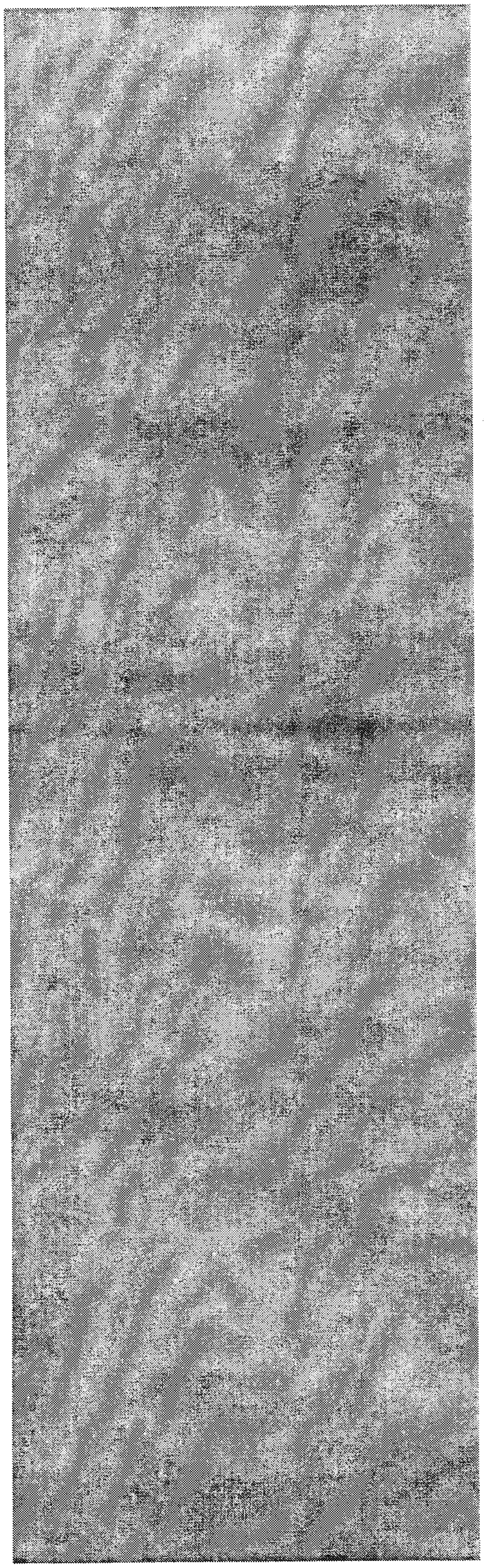
*LA-13714-MS*

*Approved for public release;*
*distribution is unlimited.*



# *Forest Surveys and Wildfire Assessment in the Los Alamos Region; 1998–1999*

**Los Alamos**
NATIONAL LABORATORY

*Los Alamos National Laboratory is operated by the University of California*
*for the United States Department of Energy under contract W-7405-ENG-36.*

*Edited by Hector Hinojosa, Group CIC-1*
*Prepared by Teresa Hiteman, Group ESH-20*

*An Affirmative Action/Equal Opportunity Employer*

*This report was prepared as an account of work sponsored by an agency of the United States Government. Neither The Regents of the University of California, the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by The Regents of the University of California, the United States Government, or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of The Regents of the University of California, the United States Government, or any agency thereof. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.*

LA-13714-MS

*Issued: June 2000*

# *Forest Surveys and Wildfire Assessment in the Los Alamos Region; 1998–1999*

*Randy G. Balice*
*Jay D. Miller**
*Brian P. Oswald***
*Carl Edminster****
*Stephen R. Yool**

**Department of Geography and Regional Development, University of Arizona, Tucson, AZ 87521.*
***College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962.*
****US Forest Service, Rocky Mountain Research Station, Flagstaff, AZ 86001.*

**Los Alamos**
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

# Contents

## Tables

# Figures

# Forest Surveys and Wildfire Assessment in the Los Alamos Region; 1998–1999

**Randy G. Balice, Jay D. Miller, Brian P. Oswald,
Carl Edminster, and Stephen R. Yool**

## Abstract

To better understand the structural characteristics of vegetation in the Los Alamos region, we conducted two years of field surveys and associated analyses. This report introduces field and office methods, lists the summarized field data, and discusses the results of preliminary spatial analyses. During 1998 and 1999, seventy-six terrestrial plant communities were sampled for topographic characteristics, soil surface features, and vegetational conditions. A nested, randomized design was used to select the plot locations and to guide the sampling of the plot. The samples included a variety of fuel types, including surface fuels and ground fuels, shrubby and small tree fuels, and overstory fuels. Species composition data were also collected. The fuels data were summarized by vegetation type and evaluated for the topographic and spatial relationships of major fuels categories. The results of these analyses indicate that many of the fuels categories depend on topographic factors in a linear and curvilinear fashion. In particular, middle elevations within the Los Alamos region tend to support more surface fuels and ground fuels, whereas large-diameter trees are most dense at higher elevations and are specific to community types at these elevations. Small-diameter trees occur in more dense stands at lower and middle elevations and on specific soil and topographic conditions. Areas that burned in 1954 were found to be relatively free of fuels. The implications are that the western portions of the Los Alamos region are at risk from wildfire during dry, summer periods.

---

## Introduction

In the region that includes Los Alamos National Laboratory (LANL) and its surroundings, forest fuels and the hazards they represent have been increasing in recent decades (Allen 1989, Balice 1996). During each growing season, the woodlands and forests in the region have added new growth. This growth becomes fuel for wildfires during hot, windy weather, which normally occurs from late April through mid July. Furthermore, recent decreases in the average winter precipitation have caused the forest vegetation to dessicate earlier and remain dessicated longer during the fire season.

These conditions have increased the probability for the occurrence of catastrophic wildfires (Balice 1996, Balice et al. 2000). Four such wildfires have already occurred since 1954 and two of these have occurred since 1996. These wildfires have damaged the forests and their natural environments, but they also have threatened LANL programs and facilities and the nearby Los Alamos townsite. In spite of these recent wildfires, the threat of catastrophic wildfire has not decreased. In fact, this threat increases with the new growth that is added to the forests each year.

The only plausible means for reducing this threat is to reduce the amount of fuels in the forests (Graham et al. 1999, Stephens 1998). This can be accomplished in a number of ways, but each fuels-reduction method requires the commitment of financial and human resources for its implementation. The level of resource commitment for each method can vary considerably, depending on

1) the nature of the specific methods under consideration,
2) the amount of fuels that need removal to reduce the wildfire hazard to acceptable levels,
3) the topographic characteristics of the site to be treated, and
4) the accessibility of the site to equipment and people.

## Purpose of This Study

LANL's Ecology Group, in collaboration with the U.S. Forest Service's Rocky Mountain Research Station (RMRS), the University of Arizona, and Stephen F. Austin State University, has initiated a program to

1) survey the fuels in the forests and woodlands of the Los Alamos region and
2) understand the spatial distribution of these fuels and forest structures.

The Los Alamos County and the Bandelier National Monument have also participated as cooperators in this program. This project was begun on an exploratory basis in 1997. In 1998, we expanded the scope to 1) include more detailed sampling protocols, 2) emphasize landscapes that are known to support the greatest amounts of fuels, and 3) provide inputs to remote sensing and geographic information system (GIS) techniques that extrapolate the plot-based results to larger landscapes. The 1997 results were reported by Balice et al. (1999). This report contains the results of the surveys conducted in 1998 and 1999 and discusses the results of preliminary spatial analyses.

## Environmental Setting

LANL covers 112 sq km (43 sq mi) of land. It is located on the eastern slopes of the Jemez Mountains, approximately 120 km (80 mi) north of Albuquerque and 40 km (25 mi) northwest of Santa Fe (Figure 1). LANL is largely but not completely circumscribed by Los Alamos County. In addition to LANL and County administered parcels, a significant portion of Los Alamos County is under the management of the U.S. Forest Service. LANL is also bordered on the south by the Bandelier National Monument and on the east by the San Ildefonso Pueblo. Two populated areas, Los Alamos townsite and White Rock townsite, are adjacent to LANL on the north and southeast, respectively.

Los Alamos County and its surroundings span an elevational gradient that ranges from approximately 1,631 m (5,350 ft), adjacent to the Rio Grande, to 3,199 m (10,496 ft) at

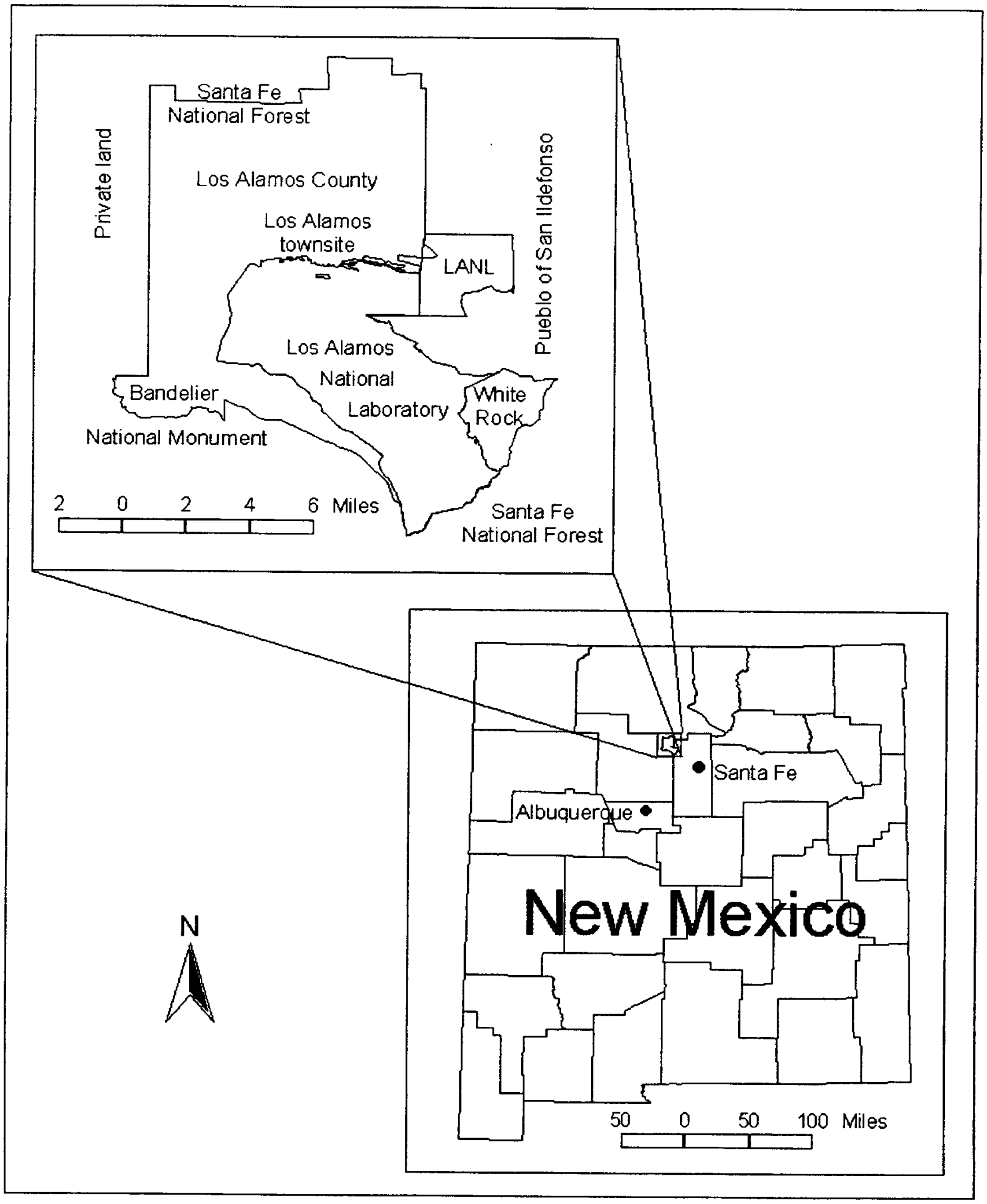


Figure 1. Location of the Los Alamos region and selected major landowners.

the crest of the Sierra de los Valles (Figure 2). Located in the western portions of Los Alamos County, the Sierra is a string of peaks, including, from south to north, Cerro Grande, Pajarito Mountain, and Cerro Rubio. Further to the west, the Sierra borders the Valle Grande, an ancient caldera.

The elevational gradient in the Los Alamos County and its surroundings encompasses several major cover types, including five vegetational zones (Figure 3). These are juniper savannas, piñon-juniper woodlands, ponderosa pine forests, mixed-conifer forests, and spruce-fir forests (Balice et al. 1997). Large acreages of grasslands and aspen forests are also found in the region. The elevational ranges of most of these major cover types are summarized in Figure 4. For further details see Balice et al. (1997) and Balice (1998).

## Sample Site Selection

### *Scope of the Study*

Within this environmental setting, the region of interest to this study was limited to forested and wooded areas at the middle and upper elevations of LANL property and in its immediate surroundings on Forest Service, Bandelier National Monument, and Los Alamos County lands (Figure 5). This consists primarily of forested or wooded mesas and canyons and mountain slopes above 2,134 m (7,000 ft), but also includes extensive acreages of grasslands. Specifically, the study area includes

1) the western 40% of LANL,
2) U.S. Forest Service land to the crest of the Sierra de los Valles and north to the Guaje Canyon area,
3) the western portions of Bandelier National Monument, including the upper sections of Frijoles Canyon,
4) the western and central portions of lands that surround the Los Alamos townsite and are administered by Los Alamos County, and
5) Department of Energy (DOE) lands that are located in Rendija Canyon.

This area is approximately 18.3 km (11.4 mi) long and 3.7 km (8.5 mi) wide: a total of 250.7 sq km (96.8 sq mi). The predominant vegetation types in this study area include ponderosa pine forests, mixed-conifer forests, spruce-fir forests, aspen forests, and grasslands.

### *Automatic Stratification Using Spectral and Spatial Data*

Multi-spectral, remotely sensed, and digital elevation model (DEM) data were used to construct a stratified random sample of field sampling locations that represents environmental conditions within the study area (Yool et al. 2000). The DEM data were combined into a base map composed of single DEM scenes mosaicked together using digital processing techniques. In particular, a multistage convolution filter was used to remove the majority of the striping from the DEMs (Crippen 1989). The resulting base map ascribes to National Map Accuracy Standards and provides overall geographic

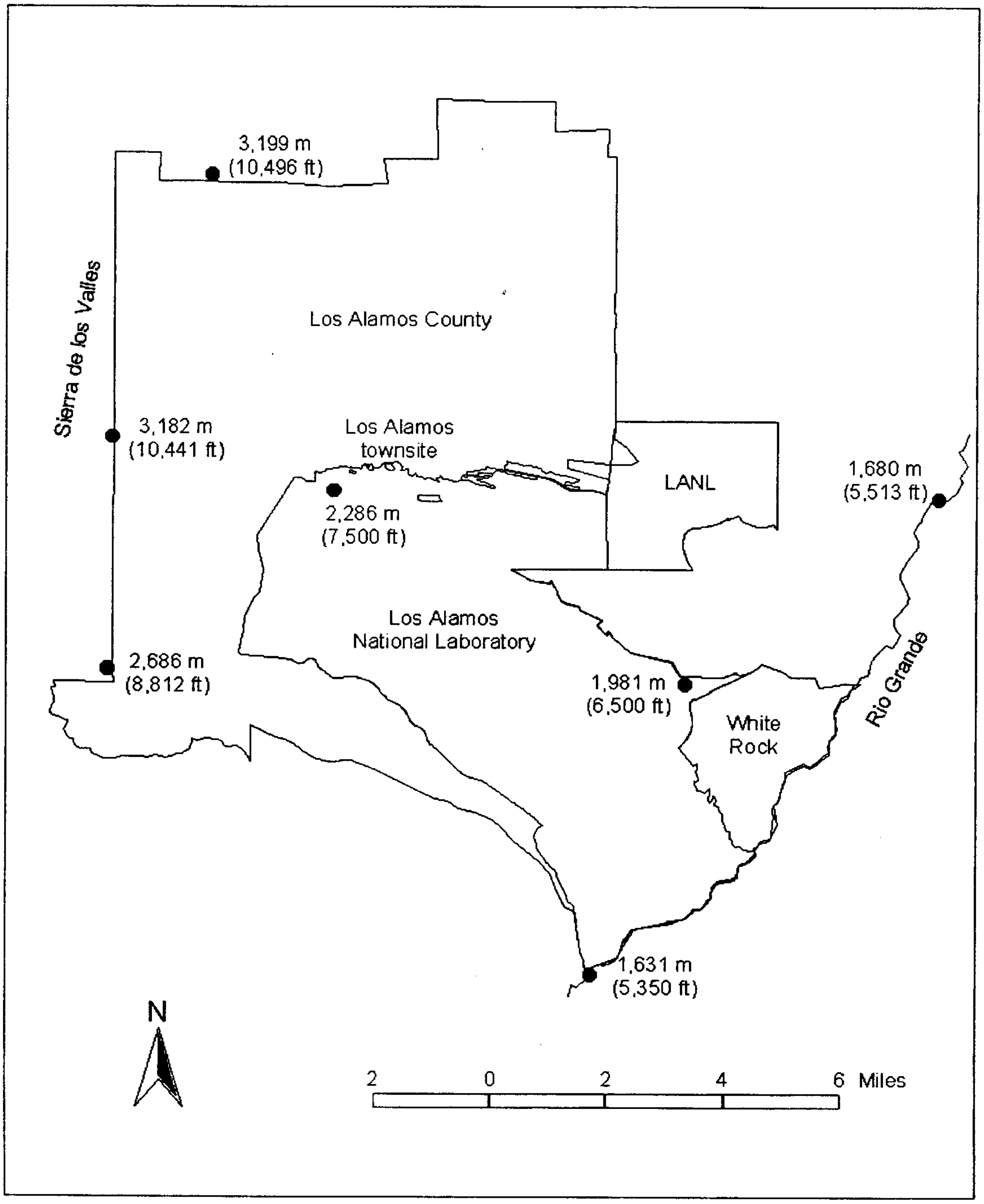


Figure 2. The elevation gradient of the Los Alamos region.

control for this project. Next, a Landsat Thematic Mapper (TM) image (July 3, 1997) was obtained and registered to the DEM base map.

Variables derived from digital terrain models were used to predict vegetation patterns and construct a random sample of potential sample sites (Davis and Goetz 1990). First, the TM-DEM data layers were stratified into combinations of overstory type and aspect categories. These include sixteen possible combinations of grass, ponderosa pine, mixed conifer, and aspen over aspect categories of north, south, east, and west. Then, one hundred possible sample points were randomly selected from each stratum. In the interest of safety, no points were chosen in areas with slopes of 56 percent or greater. In addition, each selected sample site was constrained to be spectrally and spatially homogeneous and at least 60 m by 60 m in size. This is equivalent to four 30-m by 30-m TM pixels.

### *Location of Sample Sites in the Field*

From the collection of potential sample sites that had been identified through the automated stratification procedure, individual sites were selected for further analysis on the ground. First, each of the selected sites was located in the field, with the assistance of a Geo Explorer II™ global positioning system (GPS) unit (Trimble Navigation Ltd. 1996). Then, the site was checked to verify the homogeneity of topographic, soils, and vegetational conditions for a distance of 60 m (197 ft) in any direction. If these conditions were not met, the site was rejected and either a new randomly selected point was located in the field or the original point was replaced by the nearest homogeneous area of vegetation. Assuming that the registration error of the TM data could be plus or minus one 30-m pixel, the resulting minimum mapping unit is 60 m (197 ft) or four TM pixels.

In addition to providing a random sample of data points for detailed sampling, the results of the automated stratification process were also used to select clusters of paired, triplicate, or quadruplicate plots whenever possible. The purpose of this sampling sub-strategy was to provide a means for analyzing the spatial variability of fuels and vegetational structures within the same vegetation-topographic combination. First, a sample point was selected from the output of the automated stratification process. If the area was homogeneous, this point was sampled using the field procedures described in this document. Then, a second sample point was subjectively selected at a distance of approximately 120 m (394 ft) from the first point and on roughly the same topographic position as the first point. Finally, the second point was sampled according to the field methods described below. If a sufficiently large homogeneous area was available, this subjective selection process was repeated to generate a triplicate plot or a quadruplicate plot.

## <u>Field Methods</u>

The field methods described below are generic in that they represent the minimum data collection procedures that were performed at each sample location. If time and resources were available, additional information was gathered and recorded. Since the sampling

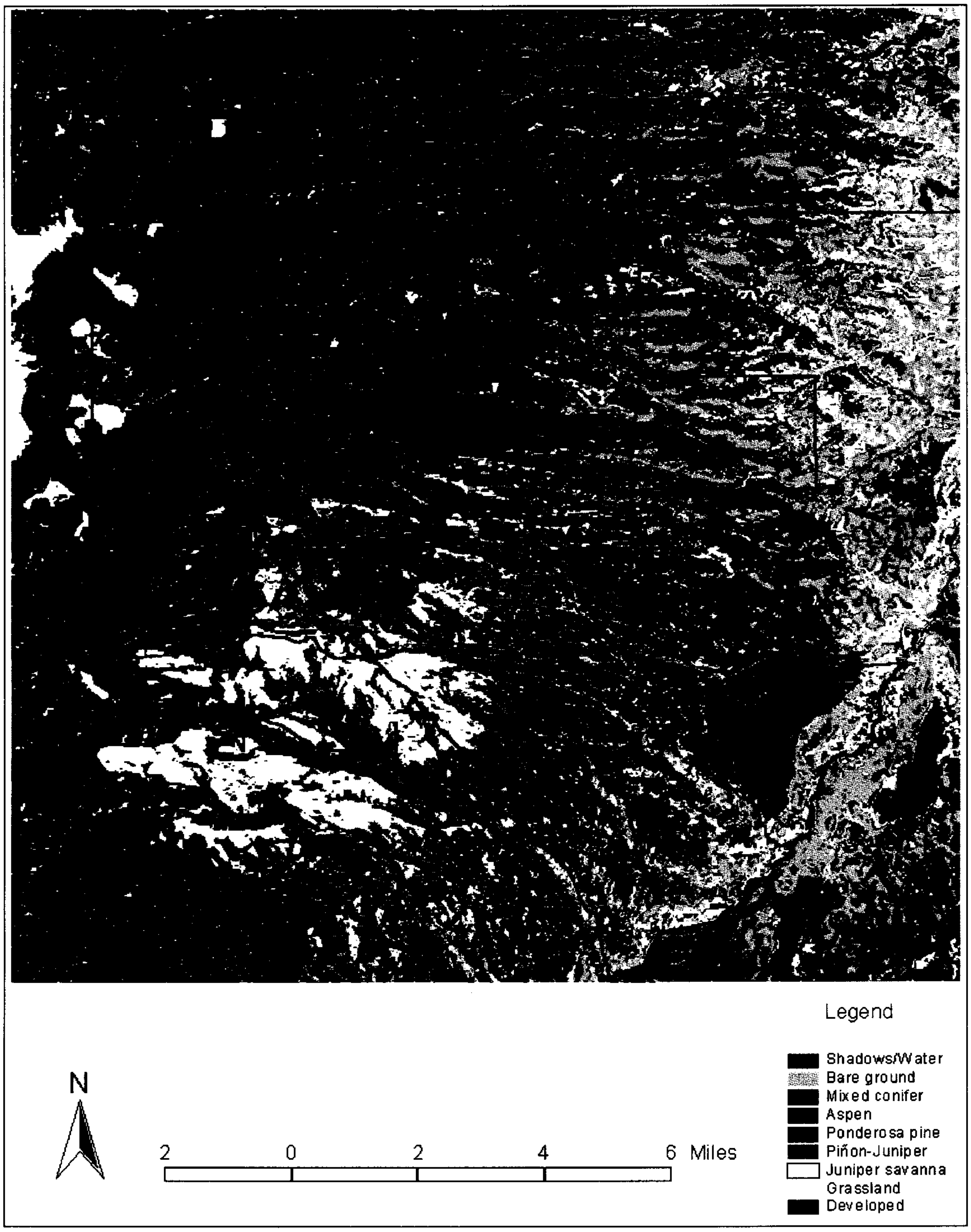


Figure 3. Selected land cover types in the Los Alamos region. Source: Koch et al. 1997.

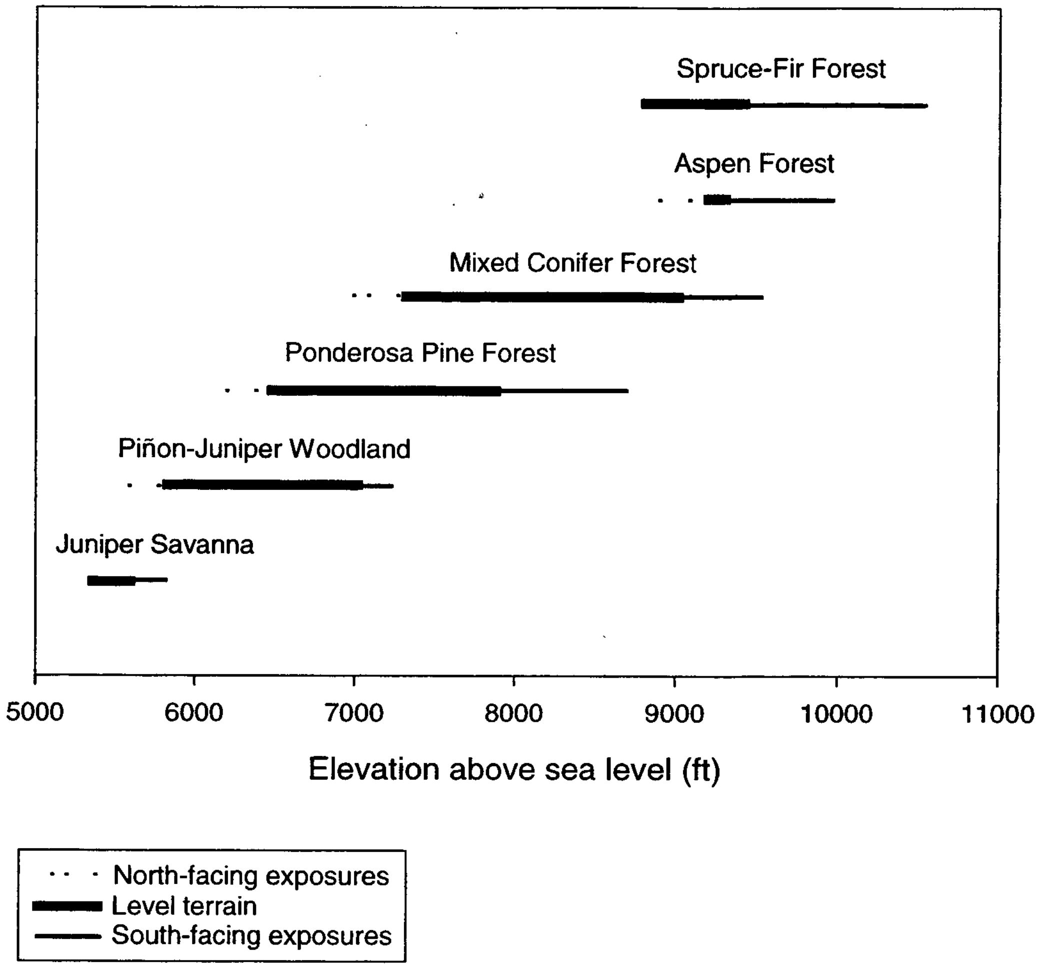


Figure 4. Elevational ranges of selected land cover types.

design used a nested approach, the collection of additional information was facilitated by merely repeating the sample process in a separate and additional subsample (i.e., subplot).

By convention, metric units were used during the plot layout procedure and for measurements made on the ground surface. English units were used for measurements made above the ground surface and for measurements of depths below the ground surface.

Appendix A includes examples of the field data forms used in this project. One Site Summary form and one Plot Layout form were used per macroplot. Since a nested design was used, all other forms were used in multiple quantities. Two Quad Summary forms and two Overstory Fuels, Complete Sample Forms were used. The remaining forms were used in multiples of four for each macroplot. That is, two subplots and six quads were sampled at some level within each macroplot.

Appendix B contains lists of all plant species that have been mentioned and discussed in this report. The plant species in these two lists are arranged in alphabetical order and by scientific name or four-letter code, respectively. A list of additional plant species encountered during the execution of this project can be found in Balice (1998).

*Sample Site Summary Information*

All of the data collected in the field were stored on field data forms and transferred to a computer database at the completion of each respective field season. In 1998, the sample sites were given alphanumeric plot numbers of the form TAXX-YYP. The actual values of the plot numbers reflect the

1) field team (T) that collected the data (Table 1),
2) agency (A) that owned or administered the land that was being sampled (Table 2),
3) remotely sensed topographic-vegetation combination (XX),
4) plot or cluster number (YY), and
5) sequence number within its respective cluster (P), where applicable.

The cluster number ranged from 1 to 16 and the sequence number was incremented sequentially beginning with 1. For paired plots, triplicate plots, etc., the cluster numbers (YY) were given alphabetical annotations (P) starting with "A" for the first, randomly selected plot in the cluster, and continuing with "B", "C", etc., respectively, for each additional plot in the cluster. In 1999, this alphanumeric system was simplified to the form TA-YYP. The remote sensing indicator number (XX) was dropped from the nomenclatural scheme.

The plot number, along with the date and the names of the field team members and information describing the directions to the plot, were recorded on the Site Summary data form. The GPS location was also collected, and the name of the GPS file and the time of its collection were recorded on the Site Summary data form. Descriptive notes pertaining to the vegetational conditions, including dominant species, disturbance history, plant

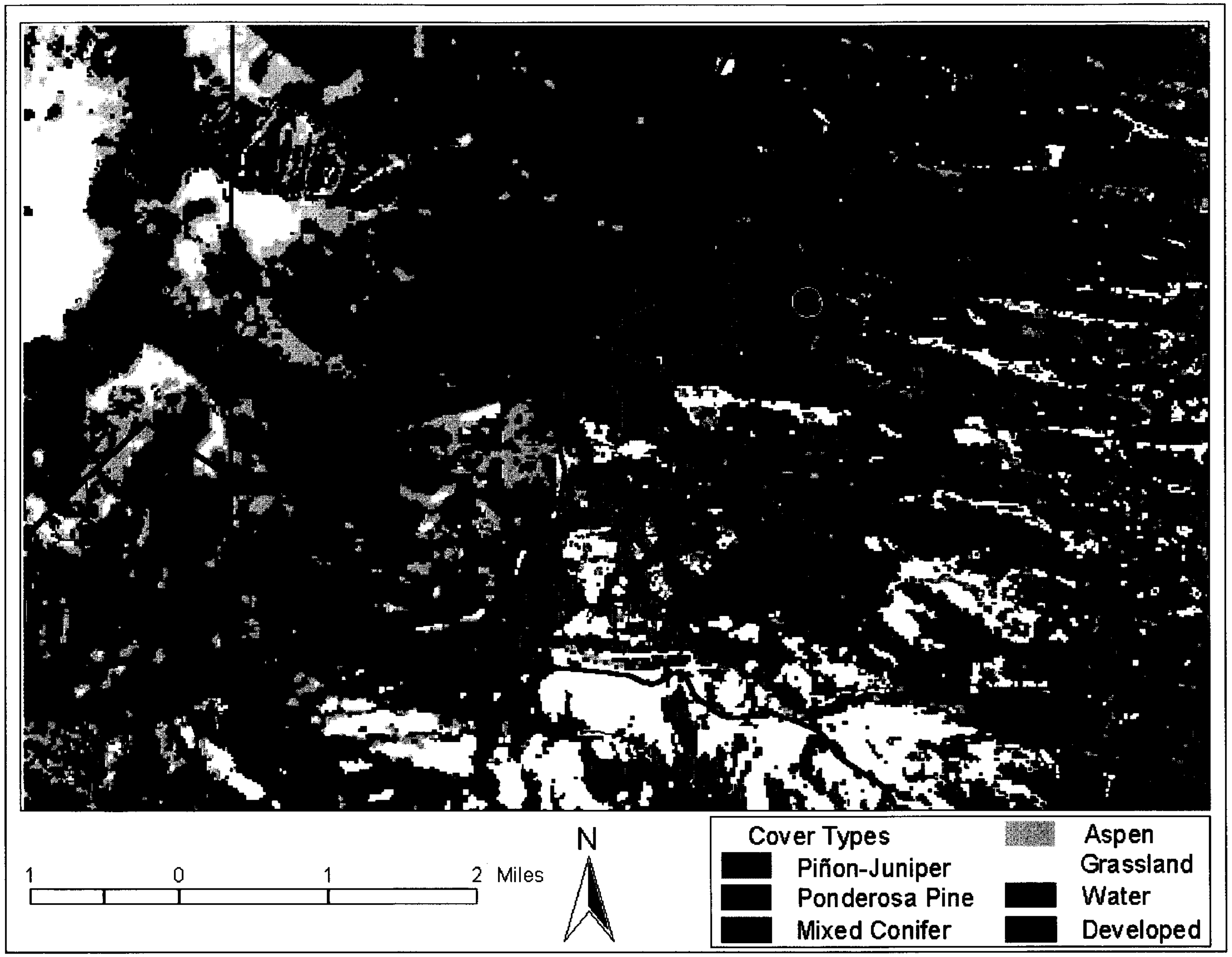


Figure 5. Major land cover types within the study region. Source: Koch et al. 1997.

Table 1. Plot number coding conventions for the field team identifier (T).

| Code | Year | Field team |
|---|---|---|
| A | 1998 | Forest Service, RMRS and Ecology Group, LANL |
| N | 1999 | Ecology Group, LANL |
| T | 1999 | Forest Service, RMRS |

Table 2. Plot number coding conventions for the agency identifier (A).

| Code | Land Management Agency |
|---|---|
| B | Bandelier National Monument |
| C | Los Alamos County |
| F | Española Ranger District, U.S. Forest Service |
| L | Los Alamos National Laboratory |
| P | Pajarito Ski Area – private |
| R | Los Alamos Area Office, U.S. Department of Energy |

diseases, soil conditions, and topographic setting were also compiled on the Site Summary form. For coniferous forests, the habitat type, or plant community type, was recorded according to previous classifications by Balice et al. (1997), Balice (1998), or DeVelice et al. (1986). For aspen forests, community classifications developed in surrounding regions were used to determine the habitat type (Mueggler and Campbell 1986, Mueggler 1988, Komarkova et al. 1988). The U.S. Forest Service fuel model was also recorded (Anderson 1982). Whenever possible, the fuel model was also compared to the fuel photo series developed for Arizona and New Mexico (U.S. Forest Service, Southwestern Region, undated report). Finally, 35-mm photographs were obtained that portray the general site conditions. The roll and photo numbers, along with the compass direction of the camera view, were recorded on the Site Summary form.

### *Plot Layout and Sampling Conventions*

A nested, randomized plot layout and sampling design was used to 1) allow for within-plot replication and measurement of statistical dispersion of fuel loads and other parameters and 2) provide a random sampling frame for statistical analyses of fuels and fire hazard variations at the pixel and subpixel level. This was accomplished by defining a macroplot about the plot center (**O**) that consisted of four subplots (Figure 6). The macroplot consisted of a square area, 60 m on each side, with each subplot being 30 m on a side. The macroplot and subplot margins were oriented along the slope contours, and the horizontal and vertical compass bearings of the macroplot axes were recorded on the Plot Layout form. The plot center (**O**) was permanently marked with rebar, and the four corners of the plot were also marked with flagging and spikes.

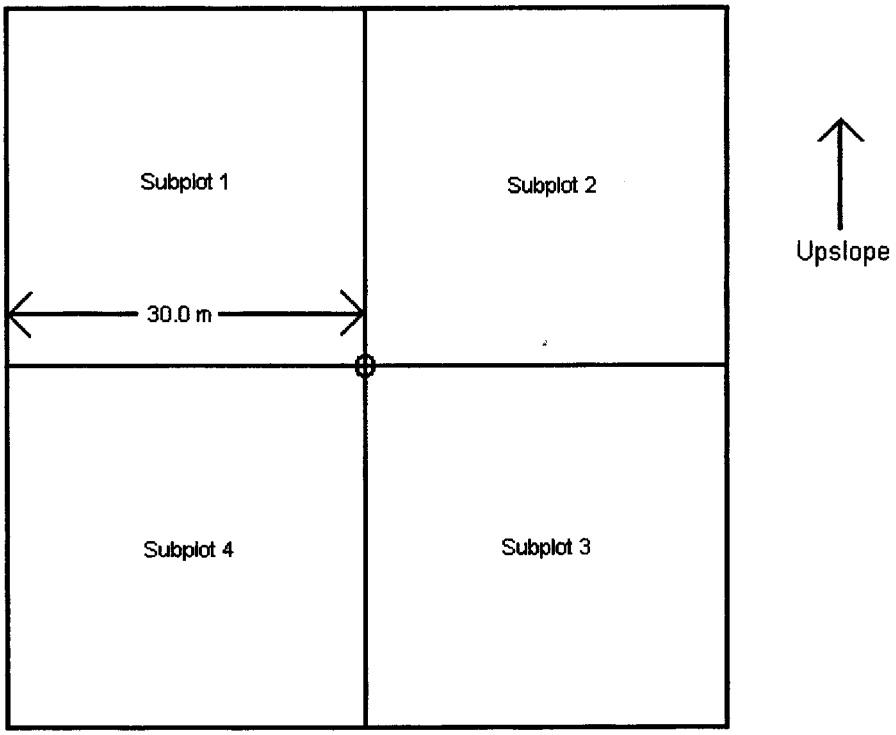


Figure 6. Macroplot layout and subplot numbering scheme. The macroplot scale is 60 m by 60 m. The subplots are numbered sequentially in clockwise direction about the plot center (**O**).

The subplots were numbered sequentially in a clockwise direction, with the subplot number 1 being arbitrarily located in the upper left corner of the macroplot. Then a subset of two subplots was randomly selected for further sampling, and their numbers were recorded on the Plot Layout form. The randomization was done using the Statistical Analysis Systems$^{TM}$ (SAS) programming language (SAS Institute Inc. 1988). Since the layout of each subplot was almost always associated with some error, this gap between the start and finish was also recorded to the nearest centimeter. This plot-layout error term allows for the estimation of the amount of variability for many of the parameters that were collected within the subplot.

Next, each of the two subplots that had been selected for sampling were further divided into quarters, or quads, that were 15 m on a side (Figure 7). The quads, within each subplot, were numbered 1 through 4 in a clockwise direction, with the upper left quarter being designated as quad number 1. Then, three of the four quads were randomly selected, and the numbers of the selected quads were recorded on the Plot Layout form. As before, the randomization was done using the SAS programming language (SAS Institute Inc. 1988).

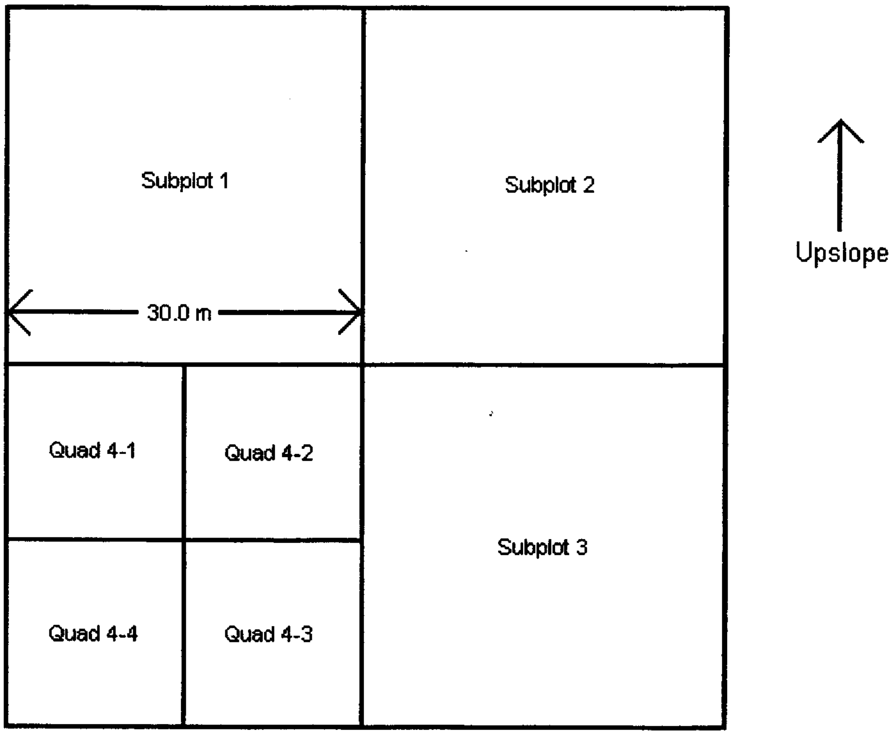


Figure 7. Plot layout with arrangement and numbering of quads shown for subplot four. The macroplot scale is 60 m and quad scale is 15 m.

In each selected subplot, two 3-m by 15-m strip plots were constructed within the first randomly selected quad (Figure 8). This was accomplished by selecting a random starting point (**X**) along the downhill border of the quad, where the lower left corner of the quad was arbitrarily defined to be the origin. This random starting point (**X**) marked the beginning of the strip plot system, where each subsequent step in the layout procedure was systematic. At the starting point (**X**), a 15-m line transect was constructed from the downhill border to the uphill border of the quad. A second 15-m line transect was constructed perpendicular to the first one, but separated by a distance of an additional 3 m from the origin. These two line transects defined a 3-m by 15-m strip plot (strip plot A).

This strip plot layout process was repeated to form a second 3-m by 15-m strip plot (strip plot B). However, the origination of strip plot B was exactly 7.5 meters from the randomly selected starting point (**X**). According to this randomized strip plot layout procedure, every point within the quad had equal chance of being selected. SAS was used to develop the randomization algorithm (SAS Institute Inc. 1988). By convention, the first line transect in each strip plot was denoted the vegetation transect and the second line transect in each strip plot was denoted the fuels transect.

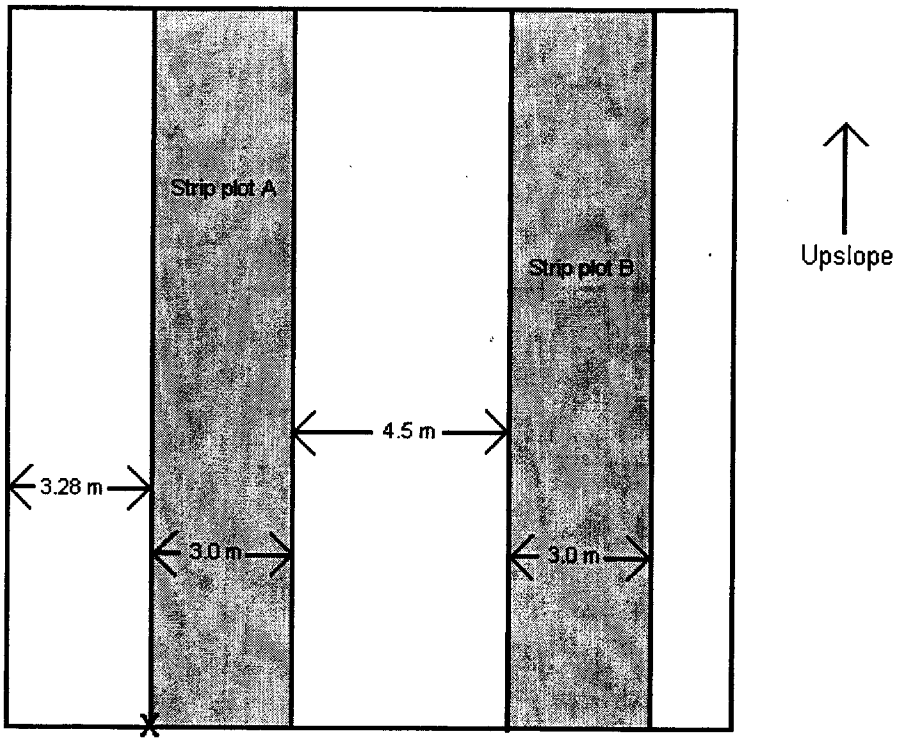


Figure 8. Arrangement of strip plots within a quad. The quad is 15 m on a side. In this example, the random starting point (**X**) for strip plot A is located at 3.28 m along the baseline from the lower left corner. Strip plot B begins at a distance of 7.5 m from the random starting point (**X**).

### *Topographic and Strip-plot Location Information*

The Quad Summary and Surface Conditions form was used to record information specific to the subplot, and its site conditions. First, the slope, aspect, elevation, topographic position, horizontal configuration, and vertical configuration of the subplot were recorded (Pfister et al. 1977). The slope was measured in percent and the aspect was measured in degrees from true north, assuming a declination of 10.5 degrees east. The topographic position was either ridge, upper slope, mid slope, lower slope, bench or flat, or drainage bottom. The horizontal and vertical configurations were listed as convex, concave, straight, or undulating. The randomized starting point (X) for strip plot A and the systematic starting point for strip plot B were also recorded on this form.

### *Downed Woody Fuels and Duff Measurements*

Within each of the strip plots, the second transect line, the fuels transect, was used to sample understory fuels as described by Brown (1974) and Brown et al. (1982) with modifications detailed below. According to this inventory procedure, woody fuels that were on or near the ground were counted or measured if they intercepted the plane of a sampling line.

To facilitate sampling and subsequent analyses of fire behaviors, these down woody fuels were subdivided into four size classes (Table 3). According to their size class, these woody fuels were sampled at varying positions along the lines. Tallies of 1-hour fuels and 10-hour fuels were completed in the first 2 m of each line. Tallies of 100-hour fuels were completed in the first 3 m of the lines. The 1000-hour fuels were sampled along the entire length of the lines, 15 m. The diameters of the 1000-hour fuels at the point of intercept were recorded to the nearest tenth of an inch. The condition of the 1000-hour fuels, sound or rotten, was also noted.

Duff depths and soil depths were also measured along the second transect of each strip plot. This was done at distances of 5 m and 10 m from the beginning of each transect. The duff depth was measured by inserting a ruler into the layer of duff and measuring its thickness to the nearest tenth of an inch. The soil depth was measured by inserting a soil probe into the soil and measuring its penetration to the nearest inch.

### *Litter-weight and Vegetation-weight Samples*

Ground-surface fuels, in the form of litter and vegetation, were sampled within rectangular microplots. Four 1-ft by 2-ft rectangles were used for this purpose. The rectangles were located along each of the fuels transects at a starting point that was 7.5 m from the lower border of the quad. From this starting point, the rectangles were systematically arranged similarly to that described by Brown et al. (1982). The primary difference from the standard procedure was that the rectangles were offset from the line by a distance of 2 ft. Then, they were located in a rectangular fashion and separated from each other by distances of 2 ft. Once the rectangles were placed at their respective locations, they were used to sample the litter biomass and understory herbaceous and shrubby vegetation. For the purposes of this study, understory herbaceous and woody vegetation is defined as grasses, forbs, and low-growing shrubs. Low-growing shrubs are those, such as *Pachistima myrsinites* (mountain lover), that typically grow to heights of less than 0.30 m (1 ft).

Litter and understory vegetation were sampled independently within the system of rectangles, but using identical methods. The example that follows is for the litter, but the sampling of understory vegetation was the same. First, the rectangle with the greatest amount of litter was exhaustively sampled and the material was placed in a labeled bag for transport and processing. Next, the litter biomass within each of the remaining three rectangles was estimated as a percent of the total amount of litter contained in the sampled rectangle. Finally, these percentages were recorded on the Quad Summary and Surface Conditions form.

Table 3. Size classes of down woody fuels. The fuel type designation reflects the time required for the fuel moisture to equilibrate with ambient atmospheric conditions.

| Fuel type | Size class |
|---|---|
| 1-hour | Less than ¼ inch in diameter |
| 10-hour | ¼ inch to 1 inch in diameter |
| 100-hour | 1 inch to 3 inches in diameter |
| 1000-hour | Greater than 3 inches in diameter |

### *Understory Vegetation Sampling*

The Surface Vegetation data form was used to record understory vegetation data and selected ground surface characteristics. The two vegetation transects were used for this purpose. The line intercept method was used to sample all herbs, graminoids, and shrubs (Canfield 1941, Bonham 1989, Elzinga et al. 1998). The intercept of each individual plant or group of plants was measured to the nearest centimeter and recorded by species and growth form. Intercepts of litter, duff, bare soil, moss, lichens, gravel, cobbles, stones, and boulders, and bedrock were also recorded. Finally, a complete list of plant species was compiled for the subplot.

### *Woody Midstory Sampling*

The two 3-m by 15-m strip plots, strip plots A and B, were used to sample all trees and shrubs that met specific height criteria. These data were recorded on the Woody Midstory form and a two-part procedure was used. First, a 3-m by 3-m microplot was used to sample all trees and shrubs less than 2 ft tall. Information recorded for each individual included the species, live or dead status, basal diameter, total height, height to live crown, and crown width to the nearest tenth of a foot. Crown shapes were also classified as a rectangle, circle, triangle, inverse triangle, diamond, or flag. Multiple stemmed individuals were noted but only the number of stems and the basal diameter of the largest stem were recorded.

Second, the entire 3-m by 15-m strip plot was used to sample all shrubs and trees greater than or equal to 2 ft tall and less than 10 ft in height. These individuals were measured and recorded in a manner similar to that used in the 3-m by 3-m microplots. However appropriate adjustments were made to the units of measure. The total heights, crown widths, and heights to live crown were measured to the nearest foot, and the basal diameters were measured to the nearest tenth of an inch. In addition, any mistletoe infestations were rated and recorded according to a rating scheme developed by Hawksworth (1977). This was done by dividing the crown of each plant into three sections, the lower third, middle third, and upper third. Within each third, the presence of mistletoe was given a numerical rating of zero for "absence" of mistletoe, one for moderately infested, and two for severely infested. Then the rating for each third was summed for a total value that can range from zero to six.

### *Overstory Sampling*

For the purposes of this study, overstory trees and shrubs were defined as those that were at least 10 ft tall. Within each subplot, the forest overstory was sampled using two levels of detail. In the first randomly selected quad, a "complete" sample was obtained and recorded on the Overstory Fuels – Complete Sample form. In the remaining two randomly selected quads, a "reduced" sample was taken and the data were recorded on the Overstory Fuels – Reduced Sample form. In either case, all trees or shrubs that were in the respective quad and were greater than or equal to 10 ft tall were sampled

For the complete sample, each tree or shrub in the quad was recorded by species and by its live or dead status. For dead trees, diameters at breast height (*dbh*) and total heights were also recorded. For each live tree, the *dbh*, total heights, heights from the ground to the live crown, greatest crown widths, crown shapes, and mistletoe infestation ratings were recorded. The total heights, crown widths, and heights to live crown were measured to the nearest foot and the diameters were measured to the nearest tenth of an inch. Crown shapes were classified as a rectangle, circle, triangle, inverse triangle, diamond, or flag. The mistletoe infestation was rated and recorded according to the method developed by Hawksworth (1977). Multiple stems, forks, presence of disease or infestations, or other unusual conditions or deformities were also noted where applicable.

From the collection of live trees sampled in the first randomly selected quad, the complete sample, a dominant, intermediate, and suppressed tree were selected and noted on the Overstory Fuels – Complete Sample form. Increment cores were extracted from each of these trees. The approximate age of each tree, at breast height, was determined from its respective increment core and recorded on the form.

Finally, the overstory canopy coverage of the quad was estimated using the densiometer method (Lemmon 1956, Strickler 1959, Ganey and Block 1994). This was done in the approximate center of the quad and the measurement was repeated four times, once for each primary axis of the plot. According to the densiometer method, 96 possible points could be covered by green foliage in the forest overstory. For each of the four densiometer measurements, the actual number of covered points, up to 96, was recorded on the Overstory Fuels – Complete Sample form.

The methods for each of the two reduced samples, in the second and third randomly selected quads, were similar to the complete sample. All trees that were greater or equal to 10 ft tall were censused. However, the Overstory Fuels – Reduced Sample form was used for each reduced sample and the recorded data were limited to the species, live or dead status, and *dbh*. In addition, four densiometer measurements of the overstory canopy coverage were also obtained.

## Office Methods and Database Development

The data forms were checked for completeness and accuracy before they were transported to the office. Once in the office, the data forms were stored in a secure area. Upon request, copies of the data forms were supplied to each of the collaborators and agency cooperators. As time became available, the data recorded on the paper forms were transferred to electronic spreadsheet versions of the data forms, by plot, and stored in a computer database.

The litter-weight and vegetation-weight samples were weighed, dried for 24 hours at $65^{\circ}$ C, and weighed again. The wet weights and the dry weights were recorded on the Quad Summary and Surface Conditions data forms and in the electronic database.

The location information was also summarized and catalogued. The GPS data were corrected using ESH-20's GPS base station and Pathfinder$^{\mathrm{TM}}$ software (Trimble Navigation Ltd. 1995). Then, the data for each plot were averaged and transformed from Latitude/Longitude, WGS 84, to State Plane coordinates, New Mexico Central Zone, and to UTM coordinates, NAD27 and NAD83 (ESRI Inc. 1994). Finally, the corrected, transformed GPS data points were labeled with the plot names and stored in an Arc/Info database. The 35-mm photographic exposures were developed and catalogued by sample plot and by date. Many of these photos were scanned and stored in an electronic folder in ESH-20's computer network.

## Data Summarization

The data for each plot were summarized by subplot and by plot using appropriate transformations and units of measure. Then, the average values for each plot were entered into a plot summary spreadsheet for each plot. This was done according to the following procedures. Unless stated otherwise, it is assumed that the data were scaled up from the original strip transect, quad, or subplot levels to the plot level.

### *Topography and Site Classification*

The two measurements of slope, in percent, and slope aspect, in degrees from true north, were averaged. Then, to adjust for downward biases in plot estimates that had been gathered on sloped terrain, the slope correction factor (*SCF*) was calculated as an intermediate result.

$$SCF = \sqrt{1 + \left( \frac{slope}{100} \right)^2} \qquad (1)$$

where *slope* = slope angle from level terrain (percent).

In addition, to partially assess the solar exposure that the sample site experiences during a growing season, the percent slope and slope aspect were entered into the following solar exposure (*SE*) function.

$$SE = slope \times \cos\left(\frac{\pi \times (aspect - 190)}{180}\right) \tag{2}$$

where $aspect$ = slope aspect (degrees from true north).

This unitless relationship assumes that a site on a relatively steep slope and with an aspect of 190° from true north receives the greatest solar input. The cosine term ranges from –1 for aspects of 10° to 1 for aspects of 190°.

For each macroplot, the approximate elevation, in feet above mean sea level, was obtained by projecting its GPS location on Arc/Info elevation data layers, including 100-ft, 20-ft, 10-ft, and 2-ft contour databases. The elevation of the sample site was visually interpolated to the nearest foot. The elevation data were also converted to metric units. Using information recorded on the sample sheets and from mapped data, the topographic position of the macroplot was determined and recorded for each plot (Table 4). The dominant overstory species or the physiognomic structure of the macroplot was also recorded (Table 5). The habitat type that had been recorded in the field was also entered into the summary spreadsheet (Table 6).

*Ground Surface Biomass and Fuels*

The downed woody fuel weights ($DWFW_i$) for the *i*th size class (see Table 3), were calculated, in tons per acre, according to the following relationship adopted from Brown (1974) and Brown et al. (1982; page 16).

$$DWFW_i = \frac{m_i \times n_i \times SCF}{N \times l} \tag{3}$$

where $m_i$ = conversion factors for the *i*th size class,
$n_i$ = the total number of intercepts for the *i*th size class,
$SCF$ = the slope correction factor,
$N$ = number of lines, and
$l$ = the length of each line (ft).

In this report, the downed woody fuel weights are reported by individual size classes and by two summary size classes. The first summary size class, the combined 1-hour to 100-hour fuels, summed over the 1-hour, 10-hour, and 100-hour down woody fuel classes. The second size class, the total 1000-hour fuels, summed over both of the 1000-hr fuel categories, sound and rotten.

Table 4. Topographic setting of the sampled plots and their data codes.

| Code | Topographic Setting |
|---|---|
| CY | Canyon |
| MS | Mesa |
| MT | Mountain |

Table 5. Database coding for overstory dominance.

| Code | Dominant Overstory Species or Vegetation Type |
|---|---|
| AS | Aspen forest |
| GR | Grassland |
| MC | Mixed conifer forest |
| PP | Ponderosa pine forest |
| SB | Shrub-pine woodland |
| SF | Spruce-fir forest |

Two independent methods for estimating duff weights appeared to give disparate results (Ffolliott et al. 1968, Wagtendonk et al. 1998). To resolve this, we obtained 19 duff samples from seven forested sites, representing *Pinus ponderosa* (ponderosa pine), *Pseudotsuga menziesii* (Douglas fir), and *Abies concolor* (white fir) vegetation. Drying and weighing of these samples resulted in bulk density estimates that were an order of magnitude lower than similar estimates from Wagtendonk et al. (1998), but within one standard deviation of the estimates for *Pinus ponderosa* forests reported by Ffolliott et al. (1968). For ponderosa pine duff, Ffolliot et al. (1968) would predict approximately 16.8 tons/acre, whereas the 95% confidence interval for the eight duff weights obtained from ponderosa pine forests in the study region returned a lower limit of 15.9 and an upper limit of 20.3 ($t_{7,0.025} = 2.365$). Therefore, conversion factors in Ffolliott et al. (1968) were used to estimate duff weights for this study.

Within each fuels transect, the average duff weight (*DW*) was calculated for the two duff depth measurements as

$$DW = 4.9 \times 3630 \times \frac{dd_1 + dd_2}{2 \times 2.54} \tag{4}$$

where $dd_i$ = the $i$th depth measurement in the transect, where $i = 1$ and 2.
4.9 = weighted-average bulk density for ponderosa pine duff from Ffolliott et al. (1968),
3630 = conversion factor from Brown et al. (1982), and
2.54 = conversion from centimeters to inches.

Table 6. Habitat type or community type database coding. The vegetation types are separated into types according to the dominant overstory species or the dominant growth form.

| Code | Habitat type or community type |
|---|---|
| Abla / Erex | Corkbark fir / Forest fleabane |
| Abla / Vamy | Corkbark fir / Whortleberry |
| Abco / Acgl | White fir / Mountain maple |
| Abco / Aruv | White fir / Kinnikinnik |
| Abco / Quga | White fir / Gambel oak |
| Abco / Erex | White fir / Forest fleabane |
| Abco / Rone | White fir / New Mexico locust |
| Mesagrass | Grassland on mesas below 8500 feet in elevation |
| Mtngrass | Grassland on mountains above 8500 feet in elevation |
| Pien / Erex | Engelmann spruce / Forest fleabane |
| Pipo / Bogr - Scsc | Ponderosa pine / Blue grama – Little blue stem |
| Pipo / Mumo | Ponderosa pine / Mountain muhly |
| Pipo / Quga | Ponderosa pine / Gambel oak |
| Potr / Feth | Aspen / Thurber fescue |
| Potr / Ptaq | Aspen / Bracken fern |
| Psme /Aruv | Douglas fir / Kinnikinnik |
| Psme / Mumo | Douglas fir / Mountain muhly |
| Psme / Quga | Douglas fir / Gambel oak |

The dry weights for the litter and ground vegetation samples were combined with the estimated percentages of litter and vegetation in the three unsampled rectangles. These results were used to estimate the amount of both vegetation biomass ($BW_1$) and litter biomass ($BW_2$), in tons per acre, within each strip plot. Relationships developed by Brown et al. (1982) were adopted for this purpose.

$$BW_i = \frac{c_i \times SCF \times wt_i \left(1 + P_{i,1} + P_{i,2} + P_{i,3}\right)}{2000} \tag{5}$$

where $i$ = indicator value: 1 = herbaceous vegetation and 2 = litter,
$c_i$ = conversion factor: herbaceous vegetation = 12.39 and litter = 24.78,

$SCF$ = slope correction factor,
$wt_i$ = dry weight (g) from the sampled vegetation or litter, and
$P_{i,j}$ = the fraction of litter or vegetation in the $j$th rectangle, where $j$ = 1, 2, and 3.

*Woody Shrub Biomass and Fuels*

The method for calculating the individual total aboveground weights of shrubs was adopted from Brown (1976). This was based on the generic equation for the shrub total weight ($STW_{i,j}$) for the $i$th individual in the $j$th shrub species, in grams, of the form

$$\ln(STW_{i,j}) = a_j + b_j \times \ln(dia_{i,j}) \tag{6}$$

where $dia_{i,j}$ = basal diameter (cm) for the $i$th shrub in the $j$th species,
$a_j$ = first coefficient for the $j$th species, from Brown (1976; Table 1), and
$b_j$ = second coefficient for the $j$th species, from Brown (1976; Table 1).

These results, in grams, were converted to tons/ac by multiplying by 0.0022.

A total of 25 species were listed in Brown (1976; Table 1), and 17 of these were the same species, such as *Acer glabrum* (mountain maple) or in the same genus, such as *Vaccinium* spp., as those encountered during the execution of this study. For those species, such as *Jamesia americana* (cliff bush), that had no counterpart in Brown (1976; Table 1), the coefficients, $a$ = 3.580 and $b$ = 2.853, that derived for combined medium-sized species were used. An exploratory data analysis indicated that these coefficients fit our data better than coefficients for low-growing or tall species. Finally, the estimates for total biomass of individual shrubs were summed for all shrubs and for all species in the strip plot and over all strip plots and quads. Then, these total shrub biomass estimates were converted from grams to tons/ac. The specific conversion factors depended on the size of the strip plot, 3 m by 3 m or 3 m by 15 m, and therefore the size of the plant, less than two ft in height or greater than or equal to 2 ft in height.

Brown (1976; Table 1) was also used to estimate the leaf weights for the shrubs sampled in the strip plots. These biomass estimates were used to partially evaluate the 1-hour fuels in the plot that are close to the ground, but not on the ground. As before, this was based on the generic equation for the shrub foliage weights ($SFW_{i,j}$) for the $i$th individual in the $j$th shrub species, in grams, of the form

$$\ln(SFW_{i,j}) = a_j + b_j \times \ln(dia_{i,j}) \tag{7}$$

where $dia_{i,j}$ = basal diameter (cm) for the $i$th shrub in the $j$th species,
$a_j$ = first coefficient for the $j$th species, from Brown (1976; Table 1), and
$b_j$ = second coefficient for the $j$th species, from Brown (1976; Table 1).

The remainder of the calculation procedure was identical to that used for total shrub biomass, as described above. For those shrubs that had no counterpart in Brown (1976;

Table 1), the coefficient values, $a = 1.945$ and $b = 2.363$, were used. The weights of dead shrubs were estimated by subtracting the foliage weight from the total shrub weight.

For calculation of total shrub biomass and shrub foliage biomass of *Quercus gambelii* (Gambel oak) in specified size ranges, a system of equations developed by Chojnacky (1988, 1992) was used. First, for those individual oaks where the diameters were measured at breast height ($dbh_i$), the diameters were converted to measures at the root crown or the base of the stem ($DRC_i$), according to

$$DRC_i = \frac{dbh_i - \beta_o}{\beta_1} \tag{8}$$

where $\beta_o = -0.5766$ and
$\beta_1 = 0.8841$.

Then, the diameter squared height ($X_i$) was calculated for the $i$th individual oak

$$X_i = \frac{DRC_i^2 \times ht_i}{1000} \tag{9}$$

where $DRC_i$ = basal diameter (cm) for the $i$th individual oak and
$ht_i$ = total height (ft) for the $i$th individual oak.

Acceptable size ranges include all *Q. gambelii* with basal diameters (*DRC*) greater than or equal to 2.0 in., otherwise the generic medium-sized shrub equations from Brown (1976) were used. Next, the diameter squared height ($X_i$) was used to calculate the gross, outside-bark bole volume ($V_{bd,i}$) for the $i$th Gambel oak according to the following relationships

$$V_{bd,i} = \beta_o + \beta_1 X_i + \beta_2 X_i^2 \qquad X_i \leq 7.1046 \tag{10}$$

or

$$V_{bd,i} = \beta_o + \beta_1 X_i + \beta_2 \left( \frac{3X_o^2 - 2X_o^2}{X_i} \right) \qquad X_i > 7.1046 \tag{11}$$

where $\beta_o = -0.0534$,
$\beta_1 = 2.3077$, and
$\beta_2 = 0.0467$.

The gross, outside-bark bole volume ($V_{bd,i}$) for the $i$th Gambel oak was used to calculate the weight of outside bark, oven-dry bole and branches, greater than 3.8 inches in diameter ($W_{bd,i}$) as

$$W_{bd,i} = sg_{Quga} \times V_{bd,i} \times dens_{H_2O} \qquad (12)$$

where $sg_{Quga}$ = specific gravity of Gambel oak wood (0.63) and
$dens_{H_2O}$ = density of water (62.4 lbs/ft$^3$).

The weight of the outside-bark, oven-dry branches, less than 3.8 inches in diameter ($W_{B,i}$) and the oven-dry foliage weight ($W_{F,i}$) for the *i*th Gambel oak were calculated according to the following general equation:

$$W_{*,i} = 10^{\left[\beta_{*,0} + \beta_{*,1} Log_{10}(W_{bd,i}) + \beta_{*,2} ht_i\right]} \qquad (13)$$

where $*$ = subscript for the weight of branch (*B*) or foliage (*F*) biomass,
$W_{bd,i}$ = weight of outside bark, oven-dry bole, and branches (>3.8 inches in diameter) for the *i*th oak,
$ht_i$ = total height (ft) for the *i*th individual oak, and
$\beta_{*,j}$ = *j*th coefficient branch (*B*) or foliage (*F*), where $j$ = 0, 1, and 2.

Finally, the oven-dry foliage weight ($W_{F,i}$) was used to estimate the 1-hour shrub fuels. The total shrub weight was estimated by summing over the weight of the outside bark, oven-dry bole and large branches ($W_{bd,i}$), the outside-bark oven-dry branches ($W_{B,i}$), and the oven-dry foliage ($W_{F,i}$).

*Biomass and Fuels for Trees Less Than Ten Feet Tall*

The weights of whole trees, for individuals less than 10 ft tall, were calculated using relationships developed by Brown (1978). The generic form of the equation for tree weight ($TW_{i,j}$), in lbs and for the *i*th tree in the *j*th species, is

$$TW_{i,j} = exp\left(a_j + b_j \ln(ht_{i,j})\right) \qquad (14)$$

where $a_j$, $b_j$ = coefficients for the *j*th species from Brown (1978, Table 6) and
$ht_{i,j}$ = total height (ft) for the *i*th individual in the *j*th species.

Coefficients for dominant trees were used for all tree species, except for *Pseudotsuga menziesii* (Douglas fir) and *Pinus ponderosa* (ponderosa pine), which were calculated using coefficients for intermediate trees. For species with no direct correspondence in Table 6 in Brown (1978), coefficients for their closest relative were used.

The resulting whole tree weights were partitioned into foliage weights, 1-hour branchwood fuels, 10-hour branchwood fuels, and 100-hour branchwood fuels using the corrected proportions from Brown (1978, Table 19). Then the foliage weights were added to the 1-hour branchwood class. For dead trees, the whole tree weights were adjusted by subtracting the predicted foliage weights.

Systems of equations for whole tree weights and foliage weights for *Populus tremuloides* (aspen) were not reported in Brown (1978). Therefore, data presented in Johnston and Bartos (1977) were investigated for this purpose. These data were subjected to regression and nonlinear modeling using SAS (SAS Institute Inc. 1988). However, the greatest R-square observed during this modeling exercise was 0.932 or less. In contrast, analyses of aspen data presented by Telfer (1969) resulted in R-squares for total weight and leaf weight of 0.988 and 0.956, respectively. Therefore, equations presented in Telfer (1969) were used for this purpose. For the total weight ($W_{qt,i}$) and the leaf weight ($W_{ql,i}$) of the $i$th aspen trees, these equations are

$$W_{qt,i} = \exp(-2.920 + 2.715 * \ln(bd_i)) \tag{15}$$

and

$$W_{ql,i} = \exp(-2.677 + 2.156 * \ln(bd_i)) \tag{16}$$

where $bd_i$ = the basal diameter (mm) of the $i$th aspen.

The composite biomass data for shrubs and trees less than 10 ft tall were summarized into groups that represent their contribution to wildfire behaviors and entered into the database. These include

1) total shrub biomass,
2) total tree biomass,
3) total biomass for both shrubs and small trees,
4) shrub and small tree 1-hour fuels,
5) shrub and small tree 10-hour fuels, and
6) shrub and small tree 100-hour fuels.

A summary database category that consisted of all understory fuels was also created. This total understory fuel category included the fuel types

1) all size classes of down woody fuels,
2) duff biomass,
3) litter biomass,
4) herbaceous and small shrub biomass, and
5) total biomass for both shrubs and trees.

### *Forest Midstory and Overstory Characteristics*

The data for trees and shrubs, greater than 10 ft tall, were incorporated into stand tables for each subplot, by species, by live or dead status, and by 4-in. diameter classes. Trees, less than 10 ft tall, which had been sampled in the strip plots were also entered into the stand tables by the height classes

1) less than 1 ft tall,

2) greater than or equal to 1 ft to 2 ft tall,
3) greater than or equal to 2 ft to 6 ft tall, and
4) greater than or equal to 6 ft to 10 ft tall.

The data were converted to numbers of stems per acre, summarized by subplot and by macroplot, and entered into the database by the following growth form-size classes

1) small trees: less than 2 ft tall,
2) shrubs: greater than or equal to 2 ft tall and less than 8 in. *dbh*,
3) ladder fuels: greater than or equal to 2 ft tall and less than 8 inches *dbh*, and
4) overstory fuels: greater than or equal to 8 inches *dbh*.

The densiometer measurements, 12 per subplot or 24 per macroplot, were converted to percent canopy cover, averaged for the macroplot, and entered into the database.

## Analysis of Remotely Sensed Data

Spectral response patterns from spaceborne sensors are useful for characterizing the forest canopy using vegetation indices (e.g., Baret and Guyot 1991) and radiative transfer modeling (e.g., Ganapol et al. 1999). To assess the biophysical characteristics of the vegetation in the study region, we applied two Kauth-Thomas (KT) linear transformations to the TM data (Kauth and Thomas 1976). The KT greenness index contrasts the near-infrared band (TM4) with the three visible TM bands (TM1, TM2, and TM3). Similarly, the KT wetness index contrasts the mid-infrared bands (TM5 and TM7) with the visible and near-infrared bands.

These indices were calculated for a single TM pixel that overlaps the coordinates of the sample sites. A correction was applied to reduce the error introduced by atmospheric scattering. However, the image processing did not translate the digital numbers recorded by the on-satellite cameras to radiances or reflectances. The KT transform rotates the data in 3-space to align the axes with the greeness, brightness, and wetness structures of the vegetation and soil planes (Crist and Cicone 1984). Since the KT is a linear transformation, the resulting data remain unitless. The final KT greenness and wetness results were stored in the database.

## Database Organization

The database for the forest surveys conducted in 1999 were combined with the summarized sample data that had been collected during the 1998 field season. The composite database contained results for a total of 29 variables in 76 macroplots. These were organized by dominant overstory structures, by plant community type, and in order of increasing elevations of the sample sites. Then for each overstory dominance-community type grouping, the average, standard deviation, standard error of the mean, and the percent coefficient of variation were calculated for each variable and added to the columns of the data base.

## Spatial Data Analysis

A subset of the variables was defined and each of these variables was subjected to spatial analysis. GS+$^{TM}$ software was used for this purpose (Gamma Design Software 1998). The list of analyzed variables includes percent canopy coverage, trees per acre >8 in. *dbh*, trees per acre <8 in. *dbh*, total understory fuels, combined 1-hr to 100-hr fuels, and total 1000-hr fuels. To analyze the data in a distribution that was approximately normal, the square-root transformation was applied to the trees per acre <8 in. *dbh* data before analysis.

Each of these variables was analyzed for spatial autocorrelations by calculating the semivariance for all possible pairs of points in the data set (Goovaerts 1997). The general form of the semivariance, $\gamma(h)$, for the interval distance class ($h$) is

$$\gamma(h) = \frac{1}{2 * N(h)} \sum [z_i - z_{i+h}]^2 \qquad (17)$$

where $z_i$ = measured sample value at point $i$,
$z_{i+h}$ = measured sample value at point $i+h$, and
$N(h)$ = total number of sample couples for interval distance class $h$.

The interval distance classes are defined by subdividing the range of distances between sample points into classes of equal distance.

These intermediate results were used to map each variable for the entire study region (Goovaerts 1997). The semivariogram results provided the variance estimates for interpolation from sampled sites to unsampled coordinates. This was done by producing regional variables through a family of least-square regression algorithms, known as kriging. In this case, block kriging was used. The three-dimensional kriging output was displayed graphically using Sigmaplot$^{TM}$ (SPSS Inc. 1998).

## Results

From the original collection of 100 potential sample points in each of 16 spectral classes, a total of 76 macroplots were sampled during the two-year period of this study. The spatial distribution of these sample sites is shown in Figure 9. The original data for each of the 76 sampled macroplots are included in Appendices C–F. Each of these appendices is arranged into separate tables according to dominance type and community type. Within the dominance-community stratifications, the individual sample sites are listed in order of increasing elevation. The plot number is listed in each of the tables within each of the appendices. The entry order and brief descriptions for the remaining variables is given in Table 7.

The means, standard deviations, and standard errors of the means, for each numeric variable, are also given in Appendices C–F. Aspect (Asp) was the only variable without these summary statistics. Since aspect ranges from 0 degrees to 360 degrees, a mean and standard deviation of the corresponding data could be meaningless. In addition, the information contained in aspect was incorporated into the solar exposure (*SE*) calculation.

Table 7. List of variables included in Appendices C–F.

| Variable | Description (units of measure) |
|---|---|
| Year | Year that the sample was obtained |
| Dom | Overstory dominance type or physiognomic characteristics |
| Comm type | Plant community type |
| Topo | Topographic position |
| Slope | Slope (percent) |
| Asp | Aspect (degrees) |
| SE | Solar exposure (unitless) |
| Elev | Elevation above mean sea level (ft) |
| 1-hr | 1-hour down woody fuels (tons/acre) |
| 10-hr | 10-hour down woody fuels (tons/acre) |
| 100-hr | 100-hour down woody fuels (tons/acre) |
| 1-1C hr | Combined 1-hour to 100-hour fuels (tons/acre) |
| 1K-hr S | Sound 1000-hour down woody fuels (tons/acre) |
| 1K-hr R | Rotten 1000-hour down woody fuels (tons/acre) |
| 1K-hr T | Total sound and rotten 1000-hour fuels (tons/acre) |
| Duff | Duff weights (tons/acre) |
| Litter | Litter weights (tons/acre) |
| Veg | Weights of herbs, graminoids, and small shrubs (tons/acre) |
| Shrubs | Total weights of shrubs, <10 ft tall (tons/acre) |
| Tree 10 | Total weights of trees, <10 ft tall (tons/acre) |
| S&T Tot | Combined weights of shrubs and trees, <10 ft tall (tons/acre) |
| Ust Total | Combined weights of woody, duff, litter, vegetation, shrubs, and trees, <10 ft tall (tons/acre) |
| ST 1hr | Shrubs and trees, <10 ft tall, 1-hour fuels (tons/acre) |
| ST 10hr | Shrubs and trees, <10 ft tall, 10-hour fuels (tons/acre) |
| ST 1Chr | Shrubs and trees, <10 ft tall, 100-hour fuels (tons/acre) |
| TPA <2' | Trees, <2 ft tall (number of trees/acre) |
| SPA <2' | Shrubs, <2 ft tall (number of shrubs/acre) |
| TPA <8" | Trees, >2 ft tall and <8 in. *dbh* (number of trees/acre) |
| TPA >8" | Trees, >8 in. *dbh* (number of trees/acre) |
| CC % | Canopy coverage (percent) |
| KT W | Kauth-Thomas wetness index (unitless) |
| KT G | Kauth-Thomas greenness index (unitless) |

The results of the spatial analyses are given in Appendix G. First, a perspective map is provided to show the approximate location of the area that was kriged and to orient the viewer of the three-dimensional graph of the kriged results (Figure G-1). Subsequent to the perspective map, the graphical outputs of the kriging, for each of the selected variables, are provided in Appendix G.

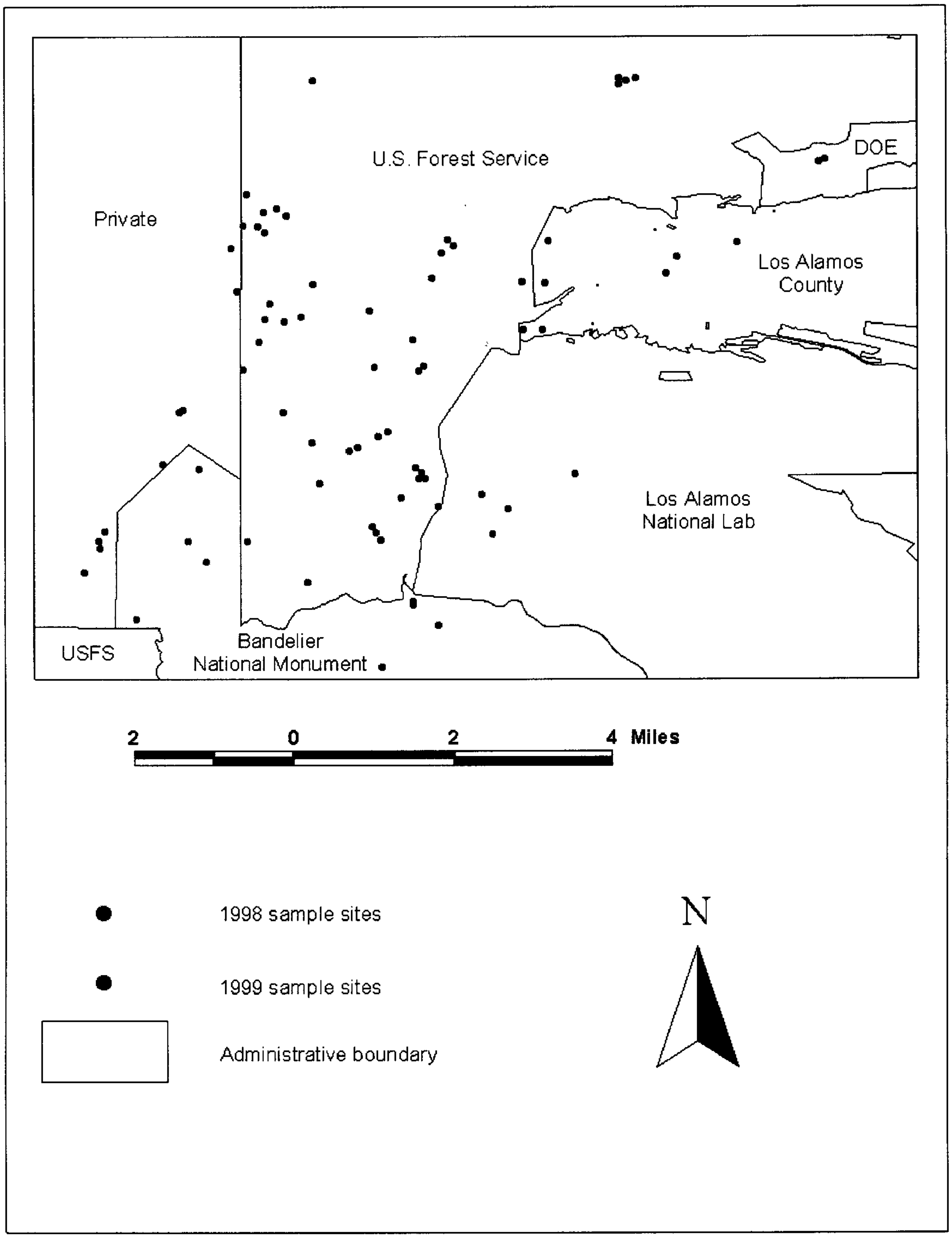


Figure 9. Distribution of sample sites. Major landowners include the U.S. Forest Service (USFS), Bandelier National Monument, Los Alamos National Lab, Los Alamos County, Department of Energy (DOE), and Baca Land and Cattle Company (Private).

Summary statistics for each of the kriged variables are shown in Table 8. Kriging resulted in interpolation for 3,685 coordinates. The average kriged value (mean), the average standard deviation for each of the kriged coordinates (Std Dev), and the percent coefficient of variation, which is the ratio of the mean to the standard deviation expressed as a percentage (CV %), are listed for each dependent variable. With the exception of the large tree component, where the CV % was very low, the approximate range of CV % values was from 20 to 75.

The first three mesh-plot figures in Appendix G show the results for kriging of overstory variables. The kriged results for percent canopy coverage (mean = 72.83) are relatively homogeneous throughout the study area (Figure G-2). The predicted canopy coverage values tend to increase to the north and the east and are the lowest in the grassland areas and where the 1954 fire occurred to the northwest of the South Gate.

Within the study area, the distribution of large trees, those greater than 8 in. *dbh*, shows a prominent tendency to increase with elevation (Figure G-3). Exceptions include the grasslands at the Pajarito Mountain and the Cerro Grande. However, these results are relative to the study area, since the overall average is approximately 120 trees per acre (Table 8). Large tree populations are still relatively dense at lower elevations. For instance, the densities of large trees in the ponderosa pine community type are approximately 106 trees per acre (Table F-1).

Table 8. Summary statistics for kriging results, by dependent variable.

| Variable | Description | Mean | Std Dev | CV % |
|---|---|---|---|---|
| CC % | Canopy coverage | 72.83 | 15.42 | 21.17 |
| TPA >8" | Trees/acre, >8 in. *dbh* | 119.95 | 0.25 | 0.21 |
| TPA <8" | Trees/acre, <8 in. *dbh*<br>– square root transformation | 20.19 | 5.20 | 25.76 |
| Ust Total | Total understory fuels | 25.49 | 13.27 | 52.06 |
| 1-1C hr | Combined 1-100 hr woody fuels | 3.28 | 2.17 | 66.16 |
| 1K-hr T | Total 1000-hour fuels | 10.11 | 7.52 | 74.38 |

The opposite pattern was displayed by the kriging results of small trees, less than 8 in. *dbh* (Figure G-4). The analysis of the square-root transformed data indicated a tendency for the density of smaller trees to increase toward the north and the east within the study area. The smaller tree populations were particularly dense in Rendija Canyon, with relatively deep soils, and on exposed ridgeline positions, with relatively sparse soils. The populations of smaller trees were less dense in the area that was burned in 1954.

The last three figures in Appendix G show the kriging results for understory variables. In Figure G-5, the results of the kriging of total understory fuels (mean = 25.49) are shown. Although, there is a considerable amount of variation throughout the study area, there is a clear tendency for the total understory fuels to be the greatest at middle and upper elevations. Total fuels are less in the area that was burned in the 1954 fire and show an inverse relationship to the density of small trees in the overstory (Figure G-4).

This trend toward higher fuels at middle elevations, in contrast to lower amounts of fuels at lower elevations under dense overstories of smaller trees, is strengthened by the kriging results for smaller down woody fuels, the 1-hr to 100-hr fuels (Figure G-6). However, the highest elevations show relatively less amounts of smaller woody fuels. The area burned in 1954 is also sparse in these types of fuels.

The larger down woody fuels, both sound and rotten, also tend to increase with elevation and decrease under dense overstories of smaller trees and in the area that was burned in 1954 (Figure G-7). However, the overall spatial variability of the larger down woody fuels is greater than for the smaller down woody fuels (Figure G-6).

## Discussion

The results of this study have increased our knowledge of the levels of fuels in the Los Alamos region and the wildfire hazards they represent. From previous results, it was determined that fuel levels generally increase with elevation (Balice et al. 1999). It was also thought that fuels tended to increase on steeper slopes and particularly on north-facing slopes. In contrast to this, Balice et al. (1999) learned that dense overstory canopies tended to be common at lower elevations in the Los Alamos region, those between 2,134 m (7,000 ft) and 2,438 m (8,000 ft) above mean sea level. However, the variability of the overstory structures at these lower elevations was generally greater than elsewhere.

These previous conclusions are still valid although the spatial distributions of specific fuel components were understood in more detail as a result of this study. First, it appears that some of the fuel categories, such as trees >8 in. *dbh*, do tend to increase linearly with elevation. In contrast, some of the fuel categories increase with elevation, but in a curvilinear manner. For instance, the 1-hr to 100-hr fuels category appears to be at a maximum at the approximate 2,743-m (9,000-ft) elevation level. As we develop predictive relationships for the spatial distributions of fuels, these relationships will undoubtedly prove to be of value (Yool et al. 2000).

The highest elevations in the Los Alamos region tend to support the greatest amounts of fuels, but the current study indicates that the relative fuel levels at these elevations also tend to vary by habitat type or community type. For instance, a perusal of the tables for aspen communities, that tend to occur on south-facing slopes, and spruce-fir communities, that tend to occur on north-facing slopes, suggests a contrast in fuel levels. The overstory densities tend to be greater in spruce-fir communities, whereas the understory fuels tend to be greater in aspen communities. A statistical analysis was not performed on this relationship. However, the opportunity arises for the reduction of fuels in aspen vegetation with the subsequent benefit that they would serve as a fuel break for the adjacent spruce-fir vegetation, while simultaneously increasing their productivity for wildlife habitat.

The site-specific productivity of fuels at lower elevations in the study area, below 2,591 m (8,500 ft), appears to be influenced by topography and soils. For instance, in ponderosa pine forests, the greatest densities of smaller trees, less than 8 in. *dbh*, were found in the bottom of Rendija Canyon, and in other areas with relatively deep alluvial soils, and on exposed ridgeline positions, with fairly sparse soils. Sites that were intermediate between these two extremes tended to have lower densities of smaller trees.

At lower and middle elevations within the study area, additional variability is introduced by variable stand histories. For instance, the lasting effects of the 1954 wildfire were clearly evident from the field data. The levels of nearly all categories of fuels were less in those areas that had been burned in 1954, than those adjacent areas that had not been burned. This points to the importance of reducing the fuel levels through thinning and prescribed fire treatments. The initial costs of these treatments may be high, but if they are done correctly, further maintenance treatments may not be needed for perhaps a decade or more.

Although the results of this study have increased our knowledge of the forest structures and wildfire hazards in the Los Alamos region, this knowledge cannot be expressed in the form of highly predictive models. The within-group variability remains relatively high and the density of sampling is spatially incomplete. As a result, the current spatial models of many wildfire hazard parameters were defined by using these general relationships to reclassify existing GIS data layers (Koch and Balice 1999). This type of deficiency will be corrected as we continue to survey the forests and grasslands of the Los Alamos region and develop more robust models of the spatial and topographic relationships among wildfire parameters.

In addition to contributing to the development of predictive models, the results of this project will allow us to monitor the effectiveness of wildfire hazard reduction treatments by conducting repeat samples at selected sample sites. Finally, these data and additional data, collected during ensuing years, will assist us in the development of improved wildfire behavior models, plant community classifications, wildlife habitat evaluations, and models of the spatial distributions of fuels and forest structures.

## Acknowledgments

We would like to thank the U.S. Forest Service, Rocky Mountain Research Station, and the Santa Fe National Forest for partially funding this project. We would also like to acknowledge and thank Carlos Orozco and Doug Tucker, Los Alamos County Fire Department, Robert Repass, Los Alamos County Emergency Management Department, John Bruin and Bill Armstrong, Santa Fe National Forest, and Brian Jacobs and Al King, Bandelier National Monument, for their advice, guidance, and support. The fieldwork was completed with the assistance of several technicians, including Suzanna Davis, Sherri Frybarger, Shelley Gardner, Jacob Knight, Melanie Martinez, Patrick Mitchell, Michael O'Brien, Randolph Robinson, and Steve Vrooman. Reviewers of previous drafts of this manuscript, including Carey Bare, Ted Doerr, Phil Fresquez, Sherri Frybarger, Hector Hinojosa, and Sam Loftin, provided many insightful and thoughtful comments.

## Literature Cited

Allen, Craig D. 1989. Changes in the landscape of the Jemez Mountains, New Mexico. Ph.D. dissertation, University of California at Berkeley, Berkeley, California.

Anderson, Hal E. 1982. Aids to determining fuel models for estimating fire behavior. General Technical Report INT-122, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Balice, Randy G. 1996. Biological assessment for the Dome Fire Emergency Actions. LA-UR-96-3615, Los Alamos National Laboratory, Los Alamos, New Mexico.

Balice, Randy G. 1998. A preliminary survey of terrestrial plant communities in the Sierra de los Valles. LA-13523-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Balice, Randy G., Scott G. Ferran, Teralene S. Foxx. 1997. Preliminary land cover classification for the Los Alamos region. LA-UR-97-4627, Los Alamos National Laboratory, Los Alamos, New Mexico.

Balice, Randy G., Brian P. Oswald, Charlie Martin. 1999. Fuels inventories in the Los Alamos National Laboratory region; 1997. LA-13572-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Balice, Randy G., Brian P.Oswald, Stephen R. Yool. 2000. Fuels inventories and spatial modeling of fire hazards in the Los Alamos Region. In *Proceedings of the Crossing the Millenium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management Conference and Workshop* (In press). Conference held June 15-17, 1999, in Boise, Idaho.

Baret, F., G. Guyot. 1991. Potential and limits of vegetation indices for LAI and APAR assessment. *Remote Sensing of Environment* 35:161–173.

Bonham, Charles D. 1989. *Measurement for terrestrial vegetation.* New York, New York.

Brown, James K. 1974. Handbook for inventorying downed woody material. USDA Forest Service, General Technical Report INT-16, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Brown, James K. 1976. Estimating shrub biomass from basal stem diameters. *Canadian Journal of Forest Research,* 6:153–158.

Brown, James K. 1978. Weight and density of crowns of Rocky Mountain conifers. USDA Forest Service, Research Paper INT-197, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Brown, James K., Rick D. Oberheu, Cameron M. Johnston. 1982. Handbook for inventorying surface fuels and biomass in the interior west. USDA Forest Service, General Technical Report INT-129, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry*, 39:388–394.

Chojnacky, David C. 1988. Juniper, pinyon, oak and mesquite volume equations for Arizona. USDA Forest Service, Research Paper INT-391, Intermountain Research Station, Ogden, Utah.

Chojnacky, David C. 1992. Estimating volume and biomass for dryland oak species. Pages 155–161 in *Ecology and management of oak and associated woodlands: Perspectives in the southwestern United States and northern Mexico*. USDA Forest Service, General Technical Report RM-218, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Crippen, Robert E. 1989. A simple spatial filtering routine for the cosmetic removal of scanline noise from Landsat TM P-tape imagery. *Photogrammetric Engineering and Remote Sensing*, 55(3):327–331.

Crist, E. P., and R. C. Cicone. 1984. Application of the tasseled cap concept to simulated Thematic Mapper data. *Photogrammetric Engineering & Remote Sensing*, 50(3):343–352.

Davis, Frank W. and Scott Goetz. 1990. Modeling vegetation pattern using digital terrain data. *Landscape Ecology*, 4(1):69–80.

DeVelice, Robert L., John A. Ludwig, William H. Moir, Frank Ronco, Jr. 1986. A classification of forest habitat types of northern New Mexico and southern Colorado. General Technical Report RM-131, USDA Forests Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Elzinga, Caryl L., Daniel W. Salazar, John W. Willoughby. 1998. Measuring and monitoring plant populations. BLM Technical Report BLM/RS/ST-98/005+1730, Bureau of Land Management, Denver, Colorado.

ESRI Inc. 1994. Arc/Info, Version 7.2.21. Environmental Systems Research Institute, Inc., Redlands, California.

Ffolliott, Peter F., Warren P. Clary, and James R. Davis. 1968. Some characteristics of the forest floor under ponderosa pine in Arizona. USDA Forest Service, Research Note RM-127, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Ganapol, Barry D., Lee F. Johnson, Christine A. Hlavka, David L. Peterson, Barbara Bond. 1999. LCM2: A coupled leaf/canopy radiative transfer model. *Remote Sensing of Environment*, 70:153–166.

Ganey, Joseph L., William M. Block. 1994. A comparison of two techniques for measuring canopy closure. *Western Journal of Applied Forestry*, 9(1):21–23.

Gamma Design Software. 1998. GS+, geostatistics for the environmental sciences, version 3.1 for Windows. Gamma Design Software, Plainwell, Michigan.

Goovaerts, Pierre. 1997. *Geostatistics for natural resources evaluation*. Oxford University Press, New York, New York.

Graham, R.T., A.E. Harvey, T.B. Jain and J.R. Tonn. 1999. The effects of thinning and similar stand treatments on fire behavior in western forests. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-463, Portland, Oregon.

Hawksworth, Frank G. 1977. The 6-class dwarf mistletoe rating system. General Technical Report RM-48, USDA Forests Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Johnston, R.S. and Dale L. Bartos. 1977. Summary of nutrient and biomass data for two aspen sites in western United States. USDA Forest Service, Research Note INT-227, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Kauth, Richard J. and G.S. Thomas. 1976. The tasseled cap – a graphic description of the spectral-temporal development of agricultural crops as seen by Landsat. Pages 41–51 in *Proceedings, Symposium on Machine Processing of Remotely Sensed Data*. Laboratory for Applications of Remote Sensing, West Lafayette, Indiana.

Koch, Steven W., Tom K. Budge, Randy G. Balice. 1997. Development of a land cover map for Los Alamos National Lab and vicinity. LA-UR-97-4628, Los Alamos National Laboratory, Los Alamos, New Mexico.

Koch, S.W., R.G. Balice. 1999. Input data development for the FARSITE fire area simulator for the Los Alamos National Laboratory region. Poster presented at the ESRI User Conference (June 26), San Diego, CA.

Komarkova, Vera, Robert R. Alexander, Barry C. Johnston. 1988. Forest vegetation of the Gunnison and parts of the Uncomphagre National Forests: A preliminary habitat type classification. General Technical Report RM-163, USDA Forests Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Lemmon, Paul E. 1956. A spherical densiometer for estimating forest overstory density. *Forest Science*, 2(1):314–320.

Mueggler, Walter F. 1988. Aspen community types of the Intermountain Region. General Technical Report INT-250, USDA Forests Service, Intermountain Research Station, Ogden, Utah.

Mueggler, Walter F. and Robert B. Campbell, Jr. 1986. Aspen community types of Utah. Research Paper INT-362, USDA Forests Service, Intermountain Research Station, Ogden, Utah.

Pfister, Robert D., Bernard L. Kovalchik, Stephen F. Arno, Richard C. Presby. 1977. Forest habitat types of Montana. General Technical Report INT-34, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

SAS Institute Inc. 1988. SAS® Language Guide for Personal Computers, Release 6.03 Edition. SAS Institute Inc., Cary, North Carolina.

SPSS Inc. 1998. SigmaPlot 5.0. SPSS Inc., Chicago, Illinois.

Stephens, S.L. 1998. Evaluation of the effects of silvicultural and fuels treatments on potential fire behaviour in Sierra Nevada mixed-conifer. Forest Ecology and Management 105:21–35.

Strickler, Gerald S. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. Research Note 180, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Telfer, E.S. 1969. Weight-diameter relationships for 22 woody plant species. *Canadian Journal of Botany*, 47:1851–1855.

Trimble Navigation Ltd. 1995. Pathfinder Office, Version 2.11. Trimble Navigation Limited, Surveying and Mapping Division, Sunnyvale, California.

Trimble Navigation Ltd. 1996. Geo Explorer II Operation Manual. Trimble Navigation Limited, Surveying and Mapping Division, Sunnyvale, California.

U.S. Forest Service, Southwestern Region. Undated report. Photo series for quantifying forest residues in the Southwestern Region. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico.

Wagtendonk, Jan W. van, James M. Benedict, Walter M. Sydoriak. 1998. Fuel bed characteristics of Sierra Nevada conifers. *Western Journal of Applied Forestry*, 13(3):73–84.

Yool, Stephen R., Jay D. Miller, Randy G. Balice, Brian P. Oswald, Carl Edminster. 2000. Mapping fuel risk at the Los Alamos urban-wildland interface. In *Proceedings of the Crossing the Millenium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management Conference and Workshop* (In press). Conference held June 15-17, 1999, in Boise, Idaho.

# Appendix A

## Examples of Data Forms Used in This Study

## Site Summary

| | | | |
|---|---|---|---|
| Plot Number | N - | Date | / / 99 |
| Team members | | | |
| Directions | Topo quad = | | |
| GIS UTM X | | GIS UTM Y | |
| GPS UTM X | | GPS UTM Y | |
| GPS time start | | GPS time stop | |

| | |
|---|---|
| Habitat Type | |
| | |
| Dominant species | |
| | |
| Vegetational notes | |
| | |
| | |
| Fuel model | |
| | |
| Disturbance | |
| | |
| Disease | |
| Soils | |
| | |
| Topography | |
| | |
| Camera, roll, photos | |
| Camera, roll, photos | |
| Camera, roll, photos | |
| Camera, roll, photos | |

Comments

## Plot Layout and Subplot/Quad Arrangement

| | | | |
|---|---|---|---|
| **1-1** | **1-2** | **2-1** | **2-2** |
| **1-4** | **1-3** | **2-4** | **2-3** |
| **4-1** | **4-2** | **3-1** | **3-2** |
| **4-4** | **4-3** | **3-4** | **3-3** |

| | | | |
|---|---|---|---|
| Plot | N - | Date | / / 99 |
| Plot Hor. Az/Back Az | | Plot Vert. Az/Back Az | |

| First Subplot | Quad 1 - Full Sample | Quad 2 - Red. Sample | Quad 3 - Red. Sample |
|---|---|---|---|
| | | | |
| Subplot Closure | | | |

| Second Subplot | Quad 1 - Full Sample | Quad 2 - Red. Sample | Quad 3 - Red. Sample |
|---|---|---|---|
| | | | |
| Subplot Closure | | | |
| Notes, Comments: | | | |

## Quad Summary and Surface Conditions

| | | | |
|---|---|---|---|
| Plot number | N - | Date | / / 99 |
| Subplot number | | Quad number | |
| Slope | | Aspect | |
| Elevation | | Topo position | |
| Horiz. Config. | | Vert. Config. | |
| Start distance (m) | | | |

| | Transect A | Transect B |
|---|---|---|
| Duff depth, 5m/10m | | |
| Soil depth, 5m/10m | | |
| 1-hr fuels to 2m | | |
| 10-hr fuels to 2m | | |
| 100-hr fuels to 3m | | |
| 1000-hr fuels, sound | | |
| 1000-hr fuels, rotten | | |
| Veg fuels, wet wt | | |
| Veg fuels, dry wt | | |
| First % | | |
| Second % | | |
| Third % | | |
| Litter fuels, wet wt | | |
| Litter fuels, dry wt | | |
| First % | | |
| Second % | | |
| Third % | | |
| Small trees, wet wt | | |
| Small trees, dry wt | | |
| First % | | |
| Second % | | |
| Third % | | |

## Overstory Fuels, >10 ft tall – Complete sample

| | | | | | |
|---|---|---|---|---|---|
| Plot | N - | Date | / / 99 | | Page |
| Subplot | | Quad | | | / |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dens. | #1 | | #2 | | #3 | | #4 | |
| Age dom | | Age int | | Age sup | | | Av Dens | |

| Species | L/D | Diam | Tot. Ht. | HTLC | C Width | C Shape | M-toe | M-stems |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

# Overstory Fuels, >10 ft tall – Reduced sample

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| Plot | N - | Date | / / 99 | Page |  |
| Subplot |  | Quad |  |  | / |

|  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Dens. | #1 |  | #2 |  | #3 |  | #4 |  |

| Species | L/D | Diam | Species | L/D | Diam | Species | L/D | Diam |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

## Woody Midstory

## Trees <2 ft (3mx3m) and Shrubs/Trees 2-10 ft (3mx15m)

Plot N -

Subplot

Date / / 99

Quad - A B

Page /

| Species | L/D | Diam | Tot. Ht. | HTLC | C Width | C Shape | M-toe | M-stems |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

# Appendix B

## Plant Species Discussed in This Report

## Plant Species Discussed in This Report
## (by common name)

| Common name | Scientific name | Code |
|---|---|---|
| Aspen | *Populus tremuloides* | Potr |
| Blue grama | *Bouteloua gracilis* | Bogr |
| Bracken fern | *Pteridium aquilinum* | Ptaq |
| Cliffbush | *Jamesia americana* | Jaam |
| Corkbark fir | *Abies lasiocarpa* | Abla |
| Douglas fir | *Pseudotsuga menziesii* | Psme |
| Engelmann spruce | *Picea engelmannii* | Pien |
| Forest fleabane | *Erigeron eximius* | Erex |
| Gambel oak | *Quercus gambelii* | Quga |
| Kinnikinnik | *Arctostaphylos uva-ursi* | Aruv |
| Little bluestem | *Schizachyrium scoparium* | Scsc |
| Mountain lover | *Pachistima myrsinites* | Pamy |
| Mountain maple | *Acer glabrum* | Acgl |
| Mountain muhly | *Muhlenbergia montana* | Mumo |
| New Mexico locust | *Robinia neomexicana* | Rone |
| Ponderosa pine | *Pinus ponderosa* | Pipo |
| White fir | *Abies concolor* | Abco |
| Whortleberry | *Vaccinium myrtillus* | Vamy |

## Plant Species Discussed in This Report
## (by scientific name and four-letter code)

| Common name | Scientific name | Code |
|---|---|---|
| White fir | *Abies concolor* | Abco |
| Corkbark fir | *Abies lasiocarpa* | Abla |
| Mountain maple | *Acer glabrum* | Acgl |
| Kinnikinnik | *Arctostaphylos uva-ursi* | Aruv |
| Blue grama | *Bouteloua gracilis* | Bogr |
| Forest fleabane | *Erigeron eximius* | Erex |
| Cliffbush | *Jamesia americana* | Jaam |
| Mountain muhly | *Muhlenbergia montana* | Mumo |
| Mountain lover | *Pachistima myrsinites* | Pamy |
| Engelmann spruce | *Picea engelmannii* | Pien |
| Ponderosa pine | *Pinus ponderosa* | Pipo |
| Aspen | *Populus tremuloides* | Potr |
| Douglas fir | *Pseudotsuga menziesii* | Psme |
| Bracken fern | *Pteridium aquilinum* | Ptaq |
| Gambel oak | *Quercus gambelii* | Quga |
| New Mexico locust | *Robinia neomexicana* | Rone |
| Little bluestem | *Schizachyrium scoparium* | Scsc |
| Whortleberry | *Vaccinium myrtillus* | Vamy |

# Appendix C

## Site Summary Data for the Macroplots

Table C-1. Plot summary information for the ponderosa pine dominance type with ponderosa pine community types.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| NR01 | 1999 | PP | Pipo/Bogr-S | CY | 4.0 | 191 | 4.0 | 6859 |
| NR03 | 1999 | PP | Pipo/Bogr-S | CY | 7.5 | 162 | 6.6 | 6860 |
| AB0705 | 1998 | PP | Pipo/Mumo | MT | 20.8 | 173 | 19.8 | 7940 |
| AC0603 | 1998 | PP | Pipo/Quga | CY | 8.0 | 288 | -1.1 | 7161 |
| AL0609 | 1998 | PP | Pipo/Quga | MS | 9.8 | 40 | -8.4 | 7535 |
| AL0709 | 1998 | PP | Pipo/Quga | MS | 3.5 | 3 | -3.5 | 7540 |
| AL0610 | 1998 | PP | Pipo/Quga | MS | 4.0 | 130 | 2.0 | 7575 |
| TC25 | 1999 | PP | Pipo/Quga | MS | 15.0 | 170 | 14.1 | 7583 |
| TB01 | 1999 | PP | Pipo/Quga | MT | 10.5 | 98 | -0.4 | 7606 |
| AB0109 | 1998 | PP | Pipo/Quga | MS | 8.8 | 123 | 3.4 | 7615 |
| AF0906 | 1998 | PP | Pipo/Quga | MT | 30.5 | 96 | -2.2 | 7750 |
| TF03C | 1999 | PP | Pipo/Quga | MT | 6.0 | 70 | -3.0 | 8038 |
| TF02A | 1999 | PP | Pipo/Quga | MT | 1.0 | 180 | 1.0 | 8087 |
| TF02B | 1999 | PP | Pipo/Quga | MT | 4.0 | 135 | 2.3 | 8109 |
| Mean | | | | | 9.5 | | 2.5 | 7590 |
| Std. Dev. | | | | | 7.9 | | 7.3 | 404 |
| Std. Err. | | | | | 2.2 | | 2.0 | 112 |

Table C-2. Plot summary information for the ponderosa pine dominance type with Douglas fir community types.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| TF06C | 1999 | PP | Psme/Aruv | MT | 24.0 | 220 | 20.8 | 8542 |
| TF06B | 1999 | PP | Psme/Aruv | MT | 9.0 | 150 | 6.9 | 8494 |
| AF1301 | 1998 | PP | Psme/Aruv | MT | 7.7 | 35 | -6.9 | 8480 |
| TF05A | 1999 | PP | Psme/Aruv | MT | 12.0 | 100 | 0.0 | 7939 |
| TF05D | 1999 | PP | Psme/Aruv | MT | 12.0 | 100 | 0.0 | 7879 |
| NF10 | 1999 | PP | Psme/Aruv | MT | 18.5 | 103 | 1.0 | 7809 |
| AC0602 | 1998 | PP | Psme/Mumo | MS | 9.8 | 309 | -4.8 | 7219 |
| TC21 | 1999 | PP | Psme/Mumo | CY | 12.0 | 86 | -2.9 | 7138 |
| NF05 | 1999 | PP | Psme/Quga | MT | 8.0 | 100 | 0.0 | 8056 |
| NC26 | 1999 | PP | Psme/Quga | MS | 17.5 | 101 | 0.3 | 7502 |
| Mean | | | | | 13.1 | | 1.4 | 7906 |
| Std. Dev. | | | | | 5.3 | | 7.7 | 510 |
| Std. Err. | | | | | 1.8 | | 2.6 | 170 |

Table C-3. Plot summary information for the mixed conifer dominance type with Douglas fir community types.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AF1302 | 1998 | MC | Psme/Aruv | MT | 3.7 | 54 | -2.7 | 8280 |
| NC52 | 1999 | MC | Psme/Aruv | MT | 11.0 | 102 | 0.4 | 7709 |
| TC24 | 1999 | MC | Psme/Aruv | MT | 25.5 | 87 | -5.7 | 7512 |
| AB0402 | 1998 | MC | Psme/Quga | MT | 29.0 | 260 | 9.9 | 9530 |
| Mean | | | | | 17.3 | | 0.5 | 8258 |
| Std. Dev. | | | | | 12.0 | | 6.8 | 909 |
| Std. Err. | | | | | 6.9 | | 3.9 | 525 |

Table C-4. Plot summary information for the mixed conifer dominance type with more xeric white fir community types.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AB0501 | 1998 | MC | Abco/Aruv | MT | 4.8 | 50 | -3.6 | 8780 |
| TF08A | 1999 | MC | Abco/Aruv | MT | 6.0 | 140 | 3.9 | 8435 |
| AB0701 | 1998 | MC | Abco/Quga | MT | 45.0 | 94 | -4.7 | 9410 |
| AF0508 | 1998 | MC | Abco/Quga | MT | 30.3 | 114 | 7.3 | 8830 |
| TF23 | 1999 | MC | Abco/Quga | MT | 26.0 | 218 | 23.0 | 8810 |
| TF19 | 1999 | MC | Abco/Quga | MT | 36.5 | 246 | 20.4 | 8794 |
| NF18 | 1999 | MC | Abco/Quga | MT | 48.5 | 129 | 23.5 | 8773 |
| NF22 | 1999 | MC | Abco/Quga | MT | 15.0 | 256 | 6.1 | 8659 |
| AF0210 | 1998 | MC | Abco/Quga | MT | 26.0 | 144 | 18.1 | 8610 |
| TF17 | 1999 | MC | Abco/Quga | MT | 33.0 | 180 | 32.5 | 8579 |
| TF06A | 1999 | MC | Abco/Quga | MT | 13.0 | 220 | 11.3 | 8531 |
| AF0301 | 1998 | MC | Abco/Quga | MT | 41.3 | 36 | -37.2 | 8203 |
| TF05B | 1999 | MC | Abco/Quga | MT | 46.0 | 70 | -23.0 | 8072 |
| TF05C | 1999 | MC | Abco/Quga | MT | 14.0 | 50 | -10.7 | 7996 |
| NL51 | 1999 | MC | Abco/Quga | CY | 63.5 | 359 | -62.3 | 7308 |
| AB0304 | 1998 | MC | Abco/Rone | MT | 22.0 | 284 | -1.5 | 9010 |
| Mean | | | | | 29.4 | | 0.2 | 8550 |
| Std. Dev. | | | | | 16.7 | | 24.6 | 482 |
| Std. Err. | | | | | 4.3 | | 6.3 | 125 |

Table C-5. Plot summary information for the shrub dominance type.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| TF03A | 1999 | SB | Pipo/Quga | MT | 2.0 | 10 | -2.0 | 8050 |
| TF03B | 1999 | SB | Pipo/Quga | MT | 6.0 | 70 | -3.0 | 8019 |
| NF02C | 1999 | SB | Psme/Quga | MT | 8.0 | 118 | 2.5 | 8138 |
| Mean | | | | | 5.3 | | -0.8 | 8069 |
| Std. Dev. | | | | | 3.1 | | 2.9 | 62 |
| Std. Err. | | | | | 2.2 | | 2.1 | 44 |

Table C-6. Plot summary information for the mixed conifer dominance type with more mesic white fir community types.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AB0302 | 1998 | MC | Abco/Acgl | MT | 20.5 | 150 | 15.7 | 9110 |
| AF0507 | 1998 | MC | Abco/Acgl | MT | 35.5 | 30 | -33.4 | 8430 |
| TB10B | 1999 | MC | Abco/Acgl | MT | 31.0 | 120 | 10.6 | 9024 |
| TB10A | 1999 | MC | Abco/Acgl | MT | 17.0 | 110 | 3.0 | 9003 |
| TB10C | 1999 | MC | Abco/Acgl | MT | 18.0 | 110 | 3.1 | 8968 |
| TF20B | 1999 | MC | Abco/Acgl | MT | 44.0 | 30 | -41.3 | 8489 |
| TF20A | 1999 | MC | Abco/Acgl | MT | 26.5 | 4 | -26.4 | 8365 |
| NF04 | 1999 | MC | Abco/Acgl | MT | 64.0 | 11 | -64.0 | 7990 |
| AF0310 | 1998 | MC | Abco/Erex | MT | 7.8 | 360 | -7.6 | 9120 |
| AB0203 | 1998 | MC | Abco/Erex | MT | 30.8 | 290 | -5.3 | 8780 |
| Mean | | | | | 29.5 | | -14.6 | 8728 |
| Std. Dev. | | | | | 16.0 | | 25.7 | 387 |
| Std. Err. | | | | | 5.3 | | 8.6 | 129 |

Table C-7. Plot summary information for the aspen dominance type.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AF0808 | 1998 | AS | Potr/Feth | MT | 32.5 | 197 | 32.3 | 9876 |
| AF0406 | 1998 | AS | Potr/Feth | MT | 26.5 | 75 | -11.2 | 9874 |
| AF0409 | 1998 | AS | Potr/Feth | MT | 38.0 | 145 | 26.9 | 9853 |
| TF11 | 1999 | AS | Potr/Feth | MT | 40.5 | 230 | 31.0 | 9760 |
| AF1305 | 1998 | AS | Potr/Feth | MT | 25.8 | 186 | 25.7 | 9675 |
| TF13 | 1999 | AS | Potr/Ptaq | MT | 48.0 | 200 | 47.3 | 9664 |
| Mean | | | | | 35.2 | | 25.3 | 9784 |
| Std. Dev. | | | | | 8.6 | | 19.5 | 98 |
| Std. Err. | | | | | 3.9 | | 8.7 | 44 |

Table C-8. Plot summary information for the spruce-fir dominance type.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AF0305 | 1998 | SF | Abla/Erex | MT | 20.5 | 42 | -17.4 | 9651 |
| NP11 | 1999 | SF | Abla/Vamy | MT | 66.5 | 62 | -40.9 | 10291 |
| AF0807 | 1998 | SF | Abla/Vamy | MT | 31.0 | 353 | -29.6 | 10215 |
| TF15 | 1999 | SF | Pien/Erex | MT | 28.0 | 50 | -21.4 | 9863 |
| TF14 | 1999 | SF | Pien/Erex | MT | 41.0 | 30 | -38.5 | 9821 |
| TF12B | 1999 | SF | Pien/Erex | MT | 34.0 | 40 | -29.4 | 9496 |
| TF12A | 1999 | SF | Pien/Erex | MT | 28.5 | 45 | -23.3 | 9404 |
| TP16 | 1999 | SF | Pien/Erex | MT | 29.0 | 1 | -28.6 | 9350 |
| Mean | | | | | 34.8 | | -28.7 | 9761 |
| Std. Dev. | | | | | 14.1 | | 8.1 | 355 |
| Std. Err. | | | | | 5.0 | | 2.9 | 125 |

Table C-9. Plot summary information for the grassland dominance type.

| Plot | Year | Dom | Comm type | Topo | Slope | Asp | SE | Elev |
|---|---|---|---|---|---|---|---|---|
| AB1209 | 1998 | GR | Mesagrass | MS | 6.0 | 146 | 4.3 | 7520 |
| AF1304 | 1998 | GR | Mtngrass | MT | 18.5 | 188 | 18.5 | 10145 |
| NB09B | 1999 | GR | Mtngrass | MT | 25.0 | 140 | 16.1 | 10067 |
| TB09A | 1999 | GR | Mtngrass | MT | 23.0 | 180 | 22.7 | 10054 |
| TF07A | 1999 | GR | Mtngrass | MT | 7.0 | 180 | 6.9 | 9851 |
| Mean | | | | | 15.9 | | 13.7 | 9527 |
| Std. Dev. | | | | | 8.9 | | 7.8 | 1127 |
| Std. Err. | | | | | 4.5 | | 3.9 | 564 |

# Appendix D

## Surface Fuels for the Macroplots

Table D-1. Surface fuels for the ponderosa pine dominance type with ponderosa pine community types.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| NR01 | 0.04 | 0.07 | 0.37 | 0.48 | 0.00 | 0.00 | 0.00 | 11.56 | 0.93 |
| NR03 | 0.07 | 0.49 | 0.00 | 0.55 | 0.00 | 0.00 | 0.00 | 14.34 | 1.01 |
| AB0705 | 0.10 | 1.07 | 1.51 | 2.67 | 3.47 | 0.84 | 4.31 | 10.64 | 1.39 |
| AC0603 | 0.16 | 0.98 | 0.25 | 1.38 | 14.13 | 3.29 | 17.41 | 7.62 | 1.15 |
| AL0609 | 0.18 | 2.16 | 1.11 | 3.45 | 0.27 | 0.78 | 1.05 | 12.87 | 1.08 |
| AL0709 | 0.16 | 2.64 | 1.85 | 4.64 | 7.67 | 0.00 | 7.67 | 7.13 | 0.78 |
| AL0610 | 0.09 | 1.81 | 0.74 | 2.63 | 0.00 | 0.00 | 0.00 | 8.88 | 1.20 |
| TC25 | 0.06 | 1.34 | 0.75 | 2.14 | 0.16 | 3.67 | 3.84 | 6.45 | 0.43 |
| TB01 | 0.02 | 1.19 | 0.37 | 1.59 | 16.14 | 0.00 | 16.14 | 10.89 | 1.01 |
| AB0109 | 0.07 | 0.77 | 0.37 | 1.21 | 1.71 | 0.00 | 1.71 | 3.76 | 0.85 |
| AF0906 | 0.35 | 2.41 | 1.03 | 3.80 | 2.07 | 0.00 | 2.07 | 10.18 | 1.22 |
| TF03C | 0.04 | 0.63 | 2.59 | 3.25 | 1.15 | 3.52 | 4.67 | 10.34 | 1.33 |
| TF02A | 0.04 | 0.63 | 0.37 | 1.04 | 0.00 | 4.40 | 4.40 | 17.45 | 0.53 |
| TF02B | 0.02 | 0.42 | 0.74 | 1.17 | 0.55 | 7.20 | 7.74 | 14.56 | 0.90 |
| Mean | 0.10 | 1.19 | 0.86 | 2.14 | 3.38 | 1.69 | 5.07 | 10.48 | 0.99 |
| Std. Dev. | 0.09 | 0.79 | 0.71 | 1.29 | 5.41 | 2.31 | 5.58 | 3.62 | 0.28 |
| Std. Err. | 0.02 | 0.22 | 0.20 | 0.36 | 1.50 | 0.64 | 1.55 | 1.00 | 0.08 |

Table D-2. Surface fuels for the ponderosa pine dominance type with Douglas fir community types.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| TF06C | 0.02 | 1.50 | 0.00 | 1.52 | 2.45 | 5.46 | 7.91 | 21.34 | 0.98 |
| TF06B | 0.11 | 1.19 | 0.00 | 1.30 | 22.75 | 10.21 | 32.97 | 14.45 | 1.18 |
| AF1301 | 0.17 | 2.70 | 2.47 | 5.33 | 3.67 | 0.94 | 4.61 | 7.21 | 0.37 |
| TF05A | 0.08 | 2.10 | 1.49 | 3.67 | 0.34 | 2.13 | 2.47 | 11.01 | 0.84 |
| TF05D | 0.03 | 0.63 | 0.37 | 1.03 | 1.69 | 38.47 | 40.16 | 10.12 | 0.86 |
| NF10 | 0.17 | 0.57 | 0.37 | 1.11 | 2.91 | 0.00 | 2.91 | 3.20 | 1.14 |
| AC0602 | 0.03 | 0.28 | 0.74 | 1.05 | 12.22 | 1.22 | 13.44 | 5.08 | 0.39 |
| TC21 | 0.11 | 0.98 | 2.60 | 3.69 | 0.60 | 3.25 | 3.85 | 14.79 | 1.12 |
| NF05 | 0.09 | 0.63 | 1.48 | 2.20 | 0.62 | 0.00 | 0.62 | 10.78 | 0.69 |
| NC26 | 0.06 | 1.55 | 0.75 | 2.36 | 0.31 | 0.57 | 0.88 | 5.34 | 0.61 |
| Mean | 0.09 | 1.21 | 1.03 | 2.33 | 4.76 | 6.22 | 10.98 | 10.33 | 0.82 |
| Std. Dev. | 0.05 | 0.76 | 0.95 | 1.46 | 7.25 | 11.76 | 14.10 | 5.50 | 0.30 |
| Std. Err. | 0.02 | 0.25 | 0.32 | 0.49 | 2.42 | 3.92 | 4.70 | 1.83 | 0.10 |

Table D-3. Surface fuels for the mixed conifer dominance type with Douglas fir community types.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AF1302 | 0.24 | 3.52 | 4.92 | 8.69 | 2.56 | 0.56 | 3.12 | 12.60 | 1.59 |
| NC52 | 0.12 | 1.05 | 0.37 | 1.54 | 0.00 | 1.29 | 1.29 | 9.89 | 1.01 |
| TC24 | 0.05 | 0.93 | 0.38 | 1.36 | 10.45 | 0.32 | 10.77 | 2.67 | 0.85 |
| AB0402 | 0.13 | 2.39 | 0.39 | 2.90 | 0.39 | 0.00 | 0.39 | 7.00 | 0.32 |
| Mean | 0.14 | 1.97 | 1.51 | 3.62 | 3.35 | 0.54 | 3.89 | 8.04 | 0.94 |
| Std. Dev. | 0.08 | 1.23 | 2.27 | 3.45 | 4.87 | 0.55 | 4.72 | 4.25 | 0.52 |
| Std. Err. | 0.05 | 0.71 | 1.31 | 1.99 | 2.81 | 0.32 | 2.73 | 2.45 | 0.30 |

Table D-4. Surface fuels for the mixed conifer dominance type with more xeric white fir community types.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AB0501 | 0.68 | 1.60 | 3.32 | 5.61 | 8.85 | 4.62 | 13.48 | 9.94 | 0.72 |
| TF08A | 0.25 | 1.32 | 2.59 | 4.16 | 1.81 | 8.09 | 9.90 | 11.45 | 0.77 |
| AB0701 | 0.52 | 1.60 | 1.21 | 3.32 | 4.84 | 37.02 | 41.86 | 15.80 | 0.82 |
| AF0508 | 0.89 | 2.03 | 3.85 | 6.77 | 3.81 | 9.35 | 13.16 | 14.40 | 4.82 |
| TF23 | 0.20 | 1.07 | 1.15 | 2.42 | 1.39 | 13.61 | 15.00 | 10.67 | 0.43 |
| TF19 | 0.42 | 1.78 | 0.00 | 2.20 | 0.00 | 8.59 | 8.59 | 7.78 | 0.26 |
| NF18 | 0.14 | 1.55 | 5.68 | 7.38 | 0.64 | 1.92 | 2.56 | 14.67 | 0.22 |
| NF22 | 0.50 | 2.18 | 3.35 | 6.03 | 0.81 | 22.90 | 23.71 | 9.34 | 0.33 |
| AF0210 | 0.10 | 1.96 | 0.75 | 2.81 | 1.17 | 0.00 | 1.17 | 15.19 | 1.48 |
| TF17 | 0.24 | 0.52 | 0.00 | 0.76 | 3.15 | 4.76 | 7.91 | 6.56 | 0.08 |
| TF06A | 0.08 | 1.12 | 0.74 | 1.94 | 5.94 | 11.39 | 17.33 | 15.45 | 1.47 |
| AF0301 | 0.63 | 1.76 | 2.38 | 4.77 | 2.52 | 5.17 | 7.69 | 16.60 | 0.62 |
| TF05B | 0.40 | 1.37 | 0.00 | 1.77 | 15.85 | 1.64 | 17.49 | 6.21 | 0.25 |
| TF05C | 0.10 | 1.26 | 0.74 | 2.11 | 0.00 | 7.41 | 7.41 | 13.90 | 0.80 |
| NL51 | 0.94 | 1.73 | 0.88 | 3.56 | 3.25 | 24.76 | 28.01 | 8.45 | 0.33 |
| AB0304 | 0.44 | 1.71 | 5.66 | 7.81 | 0.30 | 0.93 | 1.23 | 4.07 | 0.28 |
| Mean | 0.41 | 1.54 | 2.02 | 3.96 | 3.40 | 10.14 | 13.53 | 11.28 | 0.85 |
| Std. Dev. | 0.27 | 0.42 | 1.89 | 2.19 | 4.11 | 10.13 | 10.69 | 3.96 | 1.14 |
| Std. Err. | 0.07 | 0.11 | 0.49 | 0.57 | 1.06 | 2.62 | 2.76 | 1.02 | 0.29 |

Table D-5. Surface fuels for the shrub dominance type.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| TF03A | 0.00 | 0.83 | 0.37 | 1.21 | 0.66 | 1.82 | 2.49 | 8.78 | 0.39 |
| TF03B | 0.03 | 0.84 | 0.37 | 1.23 | 0.66 | 0.00 | 0.66 | 9.78 | 0.44 |
| NF02C | 0.03 | 0.77 | 1.48 | 2.28 | 1.69 | 1.23 | 2.92 | 8.56 | 0.45 |
| Mean | 0.02 | 0.81 | 0.74 | 1.57 | 1.00 | 1.02 | 2.02 | 9.04 | 0.43 |
| Std. Dev. | 0.02 | 0.04 | 0.64 | 0.61 | 0.59 | 0.93 | 1.20 | 0.65 | 0.03 |
| Std. Err. | 0.01 | 0.03 | 0.45 | 0.43 | 0.42 | 0.66 | 0.85 | 0.46 | 0.02 |

Table D-6. Surface fuels for the mixed conifer dominance type with more mesic white fir community types.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AB0302 | 1.07 | 2.35 | 1.51 | 4.92 | 10.57 | 0.34 | 10.91 | 9.94 | 0.76 |
| AF0507 | 1.89 | 3.76 | 5.42 | 11.07 | 12.56 | 1.33 | 13.88 | 14.22 | 0.47 |
| TB10B | 0.09 | 0.95 | 2.70 | 3.74 | 21.39 | 2.48 | 23.87 | 10.45 | 0.23 |
| TB10A | 0.39 | 1.55 | 1.87 | 3.82 | 8.17 | 1.43 | 9.60 | 16.01 | 0.13 |
| TB10C | 0.20 | 3.53 | 4.50 | 8.22 | 12.96 | 3.24 | 16.20 | 13.01 | 0.21 |
| TF20B | 0.78 | 2.58 | 2.42 | 5.78 | 2.65 | 1.46 | 4.10 | 9.45 | 0.34 |
| TF20A | 0.87 | 1.80 | 8.38 | 11.04 | 6.56 | 5.30 | 11.87 | 8.89 | 0.57 |
| NF04 | 0.67 | 3.28 | 3.50 | 7.46 | 14.78 | 3.09 | 17.87 | 15.23 | 0.37 |
| AF0310 | 0.32 | 1.40 | 1.11 | 2.83 | 20.76 | 4.33 | 25.09 | 9.19 | 0.10 |
| AB0203 | 0.30 | 1.16 | 2.69 | 4.14 | 0.00 | 7.62 | 7.62 | 3.72 | 0.10 |
| Mean | 0.66 | 2.24 | 3.41 | 6.30 | 11.04 | 3.06 | 14.10 | 11.01 | 0.33 |
| Std. Dev. | 0.54 | 1.02 | 2.19 | 3.02 | 7.01 | 2.20 | 6.77 | 3.68 | 0.22 |
| Std. Err. | 0.18 | 0.34 | 0.73 | 1.01 | 2.34 | 0.73 | 2.26 | 1.23 | 0.07 |

Table D-7. Surface fuels for the aspen dominance type.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AF0808 | 0.18 | 1.10 | 1.17 | 2.44 | 9.86 | 1.19 | 11.06 | 11.34 | 0.80 |
| AF0406 | 0.14 | 0.43 | 4.58 | 5.16 | 17.91 | 2.36 | 20.28 | 15.41 | 0.68 |
| AF0409 | 0.42 | 2.31 | 1.97 | 4.70 | 7.53 | 4.83 | 12.35 | 15.36 | 1.11 |
| TF11 | 0.03 | 0.90 | 3.19 | 4.12 | 23.38 | 3.14 | 26.52 | 12.34 | 0.28 |
| AF1305 | 0.23 | 1.00 | 2.65 | 3.88 | 1.53 | 1.17 | 2.69 | 22.19 | 0.80 |
| TF13 | 0.12 | 0.46 | 0.82 | 1.40 | 2.29 | 17.96 | 20.25 | 22.46 | 0.42 |
| Mean | 0.19 | 1.03 | 2.40 | 3.62 | 10.42 | 5.11 | 15.52 | 16.52 | 0.68 |
| Std. Dev. | 0.13 | 0.68 | 1.39 | 1.43 | 8.69 | 6.44 | 8.49 | 4.78 | 0.30 |
| Std. Err. | 0.06 | 0.31 | 0.62 | 0.64 | 3.89 | 2.88 | 3.80 | 2.14 | 0.13 |

Table D-8. Surface fuels for the spruce-fir dominance type.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AF0305 | 0.71 | 1.42 | 5.03 | 7.16 | 3.04 | 5.02 | 8.07 | 21.62 | 0.95 |
| NP11 | 0.27 | 0.75 | 0.88 | 1.90 | 4.74 | 22.71 | 27.45 | 14.41 | 0.29 |
| AF0807 | 1.09 | 2.38 | 4.71 | 8.18 | 4.62 | 0.00 | 4.62 | 12.49 | 2.14 |
| TF15 | 0.14 | 1.01 | 3.06 | 4.22 | 7.19 | 0.51 | 7.70 | 9.12 | 0.31 |
| TF14 | 0.26 | 2.17 | 5.64 | 8.06 | 4.23 | 3.08 | 7.31 | 8.89 | 0.33 |
| TF12B | 0.16 | 1.47 | 3.12 | 4.75 | 10.27 | 5.78 | 16.06 | 14.56 | 0.10 |
| TF12A | 0.16 | 0.94 | 3.07 | 4.17 | 49.82 | 4.06 | 53.88 | 19.68 | 0.22 |
| TP16 | 0.24 | 2.03 | 4.99 | 7.26 | 9.76 | 2.63 | 12.39 | 6.67 | 0.28 |
| Mean | 0.38 | 1.52 | 3.81 | 5.71 | 11.71 | 5.47 | 17.18 | 13.43 | 0.58 |
| Std. Dev. | 0.34 | 0.61 | 1.57 | 2.27 | 15.62 | 7.25 | 16.50 | 5.27 | 0.68 |
| Std. Err. | 0.12 | 0.22 | 0.55 | 0.80 | 5.52 | 2.56 | 5.83 | 1.86 | 0.24 |

Table D-9. Surface fuels for the grassland dominance type.

| Plot | 1-hr | 10-hr | 100-hr | 1-1C hr | 1K-hr S | 1K-hr R | 1K-hr T | Duff | Litter |
|---|---|---|---|---|---|---|---|---|---|
| AB1209 | 0.02 | 0.28 | 0.37 | 0.67 | 1.58 | 0.00 | 1.58 | 3.28 | 0.15 |
| AF1304 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 2.45 | 0.69 |
| NB09B | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.78 | 0.23 |
| TB09A | 0.00 | 0.07 | 0.38 | 0.45 | 0.00 | 0.00 | 0.00 | 9.00 | 0.00 |
| TF07A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.11 | 0.00 |
| Mean | 0.01 | 0.07 | 0.15 | 0.22 | 0.32 | 0.00 | 0.32 | 3.92 | 0.21 |
| Std. Dev. | 0.01 | 0.12 | 0.21 | 0.31 | 0.71 | 0.00 | 0.71 | 3.09 | 0.29 |
| Std. Err. | 0.00 | 0.06 | 0.10 | 0.16 | 0.35 | 0.00 | 0.35 | 1.55 | 0.14 |

# Appendix E

## Understory and Midstory Fuels for the Macroplots

Table E-1. Understory and midstory fuels for the ponderosa pine dominance type with ponderosa pine community types.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| NR01 | 0.03 | 0.00 | 0.08 | 0.08 | 13.08 | 0.02 | 0.02 | 0.04 |
| NR03 | 0.02 | 0.00 | 3.71 | 3.71 | 19.64 | 0.37 | 0.00 | 0.00 |
| AB0705 | 0.00 | 0.00 | 0.00 | 0.00 | 19.02 | 0.00 | 0.00 | 0.00 |
| AC0603 | 0.10 | 0.08 | 0.16 | 0.25 | 27.91 | 0.07 | 0.03 | 0.03 |
| AL0609 | 0.01 | 0.00 | 0.00 | 0.00 | 18.46 | 0.00 | 0.00 | 0.00 |
| AL0709 | 0.02 | 0.00 | 0.01 | 0.01 | 20.26 | 0.00 | 0.00 | 0.00 |
| AL0610 | 0.05 | 0.00 | 0.08 | 0.08 | 12.85 | 0.01 | 0.00 | 0.00 |
| TC25 | 0.01 | 1.07 | 0.35 | 1.43 | 14.28 | 0.22 | 0.11 | 0.19 |
| TB01 | 0.01 | 0.33 | 0.00 | 0.33 | 29.96 | 0.02 | 0.00 | 0.00 |
| AB0109 | 0.01 | 0.00 | 0.00 | 0.00 | 7.55 | 0.00 | 0.00 | 0.00 |
| AF0906 | 0.01 | 0.37 | 0.00 | 0.37 | 17.66 | 0.04 | 0.00 | 0.00 |
| TF03C | 0.02 | 0.31 | 0.12 | 0.43 | 20.04 | 0.07 | 0.01 | 0.00 |
| TF02A | 0.20 | 1.96 | 0.01 | 1.97 | 25.59 | 0.21 | 0.00 | 0.00 |
| TF02B | 0.22 | 0.58 | 0.01 | 0.59 | 25.20 | 0.08 | 0.01 | 0.00 |
| Mean | 0.05 | 0.34 | 0.32 | 0.66 | 19.39 | 0.08 | 0.01 | 0.02 |
| Std. Dev. | 0.07 | 0.56 | 0.98 | 1.05 | 6.27 | 0.11 | 0.03 | 0.05 |
| Std. Err. | 0.02 | 0.16 | 0.27 | 0.29 | 1.74 | 0.03 | 0.01 | 0.01 |

Table E-2. Understory and midstory fuels for the ponderosa pine dominance type with Douglas fir community types.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| TF06C | 0.00 | 0.01 | 0.42 | 0.44 | 32.20 | 0.12 | 0.12 | 0.19 |
| TF06B | 0.17 | 0.00 | 1.73 | 1.73 | 51.80 | 0.45 | 0.52 | 0.79 |
| AF1301 | 0.00 | 0.00 | 0.33 | 0.33 | 17.83 | 0.10 | 0.10 | 0.13 |
| TF05A | 0.00 | 1.55 | 1.34 | 2.89 | 20.87 | 0.51 | 0.40 | 0.66 |
| TF05D | 0.00 | 0.16 | 1.52 | 1.69 | 53.86 | 0.35 | 0.44 | 0.77 |
| NF10 | 0.03 | 0.07 | 0.27 | 0.34 | 8.72 | 0.07 | 0.08 | 0.14 |
| AC0602 | 0.00 | 0.09 | 0.20 | 0.30 | 20.25 | 0.10 | 0.06 | 0.06 |
| TC21 | 0.00 | 0.06 | 0.17 | 0.24 | 23.68 | 0.05 | 0.06 | 0.08 |
| NF05 | 0.30 | 0.70 | 0.06 | 0.76 | 15.35 | 0.11 | 0.02 | 0.03 |
| NC26 | 0.05 | 0.01 | 0.15 | 0.16 | 9.39 | 0.03 | 0.03 | 0.05 |
| Mean | 0.06 | 0.27 | 0.62 | 0.89 | 25.40 | 0.19 | 0.18 | 0.29 |
| Std. Dev. | 0.10 | 0.50 | 0.64 | 0.91 | 15.97 | 0.18 | 0.19 | 0.32 |
| Std. Err. | 0.03 | 0.17 | 0.21 | 0.30 | 5.32 | 0.06 | 0.06 | 0.11 |

Table E-3. Understory and midstory fuels for the mixed conifer dominance type with Douglas fir community types.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AF1302 | 0.04 | 0.01 | 0.25 | 0.25 | 26.29 | 0.12 | 0.06 | 0.07 |
| NC52 | 0.18 | 0.66 | 0.23 | 0.89 | 14.80 | 0.15 | 0.07 | 0.11 |
| TC24 | 0.08 | 1.01 | 0.02 | 1.03 | 16.75 | 0.10 | 0.01 | 0.00 |
| AB0402 | 0.04 | 0.00 | 0.00 | 0.00 | 10.65 | 0.00 | 0.00 | 0.00 |
| Mean | 0.08 | 0.42 | 0.12 | 0.54 | 17.12 | 0.09 | 0.04 | 0.04 |
| Std. Dev. | 0.07 | 0.50 | 0.13 | 0.50 | 6.62 | 0.06 | 0.04 | 0.05 |
| Std. Err. | 0.04 | 0.29 | 0.08 | 0.29 | 3.82 | 0.04 | 0.02 | 0.03 |

Table E-4. Understory and midstory fuels for the mixed conifer dominance type with more xeric white fir community types.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AB0501 | 0.03 | 0.05 | 0.07 | 0.12 | 29.89 | 0.06 | 0.01 | 0.01 |
| TF08A | 0.53 | 0.00 | 0.71 | 0.71 | 27.53 | 0.27 | 0.19 | 0.24 |
| AB0701 | 0.18 | 0.08 | 0.00 | 0.08 | 62.06 | 0.01 | 0.00 | 0.00 |
| AF0508 | 0.04 | 0.02 | 0.29 | 0.31 | 39.50 | 0.16 | 0.06 | 0.07 |
| TF23 | 0.07 | 0.69 | 0.15 | 0.84 | 29.44 | 0.08 | 0.03 | 0.06 |
| TF19 | 0.01 | 4.41 | 0.01 | 4.42 | 23.27 | 0.28 | 0.00 | 0.00 |
| NF18 | 0.01 | 0.35 | 0.23 | 0.58 | 25.42 | 0.18 | 0.05 | 0.09 |
| NF22 | 0.03 | 2.70 | 0.29 | 2.99 | 42.42 | 0.30 | 0.06 | 0.07 |
| AF0210 | 0.00 | 0.00 | 0.43 | 0.43 | 21.08 | 0.18 | 0.07 | 0.10 |
| TF17 | 0.07 | 0.67 | 0.37 | 1.05 | 16.42 | 0.29 | 0.10 | 0.15 |
| TF06A | 0.00 | 0.00 | 1.20 | 1.20 | 37.39 | 0.35 | 0.37 | 0.52 |
| AF0301 | 0.02 | 0.24 | 0.07 | 0.31 | 30.00 | 0.07 | 0.02 | 0.00 |
| TF05B | 0.56 | 0.09 | 0.72 | 0.81 | 27.09 | 0.29 | 0.22 | 0.23 |
| TF05C | 0.03 | 0.00 | 3.37 | 3.37 | 27.60 | 0.82 | 0.37 | 0.41 |
| NL51 | 0.06 | 1.01 | 0.11 | 1.13 | 41.53 | 0.14 | 0.04 | 0.01 |
| AB0304 | 0.03 | 0.07 | 0.40 | 0.46 | 13.88 | 0.20 | 0.08 | 0.09 |
| Mean | 0.10 | 0.65 | 0.53 | 1.18 | 30.91 | 0.23 | 0.10 | 0.13 |
| Std. Dev. | 0.18 | 1.22 | 0.82 | 1.27 | 11.71 | 0.19 | 0.12 | 0.15 |
| Std. Err. | 0.05 | 0.31 | 0.21 | 0.33 | 3.02 | 0.05 | 0.03 | 0.04 |

Table E-5. Understory and midstory fuels for the shrub dominance type.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| TF03A | 0.16 | 1.44 | 1.15 | 2.59 | 15.62 | 0.40 | 0.39 | 0.40 |
| TF03B | 0.09 | 3.83 | 0.21 | 4.04 | 16.24 | 0.41 | 0.07 | 0.11 |
| NF02C | 0.20 | 3.00 | 0.00 | 3.00 | 17.41 | 0.44 | 0.00 | 0.00 |
| Mean | 0.15 | 2.76 | 0.45 | 3.21 | 16.42 | 0.42 | 0.15 | 0.17 |
| Std. Dev. | 0.06 | 1.21 | 0.61 | 0.75 | 0.91 | 0.02 | 0.21 | 0.21 |
| Std. Err. | 0.04 | 0.86 | 0.43 | 0.53 | 0.64 | 0.01 | 0.15 | 0.15 |

Table E-6. Understory and midstory fuels for the mixed conifer dominance type with more mesic white fir community types.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AB0302 | 0.11 | 0.15 | 0.07 | 0.22 | 26.86 | 0.04 | 0.02 | 0.02 |
| AF0507 | 0.06 | 0.10 | 0.23 | 0.34 | 40.04 | 0.14 | 0.04 | 0.06 |
| TB10B | 0.19 | 0.05 | 0.62 | 0.67 | 39.15 | 0.12 | 0.06 | 0.07 |
| TB10A | 0.18 | 1.15 | 0.24 | 1.39 | 31.13 | 0.12 | 0.06 | 0.07 |
| TB10C | 0.26 | 0.03 | 0.20 | 0.23 | 38.12 | 0.10 | 0.04 | 0.06 |
| TF20B | 0.01 | 0.00 | 0.44 | 0.44 | 20.12 | 0.19 | 0.10 | 0.13 |
| TF20A | 0.01 | 0.01 | 0.54 | 0.55 | 32.94 | 0.18 | 0.11 | 0.18 |
| NF04 | 0.08 | 0.35 | 1.19 | 1.54 | 42.55 | 0.59 | 0.23 | 0.12 |
| AF0310 | 0.10 | 0.00 | 0.36 | 0.36 | 37.67 | 0.17 | 0.11 | 0.08 |
| AB0203 | 0.10 | 0.03 | 0.72 | 0.75 | 16.44 | 0.35 | 0.19 | 0.18 |
| Mean | 0.11 | 0.19 | 0.46 | 0.65 | 32.50 | 0.20 | 0.10 | 0.10 |
| Std. Dev. | 0.08 | 0.35 | 0.33 | 0.46 | 8.85 | 0.16 | 0.07 | 0.06 |
| Std. Err. | 0.03 | 0.12 | 0.11 | 0.15 | 2.95 | 0.05 | 0.02 | 0.02 |

Table E-7. Understory and midstory fuels for the aspen dominance type.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AF0808 | 0.34 | 0.00 | 0.00 | 0.00 | 25.97 | 0.00 | 0.00 | 0.00 |
| AF0406 | 0.19 | 0.00 | 0.05 | 0.05 | 41.76 | 0.03 | 0.01 | 0.01 |
| AF0409 | 0.01 | 0.00 | 0.00 | 0.00 | 33.53 | 0.00 | 0.00 | 0.00 |
| TF11 | 0.43 | 0.70 | 0.51 | 1.21 | 44.92 | 0.12 | 0.00 | 0.00 |
| AF1305 | 0.14 | 0.00 | 0.00 | 0.00 | 29.71 | 0.00 | 0.00 | 0.00 |
| TF13 | 0.13 | 2.12 | 0.51 | 2.63 | 47.28 | 0.41 | 0.00 | 0.00 |
| Mean | 0.21 | 0.47 | 0.18 | 0.65 | 37.20 | 0.09 | 0.00 | 0.00 |
| Std. Dev. | 0.15 | 0.85 | 0.26 | 1.08 | 8.69 | 0.16 | 0.00 | 0.00 |
| Std. Err. | 0.07 | 0.38 | 0.12 | 0.48 | 3.89 | 0.07 | 0.00 | 0.00 |

Table E-8. Understory and midstory fuels for the spruce-fir dominance type.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AF0305 | 0.03 | 0.00 | 0.16 | 0.16 | 38.00 | 0.09 | 0.03 | 0.04 |
| NP11 | 0.04 | 0.08 | 0.22 | 0.30 | 44.37 | 0.15 | 0.04 | 0.05 |
| AF0807 | 0.01 | 0.00 | 0.13 | 0.13 | 27.56 | 0.08 | 0.02 | 0.03 |
| TF15 | 0.06 | 0.00 | 1.17 | 1.17 | 22.58 | 0.63 | 0.22 | 0.29 |
| TF14 | 0.03 | 0.01 | 0.16 | 0.17 | 24.79 | 0.07 | 0.04 | 0.05 |
| TF12B | 0.14 | 0.00 | 1.27 | 1.28 | 36.89 | 0.67 | 0.24 | 0.37 |
| TF12A | 0.15 | 0.01 | 0.43 | 0.43 | 78.54 | 0.17 | 0.12 | 0.13 |
| TP16 | 0.06 | 0.01 | 0.31 | 0.32 | 26.97 | 0.19 | 0.06 | 0.07 |
| Mean | 0.06 | 0.01 | 0.48 | 0.50 | 37.46 | 0.26 | 0.10 | 0.13 |
| Std. Dev. | 0.05 | 0.03 | 0.47 | 0.46 | 18.23 | 0.25 | 0.09 | 0.13 |
| Std. Err. | 0.02 | 0.01 | 0.17 | 0.16 | 6.44 | 0.09 | 0.03 | 0.05 |

Table E-9. Understory and midstory fuels for the grassland dominance type.

| Plot | Veg | Shrubs | Tree 10 | S&T Tot | Ust Tot | ST 1hr | ST 10hr | ST 1Chr |
|---|---|---|---|---|---|---|---|---|
| AB1209 | 0.31 | 0.00 | 0.34 | 0.34 | 6.33 | 0.16 | 0.10 | 0.08 |
| AF1304 | 0.30 | 0.00 | 0.00 | 0.00 | 3.45 | 0.01 | 0.00 | 0.00 |
| NB09B | 0.47 | 0.00 | 0.00 | 0.00 | 1.49 | 0.00 | 0.00 | 0.00 |
| TB09A | 0.96 | 0.00 | 0.00 | 0.00 | 10.41 | 0.00 | 0.00 | 0.00 |
| TF07A | 0.61 | 0.00 | 0.00 | 0.00 | 4.72 | 0.00 | 0.00 | 0.00 |
| Mean | 0.53 | 0.00 | 0.07 | 0.07 | 5.28 | 0.03 | 0.02 | 0.02 |
| Std. Dev. | 0.27 | 0.00 | 0.15 | 0.15 | 3.37 | 0.07 | 0.04 | 0.04 |
| Std. Err. | 0.14 | 0.00 | 0.08 | 0.08 | 1.69 | 0.04 | 0.02 | 0.02 |

# Appendix F

## Overstory Fuels and Remote Sensing Results for the Macroplots

Table F-1. Overstory fuels and remote sensing results for the ponderosa pine dominance type with ponderosa pine community types.

| Plot | TPA <2’ | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| NR01 | 0.00 | 0.00 | 519.00 | 90.00 | 89.71 | -32.59 | 31.89 |
| NR03 | 0.00 | 0.00 | 504.00 | 129.00 | 87.54 | -39.34 | 30.74 |
| AB0705 | 34.00 | 0.00 | 187.00 | 37.00 | 59.75 | -46.64 | 41.01 |
| AC0603 | 90.00 | 70.00 | 201.00 | 70.00 | 58.00 | -42.44 | 29.85 |
| AL0609 | 135.00 | 5.00 | 326.00 | 169.00 | 83.67 | -35.84 | 37.96 |
| AL0709 | 0.00 | 76.00 | 97.00 | 121.00 | 69.78 | -39.25 | 36.99 |
| AL0610 | 0.00 | 304.00 | 90.00 | 130.00 | 79.92 | -33.30 | 33.40 |
| TC25 | 0.00 | 1419.00 | 594.00 | 69.00 | 78.10 | -41.25 | 39.07 |
| TB01 | 112.00 | 28.00 | 81.00 | 192.00 | 86.25 | -19.79 | 44.25 |
| AB0109 | 34.00 | 18.00 | 27.00 | 211.00 | 83.77 | -23.55 | 42.08 |
| AF0906 | 22.00 | 351.00 | 13.00 | 76.00 | 70.20 |  |  |
| TF03C | 787.00 | 2887.00 | 28.00 | 54.00 | 60.62 | -39.71 | 53.68 |
| TF02A | 0.00 | 1813.00 | 282.00 | 60.00 | 66.77 | -16.77 | 59.93 |
| TF02B | 0.00 | 3230.00 | 39.00 | 75.00 | 79.27 | -27.11 | 54.87 |
| Mean | 86.71 | 728.64 | 213.43 | 105.93 | 75.24 | -33.66 | 41.21 |
| Std. Dev. | 206.76 | 1138.92 | 201.33 | 54.12 | 10.92 | 9.27 | 9.67 |
| Std. Err. | 57.35 | 315.88 | 55.84 | 15.01 | 3.03 | 2.68 | 2.79 |

Table F-2. Overstory fuels and remote sensing results for the ponderosa pine dominance type with Douglas fir community types.

| Plot | TPA <2’ | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| TF06C | 0.00 | 22.00 | 344.00 | 72.00 | 88.33 | -28.07 | 37.40 |
| TF06B | 0.00 | 0.00 | 1404.00 | 105.00 | 96.87 | -21.82 | 43.88 |
| AF1301 | 225.00 | 0.00 | 1264.00 | 156.00 | 77.12 | -29.82 | 43.41 |
| TF05A | 0.00 | 0.00 | 1983.00 | 57.00 | 94.70 | -26.40 | 45.36 |
| TF05D | 0.00 | 46.00 | 1250.00 | 63.00 | 92.40 | -24.88 | 38.74 |
| NF10 | 0.00 | 0.00 | 647.00 | 105.00 | 81.08 | -32.57 | 35.76 |
| AC0602 | 67.00 | 24.00 | 304.00 | 73.00 | 40.77 |  |  |
| TC21 | 112.00 | 607.00 | 358.00 | 60.00 | 62.50 | -41.67 | 33.26 |
| NF05 | 0.00 | 6118.00 | 25.00 | 24.00 | 68.49 | -39.40 | 58.56 |
| NC26 | 0.00 | 90.00 | 327.00 | 102.00 | 81.60 | -33.54 | 36.85 |
| Mean | 40.40 | 690.70 | 790.60 | 81.70 | 78.39 | -30.91 | 41.47 |
| Std. Dev. | 75.53 | 1915.98 | 639.30 | 36.44 | 17.28 | 6.58 | 7.60 |
| Std. Err. | 25.18 | 638.66 | 213.10 | 12.15 | 5.76 | 2.33 | 2.69 |

Table F-3. Overstory fuels and remote sensing results for the mixed conifer dominance type with Douglas fir community types.

| Plot | TPA <2’ | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AF1302 | 382.00 | 0.00 | 298.00 | 160.00 | 72.00 | -20.49 | 43.47 |
| NC52 | 0.00 | 2338.00 | 688.00 | 123.00 | 90.89 | -33.08 | 36.40 |
| TC24 | 0.00 | 1442.00 | 255.00 | 87.00 | 61.46 | -37.14 | 36.85 |
| AB0402 | 237.00 | 0.00 | 83.00 | 328.00 | 91.21 | | |
| Mean | 154.75 | 945.00 | 331.00 | 174.50 | 78.89 | -30.24 | 38.91 |
| Std. Dev. | 188.24 | 1150.87 | 255.49 | 106.58 | 14.69 | 8.68 | 3.96 |
| Std. Err. | 108.68 | 664.46 | 147.50 | 61.54 | 8.48 | 6.14 | 2.80 |

Table F-4. Overstory fuels and remote sensing results for the mixed conifer dominance type with more xeric white fir community types.

| Plot | TPA <2’ | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AB0501 | 2057.00 | 101.00 | 1041.00 | 115.00 | 81.95 | -21.33 | 42.65 |
| TF08A | 337.00 | 0.00 | 835.00 | 99.00 | 98.75 | -25.19 | 44.74 |
| AB0701 | 1349.00 | 9.00 | 234.00 | 166.00 | 72.96 | -25.25 | 60.02 |
| AF0508 | 776.00 | 306.00 | 481.00 | 135.00 | 86.42 | -17.58 | 46.40 |
| TF23 | 674.00 | 1138.00 | 282.00 | 123.00 | 86.15 | -10.80 | 49.29 |
| TF19 | 112.00 | 3492.00 | 151.00 | 105.00 | 85.83 | -17.02 | 54.06 |
| NF18 | 0.00 | 1733.00 | 277.00 | 111.00 | 87.73 | -26.13 | 55.44 |
| NF22 | 112.00 | 255.00 | 597.00 | 129.00 | 80.50 | -12.15 | 45.75 |
| AF0210 | 101.00 | 580.00 | 553.00 | 160.00 | 79.30 | -15.36 | 48.09 |
| TF17 | 450.00 | 490.00 | 624.00 | 624.00 | 82.71 | -16.02 | 47.78 |
| TF06A | 112.00 | 0.00 | 1237.00 | 93.00 | 95.42 | -20.21 | 38.84 |
| AF0301 | 922.00 | 115.00 | 757.00 | 132.00 | 79.14 | -19.93 | 44.05 |
| TF05B | 0.00 | 6.00 | 2019.00 | 48.00 | 94.79 | -15.37 | 51.20 |
| TF05C | 0.00 | 0.00 | 2343.00 | 69.00 | 87.92 | -22.34 | 41.36 |
| NL51 | 225.00 | 582.00 | 487.00 | 108.00 | 86.37 | -14.65 | 54.47 |
| AB0304 | 2867.00 | 274.00 | 645.00 | 76.00 | 68.90 | -19.63 | 44.72 |
| Mean | 630.88 | 567.56 | 785.19 | 143.31 | 84.68 | -18.68 | 48.05 |
| Std. Dev. | 825.58 | 913.27 | 619.45 | 131.87 | 7.83 | 4.62 | 5.72 |
| Std. Err. | 213.16 | 235.80 | 159.94 | 34.05 | 2.02 | 1.19 | 1.48 |

Table F-5. Overstory fuels and remote sensing results for the shrub dominance type.

| Plot | TPA <2' | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| TF03A | 0.00 | 3758.00 | 334.00 | 42.00 | 62.92 | -50.04 | 50.61 |
| TF03B | 112.00 | 1716.00 | 142.00 | 45.00 | 53.54 | -43.91 | 49.81 |
| NF02C | 0.00 | 3026.00 | 24.00 | 81.00 | 56.86 | -42.48 | 67.50 |
| Mean | 37.33 | 2833.33 | 166.67 | 56.00 | 57.77 | -45.48 | 55.97 |
| Std. Dev. | 64.66 | 1034.54 | 156.47 | 21.70 | 4.75 | 4.02 | 9.99 |
| Std. Err. | 45.72 | 731.53 | 110.64 | 15.35 | 3.36 | 2.84 | 7.06 |

Table F-6. Overstory fuels and remote sensing results for the mixed conifer dominance type with more mesic white fir community types.

| Plot | TPA <2' | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AB0302 | 1012.00 | 92.00 | 247.00 | 137.00 | 76.54 | -21.76 | 48.01 |
| AF0507 | 641.00 | 34.00 | 609.00 | 175.00 | 84.76 | -12.88 | 49.43 |
| TB10B | 7532.00 | 85.00 | 470.00 | 99.00 | 90.63 | -19.42 | 61.42 |
| TB10A | 4609.00 | 60.00 | 390.00 | 105.00 | 83.65 | -15.00 | 55.90 |
| TB10C | 0.00 | 0.00 | 1032.00 | 75.00 | 81.46 | -18.46 | 50.88 |
| TF20B | 337.00 | 0.00 | 320.00 | 132.00 | 83.85 | -11.27 | 44.72 |
| TF20A | 1012.00 | 0.00 | 746.00 | 210.00 | 93.54 | -14.40 | 46.47 |
| NF04 | 337.00 | 1135.00 | 878.00 | 138.00 | 91.80 | -11.47 | 54.58 |
| AF0310 | 3572.00 | 0.00 | 876.00 | 198.00 | 91.68 | -19.28 | 58.10 |
| AB0203 | 5666.00 | 0.00 | 863.00 | 99.00 | 69.84 | -22.21 | 36.67 |
| Mean | 2471.80 | 140.60 | 643.10 | 136.80 | 84.77 | -16.62 | 50.62 |
| Std. Dev. | 2675.51 | 351.34 | 274.08 | 45.06 | 7.54 | 4.12 | 7.23 |
| Std. Err. | 891.84 | 117.11 | 91.36 | 15.02 | 2.51 | 1.37 | 2.41 |

Table F-7. Overstory fuels and remote sensing results for the aspen dominance type.

| Plot | TPA <2' | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AF0808 | 0.00 | 0.00 | 49.00 | 115.00 | 66.66 | -18.47 | 84.13 |
| AF0406 | 1821.00 | 0.00 | 196.00 | 119.00 | 79.35 | -20.54 | 73.99 |
| AF0409 | 67.00 | 0.00 | 656.00 | 117.00 | 89.75 | -22.63 | 68.85 |
| TF11 | 1461.00 | 37.00 | 1344.00 | 255.00 | 80.52 | -18.92 | 63.36 |
| AF1305 | 270.00 | 0.00 | 214.00 | 292.00 | 79.30 | -19.19 | 75.07 |
| TF13 | 225.00 | 2125.00 | 2071.00 | 3.00 | 96.46 | -21.77 | 80.82 |
| Mean | 640.67 | 360.33 | 755.00 | 150.17 | 82.01 | -20.25 | 74.37 |
| Std. Dev. | 789.41 | 864.63 | 799.02 | 105.90 | 10.21 | 1.68 | 7.61 |
| Std. Err. | 353.04 | 386.68 | 357.33 | 47.36 | 4.56 | 0.75 | 3.40 |

Table F-8. Overstory fuels and remote sensing results for the spruce-fir dominance type.

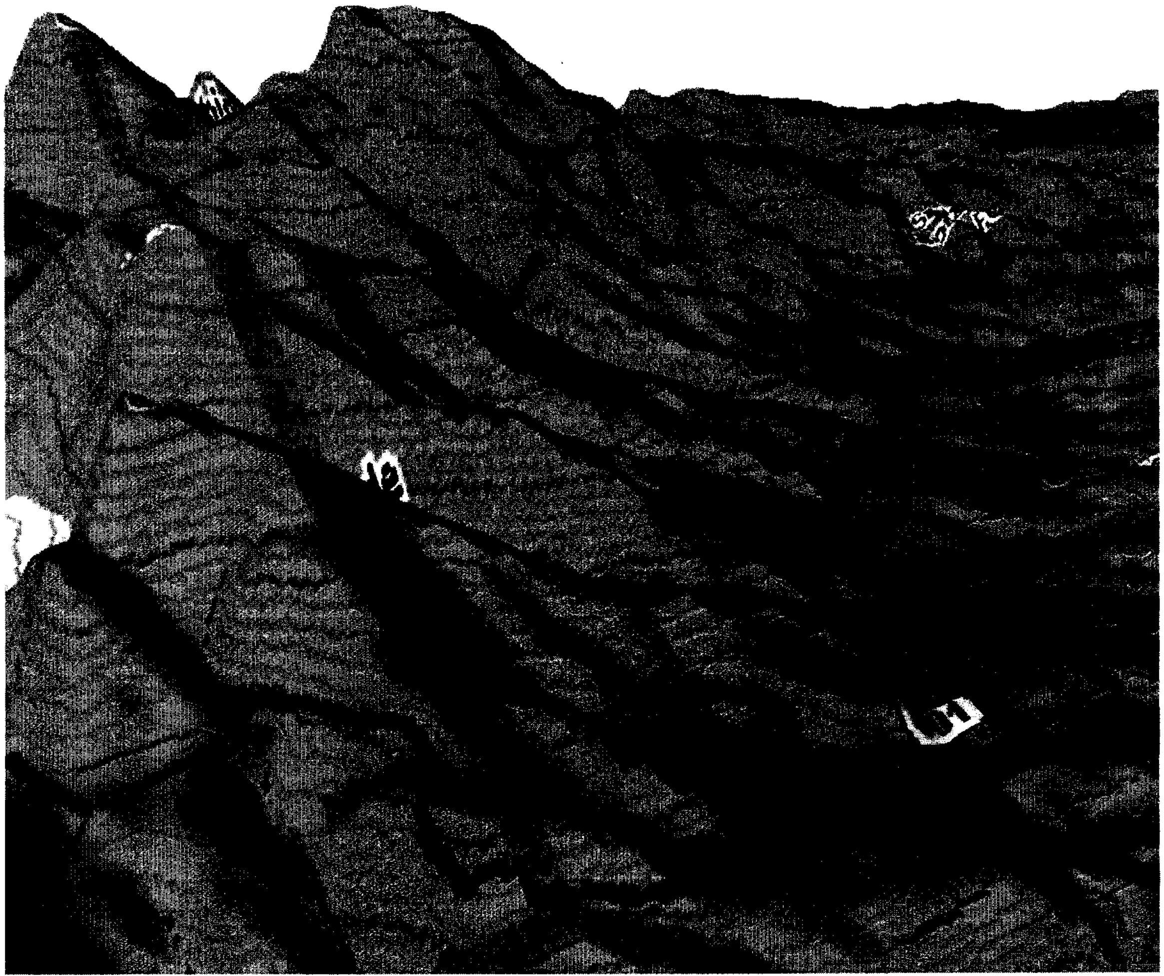
| Plot | TPA <2' | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AF0305 | 90.00 | 0.00 | 646.00 | 151.00 | 80.04 | -15.27 | 57.87 |
| NP11 | 112.00 | 382.00 | 325.00 | 216.00 | 90.23 | -24.65 | 46.53 |
| AF0807 | 101.00 | 0.00 | 1457.00 | 223.00 | 77.69 | | |
| TF15 | 112.00 | 0.00 | 950.00 | 252.00 | 90.73 | -11.27 | 61.18 |
| TF14 | 0.00 | 0.00 | 437.00 | 294.00 | 88.13 | -23.15 | 51.31 |
| TF12B | 337.00 | 0.00 | 655.00 | 240.00 | 89.48 | -17.05 | 62.16 |
| TF12A | 0.00 | 0.00 | 618.00 | 138.00 | 84.57 | -19.28 | 57.10 |
| TP16 | 450.00 | 0.00 | 580.00 | 270.00 | 93.65 | -13.21 | 70.36 |
| Mean | 150.25 | 47.75 | 708.50 | 223.00 | 86.81 | -17.70 | 58.07 |
| Std. Dev. | 159.85 | 135.06 | 352.71 | 54.56 | 5.56 | 4.97 | 7.72 |
| Std. Err. | 56.51 | 47.75 | 124.70 | 19.29 | 1.97 | 1.88 | 2.92 |

Table F-9. Overstory fuels and remote sensing results for the grassland dominance type.

| Plot | TPA <2' | SPA <8" | TPA <8" | TPA >8" | CC % | KT W | KT G |
|---|---|---|---|---|---|---|---|
| AB1209 | 472.00 | 0.00 | 342.00 | 7.00 | 19.14 | -78.93 | 29.65 |
| AF1304 | 101.00 | 0.00 | 34.00 | 11.00 | 0.52 | -49.19 | 55.83 |
| NB09B | 0.00 | 0.00 | 22.00 | 9.00 | 19.70 | -57.32 | 70.54 |
| TB09A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -52.98 | 60.24 |
| TF07A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -42.38 | 73.98 |
| Mean | 114.60 | 0.00 | 79.60 | 5.40 | 7.87 | -56.16 | 58.05 |
| Std. Dev. | 204.52 | 0.00 | 147.41 | 5.13 | 10.55 | 13.86 | 17.51 |
| Std. Err. | 102.26 | 0.00 | 73.71 | 2.56 | 5.27 | 6.93 | 8.75 |

# Appendix G

## Kriging Results for Selected Variables



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Detail 10-3 Datum: WGS84

Figure G-1. Topographic perspective of the Los Alamos study region. This approximates the perspective of the kriging results that follow. The aspect of each of these views is 245 degrees from true north. State Highway 4 can be seen in the left foreground as it proceeds below Cerro Grande. The Valle Grande is in the upper left margin, and the South Gate is at the intersection of Highway 501 and Highway 4, in the lower right.

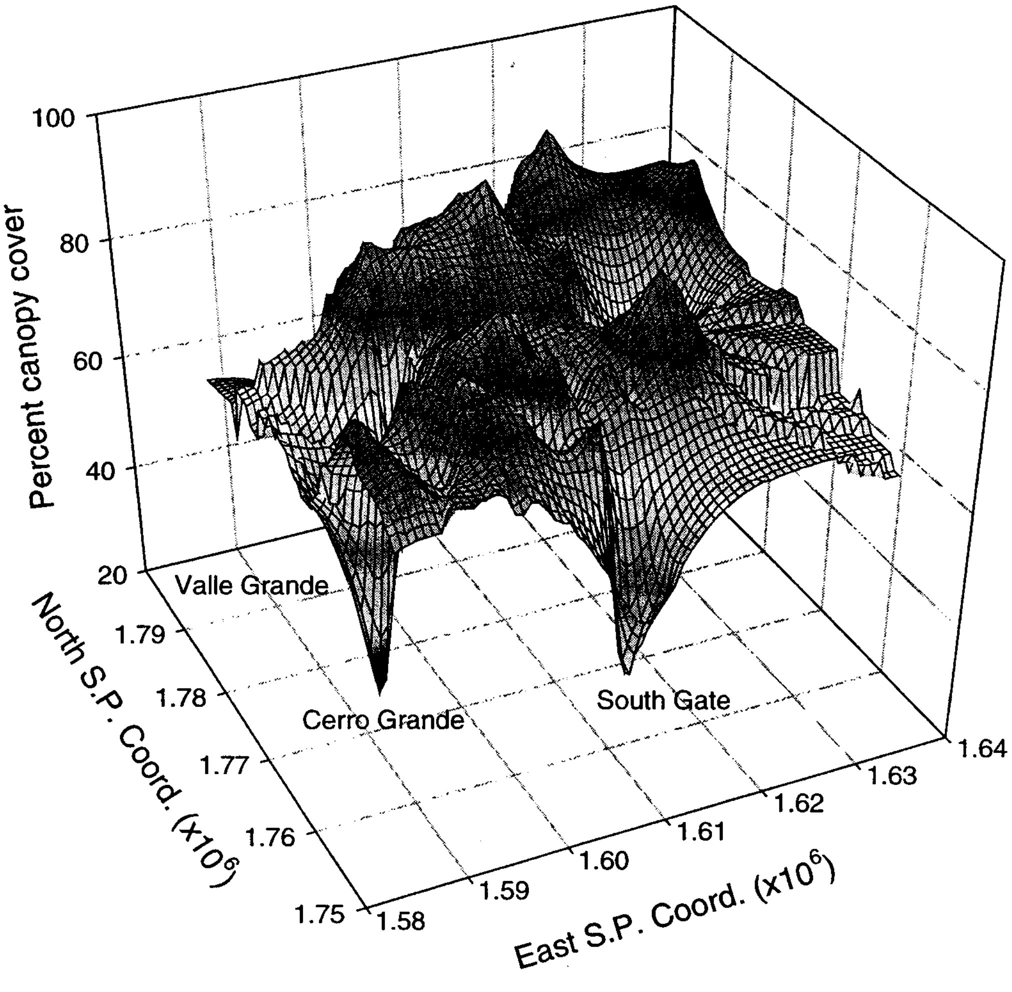


Figure G-2. Kriging results for percent canopy coverage.

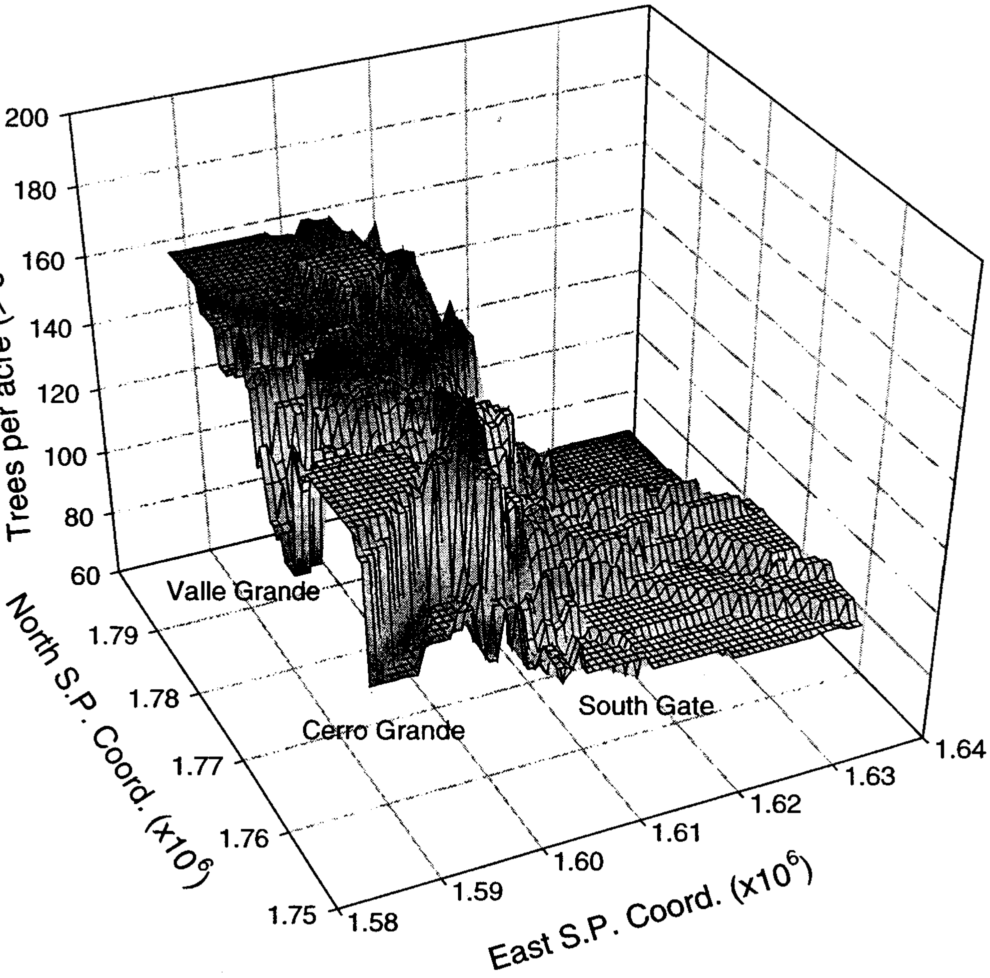


Figure G-3. Kriging results for number of trees per acre (>8 in. *dbh*).

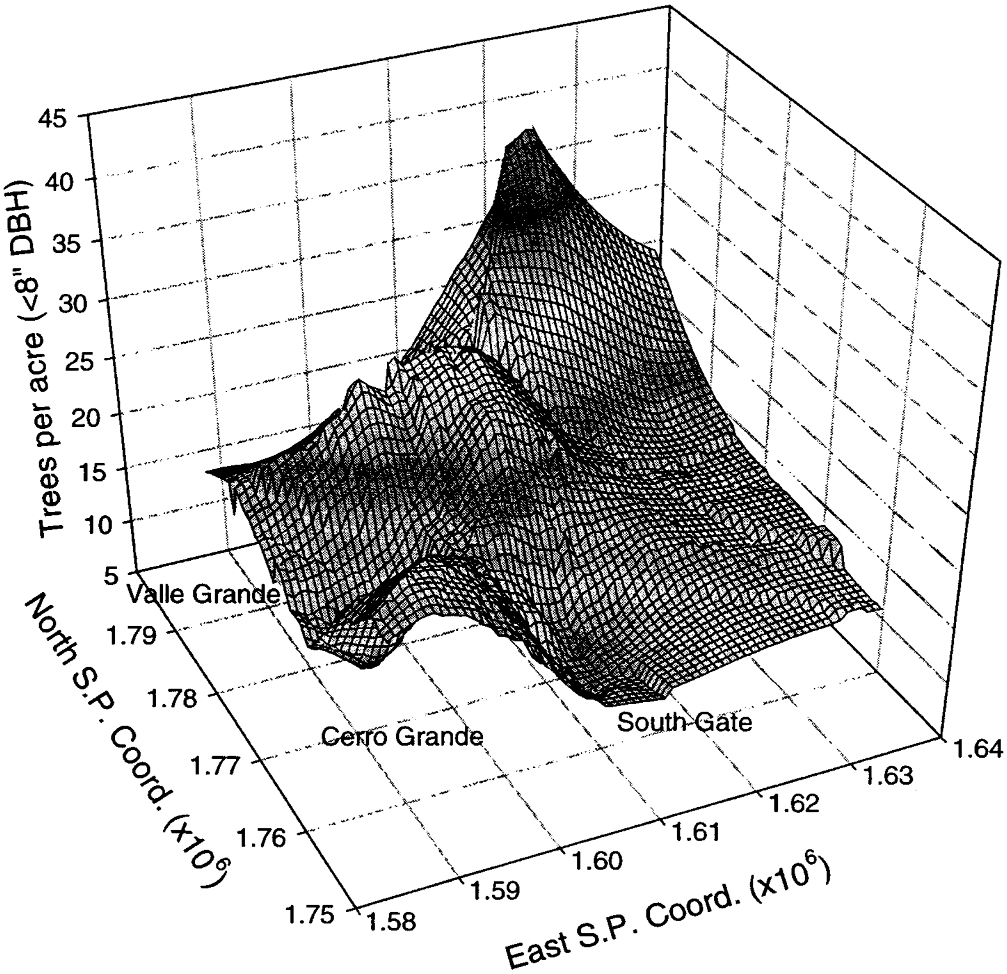


Figure G-4. Kriging results for number of trees per acre (<8 in. *dbh*).

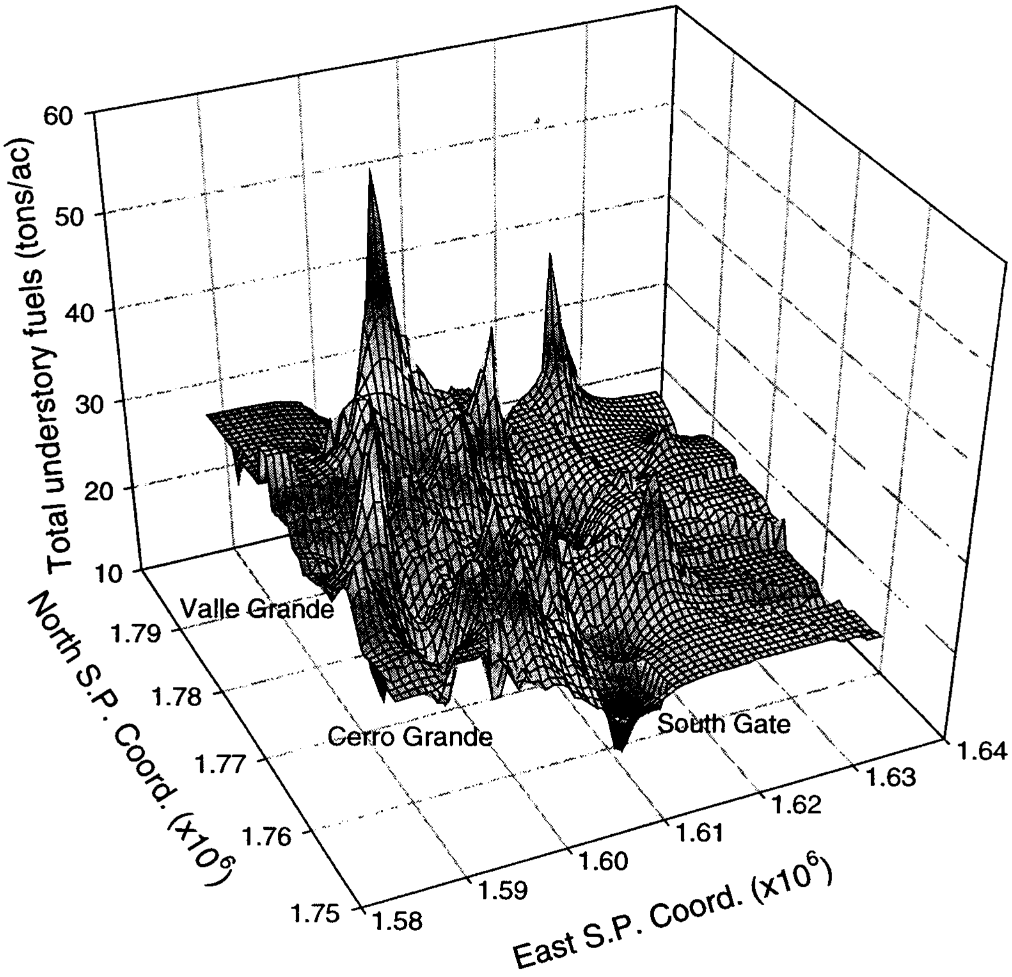


Figure G-5. Kriging results for total understory fuels (tons/acre).

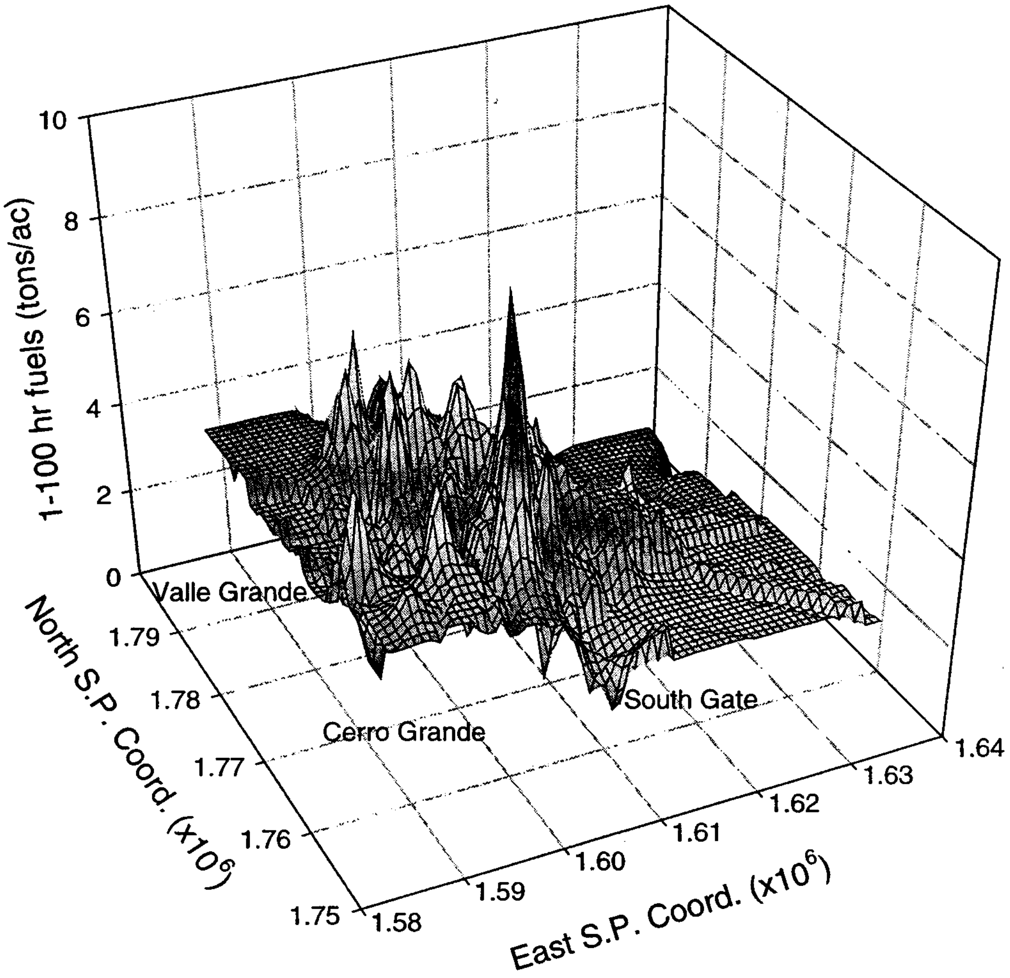


Figure G-6. Kriging results for 1-hr to 100-hr fuels (tons/acre).

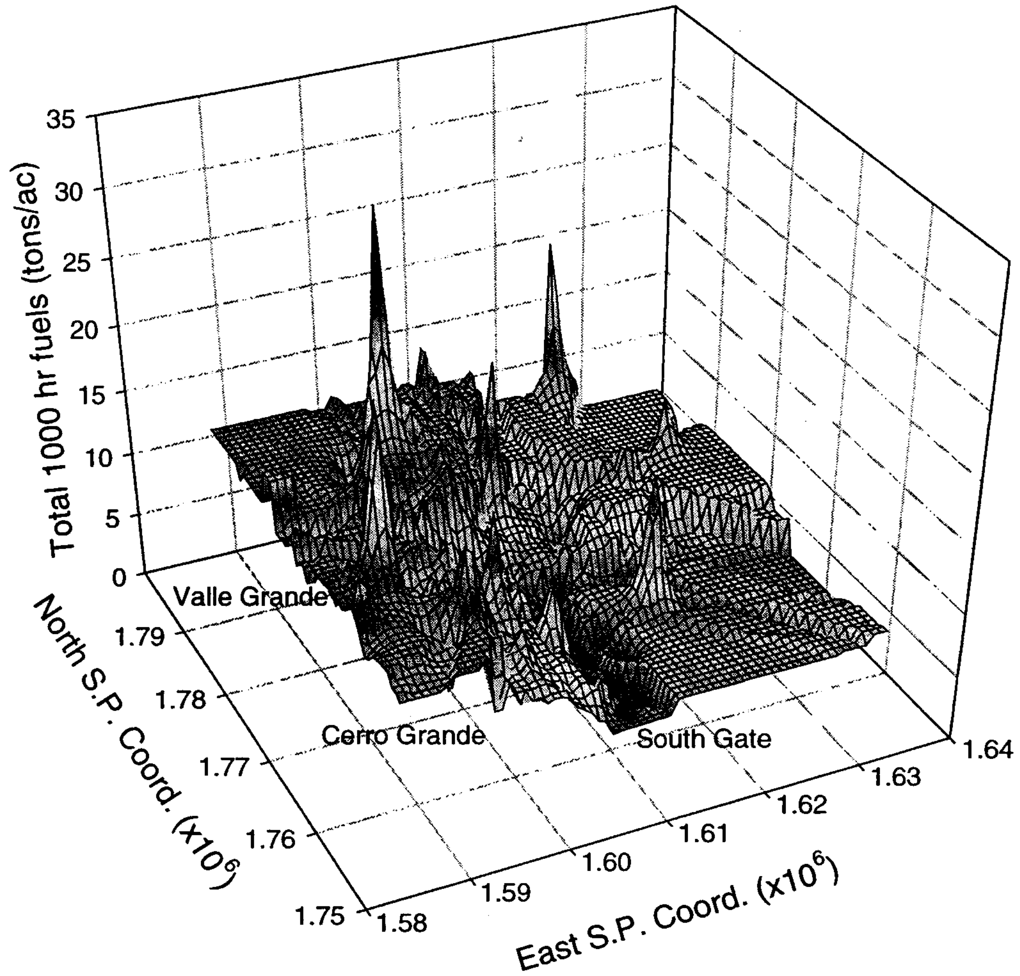


Figure G-7. Kriging results for 1000-hr fuels, both sound and rotten (tons/acre).

**Los Alamos**
NATIONAL LABORATORY

Los Alamos, New Mexico 87545