FINAL

TECHNICAL MEMORANDUM
Schofield Barracks Firing Range
Monitoring of Air Quality During Burning of Vegetation
Wahiawa, Hawaii

Prepared for

Department of the Army

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April 2008

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1.0 INTRODUCTION

Schofield Barracks is a large Army post in Hawaii, located on an 18,000 acre site in central Oahu. The Schofield Training Area totals 4,695 acres located in a large valley, with a ridgeline along the north, west, and southwest boundaries. In August 2005, spotting round bodies (SRBs) from the Cartridge, 20mm Spotting M101 associated with the Davy Crockett Light Weapon M28 made of D-38 uranium alloy, also called depleted uranium (DU), and associated tail assembly components (e.g., fins and rings) were recovered by a contractor clearing a Schofield Barracks range impact area of unexploded ordnance and scrap metal. An investigation into the source of the material determined that training for the Davy Crockett weapon system was performed at Schofield Barracks during the 1960s. DU was used in the training rounds for the Davy Crockett weapon system because of its high density and weight. The DU components are approximately four inches in length and one inch in diameter.

Prescribed burns are performed periodically at Schofield Barracks to clear vegetation from large areas of the range to provide access for normal range operations. Lightning strikes and ordnance firing can also result in fires on the range, and the prescribed burns are necessary to allow the burns to occur under more controlled conditions. The presence of DU at Schofield Barracks has resulted in concerns about potential exposures to site workers and members of the public during range fires.

The purpose of this report is to document the field efforts for evaluating potential releases of DU during prescribed burns at Schofield Barracks in July and August, 2007. A reference burn and test burn were performed to collect data for a DU hazard evaluation prior to performing a prescribed burn of the full range. The relative locations of the burns are shown in Figure 1-1. This report summarizes the results of soil, vegetation, and air particulate sampling performed before, during, and after the reference, test, and full scale burns.

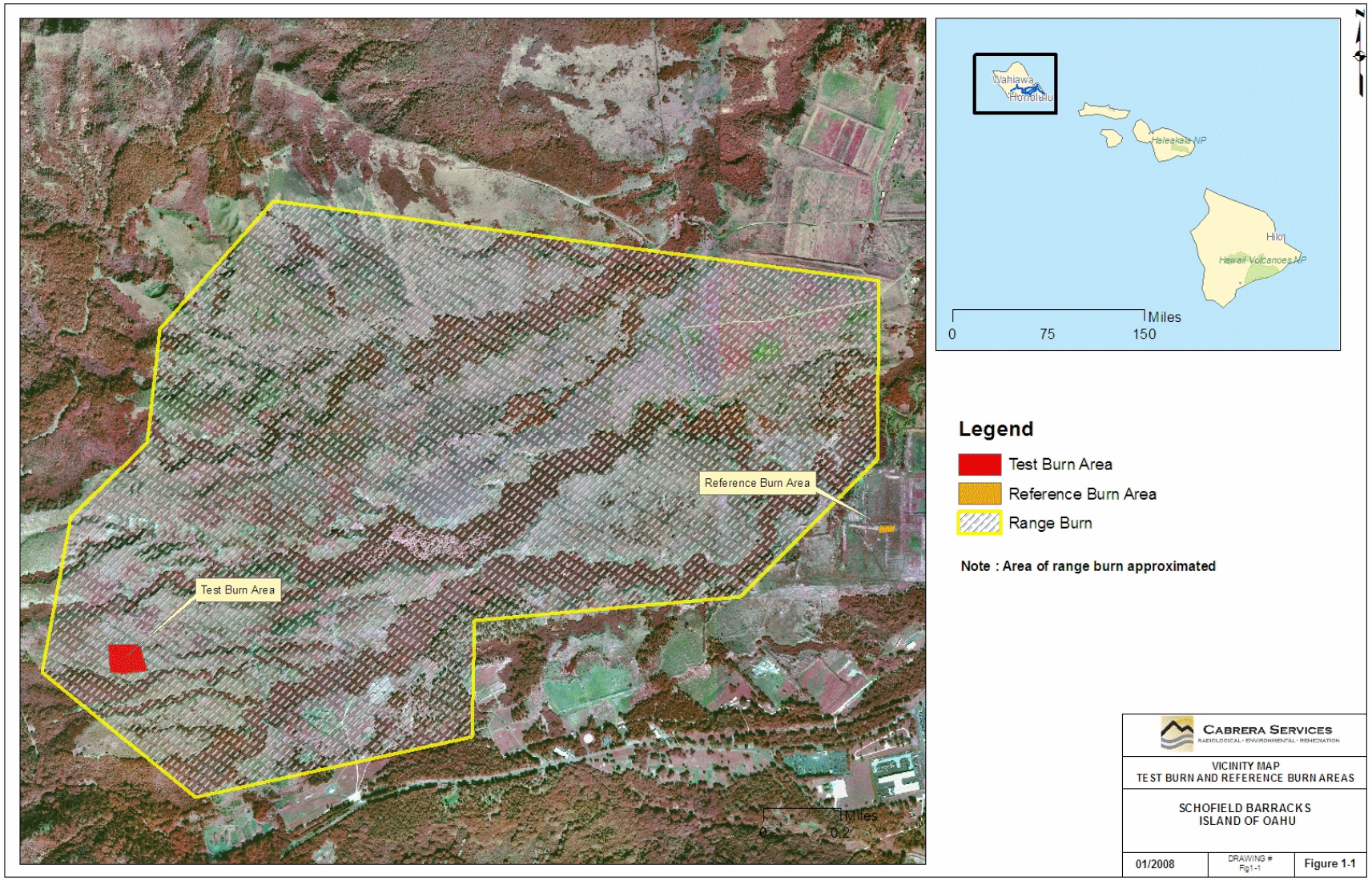

FIGURE 1-1: VICINITY MAP TEST BURN AND REFERENCE BURN AREAS

2.0 SURVEY DESIGN

Radiological surveys were performed at Schofield Barracks to evaluate the potential for range burns to result in members of the public being exposed to DU in the form of airborne particulates. The survey followed the approved plan, "Effluent Sampling Plan for Air Monitoring of Depleted Uranium During Prescribed Burns at Schofield Barracks" (Cabrera, July 2007). Three prescribed burns were scheduled to measure the concentration of uranium isotopes in airborne particulates during range burns.

2.1 Reference Burn

A reference burn was performed in an area outside the firing range to avoid the presence of DU fragments. The site was walked over to corroborate by visual and radiological indications that DU had not impacted the area. Additionally, samples of air particulates, soil, and vegetation were collected from the one acre reference area to support the determination that no DU was present. A controlled burn of vegetation in the area was performed and air particulate samples were collected during the burn. Visual observations confirmed that the air samplers intersected the smoke plume. Following the burn, ash samples were collected to measure concentrations of uranium in the environment. The reference burn was designed to provide information on uranium in the environment as well as collecting information on the behavior of smoke plumes and obtaining representative air particulate samples during prescribed burn activities.

2.2 Test Burn

A test burn was performed to obtain empirical information on potential DU concentrations in smoke during fires in areas of the firing range known to contain DU fragments. The test burn was designed to provide information on DU concentrations in airborne particulates during a prescribed burn. This information was also used to support field decisions regarding the final survey design for air monitoring during the prescribed full range burn and to assist in interpretation of results.

An approximately one acre tract was staked out by range personnel. The area was initially selected based on the observed (i.e., yellow color in soil) and measured (i.e., qualitatively with hand-held radiation detection instruments during previous site work) presence of DU fragments. Qualitative gross gamma radiation measurements and visual observations were also performed

during this evolution to verify the presence of DU in the test area. Samples of soil and vegetation were collected from this area prior to the burn to confirm the presence of DU. Air particulate samples were collected prior to the burn to evaluate the potential for wind erosion of DU, and during the burn to determine potential impacts from airborne DU during a prescribed burn. Following the burn, ash samples were collected to measure concentrations of uranium in the environment.

2.3 Range Burn

A prescribed burn of the full Schofield Training Area range was performed to remove vegetation and provide access for military training and additional DU characterization survey activities. Air particulate samples were collected during the prescribed full range burn to measure uranium concentrations in air particulates and determine the potential for exposures to members of the public.

2.4 Sample Locations

Sample locations for all three burns were selected to provide information on the potential for release of DU as airborne particulates during prescribed burns. Air filters were placed at both upwind and downwind locations during all burns. The air samplers were arrayed in patterns to accommodate actual wind, temperature, and humidity conditions so that most samplers were located downwind. Two samplers were placed in the upwind direction to serve as a control group for air particulates suspended during burn activities, as well as providing coverage in case the wind shifted during the burn.

Soil, vegetation, and ash samples were collected from locations spread throughout the reference and test burn areas. These locations provided an estimate of the average radionuclide activity concentration throughout each area and supported the determination that the reference area was non-impacted and the test area was impacted.

2.5 Sampling Techniques

Air filters were collected using Hi-Q portable high velocity air samplers and Whatman 41 paper filters. Surface soil samples were collected using a trowel to collect approximately 500 grams of solid material. Vegetation samples were collected by cutting and collecting vegetative material adjacent to soil sample locations (<1 m^2) to obtain a volume of approximately 1 liter of

vegetation. The sampling design for collecting ash samples was to place vegetation in a foil tray during the burn and collect ash from the tray following the burn. However, activities of Army personnel during the prescribed burns and high winds potentially affecting the ash or the foil trays made this approach impractical. Therefore, ash samples consisted of surface scrapes that included a mixture of soil and ash.

2.6 Sample Analysis

All samples were sent to an offsite radiochemistry laboratory for analysis of uranium isotopes using alpha spectrometry. Alpha spectrometry combines chemical separation of uranium from other elements with spectrometric measurement of alpha particles to measure concentrations of individual uranium isotopes. Analytical results were reported for three uranium isotopes: uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U). Natural uranium found in the environment contains approximately equal activity concentrations of ^{234}U and ^{238}U, while DU includes lower activity concentrations of ^{234}U relative to ^{238}U.

3.0 SURVEY IMPLEMENTATION

The reference, test, and range burns were performed in July and August 2007. The surveys were performed as described in the survey design (Cabrera, 2007) with the exception of sample locations (described in Section 2.5) and the collection of ash samples (described in Section 2.6). The data quality objectives described in the survey design were achieved.

Air samples were numbered using the following numbering methodology:

EF-BB-CC-####-DD

Where,

EF = Project designator for the effluent monitoring survey

BB = RB (reference burn), TB (test burn), or FB (full range burn)

CC = PB (pre-burn) or AB (during [air filters] or after [ash samples] burn)

= Sample number beginning at 1001 (see Table 4-1)

DD = Sample Matrix, FP (filter paper), VS (vegetation sample), or SS (soil sample)

3.1 Reference Burn

An area of approximately 40,000 square feet was identified by Army personnel as an area where the Davy Crockett weapons system was never used. This reference area consisted of a dirt berm with dense grassy vegetation concentrated along the top and sides. Five vegetation samples were collected from the top and sides of the berm on July 11, 2007. The reference burn was performed on the morning of July 12, 2007. Prior to starting the burn, eight air samplers were deployed around the reference burn area based on the wind direction. The locations of the air samplers relative to the reference burn area are shown in Figure 3-1. Locations 1016 and 1017 were upwind of the reference area, locations 1018 through 1021 were spaced about 200 feet apart in a line downwind of the reference area, and locations 1022 and 1023 were located about 200 feet apart in a second line farther downwind. Locations 1018 through 1021 were approximately 1,000 feet from the upwind edge of the reference burn area, and approximately 600 to 800 feet from the downwind edge of the reference burn area. The air samplers were run for 30 to 45 minutes to collect information on air particulates prior to the burn.

After new filters were placed in the air samplers, the samplers were started and observers were placed northeast directly upwind of the burn and approximately 1,200 feet to the southeast along

the side of the burn. Locations 1024 and 1025 were upwind of the reference area, locations 1026 through 1029 were spaced about 200 feet apart in a line downwind of the reference area, and locations 1030 and 1031 were located about 200 feet apart in a second line farther downwind. A second fire was started approximately half way back along the berm and allowed to burn back in an upwind direction. The backfire was set to provide control for the burn and to increase smoke generation time during the burn.

The upwind observers verified the smoke was moving towards the center of the array of air samplers. The crosswind observers verified the plume stayed along the ground and was intercepted by the air samplers. Figure 3-2 shows a picture of the smoke plume from a vantage point approximately 2000 feet from the south side of the burn area perpendicular to the direction of the prevailing winds. Air filter location 1026 (also location 1018) is visible on the left side of the photo near target 42. The smoke was white or gray with some brown color and was opaque, obscuring objects on the far side of the burn. The burn lasted approximately 30 minutes, and the air samplers were shut down after running for 50 minutes. The filter papers were removed from the samplers and visually inspected. Filters 1026, 1027, and 1030 were visibly darker showing collection of smoke particles on the filters.

Following the burn gross gamma count rates, dose rates, and ash samples were collected from the burn area. Since only the eastern end of the berm was included in the burn area, the five ash samples were not collected from the same locations as the vegetation samples. Dose rate and gross gamma measurements were uniform over the reference area, with dose rates ranging from 6 to 7 μR/hr at the ash sample locations.

3.2 Test Burn

An area of approximately 40,000 square feet was identified by Army personnel as a location where the spotting rounds for the Davy Crockett weapons system had been found. Site reconnaissance identified two areas where the soil was stained yellow, indicating the presence of uranium oxide. No DU fragments were observed during the site reconnaissance. Checking these locations for gamma activity with a sodium iodide detector resulted in count rates approximately five times background, confirming the presence of elevated levels of gamma radiation. The area

had been treated with herbicide to limit growth of vegetation, so the vegetation was not as dense as the reference area and areas of bare soil were present.

Three vegetation and two soil samples were collected from the test burn area on July 13, 2007. The purpose of the samples was to demonstrate that DU was present in the test burn area. Therefore, all samples were collected from locations where the soil was yellow colored, indicating the potential presence of uranium oxide.

The test burn was performed on the morning of July 13, 2007. Prior to starting the burn, eight air samplers were deployed around the test burn area based on the wind direction. The locations of the air samplers relative to the test burn area are shown in Figure 3-3. Locations 1037 and 1038 were upwind of the reference area, locations 1039 through 1042 were spaced about 200 feet apart in a line downwind of the reference area, and locations 1043 and 1044 were located about 200 feet apart in a second line farther downwind. Similar to the reference burn, Locations 1039 through 1042 were approximately 1,000 feet from the upwind edge of the test burn area, and approximately 500 feet from the downwind edge of the test burn area. The air samplers were run for 45 minutes to collect information on background levels of air particulates prior to the burn.

After new filters were placed in the air samplers, the samplers were started. Air filters 1045 and 1046 were located upwind, filters 1047 through 1050 were in the first line of samplers, and filters 1051 and 1052 were in the second line of samplers. Contracted personnel were required to leave the burn area during the test burn to meet fire safety requirements. The test burn was observed by Cabrera personnel from the range control tower with meteorological details provided by Army personnel monitoring the burn.

A fire was started along the upwind edge of test burn area to allow the wind to help move the fire through the area. This was necessary because of the patchiness of the vegetation. Army personnel needed to start additional fires several times to ensure the entire area was burned. The burn lasted approximately 40 minutes, and the air samplers ran for 60 minutes.[1] The smoke

[1] It took approximately 15 minutes for Army personnel to ensure the fire was completely extinguished and determine it was safe for contracted personnel to return to the range to collect the post-burn samples.

generated was gray white and not as thick as the smoke from the reference burn. The output of smoke was constant throughout the burn. Army personnel verified that the smoke moved along the ground and was intercepted by the line of air samplers. Air samples 1040 and 1041 had visible ash on the filter. Air samples 1043 and 1044 were visibly discolored indicating some smoke particles were present on the filters.

Following the test burn it was found that the air sampler for filter 1050 had shut down during the test burn. It was not known how long the air sampler had run, so the volume of air passing through the filter was unknown. Air filter 1050 was analyzed to provide qualitative information on the presence of DU.

Post burn observations indicated that three of the locations where pre-burn soil and vegetation samples were collected had not been burned. These patchy areas of vegetation had been missed by the fire. Five ash samples were collected from locations where sufficient amounts of ash were present for sampling, but not corresponding to the soil and vegetation sample locations selected prior to the burn. Based upon experience during the reference burn, surface scrapes were used to collect ash samples, although some surface soil and solid material (e.g., twigs, sticks) were included in the samples. The wind continually stirred up the ash making it difficult to collect ash samples.

3.3 Range Burn

The prescribed burn of the full range was not performed until analytical results from the air filters used to collect airborne particulates during the reference and test burns were completed. The uranium concentrations in samples from the reference and test burn areas were less than one-half of one percent of the U.S. Nuclear Regulatory Commission limits for inhalation exposures to members of the general public. Based on the data from the test burn, it was determined that there was no reasonable potential for airborne release of depleted uranium, and a larger scale range burn would present no hazard to monitoring personnel.

The range burn was performed from July 31 through August 3, 2007. On the morning of July 31 eight air samplers were placed around the perimeter of the training range as shown in Figure 3-4. Sample locations 1101 and 1102 were upwind of the range, while sample locations 1103 through

1108 were downwind. The air samplers were placed in locations along an access road running along the west side of the range. The air samplers were located to provide monitoring of the downwind perimeter of the range based on suspected locations of DU, areas being burned, and wind direction. The air samplers were run for 60 minutes to collect information on air particulates prior to the burn.

After new filters were placed in the air samplers, the prescribed range burn was started. The fires were started at the downwind (i.e., west) edge of the southern portion of the range to establish a firebreak approximately 1,000 meters wide. Once the firebreak was established fires were started at the upwind (i.e., east) edge of the range and allowed to move downwind. After the firebreak was established, contracted personnel were allowed to check the air filters and refuel the generators. All of the downwind air samplers were covered with ash and heavy smoke was observed along the access road where the air samplers were located. The air flow was monitored throughout the day to ensure adequate flow rates were maintained and the filters were not overloaded with particulate matter which would inhibit proper sampling. No problems were observed with sampling volume rates which remained constant at approximately 50 CFM during the range burn.

Air sampler locations for the first day of the range burn were numbered 1201 through 1208 at the same locations as the pre-range burn samples 1101 through 1108. The air filters ran for approximately 7 hours, between 411 and 440 minutes, on the first day of the burn. The colors of all of the downwind air filters were dark indicating the presence of ash on the filter. There was noticeably less material on air filter 1208 (i.e., farthest north location) compared to air filters 1203 through 1207.

The use of herbicides on the range resulted in patchy areas of vegetation and dirt similar to what was observed in the test burn area. Similar to procedures performed during the test burn, Army personnel needed to restart fires in multiple locations to ensure the range burn was complete. This resulted in a longer burn duration than originally anticipated, so a second day of air sampling was scheduled to ensure that air monitoring was performed while portions of the range potentially impacted by DU were burning.

The range burn continued on August 1, 2007. The upwind air samplers, 1301 and 1302, were located at the same locations as the previous day. However, since the portion of the range being burned had shifted to the north the downwind air samplers were moved to locations 1303 through 1308 as shown in Figure 4. The air filters ran for approximately 6 hours, between 351 and 413 minutes, on the second day of the range burn.

The wind blew steadily from the east-northeast throughout both days of the burn, so the smoke generated by the burn was always moving towards the air samplers. The smoke was gray-white in color and generally dissipated prior to reaching the air samplers located outside the range, although periods of heavy smoke were observed along the access road. The range burn continued on August 2 and 3, 2007. Due to the fact that the continuation of the prescribed burn was less intense than the initial two days and was outside of the known DU affected areas, air monitoring of the burn did not continue. While it is possible that some DU affected areas may have burned during this non-monitored period, based upon subsequently collected survey data, the monitoring of the range burn took place when the areas with the highest concentration of DU fragments were burned.

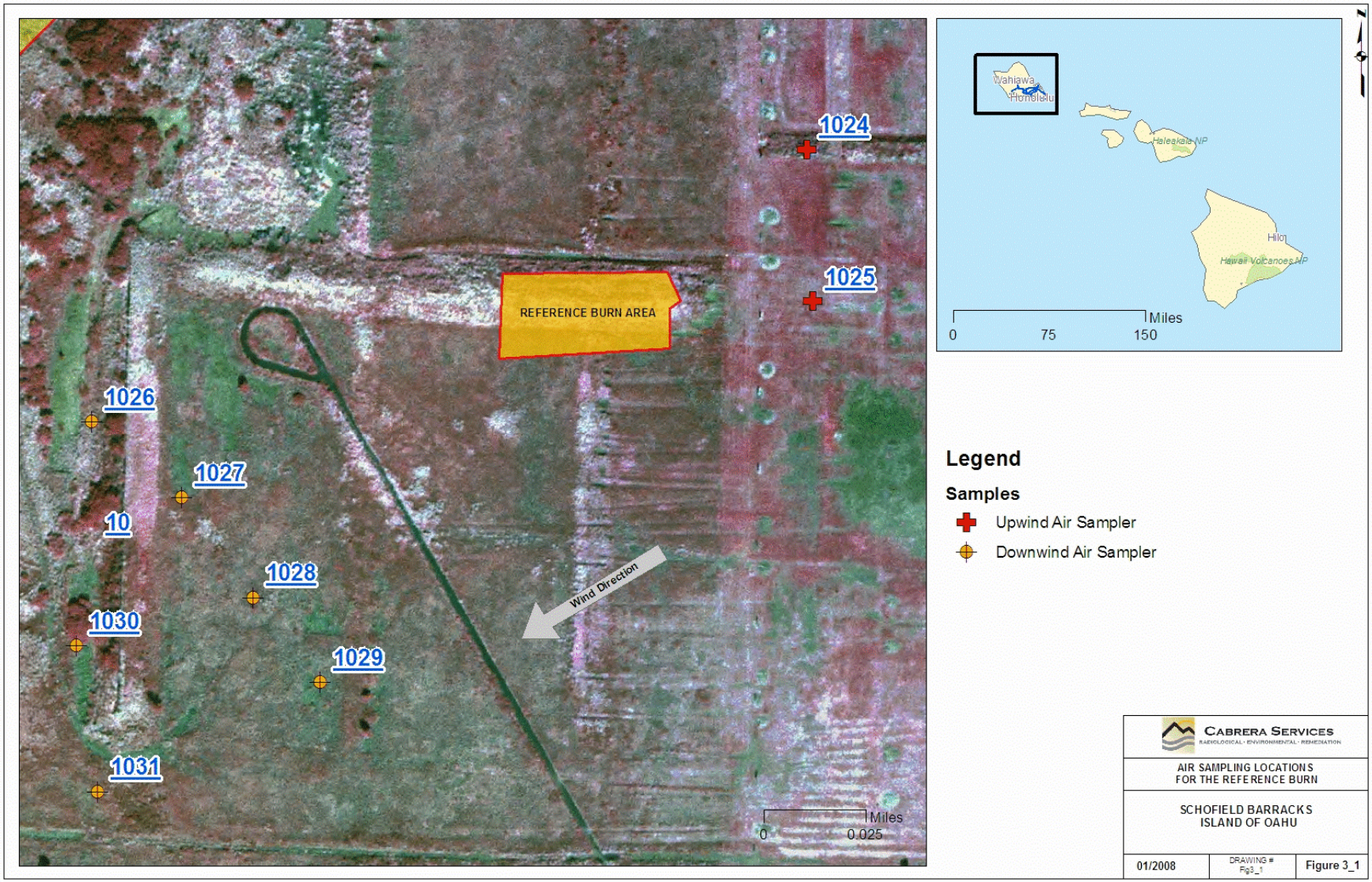

FIGURE 3-1: AIR SAMPLING LOCATIONS FOR THE REFERENCE BURN

FIGURE 3-2: PHOTOGRAPH OF REFERENCE BURN SMOKE PLUME

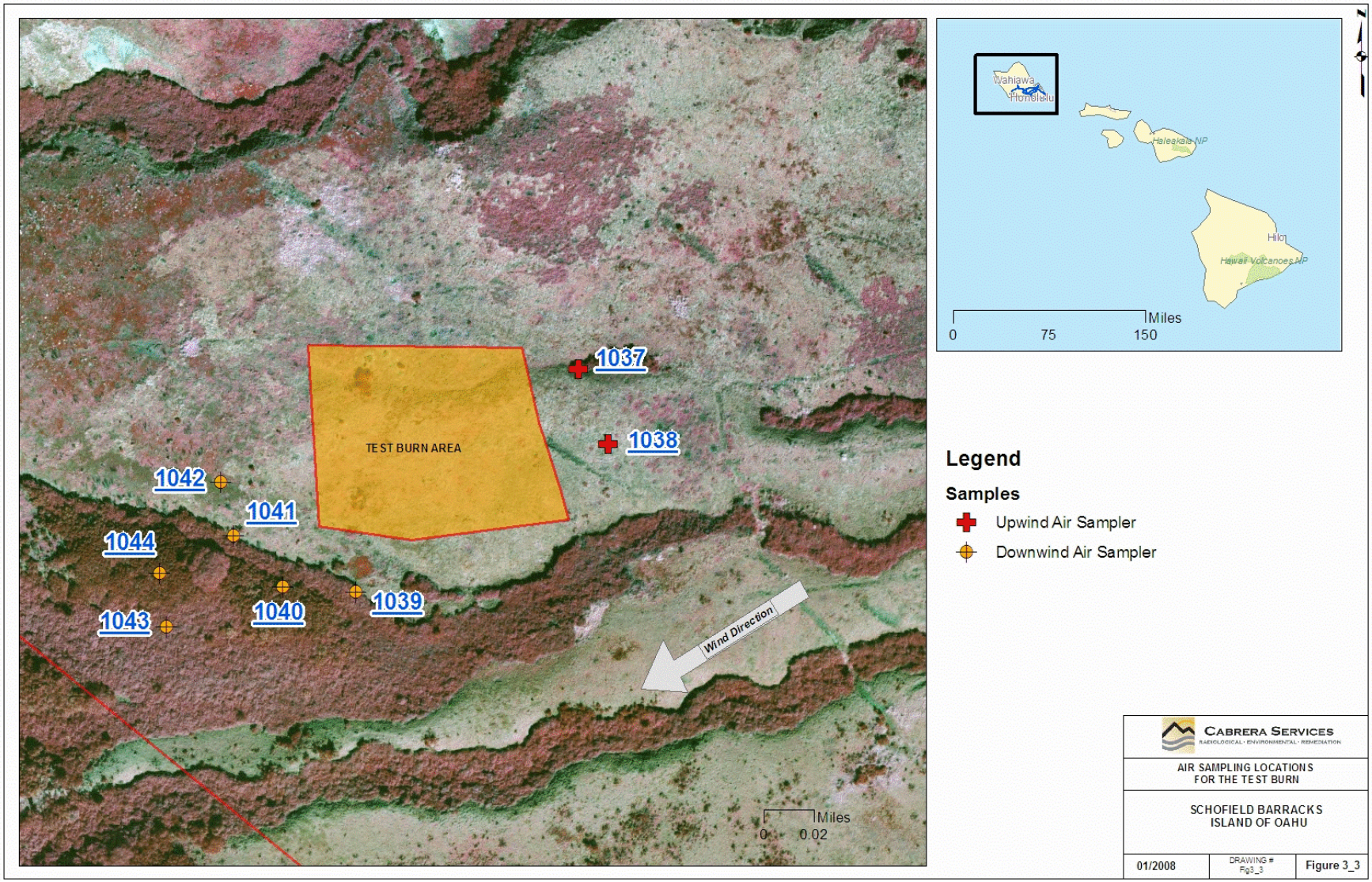

FIGURE 3-3: AIR SAMPLING LOCATIONS FOR THE TEST BURN

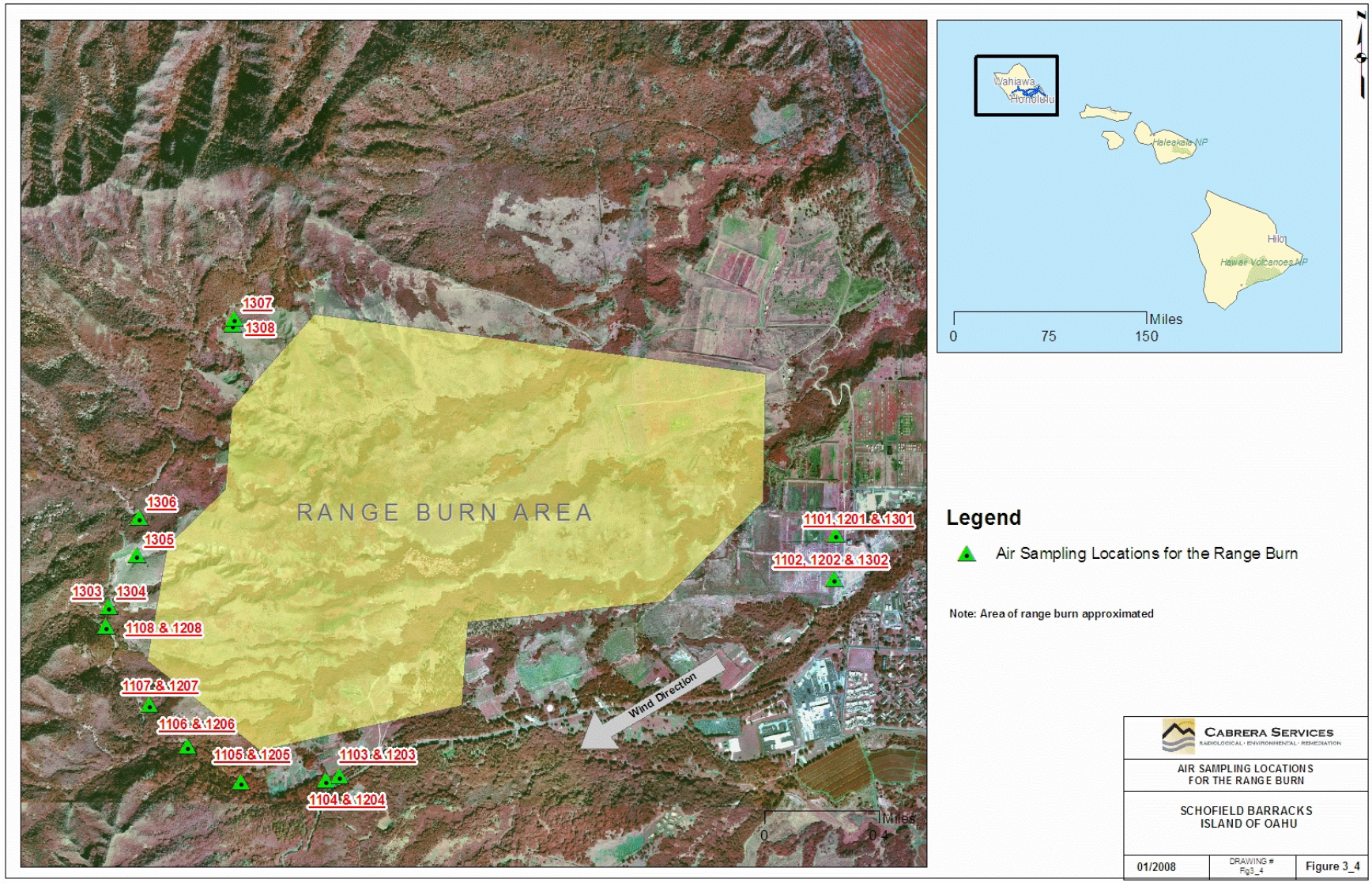

FIGURE 3-4: AIR SAMPLING LOCATIONS FOR THE RANGE BURN

4.0 ANALYTICAL RESULTS

The air filters were the primary source of information on uranium particulates found in the air during a prescribed burn. All 56 air filters collected before and during the reference, test, and range burns were analyzed for uranium activity.

For the reference burn five vegetation samples were collected prior to the burn and analyzed for uranium activity. Since the ash from vegetation was the most likely source of airborne particulates during a prescribed burn, the information on uranium activity concentrations from the vegetation samples directly addressed the survey objectives. Similarly, five post-reference burn ash samples were collected and analyzed to provide information on uranium activity concentrations in ash that did not become airborne during the burn.

For the test burn two soil samples and three vegetation samples were collected prior to the burn from judgmental locations with a potential to contain DU. The basis of the selection judgment was visual identification of yellow particles (potentially uranium oxide) and higher than expected gross gamma measurements with a field instrument for the detection of low energy radiation (FIDLER) to identify locations likely to contain DU fragments. The main purpose of these samples was to demonstrate that DU was present in the test burn area. A combination of soil and vegetation was used since the uranium uptake by local vegetation in this environment was not known. Five ash samples collected after the test burn were analyzed to provide information on uranium activity concentrations in ash that did not become airborne during the burn.

The air filters, vegetation samples, soil samples, and ash samples were sent to a National Environmental Laboratory Accreditation Program (NELAP) accredited laboratory for analysis of uranium nuclide activity concentrations by alpha spectrometry. Activity concentrations were reported for the three naturally occurring uranium radionuclides; ^{234}U, ^{235}U, and ^{238}U. The results for the reference burn air filters are listed in Table 4-1, and the results of the reference burn vegetation and ash samples are listed in Table 4-2. The results for the test burn air filters are listed in Table 4-3, and the results of the test burn soil, vegetation, and ash samples are listed in Table 4-4. The results for the full range burn air filters are listed in Table 4-5.

Verification and validation of laboratory data was performed to demonstrate that the samples were collected and analyzed properly and that the measurement system was operating properly while the samples were being counted. The laboratory analyzed a laboratory control sample, laboratory control duplicate, and process blank with each of the 8 batches of samples. Since approximately half of each air filter and vegetation sample was analyzed to provide the required detectability there was insufficient sample remaining to perform duplicate analysis of air filters or vegetation samples. One duplicate sample analysis was performed for the batch of 12 soil and ash samples from the reference and test burns. Soil sample EF-TB-PB-1010-SS collected prior to the test burn was analyzed as a duplicate. The results of all quality control measurements met the requirements for the project.

TABLE 4-1: REFERENCE BURN AIR FILTER RESULTS

Sample ID	^{234}U			^{235}U			^{238}U		
	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC
EF-RB-PB-1016-FP	5.6E-16	6.6E-16	5.1E-16	-1.5E-16	3.1E-16	1.2E-15	6.2E-17	4.5E-16	1.0E-15
EF-RB-PB-1017-FP	0.0	0.0	5.8E-16	0.0	0.0	7.2E-16	7.1E-17	5.1E-16	1.2E-15
EF-RB-PB-1018-FP	1.0E-16	7.3E-16	1.6E-15	0.0	0.0	1.0E-15	4.0E-16	9.4E-16	1.6E-15
EF-RB-PB-1019-FP	5.6E-16	6.6E-16	5.1E-16	-1.5E-16	3.1E-16	1.2E-15	5.6E-16	6.6E-16	5.0E-16
EF-RB-PB-1020-FP	5.3E-16	6.2E-16	4.8E-16	0.0	0.0	5.9E-16	0.0	0.0	4.8E-16
EF-RB-PB-1021-FP	0.0	0.0	4.3E-16	-1.3E-16	2.7E-16	1.1E-15	-5.3E-17	4.4E-16	1.0E-15
EF-RB-PB-1022-FP	9.5E-17	4.9E-16	9.3E-16	-1.2E-16	2.4E-16	9.5E-16	1.4E-16	2.9E-16	3.9E-16
EF-RB-PB-1023-FP	3.1E-16	4.4E-16	4.2E-16	0.0	0.0	5.2E-16	1.5E-16	3.1E-16	4.2E-16
EF-RB-AB-1024-FP	-4.7E-16	9.6E-16	3.8E-15	-5.8E-16	1.2E-15	4.7E-15	1.4E-15	2.0E-15	1.9E-15
EF-RB-AB-1025-FP	-8.7E-17	1.7E-16	7.0E-16	0.0	0.0	4.4E-16	0.0	0.0	3.5E-16
EF-RB-AB-1026-FP	0.0	0.0	4.2E-16	0.0	0.0	5.2E-16	-5.1E-17	4.2E-16	1.0E-15
EF-RB-AB-1027-FP	0.0	0.0	3.3E-16	1.5E-16	3.1E-16	4.1E-16	1.2E-16	2.5E-16	3.3E-16
EF-RB-AB-1028-FP	**7.0E-16**	**6.5E-16**	**3.8E-16**	-1.2E-16	2.3E-16	9.4E-16	0.0	0.0	3.8E-16
EF-RB-AB-1029-FP	1.3E-16	2.7E-16	3.6E-16	0.0	0.0	4.5E-16	0.0	0.0	3.6E-16
EF-RB-AB-1030-FP	1.9E-16	4.4E-16	7.6E-16	-1.2E-16	2.3E-16	9.3E-16	2.8E-16	4.0E-16	3.8E-16
EF-RB-AB-1031-FP	2.4E-16	3.5E-16	3.3E-16	0.0	0.0	4.1E-16	1.2E-16	2.4E-16	3.3E-16

All results are reported in μCi/mL.

Results in **BOLD** exceed the minimum detectable concentration and have measurement uncertainty less than 100% of the reported result.

TABLE 4-2: REFERENCE AREA SOLID SAMPLE RESULTS

Sample ID	^{234}U			^{235}U			^{238}U		
	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC
EF-RB-PB-1001-VS	0.022	0.031	0.030	0.0040	0.032	0.073	0.033	0.038	0.029
EF-RB-PB-1003-VS	-0.0070	0.014	0.057	0.026	0.038	0.035	**0.13**	**0.078**	**0.028**
EF-RB-PB-1005-VS	0.045	0.046	0.031	0.0	0.0	0.038	**0.19**	**0.11**	**0.073**
EF-RB-PB-1007-VS	**0.086**	**0.063**	**0.029**	0.0	0.0	0.036	**0.11**	**0.071**	**0.029**
EF-RB-PB-1009-VS	**0.13**	**0.078**	**0.028**	0.017	0.041	0.070	**0.073**	**0.058**	**0.028**
EF-RB-AB-1032-SS	**0.85**	**0.25**	**0.023**	**0.062**	**0.054**	**0.028**	**1.1**	**0.29**	**0.023**
EF-RB-AB-1033-SS	**0.88**	**0.26**	**0.024**	**0.056**	**0.053**	**0.030**	**0.86**	**0.26**	**0.024**
EF-RB-AB-1034-SS	**1.1**	**0.32**	**0.049**	**0.11**	**0.078**	**0.030**	**1.2**	**0.33**	**0.024**
EF-RB-AB-1035-SS	**0.81**	**0.24**	**0.021**	**0.078**	**0.060**	**0.026**	**0.73**	**0.22**	**0.051**
EF-RB-AB-1036-SS	**1.0**	**0.29**	**0.056**	0.057	0.057	0.057	**0.92**	**0.26**	**0.023**

Vegetation samples (VS) are reported in pCi/g ash weight.

Ash sample (SS) results are reported in pCi/g dry weight.

Results in **BOLD** exceed the minimum detectable concentration and have measurement uncertainty less than 100% of the reported result.

TABLE 4-3: TEST BURN AIR FILTER RESULTS

Sample ID	^{234}U			^{235}U			^{238}U		
	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC
EF-TB-PB-1037-FP	6.8E-16	8.0E-16	6.2E-16	9.4E-17	6.8E-16	1.5E-15	7.6E-17	5.4E-16	1.2E-15
EF-TB-PB-1038-FP	2.3E-16	4.7E-16	6.3E-16	0.0	0.0	7.7E-16	7.7E-17	5.5E-16	1.2E-15
EF-TB-PB-1039-FP	-2.3E-16	4.7E-16	1.9E-15	0.0	0.0	1.2E-15	4.7E-16	1.1E-15	1.9E-15
EF-TB-PB-1040-FP	3.2E-16	6.5E-16	8.8E-16	1.3E-16	9.6E-16	2.2E-15	0.0	0.0	8.8E-16
EF-TB-PB-1041-FP	2.7E-16	5.4E-16	7.3E-16	0.0	0.0	8.9E-16	5.3E-16	7.6E-16	7.2E-16
EF-TB-PB-1042-FP	0.0	0.0	6.5E-16	0.0	0.0	8.1E-16	2.4E-16	4.8E-16	6.5E-16
EF-TB-PB-1043-FP	3.8E-16	7.7E-16	1.0E-15	0.0	0.0	1.3E-15	3.8E-16	7.6E-16	1.0E-15
EF-TB-PB-1044-FP	2.9E-16	5.9E-16	7.9E-16	-2.4E-16	4.9E-16	1.9E-15	-9.7E-17	8.0E-16	1.9E-15
EF-TB-AS-1045-FP	7.7E-17	3.9E-16	7.5E-16	-9.5E-17	1.9E-16	7.7E-16	0.0	0.0	3.1E-16
EF-TB-AS-1046-FP	2.0E-16	2.9E-16	2.7E-16	0.0	0.0	3.4E-16	0.0	0.0	2.7E-16
EF-TB-AS-1047-FP	0.0	0.0	2.5E-16	0.0	0.0	3.0E-16	2.7E-16	3.2E-16	2.4E-16
EF-TB-AS-1048-FP	1.3E-16	3.0E-16	5.1E-16	0.0	0.0	3.1E-16	9.4E-17	1.9E-16	2.5E-16
EF-TB-AS-1049-FP	3.0E-16	3.6E-16	2.7E-16	1.2E-16	2.5E-16	3.4E-16	-1.3E-16	1.9E-16	6.6E-16
EF-TB-AS-1050-FP	0.0	0.0	2.6E-08	0.0	0.0	3.3E-08	9.7E-09	2.0E-08	2.6E-08
EF-TB-AS-1051-FP	**4.4E-16**	**4.1E-16**	**2.4E-16**	-7.3E-17	1.5E-16	5.9E-16	0.0	0.0	2.4E-16
EF-TB-AS-1052-FP	9.3E-17	1.9E-16	2.5E-16	0.0	0.0	3.1E-16	9.3E-17	1.9E-16	2.5E-16

All results are reported in µCi/mL except shaded sample 1050, which is reported in µCi/sample.

Results in **BOLD** exceed the minimum detectable concentration and have measurement uncertainty less than 100% of the reported result.

TABLE 4-4: TEST BURN SOLID SAMPLE RESULTS

Sample ID	^{234}U			^{235}U			^{238}U		
	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC
EF-TB-PB-1011-VS	0.060	0.071	0.054	0.0	0.0	0.067	0.080	0.082	0.054
EF-TB-PB-1013-VS	**28**	**6.6**	**0.32**	**2.0**	**0.99**	**0.40**	**180**	**39**	**0.16**
EF-TB-PB-1014-VS	**0.43**	**0.15**	**0.023**	**0.072**	**0.059**	**0.028**	**1.4**	**0.36**	**0.022**
EF-TB-PB-1010-SS	**1.1**	**0.30**	**0.025**	0.037	0.049	0.060	**1.4**	**0.38**	**0.049**
EF-TB-PB-1012-SS	**74**	**18**	**0.39**	**8.2**	**3.5**	**0.48**	**470**	**100**	**0.76**
EF-TB-AB-1053-SS	**0.75**	**0.23**	**0.023**	**0.064**	**0.056**	**0.029**	**1.7**	**0.44**	**0.023**
EF-TB-AB-1054-SS	**0.96**	**0.27**	**0.022**	0.034	0.044	0.055	**1.9**	**0.48**	**0.022**
EF-TB-AB-1055-SS	**0.61**	**0.20**	**0.024**	0.022	0.032	0.030	**0.69**	**0.22**	**0.024**
EF-TB-AB-1056-SS	**0.86**	**0.26**	**0.048**	0.015	0.034	0.059	**0.72**	**0.22**	**0.024**
EF-TB-AB-1057-SS	**0.66**	**0.21**	**0.024**	0.044	0.046	0.030	**1.1**	**0.30**	**0.024**

Vegetation samples (VS) are reported in pCi/g ash weight.

Soil sample and ash sample (SS) results are reported in pCi/g dry weight.

Results in **BOLD** exceed the minimum detectable concentration and have measurement uncertainty less than 100% of the reported result.

TABLE 4-5: RANGE BURN AIR FILTER RESULTS

Sample ID	^{234}U			^{235}U			^{238}U		
	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC	Activity	Uncertainty	MDC
EF-FB-AS-1101-FP	3.2E-16	3.8E-16	2.9E-16	0.0	0.0	3.6E-16	3.6E-17	2.6E-16	5.8E-16
EF-FB-AS-1102-FP	-6.3E-17	1.3E-16	5.1E-16	1.2E-16	2.4E-16	3.2E-16	0.0	0.0	2.6E-16
EF-FB-AS-1103-FP	-9.9E-17	2.0E-16	8.0E-16	0.0	0.0	5.0E-16	1.5E-16	3.0E-16	4.0E-16
EF-FB-AS-1104-FP	1.0E-16	2.1E-16	2.8E-16	-8.5E-17	1.7E-16	6.8E-16	2.0E-16	2.9E-16	2.8E-16
EF-FB-AS-1105-FP	-7.4E-17	1.5E-16	6.0E-16	0.0	0.0	3.7E-16	3.7E-17	2.7E-16	6.0E-16
EF-FB-AS-1106-FP	4.2E-16	4.9E-16	3.8E-16	0.0	0.0	4.7E-16	-9.3E-17	1.9E-16	7.5E-16
EF-FB-AS-1107-FP	1.3E-16	2.6E-16	3.5E-16	0.0	0.0	4.3E-16	0.0	0.0	3.5E-16
EF-FB-AS-1108-FP	0.0	0.0	2.6E-16	1.2E-16	2.4E-16	3.2E-16	1.9E-16	2.7E-16	2.6E-16
EF-FB-AS-1201-FP	6.4E-17	6.5E-17	4.3E-17	0.0	0.0	5.3E-17	5.3E-18	3.8E-17	8.5E-17
EF-FB-AS-1202-FP	1.9E-17	4.4E-17	7.6E-17	0.0	0.0	4.7E-17	1.4E-17	2.8E-17	3.8E-17
EF-FB-AS-1203-FP	**1.8E-16**	**1.4E-16**	**1.1E-16**	0.0	0.0	7.1E-17	**1.7E-16**	**1.3E-16**	**5.7E-17**
EF-FB-AS-1204-FP	**8.7E-17**	**7.4E-17**	**3.9E-17**	-1.2E-17	2.4E-17	9.6E-17	**8.6E-17**	**7.3E-17**	**3.9E-17**
EF-FB-AS-1205-FP	**8.1E-17**	**6.9E-17**	**3.7E-17**	0.0	0.0	4.5E-17	**9.4E-17**	**7.4E-17**	**3.7E-17**
EF-FB-AS-1206-FP	6.2E-17	6.4E-17	4.2E-17	1.9E-17	3.9E-17	5.2E-17	2.1E-17	4.9E-17	8.4E-17
EF-FB-AS-1207-FP	1.6E-17	3.2E-17	4.3E-17	0.0	0.0	5.3E-17	3.2E-17	4.5E-17	4.3E-17
EF-FB-AS-1208-FP	2.6E-17	3.8E-17	3.6E-17	0.0	0.0	4.4E-17	2.6E-17	3.8E-17	3.6E-17
EF-FB-AS-1301-FP	2.5E-17	5.8E-17	9.9E-17	0.0	0.0	6.2E-17	0.0	0.0	5.0E-17
EF-FB-AS-1302-FP	5.1E-17	6.0E-17	4.6E-17	2.1E-17	4.2E-17	5.7E-17	3.4E-17	4.8E-17	4.6E-17
EF-FB-AS-1303-FP	2.8E-17	4.0E-17	3.8E-17	1.7E-17	3.5E-17	4.6E-17	0.0	0.0	3.7E-17
EF-FB-AS-1304-FP	4.3E-17	5.1E-17	3.9E-17	3.5E-17	5.1E-17	4.8E-17	4.8E-17	6.1E-17	7.7E-17
EF-FB-AS-1305-FP	1.5E-17	3.0E-17	4.0E-17	0.0	0.0	4.9E-17	0.0	0.0	4.0E-17
EF-FB-AS-1306-FP	6.7E-17	7.4E-17	8.3E-17	0.0	0.0	5.2E-17	**9.2E-17**	**7.8E-17**	**4.2E-17**
EF-FB-AS-1307-FP	3.6E-17	5.8E-17	8.4E-17	0.0	0.0	5.2E-17	4.7E-17	5.5E-17	4.2E-17
EF-FB-AS-1308-FP	6.1E-17	6.3E-17	4.2E-17	6.3E-18	4.6E-17	1.0E-16	-1.0E-17	2.1E-17	8.3E-17

All results are reported in μCi/mL. Results in **BOLD** exceed the minimum detectable concentration with measurement uncertainty less than 100% of the reported result.

5.0 DISCUSSION OF RESULTS

5.1 Air Sampling Results

A total of 56 air filters were collected to evaluate the potential release of particulates containing uranium during prescribed burns at Schofield Barracks. All reported activity concentrations of uranium isotopes (^{234}U, ^{235}U, and ^{238}U) in air were below the action level of 5×10^{-15} microcuries per milliliter (μCi/mL) established in the Effluent Sampling Plan. The action level is equal to 10% of the air effluent limit for ^{234}U (5×10^{-14}) found in 10 CFR 20 which is the most conservative air effluent limit for the uranium isotopes present in DU (NRC 10 CFR 20). This means there is no significant dose to range workers or members of the public from inhalation of uranium released during prescribed burns at Schofield Barracks. This includes those individuals in close proximity to the range burns (i.e., range control personnel and firefighters).

Six of the air filter samples reported at least one uranium isotope with an activity concentration that exceeded the minimum detectable concentration (MDC) and with a total measurement uncertainty less than 100% of the reported activity concentration. Sample EF-RB-AS-1028-FP collected during the reference area burn reported ^{234}U with a measurement uncertainty of 93%, and sample EF-TB-AS-1051-FP collected during the test burn reported ^{234}U with a measurement uncertainty of 93%. Three samples collected during the first day of the range burn (EF-FB-AS-1203, 1204, and 1205) reported both ^{234}U and ^{238}U activity concentrations exceeding the MDC with total measurement uncertainties ranging from 76 to 85%. Sample EF-FB-AS-1306-FP collected during the second day of the range burn reported ^{238}U with a total measurement uncertainty of 85%. The highest reported concentration was 1.8×10^{-16} μCi/mL for ^{234}U in sample 1203, which is approximately 0.36% of the air effluent limit.

Uranium-238 activity concentrations reported for air filter samples collected during a burn were compared to air filter samples collected prior to a burn to determine if there was any increase in uranium activity. Ratios of ^{238}U activity during the burn to ^{238}U activity prior to the burn and error bars based on the total propagated measurement uncertainty were calculated using the data in Tables 4-1 through 4-5. Ratios and error bars were calculated for all non-zero results, since a value of zero returns a divide by zero error. Seventeen of the 32 combinations were evaluated (5 reference burn, 3 test burn, 6 range burn first day, 3 range burn second day). Figure 5-1 shows a

ratio plot comparing the ^{238}U activity ratios. Ratios greater than 1 indicate a potential increase in uranium activity concentrations. Only 4 of the 17 ratios were greater than 1, and all had very large uncertainties which extend below zero, indicating these results are not statistically significant. However, three of the filters collected on the first day of the range burn detected both ^{234}U and ^{238}U activity concentrations above the MDC. These results were for samples collected over 7 hours compared to pre-burn air filters that were collected for 1 hour. The difference in sample time changed the sample volume, which in turn lowered the MDC.

5.2 Soil/Vegetation/Ash Sampling Results

A total of 20 soil, vegetation, and ash samples were collected to evaluate the presence of DU in the reference and test burn areas. Uranium activity concentrations above the minimum detectable concentration were reported for all of the vegetation, soil, and ash samples.

The ^{238}U activity concentrations in reference area vegetation averaged approximately 0.1 pCi/g of vegetation ash, while the ash samples reported average ^{238}U activity concentrations of approximately 1 pCi/g. The difference in concentration for vegetation ash and post-burn ash is the presence of small amounts of surface soil in the post-burn ash samples, and soils in Hawaii contain approximately 1 pCi/g of naturally occurring uranium.

The ^{238}U activity concentrations in the test area soil, vegetation, and ash samples varied significantly. Samples EF-TB-PB-1011-VS (vegetation), EF-TB-AB-1055-SS (ash), and EF-TB-AB-1056-SS (ash) reported uranium concentrations consistent with those reported for similar reference area samples. The remaining samples reported significantly higher activity concentrations, including soil sample EF-TB-PB-1012-SS collected prior to the test burn with 470 pCi/g of ^{238}U. Elevated ^{238}U results were expected in the test area because the samples were collected from locations where DU was expected to be present. The difficulty in locating areas with sufficient ash for sampling described in Section 3.2 prevented matching the post-burn ash sample locations with the pre-burn soil and vegetation sample locations.

5.3 Evaluation of Uranium Depletion

Uranium activity was detected in air filter, soil, vegetation, and ash samples at Schofield Barracks. However, since uranium occurs naturally in the environment only DU is associated with Army activities. The ratio of ^{238}U to ^{234}U is approximately 1 for naturally occurring

uranium. The National Council on Radiation Protection and Measurements (NCRP) states that the ratio of ^{238}U to ^{234}U ranges from 1.09 for weathered soils to 0.877 for ocean water (NCRP, 1975). Ratios greater than 1 indicate the uranium could be depleted, with higher concentrations of ^{238}U relative to ^{234}U. Ratio Plots were prepared showing the ratio of ^{238}U to ^{234}U with error bars based on the total propagated measurement uncertainties reported in Tables 4-1 through 4-5.

Figure 5-2 shows the ^{238}U to ^{234}U ratios for all of the non-zero uranium results for air filters.[2] Ratios and error bars were calculated for 35 of the 56 air filter samples. Thirteen ^{238}U to ^{234}U ratios were greater than or equal to 1, while 22 ratios were less than 1. All of the ratios greater than or equal to 1 had error bars that extended below zero. The uncertainty associated with these ratios show the results are not statistically significant and do not indicate the presence of DU on any of the air filters. This is consistent with the findings that no significant uranium activity concentrations were detected on any of the air filters. The y-axis for Figure 5-2 has been truncated to show detail around the expected ratio of 1. The actual error bars extend from -27 to 35.

Figure 5-3 shows the ^{238}U to ^{234}U ratios for all of the uranium results for soil, vegetation, and ash samples. The figure shows the reference burn data on the left and the test burn data on the right. Each half of the figure is further divided to show the pre-burn data and post-burn data. The reference burn data has 5 ratios greater than 1 and 5 that are less than 1. There is greater uncertainty associated with the pre-burn vegetation sample results than with the post-burn ash sample results. This primarily results from the higher activity concentrations reported for the ash (1 pCi/g compared to 0.1 pCi/g for vegetation, see Section 5.2) and the correspondingly lower measurement uncertainties.

The test burn soil and vegetation data show several samples with evidence of uranium depletion. Nine of the ten results have ratios greater than 1, and only 1 ratio for vegetation sample EF-TB-PB-1011-VS has an uncertainty that extends below zero. Three samples collected prior to the burn (vegetation samples EF-TB-PB-1013 and 1014-VS, soil sample EF-TB-PB-1012-SS)

[2] Results equal to zero return divide by zero errors and were not included in the analysis. No uranium activities above the MDC were excluded from this evaluation because of zero activity for the other uranium isotope.

reported ratios significantly greater than 1, since the lower error bar is greater than 1. Two ash samples also reported ^{238}U to ^{234}U ratios significantly greater than 1 (EF-TB-AB-1053 and 1054-SS). These ratios demonstrate that DU was present in the soil, vegetation, and ash in the test area. The y-axis for Figure 5-3 has been truncated to show detail around the expected ratio of 1. The actual error bars extend from -56 to 20.

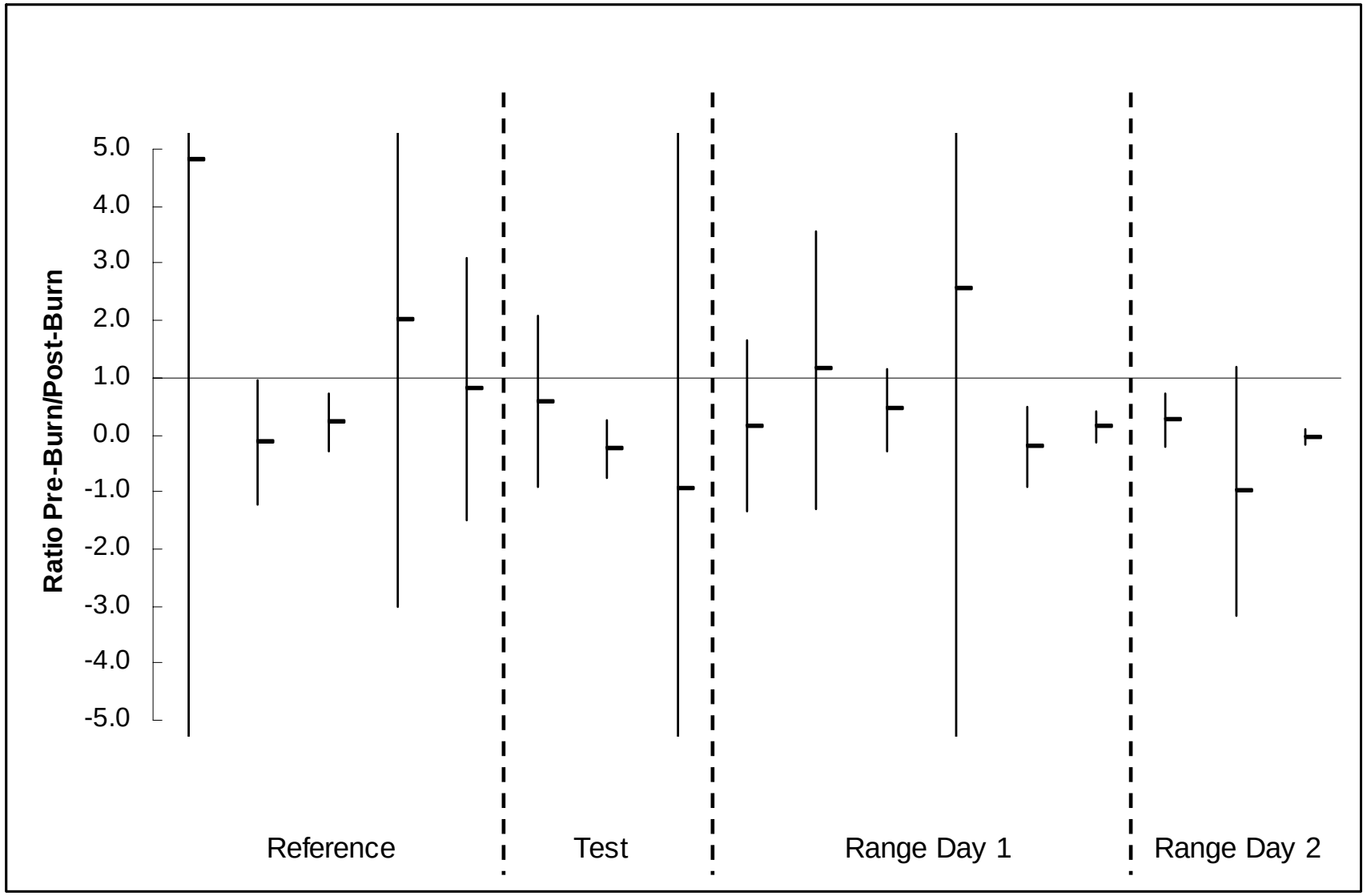

FIGURE 5-1: RATIO PLOT OF POST-BURN TO PRE-BURN ^{238}U ACTIVITY

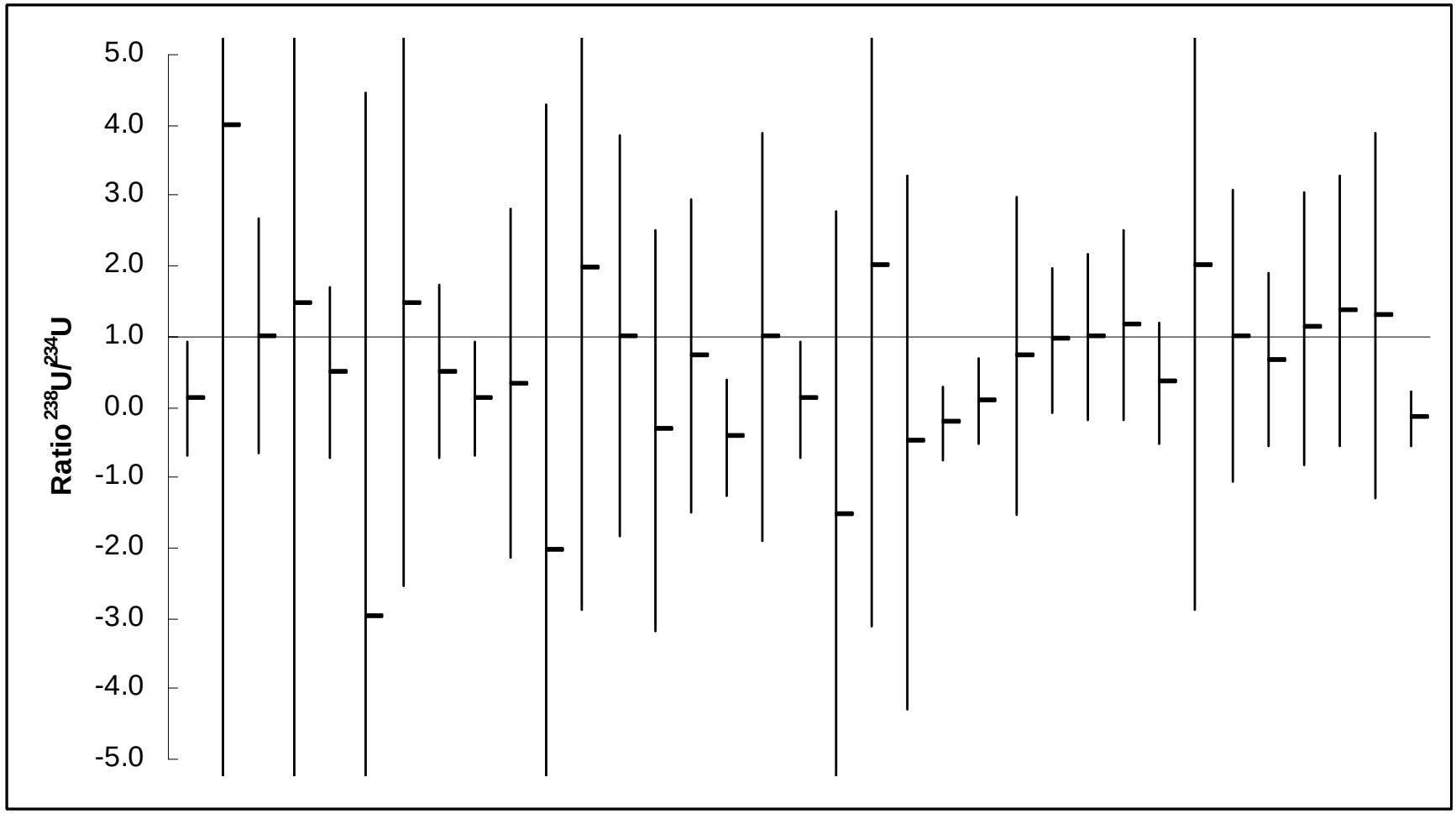

FIGURE 5-2: RATIO PLOT OF ^{238}U TO ^{234}U ACTIVITY FOR AIR FILTERS

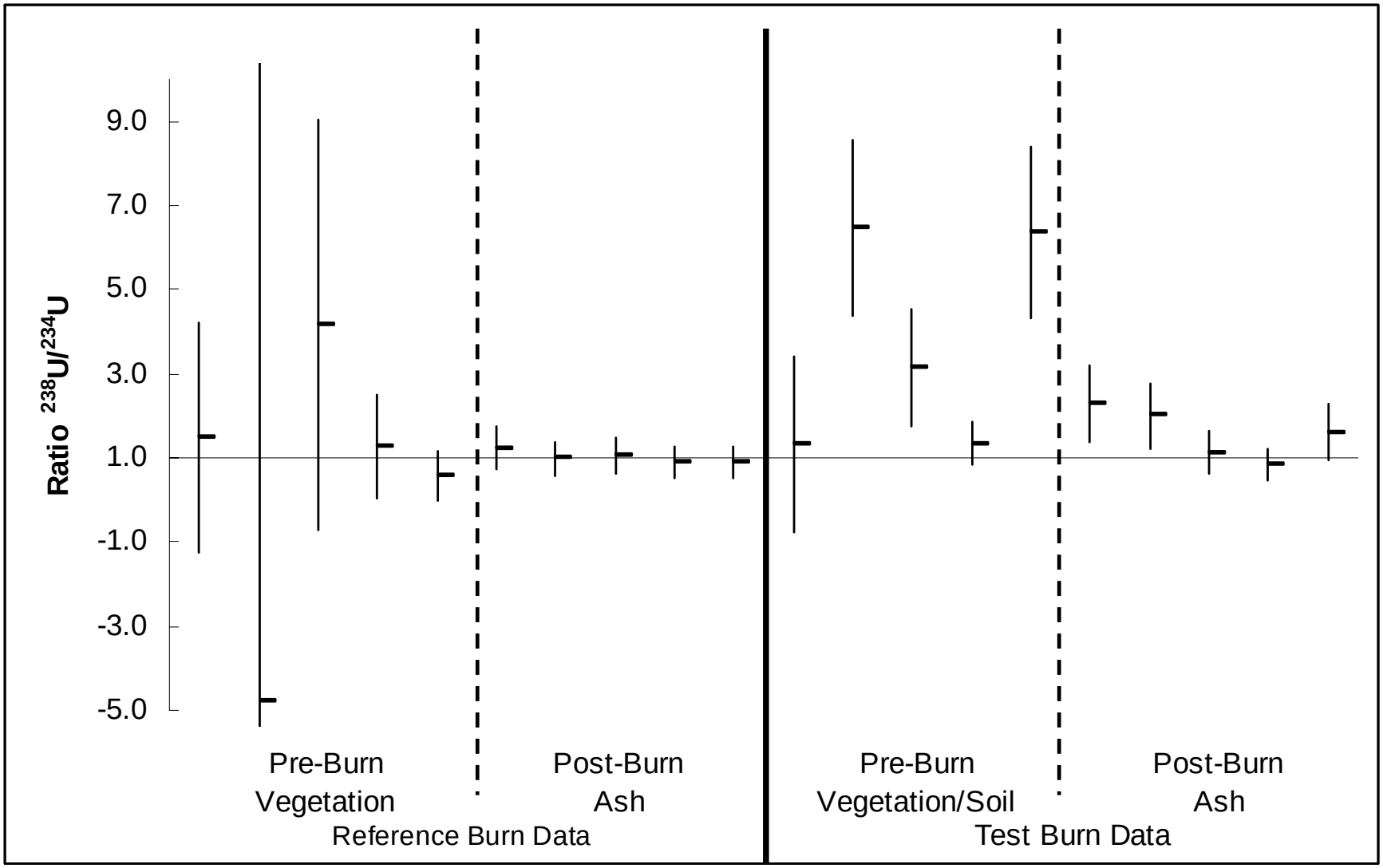

FIGURE 5-3: RATIO PLOT OF ^{238}U TO ^{234}U ACTIVITY FOR SOLID SAMPLES

6.0 CONCLUSIONS AND RECOMMENDATIONS

Visual observations, meteorological data, and the presence of ash on most of the filters support that the air samplers were properly positioned to monitor airborne particulates generated during the reference, test, and prescribed range burns. The field sample collection and laboratory quality control followed the work plan with only two minor deviations (one equipment malfunction described in Section 3.2 and the change in the ash sample collection procedure because of site conditions described in Section 3.1).

The selection of the reference area as non-impacted by DU was supported by project data. The uranium activity concentrations measured in vegetation and ash were relatively low compared to the test area results, and no evidence of uranium depletion was identified in any reference area samples. The comparison of pre-burn air filter results with air filter samples collected during the burn did not show any increase in uranium activity concentrations.

The selection of the test burn area as impacted by DU was supported by project data. The uranium activity concentrations measured in soil, vegetation, and ash were higher than activity concentrations in the reference area, which was expected. The uranium activity concentrations in the test area solid samples demonstrated that DU was present in the test area before and after the test burn. The air filters collected during the test burn did not identify any increase in uranium activity concentration compared to the pre-burn air filters and no evidence of uranium depletion was found in the air filter results. These results confirm that there was no measurable hazard during burning activities.

Based on the results of the reference and test burns, a prescribed burn of the full range was performed. Air monitoring performed during the first day of the range burn detected low concentrations of uranium. There was no evidence of uranium depletion found in any of the air filter results, and the maximum uranium activity concentration was approximately 0.36% of the air effluent limit for uranium from 10 CFR 20. The slight increase in uranium corresponds with increased amounts of ash found on the filters and the increased sampling time used to monitor the range burn.

No evidence of DU was found in air particulates generated during prescribed burns at Schofield Barracks. No significant inhalation dose from airborne uranium was identified based on results of air monitoring performed during the prescribed burns. No additional investigations of DU released during prescribed burns at Schofield Barracks are recommended.

7.0 REFERENCES

Cabrera Services, Inc., July 2007, *Effluent Sampling Plan for Air Monitoring of Depleted Uranium During Prescribed Burns at Schofield Barracks.*

NCRP, 1975. *Natural Background Radiation in the United States,* NCRP Report No. 45, National Council on Radiation Protection and Measurements, November 1975.

Nuclear Regulatory Commission (NRC), *Title 10 Code of Federal Regulations (CFR) Part 20,* Appendix B, Table 2.