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Title: The Cerro Grande Fire - From Wildfire Modeling Through the Fire Aftermath

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Los Alamos
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The Cerro Grande Fire – From Wildfire Modeling through the Fire Aftermath

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Abstract

The Cerro Grande Fire developed from a prescribed burn by the National Park Service at Bandelier National Monument near Los Alamos, New Mexico. When the burn went out of control and became a wildfire, it attracted worldwide attention because it threatened the birthplace of the atomic bomb, Los Alamos National Laboratory (LANL). Was LANL prepared for a fire? What lessons have been learned?

1.0 Introduction

In recent years, the size and intensity of wildfires has increased in many areas of the United States. Some of this has been attributed to man's interference with nature. Another factor has been climate changes.

As early as the 1930's, the U.S. population was encouraged to prevent or extinguish wildfires. During World War II, government campaigns emphasized preserving our forest resources. By the 1950's, the U.S. Forest Service had Smokey Bear as a national symbol and resource conservation was still emphasized. Since then, forest fires have been aggressively fought on a frequent basis and many forests have become unhealthy. Many forests have become unnaturally dense with debris buildup on the forest floor, heavy undergrowth, and denser stands of trees. This has resulted in a higher percentage of hotter burning, less controllable crown fires.

Also, based on our limited knowledge of our planet, scientists believe our weather patterns have been changing. In recent years, there has been less precipitation resulting in drought conditions in many portions of the U.S. New Mexico has been one of the areas experiencing less winter snow pack and drought conditions for several years.

2.0 Wildfire History

Over the past fifty years, five major wildfires and more than 300 smaller wildfires have occurred in the vicinity of Los Alamos. The major fires are identified in Table 1. Of these five major fires, three have been within the last four years and two have entered Los Alamos National Laboratory (LANL) property. All of the major fires have been during dry, windy times of the year. Containment of the first four major fires was assisted by weather changes. Unfortunately, the weather changes did not occur quickly enough with the fifth fire, the Cerro Grande Fire.

Table 1. Major Wildfires in Los Alamos Vicinity.[1, 2, 3, 4]

Year	Name of Fire	Total Acreage	Duration	Proximity to LANL	LANL Acreage Affected
June 1954	Water Canyon	3,000	Several days	Adjacent to western boundary	None, but town evacuated
June 1977	La Mesa	15,300	Contained on fifth day	Burned near high explosives bunkers and other key facilities	2,500
April25 - May 5, 1996	Dome	16,000 to 16,500 (varies by source)	Eleven days	Forests near LANL	None
June 1998	Oso	5,300	-	North of LANL and the Los Alamos town site	None
May 2000	Cerro Grande	43,000 to 47,650 (varies by source)	Started May 4 Contained on June 6 Completely controlled on July 22 Extinguished on September 25	Burned within boundaries of several LANL technical areas (TA) including high explosives storage bunkers, TA-16, TA-8, TA-46, TA-59	7,500

3.0 Planning for Wildfires

As a result of the fires prior to 2000, LANL and Los Alamos County took some actions to prepare for and to minimize the potential impact of wildfires. On July 22, 1988 a revised Mutual Fire Protection Assistance agreement was signed by the Department of Army Corps of Engineers, Bureau of Indian Affairs, Department of Energy - Los Alamos Area Office, United States Forest Service, National Park Service, and the New Mexico Department of Energy, Minerals, and Natural Resources.[5]

Following the 1996 Dome Fire, an interagency task group was formed to plan for and fight wildfires. This interagency wildfire management team consisted of the National Park Service, the Laboratory, DOE, Los Alamos County, US Forest Service, the State of New Mexico, and San Ildefonso Pueblo.[4] As the need was identified to develop and maintain a wildfire fire fighting capability in the Los Alamos area, several steps were taken. The Los Alamos County Fire Department, which provides fire fighting services to LANL as well as the county, trains its fire fighters to fight both structure and wildfires. The DOE permitted the construction of a helicopter pad, command center, and storage of fire fighting supplies at TA-49. The local area was also examined to identify what could be done to minimize the impact of future fires.[3, 6] Several of the suggestions from these examinations had either been implemented or were in progress prior to the start of the Cerro Grande Fire. These included:

- Tree and brush thinning on the Laboratory property
- Tree and brush thinning to create a firebreak around portions of the Los Alamos town site - Over the past few years, students at the Los Alamos Middle School have provided community service by removing debris from tree and brush thinning to create the fire breaks.
- The maintenance of emergency operations centers (EOC)
- Emergency plan updates including contingencies
- The development of an emergency notification system within Los Alamos County - an automatic telephone call warning system

4.0 Wildfire Scenario Analysis Before 2000

When the Site-Wide Environmental Impact Statement[3] (SWEIS) was under development in the 1990's, it was recognized during public hearings that wildfires were not common in facility-specific hazard analysis documents. As a result, a wildfire scenario designated as SITE-04 was added to the SWEIS.

The SITE-04 scenario assumed a site-wide wildfire consuming combustible structures and vegetation would occur approximately once every ten years. It was postulated that a wildfire would start to the southwest of LANL near the border of the Bandelier National Monument and the Dome Wilderness Area. The fire would start in the late April to June time frame when the fire danger was high or extreme. Both access to the fire and resources were assumed to be limited with the result of the fire entering the LANL site. The fire was also assumed to move quickly with meteorological conditions favoring the spread of the fire. The fire was assumed to sweep across the western part of LANL, to enter the canyons, to jump roads, and to enter the town site. Combustible LANL buildings were assumed to catch on fire and be destroyed. The wind was assumed to generate spot fires in advance of the main fire.

MACCS was used to calculate population doses from such a fire. The unmitigated mean population dose was estimated at approximately 675 person-rem resulting in approximately 0.34 excess latent cancer fatalities. The unmitigated dose estimate attributed 625 person-rem from the wildfire consuming buildings and 50 person-rem from burning vegetation and unidentified residual contamination in other buildings and vegetation. Seventy-five percent of this dose estimate was from TA-54. With some mitigation, the dose estimated by the analysis was reduced to 50 person-rem and 0.25 latent cancer fatalities. The analysis also identified a potential for limited exposure to chemicals.

Table 2 presents some summary information on the main contributors to the unmitigated dose estimate. The information provided in the table indicates the facilities that were considered of the most interest relative to this scenario. TA-54 shows the highest estimated population dose at 400 person-rem and the Weapons Engineering Tritium Facility (WETF) the next highest with 189 person-rem. The table does not indicate all of the facilities that were evaluated for input to the analysis. However, the table does show that some of the dose estimates were developed based on other scenarios considered in the SWEIS. For instance, aircraft crash and earthquake scenario results were adapted for some of the wildfire analysis. The original aircraft crash analyses included fires from fuels.

Contributions to the wildfire analysis for how a fire might progress were made by the Espanola District of the Santa Fe National Forest, the Bandelier National Monument of the National Park Service, the Los Alamos Fire Department, and LANL personnel. As a result of this analysis, LANL started some mitigation efforts before the SWEIS was published.[3]

Table 2. Wildfire Analysis Data from the SWEIS.[3]

Technical Area	Building Number	Facility Name	Comment	SWEIS Assessment
TA-03	66/451	Sigma Building	130 kg of fines in oil, plus 100 electrodes each 1/4-inch thick by 8-inch by 4-ft long. Remainder of 65,000 kg of depleted uranium (DU) is in fixed storage cabinets of 1/2-hour resistance. All material is in the basement. Information from facility walkdown included 6,484 lb of fuming nitric acid, 3,130 lb of hydrochloric acid, and 490 lb of 48 to 51% hydrofluoric acid.	The maximum dose from the inventory of 65,000 kg calculated for this scenario was 3 x 10^{-5} rem 50-yr. committed dose equivalent (EDE) at approximately 10 km from the release point. Chemicals below grade level and not likely to be affected by fire.
TA-16	205	Weapons Engineering Tritium Facility (WETF)	100 g tritium in process; 60 g in tubs and 1,200 g in LP-50 containers in vault storage	The maximum dose (MEI) was calculated as 0.25 rem at 4.85-km distance. Doses are less at shorter distances due to plume rise. The population dose is 189 person-rem within the 80.5-km (50-mile) radius.
TA-21	155	Tritium Science Test Assembly (TSTA)	200 g tritium	Using the RAD-05 aircraft crash and fire accident, consequences from a 200 g release of tritium oxide were 24 person-rem population exposure and mean MEI dose of 0.012 rem at State Road 502 (360 m away).
TA-21	209	Tritium Science and Fabrication Facility (TSFF)	100 g tritium	Scaling of the RAD-05 aircraft crash and fire accident consequences to a 100 g release of tritium in oxide form results in 12 person-rem population

Table 2. Wildfire Analysis Data from the SWEIS.[3]

Technical Area	Building Number	Facility Name	Comment	SWEIS Assessment
				exposure and mean MEI dose of 0.006 rem at State Road 502 (360 m away).
TA-43	1	Health Research Laboratory (HRL)	30 liters formaldehyde	Evaluated in the SWEIS earthquakes. The ERPG-2 and ERPG-3 distances were 0.17 and 0.1 miles (0.27 and 0.16 km) respectively, under conservative daytime dispersion conditions. The number of people exposed to greater than ERPG-2 and ERPG-3 were 11 and 6 respectively.
TA-48	1	Radiochemistry Laboratory	(No specifics stated in SWEIS)	Dissolving wing fire (Scenario 2) 0.3 mrem at 720 m, Alpha wing fire is 5.4 mrem at 720 m or at the Royal Crest Trailer Park. The whole facility fire is postulated at 50 mrem. Chemical exposures at this location are less than ERPG-2.
TA-54	153, 224, 226, 229, 230, 231, 232, 283, 33, 48, 49, Pad 2	Waste drum preparation and domes	Evaluated in RAD-08	The consequences of the aircraft-initiated fire in RAD-08 were 400 person-rem population exposure, and a mean MEI dose of 22 rem at both White Rock and Pajarito Road.

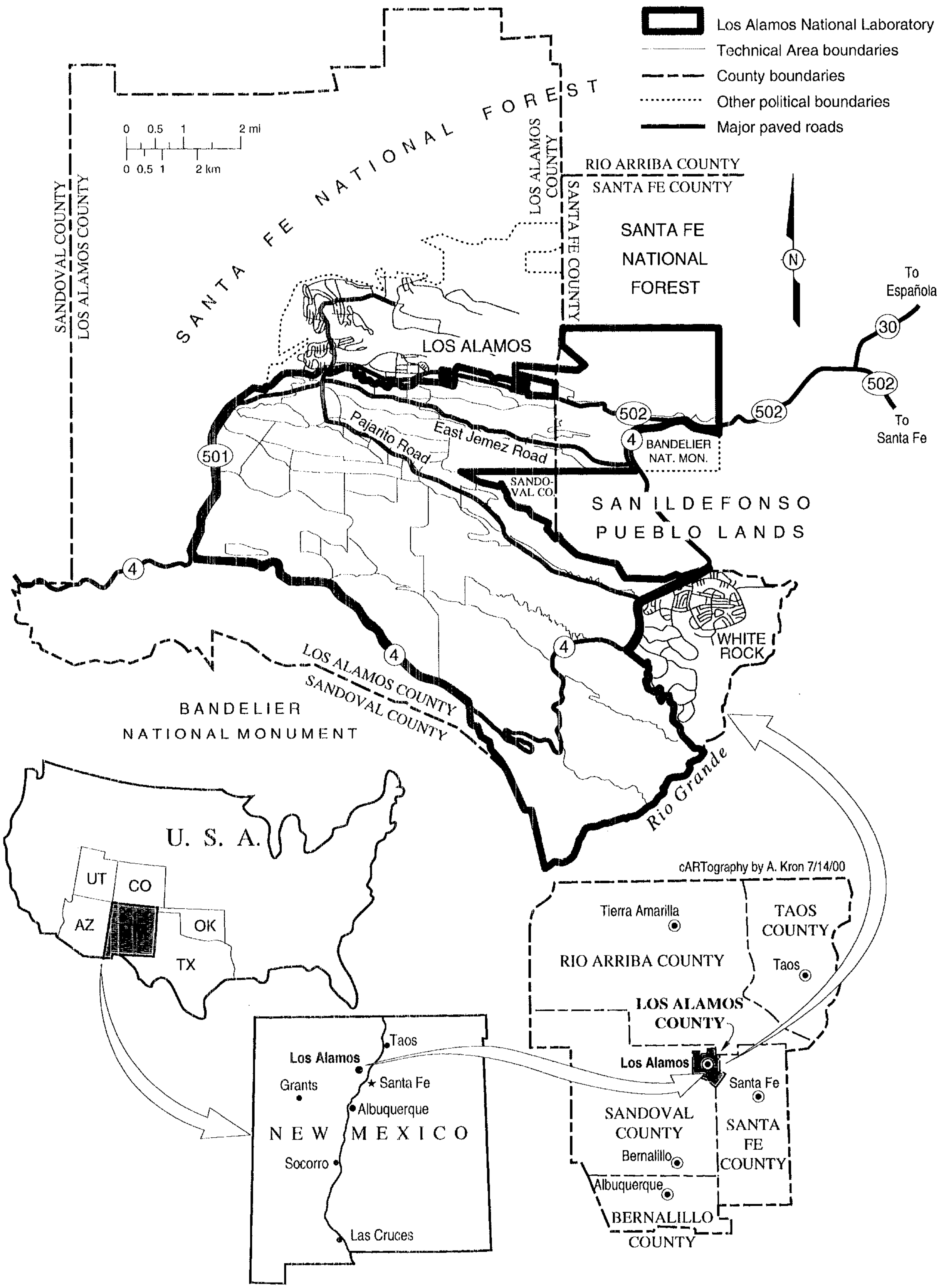
5.0 The Cerro Grande Fire

5.1 The Setting

The climate, forest conditions, and the terrain proved to be major factors with the fire.

- **Climate**: By spring 2000, there had been several years of below normal precipitation in the Los Alamos area. This included the third consecutive year with almost no snow pack in the Jemez Mountains during the winter season. This lack of moisture resulted in extremely dry forest conditions by the late April to early May 2000 timeframe.
- **Forest**: As identified earlier, the surrounding forest was dense and overgrown. Housing was encroaching against the forest edges.
- **Terrain:** The canyon, mesa, and mountain terrain of the Los Alamos area limits highway access routes to Los Alamos. As shown in Figure 1 [7], normal access is from either the Espanola Valley, such as Pojaque, or the Jemez Mountains. State Road 502 from Pojaque splits to allow three paved roads (routes 4 and 502 and East Jemez Road) into LANL and the Los Alamos town site. Route 4 serves White Rock and continues past LANL firing sites and

Figure 1. Access Routes for Los Alamos National Laboratory.



Location of Los Alamos National Laboratory.

explosives storage areas, Bandelier National Monument, LANL's WETF and Fenton Hill areas, and the Jemez Mountains. State Road 501, also known as West Jemez Road, runs from Route 4 near WETF to the intersection of East Jemez Road and State Road 502 at LANL TA-3.

5.2 The Fire Progression

The National Park Service started a prescribed burn on Bandeleir National Monument on Thursday, May 4th. By May 5th, the prescribed burn was more than the assigned staff could handle. With the winds and dry conditions, the prescribed burn was developing into a wildfire. Firefighters were called in to help.

Over the weekend, the wildland fire progressed. Access/escape routes for Los Alamos from the Jemez were restricted. LANL employees and Los Alamos residents began to feel the impact on Sunday, May 7th. Smoke and flames were visible. Due to proximity to the fire, personnel working at LANL's S-Site or TA-16 were evacuated Sunday afternoon. The Western Area, Royal Crest Trailer Park, and Quemazon areas of the townsite were evacuated for the first time that evening and crossing the Los Alamos Canyon to the main portion of LANL was not permitted.

Starting on May 8th, access to the LANL property was restricted to those required to work. Route 4 was closed to routine traffic from the Jemez past Bandelier to White Rock. Most LANL employees were told not to come to work, many businesses in the county were closed, and the schools were closed. As the fire progressed, the same held true through early afternoon on May 10th except that the residents of the Western Area were permitted to make brief visits home to retrieve some belongings. During the morning of May 10th, the unpaved Route 57 from Barranca Mesa through Rendija Canyon that went through Forest Service and San Ildefonso Pueblo lands was graded. The pueblo opened the normally locked gate at the junction with State Road 502.

It wasn't until during the day of May 10th that official requests to limit water usage were voiced. By afternoon, Los Alamos Fire Department (LAFD) personnel who had been fighting the fire in areas such as TA-16 were shifted to the Western Area of the town site. Although the fire had been burning for almost six days, the majority of the population didn't realize the seriousness of the evacuation notices when they came over the automatic phone calling system and the loud speaker announcements from vehicles driving through the residential neighborhoods. Many of those evacuating believed it was a precaution and that they would be away from home one to two nights at most.

The evacuation of the Hill, the Los Alamos town site area, went smoothly and much faster than expected. Within a few hours, the bulk of the population was evacuated from the Hill. However, it is now known that the flames had already reached the first of the Western Area homes to burn before the evacuation was completed.

During the evening hours of May 10th, it was also announced that the utilities were not functioning as desired. Multiple failures were occurring with the loss of electrical power to pump water and low water supplies. Firefighters on the ground were taking risks to attempt to save homes. Those fighting from the air were also assuming extra risk by flying over normally hazardous terrain with dangerously high winds.

By the early morning hours of May 11th, White Rock and portions of Espanola and Santa Clara Pueblo were also being evacuated due to the heavy smoke. However, these evacuations did not go as quickly. For White Rock, there was only one road out and a higher population than usual to be evacuated. Many people from the Hill had evacuated to the homes of family and friends or the temporary shelters in White Rock. It took over six hours to evacuate White Rock. Traffic in and around Espanola was so heavy that it barely moved. Shelters had also been established in Espanola. These remained open, but started accepting the additional influx of evacuees from the smoke.

With the evacuations, the media coverage intensified. What would happen with LANL? What abnormal hazards did it present to the population and the environment if portions burned? Was LANL property being protected before private homes? Which locals or former residents of the area could give accurate accounts of what was burning? How much news coverage was enough? Where were the firefighters coming from? How many could be brought in? How much equipment was available? ...

And then, there were the countless numbers of volunteers. There were those who stayed behind and kept a radio station on the air; fed the firefighters, National Guard, and the police from a small kitchen; maintained the evacuation shelters; attempted to register the evacuees; provided shelter in their homes for the evacuees and their assortment of pets; evacuated pets that had been left behind; cared for pets in temporary shelters; etc. The local radio station, KRSN, started the "Green Ribbon Campaign" to thank those who were working so hard to save/protect the homes and businesses as well as the Laboratory. Green ribbon appeared on people, their belongings, and vehicles.

With daylight on May 11th, the damage to the residential areas of Los Alamos became more visible. However, on the evening of May 11th, the fire hit the LANL property harder. It burned over and around the building housing the primary LANL EOC. From the TV coverage, it was evident that frequent explosions were occurring at the Laboratory. By the morning of May 12th, more damage at LANL was visible.

It wasn't until Mothers Day, May 14th, that those who had lost their homes were allowed a brief, escorted bus tour of their neighborhoods. It was also that day that White Rock residents were permitted to return home. For those on the Hill, some were allowed to return home on Monday, May 15th. For many whose homes survived the fire, it was weeks before they could return home. Utilities had been heavily affected by the fire - restart, repair, and/or replacement activities were required throughout the Hill and the Laboratory. Personnel who had already been working overtime spent many more days lighting each gas pilot light in homes and businesses. Members of the National Guard and a variety of police forces patrolled the residential areas and limited access to the burned areas. Citizens were recruited and trained to assist the patrols.

The fire contained on June 6th and considered extinguished on September 25th.

5.3 The Aftermath

Burned areas were evaluated for rehabilitation by the Burned Area Emergency Rehabilitation (BAER) Team and to identify what new hazards might exist. Flooding concerns were addressed where the only normal flooding concern would be to be caught in a dry arroyo or a canyon when there would be a sudden heavy summer thunderstorm. Water retention and diversion structures were built. One was placed upstream of TA-18. The Los Alamos Reservoir was emptied and strengthened. Mud slides and water carried debris now became a concern. The washout of fill bridges also became a concern. Because of LANL's work, another concern that was expressed was what toxic or hazardous contaminants would be transported by either the rain or the rainwater.

Remote area weather stations were installed in strategic locations to provide warning of heavy precipitation and allow the evacuation of canyons. Access to Los Alamos Canyon was restricted. The roadway access into the canyon was blocked by fences and gates. A summer daycare program was moved from the ice rink in the canyon to higher ground. Personnel and equipment at TA-41 were relocated. Actions were taken to ensure that the remaining structures and items at the Omega West Reactor were secured. Additional air, soil, and water monitoring began.

6.0 Impacts of the Fire

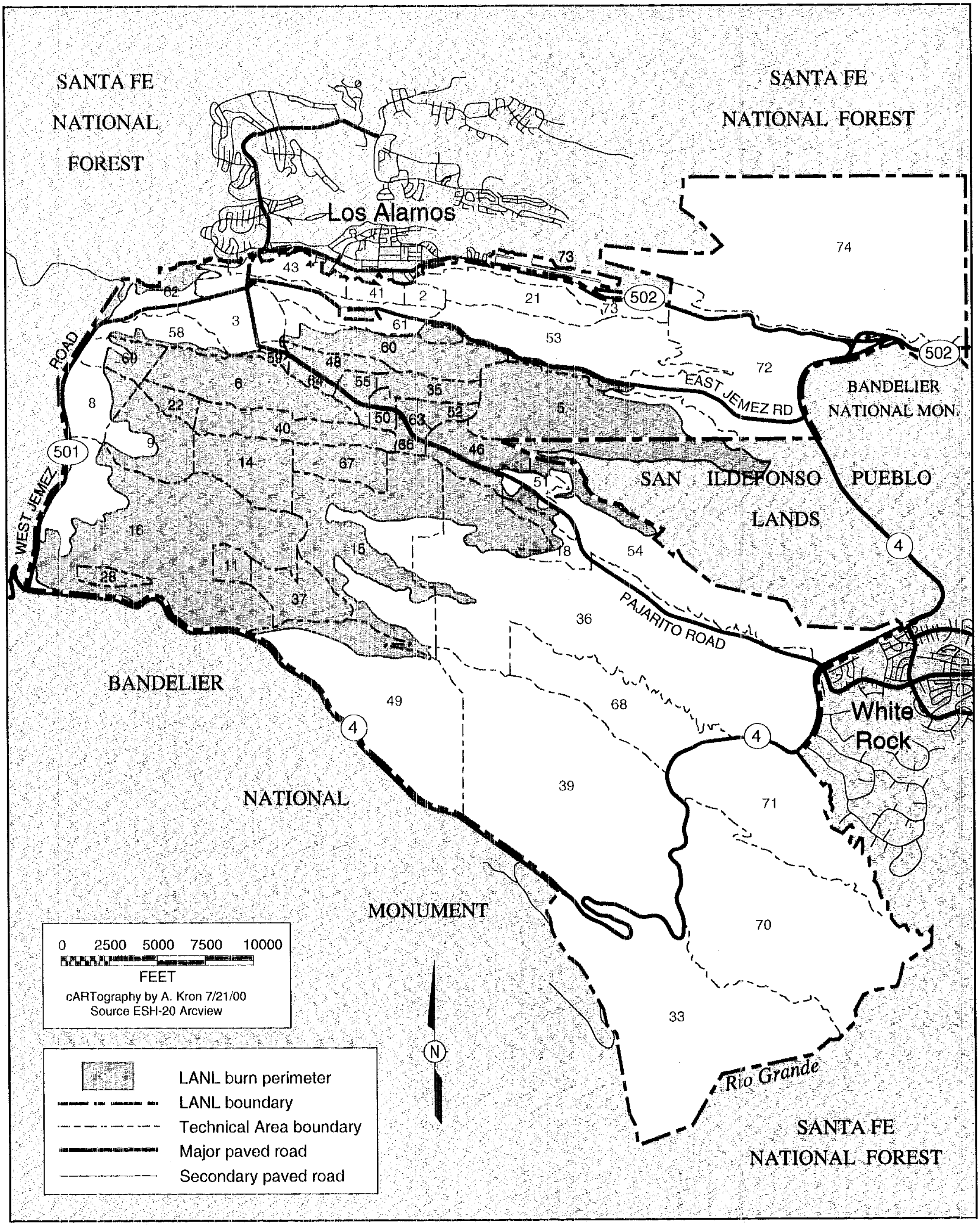
6.1 Impacts at LANL

Losses at LANL that were identified early included:

- Office trailers containing the only copy of scientists' work
- Vehicles
- Two weeks or more of paid downtime for UC staff
- Cost of recovery plan generation and implementation
- Cost of property protection from flooding and mudslides
- Cost of relocating personnel from canyons and burned or heavily damaged facilities
- Cost of temporary assignments for personnel during the fire
- Cost of temporary assignments for personnel who couldn't return to their work sites after two weeks due to damaged facilities and utilities
- Five of the original atomic bomb assembly structures at V-Site slated for historical preservation

Figure 2 [7] indicates the burned areas at LANL. Data on a few of the active LANL facilities are presented in Table 3.

Figure 2. Burned Areas at LANL.



Cerro Grande fire, area burned on Los Alamos National Laboratory.

Table 3. Summary Table of Some of the LANL Facilities Impacted by the Fire.

Location	Hazards	Proximity	Damage
TA-3: • Chemistry and Metallurgy Research (CMR) Facility • SIGMA Complex	Radioactive materials Chemicals Depleted uranium (DU) Chemicals	Burned in canyon to south of Pajarito Road	Buildings were not burned
TA-16: • Weapons Engineering Tritium Facility (WETF)	Tritium	Burned within 20 ft of the office transportables supporting WETF	Buildings sustained no damage Vegetation burned
TA-18: • Los Alamos Critical Experiments Facility (LACEF)	Radioactive materials	Burned trees on mesa to west of site	Buildings were not burned
TA-21: • Tritium Science and Fabrication Facility (TSFF) • Tritium Systems Test Assembly Facility (TSTA)	Tritium Tritium	Not applicable (NA)	Intermittent power outages delayed building reentry
TA-46: • Building 208 • Building 217/218	Radioactive materials -	Crossed Pajarito Road into Technical Area	Nearby transportables and vehicles at the TA that were adjacent to Pajarito Road burned
TA-48: • Radiochemistry (RC-1)	Radioactive materials Chemicals	Burned in canyons on both sides of the mesa and up to Pajarito Road south of the site	Buildings were not burned
TA-50: • Building 37 - Radioactive Materials Research, Operations, and Demonstration Facility (RAMROD) • Building 69 - Waste Characterization, Reduction, and Repackaging Facility (WCRRF) • Radioactive Liquid Waste Treatment Facility (RLWTF)	Radioactive wastes Radioactive wastes Low-level radioactive liquid waste	Burned in canyons on both sides of the mesa and up to Pajarito Road south of the site	Buildings were not burned
TA-53: • Los Alamos Neutron Science Center (LANSCE)	Residual radiation in equipment/targets when not operating, Radioactive sources, Chemicals Compressed gases Cryogens	Burned in canyon and up to Jemez Road south of the site	Buildings were not burned Metal sign for site on Jemez Road burned
TA-54:			

Table 3. Summary Table of Some of the LANL Facilities Impacted by the Fire.

Location	Hazards	Proximity	Damage
• Area G • Radioactive Assay Nondestructive Testing (RANT) Facility • Transuranic Waste Inspectable Storage Project (TWISP) Facility	Solid waste disposal site	Burned in canyons on both sides of the mesa and up to Pajarito Road south of the site	Buildings and storage areas were not burned
TA-55: • Plutonium Facility (PF-4)	Radioactive materials	Burned up to Pajarito Road and in adjacent canyon	Buildings were not burned
TA-59: • Emergency Operations Center (EOC)	NA	Burned through vegetation adjacent to building	Buildings were not burned Vegetation burned

Longer-term impacts have included:

- The environment, safety, and health emergency declared by the Laboratory on June 5th ended on October 11th.
- Program delays such as bringing the Dual-Axis Radiographic/Radiography Hydrotest (DARHT) facility on line.
- A delay in issuing the environmental assessment on wildfire hazard reduction[1] that had been scheduled for release in June 2000.
- Increased sampling of air, soil, and water.
- Excavating and controlling an underground fire at an old waste dumping site.
- Removal of contaminated soil in canyons to minimize the potential of increased concentrations of radioactive materials or hazardous chemicals in the runoff water.

6.2 Impacts on Los Alamos County and the Surrounding Communities

Although no human lives were lost during the fire, there were a variety of other losses within the affected communities. In Los Alamos County, the more significant losses included:

- Approximately 400 homes and their contents were destroyed.
- Utility services in burned areas were severely damaged.
- Acres of Ponderosa pine trees were burned.
- Wildlife and their habitat were destroyed.
- Personal and business incomes were lost.
- Some small businesses have closed.
- Personal security is no longer taken for granted.
- Hazardous chemicals used in the slurry drops during the fire appeared in last summer's runoff.
- Outdoor activities in the burned areas and the canyons were restricted.

There have also been changes in the county:

- A temporary mobile home village was established by FEMA to house those who lost their homes. This was placed in an open area used for recreation and required the installation of supporting utilities.
- Areas were modified to handle storm water runoff.
- Contingency plans were made to provide emergency supplies for areas that might be cutoff if heavy precipitation occurred.

In the surrounding communities, impacts included:
- Sacred grounds of the Santa Clara and San Ildefonso Pueblos were damaged and some water supplies were affected.
- Hazardous chemicals used in the slurry drops during the fire appeared in last summer's runoff.
- Acres of Ponderosa pine trees and pinon and juniper trees were burned.
- Wildlife and their habitat were destroyed.
- Personal and business incomes were lost.
- Outdoor activities in the burned areas and the canyons were restricted.
- Santa Clara Canyon remained closed over the summer.
- Logging has started in some of the burned areas.

7.0 Benefits of the Fire

LANL and Los Alamos also derived some benefits from the fire. These included:
- Some community connection beyond the Hill for Los Alamos and LANL - The separation/isolation between Los Alamos and the surrounding areas temporarily disappeared. The surrounding communities offered support by opening homes, shelters, and businesses as well as giving donations and supplying manpower to deal with the fire.
- Replace aging structures and infrastructure at LANL and the Los Alamos town site - An opportunity was presented to improve housing and utility services when it came time to replace burned structures and damaged equipment.
- Need for local communications recognized - More of an effort was made to replace KRSN's aging equipment and set up the new transmission tower that had been delayed for months.
- Community involvement – Initially, the majority of the community worked together to help each other and begin to rehabilitate the burned areas. The community cohesiveness for the rehabilitation efforts still exists a year after the fire, but the helping each other is not as evident.
- Realistic modeling of a fire scenario - The fire scenario in the SWEIS was examined in a special yearbook[7] to see how closely it paralleled the Cerro Grande Fire. The fire closely followed the path selected in the SWEIS fire scenario, but neither breached material containment nor yielded the estimated analytical doses.
- Memorial Day - Over the Memorial Day weekend, there was a community celebration at Ashley Pond for everyone to spend some time together. The University of California provided funding for the event. In addition, there was the usual observance of Memorial Day at Guaje Pines Cemetery.

- Building code and zoning changes - The county has adopted new fire resistance requirements for new structures.
- Need for defensible space around LANL structures and private homes recognized - As LANL had started doing around its structures several years ago, residents have been clearing vegetation around their homes to provide more protection to their homes from nearby fires. Initiatives have been undertaken to improve existing and to create more fire breaks at LANL in the surrounding area. Throughout the area, additional tree thinning has been done as funding and manpower permit.

8.0 Post-Fire Safety Analysis

Table 4 summarizes the information that has been accumulated to date on the treatment of wildfires in the LANL facility safety analysis documents. Not everything that happened at the facilities relative to authorization basis compliance was documented during and immediately after the fire. This was a decision made by DOE.

Table 4. Comparison of Wildfire Treatment in Facility Safety Analysis Documents.

Facility	Safety Analysis Document at Time of Fire	Wildfire Treatment	New Documentation since Cerro Grande Fire
TA-16 WETF	"The Weapons Engineering Tritium Facility Safety Analysis Report," 1989 [8]	See Section 9.0 of this paper	See Section 9.0 of this paper
TA-18 LACEF	"Safety Analysis Report for the Los Alamos Critical Experiments Facility (LACEF) and Hillside Vault (PL-26)," June 1994	(Not reviewed for inclusion in paper at this time.)	BIO in development process Flooding analysis caused a water retention structure to be constructed in the canyon upstream of the TA-18 buildings.
TA-21-209 TSFF	"Safety Assessment for the Tritium Salt Facility TA-21-209," Report No. SA 86-2, June 1986, Revised February 1987	Nothing on wildfires	None
TA-50-01 RLWTF	"Final Safety Analysis Report for Radioactive Liquid Waste Treatment Facility at TA-50-01," Volume III, October 1995	Nothing on wildfires	SAR in development process
TA-50-69 WCRRF	"Hazard Analysis for Interim Technical Safety Requirements (ITSRs) Waste	Section III. Hazard Analysis Results, page 8: "Fire Safety AC Requirements. ... the AC	(Not reviewed for inclusion in paper at this time.)

Table 4. Comparison of Wildfire Treatment in Facility Safety Analysis Documents.

Facility	Safety Analysis Document at Time of Fire	Wildfire Treatment	New Documentation since Cerro Grande Fire
	Characterization, Reduction, and Repackaging Facility (WCRRF) Technical Area 50," February 2000	requirements also address the potential hazard from vegetation and brush both on the WCRRF site and on adjacent sites near the WCRRF boundary." Section IV. Consequence Estimates, page 16: A bounding fire scenario affecting the entire inventory of radioactive material outside Building 69 was evaluated. MAR = 15 kg of Plutonium (Pu) -239, dose at 1100 m = 1.1 rem Section V. Hazard Analysis Tables, page 44: "1.1.2 Brush fire spreads to stored waste; Risk Rank 3 - undesirable"	
TA-53 LANSCE	"Basis for Interim Operation (BIO) for the 1L Target 2000-2002 Beam Delivery Periods," December 10, 1999	Nothing on wildfires	(Not reviewed for inclusion in paper at this time.)
TA-55 PF-4	"TA-55 Final Safety Analysis Report," TA-55-PRD-108-01.1, LA-CP-95-169, Rev. 1, August 1996	Chapter 11, Section 11.4.1 Fire Hazards: "The nearest distance from outdoor storage units (chemical storage units, gas bottles, or compressed gas trailers) to stands of trees (approximately 300 ft) is such that the only meaningful exposure from a wildland fire is flaming debris being thrown long distances; the noncombustible construction of the storage units makes the need for additional protection unnecessary. There are no wildland fire fuels except grasses within the TA-55 protected area and the storage units are located within paved areas. The only combustible	90% Draft TA-55 SAR Chapter 3: Identifies forest/brush fires under Other hazards. These are treated as an initiator that could lead to the creation of other hazards and were reviewed for the potential of creating a fire within the TA-55 site boundary, including PF-4, 55-185, and other buildings and areas. Only scenario in Appendix 3B hazard analysis is "Forest fire next to PF-4 impacts facility." No accident analysis.

Table 4. Comparison of Wildfire Treatment in Facility Safety Analysis Documents.

Facility	Safety Analysis Document at Time of Fire	Wildfire Treatment	New Documentation since Cerro Grande Fire
		construction within the TA-55 protected area are buildings PF-107, PF-189, and PF-218. None of these buildings represent a potential for fire spread between buildings or fire spread to hazardous materials being protected."	

9.0 Analysis for the Weapons Engineering Tritium Facility

The Weapons Engineering Tritium Facility (WETF) was in the process of revising its authorization basis documentation at the time the Cerro Grande Fire started. The following is an example of what one facility experienced with the fire, details on the treatment of wildfires in its safety analysis report (SAR) at the time of the fire, and what is currently proposed for its new documented safety analysis. The new documentation recently went through a 90% review.

9.1 The Cerro Grande Fire Effects on WETF

The Los Alamos Weapons Engineering Tritium Facility (WETF) is directly adjacent to Ponderosa Pine forested areas. In addition to the on-site process buildings, there are several transportable buildings used for offices including some with combustible wood siding exteriors. During the Cerro Grande fire in May 2000, the wildfire for the most part remained on the ground burning the fuel available there, except for totally burning a few of the nearby trees. The LANL firefighters brought a bulldozer to the site the day the fire first approached the WETF to fell some of the trees and to make a firebreak/road to hopefully protect the transportable buildings and the main facility building. A serious concern was that if the transportable buildings were to ignite that the fire would generate sufficient heat to ignite part of the exterior of the WETF itself.

The firefighters were able to save the process buildings and also protected the more vulnerable transportables. Their courageous efforts were evident upon the workers return to the site. Large quantities of water used to prevent the buildings from burning had cut trenches in the soil around the buildings as it flowed down the hill away from the structures. The fires burned through the area three times over the course of several days. Generally, fuel on the ground was consumed and the pine trees were scorched several feet up their trunks. Burned areas were evident upon return to the site within twenty feet of the transportable buildings.

9.2 Fire Hazard Analyses

Because of the concern regarding future fires, the performance of the WETF building material, the expanded styrene insulation that covers the exterior of the building, has been evaluated. The evaluation was reported in the fire hazards analysis relative to the effect of a potential future wildlands fire, and the analysis was performed in recent months since the Cerro Grande Fire during the period of time in which the ninety percent SAR has been written.

The Laboratory's Ecology Group, ESH-20, has recently provided recommendations for continuing maintenance of the wildlands around WETF[9], and provided the calculations for predicting fire behavior based on U.S. Forest Service methods. Data from these calculation worksheets were used to estimate the possible heat energy output and size of a flame front for a wildland fire near WETF.

Fire exposure of the Exterior Insulation and Finish System (EIFS) installed on much of WETF has been analyzed in an appendix of the new FHA that is part of the SAR currently being completed. This analysis has been included as an attachment (Appendix A) to this paper. Nuclear facilities in forested areas across the United States could consider performing such an analysis for their locations as part of a future SAR update or upgrade. For WETF, some data from the insulation system's manufacturer is available and has been relied upon to show wildlands fire exposure of the facility exterior is not a problem. The heat flux that WETF would be exposed to during the postulated conservative wildlands fire scenario was calculated and compared to test data provided by the manufacturer of the exterior insulation system. The Southwest Research Institute Test Report concluded that ignition of the tested assemblies does not occur with an exposure of 12.5 KW/m^2 for 20 minutes. The conclusion reported in the FHA is that this test demonstrates that the exterior insulation system is highly unlikely to ignite at lower heat flux exposure levels. The goal of the analysis in the FHA was therefore to show that the heat flux that could be expected from a wildlands fire in the future would be less than the physical experiment exposure which did not result in the ignition of the siding in a 20 minute exposure.

The layout of WETF with respect to the wildlands was measured to gather data for the analysis. From the physical measurements that were taken, the area of a flame front in the burning trees was determined. The percentage of the total flame front radiant energy that would be intercepted by the WETF wall was calculated based upon a rectangular flame front exposing an elemental area of the WETF wall parallel to the flame front plane.

The evaluation was performed based on conservative estimates of the physical phenomena that could occur during a wildlands fire near the WETF. U.S. Forest Service Fuel Model 2 was used for the evaluation. Current conditions existing at WETF are less challenging than Fuel Model 2. For the evaluation to remain conservative wildlands conditions in the proximity of WETF must continue to be maintained within the parameters of Fuel Model 2 or in a less challenging more conservative condition and the physical layout must not be inadvertently changed.

Conservatism in the calculations for WETF was using the U.S. Forest Service Model achieved by basing the scenario on:

- severe drought conditions were assumed to exist at the time of the postulated wildfire in the area of the facility,
- maximum estimated flame length was used for the view factor portion of the calculation,
- minimum estimated flame length for radiant heat flux at the flame front calculation,
- width of the flame front is assumed to be 100 times the width of the exposed wall,
- most exposed elemental area in the WETF wall is tested against the criteria by using heat energy output for a wind driven fire on 5% slope,
- also used a flame front spread rate for a fire with no wind on level ground, and
- the wall was assumed to be exposed at the maximum intensity (nearest flame approach) for the entire time it takes for the flame to travel 10 meters in the direction of the facility wall.

Recommendations from the Valerio Analysis[9]: "Based on Fuel Model 2 data, it is important to control grasses, needles, leaf litter to a maximum height of 6 inches within 100 feet of each building at the WETF complex. Thin trees within 200 feet of WETF so that their canopies do not touch. Keep grasses, needles, and leaf litter to a maximum height of 5 inches within 200 feet of WETF. Maintain fuels under the trees within 200 feet of WETF within the parameters of United States Forest Service Fuel Model 2. Areas between sidewalks and other paved surfaces, and the WETF building walls covered by the Exterior Insulation and Finish Systems should be stripped of vegetation. A non-combustible cover, such as gravel, should be placed over exposed soil to prevent vegetation growth."

The calculated heat flux exposure level of 4.48 Kw/m^2 calculated in the FHA appendix using the Forest Service Model indicates that the exterior insulation system on the process facility is extremely unlikely to ignite under the postulated wildlands fire scenario.

9.3 Current WETF SAR

The Pajarito Plateau, upon which Los Alamos is situated, has the second highest lightning strike density in the United States. A future lightning strike in the adjacent forests could again threaten the WETF if another wildlands fire were to be initiated.

Under Natural Phenomena in the currently in effect WETF SAR[8] dated 1989, it states the following:

The probability of damage to the WETF from natural phenomena is judged to be small.

<u>FIRES</u>

Although fires would be very disruptive at the WETF, the probability of their occurrence is very small. The combustible loading is very small in tritium-handling areas. Every effort is being made to eliminate Class A (wood, textile, paper) and Class B (oil, gasoline, paint, grease) combustibles from the tritium areas. The small quantities (volume and mass) of tritium used at WETF do not substantially increase the combustible loading.

Whereas a forest fire is a real peril in many unoccupied areas in TA-16, fire breaks and cleared areas around buildings have been provided to reduce this threat. The LAFD is trained and experienced in forest fire fighting and performs standby service regularly during experimental explosive shot activity. Adjacent forested lands to the south and west of the Laboratory boundaries are lands that are owned by the U.S. Park Service and the U.S. Forest Service, respectively. These organizations have fire fighting teams available on-call to fight fires in these areas. A contractor maintains the fire breaks on Laboratory property and periodically clears slash from the Laboratory's forested areas. In two previous forest fires, American Springs (June 1954) and La Mesa (June 1977), no major Laboratory buildings were damaged, although there were serious threats for several hours.

In the new SAR, the discussion is much more thorough and the discussion is supported by a Fire Hazard Analysis (Revision 0-March 23, 2001). Previous to the Cerro Grande fire, the trees in the immediate vicinity of WETF had been thinned considerably. Most of the fuel on the ground had also been removed. There was a green belt for some distance around most of the facilities, but trees were still within 50 feet of some of the transportables.

The wildlands fire hazard assessment for WETF, per NFPA 299, Standard for Protection of Life and Property From Wildfire, results in a low hazard rating. The ratings for some other structures near WETF are medium and high hazard.

Roof fires from flaming brands or radiant heat are not a concern because of the use of Class A roofing systems throughout WETF. A Class A roof is designed, tested, and listed to be extremely resistive to ignition under this type of fire exposure.

9.4 Future

The analysis concerning wildlands fire performed for WETF is the first to be performed for a facility at LANL according to the analysts that completed the study. Some of the facilities at LANL are more protected than the WETF in that they are not in the middle of a forest, or they are in the area where only smaller, and less dense pinon trees are present. As additional SARs are updated or upgraded for other LANL facilities, more of the wildlands fire analyses are certain to be performed to determine the risk to the facilities from wildlands fires.

The Pajarito Plateau, upon which Los Alamos is situated, has the second highest lightning strike density in the United States. A future lightning strike in the adjacent forests could again threaten the WETF if another wildlands fire were to be initiated. As a result, it will be a firm requirement in the new WETF SAR to maintain the areas surrounding the WETF in a condition of U.S. Forest Service Fuel Model 2 or better at all times.

10.0 Lessons Learned

10.1 Lessons Learned in the Community

Some of the lessons learned at the community level include:

- Update call lists - Some homes did not receive automated phone calls to evacuate because they were not on the county's list. The automated system does not recognize delivering the message to an answering machine versus a person.
- What neighbor means – Assistance came from many sources and in many ways. Code of the West, Thank You events, Community Celebration, statues
- Government agencies – Recovery assistance was provided by numerous government agencies. Including FEMA, the BAER Team, Forest Service, and Agriculture.
- Insurance – Insurance companies providing coverage to residents and businesses but without a local presence opened temporary offices.
- The evacuation - The multiple exit routes from the Hill versus the one exit route from White Rock made an emergency evacuation easier and faster.
- Emergency planning - Evacuation routes and approaches for White Rock need to be addressed for the future. Since the fire, the Los Alamos County Police have developed an evacuation plan for White Rock. There was no evacuation plan before the fire.
- Utility supplies – Backups and emergency sources may need to be strengthened. Water pumps requiring electricity to function may need alternate power sources for emergencies. More gravity feed water storage tanks may be needed for fighting fires. (North Mesa had no gravity feed water tank at the time of the fire.)
- Adaptation - The community has learned to relocate or modify activities rather than cancel them.

10.2 Lessons Learned at LANL

At LANL, some of the specific lessons learned included:

- Several researchers lost the sole copies of years of their work when transportables were destroyed in the fire. This has emphasized the importance of having backup for irreplacable data.
- Real data now exists on how some of LANL's nuclear, chemical, and explosive facilities withstand fire of this type. What failed and what worked can be evaluated.
- Communications have been increased for those working in remote areas.
- Weather conditions have caused more stoppage of work (Personnel working in canyons and burned areas were pulled out of those areas with the threat of thunderstorms.
- Multiple access routes are helpful. Personnel have been inconvenienced when mudslides closed roads.
- Alternate utility supplies may be desirable.
- The EOC is outdated and cramped.
- A unified command was beneficial - Los Alamos County and Laboratory officials worked together with DOE in the Laboratory's EOC.
- A single central database of Laboratory employee information is needed.

A summary report[10] was prepared identifying LANL's lessons learned during recovery. Management systems, support services and infrastructure, and the workers are discussed in this report. At the time the report was prepared, some workers were still displaced, some programmatic work had not been resumed, and some damaged or destroyed facilities had neither been reopened nor replaced. The lessons learned from recovery include:

- Management systems - basically improve institutional guidance.
  - Partnering with DOE Facility Representatives was helpful.
  - Negotiate relief from applicable regulatory and oversight organizations.
  - Establish clear institutional guidance and expectations for conditional moratoriums or exemptions, if granted, with appropriate documentation and communication.
  - Incorporate criteria for re-entry of facility and re-start recovery procedures for programmatic operations into all facility emergency plans.
  - Establish an institutional prioritized list of key or critical facilities for re-start in the event of a lab-wide emergency shutdown.
  - Evaluate facility damage expertise by emergency type.
  - Establish institutional guidance for emergency response and recovery/re-start procedures for non-nuclear facilities.
  - Improve funding allocation process for recovery activities.
  - Establish a comprehensive institutional emergency and recovery contingency plan that is documented, communicated, and trained-to.
  - Review organizational structure and requirements of emergency operations for Laboratory-wide emergency and recovery response preparedness.
  - Improve communications at all levels.
  - Consider how to deal with both short-term and long-term recovery on a site-wide basis.
  - Establish an effective change-control protocol for emergency and recovery operations.
  - Develop and provide emergency recovery procedures and training.
- Support services and infrastructure - support roles need clarification and infrastructure requires improvements.
  - Define support-service contractors' roles and responsibilities during a site-wide emergency recovery operation.
  - Evaluate institutional facility support resources required for emergency recovery efforts.
  - Evaluate institutional work process for improvements.
  - Establish a guidance template for subcontractor training and access requirements during an emergency and recovery event.
  - Enhance communication and utilization of ES&H capabilities, resources, data, and expertise to LANL community.
  - Establish an off-site data storage facility.
- Workers - improve communications.
  - Communicate institutional expectations for recovery work.
  - Clarify guidance from DOE regarding employees receiving counseling support and losing security clearances and communicate to workers.

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Appendix A
EVALUATION OF WILDLAND FIRE EXPOSURE TO WETF

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October 16, 2000

1.0 Introduction

The WETF Facility is in near proximity to Ponderosa Pine forested areas. The Pajarito Plateau, upon which Los Alamos National Laboratory is situated, has the second highest lightning strike density in the United States. Wildland fires are a common occurrence. The performance of the combustible exterior insulation system of WETF under prolonged exposed to a wildland fire is unknown. It is conceivable that the expanded styrene insulation could melt, resulting in a pool of burning styrene around the building.

2.0 Methodology

Pat Valerio, LANL – ESH-20, provided recommendations for continuing maintenance of the wildlands around WETF, and provided worksheets for predicting fire behavior based on U. S. Forest Service methods (See WETF Fire Hazard Analysis, Appendix B – WETF Wildfire Analysis). Data from these worksheets was used to estimate the possible heat energy output and size of a flame front for a wildland fire near WETF.

The physical layout of WETF with respect to the wildlands was measured (See Figure 1.) From these measurements the area of a flame front that can see WETF was determined. The view factor (the percentage of radiant energy from the flame front that is intercepted by a WETF wall) was calculated based upon a rectangular flame front exposing an elemental area of the WETF wall parallel to the flame front plane.

The heat flux that WETF would be exposed to during the postulated wildland fire scenario was calculated and compared to test data provided by the manufacturer of the exterior insulation system, (See WETF Fire Hazard Analysis, Appendix D – Omega Point Laboratories letter regarding BOCA Section 1406.2.1 Test Equivalence to NFPA 168, and Southwest Research Institute Test Report SwRI Project No. 01-4890-015.). The Southwest Research Institute Test Report concludes that ignition of the tested assemblies does not occur with an exposure of 12.5 KW/m^2 for 20 minutes.

3.0 Discussion

This evaluation is based on conservative estimates of the physical phenomena that could occur during a wildland fire near WETF. US Forest Service Fuel Model 2 was used for the evaluation. Current conditions are less challenging than Fuel Model 2. For this evaluation to remain valid, wildland conditions in the proximity of WETF must be maintained within the parameters of Fuel Model 2 or a less challenging condition, and the physical layout must not change.

Conservatism is achieved by basing the scenario on:

- severe drought conditions
- maximum estimated flame length for view factor calculation
- minimum estimated flame length for radiant heat flux at the flame front calculation
- by assuming the width of the flame front is 100 times the width of the exposed wall
- the most exposed elemental area in the WETF wall is tested against the criteria
- using heat energy output for a wind driven fire on 5% slope
- using flame front spread rate for a fire with no wind on level ground
- assuming the wall is exposed at the maximum intensity (nearest flame approach) for the entire time it takes the flame to travel 10 meters in the direction of the WETF wall

4.0 Conclusions and Recommendations

Based on this evaluation it is extremely unlikely that a wildland fire can ignite the exterior insulation system of WETF.

Recommendations from the Valerio Analysis: "Based on Fuel Model 2 data, it is important to keep grasses, needles, leaf litter to a maximum height of 6 inches within 100 feet of each building at the WETF complex. This can be accomplished by mowing 2-3 times per summer. Large fallen branches, fallen trees, etc should be removed from the 100 foot buffer area annually. New buildings should be constructed of non-flammable building materials including the roof. Existing buildings should be inspected for flammable building materials and corrected if feasible."

In addition, the approximately 10 foot space outside of the security fence, and the areas within the security fence within 100 feet of WETF, must be kept clear of all growth except grasses. Isolated ornamental shrubs are allowable within the security fence.

5.0 Calculations

Assumptions

1. The flame front can be represented as a rectangular surface with homogeneous luminosity
2. The rectangular flame front of a wildland fire and the most exposed elemental area of WETF are parallel
3. Atmospheric conditions are 90°F and 7% relative humidity

4. The width of the flame front is 2570 meters
5. The nearest exposed wall of WETF is the exterior of Rooms 100, 101, 103 & 110
6. The installed exterior insulation system will behave similarly to the systems in the Southwest Research Institute Report when under fire duress

Radiant Heat Flux from the flame front (Refer to Valerio Analysis)

HR (heat release from flame) = 242 Kw/m (837 Btu/Ft-sec);
$\chi_2 - \chi_1$ (width of flame front) = 2570 – 0 = 2570 meters (8432 Ft.);
$\gamma_2 - \gamma_1$ (minimum height of flame front that can see WETF) = 1.95 – 0 = 1.95 meters (6.39 Ft.);
A_1 (area of the flame front) = $(\chi_2 - \chi_1)(\gamma_2 - \gamma_1)$ = 5006 m^2 (53,884 Ft^2);
$\dot{Q}_{FF}$ = Heat Flux at the flame front

$$\dot{Q}_{FF} = \frac{HR(\chi_2 - \chi_1)}{A_1} = \frac{242 \bullet 2570}{5006} = 124.2\ Kw/m^2$$

Maximum Flame Height that can See WETF (Refer to Figure 1)

H (total flame height) = 10 Ft.;
h = Maximum flame height that can see WETF;
L = Maximum height of flame below the top of the berm that can see WETF;
Elevation from top of berm to top of WETF wall = 15 FT.;
Distance from top of berm to WETF wall = 72 Ft.;
Distance from top of berm to tree line (flame front) = 30 Ft.;
Height of flame below the top of the berm = H – 2 = 8 Ft.

$$\theta = \tan^{-1}\left(\frac{15}{72}\right) = 11.7683^\circ$$

$$L = 30 \tan\theta = 6.25 Ft.$$

$$h = L + 2 = 8.25 Ft.$$

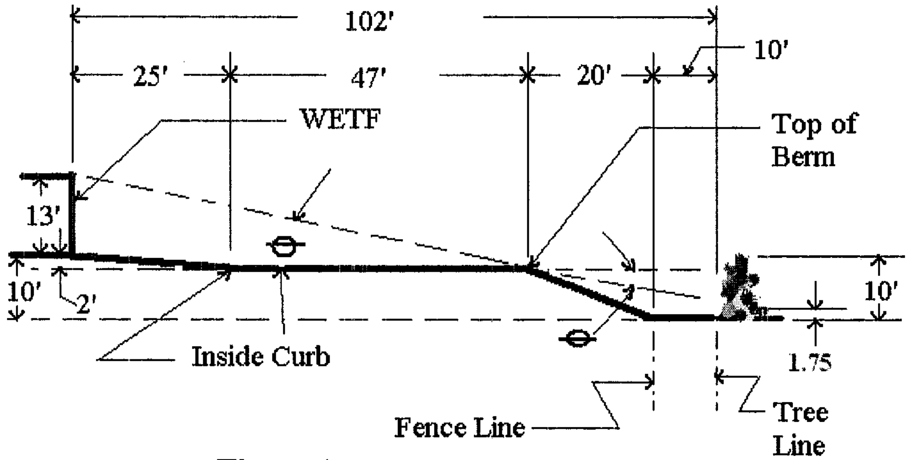

Figure 1

View factor from the flame front to the exposed wall of WETF (Refer to Figures 1 and 2)

Horizontal distance between the flame front and the exposed WETF wall = 31.1 m

H_{dA} = Location of exposed elemental wall area above the top of the flame (top of the flame and the bottom of the wall are at the same elevation)(H_{dA} = 0 is at the top of the wall)

H_F = Maximum flame height that can see WETF (dependent on H_{dA}) = $\frac{30(15 - H_{dA})}{72} + 2$

Width of flame front = 2570 m;

A_O = Area defined by ½ the width of the flame front and the height of the elemental area above the lowest level of the flame front that can be seen by the elemental area;

A_S = Area defined by ½ the width of the flame front and the height of the elemental area above the top of the flame front;

A_F = ½ the Area of the flame front that can see WETF;

$F_{2A_F \rightarrow dA}$ = View Factor from the flame front to the exposed elemental area of the WETF wall (dependent on H_{dA});

$F_{A_O \rightarrow dA}$ = View Factor between A_O and an elemental area located perpendicular to and directly opposite one corner of A_O (dependent on H_{dA});

$F_{A_S \rightarrow dA}$ = View Factor between A_S and an elemental area located perpendicular to and directly opposite one corner of A_S (dependent on H_{dA});

$F_{A_F \rightarrow dA}$ = View Factor between A_F and an elemental area located perpendicular to A_F (dependent on H_{dA})

Generally $F_{A \rightarrow dA} = \int_A \frac{\cos\beta_1 \cos\beta_2}{|\vec{R}|^2 \pi} dA$; where $\vec{R}$ is the line of sight between the elemental area and the surface element

$$F_{A_{O\,or\,S} \to dA} = \frac{1}{2\pi}\left\{\frac{X}{\sqrt{1+X^2}}\tan^{-1}\left[\frac{Y}{\sqrt{1+X^2}}\right] + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\left[\frac{X}{\sqrt{1+Y^2}}\right]\right\}$$

Where $X = (H_{dA} + H_F) \div 31.1$ for A_O, or $H_{dA} \div 31.1$ for A_S;
$Y = (2570 \div 2) \div 31.1 = 41.3$

$$F_{A_O \to dA} = F_{A_S \to dA} + F_{A_F \to dA}$$
$$F_{A_F \to dA} = F_{A_O \to dA} - F_{A_S \to dA}$$
$$F_{2A_F \to dA} = 2F_{A_F \to dA}$$

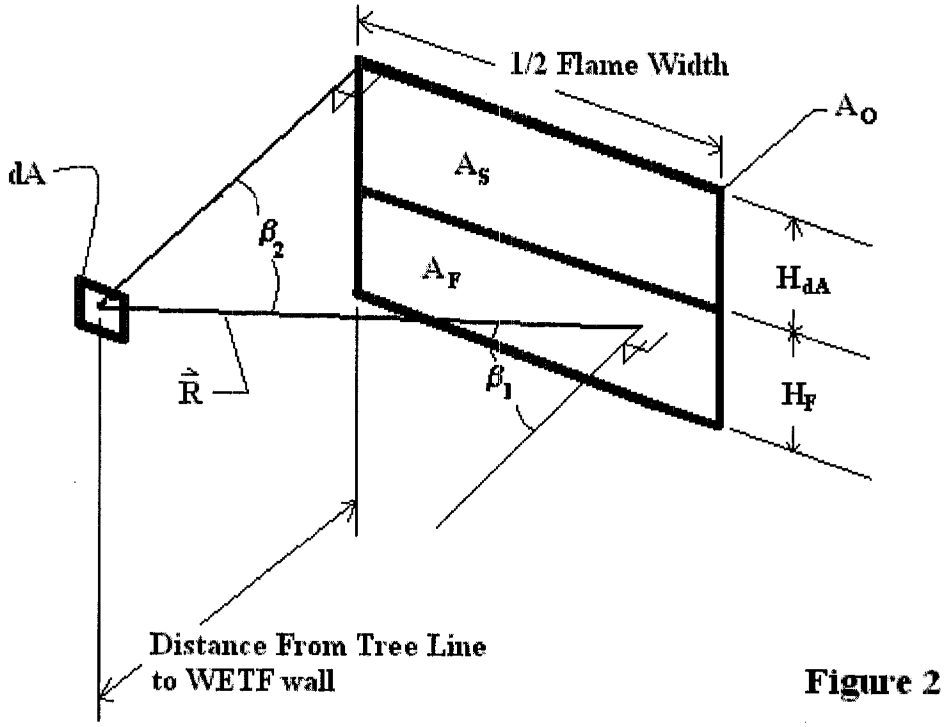

Figure 2

H_{dA}	$F_{A_O \to dA}$	$F_{A_S \to dA}$	$F_{A_F \to dA}$	$F_{2A_F \to dA}$
0	0.0510	0.0316	0.0194	0.0388
0.40	0.0467	0.0285	0.0182	0.0364
0.79	0.0424	0.0254	0.0171	0.0341
1.19	0.0381	0.0222	0.0159	0.0317
1.58	0.0338	0.0191	0.0147	0.0293
1.98	0.0293	0.0159	0.0134	0.0268
2.38	0.0248	0.0127	0.0121	0.0243
2.77	0.0205	0.0096	0.0109	0.0217
3.17	0.0159	0.0064	0.0096	0.0191
3.57	0.0114	0.0032	0.0082	0.0165
3.9624	0.0069	0	0.0069	0.0139

The maximum $F_{2A_F \rightarrow dA}$ = 0.0388 at the top of the WETF wall.

Maximum Radiant Heat Flux at the exposed WETF wall

$\dot{Q}_W$ = Radiant heat flux at the exposed WETF Wall;
τ (Transmissivity in air) = 0.93 (Handbook of Fire Protection Engineering, 2nd Ed., Fig. 3-11.20)

$$\dot{Q}_W = \tau \dot{Q}_{FF} F_{2A_F \rightarrow dA}$$

$$\dot{Q}_W = 4.48\, Kw/m^2$$

Estimation of duration of exposure

From the Valerio Analysis, a circular fire perimeter will grow at 84.5 m/hr (4.2 chains per hour) on level ground with no wind. The radial spread will be 0.223 m/min. Taking this radial spread as the ground velocity of the flame front and assuming the WETF wall is meaningfully exposed by only the 10 m of wildland nearest WETF (i.e. while burning 10 m beyond the treeline until reaching the treeline), results in an exposure time of approximately 45 minutes.

6.0 Comparing Calculated Exposure to Test Data Provided by the Manufacturer of the Exterior Insulation System

(See WETF Fire Hazard Analysis, Appendix D – Omega Point Laboratories letter regarding BOCA Section 1406.2.1 Test Equivalence to NFPA 168, and Southwest Research Institute Test Report SWRI Project No. 01-4890-015.)

Most common combustible materials will not ignite regardless of exposure duration when exposed to heat flux levels less than 12.5 Kw/m^2. The Southwest Research Institute test based on 12.5 Kw/m^2 for 20 minutes demonstrates that the exterior insulation system is highly unlikely to ignite at lower heat flux exposure levels. The calculated heat flux exposure level of 4.48 Kw/m^2 indicates that the exterior insulation system is extremely unlikely to ignite under the postulated wildland fire scenario. The Safety Factor is approximately 2.68.