TECHNICAL MEMORANDUM
FOR
SCHOFIELD BARRACKS IMPACT RANGE
BASELINE HUMAN HEALTH RISK ASSESSMENT
ADDENDUM

Contract No. W52P1J-06-D-0019
Delivery Order 0004

Submitted to:

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July 2009

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1.0 INTRODUCTION

A *Baseline Human Health Risk Assessment (BHHRA) Report* was developed to assess potential health impacts to four human receptors - current and future maintenance worker, future construction/remediation worker, future adult cultural monitor/unauthorized visitor/visitor, and future site worker from potential exposure to depleted uranium (DU) present at the Schofield Barracks Impact Area (SBIA), considering both chemical and radiological toxicity from DU (Cabrera 2008). At the request of Director of Army Safety, two additional receptor scenarios were evaluated to determine whether the DU present in the soil will result in unacceptable dose and risk to those receptors. The following sections of the report summarize the dose and risk evaluations for both receptor scenarios, construction worker (conservative evaluation) and current/future soldiers undergoing training at the facility.

2.0 FIRST EVALUATION – CONSERVATIVE CONSTRUCTION WORKER SCENARIO

During the development of the BHHRA report (Cabrera, 2008), a construction worker was considered who was exposed for 8 hours per day, 180 days a year, for one year. However, in this technical memorandum, a more conservative construction worker scenario was evaluated. Under this conservative scenario, the construction worker will be involved a 3-year construction activity at the SBIA for target modernization. In addition, the construction worker will be at the site for 250 days per year instead of 180 days per year, as assumed during the original BHHRA report. This additional evaluation was performed to determine whether the additional exposure will result in an unacceptable dose and risk to the construction worker under a more conservative scenario.

2.1 Exposure Evaluation for All Five Receptors

An exposure evaluation was performed to determine the total exposure durations, total soil ingestion rates and total inhalation rates for all four receptor scenarios along with the new construction worker scenario. Table 1.0 presents the results of exposure duration, soil ingestion rate and inhalation rates for all five receptors. Table 2.0 presents the results of total exposure duration, total soil ingestion and total inhalation for all five receptors. Increases in exposure duration for the "Conservative" future construction worker/remediation worker are based upon increased time on site based on present project completion times for the BAX construction/modernization program. These increases are based upon multiplication of exposure durations from the base exposure modeling evaluations and original BHHRA.

TABLE 1: EXPOSURE VARIABLES FOR SCHOFIELD BARRACKS IMPACT AREA RECEPTORS

Receptor	Exposure Duration			Soil Ingestion Rate	Inhalation Rate
	Years	Days/Yr	Hrs/Day	(mg/d)	(m^3/hr)
Current/Future Maintenance Worker	6.6	10	8	100	1.4
Future Construction/ Remediation Worker	1	180	8	330	3
Conservative Future Construction/ Remediation Worker	3	250	8	330	3
Future Adult Cultural Monitor/Unauthorized visitor/ Visitor	30	26	8	100	0.83
Future Site Worker	25	250	8	50	0.83

TABLE 2: TOTAL EXPOSURE DURATION, SOIL INGESTION AND INHALATION FOR RECEPTORS

Receptor	Total Exposure Duration	Total Soil Ingestion (g)	Total Inhalation (m^3)
Current/Future Maintenance Worker	**Outdoor** 10 days/yr x 6.6 yrs x 8 hrs/day = 528 hours **Indoor** = 0 hour	100 mg/day x 10 days/yr x 6.6 yrs = 6.6 g	1.4 m^3/hr x 8 hrs/day x 10 days/yr x 6.6 yrs = 739.2 m^3
Future Construction/ Remediation Worker	**Outdoor** 180 days/yr x 1 yrs x 8 hrs/day = 1,440 hours **Indoor** = 0 hour	330 mg/day x 180 days/yr x 1 yrs = 59.4 g	3 m^3/hr x 8 hrs/day x 180 days/yr x 1 yrs = 4,320 m^3
Conservative Future Construction/ Remediation Worker	**Outdoor** 250 days/yr x 3 yrs x 8 hrs/day = 6,000 hours **Indoor** = 0 hour	330 mg/day x 250 days/yr x 3 yrs = 247.5 g	3 m^3/hr x 8 hrs/day x 250 days/yr x 3 yrs = 18,000 m^3
Future Adult Cultural Monitor/Unauthorized visitor/ Visitor	**Outdoor** 180 days/yr x 1 yrs x 8 hrs/day = 1,440 hours **Indoor** = 0 hour	330 mg/day x 180 days/yr x 1 yrs = 59.4 g	3 m^3/hr x 8 hrs/day x 180 days/yr x 1 yrs = 4,320 m^3
Future Site Worker	**Outdoor** 250 days/yr x 25 yrs x 1 hrs/day = 6,250 hours **Indoor** = 250 days/yr x 25 yrs x 7 hrs/day = 43,750 hours	50 mg/day x 250 days/yr x 25 yrs = 312.5 g	0.83 m^3/hr x 8 hrs/day x 250 days/yr x 25 yrs = 41,500 m^3

The results of exposure evaluation showed that the total exposure duration, total soil ingestion and total inhalation are the highest for the future site worker. The results also demonstrate that the future site worker will receive the highest amount of exposure among all five receptors.

2.2 Radiological Dose and Risk Evaluation for Conservative Future Construction Worker

The results of dose and risk assessment for all four receptors scenarios presented in the BRHHA report showed that the future site worker incurs the highest radiological dose (3 mrem/yr) and carcinogenic risk (3E-05) due to DU fragments at SBIA. The results of the radiological risk assessment also indicate, however, that the carcinogenic risk is well within USEPA's acceptable risk range as reported in the National Contingency Plan (NCP) (i.e., risk range of 1E-04 to 1E-06). Based on the results of the exposure evaluation illustrated above in Table 2.0, the total exposure duration, total soil ingestion and total inhalation for the new conservative future

construction worker are all much less than those for the future site worker. Therefore, the results of radiological dose and risk assessment must be less than those for future site worker. Thus, the presence of DU at SBIA does not pose any adverse health impact to new conservative future construction worker.

2.3 Chemical Risk Assessment for Conservative Future Construction Worker

The results of the non-carcinogenic chemical risk assessment for all four receptor scenarios presented in the BRHHA report showed that the future construction/remediation worker incurs the maximum hazard index (HI) of 0.2. The exposure frequency for new conservative construction worker is about 1.4 times higher than that for construction worker, as defined in the BHRRA report. Therefore, the HI for new conservative construction worker will be 1.4 times higher than that for construction worker, i.e., HI for new conservative future construction worker is approximately 0.23. This new HI is still below the USEPA's acceptable risk limit, as noted in the NCP, for non-carcinogenic effects of 1.0. Therefore, the results for non-carcinogenic risk assessment demonstrate that there are no adverse impacts expected due to chemical exposure to DU.

3.0 SECOND EVALUATION – CURRENT AND FUTURE EXPOSURE TO SOLDIERS TRAINING AT THE SITE

During this second evaluation, a new radiological dose and risk assessment was performed for the soldiers who are involved in various training activities at the Site. The soldiers are assumed to be exposed to the depleted uranium (DU) present at the site. The following sections summarize the dose and risk assessment procedures performed to evaluate the soldier scenarios.

3.1 Exposure Scenarios for Soldiers

For the new receptor scenario, there are two ways a soldier is exposed to the DU present in surface soil. Based on Station Policy a soldier may be assigned to Schofield three to four times over a 20 year career, with each assignment having approximately 3 year duration for a total of 12 years. The scenario is conservative in this respect, assuming 25 year exposure duration. The most likely exposure duration would be one half of this value. Additional modeling beyond the original BHHRA was performed to determine a potential soldier's exposure and risk.

(1) Exposure to Volumetric Contamination in Soil: Under this scenario, the soldier is exposed to the volumetric contamination present in the surface soil while walking, crawling, or running around on the range for 8 hours per day, 171 days per year, for 25 years. The adult soldier is assumed to ingest 100 milligram (mg) of soil (USEPA 1989) and inhale 1.4 cubic meters of air per hour (m^3/hr) or 12,300 m^3 of air per year (m^3/yr) (ANL 1993). Similar to the other four receptor scenarios, the soldier will be exposed via the same three exposure pathways, as follows:

- external gamma radiation from radionuclides in surface soil;
- incidental ingestion of surface soil; and
- inhalation of airborne contaminated dust from surface soil.

(2) Exposure to Surface Soil Contamination in a Vehicle: Under this scenario, the same soldier spends 8 hours per day, 83 days per year inside a contaminated vehicle. The adult soldier is assumed to have the same inhalation rate of 1.4 m^3/hr or 12,300 m^3/yr of air (ANL 1993). The receptor will not ingest soil directly; instead, the receptor will ingest soil secondarily. While driving the vehicle, the soldier disturbs the soil surface and the dust generated from the soil will become airborne. The vehicle provides some protection

from gamma rays from surface soil contaminated with gamma emitting radionuclides. However, the exterior of the vehicle maneuvering in radionuclide-contaminated soil is likely to become contaminated. This contamination can then be passed on to the passenger when exiting and entering the vehicles. During this assessment, the floor, dashboard, driver-side doors, and passenger-side doors of the vehicles are assumed to be uniformly contaminated by 10% of the volumetric surface soil DU contamination. Windows are not assumed to be contaminated. The surface area for the dash and doors are assumed to be one-half of the surface area of the floor.

The sources of all four sides of the vehicle are assumed to be present at equal distance and are directly perpendicular to the receptors. The soldier is exposed externally to radiation from residual radioactivity on the surface of the equipment, as well as internally to re-suspended and inadvertently ingested contamination.

3.2 Determination of Exposure Point Concentrations

The exposure point concentration (EPC) represents a reasonable estimate of the average contaminant concentration likely to be encountered at the point of exposure over the exposure period for any receptor. The determination of EPCs for both soldier exposure scenarios to surface soil is summarized in the followings.

3.2.1 Determination of the EPC via Volumetric Contamination in Soil

Under this exposure scenario, the EPCs for three uranium isotopes of DU in surface soil were determined and reported in the BHHRA report, and they are as follows:

U-234 = 21.79 pCi/g
U-235 = 0.89 pCi/g
U-238 = 116.7 pCi/g

3.2.2 Determination of the EPC via Surface Contamination in a Vehicle

Under this exposure scenario, it is assumed that 10% of the volumetric contamination at each of four sides of the vehicle results in 1 millimeter (mm) thickness of surface contamination. Based on that, the EPC for surface contamination of DU at each vehicle side were calculated as follows

U -234 = 10% of 21.79 pCi/g x 1.5 g/cm^3 x 1 mm x (1 cm/10 mm) x (10^4 cm^2/m^2);
where, 1.5 g/cm^3 is the specific density of soil.
= 3,268.5 pCi/m^2;

U -234 = 10% of 0.89 pCi/g x 1.5 g/cm^3 x 1 mm x (1 cm/10 mm) x (10^4 cm^2/m^2);
= 133.5 pCi/m^2;

U -234 (pCi/m^2) = 10% of 116.7 pCi/g x 1.5 g/cm^3 x 1 mm x (1 cm/10 mm) x (10^4 cm^2/m^2);
= 17,505 pCi/m^2;

3.3 Dose and Risk Assessment Model

Because of the nature of the exposure scenarios, two different dose and risk assessment models were utilized during the dose and risk assessment for soldiers. The models, as well as the assigned values for the input parameters, are summarized in the following sections.

3.3.1 Dose and Risk Assessment Model for Volumetric Contamination

The *RESidual RADioactivity (RESRAD)* computer code, Version 6.3 (ANL, 2005), was used to estimate the radiological dose and risk for the soldier. This model was used during radiological dose and risk assessments for all four receptor scenarios in the BHHRA report. The EPCs for DU presented in section 3.2.1 above, were inputted to the model as the source term for this scenario. The assigned values for input parameters that are unique for the soldier are presented below. Table B-1 of Appendix B of the BHHRA report (Cabrera 2008) included the assigned values for all other input parameters.

Inhalation Rate = 12,300 m^3/yr;
Exposure Duration = 25 years;
Fraction of Time, Indoor = 0;
Fraction of Time Spent Outdoor = 0.156 (unitless);
Soil Ingestion Rate = 36.5 g/yr.

3.3.2 Dose and Risk Assessment Model for Surface Contamination

RESRAD-BUILD 3.4 was used to determine the dose and risk resulting from the surface contamination (presented in Section 3.2) of radioactive materials within the vehicle (ANL 2008). The soldier is assumed to sit inside the vehicle for an entire work year.

RESRAD-BUILD includes a "Building Exchange Rate (1/hr)" that models the circulation of air through the occupied space. Rates are typically estimated for residential or commercial facilities, but the scenario here considers the interior of a vehicle. Although specific rates are not available, it is assumed that exchange rates are high (or very high when windows are open), thus a rate of 2

per hour is conservatively used (the RESRAD-BUILD default for a habitable structure is 0.8 per hour).

Table 3.0 presents the input parameters for the vehicle occupancy scenario for soldier. The parameters are configured to resemble a room in RESRAD-BUILD and conservatively represent potential doses and risks from exposure to an interior-contaminated vehicle.

TABLE 3: PARAMETER FOR RESRAD-BUILD VEHICLE OCCUPANCY SCENARIO (SOLDIER)

Parameter	Description	Value	Justification
Time Parameter			
Exposure Duration	Amount of time that exposure occurs	365 days	Annual Dose
Indoor Fraction	Fraction of the exposure duration that is spent inside the building	0.0758	664 hours/year
Evaluation Time	Times at which doses are calculated	0 year; 1 year (other times, if max dose occurs)	NUREG/CR-5512, Volume 1, Section 3.2.1
Building Parameters			
Number of Rooms	Number of compartments in the building	1	NUREG/CR-5512, Volume 1, Section 6.2.1
Deposition Velocity	Velocity at which airborne particles are deposited onto the floor surfaces	0.01 m/sec	RESRAD-BUILD Default
Resuspension Rate	Rate at which deposited material is resuspended into the air	5.0 E-07 sec^{-1}	RESRAD-BUILD Default
Building Exchange Rate	Total volume of air going out of the building per unit time divided by the total volume of the building	2 hr^{-1}	Consistent with value of 0.75 hr^{-1} for conditioned spaces (cited by American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.)
Room Area	Floor Area of the room	9 m^2	Assumptions
Room Height	Height of the room	1.5 m	Assumption
Room Exchange Rate	Total volume of air going out of the room per unit time divided by the total volume of the room	2 hr^{-1}	Same as building exchange rate
In/Out Flow Rate	Flow rates of air into and out of the room	27 m^3/hr	Room volume (9 m^3) * Room exchange rate (2 hr^{-1})
Receptor Parameters			
Number of Receptors		1	NUREG/CR-5512, Volume 1, Section 6.2.1
Room # Location	Room in which the receptor is located	1	NUREG/CR-5512, Volume 1, Section 6.2.1

Parameter	Description	Value	Justification
Time Fraction	Fraction of time within the building that the exposed individual spends at his receptor location	1	NUREG/CR-5512, Volume 1, Section 6.2.1
Breathing Rate	Inhalation rate of airborne material at this location	33.6 m^3/day	NUREG/CR-5512 (Breathing rate = 1.4 m^3/hr)
Ingestion Rate	Ingestion rate of deposited dust for this location	1 E-04 m^2/hr	NUREG/CR-5512, Volume 1, Section 6.2.1
Receptor Location	Coordinates of the receptor wrt to the sources for external exposure	1.5m, 1.5m, 1m	Located in center of room at height of 1m; NUREG/CR-5512, Volume 1, p 6.4
Shielding Parameters			
Thickness	Thickness of the shielding between the contamination source and the receptor location	0	No intervening shielding materials between sources and building occupant
Density	Density of the shielding material	Not Applicable	
Material	Identification of the shielding material	Not Applicable	
Source Parameters			
Number of Sources		4	Floor, Dashboard, Doors
Room # location	All sources are located in Room # 1	1	
Source Type		Area	
Location	Center point of the source in the x, y, z direction	**Floor** (1.5,1.5,0); Z; 9 m^2 **Dash** (1.5,0,1); Y; 6 m^2 **Passenger Side Door** (3,1.5,1); X; 6 m^2 **Driver Side Door** (0,1.5,1); X; 6 m^2	
Direction	Axis perpendicular to the exposed area		
Geometry: Area	Area of the exposed surface over which the contamination is evenly distributed		
Air Fraction	Fraction of the eroded material that is released into the air	0.1	RESRAD-BUILD
Direct Ingestion	Direct Ingestion rate of the source by any receptor in the room	0 g/hr	Direct ingestion of source material is not modeled; indirect ingestion of dust is modeled
Removal Fraction	Fraction of the source that can be linearly removed between t =0 and t= 1 yr	0.1	10% of the contamination on the entire floor surface area is eroded over the course of one year (maximum dose in first year)
Lifetime	Amount of time in which all of the removable fraction of the source is linearly eroded	3650 days	RESRAD-BUILD
Radionuclides Concentration	U-234 U-235 U-238	3268.5 pCi/m^2 133.5 pCi/m^2 17505 pCi/m^2	Same for each source area.

3.4 Results of Radiological Dose and Risk Assessment

The results of radiological dose and risk assessment to soldier under volumetric and surface contamination exposure to DU are presented in the following sections.

3.4.1 Results of Dose and Risk Assessment for Volumetric Contamination

The results of radiological dose and risk assessment due to volumetric surface soil contamination exposure over a period of 1,000 years were obtained from the corresponding *RESRAD* dose and health risk output report. The results showed that the maximum dose and risk to the soldier are 3.5 mrem/yr and 5E-5, respectively and both of them occurred at year 0.

3.4.2 Results of Dose and Risk Assessment for Surface Contamination

The total dose and risk from surface contamination inside a vehicle were determined by summing the doses and risks across all four sources (the floor, dashboard, driver-side doors, and passenger-side doors of the vehicle) and series radionuclides. The results showed that the maximum dose and risk to the soldier are 0.4 mrem/yr and 2E-7, respectively, and they occurred at year 0.

Results of Total Dose and Risk Assessment to Soldier: Based on the results of dose and risk assessments for both exposure scenarios, the total maximum dose and risk are 3.9 mrem/yr and 5E-5, respectively, for the soldier. The results of the radiological dose assessment are less than the USNRC acceptable dose limit of 25 mrem/yr. Likewise, the results of the radiological risk assessment indicate that the risk is within USEPA's acceptable risk range of 1E-4 and 1E-6, respectively.

3.5 Results of Chemical Risk Assessments for Soldier

The results of the non-carcinogenic chemical risk assessment for the soldier both inside and outside of the vehicle are presented in Table 4.

TABLE 4: SUMMARY OF HAZARD INDEX CALCULATIONS

Receptor	Pathway-Specific Hazard Quotient [1]		Hazard Index
	Ingestion	Inhalation	
Soldier (Soil)	8E-02	1E-03	8E-02
Soldier (Vehicle)	2E-02	2E-04	2E-02
Soldier (Total)			9E-02

[1] Hazard quotients calculated based on non-carcinogenic effects of exposure to uranium.

The total HI for the soldier is less than 1.0. Thus, the non-carcinogenic chemical risk evaluation results indicate that no adverse human health impacts are likely to occur as a result of potential exposure to DU in soil.

3.6 Conclusion of the Second Risk Evaluation

The results of the radiological dose assessment and chemical and radiological risk assessments for soldiers presented in this technical memorandum demonstrate that both the doses and the risks fall within the limits for what is considered safe by the USEPA and the USNRC. Therefore, no significantly increased risks for the soldiers have been demonstrated in this memorandum. As a result, no adverse human health impacts are likely to occur as a result of exposure to the DU present in soil at SBIA.

4.0 REFERENCES

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