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ANALYSIS OF RADIATION EXPOSURE FOR MILITARY PARTICIPANTS
Exercises Desert Rock I, II, and III—Operation Buster-Jangle

M. Barrett, et al.
Science Applications International Corporation
P.O. Box 1303
McLean, VA 22102-1303

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19. ABSTRACT (*Continue on reverse if necessary and identify by block number*)

Radiation doses to observers, maneuver troops, technical projects, and support units for Exercises Desert Rock I, II, and III are reconstructed for each applicable shot of Operation Buster-Jangle (1951). Residual radiation doses are calculated from the characterized radiation environments and the activity scenarios of the participants. Uncertainties are determined from the variances of each parameter used in the calculations. Exposure to initial radiation was negligible, but the 50-year bone dose commitment from exposure to internal emitters was significant for some personnel due to the type and duration of activities in the resuspendible debris from the surface and underground shots (Sugar and Uncle). Calculated mean film badge equivalent doses for the Desert Rock exercises ranged up to 0.53 rem for observers, 0.08 rem for maneuver troops, and about 3.6 rem for a Desert Rock III engineer evaluator (Shot Uncle). Exposure of support units, if personnel had not been rotated, could have led to mean doses ranging to 3.7 rem. Internal doses were as high as 2.9 rem bone dose commitment for Desert Rock II ordinance and engineer

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19. ABSTRACT (continued)

evaluators at Shot Sugar who also returned to the site (in 1952) after the operation for final evaluation of test equipment, and 2.2 rem for engineer recovery and restoration personnel in 1952.

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INTRODUCTION

This report is an analysis of the nuclear radiation exposure for military participants in the 1951 series of nuclear tests at the Nevada Test Site (NTS). The series was designated Operation Buster-Jangle.

Operation Buster-Jangle consisted of seven shots (figure 1), detonated over a period of about six weeks, 22 October through 29 November 1951. Exercises Desert Rock I, II, and III, conducted in conjunction with the operation, consisted of military activities at three of the tests: Shots Dog, Sugar, and Uncle. Exercise Desert Rock III continued until 11 December and the participants departed 14 December 1951. As the objectives, organization, troops, and rad-safe responsibilities of the three exercises differed, this report addresses each exercise separately.

There were four types of military participation in the Desert Rock exercises. The first consisted of observers, who were military personnel sent to Camp Desert Rock (CDR) for the specific purpose of observing one shot. Observers participated in Shots Dog, Sugar and Uncle.

The second type of military participation consisted of a battalion-size maneuver unit that moved to Camp Desert Rock for the purpose of engaging in a tactical exercise to test doctrine being considered for the nuclear battlefield. One such exercise was conducted: an Army Battalion Combat Team (BCT), organized from four units, maneuvered at Shot Dog.

Third, there were the personnel assigned to CDR, who planned, administered and supported the exercises. Some support elements actually participated in shots as technical services support personnel or their effects evaluators. It is also likely that some CDR support personnel witnessed Shot Easy (Operation Buster) from the observation point.

The fourth type of participation was the use of evaluators and monitors from the technical services to assess damage and measure radiation levels. During Exercises Desert Rock II and III, monitors accompanied the observers (References 1, 2).

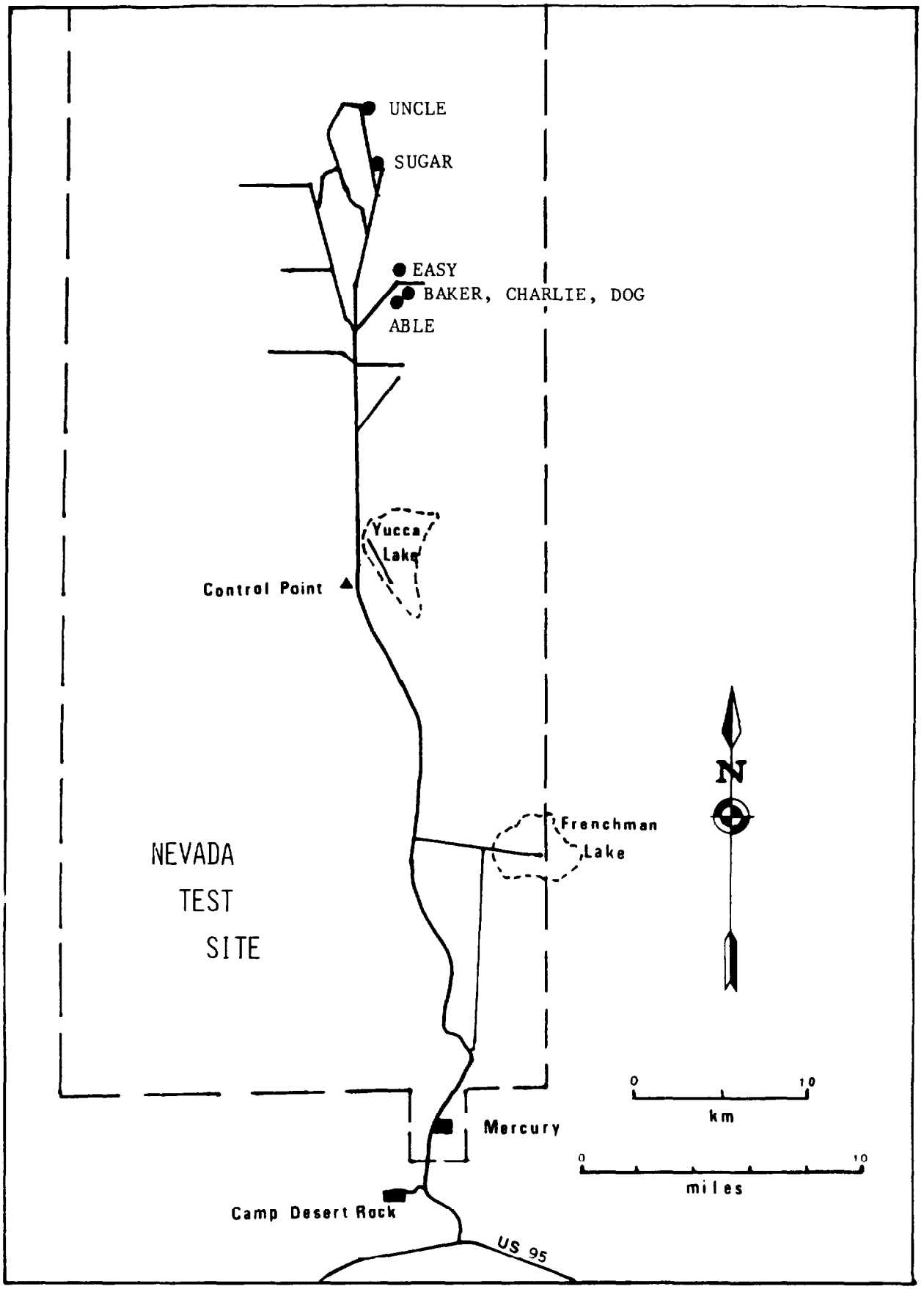

Figure 1. Shot locations, Operation Buster-Jangle.

It should be noted that a major category of military participation, not a part of Exercise Desert Rock, consisted of projects conducted under the sponsorship of Field Command, Armed Forces Special Weapons Project. These efforts, as well as the support provided by Department of Defense personnel to other test groups and to the overall operation, are to be analyzed only as necessary to supplement available film badge dosimetry.

Activities for each of the shots are traced from the pre-shot orientation through the shot activities, including any tactical maneuver and post-shot equipment inspection. Time-dependent position information is presented in order that an exposure analysis can be performed to determine the integrated dose from all contributing sources, principally the external dose due to residual radiation from the shot and applicable preceding shots.

The analysis utilizes an automated procedure, developed previously (Reference 3) for determining the external dose due to residual radiation. Radiological survey data are fit, in statistical regression analyses, to space-time models of residual radiation intensity, from which isointensity contours (isopleths) are then developed.

As in previous reports, the methodology also considers the effect of soil activation in the residual radiation analysis. This is appropriate for Shot Dog, where the residual contamination at the post-shot times of interest was primarily due to the neutron-induced activity of manganese-56 and sodium-24. For Shots Sugar and Uncle, the major contribution to residual radiation was from fission products. In all cases, the decay model is representative of actual shot conditions, verified by correlations with available data.

The methodology for determining personnel dose is essentially the same as that used in previous analyses (References 3, 4, 5), in which comparisons with dosimetric data established a high degree of confidence. For Exercise Desert Rock I, such comparison is made between calculated dose and available film badge records. Due to the lack of film badge dosimetry data for most personnel of Exercises Desert Rock II

and III, only minimal comparison of calculated dose with film badge dose is possible. However, the methodology for determining personnel dose is not significantly different than that used in previous analyses (References 3, 4), in which comparisons with dosimetric data established a high degree of confidence. Uncertainties in the results are due primarily to the uncertainties in both the radiological surveys and the time-position descriptions of troop activities. Automation of the dose estimation procedure facilitates the determination of confidence levels and aids in subsequent exposure analyses of other troop operations in the same radiologically contaminated areas.

The major finding of this report is that the external radiation doses for Exercise Desert Rock participants without surviving dosimetry ranged from less than .01 rem (observers at Shot Dog) to about 3 rem for some evaluators and support troops at the surface and underground shots. Some of these evaluators accrued another 1.9 rem in January 1952 when they returned to the test site to assess the effects on test positions not accessible earlier. There is evidence to suggest that no personnel who were not already identified in rad-safe documents exceeded the 3 rem dose limit for the exercise; e.g., different evaluators were assigned for the high exposure activities at Exercises Desert Rock II and III. However, internal (bone) dose commitments were relatively high for evaluators and support units due to the highly resuspendible debris from the underground shot (Uncle) and the late (January) reentry into the shot areas.

SECTION 2
EXERCISE DESERT ROCK I

2.1 SHOT DATA.

A summary of the five test shots detonated during the Buster phase of Operation Buster-Jangle is contained in table 1. Although Exercise Desert Rock troops participated only at Shot Dog, all shots are considered to account for any residual radiation that might have contributed to their total radiation dose.

2.2 PARTICIPATION.

Operation Buster-Jangle was the first nuclear test series during which a large number of tactical troops received realistic training in the tactical aspects of atomic warfare. To support and control the exercise, approximately 3500 troops from the Sixth Army's III Corps were assigned the mission of organizing, constructing, and staffing the support facilities that were designated Camp Desert Rock. Initial plans were to dismantle Camp Desert Rock and return all support units to their home stations following Shot Dog on 1 November 1951. However, on 3 November, orders were received from the Commanding General, Sixth Army stating, in effect, that the camp would remain open to support the troops that would participate at Shots Sugar and Uncle, the last two shots planned for Operation Buster-Jangle.

The tactical exercise held in conjunction with Shot Dog was originally designated Exercise Desert Rock, and by 20 October 1951, approximately 3700 troops arrived at Camp Desert Rock to participate in the testing and training programs. These activities included the troop observer program and a tactical troop maneuver to be conducted in the Shot Dog area. The 1095 maneuver troops were drawn primarily from the 11th Airborne Division at Fort Campbell, Kentucky; the observer troops came from all services with the majority, approximately 2300, being Army personnel (References 1,9).

For exercise direction, elements of the Desert Rock staff were responsible for advising, training, supporting, and controlling the observer and maneuver troops. The

Table 1. Buster-Jangle shot data.

Shot (AEC Designation)	Exercise Desert Rock	Date (1951) Actual (Sched)	Local Time (PST)	Location Coordinates (UTM)	Burst Height* (ft)	Yield (KT)
Able		22 October (19 October)	0600	Area 7 (5) 868042	100T	<0.1
Baker		28 October (23 October)	0720	Area 7 (3) 871045	1,118A	3.5
Charlie		30 October (26 October)	0700	Area 7 (3) 871045	1,132A	14
Dog	I	1 November (29 October)	0730	Area 7 (3) 871045	1,417A	21
Easy		5 November (1 November)	0830	Area 7 (1) 867053	1,314A	31
Sugar	II	19 November (15 November)	0900	Area 9a 854097	3.5S	1.2
Uncle	III	29 November (29 November)	1200	Area 10 850139	-17U	1.2

Source: References 1, 2, 32

* T-Tower; A-Air Drop; S-Surface; U-Underground

Control Group elements particularly involved in shot-day operations were the Control Staff and its Advisory Group, the Radiological Safety Unit, and the Effects Evaluation Teams.

- The Control Staff consisted of 19 officers and enlisted men. They were to supervise the exercise and maintain contact with the Exercise Director. The Advisory Group to the Control Staff consisted of officers from the Armed Forces Special Weapons Project (AFSWP) who provided pre-shot indoctrination briefings for the observers and maneuver troops on nuclear weapons and their effects. Post-shot, this group briefed the exercise troops as they toured the equipment displays. The Control Staff utilized military police and signal personnel to assist in the exercise operations in the forward area.

- The Radiological Safety Unit, under the direction of the AFSWP Radiological Safety Officer, was responsible for establishing and enforcing radiological safety criteria and establishing radiation surveys. Fifteen radiological monitors from the Chemical Corps School at Fort McClellan, arrived at Camp Desert Rock on 16 October. These monitors trained 45 monitors from the 1st Battalion, 188th Airborne Regiment, as well as 15 monitors from other units participating in the exercise. An additional 15 monitors were provided by the AEC who were responsible for overall radiological safety of personnel at the test site. Monitors accompanied the troops throughout their maneuver and other activities in the shot area. The Radiological Safety Unit was also responsible for personnel and equipment decontamination in the forward area and for issuing and collecting all film badges; film badges were processed by an Army Signal Corps photographic unit (Reference 1).

- The Effects Evaluation Teams, one each from the III Corps Chemical, Signal, Engineer, Medical, Ordnance, and Quartermaster sections, assessed the effects of the Shot Dog detonation on military equipment and field

fortifications. Each team was responsible for constructing or emplacing equipment displays for Shot Dog, recovering equipment after the detonation, and preparing a report of its findings. Technical assistance to the Effects Evaluation Teams was provided by the Advisory Group.

While in the forward area during rehearsals and on shot day, personnel from these staff groups formed six teams, one at each display position (positions 1-5) and the BCT position. Each team was comprised of members of the Control Staff, Advisory Group, rad-safe units, Effects Evaluation Teams, military police, signal personnel, and photographers. These teams guided the observers and maneuver troops through each display area and provided nuclear damage effects briefings. While in the forward area, these personnel were designated the Control Group. A seventh team was the Miscellaneous Group, composed primarily of rad-safe personnel trained in decontamination, medical personnel who provided aid stations in the forward area, and personnel responsible for collecting film badges from the exercise participants. Table 2 summarizes the approximate number of troops participating in the forward area. Table 3 lists the units providing support for Exercise Desert Rock I.*

2.3 CONCEPT.

The objectives of Exercise Desert Rock were to (1) provide indoctrination training in the tactical employment of nuclear weapons, (2) determine the effects of nuclear weapons on various types of ground forces equipment and various tactical formations, and (3) determine the psychological reaction of troops witnessing a nuclear detonation and passing through a radiologically contaminated area soon thereafter. Radiological safety plans were designed to minimize exposure to ionizing radiation while allowing participants to conduct realistic military exercises. The radiological safety criterion specified for the exercise was that no Desert Rock personnel were to enter any area where the intensity was greater than 1 R/hr (Reference 1). Subject to radiological constraints, the troop maneuver was allowed near ground zero as long as there was no interference with instrumentation or other experiments.

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* Reference 1 indicates that the 95th Engineer Construction Battalion was scheduled to participate in the exercise, but the unit did not participate.

Table 2. Approximate personnel allocations for participants at Exercise Desert Rock I.

Maneuver Troops	1095
Observers	
Army	2300
Navy	200
Marine Corps	188
Air Force	200
Control Group	
Control Staff	19
Display Position # 1	30
Display Position # 2	81
Display Position # 3	36
Display Position # 4	18
Display Position # 5	31
BCT Position	26
Miscellaneous Group	73
Total Participants (approx.)	4300

Source: References 1, 6, 7, 8

Table 3. Exercise Desert Rock I support units.

Unit	Home Station	Planned Complement
Headquarters and Headquarters Company, III Corps*	Camp Roberts, California	319
Headquarters and Headquarters Battery, III Corps Artillery*	Fort Lewis, Washington	122
806th Army Postal Unit	Fort Lewis, Washington	15
231st Engineer Combat Battalion*	Fort Lewis, Washington	701
Detachment, 597th Engineer Light Equipment Company (attached)*	Fort Huachuca, Arizona	24
359th Engineer Utility Detachment	Camp Cooke, California	88
90th Engineer Water Supply Company*	Fort Lewis, Washington	75
Maintenance Platoon, 705th Engineer Field Maintenance Company	Fort Huachuca, Arizona	70
374th Convalescent Center(-)*	Fort Lewis, Washington	258
94th Veterinary Food Inspection Detachment*	Fort Lewis, Washington	5
Company A, 505th Military Police Battalion*	Camp Roberts, California	154
Company C, 505th Military Police Battalion*	Camp Roberts, California	154
Headquarters and Headquarters Detachment, 393d Ordnance Battalion*	Camp Cooke, California	36
161st Ordnance Depot Company (-)*	Camp Cooke, California	98

* Available documentation indicates that some elements of these units had pre- and/or post-shot assignments in the forward area.

Table 3. Exercise Desert Rock I support units (Concluded).

Unit	Home Station	Planned Complement
3623d Ordnance Company (Medium Maintenance)*	Camp Cooke, California	195
Detachment, Headquarters and Headquarters Company, 53d Quartermaster Base Depot Company*	Utah General Depot	74
1st Platoon, 523d Quartermaster Subsistence Depot Company*	Utah General Depot	45
Platoon, 539th Quartermaster Laundry Company	Fort Lewis, Washington	73
621st Quartermaster Service Company	Fort Lewis, Washington	63
Detachment, Headquarters and Headquarters Company, 303d Signal Service Battalion (augmented)*	Camp Cooke, California	244
Detachment, Headquarters and Headquarters Company and Company B, 314th Signal Service Battalion*	Camp Cooke, California	218
Detachment, 504th Signal Base Maintenance Company*	Sacramento Signal Depot, California	18
4th Transportation Truck Company*	Camp Stoneman, California	126
92d Transportation Car Company*	Camp Roberts, California	129
562d Transportation Staging Area Company*	Camp Stoneman, California	130
	TOTAL	3434

Source: Reference 9

* Available documentation indicates that some elements of these units had pre- and/or post-shot assignments in the forward area.

The maneuver troops were organized into a composite battalion combat team. Pre-shot activities of the BCT were to include orientation briefings by AFSWP personnel on nuclear weapons and their effects, preparation of a battalion defensive position approximately 3500 yards from GZ, and several rehearsals. On shot day, the BCT, troop observers, and the Control Group were to observe Shot Dog from a point approximately seven miles south of GZ (position 6). After the initial radiological survey of the shot area, the Control Group would move forward to the equipment display areas that had been radiologically cleared. The observer troops would then follow the Control Group and view the display areas. After the observer troops departed the observation point for the display area, the BCT troops were to be transported to their previously prepared defensive position where they would inspect the damage to equipment and field fortification. The BCT was then to attack, on foot, an objective area near GZ. They were to be accompanied by radiological safety monitors who would determine, based on the criterion of 1 R/hr, the limits of safe advance. After reaching the objective area, the maneuver would be terminated and the BCT was to inspect the display areas nearest surface zero, being briefed at each area by personnel of the Control Group. Finally, all personnel were to entruck for the return trip to Camp Desert Rock (Reference 10).

2.4 OPERATIONS.

By 20 September 1951, III Corps Headquarters personnel had arrived at Camp Desert Rock and an operational staff was organized for the planning of the troop exercise to be held in conjunction with Shot Dog, scheduled for 1 November. It was announced that the troops participating in Exercise Desert Rock would be drawn primarily from the 11th Airborne Division at Fort Campbell, Kentucky. By 10 October, Operation Order 1 (Operation Thundercloud) was distributed to the participating units.

Troops of the 11th Airborne Division arrived at Camp Desert Rock during the period 12-15 October 1951, and provided the nucleus of the BCT. The participating 11th Airborne units were:

- o 1st Battalion, 188th Airborne Infantry Regiment*
- o 3d Medical Platoon, 188th Airborne Medical Company
- o Platoon, Company A, 127th Engineer Combat Battalion

In addition, Battery C, 546th Field Artillery Battalion from Fort Lewis, Washington augmented the 11th Airborne units. Troops from these four units were organized into the BCT that maneuvered at Shot Dog.

Between 16 and 20 October, the BCT received its exercise orientation and prepared a defensive position approximately 3500 yards southwest of the Shot Dog GZ (figure 2). The position included foxholes, observation posts, and military equipment. Also depicted in the figure are the objective area, the equipment display area (positions 1-5), and the observation area (position 6) from which all exercise participants observed the Shot.

The first rehearsal for Shot Dog was conducted on 21 October. This rehearsal included a simulated countdown and a post-shot maneuver by the BCT from its defensive position to the objective area (see figure 2). Display positions 1 and 2 were not yet completed, as several impending detonations (Shots Able, Baker and Charlie) would have adversely affected equipment displayed in them. After the maneuver rehearsal, the BCT may have walked through the general area of the displays prior to entrucking for the return trip to Camp Desert Rock.

The bulk of the approximately 2800 observer troops arrived at Camp Desert Rock by 26 October, in time to participate in at least one of the exercise rehearsals conducted on 21 and 27 October.

Shot Able, the first shot in the series, was conducted on 22 October 1951. There were no Exercise Desert Rock activities held in conjunction with this detonation. Between 23 and 26 October, the BCT continued to improve their defensive position in

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* Morning reports and associated documents indicate that each of the four line companies (A, B, C & D) was augmented by temporary assignments of about 30 personnel from the corresponding companies in the 2d Battalion (Companies E, F, G, and H).

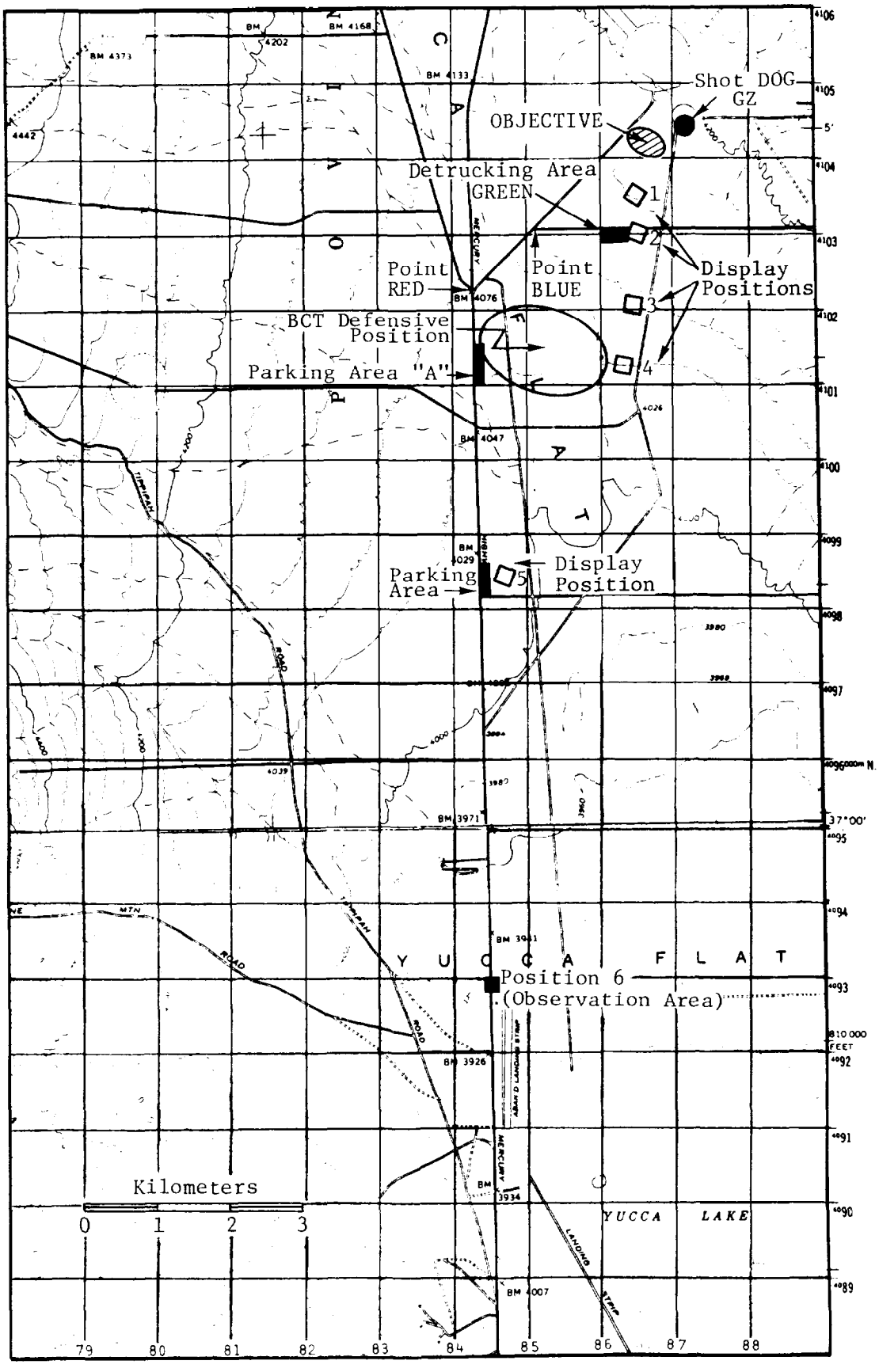


Figure 2. Shot Dog area.

the forward area and, on 27 October, the second Shot Dog rehearsal was conducted. This rehearsal should have included all of the troop observers, maneuver troops Control Group, and evaluation teams. Emplacements probably were completed at display positions 1 and 2, but equipment would not have been placed in them. It is assumed that all activities planned for shot day were accomplished during this rehearsal.

Shot Baker was detonated on 28 October and Shot Charlie was detonated on 30 October. Both of these airdrops were detonated over the same GZ as for Shot Dog. It was recorded in the morning report of the 303d Signal Service Battalion that 158 of their troops observed Shot Charlie, probably from position 6, the observation area. There are no indications that these troop went forward after the shot. As expected, Shot Charlie caused some damage to the equipment emplacements at positions 1 and 2. By the afternoon of 31 October, these emplacements had been repaired and equipment that was to be tested at Shot Dog was in place at all display areas. Also during the early afternoon of 31 October, the BCT returned to their defensive position and attached film badges and position tags to individual weapons, equipment, and vehicles to facilitate the post-shot evaluation of blast and radiation effects from the shot. All troops, except for a guard detail of three officers and ten enlisted men, then returned to Camp Desert Rock (Reference 1).

Shot Dog was detonated at 0730 hours on 1 November. All troops had arrived at the observation area by 0630 hours; the guard detail had moved from the defensive position and display areas to the observation area at 0230 hours. At shot time, all personnel were seated on the ground, facing south. Three seconds after the flash, the troops were instructed to turn around and watch the fireball, but to remain seated until the shock wave had passed.

Shortly after the detonation, an initial radiation survey of the shot area was begun by AEC monitors in a helicopter. While this survey was being conducted, members of the Radiological Safety Unit and the Control Group departed the observation area for the shot area. Based on the results of the helicopter survey, two general area surveys were undertaken by monitors in jeeps. These ground surveys determined that all areas up to and including display position 3 were free of

radioactivity and that the 1 R/hr isopleth was approximately 350 yards from GZ. By 0815 hours, all display positions were manned by the Control Group teams in preparation for the briefing of the observer and BCT troops as they toured each position.

According to the march tables in Reference 1, the first serial of observers was to move out of the observation area shortly after the detonation and proceed, by bus, to position 5. Reference 11 states that the observers departed the observation area "within 30 minutes after the shock wave." It is therefore assumed that all four serials of observers departed the observation area within 30 minutes of the detonation, and that the times specified in the march tables for the movement of the first serial of observers were adhered to. After a 10-minute briefing at position 5, the observers entrucked for the trip to Detrucking Area GREEN (see figure 2) in the vicinity of position 2, where they arrived at approximately 0820 hours. They spent approximately 30 minutes inspecting the damaged equipment at position 2 and being briefed by the Control Group team assigned to this position. Because of the restriction that observers were not to enter any area significantly contaminated with radiation, they were instructed not to proceed any closer to GZ than position 2. At approximately 0850 hours, the observers departed position 2 and proceeded on foot through positions 3 and 4, then on to Parking Area "A" in the vicinity of the BCT defensive position (figure 2). They arrived at the parking area at approximately 1030 hours and were again briefed prior to turning in their film badges and entrucking for the return trip to Camp Desert Rock at 1100 hours. Since the observer troops had not entered any significantly contaminated area, personnel monitoring and decontamination measures were not required prior to their return to the camp.

The march table in Reference 1 indicates that the BCT was to entruck immediately following the detonation for the first stage of their advance to Parking Area "A". Reference 11 indicates that this movement did not occur until nearly an hour after the shot, which suggests the maneuver was somewhat behind schedule. Upon reaching the parking area, the BCT moved to their previously prepared defensive positions and recovered the film badges that they had left the previous day. These film badges were then turned into the Film Badge Control Section at Parking Area

"A". The same reference does not specify when the BCT jumped off in their attack on Objective A. According to the march table, they were scheduled to spend slightly more than one hour at their defensive position prior to beginning their attack at 0905 hours. It is assumed that, since they were behind schedule when leaving the observation area, time spent in the defensive position was cut short in order that the maneuver could begin on schedule at 0905 hours. This assumption tends to high-side the dose calculations.

On order, the BCT moved forward toward the objective area. The attack formation was 15 columns abreast, each preceded by an AEC radiological safety monitor plus 3 BCT monitors who had been trained by personnel from the Chemical Corps School. These monitors had instructions to report any intensity readings of 1 R/hr or more as prescribed by the Exercise Director and to terminate the forward movement. Upon reaching the objective area at 1005 hours, about 500 yards from GZ, the BCT moved through position 1 to position 2, where they closed at 1038 hours. After a 15-minute briefing at position 2, 1500 yards from GZ, the troops turned in their film badges and were monitored prior to entrucking. Only background readings were obtained when the troops were monitored and decontamination was not necessary. The BCT departed Area GREEN and arrived at position 5 at approximately 1150 hours. After a short briefing on the effects of the detonation on test equipment, the BCT entrucked for the return trip to Camp Desert Rock, arriving there at approximately 1330 hours.

It is assumed that each evaluation team remained at its assigned display position throughout the duration of the exercise and did not go from one area to another. It is known that evaluators and accompanying monitors had gotten as far forward as position 1, 1000 yards from GZ, at 0815 hours and that it took approximately 5 hours to brief the inspecting troops and to complete their evaluation (Reference 1). It is therefore presumed that they left the forward area sometime after 1300 hours, which is consistent with the fact that all observer and maneuver troops had viewed the equipment displays and departed the forward area by this time. Logically, the Control Group personnel would have been the last Desert Rock personnel to depart the forward area.

Shot Easy, the final shot in the Buster phase of Operation Buster-Jangle, was detonated on 5 November 1951. There is evidence that some CDR personnel who had remained behind at Camp Desert Rock after Shot Dog, observed this detonation, probably from the Exercise Desert Rock I observation area. There is no evidence to suggest these troops went forward after the shot (References 7, 12, 13, 14).

SECTION 3
EXERCISE DESERT ROCK II

3.1 SHOT DATA.

Exercise Desert Rock II was conducted in conjunction with Shot Sugar, a surface (3½ feet above ground) test detonated at 0900, on 19 November 1951, in Area 9 at UTM coordinates 854097. The yield was 1.2 kt. The shot had been planned for 15 November but was delayed until 19 November (see table 1).

3.2 PARTICIPATION.

A total of about 2900 military personnel participated in Exercise Desert Rock II. This included 172 officer observers selected from the combat branches and technical services. The remainder were Camp Desert Rock support personnel (mostly from the III Corps), as shown in table 4. Several support units, in whole or in part, participated in activities in the test area before and after Shot Sugar, while some units or individuals performed support functions at Camp Desert Rock but did not actively participate in the exercise (References 2, 9).

3.2.1 Observers.

There were 172 official Desert Rock II Observers, all of whom were U.S. Army officers selected from various military branch schools. These official observers attended a course of instruction at Camp Desert Rock conducted by two full-time AFSWP instructors, assisted by 13 additional instructors from the AFSWP Effects Test Group and the exercise staff. These observers and their instructors witnessed Shot Sugar from a vantage point about 9 kilometers (5.7 miles) to the south of ground zero.

Others who observed the shot from the same position included the Exercise Director and his staff, members of the Effects Evaluation Teams, and the AFSWP Advisory Group (3 officers). Reference 15 states that approximately 250 military personnel witnessed the shot. This total probably included a small number of additional Desert Rock support personnel.

3.2.2 Other Desert Rock Participants.

In addition to the official observers and their instructors, other Desert Rock personnel who participated in Exercise Desert Rock II at Shot Sugar included the following:

- Effects Evaluation Teams. These teams, one each from the Desert Rock Chemical, Signal, Engineer, Ordnance, and Quartermaster Sections, were responsible for the pre-shot construction and emplacement of the military equipment displays for Shot Sugar; the post-shot evaluations of the effects of the shot on the various displays; and for post-shot recovery and/or disposition of the equipment. Each team was responsible for completing damage assessment forms for each display and for a final evaluation report of its findings. Available records identify 20 personnel involved in this activity. The records may not be complete and the actual number may have been somewhat greater (References 2, 16); however, there is no evidence that a medical evaluation team participated in this test. Technical assistance to the teams was provided by the 3 officers from AFSWP who were assigned to the Advisory Group.

- Personnel of the 231st Engineer Combat Battalion, with the assistance of the 597th Engineer Light Equipment Company, constructed the emplacements and assisted the evaluation teams in the pre-shot set-up and the post-shot recovery and disposition of displays.

- Military Police. The 505th MP Battalion provided traffic control in the forward area during the pre-shot rehearsals, on shot day, and during the periods of post-shot activities. The battalion also provided escorts for the observer bus tours as well as security details for the displays prior to and, upon clearance by the Rad-safe Officer, after the test.

- Personnel of the 3623d Ordnance Company emplaced, evaluated, and recovered vehicles and ordnance equipment.

- o Signal Corps personnel. Established and maintained wire and radio communications in the test area as well as at Camp Desert Rock. Personnel of the 303d Signal Service Battalion emplaced signal equipment and assisted in the post-shot evaluation and recovery of their equipment.

- o Transportation personnel. Transported observers and evaluators in their pre- and post-shot activities.

- o Exercise Desert Rock II project personnel. The Exercise Director conducted two projects at Shot Sugar:

  - A film badge project conducted by Desert Rock Chemical Section personnel (incorporated with the Radiological Safety Unit). Project activities consisted of pre-shot placement and post-shot recovery of high intensity film badges on equipment displays and in the revetted and unrevetted foxholes interspersed between the displays. The recovered badges were calibrated, developed and read at NTS by Evans Signal Laboratory personnel. (Reference 2).

  - Effects on Food and Water. Personnel from the Quartermaster Section placed samples of food and water in various display areas. Recovered samples were evaluated by personnel from the National Institutes of Health and the Walter Reed Army Medical Center (Reference 2).

- o Radiological Safety Unit. The Desert Rock Chemical Officer was in charge of radiological safety, including training of monitor and decontamination crews. He was assisted by two deputies. One deputy served as the Desert Rock Rad-safe Officer who controlled entry to the test positions following the shot. The Rad-safe Officer's assistant, who had been a rad-safe monitor at Shot Dog, apparently conducted the film badge test indicated above. The second deputy was responsible for two groups of monitors. Records identify at least 36 Desert Rock rad-safe monitors (References 2, 16).

Table 4 lists the units, home stations, and planned complements of the Desert Rock support units, totalling 2722 personnel as indicated. Other than the official observers group, the various categories of personnel above were drawn from these units.

Table 4. Exercise Desert Rock II support units.

Unit	Home Station	Planned Complement
Headquarters and Headquarters Battery, III Corps Artillery (augmented by Hq & Hq Co., III Corps)	Fort Lewis, Washington	122
806th Army Postal Unit (Type F)	Fort Lewis, Washington	15
231st Engineer Combat Battalion*	Fort Lewis, Washington	701
Detachment, 597th Engineer Light Equipment Company (attached)*	Fort Huachuca, Arizona	24
359th Engineer Utilities Detachment	Camp Cooke, California	88
90th Engineer Water Supply Company	Fort Lewis, Washington	75
Maintenance Platoon, 705th Engineer Field Maintenance Company	Fort Huachuca, Arizona	70
94th Veterinary Food Inspection Detachment	Fort Lewis, Washington	5
Company A, 505th Military Police Battalion*	Camp Roberts, California	154
Company C, 505th Military Police Battalion*	Camp Roberts, California	154
Headquarters and Headquarters Detachment, 393d Ordnance Battalion	Camp Cooke, California	36
161st Ordnance Depot Company (-)	Camp Cooke, California	98
3623d Ordnance Company (Medium Maintenance)*	Camp Cooke, California	195
Detachment, 53d Quartermaster Base Depot Company	Utah General Depot	74

* Available documentation indicates that some elements of these units had pre-and/or post-shot assignments in the forward area.

Table 4. Exercise Desert Rock II support units (Concluded).

Unit	Home Station	Planned Complement
1st Platoon, 523d Quartermaster Subsistence Depot Company	Utah General Depot	45
1st Platoon, 539th Quartermaster Laundry Company	Fort Lewis, Washington	24
621st Quartermaster Service Company	Fort Lewis, Washington	63
Detachment, Headquarters and Headquarters Company, 303d Signal Service Battalion (augmented)*	Camp Cooke, California	244
Detachment, Headquarters and Headquarters Company, and Company B, 314th Signal Service Battalion (-)	Camp Cooke, California	218
Detachment, 504th Signal Base Maintenance Company	Sacramento Signal Depot, California	18
4th Transportation Truck Company	Camp Stoneman, California	126
2d Platoon, 92d Transportation Car Company	Camp Roberts, California	43
562d Transportation Staging Area Company (-)	Camp Stoneman, California	130
	TOTAL	2722

Source: References 2, 9

* Available documentation indicates that some elements of these units had pre-and/or post-shot assignments in the forward area.

3.3 CONCEPT.

There were no troop maneuvers conducted at Exercise Desert Rock II. The purpose and the resultant objectives differed from those of Exercise Desert Rock I, where the emphasis was on a troop maneuver and on evaluation of the psychological reaction of the troops.

The purpose of Exercise Desert Rock II as stated in Reference 2, was ". . . to obtain information relative to the effects of surface . . . nuclear explosions on typical Army field emplacements, equipment, and materiel, and to determine, insofar as possible, the probable effects on personnel. Although no animals were involved, inferences were drawn as to effects on personnel from information obtained from Operation Jangle animal experiments conducted by AFSWP."

The specific test objectives of Exercise(s) Desert Rock II (and III) were (Reference 2):

(1) To determine nature and extent of damage sustained by standard (FM 5-15) military emplacements when subjected to the effects of surface and underground nuclear explosions.

(2) To determine nature and extent of damage sustained by military equipment and materiel when subjected to the effects of surface and underground nuclear explosions. This determination included an assessment of serviceability for immediate combat use of equipment and materiel tested.

(3) To determine the degree of protection afforded by standard field emplacements from nuclear radiation and blast effects, from both surface and underground nuclear explosions.

(4) To determine by indirect methods, through the use of film badges and observation of damage to emplacements, the probable effects on personnel when exposed to the effects of surface and underground nuclear explosions.

The concept of operations was to construct a variety of standard military emplacements at various distances from a surface nuclear burst, to install a variety of military equipment at each emplacement; and to attach film badges to the emplacements and display items. Post-shot evaluations of damage and collection of film badges would then be combined to provide the necessary data to support the test objectives. Concurrently, the official observers would be given a pre-shot indoctrination and tour, and a post-shot tour of the displays. Their observations and recommendations would then be incorporated into the post-exercise report.

Radiological safety precautions and procedures were similar to those in Exercise Desert Rock I, except for intensity restrictions. Entry into a contaminated area would not be permitted until completion of an initial survey by the Desert Rock Rad-safe Officer and release by the Exercise Director. All groups and/or individuals granted entry were to wear film badges and be accompanied by a rad-safe monitor. The maximum allowed dose accumulation for military personnel for the combined Desert Rock II and III exercises was 3 rem. The limit prescribed by the AEC Test Manager for Operation Buster-Jangle was 3.9 rem. The established limit for gamma-emitting contamination on personnel, equipment or vehicles was 0.02 R/hr. To ensure that no personnel or materiel contaminated in excess of the established limits left the forward area, a decontamination station was established 4 miles south of the Sugar GZ. There is no documentation of a field intensity restriction for Exercise Desert Rock II. Several instances of personnel traversing intensity fields of about 10 R/hr indicate that the 1 R/hr limit established for the first exercise was not in effect.

3.4 OPERATIONS.

The 172 official observers were to arrive at Camp Desert Rock prior to 14 November to receive instruction, tour the shot area, witness the shot, conduct seminar discussions and evaluations, and present their observations and findings (Reference 17). The delay of the shot from 15 November to 19 November resulted in some revision of the schedule, but they did receive the planned indoctrination, which included a tour of the shot area on D-4. They also witnessed the shot and toured the display area on D+1.

The observers prepared and submitted their seminar observations and recommendations as planned. The seminars were organized by combat branches and technical services (Infantry, Artillery, Quartermaster, etc.) as were their reports, incorporated as appendices to Reference 2.

Construction of the emplacements in the display positions, and of 19 pairs of foxholes at intervals of 40 yards between display positions, was accomplished prior to 15 November by the 231st Engineer Battalion with the assistance of the 597th Engineer Company. The Effects Evaluation Teams, assisted as necessary by the appropriate Desert Rock support units, completed the set-up and badging of the displays prior to 15 November. Personnel of the 505th MP Battalion were posted as guards in the display areas to ensure that the displays were not disturbed. The guards were to be relieved the night of D-1 and were to be reposted after the shot upon clearance by the Desert Rock Rad-safe Officer (Reference 2).

On shot day, the observers departed Camp Desert Rock at about 0630 hours and proceeded by bus to the observation point, 9 km (5.7 miles) south of GZ (figure 3), arriving at about 0815 hours. On arrival, they were briefed by advisory group instructors on the scheduled detonation and on safety procedures. In addition to the observers and their instructors, the Effects Evaluation Teams and others witnessed Shot Sugar from this vantage point. A press release from Camp Desert Rock (Reference 15) indicates that a total of 250 military personnel were in this group.

Shortly before the shot, observers were directed to sit on the ground with their backs toward GZ. After the initial flash of light from the detonation at 0900 hours, they were directed by the instructors to turn and view the fireball and the rising cloud. About 15 minutes later, the observer group returned to their buses and departed the forward area for Camp Desert Rock (Reference 17).

On the day after the shot, the observers returned by bus to the Shot Sugar test area for a tour of the displays. Figure 3 shows the display area, consisting of six displays located at 90 and 180 meters (100 and 200 yards) south of GZ, and 370, 580, 730 and 910 meters (400, 630, 800 and 1000 yards) south-southwest of GZ, respective-

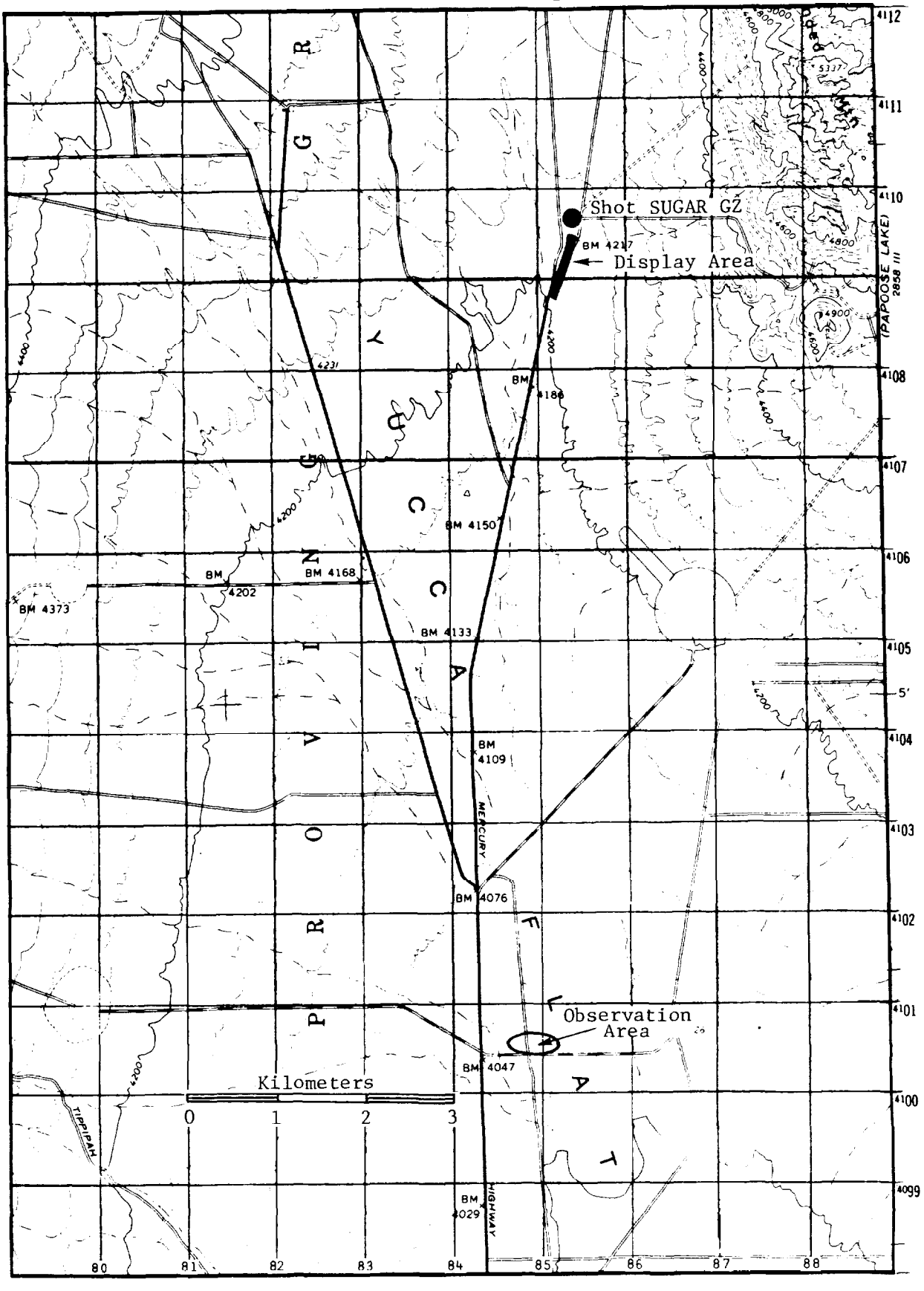


Figure 3. Shot Sugar area.

ly. They were issued film badges as they boarded the buses. Each busload of observers was accompanied by an instructor, a rad-safe monitor, and a military police escort. It is estimated that 10 buses were required. All personnel remained on the buses throughout the tour. It is inferred from Reference 17 that they went as far forward as position 2. They then returned to Camp Desert Rock, where the observers conducted their seminar discussions, and prepared, presented, and submitted their reports and recommendations.

The Effects Evaluation Teams conducted their post-shot evaluations of emplacements and displays over a six-day period from 19 through 24 November. Table 5 is a compilation of individual evaluations of equipment displays by the various technical service evaluators on the dates indicated. The individual damage assessment forms list the items evaluated at each display visited. Comparison of these forms with the planned equipment displays indicates all items that could be located after the shot. The table indicates that each evaluation team conducted at least one post-shot evaluation of each display, and thus depicts all of the post-shot evaluation activities in the test area.

The date, time of recovery and disposition of display items as well as the restoration of the terrain by the 231st Engineer Battalion and others from the Effects Evaluation Teams and supporting technical service units is not known. However, since there were several evaluations on D+4 and one on D+5, it is not likely that these activities took place before 23 November. Since the same personnel were to construct and set up the displays for Shot Uncle, scheduled for 29 November, it is not likely that recovery and restoration was delayed beyond this date.

The rad-safe report in Reference 2 states that chemical personnel recovered the film badges. It is likely that the recovery of the film badges took place no earlier than D+1 and no later than D+4, as foxholes #7-19 were backfilled on D+4 (Reference 16). Backfilling of foxholes #1-6 (near positions 1 and 2) was likely not completed until after Shot Uncle (see Section 6.2.3). According to Reference 2, the recovery and examination of rations and water samples was on D+5.

Table 5. Technical service evaluation of displays, Shot Sugar.

Tech Service	Dates	Display positions 1	2	3	4	5	6
Engineer	D+1 (20 Nov)					X	X
	D+2 (21 Nov)	X	X				
	D+4 (23 Nov)		X	X	X		
Ordnance	D-Day					X	X
	D+1					X	X
	D+2		X	X	X		
	D+4	X	X				
	D+5		X				
Quartermaster	D+2	X	X				
	D+3					X	
	D+4			X	X		X
Chemical	D+1	X	X	X	X	X	X
Signal	D+2	X	X	X	X	X	X

Source: Reference 16

As stated earlier, rad-safe monitors accompanied all Desert Rock groups and/or individuals who entered the test area after Shot Sugar. The 36 known rad-safe monitor personnel available were assigned to the Effects Evaluation Teams and provided the pool from which monitors were provided for the observers (one per bus), for project participants, and for troops involved in restoration and set-up.

The 505th MP Battalion provided escorts (one per bus) for the observer party. The battalion also provided pre- and post-shot sentries for the display area. The numbers of sentries, their exact locations, and the times that they spent in the test area are not documented.

SECTION 4
EXERCISE DESERT ROCK III

4.1 SHOT DATA.

Exercise Desert Rock III was conducted in conjunction with Shot Uncle, an underground (17 feet below surface) test detonated at 1200 hours, 29 November 1951 (the scheduled date), in Area 10 at UTM coordinates 850139. The yield was 1.2 kt. To determine radiation exposure for participants, all pertinent shots are considered for any residual radiation that might have contributed to total radiation dose (see table 1).

4.2 PARTICIPATION.

More than 2100 military personnel participated in Exercise Desert Rock III. This included 53 officer observers selected from the combat branches, the technical services, and various branch schools of the U.S. Army. Table 6 lists the units, home stations, and planned complements of the Desert Rock support units, totalling 2138 personnel as indicated. Some of the III Corps support units returned to their home stations prior to Shot Uncle. There were no maneuver troops at this exercise. Several support units and individuals participated in activities in the test area before and after Shot Uncle. Other personnel were assigned to support functions at Camp Desert Rock and remained at the camp (References 2, 9).

4.2.1 Observers.

There were 67 official observers at Exercise Desert Rock III, consisting of four generals, three aides, and the 53 officers described above. Seven observers were not identified. The 53 officer observers attended a course of instruction at Camp Desert Rock conducted by two AFSWP instructors, assisted by additional instructors from the AFSWP Effects Test Group and the exercise staff. The observers and their instructors witnessed Shot Uncle from a vantage point approximately 10 kilometers (6 miles) to the southwest (210^{o}) of ground zero at UTM coordinates 800057. Others who observed the shot from the same position included the Exercise Director and his staff, and the Advisory Group (3 officers) (References 2, 18, 19).

Table 6. Exercise Desert Rock III support units.

Unit	Home Station	Planned Complement
Headquarters and Headquarters Battery, III Corps Artillery	Fort Lewis, Washington	122
806th Army Postal Unit (Type F)	Fort Lewis, Washington	15
231st Engineer Combat Battalion*	Fort Lewis, Washington	701
Detachment, 597th Engineer Light Equipment Company (attached)*	Fort Huachuca, Arizona	23
359th Engineer Utilities Detachment	Camp Cooke, California	88
Company C, 505th Military Police Battalion*	Camp Roberts, California	154
3623d Ordnance Company (Medium Maintenance)*	Camp Cooke, California	195
Platoon, 523d Quartermaster Subsistence Depot Co	Utah General Depot	45
Detachment, Hq and Hq Co, 303d Signal Service Battalion (augmented)*	Camp Cooke, California	244
Detachment, Hq and Hq Co, and Company B, 314th Signal Service Battalion (-)	Camp Cooke, California	218
Detachment, 504th Signal Base Maintenance Company	Sacramento Signal Depot, California	18
4th Transportation Truck Company	Camp Stoneman, California	126
2d Platoon, 92d Transportation Car Company	Camp Roberts, California	43
562d Transportation Staging Area Company (-)	Camp Stoneman, California	130
Food Service Personnel (unit unknown)		16
	TOTAL	2138

Source: References 2, 9, 24, 39

* Available documentation indicates that some elements of each of these units had pre- and/or post-shot assignments in the forward area.

Personnel from the support units were permitted to observe Shot Uncle from an area near the AEC Control Point, more than 25 kilometers (16 miles) south of ground zero. All participants were accounted for at shot time and were under the control of two monitors and two guards, just south of Gate 5 (Reference 20). Other observers from AFSWP, with support personnel, also witnessed Shot Uncle from this area near the AEC Control Point.

Because these observers did not go forward of this observer area, they were not exposed to initial or residual radiation. No reconstruction of radiation dose is necessary.

4.2.2 Other Desert Rock Participants.

In addition to the official observers and their instructors, other Desert Rock personnel who participated in Exercise Desert Rock III at Shot Uncle included the following:

- Effects Evaluation Teams. These teams, one each from the III Corps Chemical, Engineer, Medical, Ordnance, Quartermaster, and Signal Sections, were responsible for the pre-shot construction and emplacement of the military equipment displays for Shot Uncle; the evaluations of the effects of the shot on the various displays; and for post-shot recovery and/or disposition of the equipment. Each team was responsible for completing damage assessment forms for each display and for a final evaluation report of its findings. Technical assistance to the teams was provided by the 3 officers from AFSWP who were assigned to the Advisory Group. Available records identify 21 personnel involved in this activity. As the records may not be complete; the actual number may have been somewhat greater (References 2, 22).

- The 231st Engineer Combat Battalion constructed the emplacements and assisted the evaluation teams in the pre-shot setup and the post-shot recovery and disposition of displays. The 597th Engineer Light Equipment Company assisted the 231st Engineer Combat Battalion in the pre-shot activities but not the post-shot activities as the unit departed on D-Day (Reference 24).

- Personnel of the 3623d Ordnance Company emplaced, evaluated, and recovered vehicles and other ordnance equipment.

- The Exercise Director conducted two projects at Shot Uncle (Film Badge Tests and Effects on Food and Water). These projects were continuations of those conducted at Shot Sugar.

- Radiological Safety Unit. The Desert Rock Chemical Officer was in charge of radiological safety, including training of monitor and decontamination crews. He was assisted by two deputies. One deputy served as the Desert Rock Rad-safe Officer, who controlled entry to the test positions both prior to and following the shot. The Rad-safe Officer's assistant was responsible for the tests associated with the film badge project and also was responsible for the Chemical Evaluation Team. The second deputy controlled the assignments of two groups of monitors, the evaluation team monitors and the observer monitors. Records identify at least 36 Desert Rock rad-safe monitors. The 303d Signal Battalion provided additional monitors for shot day (References 2, 24).

- Military Police. The 505th MP Battalion provided traffic control in the forward area during the pre-shot rehearsals, on shot day, and during the periods of post-shot activities. The battalion also provided escorts for the observer bus tours as well as security details for the displays prior to and, upon clearance by the Rad-safe Officer, after the test.

- The 303d Signal Battalion established and maintained wire and radio communications in the test area as well as at Camp Desert Rock. The battalion also provided personnel who served as monitors on shot day. The detachment from the 314th Signal Battalion maintained all long lines and pole lines. The Detachment from the 504th Signal Company maintained signal equipment for Camp Desert Rock (References 2, 24, 39).

- o Transportation personnel. The 4th Transportation Company transported observers and evaluators in their pre- and post-shot activities.

4.3 CONCEPT.

There were no troop maneuvers conducted at Exercise Desert Rock III. The purpose and the resultant objectives differed from those of Exercise Desert Rock I, but were the same as for Exercise Desert Rock II.

The purpose of Exercise Desert Rock III, as stated in Reference 2, was to obtain information relative to the effects of an underground nuclear explosion "... on typical Army field emplacements, equipment, and materiel, and to determine, insofar as possible, the probable effects on personnel. Although no animals were involved, inferences were drawn as to effects on personnel from information obtained from Operation Jangle animal experiments conducted by AFSWP."

The concept of operations was also the same as that of Desert Rock II, to construct a variety of standard military emplacements at various distances from an underground nuclear burst, to install typical military equipment at each emplacement, and to attach film badges to the emplacements and display items. Post-shot evaluations of damage and collection of film badges would then be combined to provide the necessary data to fulfill the test objectives.

Concurrently, 53 officer observers would be given a pre-shot indoctrination course and would be conducted on a pre-shot tour of the displays. Prior to their departure for their home stations they were to be provided a post-shot tour if the radiological safety criterion permitted and the Exercise Director approved. Their observations and recommendations would then be incorporated into the post-exercise report. Most likely, they departed for their home stations shortly after they submitted their report.

Radiological safety precautions and procedures were similar to those in the previous Desert Rock exercises. Desert Rock personnel could not enter the shot area

until completion of a radiation survey of the shot area and release by the Exercise Director. All groups and/or individuals granted entry were to wear film badges and be accompanied by a rad-safe monitor. The maximum allowable dose accumulation for the combined Desert Rock II and III exercises was 3 rem. The decontamination procedures and station location were the same as for Exercise Desert Rock II (References 2, 20).

4.4 OPERATIONS.

Other than the general officer observers and their aides, the official observers were to arrive at Camp Desert Rock prior to 27 November to receive instruction, witness Shot Uncle, conduct seminar discussions and present their observations and findings (Reference 2). They received the planned instruction and, on 28 November, inspected the display areas to the north and south of ground zero. Figure 4 shows the display area consisting of seven displays, located at 90 and 180 meters (100 and 200 yards) northeast (050^{o}) of GZ and 270, 370, 580, 730 and 910 meters (300, 400, 633, 800 and 1000 yards) south (185^{o}) of GZ, respectively. The Shot Uncle area, including the display areas, was in the path of the fallout from Shot Sugar, conducted on 19 November in Area 9 about 4200 meters to the south (Reference 25).

Construction of the emplacements at the seven display positions, and of 29 pairs of foxholes at intervals of 30-35 yards between display positions, would have been accomplished by the 231st Engineer Battalion (with the assistance of the 597th Engineer Company) before Shot Sugar in uncontaminated terrain. Reference 2 indicates two distinct steps in the final emplacement and set-up process. The initial basic set-up was to be accomplished under the supervision of the engineer, ordnance and quartermaster evaluators. The second step of placing, tagging, and badging of displays involved all of the evaluation teams. The 505th MP Battalion posted guards in the display areas by 1600 hours on 26 November (D-3) to insure that the displays were not disturbed. The guards were to be relieved during the night of D-1 and were to be reposted after shot day, upon clearance by the Desert Rock Rad-safe Officer (References 2, 20, 26).

On shot day, the observers departed Camp Desert Rock in buses and arrived at their observation position 10 km (6 miles) southwest of GZ prior to 1000 hours. In

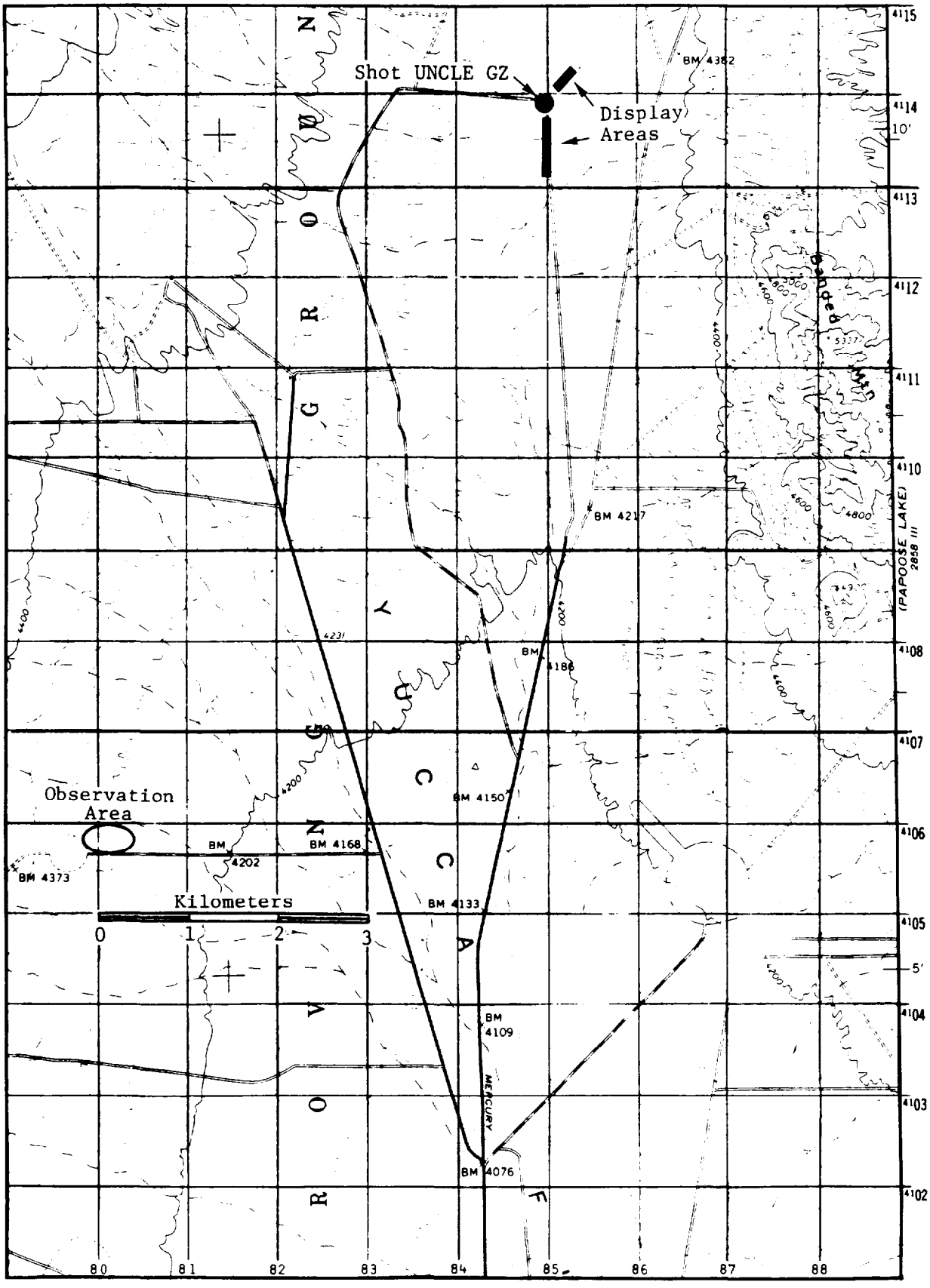


Figure 4. Shot Uncle area.

addition to the observers and their instructors, their accompanying monitors, the Effects Evaluations Teams, and others (paragraph 4.2.1) witnessed Shot Uncle from this vantage point. Partial bus lists indicate that a total of 10 buses were used to transport these personnel.

The detonation, scheduled for 1100, hours was delayed to 1200 hours due to wind conditions. The observers were able to watch the detonation without eye protection as it was known that the flash would not be harmfully visible (a small red flame was seen at the base of the explosion). They entrucked three minutes after the burst and returned to Camp Desert Rock (Reference 25).

On the morning of 1 December (45 hours after the shot), the observers returned by bus to the Shot Uncle test area to tour the displays at position 5 (Reference 25). Although not specifically stated in the reference, their tour probably also included the displays at positions 6 and 7. Radiological safety procedures did not permit inspection of the displays (1-4) closer to GZ (Reference 2, 25).

As the observers and their instructors boarded the buses, the accompanying rad-safe monitors issued each person a film badge. All personnel remained on the buses throughout the tour. On completion they returned to Camp Desert Rock where the observers prepared, presented, and submitted their reports (Reference 2).

The Effects Evaluation Teams conducted their post-shot evaluations of emplacements and displays from D-day through 11 December. Helicopter evaluations only were conducted on D-day and D+1; ground surveys began on 3 December (D+4). Table 7 is a compilation of individual ground evaluations of equipment displays by the various technical service evaluators on the dates indicated, as determined from the individual damage assessment forms. The table indicates that each evaluation team conducted at least one post-shot evaluation of positions 3 through 7. A hasty chemical evaluation was conducted at all positions on D+4. Limited assessments of other materiel, conducted on D+4, are not included in table 7. The table does depict all formal post-shot evaluation activities in the test area (References 2, 22, 29).

Table 7. Technical service evaluation of displays, Shot Uncle.

Tech Service	Dates	Display positions 1	2	3	4	5	6	7
Chemical	D+4 (3 Dec)	X[1]	X[1]	X	X	X	X	X
Engineer	D+4 (3 Dec)				X	X[2]	X[2]	X[2]
	D+5 (4 Dec)				X	X	X	X
	D+11 (10 Dec)			X[3]				
Medical	No Date[4]				X	X	X	X
	D+11 (10 Dec)			X				
Ordnance	D+5 (4 Dec)				X	X	X	X
	D+9 (8 Dec)				X	X	X	X
	D+12 (11 Dec)			X				
Quartermaster	D+5 (4 Dec)				X	X	X	X
	D+11 (10 Dec)			X				
Signal	D+4 (3 Dec)				X	X	X	X
	D+11 (10 Dec)			X				

Source: References 2, 22, 29

NOTE: Table does not include helicopter-borne evaluation of displays on D-day and D+1.

1 Wore protective masks; brief visual assessment only.

2 Including foxholes #20-29 (between positions 5 & 7).

3 A separate engineer evaluation of foxholes 5-15 on the NE line was conducted on this date.

4 Medical evaluation letter for positions 4-7, dated 6 December 1951. Actual evaluation was likely 3 or 4 December (D+4 or D+5).

On 7 December, a group of senior Army officers visited the test site and toured the test positions. This activity is known to have occurred only by virtue of the film badge records that are available for these individuals. These sixteen officers would have been accompanied by rad-safe monitors and drivers.

The date and time of recovery and disposition of display items and the restoration of the test area by the 231st Engineer Battalion, the Effects Evaluation Teams, and supporting technical service units are not known. However, since there were several evaluations of position 3 on D+11, it is not likely that recovery was inititated prior to 10 December. Roll-up operations began shortly thereafter.

The Desert Rock Rad-safe report (in Reference 2) states that chemical personnel recovered 81 percent of the film badges by D+5 and that residual radiation at the time of recovery was too high to allow the recovery party time to crawl into the emplacements (to recover film packets) on the northeast line (positions 1 and 2).

Most of the food and water samples in positions 4 through 7 were recovered on D+5 (Reference 37). Recovery from position 3 was on D+11 (Reference 38). However, the meat samples South of GZ, which were located at positions 3, 5, and 7, were recovered on D+7 (and examined on D+8 by personnel from the National Institutes of Health in their onsite laboratory) (Reference 2). Although Reference 38 indicates a 4 December meat recovery, this assertion apparently stems from the undated evaluation form for meat at position 3, which refers to an intensity measurement made on that date (evidently by film badge recovery personnel).

As stated earlier, rad-safe monitors accompanied all Desert Rock groups and/or individuals who re-entered the shot areas. Of the 36 known rad-safe monitor personnel available, 9 were assigned to the Desert Rock Evaluation Teams. The post-shot activities of these 9 are indicated in the damage assessment forms. The remaining 27 or more provided the pool from which monitors were assigned to the observers (one per bus), for project participants, and for troops involved in set-up, recovery, and restoration.

The 505th MP Battalion provided escorts (one per bus) for the observer party. The battalion also provided pre- and post-shot security details for the display areas. The number of sentries, their exact locations, and the times that they spent in the test area are not documented.

According to the morning reports of the Desert Rock support units, roll-up operations commenced on 13 December and the troops departed camp on the afternoon of 14 December. A small winterization detachment replaced the departing troop complement. According to available records, 20 of the rad-safe monitors were assigned to the winterization detachment for a period of 8 days and were to depart the camp for their home station on or about 20 December (References 27, 28).

The administrative unit for the winterization detachment was apparently the Headquarters and Service Company, Engineer Shore Battalion, 369th Engineer Amphibious Support Regiment (EASR). As tables 4 and 6 indicate, this unit was not part of the Desert Rock II or III Exercises and apparently arrived at Camp Desert Rock sometime after Shot Uncle (29 November 1951). Special Orders from Headquarters, Camp Desert Rock, dated 7 and 8 December 1981, detached several officers and enlisted personnel from the Headquarters and Headquarters Battery of the III Corps Artillery at Camp Desert Rock and attached them to the 369th EASR effective 10-12 December 1951. The morning report of the Hq & Hq Btry, III Corps Arty of 17 December 1951 indicates that a total of 8 officers and 55 enlisted personnel had been attached to the Hq & Hq Svc Co, 369th Engr Shore Bn on 9 and 10 December 1951. One of these two groups consisted of 20 Chemical Corps personnel. Their orders indicated that their TDY would be completed on or about 20 December. These were Rad-safe personnel at DR II and III. No completion date was indicated for the other larger group comprised of Ordnance, Signal, Medical, and QM personnel.

A supplement of Reference 2, dated 21 March 1952, reported the results of equipment evaluations in Uncle display positions 1 and 2 conducted on 21-23 January 1952 (Uncle D+53 through D+55). These evaluations were apparently conducted by a group of 8 officers, representing each of the pertinent branches, who were briefly attached to the 369th EASR for this purpose. Morning reports indicate that they reported on 21 January and departed for return to their parent units on 25 and 26 January 1952.

SECTION 5
INITIAL RADIATION

For all three of the Desert Rock exercises conducted at Operation Buster-Jangle, observer distances were at least 9 kilometers from the point of detonation. Previous calculations have established that, for the types of devices detonated at Buster-Jangle, there was negligible initial radiation dose (less than 0.001 rem) for personnel at this distance, whether in trenches or in the open.

For Shot Dog, film badges were placed in the BCT defensive position, 3500 to 5000 yards from GZ (see figure 2). The badges were placed in and around the prepared field fortifications on the day before the shot and collected when the troops returned to the position after the shot. These badges, identified as "equipment" badges, measured the initial gamma radiation that personnel would have received had they been in these positions at the time of the nuclear detonation. Signal Corps project personnel also placed several badges in unprotected (surface) positions at each of the Shot Dog display areas. These badges were to provide a measure of initial gamma radiation at various distances (1000-3500 yards) from the shot (Reference 1).

Film badges were issued to each member of the BCT on 31 October, the day before the shot. Each man placed the equipment badge in the receiver of his rifle, securing it by sliding the bolt forward against the badge (Reference 1). The rifles were then left in the defensive position. Some of the rifles were in protected locations (e.g., foxholes and trenches) while others remained on the surface. These badges, thus exposed at Shot Dog, are specifically identified as such on the Headquarters III Corps dosimetry forms. The doses recorded on the equipment badges are tabulated, by name, for most of the personnel in the BCT.

The results of the film badges exposed by the Signal Corps are plotted in figure 5. Also plotted is the initial gamma radiation environment as calculated with the computer code ATR 4.1 (Reference 45). It is seen that the agreement between the doses measured by the Signal Corps film badges and that (Henderson tissue dose) predicted by ATR 4.1 is excellent between 2500 and 3500 yards from GZ. The initial

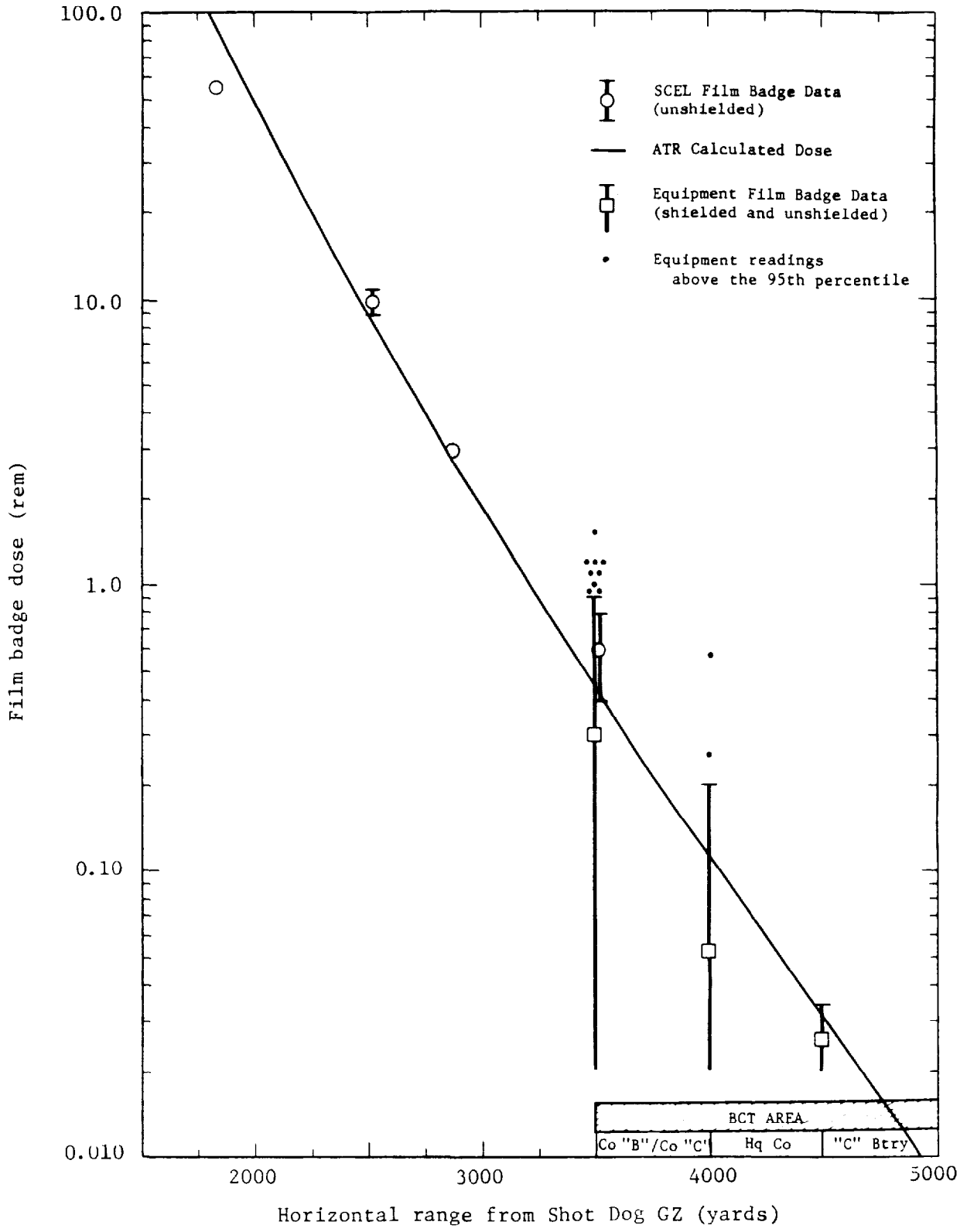


Figure 5. Shot Dog initial gamma radiation dose.

gamma dose from ATR 4.1 is plotted out to 5000 yards to compare with the film badges exposed within the BCT area.

Within the BCT area, personnel placed the badges in their specific unit areas. Four of the areas are delineated. Companies B and C areas were between approximately 3500 and 4000 yards from GZ. Behind them, between 4000 and 4500 yards from GZ, was the Headquarters Company area, while the artillery battery area was behind Headquarters Company out to approximately 5000 yards from GZ (Reference 1). Equipment badges are available for most of the personnel assigned to these elements. The locations of these areas are depicted in figure 5.

Many of the equipment film badges left in the BCT area recorded zero doses. It is assumed these badges were placed in shielded positions and are therefore not included in the present analysis. The mean dose and upper bound comprising 95-percent of the remaining non-zero badges are plotted in figure 5. The doses are plotted as if all badges were exposed on the forward boundary (closest to GZ) of each area. It is noted that the mean dose values fall below that calculated by ATR 4.1, likely because some badges were shielded to varying degrees and some badges were farther away from GZ than the leading edge of the unit area. At 3500 yards, the 95th percentile reading (0.9 rem) compares favorably with the highest reading (0.8 rem) of the Signal Corps badges. The dots indicate those readings above the 95th percentile. At 4500 yards, the badge readings are consistent with that predicted by ATR, but all are near the badge threshold of reliability. In all cases, the equipment badges provided the troops a measure of the radiation that they would have experienced had they occupied the defensive positions, and the effect of the shielding afforded by standard field fortifications. Had the troops occupied the BCT defensive position at the time of the burst, their dose would likely have been as high as about 1 rem and as low as zero, depending on their distance from the burst and their degree of protection as afforded by the foxholes and emplacements.

SECTION 6
RESIDUAL GAMMA EXTERNAL EXPOSURE

External gamma radiation doses are determined for all known participants in Exercises Desert Rock I, II, and III based on their activities in the neutron-induced fields of the pertinent shots (Charlie and Dog) and the fission product fields of Shots Sugar and Uncle. This includes the Desert Rock observers at all shots, the maneuver troops at Shot Dog, and Desert Rock support personnel assigned the various missions and duties discussed in Sections 2, 3, and 4 of this report.

A computerized methodology, described in Reference 3, is used to determine the radiological environment for each shot of interest and the radiation environment at the post-shot times pertinent to the various activities of Desert Rock personnel. Iso-intensity contours are displayed for each shot of Operation Buster-Jangle that included Desert Rock Exercise participation. These contours are developed principally from the radiation survey plots in Reference 36 and are augmented by limited radiation readings reported by Desert Rock and AFSWP projects (References 16, 22, 35). From these, a decay rate of $t^{-1.2}$ is observed, and doses are calculated based on time, location, and movement scenarios. Where specific times are not available, a D+2 reading, for example, is taken as H+48 hours. Because personnel activities and surveys were during the period 0900-1500 on the days after each shot, this introduces only trivial decay differences for the shots of major interest, Sugar (0900 hours) and Uncle (1200 hours).

The computer-calculated doses do not reflect the presence of the human body in the radiological environment. Despite the penetrating ability of gamma rays from fission and activation products, the body affords some shielding; hence, the gamma dose to any organ depends on the geometry of the radiation source and the body position. In order to represent reconstructed film badge readings, gamma doses are calculated for the surface of the chest, where a film badge is normally worn. The calculated film badge dose rate is related to the free-field gamma intensity through the conversion factor developed in Reference 4: 1 R/hr $\longrightarrow$ 0.7 rem/hr.

Observer dose calculations are categorized by the shot in which each observer group participated. Contributions from previous shots to the dose are noted as they arise.

Because of limited data concerning the details of display inspection and the timing involved, estimates are required for various parameters. Rates of movement are estimated from planned or reported times, the number of displays viewed, the calculated or reported position of radiological safety limits, and the consequent distance to be traversed. A reasonable and consistent set of parameters is 50 yds/min walking speed between display positions (including the starting and stopping of troops), 5 minutes at each position and at the limit of march toward GZ, and 70 yds/min on the return. Speeds for motor movements are taken from the operation plans or estimated from road conditions, vehicle type, and the nature of the movements. Other functions such as construction, set-up, evaluation, and recovery of displays require estimates based on standard times for the activities involved.

6.1 EXERCISE DESERT ROCK I.

6.1.1 Shots Able, Baker, and Charlie.

There was no Desert Rock participation at Shots Able and Baker. Shot Charlie, with a yield of 14 kt, was airburst at a height of 1132 feet above the terrain on 30 October 1951. The resultant neutron-induced radiation field at one hour after the burst is shown in figure 6. The figure also indicates the relative location of the display positions for Shot Dog.

As indicated in Section 2, Control Group personnel were assigned to each display position associated with Shot Dog, 2 days after Shot Charlie. These personnel were responsible for the display position set-up and associated instrumentation, post-shot evaluation, and recovery. The Shot Dog display position locations in figure 6 indicate that activities prior to Shot Dog on 30 and 31 October would have been in the vicinity of the modest radiation field from Shot Charlie. Members of the Control Group completed repairs of the equipment emplacements that had been damaged by Shot Charlie (positions 1 and 2) and completed placing all of the equipment displays by the afternoon of 31 October.

Reference 8 scheduled emplacement and installation of equipment to take place from 0800 (H+1 hour) to 1600 on 30 October and from 0800 to 1400 on 31 October.

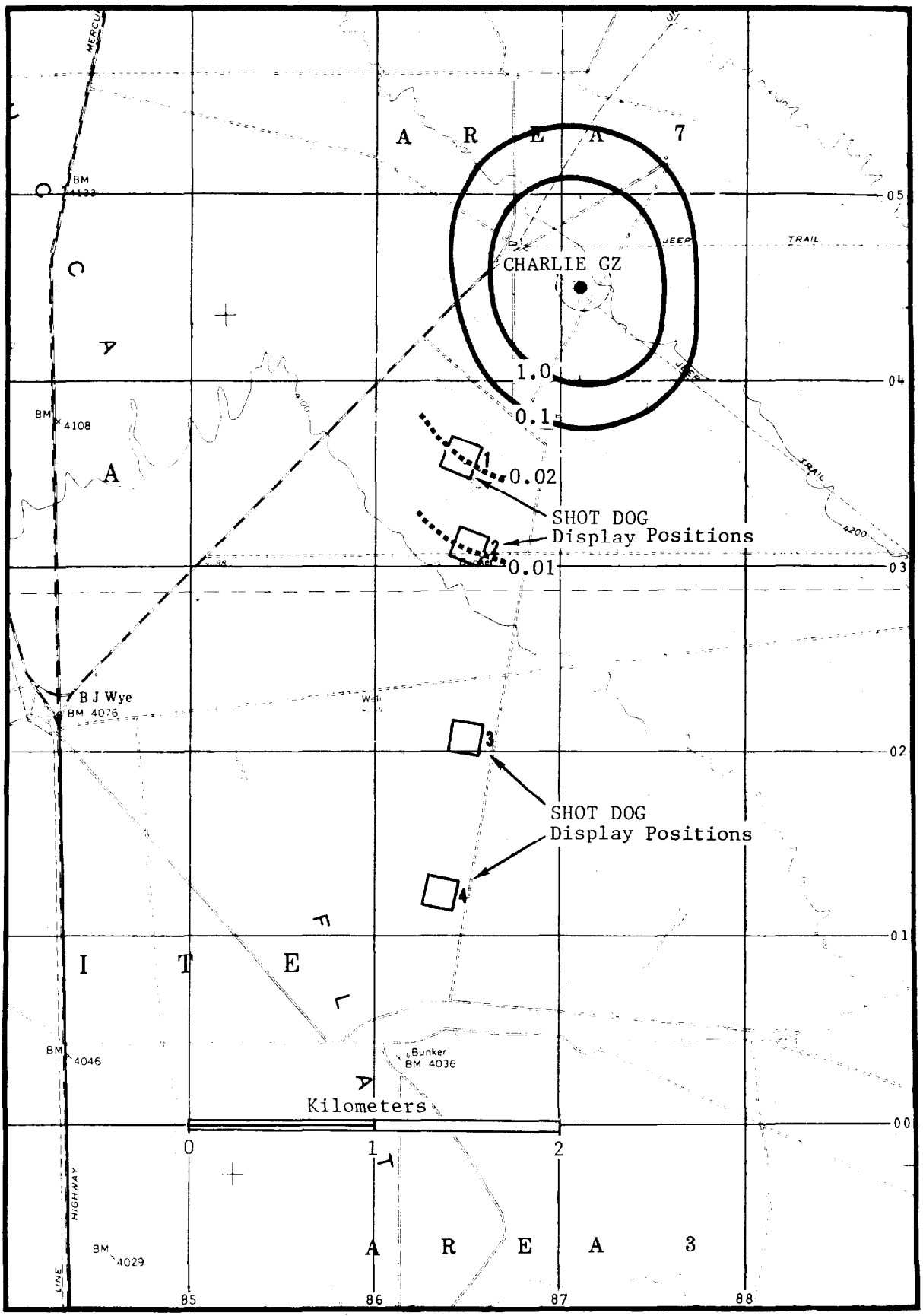


Figure 6. Shot Charlie residual radiation (R/hr @ H+1) and the Shot Dog display area.

There are no indications of any changes in this schedule. The necessary repairs at positions 1 and 2 would have been accomplished during these periods. Dose calculations are based on the decay of sodium-24 ($t_{1/2}$ = 15 hr) and manganese-56 ($t_{1/2}$ = 2.58 hr) (see Reference 3) from the H+1 levels as depicted in figure 6. The relative contribution to radiation intensity of sodium and manganese is determined from shots in the same area during Operation Tumbler-Snapper, from which more thorough radiation data are available. The zero-time contribution from manganese is about twice that from sodium. The reconstructed residual radiation dose for 8 hours at position 1 on 30 October is 92 mR x 0.7 = 64 mrem. The dose for 6 hours at this position on 31 October is 13 mR x 0.7 = 9 mrem. Control Group personnel working similar hours at position 2 would receive a dose one-half of that at position 1, or 32 and 5 mrem on 30 and 31 October, respectively. The lack of contamination at the positions more distant from GZ results in no contribution to dose from any activities there.

Many personnel from supporting units at Exercise Desert Rock I (see table 3) were sent into the forward area along with the Control Group to aid in setting up equipment displays for their respective units. Doses for these personnel are determined from the radiation environment at the closest display position they would have had to enter in order to accomplish their specific tasks. Total time in the forward area is assumed to parallel that of the Control Group. For instance, ordnance units had equipment displayed at all five display positions; hence, ordnance personnel entering the forward area on 30 and 31 October are assigned the same dose as that received by the Control Group at position 1 on these two days, 64 and 9 mrem, respectively. Personnel from support units proceeding no closer to GZ than position 2 are assigned a dose of 32 and 5 mrem on 30 and 31 October, respectively.

The 158 personnel of the 303d Signal Service Battalion who observed Shot Charlie from the observation area (Section 2) apparently did not go forward into the shot area and therefore received less than 1 mrem dose of residual radiation.

6.1.2 Shot Dog.

As indicated in Section 2, post-shot activities of Desert Rock personnel resulting in exposure to the residual radiation field of Shot Dog included the post-shot tour of

the display positions by the Desert Rock observers; the maneuver of the BCT followed by their tour of the displays; the posting of members of the control group at the display positions; and the damage evaluations and equipment recovery by other members of the control group.

The dose for the Desert Rock observers is based on the post shot planned itinerary discussed in Section 2. There are no indications in the available documentation of any departure from this schedule, which specified that the observers would not proceed toward GZ beyond position 2. Available survey data (see figure 7) indicate that the radiation intensity at position 2 was 10 mR/hr at H+1 (0830 hours), the approximate time that the observers were in this area. A one-half hour exposure at position 2 results in a reconstructed dose of 10 mR/hr x 0.5 hr x 0.7 = 4 mrem for observers at Shot Dog.

The pre-shot activities of the BCT, including the rehearsals on 21 and 27 October, discussed in Section 2 did not result in any exposure to measurable levels of radiation.

The troop maneuvers and tour of the display positions at Shot Dog included witnessing the shot from the observation area 7 miles south-southwest of GZ; entrucking and proceeding to Parking Area A; recovering the film badges that they had previously placed on various weapons, equipment, and vehicles in the BCT prepared defensive position; and forming up in attack formation and proceeding to the objective area as indicated on figure 7. Upon completion of the maneuver, they proceeded back southward through position 1 to position 2. At this position they viewed the displays; received a 15-minute briefing from Control Group personnel; turned in their badges; were checked by rad-safe monitors; and entrucked and proceeded to position 5, where they received another short briefing on the effects of the detonation on displays at that position. They then entrucked for their return trip to Camp Desert Rock. The reconstructed residual radiation dose for these activities is 87 mR x 0.7 = 61 mrem, based on sodium and manganese decay as discussed for Shot Charlie. The Charlie radiation field, which was overlain by that from Dog, contributed negligibly to the dose.

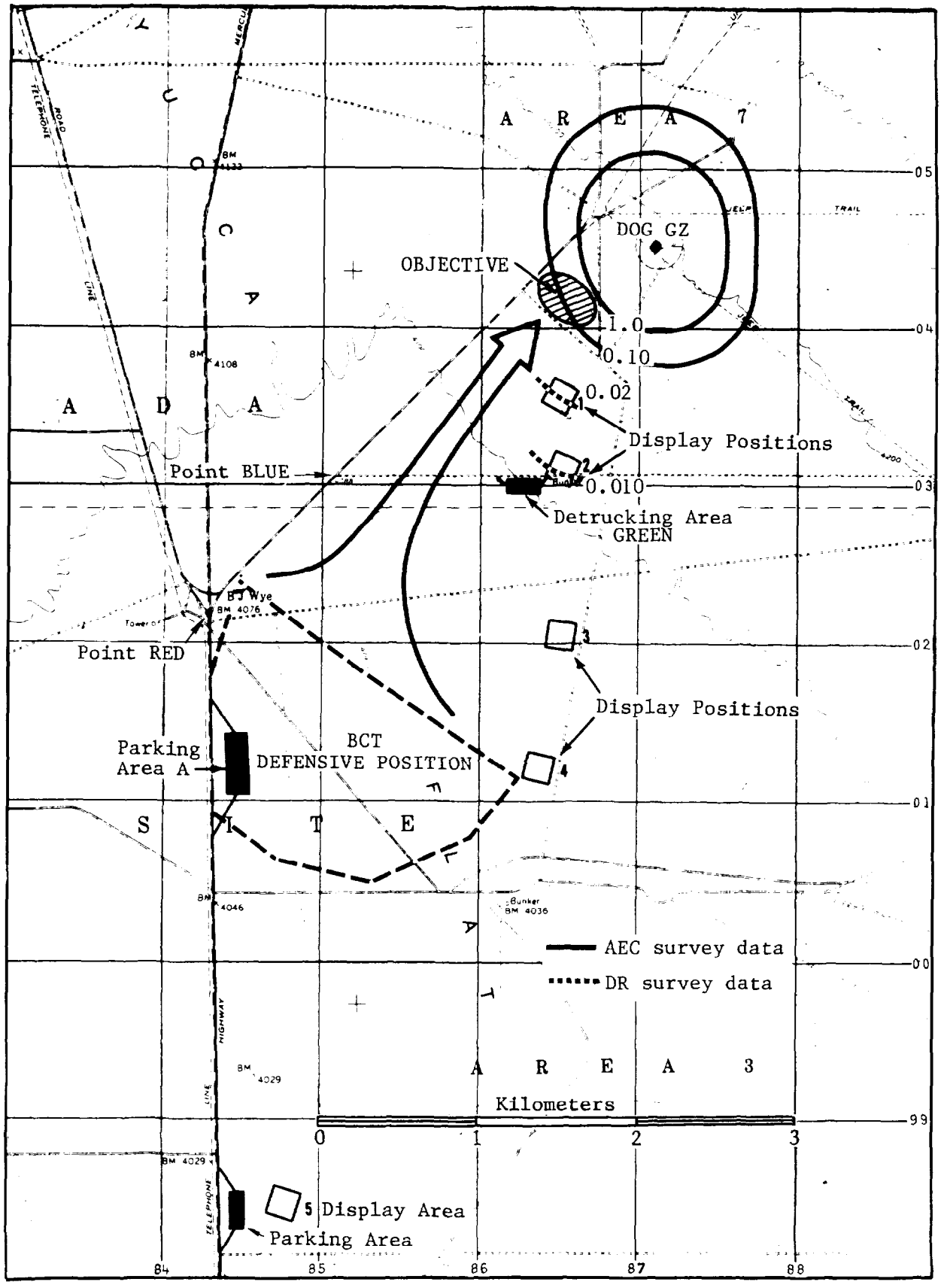


Figure 7. Shot Dog residual radiation (R/hr @ H+1) and observer and maneuver troop routes.

Control Group personnel, including equipment evaluators, photo teams, rad-safe monitors and vehicle drivers, proceeded to their assigned positions, arriving at 0815 hours (H+0.75 hours); they remained at these positions until completion of the exercise. They completed their briefing and evaluations and departed the forward area at about 1300 hours. Control Group members stationed at position 1 would have received the highest residual radiation dose. They may have spent up to 5 hours at this position; the resultant dose is 68 mR x 0.7 = 48 mrem. Control Group personnel at position 2 would have received a dose one-half that at position 1, or 24 mrem. Those remaining at more distant positions have a reconstructed dose of 0 mrem.

Reference 8 scheduled a 9-hour period in the forward area on 2 November (0800-1700) for the Control Group to complete their damage assessment activities and return repairable equipment to Camp Desert Rock. It is presumed this schedule was adhered to. Control Group personnel performing such activities at position 1 on 2 November would have received a dose of 19 mR x 0.7 = 13 mrem, while those at position 2 would have received a dose approximately one-half of this, or 7 mrem.

As with the pre-shot activities on 30-31 October associated with Shot Dog (Section 6.1.1), personnel from some Desert Rock support units would likely have been required to be in the forward area for the post-shot activities. As before, doses calculated for these units are assumed to be comparable to the doses calculated for Control Group personnel performing activities in the same display positions.

6.1.3 Shot Easy.

The Camp Desert Rock personnel who may have observed this shot (Section 2) would not have received any residual radiation dose from this or any preceding shot. There were no other Desert Rock participants in Shot Easy.

6.1.4 Summary of Calculated External Doses at Exercise Desert Rock I.

Table 8 summarizes the calculated external doses received by Exercise Desert Rock I personnel.

Table Calculated daily external doses, Exercise Desert Rock I.

Group/Unit*	Calculated dose (mrem)				
	October		November		
	30	31	1	2	5
	Shot Charlie		Shot Dog		Shot Easy
Observers	0	0	4	0	0
BCT Maneuver (1st Bn, 188 AIR, and attached units)	0	0	61	0	
Control Group (Position 1)	64	9	48	13	
(Position 2)	32	5	24	7	
Hq, III Corps & III Corps Arty	64	9	48	13	
231st Engr Bn (C)	64	9	48	13	
597th Engr Co	64	9	48	13	
90th Engr Co	32	5	24	7	
374th Conv Ctr	32	5	24	-	
94th Veterinary Det	64	9	48	-	
505th MP Bn	0	0	24	-	
393d Ord Bn; 161st, 3623d Ord Cos	64	9	48	13	
53d, 523d QM Cos	64	9	48	13	
303d, 314th Sig Bns; 504th Sig Co	64	9	48	13	
4th, 92d, 562d Trans Cos	32	5	24	7	

* Includes accompanying monitors, MPs, drivers, etc., not badged. Survey monitors, who were all badged, are not included in this table.

6.2 EXERCISE DESERT ROCK II.

As indicated in Sections 3.3 and 3.4, the concept and resultant operation of Exercise Desert Rock II at Shot Sugar did not include any troop maneuvers. Because Shot Sugar was the first surface nuclear test, the Desert Rock emphasis was on identification and evaluation of the uniqueness of the effects of such a detonation on standard military emplacements.

Table 4 identifies and indicates the planned complements of the units that comprised the Exercise Desert Rock II Support Group. In addition to these personnel, there were 172 official observers. The total number of military personnel involved in the exercise was about 2750. Of these, the 172 known official observers and an unknown number of support personnel from various units were direct participants in functions that involved post-shot activity in the area of the shot. Since no previous shot had contaminated Area 9, pre-shot activities in the test area did not involve any exposure to ionizing radiation. Pre- and post-shot activities in the forward area included the following:

Official Observers
Effects Evaluation Teams
Display Construction, Setup, Recovery, and Restoration
Desert Rock Project Personnel
Rad-safe Monitors
MP Security Detail

Residual radiation doses are reconstructed for each of these groups. Results are summarized in table 9.

6.2.1 Official Observers.

Section 3.4 describes the activities of the official observers and their accompanying advisory group instructors, rad-safe monitors, MP escorts, and drivers. At Shot Sugar they were apparently also accompanied by a small group of unofficial

Table 9. Calculated daily external doses, Exercise Desert Rock II.

Group/Unit*	Calculated dose (mrem)						
			November				December
	19 Shot Sugar	20	21	22	23	24	3
Official observers		476					
Evaluators							
Chemical		1180					
Signal			803				
Ordnance	25	4	341		1010	108	
Engineer		4	2310		149		
Quartermaster			2310	0	7		
Display set-up & recovery							
231st Engr Bn, 3623d Ord Co, 303d Sig Bn					40		1340
597th Engr Co					40		
Projects							
Film Badge Project			277				
Food and Water Project						403	
Monitors (weighted mean for 36 personnel)	1	132	168	0	37	14	74
MP security detail		18	8	5	4	3	

* Includes accompanying MPs, drivers, etc.

observers from the Desert Rock Support Group. This group of 250 military personnel (Reference 15) observed the shot from an observation point 9 km (5.7 miles) south of GZ. They remained at this position for about an hour after the shot and then returned to their vehicles and proceeded back to Camp Desert Rock. There was no exposure to measurable amounts of initial or residual radiation from either this activity or the pre-shot tour.

The official observers, their instructors, and assigned support personnel returned to the Shot Sugar test area on the day after the shot for a bus tour of the Desert Rock displays. They remained in their buses throughout their tour. Reference 17 states that the tour commenced 25 hours after the shot. The dose reconstruction assumes average bus speeds of 15 mph into and out of the area, 5 mph between display positions, and 10 minutes at each of the positions visited (2 through 6). Figure 8 shows the locations of the display positions and the iso-intensity contours from Shot Sugar at one hour after the surface shot (H+1 hour). By the time of the observers' tour (H+25 to H+27 hours) the field would have diminished nearly fiftyfold in intensity. Because of the steep intensity gradient, the time spent closest to GZ dominates the dose. The calculated intensity for the observers while at position 2 is 3600 mR/hr, which leads to an integrated intensity of 3600 mR/hr x 1/6 hr = 600 mR. Overall, the gamma radiation dose received by the 172 official observers and their accompanying instructors and support personnel is 680 mR x 0.7 = 476 mrem.

6.2.2 Effects Evaluation Teams.

As previously indicated in Subsection 3.2.2, the evaluation teams from the Desert Rock Chemical, Signal, Engineer, Ordnance, and Quartermaster Sections were responsible for the pre-shot construction and set-up of equipment in the display positions, for the post-shot evaluation of the effects on the equipment, and recovery of the equipment and restoration of the disturbed terrain. Their pre-shot activities would not have involved any exposure to initial or residual radiation.

Table 5 in Section 3 displays the evaluations conducted by the various teams on the post-shot dates indicated. The evaluation forms for the teams include the identification of the evaluators (and with a few exceptions, their assigned rad-safe

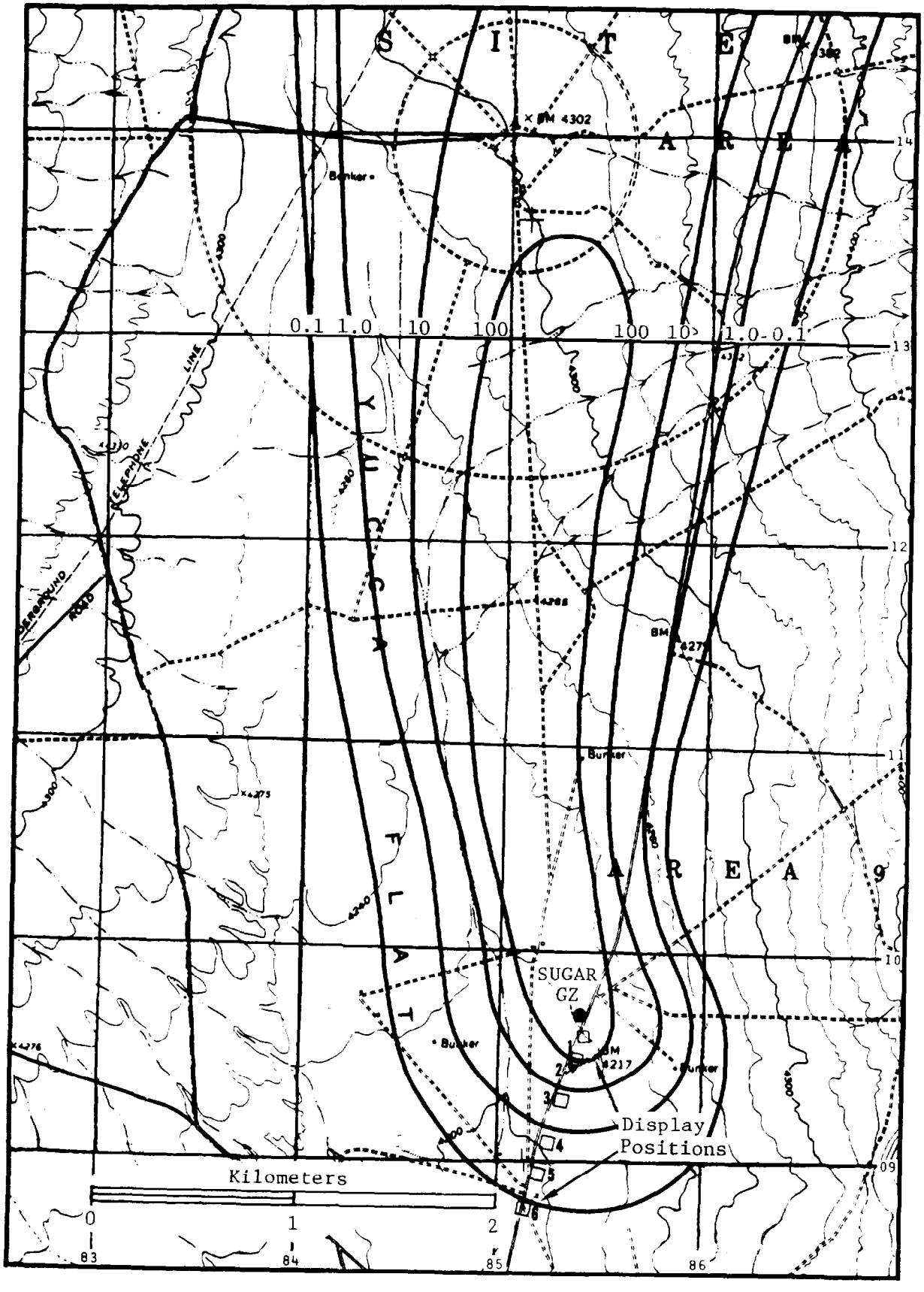


Figure 8. Shot Sugar residual radiation (R/hr @ H+1) and the Desert Rock display positions.

monitors). A total of 20 evaluators are so identified. As stated in Section 3 and indicated in table 5, the evaluation forms document at least one evaluation of each of the six display positions by each of the five service teams. It is thus likely that the forms document all of the post-Sugar evaluations of Desert Rock displays.

The reconstructed residual radiation doses for the post-shot evaluations are based on average vehicle speeds of 20 mph to and from the display area, 5 mph between display positions, and 15 minutes stay time at each position. Evaluators who needed less time are assumed to have waited for the others. Engineers who inspected foxholes between positions did so concurrently, but are given the higher position dose. Other exceptions were for the chemical and signal evaluators, who visited all six positions on D+1 and D+2, respectively (table 5). The chemical evaluator, who reported "brief" visits, had only a pair of gas masks to examine at each position, which would have taken only 3 minutes. The signal evaluator conducted a "limited search" at position 1, where only the disappearance or burial of items was noted. At this position, the stay time is estimated to have been 3 minutes.

The radiation environment for Shot Sugar is determined from data reported by evaluators as well as from data reported in rad-safe surveys and by scientific projects (References 16, 35, 36). These data were used in the automated dose procedure to characterize the radiation environment at each display position. The intensities at position 1, reported by three evaluation teams (engineer, quartermaster, and signal) on D+2, are of particular value in establishing the levels closer to GZ than were obtained by field surveys. For comparison with figure 8, the D+2 intensity of 12 R/hr at position 1, recorded by the evaluation team, corresponds to an H+1 intensity of 1250 R/hr.

The resultant doses for all evaluators, calculated using the above parameters, are shown in table 9.

6.2.3 Display Construction, Set-up, Recovery, and Restoration.

The construction of the emplacements and the interspersed foxholes was accomplished over the period prior to 15 November (the shot was originally scheduled for 15 November) by the 231st Engineer Battalion, probably with some assistance by

the detachment from the 597th Engineer Light Equipment Company. Although not specifically stated, the heavy vehicle emplacements (tanks, trucks, etc.) by the 3623d Ordnance Company as well as the set-up of communications equipment by the 303d Signal Co were probably accomplished at the same time. There was no radiation exposure involved in these activities.

The specific dates and times of equipment recovery and restoration of the terrain are not documented. However, evaluations of display items continued on D+4 (plus an ordnance evaluation at position 2 on D+5), and the same organizations were responsible for pre-shot construction activity for Shot Uncle (29 November). It is likely that the recovery and restoration took place as early as completion of evaluations would permit--D+4 (November 23) for positions 3-6. Radiation intensities at position 1, plus the requirement to begin preparation of the Shot Uncle display positions, would have necessitated the postponement of recovery and restoration of positions 1 and 2 until after Shot Uncle.

While it is likely that specific individuals and/or teams were assigned to recovery and restoration at specific positions, it is also likely that the heavy equipment employed was used at all four positions. The best estimate of the average radiation dose received by these personnel is based on a nominal individual who spent an equal amount of time at each of the positions. The calculated dose for this activity is based on an estimate of 1½ hours at each of four positions (3 through 6) on D+4. The resultant dose is 57 mR x 0.7 = 40 mrem. It is assumed that recovery and restoration of positions 1 and 2 took place on 3 December when radiation levels had decayed sufficiently to permit the teams to perform the necessary recovery work and before the Shot Uncle intensities permitted work in the Shot Uncle area. For 1½ hours at each of the two positions, the dose for the 3 December recovery at positions 1 and 2 is 1910 mR x 0.7 = 1340 mrem.

6.2.4 Desert Rock Project Personnel.

As Section 3 describes, there were two Desert Rock projects at Shot Sugar--a film badge project and a food and water project. For the film badge project, only 82 percent of the badges were recovered due to cave-ins of emplacements closest to ground zero (Reference 2). With no foxholes between positions 1 and 2, the badge

recovery rate therefore suggests that no attempt was made to recover badges at position 1, since cave-ins would have been observed by the chemical evaluator on D+1. Within the time period noted in Section 3, it is most likely that film badge recovery was on D+2, concurrent with the several evaluations on that day. It is estimated that the recovery required 10 minutes at each position and 2 minutes at each pair of interspersed foxholes (Section 3.4). Movement rates of 5 mph between stops and 15 mph in leaving the area are assumed. The dose for this project is 395 mR x 0.7 = 277 mrem.

For the food and water project, recovery was conducted on 24 November (D+5). Only a limited number of items from position 1 were recoverable, many having been destroyed and scattered as far back as position 2 (Reference 33). The recovery personnel likely followed the same procedures as other evaluators in recovering items from position 6 inward to position 2. From this point, because of the extensive scattering of material as reported by previous evaluators, they would have proceeded on foot (50 yards/min) to position 1, determined the non-recoverability of most items in a 5-minute stay time, proceeded back to their vehicle at position 2, and departed the area. The resultant calculated dose for this project is 576 mR x 0.7 = 403 mrem.

6.2.5 Rad-safe Monitors.

There were 36 rad-safe monitors from the Radiological Safety Unit at Shot Sugar. They supported all other Desert Rock activities except the MP Security Detail. There are a few instances where Desert Rock personnel assigned to post-shot activities were rad-safe qualified and served as their own monitors. An example is the officer who evaluated the Chemical Corps displays on D+1. Otherwise, all of the post-shot activities described above should have involved one or more rad-safe personnel who would have received the same doses as for those they accompanied. Multiple exposures for any particular individual could have occurred. A weighted average daily dose for rad-safe monitors may be used when a specific monitor assignment is unknown. It is derived from summing the products of the probable number of monitors in each activity times the dose received by the group monitored, and dividing by 36. For example, the weighted average monitor dose for the observers' bus tour on D+1 is: $476 \text{ mrem} \times \frac{10 \text{ bus monitors}}{36 \text{ monitors}} = 132$ mrem (table 9). The chemical evaluator served as

his own monitor for his D+1 evaluation. The doses to the monitor(s) accompanying the ordnance and engineer evaluators (4 mrem) would not affect the weighted average for this date. These weighted averages are shown in table 9. Not reflected in these doses are any monitoring assignments with activities and projects not associated with Exercise Desert Rock.

6.2.6 MP Security Detail.

Reference 2 contains the following statement under the heading of O.I.C. Effects Tests:

> (f) Insure that a guard for each position is posted in his area at 1600 hours D-2. The guards will insure that no unauthorized persons enter the area and that no equipment or materiel is moved without authority of the test position O.I.C. The guards will be relieved during the night D-1 - D-day, upon direction from Camp Desert Rock S-3. They will be re-posted after D-day, and maintained until relieved by test position O.I.C.

There is no information available concerning the actual reposting of guards in or near the test area after Shot Sugar.

Considering the close spacing of the display positions, one guard post in the vicinity of position 5 would have continued to provide the necessary access control. The post-shot guard tours would have commenced at 0600 hours on D+1 (three guards) and every 12 hours thereafter. The average intensity at this position for the first tour was 2.1 mR/hr, leading to a dose of 2.1 x 12 x 0.7 = 18 mrem. Subsequent exposures are shown in table 9.

6.2.7 Summary of Calculated External Doses at Exercise Desert Rock II.

Table 9 summarizes the calculated external doses received by Exercise Desert Rock II personnel at Shot Sugar.

6.3 EXERCISE DESERT ROCK III.

Exercise Desert Rock III was conducted at Shot Uncle with the same general concept and operation as for Exercise Desert Rock II at Shot Sugar. Shot Uncle was the first underground burst of a nuclear device (1.2 kt at a depth of 17 feet).

Table 6 identifies the units that comprised the Support Group and indicates their planned complements. Including the 67 known observers, the total number of military personnel assigned to the exercise was about 2800.

As for Exercise Desert Rock II at Shot Sugar, pre- and post-shot activities included the following:

Official Observers
Effects Evaluation Teams
Display Construction, Set-up, Recovery, and Restoration
Desert Rock Project Personnel
Rad-safe Monitors
MP Security Detail

Activities at Shot Uncle differed from those at Shot Sugar in several aspects that are significant for residual radiation dose reconstructions.

1. Figure 9 shows the residual radiation field around the Shot Uncle GZ at H+1 hour. The dotted concentric circles around GZ are the same as those near the top of figure 8. Thus, the Uncle display positions were well within the residual radiation field of Shot Sugar, and various pre-shot activities that involved exposure to residual radiation are considered in the dose reconstructions.

2. Similarly, the post-Uncle activities were conducted in the combined radiation fields of both shots. While the H+1 hour iso-intensity contours resulting from the initial survey after Shot Uncle include the decayed field

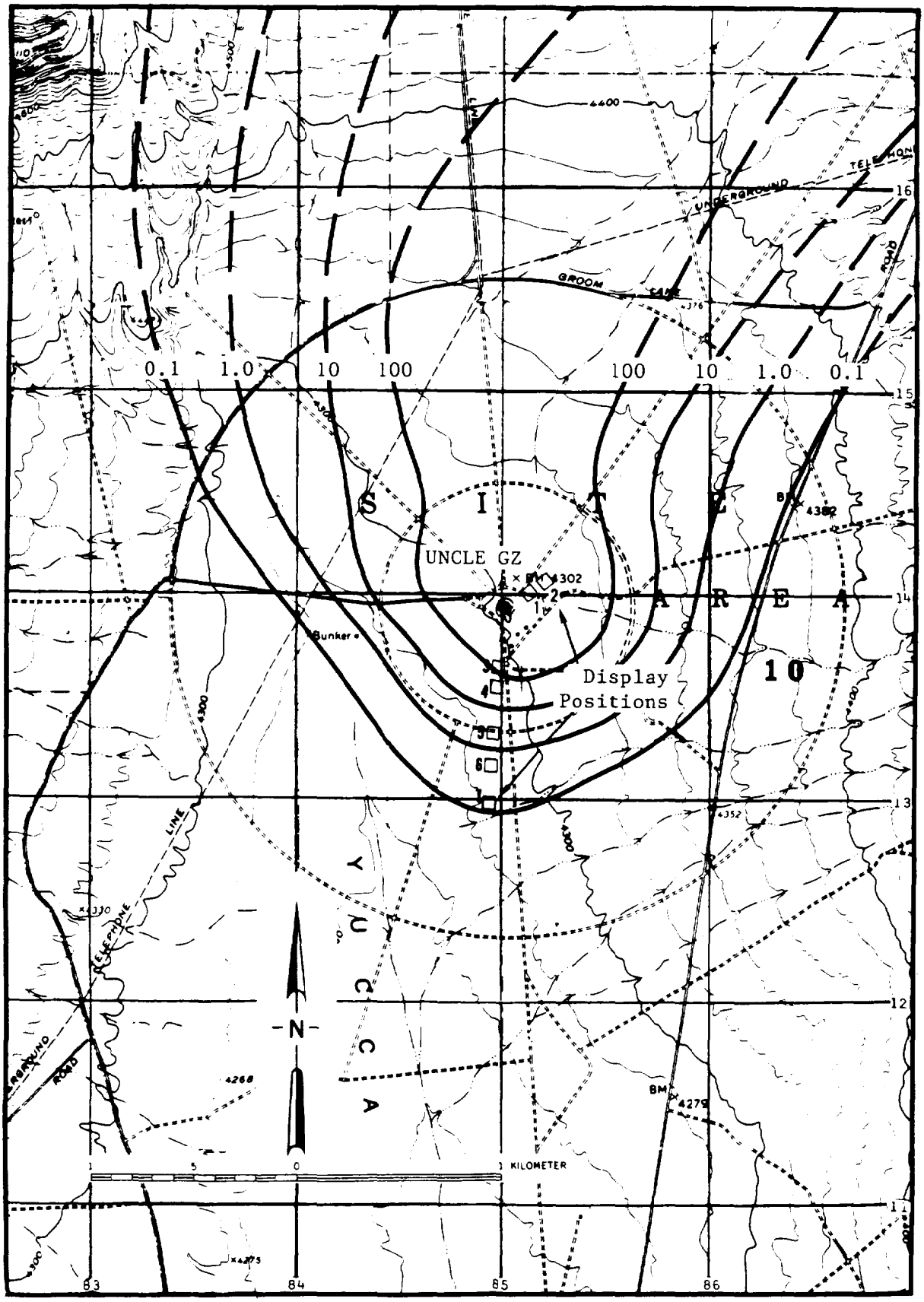


Figure 9. Shot Uncle residual radiation (R/hr @ H+1) and the Desert Rock display positions.

from Shot Sugar ten days earlier, the subsequent decay function is a combination of the power-law decay functions of both shots.

3. Shot Uncle was an underground detonation that produced a significant crater and resultant high levels of residual radiation at the closer display positions (1, 2, and 3), necessitating long delays in the evaluations at these positions and even longer delays (well after completion of the exercise) in recovery and restoration.

Considering the above differences, external doses are calculated for the pre- and post-shot activities of the groups/units that participated in the exercise. The reconstructions are described in the subsections following.

6.3.1 Official Observers.

Section 4.4 describes the pre- and post-shot activities of the official observers and their accompanying instructors, rad-safe monitors, MP escorts and drivers. Their pre-shot tour of the displays on 28 November was a bus tour conducted under the following (assumed) conditions:

- The route followed on the roads skirting the immediate area of the GZ of Shot Sugar is as indicated in figure 10.

- The observers remained in their buses throughout the tour.

- Bus speeds were 20 mph on the paved roads, below 15 mph on the dirt roads leading into the display positions, and 5 mph between positions.

- Observers spent an average of 10 minutes at each of the 7 display positions.

The resultant residual radiation dose for the pre-shot tour of the Uncle displays by the official observers and their accompanying support personnel is 79 mR x 0.7 = 55 mrem.

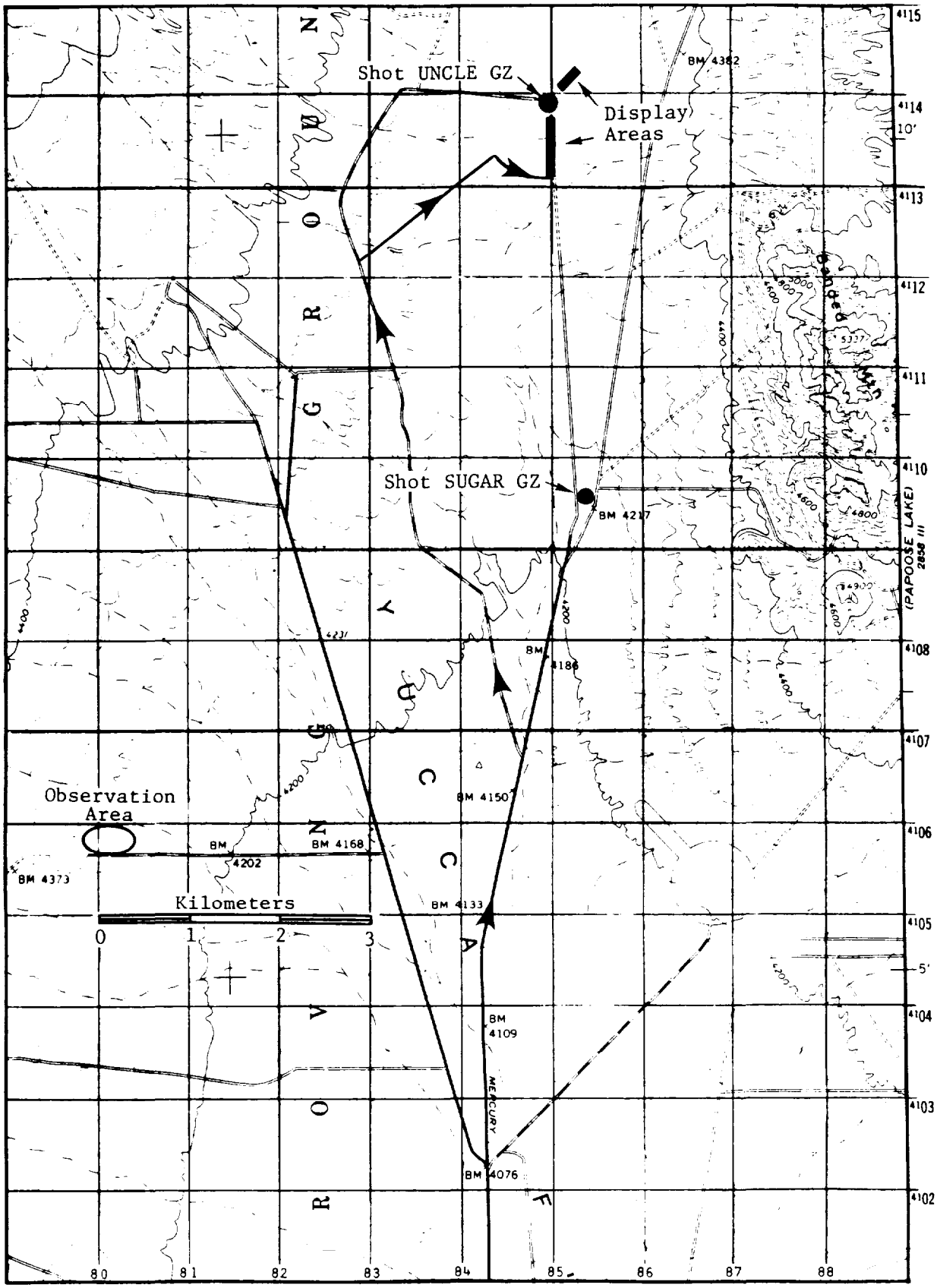


Figure 10. Routes to the Shot Uncle display areas.

On shot day, the observers witnessed the shot from the observation area indicated in figure 10. They boarded their vehicles shortly after the burst and returned to Camp Desert Rock. There was no exposure to measurable amounts of initial or residual radiation at this vantage point, 10 km (6 miles) southwest of GZ.

The reconstruction of the post-shot tour on 1 December, 45 hours after the shot, assumes the same basic route as the pre-shot tour. As indicated in Section 4, observers are known to have gone as far forward as position 5; it is assumed that they were also able to tour positions 6 and 7. The limitation of the tour to these three positions resulted in a somewhat longer (than the pre-shot) stay at each display, about 15 minutes at each of the three positions. The dose calculation for the observers and for other groups with activities in the Shot Uncle area uses the post-Uncle survey readings, appropriately decayed, to determine (through the computerized methodology) the Shot Uncle dose contribution at the time of exposure. The Shot Sugar residual, as measured before Shot Uncle, is then decayed to the post-Uncle period and added to the first dose. This high-sides the resultant total dose by the small Sugar contribution already included in the Uncle residual.

The resultant radiation dose for the observer tour after Shot Uncle is 124 mR x 0.7 = 87 mrem. The combined dose to the observers for pre-and post-shot tours at Shot Uncle is 55 + 87 = 142 mrem.

Film badge dosimetry for 7 December identifies 16 senior officers, of whom 6 were general officers. The similarity of doses indicates that this special group of observers likely made a vehicle tour of the display positions radiologically permissible for inspection on 7 December (positions 3 through 7). This group of senior officer observers would have spent about 10 minutes at each position, with a resultant calculated dose of 322 mR x 0.7 = 226 mrem.

6.3.2 Effects Evaluation Teams.

There were six evaluation teams consisting of representatives from the Chemical, Engineer, Ordnance, Quartermaster, Signal, and Medical Corps. As indicated in

Section 4, they were responsible for the pre-shot construction and emplacement of the displays as well as the post-shot evaluations, recovery, and restoration. As in the case of the observers, this resulted in exposure to residual radiation for pre-shot as well as post-shot activities.

The dates and times of pre-shot construction and set-up activities under the responsibility of the various effects evaluators are not known precisely. The Equipment Emplacement Plan in Reference 2 specified that certain equipment, such as tanks, howitzers, Bailey bridges, tactical wire, and squad tents, were to be in place by 1630 on D-3 and that the remainder was to be in place and ready for test by noon on D-1.

However, Reference 26, dated 25 November, states that test positions were established and equipment was in place by that date. Because Reference 2 notes that engineer, ordnance, and quartermaster equipment would be emplaced in two days, it is concluded that set-up of these items began on 24 November. Time and manpower planning tables (e.g., Reference 30) and military judgement lead to a high-sided estimate of 4 hours in the test area each day (some teams required far less effort).

Construction of emplacements at the seven display positions and the interspersed foxholes would have been accomplished by the 231st Engineer Battalion before Shot Sugar, in uncontaminated terrain (Section 4.4). All equipment set-up activities on 24 and 25 November were in the area contaminated by Shot Sugar. These activities were supervised by the respective technical service evaluators.

Calculated intensities within the display area during pre-shot operations range from 352 mR/hr at position 7 on D-5 to 45 mR/hr at position 1 on D-2. The dose calculations for the evaluation teams assume that the teams were exposed for four hours to the average radiation intensity among positions 1-7 on each day. The resultant dose for engineer, ordnance, and quartermaster evaluation teams on D-5 is: $\left(\frac{83 + 96 + 144 + 192 + 304 + 320 + 352}{7}\right)$mR/hr x 4 hr x 0.7 = 596 mrem. Similarly, the calculated dose for all evaluation teams on D-4 is 171 mR/hr x 4 hr x 0.7 = 479 mrem.

Reference 29 describes the Exercise Desert Rock III schedule that provides for a rehearsal of Desert Rock activities, followed by a final check of test positions, on D-2. This activity is confirmed by film badge dosimetry, which identifies chemical and ordnance evaluator personnel with recorded doses on 27 November. It is assumed that all evaluators and project personnel with test items in the display area would have visited all seven display positions on 27 November, travelling by vehicle and spending 10 minutes at each Desert Rock test position. This exposure to the Shot Sugar residual would have resulted in a dose of: $\left(\frac{45 + 55 + 81 + 108 + 172 + 181 + 200}{7}\right)$ mR/hr x 2 hr x 0.7 = 168 mrem.

Post-shot evaluations began with limited helicopter surveys planned for H+5 and D+1. It is assumed that these took place, that the intensity criterion of 1 R/hr was observed, and that the loiter time at that intensity was 5 minutes each day. The calculated dose is 1000 mR/hr x 1/12 hr x 0.7 = 58 mrem each day.

Dates of post-shot ground evaluations by the various teams are indicated in Section 4. Evaluation procedures were the same as those assumed for the post-Sugar evaluations, with the following exceptions:

1. The hasty chemical evaluation on D+4 would have required 3 minutes per position. Transiting the display area required avoidance of GZ; a circumferential road 2000 feet from GZ connected the northeast and south positions at permissible radiation levels. This activity would have required entry on the northeast line at 15 mph with 3-minute stops at positions 1 and 2, backtracking to the circumferential road, going around the circumferential at 15 mph to the south display positions, spending 3 minutes at each position 3 through 7, and exiting to the south.

2. The brief visual assessments on D+4 by the other evaluators (positions 1, 2, and 4-7) (References 2, 34) would have required 5 minutes per positions 1 and 2, the same circle back to the south positions on the circumferential road, 10 minutes at position 4 (to include observation of position 3 by binoculars), and 5 minutes at position 5, 6, 7.

3. The engineer evaluation of foxholes northeast of GZ on D+11 would have required five minutes at each of 11 foxhole pairs, 320-650 yards from GZ.

The doses calculated for all evaluators are based on the same activity parameters used for post-Sugar evaluations except as above, and lead to the doses depicted in table 10. It should be noted that the D+11 dose for engineer evaluators reflects the aforementioned activity northeast of GZ in addition to the evaluation at position 3, south of GZ. For the assessments conducted at positions 1 and 2 on D+4, the intensities were 13 R/hr and 10 R/hr, respectively, as reported in References 2 and 34. As indicated previously, residual radiation from the earlier shot (Sugar) is included in the dose calculations.

Extensive evaluations of positions 1 and 2 were performed in late January when radiation intensities had diminished to 1 R/hr and less. These evaluators were not necessarily the same personnel who had participated in Exercise Desert Rock III. Doses for these personnel are nonetheless shown in table 10.

6.3.3 Display Construction, Set-up, Recovery, and Restoration.

The pre-shot residual radiation doses calculated for the engineer and ordnance evaluators (596 and 479 mrem on D-5 and D-4, respectively) are the appropriate pre-shot doses for the 231st Engineer Battalion, the 597th Engineer Company, and the 3623d Ordnance Company. The corresponding dose for the 303d Signal Battalion is 479 mrem on D-4.

The post-shot dose calculations for remaining personnel (the 597th Engineer Company had departed) are based on recovery and restoration at positions 4 through 7 on December 8 (Uncle D+9), which is the latest known date of equipment evaluation at these positions (table 7). As the table indicates, recovery at position 3 would not have been accomplished until December 11 (Uncle D+12). Since evaluations were not completed at positions 1 and 2 until after termination of the exercise, recovery and restoration at these positions was not accomplished at Exercise Desert Rock III. These functions were apparently performed in late January 1952 by personnel from the 369th Engineer Amphibious Support Regiment (Section 6.4), a portion of which had already

Table 10. Calculated daily external doses, Exercise Desert Rock III.

Group/Unit*	Calculated dose (mrem)																	
	November							December										January
	24	25	26	27	28	29 Uncle	30	1	2	3	4	5	6	7	8	9	10	11	21-23*
Official observers					55			87											
Senior officer observers														226					
Evaluators																			
Chemical		479		168		58	58			1160									432
Signal		479		168		58	58			1500**							147		432
Ordnance	596	479		168		58	58			1500	165				98			131	1730
Engineer	596	479		168		58	58			1500**	165						369		1730
Quartermaster	596	479		168		58	58			1500	165						147		432
Medical		479		168		58	58			1500**							147		432
Display set-up & recovery																			
231st Engr Bn	596	479													342			549	
597th Engr Co	596	479																	
3623d Ord Co	596	479													342			549	
303d Sig Bn		479													342			549	
369th Engr Regt																			1300
Projects																			
Film Badge Project		479		168							3390								
Food & Water Project		479		168							165		113				147		
Monitors (weighted mean for 36 personnel)	166	200		39	15	2	2	24		88	16		3	13	40		22	19	
MP security detail		673	617	527	458		1258	689	516	425	368	325	294	267	246	228	212		

* Includes accompanying monitors, MPs, drivers, etc. Also includes post-exercise personnel.
** Normal evaluation activities resulted in a dose of 200 mrem.

arrived at Camp Desert Rock to begin preparations for Exercise Desert Rock IV, to be conducted in the April-May time frame. According to morning reports (Reference 24), most of the 303d Signal Battalion departed Camp Desert Rock on 6 December 1951. Two officers and eleven enlisted personnel, who remained behind on duty with Company B, 231st Engineer Battalion, likely performed signal equipment recovery on D+9 and D+12.

The calculation of these doses is based on an estimated time of four hours required to complete recovery and restoration at positions 4 through 7 on D+9 and one hour at position 3 on D+12. The resultant doses are 342 mrem on D+9 and 549 mrem on D+12.

6.3.4 Desert Rock Project Personnel.

As indicated in Section 4, the two projects conducted at Shot Sugar (Film Badge Project and Food and Water Project) were also conducted for Exercise Desert Rock III at Shot Uncle. Pre-shot emplacement of 354 film packets and food and water samples was likely accomplished on 25 November (D-4), in the four-hour period concurrent with the service evaluation activities, and resulted in the same dose of 479 mrem. Project personnel also participated in the final check of all positions on 27 November as described previously for evaluators, receiving the same dose of 168 mrem.

Based on experience from Shot Sugar and the nature of the residual environment after Shot Uncle, film packet recovery operations were apparently conducted on a more urgent basis during Exercise Desert Rock III. Reference 31 identifies 13 Buster-Jangle participants whose radiation dose exceeded operational limits. This included six Desert Rock officers who recovered film packets on 4 December (D+5). They recovered all but 66 of the 354 packets (Reference 2), likely in an attempt to remove them from the area before they became overexposed (indeed, of the 288 packets recovered, 35 were overexposed). It is likely that the concern about film packet overexposure led to an exception to the 1 R/hr intensity limitation in order to permit these officers to recover film packets from as many emplacements as possible without exceeding the 3 rem Desert Rock limit. One of the officers acted as the group monitor (Reference 31), but he failed to properly calibrate his survey meter, thus resulting in film badge doses of 3.45 to 5.80 rem (verified by dosimetry records).

It is assumed that these officers proceeded through the display positions as a group, fanning out to collect badges from emplacements, weapons, and vehicles. They would have started at position 7 and proceeded inward to position 3, where they would have taken a circular route (at 15 mph) to the northeast emplacements in the vicinity of position 2. They then proceeded toward GZ, where recovery became increasingly difficult due to cave-ins and ejecta burials of film packets (non-recovery of 66 packets was likely in the vicinity of positions 1 and 2). It is estimated that the officers spent 10 minutes at each position and 2 minutes at each pair of interspersed foxholes, travelling at no less than 5 mph between stops except as noted above. After leaving position 1, they departed the area at 20 mph. The resultant calculated dose is 3390 mrem.

For the food and water project, meat samples were placed at positions 2, 3, 5, and 7, and other food and water samples were placed at all positions (Reference 2). As noted in Section 4, recovery of most samples (except meat) in positions 4 through 7 was on 4 December (D+5), and from position 3 on 10 December (D+11). The meat samples, however, were recovered on 6 December from positions 3, 5, and 7. The evaluation and recovery on 4 and 10 December was the same as for the other quartermaster activities; hence, the dose is the same. The meat recovery on 6 December likely required about 5 minutes at each position (3, 5, and 7), assuming some of that time was needed to actually locate the few samples involved. A dose of 113 mrem results for meat recovery.

6.3.5 Rad-safe Monitors.

The appropriate doses for rad-safe monitors are the doses of the personnel they accompanied. As was done for Exercise Desert Rock II monitors, the weighted average dose is the dose for each activity at which a monitor was required, times the number of monitors for each such activity, divided by the total number of monitors (36). It is assumed that there was one monitor per observer bus, one monitor per evaluation team (except for the hasty assessment on D+4, when one monitor would have accompanied the group of evaluators), and one monitor per display position when units were deployed for set-up, recovery, and restoration. Weighted average doses, which may be used when specific monitor assignment is unknown, are shown on a daily basis in table 10.

6.3.6 MP Security Detail.

Reference 2 contains the following statement as one of the responsibilities of the Officer-in-Charge, Effects Tests:

> (d) Insure that sufficient guards are posted in the test area by 1600 hours U-3. The guards will be relieved during the night U-1 upon direction from Camp Desert Rock S-3. They will be reposted after U-day upon clearance by Rad-Safe O[fficer] to enter the position and maintained until relieved by OIC Effects Test.

It is noteworthy that this requirement differs from the requirement for posting guards for Shot Sugar quoted previously in that it does not specifically require a guard for each position and it does require clearance by the Rad-safe Officer prior to reposting after the shot. It is also assumed that, because display set-ups were completed by 25 November (D-4), the guards would have been posted one day earlier than planned above.

The routes to the Shot Uncle display areas shown in figure 10 indicate where the MPs may have been posted. The most likely location to control access to the Desert Rock display positions would have been on the 2000-foot arc, just west of position 5. At this point, the residual radiation from Shot Sugar would have decayed to about 82 mR/hr by the night of 25 November. Three guards from the 505th MP Battalion would have been assigned to the post at all times; the duration of each tour would have been 12 hours (1800 - 0600 - 1800 hours). The dose for each tour was 673, 617, 527, and 458 mrem, respectively, for each of the four days before Shot Uncle, as shown in table 10.

Similar guard postings after Shot Uncle would have commenced after shot day upon clearance by the Rad-safe Officer. The earliest reposting would have been on 30 November. If it is assumed that the guard post near position 5 was remanned at 0600 hours on D+1, the 12-hour tour length (3 guards each) on 30 November leads to a dose of 1258 mrem, of which 365 mrem is the contribution from Shot Sugar residual. Subsequent 12-hour tour lengths lead to the doses for guards as shown in table 10. Daily doses shown in the table reflect the higher of the two 12-hour exposures each day.

6.3.7 Summary of Calculated External Doses at Exercise Desert Rock III.

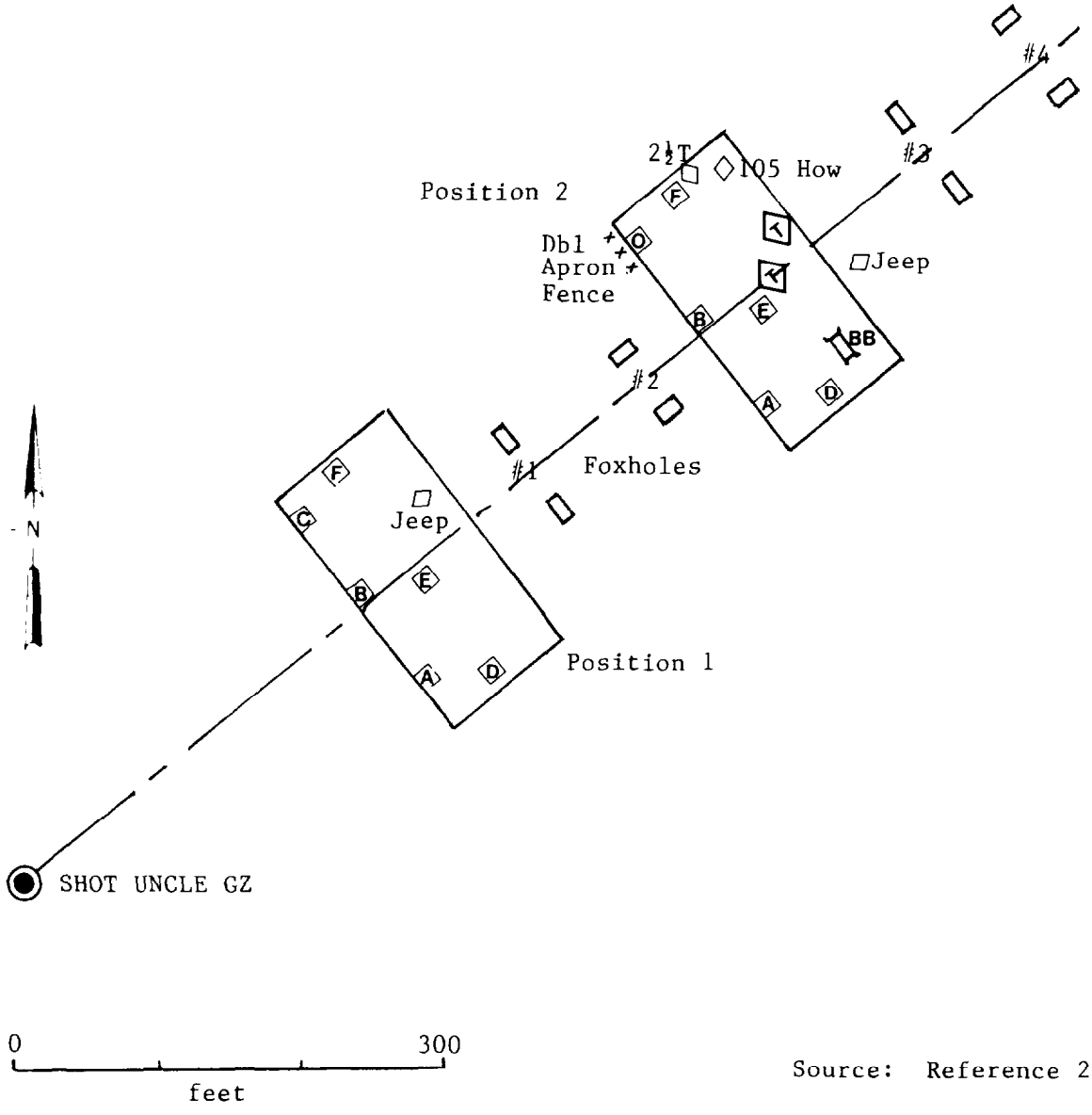
Table 10 summarizes the calculated external doses received by Exercise Desert Rock III personnel at Shot Uncle, as well as for the post-exercise activities described hereafter.

6.4 POST-EXERCISE ACTIVITIES.

As indicated in Section 4, evaluations of Shot Uncle displays at positions 1 and 2 took place well after completion of Exercise Desert Rock III and after the bulk of the Desert Rock personnel had departed. The 21 March 1952 supplement to Reference 2 (see Section 4), which reports the results of these evaluations, indicates that they took place on 21-23 January 1952. Morning Reports of the Hq & Svc Co of the Engineer Shore Battalion for the period 22 through 28 January 1952 identify the eight officers who arrived at Camp Desert Rock to conduct these evaluations. It is not clear if they were assisted by members of the winterization detachment for Camp Desert Rock. Considering the equipment requirements for recovery and restoration, it is more likely that one or more of the line elements of the 369th Engineer Amphibious Support Regiment may have arrived for the preparation phase of Exercise Desert Rock IV (Operation Tumbler-Snapper conducted in the spring of 1952) in time to provide the necessary support for these post-Desert Rock III activities.

Figure 11 is a detailed view of the displays at positions 1 and 2. The figure provides a reason for the variations in the intensity readings by the several evaluators (or rad-safe monitors, if assigned). As shown, specific displays within position 1 in particular had nontrivial differences in distance and direction from GZ. These could have resulted in some differences in intensities. In addition, irregularities in the deposition of crater ejecta, which are typical of underground bursts, could be expected to produce irregularities in the intensity field close to GZ.

The damage summaries by each of the evaluators, contained in the supplement to Reference 2, include the following radiation intensity measurements:



Source: Reference 2

Figure 11. Display Positions 1 and 2, Shot Uncle.

Section	Date Evaluated	Radiation Intensity (mR/hr) Position 1		Position 2
Engineer	21 Jan 52		none	
Signal	21 Jan 52	none		800
Medical	21 Jan 52		none	
Quartermaster	(not stated)	up to 500		up to 350
Chemical	23 Jan 52		none	
Ordnance	23 Jan 52	1000	to	300
	Average	~750		~483

It should be noted that intensities reported on 3 December (Uncle D+4) of 13 R/hr and 10 R/hr at positions 1 and 2, when decayed ($t^{-1.2}$) to 21-23 January, are consistent with the average of the above reported intensities on these dates.

The difficulty of locating some display items implies a longer duration than the 15 minutes used previously for evaluation of each position. Assuming 30 minutes at each position, the dose is 0.5 hr x (750 + 483) mR/hr x 0.7 = 432 mrem.

The times required for recovery of major display items and restoration of the terrain is assumed to be comparable to that of the earlier activity at the other display positions. There are indications that recovery of some items was more difficult due to partial burial, and that some items were not recovered due to complete burial. It is estimated that the personnel involved in recovery and restoration spent about 90 minutes at each position, for a dose of 1.5 hr x (750 + 483) mR/hr x 0.7 = 1300 mrem.

It is possible that the engineer and ordnance evaluators supervised the recovery of major items and the terrain restoration. If so, their doses would have been the same as the recovery and restoration personnel. This dose of 1300 mrem is in addition to the 432 mrem for evaluation personnel, for a total dose on 21-23 January of 1730 mrem.

SECTION 7
INTERNAL RADIATION EXPOSURE

The potential for exposure to internal radiation for Desert Rock I, II, and III participants was through the pathway of (re)suspension and subsequent inhalation of contaminated surface material. Because reentry to the forward area took place after fallout deposition and because fallout did not impact Camp Desert Rock, the direct inhalation of descending fallout was not a contributory pathway. Decontamination procedures in the forward area ensured that levels of contamination remained negligible at Camp Desert Rock. With no ingestion of foodstuffs occurring in the forward area, neither was ingestion a contributory pathway.

Body burden measurements, bioassays, or air sampling data are not available to calculate the committed dose equivalent (hereafter termed "dose commitment") to specific body organs resulting from inhaled radioactive material. Therefore, an indirect approach is necessary. The only indicators of the radiological environment to which test participants were exposed are gamma radiation intensities as measured by a survey meter or integrated external doses determined from film badges. Fortunately, such measurements can be related to an airborne activity concentration of radioactive material that can be used to calculated an internal organ dose commitment.

Bone dose commitment is reported because of the interest in this organ (red marrow dose is similar). It is not necessarily the largest internal dose; thyroid and lung, in particular, have considerably larger doses under some circumstances.

7.1 EXERCISE DESERT ROCK I.

Internal dose commitments resulting from Desert Rock I activities are exceedingly small because of the following circumstances of exposure: modest suspension of neutron-activated soil, low external doses, and lack of significant organ-seeking radionuclides among the principal contaminants.

Exposure at Shots Charlie and Dog was solely from activated soil, not from fallout. Neutron-activated soil offers much less potential for internal dose than does

fallout, per unit external dose, because it is distributed with depth rather than being readily available for suspension from the surface. In activated Nevada Test Site soil, the radionuclides that principally contribute to internal dose commitments for exposure on shot day are sodium-24, potassium-42, and manganese-56. Bone dose commitment is augmented only slightly through the most-contributing bone-seeking radionuclides in the soil, calcium-45 and phosphorus-32.

A dose determination involving the above radionuclides, a shot-day exposure, and an external dose comparable to those calculated for Desert Rock I activities is reported in Reference 40. The 50-year bone dose commitment was less than 10 mrem despite the occurrence of a dust storm. For the comparatively minor disturbance of the soil during Desert Rock I activities, conducted in more placid weather, the dose is far less.

7.2 EXERCISES DESERT ROCK II AND III.

In the case of inhalation of resuspended fallout at Shots Sugar and Uncle, the airborne concentration of radioactive material is calculated through the application of a resuspension factor, $K(m^{-1})$ which correlates the airborne activity concentration (Ci/m^3) to the amount of radioactive material on the ground or other surface (Ci/m^2) under a given set of conditions. The surface activity (SA) is not directly measured; however, it can be related to a gamma radiation intensity, I (R/hr), measured at a given distance (1 meter) above the surface. The ratio SA/I (Ci/m^2 per R/hr) is a function of the gamma energy spectrum of the time-dependent mixture of radionuclides on the surface. These concepts are incorporated into the calculation of organ dose commitments as follows:

$$D = I \times \frac{SA}{I}(t) \times K \times BR \times T \times DF(t) \qquad (1)$$

where:

D	=	Fifty-year dose commitment to the organ (rem)
I	=	Gamma radiation intensity (R/hr)
$\frac{SA}{I}(t)$	=	Surface activity--intensity ratio (Ci/m^2 per R/hr)*
K	=	Resuspension factor (Ci/m^3 per Ci/m^2, or m^{-1})

* Note that, while the quantities SA/I and DF are independent of radiation levels, they are functions of time after detonation because of the changing radionuclide inventory due to radiological decay.

BR	=	Breathing rate (m^3/hr)
T	=	Duration of exposure (hr)
DF(t)	=	Activity-weighted average (composite) dose conversion factor** for the organ for the mixture of radionuclides in the fallout (rem/Ci)*
t	=	Time after detonation of exposure (hr).

For Desert Rock applications, the requisite parameters are treated as follows. The external dose (film badge reading or calculated), which equals 0.7 x I x T, provides a substitution for I x T (or time-integrated intensity, in the more general case). A value of 1.2 m^3/hr, the breathing rate associated with light activity by a typical adult male (Reference 43), is used for BR. K is taken as $10^{-4}m^{-1}$ for most Desert Rock II and III exposures, as discussed below.

The complicated time-dependent parameters SA/I and DF have been evaluated from shot-specific radiochemistry for use in Reference 44 for various shots, including Sugar and Uncle, to determine bone dose commitments. As is most appropriate for Desert Rock II and III, the values of DF in the reference pertain to the inhalation of aerosols (with oxide clearance classification) having an activity median aerodynamic diameter (AMAD) of 1 μm.

The combination of the above parameters leads to a time-dependent relationship between internal and external dose. Adaptation of the values listed in Reference 44. provides the relationships for Sugar and Uncle shown in table 11.

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* Note that, while the quantities SA/I and DF are independent of radiation levels, they are functions of time after detonation because of the changing radionuclide inventory due to radiological decay.

** Dose conversion factors have been published to convert the intake of various radionuclides to a 50-year dose commitment to specific body organs. The particle size and the chemical and metabolic properties of the specific radionuclide are considered in the calculation of inhalation dose factors (References 41 and 42).

Table 11. Internal bone dose commitment per unit external dose.

Time After Detonation	Bone dose (mrem) per rem of external dose*	
	Sugar	Uncle
H+4 hr	2.5	2.8
D+1 day	13	13
D+2	19	19
D+3	27	26
D+4	33	32
D+5	43	42
D+6	53	52
D+7	63	63
D+8	80	80
D+9	100	100
D+10	120	120
D+11	140	140
D+12	160	170
D+13	180	200
D+14	210	230
D+15	230	N/A
D+16	250	N/A
D+17	270	N/A
D+18	300	N/A
D+19	320	N/A
D+20	340	N/A
D+21	370	N/A
D+22	400	N/A
D+55	N/A	1700
D+65	1800	N/A

* For inhalation of 1 μm AMAD particles, resuspension factor of $10^{-4}m^{-1}$, breathing rate of 1.2 m^3/hr.

Values of resuspension factor are chosen as consistent with Reference 44. Those activities involving at most walking or riding in ordinary vehicles are associated with $K=10^{-5}m^{-1}$. This value is appropriate to observers and the MP security detail. Personnel who picked up or retrieved contaminated objects, as well as those who dug or set-up in contaminated areas, are given $10^{-4}m^{-1}$. These include the evaluators, technical project personnel, and support personnel in the forward area. While Reference 44 considers retrievers of objects as small as film badges to have $K=10^{-5}m^{-1}$, the need at Sugar and Uncle to retrieve these items from foxholes suggests the higher value. Personnel in the immediate vicinity of these activities, such as supervisory personnel or rad-safe monitors, are given the same resuspension factor. Thus, except for the monitors, who take the resuspension factor of each associated party, all groups keep a consistent value of K throughout the Operation (but $K=0$ during helicopter evaluations, which, in order to satisfy rad-safe constraints, were conducted at sufficient heights not to loft surface contamination).

Fifty-year bone dose commitments are evaluated for all known group exposures based on the external doses in tables 9 and 10 and the factors in table 11 (adapting to $K=10^{-5}m^{-1}$ as necessary). Contributions from Sugar and Uncle are determined separately for post-Uncle exposures because of the different time after each shot; the contribution to external dose from each shot is used in this calculation. Daily results are shown in table 12 for Desert Rock II and in table 13 for Desert Rock III and post-exercise activities. The latter lead to the highest bone doses because of significant resuspension and external doses at late times after Uncle (note the increasing ratio of bone dose commitment to external dose with time, as shown in table 11).

Table 12. Calculated daily internal bone dose commitments, Exercise Desert Rock II.

Group/Unit*	Dose commitment (mrem)						
				November			December
	19 Shot Sugar	20	21	22	23	24	3
Official observers		1					
Evaluators							
Chemical		15					
Signal			15				
Ordnance	<1	<1	6		33	5	
Engineer		<1	44		5		
Quartermaster			44	0	<1		
Display set-up & recovery							
231st Engr Bn, 3623d Ord Co, 303d Sig Bn					1		280
597th Engr Co					1		
Projects							
Film Badge Project			5				
Food and Water Project						17	
Monitors (weighted mean for 36 personnel)	<1	2	3	0	1	1	16
MP security detail		<1	<1	<1	<1	<1	

* Includes accompanying MPs, drivers, etc.

Table 13. Calculated daily internal bone dose commitments, Exercise Desert Rock III.

Group/Unit*	Calculated dose (mrem)																	
	November										December							January
	24	25	26	27	28	29 Uncle	30	1	2	3	4	5	6	7	8	9	10	11	21-23*
Official observers					1			1											
Senior officer observers														3					
Evaluators																			
Chemical		25		13		0	0			42									740
Signal		25		13		0	0			53**							22		740
Ordnance	26	25		13		0	0			53	19				20			23	2900
Engineer	26	25		13		0	0			53**	19						58		2900
Quartermaster	26	25		13		0	0			53	19						22		740
Medical		25		13		0	0			53**							22		740
Display set-up & recovery																			
231st Engr Bn	26	25													64			99	
597th Engr Co	26	25																	
3623d Ord Co	26	25													64			99	
303d Sig Bn		25													64			99	
369th Engr Regt																			2200
Projects																			
Film Badge Project		25		13							164								
Food & Water Project		25		13							19		10				22		
Monitors (weighted mean for 36 personnel)	7	11		3	<1	0	0	<1		5	2		<1	<1	8		3	3	
MP security detail		4	4	4	4		6	6	6	6	6	6	6	6	6	6	6		

* Includes accompanying monitors, MPs, drivers, etc. Also includes post-exercise personnel.

** Normal evaluation activities resulted in a bone dose commitment of 19 mrem.

SECTION 8
UNCERTAINTY ANALYSIS AND TOTAL DOSE DETERMINATION

8.1 INTRODUCTION.

The uncertainty in the calculated external doses arises from two basic sources: (1) the gamma radiation environment, and (2) the space-time scenario of personnel movements. Where the latter is dominated by a high-sided estimate of some component parameter, the dose is considered to be high-sided and not afforded a formal uncertainty analysis. For internal dose commitments, an additional, and dominant, uncertainty involves resuspension factors. These order-of-magnitude estimates are considered to be high-sided as used in conjunction with external doses, especially because the associated disturbances of contaminated material by Desert Rock personnel rarely occurred continuously throughout the entire period of radiation exposure, and because the disturbances did not necessarily produce the fine aerosols that are presumed in the use of the inhalation pathway. Thus, the calculated bone dose commitments also represent high-sided values that are not further analyzed.

Where errors are determined, they are estimates of uncertainty in mean dose associated with the group activities described in Sections 2 through 4. No attempt is made to predict the distribution of dose within a unit. Thus, when only part of a unit was required for some activity in the forward area, no account is made of those personnel who did not participate (with the exception of the rad-safe monitors, as discussed in Section 6). Also, when no differentiation is available among personnel working concurrently at the various Desert Rock display positions, departures from the average activity scenario are not considered.

For purposes of calculation and combination for a given exposure, errors are first expressed as multiplicative factors. These permit the analytical combination of uncertainties from a series of multiplied parameters and also arise naturally from the exponential character of the spatial gradients in the fallout fields. All uncertainties are estimated at the 90-percent level, i.e., 5th to 95th percentiles. For example, if

the radiation intensity has an error factor of 1.5 and the duration of stay has an error factor of 2, the combined error factor is antilog $[(\log 1.5)^2 + (\log 2)^2]^{1/2} = 2.23$.

In order to sum the calculated doses from separate (daily) activities, the geometric (lognormal) error distributions are approximated by arithmetic (normal) distributions. For the magnitude of the error factors calculated, the arithmetic mean is slightly greater than the geometric mean (i.e., each daily value as shown in tables 8, 9, 10). The summation of arithmetic means for the various daily exposures provides the total mean dose. The combination of error bounds is as for normal distributions; this is an approximation that ignores the imperfect symmetry of the error bounds around the mean. For example:

$$(100 \begin{smallmatrix} +90 \\ -60 \end{smallmatrix}) + (150 \begin{smallmatrix} +120 \\ -80 \end{smallmatrix}) = (100 + 150) \begin{smallmatrix} +(90^2 + 120^2)^{1/2} \\ -(60^2 + 80^2)^{1/2} \end{smallmatrix} = 250 \begin{smallmatrix} +150 \\ -100. \end{smallmatrix}$$

8.2 EXERCISE DESERT ROCK I.

The uncertainty in the radiation fields, which is typically generated through an automated procedure (Reference 3), cannot be done so fully because of the condition of the radiological data. For Shots Charlie and Dog, no raw survey data are available from the AEC area survey; only single-survey contour plots are provided in Reference 36. Moreover, the depicted intensity levels do not extend as far as the Desert Rock positions. Thus, the few Desert Rock intensity readings, including positions 1 and 2 at Shot Dog, are emphasized in the dose assessment. Because these readings are greater than the intensities extrapolated from the Reference 36 contours, the doses derived therefrom are considered to be high-sided. Also, the Desert Rock data are concurrent with the shot-day activities, and the implied decay rate is consistent with that deduced from survey data for the same shot area in Operation Tumbler-Snapper. Thus, no appreciable uncertainty in dose exists via the decay rate. The similarities of the Shot Charlie contours in radius and gradient to the Shot Dog contours suggest that the intensities at Desert Rock positions were similar at corresponding times after each shot. Stay times at the positions are considered to be well known, based on the movement tables.

It is thus considered that the calculated doses for Desert Rock I support elements are high-sided and do not warrant error bounds. Only the BCT maneuver involves a more complicated interaction with the Shot Dog radiation field. The BCT dose is dominated by the intensity at closest approach to GZ (the objective). For a 50-yard uncertainty in the closest approach, the gradient implies an error factor of 1.7 in maximum intensity. With estimates of 2.0 for the error factors in the stay time at the objective and in the intensity at any position, the overall error factor is 3.0. Considering the adjusted mean, the resulting dose is $0.08 \begin{smallmatrix} + 0.10 \\ - 0.06 \end{smallmatrix}$ rem.

8.3 EXERCISES DESERT ROCK II AND III.

In contrast to Shots Charlie and Dog, abundant radiation data were collected at Sugar and Uncle. However, References 35 and 36 principally present H+1 hour intensities, derived from (undisplayed) data using $t^{-1.2}$. Thus, the full capability of the automated procedure again cannot be used. The uncertainty with respect to the present use of $t^{-1.2}$ decay is judged to be minimal because most significant readings and personnel exposures were both obtained days after the shot. For example, $t^{-1.4}$ vs $t^{-1.2}$ from D+2 to D+4 would involve only a 15 percent divergence in intensity (H+1 extrapolation is not germane). Also, as noted in Section 6, D+4 and D+53 readings demonstrated the utility of $t^{-1.2}$ decay over the longer term.

Desert Rock intensity data collected in conjunction with damage evaluations at both Sugar and Uncle augment the readings otherwise available, particularly at the innermost positions, where intensities were too great at early times for area radiation surveys. Most of the evaluators' readings were nominally of the items evaluated, but these usually reflected the general radiation environment. Those items surveyed after removal from the radiation field had markedly lower readings and could be distinguished easily. Neutron activation of display objects did not affect the readings; only close-in salt samples (sodium-rich) at Shot Sugar were mildly activated (Reference 2).

An error factor of 1.5 is estimated for the radiation intensity at Shots Sugar and Uncle at most locations relevant to Desert Rock activities. South of each GZ, the factor is based on the internal consistency of Desert Rock readings, the agreement with other survey data, and the mathematical fit obtained for intensities along the Desert Rock line using the automated procedure. For Shot Uncle, the usual

exponential fit for intensity as a function of distance suffices, but for Shot Sugar, the addition of a quadratic term in the exponent greatly improves the fit. This latter fit accommodates, for example, the particularly sharp rise in intensity from Sugar position 2 to position 1.

The same error factor is used for the Shot Sugar residual during Uncle set-up activities. The outer positions were near the Sugar hotline, where the intensity maximum is well identified by the data and of broad extent. While the inner positions are in a steeper intensity gradient, the effect of any greater uncertainty in intensity is diminished by the lesser contribution to dose.

Northeast of the Shot Uncle GZ, the intensities at positions 1 and 2 have an error factor of 1.5 based on the December and January readings and the variations within the latter (Section 6). However, outward of position 2, an error factor of 2 is assigned. The engineer evaluator readings at foxholes approaching position 2 extrapolate to considerably lower intensities at position 2 than otherwise obtained. For groups that reached positions 1 and 2, the impact on dose is minor, however.

The greatest impact on dose from uncertainty in the personnel activity scenario is from the stay time at the various positions, particularly for the position closest to GZ. For official observers, the estimated error factor in stay time is 1.5; movement scheduling information as well as experience with observer movements from other Desert Rock exercises minimizes this uncertainty. For evaluators and project personnel, as well as the senior officers who toured the test positions at Shot Uncle, less timing information is available; the estimated error factor is 2.

Extended exposures in the forward area, such as display set-up and recovery, involve less uncertainty in stay time because of military estimates based on the work required and reasonable scheduling around the length of a work day (discounting transportation time to and from the forward area). The associated error factor is estimated as 1.3. Because signal work is not considered to have been as extensive as the engineer and ordnance work, signal personnel would not have remained for the full duration in the higher-intensity areas; thus their dose as derived is taken to be high-sided. For some of these activities, the date of performance is estimated. Bounds on

possible dates translate into uncertainties in dose through the time dependance of radiation intensity.

Movement rates have little impact on uncertainty in dose, especially because most travel was motorized. An error factor of 1.5 for all rates is assumed.

Uncertainties are not determined for the weighted-average daily doses for rad-safe monitors. The great number of exposures associated with the mean total monitor dose ensures that the overall error factor would be small. For individual monitors known to have engaged in specific activities, the uncertainties for the associated group or element may be used.

Mean doses and error bounds are derived below for the more significant daily exposures.

For evaluators at Shot Sugar, a common set of error factors describes their exposures as indicated in Section 6. Factors of 1.5 for field intensity and 2 for stay time apply to almost all of each daily dose. The overall error factor is about 2.2. The resultant doses are as follows:

Chemical, D+1	$1.3^{+\ 1.3}_{-\ 0.8}$ rem
Signal, D+2	$0.90^{+\ 0.90}_{-\ 0.54}$
Ordnance, D+4	$1.1^{+\ 1.1}_{-\ 0.6}$
Engineer and Quartermaster, D+2	$2.6^{+\ 2.5}_{-\ 1.6}$

The recovery operations at Sugar positions 1 and 2 are estimated to have occurred on 3 December, but could have occurred at any time from 30 November (if not precluded by intensity limits for recovery operations) to 7 December without interfering with Uncle activities. The error factor on intensity is 1.35 on this account, which combines with the 1.5 for the intensity field and 1.3 for work duration to yield an overall factor of about 1.8. The mean dose, including the small increment on D+4, is $1.5^{+\ 0.9}_{-\ 0.7}$ rem.

Set-up activities before Shot Uncle are not specifically dated in the available references, but no dates other than 24 and 25 November are consistent with other activities and documentation; thus, no error in dating is considered. Error factors of 1.5 for the Sugar intensity and 1.3 for the duration of work apply. The overall error factor of 1.6 implies a mean dose of $0.63^{+\ 0.33}_{-\ 0.26}$ rem for evaluators and support units involved in preliminary set-up on 24 November, and a mean dose of $0.51^{+\ 0.26}_{-\ 0.21}$ rem for all participants on 25 November. For those personnel working on both days, the mean set-up dose is $1.14^{+\ 0.42}_{-\ 0.33}$ rem.

The MP detail that guarded Uncle positions starting on the evening of the day after Uncle accrued the greatest dose. Although the location of the guard position was not documented, the estimated position is judged to have served at least as well as any at a higher radiation level. It is possible that a looser guard was established at a more distant location, but the greatly diminished dose that results is not considered in the uncertainty analysis. Error factors of 1.3 for workshift length and 1.5 for the intensity fields combine to 1.6 overall, which implies a mean dose of $1.3^{+\ 0.7}_{-\ 0.5}$ rem for the stated shift.

The hasty chemical evaluation and the brief visual assessments by other evaluators on Uncle D+4 have uncertainties in dose that are dominated by the error factor of 2 for stay times at positions and 1.5 for the field intensity. The resulting combined error factor of 2.2 implies a mean dose of $1.3^{+\ 1.3}_{-\ 0.8}$ rem to the chemical evaluator and $1.7^{+\ 1.6}_{-\ 1.0}$ rem to the other evaluators who viewed items northeast of GZ.

For the personnel who retrieved film packets on Uncle D+5, the error factor on stay time is estimated as only 1.5 because of the firmer judgment regarding retrieval requirements as well as the number and approximate location of those packets that were successfully retrieved. The field intensity has an error factor of 1.5 or 2, depending on location. Overall, the error factor in dose is about 1.9, which implies a mean dose of $3.7^{+\ 2.7}_{-\ 1.9}$ rem.

The dates of post-Uncle recovery activities are reasonably firm based on the dates of preceding evaluations and rapidity with which Exercise Desert Rock III was

concluded. Error factors for the intensity field and work duration are as for set-up operations. The dose for signal personnel is again considered to be high-sided. The mean doses for 8 and 11 December are $0.36^{+\ 0.19}_{-\ 0.15}$ rem and $0.58^{+\ 0.30}_{-\ 0.24}$ rem, which combine to $0.94^{+\ 0.36}_{-\ 0.28}$ rem.

The evaluations at Uncle positions 1 and 2 in January 1952 have associated error factors of 1.5 for radiation intensity and 2 for duration of stay. The overall error factor in dose is about 2.2, resulting in a mean dose of $0.48^{+\ 0.47}_{-\ 0.28}$ rem for most evaluators. Recovery operations, as previous, have a combined error factor of 1.6 for these positions, resulting in a mean dose of $1.4^{+\ 0.7}_{-\ 0.6}$ rem. The engineer and ordnance evaluators who supervised the recovery have a total mean dose of $1.9^{+\ 0.8}_{-\ 0.7}$ rem.

8.4 TOTAL DOSE SUMMARY.

Total doses for each Desert Rock exercise are derived from the daily dose tables (8, 9, 10) as described in Section 8.1. These exercise doses are shown for each group or unit in the Desert Rock exercise columns of table 14. In the absence of specific knowledge to the contrary, the total exercise dose for a given group or unit is the sum of the daily doses within the time span of each table. A typical exception, however, would be for MP guards at the Uncle displays. Because guard duty is a rotational duty, no individual would have had to perform such more than once in the exercise (or even in the operation); hence, the unit dose for the exercise is the highest daily dose that one could have received, not the sum of the daily doses.

Dose summing for the entire operation, or for participation in more than one exercise, is again based on known combinations of multiple exposures. That is, when there is evidence to suggest that units or groups engaged in activities involving radiation exposure on successive exercises, the exercise-to-exercise doses are summed in table 14. This is particularly appropriate for many units that supported the various Desert Rock exercises, or for the projects that participated at both Exercises Desert Rock II and III. Dose summing is not generally appropriate for observers; hence, the total dose given in table 14 for observers is the dose for the highest observer exposure.

Table 14. Dose summary, Exercises Desert Rock I, II, and III.

Group/Unit[1]	Dose (rem) EDR I	EDR II[2]	EDR III[2]	Post-Ex (1952)	Total Ext.Dose[2]	Total Int.Dose[2, 3]
Observers	<0.01	$0.53^{+0.52}_{-0.31}$	$0.25^{+0.25}_{-0.15}$	-	$0.53^{+0.52}_{-0.31}$	<.15
Maneuver Troops	$0.08^{+0.10}_{-0.06}$	-	-	-	$0.08^{+0.10}_{-0.06}$	<.15
Control Group	0.14	-	-	-	0.14	<.15
Headquarters Staff	0.14	-	-	-	0.14	<.15
Evaluators						
Chemical	-	$1.3^{+1.3}_{-0.8}$	$2.1^{+1.3}_{-0.8}$	$0.48^{+0.47}_{-0.28}$	$2.1^{+1.3}_{-0.8}$	0.74
Signal	-	$0.90^{+0.90}_{-0.54}$	$2.7^{+1.6}_{-1.0}$	$0.48^{+0.47}_{-0.28}$	$2.7^{+1.6}_{-1.0}$	0.74
Ordnance	-	$1.6^{+1.2}_{-0.6}$	$3.5^{+1.7}_{-1.1}$	$1.9^{+0.8}_{-0.7}$	$3.5^{+1.7}_{-1.1}$	2.9
Engineer	-	$2.7^{+2.5}_{-1.6}$	$3.7^{+1.7}_{-1.1}$	$1.9^{+0.8}_{-0.7}$	$3.7^{+1.7}_{-1.1}$	2.9
Quartermaster	-	$2.6^{+2.5}_{-1.6}$	$3.5^{+1.7}_{-1.1}$	$0.48^{+0.47}_{-0.28}$	$3.5^{+1.7}_{-1.1}$	0.74
Medical	-	-	$2.7^{+1.6}_{-1.0}$	$0.48^{+0.47}_{-0.28}$	$2.7^{+1.6}_{-1.0}$	0.74
Projects						
Film Badge	-	$0.34^{+0.54}_{-0.25}$	$0.70^{+0.32}_{-0.24}$	-	$1.0^{+0.7}_{-0.3}$	0.21[5]
Food and Water	-	$0.45^{+0.44}_{-0.27}$	$1.1^{+0.4}_{-0.3}$	-	$1.6^{+0.6}_{-0.4}$	<.15
Support Units[4]						
374th Conv Ctr	0.06	-	-	-	0.06	<.15
369th Engr Regt	-	-	-	$1.4^{+0.7}_{-0.6}$	$1.4^{+0.7}_{-0.6}$	2.2
231st Engr Bn	0.14	$1.5^{+0.9}_{-0.7}$	$2.1^{+0.5}_{-0.4}$	-	$3.7^{+1.0}_{-0.8}$	0.50
90th Engr Co	0.07	-	-	-	0.07	<.15
597th Engr Co	0.14	$0.04^{+0.03}_{-0.02}$	$1.1^{+0.4}_{-0.3}$	-	$1.3^{+0.4}_{-0.3}$	<.15
505th MP Bn	0.02	0.02	$1.3^{+0.7}_{-0.5}$	-	$1.3^{+0.7}_{-0.5}$	<.15
393d Ord Bn	0.14	-	-	-	0.14	<.15
161st Ord Co	0.14	-	-	-	0.14	<.15
3623d Ord Co	0.14	$1.5^{+0.9}_{-0.7}$	$2.1^{+0.5}_{-0.4}$	-	$3.7^{+1.0}_{-0.8}$	0.50
53d QM Co	0.14	-	-	-	0.14	<.15
523d QM Co	0.14	-	-	-	0.14	<.15
303d Sig Bn	0.14	1.4	1.4	-	2.9	0.47
314th Sig Bn	0.14	-	-	-	0.14	<.15
504th Sig Co	0.14	-	-	-	0.14	<.15
4th Trans Co	0.07	-	-	-	0.07	<.15
92d Trans Co	0.07	-	-	-	0.07	<.15
562d Trans Co	0.07	-	-	-	0.07	<.15
94th Vet Det	0.13	-	-	-	0.13	<.15
Monitors	-	0.43	0.65	-	1.1	<.15

NOTE: Where no uncertainty is displayed, the dose given is the upper limit.

1. Also includes post-exercise activities/units.
2. Based on known or deduced combinations of multiple exposures.
3. 50-year bone dose commitment.
4. If support is to another group/unit with known activity, use dose for the supported activity.
5. External dose does not include six identified officers with film badge doses of about 4-6 rem, but internal dose includes such.

If more is known about participation in (a) specific shot(s) or exercise(s), the dose for the actual participation should be used instead of the highest dose given in the total dose column of table 14. As was noted previously, evaluation reports provide evidence that evaluators were generally not the same from one exercise to another, or that a high dose activity at one exercise caused the same evaluator to engage in lower exposure activities at a subsequent activity. Even with such rotation of personnel, doses for evaluators sometimes exceeded the 3 rem criterion established for the combined exercises. Thus, summing of doses from exercise to exercise is inappropriate for groups and units when there is evidence (such as evaluation reports with named personnel) to suggest that the same personnel were not used in the highest exposure activity for all exercises. However, when there is no evidence to support this selectivity, the doses are summed to give the benefit of the doubt to the participant. An extension of this is seen for monitors, where specific participation information is not given. Because so few monitors from the group would have been required, a weighted average dose is given for each day (tables 8-10) and for each exercise (table 14). For a monitor who was known to be present at both Exercises Desert Rock II and III, summing of the weighted averages is appropriately done in table 14.

The total internal doses shown in table 14 are summarized from tables 11-13. Again, the highest combinations of exposures are used to derive the total, and thus should be used only when there is insufficient information on specific shot or exercise participation. However, it should be noted that the total external dose shown in table 14 for a group or unit may not necessarily be from the same exposure that led to the total internal dose. This is because the combinations of exposures that lead to the highest external doses may be different from the sets of combinations that lead to the highest internal doses. However, if specific participation information is not available, the use of the highest combinations of each dose high-sides the totals. Internal doses less than 150 mrem (50-year bone commitment) are not provided. This is consistent with the policy of the Defense Nuclear Agency that establishes a threshold level at one-hundredth the annual limit guideline for occupational exposure. Bone is the indicator organ because, as noted in Reference 44, many radionuclides give a higher dose to the skeleton than to other body parts. It should be noted, however, that thyroid doses from exposure to fission debris at early times after the shot could be higher than the bone dose given. Therefore, if thyroid dose is an issue, it should be assessed separately.

SECTION 9
FILM BADGE DOSIMETRY

Film badge records are available for most Desert Rock participants who entered the forward area during the first five shots of Operation Buster-Jangle. The majority of these badges were issued to document exposures associated with the pre-and post-shot activities associated with Shot Dog. These activities included final preparations in the Shot Dog display areas on 30-31 October by Control Group personnel, the post-shot tour through the display areas by observer personnel (being supervised and briefed by the Control Group at each area) on 1 November, and the post-shot maneuver by the BCT troops. Sufficient dosimetry is available for these personnel to provide a meaningful comparison with the doses calculated for them in Section 6.

Approximately 25 Camp Desert Rock personnel were responsible for setting up equipment displays and providing effects evaluation briefings at display position 1, 1000 yards south-southwest of the Shot Dog ground zero. In Section 6, doses calculated for this group on 30 and 31 October and 1 November are 64, 9, and 48 mrem, respectively. The dosimetry for these personnel is as follows:

Control Group Dosimetry: Display Position #1

	Number of personnel badged on		
Dose (mrem)	10/30/51	10/31/51	11/01/51
0	14	9	0
20	3	4	4
34	2	4	7
50	1	-	4
60	-	-	7
80	-	-	1
95	-	-	1

It is apparent that, on 1 November, there is a definite increase in the mean of the dose distribution as derived from the dosimetry, which suggests increased radiation levels at display position 1 resulting from Shot Dog. The average dose is about 45 mrem,

which compares favorably with the calculated film badge dose of 48 mrem on this day. The two highest dose badges (95 and 80 mrem) are for a rad-safe monitor and for a photographer responsible for documenting the weapon's effects on displayed equipment, activities likely associated with higher than average exposures. On 31 October, the calculated dose of 9 mrem is consistent with the dosimetry, where all badge readings are well below 50 mrem (which subsequently became a reporting threshold for specific badge readings, suggesting that specific readings less than 50 mrem indicated an exaggerated precision). On 30 October, the calculated dose of 64 mrem is greater than all doses recorded on that day. This supports the contention made in Section 6 that, by assuming radiation levels at positions 1 and 2 following Shot Charlie were identical to those levels following Shot Dog, subsequent dose calculations for Shot Charlie would be high-sided.

A similar comparison can be made for the approximately 80 personnel assigned to the Control Group at display position 2, 1500 yards south-southeast of ground zero. Calculated doses for this group on 30 and 31 October and 1 November, are 32, 5, and 24 mrem, respectively. The following table is an analysis of the dosimetry for these personnel:

Control Group Dosimetry: Display Position #2

	Number of personnel badged on		
Dose (mrem)	10/30/51	10/31/51	11/01/51
0	18	9	40
20	2	3	8
34	4	3	14
50	3	1	2
60	-	-	-
80	-	-	-
95	-	-	1

Unlike the dosimetry from position 1, the dosimetry from position 2 indicates no significant increase in radiation levels resulting from Shot Dog on 1 November; on each day, the non-zero badges issued represent approximately the same percentage of the total badges issued. This would suggest that a fairly uniform, low-level radiation

field persisted at position 2 following Shots Charlie and Dog. Calculated doses are consistent with the dosimetry on these days when one considers that, with the exception of one film badge issued on 1 November, all badges read at or below 50 mrem. It should be reiterated that the calculated dose of 32 mrem on 30 October is considered quite high-sided for reasons previously mentioned. The highest dose badge (95 mrem) is for a medical officer assigned to position 2 on 1 November, which suggests that he ventured farther forward than position 2.

According to Reference 1, film badges were issued to observers by the Visitors Bureau when the individual reported to Camp Desert Rock. The dosimetry records indicate that virtually all observer badges have dates of 29, 30, 31 October, and 1 November. It is presumed these dates refer to the issue date and that all observer badges were collected following Shot Dog on 1 November. Approximately 2800 observers were issued one badge each during the interval 29 October to 1 November; this number agrees with the total number of Shot Dog observer personnel cited in Section 2. The following is a breakdown of the observer dosimetry for Shot Dog.

Dosimetry for Shot Dog observers

	Number of observers issued badges on				
Dose (mrem)	10/29/51	10/30/51	10/31/51	11/01/51	Total
0	271	374	1312	482	2439
20	38	61	114	22	235
34	5	38	33	22	98
50	1	1	7	5	14
60	1	0	4	3	8
80	0	1	0	1	2
95	2	0	1	1	4
110		0	1	1	2
125		1	1		2
140		1	0		1
150		0	1		1
240		0	1		1
320		1	0		1
750			1		1
Total	318	478	1476	537	2809

It is evident that the calculated dose of 4 mrem for observers at Shot Dog (Section 6) is supported by the vast majority of the dosimetry records; 87 percent of the film badges recorded a zero dose while about 99 percent of the doses are less than 50 mrem. Reference 1 depicts an analysis of 2714 film badges worn by observers at Shot Dog. The results indicate a low dose of less than 20 mrem, an average dose of 31 mrem, and a maximum dose of 320 mrem. The reference also indicates that the average dose "includes only those readings of at least 20 mrem." Disregarding the 2439 zero dose records (and the 750 mrem badge, thought to be an equipment badge) in the distribution above, the average dose is 30 mrem, which is in excellent agreement with Reference 1. If the 2439 zero dose badges are included in the analysis, the average dose is only 4 mrem, which is consistent with the calculated dose. Moreover, low doses are consistent with the constraint noted in Reference 1 that "The observer group will not enter a radioactively contaminated area, nor proceed closer to ground zero than EGG Road, [position 2]." Reference 1 also states that, of the 2714 badges worn by the observers, "with exceptions as noted in the summary, none of this group proceeded closer than 1500 yards from ground zero [position 2]." If it is considered that the film badge threshold of reliability was about 50 mrem, the 37 badges at or above this level are likely due to the unauthorized excursions (documented in Reference 1) of personnel who proceeded closer to ground zero than the remainder of the observer group.

For the BCT, the 846 film badges worn on 1 November are analyzed as follows:

Dosimetry for maneuver units

Element	Number of Badges	Dose (mrem) Low	Average	Maximum
Hq Co, 1st Bn	169	0	56	125
Co A	140	0	53	125
Co B	145	0	57	125
Co C	167	0	48	140
Co D	109	0	70	200
C Btry	116	0	64	95
BCT as a group	846	0	57	200

Only 12 badges recorded a dose greater than 100 mrem, and 7 of these were in Company D. If the zero dose badges are excluded, the results are the same as that presented in Reference 1, which indicates that the badges turned in by the BCT troops had a minimum dose of 20 mrem, an average dose of 59 mrem, and a maximum dose of 200 mrem. The calculated mean dose of $0.08^{+0.10}_{-0.06}$ rem for the BCT troops (Section 8) is in good agreement with the film badge dosimetry.

As indicated in Section 6, only a few film badge records for Exercises Desert Rock II and III personnel (Shots Sugar and Uncle) are available.* Records are available for 27 November for six Desert Rock personnel (including evaluators) and for rad-safe monitors who were not necessarily involved with Desert Rock activities. The doses apparently reflect exposures associated with the evaluator pre-shot checks of the Uncle display positions. The badge doses range from 0.11 to 0.21 rem (average 0.152 rem). The reconstructed mean dose for this activity is $0.19^{+0.18}_{-0.11}$ rem.

Sixteen film badge records for a group of senior Army officers who toured some of the display positions on 7 December (Uncle, D+8) are available. The badge doses range from 0.12 to 0.19 rem with an average of 0.148 rem. There are no other records for that date that could pertain to their drivers, monitors, or MP escort, if any. The dose calculations assume that these senior officers toured positions 3 through 7, resulting in a mean dose of $0.25^{+0.25}_{-0.15}$ rem.

Reference 31 lists a total of 13 Buster-Jangle participants who exceeded 3.9 rem. Three of these individuals are identified as Desert Rock, while three others were with activities associated with Desert Rock (Reference 36). All six were officers who recovered film packets from display positions on 4 December (Uncle D+5). Reference 31 also states that one of these officers, who had served as their monitor, had failed to account for a large instrument calibration factor and that his oversight resulted in the following film badge doses (average 5.15 rem): 4.65, 4.90, 4.90, 5.08, 5.54, and 5.80 rem.

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* Reference 2 states that the film badges for Desert Rock evaluation personnel at Shot Sugar and Uncle were collected and turned in to the film badge laboratory at the AEC Control Point. The Desert Rock Rad-safe Officer obtained film badge reports from the laboratory and maintained an operational chart on total dose received by each member of the evaluation teams. These records have not been located.

The calculated mean dose for these officers for their likely activites on this date is $3.7^{+\ 2.7}_{-\ 1.9}$ rem. Reference 36 also depicts activities in which individuals exceeded 3.0 rem. It is noteworthy that no other Desert Rock individuals are listed, thus suggesting that overexposures to Desert Rock personnel were limited to those individuals described above and in Reference 31.

In summary, while dosimetry for Exercise Desert Rock I is extensive and correlates well with calculated doses (Section 6), the few film badge records available for Exercises Desert Rock II and III, although representative only of unique activities by small groups of individuals, nonetheless agree with calculated doses. These, together with excellent correlation for Shot Dog, provide high confidence in the reconstruction methodology. The calculated doses for Shots Sugar and Uncle are thus considered valid.

SECTION 10
CONCLUSIONS

Exercise Desert Rock personnel engaged in activities at five of the seven test shots of Operation Buster-Jangle. No personnel were located closer than 10,000 yards (9 kilometers) from ground zero at the time of any of the detonations; thus, initial radiation dose was insignificant for all participants.

Residual radiation doses to the bulk of the military personnel in the three exercises were modest. For example, doses were 0.14 rem or less for all units and groups in Exercise Desert Rock I. Doses for some groups at Exercises Desert Rock II and III were near the rad-safe limit of 3 rem. Fifty-year bone dose commitments for all observers and maneuver troops at any of the exercises were less than 0.15 rem.

Calculated external doses from residual radiation (mean film badge equivalent doses) and 50-year bone dose commitments to various categories of staff and support personnel, military equipment evaluators, and Desert Rock project personnel varied due to the nature, intensity, and duration of radiation fields (air, surface, and sub-surface bursts) and the timing, duration, and types of activity involved. Moreover, the apparent non-specific intensity limit for Exercise Desert Rock II led to higher doses (but within the 3 rem dose limit) than would have accrued if an intensity limit had been in effect (as it was for the other two exercises).

Exercise Desert Rock I involved activities resulting in exposures to residual radiation (neutron-activated soil) from Shots Charlie and Dog. The highest resultant external dose of 0.14 rem was received by personnel of the Control Group assigned to Display Position 1 and supporting units involved in set-up and recovery operations at this position. Bone dose commitments were much less than 0.15 rem.

Desert Rock II and III activities in the residual radiation (fission product) fields of the surface and sub-surface bursts of Shots Sugar and Uncle resulted in some instances of significant external radiation exposure and 50-year bone dose commitments for evaluators and project personnel, and for units involved in display

set-up and recovery. The technical service evaluators at Shots Sugar and Uncle, as well as several support units involved in equipment set-up and recovery, accrued the highest external doses of all exercise participants. These doses, in some cases, approached or slightly exceeded the dose limit of 3 rem established for the combined exercises. It is noted that these doses are likely not applicable to the entire units, but nonetheless would have been even higher had it not been realized at the time that some individuals were approaching the established dose limit, thus causing others to be used, when available, in subsequent high exposure activities. Post-exercise activites resulted in additional exposures, the doses for which should be recorded for 1952.

Internal bone dose commitments, while below the 0.15 rem screen threshold for the first exercise, exceeded 0.15 for several classes of participants at the surface and underground tests as well as for recovery operations in January 1952.

Calculated doses, both for low exposure and relatively high exposure situations, correlate well with available film badge dosimetry records, thus providing a high confidence in the calculations.

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