratory will report vegetation and rinsate sample activities per gram of ash weight (e.g., pCi/g_{ash}) and per liter of rinsate (e.g., pCi/L), respectively.

The laboratory will avoid splitting samples in order to maintain a large sample size and to improve the detection capability, as discussed above. To maintain quality control, the Army plans to provide blanks and duplicate samples to the laboratory. The NRC staff finds this procedure practical and consistent with industry best practices.

The NRC staff finds that the record keeping as described in Section 5 of the plan, and the manner in which the Army proposes to maintain the records, are adequate to provide documentation of the vegetation-sampling program results. In many cases, most of the detected radioactivity associated with plants is found in the soil deposited on the plant surface. Rain can increase the concentration by splashing soil onto the plant and wind can deposit dust onto the plant surface. Therefore, the staff recommends that additional relevant information, e.g., recent weather or rainfall, should also be recorded. The NRC staff notes that in Section 5.1.5, the following sentence pertains only to air sampling and therefore should be deleted: "Under the comments section, the volume will be included for each air filter." The Army and laboratory will maintain chain of custody for all samples. Calibration and source check procedures are consistent with NUREG-1556, Volume 7, Section 8.10.2.

5.0 References

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