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Title **Final Progress Report on Los Alamos National Laboratory Cerro Grande Fire Rehabilitation Activities**

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Cover Photo: June 2003, native vegetation recovery and wattles near Cañon de Valle on Los Alamos National Laboratory.

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1.0 INTRODUCTION

This report details the treatments and results of the Emergency Rehabilitation treatments installed at Los Alamos National Laboratory (LANL) over the past four years (2000–2003). The Laboratory has been directed by the Department of Energy (DOE) through the Special Environmental Analysis (SEA) (DOE 2000) to conduct assessments, implement mitigation, and monitor annually the condition of the burned area. The SEA directed LANL to repair, replace, or repeat rehabilitation actions until at least 90% of the pre-fire vegetation is achieved or until post-fire storm events approximate pre-fire rates.

To meet the requirements of the SEA, the Risk Reduction & Environmental Stewardship Water Quality & Hydrology (RRES-WQH) and Ecology (RRES-ECO) groups, with the help of the Forest Service and Merrick and Co., developed the Burned Area Rehabilitation Tracking (BART) system. BART is a geographic information system (GIS)-based tracking and monitoring system designed to identify and generate reports of additional work needed in the treatment units based on field assessments. Five BART assessments have been completed for this report.

1.1 Regional Setting

LANL and the associated residential areas of Los Alamos and White Rock are located in Los Alamos County, north-central New Mexico, approximately 60 miles (100 km) north-northeast of Albuquerque and 25 miles (40 km) northwest of Santa Fe (Fig. 1).

The 25,600-acre (10,240-ha) LANL site is situated on the Pajarito Plateau. This plateau is a series of finger-like mesas separated by deep east-to-west-oriented canyons that are cut by intermittent streams. Mesa tops range in elevation from approximately 7,800 ft (2,400 m) on the eastern flanks of the Jemez Mountains to about 6,200 ft (1,900 m) at their eastern termination above the Rio Grande.

Most of the finger-like mesas in the Los Alamos area are formed from Bandelier Tuff, which is composed of ash fall, ash-fall pumice, and rhyolite tuff. The tuff, ranging from nonwelded to welded, is more than 1,000 ft (300 m) thick in the western part of the plateau and thins to about 260 ft (80 m) eastward above the Rio Grande. Major eruptions in the volcanic center of the Jemez Mountains deposited the tuff about 1.2 to 1.6 million years ago.

On the western part of the Pajarito Plateau, the Bandelier Tuff overlaps onto the Tschicoma Formation, which consists of older volcanic materials that form the Jemez Mountains. The conglomerate of the Puye Formation underlies the tuff in the central plateau and near the Rio Grande. Chino Mesa basalts inter-finger with the conglomerate along the river. These formations overlay the sediments of the Santa Fe Group, which extend across the Rio Grande Valley and are more than 3,300 ft (1,000 m) thick. LANL is bordered on the east by the Rio Grande and is within the Rio Grande rift. Because the rift is slowly widening, the area experiences frequent minor seismic disturbances.

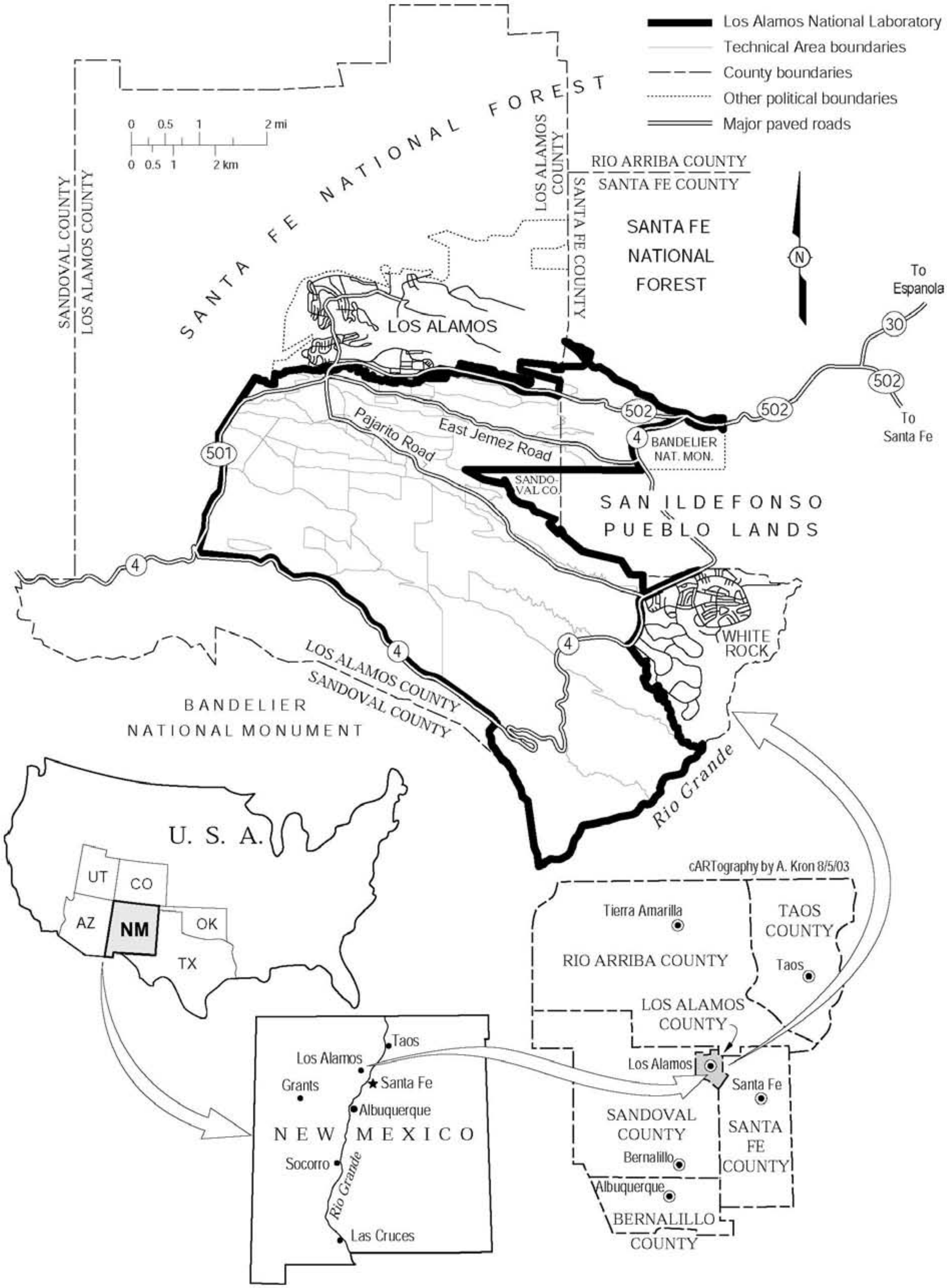


Figure 1. Location of LANL.

Los Alamos has a temperate, semiarid mountain climate. However, elevation strongly influences the climate, and the topography causes large temperature and precipitation differences in the area. The average annual precipitation in Los Alamos is 18.73 inches (47.57 cm). The summer rainy season accounts for 48% of the annual precipitation. During the July–September period, thunderstorms form when moist air from the Gulf of Mexico and the Pacific Ocean moves up the sides of the Jemez Mountains. These thunderstorms can bring large downpours, but sometimes they only cause strong winds and lightning. Hail frequently occurs from these rainy-season thunderstorms.

Surface water in the Los Alamos area occurs primarily as short-lived or intermittent reaches of streams. Perennial springs on the flanks of the Jemez Mountains supply base flow into upper reaches of some canyons, but the volume is insufficient to maintain surface flows across the LANL site before evaporation, transpiration, and infiltration deplete the springs. In previous years, runoff from heavy thunderstorms or heavy snowmelt reaches the Rio Grande several times a year in some drainage areas. Effluents from sanitary sewage, industrial waste-treatment plants, and cooling-tower blow-down enter some canyons at rates sufficient to maintain surface flows for varying distances.

The Pajarito Plateau, including the Los Alamos area, is biologically diverse. This diversity of ecosystems is partly caused by the dramatic 5,000-ft (1,500-m) elevation gradient from the Rio Grande on the east to the Jemez Mountains 12 miles (20 km) to the west and partly by the many steep canyons that dissect the area. Five major types of vegetative cover are in Los Alamos County: juniper (*Juniperus monosperma* Englem.)-savanna, piñon (*Pinus edulis* Engelm.)-juniper woodland, ponderosa pine (*Pinus ponderosa* P.& C. Lawson) forest, mixed conifer forest, which includes Douglas fir (*Pseudotsuga menziesii* [Mirbel] Franco), white fir (*Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.), and ponderosa pine, and spruce-fir forest which includes Engelmann spruce (*Picea engelmannii* Perry ex Engelm.), subalpine fir (*Abies lasiocarpa* [Hook.] Nutt. var. *lasiocarpa*), and corkbark fir (*Abies lasiocarpa* [Hook.] Nutt. var. *arizonica* [Merriam] Lemmon).

Two cover types dominate LANL:

- The piñon-juniper woodland cover type, generally in the 6,200- to 6,900-ft (1,900- to 2,100-m) elevation range, covers large portions of the mesa tops and north-facing slopes at the lower elevations.
- Ponderosa pine forest is in the western portion of the plateau in the 6,900- to 7,500-ft (2,100- to 2,300-m) elevation range.

The mixed-conifer cover type, at an elevation of 7,500 to 9,500 ft (2,300 to 2,900 m), overlaps the ponderosa pine community in the deeper canyons and on north-facing slopes and extends from the higher mesas onto the slopes of the Jemez Mountains. Subalpine grassland and spruce-fir forest are at higher elevations of 9,500 to 10,500 ft (2,900 to 3,200 m). Twenty-seven wetlands and several riparian areas enrich the diversity of flora and fauna on LANL lands.

1.2 Cerro Grande Fire Impacts

The Cerro Grande Fire of May 2000 burned approximately 7,400 ac (3,000 ha) of LANL property. Shortly after the fire an Emergency Rehabilitation Team was created to evaluate and estimate the impacts of the Cerro Grande Fire on LANL property, design appropriate mitigation methods for erosion and increased runoff, and implement these methods to prevent further damage to people, property, and the environment. Since that time the Cerro Grande Rehabilitation Project (CGRP) has assumed the role of the Emergency Rehabilitation Team. In all, 950 ac (385 ha) of LANL property were treated by hand following the Cerro Grande Fire. Of these 950 ac (385 ha), 599 ac (240 ha) are monitored under the BART system.

1.2.1 Impacts on Vegetation

The Cerro Grande Fire (Fig. 2) burned approximately 43,000 ac (17,400 ha) and significantly altered the soils, vegetation, and surface hydrology throughout the region. An assessment of fire-induced vegetation mortality was made by the Burned Area Emergency Rehabilitation (BAER) team methodology. The vegetation mortality classification generally corresponds to the burn-severity ratings (Fig. 3). Areas of high-burn severity have experienced 70%–100% vegetation mortality. Moderate-burn severity corresponds to 10%–40% mortality and low-burn severity to less than 10% mortality. Areas with a mosaic of high- and moderate-burn severity have experienced 40%–70% mortality. LANL had approximately 6,376 ac (2,580 ha) of low-burn severity, 825 ac (334 ha) of moderate-burn severity, and 203 ac (82 ha) of high-burn severity.

The fire also indirectly affected vegetation in the following ways:

- High- and moderate-severity fires often consume seed reserves, thus inhibiting recovery of native vegetation.
- It is generally assumed by professional foresters that trees with 30% live, or green, canopy will survive. However, the Cerro Grande area had experienced two years of winter drought conditions before the fire and the vegetation would have been under more stress than usual. Precipitation following the fire was above average the first year but well below average in the second year. At this point in time we do not know how the interaction of the fire and weather will affect the vegetation.
- Bark beetles and wood-boring insects attracted to trees damaged or killed in a fire can also attack and kill living trees.
- Invasive exotic species may be introduced or expanded by
  - use of contaminated seed for rehabilitation purposes,

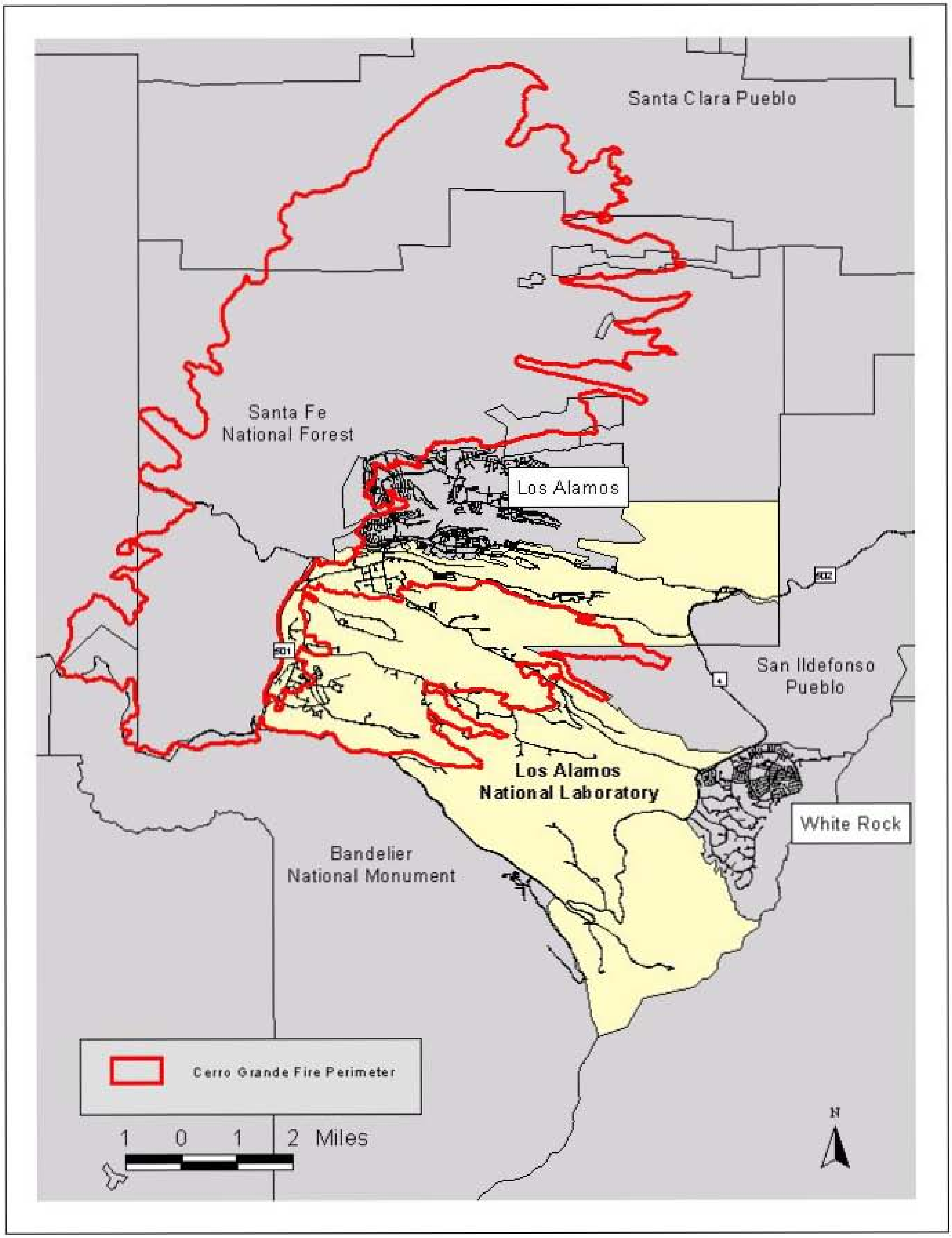


Figure 2. Cerro Grande Fire perimeter.

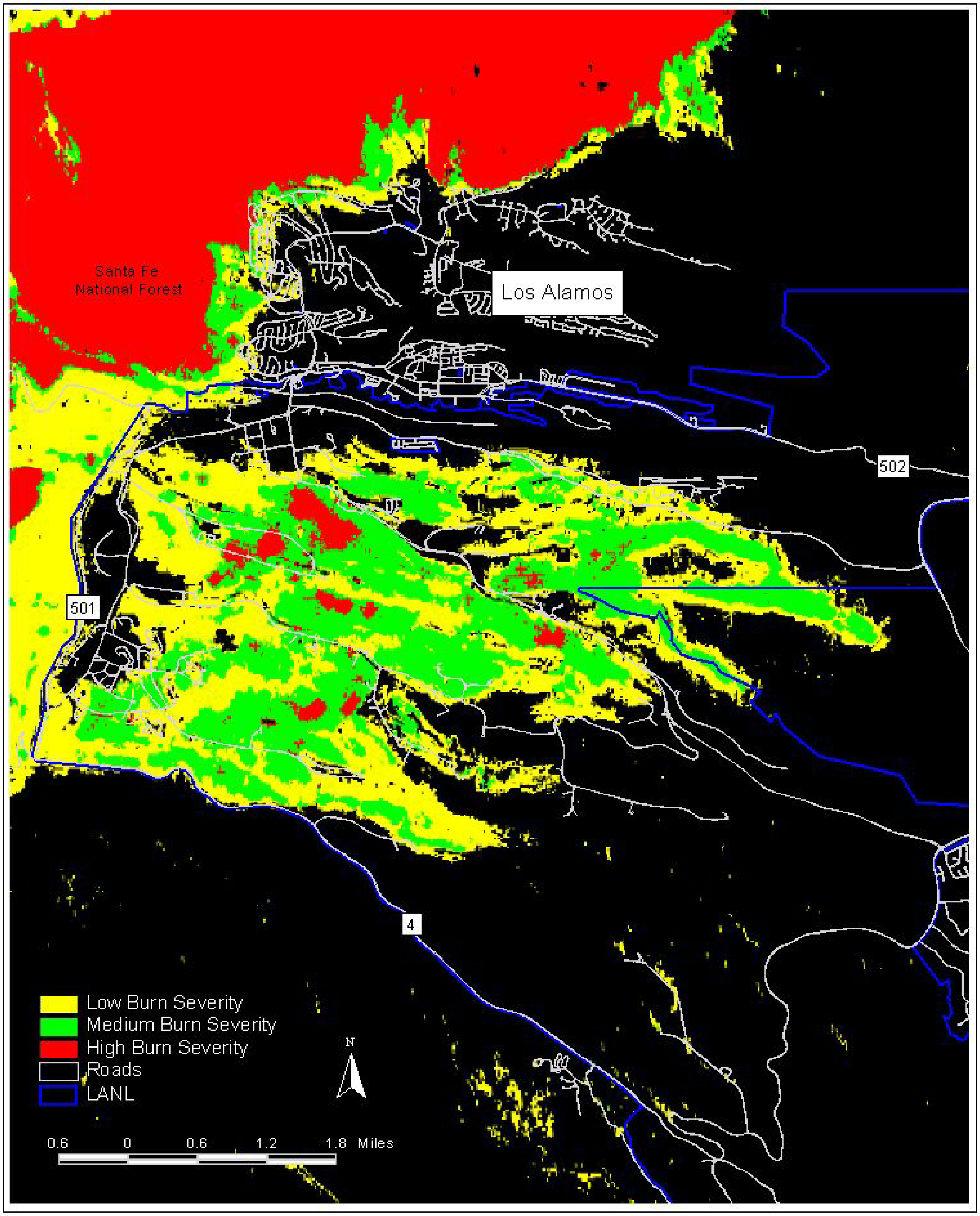


Figure 3. Burn severity at LANL based on GENIE[1] technology.

[1] Brumby, Steven P., Neal R. Harvey, Jeffrey J. Bloch, James Theiler, Simon Perkins, A. Cody Young, and John J. Szymanski. 2001. Evolving forest fire burn severity classification algorithms for multi-spectral imagery. Proc. SPIE vol. 4381, pp. 236–245.

- transporting plants from other regions by fire-suppression equipment and personnel, and
- expansion in the post-fire environment of already existing small isolated populations of plants, resulting in serious consequences to native plant and animal populations.

The ultimate effects of the fire on vegetation mortality may not be known for many years.

1.2.2 Impacts on Soils and Hydrology

Fire alters surface soil properties in the following ways:

- Intense heat (high-burn severity) can break down soil structure and create a hydrophobic layer that resists water infiltration.
- The loss of effective ground cover (vegetation and litter) can lead to a significant increase in soil erosion and runoff during storms.
- Areas with moderate- and low-severity burns can experience increased rates of soil erosion primarily caused by loss of effective ground cover.

Post-fire conditions along the hills and ridges at elevations higher than that of LANL, as well as such features within LANL, pose a very high risk for erosion and flood damage at the LANL facilities and to nearby residential communities situated downstream all the way to the Rio Grande. This high risk for flooding also exists for portions of the Los Alamos town site located north of LANL, as well as for pueblo lands and residences located downstream of the town site.

Seventy-seven contaminant potential release sites (PRSs) and two nuclear facilities at LANL that contain hazardous and radioactively contaminated soils and materials are located within floodplain areas. Without DOE action, these PRSs and nuclear facilities could potentially release contaminants and materials downstream. In 2003, one of these nuclear facilities was decommissioned and removed from the floodplain. Numerous cultural resource sites and traditional cultural properties are located in canyons or along drainage areas. These sites are now at increased risk of flood damage. Information on stabilization of PRSs can be found in Veenis (2000) and Veenis and Johnson (2001).

Flooding could also affect area canyons that provide potential habitat for federally listed threatened and endangered species. Before the fire, canyon storm-water-discharge flow measurements for a 6-h storm with a 1-in-100-year return rate at LANL typically were in the range of about 35 to 590 ft^3/s (1.05 to 17.7 m^3/s). Modeling for the same canyons estimated post-fire discharge flows (before rehabilitation work) to be in the range of 90 to 3,276 ft^3/s (2.7 to 98.3 m^3/s) for storms of the same duration. Some canyons are expected to have even greater flow amounts over some areas because of location-specific site conditions after the fire. The potential for flooding onto and across LANL property will exist for the next several years, decades in some locations, until enough vegetation covers hillsides and canyons to sufficiently deter soil erosion and threat of flooding.

2.0 EMERGENCY POST-FIRE RESTORATION AND REHABILITATION

One of the goals of LANL's Emergency Rehabilitation Team and the CGRP was to address potential impacts of increased runoff that could result from the Cerro Grande Fire and to look at potential long-term issues that could result from the fire. Assessment of PRSs began May 16, 2000, and general field rehabilitation began on June 9, 2000.

The Laboratory performed the following operations:

- conducted on-the-ground evaluations of burned areas to ground-truthed burned-area maps and determined areas for and types of needed restoration activities,
- instructed professional forestry and subcontractor crews on proper rehabilitation techniques and locations for work,
- coordinated procurement of materials, escorts, and access for work on LANL property, and
- worked seven days a week to complete initial land rehabilitation treatments before heavy summer rains that could cause erosion and flooding.

The goal of the LANL rehab efforts was to reduce the risk of contaminant movement and potential flooding from LANL property. Treatments were designed to stabilize ash and soil, reduce runoff, improve infiltration, and replace fire-consumed litter. Rehabilitation efforts on LANL property lasted for approximately 10 weeks. During this time 1,800 ac (728 ha) were treated, of which 950 ac (385 ha) were treated by hand crews. Completed land treatments follow the BAER specifications for the Cerro Grande Fire. Rehabilitation treatments such as felling of trees, raking, placing of wattles, and building of log structures and rock check-dams are all done on the contour to decrease erosion caused by water runoff. The following pages summarize the actions taken. Table 1 shows approximate areas for each treatment and Figure 4 illustrates each action (except contour raking).

Table 1. Approximate Treatment Acreages

Treatment	Acres (Ha)	Treatment Rate (lbs/acre)	Total Materials Used
Aerial seeding	**650 (263)**	36	13,000 lb
Air hydromulch	**145 (59)**	NA	NA
Truck hydromulch	**125 (50)**	NA	NA
Hydromulch		2000	250,000 lb
Tackifier		240	30,000 lb
Seed		35	4,375 lb
Rehabilitation by hand	**950* (384)**		
Hand seeding	700 (283)	35	
Wattles	736 (298)	NA	7,550 wattles
Contour felling	886 (358)	NA	NA
Raking	736 (298)	NA	NA
Straw mulch	736 (298)	540	5,000 bales

*Note: The acreage listed is per unit treated. Several units required a combination of treatments.

3.0 METHODS

Post-fire rehabilitation treatments were designed to stabilize soils, decrease runoff and sediment transport, increase infiltration of precipitation, and provide a suitable microhabitat for plant growth. Rehab treatments included contour felling, raking, wattles and rock and log check-dams.

Aerial Seeding. Crop-duster-type aircraft performed aerial seeding at a rate of 35 lb/ac. Workers used the BAER-recommended seed mixture for aerial and hand seeding. This mixture included both annual and perennial seed (10% annual rye grass [*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot], 25% mountain brome [*Bromus marginatus* Nees ex Steud.], 25% slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners], and 40% cereal barley [*Hordeum vulgare* L.]).

Hydromulching (aerial and truck). Crews performed hydromulching by air along specified canyon walls in Pajarito and Water Canyons and on areas that were steep and inaccessible by road. Land hydromulching took place on ground that was steep but had road access. The hydromulching application included the Cerro Grande BAER seed mix, hydromulch, water, and tackifier.

Hand seeding. Rehabilitation crews used seeders set at a rate of 35 lb/ac to hand seed the Cerro Grande BAER mix.

Contour raking. Crews used heavy rakes to break up the soil surface. They raked on contours to slow overland runoff and to increase precipitation infiltration rates on hydrophobic soils.

Straw mulching. Crews spread straw mulch where preburn ground cover had been consumed by the fire and the expected overland runoff would threaten high values at risk, such as buildings in valley bottoms, archeological sites, or anything that could be damaged due to fire-related flooding.

Straw wattles. Straw wattles are 9-in. by 25-ft rolls of rice straw placed by hand crews on slopes. These wattles act as terraces to prevent slope erosion and to facilitate revegetation. Straw wattles also act as grade-control structures in stream channels with flatter gradients, finer streambed materials, or uneven bottoms.

Log structures and rock check-dams. Crews built these structures to control flow in stream channels. Reducing water velocity lowers the in-channel erosive force to prevent down cutting and to capture sediment of the flowing stream.

Contour tree felling. Crews felled trees on contours to break up straight line sheet flow from burned areas. In some cases, contour trees were turned into log erosion barriers by securing the tree bole in a trench dug into the hill slope.

Aerial Seeding/Aerial Hydromulching

Truck Hydromulching

Contour Tree Felling

Hand Seeding

Log Erosion Barrier with Wattle

Straw Mulching

Figure 4. Treatment actions taken after the Cerro Grande Fire.

3.1 The BART System

The BART system was developed as a GIS-based tracking and monitoring data management system. BART provides easy access to information used to generate reports on treatment area status and trend. In addition, in-field recommendations for additional work are recorded and tracked.

A global positioning system (GPS) unit was used to document and map the burned area boundaries and the associated treatments. Treatment areas were broken into units and the boundaries were mapped (Fig. 5). Additional information was collected on the treatment types, amounts of materials used, and crew identification**.**

A field form was developed to standardize the type of information collected when monitoring and assessing the treatment units (Buckley et al. 2002). Percent total ground cover (vegetation, litter, straw, wattles, logs, etc.) and percent vegetation cover are estimated in each rehab unit. Observers walk throughout the unit estimating these two measurements using a 0.5-m^2 quadrat as a frame of reference. Percentages are averaged for the entire unit and recorded on the data sheet.

Information was also collected on the percentage of wattles filled with sediment and the percentage of wattles that have failed. The percentages are averaged for the entire unit and recorded on the data sheet. Additional information collected includes condition of treatment unit, additional work required, maintenance requirements, etc. Completed monitoring forms were entered into the BART database, and maintenance reports were generated based on the type of repair or additional treatment needed in the rehabilitation area. In addition, photo points were established within each treatment unit to document the dominant landscape vegetation. Digital photos were taken during each assessment. Comparison of photos of the same site over time will provide visual evidence of vegetation changes and site recovery.

Areas needing treatment that were not treated previously, were identified and the locations were recorded with GPS. Based on the findings of the BART surveys, areas needing additional work will be prioritized and rehabilitation work will be completed.

BART data were analyzed for statistical significance using analysis of variance (ANOVA) and independent samples t-test procedures on SPSS 11.0. The univariate ANOVA procedure was used instead of a repeated-measures ANOVA because of problems with missing data.

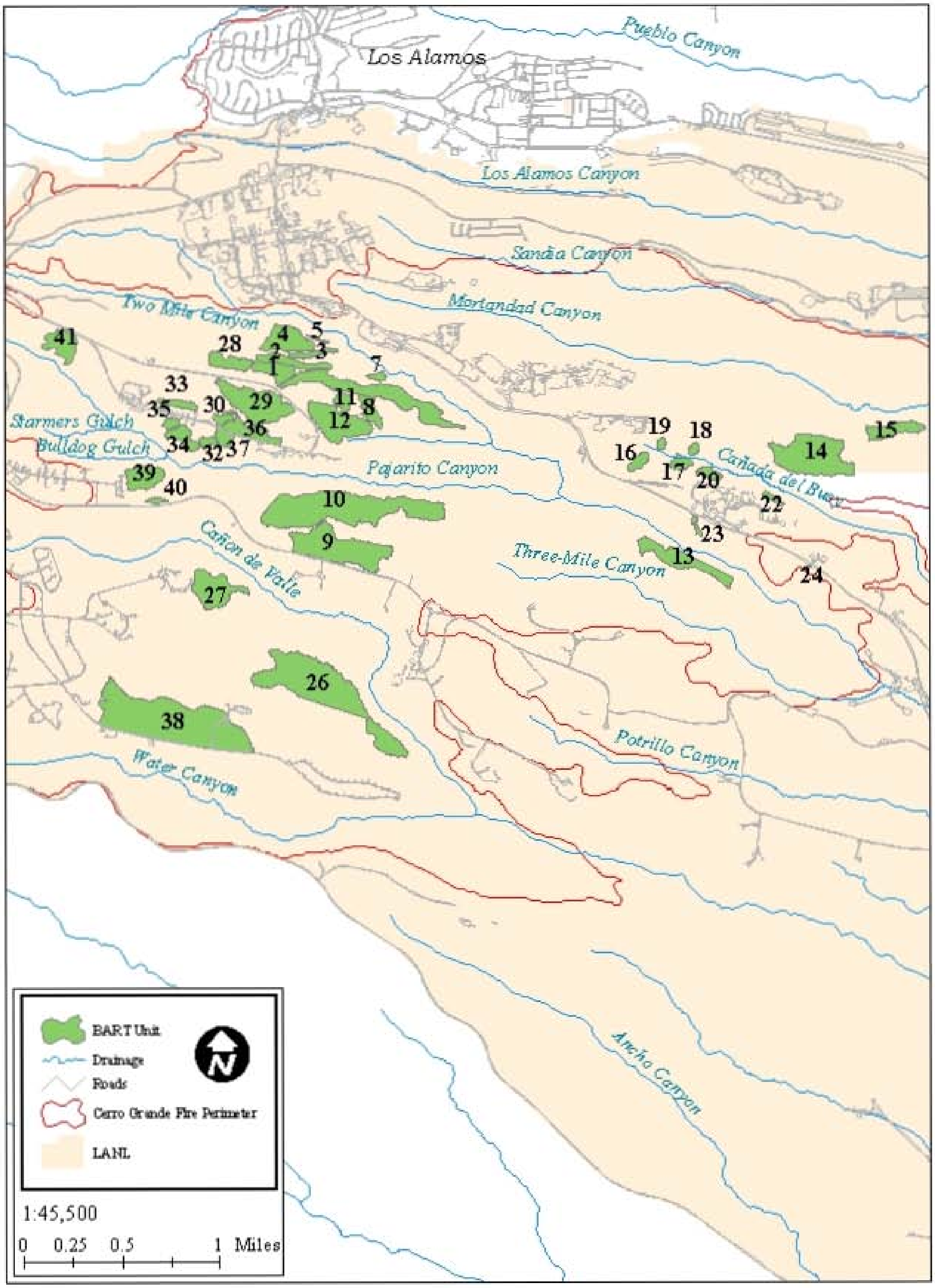


Figure 5. BART Rehabilitation Units at LANL.

3.2 Post-Fire Storm Runoff

One of the requirements of the SEA was to conduct assessments, implement mitigation, and monitor annually the condition of the burned area. The SEA directed LANL to repair, replace, or repeat rehabilitation actions until at least 90% of the pre-fire vegetation is achieved or until post-fire storm events approximate pre-fire rates. The BART system met the requirements of the rehabilitation portion of the SEA.

To address the post-fire storm flow requirement, an assessment was conducted of precipitation and fire-related storm runoff events during 2001 and 2002 (Koch et al. 2003). Data on storm runoff was obtained from the RRES-WQH stream-gaging network. Precipitation information was obtained from available data. The assessment has been summarized to provide information on post-fire storm runoff on LANL-occupied watersheds where BART treatments were conducted.

3.3 Photo Point Monitoring

In addition to collecting information about the condition of the rehabilitation treatments, 44 photo points were created in or near the BART units to track landscape changes in vegetation over time. Photo point monitoring allows for quick inexpensive documentation of vegetative change over time. Photo point locations were selected to capture a view of the BART unit that included rehabilitation techniques. Stumps from felled trees were most often chosen for a landmark to take the photos from. At most photo point locations, two photos were taken. For each photo, a compass was used to determine the direction that the photo was taken. The location of the photo point was recorded with GPS. An aluminum tag recording the photo point number and compass direction was nailed to the stump. GPS locations were saved as waypoints in the GPS so that each photo point could be navigated to and photos retaken.

4.0 RESULTS

4.1 BART

4.1.1 Vegetative and Total Ground Cover

Total percent vegetation cover decreased significantly from a high of over 45% in fall 2001 to the low of just over 20% in summer 2003 (Fig. 6), which is an overall change of approximately 24%. The decline in vegetation cover coincides with a decrease in annual precipitation and may have been exacerbated by thinning treatments implemented after summer 2002. A significant increase in vegetation cover cannot be expected without adequate precipitation.

Total percent ground cover includes vegetation cover as well as any cover, such as litter, gravel, straw mulch, and pine needles, that protects the soil surface from erosion. Because decomposition rates are relatively slow, this form of cover is more stable than vegetation cover. There has been a significant decline in ground cover from a high of around 63% in spring 2001 to a low of around 50% in fall 2002 (Fig. 6). The slight increase in summer 2003 is not significantly different from spring 2001. Percent total ground cover has varied by approximately 13%. With the cessation of rehabilitation treatments, the only inputs to ground cover will be material from live or dead plants. Again, significant increases in ground cover are not expected until live plant productivity increases.

Extensive thinning activities were implemented on some of the rehab units. Thinning has occurred on 484 ac (196 ha) of the 599 ac (242 ha), or 81%, of the total area that received rehab treatments. In most cases trees were cut on the site and chipped or skidded off site. In some cases all of the ground cover, including the rehabilitation treatments, was removed from the site. Figure 7 shows the differences between total vegetation cover on thinned and unthinned plots. There was significantly less cover on thinned units in fall 2002. In summer 2003, cover had declined in both thinned and unthinned units but much more so on the unthinned units, to the point where they are no longer significantly different. Total ground cover was also significantly less on thinned units in fall 2002 (Fig. 8). However, ground cover decreased on unthinned units and increased on thinned units to where they were no longer significantly different in summer 2003.

Overall, vegetation and ground cover levels are adequate to protect soil from erosion. Revised Universal Soil Loss Equation (RUSLE) estimates conducted in 2003 (Buckley and Loftin 2003) found that ground cover was sufficient to prevent soil loss in excess of the Natural Resource Conservation Service acceptable rate of soil loss. Exceptions were usually small in area and will receive additional rehab treatments. However, if drought conditions continue, additional treatments may be necessary.

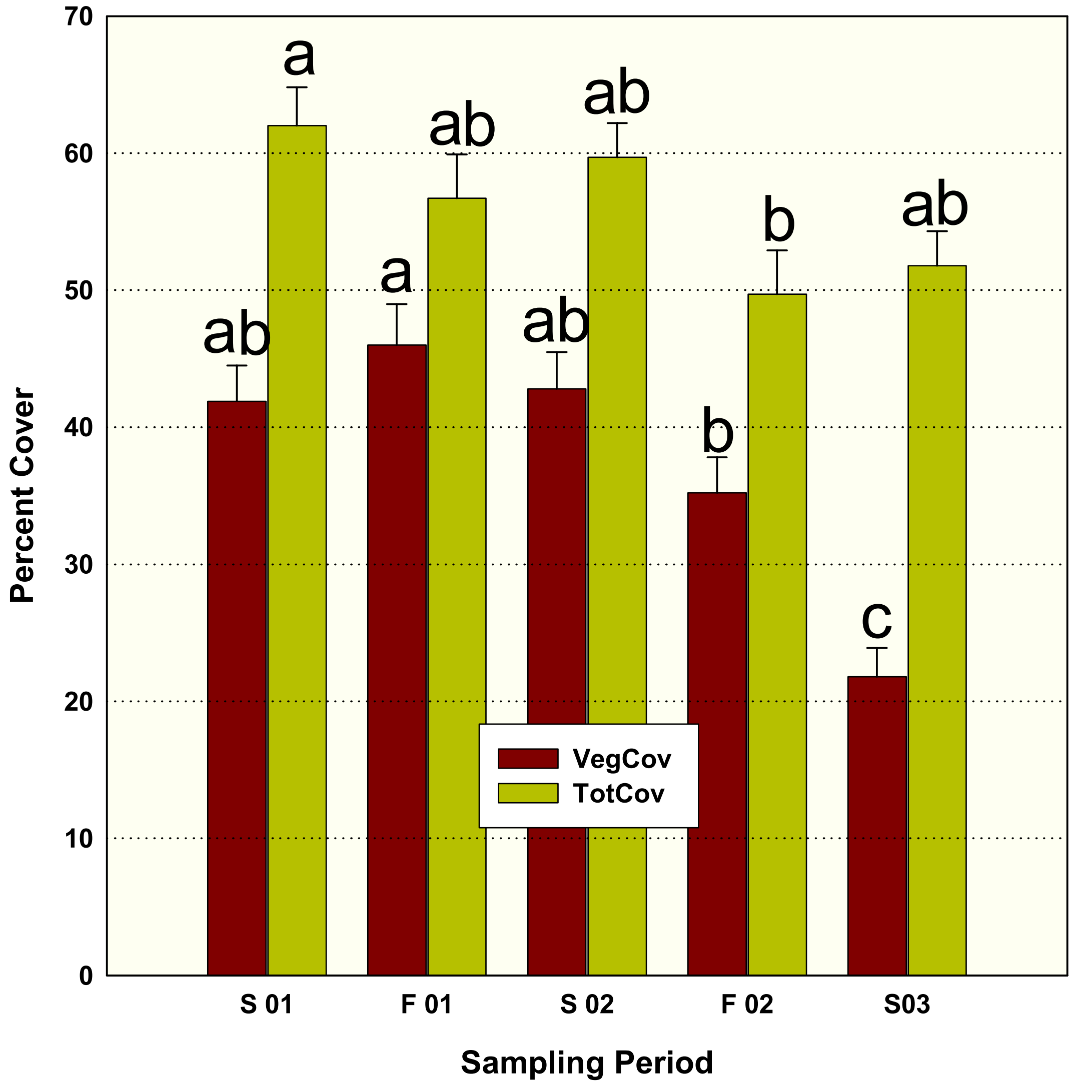


Figure 6. Total percent vegetation and ground cover for BART units. Sampling periods include summer 2001 (S 01), fall 2001 (F 01), summer 2002 (S 02), fall 2002 (F 02), and summer 2003 (S 03). Columns with the same letter (within a cover category) are not significantly different (p>0.05).

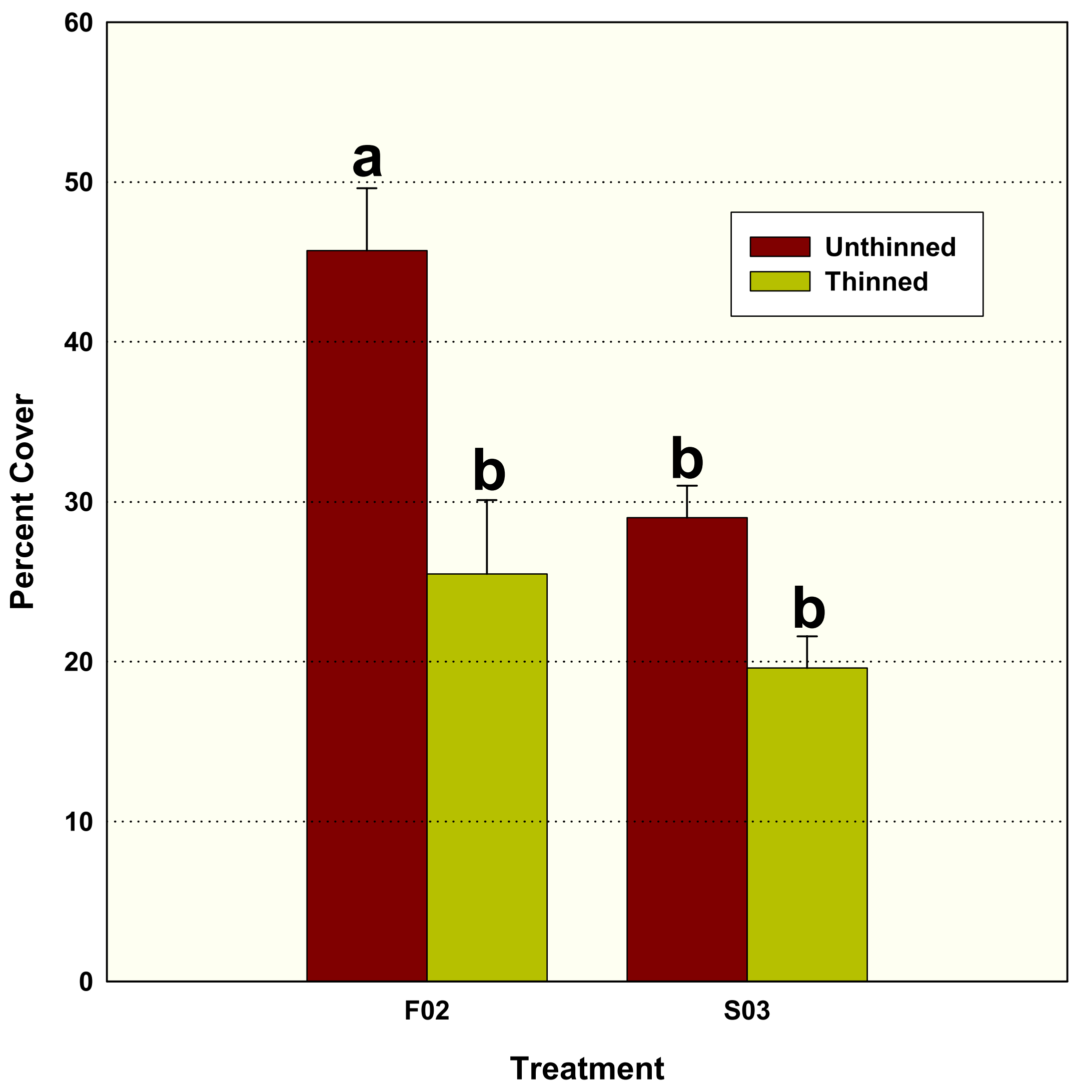


Figure 7. Total percent vegetation cover from thinned and unthinned BART units. Sampling periods include fall 2002 (F02) and summer 2003 (S03). Columns with the same letter are not significantly different ($p>0.05$).

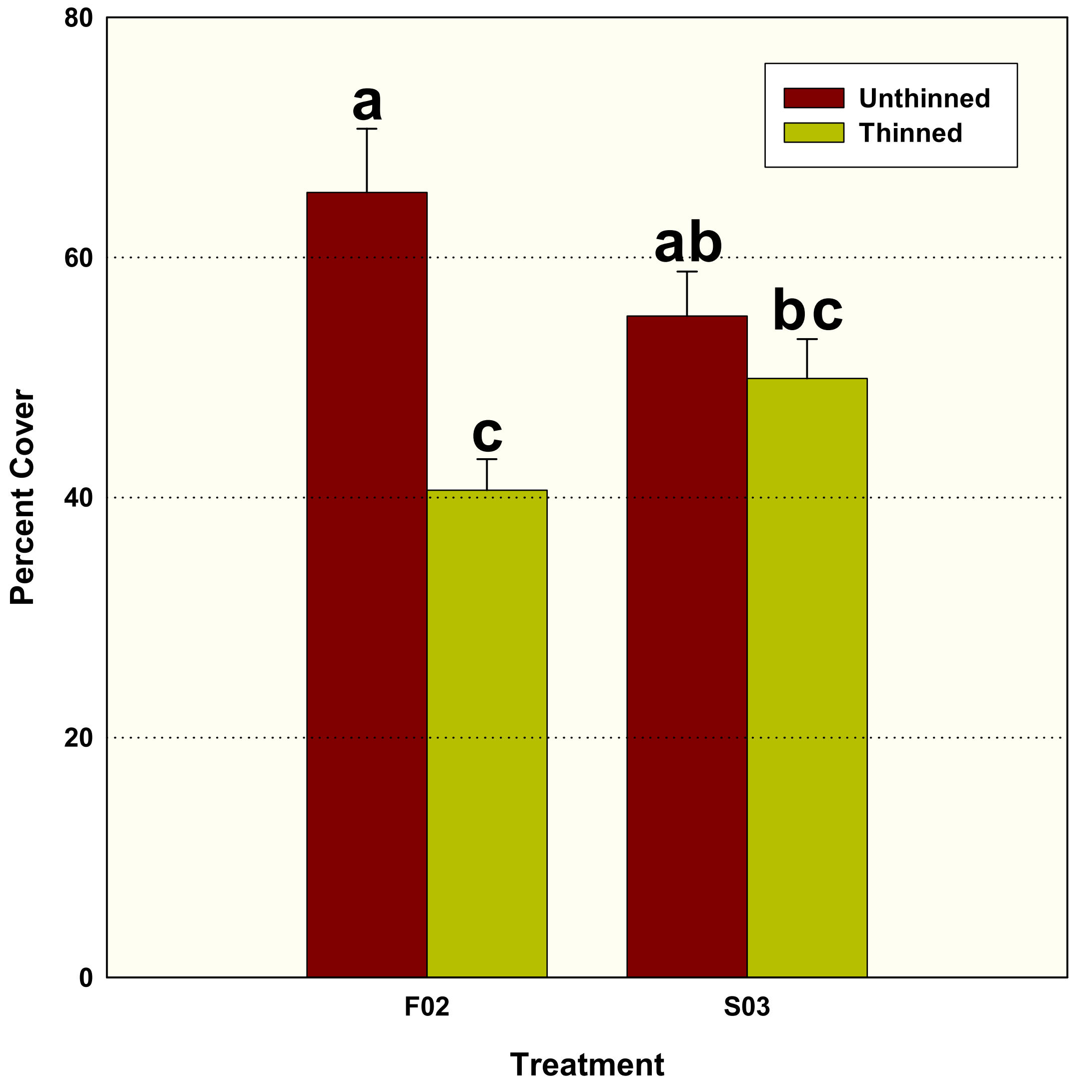


Figure 8. Total percent ground cover from thinned and unthinned BART units. Sampling periods include fall 2002 (F02) and summer 2003 (S03). Columns with the same letter are not significantly different (p>0.05).

4.1.2 Straw Wattles

Straw wattles are tubes of straw packaged in plastic netting that are 9 in. by 25 ft long. Wattles are laid in trenches on slope contours and secured with wood stakes to prevent undercut by runoff. Wattles were used in all areas on LANL that had high- and moderate-burn severity. Burned slopes were left bare of vegetation and ground cover. In un-burnt conditions, ground cover and vegetation help to protect the soil from the impact and transport of sediment caused by rainfall. Straw wattles were used with straw mulch to slow the velocity of the runoff from rain, helping to prevent the development of rills and gullies that erode slopes. Wattles help to stabilize bare slopes by acting like a terrace. Each wattle slows down overland flow during runoff causing sediment to accumulate behind the wattle. In most cases, seed placed on the slope washes down with the runoff and then grows on the sediment accumulated behind the wattle. Straw wattles have been used in addition to contour tree felling for erosion control. In some cases, straw wattles were placed behind contour logs to block the gap that can exist due to irregularities in the tree bole. This was the most effective use of a wattle.

Over the past three seasons, data on the percentage of wattles filled with sediment and the percentage of wattles that have failed have been collected during BART surveys. On average, 18% of the wattles in a BART unit were filled with sediment the first year. The percentage of wattles filled with sediment only increased slightly over the next two years, 20% in 2002 and 21% in 2003.

The percentage of wattles that failed stayed relatively consistent for the first year at 6%. In 2002 and 2003, thinning occurred in 32 of the BART units. The average percentage of failed wattles increased to 34% in 2002 and 46% in 2003. In BART units where thinning was not conducted (nine units) the total average percentage of failed wattles was 8.9%. In BART units (32 units) where thinning was conducted, a total average of 57.3% of the wattles failed (Fig. 9).

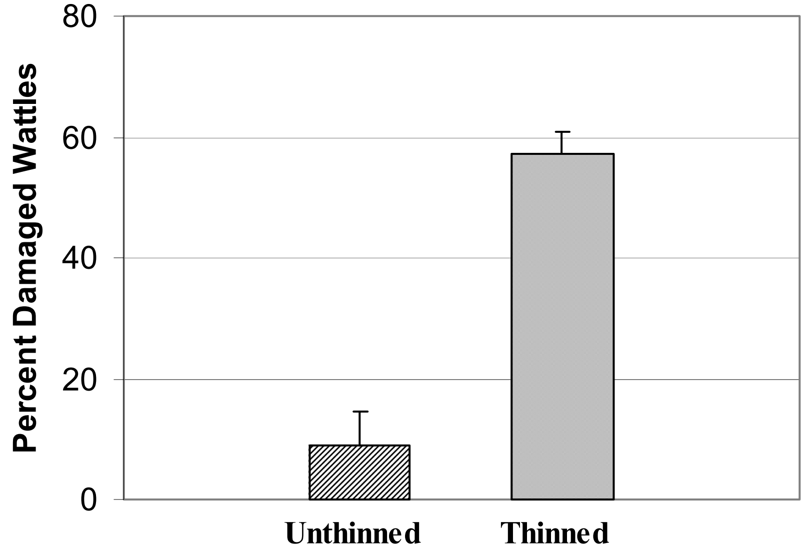


Figure 9. Differences in the percentage of damaged wattles in thinned and unthinned BART units. Samples were significantly different (p<0.001) between unthinned and thinned units.

4.2 Additional Work/Required Maintenance

In addition to data on the amount of cover and condition of the wattles installed in the units, information on additional work needed, if any, was collected during field visits to BART units. In 2003, 12 units were identified as needing additional work (Appendix). The majority of the additional work was associated with thinning and roads and skid trails used for tree cutting.

4.3 Post-Fire Storm Runoff

The SEA directed LANL to repair, replace, or repeat rehabilitation actions until at least 90% of the pre-fire vegetation is achieved or until post-fire storm events approximate pre-fire rates. Most of the discharge generated from watersheds in this area comes from the higher elevations. LANL occupies the middle section of most of the watersheds that cross its boundaries; therefore, LANL rehabilitation activities are unlikely to have much of an effect on post-fire storm events that occurred in the upper watersheds. For storm events that occur over LANL, BART treatments can help to reduce runoff and erosion. We present this information as an overall evaluation of watershed recovery relative to pre-fire hydrologic conditions.

Storm water runoff usually occurs from June to October each year as the result of convective thunderstorms. These thunderstorms are usually short-duration, high-intensity rainfall events. On average, the Pajarito Plateau receives 18.7 inches (47.6 cm) of precipitation. Before and after the Cerro Grande Fire, the Pajarito Plateau has experienced drought. Precipitation was 26% less than average (47.6 cm) in 2000 (35.1 cm), 22% less in 2001 (36.6 cm), and 37% less in 2002 (29.7 cm). Total storm water runoff measured from watersheds at LANL in 2000 was 2.6 times greater than the historic average in 2000, 1.8 times greater in 2001, and 0.8 times less than average in 2002 (Table 2). Because of rainfall variability, we do not have enough data at this time to be certain we have met the goals of the SEA.

Table 2. Runoff Volume in Acre-Feet, Pre- and Post-Cerro Grande Fire

Watershed	**Gage**	**Average Annual Runoff in acre-feet* (1995 to 1999)**	**2000 Runoff Volume (acre-feet)**	**2001 Runoff Volume (acre-feet)**	**2002 Runoff Volume (acre-feet)**
Los Alamos	E026	48	137	83.6	6.8
	E042	40	51.7	105.1	19.2
Cañada del Buey	E230	12	4.7	0.1	9.2
Pajarito Canyon	E240	40	65.8	12.8	48.3
	E245	39	55	28.1	29.7
	E250	3.2	11.9	11.2	5.4
Water Canyon/ Cañon de Valle	E252	2.4	68.8	62.7	9.6
	E265	0.4	90.8	22.1	22

*One acre-foot is equivalent to 325,851 gallons or 1 foot of water covering an acre of land.
Data Source: Koch et al. (2003).

In general, after the Cerro Grand Fire, storm water peak flows are higher than pre-fire flows for watersheds occupied by LANL except for Cañada del Buey and the downstream gages in the Los Alamos and Pajarito watershed (Koch et al. 2003). Cañada del Buey is a small watershed that starts on LANL property. Lack of precipitation in the watershed may account for the low flow post-fire. The same lack of precipitation in the lower portions of watersheds at LANL may account for low flow at Pajarito as well. Los Alamos has a reservoir in the upper portion of the watershed that stored most of the flow from upper watershed storms.

4.4 Photo Point Monitoring

The following pages illustrate some of the post-fire changes in vegetation on BART units over the past three years. BART units 1, 2, 22, and 33 were chosen as a representative sample of the rehab units. Changes in vegetation are apparent in the photos. Units 1, 22, and 33 were located in areas that the CGRP thinned for fire protection. The figures on each page show results of BART vegetation and total cover sampling. There are no cover data for the summer 2000 photos. Because most BART units are in high-burn severity, it is assumed that vegetative and ground cover were near zero in 2000.

GPS Unit and Field Form at Photo Point

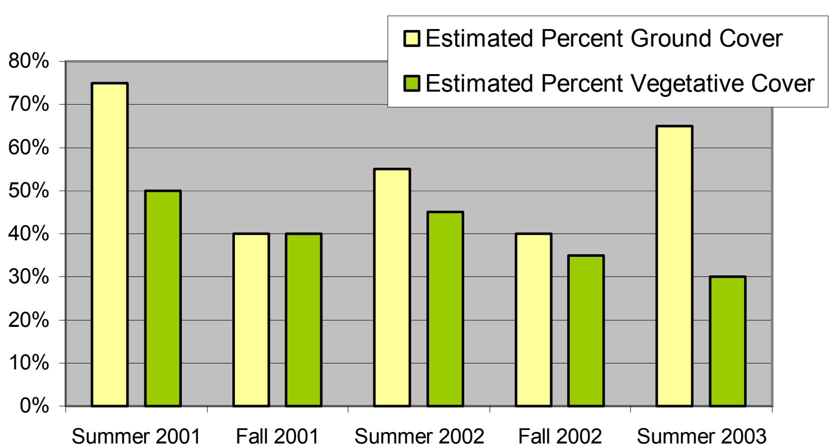
Changes in Vegetation Over Three Years on BART Unit 1, LANL TA-06

BART Unit 1, July 2000

BART Unit 1, June 2001

BART Unit 1, October 2002

BART Unit 1, June 2003



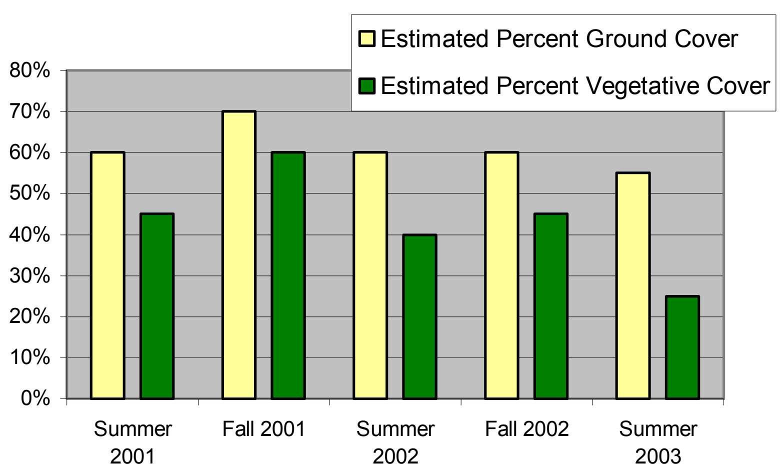
Changes in Vegetation Over Three Years on BART Unit 2, LANL TA-06

BART Unit 2, July 2000

BART Unit 2, June 2001

BART Unit 2, October 2002

BART Unit 2, July 2003



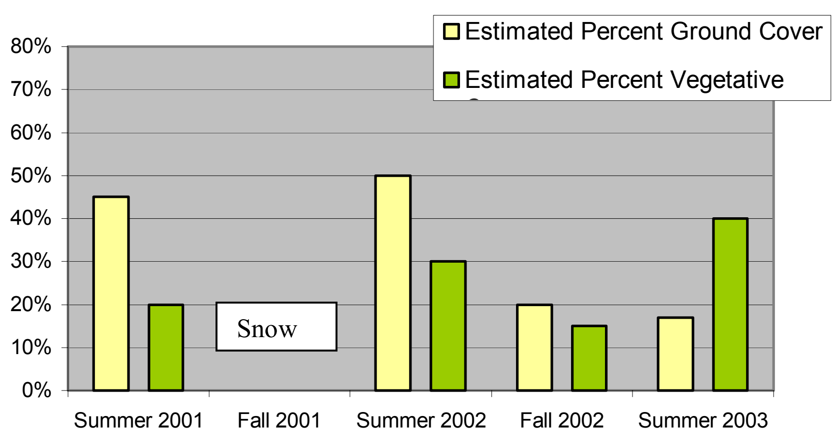
Changes in Vegetation Over Three Years on BART Unit 22, LANL TA-46

BART Unit 22, September 2000

BART Unit 22, July 2001

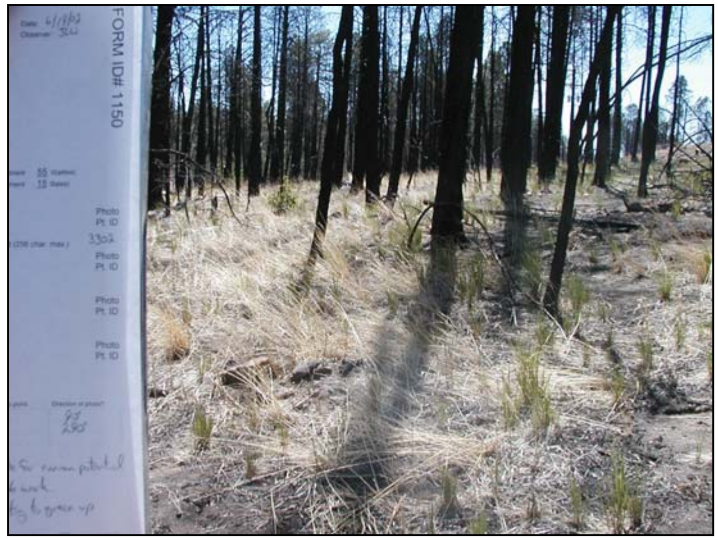
BART Unit 22, October 2002

BART Unit 22, July 2003



Changes in Vegetation Over Three Years on BART Unit 33, LANL TA-22

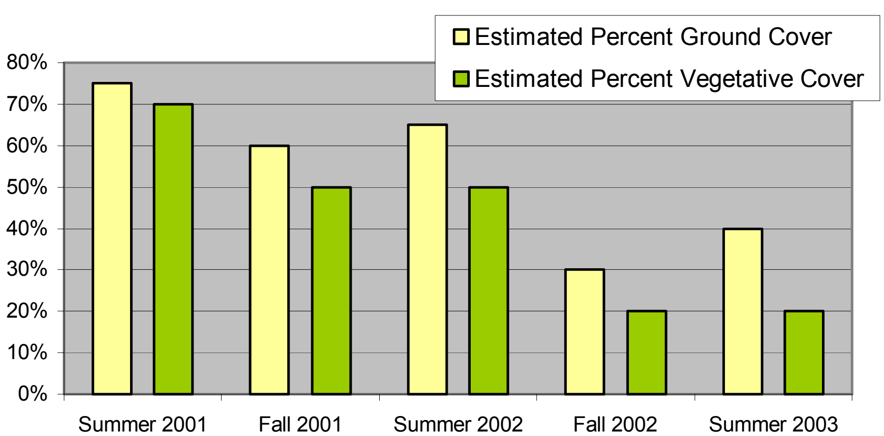
BART Unit 33, June 2001



BART Unit 33, June 2002

BART Unit 33, November 2002

BART Unit 33, July 2003



5.0 DISCUSSION

In May of 2000, approximately 7,400 ac (3,000 ha) of LANL were burnt by the Cerro Grande Fire. Immediately there were concerns about the impacts on potentially contaminated soil and sediment from erosion and flooding. To reduce the potential of sediment leaving the site due to erosion and flooding, LANL initiated an Emergency Rehabilitation Plan to evaluate the impacts of the fire and to design and implement appropriate mitigation methods for modeled erosion and runoff. LANL management directed the team assigned to conduct this work to meet with Department of Agriculture BAER specialist assigned to the fire and implement techniques used on the National Forest on LANL.

Under the DOE SEA, the Laboratory was to conduct mitigation and monitor annually the condition of the burned area. In all, LANL treated over 1,800 ac (728 ha) with techniques similar to those used by the BAER team. To monitor the rehabilitation effort the BART system was developed. BART is a GIS-based tracking and monitoring system designed to identify and generate reports of additional work needed in the treatment units based on field assessments.

BART surveys were conducted summer and fall in 2001 and 2002 and again in summer 2003. Each survey looked at recovery and condition of rehabilitation treatments in 42 units covering almost 600 ac (243 ha).

Over the past three years, vegetation cover has increased from near 0% after the fire to an average of 22% in 2003. Percent total ground cover has increased from near 0% to an average of 52% for all BART units. Recovery of vegetation over the past three years has been impacted by the lack of winter and summer precipitation. Total ground cover has decreased slightly from fall 2000 to summer 2003 due to natural decomposition, wind, and disturbance due to land management activities such as thinning. However, RUSLE estimates conducted in 2003 (Buckley and Loftin 2003) found that overall, effective ground cover was sufficient to prevent soil loss in excess of the Natural Resource Conservation Service acceptable rate of soil loss.

In 2002 and 2003, the CGRP conducted thinning on 484 ac (196 ha) of the 600 ac (243 ha), or 81%, occupied by BART units. There has been much debate over the effects, both good and bad of post-fire logging. Some arguments for include, reduction in fuel loads, reduction in forest pest habitat, increase in habitat for some wildlife species, and reductions in soil hydrophobicity by the action of the heavy equipment tires. Arguments against include removal of ecological functions of the dead trees such as biomass from the site, loss of shade for new vegetation, loss of wildlife habitat for some species, and damage to post-fire rehabilitation treatments. On LANL, burnt trees were removed to reduce the fire hazard. The BART data suggest that in units that were thinned, a high percentage of wattles failed or were damaged. In these BART units it was observed that damage to wattles was a direct result of heavy equipment used to harvest trees. In addition, studies have shown that roads and road building in thinned areas are a large source of sediment (McIver and Starr 2000). The majority of the additional required work in BART units surveyed in 2003 was associated with roads and skid trails used for thinning. In thinned units, there was a trend towards a reduction in both ground cover and vegetation cover. In many of these thinned areas, best management practices, such as seeding and removal of roads and skid trails, were not implemented after operations had ended. If drought conditions continue, it may be necessary to implement rehabilitation treatments on these sites.

6.0 ACKNOWLEDGMENTS

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APPENDIX
UNITS NEEDING ADDITIONAL REHABILITATION WORK

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
15	6/19/2003	No	Yes

- [x] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required runoff from road, down cutting and depositing sediment, R061915a gps file, r061915b gps file. Wattles needed at road for above.

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
16	6/19/2003	No	Yes

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [x] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required reseed the CGRP disturbed area

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
19	6/19/2003	No	No

- [ ] Additional wattles needed?
- [x] Additional straw mulch needed?
- [x] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [x] Do areas near the unit require additional rehabilitation efforts?

Maintenance required additional units to the east needing rehab.

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
20	6/19/2003	No	No

- [ ] Additional wattles needed?
- [x] Additional straw mulch needed?
- [x] Additional reseeding needed?
- [ ] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
22	6/19/2003	No	No

- [ ] Additional wattles needed?
- [x] Additional straw mulch needed?
- [x] Additional reseeding needed?
- [ ] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required

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Unit ID	Inspection date	High priority site?	Site needs revisited this year?
23	7/16/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required runoff from Pajarito Road is eroding unit - KSL fix -Roads and ground.

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
26	7/11/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required fix road - water bar, seed - see GPS file from past surveys.

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
33	7/8/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [x] Do areas near the unit require additional rehabilitation efforts?

Maintenance required

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
35	7/16/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required access road needs to be ripped, seeded, mulched. Chip piles are too thick - need to be spread out. Could pull chip piles onto roads.

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
39	7/10/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required skid trail need rehab - water bar stabilize

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
41	7/16/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required: skid trails need seed, Rip

Unit ID	Inspection date	High priority site?	Site needs revisited this year?
43	7/16/2003	No	No

- [ ] Additional wattles needed?
- [ ] Additional straw mulch needed?
- [ ] Additional reseeding needed?
- [x] Requires other additional rehabilitation efforts?
- [ ] Do areas near the unit require additional rehabilitation efforts?

Maintenance required: skid trails and chip piles need to be ripped.

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