Statistical Confidence as it Relates to Soil Sampling at Rocky Flats

Rik Getty, Technical Adviser, Rocky Flats Coalition of Local Governments (RFCLOG)

Introduction

The Board of Directors of RFCLOG requested that I author a short discussion for the general public on what statistical confidence means relative to soil sampling at Rocky Flats. Over the course of many briefings by the Department of Energy (DOE) and their primary clean-up contractor, Kaiser-Hill (K-H), to the RFCLOG Board and general public, various statistical confidence levels have been mentioned. Unless one is quite familiar with basic statistical sampling methods it can be quite a daunting task to understand what these various types of statistical methods actually mean in lay terms.

To begin this discussion I thought I would start with a brief background on how soil sampling methodology was developed for Rocky Flats and then have a short discussion of sampling statistics in general. Finally I would transition into real examples used by DOE and K-H to describe statistical confidence in their soil sampling.

Rocky Flats Soil Sampling Methodology

The soil sampling methodology used at Rocky Flats is a combination of various techniques that are in widespread use around the world. In the U.S., CERCLA sites like Rocky Flats use many of the guidelines established by the U.S. EPA for soil sampling. In addition, geostatistical sampling methods developed for different geological-based industries are also used for soil sampling. The site (DOE, K-H, and their subcontractors) formed a working group with regulatory staff from the EPA and CDPHE to develop the Sampling & Analysis Plans (SAPs) for the Buffer Zone (most of which is slated to become part of the Wildlife Refuge) and the Industrial Area (all of which will remain as DOE-retained land).

The working group selected different soil sampling strategies depending on what existing characterization data was available for a given location. For example, areas where there was known contamination due to releases of:

- Radionuclides (primarily plutonium, americium, and uranium isotopes);
- volatile organic compounds (VOCs; primarily chlorinated solvents);
- semivolatile organic compounds (SVOCs; liquid chemicals that don't evaporate readily like machining oils, polychlorinated biphenyls);
- hazardous metals (e.g., lead, cadmium, chromium, etc.); and,
- other regulatory chemicals such as nitrates.

Generally speaking the vast majority of areas contaminated with the contaminant species listed above were located in the Industrial Area. Due to their known locations of contamination, targeted soil sampling was selected as the appropriate sampling methodology. Targeted sampling involves determining the general contamination levels within a known area.

Areas where there was no indication of prior contamination, primarily in the Buffer Zone, utilized a statistical grid sampling methodology. The grid spacing for sample locations was determined by the working group based on the required statistical confidence. Typically a 90% confidence was used to characterize soils in the Buffer Zone (I will discuss the 90% confidence later in this briefing).

Some areas such as the 903 Lip Area required both targeted and grid spacing soil sampling per the working group requirements. The 903 Lip Area was the largest (36 acres) remedial project at the site. It is considered part of the Buffer Zone but will remain as part of the DOE-retained land and will not be transferred to the Wildlife Refuge. I will present soil sampling data on the 903 Lip Area at the end of this briefing.

Basic Statistical Sampling

When one is trying to understand statistical sampling applications there are a few basic parameters to define (after that statistics delves into very complex scenarios). However for the sake of this briefing I want to confine my explanations of statistical sampling to a basic level.

Many things exhibit properties of statistics in nature and the everyday world. I'm sure the reader of this briefing has some personal experiences that delve into aspects of statistics. Examples could be the outcome of simple coin tosses, gambling experiences, voter survey results, or perhaps even some who utilize more complicated statistics as part of their work or hobbies. Whatever the case, statistics are a very useful tool in a wide variety of applications.

In this briefing we are interested in how statistics are used for soil sampling at the site. Sampling of soil generates a collection of data that must be interpreted. Suppose you have a large number of results (a population) for a given analysis. The simplest statistical model for a population of results is that of a "normal" or Gaussian (Gauss was a famous statistician) distribution of results. The normal distribution of results exhibits behavior like that shown in Figure 1 (page 4). The x-axis represents the different range of values of the results. The y-axis represents the relative frequency of the values. In other words the more results there are with the same value the higher the relative frequency. Normal sample distributions are centered around a "central" value known as the population mean (average value). The shape of the normal distribution curve tails off to the left and right of the mean value. As one follows the curve to the right of the mean, the values increase (+) and their relative frequency decreases. As one follows the curve to the left the values decrease (-) and their relative frequency decreases. The total area under the curve, including the "wing" sections to the left and right represent the total sample population.

Not all sample populations exhibit a normal distribution. Figure 2 (page 4) shows a normal distribution as well as a population which has the same mean but exhibits different +/- ranges. There are several other types of sample distributions such as "log-normal" distributions. I will not delve into their behavior but instead focus on normal distributions.

Figure 3 (page 5) is a normal distribution with 90% and 95% confidence ranges added for illustrative purposes. If one were to take the total area under the curve between the two 90% values then that area represents 90% of the sample population. It also tells you the range of the sample values for 90% of the population. Likewise the two 95% values represent 95% of the sample population.

903 Lip Area Example

As previously mentioned, the 903 Lip Area remediation project was the largest environmental restoration project at the site encompassing 36 acres. The regulator-approved (EPA & CDPHE) Buffer Zone SAP specified a combination of targeted and grid spacing soil samples for the 903 Lip Area. The remediation required the site to remove contaminated soil which exceeded the Wildlife Refuge Worker Action Level of 50 picocuries of plutonium activity per gram of soil (50 pCi/g). The site used a geostatistical technique known as probability Krieging to determine the boundaries of the remediation project. The stated objective of the probability Krieging was to have a 90% level of confidence that all of the contaminated areas in the 903 Lip Area which exceeded the 50 pCi/g Pu were contained within the Krieging boundary. Of course that objective means there is a 10% probability that there were areas which exceeded the 50 pCi/g limit outside the Krieging boundary.

The 903 Lip Area remediation was broken down into small sections of remediation work. Contaminated soil which exceeded the 50 pCi/g was removed from a section and then confirmation samples were taken to verify that the section was below the 50 pCi/g limit. Many times, the confirmation samples failed (exceeded 50 pCi/g) and more contaminated soil had to be removed. This required additional confirmation samples until the section met the requirements. Hundreds of confirmation samples were taken by the site during this remediation project. After completion, the mean value for remaining plutonium contamination in the remediated sections was 14 pCi/g.

Figure 4 (page 5) is an example of one way the remaining contamination in the 903 Lip Area sections can be viewed. This depiction may not be accurate but is for illustrative purposes only. The site's confirmation sampling and probability Krieging specified a 90% confidence level. The distribution curve in Figure 4 is not a normal distribution in the sense that the curve is shifted somewhat to the right. This shift is to reflect the fact that there is a probability of some of the soils exceeding 50 pCi/g. The site's confirmation sampling concluded there were no areas in the remediated 903 Lip Area which exceeded 50 pCi/g plutonium at the 90% confidence level.

After the remediation was completed, DOE retained an independent contractor (Oak Ridge Institute for Science and Education, a.k.a. ORISE) to verify the remaining soil conditions in the 903 Lip Area remediation. ORISE's examined two areas or survey units each about 45 meters by 45 meters (2025 square meters). The initial soil samples from these two survey units was in close agreement with the site's values. None of the ORISE samples exceeded 50 pCi/g plutonium. ORISE specified a 95% confidence in their sample results. After ORISEZ performed the confirmation sampling additional "hand scans" were performed with file-portable instrumentation. Using this technique ORISE found several "hotspots" which exceeded the 50 pCi/g plutonium. These areas were further characterized by the site and ORISE and were subsequently remediated. The total area of the hotspots was only 1.6% of the total area of the 2 survey units. So in practical terms, the "discovery" of the hotspots should not come as a surprise since the site's stated confidence in detecting hotspots was 90%. ORISE's report to the site on their verification activities stated that the presence of hotspots in the 2 survey units are likely representatative of the remaining 903 Lip Area.

<u>Closing Remarks</u>

I hope this briefing has not been overly tedious and confusing. I had a challenging time deciding how to approach the briefing structure.

FIGURE 1. "NORMAL" OR GAUSSIAN SAMPLE DISTRIBUTION

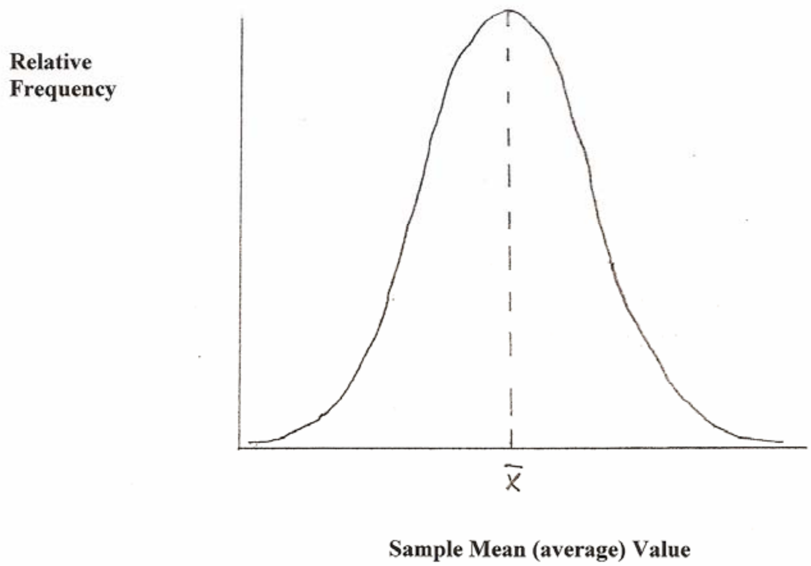

FIGURE 2. TWO DIFFERENT SAMPLE DISTRIBUTIONS WITH SAME MEAN

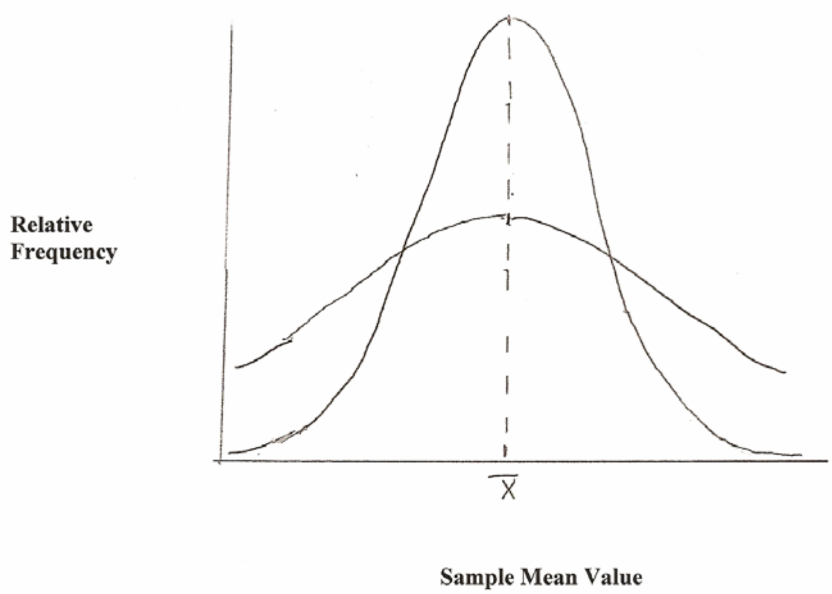

FIGURE 3. NORMAL DISTRIBUTION WITH 90% & 95% CONFIDENCE

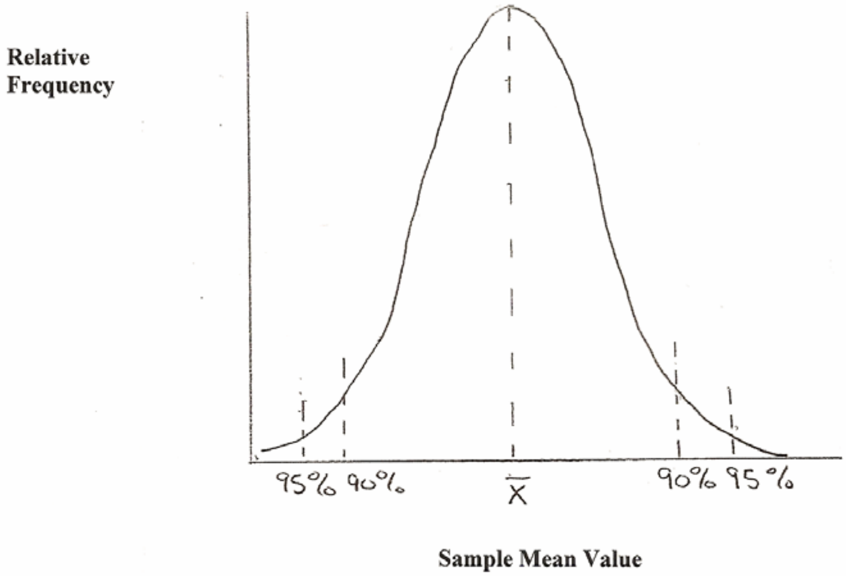

FIGURE 4. EXAMPLE OF REMAINING Pu CONTAMINATION IN 903 LIP AREA