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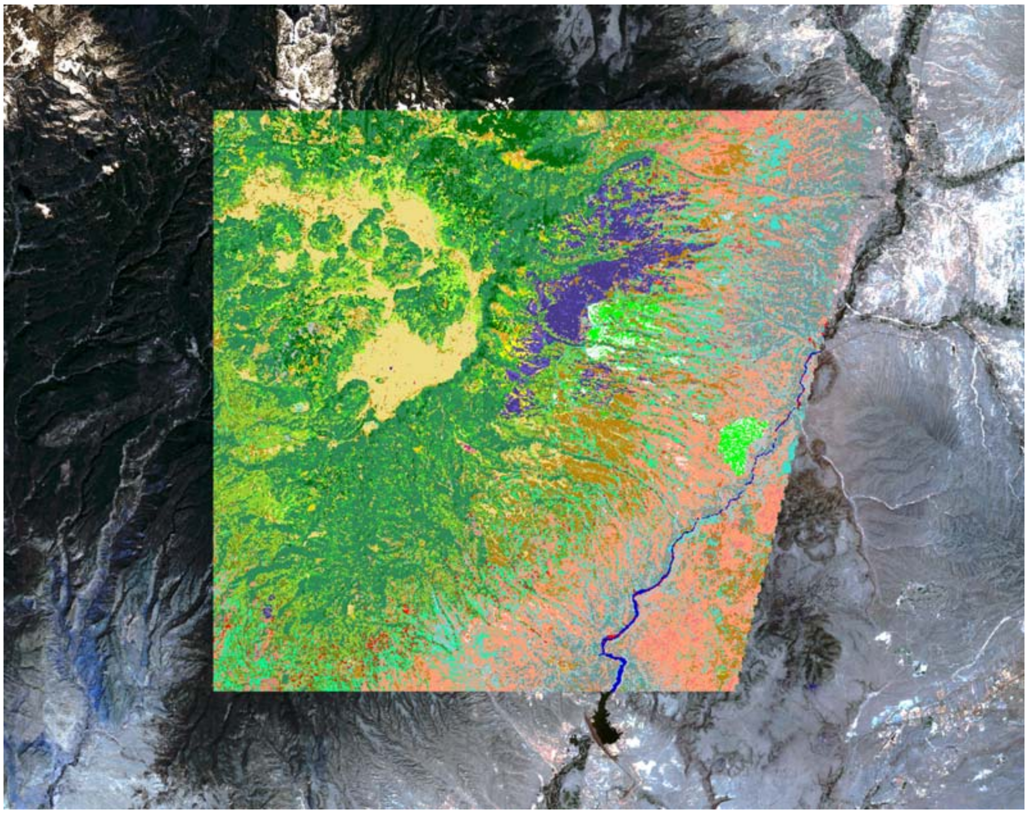
Land Cover Map for the Eastern Jemez Region



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Edited by Hector Hinojosa, Group IM-1

Front Cover: Background image composed of a mosaic of ETM+ Landsat 7 scenes provided by the New Mexico portion of the Southwest Regional Gap Analysis Project. Image processing was done by Scott Schrader. Forward image is the land cover map created by Brad McKown in conjunction with the Earth Data Analysis Center at the University of New Mexico. The map is a quarter-hectare smoothed classification map with 30 vegetation classes represented.

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LA-14029
Issued: June 2003

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Land Cover Map for the Eastern Jemez Region

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ABSTRACT

A post-Cerro Grande Fire land cover map has been developed by the Ecology group of the Risk Reduction and Environmental Stewardship division at Los Alamos National Laboratory with the support of the Earth Data Analysis Center at the University of New Mexico. This map was developed to support forest growth and yield modeling, endangered species habitat modeling, and other region-wide environmental studies. A Landsat Enhanced Thematic Mapper Plus satellite scene, acquired over the area on June 4, 2001, was used to map the natural vegetation of the study area. This area includes Los Alamos County, Los Alamos National Laboratory, Bandelier National Monument, the Valles Caldera National Preserve, and parts of Santa Fe National Forest. Five hundred eighty-three training sites were acquired from field sampling, screen digitizing, and data from previous projects. The draft classification contains 34 classes that conform with the National Vegetation Classification System (NVCS). As additional field data were acquired, the classification was refined to a final 30 classes. Initially, two versions of this land cover map were produced: one at the original Landsat resolution of 15 m and one smoothed to a quarter-hectare minimum mapping unit. The dominant class within the entire study area with the 15-m map was *Abies concolor-Pseudotsuga menziesii* Forest at 16 percent or 298 km^2 (115 mi^2). Next, additional data were collected at 242 sites and used to independently assess the accuracy of the maps. The resulting accuracy of the 15-m map was 52 percent and the quarter-hectare map was 55 percent. Finally, the map classes were variously combined to aggregated classifications at the physiognomic level (14 classes), NVCS class level (9 classes), and taxonomic level (9 classes). The accuracy of these levels for the 15-m map was 73 percent, 76 percent, and 76 percent, respectively. For the quarter-hectare map, the accuracies were 71 percent, 77 percent, and 75 percent, respectively.

INTRODUCTION

The Ecology group of the Risk Reduction and Environmental Stewardship division (RRES-ECO) at Los Alamos National Laboratory (LANL), with the support of the Earth Data Analysis Center (EDAC) at the University of New Mexico, has developed a post-Cerro Grande Fire land cover map. This map was developed to support wildfire hazard reduction activities, fire behavior modeling, forest growth and yield modeling, endangered species habitat modeling, and other region-wide environmental studies. It can also be used by other groups within LANL and by outside agencies for their research and management purposes.

RRES-ECO and EDAC have previously collaborated in the production of a land cover map for the Los Alamos region (Koch et al. 1997). This land cover map contained 10 land cover classes and was used for a variety of purposes by RRES-ECO and other organizations. However, the Cerro Grande Fire resulted in catastrophic landscape changes in May 2000, causing the earlier map to be obsolete. To meet our current management needs, a new land cover map was required. As in the previous mapping exercise, Landsat Enhanced Thematic Mapper Plus (ETM^+) satellite imagery was chosen to develop the new map because of its high spectral discrimination, its adaptability for producing a final product over a large area relatively quickly, and its comparitively low cost.

STUDY AREA

The study area is located in the eastern slope of the Jemez Mountains in northern New Mexico. The majority of the study area is contained within the Los Alamos Quadrangle of the 1:100,000 scale series US Geological Survey topographic maps of New Mexico. The town sites of Los Alamos and White Rock and LANL are situated just east of center and are the only major developed areas. The east-west extent of the study site ranges from the Rio Grande to the western boundary of the Valles Caldera National Preserve. The north-south extent ranges from Cochiti Reservoir on the south to just north of the Santa Clara Pueblo.

The study area contains lands within Los Alamos, Sandoval, Rio Arriba, and Santa Fe counties (Figure 1). Land owner and administration units include LANL, Bandelier National Monument, Santa Fe National Forest, the Valles Caldera National Preserve, San Ildefonso Pueblo, Santa Clara Pueblo, Jemez Pueblo, Cochiti Pueblo, Bureau of Land Management, and State and private lands. The overall extent of the study area is 1821 km^2 (703 mi^2). The portion of the study area that includes LANL is 112 km^2 (43 mi^2).

The elevation of the study area ranges from approximately 1615 m (5300 ft) on the Rio Grande near the Cochiti Reservoir, to 3523.8 m (11561 ft) at the top of Chicoma Mountain located on the northern margin of the study area. In a broad sense, the study area includes two major geologic zones, the eastern and southern portions of the Jemez Mountains, and a small segment of the Rio Grande Rift, which borders on the eastern one-third of the area (West 1973). The Jemez Mountains were originally formed by Tertiary volcanic flows and eruptions that ultimately grew into a large volcano (Nyhan et al. 1978, Ellisor et al. 1996). Subsequently, a series of major eruptions, occurring between 1.2 and 1.6 million years ago, destroyed all but the rim of the volcano and deposited ash and tuff to form plateaus along its flanks (Nowell 1996). Subsequent subsidence and resurgent dome formation within the caldera created what is now referred to as the Valles Caldera. In contrast to the Jemez Mountains, the Rio Grande Rift is a north-south-oriented subsidence basin that was initiated in the Oligocene or early Miocene (Chapin and Cather 1994). The Rio Grande was established throughout the length of this basin during the Pleistocene.

Within these two major geologic zones of the study area, nine physiographic regions can be defined. Seven of these are shown in Figure 2. Two minor physiographic regions are not shown in Figure 2, but are discussed below. Many of the geologic details of these provinces and of the study region in general can be found in Goff et al. (1996). With regard to the Rio Grande Rift, the Cerros del Rio, Santo Domingo Basin, Española Basin (not shown in Figure 2), and White Rock Canyon physiographic provinces can be identified. The Cerros del Rio section was formed by lava flows and up to 60 cinder-spatter cones originating from vents in the area (Aubele 1972). Montoso Peak, at 2229.6 m (7315 ft), is the highest point in this physiographic region. Within the window defined for this study, the Cerros del Rio

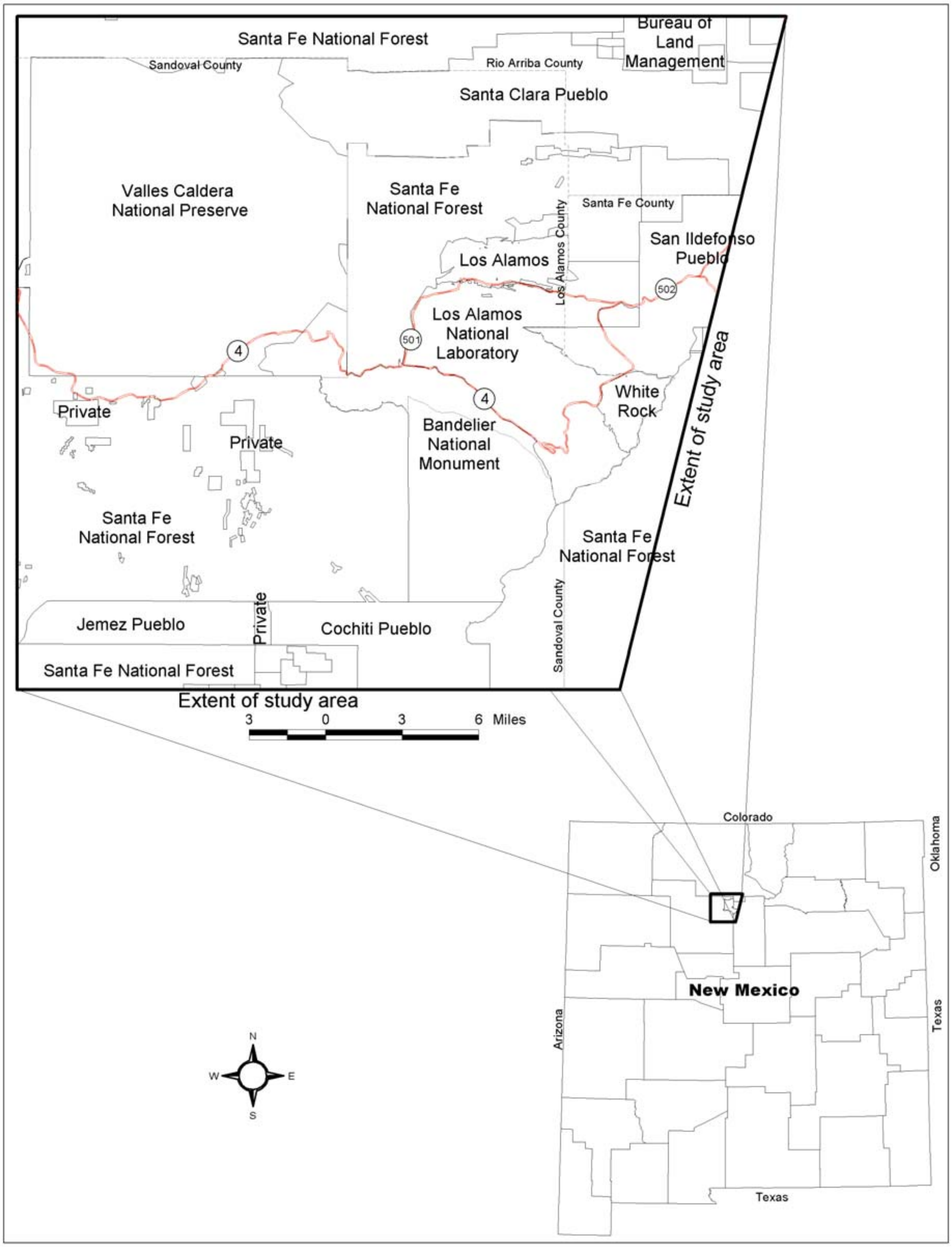

Figure 1. Location of the study area showing major landowners and roadways.

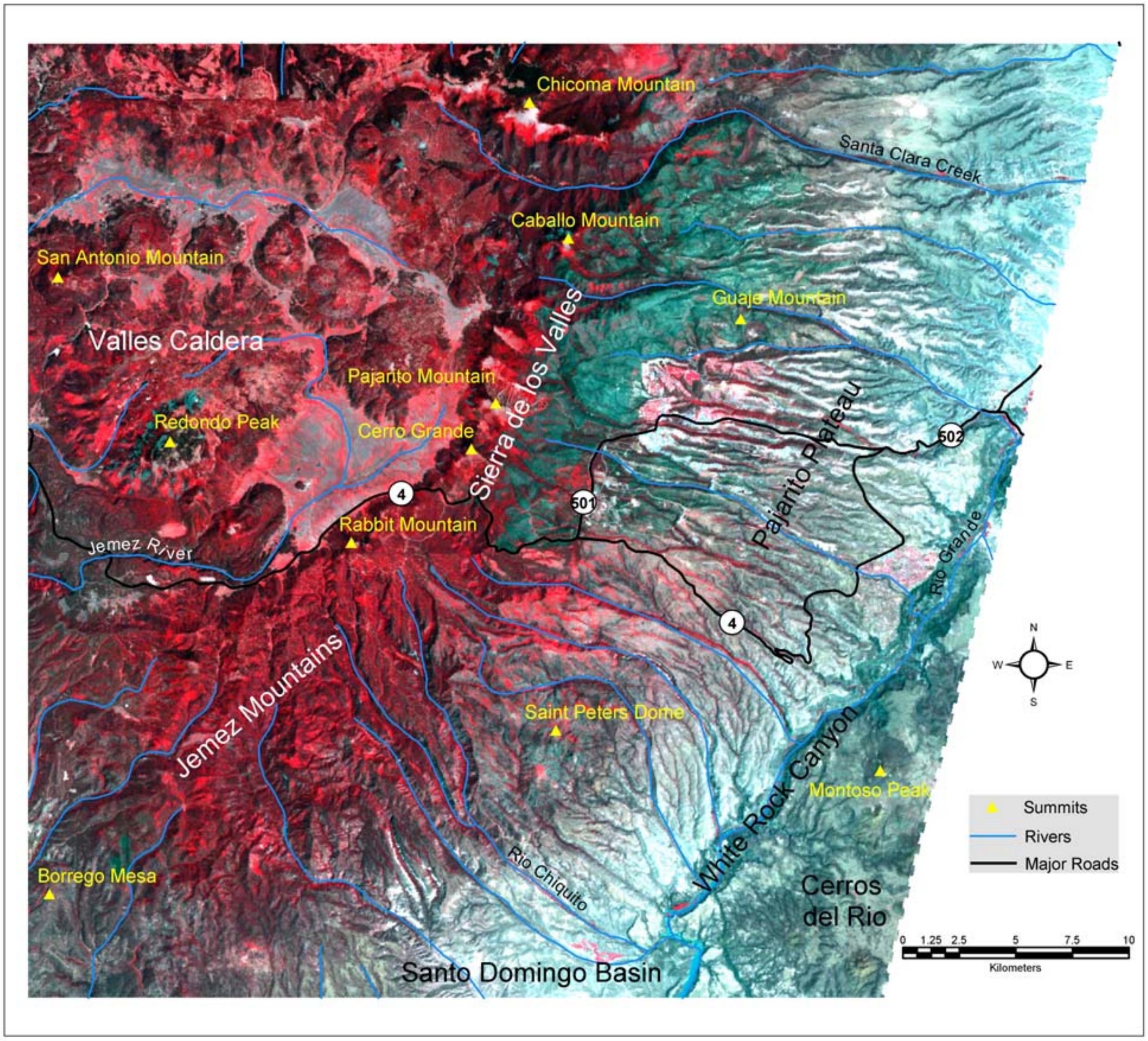

Figure 2. Physiographic zones, summits, rivers, and major roads within the Landsat ETM$^+$ scene.

slopes from Montoso Peak to the eastern edge of White Rock Canyon, at approximately 1890 m (6200 ft). The plateaus and flats are vegetated by big sagebrush (*Artemisia tridentata)* and galleta (*Pleuraphis jamesii*). The rocky hills are vegetated with open canopies of piñon (*Pinus edulis)* over grasses, such as black and side oats grama (*Bouteloua eriopoda* and *B. curtipendula)*.

The Cerros del Rio separates the Española Basin (not shown in Figure 2) to the north and the Santa Domingo Basin to the south (see Figure 2). The Santa Domingo Basin contains the lowest elevations in the study area. It is bounded by the La Bajada Fault and the Cerros del Rio on the east, by the Santa Ana fault and the Jemez Mountains on the west, and by the Pajarito Plateau on the north (Smith et al. 2001). Both of these basins are vegetated by shrublands, grasslands, juniper (*Juniperus monosperma*) savannas, and piñon (*Pinus edulis*)-juniper woodlands.

White Rock Canyon is also found between these two basins and to the northwest of the Cerros del Rio (Kelson et al. 1996, Reneau and Dethier 1996). This canyon is marked by rugged terrain and by large amounts of sparse vegetation and bare rock. The elevations within White Rock Canyon range from approximately 1631 m (5350 ft) to 1890 m (6200 ft). The Rio Grande traverses both of these basins and cuts through White Rock Canyon. The major vegetation types include piñon-juniper woodlands, juniper grassland communities, grasslands, and shrublands, such as big sagebrush. Willows (*Salix* spp.) and cottonwoods (*Populus* spp.) predominate along the Rio Grande and in riparian zones.

The Jemez Mountains are more difficult to define, both as a unit and as subunits that can be recognized as physiographic regions. From a review of the literature and after consultations with Steven Reneau, we chose to subdivide the Jemez Mountains into five physiognomic provinces: the Pajarito Plateau, the Sierra de los Valles, the Valles Caldera, the Jemez Mountains proper, and the Jemez Plateau (not shown in Figure 2).

The Pajarito Plateau, ranging from the top elevation of White Rock Canyon westward to approximately 2400 m (7800 ft) consists of a series of finger-like mesas separated by canyons that extend from the higher mountains eastward and southward toward the Rio Grande (Koch et al. 1997). Much of the plateau was formed by deposition of more than 600 km^3 (144 mi^3) of rhyolitic pyroclastic material during the eruptions of the former volcano (Smith 1979, Rogers et al. 1996). This was followed by erosion of these deposits into mesas and canyons. Minor peaks, such as Guaje Mountain and Saint Peters Dome, rise above the plateau (see Figure 2). At lower elevations on the mesas, the vegetation is comprised of piñon-juniper woodlands mixed with sparse ponderosa pine (*Pinus ponderosa*) and a variety of shrub species, such as wavy-leaf oak (*Quercus undulata*). At higher elevations on the mesas, ponderosa pine becomes more dense and grows with Gambel oak (*Quercus gambelii*). Canyons with deeper, narrower characteristics and at higher elevations can contain various riparian species such as willows and cottonwoods. They can also support dense stands of ponderosa pine and mixed conifer forests. The wider, shallower canyons and canyons at lower elevations typically contain sparse stands of ponderosa pine mixed with piñon-juniper woodlands, shrublands, and open piñon-juniper savannas. The Pajarito Plateau contains all of the major developed sites in the study area, including LANL, the Los Alamos town site, and the White Rock town site. The Cerro Grande Fire burned significant portions of the northern Pajarito Plateau.

Above 2400 m (7800 ft) the Sierra de los Valles rises above the Pajarito Plateau. This province roughly begins to the north of State Highway 4 and continues to the northern boundary of the study area. Primarily, this province is derived from the eastern rim of the caldera. From south to north, the highest mountain peaks in this region include the Cerro Grande at 3108.7 m (10,199 ft), Pajarito Mountain at 3182.4 m (10,441 ft), Caballo Mountain at 3504.0 m (10,496 ft), and Chicoma Mountain at 3523.8 m (11,561 ft). The area drains to the east and to the south, initiating canyons in the Pajarito Plateau. The predominant vegetation in the area includes forests of ponderosa pine, mixed conifer, spruce (*Picea* *engelmannii*)-fir (*Abies lasiocarpa*), and aspen (*Populus tremuloides*) communities. The Cerro Grande Fire burned over much of the southern and eastern portions of the Sierra de los Valles.

To the west of the Sierra de los Valles, the Valles Caldera forms one of the prominent regions of the Jemez Mountains (see Figure 2). This province also includes the Toledo Embayment on its northeastern boundaries (Gardner and Goff 1996, Nowell 1996). The bottom of the caldera was covered by a lake soon after its formation, but is now covered by a variety of grasslands. The resurgent domes form a ring of peaks within the caldera. Redondo Peak, in the west-central portion of the study area, is the highest of these resurgent domes at 3430.2 m (11,254 ft). Other peaks within the caldera include Santo Domingo Mountain at 3044.0 m (9987 ft), Cerros del Abrigo at 3149.2 m (10,332 ft), and Cerros del Medio at 3011.7 m (9881 ft). These peaks are vegetated by ponderosa pine forests, mixed conifer forests, aspen forests, and spruce-fir forests. The bottoms of the caldera can be separated into several grasslands: the Valle Grande in the southeast, the Valle in the southwest, and, from west to east, the Valle San Antonio and the Valle Toledo in the northern portions of the Caldera. The elevations of these grasslands range from approximately 2591 m (8500 ft) in the Valle Grande to 2743 m (9000 ft) in the Valle Toledo. The basins of the caldera also form the two major drainages of the Valles Caldera: the Jemez River to the southwest and the San Antonio Creek to the northwest. The lowest elevations in the Valles Caldera at approximately 2499 m (8200 ft) are found in the southwest area, known as the Banco Bonito region, where the Jemez River passes to the west.

Although the entire mountain range that consists of all the remnants of the ancient volcano is known as the Jemez Mountains, the section of this mountain range to the south of the Valles Caldera is also known as the Jemez Mountains physiognomic province (see Figure 2). This province slopes from higher elevations to the north toward the Santo Domingo Basin to the southeast and to the Albuquerque Basin to the south. To the east, the Jemez Mountains Province is bordered by the Pajarito Plateau. The highest peaks in the north include Rabbit Mountain at 3029.1 m (9938 ft), Cerro los Griegos at 3083.1 m (10,115 ft), and Cerro Pelado at 3082.4 m (10,113 ft). The highest elevations in the southern portions of this province are found at Borrego Mesa, which is 2417.1 m (7930 ft), and at Bear Springs Peak, which is 2497.8 m (8195 ft). The lowest points within this province can be found at the southern border of the study region where the Jemez Mountains merge into the Albuquerque Basin at approximately 2103 m (6900 ft) in Borrego and La Jara Canyons. The dominant vegetation of this province consists of a wide range of plant communities ranging from piñon-juniper woodlands to spruce-fir forests.

Although the northern rim of the Valles Caldera is also part of the Jemez Mountains, it is not typically given a designated province range (see Figure 2). This region is at high elevations, throughout the study region, and is similar in many regards to the southern rim of the Valles Caldera, within the Jemez Mountains Province, and to the Sierra de los Valles. The highest peaks in the northern rim of the Valles Caldera that are within or near the study area include Cerro Pelon at 3002.6 m (9851 ft), Cerro Pavo at 3142.5 m (10,310 ft), and Cerro del Grant at 3179.7 m (10,432 ft).

Small segments of the Jemez Plateau appear in the study area. Although not specifically designated in Figure 2, this province is in the extreme northwest portion of the study area and in the west-central portion at the Jemez River and adjacent to the Banco Bonito. This province is vegetated by ponderosa pine and mixed conifer forests.

METHODS

The project began in March 2002, with a draft land cover classification. The draft classification was based on previous classification work that had been completed for the study area and on previously existing field data. These data were augmented by training data collected in the field from April to August. This led to updates and refinements that resulted in the final land cover classification scheme and in the development of the draft land cover map. Independent accuracy assessment data were collected from August to October. Several types of data collection methods were used including the use of existing data from previous projects conducted by RRES-ECO.

Training site data collection and processing, accuracy assessment, and analysis were conducted by RRES-ECO of LANL. Image processing and analysis were conducted by EDAC. A supervised classification method was chosen to perform the classification. The acquisition of homogeneous training sites to generate unique spectral signatures in order to determine to which landscape type each pixel in the image is most likely to belong is known as a supervised classification (Wilkie and Finn 1996). Supervised training is appropriate when there are relatively few classes of interest, when verifiable training sites are available, or when distinct, homogeneous regions that represent each class are identifiable (ERDAS 1999). Lillesand and Keifer (2000) and Foody (2000) describe the process of developing a supervised classification having three main steps: the training stage, the classification or allocation stage, and the output or testing stage. For the training stage, training sites were collected for each of the land cover classes developed. Existing data, screen digitized points from photo-interpretation, point data collected in the field, and field-verified photo-interpreted polygons were all methods used to collect training site data. For the classification stage, the combined data were given to EDAC for image analysis and classification. These two stages were iterative between EDAC and RRES-ECO in order to develop a final classification and aide in the collection of more training site data. For the output or testing stage, land cover maps were produced, area tables were generated, and an independent accuracy assessment was conducted.

Coordinate Systems

The LANL standard for the horizontal spatial reference system, which is primarily intended for the collection and display of geospatial data, remote sensing data, and data from field surveys at the LANL site, is the New Mexico State Plane Coordinate System (Transverse Mercator), Central Zone, North American Datum 1983, US survey foot. All data used in the classification process were projected into this system. For data not in this system, the original coordinate system and the projection process are described where appropriate.

Software and Hardware Used

For the image processing and analysis, EDAC principally used ERDAS Imagine 8.5 throughout the mapping process. All digital imagery and geographic information system (GIS) coverages were processed, manipulated, and used as overlays for analysis within the Imagine environment. The ERDAS Imagine software was loaded on a PC using the Windows NT operating system. EDAC also used Arc/Info 8.0 and ArcView 3.1 to create, import, and manipulate vector coverages.

For the training site data collection and processing, LANL used a laptop running Windows 2000, with ArcView 3.2a and the Xtools (DeLaune 2001) and Spatial Analyst extensions, and ArcGIS 8.2. All field position coordinates were collected using a Trimble Geoexplorer 3 global positioning system (GPS) receiver. All data from the GPS receiver were differentially corrected using GPS Pathfinder Office 2.90 at the RRES-ECO base station. Accuracy assessment and analysis were completed on a desktop PC running Windows 2000 using ERDAS Imagine 8.5.

Draft Land Cover Classes

Before the classification of the ETM^+ image could begin, we first needed to develop a classification scheme (see Glossary), or a set of target classes. The purpose of a classification scheme or system is to provide a framework for organizing and categorizing the information that can be extracted from the data (Jensen 1983). The proper classification scheme includes classes that are both important to the study and discernible from the available data (ERDAS 1999). ERDAS also recommends that the classes are initially defined using previously developed schemes.

The land cover classes used in the development of this land cover map were compiled in draft form in March 2002. To develop this classification, classes were initially adopted from Balice et al. (1997) and Balice (1998). New information that had been gathered during field sampling conducted from 1999 through 2002 was incorporated into the existing classification and new classes were added, as supported by the field data. Since the majority of the data used to develop this classification system were gathered in the Los Alamos region, the validity of these classes will decline with increasing distance from the core area.

In addition to modifications and additions to the existing classification scheme, the class names and the structure of the classification were also edited to conform with the National Vegetation Classification Standard (NVCS) (Grossman et al. 1994, 1998, FGDC Vegetation Subcommittee 1997). As part of this process, naming systems employed during previous classifications of the Jemez Mountains regions (e.g., DeVelice et al. 1986, Larson et al. 1995) were also accommodated, where possible. The goal of the draft classification was to attain the association level of the national system. However, it was not always possible to achieve this level of detail because of variations in the study region, because of limited knowledge of individual community types, and because of the limited number of communities from which to obtain sample data. As a result, many of the class names are consistent with the alliance and formation levels of the NVCS. For further information concerning the development of the draft land cover classification, see Appendix A.

Training Site Data

Training site data were compiled from April to August 2002. Point data were first assembled from previously collected field data. Specific sites were chosen based on whether or not the data were sufficient to classify the site into one of the existing land cover classes. All existing data were adopted from two multi-year studies conducted by Balice et al. (1999, 2000).

Color digital orthophotos were used to augment field data in inaccessible areas. The orthophotos were collected on June 13 and 14, 2000, by LANL (Carey and Cole 2001). The orthophotos had a 2 ft pixel resolution and were each 3000 (E-W) by 2000 (N-S) pixels in size. The orthophotos only covered the portion of the land cover map extent immediately surrounding the Laboratory boundary. For this reason all screen digitized points were limited to the area immediately surrounding LANL.

Additional field data were collected from late April to August 2002. Point data were collected in areas that were not easily accessible by road. Sites were chosen based on size and homogeneity. Sites had to be 90 by 90 m or larger. Each site had to be within a uniform, homogeneous stand, and be consistent with the characteristics of one of the land cover classes. Each location was given a specific plot number. In addition, general directions to the site were recorded, and its coordinates were stored in a GPS unit. For each site, basic species data and site-specific ecological data were taken. Species data included a list of the dominant species within three main strata, trees, shrubs, and graminoids/forbs. The overall percent canopy cover was also ocularly estimated for each stratum. Site-specific ecological data included the overall slope and aspect of the site.

Site data in the form of field-verified screen digitized polygons were collected in areas that were accessible by roads. For areas within and directly adjacent to LANL, the color orthophotos were used (Carey and Cole 2001). For areas outside of this, specifically the Valles Caldera National Preserve and the southwest portion of the study area, digital orthophotoquads (DOQs) were obtained (Earth Data Analysis Center 2001). The DOQs were created by the US Geological Survey and were black and white air photos with a 1 m spatial resolution, acquired over the area in 1996, and in the UTM NAD83 coordinate system. Polygons collected using these DOQs were reprojected into State Plane NAD83 using ArcTools. Finally, the DOQs and the orthophotos were stored on a laptop computer for access in the field.

At each selected location in the field, the site was located on the DOQ or orthophoto using a GPS. The area on the orthophoto was then compared with observations on the ground, including the species composition and cover class, and a polygon closely matching the boundary of the homogeneous site was digitized using ArcView. Each polygon was given a unique plot number and added to a shapefile containing all previous polygons obtained. Specific notes were taken at each site regarding the specific class, species composition, and cover, similarly to the data recorded on the field form for the point data.

Not all areas of the entire study region were represented by training site data. Some areas, such as Bandelier National Monument, were inaccessible due to time and budgetary constraints. In addition, Pueblo lands were less densely sampled because of access restrictions. Many areas also had limited access either because of current fire danger or restrictions due to recovery from recent fire events. The south-central and southwest portions of the National Forest Service lands were mostly inaccessible due to fire restrictions and lack of open roads. Similarly, the northern portions of the National Forest Service lands were not accessed due to time and budgetary constraints, as no easily accessible route from Los Alamos exists.

Two shapefiles were produced and submitted to EDAC for the supervised classification process, one file containing point data and one containing polygons. The sites in each file also contained the appropriate class name and number.

Image Processing and Analysis

Landsat ETM$^+$ satellite imagery was used to map the natural vegetation for the study area. The scene was acquired over the area on June 4, 2001, by the Landsat 7 platform. It was imported into ERDAS Imagine where all raster processing and analyses were accomplished. The ETM$^+$ scene was of good quality with no clouds, or scan line defects. A near infrared color composite of this scene is used in Figures 2, 3, and 6.

The quantitative spectral and spatial aspects of ETM$^+$ imagery add particularly important dimensions to the mapping process. Multi-spectral satellite imagery records the variable reflection of natural radiation of surface materials such as rocks, plants, soils, and water, differently. Variations in plant reflection and absorption due to biochemical composition will register distinct spectral “signatures.” These signatures provide a quantitative measure of reflectance at specific wavelengths, which can then be statistically analyzed to develop a land cover map of spectrally similar classes of polygons.

Landsat ETM$^+$, with six spectral bands, one thermal band, and one panchromatic band, has the highest spectral discrimination among commercially available, non-research, space-based sensors (USGS 2003). Each band represents a specific range of wavelengths from the electromagnetic spectrum (Table 1). The six spectral bands cover discrete bandwidths from the visible blue to the mid-infrared and record the response at an approximately 98 ft (30 m) spatial resolution. For vegetation mapping, bands 2, 3, 4, and 5 are particularly useful. ETM$^+$ bands 3, 5, and 7 are useful for detecting variations in surface geology. Surface geology and soil discrimination are important in developing mapping units of the vegetation communities in sparsely vegetated areas that occur within the study area. ETM$^+$ band 6 records in the thermal wavelengths, which directly measures surface temperature and indirectly the moisture content; this can be important for discriminating between different plant and soil types, but its spatial resolution of 197 ft (60 m) was considered too coarse for mapping the detail found in this terrain. ETM$^+$ band 8 records the overall brightness in the visible and near-infrared wavelengths, but it has the best spatial resolution of all of the bands at approximately 50 ft (15 m) and therefore is considered useful. From this evaluation, we adopted and used bands 1, 2, 3, 4, 5, 7, and 8 to conduct the image classifications for this project.

Table 1. Landsat ETM^+ bands, their spectral ranges, and spectral locations (USGS 2003).

Band	Spatial Resolution	Wavelength (microns)	Spectral Location
1	98 ft (30 m)	0.45 to 0.52	Visible blue
2	98 ft (30 m)	0.52 to 0.60	Visible green
3	98 ft (30 m)	0.63 to 0.69	Visible red
4	98 ft (30 m)	0.76 to 0.90	Near-infrared
5	98 ft (30 m)	1.55 to 1.75	Mid-infrared
6	197 ft (60 m)	10.4 to 12.5	Thermal infrared
7	98 ft (30 m)	2.08 to 2.35	Mid-infrared
8	50 ft (15 m)	0.52 to 0.90	Visible, Near-infrared

Ancillary Data

In addition to the above data sources, several other data sets were created to aid in map development. These included coverages for roads and built-up areas. The road and built-up area coverages were created from the US Geological Survey DOQs. The National Elevation Dataset (NED) Digital Elevation Model (DEM) with a spatial resolution of 98 ft (30 m) was also clipped to the area and used for this study. Both of these coverages were obtained from the RGIS website (Earth Data Analysis Center 2001).

Geometric and Terrain Correction

The ETM^+ scene was rectified to a map-based coordinate system using a nearest-neighbor interpolation. This process makes the image planimetric so that area, direction, and distance measurements can be performed. The image-to-map rectification process involves selecting a point on the map with its coordinate and the same point on the image with its x and y coordinates. The DOQs were used as the map reference, and the terrain distortion was modeled using the NED DEMs. The root mean square error (RMS_{error}) is computed to determine how well the map and image coordinates fit in a least-squares regression equation. The images were projected into the State Plane Coordinate System, New Mexico Central Zone, using the 1983 North American Datum and the 1980 Geodetic Reference Spheroid.

Normalized Difference Vegetation Index

A Normalized Difference Vegetation Index (NDVI) was created from selected ETM^+ bands (Table 1), according to the following relationship.

$$NDVI = \frac{ETM^+ Band4 - ETM^+ Band3}{ETM^+ Band4 + ETM^+ Band3}$$

where

$ETM^+ Band4$ = spectral reflectance value (0 to 255) for the near-infrared ETM^+ band, and
$ETM^+ Band3$ = spectral reflectance value (0 to 255) for the visible red ETM^+ band.

The resulting NDVI image was then combined with the other image bands to be used in the classification.

The NDVI enhances the spectral response of vigorous vegetation over the response from other major surface features. This was used to help emphasize vegetation response patterns in the classification. The NDVI also allows for a quick assessment of class signatures. For example, the forested areas should have a higher NDVI response than the senescent grasslands.

Variance Filter

The amount of change of response from one cell to another cell is an important spatial component that is provided by the ETM^+ band 8, given its higher spatial resolution. The variance in the photo was modeled in the panchromatic band for every 3 by 3, 5 by 5, and 7 by 7 cell window in the image according to the following:

$$V = \frac{\sum_{i=1}^{n}(DN_i - \mu)^2}{n-1}$$

where

V = the variance for a particular pixel and window combination,

DN_i = the spectral reflectance value or digital number (0 to 255) for pixel i,

μ = the mean DN for the 3 by 3, 5 by 5, and 7 by 7 windows, and

n = the number of pixels in the respective 3 by 3, 5 by 5, and 7 by 7 windows.

This resulted in three variance estimates for each pixel, which were then averaged. The process was then repeated for the next pixel. The resulting variance-filter image was then combined with the other ETM^+ data for the classification.

As a result of this analysis of the selected ETM^+ scene, nine sets of data were available for classifying the image. These include bands 1, 2, 3, 4, 5, 7, and 8 from the original ETM^+ scene, the NDVI data layer, and the variance filter that were derived from the original data.

Image Classification

Seeding

The image classification procedure synthesizes the nine satellite-image data layers with the field plot data. In our case, we adopted a supervised classification strategy to create the land cover map from information contained in the training data. In essence, this strategy identifies spectral classes based on ground locations with known characteristics such as vegetation composition and landscape context.

In our supervised classification strategy, the field data are applied to the image data through an interactive process called "seeding" (ERDAS 1999). In the seeding process, the image pixel corresponding to one of the field plot or polygon locations was selected and its spectral characteristics were used to gather other similar contiguous pixels to create a statistical model or "seed" of the field plot. The seeding algorithm examines the pixels surrounding that point that are within user-defined limits. These limits might be defined in terms of 1) distance from the original pixel to the candidate pixel, 2) the area around the original pixel, and 3) the spectral distance from the original pixel to a candidate pixel. In our case, the spatial distance was not considered. The default for the areal extent was 5 ha (12.4 ac). Cover types that occur as more linear features were set to 1 ha (2.5 ac). The minimum area used in this project was 3 pixels by 3 pixels. The minimum value for the spectral distance was initially set to be equal to the number of bands used for classification, nine. As heterogeneity increased, this number was doubled to 18. The upper limit for the spectral distance typically ranged from 10 to 20. However, for heterogeneous cover classes, such as bare ground, the spectral distance often ranged from 100 to 200. Using these limits, pixels that are contiguous to the selected plot pixel were examined sequentially and combined with the field plot pixel to form a new group, or "seed," or they were rejected. This process continued in an outward expanding search of contiguous pixels until no additional pixels satisfied the predefined criteria.

The calculation of the spectral distance is based on the equation for Euclidean distance, as follows:

$$SD_c = \sqrt{\sum_{i=1}^{n} (\mu_{ci} - X_i)^2}$$

where

SD_c = the spectral distance between a new pixel and the mean of the current seed group that is based on the field plot (*c*),

μ_{ci} = the mean of the current seed group of pixels for an image band (*i*) and for the selected field plot (*c*),

X_i = the spectral value of the new pixel for a certain band (*i*), and

n = the number of image bands in the analysis (9).

The spectral distance algorithm was used, in an iterative process, to construct the best seed model for the selected field plot. At the completion of each iteration, a signature file was created that contained the field plot or polygon number, mean values for each image band for the particular seed group, the covariance matrix, number of pixels that were used to create the seed, and the minimum and maximum spectral distance values that resulted during the analysis of the set of contiguous pixels. The spatial arrangement of the pixels in the candidate seed group was compared against the original field point or polygon on the corresponding DOQ. In addition, the covariance matrix was tested to determine if it could be inverted. Inversion of the covariance matrix is a requirement of the multivariate classification algorithm used in this study. From this evaluation, the seed group of pixels was either accepted or it was rejected and a new analysis was initiated after the user-defined limits for the field plot or polygon had been appropriately adjusted.

The seeding algorithm was applied to each of the field plot or polygon locations. This resulted in a final signature file of seed statistics for each field plot or polygon.

Supervised Classification

Statistics gathered in the seeding process were used to perform a supervised classification (ERDAS 1999). Our supervised classification strategy was based on a maximum likelihood decision rule that contains a Bayesian classifier. This technique assumes the statistical signatures within each seed group have a normal distribution. Since the prior probabilities in this study are unknown, they were set to one, and the maximum likelihood equation for each candidate pixel and for each field plot or polygon seed group (*c*) simplifies to

$$D = -\left[0.5\ln\left(\left|Cov_c\right|\right)\right] - \left[\left(X - M_c\right)' Cov_c^{-1}\left(X - M_c\right)\right]$$

where

D = the weighted distance or likelihood,
X = the measurement vector of spectral reflectance values (0 to 255) for the candidate pixel,
M_c = the mean vector of spectral reflectance values (0 to 255) for the seed group derived from field plot or polygon *c*, and
Cov_c = the covariance matrix of pixels in the seed group for field plot or polygon *c*.

For each pixel, the maximum likelihood classifier is applied to each of the seed groups and the pixel is assigned to the seed group with the lowest weighted distance. This process is repeated for each pixel in the scene.

This maximum likelihood decision rule is considered the most accurate because it not only uses a spectral distance as the minimum distance decision rule, but it also takes into account the variance of each of the signatures (ERDAS 1999). The variance is important when comparing a pixel to signatures with variable homogeneity. For example, a juniper grassland community might be fairly heterogeneous compared to a water class, which is more homogeneous.

Several preliminary land cover maps were derived by EDAC and reviewed by RRES-ECO while training site data collection was in progress. This was an iterative process done in order to refine the classification based on informal accuracy reviews of the preliminary maps and to tune our training site collection to classes and areas that were under-represented.

No attempt was made to classify buildings, pavement, concrete, or lawns due to the heterogeneity of reflecting surfaces. Roads were digitized from the DOQs and buffered for their appropriate width. Similarly, built-up areas were digitized into polygons from the DOQs. The road buffer polygons and built-up areas polygons were then used to create the map units for urban—barren and urban—vegetated classes based on whether the underlying map units represented vegetated or barren categories.

To locate problems, informal accuracy checking was used based on field data, air photos, personal knowledge of a site, and ancillary information. If a distribution problem with a seed was detected during the seeding process, the seed was rechecked on the ground to ensure it was properly modeling the land cover type and the landscape.

Each preliminary land cover map was based on the seeding algorithm, which developed a group of seed pixels for each of the input field plots and polygons. As a result, these preliminary maps contained as many classes as the number of field points and polygons that were used to develop them. The final map was created by aggregating the collection of polygons for each field-plot class into their respective land cover classes.

Final Land Cover Classes

The draft land cover classification and the data collected in the field were also used to guide the initial supervised classifications of the ETM^+ image and to direct the fieldwork for obtaining training data and accuracy assessment data. These evaluations were performed iteratively between the land cover classification and the image classification through consultations between RRES-ECO and EDAC. As a result of this process, a final set of land cover classes was produced. In the final classification certain classes were deleted as they were found to be impractical for mapping purposes and other previously unanticipated classes were added as they were found to exist within the study area.

In a manner similar to the development of the draft land cover classification, the goal of developing the final set of land cover classes was to attain the association level of the NVCS (Grossman et al. 1994, 1998, FGDC Vegetation Subcommittee 1997). However, because of variations within the study region, the limited time available for gathering field data, and the limitations of the remote sensing technology, this goal was not always achievable. As a result, many of the land cover classes are consistent with the alliance level or the formation level of the national system. Further details of the development of the land cover classification scheme are provided in Appendix A.

Smoothing of the Classified Image

The final output from the image classification process was a georeferenced data layer where each pixel was classified with one of the final land cover classes. The pixel resolution of this data layer was 15 m by 15 m (225 sq m, 0.0225 ha, 0.0556 ac). Throughout the remainder of this report, the final data layer produced by the image classification process will be referred to as the 15-m map. Reviews of this map indicated that it contained “speckle,” or pixels that were classified anomalously or were assigned classes that appear to be in isolation from the geographic region where these classes would be expected to occur. Maps with speckle may be less suitable for production of user-defined mapping products, for modeling purposes, and for accommodating the needs of wildlife management. As a result, it was decided to smooth the original 15-m map to versions with larger map units, evaluate their comparative accuracies, and retain the smoothed versions of the 15-m data layer that were deemed to be useful for mapping and modeling.

Image smoothing is a process that compares isolated pixel classes with the classes of surrounding pixels and reassigns the isolated pixel to the dominant class of the surrounding pixels (Lillesand and Kiefer 2000). This process is continued until the sizes of all the identically classified pixel groups are at least as large as the specified minimum map unit. For the purposes of this project, we smoothed the original 15-m map to map units of 0.25 ha (2500 sq m, 0.618 ac), 0.5 ha (5000 sq m, 1.236 ac), 1.0 ha (10,000 sq m, 2.471), and 2.0 ha (20,000 sq m, 4.942 ac) in size. These smoothed versions of the original map consist of polygons each containing a minimum of 12 pixels, 23 pixels, 45 pixels, and 89 pixels, respectively. Throughout the remainder of this report, these smoothed map products will be respectively referred to as the quarter-hectare map, the half-hectare map, the one-hectare map, and the two-hectare map.

In order to determine which smoothed land cover map had the highest relative accuracy and best fit the objectives of the project, a comparative accuracy assessment between all versions of the map and the original training site data was conducted. Although this is a good method to compare accuracies of complementary data sets it cannot be used as an absolute measure of accuracy because it creates biases in the results since the training sites are the basis of the comparative accuracy analysis, as well as the classification (ERDAS 1999). Based on this comparative accuracy assessment, only the land cover maps that had the highest levels of accuracy, and that maintained the detail desired for the objectives of this project, were selected for further analyses and formal accuracy assessments.

Reclassification of the Images

The original 15-m map and each of the retained smoothed images had a large number of classes, as defined by the final land cover classification scheme (see Appendix A for details). The accuracy and usefulness of maps with large numbers of classes may suffer, and this can be partly resolved by revising the classification scheme to one that contains fewer numbers of classes (Wilkie and Finn 1996). A classification scheme with fewer numbers of classes would also allow for more direct comparisons and analyses using the land cover map previously developed by RRES-ECO (Koch et al. 1997).

To accomplish these goals, we aggregated individual classes from the original classification scheme by merging similar classes into more generalized classes. As a result, the association level classification scheme was redefined at the physiognomic level, the taxonomic level, and the class level, respectively. Physiognomic classes are determined by the overall structure of the vegetation. The taxonomic level was defined by dominant plant species or groups of species. The class level was adopted from the NVCS (Grossman et al. 1994, FGDC Vegetation Subcommittee 1997). The class level is also consistent with a land cover classification system that had been developed for remote sensing applications (Anderson et al. 1976). In each of these cases, the pixels of the 15-m map and smoothed maps were reassigned with classes, as defined by the reduced classification schemes. The results were saved as separate output files.

Accuracy Assessment

The original 15-m map, the smoothed maps, and the reclassified maps were subjected to independent accuracy assessments. To be a valid measure of accuracy, the accuracy reference samples should be selected independently of data used for training or for developing the classification (Stehman 1997). The widely accepted standard for an accuracy assessment is the establishment of a minimum of 30 accuracy sites per cover class, with 50 sites being the preferred guideline (Congalton 1991, 2001; Congalton and Green 1999). However, budgets, accessibility, and other practical constraints often render these sampling criteria to be unobtainable (Foody 2002). These constraints were applicable to this project. As a result, we established 10 accuracy assessment sites per class as the desired goals.

Sampling in the field at the accuracy assessment sites was conducted from August to October 2002. Data collection techniques for these sites were similar to the training site collection. In the office, the accuracy assessment data were also manipulated in a manner similar to the training data. The accuracy assessment data were then imported into ERDAS Imagine. A window of 3 by 3 pixels was defined at each accuracy assessment site and a simple majority rule was used to determine the land cover classes of the windows. The classification results and the accuracy assessment results were then compared, and the results of these analyses were used to construct an error matrix. These matrices were then summarized into accuracy totals reports. Accuracy totals reports calculate the statistics of the percentages of accuracy, based on the results of the error matrices using two measures of the proportion correct (ERDAS 1999). These are the user's accuracy or commission error, and the producer's accuracy or omission error.

Estimates of Areal Coverage

Estimates of the areas occupied by each of the land cover classes on the classified images were calculated. This was done for the 15-m map, each of the retained smoothed images, and the physiognomic, taxonomic, and class versions of these maps. ERDAS Imagine was used to calculate the hectares, acres, square miles, and square kilometers, and the percentages of the total area for each land cover class on each map. In addition to areal estimates for the entire study region (map), estimates were also calculated for the lands within the LANL boundaries.

RESULTS

Draft Land Cover Classes

Reviews of previous land cover classifications and existing data resulted in the development of 34 draft land cover classes for the Los Alamos region (Table 2). Previously collected field data representing a total of 127 quantitatively sampled plots were used as part of this process. Thirteen of these classes were first recognized or documented as part of this study. The following four classes, directly related to the Cerro Grande Fire, did not exist before 2000.

Cerro Grande Fire, High-burn severity, Seeded grassland
Cerro Grande Fire, High-burn severity, Bare ground
Cerro Grande Fire, High-burn severity, Straw mulch
Populus tremuloides <3 m tall

Table 2. Draft classification.

Draft classification
Pinus ponderosa/Native Species Forest
Pinus ponderosa/Seeded grass species Forest
Abies concolor-Pseudotsuga menziesii Forest
Abies lasiocarpa-Picea engelmannii Forest
Populus tremuloides Forest
Mixed *Populus tremuloides*-Evergreen Forest
Pinus edulis/Bare ground Woodland
Pinus edulis/Bare rock Woodland
Pinus edulis/Artemisia tridentata Woodland
Pinus edulis/Bouteloua gracilis Woodland
Pinus ponderosa/Bouteloua gracilis-Schizachyrium scoparium Woodland
Pinus ponderosa/Quercus gambelii Woodland
Pinus ponderosa/Poa pratensis-Seeded grass Woodland
Pinus ponderosa-Pinus edulis Woodland
Abies concolor-Pseudotsuga menziesii Woodland
Temperate Cold-Deciduous Shrubland
Populus tremuloides <3 m tall
Quercus gambelii Shrubland
Robinia neomexicana Shrubland
Montane Grassland
Submontane Grassland
Valle Grande Grassland
Cerro Grande Fire, High-burn severity, Seeded Grassland
Pinus ponderosa-Pinus edulis-Juniperus monosperma/Grassland
Pinus edulis-Juniperus monosperma/Grassland
Juniperus monosperma/Grassland
Rock, cliff, pavement, bare ground with <10% vegetation cover
Cerro Grande Fire, High-burn severity, Bare ground
Cerro Grande Fire, High-burn severity, Straw mulch
River
Lake or Reservoir
Urban, paved and buildings or Non-urban, paved road
Urban, vegetated
Riparian

The *Pinus ponderosa/Poa pratensis*-Seeded grass Woodland class had also not been recognized for two reasons. First, the *Pinus ponderosa*/*Poa pratensis* association had not been sampled until 1999. Second, the seeded grass complement of this association was also a new addition that was associated with the Cerro Grande Fire. Also, detailed variants of the *Pinus edulis*/*Juniperus monosperma* Woodlands had been previously recognized by regional scientists, but had not been formally documented before this study. These include

Pinus edulis/Bare ground Woodland
Pinus edulis/Bare rock Woodland
Pinus edulis/Artemisia tridentata Woodland

Several new classes were created to accommodate the NVCS distinction between forests (overstory canopy cover greater than 60 percent) and woodlands (overstory canopy cover less than 60 percent). For instance, several woodland categories were recently created as a result of moderate- or low-severity burning during the Cerro Grande Fire or as a result of wildfire hazard reduction thinning operations. These include

Pinus ponderosa/Quercus gambelii Woodland
Abies concolor-Pseudotsuga menziesii Woodland

Several other classes were created for this study or were adopted from previous research to accommodate the NVCS criterion for including mixture classes where several species share dominance in the overstory, but where none of these species are present in greater than 75 percent of the total overstory canopy cover. These include

Mixed *Populus tremuloides*-Evergreen Forest
Pinus ponderosa-Pinus edulis Woodland
Pinus ponderosa-Pinus edulis-Juniperus monosperma/Grassland

The Temperate Cold-Deciduous Shrubland was also created for this study to include a collection of plant communities that are dominated by a variety of shrubland species.

Although not new classes to the Los Alamos region, several other classes were created for this project by subdividing classes that had been previously identified by Koch et al. (1997). For instance, the former Developed (Urban) class was subdivided into Urban, paved and Urban, vegetated classes for purposes of the current work. Also, the previous grassland class in Koch et al. (1997) was subdivided into Montane Grassland, Submontane Grassland, and Valles Caldera Grassland. Finally, Koch et al. (1997) did not include any classes for shrublands. As a consequence, the shrubland classes are new to RRES-ECO mapping projects.

Final Land Cover Classes

Additional data collected in the field and reviews of the preliminary classifications of the ETM^+ image were used to guide revisions and updates to the draft land cover map. This resulted in 30 classes that were used throughout the rest of this project (Table 3).

To arrive at these 30 final classes, several classes were deleted from the draft classification scheme, others were combined, and one new class was added. Four classes were removed from the list of draft land cover classes because they presented difficulties during the image classification process or were not found in the study region in sufficiently large homogeneous areas to justify their retention. These include

Pinus ponderosa/Seeded grass species Forest
Pinus ponderosa-Pinus edulis Woodland
Pinus ponderosa-Pinus edulis-Juniperus monosperma/Grassland
Cerro Grande Fire, High-burn severity, Straw mulch

In addition, the River and Lake/Reservoir classes from the draft land cover classes were combined into a final class called Open Water because of their similar spectral response. Finally, the *Pinus edulis* Forest class was added to the scheme after several sites were located that supported *Pinus edulis* communities with greater than 60 percent overstory cover.

Several of the classes in the draft classification scheme were also renamed in the final scheme to more closely correspond with the NVCS or other classification nomenclatural criteria. The final classification contained 30 classes. This includes six forest classes, eight woodland classes, four shrubland classes, six grassland classes, two bare ground classes, one riparian/wetland class, one open water class, and two urban classes. Table 3 also shows the class numbers that were assigned to each class and were used throughout the remainder of this project for image classification and accuracy assessment purposes.

Appendix A contains details of the methods for deriving these classes, as well as their full names, their reduced map names (see Table 3), and brief descriptions of the classes. Appendix A also includes the number of previously sampled plots that were used to develop each class.

Table 3. Final land cover classification with number of training sites and accuracy assessment sites per class.

Class No.	Association Level Map Names	No. of Original Training Sites	No. of Accuracy Assessment Sites
1	Valles Caldera Grassland	36	5
2	Montane Grassland	25	5
3	ABCO-PSME Woodland	11	1
4	ABCO-PSME Forest	30	23
5	Evergreen-POTR Forest	15	11
6	Sparse-Bare soil	12	11
7	Open water	22	5
9	Riparian-Wetland	23	5
10	Sparse-Bare rock	36	7
11	PIED-JUMO/BOGR Woodland	70	20
12	PIPO/BOGR-SCSC Woodland	14	10
13	QUGA Shrubland	19	13
14	PIED-JUMO/Sparse-Soil Woodland	13	6
15	Submontane Grassland	38	18
16	PIED-JUMO/Sparse-Rock Woodland	5	5
17	Other Shrubland	46	13

Table 3. continued

Class No.	Association Level Map Names	No. of Original Training Sites	No. of Accuracy Assessment Sites
18	PIED-JUMO/ARTR Woodland	17	4
19	PIED-JUMO/BOER Wooded Grassland	12	3
20	BRCA-AGTR Grassland	6	11
21	PIPO Forest	29	15
23	PIPO/QUGA Woodland	22	9
24	ABLA-PIEN Forest	12	4
25	POTR Shrubland	4	2
26	POTR Forest	11	11
27	PIPO/Other grass Woodland	8	2
28	JUMO Wooded Grassland	29	1
29	RONE Shrubland	3	1
30	PIED Forest	15	5
31	Urban, Vegetated	NA	8
32	Urban, Paved	NA	8
	Total	583	242

Training Data

Training data were compiled from existing data, screen digitized points from photointerpretation, point data collected in the field, and field-verified photo-interpreted polygons. This resulted in a total of 583 points or polygons (Figure 3). Of these, 114 were adopted from previously collected data. In addition, there were 260 screen points obtained from orthophotos. A total of 209 additional field sites were sampled, including 44 points and 165 polygons.

This compilation of training sites resulted in an average of 19.4 training sites per class. The PIED-JUMO/BOGR Woodland class had the most training sites, at 70. The RONE Shrubland class was the least represented in the training data set, with three sites. In addition to RONE Shrubland, only the PIED-JUMO/Sparse-Rock Woodland (5), BRCA-AGTR Grassland (6), POTR Shrubland (4), and PIPO/Other grass Woodland had less than 10 training sites. No attempt was made to collect training data for the Urban, Vegetated or Urban, Paved classes.

Image Processing and Classification

The selected Landsat ETM^+ scene (June 4, 2001) was cropped to the study region and combined with the ancillary data layers. The study region includes much of the southeastern two-thirds of the Jemez Mountains, the entire Pajarito Plateau, White Rock, and the northwestern portions of the Cerros del Rio. This covers 1821 km^2 (703 mi^2) and includes all of LANL. The geometric and terrain rectification of the ETM^+ scene resulted in an RMS_{error} of 0.96 cell error or approximately 14.63 m (48 ft).

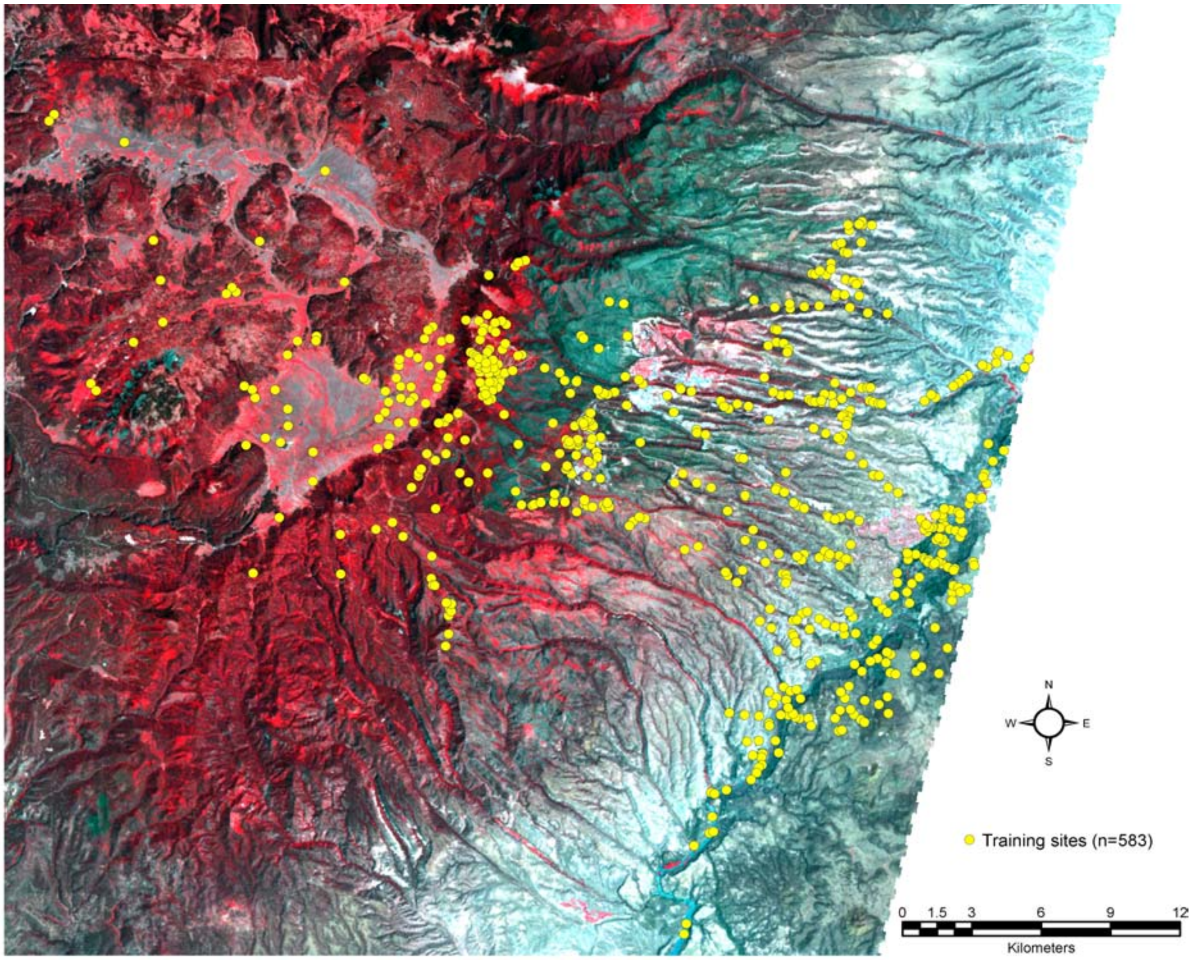

Figure 3. Training sites (n = 583) overlaid on the Landsat ETM$^+$ scene.

The rectified image, along with the ancillary data, NDVI, and variance-filtered images were applied to the seeding process and to the maximum likelihood algorithm. Ancillary data were used subjectively for photointerpretive analysis of the quality of the resulting classification. This was done iteratively between the training data, the seeding, and the multivariate analysis. The normality assumption of the maximum likelihood estimation was examined through use of histograms or based on experience. The seed groups for the vegetation classes were typically consistent with the normality assumption. However, water, bare ground, and bare rock frequently required further manipulations before the data in the respective seed groups became consistent with normality. The final supervised classification, with a 15-m by 15-m pixel resolution, which resulted from the application of this supervised strategy, is shown in Figure 4.

Image Smoothing

The original 15-m map with the association level land cover classification was smoothed to versions with minimum mapping units of 0.25 ha, 0.5 ha, 1.0 ha, and 2.0 ha in size. For the purposes of comparison to the original image, the quarter-hectare map is shown in Figure 5.

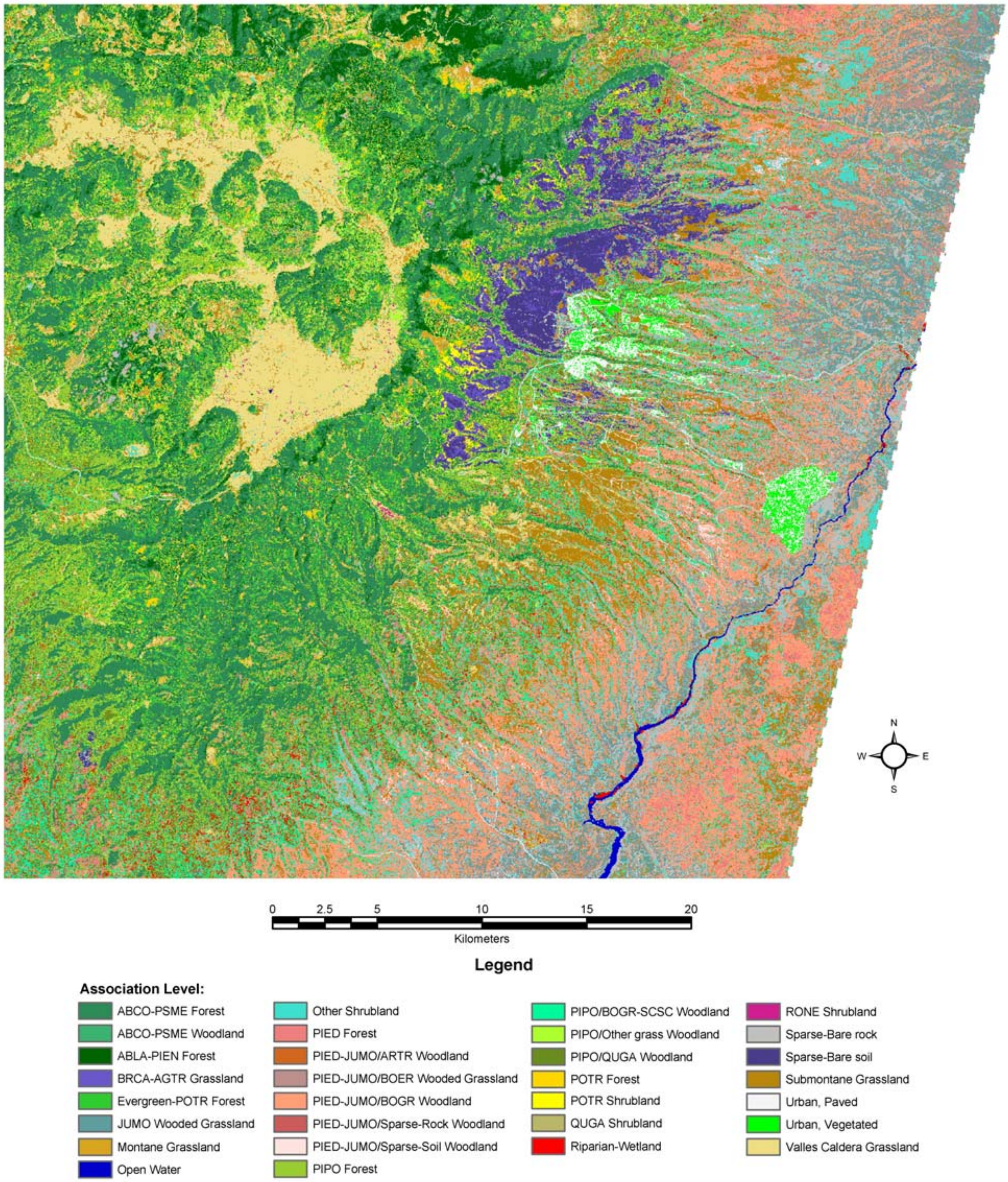

Figure 4. 15-m land cover map.

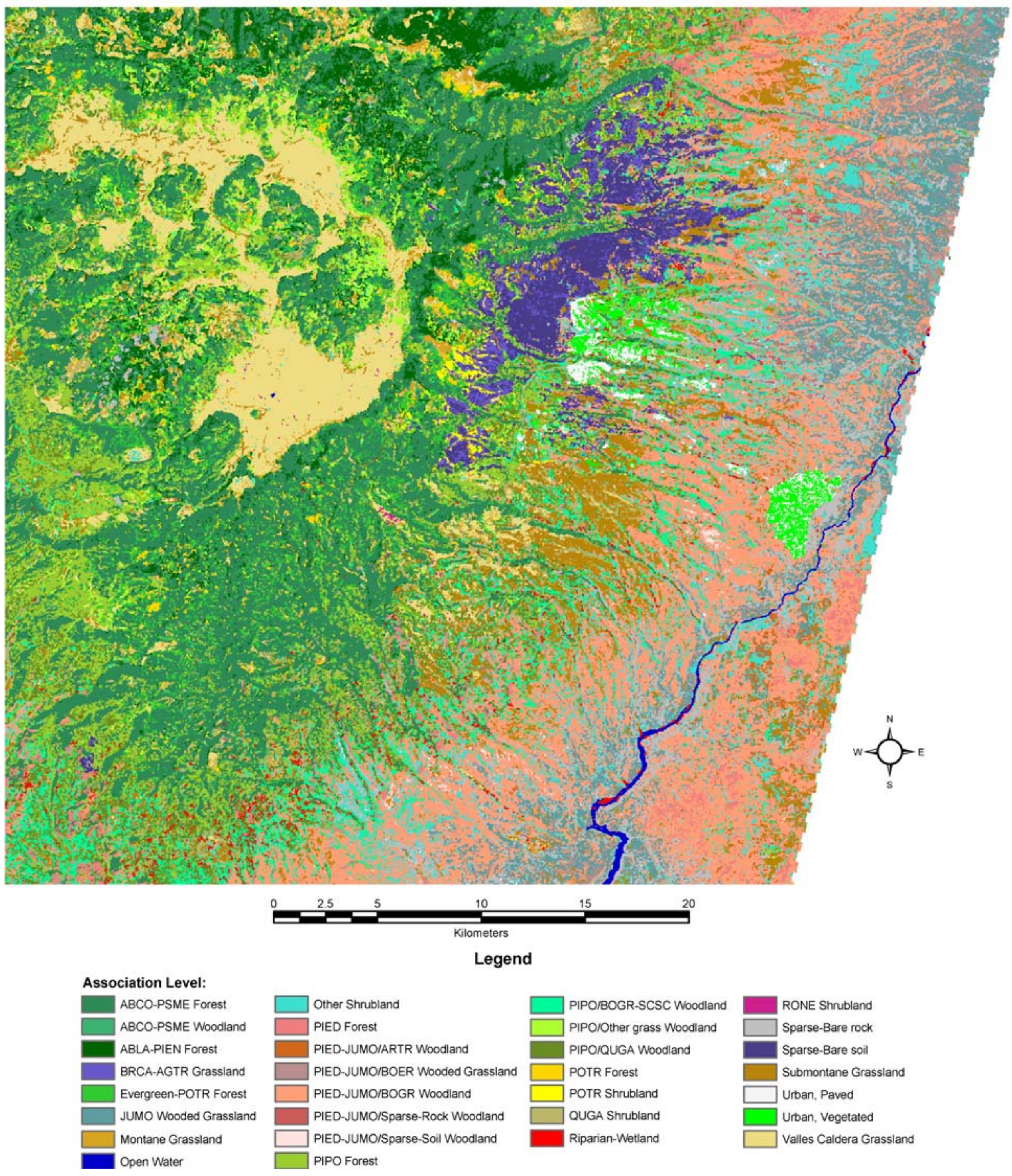

Figure 5. Quarter-hectare land cover map.

The comparative accuracies of these maps vary from 74.4 percent, for the two-hectare map, to 88.7 percent, for the quarter-hectare map (Table 4). The comparative accuracy for the 15-m map was 86.4 percent. Reviews of these comparative accuracies and comparisons of the image detail provided by each smoothing resulted in a decision to retain the 15-m map

Table 4. Comparative classification accuracies of the 15-m map and the smoothed maps.

Land cover map	Comparative Classification Accuracy
15-m	86.45%
Quarter-Hectare	88.68%
Half-Hectare	86.79%
One-Hectare	83.70%
Two-Hectare	74.44%

and the quarter-hectare map for further analyses. The remaining three maps were not considered further as part of this project. Of particular note, the comparative accuracy of the half-hectare map (86.8 percent) was slightly greater than that for the 15-m map. However, because linear map features important to wildlife and to other management issues appeared to be removed by the smoothing to the half-hectare level, this version was rejected along with the one-hectare version and the two-hectare version.

The accuracy totals reports for each of the classified and smoothed images are reproduced in Appendix B. For the 15-m map, the PIED Forest resulted in a user's accuracy and producer's accuracy of 100 percent. Using the criteria of 100 percent and greater than 75 percent for any combination of the user's accuracy and the producer's accuracy, the Open water and PIPO/BOGR-SCSC Woodland were also classified with high levels of accuracy.

The quarter-hectare smoothing resulted in eight classes with user's accuracies and producer's accuracies that were greater than 75 percent with one of them being 100 percent (Appendix B). In addition to the three classes previously described for the 15-m map, these include

- Montane Grassland
- ABCO-PSME Woodland
- Sparse-Bare rock
- PIED-JUMO/Sparse-Soil Woodland
- Other Shrubland

With regard to the half-hectare map, the PIED Forest class was classified with 100 percent for both the user's accuracy and the producer's accuracy (Appendix B). Five additional classes attained an accuracy of 100 percent for either one of the accuracy estimates and greater than 75 percent for the other accuracy estimate, including

- Montane Grassland
- Sparse-Bare rock
- PIED-JUMO/BOGR Woodland
- QUGA Shrubland
- JUMO Wooded Grassland

The one-hectare map produced a slightly different combination of classes with relatively high accuracies (Appendix B). Two classes, Valles Caldera Grassland and PIED Forest, were classified with 100 percent accuracies. The following five additional classes were classified with a combination of 100 percent accuracy and greater than 75 percent accuracy.

- Montane Grassland
- PIED-JUMO/BOGR Woodland
- PIED-JUMO/BOER Wooded Grassland
- POTR Shrubland
- JUMO Wooded Grassland

At the two-hectare level of resolution, none of the classes classified with 100 percent accuracy for both the user's accuracy and the producer's accuracy (Appendix B). However, four classes resulted in relative accuracies of 100 percent for one of the measures and of at least 75 percent for the other measures, including

- Valles Caldera Grassland
- ABLA-PIEN Forest
- JUMO Wooded Grassland
- PIED Forest

Reclassification

The final land cover classification scheme contained 30 classes (Appendix A). To meet a variety of scientific and management needs that may benefit from fewer classes, we reclassified the original association-level classification scheme into groups based on physiognomic, taxonomic, and class criteria. Physiognomic classes were based on major structural characteristics of the vegetation. Taxonomic classes were developed according to dominant species groups or the dominant growth forms that were common to the association classes. Class levels of aggregation were chosen to correspond with higher levels of the NVCS.

The correspondence between the associations level (30), the physiognomic classes (14), and the class level (9) of the classification system are shown in Table 5. The vegetation groups in the physiognomic classes generally represent subgroups of forests, woodlands, shrublands, and grasslands. Since BRCA-AGTR Grassland and Sparse-Bare soil were both found in areas that were burned at high severities by the Cerro Grande Fire, they were combined into a single physiognomic class to reflect this relationship. Open water, Urban and Riparian-Wetland also form separate groups at the physiognomic level.

Groupings at the class level complete the aggregation process that was initiated at the physiognomic level (Table 5). The resulting nine class-level classes are Forest, Woodland, Shrubland, Grassland, Sparse-Bare Rock, Cerro Grande Fire High-burn severity, Urban, and Riparian-Wetland. The Forest, Woodland, and Grassland classes aggregate smaller groups from the physiognomic level. The remaining classes are the same in both the physiognomic and the class levels of the classification scheme.

Table 5. Relationships between the association, physiognomic, and class classification levels.

Association Level	Class No.	Physiognomic Level	Class No.	Class Level	Class No.
PIPO Forest	21	Ponderosa Pine Forest	59	Forest	108
PIED Forest	30	Piñon-Juniper Forest	53		
ABCO-PSME Forest	4	Mixed conifer-Spruce-Fir Forest	60		
ABLA-PIEN Forest	24				
POTR Forest	26	Aspen Forest	61		
Evergreen-POTR Forest	5				
PIED-JUMO/Sparse-Soil Woodland	14	Piñon-Juniper Woodland	52	Woodland	107
PIED-JUMO/Sparse-Rock Woodland	16				
PIED-JUMO/ARTR Woodland	18				
PIED-JUMO/BOGR Woodland	11				
PIPO/BOGR-SCSC Woodland	12	Ponderosa pine-Mixed conifer Woodland	58		
PIPO/QUGA Woodland	23				
PIPO/Other grass Woodland	27				
ABCO-PSME Woodland	3				
Other Shrubland	17	Shrubland	56	Shrubland	106
POTR Shrubland	25				
QUGA Shrubland	13				
RONE Shrubland	29				
Montane Grassland	2	Grassland	55	Grassland	105
Submontane Grassland	15				
Valles Caldera Grassland	1				
PIED-JUMO/BOER Wooded Grassland	19	Piñon-Juniper/Grassland	51		
JUMO Wooded Grassland	28				
Sparse-Bare rock	10	Sparse-Bare rock	50	Sparse-Bare rock	103
BRCA-AGTR Grassland	20	Cerro Grande Fire High-burn severity	45	Cerro Grande Fire High-burn severity	102
Sparse-Bare soil	6				
Open water	7	Open water	47	Open water	100
Urban, Paved	32	Urban	40	Urban	101
Urban, Vegetated	31				
Riparian-Wetland	9	Riparian-Wetland	49	Riparian-Wetland	104

The correspondence between the class level and the scheme developed by Anderson et al. (1976) is show in Table 6. The Rangeland class from Anderson et al. corresponds to the Woodland, Shrubland, and Grassland of the current system. However, Woodland could also be considered to be Forest in the Anderson et al. scheme. The Cerro Grande Fire High-burn severity, which had been developed for our local situation, had no direct correspondence with the Anderson et al. system. Conversely, the Anderson et al. classes of Agricultural Land, Tundra, and Perennial Snow and Ice were not represented in the current scheme.

Table 6. Correspondence between the class level and Anderson et al. 1976.

Class Level	Anderson et al. 1976
Forest	Forest Land
Woodland	Rangeland
Shrubland	Rangeland
Grassland	Rangeland
Sparse-Bare rock	Barren Land
Cerro Grande Fire High-burn severity	NA
Open water	Water
Urban	Urban or Built-up Land
Riparian-wetland	Wetland
NA	Agricultural Land
NA	Tundra
NA	Perennial Snow or Ice

The relationships between the association level (30) of the classification scheme and the taxonomic level (9) are shown in Table 7. Major vegetation taxonomic groups, or growth form groups, include Ponderosa Pine, Mixed conifer-Spruce-Fir, Aspen-Riparian-Wetland, Piñon-Juniper, Shrub species, Grass species, Cerro Grande Fire High-burn severity, Open water, and Urban-Sparse-Bare rock.

Table 7. Relationship between the association and taxonomic classification levels.

Association Level	Class No.	Taxonomic Level	Class No.
PIPO Forest	21	Ponderosa Pine	81
PIPO/BOGR-SCSC Woodland	12		
PIPO/QUGA Woodland	23		
PIPO/Other grass Woodland	27		
ABCO-PSME Forest	4	Mixed conifer-Spruce-Fir	82
ABLA-PIEN Forest	24		
ABCO-PSME Woodland	3		
POTR Forest	26	Aspen-Riparian-Wetland	90
Evergreen-POTR Forest	5		
POTR Shrubland	25		
Riparian-Wetland	9		
PIED Forest	30	Piñon-Juniper	80
PIED-JUMO/Sparse-Soil Woodland	14		
PIED-JUMO/Sparse-Rock Woodland	16		
PIED-JUMO/ARTR Woodland	18		
PIED-JUMO/BOGR Woodland	11		
PIED-JUMO/BOER Wooded Grassland	19		
JUMO Wooded Grassland	28		
Other Shrubland	17	Shrub species	76
QUGA Shrubland	13		
RONE Shrubland	29		

Table 7. continued

Association Level	Class No.	Taxonomic Level	Class No.
Montane Grassland	2	Grass species	75
Submontane Grassland	15		
Valles Caldera Grassland	1		
BRCA-AGTR Grassland	20	Cerro Grande Fire High-burn severity	45
Sparse-Bare soil	6		
Open water	7	Open water	47
Sparse-Bare rock	10	Urban-Sparse-Bare rock	70
Urban, Paved	32		
Urban, Vegetated	31		

The taxonomic level of the current scheme closely corresponds with the land cover classification developed previously for use in the Los Alamos region (Koch et al. 1997). The comparison of these two systems is show in Table 8. The Ponderosa Pine, Grassland, and Water classes are similar in both cases. The Mixed Conifer classes are also similar because they both include Spruce-fir. The current class for Aspen-Riparian-Wetland is similar to the previous Aspen class, except for the addition of riparian and wetland cover types, and except for the tendency of the former Aspen class to include many areas dominated by shrub species. The current Piñon-Juniper class includes both the former Piñon-Juniper class and the former Juniper Savanna class. The current Urban-Sparse-Bare rock class contains both the former Developed class and the former Bare. There is not correspondence in the previous classification system for the Cerro Grande Fire. Similarly, no attempt was made to classify shrublands in the previous version of the land cover map. Therefore, there is no correspondence for the current Shrub species class.

Table 8. Correspondence between the taxonomic level and Koch et al. (1997).

Taxonomic Level	Koch et al. 1997
Ponderosa Pine	Ponderosa Pine
Mixed conifer-Spruce-Fir	Mixed conifer (including Spruce-fir)
Aspen-Riparian-Wetland	Aspen
Piñon-Juniper	Piñon-Juniper
Piñon-Juniper	Juniper Savanna
Shrub species	NA
Grass species	Grasslands
Cerro Grande Fire High-burn severity	NA
Open water	Shadows/Water
Urban-Sparse-Bare rock	Developed
Urban-Sparse-Bare rock	Bare

Accuracy Assessment

A total of 242 field sites were sampled to provide data for an independent accuracy assessment (Table 3). This was accomplished between August and October of 2002 (Figure 6). The goal was to sample 10 sites for each of the 30 classes. In spite of this effort, only one site was located that provided suitable accuracy assessment data for ABCO-PSME Woodland, JUMO Wooded Grassland, and RONE Shrubland. Sixteen additional classes

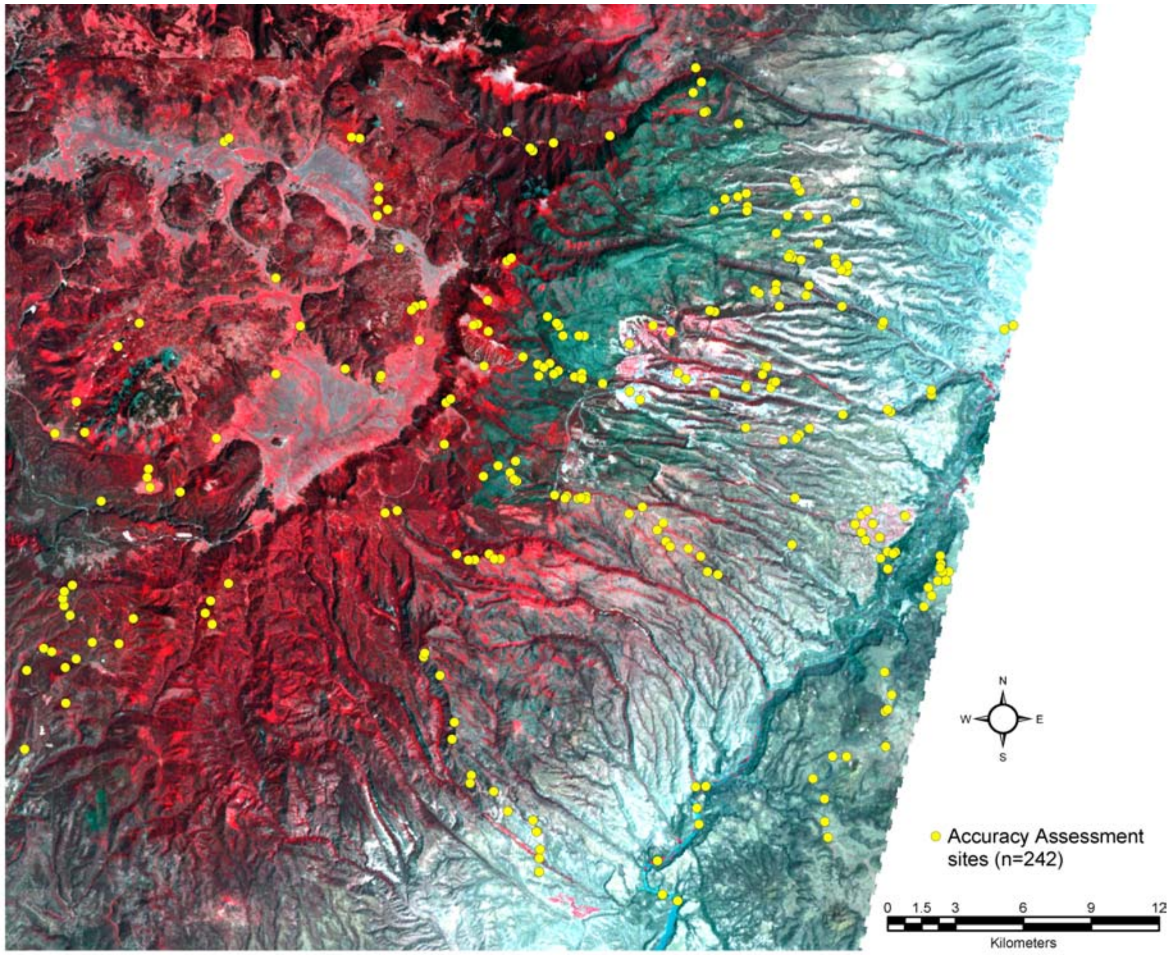

Figure 6. Accuracy assessment sites (n = 242) overlaid on the Landsat ETM$^+$ scene.

produced fewer than 10 accuracy assessment sites. Eleven classes had at least 10 accuracy assessment samples. The most accuracy assessment sites were gathered for the ABCO-PSME Forest class (23). Additional classes that resulted in a large number of accuracy samples include PIED-JUMO/BOGR Grassland (20), Submontane Grassland (18), and PIPO Forest (15).

The independently collected data were used to assess the accuracy of the 15-m map and the quarter-hectare map, as well as the physiognomic, taxonomic, and class level reclassifications of these association-level maps. The error matrices for the 15-m and quarter-hectare land cover maps are shown in Tables 9 and 10, respectively. The corresponding accuracy totals reports are reproduced in Appendix C. With regard to the error matrices, the ground accuracy assessment data are listed across the rows and are used to calculate the producer's accuracy. The corresponding map classification values are down the columns and these data result in the user's accuracy. The 15-m map has an overall accuracy of 52.5 percent. The quarter-hectare map accuracy is 55.0 percent.

The highest combined user's accuracy and producer's accuracy for the 15-m map was obtained for Open Water (100 percent and 100 percent, n = 5). Among the classes that had at

Table 9. Error matrix for the 15-m map, at the association level.

Land cover map:	Level:	Sites used:
15 m	Association	Accuracy assessment

Ground Accuracy Plots \ Map Classification	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31	32	Reference Totals	Producer's Accuracy
1	**3**															2															5	60%
2	2	**2**												1																	5	40%
3		1																													1	0%
4				**18**	1						2	1										1									23	78%
5				3	**5**															1		1		1							11	45%
6						**8**													2						1						11	73%
7							**5**																								5	100%
9				1				**4**																							5	80%
10									**6**					1																	7	86%
11									1	**10**	1	1	1				3				1					1		1			20	50%
12										3	**1**			1							3					1		1			10	10%
13	2			1	1							**5**		2							1		1								13	38%
14										2			**1**			1										2					6	17%
15										3				**13**		1		1													18	72%
16									3	1								1													5	0%
17										1		1				**7**					2					2					13	54%
18										3							**1**														4	25%
19														2												1					3	0%
20						4													**4**		1		2								11	36%
21				4							1									**9**	1										15	60%
23										1		2								4	**1**				1						9	11%
24				3																		**1**									4	25%
25																							**1**	1							2	50%
26	1				3																			**6**	1						11	55%
27	1		1																												2	0%
28																1															1	0%
29		1																													1	0%
30								1		1						1												**2**			5	40%
31																													**8**		8	100%
32																													2	**6**	8	75%
Classified Totals	9	4	1	30	10	12	5	5	10	25	5	10	2	20	0	13	4	2	6	14	10	3	4	8	3	7	0	4	10	6	**242**	
User's Accuracy	33%	50%	0%	60%	50%	67%	100%	80%	60%	40%	20%	50%	50%	65%	-------	54%	25%	0%	67%	64%	10%	33%	25%	75%	0%	0%	-------	50%	80%	100%	**Overall accuracy: 52.5%**	

Table 10. Error matrix for the quarter-hectare map, at the association level.

Land cover map:	**Level:**	**Sites used:**
Quarter hectare	Association	Accuracy assessment

Map Classification (columns); Ground Accuracy Plots (rows)

	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31	32	Reference Totals	Producer's Accuracy
1	**3**															2															5	60%
2	1	**3**												1																	5	60%
3																									1						1	0%
4				**17**	1						2											3									23	74%
5				3	**5**																1	2									11	45%
6						**9**													2												11	82%
7							**5**																								5	100%
9				1				**4**																							5	80%
10									**7**																						7	100%
11										**11**	1	1	1			1	3									1		1			20	55%
12									1	3	**1**			1							3							1			10	10%
13	3				1							**5**		2						1			1								13	38%
14										2			**1**			1										2					6	17%
15										2				**13**		2		1													18	72%
16									3	2																					5	0%
17										2		1				**7**					1					2					13	54%
18										3							**1**														4	25%
19										1				2																	3	0%
20						5													**4**				2								11	36%
21				4																**10**	1										15	67%
23												2								3	**2**				1			1			9	22%
24				3																		**1**									4	25%
25																							**1**	1							2	50%
26	1				3																			**6**	1						11	55%
27	1	1																													2	0%
28																1															1	0%
29	1																														1	0%
30								1		2																		**2**			5	40%
31																													**8**		8	100%
32																													1	**7**	8	88%
Classified Totals	10	4	0	28	10	14	5	5	11	28	4	9	2	19	0	14	4	1	6	14	8	6	4	7	3	5	0	5	9	7	**242**	
User's Accuracy	30%	75%	------	61%	50%	64%	100%	80%	64%	39%	25%	56%	50%	68%	------	50%	25%	0%	67%	71%	25%	17%	25%	86%	0%	0%	------	40%	89%	100%	**Overall accuracy: 55.0%**	

least 10 accuracy assessment samples, the highest combined accuracy estimates are listed below in order of decreasing combined accuracy levels.

Sparse-Bare soil (Producer's accuracy = 67 percent, User's accuracy = 73 percent)
ABCO-PSME Forest (Producer's accuracy = 60 percent, User's accuracy = 78 percent)
Submontane Grassland (Producer's accuracy = 65 percent, User's accuracy = 72 percent)
POTR Forest (Producer's accuracy = 75 percent, User's accuracy = 55 percent)
PIPO Forest (Producer's accuracy = 64 percent, User's accuracy = 60 percent)

Among this same set of classes, the least accurate classes are listed below in order of increasing combined accuracy.

PIPO/BOGR-SCSC Woodland (Producer's accuracy = 20 percent, User's accuracy = 10 percent)
QUGA Shrubland (Producer's accuracy = 50 percent, User's accuracy = 38 percent)
PIED-JUMO/BOGR Woodland (Producer's accuracy = 40 percent, User's accuracy = 50 percent)
ABCO-PSME Forest (Producer's accuracy = 50 percent, User's accuracy = 45 percent)

Appendix D includes the accuracy totals reports for the reclassified versions of the 15-m map and the quarter-hectare map. This includes physiognomic, class, and taxonomic level reclassifications. The class numbers used for identification purposes correspond to the physiognomic and class level numbers and names in Table 5 and the taxonomic level class numbers and names in Table 7. The overall classification accuracy estimates for each of these maps was greater than 70 percent. These accuracy estimates are listed below, in order of decreasing accuracy level.

Quarter-hectare, class level	77.3 percent
15-m, taxonomic level	76.4 percent
15-m, class level	75.6 percent
Quarter-hectare, taxonomic level	74.8 percent
15-m, physiognomic level	73.1 percent
Quarter-hectare, physiognomic level	70.7 percent

From a comparison of these accuracy assessments, there appears to be no difference between the 15-m versions and the quarter-hectare versions of the map. However, the class level appears to result in higher accuracies than the taxonomic level, and both of these reclassifications are of higher accuracies than the physiognomic level.

The individual class accuracies for each smoothing-classification level combination are also listed in the accuracy totals reports (Appendix D). For the 15-m map at the physiognomic level, only the Water class was classified at 100 percent for both user's accuracy and producer's accuracy. Of the subset of physiognomic classes that had at least 10 accuracy assessment plots, several classes were correctly classified with 70 percent or greater accuracy levels. These include

Urban
Cerro Grande Fire High-burn severity
Piñon-Juniper Woodland
Mixed conifer-Spruce-Fir Forest

These same classes were also mapped with a high level of accuracy on the quarter-hectare map at the physiognomic level. Moreover, the Urban class increased to 100 percent accuracy.

For both the 15-m map and the quarter-hectare map at the taxonomic level, only one class, Water, was classified at 100 percent (Appendix D). However, there were only five accuracy assessment data points available for this class. Each of the remaining classes had greater than 10 independent field points available for use in the accuracy assessment. Of these, four classes resulted with accuracies consistently greater than 70 percent. These are listed below.

Cerro Grande Fire High-burn severity
Urban-Sparse-Bare rock
Piñon-Juniper
Mixed conifer-Spruce-Fir (15-m map, only)

The class level reclassification for the 15-m map and the quarter-hectare map resulted in three classes with fewer than 10 accuracy assessment samples (Appendix D). Of these Water was always classified at 100 percent accuracy. On the quarter-hectare map the Riparian-Wetland class was also classified with a high level of accuracy, 80 percent. Of the remaining classes with greater than 10 accuracy assessment field data points, the Urban class was classified correctly 100 percent of the time on the quarter-hectare map and greater than 90 percent of the time on the 15-m map. Other classes that recorded greater than 70 percent accuracy included the Cerro Grande High-burn severity class and the Forest class.

Estimates of Areal Coverage

The results of the area calculations for the 15-m map at the association level, and for the physiognomic, class, and taxonomic reclassifications of this map are contained in Appendix E. These calculations were repeated for both the entire map region and for LANL property only. The entire map covers 1821 km^2 (703 mi^2, 450,010 ac). The portion of the map that includes LANL consists of 113 km^2 (43 mi^2, 27,835 ac).

15-m Map, Association Level, Entire Study Region

For the entire study region, the five most abundant classes on the 15-m map at the association level are listed below.

ABCO-PSME Forest	298 sq km	703 sq mi	16.4 percent
PIED-JUMO/BOGR Woodland	234 sq km	91 sq mi	12.9 percent
PIPO Forest	135 sq km	52 sq mi	7.5 percent
Valles Caldera Grassland	102 sq km	39 sq mi	5.6 percent
Pipo/Quga Woodland	94 sq km	36 sq mi	5.1 percent

Open- and closed-canopied ponderosa pine forest combined for 12.6 percent of the total map area. Noting that the Submontane Grassland class was the sixth most abundant, at 4.8 percent, there appears to also be a preponderance of grasslands in the study region. Open Water was the least represented class at 4.0 km^2 (1.6 mi^2, 0.2 percent). RONE Shrubland was the second least most abundant class.

15-m Map, Association Level, LANL

The 15-m map at the association level results in a different combination of classes that are dominant on LANL property (Appendix E). The five most abundant classes are listed below, in order of decreasing dominance.

PIED-JUMO/BOGR Woodland	30.3 sq km	11.7 sq mi	26.9 percent
Submontane Grassland	10.5 sq km	4.1 sq mi	9.3 percent
PIPO/BOGR-SCSC Woodland	9.8 sq km	3.8 sq mi	8.7 percent
Other shrubland	9.6 sq km	3.7 sq mi	8.6 percent
Urban, Paved	7.6 sq km	3.0 sq mi	6.8 percent

All 30 of the land cover classes were represented on LANL property. As in the previous mapping project, a piñon-juniper woodland class is the most abundant class (Koch et al. 1997). The least most abundant class on LANL was POTR Forest at 0.09 km^2 (0.04 mi^2, 0.08 percent).

15-m Map, Physiognomic Level, Entire Study Region

The total areas of each class were also calculated for the 15-m map at the physiognomic level (Appendix E). For the entire study area, the five most dominant classes include

Mixed conifer-Spruce-Fir Forest	369 sq km	142 sq mi	20.3 percent
Piñon-Juniper Woodland	272 sq km	105 sq mi	14.9 percent
Ponderosa pine-Conifer Woodland	266 sq km	103 sq mi	14.6 percent
Grassland	212 sq km	82 sq mi	11.7 percent
Shrubland	149 sq km	58 sq mi	8.2 percent

High-elevation forests are the most abundant classes. However, the combined woodland classes (29.5 percent) exceed the overall abundance of Mixed conifer-Spruce-Fir Forest and Ponderosa pine Forest (27.7 percent). The Open Water class was the least abundant class recorded on this map at 4.03 km^2 (1.6 mi^2, 0.2 percent).

15-m Map, Physiognomic Level, LANL

The subset of the 15-m map at the physiognomic level that includes all the LANL property presents a similar list of the five most abundant classes (see Appendix E).

Piñon-Juniper Woodland	36.3 sq km	14.0 sq mi	32.2 percent
Ponderosa pine-Conifer Woodland	17.0 sq km	6.6 sq mi	15.1 percent
Shrubland	12.9 sq km	5.0 sq mi	11.4 percent
Grassland	11.2 sq km	4.3 sq mi	10.0 percent
Urban	9.4 sq km	3.6 sq mi	8.4 percent

The Urban class becomes important in this subset of the study region. The Piñon-Juniper/Grassland class is the sixth most abundant, followed by Sparse-Bare rock and Ponderosa pine Forest. As before, the Open water class was recorded in the least amount at 0.13 km^2 (0.05 mi^2, 0.11 percent).

15-m Map, Class Level, Entire Study Region

The area calculations for the 15-m map at the class level were consistent between the analysis for the entire study region and for LANL property (Appendix E). The five most abundant classes for the entire study region are listed below.

Forest	635 sq km	245 sq mi	35 percent
Woodland	538 sq km	208 sq mi	30 percent
Grassland	320 sq km	124 sq mi	18 percent
Shrubland	149 sq km	58 sq mi	8 percent
Sparse-Bare rock	65 sq km	25 sq mi	4 percent

The sixth most abundant class was Cerro Grande Fire High-burn severity (3.3 percent), which was almost twice as much as Urban (1.8 percent). Open water, at 4.0 km^2 (1.6 mi^2, 0.22 percent), is the least abundant class at the physiognomic level of the 15-m map for the entire study region.

15-m Map, Class Level, LANL

The area calculations for the portion of the 15-m map at the class level that include LANL property only has a similar order of relative dominance (Appendix E). As listed below, the presence of the Urban class in the five most dominant classes and the reduced importance of the Forest class are the major exceptions.

Woodland	53.3 sq km	20.6 sq mi	47.3 percent
Grassland	17.3 sq km	6.7 sq mi	15.3 percent
Shrubland	12.9 sq km	5.0 sq mi	11.4 percent
Urban	9.4 sq km	3.6 sq mi	8.4 percent
Forest	9.2 sq km	3.5 sq mi	8.1 percent

The Cerro Grande Fire High-burn severity class was present on LANL property (3.4 percent) in approximately the same proportion as the entire study region (3.3 percent). Open water was the least abundant class, at 0.13 km^2 (0.05 mi^2, 0.11 percent).

15-m Map, Taxonomic Level, Entire Study Region

The analysis of relative areas for the 15-m map, at the taxonomic level, for the entire study region indicates a preponderance of forest and woodland species (Appendix E). The five most abundant classes are listed below.

Mixed conifer-Spruce Fir	421 sq km	163 sq mi	23 percent
Piñon-Juniper	419 sq km	162 sq mi	23 percent
Ponderosa Pine	349 sq km	135 sq mi	19 percent
Grass species	212 sq km	82 sq mi	12 percent
Shrub species	141 sq km	54 sq mi	8 percent

Approximately 60 percent of the entire study region is occupied by upland forest or woodland species. The Open water class produced the same results as for the analysis at the class level.

15-m Map, Taxonomic Level, LANL

The corresponding analysis of the 15-m map, at the taxonomic level, for LANL property resulted in the following list of five most abundant classes (see Appendix E).

Piñon-Juniper	44.4 sq km	17.2 sq mi	39.4 percent
Ponderosa Pine	21.2 sq km	8.2 sq mi	18.8 percent
Urban-Sparse-Bare rock	14.7 sq km	5.7 sq mi	13.0 percent
Shrub species	12.6 sq km	4.9 sq mi	11.2 percent
Grass species	11.2 sq km	4.3 sq mi	10.0 percent

The Open water class produced the same results as for the corresponding analysis at the class level.

Quarter-Hectare Map, Association Level, Entire Study Region

The areal calculations for the quarter-hectare map at the association, physiognomic, class, and taxonomic levels are presented in Appendix F. For each of these classification levels, separate analyses were completed for the entire study region and for LANL property only. For the entire study region at the association level, the five most abundant classes are listed below, ordered by decreasing abundance.

ABCO-PSME Forest	358 sq km	138 sq mi	19.7 percent
PIED-JUMO/BOGR Woodland	281 sq km	108 sq mi	15.4 percent
PIPO Forest	145 sq km	56 sq mi	8.0 percent
Valles Caldera Grassland	114 sq km	44 sq mi	6.3 percent
Submontane Grassland	33 sq km	85 sq mi	4.7 percent

This is identical to the 15-m map at the association level except for the replacement of PIPO/QUGA Woodland with Submontane Grassland in the fifth place. This suggests that the Submontane Grassland was present in more monolithic groups than PIPO/QUGA Woodland. RONE Shrubland was the least abundant class at 1.13 km^2 (0.44 mi^2, 0.06 percent). Open water became the fifth least most abundant class, surpassing PIED-JUMO/Sparse-Rock Woodland, PIED-JUMO/Sparse-Soil Woodland, and POTR Shrubland.

Quarter-Hectare Map, Association Level, LANL

The comparative areal analysis of LANL property at the quarter-hectare smoothing and at the association level resulted in the following list of classes that were found in the greatest abundance (see Appendix F).

PIED-JUMO/BOGR Woodland	39.8 sq km	15.4 sq mi	35.3 percent
Submontane Grassland	11.6 sq km	4.5 sq mi	10.3 percent
PIPO/BOGR-SCSC Woodland	11.2 sq km	4.3 sq mi	10.0 percent
Other shrubland	8.4 sq km	3.2 sq mi	7.5 percent
Sparse-Bare rock	5.3 sq km	2.0 sq mi	4.7 percent

This is similar to the analysis of the corresponding 15-m map. The major exception being the replacement of Urban, Paved with Sparse-Bare rock. The Urban, Paved class is ninth most abundant in the current analysis. ABLA-PIEN Forest is the least most abundant class, at 0.02 km^2 (0.01 mi^2, 0.02 percent). The Open water class increased in importance to the fifth least abundant class.

Quarter-Hectare Map, Physiognomic Level, Entire Study Region

The calculations of areal extents for each of the classes on the quarter-hectare map at the physiognomic level resulted in the following list of five most abundant classes (see Appendix F).

Mixed conifer-Spruce-Fir Forest	423 sq km	163 sq mi	23.2 percent
Piñon-Juniper Woodland	301 sq km	116 sq mi	16.5 percent
Ponderosa pine-Conifer Woodland	229 sq km	88 sq mi	12.6 percent
Grassland	217 sq km	84 sq mi	11.9 percent
Ponderosa pine Forest	145 sq km	56 sq mi	8.0 percent

This list is identical to the corresponding analysis of the 15-m map, except Ponderosa pine Forest replaced the Shrubland class. For the first four classes, their relative percentages increased from that on the 15-m map. For this map and for each of the remaining areal analyses, the Open water class is the least abundant in proportions that are similar or identical to the analyses of the corresponding versions of the 15-m map.

Quarter-Hectare Map, Physiognomic Level, LANL

For the subset of the entire study region that includes only LANL property, the comparative areal analysis was repeated for the quarter-hectare map at the physiognomic level (Appendix F). The five most abundant classes that resulted from this analysis are listed below.

Piñon-Juniper Woodland	42.7 sq km	16.5 sq mi	37.9 percent
Ponderosa pine-Conifer Woodland	16.5 sq km	6.4 sq mi	14.6 percent
Grassland	12.0 sq km	4.6 sq mi	10.6 percent
Shrubland	11.6 sq km	4.5 sq mi	10.3 percent
Urban	5.6 sq km	2.2 sq mi	5.0 percent

These are identical to the list that resulted from the analysis of the corresponding 15-m map, except that the order of the Grassland and Shrubland classes is reversed. The Piñon-Juniper Woodland and the Grassland classes increased in relative importance as a result of the quarter-hectare smoothing. Each of the remaining classes listed above decreased in relative importance.

Quarter-Hectare Map, Class Level, Entire Study Region

The areal calculations for the entire quarter-hectare map at the class level are listed in Appendix F. The five most abundant classes are listed below.

Forest	679 sq km	262 sq mi	37 percent
Woodland	530 sq km	205 sq mi	29 percent

Grassland	325 sq km	125 sq mi	18 percent
Shrubland	122 sq km	47 sq mi	7 percent
Cerro Grande Fire High-burn severity	65 sq km	25 sq mi	4 percent

This list is similar to the results of the 15-m map. In the current version, the Cerro Grande Fire High-burn severity class replaces Sparse-Bare rock as the fifth most abundant class. Each of these top five classes increased in relative importance in the analysis of the quarter-hectare map, except the Woodland class. In the case of the Forest class, the increase in relative abundance was approximately 7 percent.

Quarter-Hectare Map, Class Level, LANL

The similar analysis was completed for the quarter-hectare map at the class level for LANL property (Appendix F). The five most abundant classes are as follows.

Woodland	59.2 sq km	22.8 sq mi	52.5 percent
Grassland	17.4 sq km	6.7 sq mi	15.4 percent
Shrubland	11.6 sq km	4.5 sq mi	10.3 percent
Forest	9.0 sq km	3.4 sq mi	7.9 percent
Urban	5.6 sq km	2.2 sq mi	5.0 percent

This list is identical to that produced for the 15-m map, except that the order of the Forest and Urban classes are reversed. As a result of the smoothing to a quarter-hectare minimum mapping unit, the Woodland class increased by 11 percent from the 15-m map. The Grassland class also increased slightly in relative abundance. The remaining classes decreased in relative abundance.

Quarter-Hectare Map, Taxonomic Level, Entire Study Region

The areal comparisons for the entire study region with the quarter-hectare map at the taxonomic level resulting in the following list of five most abundant classes (see Appendix F).

Mixed conifer-Spruce Fir	451 sq km	174 sq mi	25 percent
Piñon-Juniper	446 sq km	172 sq mi	24 percent
Ponderosa Pine	346 sq km	134 sq mi	19 percent
Grass species	217 sq km	84 sq mi	12 percent
Shrub species	118 sq km	45 sq mi	6 percent

This list is identical to that for the corresponding analysis of the 15-m map. Two of the classes increased substantially in relative abundance as a result of smoothing to a quarter hectare. These include Mixed conifer-Spruce Fir (7 percent) and Piñon-Juniper (6 percent). The Grass species class also increased slightly. The remaining classes decreased in relative abundance.

Quarter-Hectare Map, Taxonomic Level, LANL

The areal calculations for the portion of the quarter-hectare map at the taxonomic level that included the LANL property resulted in the following five most abundant classes (see Appendix F).

Piñon-Juniper	49.8 sq km	19.2 sq mi	44.2 percent
Ponderosa pine	21.0 sq km	8.1 sq mi	18.7 percent
Grass species	12.0 sq km	4.6 sq mi	10.6 percent
Shrub species	11.4 sq km	4.4 sq mi	10.1 percent
Urban-Sparse-Bare rock	10.9 sq km	4.2 sq mi	9.7 percent

This list contains the same classes as for the analysis of the corresponding 15-m map. However, the order of the last three classes is changed. In particular, the Urban-Sparse-Bare rock class changed from third place to fifth place. The Piñon-Juniper class increased in relative importance from the 15-m map by 12 percent. The remaining classes decreased in importance. For Urban-Sparse-Bare rock, this decrease was approximately 26 percent.

DISCUSSION

The land cover map for the Los Alamos region that is replaced by the results described in this report was completed in 1997 (Koch et al. 1997). The former project was completed to meet the needs of identification and analysis of habitat for threatened and endangered species and other forms of wildlife. Threatened and endangered species management at LANL is required to comply with the Endangered Species Act and to facilitate the implementation of the Department of Energy mission at LANL (Foxx 1997). The map created in 1997 was satisfactory for the needs of that time period, but several issues have arisen since that time requiring the production of a new map.

The documentation for the 1997 land cover map acknowledged that landscape changes, such as those caused by wildfire, would have to be accounted for with future versions of the map (Koch et al. 1997). The need for the addition of a shrubland class was also discussed. The new land cover map that was created in late 2002 and early 2003, and described in this report, meets these two needs. Recent landscape changes that were known to exist in 1997, such as those caused by the Dome Fire, have been accounted for. Also, several shrubland classes were added to the current map.

In addition, extensive changes to the landscape of the Los Alamos region occurred during the Cerro Grande Fire (BAER 2000, Site-Wide Issues Program Office 2000). Approximately 17,200 ha (43,000 ac) of land were burned during this fire, many at high-burn severity. In addition, much of the land burned at low-burn severity or at moderate-burn severity also experienced significant changes to the land cover types. The Cerro Grande Fire was also followed by the application of extensive rehabilitation treatments to the burned lands. The direct and indirect effects of the Cerro Grande Fire needed to be documented in a new land cover map.

The Cerro Grande Fire was not the only source of land-use change in the Los Alamos region between 1997 and 2002. Approximately 320 ha (800 ac) of forest at LANL were thinned for the purposes of reducing their contribution to wildfire hazards between 1997 and 1999 (Bare et al. 2001). After the Cerro Grande Fire, a project was initiated for reducing the wildland fuels at LANL through applications of extensive thinning treatments (e.g., CGRP 2001). Changes to the structure and function of the landscape also occur as a result of the development of new buildings and facilities at LANL and the additions of new urban areas in the Los Alamos town site. These and other landscape changes made it necessary to create a new land cover map.

The area of the land cover map produced in 1997 included LANL, Los Alamos County, Bandelier National Monument, the majority of the Española Ranger District of the Santa Fe National Forest, and some additional surrounding lands (Koch et al. 1997). The coverage of this earlier study region was approximately 861.4 km^2 (344 mi^2, 220,000 ac). However, expanding spheres of interest and increasing collaborations between these and other agencies plus the addition of the Valles Caldera National Preserve to the public management system made it desirable to double the size of the study region for the current mapping project.

The management responsibilities of RRES-ECO and LANL have also expanded since 1997. In addition to management of habitat for threatened and endangered species and for other species of wildlife, RRES-ECO and LANL have also become increasingly involved in active management of the landscape for other purposes. This is exemplified by the development of a system for modeling the behaviors of wildfires in the LANL region (Balice et al. 2002). This wildfire behavior model was recently adopted for emergency operations at LANL (Balice and Koch 2002). RRES-ECO has also recently initiated a project to model the growth and development of fuels in forests and woodlands at LANL (Balice and Paul 2002). These and other region-wide environmental studies require the availability of current land cover maps.

The land cover classification scheme used to produce the previous land cover map contained nine classes; shadows/water, bare, mixed conifer, aspen, ponderosa pine, piñon-juniper, juniper savanna, grasslands, and developed (Koch et al. 1997). This was expanded to 30 classes in the final classification scheme used to produce the current land cover map. Several issues contributed to this expansion. First, the Cerro Grande Fire created many new landscape conditions that did not exist before 2000. Second, several shrubland classes were added to the scheme. Third, the former grassland class was subdivided into three grassland classes. Fourth, the NVCS distinguished between forests and woodlands based on whether the overstory canopy cover was greater than or less than 60 percent. This created a woodland class and a forest class for some of the groups, such as ponderosa pine, that were merely classified as forest in 1997. Coincidentally, the 60 percent criterion is of management value because this upper limit was used as one measure of acceptance for stands that had been thinned to reduce the wildfire hazard (Bare et al. 2001). Fifth, there was interest in determining different ground covers under some of the types. For example, we attempted to distinguish between PIED-JUMO/BOGR Woodland, PIED-JUMO/Sparse-Soil Woodland, PIED-JUMO/Sparse-Rock Woodland, and PIED-JUMO/ARTR Woodland. Each of these were included in the piñon-juniper class in the 1997 map, but were separated with reasonably high accuracy in the current version. Sixth, the developed class was divided into two urban classes.

The collection of additional training data and accuracy assessment data proved to be invaluable to the success of this mapping project. However, temporal-financial constraints and the lack of access to many of the subsections of the study region were a hindrance to sampling at suitable numbers of sites for each class. For production of an updated map in the future, this problem could be resolved by initiating a two-year production cycle and maintaining continuous field sampling throughout each cycle. Since the current map was created from 2001 imagery, 2003 would be an optimal time to initiate the creation of an updated map. This would be consistent with the rapid changes that are currently occurring in the study region from response to the Cerro Grande Fire, continued wildfire hazard reduction activities, and other active management actions. The first year of this cycle, 2003, would consist of obtaining cloud-free satellite imagery and sampling in the field for training sites. The second year of the cycle would consist of classifying the imagery and sampling in the field for accuracy assessment sites. If necessary, the two-year mapping cycle may also provide an opportunity to introduce multi-seasonal imagery or multi-year imagery into the mapping process, thereby increasing the accuracy of the final map product.

An attempt was made to collect accuracy assessment data in areas that were not well represented in the original training site data. Although this practice led to an overall greater representation of area covered within the project, it may have resulted in a conservative accuracy assessment for some classes.

DATA AVAILABILITY

All eight land cover maps developed and used in the analysis will be available for distribution. The land cover maps will be distributed in Arc export (.e00) format, along with all associated metadata. Data will be available on compact disks. Please contact Steve Koch, 505-665-9875, or Brad McKown, 505-665-8424.

ACKNOWLEDGMENTS

We gratefully acknowledge the Cerro Grande Rehabilitation Project and the Biological Resources Management Project for funding this project. Appreciation is also extended to Carl Edminster and the U.S. Forest Service Rocky Mountain Research Station in Flagstaff, Arizona, for funding the collection of field data that were used to develop the draft land cover classification. We would also like to thank the following agencies for access to lands administered by them: Bandelier National Monument, Jemez and Española Ranger Districts of the Santa Fe National Forest, Santa Clara Pueblo, and the Valles Caldera National Preserve. Many people helped with various aspects of this project. Terry Foxx provided the data and other information that were used to develop the Submontane grassland class. Will Barnes provided documentation and descriptive details that were used to develop the Valles Caldera grassland class. Additional gratitude is extended to Craig Allen for helping with access to Valles Caldera National Preserve; Carey Bare who initiated this project under the Biological Resources Management Program and for his guidance during its initial stages; Sam Loftin for collections and analyses of field data and for his technical assistance; Leslie Hansen for assisting in the field, for managing much of the data that were used to develop the land cover classes, and for providing insightful comments; Steve Reneau for his informed consultations on the geological conditions and physiographic setting; Tom Budge for his technical assistance with remote sensing questions; Marjorie Wright, Hector Hinojosa, and Teresa Hiteman for assistance with editing and document preparation; and the students of RRES-ECO for their assistance in the collection of field data.

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GLOSSARY

Bayesian classifier

A variation of maximum likelihood estimation that allows for the *a priori* weighting factors, representing the probabilities that a pixel is assigned to each class (ERDAS 1999). Since the Bayesian method incorporates the natural logarithm of the prior probability, probability values of one become zero.

Class numbers

Corresponds with the class numbers in Table 6.

Classification scheme or classification system

A set of target classes for classification of the satellite imagery. The purpose of such a scheme is to provide a framework for organizing and categorizing the information that can be categorized from the data (ERDAS 1999). Also see the definition by Wilkie and Finn (1996) in the introduction to the Methods section of this report.

Classified totals

The number of sites per class based on the classification, the classified or predicted class. Also referred to as the thematic data (Stein et al. 1999).

Contiguous

Connecting without a break, or sharing an edge or boundary (Soukhanov 1992).

Decision rule

A mathematical algorithm that, using data contained in the signature, performs that actual sorting of pixels into distinct classes (ERDAS 1999).

Maximum likelihood estimation

A statistical process that estimates a value of an unknown parameter which maximizes the likelihood of the given observation (Mardia et al. 1979).

Multispectral classification

The process of sorting into a finite number of individual classes, or categories, of data based on their data file values (ERDAS 1999).

Number correct

The number per class of correctly classified sites.

Producer's accuracy

The probability of a reference sample being correctly classified. A measure of omission error (Story and Congalton 1986).

Reference totals

The number of accuracy assessment or training sites used per class, or the actual class. Also called ground truth or verification data (Stein et al. 1999).

Seed pixel

A pixel that is selected as a model pixel, against which the pixels that are contiguous to it are compared based on user-defined parameters (ERDAS 1999). When one or more of the contiguous pixels is accepted, the mean of the sample is calculated from the collection of accepted pixels. Then, the pixels that are contiguous to the sample are compared in the same way. This process repeats until no pixels that are contiguous to the sample satisfy the parameters.

Signature

A set of statistics that defines a training sample or cluster (ERDAS 1999).

Sites used

The collection of sites that were used to perform the assessment.

Speckle

Isolated pixels in a classified scene that take on unusual class assignments and may merely reflect local spectral anomalies within these isolated pixels.

Spectral distance

The distance, similar to Euclidean distance, in multivariate space, as defined by the ETM^+ bands and other derived data sources, used in the classification of an ETM^+ image (ERDAS 1999).

Spectral space

An abstract space that is defined by the amount of electromagnetic radiation recorded in each data layer of the satellite image (ERDAS 1999). Typically, these are the original ETM^+ bands. However, they also could be derived data , such as NDVI and the variance filter.

Supervised classification

The process by which pixels that represent recognizable and identifiable patterns or land cover features are selected. The computer system is then instructed to select pixels with similar characteristics (ERDAS 1999).

Training

The process of defining the criteria by which the computer system recognizes patterns in the data (Hord 1982).

User's accuracy

The probability that a sample classified on the map actually represents that category on the ground. A measure of commission error (Story and Congalton 1986).

APPENDIX A: Land Cover Classes for Land Cover Mapping in the Jemez Mountains

This appendix contains brief descriptions and summary data for the majority of land cover classes that were adopted for use in this study. The only classes that are not described are open water and urban classes.

Unless otherwise specified, the cover classes are dominated by native plant species, are growing under natural or semi-natural conditions, and are typical of temperate climates. These classes are based on existing vegetation, not potential vegetation. Most of the names of the cover classes correspond to formations, alliances, and associations that are integral to the National Vegetation Classification System (Grossman et al. 1994, 1998, FGDC Vegetation Subcommittee 1997) as expressed in the NatureServe database (NatureServe 2002), and where possible they are also consistent with community type nomenclature from previous classification efforts (e.g., DeVelice, et al. 1986, Larson et al. 1995). The corresponding shorter names that are used to identify the map polygons are also given for each class.

The sample sizes refer to the number of original sample plots that provided data for the development of the draft land cover classes. This original dataset was augmented, where possible, by additional qualitative field data collected for training purposes and for accuracy assessment purposes.

The National Vegetation Classification System is arranged in a hierarchy that includes, in order of increasing detail, Division, Order, Physiognomic Class, Physiognomic Subclass, Subgroup, Formation, Alliance and Community Association (FGDC Vegetation Subcommittee 1997). The Division distinguishes between vegetated, with greater than 1 percent vegetation cover, and non-vegetated areas. The Order is differentiated into dominant life forms; tree, shrub, dwarf shrub, herbaceous, and non-vascular. Shrubs and dwarf shrubs are distinguished according to height; greater or less than 0.5 m tall. However, there are no similar distinguishing characteristics given for the differences between trees and shrubs. In general, trees are recognized as taller plants, with a single main stem and foliage elevated above the ground, and shrubs are considered to be shorter plants with more than one main stem and foliage that extends closer to the ground level (Benson 1959, Kearney and Peebles 1960, Steen 1971, Harris and Harris 1994). The height break between shrubs and trees has been variously defined as 3.0 m (10 ft) by Treshow et al. (1970), by Foxx and Hoard (1995) and by Elmore and Janish (1976); 6.1 m (20 ft) by Fuller and Ritchie (1967); and 10 m (32.8 ft) by Allaby (1998). For the purposes of this work, we have defined shrubs to be less than 3.0 m (10 ft) and trees to be greater than or equal to 3.0 m (10 ft).

From the data that was available to develop these land cover classes it was usually possible to be consistent with the formation, alliance, or the community association levels of the National Vegetation Classification Standard (FGDC Vegetation Subcommittee 1997). A formation is a level in the system that is based on ecological groupings of vegetation units with broadly defined environmental and additional physiognomic factors in common. An alliance is a physiognomically uniform group of associations sharing one or more diagnostic (dominant, differential, indicator, or character) species that, as a rule, are found in the uppermost stratum of the vegetation. A community association or association is the finest level of the classification system. This is a physiognomically uniform group of vegetation stands that share one or more diagnostic overstory and understory species. These elements occur as repeatable assemblages across the landscape, and are generally found under similar habitat conditions.

The plant species listed as diagnostic for each cover class are cross-referenced with their four-letter codes and common names in Table A-1. Nomenclature follows one or more of the following; the Flora of North America (e.g., Flora of North America Editorial Committee 1993), the Intermountain Flora (e.g., Cronquist et al. 1972), the Working Index for New Mexico Vascular Plant Names (Roalson and Allred 1995), and the National Plants Database (USDA-NRCS 2002).

<u>Tree-dominated vegetation forming closed-canopied forests (60 percent to 100 percent cover)</u>

Pinus ponderosa Forest PIPO Forest
Sample size = 19, Class number = 21

This is a tree-dominated, evergreen forest type with greater than 60 percent overstory canopy cover. Tree crowns tend to be rounded. This cover class potentially consists of several associations, including the *Pinus ponderosa*/*Quercus gambelii* association. *Pinus ponderosa* is typically the sole dominant overstory species, although significant amounts of *Abies concolor* and *Pseudotsuga menziesii* may also be present in the midstory and understory. The understory contains varying amounts of *Quercus gambelii* (average canopy cover is at least 11.7 percent), limited cover of graminoids, including *Carex geophila* (average canopy cover = 3.1 percent), and pine litter. The average overstory canopy cover of this class is 78.9 percent (standard deviation = 7.4 percent). The range of elevations for these plots is from 2090.6 m (6859 ft) to 2359.2 m (7740 ft).

Pinus edulis Forest PIED Forest
Sample size = 0, Class number = 30

This is a tree-dominated, closed-canopied forest type with needle-leaved evergreen species. Tree crowns are round-shaped and canopy cover is greater than 60 percent. This class is indistinguishable from *Pinus ponderosa*/*Quercus gambelii* Forests (Class 21) at the formation level. This cover class potentially consists of *Pinus edulis*/*Bouteloua gracilis* and *Pinus edulis*/Sparse associations. *Pinus edulis* dominates, with scattered individuals of *Juniperus monosperma*. The understory includes *Cercocarpus montanus* and *Quercus undulata* in the shrub layer, whereas *Bouteloua gracilis* is the most common graminoid. The ground surface is covered by gravel and cobble. The average overstory canopy cover of this class is 68.8 percent (standard deviation = 4.8 percent). The range of elevations for the sample plots in this cover type is from 1700.8 m (5580 ft) to 2316.5 m (7600 ft). This cover type is found on north-facing aspects. These descriptive comments are preliminary and are based on qualitative sample data collected during the acquisition of training data.

Abies concolor-Pseudotsuga menziesii Forest ABCO-PSME Forest
Sample size = 15, Class number = 4

This class consists of tree-dominated evergreen forests with greater than 60 percent overstory canopy cover. Tree crowns tend to be conical in shape, and this is the distinguishing characteristic between this group and the *Pinus ponderosa*/*Quercus gambelii* Forest (Class 21) type. This class consists of two alliances, according to NatureServe (2002), including the *Abies concolor* alliance and the *Pseudotsuga menziesii* alliance. A variety of associations characterize this land cover class. These include *Abies concolor*/*Acer glabrum*, *Abies concolor*/*Arctostaphylos uva-ursi*, *Abies concolor*/*Erigeron eximius*, *Abies concolor*/*Quercus gambelii*, *Abies concolor*/*Robinia neomexicana*, and *Pseudotsuga menziesii*/*Quercus gambelii*. This land cover class is also floristically diverse. Combinations of *Pseudotsuga menziesii* and *Abies concolor* dominate the overstory, with varying amounts of *Pinus ponderosa*, *Pinus flexilis,* and *Acer glabrum*. Shrub species that are commonly found include *Quercus gambelii*, *Clematis pseudoalpina*, *Pachystima mysrinites*, and *Arctostaphylos uva-ursi*. Forbs include *Thalictrum fendleri*, *Lathyrus arizonicus*, *Erigeron eximius*, *Fragaria vesca*, *F. virginiana*, *Geranium caespitosum,* and *Viola canadensis*. *Bromus ciliatus*, *Carex occidentalis* and *C. geophila* are the most widely distributed graminoids. The average overstory canopy cover of this class is 81.3 percent (standard deviation = 8.7 percent). *Populus tremuloides* constitutes only 5.2 percent (standard deviation = 7.1 percent) of the total overstory populations. The range of elevations for the sample plots in this cover type is from 2130.6 m (6990 ft) to 2952.0 m (9685 ft).

Abies lasiocarpa-Picea engelmannii Forest ABLA-PIEN Forest
Sample size = 3, Class number = 24

This class is a tree-dominated evergreen forest type, with greater than 60 percent canopy cover and with conical-shaped tree crowns. According to the National Vegetation Classification System, this class is indistinguishable from the *Abies concolor-Pseudotsuga menziesii* Forest (Class 4) at the formation level. This cover type consists of two alliances, according to NatureServe (2002), the *Abies lasiocarpa* alliance and the *Picea engelmannii* alliance. Three associations are included in this cover class: *Abies lasiocarpa*/*Erigeron eximius*, *Abies lasiocarpa*/*Vaccinium myrtillus,* and *Picea engelmannii*/*Erigeron eximius*. The tree layer is dominated by *Abies lasiocarpa* and *Picea engelmannii*, with lesser amounts of *Abies concolor*, *Acer glabrum,* and *Pseudotsuga menziesii*. *Vaccinium mytrillus* and *Pachystima mysrinites* are the most common shrubs at higher and lower elevations, respectively. Forbs are more common at lower elevations and include *Artemisia franserioides*, *Erigeron eximius*, *Lathyrus arizonicus,* and *Smilacina stellata*. The average overstory canopy cover of this class is 87.7 percent (standard deviation = 8.7 percent). *Populus tremuloides* constitutes only 4.9 percent (standard deviation = 4.2 percent) of the overstory populations. The range of elevations for the sample plots in this cover type is from 2849.9 m (9350 ft) to 3136.7 m (10,291 ft).

Populus tremuloides Forest POTR Forest
Sample size = 6, Class number = 26

This class consists of tree-dominated, montane, cold-deciduous forests, with greater than 60 percent cover. This cover class is primarily represented by the *Populus tremuloides/Festuca thurberi,* association, with occasional examples of *Populus* *tremuloides/Pteridium aquilinum* at lower elevations. *Populus tremuloides* occupies the majority of the overstory canopy cover, with some presence by *Abies concolor*, *Pinus flexilis*, and *Pseudotsuga menziesii*. Common herbs and graminoids include *Achillea millefolium*, *Fragaria virginiana*, *Geranium caespitosum*, *Lathyrus arizonicus*, *Pteridium aquilinum*, *Smilacina stellata*, *Vicia americana*, *Bromus ciliatus*, *Festuca thurberi,* and *Poa pratensis*. The average overstory canopy cover of this class is 81.2 percent (standard deviation = 10.4 percent). Coniferous tree species constitute only 5.6 percent (standard deviation = 3.3 percent) of the overstory populations. The range of elevations for the sample plots in this cover type is from 2945.6 m (9664 ft) to 3033.7 m (9953 ft). Plots of this cover type occupy south-facing and east-facing slope positions.

Mixed Needle-leaved evergreen-*Populus tremuloides* Forest — Evergreen-POTR Forest
Sample size = 10, Class number = 5

This class is a tree-dominated cover type consisting of closed-canopied forests that include a mixture of needle-leaved evergreen species and cold deciduous species. The overstory canopies are greater than 60 percent cover. This cover class consists of a variety of associations. The most common of these is *Picea engelmannii*/*Erigeron eximius* at higher elevations and on north-facing aspects. *Abies lasiocarpa*/*Erigeron eximius* is also represented by one plot on a north-facing, higher elevation location. *Abies concolor*/*Acer glabrum*, *Abies concolor*/*Erigeron eximius,* and *Populus tremuloides/Festuca thurberi* are also represented by one plot each at a range of elevations and slope positions. The overstories are equally diverse with *Abies lasiocarpa*, *A. concolor*, *Populus tremuloides*, *Picea engelmannii,* and *Pseudotsuga menziesii* each being represented in varying amounts. The understories are represented by a variety of forbs that are common to high-elevation forests. Shrubs are not common. The average overstory canopy cover of this class is 86.1 percent (standard deviation = 10.4 percent). *Populus tremuloides* occupies 57.2 percent (standard deviation = 3.3 percent) of the overstory populations. The range of elevations for the sample plots in this cover type is from 2776.7 m (9110 ft) to 3009.6 m (9874 ft).

<u>Tree-dominated vegetation forming open-canopied woodlands (25 percent to 60 percent cover)</u>

Pinus edulis-*Juniperus monosperma*/Sparsely vegetated-Bare soil Woodland — PIED-JUMO/Sparse-Soil Woodland
Sample size = 1, Class number = 14

This cover type consists of an open-canopied woodland with rounded crowns. Trees are needle-leaved, evergreen species. Two associations can be found in this cover type: *Pinus edulis*/*Artemisia tridentata* and *Pinus edulis*/*Bouteloua gracilis*. *Pinus edulis* and *Juniperus monosperma* are the only overstory species. Understories are sparse but may consist of *Artemisia tridentata*, *Cercocarpus montanus*, *Bouteloua gracilis,* and other species. The distinguishing characteristic of this cover class is the high coverage of bare soil, up to 60 percent, and the potentially eroded conditions of the site. The overstory canopy coverage of this type is 25 percent to 30 percent, and thus on the low end of the woodland category. The elevation of the plot that was sampled in this cover type is 1984.2 m (6510 ft).

Pinus edulis-*Juniperus monosperma*/Sparsely vegetated-Bare rock Woodland

PIED-JUMO/Sparse-Rock Woodland

Sample size = 1, Class number = 16

This is an open-canopied woodland with needle-leaved evergreen tree species that are characterized by rounded crowns. The association that characterizes this type has not been named. *Juniperus monosperma* dominates the overstory with lesser amounts of *Pinus edulis*. Bare rock covers 62 percent of the ground surface and this is the distinguishing characteristic between this cover class and *Pinus edulis*/Sparse-Bare soil Woodland (class 14). The overstory canopy cover is approximately 30 percent. The elevation of the plot within this cover type is 1911.1 m (6270 ft).

Pinus edulis-*Juniperus monosperma*/*Artemisia tridentata* Woodland

PIED-JUMO/ARTR Woodland

Sample size = 4, Class number = 18

This is an open-canopied woodland with needle-leaved evergreen tree species that are characterized by rounded crowns. This cover type typically occurs on sandy, alluvial sites in canyons and on depositional flats. The overstory is dominated by *Pinus edulis*. The understory is characterized by *Artemisia tridentata* and *Bouteloua gracilis*. There may also be 20 percent to 50 percent bare soil. The overstory canopy cover is 41.9 percent (standard deviation = 7.6 percent). The elevation of this cover type ranges from 1991.0 m (6532 ft) to 2012.9 m (6604 ft).

Pinus edulis-*Juniperus monosperma*/*Bouteloua gracilis* Woodland

PIED-JUMO/BOGR Woodland

Sample size = 13, Class number = 11

This is an open-canopied woodland with needle-leaved evergreen tree species that are characterized by rounded crowns. The distinguishing characteristics between this class and *Pinus edulis*/*Artemisia tridentata* Woodland (Class 18) are tendency for this cover type to occupy more upland positions with residual soils and the absence of *Artemisia tridentata*. *Pinus edulis* is the dominant species in the overstory with *Juniperus monosperma* also being present in significant amounts. The most common species in the understory include *Bouteloua gracilis*, *Cercocarpus montanus*, and *Opuntia erinacea*. Exposures of bare soil may be more than 30 percent. The average overstory canopy cover is 35.8 percent (standard deviation = 9.8 percent). The elevation of this cover type ranges from 1991.9 m (6535 ft) to 2154.9 m (7070 ft).

Pinus ponderosa/*Bouteloua gracilis*-*Schizachyrium scoparium* Woodland

PIPO/BOGR-SCSC Woodland

Sample size = 4, Class number = 12

This cover class consists of open-canopied woodlands with needle-leaved evergreen tree species. Crown shapes are rounded. The overstory has two layers: an upper layer with *Pinus ponderosa* at approximately 30 percent canopy cover and a subordinate layer of *Juniperus monosperma* and *Pinus edulis* with approximately 10 percent canopy cover. Common species in the understory include *Bouteloua gracilis*, *Schizachyrium scoparium*, *Cercocarpus montanus*, *Quercus undulata,* and *Rhus trilobata*. The average overstory canopy cover is 37.7 percent (standard deviation = 11.8 percent). The elevation of this cover type ranges from 2054.4 m (6740 ft) to 2139.7 m (7020 ft).

Pinus ponderosa/*Quercus gambelii* Woodland PIPO/QUGA Woodland
Sample size = 8, Class number = 23

This is an open-canopied woodland cover type with needle-leaved evergreen tree species that have round-shaped crowns. This is identical to *Pinus ponderosa*/*Quercus gambelii* Forest (class 21) except for the less dense overstory canopy cover and for the increased cover by shrub, forb, and graminoid species. In addition to the *Pinus ponderosa*/*Quercus gambelii* association, these communities may be successional to *Pseudotsuga menziesii*/*Quercus gambelii* at higher-elevation sites. The higher-elevation sites of this cover type were burned in the Water Canyon Fire that occurred in 1954, and the lower-elevation sites were thinned between 1996 and 2001. *Pinus ponderosa* is the only tree species in the overstory. Cover of *Quercus gambelii* can be as much as 31 percent. *Robinia neomexicana* is also common in the shrub layer. *Antennaria parvifolia* is the most common forb. Common graminoids include *Carex geophila*, *Muhlenbergia montana*, *Poa fendleriana,* and *P. pratensis*. The ground surface is typically covered by a dense mat of pine litter. The average overstory canopy cover is 43.7 percent (standard deviation = 13.1 percent). The elevation of this cover type ranges from 2334.8 m (7660 ft) to 2453.6 m (8050 ft).

Pinus ponderosa/Other Grass Woodland
PIPO/Other grass Woodland
Sample size = 2, Class number = 27

This cover type is an open-canopied woodland with needle-leaved evergreen tree species that have rounded crowns. This class is similar in all respects to the *Pinus ponderosa*/*Quercus gambelii* Woodland type (class 23) except for the reduced amounts of *Quercus gambelii* and the absence of *Robinia neomexicana* in the shrub layer and the relative dominance of graminoids on the ground surface. These graminoid species consist of *Bromus ciliatus*, *Carex geophila,* and *Poa pratensis* at higher elevations with the addition of or replacement by recently seeded grass species (*Bromus carinatus*, *Agropyron trachycaulum*, *Lolium multiflorum,* and *Hordeum vulgare*) at lower elevations. Lower-elevation sites are heavily influenced by the Cerro Grande Fire, subsequent rehabilitation, and the occurrence of any thinning activities. The most common forb species include *Achillea millefolium*, *Artemisia ludoviciana,* and *Vicia americana*. The average overstory canopy cover is 42.5 percent (standard deviation = 14.8 percent). The elevation of this cover type ranges from 2307.3 m (7570 ft) to 2480.5 m (8138 ft).

Abies concolor-Pseudotsuga menziesii Woodland ABCO-PSME Woodland
Sample size = 3, Class number = 3

This cover type consists of open-canopied woodland communities with needle-leaved evergreen tree species that have conical-shaped crowns. This class was recently introduced to the region of interest by the modification of *Abies concolor-Pseudotsuga menziesii* Forests (class 4) caused by the Cerro Grande Fire as it burned in some areas at low- or moderate-fire intensities. This class consists of two alliances, according to NatureServe (2002), including the *Abies concolor* alliance and the *Pseudotsuga menziesii* alliance. All of the sample sites for this cover type were members of the *Abies concolor*/*Quercus gambelii* association. *Abies concolor* and *Pseudotsuga menziesii* were always present, with codominance in the overstory often shared with *Pinus ponderosa*. *Populus tremuloides* was sometimes present, but with less than 25 percent overstory canopy cover. *Quercus gambelii* and *Robinia neomexicana* were the most common shrub species. The most common forb was *Fragaria vesca*. Graminoids included *Bromus ciliatus*, *Carex geophila,* and *Poa pratensis* throughout, joined by *Poa fendleriana* and *Koeleria nitida* at lower elevations and by *Danthonia parryi* and *Festuca thurberi* at higher elevations. The average overstory canopy cover is 39.4 percent (standard deviation = 8.5 percent), which represents a 52 percent reduction in canopy cover from pre-Cerro Grande Fire conditions. The elevation of this cover type ranges from 2227.5 m (7308 ft) to 2868.2 m (9410 ft).

<u>Vegetation dominated by shrubs >0.5 m tall generally with >25 percent canopy cover</u>

Other Shrubland — Other Shrubland

Sample size = 4, Class number = 17

This cover type consists of evergreen, microphyllous shrub species or temperate, cold-deciduous species. The limited overall extent of this cover type and the variable nature of its composition resulted in the inclusion of a wide variety of species combinations. *Artemisia tridentata* and *Chrysothamnus nauseosus* are typically the dominant shrub species, especially at lower elevations. However, *Atriplex canescens*, *Cercocarpus montanus*, *Fallugia paradoxa*, *Rhus trilobata,* and *Ribes cereum* may be common or even dominant. In the Valles Caldera, *Potentilla fruticosa* forms pure stands of shrubs. The average canopy cover of the shrub layer is 47.0 percent (standard deviation = 12.2 percent). Exposures of bare soil may reach 37 percent. Based on 46 sites that were sampled during the acquisition of training data, the elevation of this cover type ranges from 1640.1 m (5381 ft) to 2672.8 m (8769 ft).

Populus tremuloides Shrubland — POTR Shrubland

Sample size = 1, Class number = 25

This cover class is a temperate, cold-deciduous shrubland type. It is derived from *Populus tremuloides* Forests (class 26) that were severely burned in the Cerro Grande Fire. As such, the forest overstory of *Populus tremuloides* was removed and replaced by sprouts that are less than 3.05 m tall (10 ft). The sprouts grow to heights ranging from 1.0 m (3.3 ft) to 2.0 m (6.6 ft) within two years after the fire. The canopy cover of these sprouts is 41.0 percent. Based on the previously sampled plot plus four additional samples collected during the gathering of training data, the elevation of this cover type ranges from 2813.9 m (9232 ft) to 3003.2 m (9853 ft).

Quercus gambelii Shrubland — QUGA Shrubland

Sample size = 2, Class number = 13

This cover class is a temperate, cold-deciduous shrubland type. It is distinguished from *Populus tremuloides* Shrubland (class 25) by the replacement of *Populus tremuloides* with *Quercus gambelii*. *Pinus ponderosa*, *Pseudotsuga menziesii,* and other coniferous tree species may also be present with canopy cover up to 13 percent. *Bouteloua gracilis*, *Muhlenbergia montana,* and *Schizachyrium scoparium* are the dominant graminoids. The average canopy cover of the shrub layer is 66.1 percent (standard deviation = 22.6 percent). Based on 19 communities sampled during the gathering of training data, the elevation of this cover type ranges from 2044.6 m (6708 ft) to 2732.2 m (8964 ft).

Robinia neomexicana Shrubland RONE Shrubland
Sample size = 0, Class number = 29

This cover class is a temperate, cold-deciduous shrubland type. As in the previous two cover types, it is distinguished by a single shrub species: *Robinia neomexicana*, which is present with approximately 60 percent cover. *Quercus gambelii* is also present with up to 5 percent cover. An occasional *Pinus ponderosa* may also be present. Graminoids, including *Bouteloua gracilis*, *Muhlenbergia montana,* and *Schizachyrium scoparium*, are also abundant on the ground surface with up to 60 percent cover. Based on three sites sampled during the collection of training data, the elevation of this cover type ranges from 2266.5 m (7436 ft) to 2644.8 m (8677 ft).

<u>Herbaceous vegetation >25 percent cover with >50 percent dominance by graminoids</u>

Montane Grassland Montane Grassland
Sample size = 8, Class number = 2

This is a temperate, medium-tall, bunch grassland type. The dominant species include *Danthonia parryi* and *Festuca thurberi*. Common forbs include *Achillea millefolium*, *Antennaria parvifolia*, *Potentilla hippiana*, and *Pseudocymopterus montanus*. This cover class is found at the highest elevations in the mountains, on south-facing slopes. Graminoid cover is 60.6 percent (standard deviation = 17.1 percent). The range of elevations for these plots is from 2977.9 m (9770 ft) to 3092.2 m (10,145 ft).

Submontane Grassland Submontane Grassland
Sample size = 0, Class number = 15

This cover type consists of temperate, medium-tall, bunch grassland communities. They are mostly persistent relicts of the La Mesa Fire, which burned through former pine forests and woodlands in 1977. The following species accounts were assembled from information provided by Brian Jacobs and Terry Foxx. *Blepharoneuron tricholepis*, *Muhlenbergia montana,* and *Schizachyrium scoparium* are the dominant graminoids. *Festuca ovina* and *Muhlenbergia wrightii* are locally abundant at higher elevations in areas that were rehabilitated after the La Mesa Fire. *Bouteloua gracilis* becomes more common at lower elevations. Major herb species include *Lupinus caudatus* at higher elevations and *Chrysopsis villosa* at lower elevations. *Bahia dissecta* and *Thelesperma trifidum* are also common. Based on 38 plots that were sampled during the gathering of training data, the elevations of this cover type range from 1686.5 m (5533 ft) to 2317.4 m (7603 ft).

Valles Caldera Grassland Valles Caldera Grassland
Sample size = 0, Class number = 1

This cover type is a combination of temperate, medium-tall, bunch grassland communities (Mountain Valley Dry) and seasonally or temporarily flooded, medium-tall grasslands (Mountain Meadow Wet). These are located throughout the Valles Caldera and are distinguished by their relative slope positions. The following accounts of the common species were compiled from information provided by Barnes (2002). Within the Valle Grande proper, the Mountain Meadow Wet communities can be further subdivided into two major community types based on the seasonality of soil moisture. The more moist sites support *Carex utriculata*. The less moist sites are dominated by *Carex microptera*, *Deschampsia caespitosa,* and *Poa palustris*. Common forbs include *Achillea millefolium*, *Blepharoneuron tricholepis*, and *Juncus balticus*. Mountain Valley Dry grasslands can also be subdivided into two types according to their relative slope position. Lower slopes are populated by *Festuca arizonica*, *F. idahoensis*, *Erigeron formosissimus,* and *Achillea millefolium*. Upper slope positions are somewhat similar to Montane Grasslands (class 2) with *Danthonia parryi* and *Festuca arizonica*. *Antennaria parvifolia*, *Erigeron formosissimus,* and *Potentilla hippiana* are common in the herb layer. Grasslands in the southwestern portion of the Valles Caldera are dominated by *Bouteloua gracilis*, *Agropyron trachycaulon,* and *A. smithii*. The most common grass species in the San Antonio drainage include *Festuca arizonica* and *F. idahoensis* at higher elevations. At lower elevations in the San Antonio drainage, *Bouteloua gracilis* and *Agropyron trachycaulon* become more common. In the Valle Toledo area, *Danthonia parryi* and *Festuca arizonica* are the most common graminoid species. Based on 36 plots sampled during the gathering of training data, the elevations of Valles Caldera Grasslands range from 2570.4 m (8433 ft) to 2744.1 m (9003 ft).

Bromus carinatus-*Agropyron trachycaulum* Grassland BRCA-AGTR Grassland
Sample size = 6, Class number = 20

This cover type is a temperate, medium-tall, bunch grassland vegetation type. It resulted from high-severity fire that occurred during the Cerro Grande Fire. During this fire, all vegetation was consumed and the ground surface was burned to the A-horizon of the soil. The area was subsequently seeded with *Bromus carinatus*, *Agropyron trachycaulum*, *Lolium multiflorum,* and *Hordeum vulgare*. Straw was also frequently added as mulch. The total graminoid cover averages 34.3 percent (standard deviation = 10.6 percent), nearly all of which is made up of seeded grasses (32.4 percent). The canopy cover of the four seeded grasses averaged 11.2 percent, 7.7 percent, 10.3 percent, and 3.3 percent, respectively. *Lolium multiflorum* attained coverages of 15 percent to 20 percent at higher elevations. Straw litter covers 32.6 percent (standard deviation = 21.2 percent) of the ground surface. Much of the ground surface is also covered by bare soil, ash, and various lithic components, 60.3 percent (standard deviation = 23.9 percent). The elevations of these sites range from 2053.4 m (6737 ft) to 2691.4 m (8830 ft).

Pinus edulis-*Juniperus monosperma*/*Bouteloua eriopoda* Wooded Grassland
PIED-JUMO/BOER Wooded Grassland
Sample size = 2, Class number = 19

Plant communities in this cover type are temperate, short, bunch grasslands with sparse needle-leaved, evergreen, rounded crown tree layers. They occupy south-facing positions at the lower elevations and in the canyons. Equal amounts of *Pinus edulis* and *Juniperus monosperma* occur in the overstory. *Rhus trilobata* is also present in the shrub layer. The dominant graminoid is *Bouteloua eriopoda*. The overstory canopy cover of the permanent plot included in this study was 13 percent. Based on 12 sites sampled as part of the gathering of training data, the elevations of this cover type range from 1796.2 m (5893 ft) to 2084.8 m (6840 ft).

Juniperus monosperma Wooded Grassland JUMO Wooded Grassland
Sample size = 0, Class number = 28

This cover type consists of temperate, short, bunch grassland communities with sparsely distributed needle-leaved, evergreen, rounded-crown trees. *Juniperus monosperma* is the only tree species present. Canopy coverages in the tree layer are less than 20 percent. Graminoids are variable but *Bouteloua gracilis* and *Stipa comata* may be the most common species in many locations. Coverage of bare soil may exceed 40 percent. Based on site location data collected at 29 sites in this cover type, the elevations of this cover type range from 1671.5 m (5484 ft) to 1972.1 m (6470 ft). The description of this class is preliminary because the areas that support this type are inaccessible. As a result, this description is based on qualitative observations and from interpretations of aerial photography.

<u>Vegetation not dominant, sparse with <10 percent cover or unvegetated with <1 percent cover</u>

Sparsely vegetated or unvegetated bare rock Sparse-Bare rock
Sample size = 0, Class number = 10

This cover type is a combination of consolidated rock and cliffs, boulders, or talus. Both steep slopes and flats are represented. The major plant species vary from place to place but can include *Pinus edulis*, *Juniperus monosperma*, *Quercus undulata*, *Q. gambelii*, *Cercocarpus montanus*, *Rhus trilobata,* and *Fallugia paradoxa*. Based on 35 sample sites that were incorporated into the training data, the elevations of this cover type range from 1658.7 m (5442 ft) to 2802.3 m (9194 ft). This class was typically located in isolated areas or consisted of communities that did not meet our minimum sampling requirements. As a result, this description is based on qualitative observations and from interpretations of aerial photography.

Sparsely vegetated or unvegetated bare soil Sparse-Bare soil
Sample size = 12, Class number = 6

This cover type largely consists of soil and other unconsolidated material occupying sparsely vegetated and unvegetated slopes or flats. Considerable amounts of gravel may also be present. These areas were created in locations where the Cerro Grande Fire burned with high severity and where rehabilitation was either not applied or was unsuccessful. The average canopy cover for all plant species is 7.2 percent (standard deviation = 4.5 percent). The canopy cover of litter is 1.7 percent (standard deviation = 2.3 percent). Bare soil, ash, and gravel constitute the majority of bare surface coverage. The total bare ground cover is 90.8 percent (standard deviation = 9.5 percent). The elevations of these sample sites range from 2289.7 m (7512 ft) to 2603.6 (8542 ft).

<u>Tree-dominated closed-canopied riparian forests or shrub-dominated riparian wetlands</u>

Forest or Shrub dominated riparian or wetland communities Riparian-Wetland
Sample size = 0, Class number = 9

This cover type is a combination of closed-canopied forests and shrublands. In either case they are cold deciduous, seasonally or temporarily flooded forests or shrublands. This is the primary group of non-graminoid communities that occupy seasonally or saturated soils. The dominant species include *Populus* spp. in forested wetlands and *Salix exigua* in shrub-dominated wetlands. The communities are typically found along the Rio Grande and its tributaries. According to 23 sample areas that were used to develop the set of training data, the elevations of these communities range from 1625.2 m (5332 ft) to 2316.8 m (7601 ft). This cover type was typically located in isolated canyons where sampling was impractical or consisted of communities that did not meet our minimum sampling requirements. As a result, this description is based on qualitative observations and from interpretations of aerial photography.

Table A-1. Plant species that are common to land cover classes of the Jemez Mountains.

Code	Scientific name	Common name
ABCO	*Abies concolor*	White fir
ABLA	*Abies lasiocarpa*	Subalpine fir
ACGL	*Acer glabrum*	Mountain maple
ACMI	*Achillea millefolium*	Western yarrow
AGTR	*Agropyron trachycaulum*	Slender wheatgrass
ANPA	*Antennaria parvifolia*	Small-leaf pussytoes
ARFR	*Artemisia franserioides*	Ragweed sagebrush
ARLU	*Artemisia ludoviciana*	Louisiana wormwood
ARTR	*Artemisia tridentata*	Big sagebrush
ARUV	*Arctostaphylos uva-ursi*	Kinnikinnik
ATCA	*Atriplex canescens*	Four-wing saltbush
BADI	*Bahia dissecta*	Yellow ragweed
BOER	*Bouteloua eriopoda*	Black grama
BOGR	*Bouteloua gracilis*	Blue grama
BLTR	*Blepharoneuron tricholepis*	Pine dropseed
BRCA	*Bromus carinatus*	Mountain brome
BRCI	*Bromus ciliatus*	Fringed brome
CAGE	*Carex geophila*	White Mountain sedge
CAMI	*Carex microptera*	Small-wing sege
CAOC	*Carex occidentalis*	Western sedge
CAUT	*Carex utriculata*	Northwest Territory sedge
CEMO	*Cercocarpus montanus*	Mountain mahogany
CHNA	*Chrysothamnus nauseosus*	Chamisa
CHVI	*Chrysopsis villosa*	Hairy golden aster
CLPS	*Clematis pseudoalpina*	Rocky Mountain clematis
DAPA	*Danthonia parryi*	Parry's danthonia
DECA	*Deschampsia caespitosa*	Tufted hairgrass
EREX	*Erigeron eximius*	Forest fleabane
ERFO	*Erigeron formosissimus*	Beautiful fleabane
FAPA	*Fallugia paradoxa*	Apache plume
FEAR	*Festuca arizonica*	Arizona fescue
FEID	*Festuca idahoensis*	Idaho fescue
FEOV	*Festuca ovina*	Sheep fescue
FETH	*Festuca thurberi*	Thurber fescue
FRVE	*Fragaria vesca*	Woodland strawberry
FRVI	*Fragaria virginiana*	Mountain strawberry
GECA	*Geranium caespitosum*	Rose crane's bill
HOVU	*Hordeum vulgare*	Barley
JUBA	*Juncus balticus*	Baltic rush
JUMO	*Juniperus monosperma*	One-seed juniper
KONI	*Koeleria nitida*	Junegrass
LAAR	*Lathyrus arizonicus*	Arizona lathyrus

Table A-1. Plant species that are common to land cover classes of the Jemez Mountains (continued).

Code	Scientific name	Common name
LOMU	*Lolium multiflorum*	Italian ryegrass
LUCA	*Lupinus caudatus*	Spurred lupine
MUMO	*Muhlenbergia montana*	Mountain muhly
MUWR	*Muhlenbergia wrightii*	Spike muhly
OPER	*Opuntia erinacea*	Grizzly-bear prickly-pear cactus
PAMY	*Pachystima myrsinites*	Mountain lover
PIEN	*Picea engelmannii*	Engelmann spruce
PIED	*Pinus edulis*	Piñon
PIFL	*Pinus flexilis*	Limber pine
PIPO	*Pinus ponderosa*	Ponderosa pine
POFE	*Poa fendleriana*	Mutton grass
POFR	*Potentilla fruticosa*	Shrubby cinquefoil
POHI	*Potentilla hippiana*	Woolly cinquefoil
POPA	*Poa palustris*	Fowl bluegrass
POPR	*Poa pratensis*	Kentucky bluegrass
POTR	*Populus tremuloides*	Quaking aspen
PSME	*Pseudotsuga menziesii*	Douglas fir
PSMO	*Pseudocymopterus montanus*	Yellow mountain parsley
PTAQ	*Pteridium aquilinum*	Bracken fern
QUGA	*Quercus gambelii*	Gambel oak
QUUN	*Quercus undulata*	Wavy leaf oak
RHTR	*Rhus trilobata*	Skunkbush sumac
RICE	*Ribes cereum*	Wax currant
RONE	*Robinia neomexicana*	New Mexico locust
SAEX	*Salix exigua*	Coyote willow
SCSC	*Schizachyrium scoparium*	Little bluestem
SMST	*Smilacina stellata*	Star Solomon's plume
STCO	*Stipa comata*	Needle and thread
THFE	*Thalictrum fendleri*	Fendler meadowrue
THTR	*Thelesperma trifidum*	Green thread
VAMY	*Vaccinium myrtillus*	Myrtle-leaf blueberry
VIAM	*Vicia americana*	American vetch
VICA	*Viola canadensis*	Canada violet

APPENDIX B: Comparative Accuracy Totals Reports; 15-m map and smoothed maps

B-1

Accuracy totals:

Map:	Sites used:
15-m association	Training

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	36	37	33	91.67%	89.19%
Montane Grassland	25	24	23	92.00%	95.83%
ABCO-PSME Woodland	11	12	10	90.91%	83.33%
ABCO-PSME Forest	30	30	25	83.33%	83.33%
Evergreen-POTR Forest	15	10	9	60.00%	90.00%
Sparse-Bare soil	12	13	10	83.33%	76.92%
Open water	22	17	17	77.27%	100.00%
Riparian-Wetland	23	18	17	73.91%	94.44%
Sparse-Bare rock	36	32	30	83.33%	93.75%
PIED-JUMO/BOGR Woodland	70	77	67	95.71%	87.01%
PIPO/BOGR-SCSC Woodland	14	18	14	100.00%	77.78%
QUGA Shrubland	19	17	16	84.21%	94.12%
PIED-JUMO/Sparse-Soil Woodland	13	10	9	69.23%	90.00%
Submontane Grassland	38	36	34	89.47%	94.44%
PIED-JUMO/Sparse-Rock Woodland	5	8	5	100.00%	62.50%
Other Shrubland	46	43	42	91.30%	97.67%
PIED-JUMO/ARTR Woodland	17	17	16	94.12%	94.12%
PIED-JUMO/BOER Wooded Grassland	12	12	10	83.33%	83.33%
BRCA-AGTR Grassland	6	5	3	50.00%	60.00%
PIPO Forest	29	31	27	93.10%	87.10%
PIPO/QUGA Woodland	22	15	14	63.64%	93.33%
ABLA-PIEN Forest	12	11	9	75.00%	81.82%
POTR Shrubland	4	4	3	75.00%	75.00%
POTR Forest	11	14	10	90.91%	71.43%
PIPO/Other grass Woodland	8	11	8	100.00%	72.73%
JUMO Wooded Grassland	29	27	26	89.66%	96.30%
RONE Shrubland	3	8	2	66.67%	25.00%
PIED Forest	15	15	15	100.00%	100.00%
Urban, Vegetated	0	3	0	---	---
Urban, Paved	0	3	0	---	---
Totals	583	583	504		

Overall Classification Accuracy = 86.45%

B-2

Accuracy totals:

Map:	**Sites used:**
Quarter-hectare association	Training

Class Names	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Valles Caldera Grassland	36	37	33	91.67%	89.19%
Montane Grassland	25	23	23	92.00%	100.00%
ABCO-PSME Woodland	11	9	9	81.82%	100.00%
ABCO-PSME Forest	30	31	25	83.33%	80.65%
Evergreen-POTR Forest	15	12	10	66.67%	83.33%
Sparse-Bare soil	12	12	10	83.33%	83.33%
Open water	22	17	17	77.27%	100.00%
Riparian-Wetland	23	17	17	73.91%	100.00%
Sparse-Bare rock	36	31	31	86.11%	100.00%
PIED-JUMO/BOGR Woodland	70	78	69	98.57%	88.46%
PIPO/BOGR-SCSC Woodland	14	18	14	100.00%	77.78%
QUGA Shrubland	19	19	17	89.47%	89.47%
PIED-JUMO/Sparse-Soil Woodland	13	11	11	84.62%	100.00%
Submontane Grassland	38	35	34	89.47%	97.14%
PIED-JUMO/Sparse-Rock Woodland	5	7	4	80.00%	57.14%
Other Shrubland	46	43	43	93.48%	100.00%
PIED-JUMO/ARTR Woodland	17	17	16	94.12%	94.12%
PIED-JUMO/BOER Wooded Grassland	12	12	10	83.33%	83.33%
BRCA-AGTR Grassland	6	6	4	66.67%	66.67%
PIPO Forest	29	32	28	96.55%	87.50%
PIPO/QUGA Woodland	22	19	16	72.73%	84.21%
ABLA-PIEN Forest	12	12	10	83.33%	83.33%
POTR Shrubland	4	4	4	100.00%	100.00%
POTR Forest	11	11	10	90.91%	90.91%
PIPO/Other grass Woodland	8	10	8	100.00%	80.00%
JUMO Wooded Grassland	29	28	27	93.10%	96.43%
RONE Shrubland	3	8	2	66.67%	25.00%
PIED Forest	15	15	15	100.00%	100.00%
Urban, Vegetated	0	3	0	---	---
Urban, Paved	0	1	0	---	---
Totals	583	583	517		

Overall Classification Accuracy = 88.68%

B-3

Accuracy totals:

Map:	Sites used:
Half-hectare association	Training

Class Numbers	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	36	38	33	91.67%	86.84%
Montane Grassland	25	23	23	92.00%	100.00%
ABCO-PSME Woodland	11	8	8	72.73%	100.00%
ABCO-PSME Forest	30	32	26	86.67%	81.25%
Evergreen-POTR Forest	15	12	10	66.67%	83.33%
Sparse-Bare soil	12	12	10	83.33%	83.33%
Open water	22	18	17	77.27%	94.44%
Riparian-Wetland	23	16	16	69.57%	100.00%
Sparse-Bare rock	36	29	29	80.56%	100.00%
PIED-JUMO/BOGR Woodland	70	78	70	100.00%	89.74%
PIPO/BOGR-SCSC Woodland	14	19	14	100.00%	73.68%
QUGA Shrubland	19	16	16	84.21%	100.00%
PIED-JUMO/Sparse-Soil Woodland	13	8	8	61.54%	100.00%
Submontane Grassland	38	37	34	89.47%	91.89%
PIED-JUMO/Sparse-Rock Woodland	5	8	4	80.00%	50.00%
Other Shrubland	46	41	37	80.43%	90.24%
PIED-JUMO/ARTR Woodland	17	17	15	88.24%	88.24%
PIED-JUMO/BOER Wooded Grassland	12	11	10	83.33%	90.91%
BRCA-AGTR Grassland	6	6	4	66.67%	66.67%
PIPO Forest	29	30	27	93.10%	90.00%
PIPO/QUGA Woodland	22	21	18	81.82%	85.71%
ABLA-PIEN Forest	12	12	10	83.33%	83.33%
POTR Shrubland	4	4	4	100.00%	100.00%
POTR Forest	11	11	10	90.91%	90.91%
PIPO/Other grass Woodland	8	10	8	100.00%	80.00%
JUMO Wooded Grassland	29	31	29	100.00%	93.55%
RONE Shrubland	3	7	1	33.33%	14.29%
PIED Forest	15	15	15	100.00%	100.00%
Urban, Vegetated	0	3	0	---	---
Urban, Paved	0	5	0	---	---
Totals	583	583	506		

Overall Classification Accuracy = 86.79%

B-4

Accuracy totals:

Map:	Sites used:
One-hectare association	Training

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	36	36	36	100.00%	100.00%
Montane Grassland	25	22	22	88.00%	100.00%
ABCO-PSME Woodland	11	7	7	63.64%	100.00%
ABCO-PSME Forest	30	32	24	80.00%	75.00%
Evergreen-POTR Forest	15	11	10	66.67%	90.91%
Sparse-Bare soil	12	14	11	91.67%	78.57%
Open water	22	19	17	77.27%	89.47%
Riparian-Wetland	23	12	12	52.17%	100.00%
Sparse-Bare rock	36	33	30	83.33%	90.91%
PIED-JUMO/BOGR Woodland	70	85	70	100.00%	82.35%
PIPO/BOGR-SCSC Woodland	14	19	14	100.00%	73.68%
QUGA Shrubland	19	14	13	68.42%	92.86%
PIED-JUMO/Sparse-Soil Woodland	13	8	8	61.54%	100.00%
Submontane Grassland	38	38	34	89.47%	89.47%
PIED-JUMO/Sparse-Rock Woodland	5	7	3	60.00%	42.86%
Other Shrubland	46	37	32	69.57%	86.49%
PIED-JUMO/ARTR Woodland	17	15	13	76.47%	86.67%
PIED-JUMO/BOER Wooded Grassland	12	10	10	83.33%	100.00%
BRCA-AGTR Grassland	6	4	3	50.00%	75.00%
PIPO Forest	29	28	25	86.21%	89.29%
PIPO/QUGA Woodland	22	24	17	77.27%	70.83%
ABLA-PIEN Forest	12	13	10	83.33%	76.92%
POTR Shrubland	4	5	4	100.00%	80.00%
POTR Forest	11	11	10	90.91%	90.91%
PIPO/Other grass Woodland	8	9	8	100.00%	88.89%
JUMO Wooded Grassland	29	30	29	100.00%	96.67%
RONE Shrubland	3	3	1	33.33%	33.33%
PIED Forest	15	15	15	100.00%	100.00%
Urban, Vegetated	0	3	0	---	---
Urban, Paved	0	14	0	---	---
Totals	583	583	488		

Overall Classification Accuracy = 83.70%

B-5

Accuracy totals:

Map:	Sites used:
Two-hectare association	Training

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	36	37	36	100.00%	97.30%
Montane Grassland	25	23	19	76.00%	82.61%
ABCO-PSME Woodland	11	3	3	27.27%	100.00%
ABCO-PSME Forest	30	38	25	83.33%	65.79%
Evergreen-POTR Forest	15	11	8	53.33%	72.73%
Sparse-Bare soil	12	14	11	91.67%	78.57%
Open water	22	24	17	77.27%	70.83%
Riparian-Wetland	23	5	5	21.74%	100.00%
Sparse-Bare rock	36	32	25	69.44%	78.13%
PIED-JUMO/BOGR Woodland	70	102	70	100.00%	68.63%
PIPO/BOGR-SCSC Woodland	14	14	9	64.29%	64.29%
QUGA Shrubland	19	14	12	63.16%	85.71%
PIED-JUMO/Sparse-Soil Woodland	13	5	5	38.46%	100.00%
Submontane Grassland	38	34	30	78.95%	88.24%
PIED-JUMO/Sparse-Rock Woodland	5	4	2	40.00%	50.00%
Other Shrubland	46	26	25	54.35%	96.15%
PIED-JUMO/ARTR Woodland	17	11	11	64.71%	100.00%
PIED-JUMO/BOER Wooded Grassland	12	10	9	75.00%	90.00%
BRCA-AGTR Grassland	6	4	3	50.00%	75.00%
PIPO Forest	29	29	23	79.31%	79.31%
PIPO/QUGA Woodland	22	19	12	54.55%	63.16%
ABLA-PIEN Forest	12	11	11	91.67%	100.00%
POTR Shrubland	4	5	4	100.00%	80.00%
POTR Forest	11	10	9	81.82%	90.00%
PIPO/Other grass Woodland	8	5	5	62.50%	100.00%
JUMO Wooded Grassland	29	33	29	100.00%	87.88%
RONE Shrubland	3	1	1	33.33%	100.00%
PIED Forest	15	16	15	100.00%	93.75%
Urban, Vegetated	0	2	0	---	---
Urban, Paved	0	36	0	---	---
Totals	583	583	434		

Overall Classification Accuracy = 74.44%

APPENDIX C: Accuracy Totals Reports; 15-m and Quarter-hectare Association Maps

C-1

Accuracy totals:

Map:	Sites used:
15-m association	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	5	9	3	60.00%	33.33%
Montane Grassland	5	4	2	40.00%	50.00%
ABCO-PSME Woodland	1	1	0	0.00%	0.00%
ABCO-PSME Forest	23	30	18	78.26%	60.00%
Evergreen-POTR Forest	11	10	5	45.45%	50.00%
Sparse-Bare soil	11	12	8	72.73%	66.67%
Open water	5	5	5	100.00%	100.00%
Riparian-Wetland	5	5	4	80.00%	80.00%
Sparse-Bare rock	7	10	6	85.71%	60.00%
PIED-JUMO/BOGR Woodland	20	25	10	50.00%	40.00%
PIPO/BOGR-SCSC Woodland	10	5	1	10.00%	20.00%
QUGA Shrubland	13	10	5	38.46%	50.00%
PIED-JUMO/Sparse-Soil Woodland	6	2	1	16.67%	50.00%
Submontane Grassland	18	20	13	72.22%	65.00%
PIED-JUMO/Sparse-Rock Woodland	5	0	0	---	---
Other Shrubland	13	13	7	53.85%	53.85%
PIED-JUMO/ARTR Woodland	4	4	1	25.00%	25.00%
PIED-JUMO/BOER Wooded Grassland	3	2	0	0.00%	0.00%
BRCA-AGTR Grassland	11	6	4	36.36%	66.67%
PIPO Forest	15	14	9	60.00%	64.29%
PIPO/QUGA Woodland	9	10	1	11.11%	10.00%
ABLA-PIEN Forest	4	3	1	25.00%	33.33%
POTR Shrubland	2	4	1	50.00%	25.00%
POTR Forest	11	8	6	54.55%	75.00%
PIPO/Other grass Woodland	2	3	0	0.00%	0.00%
JUMO Wooded Grassland	1	7	0	0.00%	0.00%
RONE Shrubland	1	0	0	---	---
PIED Forest	5	4	2	40.00%	50.00%
Urban, Vegetated	8	10	8	100.00%	80.00%
Urban, Paved	8	6	6	75.00%	100.00%
Totals	242	242	127		

Overall Classification Accuracy = 52.48%

C-2

Accuracy totals:

Map:	Sites used:
Quarter-hectare association	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Valles Caldera Grassland	5	10	3	60.00%	30.00%
Montane Grassland	5	4	3	60.00%	75.00%
ABCO-PSME Woodland	1	0	0	---	---
ABCO-PSME Forest	23	28	17	73.91%	60.71%
Evergreen-POTR Forest	11	10	5	45.45%	50.00%
Sparse-Bare soil	11	14	9	81.82%	64.29%
Open water	5	5	5	100.00%	100.00%
Riparian-Wetland	5	5	4	80.00%	80.00%
Sparse-Bare rock	7	11	7	100.00%	63.64%
PIED-JUMO/BOGR Woodland	20	28	11	55.00%	39.29%
PIPO/BOGR-SCSC Woodland	10	4	1	10.00%	25.00%
QUGA Shrubland	13	9	5	38.46%	55.56%
PIED-JUMO/Sparse-Soil Woodland	6	2	1	16.67%	50.00%
Submontane Grassland	18	19	13	72.22%	68.42%
PIED-JUMO/Sparse-Rock Woodland	5	0	0	---	---
Other Shrubland	13	14	7	53.85%	50.00%
PIED-JUMO/ARTR Woodland	4	4	1	25.00%	25.00%
PIED-JUMO/BOER Wooded Grassland	3	1	0	0.00%	0.00%
BRCA-AGTR Grassland	11	6	4	36.36%	66.67%
PIPO Forest	15	14	10	66.67%	71.43%
PIPO/QUGA Woodland	9	8	2	22.22%	25.00%
ABLA-PIEN Forest	4	6	1	25.00%	16.67%
POTR Shrubland	2	4	1	50.00%	25.00%
POTR Forest	11	7	6	54.55%	85.71%
PIPO/Other grass Woodland	2	3	0	0.00%	0.00%
JUMO Wooded Grassland	1	5	0	0.00%	0.00%
RONE Shrubland	1	0	0	---	---
PIED Forest	5	5	2	40.00%	40.00%
Urban, Vegetated	8	9	8	100.00%	88.89%
Urban, Paved	8	7	7	87.50%	100.00%
Totals	242	242	133		

Overall Classification Accuracy = 54.96%

APPENDIX D: Accuracy Totals Reports for each of the re-classified maps

D-1

Accuracy totals:

Map:	Sites used:
15-m physiognomic	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Urban	16	17	16	100.00%	94.12%
Cerro Grande Fire High-burn severity	22	18	18	81.82%	100.00%
Open water	5	5	5	100.00%	100.00%
Riparian-Wetland	5	5	4	80.00%	80.00%
Sparse-Bare rock	7	10	7	100.00%	70.00%
Piñon-Juniper/Grassland	4	7	0	0.00%	0.00%
Piñon-Juniper Woodland	35	32	25	71.43%	78.13%
Piñon-Juniper Forest	5	5	2	40.00%	40.00%
Grassland	28	32	22	78.57%	68.75%
Shrubland	29	27	18	62.07%	66.67%
Ponderosa pine-Mixed conifer Woodland	22	24	12	54.55%	50.00%
Ponderosa pine Forest	15	10	10	66.67%	100.00%
Mixed conifer-Spruce-Fir Forest	27	32	23	85.19%	71.88%
Aspen Forest	22	18	15	68.18%	83.33%
Totals	242	242	177		

Overall Classification Accuracy = 73.14%

D-2

Accuracy totals:

Map:	Sites used:
15-m class	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Open water	5	5	5	100.00%	100.00%
Urban	16	17	16	100.00%	94.12%
Cerro Grande Fire High-burn severity	22	18	18	81.82%	100.00%
Sparse-Bare rock	7	9	6	85.71%	66.67%
Riparian-Wetland	5	3	2	40.00%	66.67%
Grassland	32	43	26	81.25%	60.47%
Shrubland	29	26	15	51.72%	57.69%
Woodland	57	53	36	63.16%	67.92%
Forest	69	68	59	85.51%	86.76%
Totals	242	242	183		

Overall Classification Accuracy = 75.62%

Accuracy totals:

Map:	Sites used:
15-m taxonomic	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Cerro Grande Fire High-burn severity	22	18	18	81.82%	100.00%
Open water	5	5	5	100.00%	100.00%
Urban-Sparse-Bare rock	23	26	23	100.00%	88.46%
Grass species	28	32	22	78.57%	68.75%
Shrub species	27	23	16	59.26%	69.57%
Piñon-Juniper	44	42	33	75.00%	78.57%
Ponderosa Pine	36	40	26	72.22%	65.00%
Mixed conifer-Spruce Fir	28	31	23	82.14%	74.19%
Aspen-Riparian-Wetland	29	25	19	65.52%	76.00%
Totals	242	242	185		

Overall Classification Accuracy = 76.45%

D-3

Accuracy totals:

Map:	Sites used:
Quarter-hectare physiognomic	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Urban	16	16	16	100.00%	100.00%
Cerro Grande Fire High-burn severity	22	20	20	90.91%	100.00%
Open water	5	5	5	100.00%	100.00%
Riparian-Wetland	5	5	4	80.00%	80.00%
Sparse-Bare rock	7	11	7	100.00%	63.64%
Piñon-Juniper/Grassland	4	5	0	0.00%	0.00%
Piñon-Juniper Woodland	35	34	25	71.43%	73.53%
Piñon-Juniper Forest	5	5	2	40.00%	40.00%
Grassland	28	34	22	78.57%	64.71%
Shrubland	29	28	16	55.17%	57.14%
Ponderosa pine-Mixed conifer Woodland	22	16	7	31.82%	43.75%
Ponderosa pine Forest	15	12	9	60.00%	75.00%
Mixed conifer-Spruce-Fir Forest	27	34	24	88.89%	70.59%
Aspen Forest	22	17	14	63.64%	82.35%
Totals	242	242	171		

Overall Classification Accuracy = 70.66%

D-4

Accuracy totals:

Map:	**Sites used:**
Quarter-hectare class	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Open water	5	5	5	100.00%	100.00%
Urban	16	16	16	100.00%	100.00%
Cerro Grande Fire High-burn severity	22	20	20	90.91%	100.00%
Sparse-Bare rock	7	11	7	100.00%	63.64%
Riparian-Wetland	5	5	4	80.00%	80.00%
Grassland	32	40	24	75.00%	60.00%
Shrubland	29	27	15	51.72%	55.56%
Woodland	57	48	36	63.16%	75.00%
Forest	69	70	60	86.96%	85.71%
Totals	242	242	187		

Overall Classification Accuracy = 77.27%

Accuracy totals:

Map:	**Sites used:**
Quarter-hectare taxonomic	Accuracy assessment

Class Names	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
Cerro Grande Fire High-burn severity	22	20	20	90.91%	100.00%
Open water	5	5	5	100.00%	100.00%
Urban-Sparse-Bare rock	23	26	23	100.00%	88.46%
Grass species	28	34	22	78.57%	64.71%
Shrub species	27	23	13	48.15%	56.52%
Piñon-Juniper	44	45	34	77.27%	75.56%
Ponderosa Pine	36	28	20	55.56%	71.43%
Mixed conifer-Spruce Fir	28	35	24	85.71%	68.57%
Aspen-Riparian-Wetland	29	26	20	68.97%	76.92%
Totals	242	242	181		

Overall Classification Accuracy = 74.79%

APPENDIX E: Area Calculations for the 15-m Map; in total and LANL only.

E-1

Area calculations for the 15-m association map.

Class #	Association Level	Hectares	Acres	Square miles	Square kilometers	Percent
7	Open water	403.22	996.39	1.56	4.03	0.22
29	RONE Shrubland	487.56	1204.78	1.88	4.88	0.27
14	PIED-JUMO/Sparse-Soil Woodland	764.43	1888.95	2.95	7.64	0.42
16	PIED-JUMO/Sparse-Rock Woodland	780.67	1929.07	3.01	7.81	0.43
25	POTR Shrubland	795.32	1965.28	3.07	7.95	0.44
31	Urban, Vegetated	1030.95	2547.53	3.98	10.31	0.57
9	Riparian-Wetland	1556.04	3845.05	6.01	15.56	0.85
20	BRCA-AGTR Grassland	2024.21	5001.91	7.82	20.24	1.11
18	PIED-JUMO/ARTR Woodland	2199.77	5435.74	8.49	22.00	1.21
32	Urban, Paved	2319.43	5731.42	8.96	23.19	1.27
2	Montane Grassland	2322.68	5739.46	8.97	23.23	1.28
26	POTR Forest	2743.51	6779.35	10.59	27.44	1.51
19	PIED-JUMO/BOER Wooded Grassland	2990.47	7389.60	11.55	29.90	1.64
30	PIED Forest	3865.39	9551.57	14.92	38.65	2.12
6	Sparse-Bare soil	4017.48	9927.38	15.51	40.17	2.21
27	PIPO/Other grass Woodland	4793.41	11844.74	18.51	47.93	2.63
13	QUGA Shrubland	4968.07	12276.33	19.18	49.68	2.73
3	ABCO-PSME Woodland	5209.24	12872.29	20.11	52.09	2.86
5	Evergreen-POTR Forest	6487.02	16029.73	25.05	64.87	3.56
10	Sparse-Bare rock	6503.62	16070.76	25.11	65.04	3.57
24	ABLA-PIEN Forest	7104.41	17555.33	27.43	71.04	3.90
12	PIPO/BOGR-SCSC Woodland	7262.14	17945.08	28.04	72.62	3.99
28	JUMO Wooded Grassland	7815.31	19311.99	30.17	78.15	4.29
17	Other Shrubland	8670.67	21425.64	33.48	86.71	4.76
15	Submontane Grassland	8685.74	21462.88	33.54	86.86	4.77
23	PIPO/QUGA Woodland	9357.67	23123.24	36.13	93.58	5.14
1	Valles Caldera Grassland	10224.76	25265.87	39.48	102.25	5.61
21	PIPO Forest	13497.22	33352.27	52.11	134.97	7.41
11	PIED-JUMO/BOGR Woodland	23443.88	57930.93	90.52	234.44	12.87
4	ABCO-PSME Forest	29788.63	73609.13	115.01	297.89	16.36
Sums		182112.93	450009.70	703.14	1821.13	100.00

E-2

Area calculations for the 15-m association map within LANL boundary.

Class #	Association Level	Hectares	Acres	Square miles	Square kilometers	Percent
26	POTR Forest	9.17	22.67	0.04	0.09	0.08
7	Open water	12.61	31.16	0.05	0.13	0.11
24	ABLA-PIEN Forest	14.70	36.33	0.06	0.15	0.13
2	Montane Grassland	21.37	52.80	0.08	0.21	0.19
29	RONE Shrubland	27.87	68.87	0.11	0.28	0.25
25	POTR Shrubland	30.40	75.13	0.12	0.30	0.27
5	Evergreen-POTR Forest	30.57	75.53	0.12	0.31	0.27
1	Valles Caldera Grassland	47.82	118.17	0.18	0.48	0.42
3	ABCO-PSME Woodland	56.14	138.72	0.22	0.56	0.50
27	PIPO/Other grass Woodland	121.40	299.99	0.47	1.21	1.08
9	Riparian-Wetland	131.48	324.90	0.51	1.31	1.17
20	BRCA-AGTR Grassland	152.80	377.58	0.59	1.53	1.36
16	PIED-JUMO/Sparse-Rock Woodland	158.66	392.05	0.61	1.59	1.41
14	PIED-JUMO/Sparse-Soil Woodland	168.99	417.59	0.65	1.69	1.50
31	Urban, Vegetated	177.61	438.88	0.69	1.78	1.58
4	ABCO-PSME Forest	178.10	440.08	0.69	1.78	1.58
19	PIED-JUMO/BOER Wooded Grassland	200.46	495.35	0.77	2.00	1.78
30	PIED Forest	204.20	504.59	0.79	2.04	1.81
6	Sparse-Bare soil	232.98	575.70	0.90	2.33	2.07
18	PIED-JUMO/ARTR Woodland	266.19	657.77	1.03	2.66	2.36
13	QUGA Shrubland	266.28	658.00	1.03	2.66	2.36
28	JUMO Wooded Grassland	410.52	1014.41	1.59	4.11	3.64
21	PIPO Forest	479.20	1184.12	1.85	4.79	4.25
10	Sparse-Bare rock	527.00	1302.23	2.03	5.27	4.68
23	PIPO/QUGA Woodland	540.26	1335.00	2.09	5.40	4.80
32	Urban, Paved	764.25	1888.49	2.95	7.64	6.78
17	Other Shrubland	964.25	2382.70	3.72	9.64	8.56
12	PIPO/BOGR-SCSC Woodland	982.27	2427.24	3.79	9.82	8.72
15	Submontane Grassland	1052.27	2600.22	4.06	10.52	9.34
11	PIED-JUMO/BOGR Woodland	3034.77	7499.05	11.72	30.35	26.94
Sums		11264.58	27835.32	43.49	112.65	100.00

E-3

Area calculations for the 15-m physiognomic map.

Class #	Physiognomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	403.22	996.39	1.56	4.03	0.22
49	Riparian-Wetland	1556.04	3845.05	6.01	15.56	0.85
40	Urban	3350.38	8278.95	12.94	33.50	1.84
53	Piñon-Juniper Forest	3865.39	9551.57	14.92	38.65	2.12
45	Cerro Grande Fire High-burn severity	6041.68	14929.29	23.33	60.42	3.32
50	Sparse-Bare rock	6503.62	16070.76	25.11	65.04	3.57
61	Aspen Forest	9230.53	22809.08	35.64	92.31	5.07
51	Piñon-Juniper/Grassland	10805.78	26701.60	41.72	108.06	5.93
59	Ponderosa pine Forest	13497.22	33352.27	52.11	134.97	7.41
56	Shrubland	14921.62	36872.03	57.61	149.22	8.19
55	Grassland	21233.19	52468.21	81.98	212.33	11.66
58	Ponderosa pine-Mixed conifer Woodland	26622.46	65785.35	102.79	266.23	14.62
52	Piñon-Juniper Woodland	27188.75	67184.69	104.98	271.89	14.93
60	Mixed conifer-Spruce-Fir Forest	36893.04	91164.45	142.44	368.93	20.26
Sums		182112.93	450009.70	703.14	1821.13	100.00

Area calculations for the 15-m physiognomic map within LANL boundary.

Class #	Physiognomic Level	Hectares	Acres	Square miles	Square Kilometers	Percent
47	Open water	12.61	31.16	0.05	0.13	0.11
61	Aspen Forest	39.74	98.20	0.15	0.40	0.35
49	Riparian-Wetland	131.48	324.90	0.51	1.31	1.17
60	Mixed conifer-Spruce-Fir Forest	192.80	476.41	0.74	1.93	1.71
53	Piñon-Juniper Forest	204.20	504.59	0.79	2.04	1.81
45	Cerro Grande Fire High-burn severity	385.78	953.29	1.49	3.86	3.42
59	Ponderosa pine Forest	479.20	1184.12	1.85	4.79	4.25
50	Sparse-Bare rock	527.00	1302.23	2.03	5.27	4.68
51	Piñon-Juniper/Grassland	610.98	1509.76	2.36	6.11	5.42
40	Urban	941.86	2327.37	3.64	9.42	8.36
55	Grassland	1121.46	2771.19	4.33	11.21	9.96
56	Shrubland	1288.81	3184.70	4.98	12.89	11.44
58	Ponderosa pine-Mixed conifer Woodland	1700.07	4200.94	6.56	17.00	15.09
52	Piñon-Juniper Woodland	3628.61	8966.46	14.01	36.29	32.21
Sums		11264.58	27835.32	43.49	112.65	100.00

E-4

Area calculations for the 15-m class map.

Class #	Class Level	Hectares	Acres	Square miles	Square kilometers	Percent
100	Open water	403.22	996.39	1.56	4.03	0.22
104	Riparian-Wetland	1556.04	3845.05	6.01	15.56	0.85
101	Urban	3350.38	8278.95	12.94	33.50	1.84
102	Cerro Grande Fire High-burn severity	6041.68	14929.29	23.33	60.42	3.32
103	Sparse-Bare rock	6503.62	16070.76	25.11	65.04	3.57
106	Shrubland	14921.62	36872.03	57.61	149.22	8.19
105	Grassland	32038.97	79169.81	123.70	320.39	17.59
107	Woodland	53811.21	132970.04	207.77	538.11	29.55
108	Forest	63486.19	156877.38	245.12	634.86	34.86
Sums		182112.93	450009.70	703.14	1821.13	100.00

Area calculations for the 15-m class map within LANL boundary.

Class #	Class Level	Hectares	Acres	Square miles	Square kilometers	Percent
100	Open water	12.61	31.16	0.05	0.13	0.11
104	Riparian-Wetland	131.48	324.90	0.51	1.31	1.17
102	Cerro Grande Fire High-burn severity	385.78	953.29	1.49	3.86	3.42
103	Sparse-Bare rock	527.00	1302.23	2.03	5.27	4.68
108	Forest	915.94	2263.32	3.54	9.16	8.13
101	Urban	941.86	2327.37	3.64	9.42	8.36
106	Shrubland	1288.81	3184.70	4.98	12.89	11.44
105	Grassland	1732.44	4280.95	6.69	17.32	15.38
107	Woodland	5328.67	13167.40	20.57	53.29	47.30
Sums		11264.58	27835.32	43.49	112.65	100.00

E-5

Area calculations for the 15-m taxonomic map.

Class #	Taxonomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	403.22	996.39	1.56	4.03	0.22
45	Cerro Grande Fire High-burn severity	6041.68	14929.29	23.33	60.42	3.32
70	Urban-Sparse-Bare rock	9854.01	24349.72	38.05	98.54	5.41
90	Aspen-Riparian-Wetland	11581.90	28619.42	44.72	115.82	6.36
76	Shrub species	14126.29	34906.74	54.54	141.26	7.76
75	Grass species	21233.19	52468.21	81.98	212.33	11.66
81	Ponderosa Pine	34910.43	86265.33	134.79	349.11	19.17
80	Piñon-Juniper	41859.92	103437.86	161.62	418.60	22.99
82	Mixed conifer-Spruce Fir	42102.29	104036.74	162.56	421.02	23.12
Sums		182112.93	450009.70	703.14	1821.13	100.00

Area calculations for the 15-m taxonomic map within LANL boundary.

Class #	Taxonomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	12.61	31.16	0.05	0.13	0.11
90	Aspen-Riparian-Wetland	201.62	498.22	0.78	2.02	1.79
82	Mixed conifer-Spruce Fir	248.94	615.13	0.96	2.49	2.21
45	Cerro Grande Fire High-burn severity	385.78	953.29	1.49	3.86	3.42
75	Grass species	1121.46	2771.19	4.33	11.21	9.96
76	Shrub species	1258.40	3109.57	4.86	12.58	11.17
70	Urban-Sparse-Bare rock	1468.85	3629.60	5.67	14.69	13.04
81	Ponderosa Pine	2123.13	5246.34	8.20	21.23	18.85
80	Piñon-Juniper	4443.79	10980.81	17.16	44.44	39.45
Sums		11264.58	27835.32	43.49	112.65	100.00

APPENDIX F: Area Calculations for the Quarter-Hectare Map; in total and LANL only

F-1

Area calculations for the entire quarter-hectare association map.

Class	Association Level	Hectares	Acres	Square miles	Square kilometers	Percent
29	RONE Shrubland	113.06	279.39	0.44	1.13	0.06
16	PIED-JUMO/Sparse-Rock Woodland	267.75	661.62	1.03	2.68	0.15
14	PIED-JUMO/Sparse-Soil Woodland	383.20	946.92	1.48	3.83	0.21
25	POTR Shrubland	445.59	1101.07	1.72	4.46	0.24
7	Open water	446.36	1102.97	1.72	4.46	0.25
9	Riparian-Wetland	943.67	2331.85	3.64	9.44	0.52
32	Urban, Paved	976.88	2413.92	3.77	9.77	0.54
31	Urban, Vegetated	1247.65	3083.00	4.82	12.48	0.69
18	PIED-JUMO/ARTR Woodland	1354.98	3348.21	5.23	13.55	0.74
26	POTR Forest	1467.37	3625.93	5.67	14.67	0.81
2	Montane Grassland	1816.80	4489.40	7.01	18.17	1.00
20	BRCA-AGTR Grassland	2030.08	5016.43	7.84	20.30	1.11
19	PIED-JUMO/BOER Wooded Grassland	2343.03	5789.74	9.05	23.43	1.29
3	ABCO-PSME Woodland	2785.95	6884.21	10.76	27.86	1.53
30	PIED Forest	3784.85	9352.53	14.61	37.85	2.08
27	PIPO/Other grass Woodland	4048.34	10003.65	15.63	40.48	2.22
6	Sparse-Bare soil	4466.50	11036.94	17.25	44.67	2.45
13	QUGA Shrubland	4563.47	11276.55	17.62	45.63	2.51
5	Evergreen-POTR Forest	5813.44	14365.29	22.45	58.13	3.19
10	Sparse-Bare Rock	6433.55	15897.61	24.84	64.34	3.53
24	ABLA-PIEN Forest	6522.16	16116.56	25.18	65.22	3.58
17	Other Shrubland	7091.70	17523.94	27.38	70.92	3.89
12	PIPO/BOGR-SCSC Woodland	7606.81	18796.78	29.37	76.07	4.18
28	JUMO Wooded Grassland	8432.53	20837.19	32.56	84.33	4.63
23	PIPO/QUGA Woodland	8472.20	20935.22	32.71	84.72	4.65
15	Submontane Grassland	8485.56	20968.22	32.76	84.86	4.66
1	Valles Caldera Grassland	11409.91	28194.43	44.05	114.10	6.27
21	PIPO Forest	14475.24	35769.00	55.89	144.75	7.95
11	PIED-JUMO/BOGR Woodland	28080.23	69387.58	108.42	280.80	15.42
4	ABCO-PSME Forest	35804.05	88473.50	138.24	358.04	19.66
Sums		182112.91	450009.64	703.14	1821.13	100.00

F-2

Area calculations for the quarter-hectare association map within LANL boundary.

Class #	Association Level	Hectares	Acres	Square miles	Square kilometers	Percent
24	ABLA-PIEN Forest	2.39	5.91	0.01	0.02	0.02
2	Montane Grassland	3.41	8.44	0.01	0.03	0.03
26	POTR Forest	5.25	12.97	0.02	0.05	0.05
29	RONE Shrubland	11.38	28.12	0.04	0.11	0.10
7	Open water	15.05	37.19	0.06	0.15	0.13
5	Evergreen-POTR Forest	15.98	39.49	0.06	0.16	0.14
25	POTR Shrubland	16.86	41.67	0.07	0.17	0.15
3	ABCO-PSME Woodland	20.21	49.93	0.08	0.20	0.18
1	Valles Caldera Grassland	30.43	75.18	0.12	0.30	0.27
27	PIPO/Other grass Woodland	50.35	124.43	0.19	0.50	0.45
9	Riparian-Wetland	58.04	143.42	0.22	0.58	0.52
16	PIED-JUMO/Sparse-Rock Woodland	73.53	181.70	0.28	0.74	0.65
14	PIED-JUMO/Sparse-Soil Woodland	93.76	231.69	0.36	0.94	0.83
20	BRCA-AGTR Grassland	120.61	298.04	0.47	1.21	1.07
18	PIED-JUMO/ARTR Woodland	127.93	316.12	0.49	1.28	1.14
19	PIED-JUMO/BOER Wooded Grassland	148.46	366.85	0.57	1.48	1.32
30	PIED Forest	160.63	396.93	0.62	1.61	1.43
31	Urban, Vegetated	185.23	457.70	0.72	1.85	1.64
4	ABCO-PSME Forest	232.07	573.46	0.90	2.32	2.06
6	Sparse-Bare soil	272.63	673.67	1.05	2.73	2.42
13	QUGA Shrubland	287.98	711.61	1.11	2.88	2.56
32	Urban, Paved	379.02	936.58	1.46	3.79	3.36
28	JUMO Wooded Grassland	392.96	971.02	1.52	3.93	3.49
23	PIPO/QUGA Woodland	451.33	1115.25	1.74	4.51	4.01
21	PIPO Forest	478.41	1182.17	1.85	4.78	4.25
10	Sparse-Bare Rock	527.30	1302.98	2.04	5.27	4.68
17	Other Shrubland	840.24	2076.28	3.24	8.40	7.46
12	PIPO/BOGR-SCSC Woodland	1124.32	2778.25	4.34	11.24	9.98
15	Submontane Grassland	1161.39	2869.84	4.48	11.61	10.31
11	PIED-JUMO/BOGR Woodland	3977.44	9828.43	15.36	39.77	35.31
Sums		11264.58	27835.32	43.49	112.65	100.00

F-3

Area calculations for the quarter-hectare physiognomic map.

Class #	Physiognomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	446.36	1102.97	1.72	4.46	0.25
49	Riparian-Wetland	943.67	2331.85	3.64	9.44	0.52
40	Urban	2224.53	5496.92	8.59	22.25	1.22
53	Piñon-Juniper Forest	3784.85	9352.53	14.61	37.85	2.08
50	Sparse-Bare rock	6433.55	15897.61	24.84	64.34	3.53
45	Cerro Grande Fire High-burn severity	6496.59	16053.37	25.08	64.97	3.57
61	Aspen Forest	7280.81	17991.22	28.11	72.81	4.00
51	Piñon-Juniper/Grassland	10775.56	26626.93	41.60	107.76	5.92
56	Shrubland	12213.83	30180.95	47.16	122.14	6.71
59	Ponderosa pine Forest	14475.24	35769.00	55.89	144.75	7.95
55	Grassland	21712.27	53652.04	83.83	217.12	11.92
58	Ponderosa pine-Mixed conifer Woodland	22913.30	56619.86	88.47	229.13	12.58
52	Piñon-Juniper Woodland	30086.16	74344.32	116.16	300.86	16.52
60	Mixed conifer-Spruce-Fir Forest	42326.21	104590.06	163.42	423.26	23.24
Sums		182112.91	450009.64	703.14	1821.13	100.00

Area calculations for the quarter-hectare physiognomic map within LANL boundary.

Class #	Physiognomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	15.05	37.19	0.06	0.15	0.13
61	Aspen Forest	21.23	52.46	0.08	0.21	0.19
49	Riparian-Wetland	58.04	143.42	0.22	0.58	0.52
53	Piñon-Juniper Forest	160.63	396.93	0.62	1.61	1.43
60	Mixed conifer-Spruce-Fir Forest	234.47	579.38	0.91	2.34	2.08
45	Cerro Grande Fire High-burn severity	393.24	971.71	1.52	3.93	3.49
59	Ponderosa pine Forest	478.41	1182.17	1.85	4.78	4.25
50	Sparse-Bare rock	527.30	1302.98	2.04	5.27	4.68
51	Piñon-Juniper/Grassland	541.42	1337.87	2.09	5.41	4.81
40	Urban	564.25	1394.29	2.18	5.64	5.01
56	Shrubland	1156.46	2857.68	4.47	11.56	10.27
55	Grassland	1195.23	2953.47	4.61	11.95	10.61
58	Ponderosa pine-Mixed conifer Woodland	1646.21	4067.85	6.36	16.46	14.61
52	Piñon-Juniper Woodland	4272.66	10557.94	16.50	42.73	37.93
Sums		11264.58	27835.32	43.49	112.65	100.00

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Area calculations for the quarter-hectare class map.

Class #	Class Level	Hectares	Acres	Square miles	Square kilometers	Percent
100	Open water	446.36	1102.97	1.72	4.46	0.25
104	Riparian-Wetland	943.67	2331.85	3.64	9.44	0.52
101	Urban	2224.53	5496.92	8.59	22.25	1.22
103	Sparse-Bare rock	6433.55	15897.61	24.84	64.34	3.53
102	Cerro Grande Fire High-burn severity	6496.59	16053.37	25.08	64.97	3.57
106	Shrubland	12213.83	30180.95	47.16	122.14	6.71
105	Grassland	32487.83	80278.97	125.44	324.88	17.84
107	Woodland	52999.46	130964.18	204.63	530.00	29.10
108	Forest	67867.10	167702.83	262.04	678.67	37.27
Sums		182112.91	450009.64	703.14	1821.13	100.00

Area calculations for the quarter-hectare class map within LANL boundary.

Class #	Class Level	Hectares	Acres	Square miles	Square kilometers	Percent
100	Open water	15.05	37.19	0.06	0.15	0.13
104	Riparian-Wetland	58.04	143.42	0.22	0.58	0.52
102	Cerro Grande Fire High-burn severity	393.24	971.71	1.52	3.93	3.49
103	Sparse-Bare rock	527.30	1302.98	2.04	5.27	4.68
101	Urban	564.25	1394.29	2.18	5.64	5.01
108	Forest	894.73	2210.92	3.45	8.95	7.94
106	Shrubland	1156.46	2857.68	4.47	11.56	10.27
105	Grassland	1736.65	4291.34	6.71	17.37	15.42
107	Woodland	5918.87	14625.80	22.85	59.19	52.54
Sums		11264.58	27835.32	43.49	112.65	100.00

F-5

Area calculations for the quarter-hectare taxonomic map.

Class #	Taxonomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	446.36	1102.97	1.72	4.46	0.25
45	Cerro Grande Fire High-burn severity	6496.59	16053.37	25.08	64.97	3.57
70	Urban-Sparse-Bare rock	8658.08	21394.53	33.43	86.58	4.75
90	Aspen-Riparian-Wetland	8670.07	21424.14	33.48	86.70	4.76
76	Shrub species	11768.24	29079.87	45.44	117.68	6.46
75	Grass species	21712.27	53652.04	83.83	217.12	11.92
81	Ponderosa Pine	34602.60	85504.66	133.60	346.03	19.00
80	Piñon-Juniper	44646.57	110323.78	172.38	446.47	24.52
82	Mixed conifer-Spruce Fir	45112.15	111474.27	174.18	451.12	24.77
Sums		182112.91	450009.64	703.14	1821.13	100.00

Area calculations for the quarter-hectare taxonomic map within LANL boundary.

Class #	Taxonomic Level	Hectares	Acres	Square miles	Square kilometers	Percent
47	Open water	15.05	37.19	0.06	0.15	0.13
90	Aspen-Riparian-Wetland	96.13	237.55	0.37	0.96	0.85
82	Mixed conifer-Spruce Fir	254.67	629.31	0.98	2.55	2.26
45	Cerro Grande Fire High-burn severity	393.24	971.71	1.52	3.93	3.49
70	Urban-Sparse-Bare rock	1091.55	2697.27	4.21	10.92	9.69
76	Shrub species	1139.60	2816.01	4.40	11.40	10.12
75	Grass species	1195.23	2953.47	4.61	11.95	10.61
81	Ponderosa Pine	2104.41	5200.09	8.13	21.04	18.68
80	Piñon-Juniper	4974.71	12292.74	19.21	49.75	44.16
Sums		11264.58	27835.32	43.49	112.65	100.00

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