LA-UR-13-25871
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Intended for: Report

Issued: 2013-07-25

On-site Measurements and Calculations of the Maximally Exposed Individual (MEI) at LANL

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July 16, 2013

1. Introduction

DOE Order 458.1 (DOE 2011 Section 4e(1)(a)) requires calculation of the dose to the maximally exposed individual (MEI) member of the public both on site and off site. This paper describes the measurements and calculations of the on-site MEI during 2012.

The publicly accessible on-site locations are:

- State Road 4, especially near the "Y", near the intersection of State Roads 4 and 502;
- State Road 4 from White Rock past Bandelier National Monument to State Road 501;
- State Road 501 and West Jemez Road, past TA-16, TA-8, and TA-3;
- the hiking trails in Los Alamos Canyon;
- East Jemez Road, a.k.a. the truck route.

Each of these is considered in the following sections.

2. State Road 4 near the "Y"

The "Y" is the parking and carpool area near the junction of the main hill road (State Road 502) and the road to White Rock (State Road 4). It is on DOE land next to the Los Alamos Canyon weir. The sediment in the weir contains on the order of 1 pCi/g of each of: plutonium-239, cesium-137, and strontium-90. These concentrations are less than those at off-site locations: near the TA-1 Hillsides (137 and 138), Acid Canyon, Pueblo Canyon, and Bayo Canyon. Re-suspended plutonium from Hillside 137 is measured by AIRNET and results in a dose of a few tenths of a millirem per year to a potential resident near the AIRNET station. The potential MEI dose at the parking area near the weir is much less for three reasons: the sediment is often wet; the concentrations are about two orders of magnitude lower; and the occupancy factor is one or two orders of magnitude smaller. We conclude that the potential MEI dose near the Y is several orders of magnitude less than 0.1 mrem/year.

3. State Road 4 south of White Rock

Along State Road 4 from White Rock past Bandelier National Monument, to the intersection with State Road 501, there are no measurable sources and no locations with the potential for a measurable MEI dose. Ancho Canyon and the hiking trails were assessed for the 2010 Environmental Report (LANL 2011 Chapter 3 Section B.3.e.ii) and we concluded that the potential MEI dose is much less than 0.1 mrem.

4. West Jemez Road (State Road 501)

West Jemez Road has been monitored extensively, especially near TA-3, TA-8, and TA-16, by stack monitors, by AIRNET, and by DPRNET. The AIRNET and DPRNET data do not measure anything above background, and stack data show that the potential MEI dose is much less than 0.1 mrem.

5. Hiking trails in Los Alamos Canyon

In Los Alamos Canyon, there are hiking trails that lead to the hillsides near TA-1. Most hikers stay to the west of TA-1 where the legacy contamination is much less than at Hillsides 137 and 138. Even if they hiked on Hillsides 137 and 138, the small occupancy factor would result in doses much smaller than those reported for the off-site MEI. In summary, the potential doses are much less than 0.1 mrem/year.

6. East Jemez Road (the truck route)

The largest potential source of radioactivity is LANSCE in TA-53. We focus on this case in detail because LANSCE has often been the source of the off-site MEI. Furthermore, although the present dose is small, there is a potential for larger doses.

6.1 LANSCE Emissions and CAP88

The doses from the LANSCE emissions are calculated using CAP88 (EPA 2013). The off-site-MEI dose from LANSCE is a few tenths of a mrem, assuming 100% occupancy. At East Jemez Road, the occupancy is at least an order of magnitude smaller so the dose to the on-site MEI is much less than 0.1 mrem.

6.2 Neutrons

The neutron dose within TA-53 is measured by 8 albedo TLDs. The background recorded by these TLDs is not the true dose from cosmic rays for two reasons. The TLDs are calibrated with a deuterium-oxide-moderated Cf-252 source, which has a very different energy spectrum from cosmic-ray neutrons. And second, part of the cosmic-ray dose is effectively subtracted because zero is effectively defined by the TLDs that are kept in a vault, and cosmic-ray neutrons penetrate the 2-inch-steel walls of this vault.

The neutron background is 0.5 ± 0.5 mrem/quarter or 2 ± 1 mrem/year. At the background stations, the dose is as high as 2 mrem/quarter for about 2% of the quarters, higher than predicted by Gaussian statistics, so the distribution is not perfectly Gaussian. Occasional values of 2 mrem in a single quarter or 3 mrem in a single year happen occasionally and are not statistically significant. However, the ten-year annual averages listed in Table 1 have smaller uncertainties and show statistically significant doses above background at all locations within TA-53.

Table 1: Neutron doses at TA-53 during 2012

ID #	Direction from LANSCE	latitude, longitude	Average neutron dose (mrem/yr)
19	NW	35.87024, -106.26761	4
64	NNE	35.8706, -106.2571	5
65	NNW	35.8703, -106.2586	6
114	E	35.8677, -106.2494	3
115	ENE	35.8688, -106.2507	3
123	SW	35.8671, -106.2656	4
124	S	35.8659, -106.25955	6
125	NE	35.8704, -106.2544	3

This distribution of doses is not consistent with a single source of neutrons. Rather, it indicates multiple sources: the isotope production facility to the west, lines B and C to the north, and line D to the south. The largest dose is usually observed at TLD location # 124, which is 0.2 km south of the line-D targets. Jemez Road is 0.35 km south of these targets, and the road is in Sandia Canyon, partially shielded by the canyon walls, so it does not receive direct radiation, only sky shine from neutrons scattered in the air.

Most neutrons are moderated by steel, concrete, and hundreds of meters of air. MCNP calculations show that the largest dose at Jemez Road results from 2-MeV neutrons. Lower energy neutrons are attenuated by hundreds of meters of air, whereas higher energy neutrons scatter less and so create less sky shine. For the worst case 2-MeV neutrons, MCNP shows that the dose at Jemez Road is 10% of the dose measured by TLD # 124.

6.3 Gammas

Above-background gamma doses have only been observed at two TA-53 locations: #114 and #115. These gammas are from the “tanks” at latitude-longitude location 35.8678 -106.2508. Background is 150 mrem/year. Although these two locations are about the same distance from the ponds, #114 is shielded by the concrete wall of the tanks, by the water in the tanks, and by the nearby trees, so the measured and calculated dose rate at #114 is about ¼ that at #115. Location #114 is about 3 meters lower than the tanks so it does not receive any un-scattered photons, only sky shine.

Location #115 is 100 m north of the north wall of the pond and about 10 m higher so the surface of the pond is visible from the TLD locations and it receives some un-scattered photons. However, most photons originate beneath the surface and lose energy by Compton-scattering in the water.

The worst case corresponds to the highest energy gammas from Cobalt-60. For these gammas, MCNP shows that the dose at Jemez road is 0.2% of that measured by TLD #115, which is typically about 100 mrem per year.

7. Procedure to calculate the dose to the on-site MEI

First calculate the dose assuming full-time occupancy.

Select the largest neutron dose measured by an environmental TLD (normally #124) and subtract 2 mrem/year background. The MEI dose for full-time occupancy is 10% of the neutron dose measured by the TLD and corrected for background. Typically, this is about 0.5 mrem per year.

Select the largest gamma dose measured by an environmental TLD (normally #115) and subtract 150 mrem/year background. The MEI dose for full-time occupancy is 0.2% of the gamma dose measured by the TLD and corrected for background. Typically, this is about 0.2 mrem per year.

Add the neutron dose, the gamma dose, and the CAP88 dose, and apply an occupancy factor. The default occupancy factor of 1/16 is an overestimate. If the result is less than the off-site MEI dose and is less than 0.1 mrem/year it may be reported as: less than 0.1 mrem/year.

8. Conclusion

The on-site MEI should normally be reported as the dose on East Jemez Road calculated by the above procedure. After applying an occupancy factor, it will normally be less than 0.1 mrem/year.

9. References

DOE 2011: "Radiation Protection of the Public and the Environment," US Department of Energy Order 458.1 (June 2011).

EPA 2013: "CAP88-PC Version 3.0 User Guide," Trinity Engineering Associates, Inc., Environmental Protection Agency (February 2013).

LANL 2011: "Environmental Report 2010," LA-14445-ENV (2011).

Appendix containing supplementary materials

MCNP input file for neutrons from Line D

```
TA53
1    1 -0.001  3  -4  5  -6 12 -13 imp:N=1 $source
2    1 -0.001  3  -4  6  -7 12 -13 imp:N=2 $air above mesa
3    2 -1.6    1  -3  5  -7 12 -13 imp:N=0.1 $gnd beneath mesa
4    1 -0.001 14  -4  7  -8 12 -13 imp:N=4 $air above n slope
5    2 -1.6    1 -14  7  -8 12 -13 imp:N=0.5 $gnd beneath n slope
6    1 -0.001  2  -4  8  -9 12 -13 imp:N=8 $air above valley
7    2 -1.6    1  -2  8  -9 12 -13 imp:N=1 $gnd beneath valley
8    1 -0.001 -15 -4  9 -10 12 -13 imp:N=8 $air above s slope
9    2 -1.6    1  15  9 -10 12 -13 imp:N=1 $gnd beneath s slope
10   1 -0.001  3  -4 10 -11 12 -13 imp:N=8 $air above mesa
11   2 -1.6    1  -3 10 -11 12 -13 imp:N=0.5 $gnd beneath mesa
12   0   -1 : 4 : -5 : 11 : -12 : 13 imp:N=0 $void

1    PY  -99.      $very deep
2    PY  0.        $valley
3    PY  7000.     $mesa
4    PY  99999.    $very high
5    PX  -1.       $far
6    PX  0.        $source
7    PX  20000.    $nearer edge of mesa
8    PX  30000.    $nearer edge of valley
9    PX  60000.    $farther edge of valley
10   PX  70000.    $far mesa
11   PX  99999.    $very far
12   PZ -99999.    $very far east-west
13   PZ  99999.    $very far east-west
14   P  0.7  1. 0. 21000.  $slope at n of valley
15   P  0.7 -1. 0. 42000.  $slope at s of valley

mode  n
c source
sdef  X=D1 Y=D2 Z=D3 erg 2.
SI1   -0.9 -0.1
SP1   0  1
SI2   7001. 7031.
SP2   0  1
SI3   -1000. 1000.
SP3   0  1
c phys:p nocoh 1 emcpf 0.001
c phys:p  0.001
c
m1    7014  0.785  8016 0.21   18040 0.005   $ air
m2    14000 .19 8016 .56 1001 .18 13027 .04 11023 .01 19000 .01 26000 .01 $tuff
```

```
c
e0   .02 .04 .1 .2 .4 1. 2. 4. 10. 20. 40. 100. 200. 400. 800.
*F1:N  6 7 8 9 10
F5:N  10000. 7100. 0. 90. $mesa (x y z  dxtran)
F15:N 20000. 7100. 0. 90. $mesa
F25:N 30000. 7100. 0. 90. $rim and surface 7
F35:N 35000.  100. 0. 90. $valley and surface 8
F45:N 40000.  100. 0. 90. $valley
F55:N 60000.  100. 0. 90. $valley and surface 9
F65:N 70000. 7100. 0. 90. $mesa and surface 10
F75:N 80000. 7100. 0. 90. $mesa
c
*F105:N 10000. 7100. 0. 90. $mesa (x y z  dxtran)
*F115:N 20000. 7100. 0. 90. $mesa
*F125:N 30000. 7100. 0. 90. $rim and surface 7
*F135:N 35000.  100. 0. 90. $valley and surface 8
*F145:N 40000.  100. 0. 90. $valley
*F155:N 60000.  100. 0. 90. $valley and surface 9
*F165:N 70000. 7100. 0. 90. $mesa and surface 10
*F175:N 80000. 7100. 0. 90. $mesa
c
ctme  60
```

MCNP input file for gammas from the tanks

```
TA53
1    1 -0.001  3  -4  5  -17 12 -13 imp:p=1 $source
2    1 -0.001  3  -4  6  -7 12 -13  imp:p=2 $air above mesa
3    2 -1.6    1  -3  5  -7 12 -13  imp:p=0.1 $gnd beneath mesa
4    1 -0.001 14  -4  7  -8 12 -13  imp:p=4 $air above n slope
5    2 -1.6    1 -14  7  -8 12 -13  imp:p=0.5 $gnd beneath n slope
6    1 -0.001  2  -4  8  -9 12 -13  imp:p=8 $air above valley
7    2 -1.6    1  -2  8  -9 12 -13  imp:p=1 $gnd beneath valley
8    1 -0.001 -15 -4  9 -10 12 -13  imp:p=8 $air above s slope
9    2 -1.6    1  15  9 -10 12 -13  imp:p=1 $gnd beneath s slope
10   1 -0.001  3  -4 10 -11 12 -13  imp:p=8 $air above mesa
11   2 -1.6    1  -3 10 -11 12 -13  imp:p=0.5 $gnd beneath mesa
12   1 -2.5    3  -16  17  -6 12 -13 imp:p=1 $wall
13   1 -0.001  16  -4  17  -6 12 -13 imp:p=1 $air above wall
14   0   -1 : 4 : -5 : 11 : -12 : 13 imp:p=0 $void

1    PY  -99.      $very deep
2    PY  0.        $valley
3    PY  7000.     $mesa
4    PY  99999.    $very high
5    PX  -2000.    $far
6    PX  0.        $source
7    PX  30000.    $edge of mesa
8    PX  40000.    $near edge of valley
9    PX  60000.    $far edge of valley
10   PX  70000.    $far mesa
11   PX  99999.    $very far
12   PZ -99999.    $very far east-west
13   PZ  99999.    $very far east-west
14   P  0.7  1. 0. 28000.  $nearer slope of valley
15   P  0.7 -1. 0. 42000.  $farther slope of valley
16   PY  7100.     $wall
17   PX  -30.      $wall

mode  p
c source
sdef  X=D1 Y=D2 Z=D3 erg 1.33
SI1   -2000. -30.
SP1   0  1
SI2   7070. 7071.
SP2   0  1
SI3   -1000. 1000.
SP3   0  1
c phys:p nocoh 1 emcpf 0.001
c phys:p  0.001
c
```

```
m1    7014  0.785  8016 0.21   18040 0.005   $ air
m2    14000 .19 8016 .56 1001 .18 13027 .04 11023 .01 19000 .01 26000 .01 $tuff
c
e0   .02 .05 .1 .2 .3 .4 .5 .6 .7 .8 .9 1. 1.1 1.2 1.33
*F1:P  6 7 8 9 10
F5:P  10000. 7100. 0. 90. $near mesa (x y z  dxtran)
F15:P 10000. 8100. 0. 90. $near mesa (10 m higher)
F25:P 30000. 7100. 0. 90. $rim and surface 7
F35:P 40000.  100. 0. 90. $valley and surface 8
F45:P 50000.  100. 0. 90. $valley
F55:P 60000.  100. 0. 90. $valley and surface 9
F65:P 70000. 7100. 0. 90. $mesa and surface 10
F75:P 80000. 7100. 0. 90. $far mesa
c
*F105:P 10000. 7100. 0. 90. $near mesa (x y z  dxtran)
*F115:P 10000. 8100. 0. 90. $near mesa (10 m higher)
*F125:P 30000. 7100. 0. 90. $rim and surface 7
*F135:P 40000.  100. 0. 90. $valley and surface 8
*F145:P 50000.  100. 0. 90. $valley
*F155:P 60000.  100. 0. 90. $valley and surface 9
*F165:P 70000. 7100. 0. 90. $mesa and surface 10
*F175:P 80000. 7100. 0. 90. $far mesa
c
ctme  60
```

Description of TLD locations at TA-53

#19: is on the NE corner of the fence that surrounds the electrical substation near TA-53-1.

#64: is on the mesa north of Area B; hike up the dirt road north of the NTOF flight path, and walk west until you see the 110-V electrical power outlet near the man-made “cliff”; (the conduit is visible from below); it is in line with the western edge of the Area B building; then walk to the north rim of the mesa and look for the Lucite block; it is in a tree.

#65: drive along the mesa north of the accelerator until you come to the turnaround area near the cooling tower just west of the cut; the Lucite block is visible from the turnaround area, near the north edge of the mesa.

#114: walk 105 m east from the east wall of the “tank”; the Lucite block is in a pinon tree.

#115: the Lucite block is visible from the garage-like building north of the “tank”; it is 100 m north of the north wall of the “tank”, in a tree, in line with the wall separating the east and west “tanks”.

#123: drive south along the perimeter road until the road curves toward the east; it is visible over the guardrail to the right (southwest.)

#124: it is at the south edge of the parking area (or storage area) near the south edge of the mesa; it might be hidden by miscellaneous stacks of stuff.

#125: it is a few meters NW of the concrete pad that anchors the NW cable of the TA-53 meteorological tower.