Use of Aerial Radiological Surveys to Assist in Environmental Decision Making - 10339

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Abstract

Corrective action decisions need to be made at multiple locations at the Nevada Test Site (NTS) that were contaminated from releases associated with past atmospheric nuclear tests. While many historical sources of information regarding the distribution and areal extent of radioactive contamination are available, none were found to be of sufficient quality to satisfy the data quality objectives for the Soils Project at the NTS (Nevada Site Office, U.S. Department of Energy). One significant historical source of information is maps of the exposure rate from anthropogenic radionuclides in surface soils. These maps were developed from various aerial radiological surveys performed at the NTS over the course of several years. While exhibiting certain limitations, the maps proved to be a valuable resource in pre-project planning and as a guide to locating on-the-ground field measurements. Ground-based survey and mapping techniques provide improved resolution, but are costly and can realistically only be applied to small areas relative to the entire site. Neither method, taken alone, are effective in making a decision over the appropriate scale. When used jointly, these techniques provide sufficient information on contaminant distribution to allow high quality corrective action decisions.

Performance of Aerial Radiological Surveys

Background

Nuclear testing at the Nevada Test Site (NTS) produced radionuclide contamination of the surface and near-surface soils. The Environmental Restoration Soils Project of the U.S. Department of Energy (DOE), Nevada Site Office (NSO) has the mission to characterize near-surface soil contamination sites and to perform corrective actions where it is cost effective to do so and where there is a significant reduction in risk to human health and the environment (1). Soils Project Corrective Action Units (CAUs) are divided into five main groups; storage and transportation tests involving nuclear materials, cratering nuclear experiments, atmospheric nuclear tests, hydronuclear experiments, and nuclear rocket engine experiments. There are in excess of 100 individual corrective actions sites which require evaluation. Many sites are located in very remote areas of the 1,375 square-mile NTS. The size of a site can vary from a low of several hundred square-meters to an area in excess of 10 million square-meters for the Sedan cratering experiment.

Evaluation of a Soils Project site culminates in a determination as to whether soil contamination could reasonably result in a Total Effective Dose (TED) of 25 milli-rem per year to a receptor under an established exposure scenario. Several existing historical sources of external exposure rate and soil contaminant concentrations are available, but none were found to be of sufficient quality to support decision-making; requiring that additional site investigation be conducted. The additional investigation involves the direct measurement of external exposure rates and the collection of surface soils samples to estimate the potential internal exposure rates. The project team found the historical information to be valuable in planning the additional investigation efforts. One significant source of this historical information is aerial radiological surveys of selected areas of the NTS, as performed by the DOE's Remote Sensing Laboratory (RSL).

The AMS

The DOE maintains an Aerial Measuring System (AMS) capability within the RSL, with facilities located in Las Vegas and at the Andrews Air Force Base. The AMS mission is to provide a rapid response to radiological emergencies with helicopters and fixed-wing aircraft equipped to detect and measure radioactive materials on the ground. The acquired data are stored and used to produce maps of radiation exposure and relative contaminant concentration.

The capability to perform the aerial radiological surveys was initiated in the 1950s at the Nevada Test Site (NTS) and was driven by the need to map the radioactive fallout from above-ground nuclear tests. The Atomic Energy Commission (a predecessor of the DOE) then began a program in 1958 to map the terrestrial gamma radiation environment in and around facilities that have produced, used, or stored radioactive materials. As part of this ongoing program, the RSL routinely conducts aerial surveys for the U.S. DOE, the U.S. Nuclear Regulatory Commission, and other government agencies (2). An extensive survey of the NTS was conducted in 1994 by the RSL. Additional surveys of more limited areas of the NTS have been conducted as part of routine proficiency flights or upon special request to support a specific mission.

The basic components of an AMS include an airborne vehicle (Figure 1), an array of gamma-sensitive radiation detectors, a system for plotting the vehicle's position and displaying the planned route over the area to be investigated, and computers for data logging and analysis. Significant advances in each of these basic components have been made since the inception of the AMS effort. For example:

1. A shift from fixed-wing aircraft to helicopters has allowed for aerial surveys at lower altitudes and slower ground speeds, which significantly improves survey resolution and lowers the detection limits.
2. Improvements in radiation detection capability and reduction in equipment costs now allow for high resolution gamma spectroscopy while airborne.
3. The Global Positioning System (GPS) significantly improves the accuracy of position data while easing position data collection efforts.
4. Improvements in computer technology allow for rapid post-processing of AMS data (which can involve significant efforts).

Figure 1: A Bell 412 Helicopter With Instrument Array

Aerial Radiological Survey Advantages

AMS offers significant survey advantages for projects which need to investigate large areas or areas with difficult terrain features. Many areas where atmospheric nuclear testing were conducted were (necessarily) located in remote areas of the NTS. Access roads to the areas can be quite old, unmaintained, and very rough. At the testing sites themselves, the land areas affected by the deposition of radioactive materials can often only be accessed by foot due to the rough terrain. These factors result in ground-based survey efforts that require long lead-times, are labor-intensive, and are limited in their scope or scale to key areas of interest. The ability to fly directly to and over a remote area obviates these concerns.

The ability of the AMS to collect gamma ray spectra offers a second significant advantage. Following a single survey effort, data is post-processed and can then be mapped in several representations, including (for example): total gross count-rate, exposure-rate from anthropogenic radionuclides, or regions of Americium-241 deposition. If a particular gamma-emitting radionuclide is of interest, its spectrum can be extracted and mapped separately (e.g., Cesium-137).

The ability to cover large land areas also allows for a more comprehensive picture of site conditions. The relationship between relative contaminant concentrations and distance from the point of release is more quickly and clearly discernable. Areal distributions can be mapped and overlain over topographic maps or photographs to understand terrain features and challenges to follow-up ground-based investigations. The effects of large-scale remediation efforts can be monitored and contaminant migration (if any) may be discernable.

Aerial Radiological Survey Challenges

One challenge involves the planning and execution of aerial radiological surveys, which can be compounded by poor weather, restrictions on airspace, and the presence of obstructions to low-flying aircraft. The process of obtaining the needed permissions and for alerting law enforcement agencies of the planned presence of low-flying aircraft can be arduous and time-consuming. Following the events of the September 11, 2001 attacks in New York City, public alarm at the presence of such aircraft in urban areas must also be considered.

A second challenge is more technical in nature, involving concerns for aerial resolution. A common rule of thumb for the AMS is that the detector field of view is a circle with a diameter that is twice the height of the detector above the ground surface. For an aerial radiological survey conducted at a typical height of 15 meters, the detector field of view is an approximate circle with a diameter of 30 meters. This translates to an area of about 730 square meters, which is the smallest area over which information can be gathered about the site (or the smallest area that can be "resolved" by the detector). Initially, this resolution may seem reasonable for the evaluation of a land area. For example, a Class 1 survey unit under the Multi-Agency Radiation Survey and Site Investigation Manual approach (3) may encompass an area of up to 2,000 square meters, while the Derived Concentration Guidelines (DCGs) for the Soils Project at the NTS were derived for an area of 1,000 square meters. In practice however, concern for the detection of small areas of elevated activity may make this resolution unsatisfactory. Additionally, DOE Order 5400.5 specifies that "residual concentrations of radioactive material in soil are defined as those in excess of background concentrations averaged over an area of 100 m^2" (4).

Use of Aerial Radiological Surveys in Environmental Investigations

Preliminary Planning

Aerial radiological surveys have proven to be valuable in the initial planning of site investigations for soils projects at the NTS. The maps are loaded into a Geographical Information System (GIS) and provide information on the general shape and extent of contaminant plumes, as well as an indication of the expected relative concentrations of radioactive material (Figure 2).

In instances were multiple above-ground tests were conducted in the same relative geographical area, the maps indicate if contaminant plumes may be overlapping, which facilitates the development of the conceptual site model and field sampling plan (Figure 2). Areas of elevated activity can be identified and selected for further investigation (Figure 3). Site features which might be facilitating contaminant migration can be identified and evaluated (Figure 3).

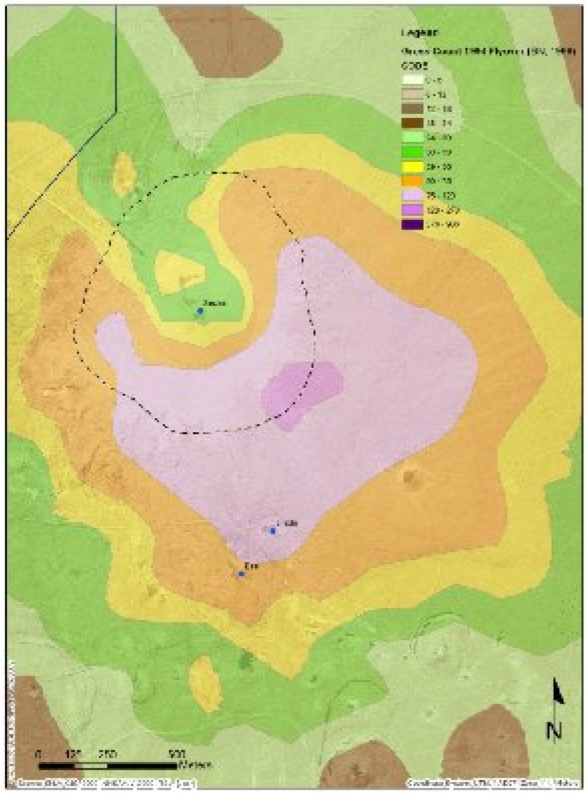

Figure 2: Distribution and Relative Concentrations of Gamma-Emitting Radionuclides at Sedan, Uncle, and Ess

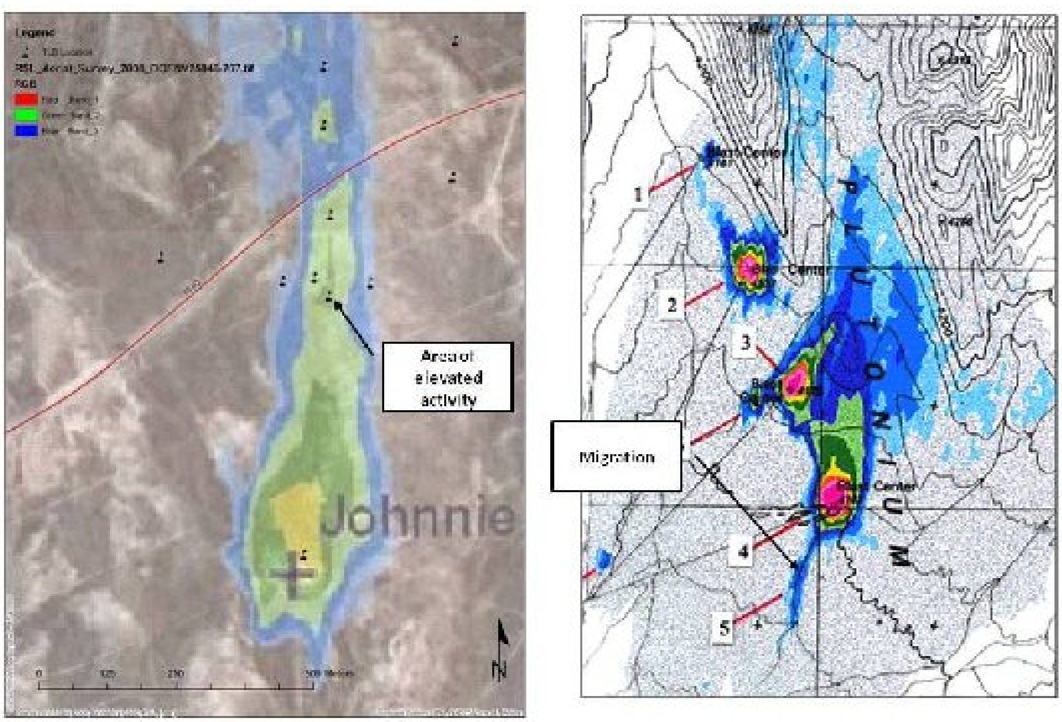

Figure 3: An Area of Elevated Activity & Evidence of Contaminant Migration

Additional Investigation

The evaluation of Soils Project sites on the NTS entails a determination of the Total Effective Dose (TED) through the collection of soil samples to estimate the potential internal exposure and the emplacement of thermoluminescent dosimeters (TLDs) to estimate the potential external exposure. The soil samples are collected within a sampling plot of about 100 square-meters. When considered over the scale of the entire site, which can encompass 1 million square-meters or more, these determinations of the TED are essentially point estimates.

To guard against a poor decision due to errors in the placement of the sampling plot, ground-based radiological surveys are conducted to field locate the plots. One approach that has proven quite effective is a GPS-assisted gamma walkover survey (GWS) that is performed at ground level. Because the radiation detector is carried at a height of about 0.5 meters above the ground surface, the detector field of view is about 0.8 square-meters. This vastly improved resolution, coupled with a significantly lowered scanning speed, allows for an increased ability to detect small areas of elevated activity and/or contaminant migration on a much smaller scale. This improvement must be tempered, of course, by the reality that budget and schedule considerations may allow for such surveys over only a small portion of the site. The aerial radiological survey can be used to identify specific areas and site features to appropriately focus ground-based radiological surveys.

Discussion

Step 4 of the U.S. Environmental Protection Agency's (EPA) Data Quality Objective process (5) includes considerations for establishing the "scale of decision making". Among other considerations, this includes an evaluation of the physical area over which a decision is necessary and relevant. For example, if a supposed "residential farmer" exposure scenario to be applied to a site assumes that the surface soils are evenly contaminated over several thousand square-meters, then the discovery of a few 10 square-meter areas of elevated activity may not be relevant to the overall decision. The site evaluation approach should include a method for determining the risk from these small areas, but most importantly, the approach should be focused on gathering data on the scale (i.e., over a land area) that is most relevant to the exposure scenario.

Aerial radiological surveys can efficiently gather information about large land areas, but several factors make the data, taken alone, insufficient for decision-making at Soils Project Sites. Direct measurement of site conditions on the ground, via soil sampling plots, yield high-quality data, but are labor intensive and can only evaluate very small portions of a site. The advantages of both methods can be leveraged if the soil sampling plots are carefully selected to establish a relationship between the data as collected in the aerial radiological survey and the conditions as found on the ground. Soil sampling plots are also selected in regions where areas of elevated activity may be of concern or where the resolution of the aerial data raises questions. Refer to Figure 4 for an example of soil sampling plot selection.

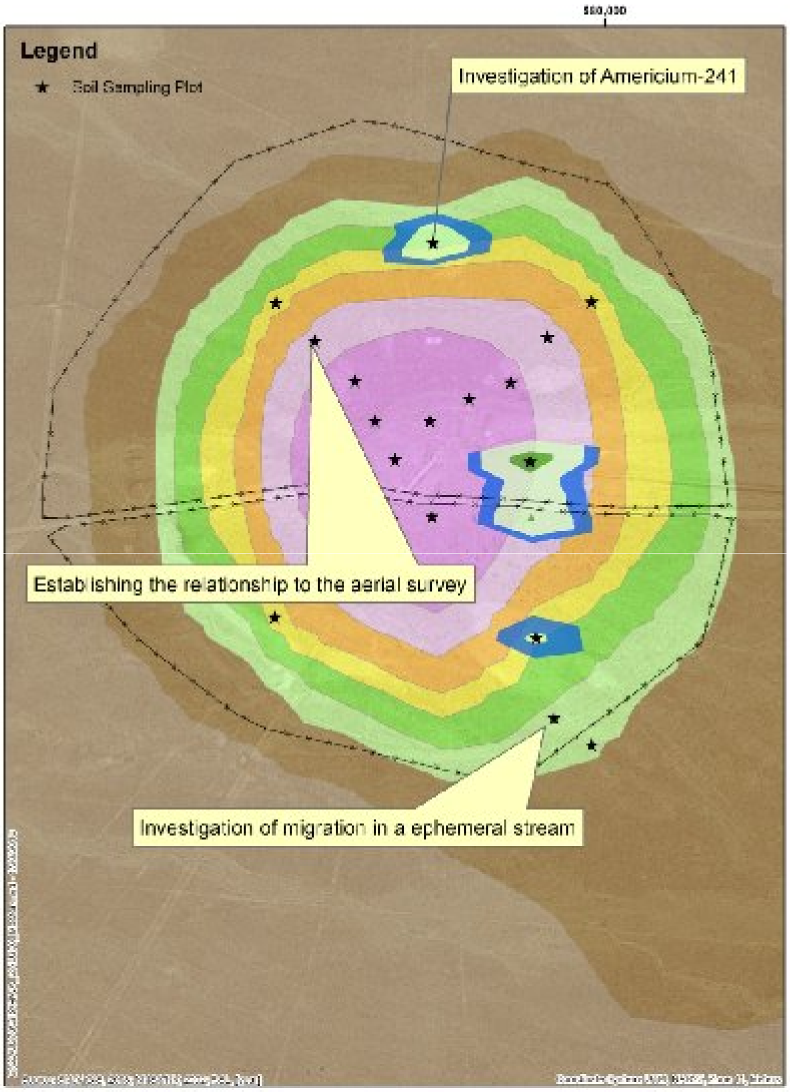

Figure 4: Selection of Soil Sampling Plots at the T-4 Site

Conclusion

Aerial radiological surveys exhibit a resolution that may be appropriate for most exposure scenarios at the NTS, but cannot evaluate 100 square-meters areas as described in DOE Order 5400.5. Ground-based methods exhibit greatly improved resolution, but are labor intensive and may only be appropriate for a small fraction of an atmospheric test site. Both approaches, when applied systematically, work synergistically to meet project objectives, as has been demonstrated through successful closure of the T-4 site at the NTS.

At the T-4 site, an aerial radiological survey from 1994 was supplemented with carefully selected soil sampling plots which were used to establish the relationship between the TED and distance from the ground zero (GZ) as reflected in the aerial survey map (Figure 4). Several additional sampling plots were located near the GZ to determine if the resolution of the aerial survey could be of concern. Biased sampling plots were located in the center of each of three Americium-241 plumes (Note: there were four atmospheric nuclear tests at the T-4 site). A ground-based GWS was conducted in three ephemeral streams to investigate the potential for contaminant migration, and two sampling plots were biased to locations where evidence of contaminant migration was observed on the ground-based survey. As a result of this investigation, the 1994 aerial radiological survey was able to be utilized to establish a corrective action boundary around the T-4 site. This boundary was then extended to include a small area of contaminant migration in a ephemeral stream. The number of soil samples needed to make a decision at the T-4 site was significantly reduced when compared to site evaluation methods which rely solely on systematic soil sampling.

References

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