RAC Report No. 5-NMED-2002-DRAFT

General (Cerro Grande Fire)

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Summary for the Layperson of the Analysis of Exposure and Risks to the Public from Radionuclides and Chemicals Released by the Cerro Grande Fire at Los Alamos

June 3, 2002

Submitted to New Mexico Environment Department

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ACRONYMS

DNB	1,3-Dinitrobenzene
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration Project
ESH	Environment, Safety, and Health (Division)
HE	High explosives
HQ	Hazard quotient
LANL	Los Alamos National Laboratory
NMED	New Mexico Environment Department
PAH	Polycyclic aromatic hydrocarbon
PM10	Particulate matter less than 10 μm in diameter
POE	Point of exposure
PRG	Preliminary remediation goals
PRS	Potential release site
RAC	*Risk Assessment Corporation*
RDX	Royal Demolition Explosive
RfD	An estimate (with uncertainty spanning perhaps a factor of 10) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without a significant risk of negative health effects.
TNT	2,4,6-Trinitrotoluene
TSS	Total suspended solids
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

INTRODUCTION

The Cerro Grande Fire burned about 45,000 acres (~180 km^2) in northern New Mexico in May 2000. It originated in the Bandelier National Monument on the evening of May 4, 2000, and spread east-northeast over the next 16 days consuming residential structures within the County of Los Alamos. The fire burned approximately 7500 acres (~30 km^2) within the Los Alamos National Laboratory (LANL) boundary, causing significant damage to structures and property on LANL land. Some of the areas that burned were known or suspected to be contaminated with radionuclides and chemicals.

At the request of the New Mexico Environment Department (NMED), the Department of Energy (DOE) provided funds for an independent study of public health risks from radionuclides and chemicals associated with the LANL facility released as a result of the fire. NMED contracted with *Risk Assessment Corporation* (*RAC*) to estimate the potential increased health risk to the communities of northern New Mexico from these radionuclides and chemicals.

A team of national and international scientists led by Colorado State University provided technical peer review of the work. The NMED provided opportunities for public input throughout the 18-month study period. In addition, *RAC* held three public meetings during the project to answer questions and to talk about study findings.

Objectives

The primary goal of the study was to analyze the immediate and longer-term impacts of the Cerro Grande Fire in terms of increased public exposures and potential risks from radionuclides and chemicals associated with the LANL facility that were released to air and surface water as a result of the fire. The study did not specifically address the impact the fire may have in the future on groundwater.

The three major objectives of the project were to

- Estimate increased exposure and associated risks to the public, emergency response personnel, and firefighters from transport of LANL-derived radionuclides and chemicals released as a result of the fire through the ***air pathway***. We also performed a preliminary evaluation of risks from naturally occurring radionuclides and metals released from burning of the forests around the LANL site.
- Estimate increased exposure and associated risks to the public from transport of LANL-derived radionuclides and chemicals released as a result of the fire through ***surface water pathways***. We also evaluated risks related to ash from areas burned around the LANL site.
- Provide conclusions of the study and recommendations for similar events in the future. An important goal of the study was to actively, openly, and accurately convey information about the risks from the fire to the public, including the lessons learned regarding calculating and communicating risk.

> ***Pathways***
> *Routes of transport by which radionuclides and chemicals can travel from the location of a release to human populations.*

ESTIMATED RISKS FROM RELEASES TO AIR

Methodology and Approach

The Cerro Grande Fire released chemicals and radionuclides to the air from the burning and heating of materials located in vegetation and soils across the LANL facility and the surrounding area. In order to calculate the potential risks associated with these releases, we

- Evaluated the available air monitoring data and procedures,
- Identified the sources and amounts of chemical and radionuclide releases to the air during the fire,
- Used computer modeling to estimate the release and transport of chemicals and radionuclides carried in the fire plume,
- Identified representative individuals for defining ***exposure scenarios***, and
- Estimated the associated health risks and the uncertainties of those risks.

> ***Exposure scenario***
> *Characterization of a lifestyle or voluntary activity that may result in contact with radionuclides and chemicals*

Before making any calculations, we first established the model domain, or geographical area of study (shown below). The total extent of the model domain was 37 × 35 mi (60 × 55 km). It encompassed approximately 815,000 acres (3300 km^2), and included the cities of Santa Fe and Española, as well as Cochiti Lake. We also investigated potential exposures at locations outside the study area (such as Taos). Exposures at these locations were less than the maximum exposures calculated within the study area.

Figure 1. Regional model domain for analysis of the Cerro Grande Fire.

Available Monitoring Data

The data available to assess the concentrations of radionuclides and chemicals in the air during the Cerro Grande Fire included air and soil samples collected before, during, and after the fire; soil characterization data for contaminated sites at LANL that burned during the fire; meteorological data; and data for airborne contaminants measured in other fires.

> ***Source term***
> *The release rate of chemicals and radionuclides from an area or event.*

When we started the project, we anticipated that the environmental air monitoring data would be complete enough to allow us to estimate ***source terms*** based on the measured concentrations in air combined with computer transport modeling and that this would provide the basis to calculate the risks from the fire. However, the air monitoring data could not be used directly because not enough different locations were monitored, only a limited number of chemicals and radionuclides were measured, and the documentation for some of the data was incomplete. In addition, most of the concentrations measured were below the detection limits of the laboratory equipment used to analyze the samples.

Screening and Source Term Calculation

Because the environmental monitoring data were less useful than originally anticipated, the soil characterization data for contaminated areas of LANL (potential release sites or PRSs) that burned during the fire became the main source of information available on radionuclides and chemicals that may have been released. We identified a large number of radionuclides and chemicals that were potentially released during the fire, so we used a screening procedure to identify those that were most important in terms of health risk. We developed ***conservative*** source term estimates for the radionuclides and chemicals that were identified as possibly resulting from LANL operations. We removed contaminants from consideration that had a cancer incidence screening ***risk estimate*** of less than 1 chance in 100,000 (for cancer-causing chemicals and radionuclides) or a screening ***hazard quotient*** (HQ) of less than 1.0 (for chemicals causing non-cancer health effects), when risk was calculated conservatively.

> ***Conservative***
> *Using cautious assumptions to ensure that endpoints are not underestimated.*

> ***Risk estimate***
> *A description of the probability that individuals exposed to a chemical or radionuclide will develop an adverse reaction, such as cancer.*
> *The range of acceptable risks defined by the U.S. Environmental Protection Agency (EPA) is from 1 to 100 chances in 1 million.*

> ***Hazard quotient (HQ)***
> *The ratio of the average daily intake of a contaminant per unit body weight to an acceptable reference value.*
> *An HQ<1.0 indicates no increase in risk.*

Then, for this list of radionuclides and chemicals that were most important in terms of health risk, we calculated source terms using available information on the quantities present at the contaminated sites and how they may have been released to the air during the Cerro Grande Fire. We used these source terms to calculate estimated air concentrations.

Atmospheric Transport and Air Concentration Calculation

Calculating transport of radionuclides and chemicals released into the air during burning of the PRSs first required an understanding of the behavior of the fire itself. We used computer models to estimate the movement of combustion products common to all wildfires in the study area. ***PM10*** was measured in air at a number of locations in the model domain. We compared the computer model-estimated concentrations of PM10 with the measured concentrations to confirm the computer model estimates and to better understand the uncertainty associated with the results.

> ***PM10***
> *Particulate matter less than 10 μm in diameter. Produced by all wildfires.*

The process of calibrating the model to PM10 measurements involved (1) identifying the geographical area that was burned, (2) defining the time history of the fire, (3) estimating the amount of PM10 released by the fire and the heat generated during burning, (4) modeling the transport in air of pollutants released by the fire, and (5) calibrating predicted concentrations of PM10 with measured values. Contributions of PM10 from sources other than the fire were accounted for in the calibration.

We then assumed the release and transport of radionuclides and chemicals from LANL sources to be proportional to the release and transport of PM10 from the fire. The dispersion of PM10, therefore, served as a "tracer" for particulate releases of radionuclides and chemicals. For volatile chemicals, carbon monoxide was used as a tracer.

Using the process described earlier, we calculated concentrations of radionuclides and chemicals identified as important through the screening process. In general, most predicted air concentrations were below standard detection limits of laboratory instruments. However, the predicted air concentrations and deposition amounts for the explosive compounds RDX, HMX, DNB, and TNT were relatively high. After the fire, however, explosive compounds were not detected in the limited soil sampling performed. The predicted deposition of these compounds would have been easily detected in soil, and this suggested that we overestimated the source terms for these compounds because of the cautious assumptions we made in our calculations.

Risk Estimates

We used four exposure scenarios to determine the risks to representative individuals from the LANL-derived radionuclides and chemicals released to the air during the fire; a resident adult, a firefighter, an emergency response worker, and a resident child. For each scenario we calculated cancer risk for radionuclides and ***carcinogenic*** chemicals, and HQ values for noncarcinogenic chemicals, using the model-estimated concentrations at eight representative exposure locations, as well as the maximum predicted concentration in the study area. Risks from ***naturally occurring radionuclides and chemicals*** on vegetation that burned during the Cerro Grande Fire were calculated for the adult resident scenario only. These risks would be associated with any forest fire and are not specific to LANL.

> ***Carcinogenic***
> *Cancer causing.*

> *Naturally occurring radionuclides and chemicals, as well as radionuclides from global atmospheric weapons tests, are present in and on all natural vegetation and are released during any wildfire.*

For LANL-derived chemicals and radionuclides, the maximum risk occurred within the active burned area and on LANL property. The maximum total cancer incidence risk from breathing any LANL-derived radionuclide released to the air during the fire was less than 1 chance in 10 million. In contrast, cancer incidence risks from breathing radionuclides released to the air from natural

> *Cancer incidence risks for LANL-derived chemicals and radionuclides released to the air during the fire were less than 1 chance in 1 million.*

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vegetation during the fire were estimated to be approximately 1 chance in 1 million. Cancer incidence risks from LANL-derived chemicals released during the fire were generally less than 1 chance in 1 million. The explosive compound RDX was a major contributor to this risk estimate, and we believe the source term and risk for this compound were overestimated. Cancer incidence risks from metals detected in natural vegetation and released during the fire were also approximately 1 chance in 1 million.

HQ values indicated that intakes of LANL-derived noncarcinogenic chemicals and radionuclides released during the fire exceeded acceptable levels only in a small area of the LANL site.

The total HQ used to assess non-cancer health effects was generally less than or equal to 0.1 throughout the model domain for LANL derived chemicals. Near areas where the fire burned, however, HQ values exceeded 1.0 and reached a maximum value of 2.0 for the resident adult scenario. This excursion above the acceptable level of 1.0 was limited to a small area within the LANL site near its western boundary. Most of the non-cancer risk was associated with the explosive compounds RDX, HMX, DNB, and TNT. As stated previously, we believe the sources terms for these compounds were overestimated.

Reference dose (RfD)
An estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without a significant risk of negative health effects.

Hazard quotients for metals released during the fire from natural vegetation were extremely high. They were attributed to inhalation of manganese and, to a lesser extent, aluminum. However, the ***reference doses (RfD)*** available to calculate the non-cancer health effects from these two metals were developed to evaluate chronic, or long-term, exposures, not short-term exposures such as those during the Cerro Grande Fire. They equated to air concentrations that were much lower than the occupational standards for these metals. We believe the use of these chronic RfDs caused the HQ values calculated for these metals to be unrealistically high. Using a reference dose based on occupational standards resulted in a maximum HQ of less than 1.0.

Concentrations of PM10 in the model domain were sufficient to cause adverse health effects; however, we did not calculate risks from PM10 exposure.

Conclusions

While the modeling we developed using the PM10 data is quite reliable, the estimates of the quantities of materials available for release to the air, the rate at which these materials were released to the air, and the risk associated with short-term exposure to some chemicals are less certain. Therefore, we made conservative or cautious assumptions to ensure the risks were not underestimated.

Our analysis indicates that exposure to LANL-derived chemicals and radionuclides during the Cerro Grande Fire did not result in a significant increase in health risk over the risk from the fire itself. The risk of cancer from exposure to radionuclides and metals in and on vegetation that burned was many times greater than that from radionuclides and chemicals released from contaminated sites at LANL. All cancer risks were below the U.S. EPA range of acceptable risks of 10^{-6} to 10^{-4} (1 to 100 chances in 1 million). Hazard quotients from exposure to noncarcinogenic LANL-derived chemicals exceeded the 1.0 level at some locations on LANL property. However, the estimated HQ values are conservative and likely overestimate the actual risks that occurred. It is likely that the risks from exposure to PM10 far outweigh the risks from LANL-derived radionuclides and chemicals and those released from natural vegetation during the fire.

ESTIMATED RISKS FROM RELEASES TO SURFACE WATER

Methodology and Approach

The Cerro Grande Fire destroyed vegetation and changed the surface soil, which has increased the amount of storm water that could flow through the canyons. This increased storm water flow has the potential to carry with it greater amounts of soil, sediment, and ash from the entire impacted watershed, including some areas at LANL that contain elevated levels of chemicals and radioactive materials. In order to estimate the potential increased exposure through the surface water pathway that occurred as a result of the fire and the associated risks, we

- Developed a surface water model domain (study area),
- Evaluated the available surface and storm water monitoring data,
- Identified the sources and amounts of chemical and radionuclide releases,
- Modeled the release and transport of radionuclides and chemicals in surface and storm water,
- Identified representative individuals for defining exposure scenarios, and
- Estimated the associated health risks.

The surface water model domain encompassed approximately 182,000 acres (738 km^2). In relation to the LANL facility, the study area extended to the west to include the upper Pajarito Plateau watersheds for the canyons that cross the LANL facility, to the north to include the extent of the burned area in Santa Clara Canyon, to the east to include the Rio Grande, and to the south along the Rio Grande and downstream of Cochiti Dam.

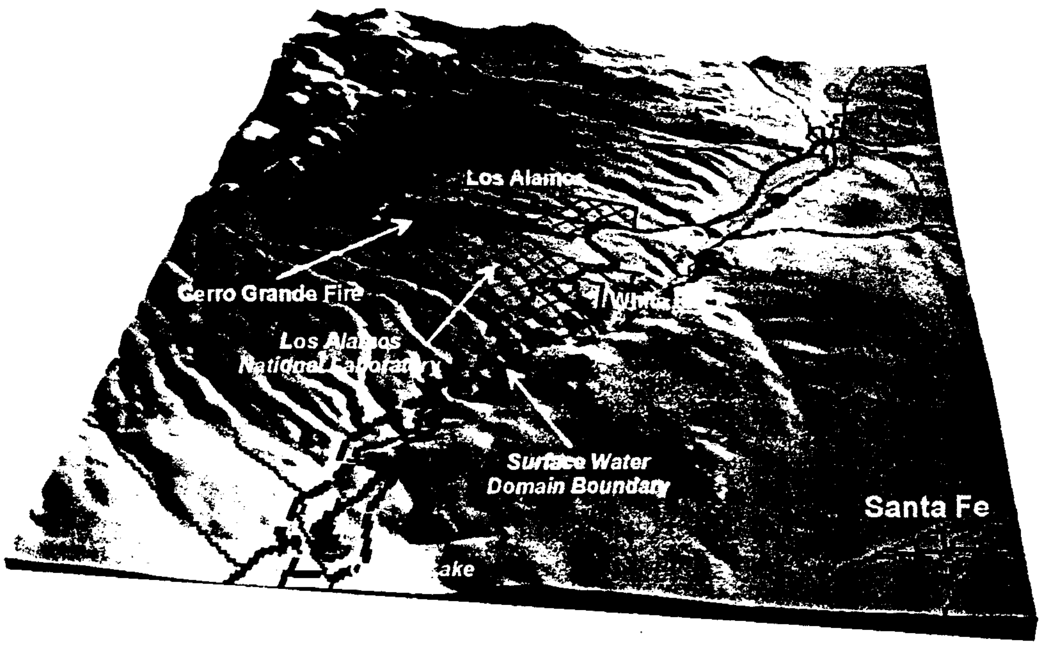

Figure 2. Surface water model domain for analysis of the Cerro Grande Fire.

Monitoring Data Evaluation

We reviewed water and sediment monitoring data from LANL and from NMED. Because of the large number of measured chemicals and radionuclides, we developed a two-stage screening procedure to focus the analysis on those that were most likely to contribute to the health risk of those exposed directly or indirectly to surface water runoff from LANL. We used the available monitoring data for radionuclides and chemicals collected after the fire, along with available information about risk from exposure to radionuclides and chemicals to calculate a screening index.

Of the more than 250 chemicals and 75 radioactive materials evaluated during this screening process, we identified 45 chemicals and radionuclides as most important in terms of the potential human health risk. We focused our monitoring data evaluation on the man-made radionuclides in this list because there is a lack of post-fire monitoring data for many of the chemicals and, for other chemicals, the results were below detection limits so few conclusions could be drawn. As a result, the monitoring data evaluation focused primarily on the analysis of the radionuclides, americium-241, cesium-137, strontium-90, plutonium-238, and plutonium-239,240 in surface water, storm water, and sediment. The monitoring data were useful for identifying apparent increases in concentration for some radionuclides and chemicals following the fire and also for identifying the possibility of LANL impact on measured concentrations.

Source Term Development

The most critical step in the risk estimation process is calculating the source term. Our modeling approach for estimating concentrations of chemicals and radionuclides in source areas used measured concentrations of chemicals and radionuclides in soil or sediment across defined source areas, along with water runoff and sediment erosion yields. We then calculated downstream concentrations of chemicals and radionuclides at defined ***points of exposure (POE)***, focusing on those that were most important in terms of potential health risk.

> ***Points of exposure (POE)***
> *Locations where an individual would likely come in contact with surface water, suspended sediments, or deposited sediments containing concentrations of chemicals or radionuclides.*

To identify the most important radionuclides and chemicals, we performed the following steps:

- Calculated average concentrations of chemicals and radionuclides across each source area and compared the highest average concentration to the EPA residential combined preliminary remediation goals (PRG) for soil.
- Eliminated general water quality sampling results for which associated risks are not expected, and some other general categories of materials (like total petroleum hydrocarbons and lubricant range organics) for which information needed to calculate risk is not available.
- Selected the chemicals and radionuclides that were identified through the screening process used to evaluate the environmental monitoring data, and if not already included, added chemicals or radionuclides that had significantly elevated concentrations in burned area ash.
- Added chromium, mercury, RDX (a high explosive compound) and uranium because of either known public concern or high source area concentrations.

This process resulted in a final list of 37 chemicals and radionuclides for which we developed source term estimates.

Development of Scenarios and Points of Exposure

We designed 4 exposure scenarios to represent the different ways that individuals may have been exposed to radionuclides and chemicals released to surface water during and after the Cerro Grande Fire. We developed the scenarios with caution so that all types of potential exposures would be represented. However, the hypothetical individuals described in the scenarios do not represent known individuals with these characteristics at these locations. Risks estimated for the hypothetical individuals in the scenarios would be greater than risks of other individuals who might be in the area for less time or under less exposed conditions.

The hypothetical individuals included (1) a local hunter, (2) a resident family (adult and child) living below Cochiti Lake, (3) a resident living below Water Canyon, and (4) a local fire cleanup worker at the LANL Site. The points of exposure for these individuals are shown in Figure 3.

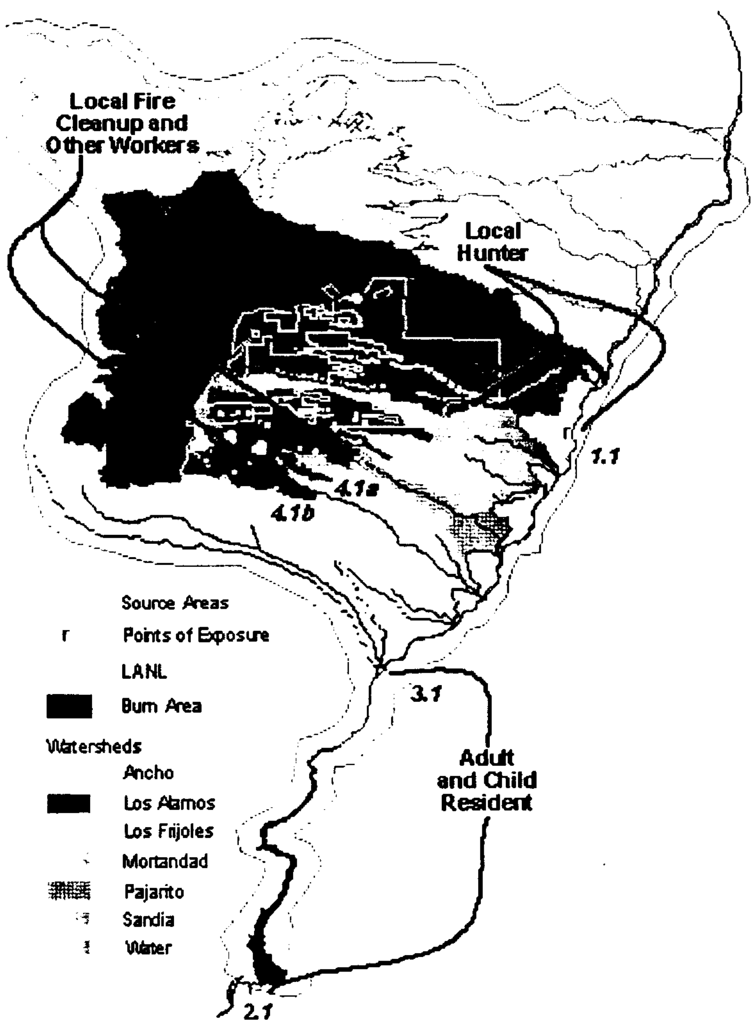

Figure 2. Points of exposure (POE) for the exposure scenarios used in the surface water pathway risk analysis of the Cerro Grande Fire.

Table 1: Exposure Scenarios for the Surface Water Pathway Risk Analysis

Exposure Pathways	Hypothetical Individuals 1	2	3	4
Drinking untreated water from the Rio Grande or Cochiti Lake	ŏ	ŏ	ŏ	
Sediment exposure (ingestion, external exposure, and dermal contact)	ŏ	ŏ	ŏ	ŏ
Swimming or contact with water in Cochiti Lake and the Rio Grande (immersion and accidental ingestion)		ŏ		
Eating fish from the Rio Grande and Cochiti Lake	ŏ	ŏ	ŏ	
Eating garden produce irrigated with river water		ŏ	ŏ	
Eating beef from cattle using water from the river and Cochiti Lake		ŏ	ŏ	

Transport Modeling

To estimate the concentration at the points of exposure for chemicals and radionuclides in environmental media, including storm water and surface water, the dissolved phase of storm water and surface water, suspended sediments, and deposited sediments, we:

- Estimated the surface water flow within the watersheds and at outlets to the Rio Grande for storm events 6 hours in length (2-, 5-, 10-, 25-, 50-, 100-, and 500-year design storm events).
- Developed estimates of suspended sediment concentrations before and after the fire based on an analysis of pre-fire and post-fire total suspended solids (TSS) sampling data.
- Identified the watershed contributing storm water flow to each point of exposure and the important source areas in the watershed.
- Estimated the maximum potential chemical mass and radionuclide activity that could be present at each point of exposure as a result of storm water flow across a source area.
- Identified background, or typical, storm water flow and suspended sediment concentration in the Rio Grande and in Cochiti Lake.
- Estimated distribution of the chemical mass and radionuclide activity in environmental media to estimate concentrations at each point of exposure.

The results of the transport modeling suggest that while the fire did impact the potential transport of chemicals and radionuclides, there was no consistent change in the resulting concentrations from pre-fire to post-fire. Pre-fire and post-fire concentrations differed by less than a factor of ten. Concentrations of chemicals and radionuclides decrease as the point of exposure is moved further away from the source areas, resulting in higher concentrations within the canyons immediately below the LANL facility than along the Rio Grande and Cochiti Lake.

Comparison to Measured Values

The comparisons we were able to make between available measured concentrations and predicted concentrations suggest that our predictions were overestimated, at least for some materials.

We compared predicted and measured concentrations in surface water and sediment at each point of exposure. The comparisons suggest that our predicted concentrations are consistently greater than measured values (10 to 100 times greater) for americium-241, cesium-137, plutonium-238, and plutonium-239,240 in sediments. Predicted concentrations for the explosive RDX and polycyclic aromatic hydrocarbons (PAH) are generally 10 to 1,000 times greater than measured concentrations. This over prediction supports the noted conservatism of both our source term development and transport calculations. The over prediction is generally greater for water than for sediment.

Risk Estimates

We presented risk estimates as cancer incidence risks for carcinogenic chemicals and radionuclides or as hazard quotients (HQ) for noncarcinogens. We estimated the potential annual cancer risk from the Cerro Grande Fire burning on the LANL site to be less than 3 in one million from exposure to any LANL-derived chemical or radionuclide that may have been carried in the surface water and sediments to the Rio Grande and Cochiti Lake. If exposure to the same concentrations of LANL-derived chemicals or radioactive materials was assumed to continue for 7 years (the time it may take to return to pre-fire vegetation conditions in the area), then the potential cancer risk was greater at about 20 in 1 million. Estimated intakes of noncarcinogenic LANL-derived chemicals were less than acceptable intakes (a hazard quotient <1.0) established by the U.S. Environmental Protection Agency (EPA).

> *Cancer risks for LANL-derived radionuclides and chemicals were within the range of acceptable risks defined by the U.S. EPA.*
>
> *Estimated intakes of noncarcinogenic LANL-derived chemicals were less than the U.S. EPA's acceptable intakes.*

Of the different individuals considered in the hypothetical exposure scenarios, the health risks were highest for the hypothetical resident living year round on the bank of the Rio Grande near the confluence of Water Canyon. The type of exposure contributing most to the potential risk was eating fish. However, the risks should be viewed as upper bound, or maximum, values because of the conservatism we assumed in estimating concentrations and in selecting lifestyle activities and values for the hypothetical individuals. The risks for all other types of exposure are lower than those for eating fish.

The hunter and firefighter, who were potentially exposed to higher concentrations in water and sediments, spent less time at those locations and had fewer types of exposures. Risk estimates and hazard quotients for the child and the adult at Cochiti Lake were generally similar. Risks for all pathways associated with the 500-year storm event are generally higher by less than a factor of 10 than the risks from the 2-year storm event, and the differences are likely within the uncertainties of the calculations.

CONCLUSIONS

An important tool from this work is the ability to look at the impact of individual PRSs or other source areas on potential exposures. An individual PRS can have a significant impact on the concentrations at a point of exposure, and there is a need for further and continuing investigations into the magnitude and extent of chemicals and radionuclides at these PRSs. In addition, concentrations of chemicals and radionuclides in stream segments and reaches below the LANL facility can have a significant impact at the point of exposure, and there is a need to characterize additional stream segments and reaches.

CALCULATING AND COMMUNICATING RISKS: OBSERVATIONS AND RECOMMENDATIONS

Following the Cerro Grande Fire, it was also essential to study how available technical information was used to make rapid decisions and communicate information about the potential risks to local residents and emergency response personnel. We made specific recommendations to improve calculation and communication of LANL-related health risks from impacted areas contaminated with radionuclides and chemicals, as well as a number of general recommendations that may be applicable to LANL and other sites. We examined two broad areas regarding lessons that can be learned to prepare for and be responsive to future emergencies: calculating health risks and communicating health risks.

The following recommendations are based on our experiences and efforts during this project of independently assessing potential risks to the public as a result of the Cerro Grande Fire. Although these recommendations are directed at identifying areas where improvements or changes could be made, certain considerations may complicate their implementation. While improved site characterization would greatly enhance our understanding of potential risks, public interests to "stop characterizing and start clean up" create conflicting pressures. As another example, a key to building trust and credibility involves ensuring that statements about risk are tied to valid and thoroughly analyzed data, but there is a competing desire by the public to have information provided immediately.

Recognizing these potentially conflicting issues by State and federal officials and members of the public is critical to developing and adopting procedures that meet stakeholders' needs. There will always be limitations related to collecting, compiling, interpreting, and disseminating information. At the same time, identifying areas where changes could result in more efficient, timely, or comprehensive availability of data is important. It is important to strike a balance between responding to public wishes, working efficiently to calculate and communicate potential risks, and realizing practical limitations on what is possible to achieve. The key to successfully implementing these recommendations will be involving all stakeholders in developing and adopting new procedures.

Recommendations for Calculating Health Risks

- Refine the existing routine and emergency monitoring programs and their goals to design and establish a comprehensive monitoring program that addresses current and potential needs for data collection. The program must be focused to provide timely information for the appropriate locations and a basis for early assessments and decisions.
- Establish a systematic and comprehensive effort to determine the amount of chemicals and radionuclides that may be available for release from contaminated areas, and rank the relative importance of those areas and the chemicals and radionuclides in terms of public health risk.
- Design and implement consistent and integrated methods for monitoring and data compilation that are based on identified uses and needs for the data that are collected. Determine what additional information will help most to refine risk calculations, reduce and quantify uncertainties, and meet established goals (including regulatory requirements) so

that an understanding of public risk, as well as minimization of the risk, is achieved efficiently and effectively.

- Define "background", or typical, conditions throughout the site and surrounding area so that increases in contaminant concentrations in the future can be statistically verified.
- Collect data to understand typical short-term (e.g., hourly or daily) changes in air concentration, which can vary significantly depending on the time of year or season. Averaging times must be reported along with measured air concentrations.
- Maintain data collection and storage in a consistent and easily retrievable format so that preliminary risk results are timely, respond to public concerns, and can be easily understood by independent organizations.
- Link issues affecting the interpretation of data to the actual data. Design data collection to allow for rapid comparison of monitoring data to appropriate background values, protective standards, risk coefficients, or other relevant values.

Recommendations for Communicating Health Risks

- Give the primary responsibility of *risk communication* to an independent agency that is working closely with the agencies involved in the emergency. When there is potential for public risk, the agency that the public views as responsible for the risk should not be the initial or primary source for communicating that risk to the public.
- Maintain a central point for issuing statements about health risk to avoid conflicting messages. Establish a way to reach agreement between agencies about statements that are issued. Develop a method to allow communication of other interpretations or opinions if complete agreement is not possible.
- Implement a well-coordinated and practiced emergency response plan that clearly identifies the responsibilities and capabilities of LANL, State and federal agencies, local communities, Pueblos, and other stakeholders with regard to understanding and communicating risks.
- Involve members of the local community in coordinating efforts to provide information about the emergency. Adopt a consistent method to provide appropriate perspective on the magnitude of measured concentrations.
- Base statements about immediate risks and potential future risks on available data only, and identify limitations, such as data gaps or uncertainties. Clearly identify the origin of the risk and the nature of the risk endpoint.
- Establish a method to allow environmental monitoring by groups, independent of State and federal agencies, in order to provide additional confidence in the results obtained by the site and regulatory agencies normally involved in data collection. Encourage constructive criticism by all stakeholders.
- Maintain a concerted effort to actively and effectively involve the local citizens in emergency and other planning. Continue to foster trust among all stakeholders.

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Summary for the [illegible] of the Analysis of Exposure and Risk to the Public from Radionuclides and Chemicals Released by the Cerro Grande Fire at Los Alamos

June 3, 2002

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The primary goal of the study was to analyze the immediate and longer-term impacts of the Cerro Grande Fire in terms of increased public exposures and potential risks from radionuclides and chemicals associated with the LANL facility that were released to air and surface water as a result of the fire. The study did not specifically address the impact the fire may have in the future on groundwater.

The three major objectives of the project were to

- Estimate increased exposure and associated risks to the public, emergency response personnel, and firefighters from transport of LANL-derived radionuclides and chemicals released as a result of the fire through the ***air pathway***. We also performed a preliminary evaluation of risks from naturally occurring radionuclides and metals released from burning of the forests around the LANL site.

> ***Pathways***
> *Routes of transport by which radionuclides and chemicals can travel from the location of a release to human populations.*

- Estimate increased exposure and associated risks to the public from transport of LANL-derived radionuclides and chemicals released as a result of the fire through ***surface water pathways***. We also evaluated risks related to ash from areas burned around the LANL site.
- Provide conclusions of the study and recommendations for similar events in the future. An important goal of the study was to actively, openly, and accurately convey information about the risks from the fire to the public, including the lessons learned regarding calculating and communicating risk.

ESTIMATED RISKS FROM RELEASES TO AIR

Methodology and Approach

The Cerro Grande Fire released chemicals and radionuclides to the air from the burning and heating of materials located in vegetation and soils across the LANL facility and the surrounding area. In order to calculate the potential risks associated with these releases, we

- Evaluated the available air monitoring data and procedures,
- Identified the sources and amounts of chemical and radionuclide releases to the air during the fire,
- Used computer modeling to estimate the release and transport of chemicals and radionuclides carried in the fire plume,
- Identified representative individuals for defining ***exposure scenarios***, and
- Estimated the associated health risks and the uncertainties of those risks.

> ***Exposure scenario***
> *Characterization of a lifestyle or voluntary activity that may result in contact with radionuclides and chemicals*

Before making any calculations, we first established the model domain, or geographical area of study (shown below). The total extent of the model domain was 37 × 35 mi (60 × 55 km). It encompassed approximately 815,000 acres (3300 km^2), and included the cities of Santa Fe and Española, as well as Cochiti Lake. We also investigated potential exposures at locations outside the study area (such as Taos). Exposures at these locations were less than the maximum exposures calculated within the study area.

Figure 1. Regional model domain for analysis of the Cerro Grande Fire.

Available Monitoring Data

The data available to assess the concentrations of radionuclides and chemicals in the air during the Cerro Grande Fire included air and soil samples collected before, during, and after the fire; soil characterization data for contaminated sites at LANL that burned during the fire; meteorological data; and data for airborne contaminants measured in other fires.

> **Source term**
> *The release rate of chemicals and radionuclides from an area or event.*

When we started the project, we anticipated that the environmental air monitoring data would be complete enough to allow us to estimate ***source terms*** based on the measured concentrations in air combined with computer transport modeling and that this would provide the basis to calculate the risks from the fire. However, the air monitoring data could not be used directly because not enough different locations were monitored, only a limited number of chemicals and radionuclides were measured, and the documentation for some of the data was incomplete. In addition, most of the concentrations measured were below the detection limits of the laboratory equipment used to analyze the samples.

Screening and Source Term Calculation

Because the environmental monitoring data were less useful than originally anticipated, the soil characterization data for contaminated areas of LANL (potential release sites or PRSs) that burned during the fire became the main source of information available on radionuclides and chemicals that may have been released. We identified a large number of radionuclides and chemicals that were potentially released during the fire, so we used a screening procedure to identify those that were most important in terms of health risk. We developed ***conservative*** source term estimates for the radionuclides and chemicals that were identified as possibly resulting from LANL operations. We removed contaminants from consideration that had a cancer incidence screening ***risk estimate*** of less than 1 chance in 100,000 (for cancer-causing chemicals and radionuclides) or a screening ***hazard quotient*** (HQ) of less than 1.0 (for chemicals causing non-cancer health effects), when risk was calculated conservatively.

> **Conservative**
> *Using cautious assumptions to ensure that endpoints are not underestimated.*

> **Risk estimate**
> *A description of the probability that individuals exposed to a chemical or radionuclide will develop an adverse reaction, such as cancer.*
> *The range of acceptable risks defined by the U.S. Environmental Protection Agency (EPA) is from 1 to 100 chances in 1 million.*

> **Hazard quotient (HQ)**
> *The ratio of the average daily intake of a contaminant per unit body weight to an acceptable reference value.*
> *An HQ<1.0 indicates no increase in risk.*

Then, for this list of radionuclides and chemicals that were most important in terms of health risk, we calculated source terms using available information on the quantities present at the contaminated sites and how they may have been released to the air during the Cerro Grande Fire. We used these source terms to calculate estimated air concentrations.

Atmospheric Transport and Air Concentration Calculation

Calculating transport of radionuclides and chemicals released into the air during burning of the PRSs first required an understanding of the behavior of the fire itself. We used computer models to estimate the movement of combustion products common to all wildfires in the study area. ***PM10*** was measured in air at a number of locations in the model domain. We compared the computer model-estimated concentrations of PM10 with the measured concentrations to confirm the computer model estimates and to better understand the uncertainty associated with the results.

> ***PM10***
> *Particulate matter less than 10 μm in diameter. Produced by all wildfires.*

The process of calibrating the model to PM10 measurements involved (1) identifying the geographical area that was burned, (2) defining the time history of the fire, (3) estimating the amount of PM10 released by the fire and the heat generated during burning, (4) modeling the transport in air of pollutants released by the fire, and (5) calibrating predicted concentrations of PM10 with measured values. Contributions of PM10 from sources other than the fire were accounted for in the calibration.

We then assumed the release and transport of radionuclides and chemicals from LANL sources to be proportional to the release and transport of PM10 from the fire. The dispersion of PM10, therefore, served as a "tracer" for particulate releases of radionuclides and chemicals. For volatile chemicals, carbon monoxide was used as a tracer.

Using the process described earlier, we calculated concentrations of radionuclides and chemicals identified as important through the screening process. In general, most predicted air concentrations were below standard detection limits of laboratory instruments. However, the predicted air concentrations and deposition amounts for the explosive compounds RDX, HMX, DNB, and TNT were relatively high. After the fire, however, explosive compounds were not detected in the limited soil sampling performed. The predicted deposition of these compounds would have been easily detected in soil, and this suggested that we overestimated the source terms for these compounds because of the cautious assumptions we made in our calculations.

Risk Estimates

We used four exposure scenarios to determine the risks to representative individuals from the LANL-derived radionuclides and chemicals released to the air during the fire; a resident adult, a firefighter, an emergency response worker, and a resident child. For each scenario we calculated cancer risk for radionuclides and ***carcinogenic*** chemicals, and HQ values for noncarcinogenic chemicals, using the model-estimated concentrations at eight representative exposure locations, as well as the maximum predicted concentration in the study area. Risks from ***naturally occurring radionuclides and chemicals*** on vegetation that burned during the Cerro Grande Fire were calculated for the adult resident scenario only. These risks would be associated with any forest fire and are not specific to LANL.

> ***Carcinogenic***
> *Cancer causing.*

> *Naturally occurring radionuclides and chemicals, as well as radionuclides from global atmospheric weapons tests, are present in and on all natural vegetation and are released during any wildfire.*

For LANL-derived chemicals and radionuclides, the maximum risk occurred within the active burned area and on LANL property. The maximum total cancer incidence risk from breathing any LANL-derived radionuclide released to the air during the fire was less than 1 chance in 10 million. In contrast, cancer incidence risks from breathing radionuclides released to the air from natural

> *Cancer incidence risks for LANL-derived chemicals and radionuclides released to the air during the fire were less than 1 chance in 1 million.*

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vegetation during the fire were estimated to be approximately 1 chance in 1 million. Cancer incidence risks from LANL-derived chemicals released during the fire were generally less than 1 chance in 1 million. The explosive compound RDX was a major contributor to this risk estimate, and we believe the source term and risk for this compound were overestimated. Cancer incidence risks from metals detected in natural vegetation and released during the fire were also approximately 1 chance in 1 million.

HQ values indicated that intakes of LANL-derived noncarcinogenic chemicals and radionuclides released during the fire exceeded acceptable levels only in a small area of the LANL site.

The total HQ used to assess non-cancer health effects was generally less than or equal to 0.1 throughout the model domain for LANL derived chemicals. Near areas where the fire burned, however, HQ values exceeded 1.0 and reached a maximum value of 2.0 for the resident adult scenario. This excursion above the acceptable level of 1.0 was limited to a small area within the LANL site near its western boundary. Most of the non-cancer risk was associated with the explosive compounds RDX, HMX, DNB, and TNT. As stated previously, we believe the sources terms for these compounds were overestimated.

Reference dose (RfD)
An estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without a significant risk of negative health effects.

Hazard quotients for metals released during the fire from natural vegetation were extremely high. They were attributed to inhalation of manganese and, to a lesser extent, aluminum. However, the ***reference doses (RfD)*** available to calculate the non-cancer health effects from these two metals were developed to evaluate chronic, or long-term, exposures, not short-term exposures such as those during the Cerro Grande Fire. They equated to air concentrations that were much lower than the occupational standards for these metals. We believe the use of these chronic RfDs caused the HQ values calculated for these metals to be unrealistically high. Using a reference dose based on occupational standards resulted in a maximum HQ of less than 1.0.

Concentrations of PM10 in the model domain were sufficient to cause adverse health effects; however, we did not calculate risks from PM10 exposure.

Conclusions

While the modeling we developed using the PM10 data is quite reliable, the estimates of the quantities of materials available for release to the air, the rate at which these materials were released to the air, and the risk associated with short-term exposure to some chemicals are less certain. Therefore, we made conservative or cautious assumptions to ensure the risks were not underestimated.

Our analysis indicates that exposure to LANL-derived chemicals and radionuclides during the Cerro Grande Fire did not result in a significant increase in health risk over the risk from the fire itself. The risk of cancer from exposure to radionuclides and metals in and on vegetation that burned was many times greater than that from radionuclides and chemicals released from contaminated sites at LANL. All cancer risks were below the U.S. EPA range of acceptable risks of 10^{-6} to 10^{-4} (1 to 100 chances in 1 million). Hazard quotients from exposure to noncarcinogenic LANL-derived chemicals exceeded the 1.0 level at some locations on LANL property. However, the estimated HQ values are conservative and likely overestimate the actual risks that occurred. It is likely that the risks from exposure to PM10 far outweigh the risks from LANL-derived radionuclides and chemicals and those released from natural vegetation during the fire.

ESTIMATED RISKS FROM RELEASES TO SURFACE WATER

Methodology and Approach

The Cerro Grande Fire destroyed vegetation and changed the surface soil, which has increased the amount of storm water that could flow through the canyons. This increased storm water flow has the potential to carry with it greater amounts of soil, sediment, and ash from the entire impacted watershed, including some areas at LANL that contain elevated levels of chemicals and radioactive materials. In order to estimate the potential increased exposure through the surface water pathway that occurred as a result of the fire and the associated risks, we

- Developed a surface water model domain (study area),
- Evaluated the available surface and storm water monitoring data,
- Identified the sources and amounts of chemical and radionuclide releases,
- Modeled the release and transport of radionuclides and chemicals in surface and storm water,
- Identified representative individuals for defining exposure scenarios, and
- Estimated the associated health risks.

The surface water model domain encompassed approximately 182,000 acres (738 km^2). In relation to the LANL facility, the study area extended to the west to include the upper Pajarito Plateau watersheds for the canyons that cross the LANL facility, to the north to include the extent of the burned area in Santa Clara Canyon, to the east to include the Rio Grande, and to the south along the Rio Grande and downstream of Cochiti Dam.

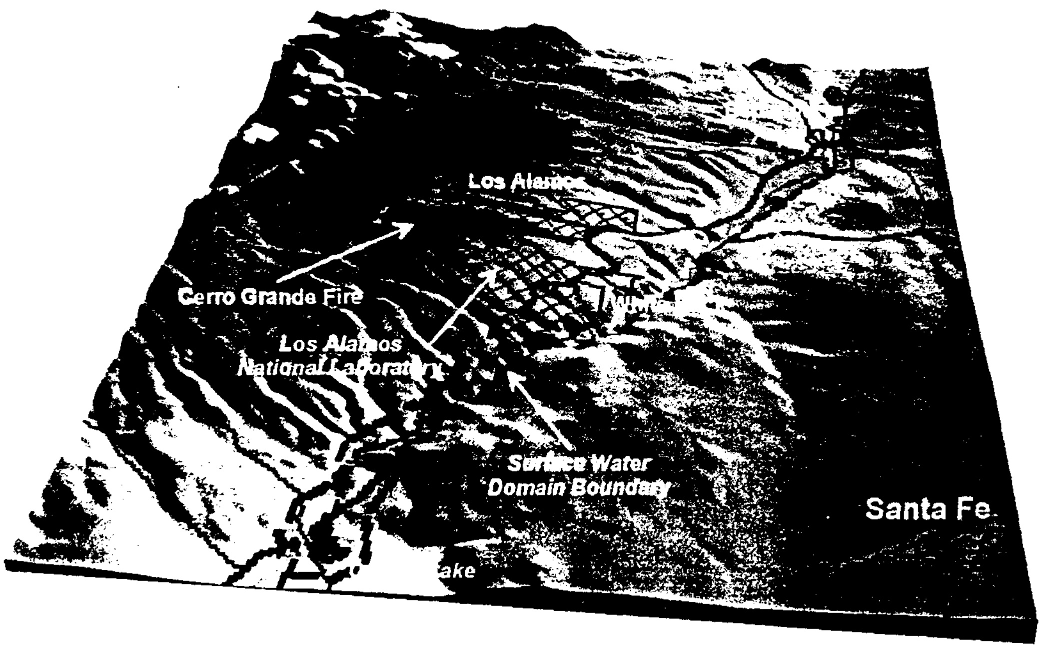

Figure 2. Surface water model domain for analysis of the Cerro Grande Fire.

Monitoring Data Evaluation

We reviewed water and sediment monitoring data from LANL and from NMED. Because of the large number of measured chemicals and radionuclides, we developed a two-stage screening procedure to focus the analysis on those that were most likely to contribute to the health risk of those exposed directly or indirectly to surface water runoff from LANL. We used the available monitoring data for radionuclides and chemicals collected after the fire, along with available information about risk from exposure to radionuclides and chemicals to calculate a screening index.

Of the more than 250 chemicals and 75 radioactive materials evaluated during this screening process, we identified 45 chemicals and radionuclides as most important in terms of the potential human health risk. We focused our monitoring data evaluation on the man-made radionuclides in this list because there is a lack of post-fire monitoring data for many of the chemicals and, for other chemicals, the results were below detection limits so few conclusions could be drawn. As a result, the monitoring data evaluation focused primarily on the analysis of the radionuclides, americium-241, cesium-137, strontium-90, plutonium-238, and plutonium-239,240 in surface water, storm water, and sediment. The monitoring data were useful for identifying apparent increases in concentration for some radionuclides and chemicals following the fire and also for identifying the possibility of LANL impact on measured concentrations.

Source Term Development

The most critical step in the risk estimation process is calculating the source term. Our modeling approach for estimating concentrations of chemicals and radionuclides in source areas used measured concentrations of chemicals and radionuclides in soil or sediment across defined source areas, along with water runoff and sediment erosion yields. We then calculated downstream concentrations of chemicals and radionuclides at defined ***points of exposure (POE)***, focusing on those that were most important in terms of potential health risk.

> ***Points of exposure (POE)***
> *Locations where an individual would likely come in contact with surface water, suspended sediments, or deposited sediments containing concentrations of chemicals or radionuclides.*

To identify the most important radionuclides and chemicals, we performed the following steps:

- Calculated average concentrations of chemicals and radionuclides across each source area and compared the highest average concentration to the EPA residential combined preliminary remediation goals (PRG) for soil.
- Eliminated general water quality sampling results for which associated risks are not expected, and some other general categories of materials (like total petroleum hydrocarbons and lubricant range organics) for which information needed to calculate risk is not available.
- Selected the chemicals and radionuclides that were identified through the screening process used to evaluate the environmental monitoring data, and if not already included, added chemicals or radionuclides that had significantly elevated concentrations in burned area ash.
- Added chromium, mercury, RDX (a high explosive compound) and uranium because of either known public concern or high source area concentrations.

This process resulted in a final list of 37 chemicals and radionuclides for which we developed source term estimates.

Development of Scenarios and Points of Exposure

We designed 4 exposure scenarios to represent the different ways that individuals may have been exposed to radionuclides and chemicals released to surface water during and after the Cerro Grande Fire. We developed the scenarios with caution so that all types of potential exposures would be represented. However, the hypothetical individuals described in the scenarios do not represent known individuals with these characteristics at these locations. Risks estimated for the hypothetical individuals in the scenarios would be greater than risks of other individuals who might be in the area for less time or under less exposed conditions.

The hypothetical individuals included (1) a local hunter, (2) a resident family (adult and child) living below Cochiti Lake, (3) a resident living below Water Canyon, and (4) a local fire cleanup worker at the LANL Site. The points of exposure for these individuals are shown in Figure 3.

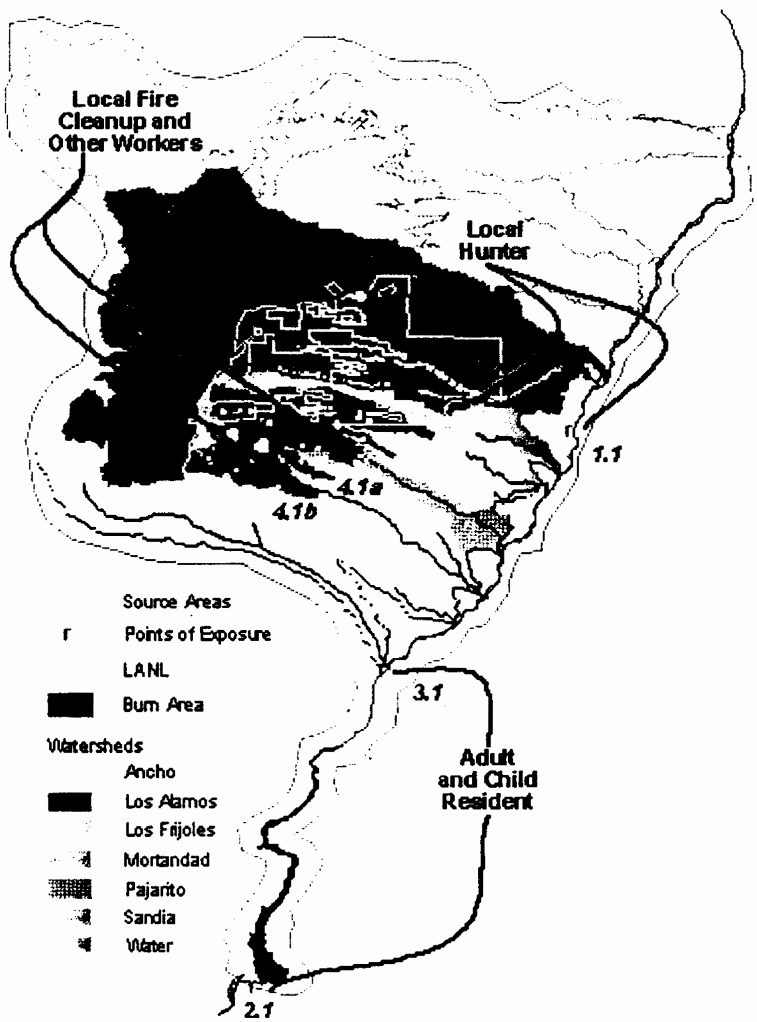

Figure 2. Points of exposure (POE) for the exposure scenarios used in the surface water pathway risk analysis of the Cerro Grande Fire.

Table 1: Exposure Scenarios for the Surface Water Pathway Risk Analysis

Exposure Pathways	Hypothetical Individuals			
	1	2	3	4
Drinking untreated water from the Rio Grande or Cochiti Lake	ŏ	ŏ	ŏ	
Sediment exposure (ingestion, external exposure, and dermal contact)	ŏ	ŏ	ŏ	ŏ
Swimming or contact with water in Cochiti Lake and the Rio Grande (immersion and accidental ingestion)		ŏ		
Eating fish from the Rio Grande and Cochiti Lake	ŏ	ŏ	ŏ	
Eating garden produce irrigated with river water		ŏ	ŏ	
Eating beef from cattle using water from the river and Cochiti Lake		ŏ	ŏ	

Transport Modeling

To estimate the concentration at the points of exposure for chemicals and radionuclides in environmental media, including storm water and surface water, the dissolved phase of storm water and surface water, suspended sediments, and deposited sediments, we:

- Estimated the surface water flow within the watersheds and at outlets to the Rio Grande for storm events 6 hours in length (2-, 5-, 10-, 25-, 50-, 100-, and 500-year design storm events).
- Developed estimates of suspended sediment concentrations before and after the fire based on an analysis of pre-fire and post-fire total suspended solids (TSS) sampling data.
- Identified the watershed contributing storm water flow to each point of exposure and the important source areas in the watershed.
- Estimated the maximum potential chemical mass and radionuclide activity that could be present at each point of exposure as a result of storm water flow across a source area.
- Identified background, or typical, storm water flow and suspended sediment concentration in the Rio Grande and in Cochiti Lake.
- Estimated distribution of the chemical mass and radionuclide activity in environmental media to estimate concentrations at each point of exposure.

The results of the transport modeling suggest that while the fire did impact the potential transport of chemicals and radionuclides, there was no consistent change in the resulting concentrations from pre-fire to post-fire. Pre-fire and post-fire concentrations differed by less than a factor of ten. Concentrations of chemicals and radionuclides decrease as the point of exposure is moved further away from the source areas, resulting in higher concentrations within the canyons immediately below the LANL facility than along the Rio Grande and Cochiti Lake.

Comparison to Measured Values

We compared predicted and measured concentrations in surface water and sediment at each point of exposure. The comparisons suggest that our predicted concentrations are consistently greater than measured values (10 to 100 times greater)

The comparisons we were able to make between available measured concentrations and predicted concentrations suggest that our predictions were overestimated, at least for some materials.

for americium-241, cesium-137, plutonium-238, and plutonium-239,240 in sediments. Predicted concentrations for the explosive RDX and polycyclic aromatic hydrocarbons (PAH) are generally 10 to 1,000 times greater than measured concentrations. This over prediction supports the noted conservatism of both our source term development and transport calculations. The over prediction is generally greater for water than for sediment.

Risk Estimates

We presented risk estimates as cancer incidence risks for carcinogenic chemicals and radionuclides or as hazard quotients (HQ) for noncarcinogens. We estimated the potential annual cancer risk from the Cerro Grande Fire burning on the LANL site to be less than 3 in one million from exposure to any LANL-derived chemical or radionuclide that may have been carried in the surface water and sediments to the Rio Grande and Cochiti Lake. If exposure to the same concentrations of LANL-derived chemicals or radioactive materials was assumed to continue for 7 years (the time it may take to return to pre-fire vegetation conditions in the area), then the potential cancer risk was greater at about 20 in 1 million. Estimated intakes of noncarcinogenic LANL-derived chemicals were less than acceptable intakes (a hazard quotient <1.0) established by the U.S. Environmental Protection Agency (EPA).

Cancer risks for LANL-derived radionuclides and chemicals were within the range of acceptable risks defined by the U.S. EPA.

Estimated intakes of noncarcinogenic LANL-derived chemicals were less than the U.S. EPA's acceptable intakes.

Of the different individuals considered in the hypothetical exposure scenarios, the health risks were highest for the hypothetical resident living year round on the bank of the Rio Grande near the confluence of Water Canyon. The type of exposure contributing most to the potential risk was eating fish. However, the risks should be viewed as upper bound, or maximum, values because of the conservatism we assumed in estimating concentrations and in selecting lifestyle activities and values for the hypothetical individuals. The risks for all other types of exposure are lower than those for eating fish.

The hunter and firefighter, who were potentially exposed to higher concentrations in water and sediments, spent less time at those locations and had fewer types of exposures. Risk estimates and hazard quotients for the child and the adult at Cochiti Lake were generally similar. Risks for all pathways associated with the 500-year storm event are generally higher by less than a factor of 10 than the risks from the 2-year storm event, and the differences are likely within the uncertainties of the calculations.

CONCLUSIONS

An important tool from this work is the ability to look at the impact of individual PRSs or other source areas on potential exposures. An individual PRS can have a significant impact on the concentrations at a point of exposure, and there is a need for further and continuing investigations into the magnitude and extent of chemicals and radionuclides at these PRSs. In addition, concentrations of chemicals and radionuclides in stream segments and reaches below the LANL facility can have a significant impact at the point of exposure, and there is a need to characterize additional stream segments and reaches.

CALCULATING AND COMMUNICATING RISKS: OBSERVATIONS AND RECOMMENDATIONS

Following the Cerro Grande Fire, it was also essential to study how available technical information was used to make rapid decisions and communicate information about the potential risks to local residents and emergency response personnel. We made specific recommendations to improve calculation and communication of LANL-related health risks from impacted areas contaminated with radionuclides and chemicals, as well as a number of general recommendations that may be applicable to LANL and other sites. We examined two broad areas regarding lessons that can be learned to prepare for and be responsive to future emergencies: calculating health risks and communicating health risks.

The following recommendations are based on our experiences and efforts during this project of independently assessing potential risks to the public as a result of the Cerro Grande Fire. Although these recommendations are directed at identifying areas where improvements or changes could be made, certain considerations may complicate their implementation. While improved site characterization would greatly enhance our understanding of potential risks, public interests to "stop characterizing and start clean up" create conflicting pressures. As another example, a key to building trust and credibility involves ensuring that statements about risk are tied to valid and thoroughly analyzed data, but there is a competing desire by the public to have information provided immediately.

Recognizing these potentially conflicting issues by State and federal officials and members of the public is critical to developing and adopting procedures that meet stakeholders' needs. There will always be limitations related to collecting, compiling, interpreting, and disseminating information. At the same time, identifying areas where changes could result in more efficient, timely, or comprehensive availability of data is important. It is important to strike a balance between responding to public wishes, working efficiently to calculate and communicate potential risks, and realizing practical limitations on what is possible to achieve. The key to successfully implementing these recommendations will be involving all stakeholders in developing and adopting new procedures.

Recommendations for Calculating Health Risks

- Refine the existing routine and emergency monitoring programs and their goals to design and establish a comprehensive monitoring program that addresses current and potential needs for data collection. The program must be focused to provide timely information for the appropriate locations and a basis for early assessments and decisions.
- Establish a systematic and comprehensive effort to determine the amount of chemicals and radionuclides that may be available for release from contaminated areas, and rank the relative importance of those areas and the chemicals and radionuclides in terms of public health risk.
- Design and implement consistent and integrated methods for monitoring and data compilation that are based on identified uses and needs for the data that are collected. Determine what additional information will help most to refine risk calculations, reduce and quantify uncertainties, and meet established goals (including regulatory requirements) so

that an understanding of public risk, as well as minimization of the risk, is achieved efficiently and effectively.

- Define "background", or typical, conditions throughout the site and surrounding area so that increases in contaminant concentrations in the future can be statistically verified.
- Collect data to understand typical short-term (e.g., hourly or daily) changes in air concentration, which can vary significantly depending on the time of year or season. Averaging times must be reported along with measured air concentrations.
- Maintain data collection and storage in a consistent and easily retrievable format so that preliminary risk results are timely, respond to public concerns, and can be easily understood by independent organizations.
- Link issues affecting the interpretation of data to the actual data. Design data collection to allow for rapid comparison of monitoring data to appropriate background values, protective standards, risk coefficients, or other relevant values.

Recommendations for Communicating Health Risks

- Give the primary responsibility of *risk communication* to an independent agency that is working closely with the agencies involved in the emergency. When there is potential for public risk, the agency that the public views as responsible for the risk should not be the initial or primary source for communicating that risk to the public.
- Maintain a central point for issuing statements about health risk to avoid conflicting messages. Establish a way to reach agreement between agencies about statements that are issued. Develop a method to allow communication of other interpretations or opinions if complete agreement is not possible.
- Implement a well-coordinated and practiced emergency response plan that clearly identifies the responsibilities and capabilities of LANL, State and federal agencies, local communities, Pueblos, and other stakeholders with regard to understanding and communicating risks.
- Involve members of the local community in coordinating efforts to provide information about the emergency. Adopt a consistent method to provide appropriate perspective on the magnitude of measured concentrations.
- Base statements about immediate risks and potential future risks on available data only, and identify limitations, such as data gaps or uncertainties. Clearly identify the origin of the risk and the nature of the risk endpoint.
- Establish a method to allow environmental monitoring by groups, independent of State and federal agencies, in order to provide additional confidence in the results obtained by the site and regulatory agencies normally involved in data collection. Encourage constructive criticism by all stakeholders.
- Maintain a concerted effort to actively and effectively involve the local citizens in emergency and other planning. Continue to foster trust among all stakeholders.