Measured radiation levels for the Central Operable Unit inside the Rocky Flats National Wildlife Refuge

D. M. Wood, June 2019

Contents

Note: Kim Griffiths, as a member of the Rocky Flats Stewardship Council, took all of the measurements reported here.

Introduction

The Central Operable Unit (COU) (see Fig. 1) is the 'donut hole' in the Rocky Flats National Wildlife Refuge, the region originally occupied by the miniature city where the plutonium processing plant was before the Superfund cleanup that was completed in 2005. It remains under Department of Energy (Office of Legacy Management) control and is not accessible to the public. From time to time there are escorted, DOE-authorized trips into the COU.

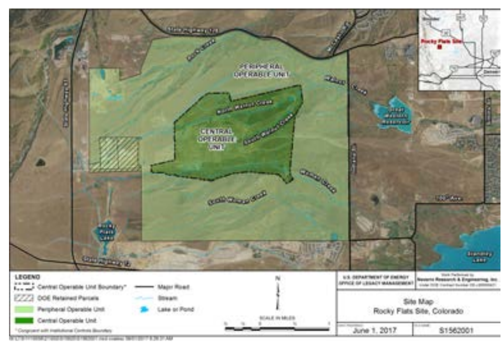


Figure 1: Central operable unit. From Fig. 1 of the 2017 Five-Year Review Report.

One of DMW's college professors enunciated Wheeler's First Moral Principle: "Never make a calculation until you know the answer. Make an estimate before every calculation. . . . . . Guess the answer to every paradox and puzzle. Courage: No one else needs to know what the guess is. Therefore make it quickly, by instinct. A right guess reinforces this instinct. A wrong guess brings the refreshment of surprise."

DMW wrote the following before Kim's trip to the Central Operable Unit from Candelas on June 10, 2019.

> It would be interesting if the ambient dose equivalent rate (ADER) were significantly higher in the COU than in the Refuge, but it's very unlikely. Here's why: (i) the "Rocky Flats isotopes" constitute less than 3% of total soil radioactivity, so it would require quite precise measurements to see their effect at all; (ii) plutonium emits almost 100% alpha particles, whose range in air is about 4 inches; beyond that distance the alphas have disappeared (having slowed down and been neutralized, becoming helium atoms), and the measurement of the ADER mandates that the detector be 1 meter off the ground; (iii) a relatively small number of gamma rays are emitted during the alpha decay. These are the only particles from ^{239,240}Pu decay that we can hope to detect. ^{241}Am (used in smoke detectors) is also an alpha emitter so is also undetectable except for some low-energy gamma rays. ^{241}Am contributes

> less than 1% of total soil radioactivity so would be even harder to measure. So: my predictions are: no discernible difference in the ADER inside and outside the COU unless there are "hot spots". If I'm wrong, I'll comment after the measurement.

In fact, DMW *was* partly wrong. The ambient radiation rate in the COU *is* virtually identical to what was already measured on the trails in the Wildlife Refuge, but is actually *lower* than over the trip to/from Candelas. A trip to the COU from Candelas (and back) shows two distinct regions, almost definitely determined by soil mineral content (uranium?) south and west of the Refuge. Kim's trip consisted of

Figure 2: Trip overview (from a Google Earth KML downloaded from SAFECAST). Sampling points (every 5 seconds) are obviously further apart at car speeds, closer together for the minivan moving slower through the Refuge, and much closer together when on foot.

the drive to the western (restricted) road entrance to the Refuge and on to a parking lot. Thereafter there were short drives in a minivan punctuated by 20-30 minute inspections on foot of structures or locations in the COU. The path there and back is shown in Figure 2. The bGeigie Nano (bGN) Geiger-Müller counter used to acquire data is described thoroughly in the document Recently measured radiation levels inside the Rocky Flats National Wildlife Refuge elsewhere on our web site.

Data and analysis

Figure 3 shows in panel (a) the measured counts per minute from the bGN counter, updated every 5 seconds from the previous 60 seconds. This unsmoothed data is used (once partitioned into regions, as described below) to produce histograms of count rates and hence data points for curve fitting. Without examining the actual Geiger-Müller counting data [in this case, the 'counts per minute' (CPM)] it is easy to overlook large fluctuations present because radiation emission is a random Poisson process. But it is also clear that there is a 'sag' in the middle–a region of the path taken where the CPM drops, indicating a lower radiation rate.

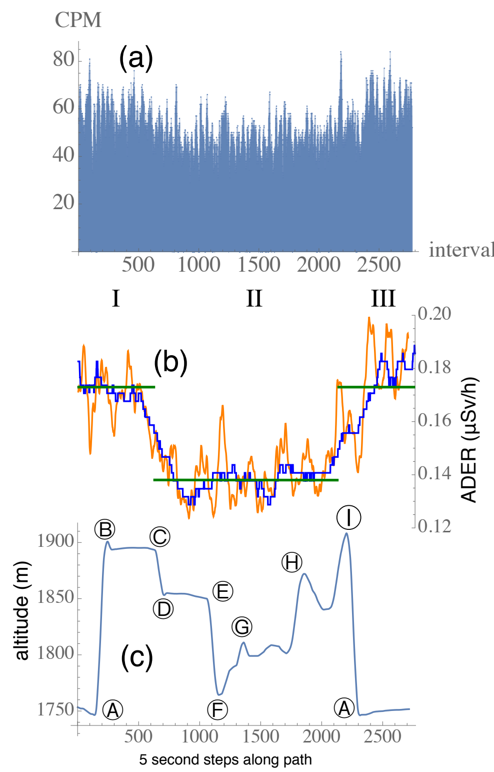


Figure 3: Raw counts per minute rate over trip from Candelas to COU and back, panel (a). Smoothed measured count rates converted into equivalent ADER, panel (b), which also shows (blue bars) regions over which rates are approximately constant, used for later fitting. Panel (c): measured altitude (in meters), with geographic features labeled.

This data is 'noisy' and so has been smoothed. In panel (b) are shown the result of a 59-point 'moving average' of the measured CPM, converted (on the right y axis) into an ambient dose equivalent [radiation] rate measured in microSieverts per hour (μSv/h) using the bGeigie Nano nominal calibration rate of 334 counts/min = 1μSv/h. This curve is shown in orange; an alternative smoothing method (a non-linear 'median' filter, replacing each value by the median over its 100 nearest neighbors) is shown in blue. Some features survive these rather severe smoothing methods: it *does* appear as if the central region (labeled II in panel (b)) is roughly constant (apart from random fluctuations consistent with a Poisson distribution with the mean count rate in region II). Regions I and II have approximately the same average values. This is not surprising since at least part of the total trip consisted of Kim's car retracing the original path to the west Refuge entrance. In the bottom panel [(c)] is shown the lightly smoothed (again, a 59-point moving average) altitude for each measured point. Significant geographical features in the path have been labeled with circled capital letters. The locations A-I will be specified in a later figure.

This is significantly different that the situation found on the trails of the Refuge: See Figure 4 of Recently measured radiation levels inside the Rocky Flats National Wildlife Refuge. In that case there were no clear distinctions between radiation rates in different regions.

The wiggles in the ADER will be familiar to those who have read the document Recently measured radiation levels inside the Rocky Flats National Wildlife Refuge about measured values in the Refuge itself. As we saw there, generally the rapid oscillations are due to statistical noise that would be present in any counting device. The range of up/down fast oscillations about the blue lines is about the same in the regions labeled I, II, and III in the figure. On the other hand, unlike the Refuge situation, the behavior of the ADER appears to be similar in regions I ('going there') and III ('coming back'), and different in region II ('in the COU').

Figure 4 shows geographically most of the features specified by altitude in panel (c) of Fig. 3.

The locations not shown in the detailed map are

- Point A, near the intersection of McIntyre Street and Lupine Way in Candelas
- Point B, on CO 93 just north of intersection with Coal Creek Canyon Road
- Point I, essentially same as point B.

Partitioning data into distinct regions

As always, acknowledging that there are different behaviors in different regions is important. It increases the reliability of the data extracted from each region and may provide insight into what causes the differences.

Point D is manifestly in the COU, but it is convenient to take the boundary between I and II (see Fig. 5) as the southwest corner of the rectangular box whose sides were traversed at different times during the trip. In fact, the altitude difference between this corner and point D (which appears as roughly the beginning of region II in Fig. 3) is only 2.5 meters.

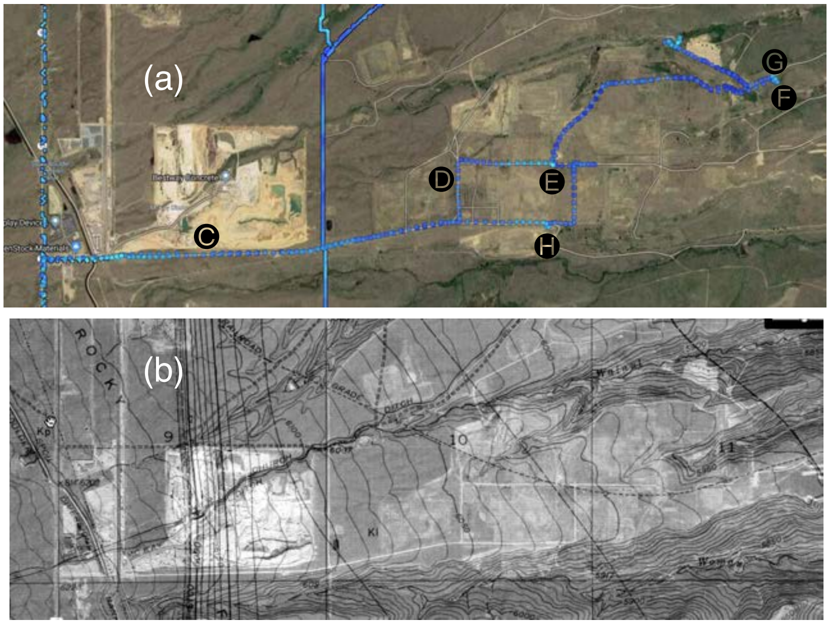


Figure 4: Upper panel: map points corresponding to points C-H of Fig. 3 panel (c), from SAFECAST. Lower panel shows a grayscale, contrast-enhanced superposition of aerial photos with contour lines, taken from a convenient USGS composite map displaying (by means of an opacity mixer) topo map and satellite imagery features.

Figure 5: Boundary of COU (light gray region) will be taken as southwest box corner, indicated as a red circle.

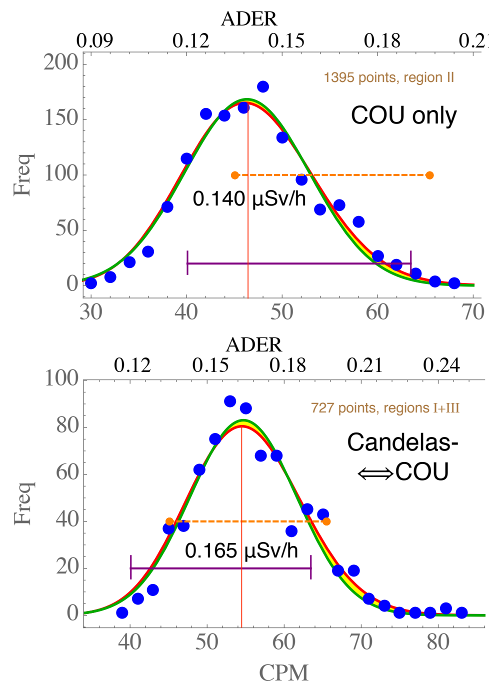


Figure 6: Fits to histogrammed data inside the COU (upper) and outside (lower). Red curves are Poisson distribution, green are a Gaussian.

Because Kim Griffith's trip to and from the COU (but not inside) used exactly the same paths, there is an advantage to grouping regions I and III together on the same footing (better statistics). Thus we select region III to begin at precisely the same southwest corner of the rectangle where region II ends. Thus regions I and III now include some parts of the Refuge and the trip to and from Candelas while region II consists entirely of the COU.

The regions of slightly higher ADER (I and III) are south and west of the Refuge. Why this should be so is discussed later.

Extracted information

In Figure 6 we show fitting results for [panel (a)] the COU alone (region II) and for [panel (b)] the trips from and back to Candelas (regions I and III). We find an ambient dose equivalent [radiation] rate (ADER) of 0.1395 ± 0.0009 μSv/h in the Central Operable Unit and 0.165 ± 0.001 μSv/h for the trips to and from the COU from Candelas. In each case the $\pm$ figures are the standard error of the ADER. In both cases we have shown: (i) as a purple horizontal bar, the range of total background radiation levels expected along the Front Range on the basis of altitude and naturally-occurring radioactive mineral content [1], and (ii) as two orange dots the range quoted by Stone *et al.* [2] from a 1999 paper surveying background radiation rates along the I-70 corridor and in 40 communities along the Front Range.

It is somewhat surprising that ambient radiation levels *outside* the

We will henceforth quote this number as 0.140; more decimal places were quoted to distinguish this from what had been measured in April 2019 along trails in the Refuge itself: 0.1404 ± 0.0012 μ Sv/h, better reported as 0.140 ± 0.001.

This means that, if repeated many times, one would expect the rangeV 1.1 of outcomes to lie between the lower and upper limits 95.5% of the time, statistically speaking.

COU and on the way to Candelas are 18% higher than in the COU. Why should this be? In the 1957 report *Geology of the Ralston Buttes district, Jefferson County, Colorado: a preliminary report*, available from the USGS, it is stated "The Ralston Buttes district in Jefferson County is one of the most significant new uranium districts located east of the Continental Divide in Colorado . . . The uranium deposits are concentrated in two areas, the Ralston Creek area and the Golden Gate Canyon area." The famous Schwartzwalder Mine, north of White Ranch Park and southwest of the Refuge, was one of the largest underground (vein-type) uranium mines in the U.S.

Figure 7: The Ralston Buttes are 1.76 miles from the intersection of Coal Creek Canyon Road and CO 93. (Google Maps).

A screen grab from a USGS map (Fig. 8 shows uranium mines as blue dots. It is clear that if there *is* a significant from either uranium-bearing minerals or mine tailings, it will be on the south and west sides of the approaches to the COU from the west side.

In conclusion:

1. From the viewpoint of *ambient radiation* levels, the COU cannot be distinguished from the Refuge itself. Since the topography is virtually identical, this is no surprise. In both cases the ADER of 0.140 μSv/h is well within the range of background radiation expected for the Front Range of Colorado.

2. Somewhat surprisingly, ambient radiation levels are actually *higher* (at least west and south) outside of the Refuge than inside! Because altitude variations are not very significant between inside and outside this difference is ascribed to differences in natural soil radioactivity and very tentatively assigned to uranium.

Figure 8: Screen grab of a map of uranium mines southwest of the Wildlife Refuge, from the USGS.

Takeaway points

- The Central Operable Unit inside the Rocky Flats National Wildlife Refuge shows a background radiation level of 0.140 μSv/h, indistinguishable from that on trails *in the Refuge*, described previously.

- A trip from the south or south east of the western entrance to the COU will traverse a (possibly large) region of higher background radiation (south and west sides of the Refuge). This was analyzed apart from the COU data and yielded an ambient dose equivalent [radiation] rate of 0.165 μSv/h. It was tentatively concluded that this is due to proximity to large deposits of uranium-bearing ores not far away.

- The ambient radiation levels in the COU and outside are well within normal background levels for the Front Range of Colorado

While several isotopes of uranium were handled at the Rocky Flats plant, naturally occurring soil quantities are much higher and there is no evidence of off-site uranium from Rocky Flats, which would have been deposited mostly east and south of the plant, as was the case for plutonium.

Of course *plutonium and americium* levels within the COU reach average values roughly twice what is present in the Refuge according to the CDPHE, but these radioisotopes contribute less than 3% of the total soil radioactivity and are thus (i) undetectable by the survey method used and (ii) entirely swamped by ordinary fluctuations in concentrations from place to place of naturally occurring radioisotopes.

A short visual tour of the Central Operable Unit

The photographs taken on the final page were taken by Kim Griffiths at the locations shown on the following map. The public is seldom

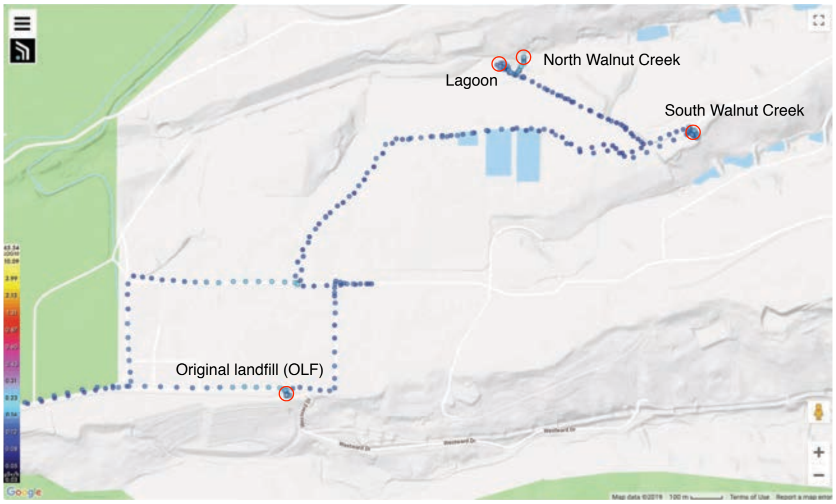


Figure 9: Locations where photographs were taken.

permitted to visit, so these make visible what's there. These are best viewed on screen, not on paper.

DMW expected dry, dusty bulldozed areas based on the aging post-cleanup aerial imagery mostly available. The photographs make clear how closely the terrain and vegetation in the COU (apart from monitoring stations and water diversion equipment) match what is in the Refuge.

Appendix A: are there any "hot spots"?

A highly radioactive ('hot') particle would occupy a size much smaller than the distance between adjacent measurements if the detector is moving, and would appear as a very high peak in the count rate surrounded by much lower count rates. There is almost no chance of discovering one unless you are moving quite slowly and know where to look. Much more plausible in general is finding a 'hot spot'—a small patch of ground or an extended area that has a much higher than average count rate. In fact, this term is no longer in official use since it is imprecise; the phrase 'area of elevated activity' is preferred in the U.S. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). On the other hand, Chapter RP-5 on radiation protection in the training materials available from the NukeWorkers web site remarks that

> When performing a general area dose rate survey three objectives apply:
>
> - We want to determine the dose rate in areas that may be occupied by radiation workers.
> - We want to locate any 'hot spots', radiation areas where the dose rate is approximately 4 times the background rate.

- We want to survey certain fixed survey points to establish whether there has been any significant change in levels since the previous survey.

so we can informally use this criterion.

If we examine the count data from the Candelas⇔COU part of Kim Griffith's trip shown in Fig. 10 upper panel, we see that there are *no* regions where the count rate is anywhere near $4 \times 55 = 220$ counts per minute (CPM). It's also useful to compare such real data with 'synthetic' data (with the same mean or average CPM) generated from a Poisson distribution, as shown in the lower panel in red. The distribution of count heights is (by construction) very similar. What *is* different, however, is that the 'peaks' in the real data appear wider (longer lasting as the Geiger-Müller moves along the path). This means that in real data the peaks correspond to spatial regions in which the ambient radiation level is slightly higher than nearby. Such fluctuations are common since the distribution of radioactive soil minerals certainly depends on very local geology and land use.

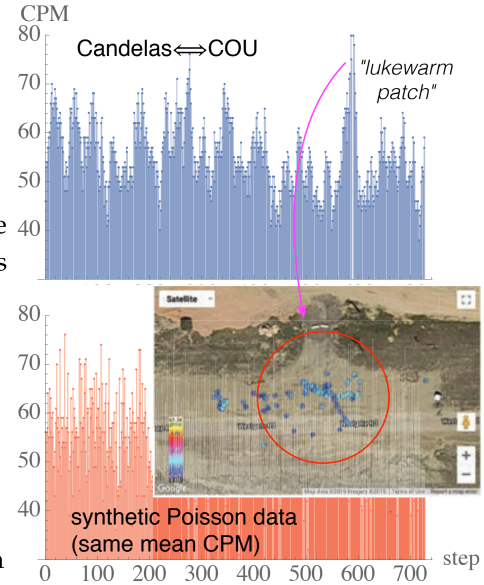


Figure 10: Measured count rates from Candelas to and from the COU, top. Lower panel (red) shows count rate for Poisson random data with the same mean count rate. The inset shows aerial imagery (Google Maps) corresponding to the 'lukewarm patch' identified in the upper panel.

Among all the peaks in the real data, the one that occurs near 600 steps into the data set is the most prominent. We might call this a 'lukewarm patch'. From the time stamps of these points we can identify that they came from near where Kim Griffiths parked just north of Westgate Rd (what had originally been the main gate to the Rocky Flats plant) just south of a gate used for access to Bestway Concrete. ADER values there range from 0.19 to 0.25 μSv/h, still completely consistent with ordinary background radiation.

References

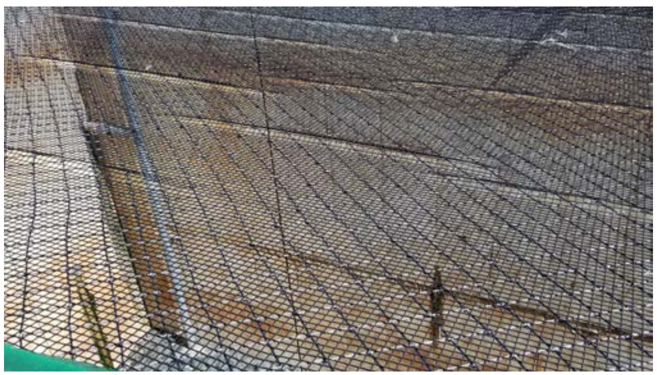
[1] D M Wood. *Recently measured radiation levels inside the Rocky Flats National Wildlife Refuge*. Tech. rep. 2019. URL: `https://rockyflatsneighbors.org/wp-content/uploads/OptInsideRF.pdf`.

[2] J Stone et al. "Spatial variations in natural background radiation: absorbed dose rates in air in Colorado". In: *Health Physics* 76.5 (1999), pp. 516–523.

Central Operable Unit tour

June 10, 2019

North Walnut Creek flume and surface water automated sampling system . Runs 24/7 and grabs samples based on flow rates of water through the flume. Telemetry monitoring by DOE ensures operating integrity.



Lagoon below old solar ponds that has bacteria which eat nitrates and fix uranium. Water is pumped in at metered doses to ensure the environment is just right for bacteria to do their work.

ALL PICTURES BY KIM GRIFFITHS

The 'original landfill' (OLF) with slumping that will receive major repairs to stabilize starting this August.

Surface water measuring at South Walnut Creek (East trenches plume treatment system)