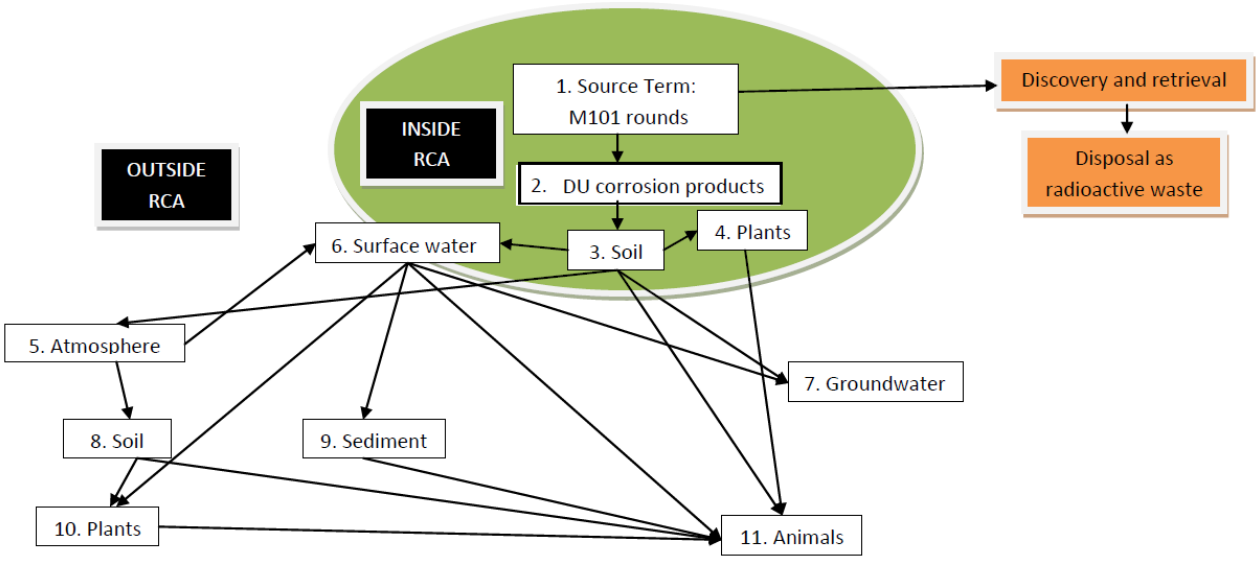
Programmatic Approach for Preparation
of Site-Specific Environmental Radiation Monitoring Plans

1. Introduction

The purpose of this document is to provide guidance to garrison personnel on the design of site-specific environmental radiation monitoring plans (ERMPs). The Nuclear Regulatory Commission (NRC) requires the Army to develop and implement these plans at every garrison named on NRC license number SUC-1593, which the NRC issued to CG IMCOM.

The purpose of a site-specific ERMP is to describe the environmental radiation sampling program to detect M101 spotting round depleted uranium (DU) leaving the radiation control area (RCA). The plan explains, for a specific RCA, which environmental pathways require evaluation, which samples will be taken for those



Pathway	Comment
1→2	Rate of oxidation (corrosion) depends on environmental conditions in RCA
2→3	Oxidized uranium becomes part of soil matrix in immediate vicinity of M101 round in RCA
3→4	Plants in RCA uptake oxidized uranium
3→5	Soil windblown from RCA
3→6	Water flowing through RCA erodes soil and carries it outside RCA, or precipitation dissolves oxidized uranium and carries it to surface water flowing away from RCA
3→7	Precipitation dissolves oxidized uranium and seeps into groundwater
3→11 8→11	Animals ingest soil containing oxidized uranium
4→11 10→11	Animals ingest DU-affected plants (or animals ingest other animals that ingested DU-affected plants) and proceed outside the RCA
5→6	Windblown soil deposits on surface water outside RCA
5→8	Windblown soil deposits on soil outside RCA
6→7	Surface water with dissolved oxidized uranium seeps into groundwater
6→9	Surface water carrying oxidized uranium (in suspended soil or in solution) transfers it to sediment
6→10	Plants outside RCA and adjacent to stream uptake dissolved oxidized uranium
6→11	Animals drink surface water containing dissolved oxidized uranium
8→10	Plants outside RCA uptake soil containing oxidized uranium
9→11	Animals ingest sediment that contains oxidized uranium

Figure 1 Environmental Pathways for M101 depleted uranium leaving a radiation controlled area

evaluations, where these samples will be taken, how often these samples will be taken, and how these samples will be analyzed for DU.

Figure 1 shows generic environmental pathways (depicted by arrows) that DU could follow from inside the RCA (inside the shaded oval) to outside the RCA (outside the shaded oval). Rectangles inside the shaded oval depict media in which DU resides inside the RCA. Rectangles outside the shaded oval depict potential sample media outside the RCA.

2. Risk Assessment

According to the "standardized Army risk matrix" (US Army 2014a), entry into an area know to contain unexploded ordnance (UXO) involves "high risk."[1] "High risk" means "… high potential for serious injury to personnel … if hazards occur during the mission. This implies that, if a hazardous event occurs, serious consequences will occur. The decision to continue must be weighted carefully against the potential gain to be achieved by continuing this [course of action]" (US Army 2014a).

Entry into a UXO area requires support from explosive ordnance disposal (EOD) personnel.[2] While EOD support mitigates the risk of entry into a UXO area, it does not eliminate the risk.

The "potential gain to be achieved" by collection of environmental radiation samples in a UXO area is knowledge of the concentration of DU in samples of soil, water, air, or biota in the UXO area. However, according to results of RESRAD calculations,[3] it is almost certain that laboratory results from analyses of these samples will indicate DU concentrations (if any DU is detected at all) and implied average annual doses that are far below NRC standards. That is, the potential gain is minimal.

Therefore, collection of environmental radiation samples in UXO areas generally will not occur. Exceptions will occur only with documented consultation among the License Radiation Safety Officer, garrison safety personnel, and range control personnel, who will advise the garrison commander (that is, they will prepare a formal risk assessment (US Army 2014a)). The garrison commander will then decide whether to allow the collection.

[1] From Table 3-3, Standardized Army risk matrix, in DA PAM 385-63 (US Army 2014a): [*Severity* (expected consequence) = Catastrophic (Death, unacceptable loss …) vs. *Probability* (expected frequency) = Seldom (infrequent occurrences)] → *H* = "high risk."

[2] "Access into temporary and/or dedicated impact areas will be strictly controlled. Those portions of temporary and dedicated impact areas authorized for training or other authorized purposes will be surface cleared of UXO before access is permitted." (US Army 2014b)

[3] See "Bounding Calculations Using RESRAD 7.0 and RESRAD-OFFSITE 3.1," which is included with this license amendment application.

3. Principles

Each garrison named in the license will produce a site-specific ERMP following the guidance in this document. The ERMP will describe:

- why each potential sample media is or is not being sampled,
- how many samples will be taken of each media,
- how often the samples will be taken,[4]
- where these samples will be taken, and
- why those locations were chosen.

Each garrison will provide a site-specific ERMP for each RCA to the License Radiation Safety Officer (RSO) within six months of the date of the NRC's approval of this document.[5] The License RSO will review those ERMPs and ask for changes or corrections, as necessary. The Garrison and License RSO will work together to produce final ERMPs within the next six months. The Garrison will retain these final ERMPs and begin immediate implementation of them. The ERMPs and their implementations are then subject to NRC inspection.

The NRC issued the Davy Crockett M101 spotting round legacy DU license to Commanding General, US Army Installation Management Command (IMCOM). Therefore, the garrison will bear all costs for preparation and implementation of the ERMP and for collection, shipping, and radiochemical analyses of environmental samples. As necessary, the garrison should request funding for these costs through the usual channels in the usual way from HQ IMCOM.

The ERMP will include the name and contact information for each radiochemistry laboratory used for analysis and a protocol for sampling each type of media.[6]

The ERMP will include criteria for adjusting sampling. The adjustments could be to increase or reduce number of sampling locations or to increase or reduce the sampling frequencies. Decisions to make adjustments will consider, for example, previous results of sampling, changing environmental conditions, and increased understanding of environmental hazards.

Although natural uranium is ubiquitous, DU, which is depleted in uranium isotopes uranium-234 (^{234}U) and uranium-235 (^{235}U) relative to natural uranium, does not occur in nature. Hence, background reference areas and background sampling for DU is unnecessary.

Each ERMP will include the statement (USNRC 2013), "When analytical sampling results from locations outside of the Radiation Control Area indicate that the U-238/U-

[4] Samples at each location will be taken at least annually but should be taken more often (semiannually or quarterly) if seasonal variations are prevalent.
[5] The approval will be in the form of an amendment to NRC License Number SUC-1593.
[6] The radiochemistry laboratory to which samples will be sent should provide definitive information about how it wants the samples taken, packaged, and shipped.

234 activity ratio exceeds 3, the licensee shall notify NRC within 30 days and collect additional environmental samples within 30 days of the notification of NRC, unless prohibited by the absence of the sampling media."

The ERMP will show the distance and direction to the nearest normally occupied areas (for example, residential areas, commercial areas, and business areas) for each RCA at that installation. The ERMP will provide a description/narrative of the physical environment of each RCA on that installation.

The License Radiation Safety Officer and Army Environmental Command (AEC) personnel will assist and guide the production of these ERMPs. The License RSO, in consultation with AEC personnel, will approve each site-specific ERMP before it becomes effective.

Each garrison named in the license will implement its site-specific ERMP upon License RSO approval. Assume that the NRC will inspect ERMPs and results of implementing ERMPs during its site inspections.

Garrisons are not in isolation regarding their ERMPs and sampling programs. The License RSO will identify "best practices" and provide them to all the M101 spotting round-affected garrisons. Garrisons can obtain additional guidance from AEC, which has pledged to support license activities.

If results of sampling certain media over time for an RCA indicate that M101 spotting round DU is not migrating outside the RCA into that media, the License RSO may ask the NRC to relieve the Army from continued sampling of that media or to allow reduced sampling frequency of that media.

This document cannot address every environmental circumstance at every installation. Local information and data should be incorporated in site-specific ERMPs. In particular, the Army Operational Range Assessment Program (ORAP 2013) has produced environmental data for many ranges.[7] The garrison should refer to relevant ORAP reports for its M101 spotting round-affected ranges.

4. Inside the RCA

Each RCA is within a larger impact area that is part of an Army training area or range facility. Generally, RCAs are open, grassy areas, but young trees and large undergrowth could be present. Their minimum distances from normally occupied areas outside the training area or range facility depends on the type of munitions used in the large impact areas, but typically are a few kilometers.[8]

Given the purpose of an ERMP, sampling will not usually be performed inside the RCA.

[7] The License RSO has asked and ORAP has agreed to continue to produce environmental uranium data for its reports even when ORAP's protocols indicate that uranium should not be a contaminant of concern.
[8] For specific information on range safe distances, see DA PAM 385-63 (US Army 2014b).

a. M101 spotting rounds

The original source of DU contamination is M101 spotting rounds fired into an impact area, which is now an RCA. Upon impact, these rounds remained intact or mostly intact on or near the surface of the RCA. It is not known for any RCA, except for part of the RCA at Schofield Barracks (Cabrera 2013), whether a cleanup or retrieval of these rounds ever occurred, so the assumption is that most, if not all, the DU in rounds fired into an RCA remain in the RCA in some form.

Any M101 spotting round DU removed from the RCA in accordance with the guidance in the Radiation Safety Plan will be held for proper disposition as radioactive waste.

No conditions require collection or sampling of DU metal alloy in the RCA.

b. Pathway: M101 spotting rounds → DU corrosion products

The rate of corrosion of the DU in the DU-molybdenum alloy in the M101 spotting rounds left in the environment is not known. A contractor working at Schofield Barracks in 2012 found both contaminated soil and solid DU fragments (Cabrera 2013).

An Army contractor working on the Jefferson Proving Ground (JPG) decommissioning project for DU penetrators consisting of DU-tungsten-carbide alloy reported (SAIC 2013):

QUOTE

> Corrosion of DU penetrators and subsequent dissolution of the corrosion products is the primary mechanism for introducing DU into the soil and for subsequent transport to the media (e.g., surface runoff to surface water and sediment). The rates of corrosion and dissolution were determined based on laboratory testing and field observations for conditions similar to those experienced by the DU penetrators at the DU Impact Area. Based on this information, the most likely time to complete corrosion and dissolution of a JPG penetrator was calculated to be approximately 107 years.

UNQUOTE

Although M101 spotting rounds and DU penetrators have geometries and DU alloys that are different from the DU penetrators at JPG, the above observations imply that most M101 spotting rounds have not corroded completely since the Army fired them in the 1960s.

c. DU corrosion products

Corrosion products initially will be on the surfaces of M101 spotting rounds that are then subject to spalling. Sampling of corrosion products in the RCA is unnecessary.

No conditions require collection or sampling of DU corrosion products in the RCA.

d. Pathway: DU corrosion product → Soil

Corrosion products attach loosely to M101 spotting round surfaces. They gradually will leave those surfaces (spalling). Therefore, corrosion products will be present on and near the soil surface in an RCA.

e. Soil

The contractor at JPG observed (SAIC 2013), "… each penetrator or portion thereof served as a point source rather than forming a homogeneous mixture of DU in site soils." Analysis … of data obtained at Schofield Barracks during a characterization survey [(Cabrera 2008a)] showed that DU contamination was concentrated in specific locations in the surveyed area and that the rest of the surveyed area was at background concentrations of natural uranium.

An Army contractor reported (Cabrera 2008b), "The mobility and persistence of DU in the environment is influenced by the amount, form, and oxidation state of the metal, as well as by the composition and physicochemical properties of the affected media. In the metal form, DU tends to persist in the soil, and undergo few chemical changes other than oxidation due to weathering and exposure. [Figure 2] illustrates the appearance of Davy Crockett round fragments found at [Schofield Barracks]. Note the oxidized state (bright yellow) of the fragments. … The nature of the underlying soils, coupled with the relatively dry climate favors the retention and reduced solubility of metals, thereby reducing their mobility."

Durante and Pugliese wrote (Durante and Pugliese 2003), "… studies of radiological contamination in the soil from impacted DU rounds [in Bosnia in 1994 and 1995] suggest that dispersion and deposition are localized within 10 m from the hit target."

The Director of the NRC's Office of Nuclear Material Safety and Safeguards wrote, regarding environmental sampling in Vieques, Puerto Rico (Kane 2001):

QUOTE

> From May 29 to June 12, 2000, the U.S. Navy performed radiological surveys of the [Live Impact Area (LIA)]. … The surveys conducted by the U.S. Navy, and independently observed by the NRC, concluded that there were no elevated exposure rates or count rates indicative of radioactive contamination on areas of the LIA exclusive of the North Convoy Site, where the DU was fired during the February 19, 1999, incident. While observing the U.S. Navy survey activities between May 31 and June 12, 2000, the NRC staff also performed numerous surveys and collected soil samples. Soil samples were collected from the areas where DU penetrators had already been excavated. In addition, soil samples were collected downhill of areas known to have been impacted by the DU

Figure 2 Typical form of DU at Schofield Barracks (Cabrera 2008b)

> penetrators. … [A] purpose was … to determine whether the surrounding environment and members of the public had been exposed to DU.
>
> … The NRC Inspection Reports dated July 13, 2000, and September 28, 2000, document the performance and results of the environmental samples taken in June 2000. Copies of these reports are available in ADAMS (ML003767608 and ML003755565). The NRC samples demonstrated that there was no spread of DU contamination to areas outside of the LIA and that contamination from the DU inside the LIA was limited to the soil immediately surrounding the DU penetrators. With the exception of the soil samples taken from holes where the Navy had recovered DU penetrators, neither the direct measurement nor the environmental sample results identified the presence of radioactive materials exceeding those associated with naturally occurring radioactive materials routinely found in the environment.

UNQUOTE

A review of United Nations Environment Programme (UNEP) reports [(UNEP 2001) (UNEP 2002) (UNEP 2003)] (Papastefanou 2002) summarized those reports, “There was no detectable widespread contamination of the ground surface by depleted

uranium. This was in such low levels that it cannot be detected or differentiated from the natural uranium existing in soil globally. Detectable ground surface contamination by depleted uranium is limited to areas around and below penetrators and the associated points of concentrated contamination."

Uyttenhove et al. reported on independent measurements in Kosovo (Uyttenhove, Lemmens and Zizi 2002) and wrote, "Based on our [minimum detectable activity (MDA)]-considerations (and the experimental confirmation with calibration samples), we can state with good confidence that there is no DU present at our 50 sampling points in Kosovo, with MDA values as low as 15 Bq [corresponding approximately to a milligram of DU in a typical sample (100–150 g)]. Some samples, taken near places where DU-ammunitions were used, have been re-examined very carefully with extra long measuring times (27.8 h), always with negative results."

The Air Force did not find DU outside range boundaries at Eglin Air Force Base. As an NRC staffer (Spitzberg 2005) wrote, "The licensee sampled the environs of the site as part of the site characterization process. Radioactive material in excess of the NRC-approved [derived concentration guideline limits] was not identified offsite during … site characterization studies suggesting that the DU material, a heavy metal, was not migrating outside of the site boundary."

The US Army Environmental Policy Institute wrote (USAEPI 1995), "Investigations of DU migration at U.S. test sites have not identified significant migration in the environment."

An Army contractor that has performed environmental monitoring for DU at JPG for many years has never detected DU in soil or sediment samples outside the DU impact area. Reports dating back to 2005 are available on the NRC ADAMS website.[9]

The US Department of the Army Soldier and Biological Chemical Command (USASSBC) took sediment samples at JPG and reported (USASSBC 2002), "Sediment samples were collected at the same locations where surface water samples were obtained during the scoping survey. The total uranium concentration in sediment samples ranged from 0.88 to 1.09 pCi/g within the DU Impact Area. Along the firing line trajectories, the total uranium concentration in sediment was measured at 2 and 3 pCi/g along two different streams south of the DU Impact Area. The U-238 to U-234 activity ratio in the sediment samples collected during the scoping survey indicates that the uranium is naturally occurring."

Also for JPG in 1995, an Army contractor (Scientific Ecology Group 1995) reported that all results of samples taken in the impact area showed $^{238}U/^{234}U$ ratios less than three.

In 2010, the current License RSO performed an analysis of results in a contractor's characterization survey report for the RCA in the Battle Area Complex at Schofield Barracks (Cabrera 2008a). The results of his analysis (see the Appendix) showed that

[9] http://www.nrc.gov/reading-rm/adams.html

unbiased soil samples taken in the RCA contained only natural uranium. The contractor's report showed that biased samples contained both natural uranium and DU. A conclusion is that DU remains close to its point of original deposition in the RCA and is not likely to move outside the RCA in appreciable amounts.

An implication of the above is that M101 spotting round DU does not migrate readily in soil in many, if not almost all, cases. Once it becomes part of the soil matrix, it remains in the same soil matrix for many years.

Generic calculations (Cherry 2012) have shown that if in a typical RCA (a one-kilometer square) 1000 M101 spotting rounds have completely corroded with the corrosion products completely dispersed in the top 15 centimeters of soil, the resulting uranium activity concentration in RCA soil would be about 0.3 picocurie of DU per gram of soil (pCi/g).[10] This value is scalable for different RCA areas and different numbers of rounds.[11]

Table 1 is a derivation from Table 3.4 in National Council on Radiation Protection and Measurements (NCRP) Report No. 160 (NCRP 2009):

Table 1 Summary of soil concentration data for uranium

Natural Uranium in Soil	Mean	Median	Standard Deviation	5th Percentile	95th Percentile
Parts per million by weight	1.84	1.81	0.7	0.63	3.1
Activity concentration (pCi U/g soil)[a]	1.25	1.23	0.5	0.43	2.1

[a] Specific activity of natural uranium = 6.77×10^{-7} Ci U/g U

The table shows that typical the typical natural uranium concentration in soil (about 1.2 pCi/g) is about four times more than the typical DU activity concentration in RCA soil (about 0.3 pCi/g after complete corrosion and distribution in surface soil).

Sampling of soil in the RCA is unnecessary. We expect DU to be in RCA soil.

No conditions require deliberate collection or sampling of soil within the RCA.

f. Pathway: Soil → Plants in RCA

The following is an extract from Table 6.4 in Till and Grogan (Whicker and Rood 2008):

[10] According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) the normal concentration of uranium in soil is 300 micrograms per kilogram to 11.7 milligrams/kilogram (0.1 pCi/g to 3.9 pCi/g) (UNSCEAR 1993).

[11] The NRC's derived default screening level for decommissioning is 14 pCi DU/g soil (NRC 2006). For the derivation of this value, see "Arguments against Air Sampling during HE Fire into RCAs" included with this license amendment application.

Table 2 Typical plant/soil concentration ratios for selected elements and crops, adapted from the International Atomic Energy Agency (IAEA 1994)

Element	Crop	Concentration Ratio (dry mass basis)	
		Expected	Range (95%)
Uranium	Cereal grains	0.001	
	Fruits, tubers	0.01	0.0008 to 0.14
	Grass	0.02	0.002 to 0.2

Some plants, such as lichens, concentrate uranium in their tissues more than most plants do. For example, The USASSBC took vegetation samples at JPG and reported (USASSBC 2002), "Twenty vegetation samples were collected during the scoping survey using the same methods for soil sampling. Fourteen samples were obtained from within the DU Impact Area, and six samples were obtained along the firing line trajectories. The total uranium concentration in vegetation samples was less than 0.7 pCi/g in all samples. Two lichen samples from the south-central portion of the DU Impact Area had U-238 to U-234 activity ratios of 2.3 and 2.6, which indicate DU contamination."

The UNEP also detected DU in lichen in the three areas it surveyed [(UNEP 2001) (UNEP 2002) (UNEP 2003)]. According to UNEP, "This indicates that at least some of the penetrators at these sites hit hard targets and surfaces, partly aerosolized into dust, and dispersed into the air" (UNEP 2003). The M101 spotting rounds hit no such hard targets and surfaces, therefore no aerosolization occurred.

The above indicates that plant uranium concentrations are expected to be no more than about two percent of the uranium concentration in the soil where the plant is growing, except for plants such as lichens. However, the uranium concentrations in a plant could be as high as about 20 percent of the uranium concentration in the soil where the plant is growing.

g. Plants in RCA

Sampling of plants in the RCA is generally unnecessary.

The Army allows livestock (beef cattle) to graze in an RCA at Fort Hood. RESRAD bounding calculations[3] show that the maximum annual total dose to a resident farmer on the RCA at Fort Hood is about 0.14 millirem. The consumption of meat contributes less than 2 percent of that dose, or less than 0.003 millirem.

The calculations assumed that all meat that the resident farmer consumes derives from livestock grazing only in the RCA. In the case of Fort Hood, the livestock graze over a much larger area that includes the RCA, and consumers of that meat also consume meat from numerous other sources. The conclusion is that sampling plants in the RCA will provide little or no useful information.

No conditions require deliberate collection or sampling of plants within the RCA.

h. Pathway: Soil → Surface water in the RCA

The most common forms of uranium oxide are U_3O_8 and UO_2. Both oxide forms are solids that have low solubility in water and are relatively stable over a wide range of environmental conditions (Argonne National Laboratory n.d.). Triuranium octaoxide (U_3O_8) is the most stable form of uranium and is the form most commonly found in nature. Uranium dioxide (UO_2) is the form in which uranium is most commonly used as a nuclear reactor fuel. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

i. Surface water in RCA

Sampling of static surface water, such as water in a pond, entirely in the RCA is unnecessary.

No conditions require deliberate collection or sampling of surface water within the RCA.

5. Outside the RCA

a. Pathway: Soil → Atmosphere

RESRAD bounding calculations[3] show that the maximum possible ^{238}U air concentration for any site is about 1.3×10^{-4} pCi/m^3. However, the Army has found many M101 spotting rounds on RCAs that seem to be mostly intact with corrosion products in or on the soil in the immediate area adjacent to the round. This means that not all the DU in an RCA is available for suspension into the atmosphere. The expected ^{238}U air concentration due to dust will be much less than the maximum possible value.

For comparison, the NRC effluent standard for ^{238}U in air is 6×10^{-14} µCi/mL = 0.06 pCi/m^3 (NRC 2012), which is more than 450 times greater than the highest possible ^{238}U concentration in air due to DU in the soil.

The NRC did not require the Air Force to perform air sampling during DU remediation at a range at Eglin Air Force Base (Spitzberg 2005): "… perimeter sampling was only required at the discretion of the on-site radiation safety officer. The permittee planned to establish environmental controls to prevent erosion, to manage storm water runoff, and to minimize dust emissions. The permittee subsequently discontinued some of these environmental controls because reclamation activities had a minimal impact on the environment."

The NRC has never required the Army to perform air sampling at Jefferson Proving Ground since test operations ceased there in 1995. The NRC source materials license number SUB-1435[12] allows JPG to possess up to 80,000 kg of DU at a single site,

[12] ADAMS ML073030415

which is 14 times greater than the estimated total of all M101 spotting round DU at 16 Army installations.

The Army provided a contractor-prepared report to the NRC (Shia 2005),[13] which said "The assessments at [Jefferson Proving Ground], [Los Alamos National Laboratory], and [Aberdeen Proving Ground], among other sites indicate that risks associated with potential transport of DU in the air from controlled burns are negligible. The benefit/cost ratio of an air sampling program is extremely low (i.e., the benefits are small and the costs of the program high). Therefore, an air monitoring program is not recommended given the low probability of DU release and transport and the negligible effects on receptors."

The Enewetak Cleanup Project (1977-1980) was a joint DOD-Department of Energy (DOE) project to remove debris and radioactive contamination (mostly uranium and plutonium, not fission products) from the islands and lagoon of the atoll. Since both are actinides, uranium and plutonium behave similarly in the environment. The DOD operated air samplers whenever contaminated soil movements[14] were underway. The report of the project (Defense Nuclear Agency 1981) concluded, "Throughout the cleanup project, over 760,000 cubic meters of air were sampled on the controlled islands plus more than 211,000 cubic meters at Lojwa. Nearly 5,200 air samplers [sic] filters were analyzed by the lab. No significant airborne radioactivity of any type (including beta) was detected. It is clear from these results – as it was from resuspension experiments performed during early [Radiation Safety Advisory and Inspection Team] visits to the atoll – that the Enewetak contamination situation was not conducive to creation of a resuspension hazard."

The Environmental Protection Agency (USEPA 2006) says, "The amount of uranium in the air is usually very small and effectively insignificant for remedial operations. … The high density of DU in most particulate forms limits the air transport of DU to relatively small particles. … It is reported that most of the DU dust will be deposited within a distance of 100 meters from the source."

b. Atmosphere

Air sampling is generally unnecessary. Remedial actions, discussed above and which did not produce significant air concentrations, are not underway at any RCA. In addition, the NRC allowed high explosive testing throughout the JPG impact area, to include the DU impact area, without a requirement for air sampling.

The document, "Arguments against Air Sampling during HE Fire into RCAs," included with this license amendment application, presents four different arguments to

[13] ADAMS ML070090201
[14] "Movements" of Pu-contaminated soil included digging and scraping soil, pushing soil into windrows, loading soil into trucks, dumping soil from trucks into boats, transporting soil to the "storage" island, unloading soil from boats into trucks, dumping the soil at a plant for mixing with concrete, and dumping the mixture into a crater for disposal.

demonstrate that air sampling during HE detonations in a DU impact area is unnecessary and likely to be ineffectual.

No conditions require air sampling.

c. Pathway: Soil → Surface water flowing from the RCA

The most common forms of uranium oxide are U_3O_8 and UO_2. Both oxide forms are solids that have low solubility in water and are relatively stable over a wide range of environmental conditions (Argonne National Laboratory n.d.). The most stable form of uranium is U_3O_8, which is the form most commonly found in nature. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

d. Pathway: Atmosphere → Surface water

As discussed above, "The amount of uranium in the air is usually very small and effectively insignificant [even] for remedial operations" (USEPA 2006). Therefore, transfer from the atmosphere to surface water outside the RCA is also "effectively insignificant."

e. Pathway: Surface water in RCA → Surface water outside the RCA

The DU concentration in surface water outside the RCA that has flowed from the RCA should be about the same as that the concentration in the flowing water at the RCA boundary.

f. Surface water

The low solubility of uranium in water and the low concentration of DU in soil in the RCA compared to the concentration of natural uranium in soil make it improbable that DU is detectable in surface water. A slow flow rate makes detection more likely.

The Army and its contractors sampled surface water extensively at JPG over the last twenty years (SAIC 2013). The amount of DU at JPG is about 73,000 kg, whereas the largest amount of M101 spotting round DU at any one installation is 1843 kg at Fort Benning. Detection of DU in surface water at JPG occurred, albeit rarely and always well within NRC effluent limits and USAEPA drinking water standards.

If surface water routinely flows from the RCA, then sampling of this surface water will occur. If flow occurs throughout the year, then sampling will occur every three months. If flow is intermittent, then sampling will occur during that flow, but no less than three months apart.

g. Pathway: Soil → Groundwater

The DU concentration in groundwater depends on several factors, including distance of the groundwater from the soil surface, acidity/alkalinity of the soil and leaching water,

soil porosity, amount of precipitation, and so on. The Army has not measured most of the influencing factors for this pathway for any RCA.

h. Pathway: Surface water → Groundwater

The low solubility of uranium oxide in water and the low concentration of DU in soil in the RCA make it improbable that surface water contributions to DU in groundwater are significant.

i. Groundwater

Only existing wells potentially influenced by DU in the RCA will be sampled. The Army will create no new wells solely for the purpose of DU sampling because the cost-benefit ratio is highly unfavorable.

The Army will make available for NRC review upon request the results of all Army measurements of uranium concentration in groundwater that were taken with the purpose of meeting Safe Drinking Water Act requirements.

If existing wells potentially influenced by DU in the RCA are available, then whenever anyone samples these wells for any purpose, he or she will also require analyses for isotopes of uranium and report the results to the Garrison Radiation Safety Officer. Otherwise, no conditions require groundwater sampling.

j. Pathway: Atmosphere → Soil

Since the atmosphere is unlikely to carry more than barely detectable amounts of DU from inside to outside the RCA, this pathway will contribute virtually immeasurable amounts of DU to soil outside the RCA.

k. Soil

Soil sampling is generally unnecessary because DU contamination tends to remain in place in the RCA (see paragraph 4e). However, if a local condition indicates that massive erosion of soil from the RCA to areas outside the RCA has occurred, sampling the soil deposited due to that erosion will occur (following risk assessment if UXO is present).

If an area of soil greater than 25 m^2 eroded from an RCA is clearly discernible, then that deposit will be sampled semiannually with one sample taken per 25 m^2. No other conditions require soil sampling.

l. Pathway: Surface water → Sediment

Water flowing out of the RCA could carry DU-contaminated sediment. Sediment sampling at JPG has occasionally detected small amounts of DU in sediment inside the RCA, but never outside the RCA.

m. Sediment

If surface water sampling occurs, sediment sampling will also occur at the same time and near the same place. No other conditions require sediment sampling.

n. Pathway: Surface water → Plants

The DU concentration in surface water will be low if it is even detectable. However, some plants, such as lichens discussed above, can concentrate DU above ambient levels.

o. Pathway: Soil →Plants

The DU concentration in soil outside the RCA will be much lower than it is in the RCA, if it is even detectable. However, some plants, such as lichens discussed above, can concentrate DU levels.

p. Plants

No condition requires plant sampling.

q. Pathway: Soil → Animals

The DU concentration in soil outside the RCA will be much lower than that in the RCA, if it is even detectable. However, some animals could concentrate DU in their bodies above ambient levels.

The following is an extract from Table 6.8 in Till and Grogan (Whicker and Rood 2008) that demonstrates this possibility:

Table 3 Expected values for transfer coefficients (day/kg^{-1}) in various animal food products (IAEA 1994)[b]

Element	Beef	Pork	Poultry
Uranium	3×10^{-4}	6×10^{-2}	1

[a] The transfer coefficient TC is defined as TC = $C_{prod}(eq)/R$, where $C_{prod}(eq)$ is the measured equilibrium (activity per unit mass) in the product of interest at equilibrium and R is the radionuclide ingestion rate (activity per unit time), in this case the rate of entry into the mouth.

[b] See original source for other data and ranges of values

r. Pathway: Plants in RCA → Animals

Plants that herbivorous and omnivorous animals normally consume do not concentrate uranium above ambient levels, and neither do the herbivorous, carnivorous, and omnivorous animals themselves.

s. Pathway: Surface water → Animals

Depleted uranium concentrations in any water that animals consume are orders of magnitude less than the uranium concentrations that NRC effluent standards and EPA drinking water regulations limit. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

t. Pathway: Soil → Animals

Depleted uranium concentrations in any RCA soil that animals consume are, on the average, less than the default derived concentration guideline limits.[11] The DU concentration in soil outside the RCA is less than that for soil in the RCA. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

u. Pathway: Sediment → Animals

Depleted uranium concentrations in any RCA sediments that animals consume are, on the average, less than the default derived concentration guideline limits.[11] The average DU concentration in sediments outside the RCA is less than that for sediments in the RCA. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

v. Animals

The USASSBC took biological samples at Jefferson Proving Ground and reported (USASSBC 2002), "A total of eight biological samples were collected from deer, freshwater clams, fish, and a soft-shelled turtle. All of the biological samples from Big Creek were collected from the area adjacent to the DU Impact Area. The total uranium concentrations ranged from 0.091 pCi/g in deer liver to a maximum of 0.774 pCi/g in a freshwater clam. … The U-238 to U-234 activity ratio ranged from 0.4 to 1.2 and does not indicate the presence of DU contamination."

An Army contractor working at Jefferson Proving Ground wrote (SAIC 2013), "To evaluate the total effective dose equivalent (TEDE) associated with consumption of deer meat, a total of 132 tissue samples from 30 deer were collected and analyzed during the winter of 2005/2006. DU was not detected in any tissue sample during laboratory analysis."

No conditions require animal sampling.

6. Radiochemistry

Only accredited[15] laboratories will perform radiochemical analyses for the purposes of NRC license compliance. The laboratories will use alpha spectroscopy to analyze samples for ^{234}U and ^{238}U activities and concentrations.

The NRC's criterion is that a $^{238}U/^{234}U$ concentration or activity ratio less than 3 is assumed representative of natural uranium, whereas higher ratios are potentially indicative of the presence of DU.

All samples with a $^{238}U/^{234}U$ concentration or activity ratio greater than 3 will be reanalyzed using inductively coupled plasma-mass spectroscopy (ICP-MS) for their ^{235}U and ^{238}U content in an effort to identify samples with DU content.

7. Other requirements

The ERMP will address all other requirements normally associated with environmental sampling, such as chain-of-custody, health and safety, packaging for shipment, shipping, and so on.

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Appendix

The following table was produced in 2010 from laboratory data with the purpose of demonstrating whether the background reference area for a characterization survey in the RCA in the Battle Area Complex at Schofield Barracks (Cabrera 2008a) was chosen appropriately. The assumption was made that the results of analyzing 416 unbiased samples from the RCA were indicative of background radionuclide concentrations and did not contain depleted uranium contamination. The resulting ^{234}Th (surrogate for ^{238}U) concentration in soil in the RCA was less than that in the chosen background reference area (calculated from 12 samples) and, therefore, supported the assumption. This also indicates that DU has not migrated far from the M101 spotting round points of impact in the fifty years since it was deposited.

Table — Calculation of background soil concentrations from laboratory results for the Davy Crockett impact area and for the background reference area at Schofield Barracks

Matrix	Activity Concentration (pCi/g)[a b]																	
	^{40}K		^{232}Th Progeny								^{238}U Progeny						^{235}U	
			^{208}Tl		^{212}Bi		^{212}Pb		^{228}Ac		^{214}Bi		^{214}Pb		^{234}Th[c]			
	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA
Surface soil	3.16 ± 0.15	5.2 ± 0.2	0.278 ± 0.013	0.293 ± 0.016	0.60 ± 0.07	0.62 ± 0.07	0.96 ± 0.02	0.85 ± 0.04	1.02 ± 0.05	0.94 ± 0.05	0.87 ± 0.03	0.79 ± 0.04	0.95 ± 0.03	0.79 ± 0.04	1.47 ± 0.11	1.09 ± 0.12	0.01 ± 0.04	0.04 ± 0.03
Subsurface soil	3.31 ± 0.18	4.3 ± 0.2	0.350 ± 0.017	0.303 ± 0.016	0.78 ± 0.09	0.66 ± 0.06	1.07 ± 0.03	0.91 ± 0.04	1.18 ± 0.06	0.99 ± 0.05	0.88 ± 0.04	0.60 ± 0.06	0.95 ± 0.03	0.66 ± 0.03	1.77 ± 0.13	1.19 ± 0.13	0.05 ± 0.04	0.06 ± 0.03
Combined	3.22 ± 0.11	4.70 ± 0.16	0.307 ± 0.010	0.298 ± 0.012	0.67 ± 0.05	0.65 ± 0.05	1.00 ± 0.02	0.88 ± 0.03	1.09 ± 0.04	0.96 ± 0.04	0.87 ± 0.02	0.67 ± 0.03	0.95 ± 0.02	0.72 ± 0.02	1.60 ± 0.08	1.14 ± 0.09	0.02 ± 0.03	0.05 ± 0.02

[a] pCi/g = picocurie/g; BRA = background reference area; DCIA = Davy Crockett impact area. The background reference area is more than seven miles from the Schofield Barracks Davy Crockett impact area.

[b] Activity concentrations are weighted means of laboratory results for unbiased samples from the DCIA and from the background reference area. Uncertainties are two standard deviations.

[c] ^{234}Th is a surrogate for ^{238}U.

Conclusion: The uranium concentration in the background reference area does not well represent the background uranium concentration in the DCIA. It is assumed that it is unlikely that DU is contained in any of the unbiased DCIA samples and so the uranium in these samples is naturally occurring.