Cerro Grande Ash as a Source of Elevated Radionuclides and Metals

#72660

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The Cerro Grande fire in 2000 burned a large area in the eastern Jemez Mountains, Los Alamos townsite, and on Los Alamos National Laboratory (LANL) land (BAER, 2000). Because of the potential for large floods generated in the upper portions of burned watersheds to erode and transport contaminated sediments in the canyons, the laboratory is implementing a comprehensive sampling and monitoring effort to characterize the impacts of flooding. The main purpose of the sampling is to obtain data to evaluate the impacts of post-fire floods on sediments, soils, surface and storm water, alluvial ground water, and biota. This information will be used to assess human health and ecological risk for areas that are affected by the floods. Data will also be used to document changes in the spatial distribution of existing contaminant inventories and concentrations (e.g., Reneau et al., 1998; Katzman et al., 1999) as a function of erosion and deposition of sediments and changing hydrology within affected watersheds.

The initial sampling effort focused on the collection of ash and muck (post-fire sediments that are dominated by reworked ash) from locations west of the laboratory. The locations were selected to be representative of background conditions upstream of known laboratory releases and predominantly upwind from airborne releases from stacks at the laboratory facilities. Ash and muck samples were also collected in the Viveash fire area (near Pecos, New Mexico) for comparison. The ash is composed of the concentrated remains of burned vegetation and forest litter (pine, fir, spruce needles, and leaves), and non-flammable, non-volatile constituents like minerals and metals (including radioactive elements). Some researchers have used tree-ring analysis to quantify the timing and magnitude of radionuclide uptake from locations around the world (e.g., Garrec et al., 1995). Thus, it was expected that detectable radionuclide concentrations associated with global fallout from aboveground nuclear testing conducted primarily in the 1950s and 1960s would be present and likely concentrated in the ash. The data from the ash and muck samples are important for interpreting concentrations of radionuclides that may be present in storm runoff and sediment deposits, and are necessary for distinguishing fire-related constituents in storm water and sediments from legacy-contamination in canyons on the laboratory. The ash and muck data provide a necessary post-fire baseline to support the assessment of potential impacts to the laboratory and offsite (e.g., the Rio Grande and Cochiti Reservoirs) from fire-related contaminants found in storm runoff.

An Interagency Flood Risk Assessment Team (IFRAT) consisting primarily of representatives of the New Mexico Environment Department, Los Alamos National Laboratory, the New Mexico Department of Health, the Environmental Protection Agency, the University of New Mexico Center for Population Health, and the Department of Energy are organized to evaluate the data in the context of risk and communicate that information to the public via press releases, the internet, and public meetings.

Expected Hydrologic and Geomorphic Effects

The Cerro Grande fire produced significant hydrologic changes to large portions of several watersheds above the laboratory (BAER, 2000). These hydrologic changes are primarily due to altered soil conditions in the burned areas. Loss of plant cover and forest litter, development of ash covers, and locally extreme water-repellent (hydrophobic) soil conditions have greatly reduced infiltration rates on hillslopes. Under these conditions, reduced infiltration rates produce extremely rapid surface runoff especially during thunderstorms, mobilizing ash, eroding surface soils, and repeatedly generating large floods in the canyons. The 1977 La Mesa fire and the 1996 Dome fire, which burned large parts of the Frijoles Canyon and Capulin Canyon watersheds, respectively, provide examples of expected hydrologic and geomorphic responses of watersheds to the Cerro Grande fire. Peak post-fire flood discharges in these canyons were up to 100 times higher than before the fires, and the most extreme effects occurred in the first 2 years after the fires (Veenhuis, 1999). The effects of flooding can include extensive bank erosion and/or vertical incision, consequently remobilizing large volumes of canyon floor sediment, some containing contamination (Fig. 1). It is expected that contaminants in any remobilized sediment would be mixed with large volumes of uncontaminated sediment derived from the upper watersheds and from downstream reaches, resulting in lower contaminant concentrations than in the original deposits.

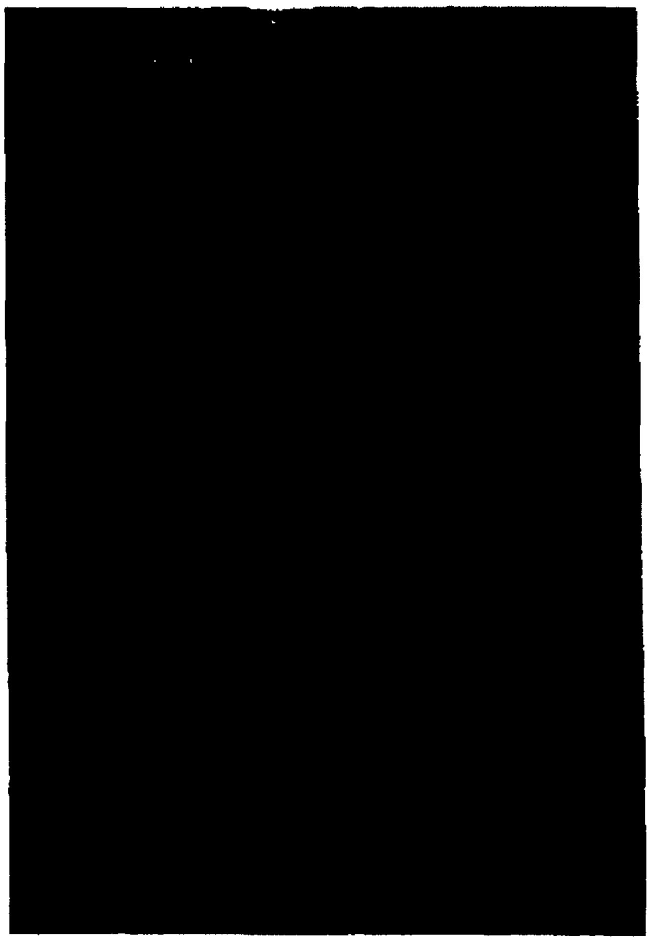

FIGURE 1—Photo showing the vertical incision and channel widening in upper South Fork of Pajarito Canyon following several recent, moderate-intensity storms.

Results

The box plots in Fig. 2 show that concentrations of representative radionuclides in ash and muck are greater than pre-fire background concentrations in soil and sediment determined for the laboratory area (Ryti et al., 1998). The concentrations of cesium-137 and strontium-90 in Viveash area ash and muck are similar to concentrations found in the Cerro Grande fire area, supporting the hypothesis that the source of these elevated constituents is atmospheric fallout. The concentrations of cesium-137 are also comparable to the values reported by Ferber and Hodgdon (1991) for samples of ash from wood collected across the United States. It is worth noting, however, that concentrations of plutonium-239, 240 are greater in the Cerro Grande fire samples. Thus, it is possible that some of the plutonium-239, 240 measured in Cerro Grande ash had its source as stack emissions from laboratory facilities, which would explain a slightly greater concentration near Los Alamos. Data previously reported by the laboratory's Environmental Surveillance Group support this interpretation by showing that laboratory perimeter locations have 3–4 times the regional average for plutonium-239, 240 (Fresquez et al., 1996).

Similar patterns are observed for metals, and the ash and muck samples contain greater concentrations of several metals than measured in pre-fire background soil and sediment samples. The metals most elevated in the ash are those that are readily taken up into plant tissue, including barium, manganese, and calcium. These relationships further confirm that the source for the elevated concentrations of most ash constituents is from the natural process of uptake into plants and concentration of non-flammable, non-volatile constituents during the fire.

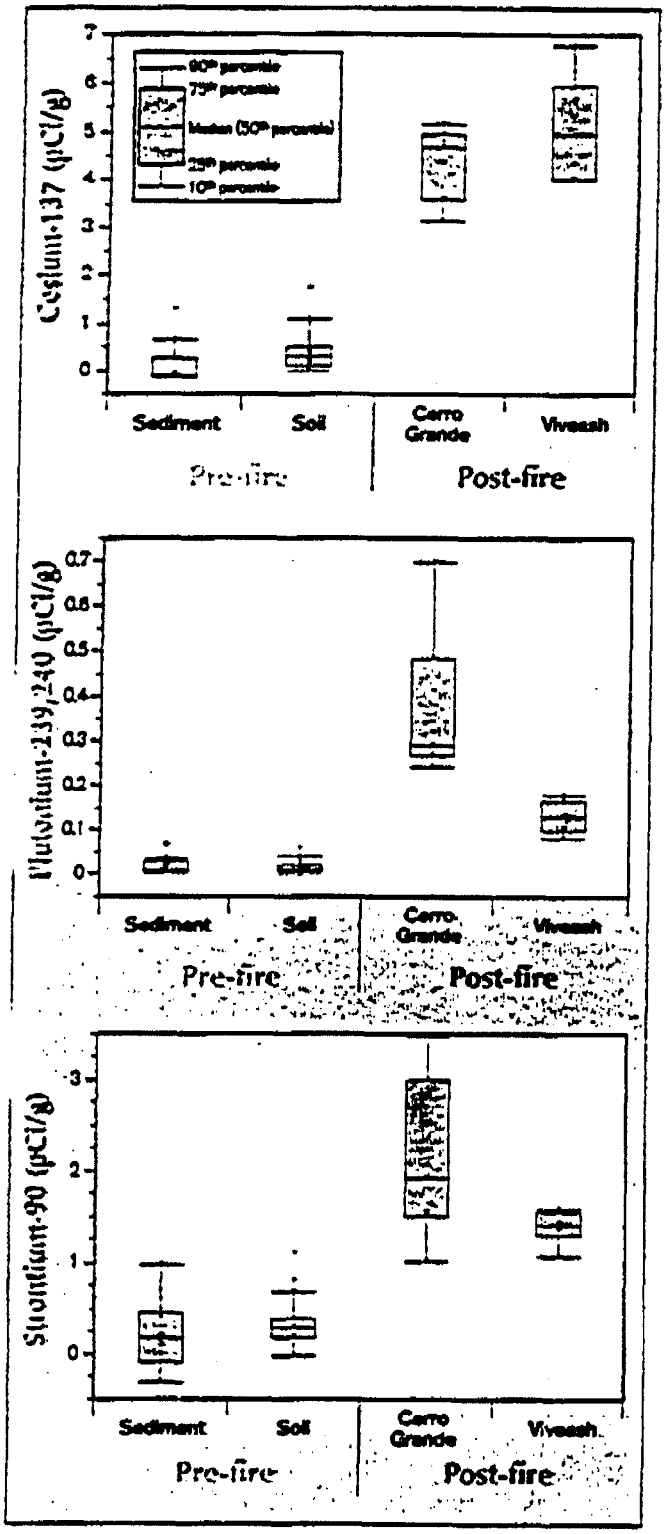

FIGURE 2—Box plot comparison of concentrations of three radionuclides (cesium-137, plutonium-239, 240, and strontium-90). Plots show pre-fire background concentrations in soil and sediment at LANL and post-fire ash and muck samples from the Cerro Grande and Viveash areas.

Conclusions

These findings are important for understanding the effect of large, post-fire floods on the transport and deposition of metals and radionuclides that are present as contaminants in canyons draining the laboratory. Concentrations of fallout radionuclides and metals transported in floods should decrease over time as ash is stripped from the slopes in the upper watersheds. In some canyons, deposition of muck during flooding will leave a radionuclide and metal inventory higher than existed before the fire, and much of the "contamination" transported to the Rio Grande may be unrelated to the laboratory. Risk assessors should not, however, discriminate between sources of contamination in their assessments because the potential effects of exposure to radionuclides and metals are irrespective of their source. Knowledge of the source of contamination primarily guides the nature and location of potential mitigation measures.

Acknowledgments

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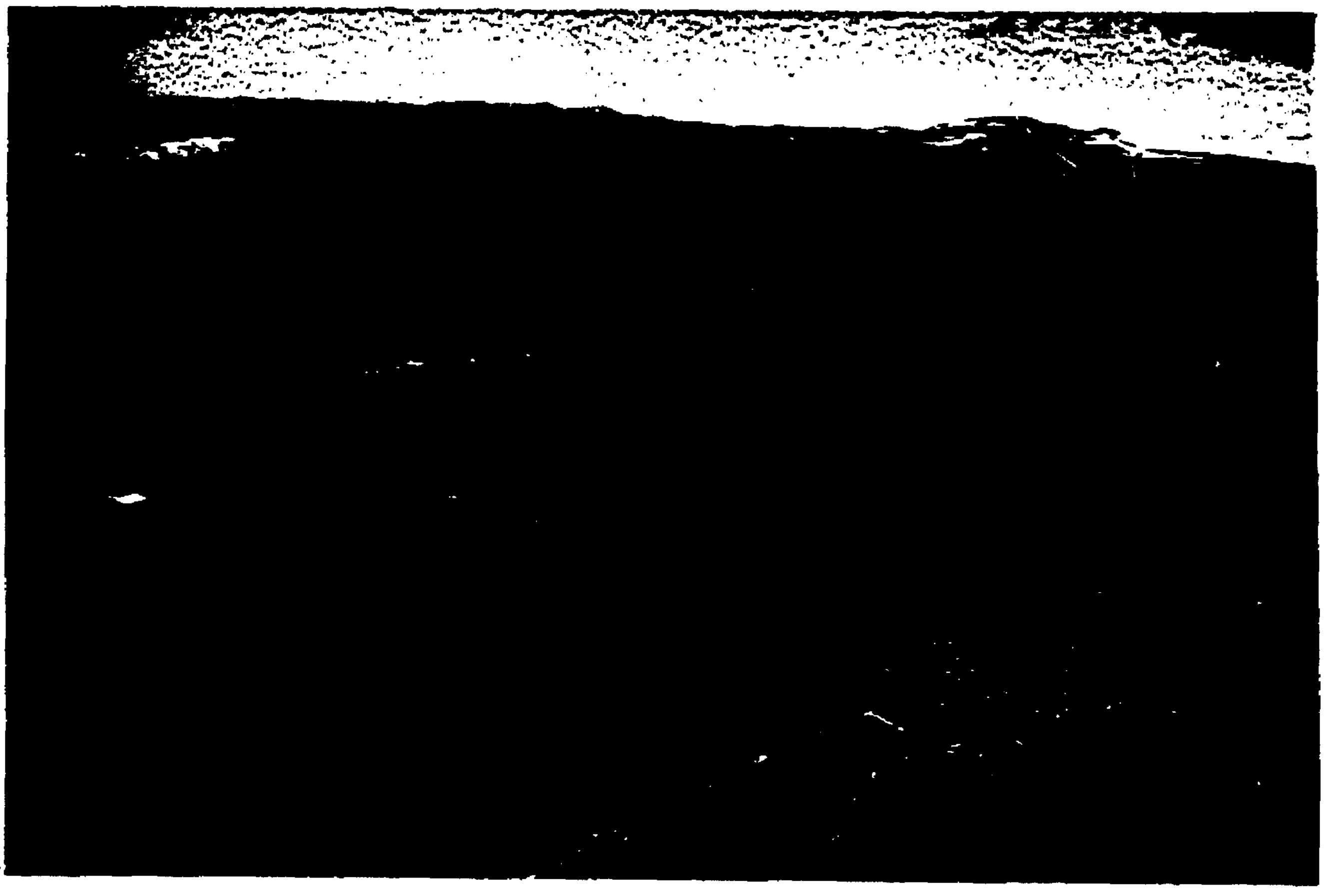
Danny Katzman has 10 years experience in applied environmental sciences. He worked for 2 years for the New Mexico Environment Department in the RCRA program. Since coming to LANL, his emphasis has been on geomorphologic and hydrologic investigations to characterize the distribution and transport of contaminants in the environment. Additional consulting work is conducted periodically for an oil exploration company on evaluation of outcrop analogues to address sequence stratigraphy problems in Venezuela.



View southwest of the Pajarito Plateau and Jemez Mountains. Los Alamos is situated on mesas set between deep canyons eroded into the Bandelier Tuff. Pajarito Ski Area and Redondo Peak (11,254 ft) are at the upper right skyline. Photo by Paul G. Logsdon; copyright © Marcia L. Logsdon.

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