SWCA
ENVIRONMENTAL CONSULTANTS

ESTANCIA BASIN
WATERSHED HEALTH AND MONITORING PROJECT: YEAR ONE ANNUAL REPORT, 2007-2008

Prepared for

ESTANCIA BASIN WATERSHED HEALTH, RESTORATION AND MONITORING STEERING COMMITTEE

Composed of: Claunch Pinto Soil and Water Conservation District, Edgewood Soil and Water Conservation District, East Torrance Soil and Water Conservation District, Estancia Basin Water Planning Committee, Chillili Land Grant, Manzano Land Grant, New Mexico State Forestry, New Mexico Environment Department, New Mexico Forest and Watershed Restoration Institute, New Mexico Department of Agriculture.
(with funding through the New Mexico Water Trust Board)

CLAUNCH-PINTO SOIL AND WATER CONSERVATION DISTRICT
Fiscal agent

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EXECUTIVE SUMMARY

The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee) oversees forest thinning projects and monitoring of forest and watershed health in the Estancia Basin in coordination with the New Mexico Forest and Watershed Restoration Institute. The primary goals of the Steering Committee are to improve forest health and create defensible space from wildfire. Funding for forest and watershed monitoring was provided by the New Mexico Water Trust Board.

SWCA Environmental Consultants (SWCA) was awarded a contract to conduct monitoring for forest thinning effectiveness on the eastern slopes of the Manzano Mountains in 2007. SWCA finalized a comprehensive monitoring plan in March 2008—which is available online at the New Mexico Forest and Watershed Restoration Institute's website—that provides background information and a discussion of methods relative to forest thinning and monitoring. The monitoring plan calls for two years of pre-thinning data to provide background information on all study sites prior to implementing thinning treatments and monitoring treatment effectiveness. The principal goals of forest and watershed monitoring are to determine the effectiveness of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife. SWCA is responsible for planning and implementing forest thinning monitoring in order to evaluate the effectiveness of forest thinning treatments relative to soils, hydrology, vegetation, and wildlife. SWCA has also assumed responsibility for the South Mountain Weather Station that had been previously installed by another contractor. After monitoring began, three major wildfires (Ojo Peak, Trigo, and Big Spring) occurred in the monitoring area in late 2007 and early 2008. The Trigo fire destroyed one of the forest thinning monitoring sites, which was replaced during summer 2008. SWCA has additionally initiated a monitoring study of post-Trigo fire recovery of private forest lands.

This annual report provides information on the results of forest thinning and post-wildfire monitoring. We provide summaries of weather data from the South Mountain Weather Station that was installed in 2006, which serves as a baseline for monitoring area climate data. Initial baseline pre-treatment monitoring data from permanent monitoring study sites provide information on rainfall, ambient and soil temperatures, soil moisture, soil surface profiles to assess erosion over time, soil surface stability, soil chemistry, vegetation composition, structure and cover, and bird and small mammal composition and relative abundance. The monitoring sampling design employs paired monitoring plots at two piñon/juniper woodland sites and two ponderosa pine sites. One plot of each pair will be randomly selected and treated by forest thinning in late 2009 and early 2010. We will then monitor the above mentioned parameters until at least 2011 to examine the impacts and effectiveness of forest thinning treatments. Not only will paired study plots be compared to each other in a treatment/control design, but also each treated plot will be monitored over time in order to assess change resulting from thinning treatments.

Results for the first year of monitoring show that few significant differences in parameters were measured between the paired study plots. In situations where we did find significant differences between paired treatment and control plots, we will be able to interpret future monitoring data from those naturally occurring differences and focus more on study plot assessments of change over time, relative to each of the paired plots.

First-year results from the post-wildfire monitoring suggest that the Trigo burn area was impacted by a range of fire behavior that created a mosaic of fire effects. Tree mortality was mixed from 100% loss across a stand to patchy mortality. Complete consumption of ponderosa in large areas could cause a significant change to the overstory species composition, particularly as ponderosa pine regeneration is expected to be slow where the fire caused severe damage to the soil substrate. Measurements in 2009 will help determine whether scorched trees can survive the initial burn damage. Initial observations suggest that herbaceous species recovery in some areas, particularly areas that received low-severity burn, will be significant over the coming years. High-severity areas are showing signs of elevated levels of erosion, which will be more easily quantified when compared with 2009 measurements. Hydrology findings suggest areas affected by severe burn will likely see increased runoff and reduced infiltration. The magnitude at which this occurs may be reduced in upcoming years as vegetation regrowth reduces the speed at which water runoff occurs. A study across the project area suggests that burn severity varies with stand density, with a visible trend of increasing severity with tree density. Severity did vary across the burn area, however, suggesting the importance of other variables, including weather, topography, and neighboring stand structure and composition. A comparison of thinned forest areas to adjacent untreated areas shows that thinning has reduced wildfire intensity.

The Trigo fire is likely to have long-term implications on hydrologic processes throughout the basin. Stream piezometer have been installed on several drainages below both the Trigo burn area and future forest thinning areas, including our monitoring sites, to measure and document changes in runoff. Preliminary hydrology monitoring suggests that the fire has caused an increase in runoff and is likely to contribute to additional erosion and sediment load being carried down ephemeral channels.

We will continue the current monitoring efforts for year two of this project. Forest thinning treatments will be implemented in the autumn and winter of 2009/2010, and we will then begin monitoring post-thinning treatment conditions in spring 2010. Post-wildfire monitoring will continue through 2009 and perhaps beyond depending on the availability of funding. At this time, we do not anticipate changes in the current monitoring designs or methods.

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INTRODUCTION

The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee) is overseeing forest thinning and effectiveness monitoring of forest thinning on ponderosa pine (*Pinus ponderosa*) forests and piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodlands on private and state lands on the eastern slopes of the Manzano Mountains, New Mexico. Principal members of the Steering Committee include the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts; New Mexico State Forestry; and the New Mexico Forest and Watershed Restoration Institute (Restoration Institute). The Restoration Institute is additionally providing oversight and public relations for forest thinning and monitoring activities.

The principal goals of the Steering Committee are to create defensible space around homes and other structures from wildfire and to improve overall forest health, following forest thinning prescriptions determined by New Mexico State Forestry. The primary goals of forest thinning monitoring are to determine the impacts of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife.

The scope of work for this particular monitoring project was described in the Steering Committee's 2007 request for proposals as follows:

1. Plan and implement methods to determine how vegetation thinning and removal affect water yield.
2. Plan and implement methods of establishing reliable and repeatable vegetation monitoring methods to allow for both qualitative interpretation and quantitative documentation of change in vegetative structure and composition over time.
3. Plan and implement methods of monitoring small mammal and avian populations, which are indicators of ecosystem health.

The environmental effectiveness monitoring of forest thinning projects in the Estancia Basin was contracted to private consulting companies with funding provided primarily by the New Mexico Water Trust Board. EnviroLogic, Inc. (EnviroLogic), initiated monitoring efforts in 2005 and 2006 by installing the South Mountain Weather Station. SWCA Environmental Consultants (SWCA) was then contracted in 2007 to develop and to implement a forest monitoring plan. SWCA produced a comprehensive forest thinning monitoring plan in March 2008 and implemented monitoring studies in early 2008. The "Estancia Basin Watershed Health and Monitoring Project: Monitoring Plan Evaluation" (Monitoring Plan) (SWCA 2008) is available at the Restoration Institute website (http://www.nmfwri.org/). The Monitoring Plan provides detailed information on the background knowledge of forest thinning in the Southwest and goals and methodologies for the Estancia Basin forest thinning monitoring project. SWCA is currently under contract for five years of monitoring, beginning in 2008, and is responsible for study site maintenance, data collection, data management, data analysis and interpretation, and information dissemination (including monthly meetings, monthly reports, and annual reports). The current plan calls for two years of baseline pre-thinning treatment monitoring, thinning treatments implemented in 2009/2010, and post-treatment monitoring from 2010 through 2011.

Several new subprojects have been added to the overall monitoring project in 2008, including 1) 2) conducting post-fire monitoring of soils, hydrology, vegetation, and wildlife on private forest lands following the Trigo wildfire; and 3) developing and partially implementing ephemeral stream and groundwater monitoring to assess the effects of both forest thinning and the Trigo fire on water resources; and assuming the operation and reporting for the South Mountain Weather Station (SMWS), initiated by EnviroLogic in 2006. A map of all study sites for these projects is presented in Figure 1 (note that SMWS is located north of Edgewood, New Mexico, and is not on the map presented in Figure 1, but is on maps presented in Figure 95 and Figure 96).

Numerous discrete datasets have been collected, and SWCA has been active in creating data collection, storage, and management plans for each of these subprojects. SWCA has created metadata for each of these datasets that outlines the date range of each dataset, the collection methods, the unit measurements, and the abbreviations and codes used within each data file. The metadata files will also state any caveats or general comments to which the viewer should be aware before analyzing the data.

SWCA intends to make these data available in a form that can be easily disseminated, using readily available software packages such as Microsoft Word and Excel. Some information, such as those data collected from the WatchDog Mini Weather Stations, is collected using proprietary software. These data are being converted into Microsoft Excel files so they can be viewed by the general public. We also intend to make the data available in forms that are easy to analyze. Some data, such as those related to the flumes, which are recorded in five-minute intervals, must be partitioned into several files as the data exceeds Microsoft Excel's capacity of data rows. All of these data are being made available to the Restoration Institute for dissemination on their website. Note that measurements from various aspects of the monitoring are reported in English units (e.g., feet, acres), while others are reported in metric units (meters, hectares). The protocols for monitoring measurements were obtained from different sources that use different units of measure. The U.S. Department of Agriculture (USDA) Agricultural Research Service Rangeland Monitoring Manual (Herrick et. 2005) uses metric units, while the U.S. Forest Service Forest (USFS) Inventory and Analysis manual (USFS 2005) uses English units. In general, scientific research worldwide has adopted the metric system as the standard for measurements, while some federal and state agencies use English units of measure. Values are presented in the report with both English and metric units.

This annual report provides summaries of findings from field monitoring measurements conducted during the calendar year 2008 for the above mentioned projects and subprojects. This report is partitioned into different sections for each subproject: 1) the original forest thinning monitoring; 2) newly added post-wildfire monitoring; 3) updated ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; 4) South Mountain Weather Station; and 5) overall plans for year two (2009).

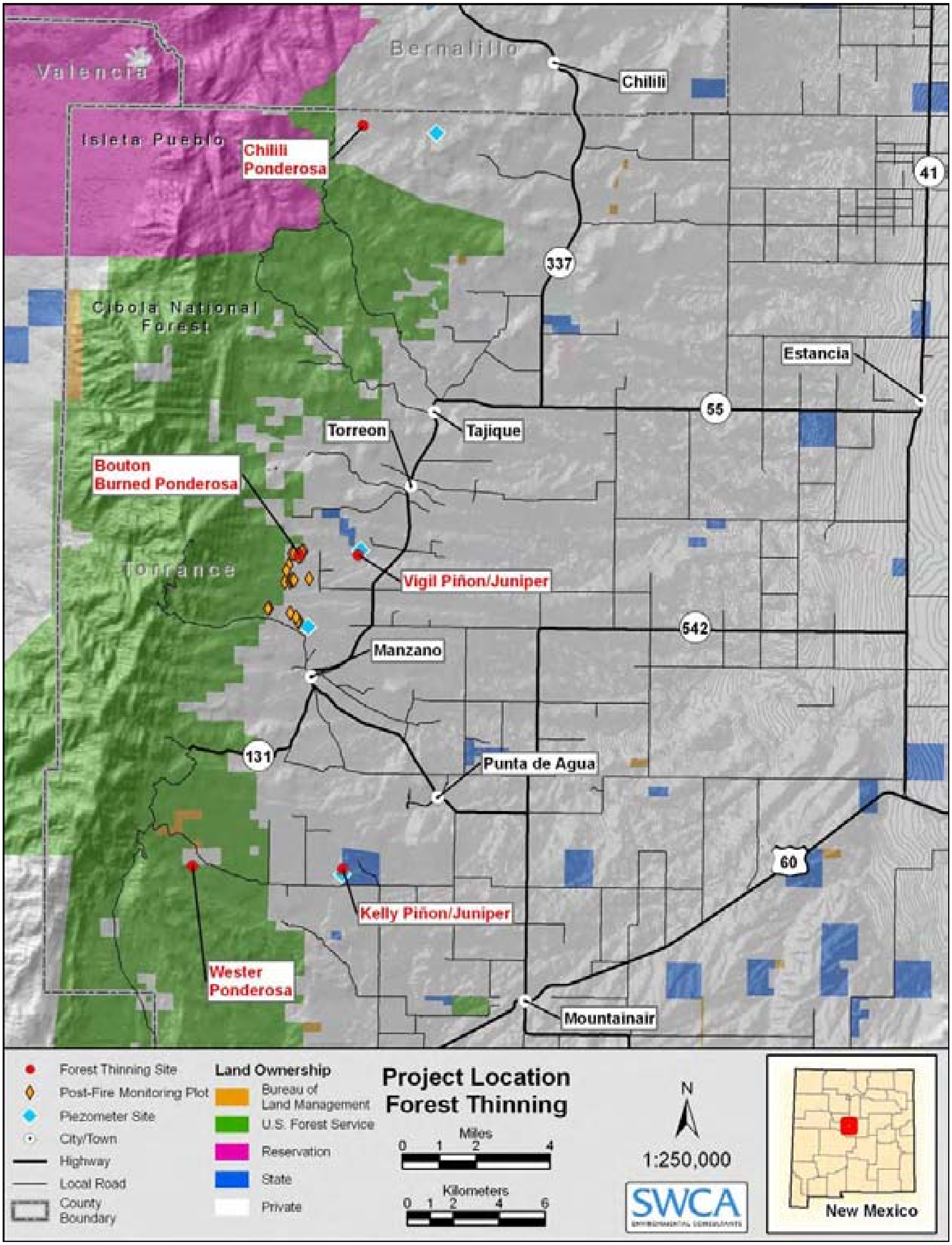

Figure 1. Map of all Estancia Basin forest and watershed monitoring locations addressed in this report.

FOREST THINNING MONITORING

Details of forest thinning monitoring are provided in the Monitoring Plan (SWCA 2008), which was submitted to the Steering Committee in March 2008. Background information on the known environmental effects of forest thinning on southwestern forest ecosystems is presented in the Monitoring Plan, along with detailed discussions of the experimental study design and methods used in this research to measure various environmental responses to forest thinning treatments.

Forest thinning projects on private lands on the eastern slopes of the Manzano Mountains are overseen by the Steering Committee and include projects in both ponderosa pine forests and piñon/juniper woodlands. Forest thinning monitoring has been designed to address forest thinning in both of these forest types, so four monitoring study sites have been established: two in ponderosa pine forests and two in piñon/juniper woodlands. Each ponderosa pine site has been paired with a piñon/juniper site in the same watershed, so that each of two watersheds have a ponderosa pine and a piñon/juniper monitoring site. One pair of sites is situated at the northern end of the study area (eastern slopes of the Manzano Mountains), and the other at the southern end (see Figure 1). Two paired study plots have been installed at each of the four study sites. One plot of each pair will be randomly selected for forest thinning treatments, and the other plot of the pair will serve as an untreated control.

Actual forest thinning treatments will not be implemented until late 2009 or early 2010, so this year-one report presents pre-thinning treatment baseline data and comparisons of paired study plots. Once forest thinning treatments have been implemented, the various environmental parameters being measured will be compared between the treatment and control study plots, and each study plot will be compared to itself over time.

Recent wildfires in the Estancia Basin have exemplified the need for forest thinning activities and monitoring. The Trigo fire burned 13,790 acres of primarily ponderosa pine forest on the eastern slopes of the Manzano Mountains in April 2008. One of the ponderosa forest thinning monitoring sites, the Bouton site, was burned in the Trigo fire. One of the paired study plots (plot 1) burned intensely by crown fire, and most trees were destroyed (Figure 2a). The other plot (plot 2), only 100 m (328 feet) away, was burned lightly by ground fire with most trees surviving the fire (Figure 2b). The rain gauge and hydrology flume data loggers were destroyed at plot 1, but not damaged at plot 2. Since the site was burned, we could no longer use it for forest thinning monitoring. The Steering Committee decided to maintain the site as a fire monitoring site and to establish a new replacement ponderosa pine monitoring site. Please see the Post-fire Monitoring section of this report relative to the Bouton monitoring site.

Figure 2. Bouton ponderosa pine forest thinning study site plots burned in the Trigo fire, May 2008.
a. Bouton plot 1, intensely burned. b. Bouton plot 2, lightly burned.

Most of the existing ponderosa pine forest on private lands near the Bouton site has been destroyed in the Trigo fire. We have located and established a new replacement ponderosa pine forest site as close as we could to the Bouton site, on the Chilili Land Grant, approximately 20 km (12 miles) to the northwest (Figure 3). The new Chilili ponderosa pine site has been installed with the same experimental design of two paired study plot locations approximately 100 m (328 feet) apart. Each of the paired plot locations are situated within a separate but adjacent subwatershed and include a vegetation and soils measurement study plot, an adjacent bird and small mammal sampling plot, an automated rain gauge, and a hydrology flume. See Figure 1 for a map of all four forest thinning sites, including the replacement Chilili ponderosa pine site.

Most of the graphical results presented in this report focus on the Kelly piñon/juniper woodland and the Wester ponderosa pine forest sites to provide examples of findings. The same types of graphs and analyses can be produced for all four study sites. Data for all sites will be available by early 2009 at the Restoration Institute website (http://www.nmfwri.org/).

Figure 3. Photo point at the new Chilili ponderosa pine site.

AUTOMATED RAIN GAUGE AND TEMPERATURE RECORDING STATIONS

Spectrum WatchDog automated data-logging rain gauges installed at each of the paired vegetation and soils monitoring plots (8 total at 4 sites) have run continuously since they were installed in November 2007 (Figure 4). The tipping bucket rain gauges are set to record rainfall and snowmelt sums at one-hour intervals continuously. In autumn 2008, a graduated cylinder rain gauge was added to each of the automated rain gauge locations to serve as backups in case of power failure or other malfunction of the data logger. These graduated rain gauges and their recorded values are checked monthly when Time Domain Reflectometer (TDR) soil moisture and temperature readings are taken (see section on soil water content below). Mineral oil is added to the rain gauges to prevent evaporation of water collected. The WatchDog stations are also set to record ambient temperature, soil moisture 10 cm (4 inches) below the soil surface (-10 cm), and soil temperature -10 cm, all at one-hour increments. The WatchDog station soil moisture and temperature data are meant to provide baseline comparisons for the Field Scout TDR 200 soil water content and soil temperature data that are sampled monthly at each study plot (see below). All data from those stations are off-loaded approximately every three months and entered into a database. Although data has been recorded since November 2007, measurements were not initiated at the new Chilili site until September 2008; therefore, the results for rainfall, ambient temperature, soil moisture, and soil temperature from the Wester ponderosa site and the Kelly piñon/juniper woodland site are presented as examples.

Figure 4. WatchDog automated Mini Weather Station.

Precipitation (rainfall and snow)

Hourly precipitation totals have been summed to monthly totals, and Figure 5 and Figure 6 show similar monthly precipitation totals between the paired study plots (1 and 2) at the Kelly piñon/juniper and Wester ponderosa study sites. Precipitation amounts at the Kelly site plots are especially similar. Precipitation amounts in May and June at the Wester study plots vary slightly more than the Kelly plots, indicating spatial variation in rainfall from thunderstorms. We used standard t-tests to test the hypothesis of no difference in mean monthly precipitation between the paired plots at both sites over the one-year period, and the results of those tests show no significant differences in precipitation between each of the two sets or paired study plots.

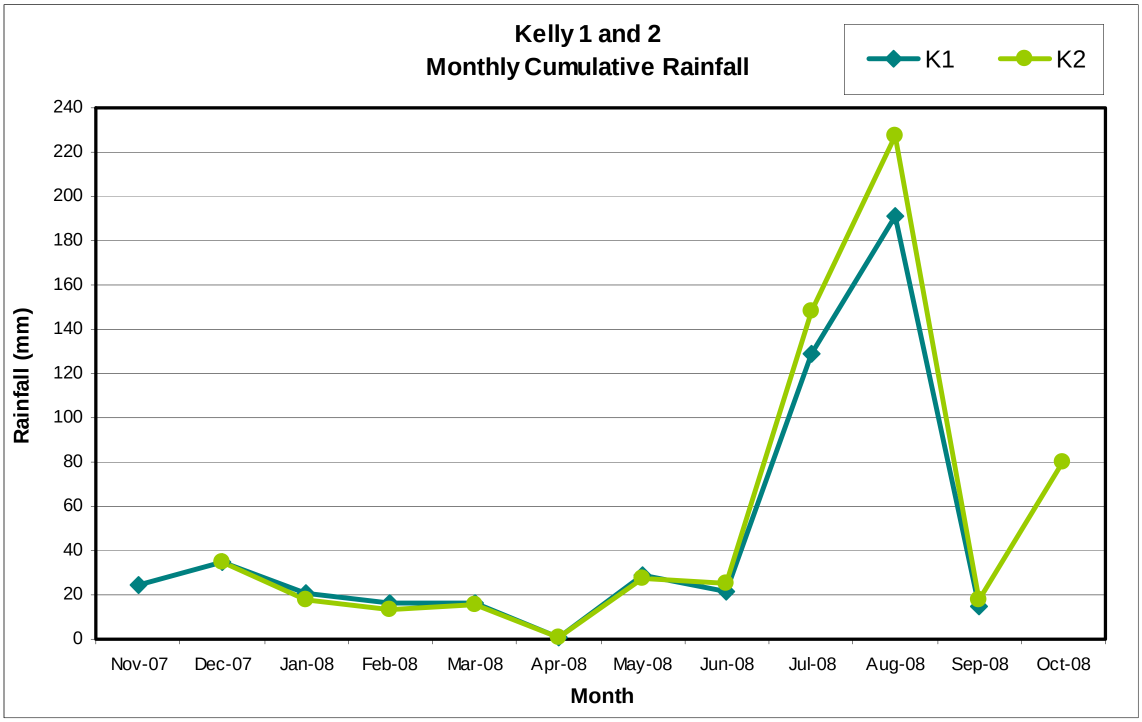

Figure 5. Monthly cumulative precipitation (rainfall and snow) from the two paired Kelly piñon/juniper study plots.

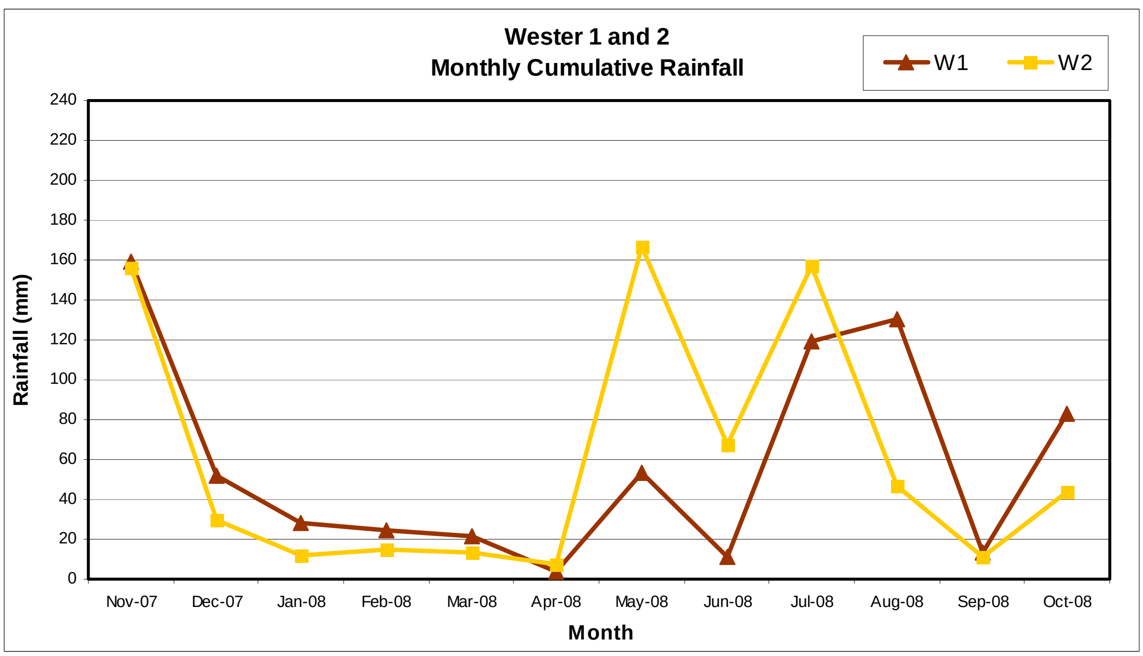

Figure 6. Monthly cumulative precipitation (rainfall and snow) from the two paired Wester ponderosa pine study plots.

Ambient Temperature

Monthly averages of hourly ambient temperatures are presented in Figure 7 and Figure 8 for the Kelly piñon/juniper and Wester ponderosa sites. These graphs show similar monthly average ambient temperatures between the paired study plots (1 and 2) at both study sites. However, Figure 7 shows ambient temperature values for August through October as being negative, and Figure 8 shows negative values for April through July at plot 2 of the Wester site. These negative values for ambient temperature are clearly incorrect and coincide with periods following times (March, July, and August) when data were off-loaded from the data loggers and parameters were reset. These parameters for temperature were apparently reset erroneously, leading to the incorrect negative temperature readings for these periods. Data values for these dates and study plots have been deleted and reported as erroneous in the data files.

We used standard t-tests to test the hypothesis of no difference in mean monthly average ambient temperatures between the paired plots at both sites over the one-year period, using data not including the erroneous values mentioned above. The results of these tests show no significant differences in ambient temperatures between each of the two sets or paired study plots.

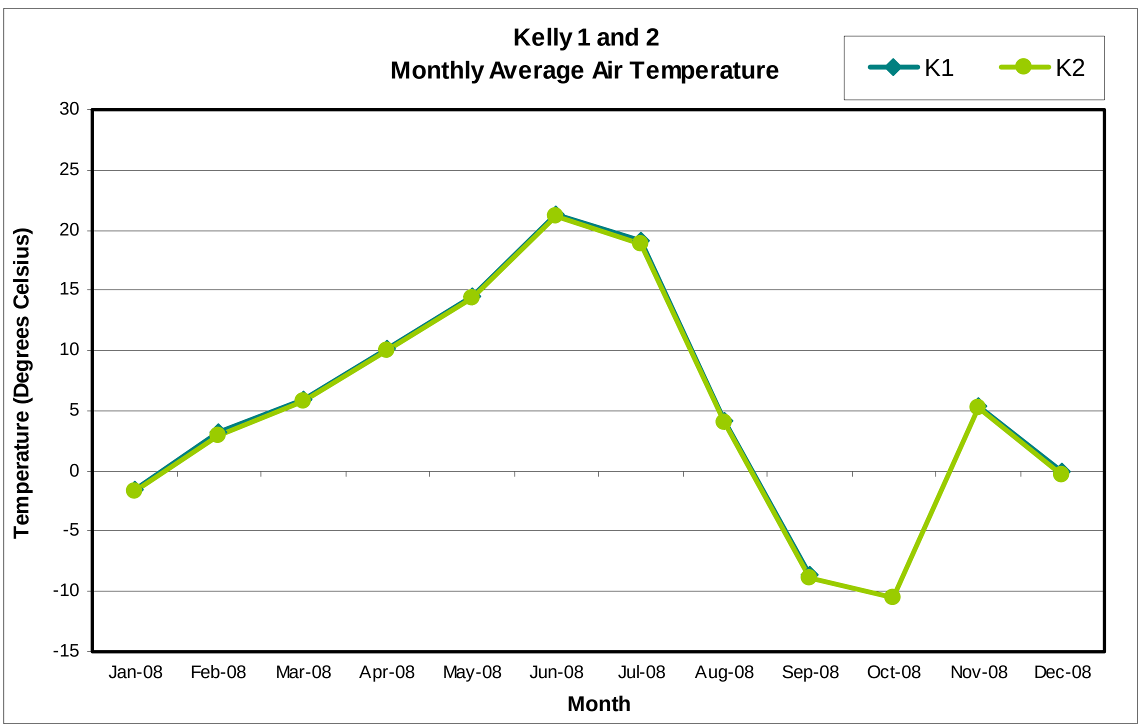

Figure 7. Monthly average ambient temperatures from the two paired Kelly piñon/juniper study plots. Note: Data points for both plots K1 and K2 during August, September, and October are in error and were deleted from the data file.

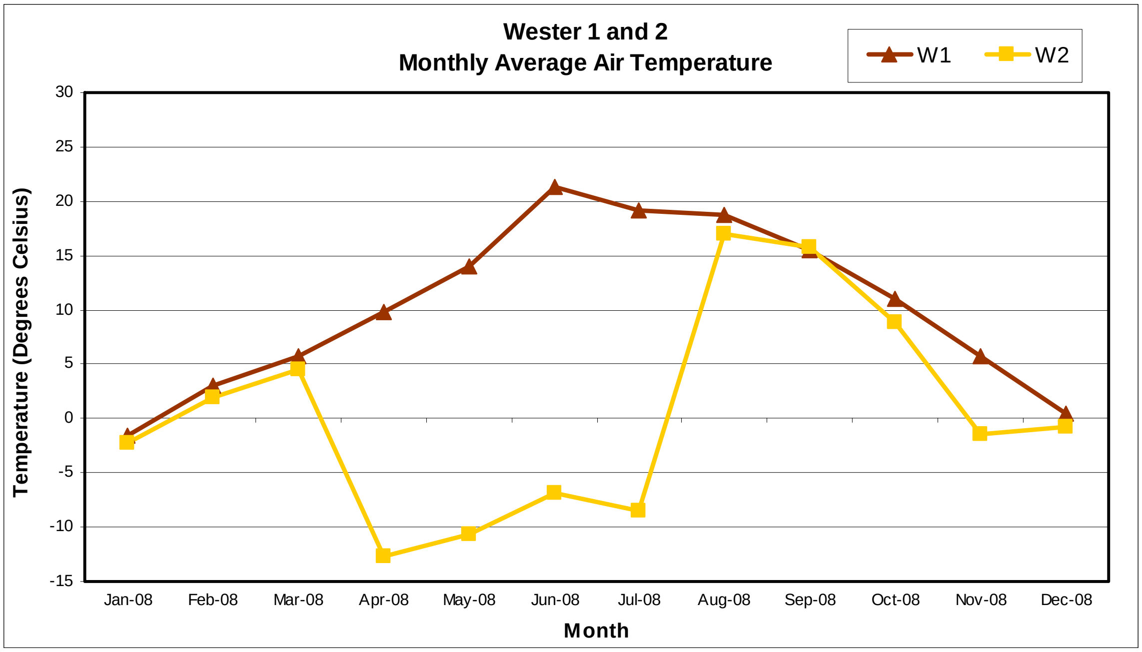

Figure 8. Monthly average ambient temperatures from the two paired Wester ponderosa pine study plots. Note: Data points for plot W2 during April, May, June, and July are in error and were deleted from the data file.

Soil Moisture

Monthly averages of hourly -10 cm soil moisture readings are presented in Figure 9 and Figure 10 for the Kelly piñon/juniper and Wester ponderosa sites. Soil moisture was measured with Watermark soil moisture probes that measure soil water tension in kilopascal (kPa) values that are directly equivalent to California Bearing Ratio (cbr) values for soil water saturation.

Figure 9 and Figure 10 show similar monthly average soil moisture totals between the paired study plots (1 and 2) at both study sites. We used standard t-tests to test the hypothesis of no difference in mean monthly soil moisture values between the paired plots at both sites over the one-year period, and the results of those tests show no significant differences in soil moisture values between each of the two sets or paired study plots.

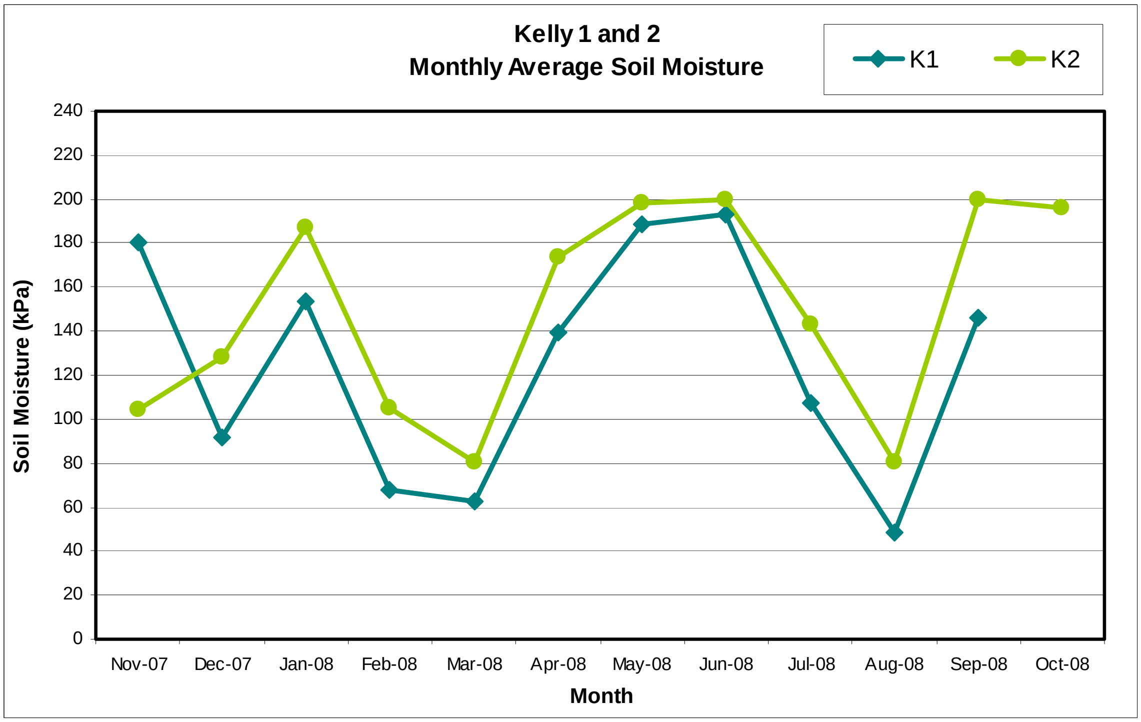

Figure 9. Monthly average soil moisture (-10 cm) from the two paired Kelly piñon/juniper study plots.

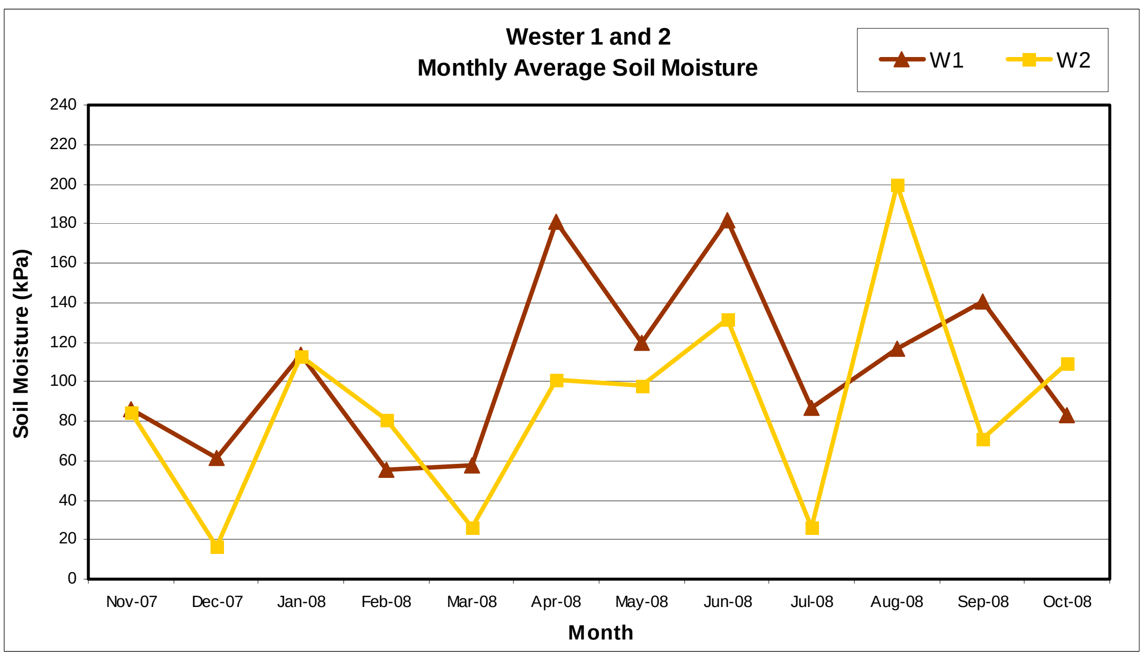

Figure 10. Monthly average soil moisture (-10 cm) from the two paired Wester ponderosa pine study plots.

Soil Temperature

Monthly averages of hourly -10 cm soil temperature readings are presented in Figure 11 and Figure 12 for the Kelly piñon/juniper and Wester ponderosa sites. The graphs show similar monthly average soil temperatures between the paired study plots (1 and 2) at both study sites. However, Figure 11 shows soil temperature values for August through October as being negative, and Figure 12 shows negative values for April through July at plot 2 of the Wester site. These negative values for soil temperature are clearly incorrect and coincide with periods following times (March, July, and August) when data were off-loaded from the data loggers and parameters were reset. These parameters for temperature were apparently reset erroneously, leading to the incorrect negative temperature readings for these periods. The same problem is noted for ambient temperature readings above. Data values for these dates and study plots have been deleted and reported as erroneous in the data files.

We used standard t-tests to test the hypothesis of no difference in mean monthly average soil temperatures between the paired plots at both sites over the one-year period, using data not including the erroneous values mentioned above. The results of these tests show no significant differences in soil temperatures between each of the two sets or paired study plots.

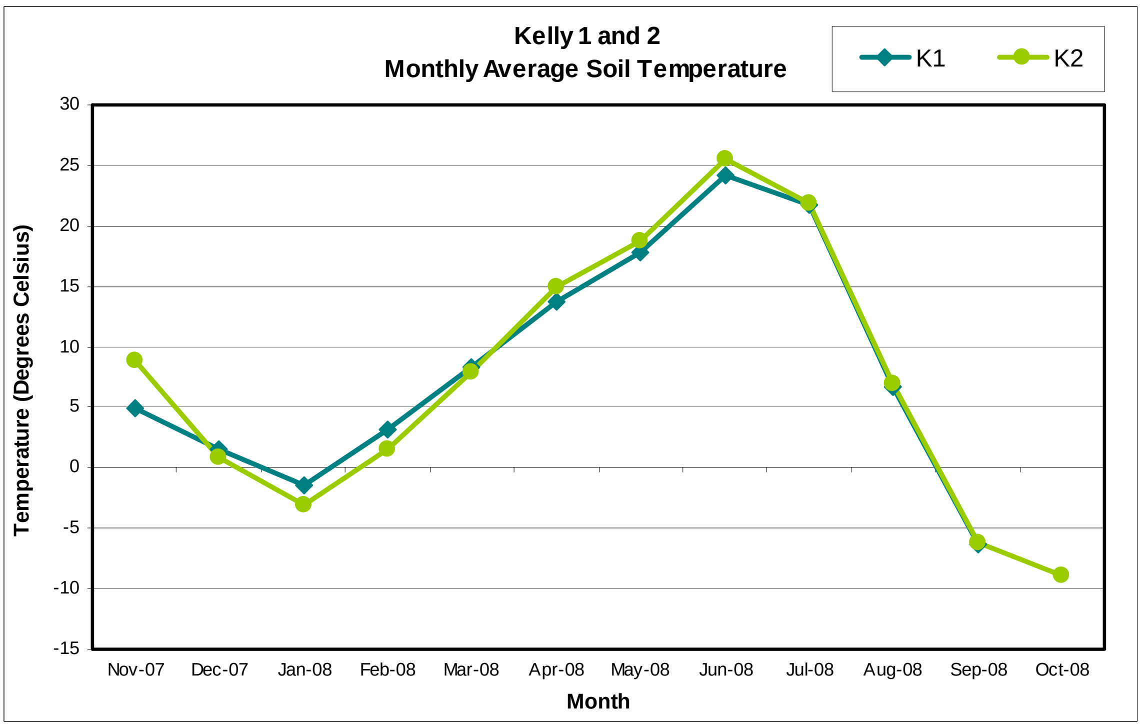

Figure 11. Monthly average soil temperature (-10 cm) from the two paired Kelly piñon/juniper study plots. Data points for both plots K1 and K2 during August, September, and October are in error and were deleted from the data file.

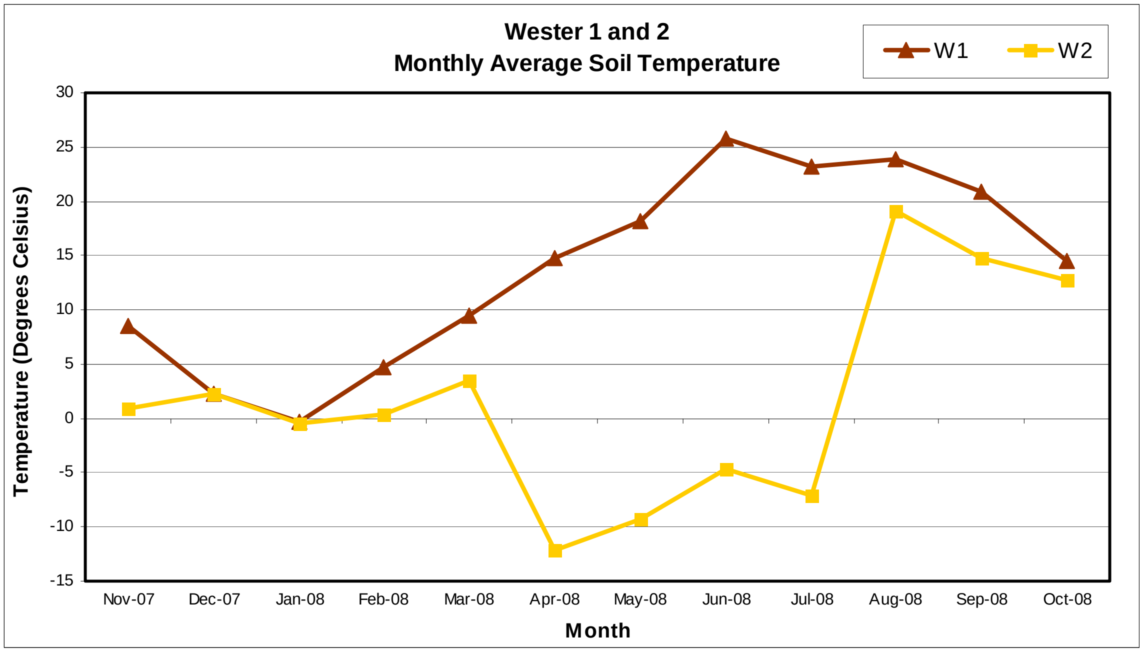

Figure 12. Monthly average soil temperature (-10 cm) from the two paired Wester ponderosa pine study plots. Note: Data points for plot W2 during April, May, June, and July are in error and were deleted from the data file.

Soil Measurements

Soil characterization measurements on the forest thinning monitoring plots include soil surface stability, soil erosion, and soil chemistry. Soil measurements were taken from each of the paired vegetation and soils monitoring plots from all four sites for a total of eight sets of measurements (However, starting in September 2008 at the Chilili ponderosa site). All soil measurements are made in May of each year when soils tend to be dry. The results of year-one soil measurements are presented below. Soil measurements have not yet been made at the new Chilili site that was installed in August 2008; these measurements will be made in May 2009.

Soil Stability

Soil surface stability was measured and scored in May 2008 using the Soil Stability Test Kits developed by the USDA Agricultural Resource Service (Herrick et al. 2005) (Figure 13). A total of 18 random sub-sampling points were located on a 30-m (98-foot) line along one side of each of the 33 × 10–m (98 × 33–foot) vegetation and soils monitoring subplots at each of the eight total monitoring plots at four sites. Each of the 18 sub-samples was scored on a rank scale from 1 to 6; the higher the score, the more stable the soil surface. Figure 14 provides average soil surface stability scores for each of three subplots representing each of the vegetation and soils sampling plots from three sites (Chilili not included). Scores are partitioned by subplot and overstory vegetation canopy type. Figure 15 provides average soil subsurface (1 cm below the soil surface) stability scores for each of three subplots.

Figure 14 and Figure 15 show considerable variation in soil surface and subsurface stability across plots, subplots, and overstory vegetation. In general, soils under tree canopies had higher scores, probably based largely upon the presence of more organic matter. Most of those soils were underneath dead leaf litter layers and contained organic material and fungi. Statistical tests for differences in surface and subsurface soil stability between paired study plots were performed for data from the Kelly piñon/juniper and the Wester ponderosa pine sites. Analysis revealed no significant difference in soil surface stability scores between plots at the Kelly site, but subsurface scores were significantly different (P=0.049), with higher mean scores on plot 2. No significant difference in soil surface stability scores we observed between Wester plots as well, but subsurface scores were significantly different (P=0.007), with higher mean scores on plot 1.

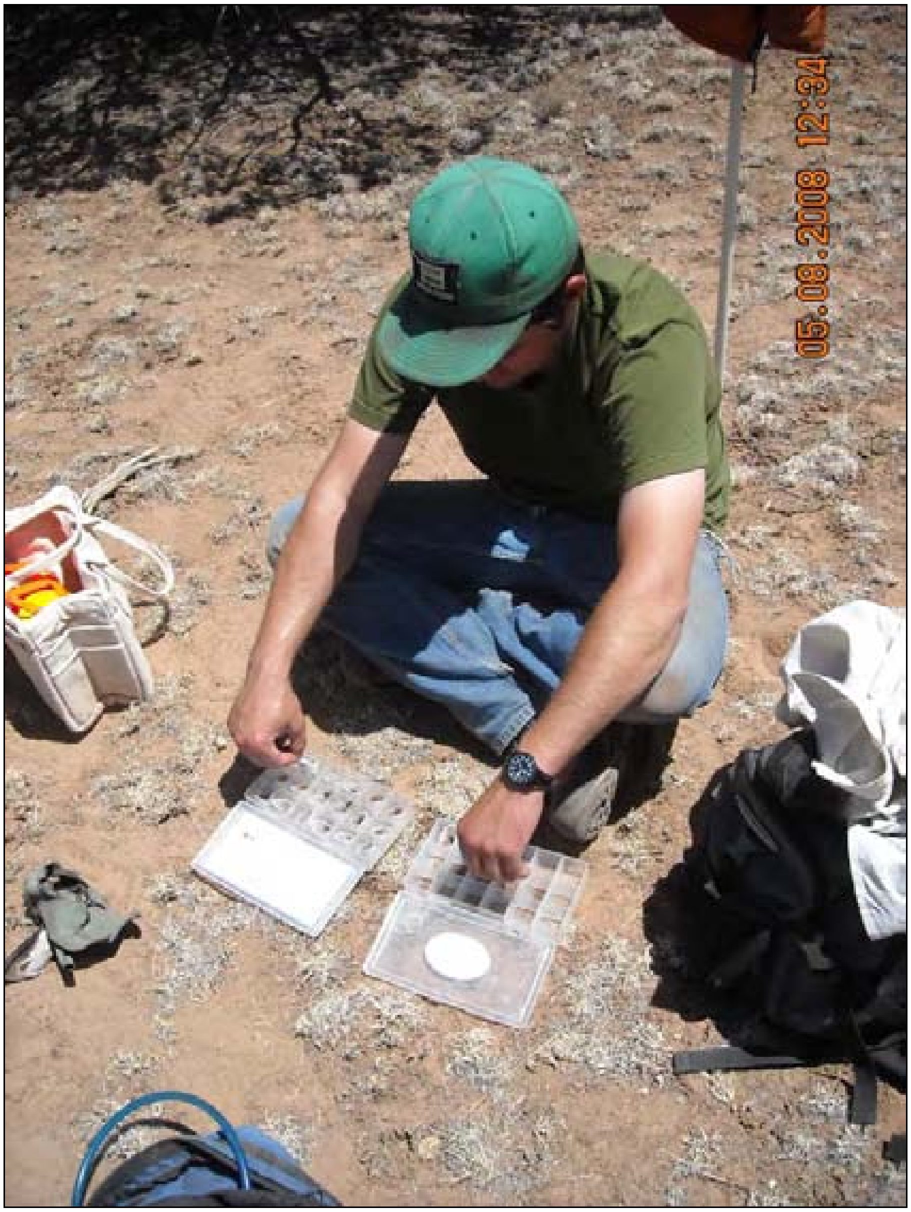

Figure 13. Soil stability test kit being used.

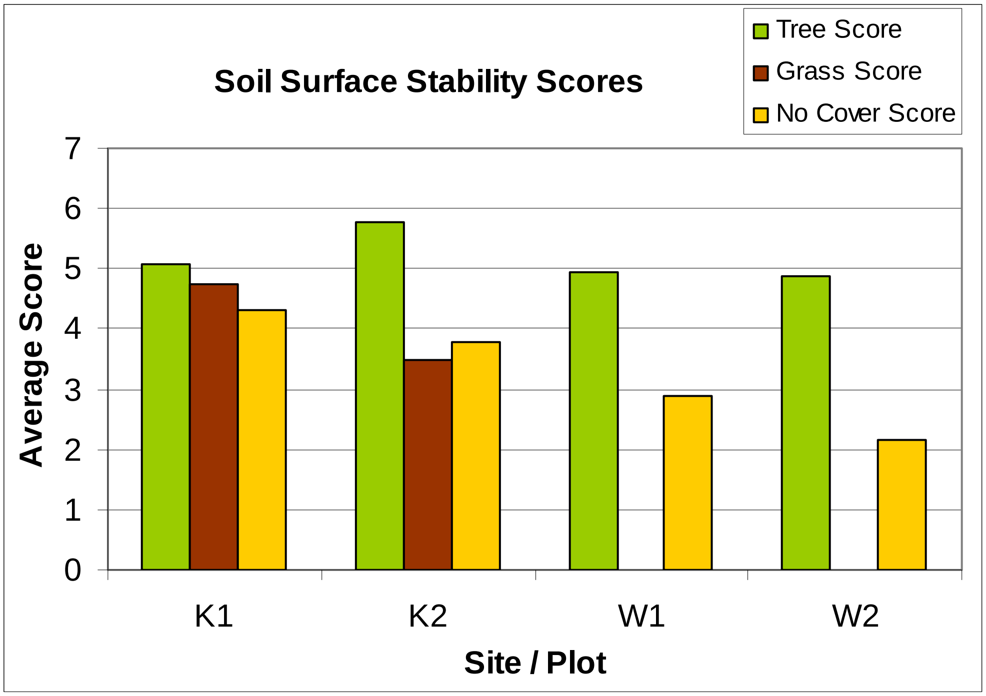

Figure 14. Soil surface stability average scores by site, plot, and subplot (18 subsamples/subplot) and by overstory vegetation canopy type.

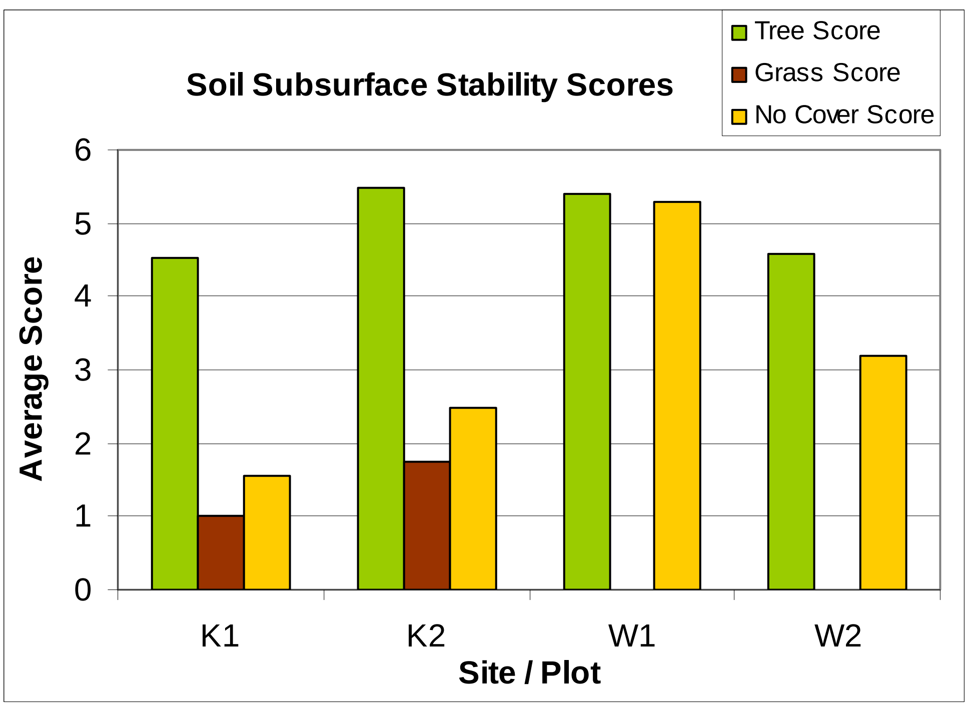

Figure 15. Soil subsurface (- 1 cm) stability average scores by site, plot, and subplot (18 subsamples/subplot) and by overstory vegetation canopy type.

Soil Erosion

Soil erosion is being monitored by use of soil erosion bridges modeled after White and Loftin (2000). Permanent bridge support posts have been installed at consistent, systematically determined, and unbiased locations at one of each of the vegetation and soil subplots for a total of three bridges at each paired plot at all four sites. We have constructed two portable steel bridges with 20 pin-drop holes each (Figure 16). Measurements are made at 5-cm (2-inch) intervals along a 1-m (3-foot) length of soil surface profile by dropping a thin steel rod through each hole on the bridge and measuring the distance from the bottom of the bridge to the soil surface in mm. A soil surface profile can then be obtained from the 20 point measures, and distances between the bottom of the bridge and the soil surface can be accurately remeasured over time to document any loss or gain to the soil surface. The same one of two bridges will always be used at the each initial measurement location in case there are slight differences in each of the two the bridge dimensions.

Figure 16. Soil erosion bridge measurements being taken.

The steel support posts are permanent, so the bridge will always be placed at the same initial distance above the soil surface, and a set point consisting of a permanent steel spike has been positioned at the middle of each bridge to provide a reference point to assess repeat placement accuracy. Baseline measurements were made at all sites except Chilili in May 2008. Figure 17 shows one baseline soil profile measured from one of three bridges at the Kelly site, plot 1. Analysis of soil surface erosion will start after year two when year-one profiles are compared to year-two profiles and net loss or gain is calculated for each bridge. Over a series of years, the study will document losses or gains to the soil surface profiles at each bridge and provide average values for each plot.

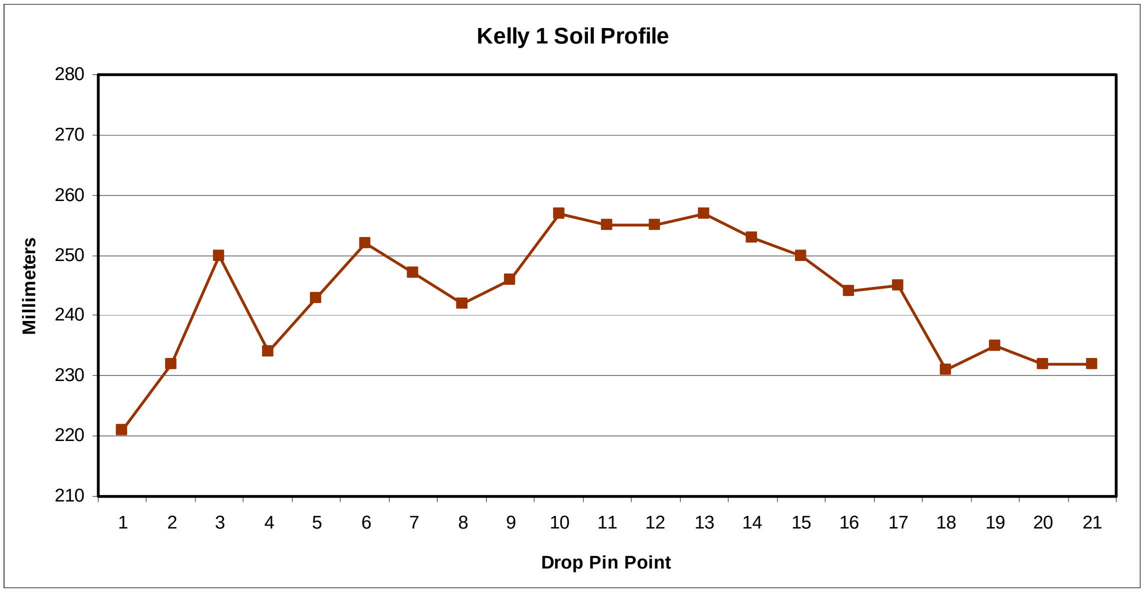

Figure 17. Graph showing soil surface profile from one of three soil erosion bridge locations from plot 1 at the Kelly piñon/juniper site. Each point 1–21 on the Y axis represents one measurement point from the soil surface to the level bridge above the surface.

Soil Water Content and Temperature

Continuous hourly soil moisture and temperature measurements presented from the WatchDog Mini Weather Station at each plot only provide a single reference point measurement for each plot, measured and recorded hourly. In order to sample soil moisture and temperature from locations throughout each vegetation and soils monitoring plot, we used a portable Field Scout 200 TDR soil moisture meter. Beginning in April 2008, the data were collected once each month (near the 15th day of each month) from 12 systematically located measurement points on each vegetation and soils monitoring plot. Repeat samples were taken from the same general measurement point locations each time. Soil volumetric water content and temperature values for each reading are summarized for a virtual soil cylinder that is 12 cm (5 inches) deep by 9 cm (3.5 inches) diameter. Results of average percent soil volumetric water content and temperature readings from the Kelly and Wester vegetation and soils study plots are shown in Figure 18 through Figure 21.

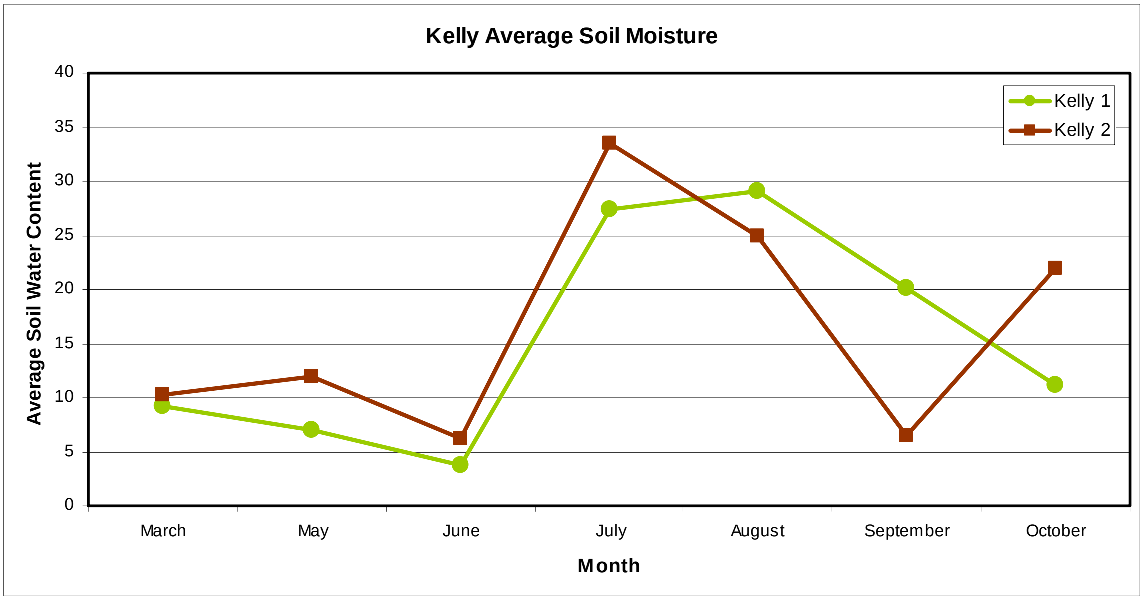

Figure 18. Soil percent volumetric water content (12 cm deep by 9 cm diameter cylinder) averaged from 12 measurement points from the two paired Kelly piñon/juniper study plots.

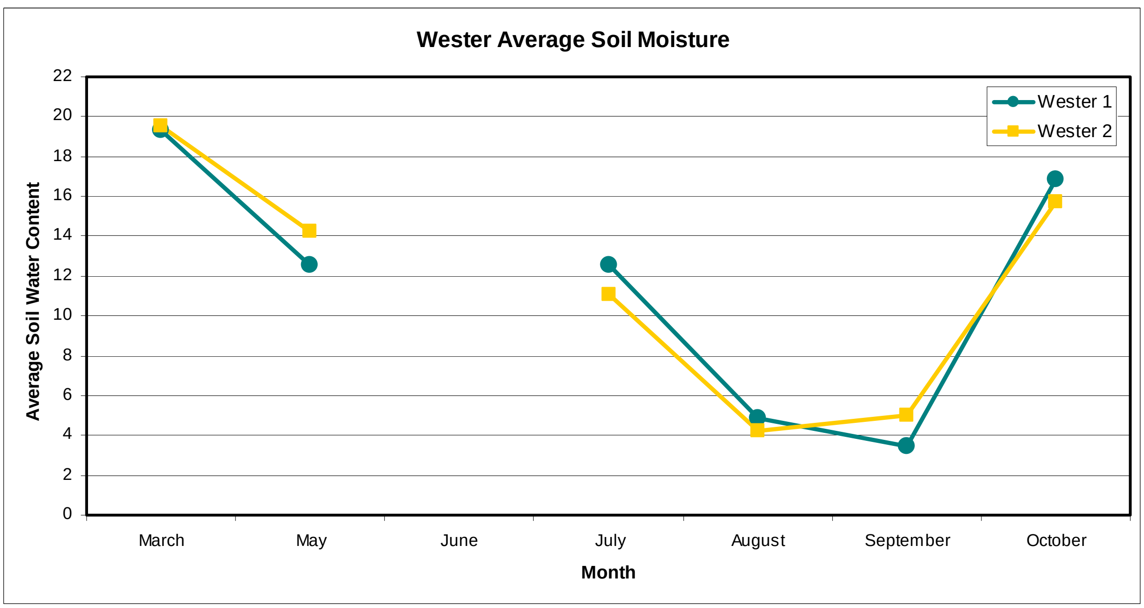

Figure 19. Soil percent volumetric water content (12 cm deep by 9 cm diameter cylinder) averaged from 12 measurement points from the two paired Wester ponderosa pine study plots.

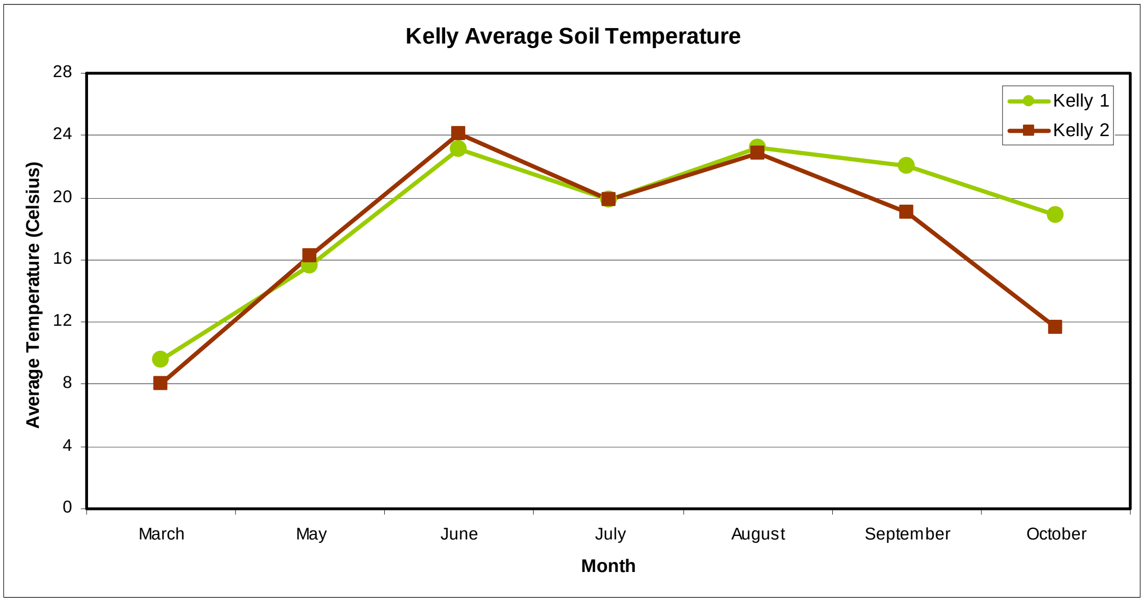

Figure 20. Soil temperature (-12 cm) averaged from 12 measurement points from the two paired Kelly piñon/juniper study plots.

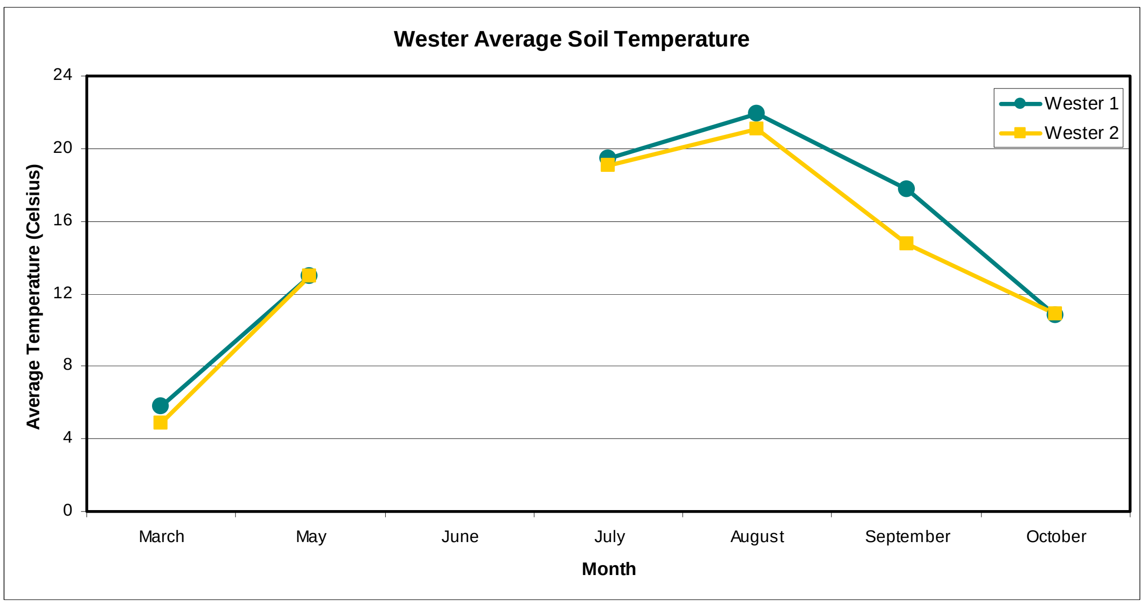

Figure 21. Soil temperature (-12 cm) averaged from 12 measurement points from the two paired Wester ponderosa pine study plots.

Figure 18 through Figure 21 indicate little difference in soil water content and soil temperatures between the two paired plots at both the Kelly piñon/juniper and Wester ponderosa sites. Standard statistical t-test analyses were run to compare mean values of both soil water content and soil temperatures between the two paired plots at each of the two sites, and in both cases differences are not significantly different. Although soil water content appears to differ slightly between plots 1 and 2 at the Kelly site, this difference is not statistically significant. Overall, no statistically significant differences in soil water content and soil temperatures between the paired plots at the two sites have been observed.

Soil Chemistry

Impact soil cores (15 cm [6 inches] deep by 4 cm [1.4 inches] diameter) were collected from 12 systematically located points on each of the vegetation and soils monitoring subplots at three of the four study sites, but not yet at the Chilili site. Soil core samples were combined for each of the three vegetation and soils subplots per study plot to provide three samples per study plot. Soil cores were collected into paper bags, dried, and stored in a freezer. We are attempting to use Cardy soil chemistry measurement devices to obtain measures of soil chemistry but have run into some problems with the analysis. Analysis will continue during this winter and should be available by spring 2009.

Forest Thinning Hydrologic Monitoring

Monitoring flumes (Parshall flumes) complete with pressure transducers were installed in thinned and control plots at the Vigil, Kelly, Wester, and Chilili study sites in order to study impacts of tree thinning on surface flow and runoff (Figure 22 through Figure 24).

For the forest thinning monitoring, a paired watershed approach has been adopted. This involves installing two flumes at each of the study areas in separate watersheds that are near replicates of each other. This means they have been chosen on the grounds of being as close in soil type, vegetation type and density, elevation, slope, aspect, and slope gradient as possible. Considerable field work was conducted in late 2007 and 2008 to select these sites for the study. At each site, one of the paired sites will be given the treatment (thinning in 2009/2010) and the other will remain unchanged to serve as the control. The difference in runoff will then be compared.

The flumes use Troll 500 pressure transducers to record the level of water passing through the flume. Parshall flumes are designed so that there is a unique mathematical relationship between the flow rate of water through the flume and stage height. Based on the height of water recorded, the flow can be determined, as can the total volume of water leaving the watershed. The drainage area feeding into each flume has been delineated (Figure 25 through Figure 27), so it is also possible to determine the amount of runoff reaching the flume per given area, expressed in acres (Table 1). Information is then controlled for precipitation, which is accomplished by comparing the flume data with those data downloaded from the WatchDog Mini Weather Stations installed near each flume (Figure 28). These data also provide an indication of the ratio between total volume of precipitation and total volume of runoff (the rainfall/runoff ratio).

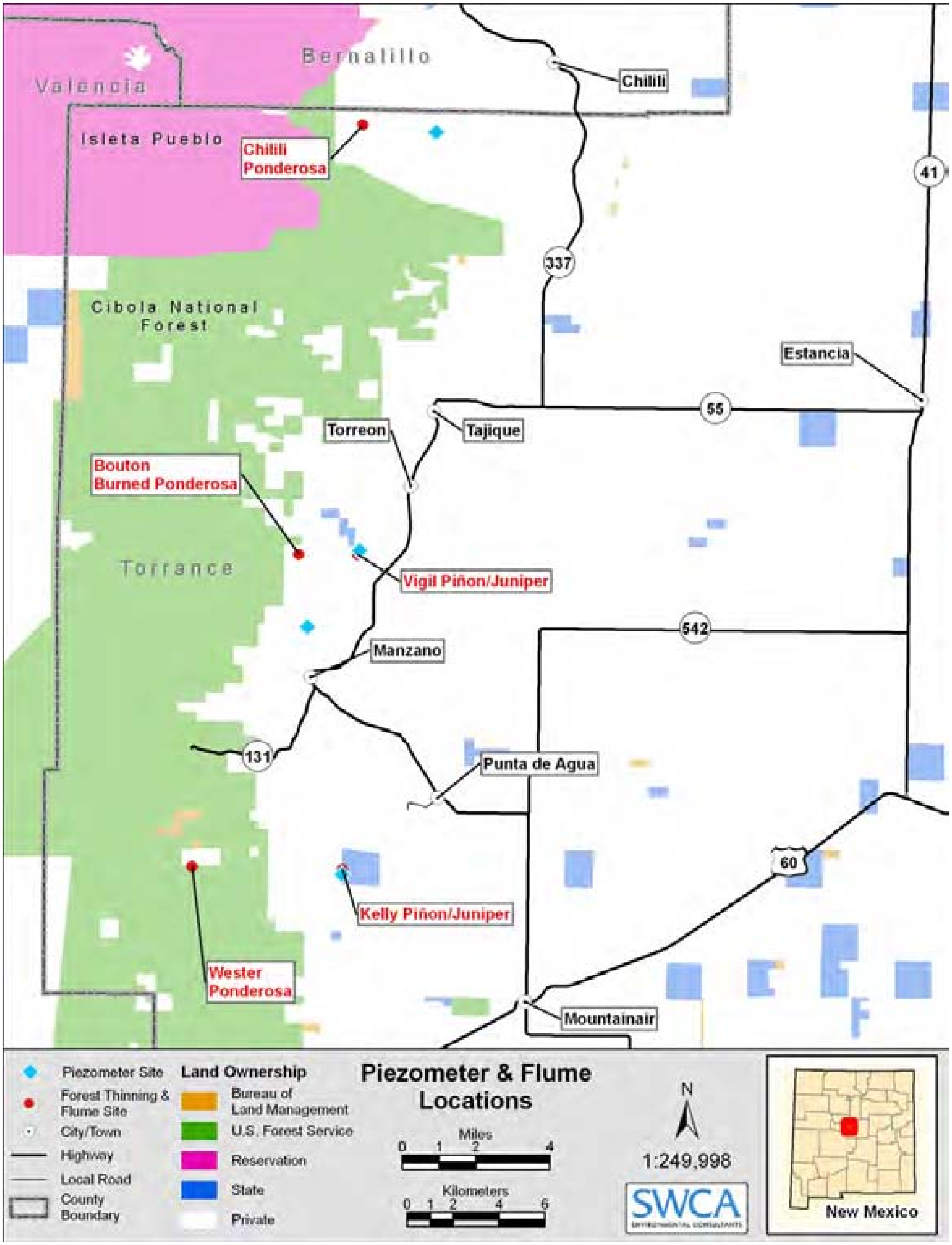

Figure 22. Flume locations.

Figure 23. Vigil 2 flume.

Figure 24. Wester 2 flume.

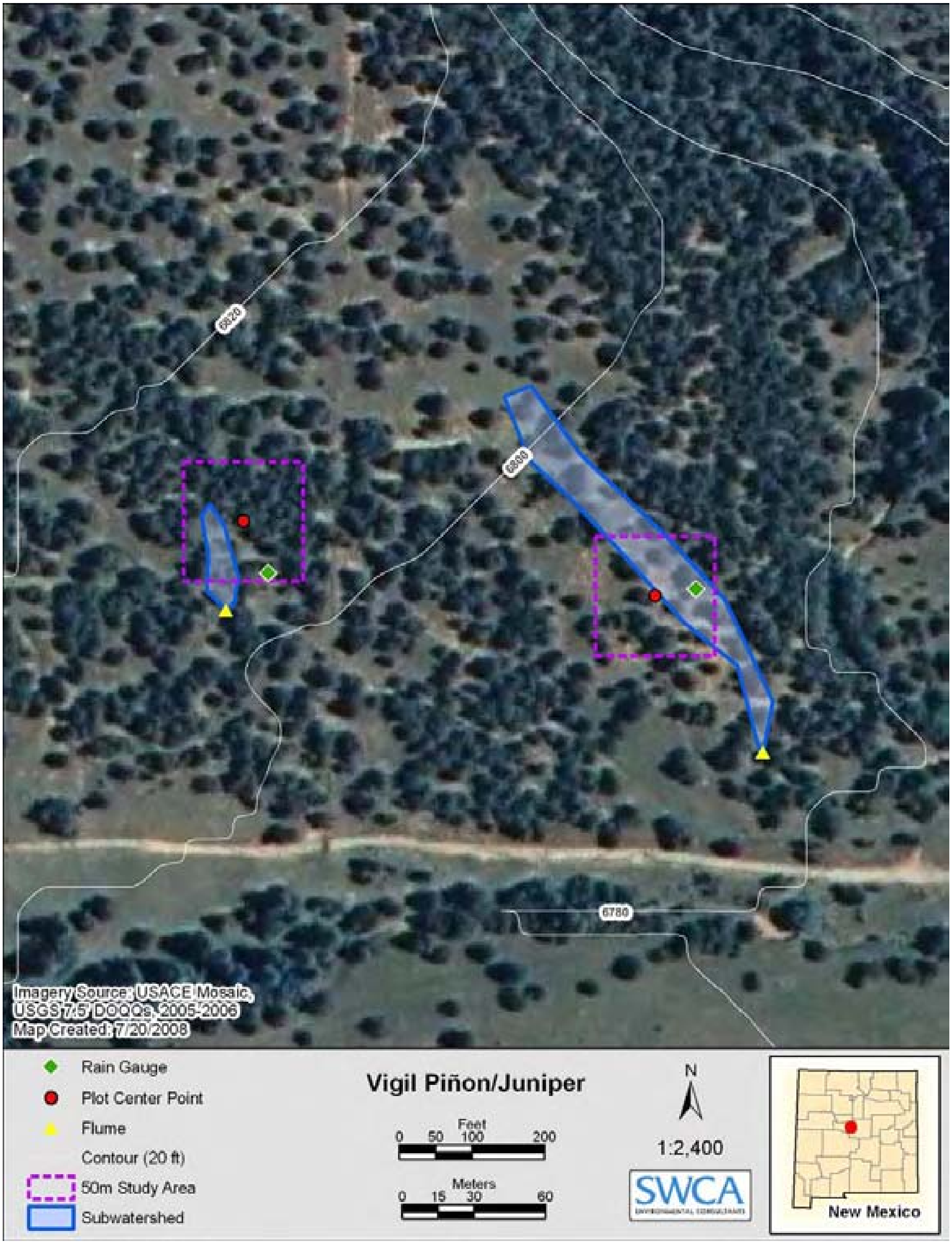

Figure 25. Vigil flume subwatersheds. The Vigil plot 1 is on the east, and plot 2 is on the west.

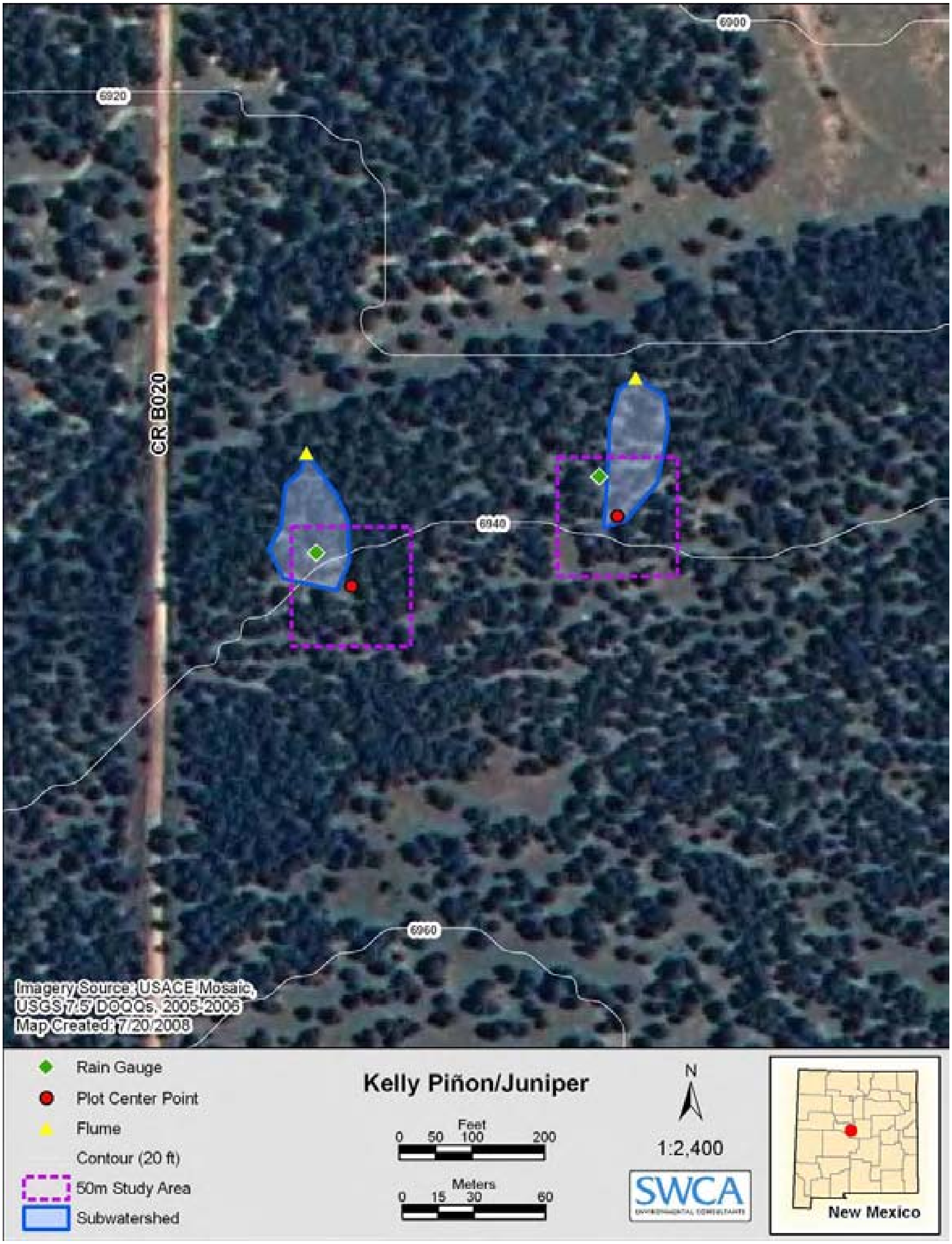

Figure 26. Kelly flume subwatersheds. The Kelly plot 1 is on the east, and plot 2 is on the west.

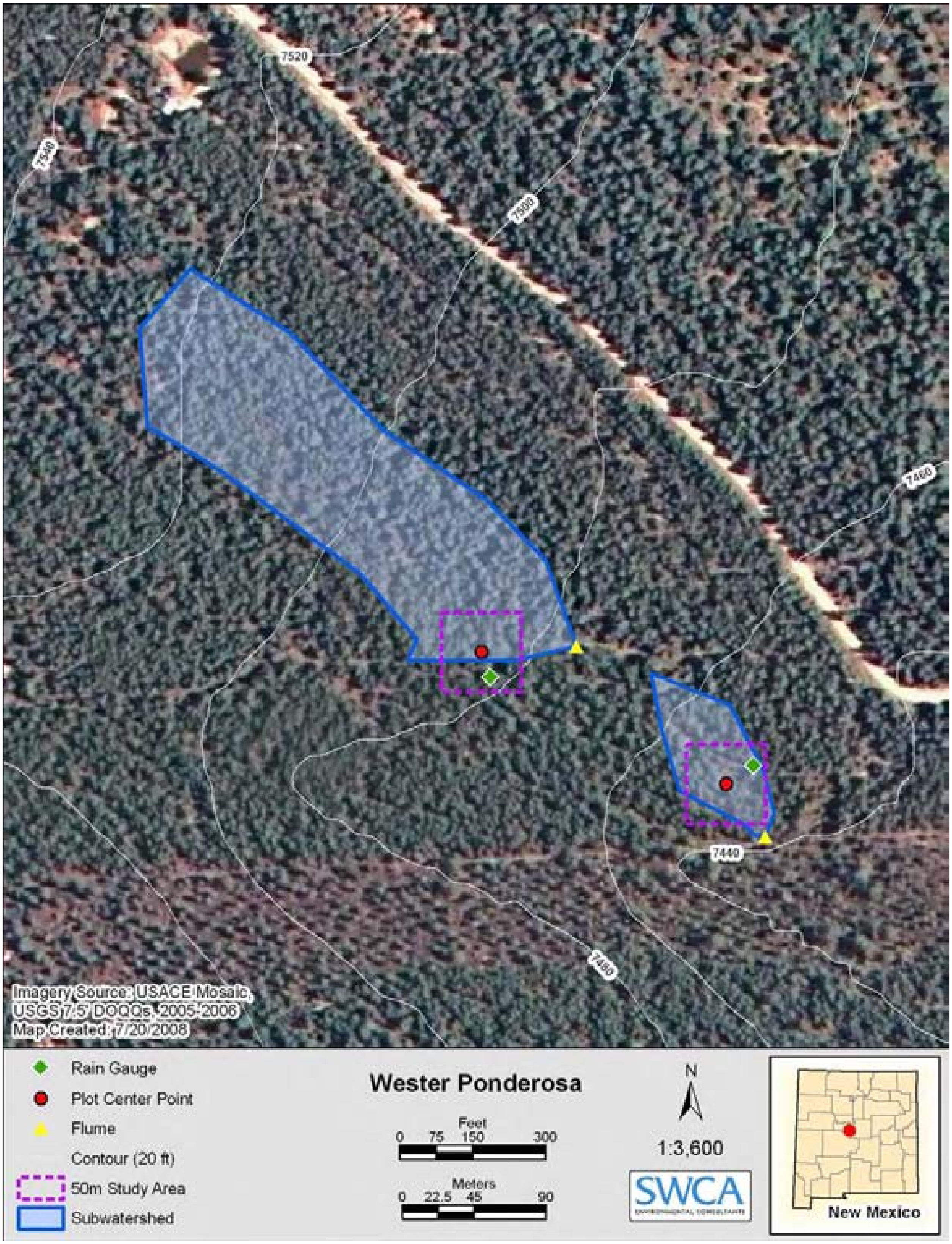

Figure 27. Wester flume subwatersheds. The Wester plot 1 is on the east, and plot 2 is on the west.

Table 1. Acreages of the Subwatersheds Containing Flumes

Subwatershed	Acreage
Wester Ponderosa 2	6.76
Wester Ponderosa 1	1.03
Kelly Piñon/Juniper 2	0.31
Kelly Piñon/Juniper 1	0.29
Vigil Piñon/Juniper 2	0.10
Vigil Piñon/Juniper 1	0.68
Chilili W	9.20
Chilili E	--

Note: The acreage of the Chilili East site has not yet been determined.

Figure 28. WatchDog Mini Weather Station and a graduated cylinder as a backup to collect precipitation data. These stations have been installed at each forest thinning plot and near fire monitoring plots.

The goal of the study will be to determine whether there are statistically significant differences in runoff between plots or subwatersheds that are thinned, compared to the adjacent control plots that will not be thinned. Currently, baseline data is being recorded at each flume site so patterns and the quantity of precipitation-related runoff levels can be studied. The forest thinning is scheduled to occur in winter 2009/2010, and preliminary analysis of the differences among sites is tentatively scheduled to begin in 2010.

Analyzing the July 20, 2008, rain event, a strong correlation can be seen between the rainfall and flume flows at the Kelly site. A total of 39.3 mm (1.55 inches) of rain was recorded at the Kelly plot 1 WatchDog station, and a maximum stage height of 0.07 m (0.23 foot) was recorded at the Kelly plot 1 flume (Figure 29). Surprisingly, no rain events recorded flow at either of the Wester flumes from April 22 to September 9, 2008, despite several rain events in which total precipitation was over 25.4 mm (1 inch) in 24 hours. Figure 30 through Figure 32 provide Kelly site flume and WatchDog rainfall data, and Table 2 summarizes Kelly site flume data.

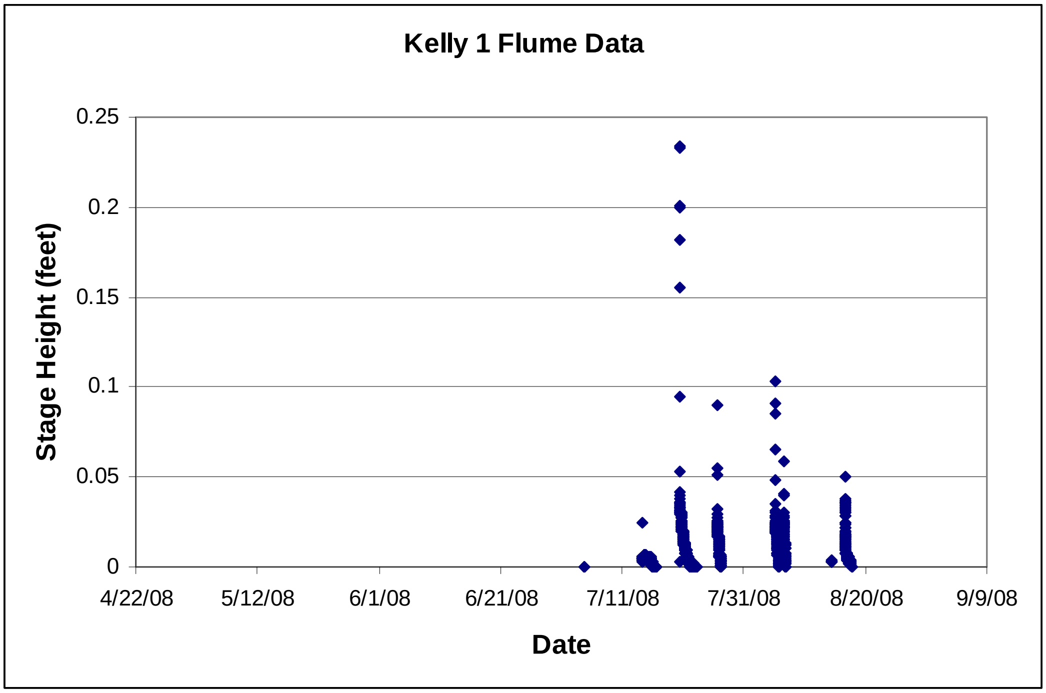

Figure 29. Kelly 1 flume data, April 22–September 9, 2008.

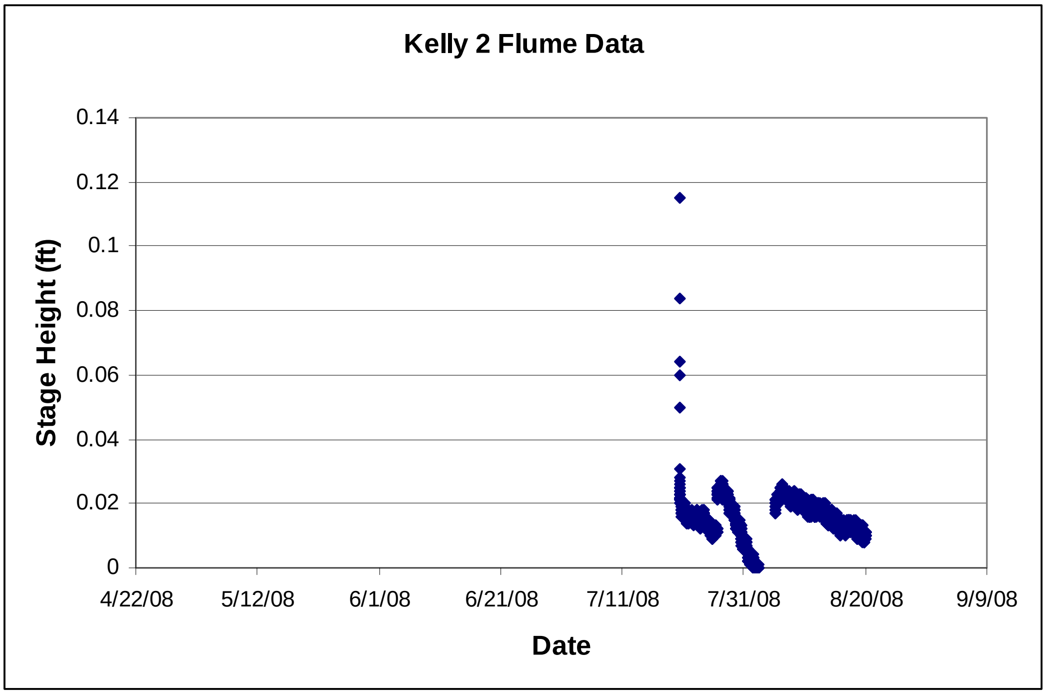

Figure 30. Kelly 2 flume data, April 22–September 9, 2008.

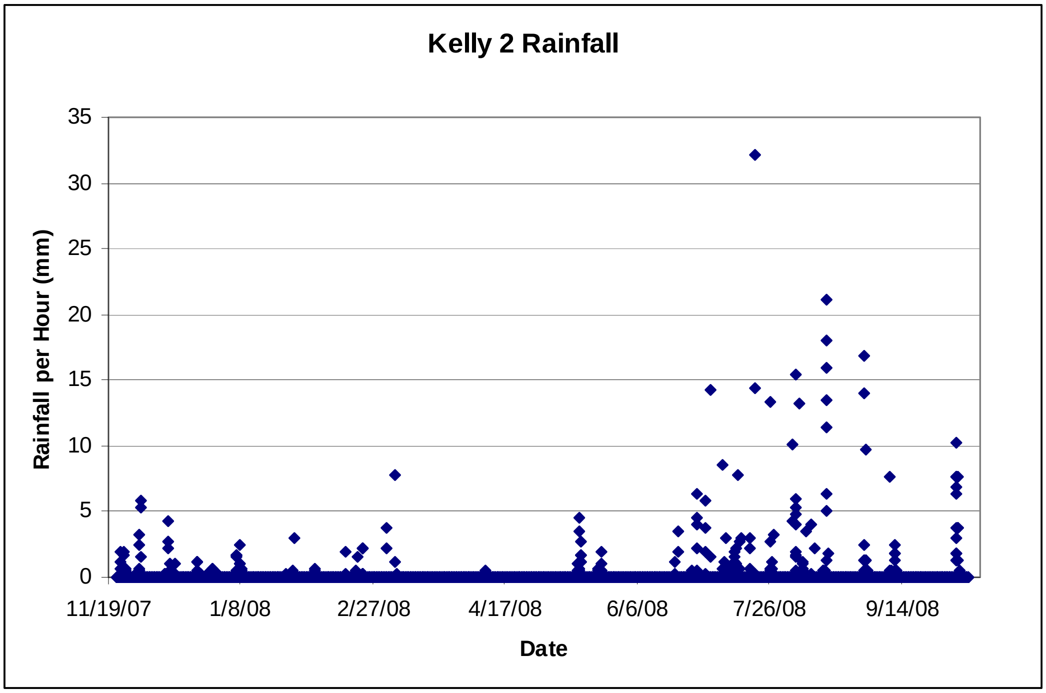

Figure 31. Kelly 2 WatchDog rainfall data.

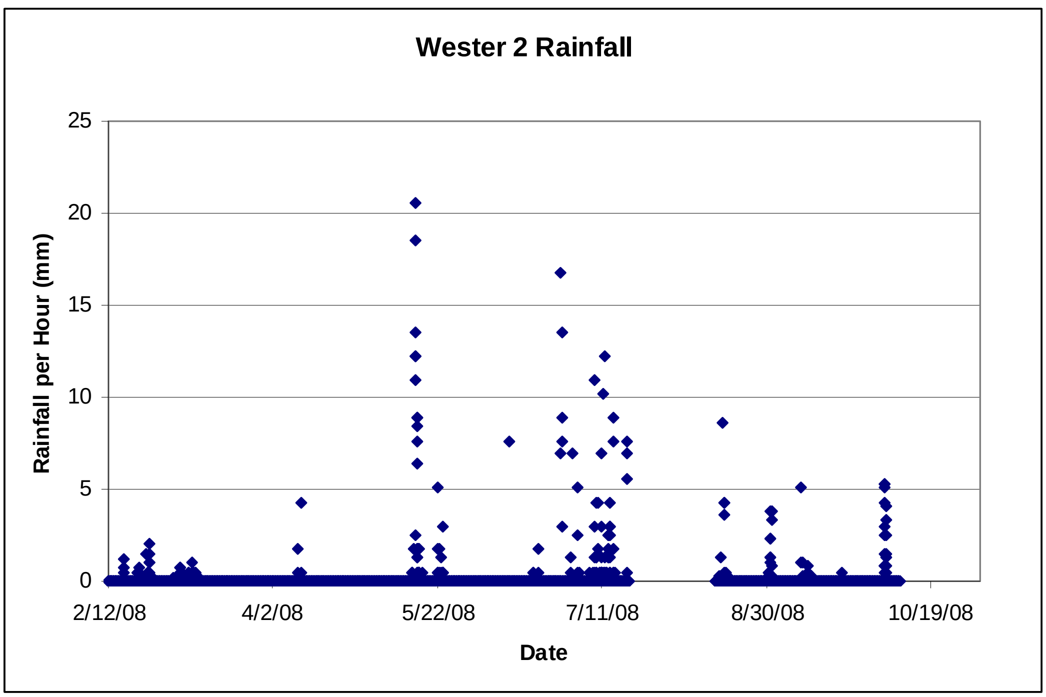

Figure 32. Kelly 2 WatchDog rainfall data.

Table 2. Summary of Flume Data

Location	Date	Duration (hrs)	Peak Stage Height (ft)	Peak Flow (cfs)	Total Volume (acre-feet)
Kelly 1	07/20/08	3	0.23	0.004	0.006
Kelly 2	07/20/08	3	0.12	0.039	0.004

cfs = cubic feet per second.

VEGETATION

Vegetation measurements were made on all study plots in late September and early October 2008. Vegetation measurements will always be made annually at the end of the growing season to consistently capture maximum yearly aboveground plant canopy production. Vegetation measurements include qualitative repeat photographs of vegetation, continuous line-intercept and vegetation quadrat measurements of herbaceous plants, measurements of trees on circular plots, and measurements of vertical vegetation structure, all on each of three vegetation and soils subplots at each of the four study sites.

Repeat Photo Points

Study plot photographs were taken along the axis line of each 30 × 10–m (98 × 33–foot) vegetation and soils monitoring subplot in early autumn at the end of the growing season. Photographs were taken with an 8 megapixel digital camera from the center of each study plot, with a view outward along the center line of each subplot. Figure 33 shows an example photograph taken at the Wester ponderosa pine site. Repeat photographs will be taken annually at the end of the growing season to provide a visual and qualitative record of vegetation changes on each of the study plots and subplots.

Figure 33. Example of a repeat photo point taken of the west subplot of the Wester ponderosa pine study plot 1. Note that the label and flag in the foreground are the start of the 30 m transect line, and the marked pole in the background is the end of the 30 m transect line.

Trees

Tree monitoring was carried out in October 2008 on all four thinning sites: Wester and Chilili (ponderosa), and Kelly and Vigil (piñon/juniper). Tree measurements were carried out in four circular plots, one positioned at the center of the plot and one at the end of each transect line (3) of the thinning plot. These four plots have a radius of 7.3 m (24 feet).

Tree measurements included:

- Identification of species (note 4-letter codes are the first two letters of the genus and the first two letters of the species, and are used in some of the below figures).
    - Ponderosa pine; *Pinus ponderosa* (PIPO)
    - Piñon pine; *Pinus edulis* (PIED)
    - Rocky mountain juniper; *Juniperus scopulorum* (JUSC)
    - One-seed juniper; *Juniperus monosperma* (JUMO)
    - Alligator juniper; *Juniperus deppeana* (JUDE)
- Height (feet)
- Live/Dead
- Diameter at breast height (DBH)/diameter at root crown (DRC) (inches)
- Crown base height (CBH) (feet)
- Crown position (dominant, co-dominant, intermediate, over-topped)
- Tree damage (insect, wind, fire, drought)
- Disease (scales, tip moths/beetles, bark beetles, mistletoe)
- Crown ratio (%)
- Crown vigor
- Crown die back (%)
- Drip zone (feet) - on piñon/juniper plots only

On piñon/juniper plots, diameters of one-seed juniper were measured at the root crown, and diameters of piñon were measured at DBH. All trees were tagged at the root collar. Many of the one-seed juniper trees were heavily branched (Figure 34), sometimes from below the ground surface. We measured all branches that were greater than 5 cm (2 inches) in diameter. Branches less than 5 cm (2 inches) in diameter at the root crown were tallied and counted across the plot. Where branching occurred greater than 10 cm (4 inches) from the ground surface, the combined root crown was measured. Because many of the separate branches form a unified crown, the canopy measurements for the branches were combined and a single measurement was made of the unified crown. The individual branches were bracketed to avoid confusion. Tree height was measured using a graduated pole (Figure 35). Small trees less than 5 cm (2 inches) in DRC were tallied by species and live and dead status.

Figure 34. Multi-branched one-seed juniper.

Figure 35. Measuring the height of the unified crown.

In addition to measuring juniper height, the drip zone of the juniper and piñon were measured since species composition and vegetation cover beneath piñon/juniper varied considerably when compared to the unshaded herbaceous layer. The drip zone was measured along the widest axis and then perpendicular to this axis (Figure 36). Drip zones at the Kelly site were highly variable, ranging from 0.5 m^2 (1.6 square feet) to 31.5 m^2 (103.3 square feet), with an average of 3.68 m^2 (12.07 square feet).

Figure 36. Measuring the drip zone.

Ponderosa pine diameters are measured at breast height, and any trees less than 5 cm (2 inches) at DBH were tallied and classified as regeneration trees. All ponderosa were tagged at DBH. Figure 37 shows the relationship between the height and DBH of tagged trees on the Wester and Chilili plots. There is a non-linear relationship between the two parameters, and the R2 value of 0.77 suggests that 77% of the variance in the data is explained by that relationship.

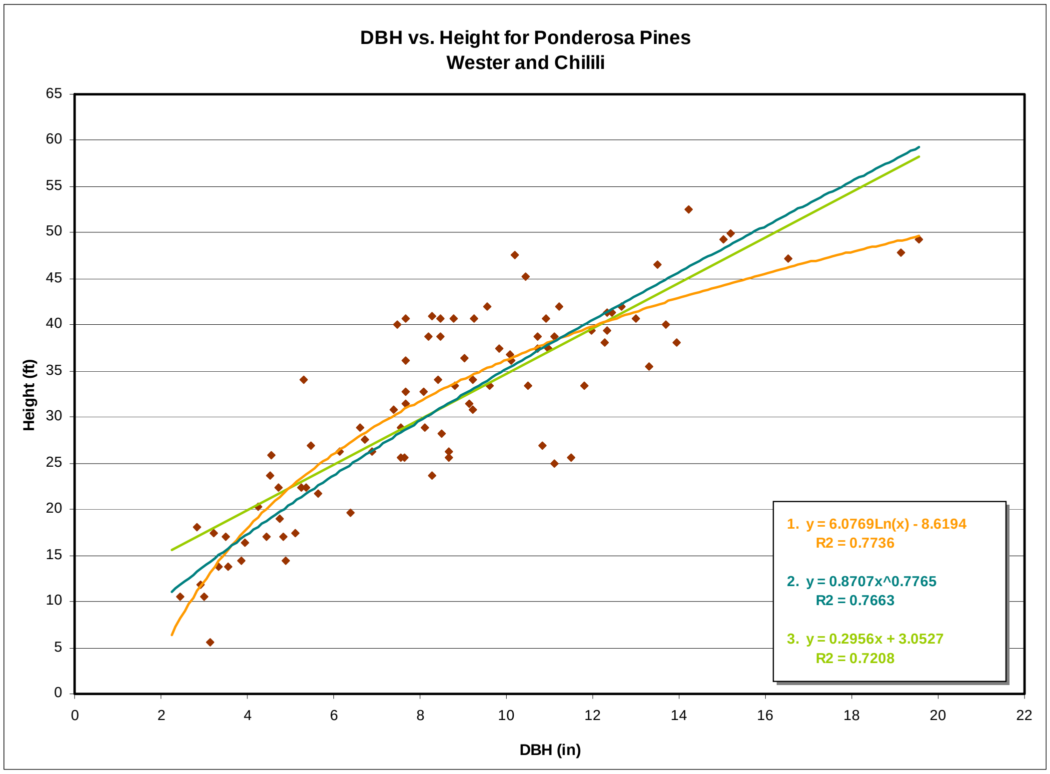

Figure 37. Relationship between Height and DBH of ponderosa pine in Chilili and Wester plots.

As presented in Figure 38, the average tree height for ponderosa at the Wester and Chilili sites was approximately 9 m (30 feet). The heights of piñon pine and juniper at the Kelly and Vigil plots ranged from 3 to 5 m (11–17 feet) (Figure 38). The DBH of ponderosa at Wester and Chilili was also consistent at around 18 cm (7 inches), and the average piñon pine and juniper ranged from 10 to 15 cm (4–6 inches) across the Kelly and Vigil plots (Figure 39).

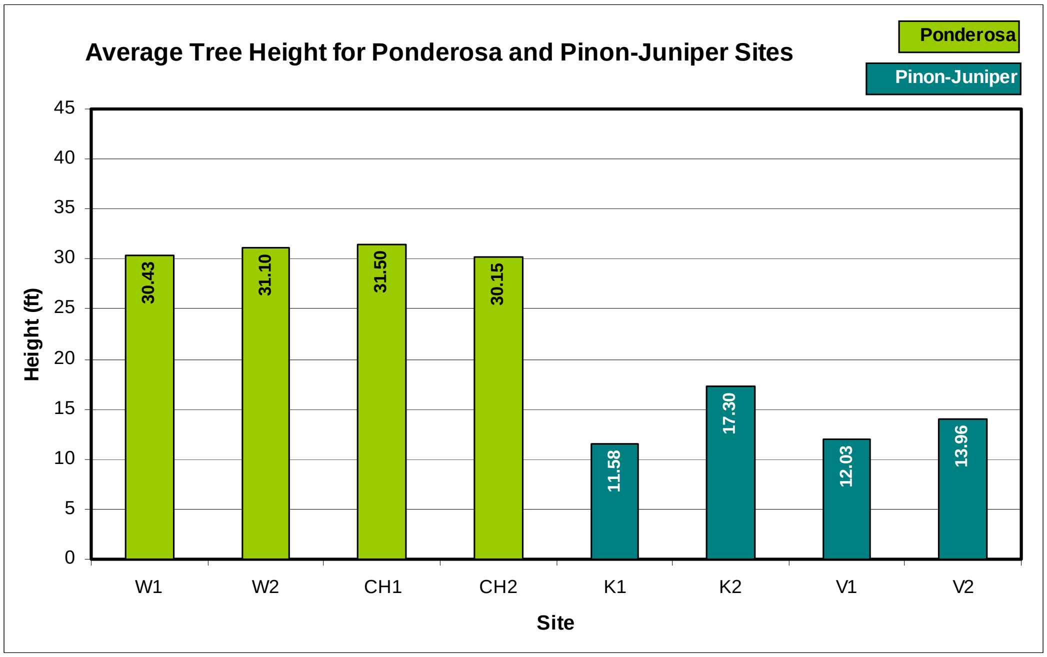

Figure 38. Average tree height of ponderosa and piñon/juniper (combined species) for all thinning plots.

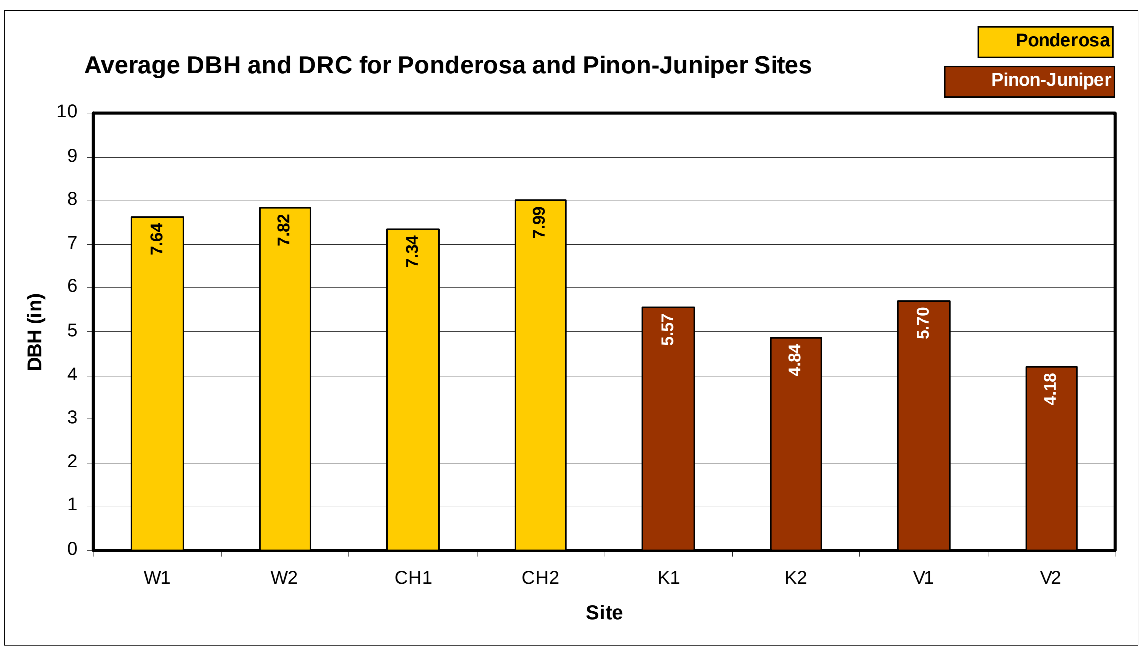

Figure 39. Average DBH and DRC of ponderosa and piñon/juniper (combined species) for all thinning plots.

In order to describe the size class distribution of ponderosa at the Wester site, the following graphs illustrate the variation in height and DBH (Figure 40 and Figure 41).

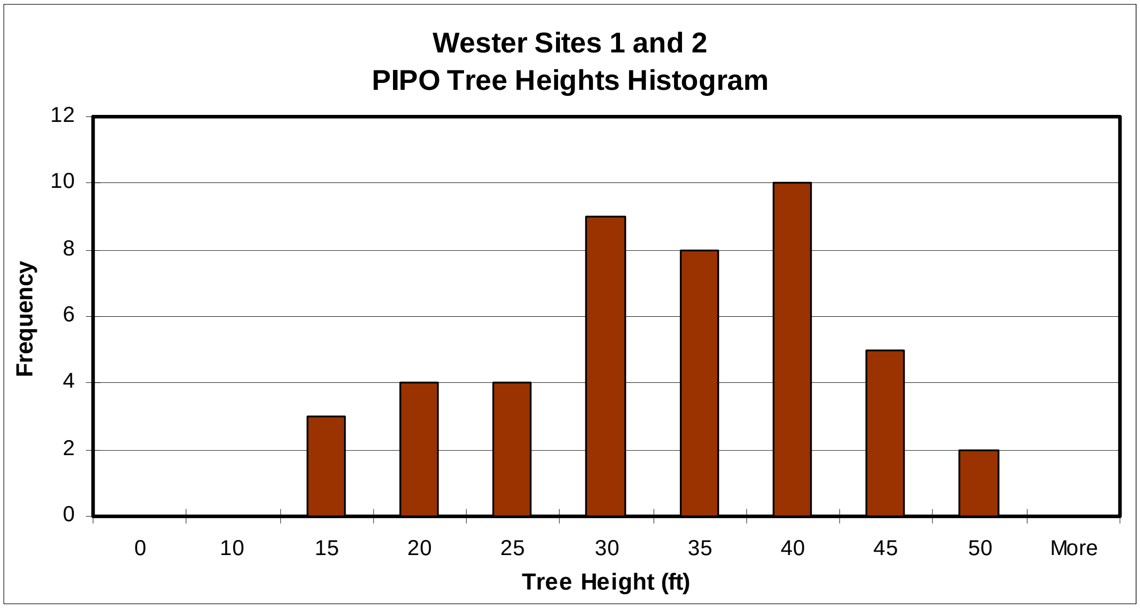

Figure 40. Height distribution of ponderosa on the Wester plots.

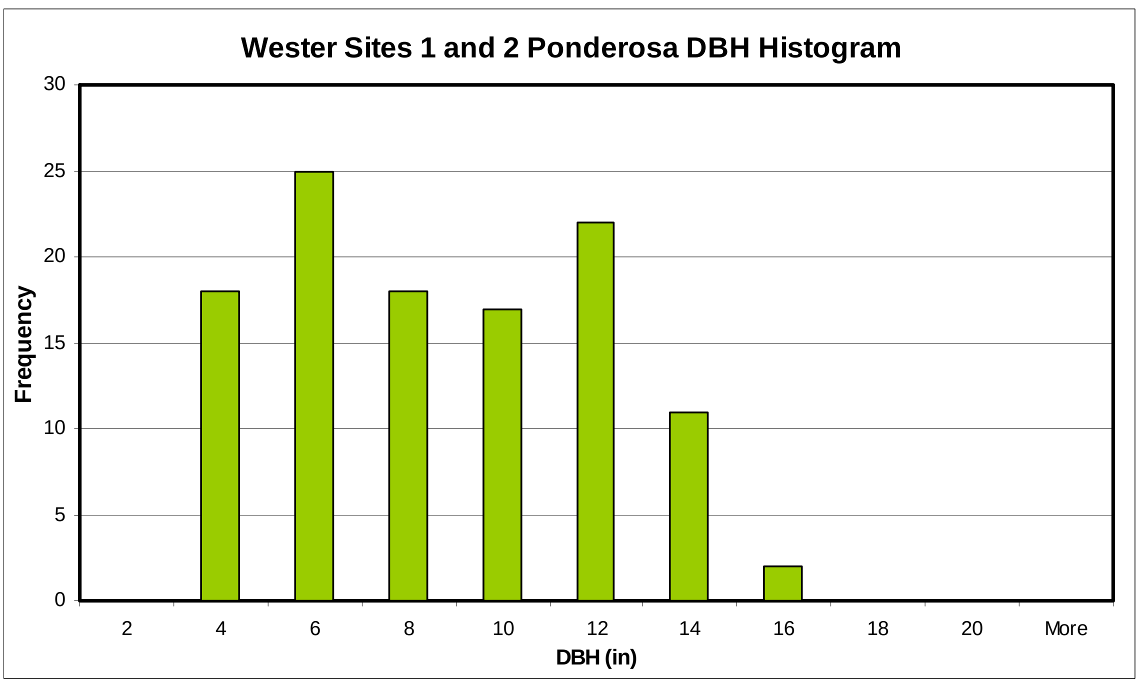

Figure 41. DBH distribution of ponderosa pine on the Wester plots.

The majority of ponderosa trees at the Wester site were in a mid-size range from 9 to 12 m (30–40 feet) and 15- to 30-cm (6- to 12-inches) DBH. A few very large trees were found on the Wester plots, but no trees exhibited DBH measurements greater than 41 cm (16 inches). Small saplings and seedlings were excluded from this graph as heights were only measured on trees greater than 5 cm (2 inches) DBH. There were very few dominant upper canopy trees greater than 14 (45 feet).

The height distribution of one-seed juniper (the dominant species) on the Kelly plots is presented in Figure 42. As before, trees less than 2 m (6 feet) were not included in this graph because trees less than 5 cm (2 inches) DRC were only tallied and considered as regeneration. The majority of one-seed juniper trees on the Kelly plots were 3.7 to 4.3 m (12–14 feet) high.

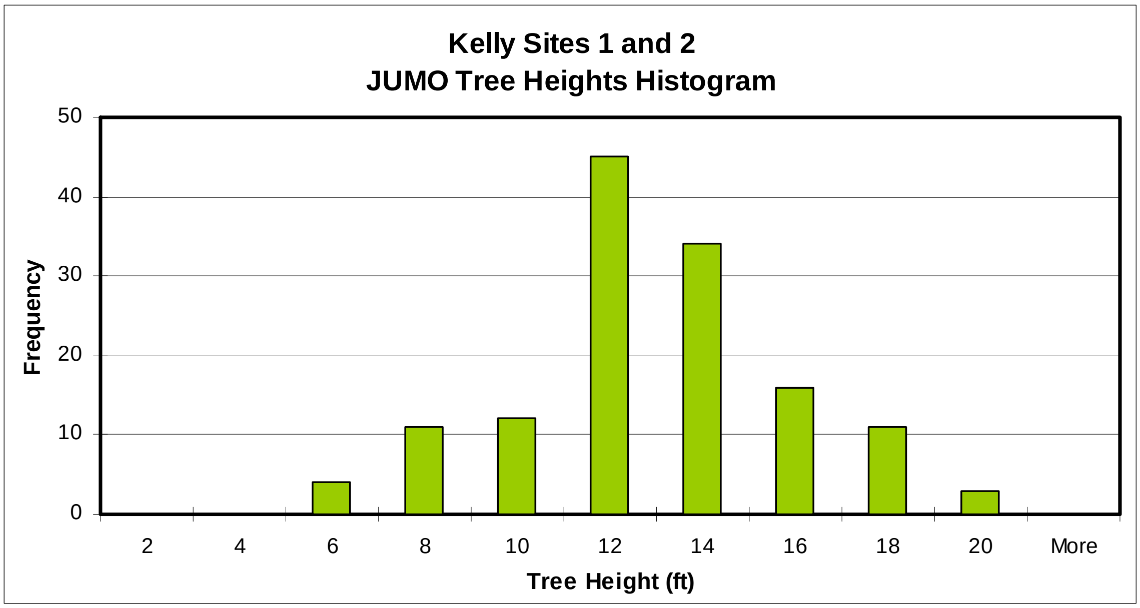

Figure 42. Height distribution of one-seed juniper on the Kelly plots.

Figure 43 presents the seedling and sapling data for all thinning plots. Juniper seedlings and saplings were dominant over pine species in nearly all plots, including the ponderosa-dominated plots at the Wester and Chilili sites. Piñon pine was dominant on the Vigil plots, with over 600 piñon seedlings recorded on the Vigil 2 plot. Alligator juniper seedlings were absent from the Vigil plots but present on all other plots. Rocky Mountain juniper was found only on the ponderosa plots.

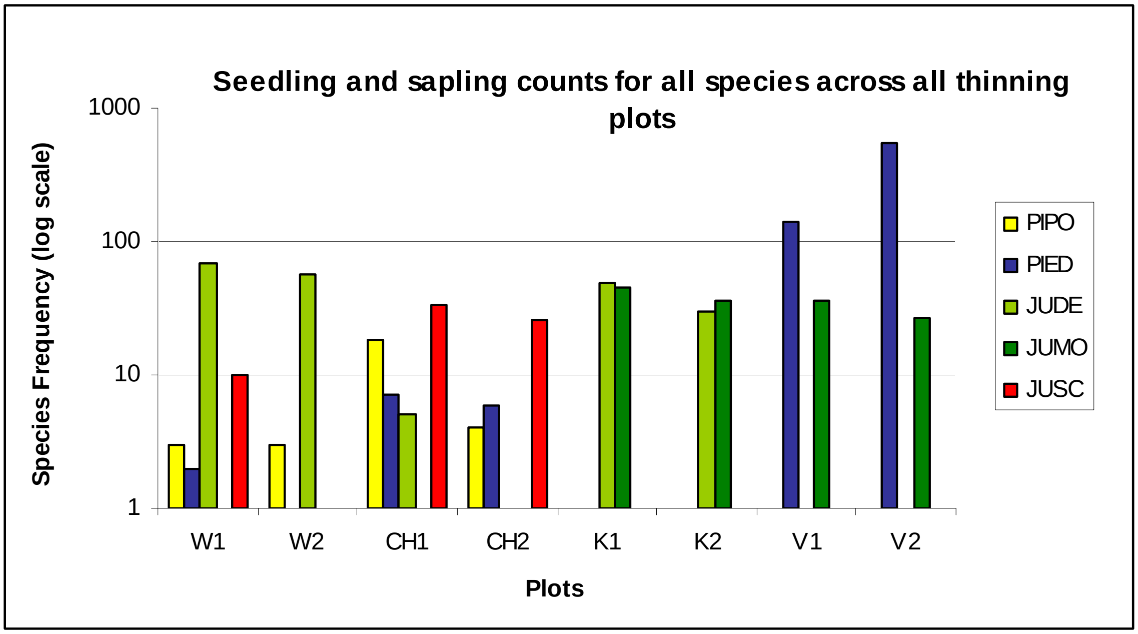

Figure 43. Number of seedlings/saplings in each thinning monitoring plot by species

Figure 44 and Figure 45 present data on crown dieback for the Wester and Kelly plots. Ponderosa pine dieback for most trees tagged on Kelly plots was approximately 20%, representing natural annual dieback. Some smaller trees, particularly those that were overtopped by upper canopy trees, exhibited needle stress, with dieback reaching up to 80% to 90% of the crown volume.

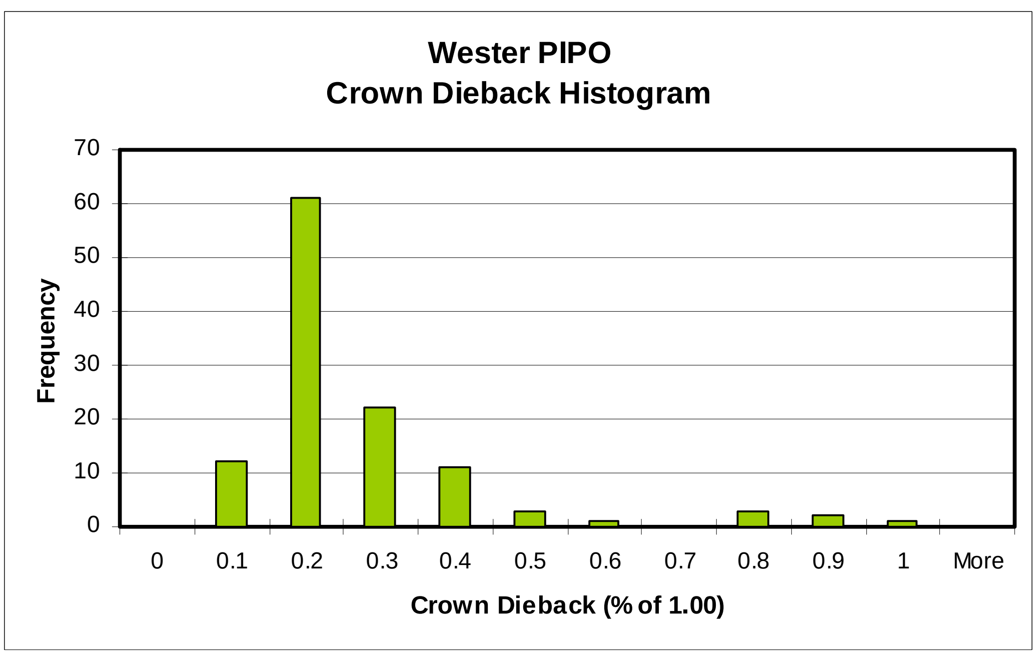

Figure 44. Percent crown dieback recorded for tagged trees on both Wester plots.

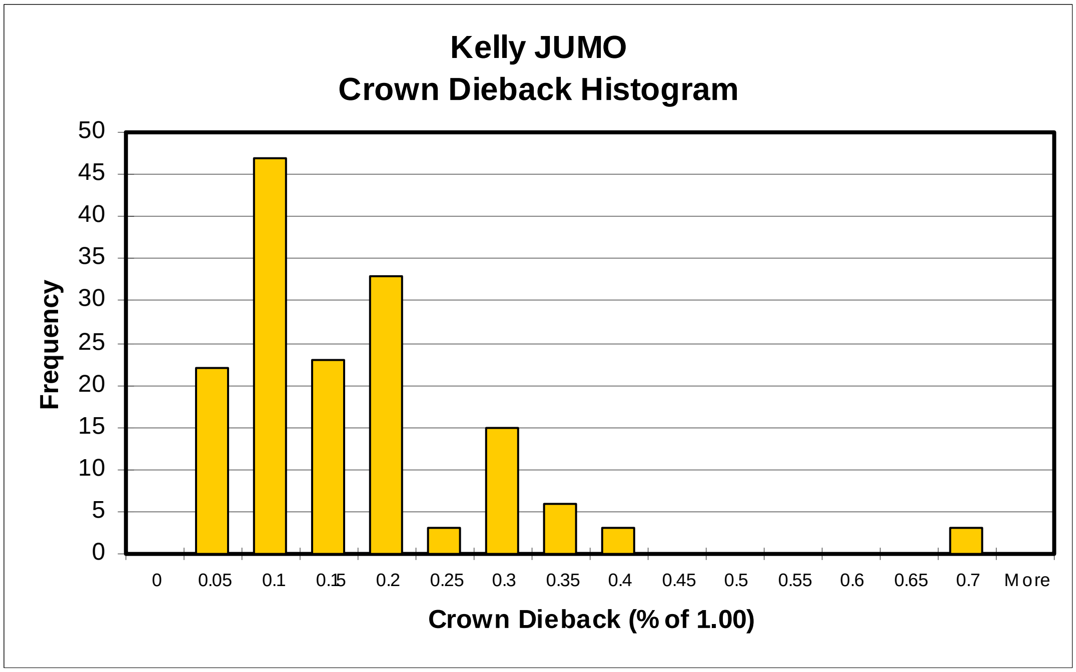

Figure 45. Percent crown dieback recorded for tagged one-seed juniper on both Kelly plots.

The majority of one-seed juniper on the Kelly piñon/juniper plots exhibited 5% to 20% dieback. Some trees, however, showed signs of significant stress, with over 40 trees (approximately one-third of all one-seed juniper) showing greater than 30% dieback. Bark beetle damage to piñon pine was also identified on some isolated piñon at the Kelly site. Mistletoe was prevalent, but was most pronounced at the Vigil piñon/juniper site.

Herbaceous Vegetation

A matrix of all plant species found at each of the four study sites is presented in Appendix A. At this time, we are still identifying some plant species that we could not identify in the field, but voucher specimens were collected and have been assigned temporary code names. We anticipate completing these identifications over the winter of 2008/2009 and will update the species lists, data, and data analysis once those identifications are complete.

Vegetation canopy cover was measured as relative values by species on a continuous line-intercept transect across each vegetation and soils monitoring subplot, and as absolute cover per square meter on vegetation quadrats on each subplot. Figure 46 shows overall herbaceous vegetation cover on the Kelly piñon/juniper and Wester ponderosa study plots. We used standard t-tests to test the hypothesis of no difference in mean vegetation cover values between the paired plots at both sites. The paired study plots at the Kelly piñon/juniper and Wester ponderosa pine sites were not significantly different from each other. In the future, we will continue to assess differences in vegetation cover between paired study plots, and ultimately we will examine differences in vegetation based on life form, life history, and certain dominant species.

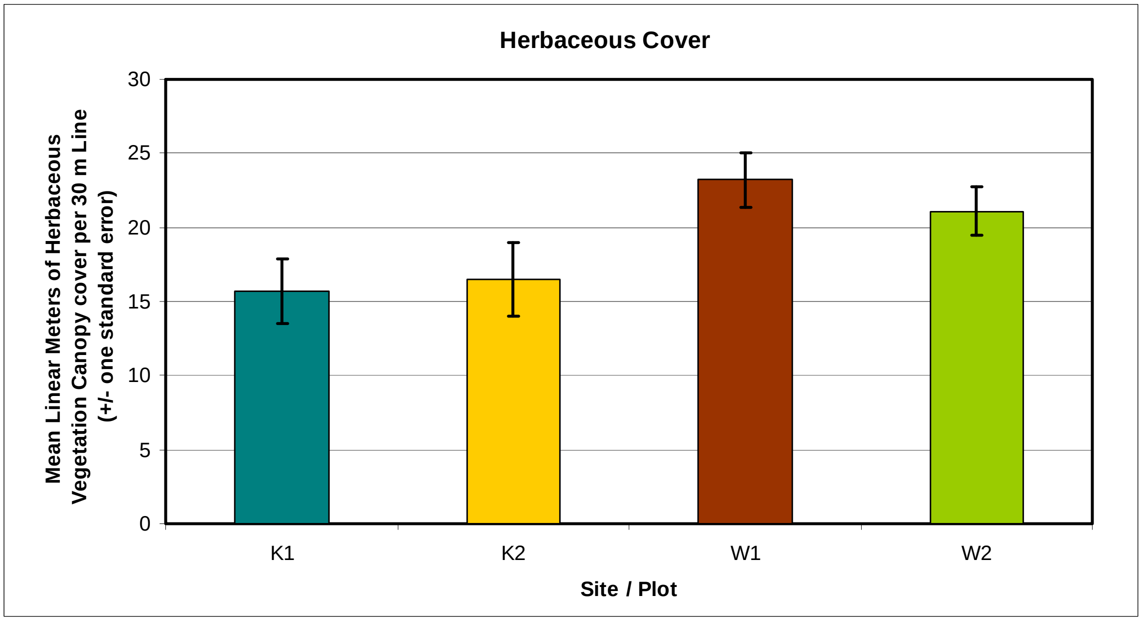

Figure 46. Linear meters of herbaceous vegetation canopy cover per 30-m lines (means and standard errors) measured at the Kelly piñon/juniper and Wester ponderosa pine sites.

Vegetation Structure

Vegetation vertical canopy structure was measured on each of the three vegetation and soils subplots. The method was adapted from Herrick et al. (2005) and consisted of a 2-m (6.5-foot) long, 5-cm (2-inch) diameter white PVC pipe pole partitioned into three different 2-m (6.5-foot) height layers, each with continuous 10-cm (4-inch) black/white increment markings (Figure 47). An observer recorded vegetation canopy obstruction of the black and white marked areas on the pole while another person held the pole vertical at three locations across the center line of each 30-m (98-foot) vegetation and soils monitoring subplots, one reading at 10 m (33 feet), one at 20 m (66 feet), and one at 30 m (98 feet). The observer was located 10 m (33 feet) toward the center of the plot from the pole for each canopy measurement. An overall visual obstruction average score was then calculated for each of the three lines per subplot, and an overall average score was calculated for each plot. Scores for the Kelly and Wester plots are shown in Figure 48. Vertical vegetation structure was similar between paired plots at the Kelly piñon/juniper site, but plot 2 at the Wester ponderosa pine site had considerably denser canopy structure than plot 1. Monitoring vertical vegetation structure profiles is not only important for assessing wildlife habitat, but also for fire fuels structure.

Figure 47. Photograph of vegetation structure pole used to quantify vertical vegetation canopy structure.

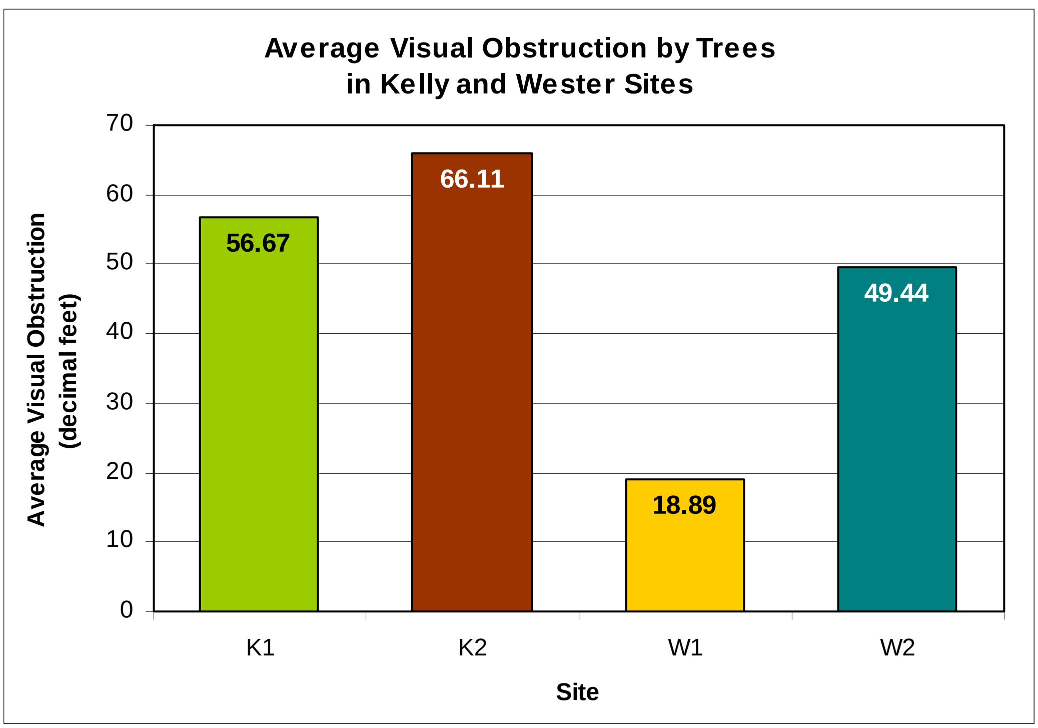

Figure 48. Average visual obstruction values from Kelly piñon/juniper and Wester ponderosa pine study plots.

WILDLIFE

Birds and small mammals are being monitored in order to determine if forest thinning affects native wildlife species. Both birds and small mammals are recorded from separate 50 × 50–m (164 × 164–foot) wildlife study plots that are immediately adjacent to each of the two vegetation and soils monitoring study plots at each of the four study sites. Birds and mammals are measured in late spring (May) and early autumn (September/October) for three consecutive days on each of the study plots.

Birds

The species composition and relative abundance of birds on all study plots were recorded by observing birds by point counts from one location at the center of each wildlife study plot. Each point count was conducted for 20 minutes at dawn for three consecutive mornings on each study plot in both spring and autumn. Spring counts are intended to assess breeding bird use of the forest and woodland habitats, and autumn counts are intended to assess migratory bird use of the same habitats. Many of the bird observations were based on hearing songs and calls and identifying those to species. Additionally, visual observations were often recorded. A list of all bird species observed across the four study sites and counts of individuals are presented in Appendix B. We encountered a total of 40 bird species from all of the study sites. The total numbers of birds observed during the autumn counts at the Kelly and Wester sites are shown in Figure 49 and Figure 50. Bird species composition at the Kelly site was similar between the two paired study plots. Bird species composition was also similar between the paired plots at the Wester site, but more individuals were recorded from plot 1 than plot 2.

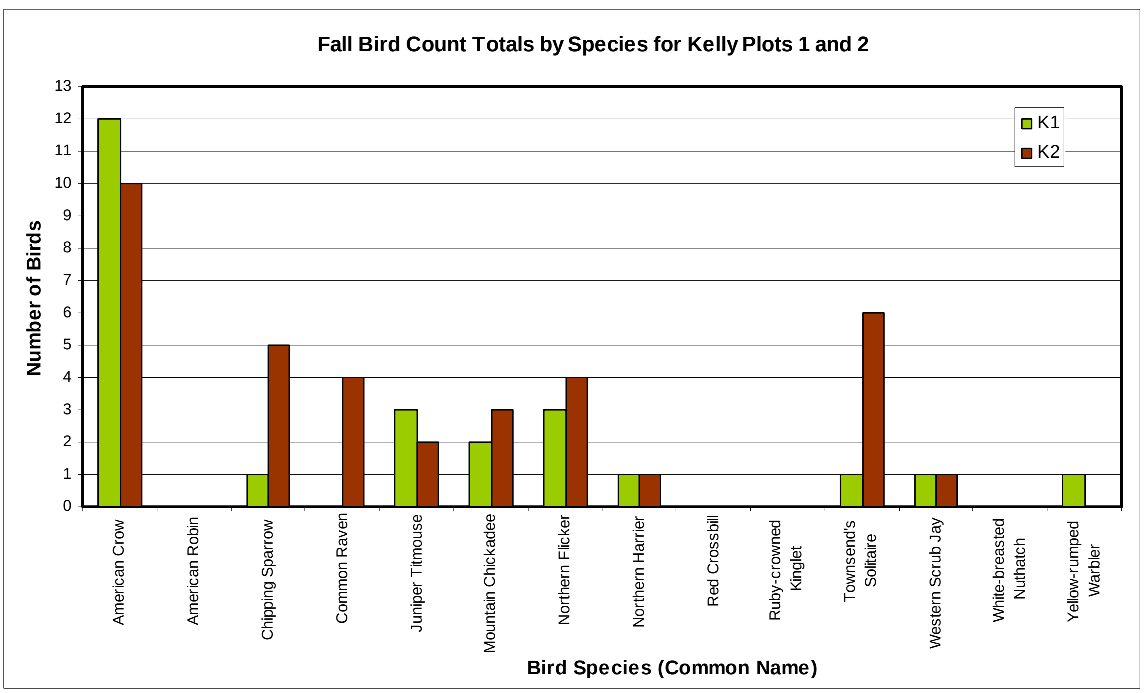

Figure 49. Numbers of birds observed at the Kelly piñon/juniper plots in autumn 2008 from point counts.

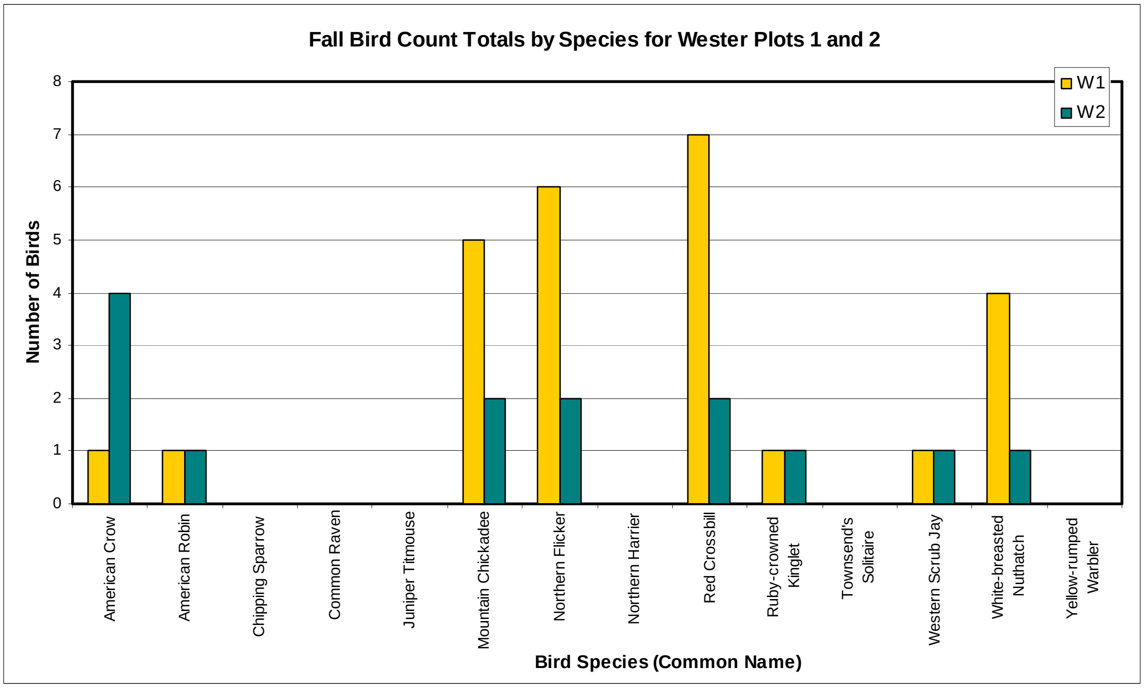

Figure 50. Numbers of birds observed at the Kelly piñon/juniper plots in autumn 2008 from point counts.

Small Mammals

Small mammals (rodents) were sampled from a 6 trap × 6 trap grid of live-capture rodent traps set at 10-m (33-foot) intervals on each of the wildlife monitoring plots for three consecutive nights in spring and autumn. Samples from spring and autumn are useful to follow trends in adults and juveniles in order to assess breeding status and production over the year. We encountered a total of five rodent species from all study sites (see Appendix B). The total numbers of rodents observed during the autumn counts at the Kelly and Wester sites are shown in Figure 51. Overall rodent numbers were very low during 2008 at all sites. The piñon mouse (*Peromyscus truei*) dominated the rodents at the Kelly site, and more individuals were found on plot 2 than plot 1. Only one rodent, a piñon mouse was found at the Wester site in both the spring and autumn. Long-term rodent trapping is also being conducted at the Sevilleta National Wildlife Refuge, just southwest of our study area. Rodent numbers at the Sevilleta National Wildlife Refuge also were very low in 2008 (Mike Friggens, Sevilleta Long-Term Ecological Research Program, University of New Mexico, personal communication 2008).

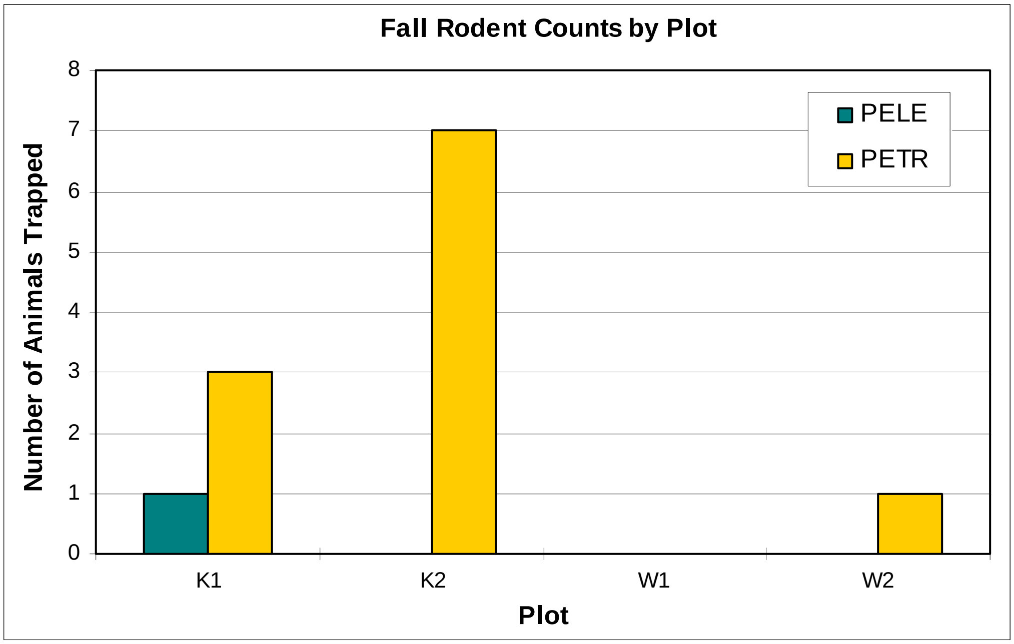

Figure 51. Numbers of rodents captured at the Kelly piñon/juniper and Wester ponderosa pine study plots in autumn 2008. PELE is the white-footed mouse (*Peromyscus leucopus*) and PETR is the piñon mouse.

POST-FIRE MONITORING

In April 2008 a large area of the Estancia Basin watershed was burned in the 13,709-acre Trigo fire (Figure 52). This burn area encompassed a large portion of the Cibola National Forest and also included 3,712 acres of private land on its eastern fringe. Fire creates significant impacts to watershed health, which in turn impacts water yield and groundwater recharge. Since three large wildfires (Ojo Peak, Trigo, and Big Spring) have now burned a considerable portion of the eastern slopes of the Manzano Mountains (Figure 52), the impacts of wildfire on Estancia Basin watershed health are likely significant. The Steering Committee recently awarded SWCA additional funding to develop and implement post-fire monitoring to evaluate wildfire impacts to Estancia Basin watershed health. Of the three major wildfires, Ojo Peak, Trigo, and Big Spring, we have chosen to focus efforts on the Trigo fire. Replicated study sites across watersheds will be more comparable if they are located within an area that burned at about the same time. The Trigo fire also was the largest of the three, it was centrally located within the study region and relative to our existing forest thinning monitoring site, and it burned more watersheds than the other two. The Trigo fire also burned two existing thinning plots on the Bouton property. These two plots have been transitioned over to the fire monitoring study. Understory measurements on the Bouton plots will continue to follow the thinning monitoring protocols, while the tree measurements will follow the fire monitoring protocols in order that monitoring captures fire effects to the trees and overall burn severity to the plot. The full fire monitoring plan for this project was prepared and submitted to the Steering Committee in July 2008, and can be found in Appendix C. That plan provides sampling plot designs and measurement methods.

The fire monitoring occurred from mid September to early November 2008, approximately six to eight months after the Trigo fire. Suitable plot locations were selected in early September 2008 and were identified by stratified random sampling by burn severity from the Burned Area Emergency Response (BAER) map for the burn. Actual plot locations were then chosen through field scouting so that all plots were comparable in terms of vegetation type, topography, slope, and soils.

Plots were selected in Arroyo de Cuervo (Cuervo1 and Cuervo 2) and in the Arroyo de Manzano (Manzano1) watersheds. Three low-severity (Figure 53) and three high-severity (Figure 54) plots were identified in each watershed, and three unburned plots were located across the watersheds (Figure 55). With the permission of landowners, the plots were selected on seven different private parcels of land: Bouton, Sanchez, Manzano Mountain Retreat, Salazar, Candelaria, Mitchell, and Neff. Low- and high-severity areas were widespread across the burn, but unburned ponderosa pine areas with similar topography and slope were limited. As a result, two unburned plots were located in the Cuervo 2 watershed (on the Bouton property) and one unburned plot in the Cuervo 1 watershed (on the Manzano Mountain Retreat property). This Cuervo 1 plot will act as a reference site for plots in the Manzano 1 watershed. Plots were installed with rebar and flagging prior to monitoring, and plot centers were global positioning system (GPS) located and mapped (see Figure 55).

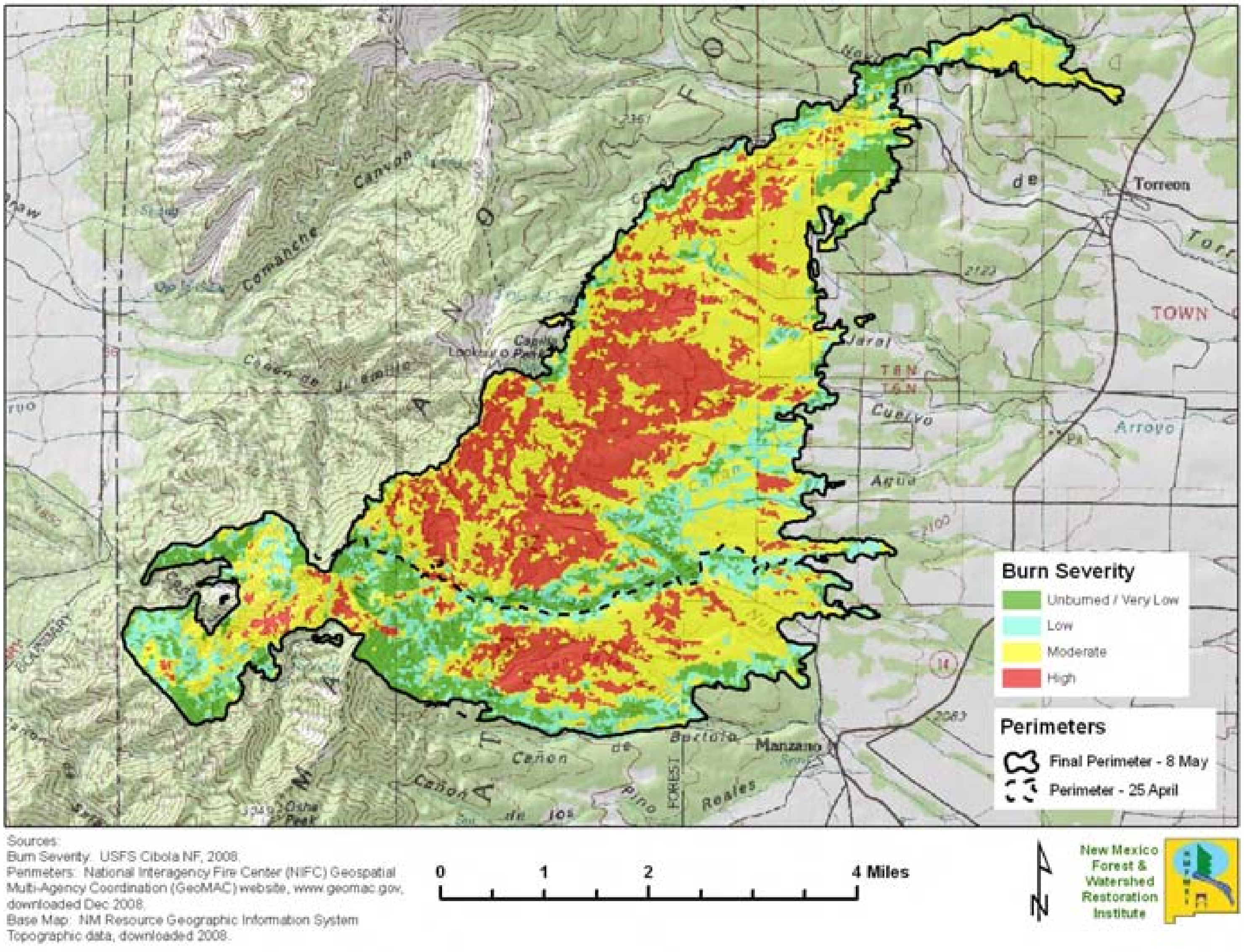

Figure 52. Burn severity map for the Trigo fire showing the final burn perimeter (5/8/2008). ***Source: Restoration Institute.***

Figure 53. Typical low-severity plot in the Trigo burn area.

Figure 54. Typical high-severity plot in the Trigo burn area.

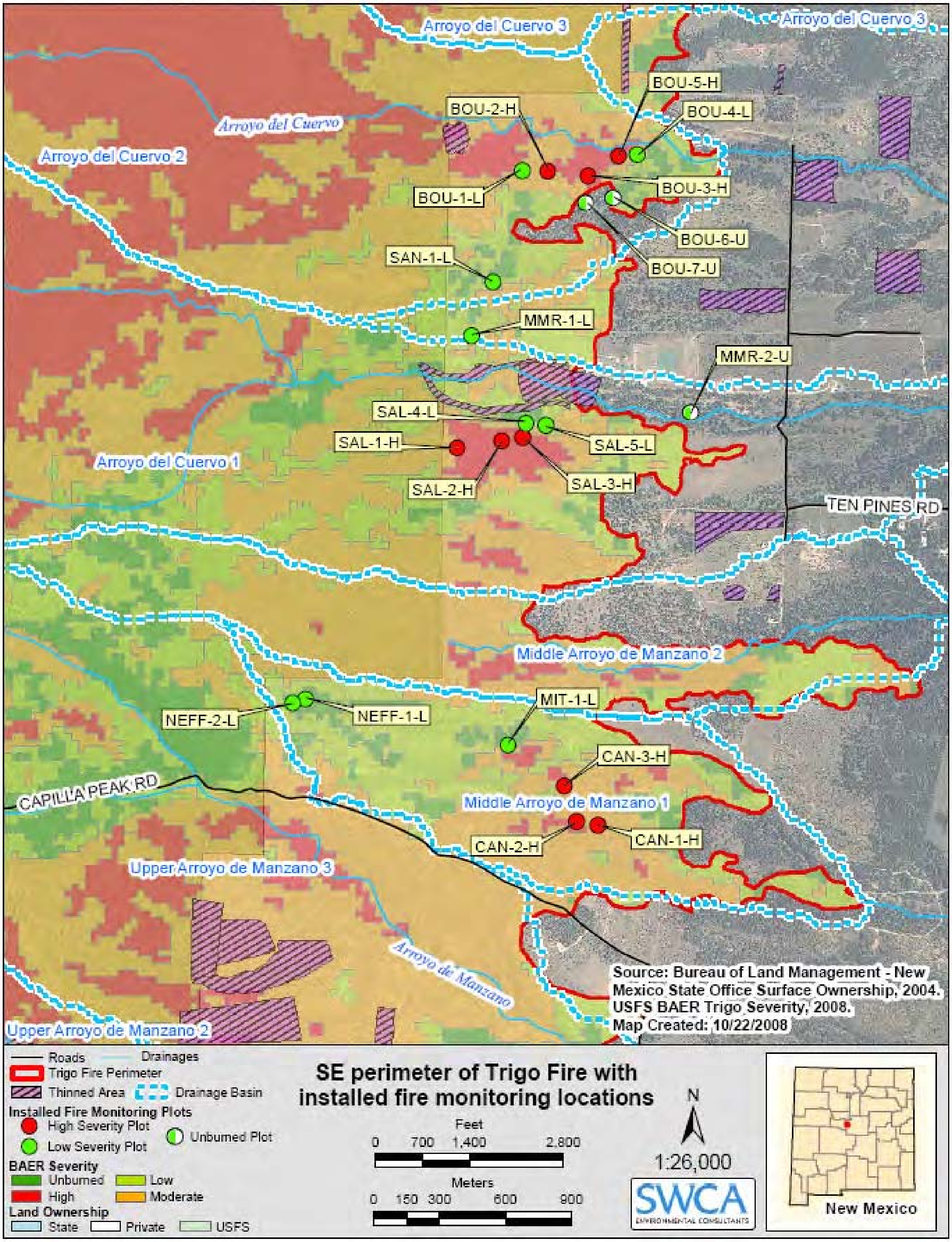

Figure 55. Fire monitoring plot locations.

MEASUREMENTS

Monitoring on each plot consisted of understory measurements (herbaceous species composition, percent cover and structure, and fuel loading), overstory measurements (tree measurements and burn severity), and soil measurements (erosion and sampling) (see Appendix C for details).

Understory Measurements

Line-intercept

Continuous line-intercept measurements focused on the cover type along each of the four transects. Categories included bare ground, litter, grass, forb, and shrub. Figure 56 through Figure 58 illustrate line-intercept data for low-severity, high-severity, and unburned plots. Only example plots are presented here. The low-severity plot was dominated by leaf litter, attributed primarily to needle cast. Half of the high-severity plot was bare ground, but the forb and grass cover was notably greater than in the low-severity plot. This could be a result of early colonizers that took advantage of the exposed soil bed, as well as prevalence of seeded grasses. Both plots showed the presence of forbs, which were not present on the unburned reference site.

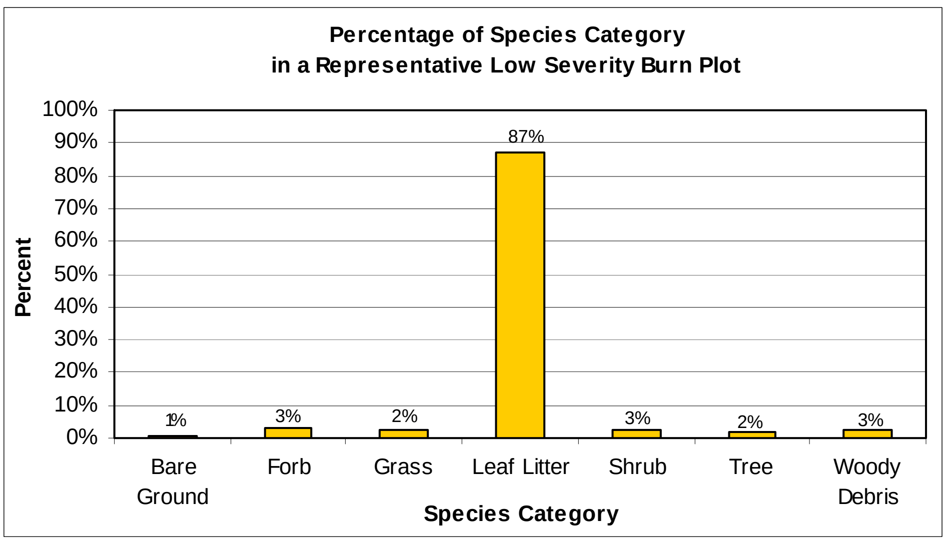

Figure 56. Line-intercept data from a low-severity plot.

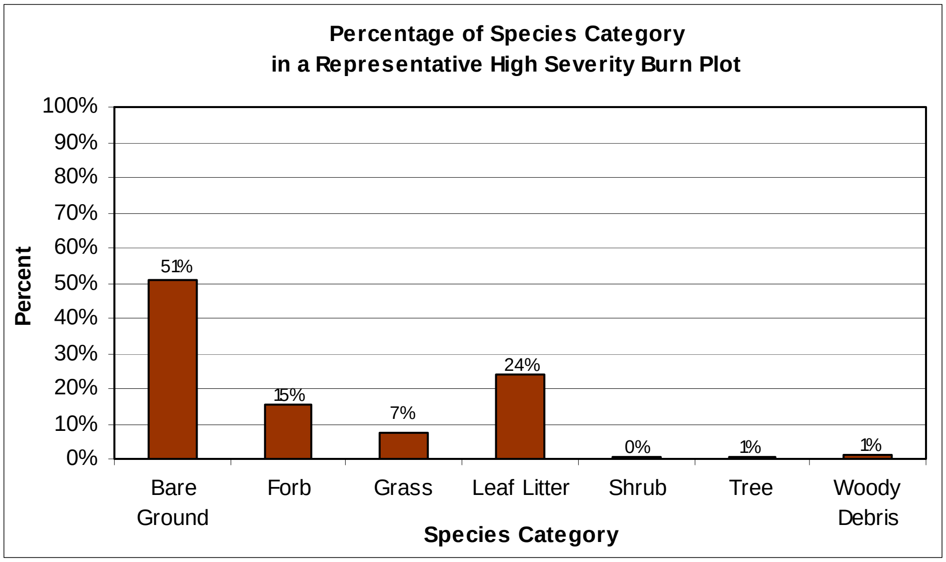

Figure 57. Line-intercept data from a high-severity plot.

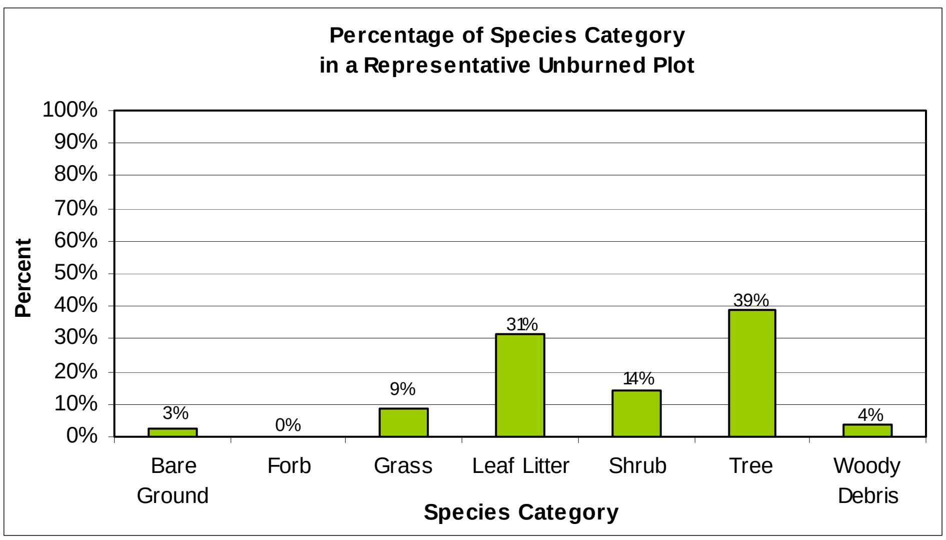

Figure 58. Line-intercept data from an unburned reference plot.

Quadrat Data

Quadrat measurements focused on cover density by species type so that an assessment of the dominant species could be made. The dominant vegetation found in low-severity areas were grass species (70%). The dominant species in high-severity areas were Wright's deervetch (*Lotus wrightii)* and perennial ryegrass (*Lolium perenne*). For two representative plots, Candelaria 3 (high severity) and Mitchell 1 (low severity) on the high-severity plot, the dominant cover was bare ground (Figure 59). Conversely in low-severity plots, the dominant cover was leaf litter.

The unburned reference site at Bouton showed that understory vegetation was minimal in the ponderosa sites. Dominant species include Gambel oak (*Quercus gambelii*), ragleaf bahia (*Bahia dissecta*), blue grama (*Bouteloua gracilis*), redroot buckwheat (*Eriogonum racemosum*), and purple cluster geranium (*Geranium caespitosum*). The high-severity plot had a small percent cover of forbs and no grass, while grass was the only herbaceous vegetation found in this particular low-severity plot.

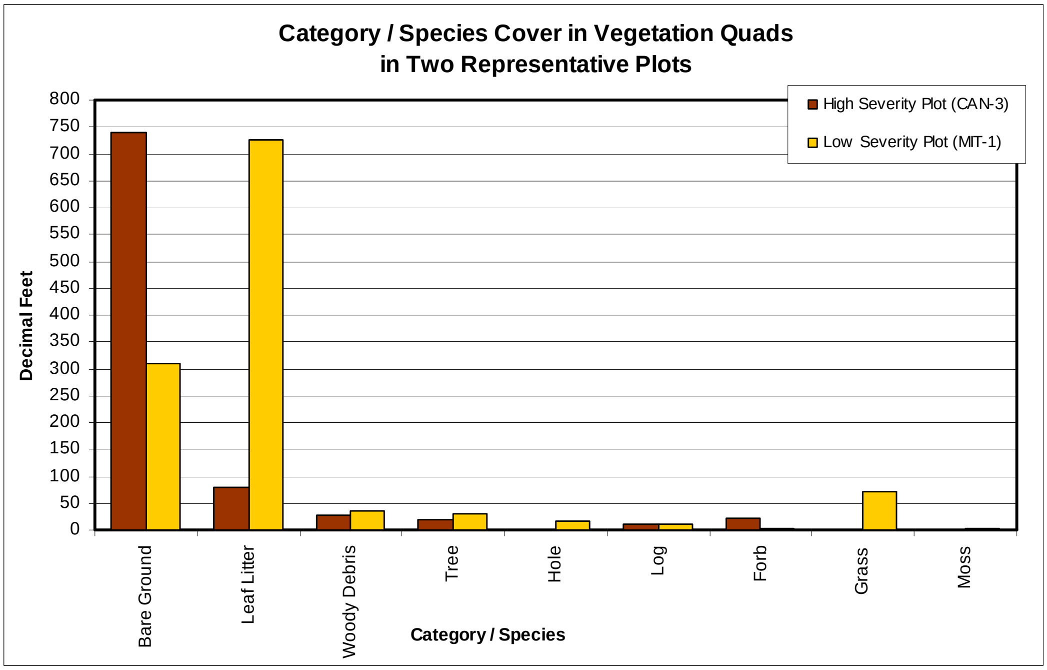

Figure 59. Vegetation quadrat data for a high- and low-severity plot.

Trees

Tree measurements took place on 8-m (25-foot) radius plots measured from the center of the fire monitoring plot. Trees were tagged in a clockwise direction from the north transect. Because of the large number of trees, only the height of every other tree was measured, but all other parameters were recorded for every tree (Figure 60). Heights of the remaining trees were later calculated using a regression equation developed from the relationship between DBH and tree height (Figure 61). Only ponderosa pine greater than 1.3 m (4.5 feet) were tagged, but all trees less than 1.3 m (4.5 feet) high were tallied, and their species and status (live or dead) were recorded.

Figure 60. Post-wildfire tree monitoring.

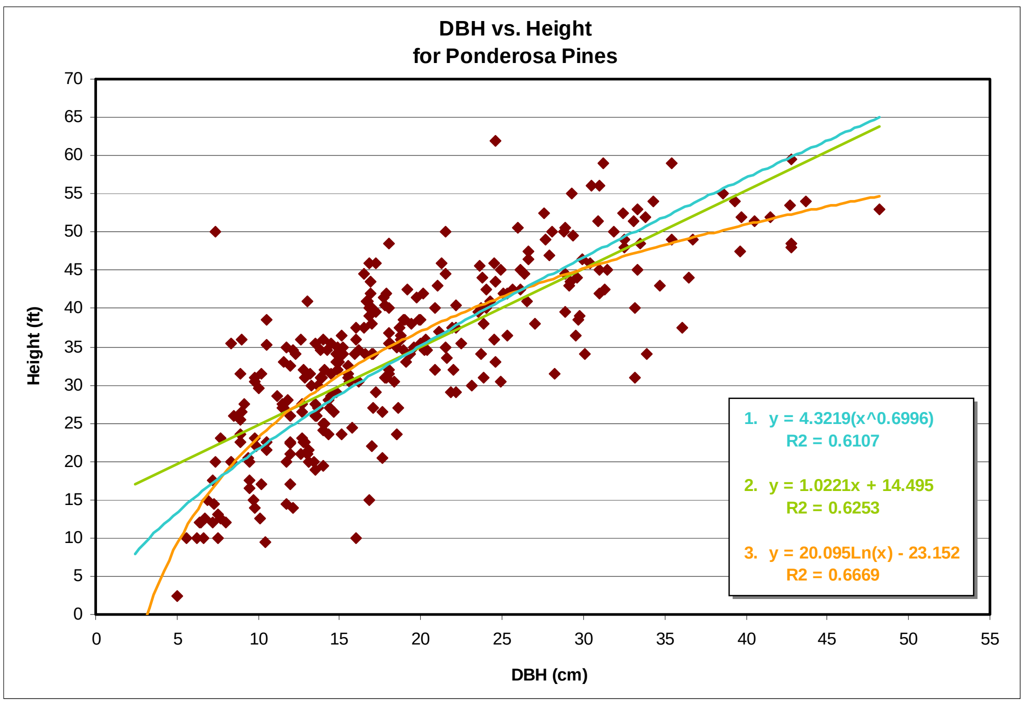

Figure 61. Relationship between height and DBH for tagged ponderosa pine across all fire monitoring plots.

Figure 61 shows the relationship between DBH and tree height for measured ponderosa pine in all plots. There is a slight non-linear relationship between the two parameters, and the R2 value of 0.66 suggests that 66% of the variance in the data is explained by that relationship.

Tree Count

The number of tagged and untagged trees (trees < 1.3 m [4.5 feet]) on each plot was recorded. In future years, regeneration will be recorded by tallying seedling numbers for each species. Some species were already showing signs of recovery, particularly Alligator juniper (Figure 62) and Gambel oak.

Figure 62. Alligator juniper resprouting from dead overstory

Height Measurements

The tree heights of ponderosa pine across the plots from north to south ranged from 15 m (48 feet) at the Manzano Mountain Retreat (Figure 63) plots to 8.5 m (28 feet) at the Neff plots; the average height across all plots was 9.6 m (31.6 feet) (Figure 64). The average height for trees on the Manzano Mountain Retreat plots was noticeably greater than on other plots, because many of the smaller pole-sized trees had previously been removed in a thinning from below.

Figure 63. Manzano Mountain Retreat ponderosa pine.

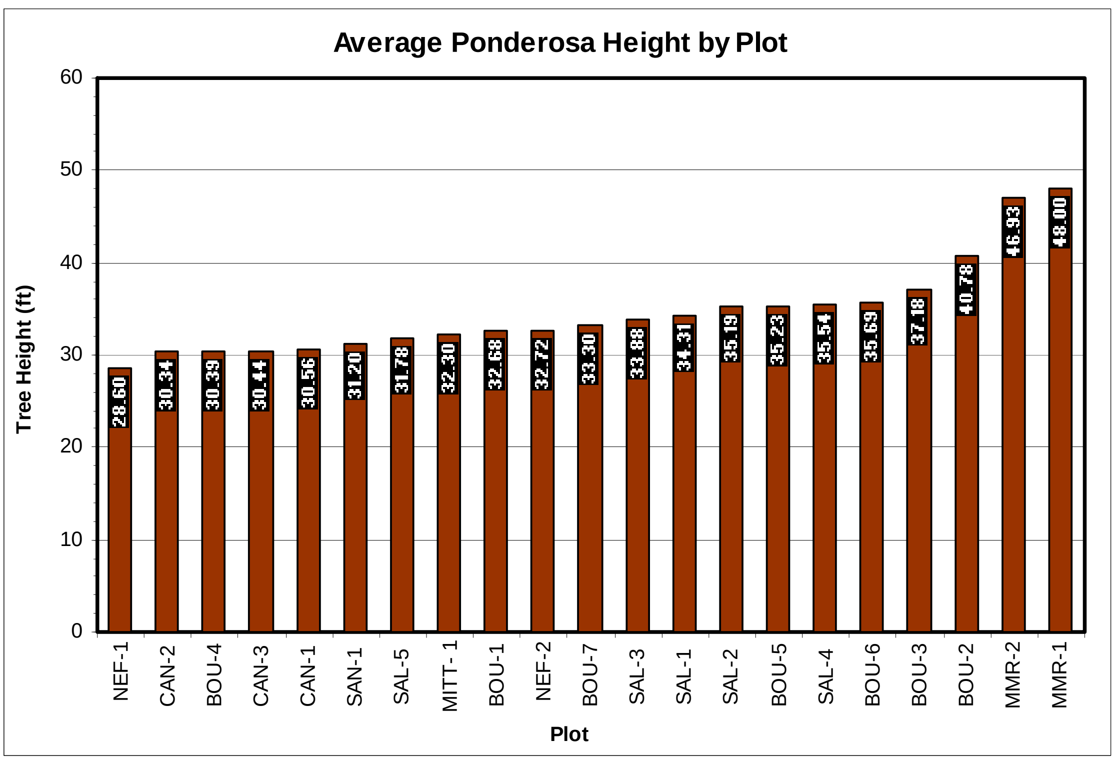

Figure 64. Average height of ponderosa pine across all fire monitoring plots

Canopy Density Measurements

Canopy density was measured using a Convex Densiometer at the plot center in each cardinal direction. Table 3 shows the percentage canopy density for all fire monitoring plots. The densities remained relatively consistent across all plots.

Table 3. Overstory Density of Each Fire Monitoring Plot

Plot	Burn Severity	% Overstory Density
SAL-1	H	77.12
SAL-2	H	77.12
SAL-3	H	78.42
SAL-4	H	77.38
SAL-5	L	76.08
MMR-1	L	80.76
MMR-2	U	84.4
BOU-1	L	76.6
BOU-2	H	79.2
BOU-3	H	78.94
BOU-4	L	78.16
BOU-5	H	79.2
BOU-6	U	77.12
BOU-7	U	75.04
SAN-1	L	82.06
MIT-1	L	76.08
NEF-1	L	79.46
NEF-2	L	77.9
CAN-1	H	79.72
CAN-2	H	76.21
CAN-3	H	81.54
BOU- T*	H	73.05
BOU- T*	L	67.45

H = High; L = Low; = Unburned.
* Bouton T plots are the original thinning plots that burned in the Trigo fire.

Fire Severity and Tree Mortality Measurements

Fire severity was measured on each tree in terms of the percent scorch, percent consumption, bole char, and tree mortality. When crown consumption is graphed against tree density for all plots, there appears to be little statistical relationship (Figure 65). It should be noted, however, that plot level crown consumption is impacted by a number of variables, including fire behavior (active/passive crown fire), wind, topography, and neighboring stand conditions. Crown consumption tended to be either 0% or 100%, suggesting the fire either remained on the ground or torched the crowns with minimal variation in between.

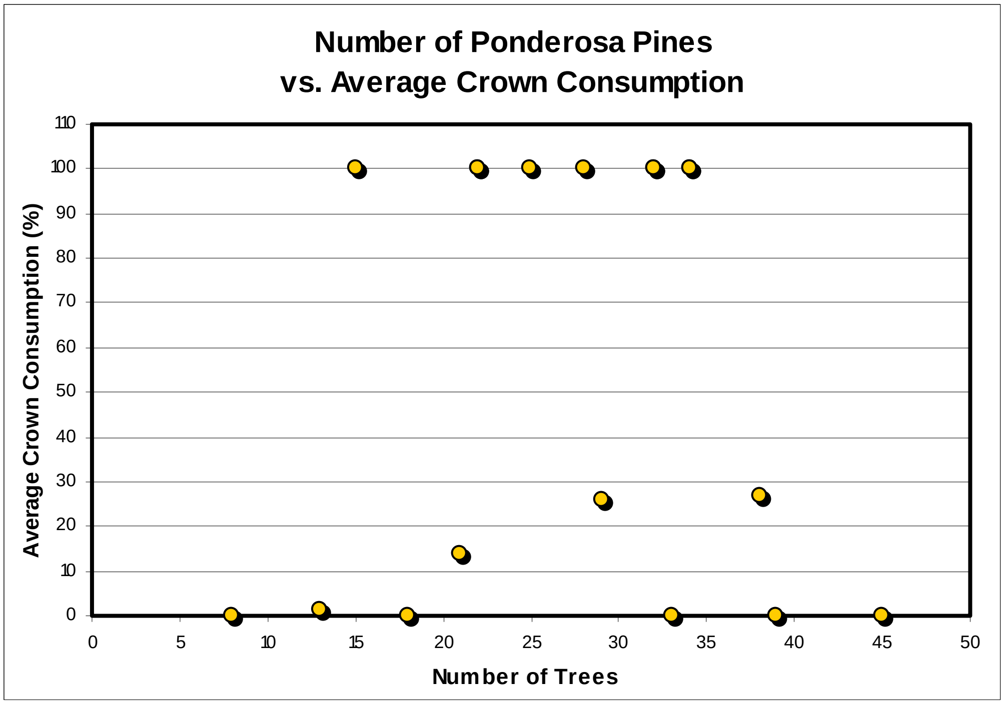

Figure 65. Crown consumption against number of trees per 25-foot radius plot.

Fuels

Fuels measurements were taken along a 23-m (75-foot) transect set along a random azimuth from the fire monitoring plot center. Fuels measurements followed a similar protocol to that developed by the Restoration Institute and the conventional Brown's transect (Brown et al. 1982). Fuels were categorized into 1-, 10-, 100-, and 1,000-hour particle sizes. Duff depth measurements were also made at 8 m (25 feet) and 15 m (50 feet) along the transect line. Figure 66 illustrates the composition of fuel particle sizes measured on high-severity, low-severity, and unburned plots in the Cuervo 1 watershed.

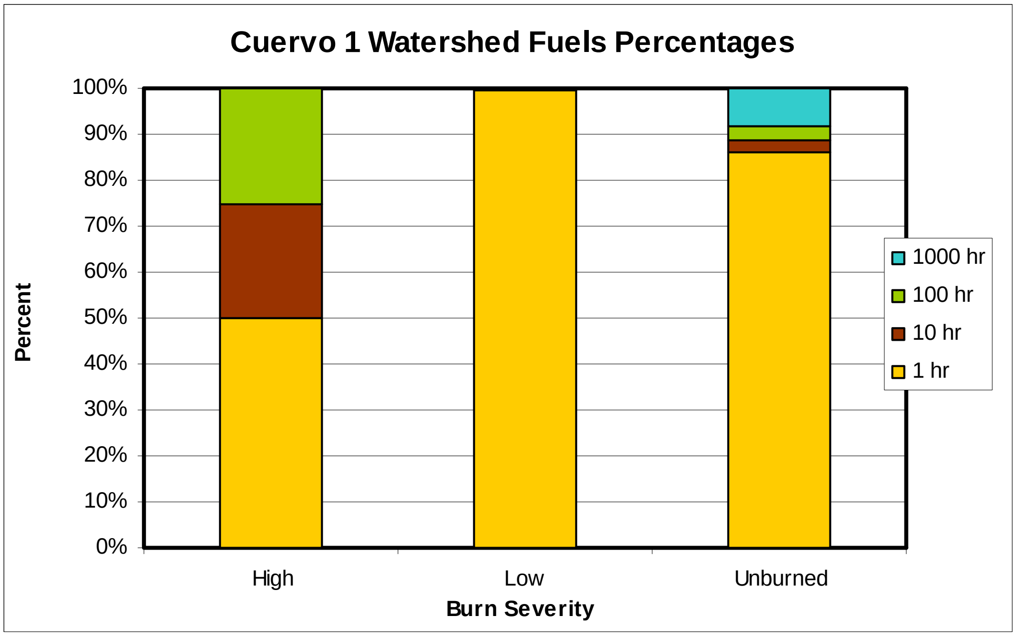

Figure 66. Percent composition of fuels of differing size class on high-severity, low-severity, and unburned plots in the Cuervo 1 watershed.

Using the unburned plot as a reference, the high-severity plot exhibited the greatest loss of fine fuels relative to the low-severity plot, leaving a larger proportion of 10-hour and 100-hour fuels that were not consumed. Low-severity plots had almost 100% cover by fine fuels. Field observations showed minimal impact to large 100- and 1,000-hour fuels where present. The reference plot shows that these ponderosa pine stands consist primarily of a fine fuel understory of needle cast with limited large woody debris. Duff consumption measurements were also made on the fuels transects. Duff consumption was minimal on low-severity plots (Figure 67a) but was almost 100% on most high-severity plots (Figure 67b). In future years, additional fuels transects will be carried out on each plot to determine the degree of needle cast on scorched plots and additions to dead and downed materials that may result from tree mortality.

Figure 67. a (left). Low-severity plot - needle cast and pine litter; b (right). High severity plot - bare ground.

The Bouton Plots

Two of the original ponderosa thinning plots were burned during the Trigo fire. One burned with low severity and the other with high severity. The Bouton high-severity plot had a number of trees in just a few size classes (10–25 cm [4–10 inches]) clumped together; there were no large trees over 25 cm (10 inches) in diameter Figure 68. The low-severity plot had a greater range of size classes from 5 to 41 cm (2–16 inches) in diameter, with larger gaps between the size classes that would suggest a more varied stand structure with fewer ladder fuels. The high-severity plot is characteristic of a more homogeneous stand structure, while the low-severity plot is characteristic of a more heterogeneous stand.

Understory measurements on the Bouton plots were carried out following the same protocol as in the thinning study. The high- and low-severity plots followed similar patterns of revegetation as was observed on other high- and low- severity fire monitoring plots.

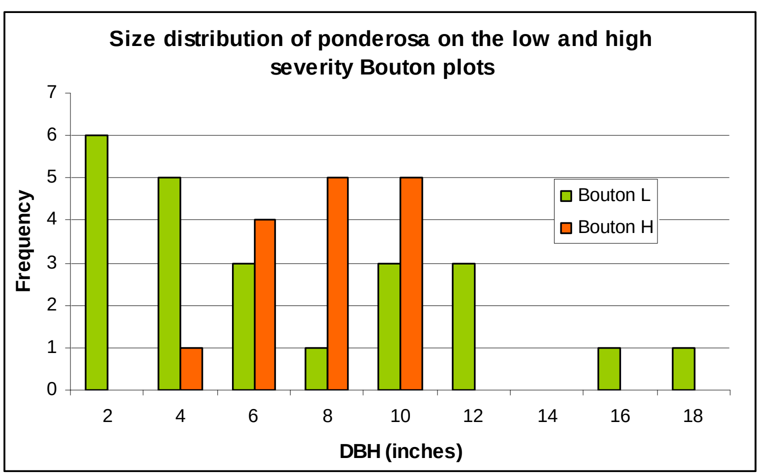

Figure 68. Distribution of size class for ponderosa pine on both the low- and high-severity Bouton plots.

The high-severity plot exhibited 100% canopy consumption (Figure 69); the low-severity plot received a maximum of 5% consumption but a range of canopy scorch (Figure 70) from 5% to 100%.

Figure 69. Bouton original thinning plot burned with high severity.

Figure 70. Bouton original thinning plot burned with low severity.

Composite Burn Index Fire Severity Study

As part of the fire monitoring project, we carried out an assessment of burn severity on plots selected within the Trigo fire perimeter. Plots were first broken into thinned and unthinned classifications, and later further classified into density classes (ranked from 1 - low density to 5 - high density (Figure 71) since thinning prescriptions varied across the study area. In total, 103 plots were measured across the burn area; 21 of them were measured on the installed fire monitoring plots. Because of limited thinning of ponderosa pine within the study area, 33 plots were added on USFS land adjacent to the private land in order to increase coverage in thinned areas of the burn.

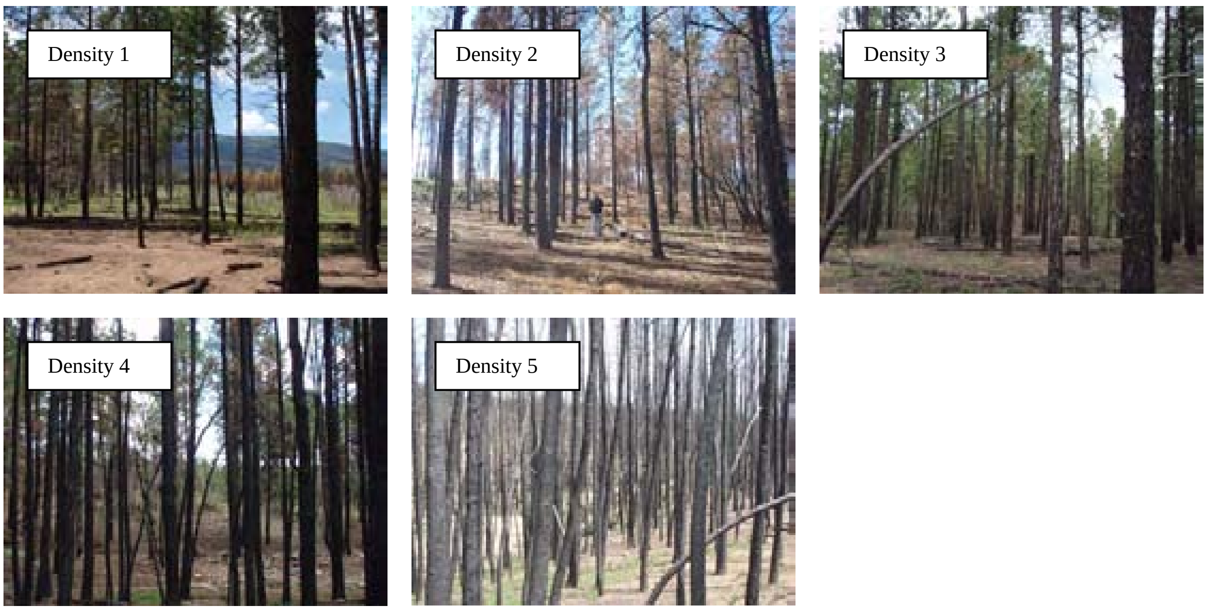

Figure 71. Example density classes.

We chose to use the Composite Burn Index (CBI) methodology (Key and Benson 1999) to classify severity, because it allows quick and accurate measurement of burn severity across a large area. CBI measures burn severity of a plot on a scale of 0.0 to 3.0:

- CBI: 0.0–0.5 = unburned
- CBI: 0.5–1.5= low severity
- CBI: 1.5–2.5= moderate
- CBI: 2.5–3.0= high

CBI plots are circular nested plots with a 6-m (20-foot) radius plot nested inside another 8-m (25-foot) radius plot. The smaller plot is used to measure fire effects to the understory strata, which includes parameters of soil, litter, duff, herbaceous vegetation, and shrubs (understory). The larger, outer plot is used to measure fire effects to the sub-canopy and dominant canopy strata, which include trees greater than 5 m (16 feet) (overstory). All measurements are ocular estimates of fire damage to parameters across the plot, and measurements are made by the same person in order to limit error through subjectivity. CBI values are calculated for the understory and overstory strata, and then a total plot CBI average is calculated from these two values (Figure 72 a–d).

72-a. Low-severity, low-density area: CBI 1.5

72-b. High-severity, low-density area: CBI 2.7

72-c. Low-severity, high-density area: CBI 1.2

72-d. High-severity, high-density area: CBI 3.0

Figure 72 (a–d). Example CBI scores for plots located within the Trigo fire perimeter.

The following chart (Figure 73) shows the average CBI values across all plots for understory, overstory, and total. The plots are classified into densities 1 through 5. This chart shows a trend towards increasing severity with increasing tree density. Plots with a lower tree density had lower CBI values (lower burn severity) for both understory and overstory than plots with higher densities. The understory severity is greater than overstory severity in lower density plots (densities 1–4), suggesting that the burn was dominated by surface fire; plots classified with the greatest density (5) experienced higher severity damage to the overstory characteristic of crown fire.

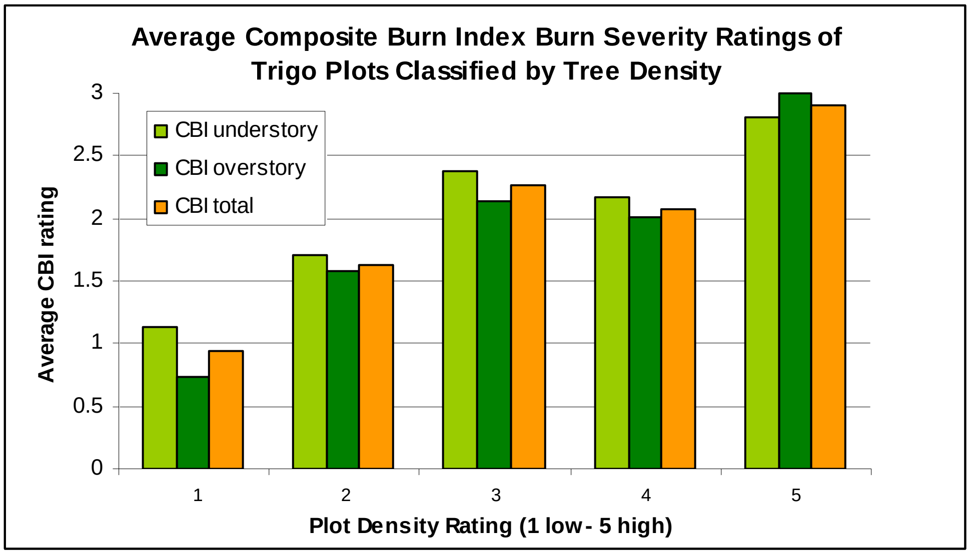

Figure 73. Average CBI ratings for 103 plots distributed on private and public land throughout the Trigo burn area. Plots are classified by tree density, and bars represent understory burn severity, overstory burn severity, and overall plot burn severity.

Duff damage and upper tree canopy mortality generally increases with plot density (Figure 74). Lower-density plots experienced more damage to the duff layer relative to the upper canopy, while higher-density plots received higher levels of severity to the upper canopy trees relative to the duff layers; however, both strata received high levels (>2.5 CBI) of damage at these high densities.

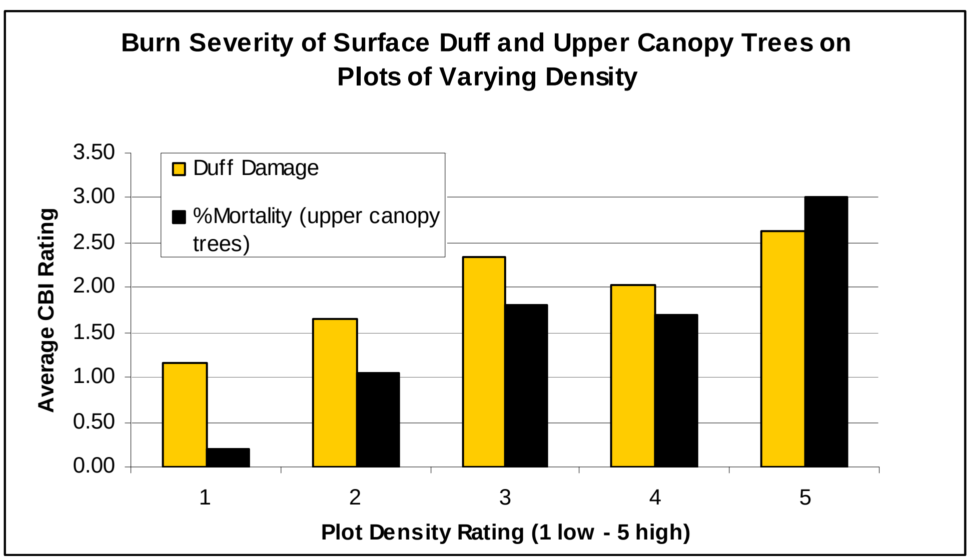

Figure 74. Average CBI ratings for damage to the duff layer and upper canopy trees across plots of varying density.

SOILS

Soil measurements completed this year included soil sampling to test for macro-nutrients and installation of soil erosion bridges.

Four soil samples were collected from each plot (one in each quadrant of the plot) and returned to the SWCA lab in quart size bags for analysis. The soils are being analyzed for macro-nutrients such as potassium, phosphorous, and sodium. This process is ongoing and results will be made available as soon as the process is complete.

Two soil erosion bridges were located at the ends of the north and south transects on each plot. Measurements were made using a custom made device that measures changes to the soil surface in relation to a permanent marker (Figure 75).

Figure 75. Soil erosion bridge measurements.

Significant erosion has been already observed on some plots. The loss of duff, litter, and surface soils were visible from burn stains on rocks and outcroppings (Figure 76). These stains were measured in August 2008 at the Bouton site, and showed an average 10-cm (4-inch) loss of the top soil and litter layers. In some places the litter and duff layers exceeded 30 cm (12 inches). The soil erosion bridges will allow us to measure the amount of soil loss in these areas.

Figure 76. Surface litter and duff consumption

RESTORATION EFFORTS

Fire restoration efforts as part of the Emergency Watershed Protection (EWP) program were underway before, during, and after monitoring began. These measures included aerial seeding of all Cibola National Forest and private land impacted by the fire (Figure 77), contour felling of high-severity burn areas (Figure 78), and installation of trash racks in the arroyo.

Figure 77. Seeded area showing dominance of annual rye.

Figure 78. Contour felled area.

These activities impacted all of the monitoring plots in some way, and it has been determined that we will continue the monitoring as planned, but the restoration will be incorporated as an additional variable to measure.

Three of the plots were heavily impacted by the contour felling (Figure 79); therefore, measurement of trees on these plots will be minimal. Investigating how the increased heavy fuel loading on the ground impacts vegetation recovery compared to untreated plots will be an important new component of the study.

Figure 79. Fire monitoring plot that later underwent EWP felling.

WILDLIFE

Three automatic wildlife infrared sensor cameras were installed in November 2008. These cameras will be moved between each watershed on a bi-monthly basis, and data regarding species presence will be reported in monthly progress reports.

FIRE MONITORING FLUME DATA

Before the Trigo fire, two Parshall flumes were installed at the Bouton thinning sites to monitor runoff. These two sites were both burned in the fire, leaving one flume destroyed but the other still intact. In order to study the impact the fire has had on runoff rates, the burned flume was re-installed. Data from these flumes will help determine the impact that the Trigo fire has had on runoff and infiltration rates.

Since the flumes had been installed for the forest thinning sites, a paired watershed approach was adopted (Figure 80). One flume was situated in a plot that burned with high severity (Figure 81), while the other was in an area that burned with low severity (Figure 82) (Table 4). Like the forest thinning study, the flumes use Troll 500 pressure transducers to record the level of water passing through the flume. It is expected that the areas impacted by fire will have higher runoff and lower levels of infiltration and groundwater recharge than those areas not impacted by fire.

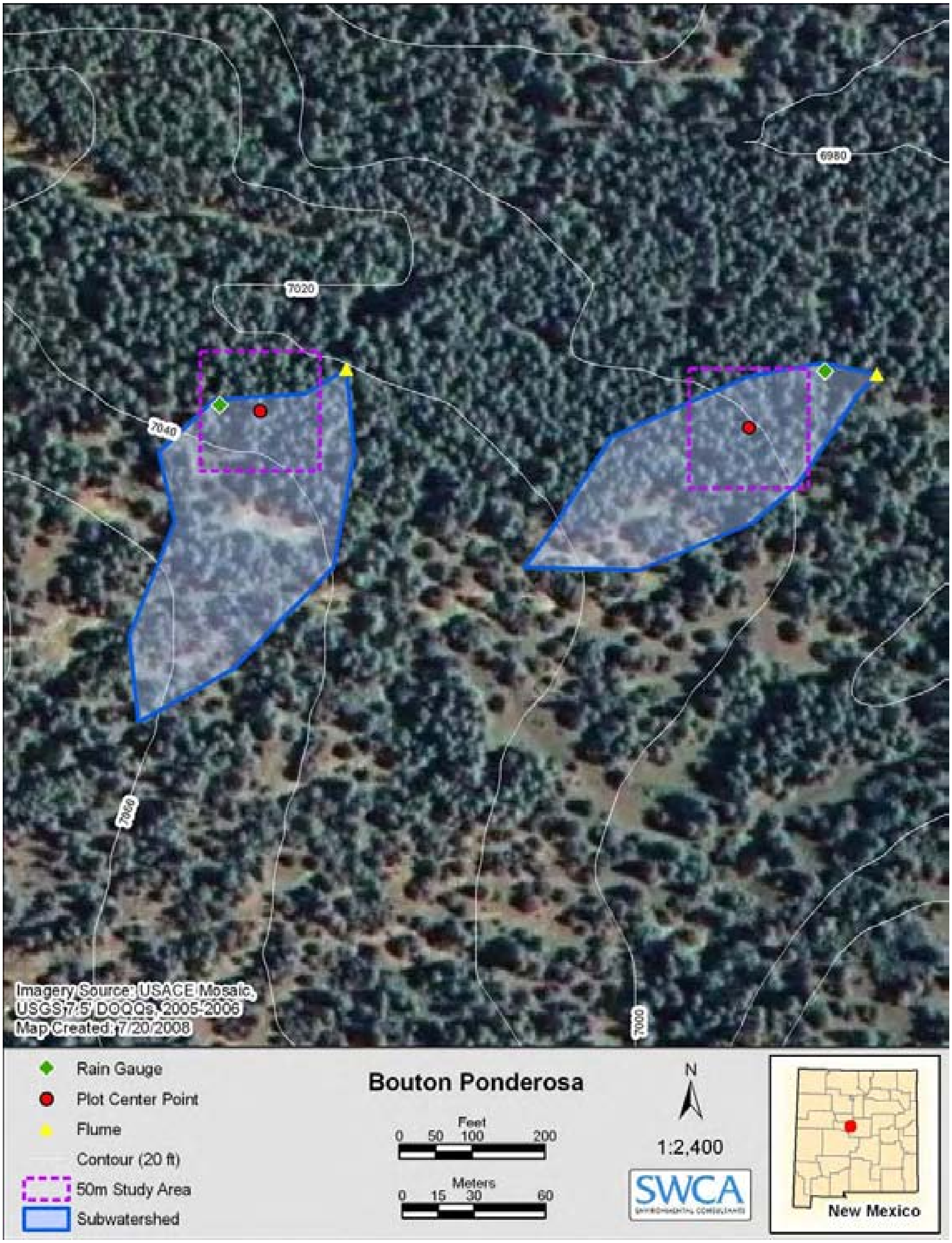

Figure 80. Bouton flume sites. The western watershed (on the left) was impacted by high-severity burn. The image was taken before the Trigo fire.

Figure 81. The Bouton high-severity burn site flume, plot 2.

Figure 82 . The Bouton low-severity burn site flume, plot 1.

Table 4. Acreages for the Bouton Post-fire Monitoring Watersheds Containing Flumes

Watershed	Acreage
Bouton Ponderosa 2	2.06
Bouton Ponderosa 1	1.60

The data from the Bouton high-severity flumes are limited; the flume was re-installed in September 2008. Small rainfall events usually do not provide adequate runoff to register readings in the flumes. It is anticipated that the high-intensity summer rainfalls in 2009 will provide the first period of consistent data points that can be analyzed. The low-intensity burn site flume was not destroyed in the Trigo fire and has been recording data consistently since its installation in November 2007. This data will provide useful baseline data for this watershed that will allow comparisons of rainfall events and the corresponding runoff into the flumes between years.

INTERPRETATION OF YEAR-ONE POST-FIRE MONITORING FINDINGS

Much of the fire monitoring data from this year's study will act as baseline data to be compared to future years. The CBI study was carried out as an immediate assessment of burn severity and as such will not be repeated in future years. A more detailed analysis of this data will be carried out and presented to the Steering Committee. With the Steering Committee's approval, we intend to publish this data to disseminate our findings to the wider community.

It is evident that the Trigo burn area was impacted by a range of fire behavior that created a mosaic of fire effects. Initial observations suggest that plant recovery in some areas, particularly areas that received low-severity burn, will be significant over the coming years. Many herbaceous and woody plants are already colonizing areas; Gambel oak is proving to be very resilient in many areas and dominates the understory. Tree mortality is mixed from 100% loss across a stand to patchy mortality. Complete consumption of ponderosa in large areas could cause significant species composition changes to overstory cover for an extended period since regeneration of ponderosa is expected to be slow; alligator juniper and other basal sprouting species are likely to maintain presence, even when fully consumed by fire. Many low-severity areas still have high levels of scorch, and 2009 measurements will help determine whether scorched trees can survive the initial burn damage. High-severity areas are showing signs of elevated levels of erosion, which will be more easily quantified when compared with 2009 measurements.

A study of burn severity across the project area suggests that burn severity varies with stand density, with a visible trend of increasing severity with density. Severity did vary across the burn area, however, suggesting the importance of other variables including weather, topography, and neighboring stand structure and composition.

EPHEMERAL STREAM AND GROUNDWATER MONITORING

The hydrologic monitoring protocol was designed to determine how forest thinning and wildfire impacts watersheds and water resources in the Estancia Basin. Wildfire alters the hydrologic response of watersheds, including total amount of water leaving the watershed, peak discharge resulting from rain events, transport of sediment, and rate of erosion and deposition (Martin and Moody 2001; Moody 2001; Veenhuis 2002; Gallaher and Koch 2004; Moody and Martin 2001a, 2001b). Flooding and erosion following wildfires are well-recognized phenomena in montane areas of the western United States (Martin and Moody 2001). The removal of duff litter and the forest canopy along with the physical and chemical alteration of soil by fire changes the erosional threshold of burned watersheds (Martin and Moody 2001). A relationship referred to as the rainfall-runoff relation indicates that a threshold of rainfall intensity exists above which severe flash floods occur (Moody and Martin 2001b).

To study the impacts of the Trigo fire, surface water gages were installed in four drainages to measure runoff downstream of the burn area and downstream of control sites. To do this, stage-height gages were constructed and installed into the drainage channels. Each of these devices contains a Troll 100 pressure transducer to measure the height of the water. The location of these devices was chosen based on its location downstream of fire monitoring plots (Figure 83–Figure 86). The U.S. Geological Survey also installed gages downstream of the burn perimeter. The pressure transducers provide data on the duration, peak level, and flashiness (the pulse of runoff) in the channel. The profiles of the channels monitored were measured in November 2008; information gathered from channels provides the necessary information that flow rate can be estimated using the Manning equation.

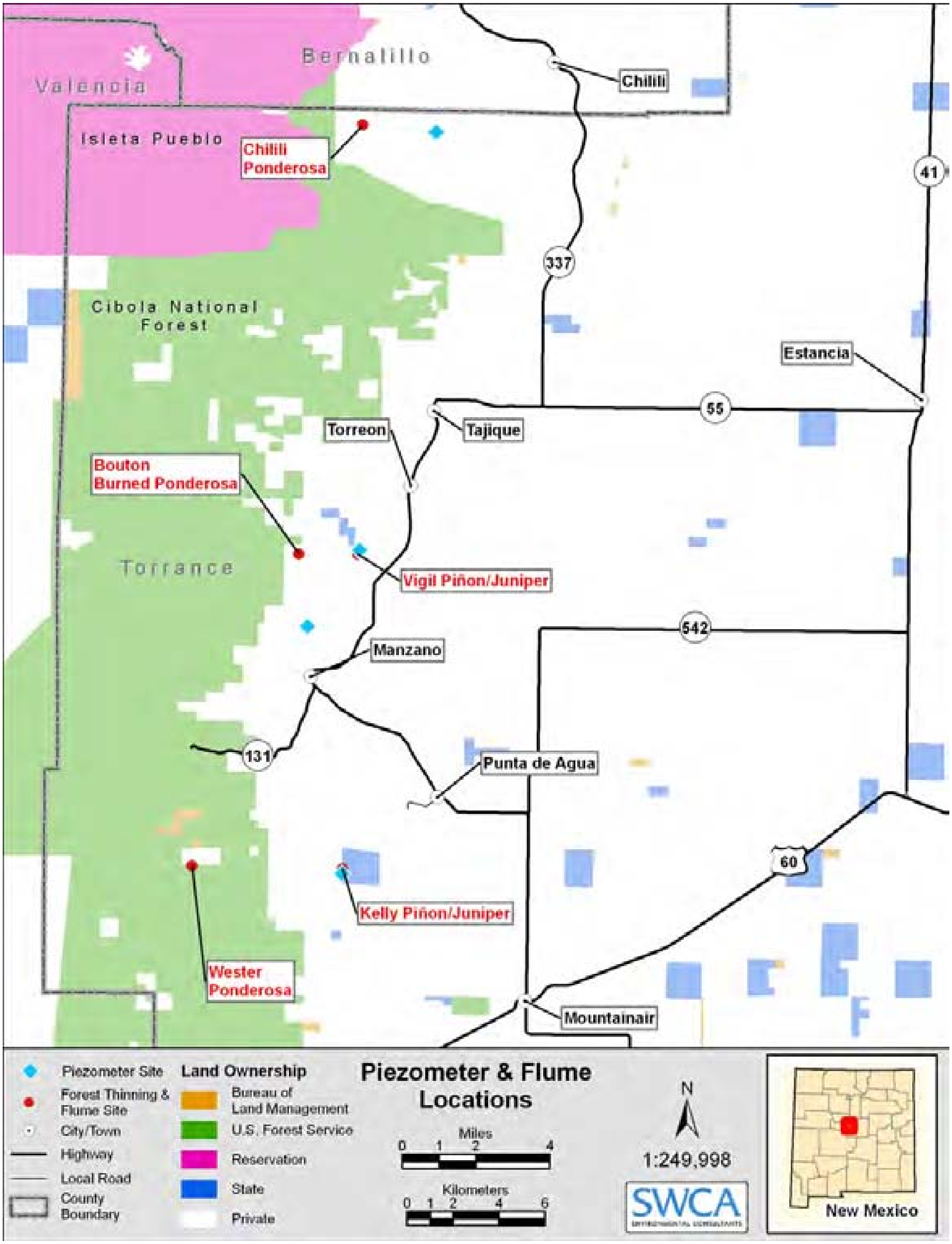

Figure 83. Piezometer and flumes locations (same map as Figure 22 above).

Figure 84. Candelaria piezometer.

Figure 85. Downstream view of the Chilili piezometer.

Figure 86. Upstream view of the Kelly piezometer.

To use Manning's equation, the cross-sectional profile and the slope of the channel needs to be known (Figure 87) so that the cross-sectional area and wetted perimeter can be calculated at any given water level. Channel cross section surveys were conducted in fall 2008 using survey-grade GPS technology. Cross section surveys will be conducted on an annual basis to account for modifications to the gauged drainages.

Because of the dynamic nature of drainages, some locations may experience seasonal changes to their profile. In these cases, the piezometer data will only yield water levels, which will provide information on changes in the frequency, severity, and duration of streamflow events, but will not allow calculation of actual flow rates or volumes. As part of the ongoing maintenance of the piezometer locations, the channel will be remeasured annually or as channel variation is noticed.

Ideally, this project will evaluate infiltration rates in the control areas versus burned areas and relate this information to nearby groundwater levels. This could be accomplished by monitoring private wells located close to stream monitoring locations. Sandia National Labs and the U.S. Geological Survey are initiating well monitoring programs. Both entities have been receptive to sharing data when they become available, though neither knows if data would be available near our piezometer locations in the immediate future. The monitoring will use deep pressure sensors to monitor the level of groundwater in relation to stream flow events. If these data are available, they will be compared to the collected data from this project.

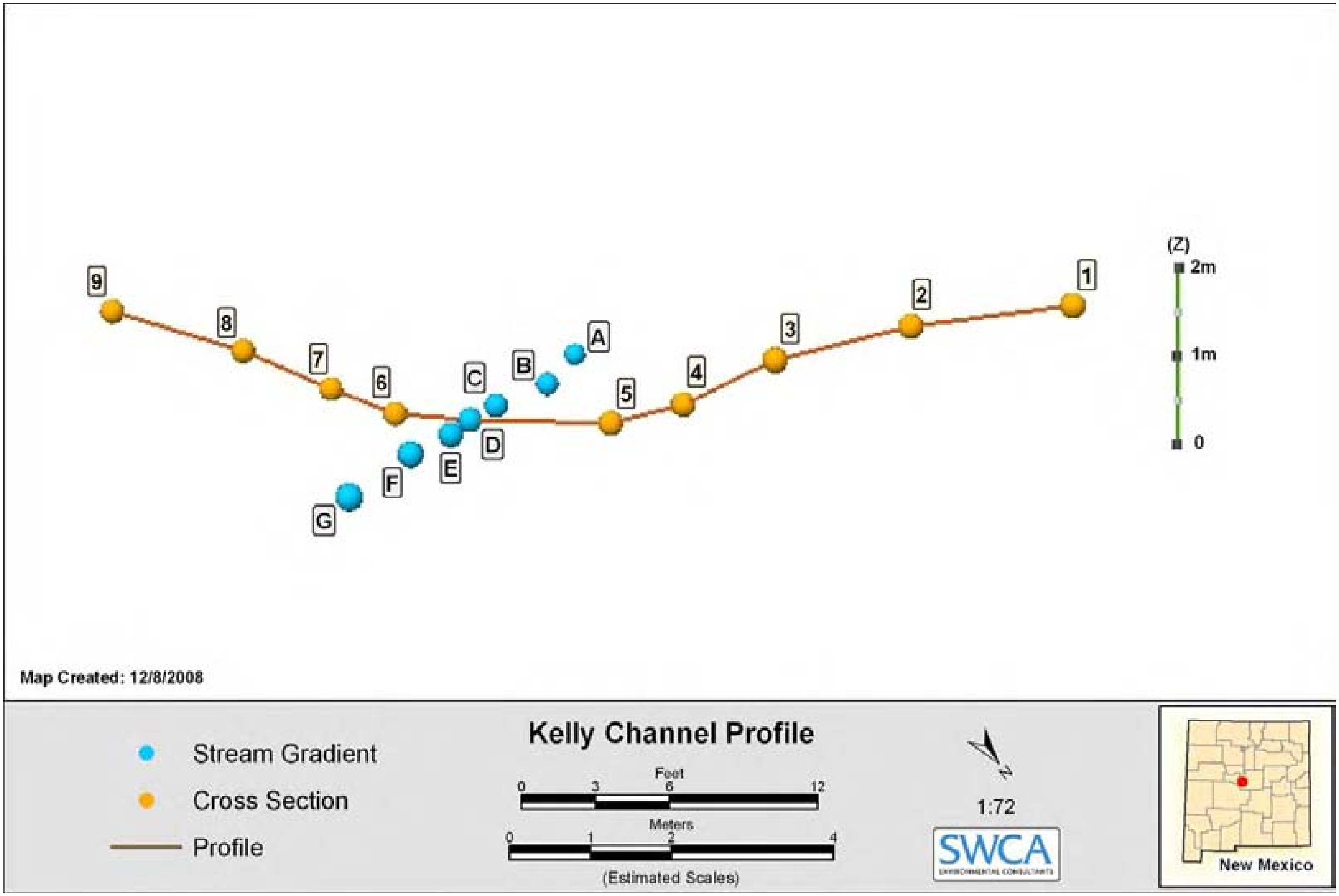

Figure 87. Cross section at the Kelly piezometer.

2008 Monitoring Results

The surface water piezometers were installed in late September 2008 and as such have limited data available. Even so, some rainfall events have been recorded, and preliminary data are available.

The data from the Vigil and Kelly piezometer sites and precipitation levels near the piezometers (Figure 88–Figure 93) are summarized below. The Vigil piezometer site is in a rocky drainage downstream of the Bouton burn site. It is also near the Vigil monitoring plots, so rainfall data near the gage are available from one of the WatchDog Mini Weather Stations installed as part of the forest thinning monitoring. The October 5, 2008, rain event resulted in a significant increase in stream levels, with a rise of nearly 0.5 m (1.5 feet). According to the Vigil 1 WatchDog data (see Figure 90), 41 mm (1.6 inches) of rain were recorded at this site between October 4 and October 5.

Figure 89 shows the positive values recorded by the pressure transducer. Point A show the peak of the runoff at approximately 0.5 m (1.5 feet), and Point B shows the point in which runoff ceases; the values are still positive beyond this. There are several possible reasons for these false-positive readings. Water takes a period of time to leave the well, and this is particularly true when the well tip of the piezometer is surrounded by depositional materials like at the Vigil piezometer. As such, the pressure sensor reads positive values despite the lack of any additional incoming water for a period of a day. Point C shows water height above the baseline established when the piezometer was installed. However, the well was tilted during the peak runoff (see Figure 88), and from this point until the data were downloaded and the piezometer was straightened, the readings were artificially high.

Figure 88. The Vigil piezometer after the October 5, 2008, storm. Maintenance was required at this site as several inches of sediment were deposited near the piezometer during this storm.

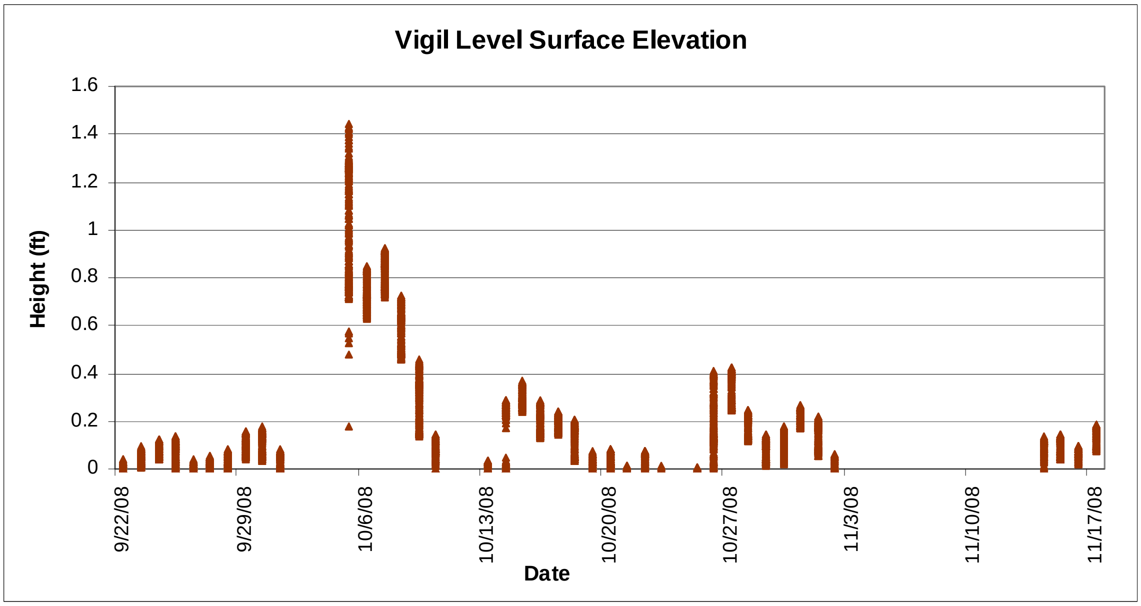

Figure 89. Hydrograph at the Vigil site, September–November 2008.

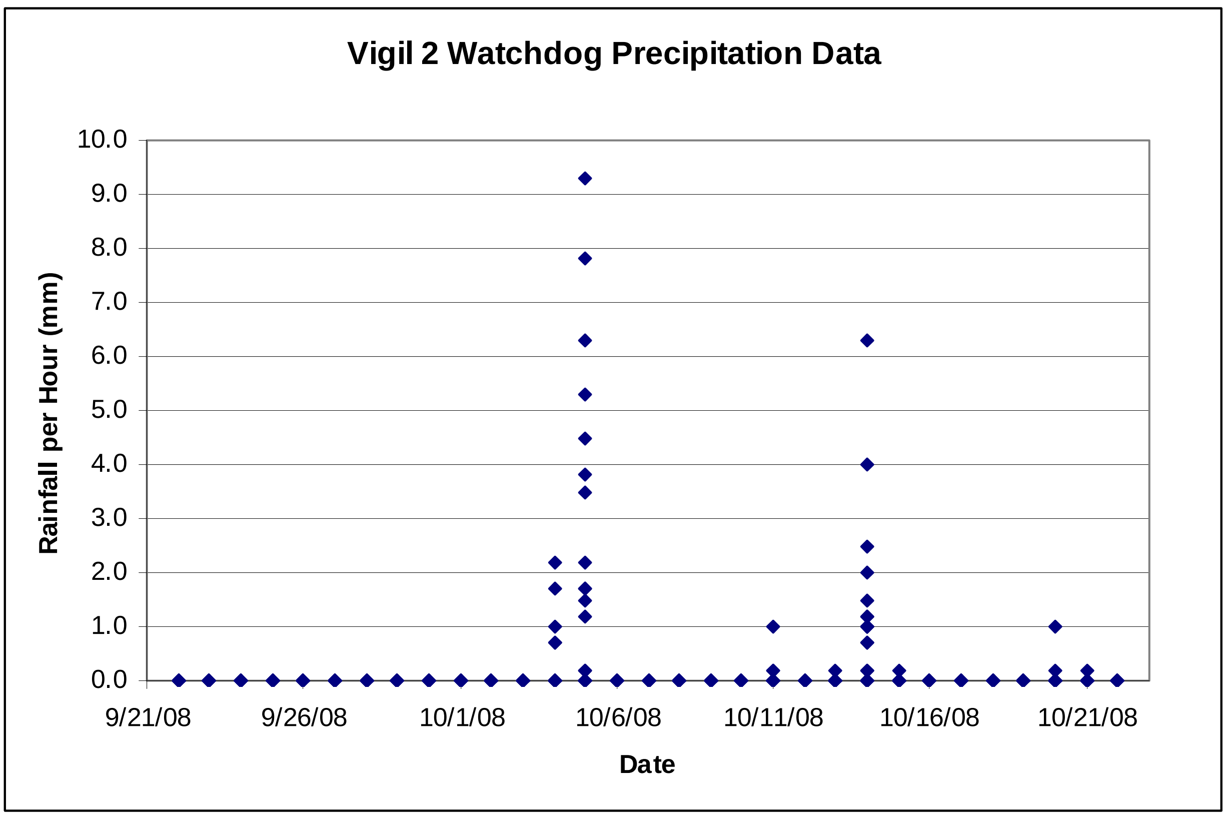

Figure 90. Rainfall at the Vigil 2 WatchDog Mini Weather Station, September–November 2008.

Figure 91. Vigil WatchDog Mini Weather Station.

The Kelly piezometer showed no response (Figure 92) to the October 5 rainfall event. At the Kelly location, near the Kelly forest thinning monitoring site, the WatchDog Mini Weather Station recorded a total of 5.55 cm (2.18 inches) of rain (Figure 93). The comparison of flows recorded by the piezometers at the two sites can be seen in Table 5.

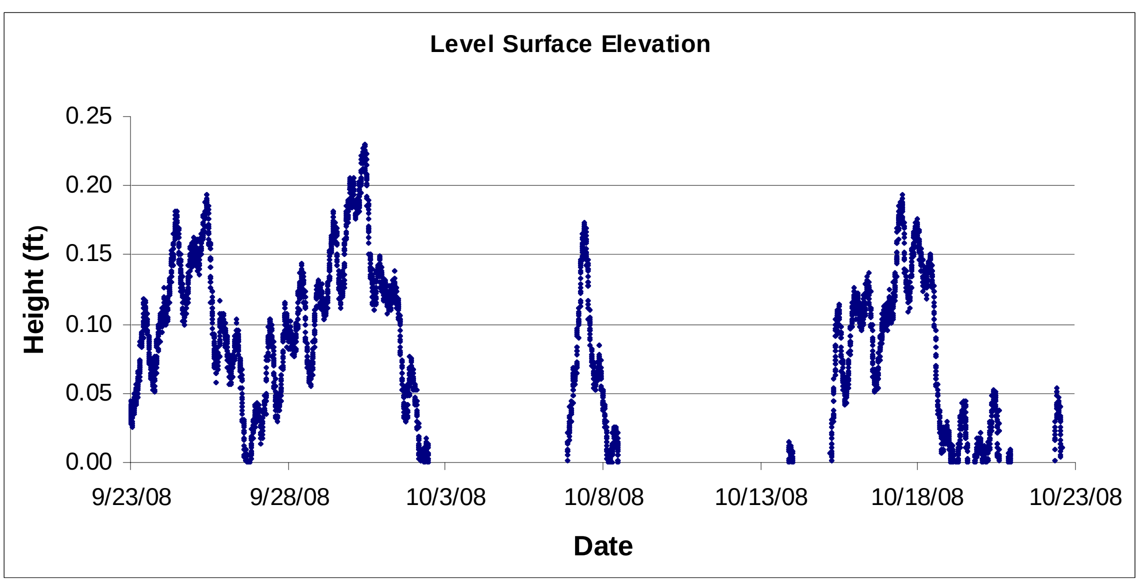

Figure 92. Kelly piezometer stage height.

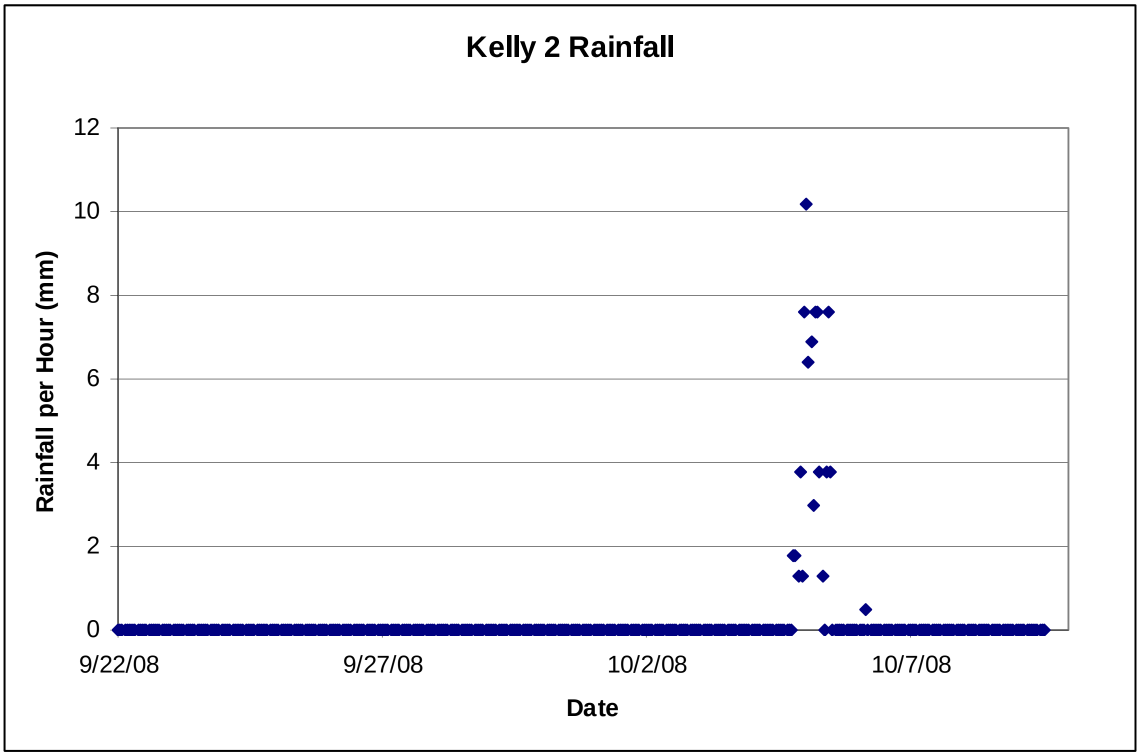

Figure 93. Kelly 2 rainfall data.

Table 5. Summary of Piezometer Data

Location	Date	Duration (hrs)	Peak Stage Height (ft)	Peak Flow (cfs)	Total Volume (acre-feet)
Vigil	10/5/08	24	1.44	30.03	40.39
Kelly	10/5/08	24	0.00	0.00	0.00

SOUTH MOUNTAIN WEATHER STATION

The South Mountain Weather Station (SMWS) (Figure 94) was installed by EnviroLogic, Inc. to provide meteorological, soil moisture, and temperature data as part of the Estancia Basin Watershed Health and Restoration Program overseen by the Steering Committee. EnviroLogic installed the SMWS in September 2006 to initiate site-specific monitoring of rainfall and soil water content at various soil depths. The SMWS is within the Edgewood Soil and Water Conservation District, on the private property, near South Mountain, Santa Fe County, New Mexico, approximately 19 km (12 miles) north of the town of Edgewood (Figure 965–96). The intent of EnviroLogic was to assess water infiltration through soil depths, relate that to meteorological variables, and then compare two measured locations to determine the effects of forest thinning projects on groundwater recharge.

The SMWS measures precipitation, wind speed and direction, air temperature, humidity, and solar radiation. Soil moisture and temperature probes are situated at various depths at two locations with distinct vegetation structure types: one site within a piñon/juniper stand and one site in an adjacent open area consisting of short-grasses. EnviroLogic referred to these locations as “Tree” and “Meadow,” respectively. The Tree site (Figure 97) is situated approximately 30 m (98 feet) northeast of the SMWS within a grouping of one-seed juniper and piñon pine trees. The Meadow site (Figure 98) is situated approximately 11 m (36 feet) northwest of the SMWS, in vegetation dominated by blue grama grass and broom snakeweed (*Gutierrezia sarothrae*).

SWCA is now responsible for the management of the SMWS and the maintenance, summation, and distribution of the data collected at this station. The following sections summarize the data collected since SWCA assumed responsibility for SMWS in April 2008. SWCA prepared a report “South Mountain Weather Station: History, data summaries, and continued operation” summarizing the data collected from 2006 and 2007 by Envirologic, and submitted that report to the Steering Committee. That report is available at the Restoration Institute’s web site.

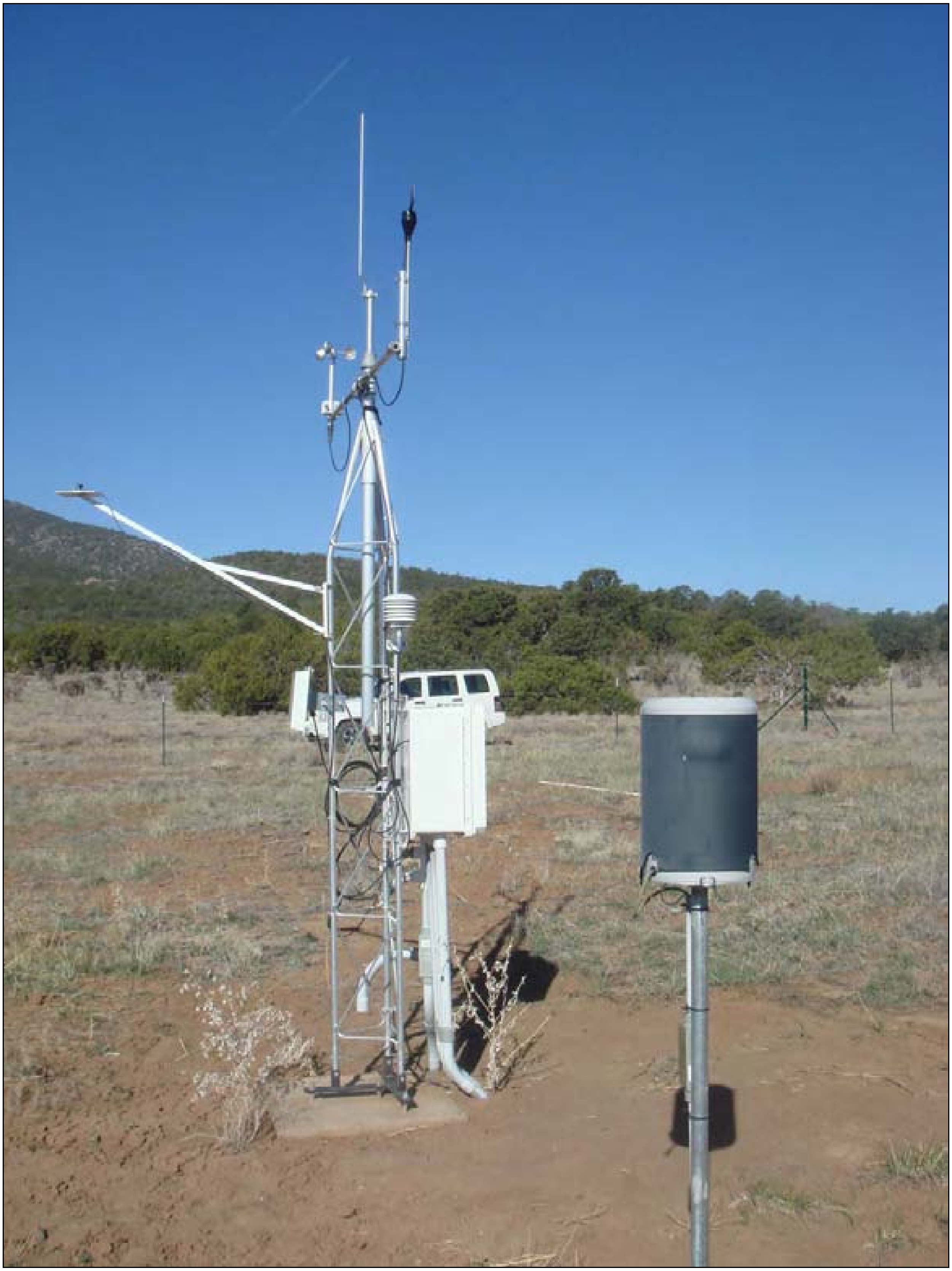

Figure 94. South Mountain Weather Station.

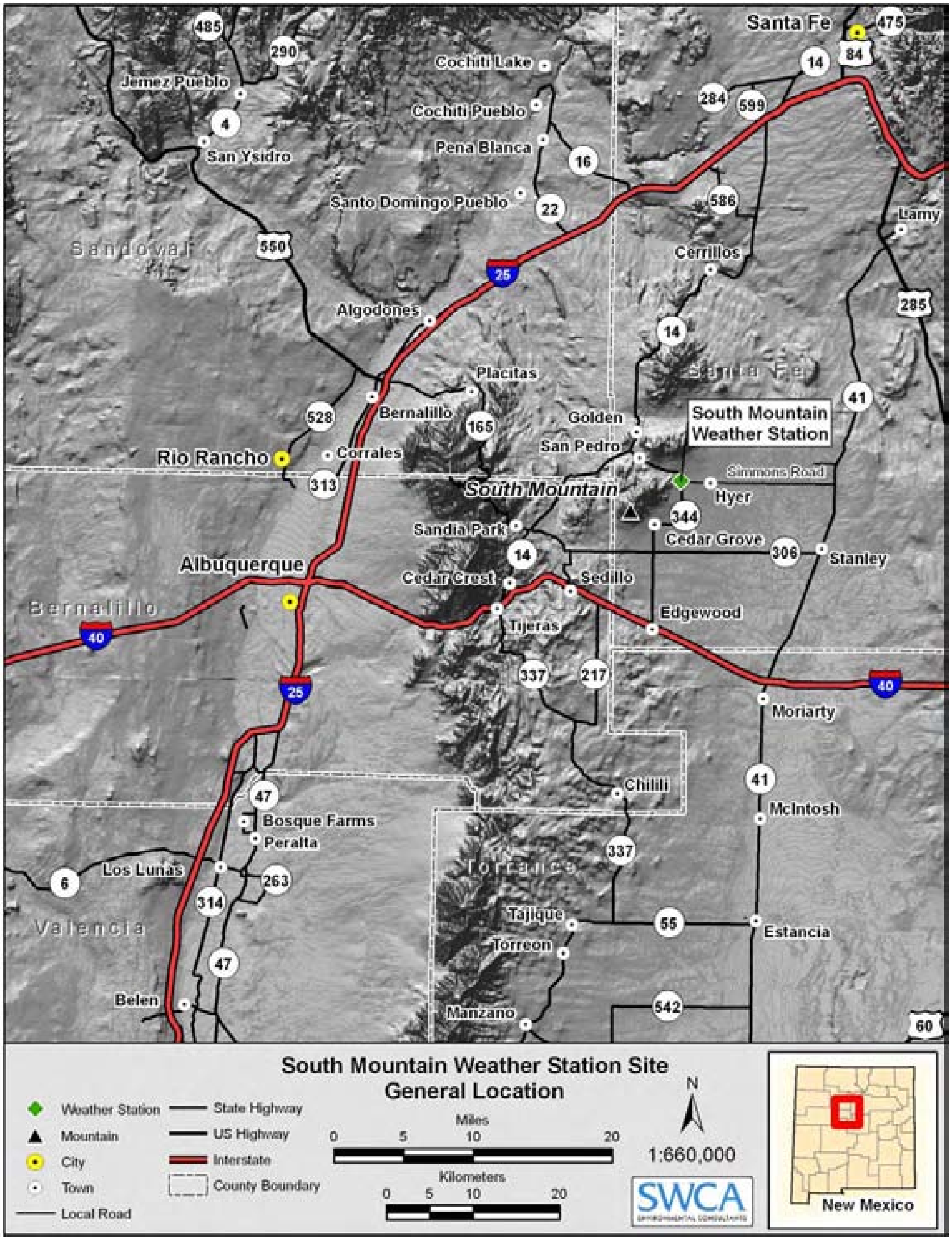

Figure 95. Location of the South Mountain Weather Station, near South Mountain and Edgewood, Santa Fe County, New Mexico.

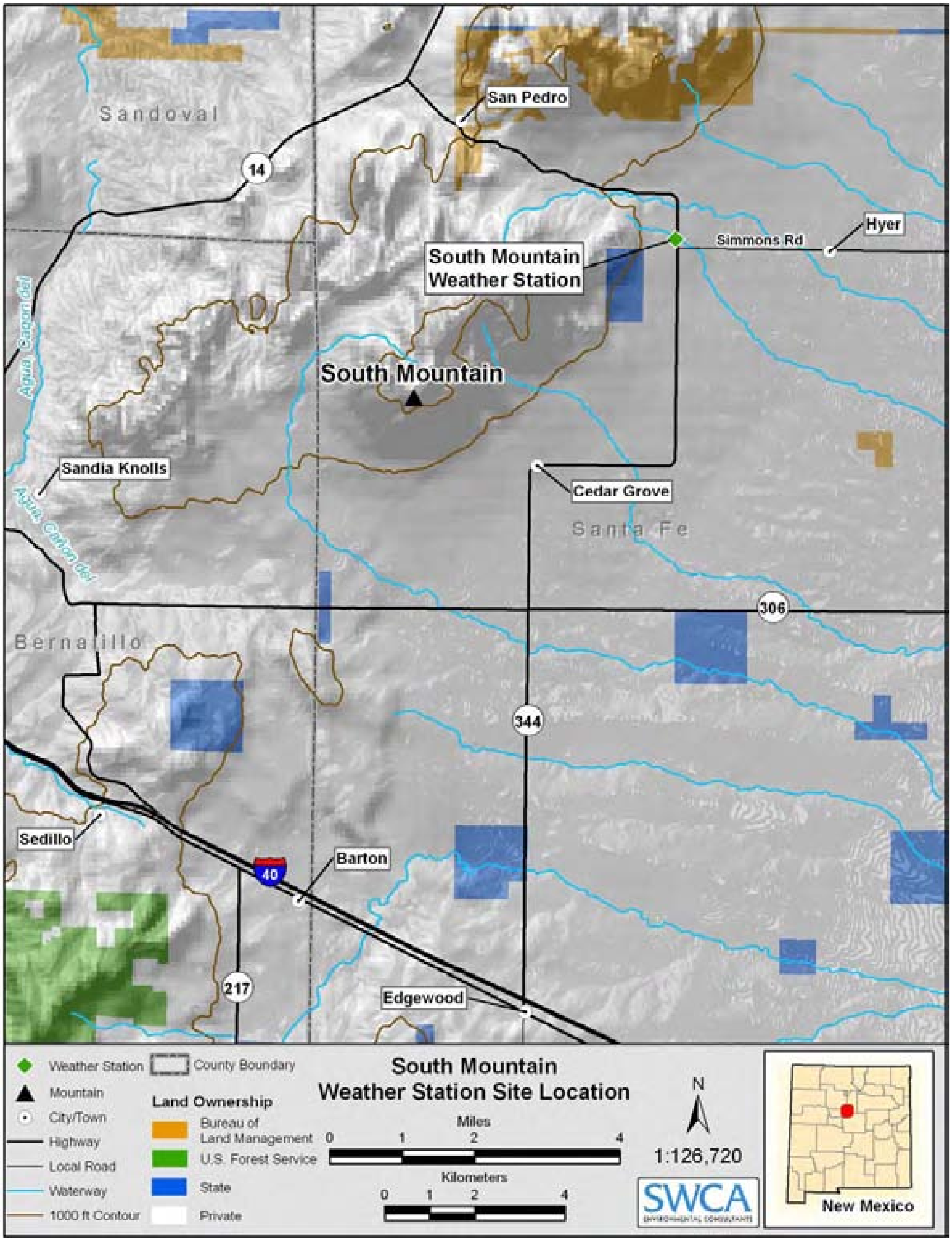

Figure 96. Location of the South Mountain Weather Station, near South Mountain and Edgewood, Santa Fe County, New Mexico.

Figure 97. SMWS tree site.

Figure 98. SMWS meadow site.

METHODS

Starting in April 2008, SWCA began direct download of the data from SMWS.

The data available includes:

- maximum wind speed in miles per hour (mph)
- average wind speed in mph
- average air temperature in degrees Fahrenheit
- maximum air temperature in degrees Fahrenheit
- minimum air temperature in degrees Fahrenheit
- relative humidity (in percent)
- total precipitation in inches

The daily average values were calculated as the means from 10-minute recording on the SMWS data logger. Graphs were then created for some of these parameters based on the data in the modified tables that were created in Microsoft Excel. To do this, fields with no recorded data (recorded as -9999 and -9998) were recorded to read No Data. This step was necessary in order to prevent Microsoft Excel reading these items as data values, which would skew subsequent graphs. However, the drawback of this approach was that "no data" items were read by Excel as a zero when making graphs. For this reason, the reader should ignore those values that read "no value" in any output graphs.

SUMMARY OF APRIL TO OCTOBER 2008 DATA

Figure 99 through Figure 107 show some of the data collected and graphed. Note that only examples are presented here, similar summaries and graphs could be prepared for a wide-variety of parameters over different periods of time.

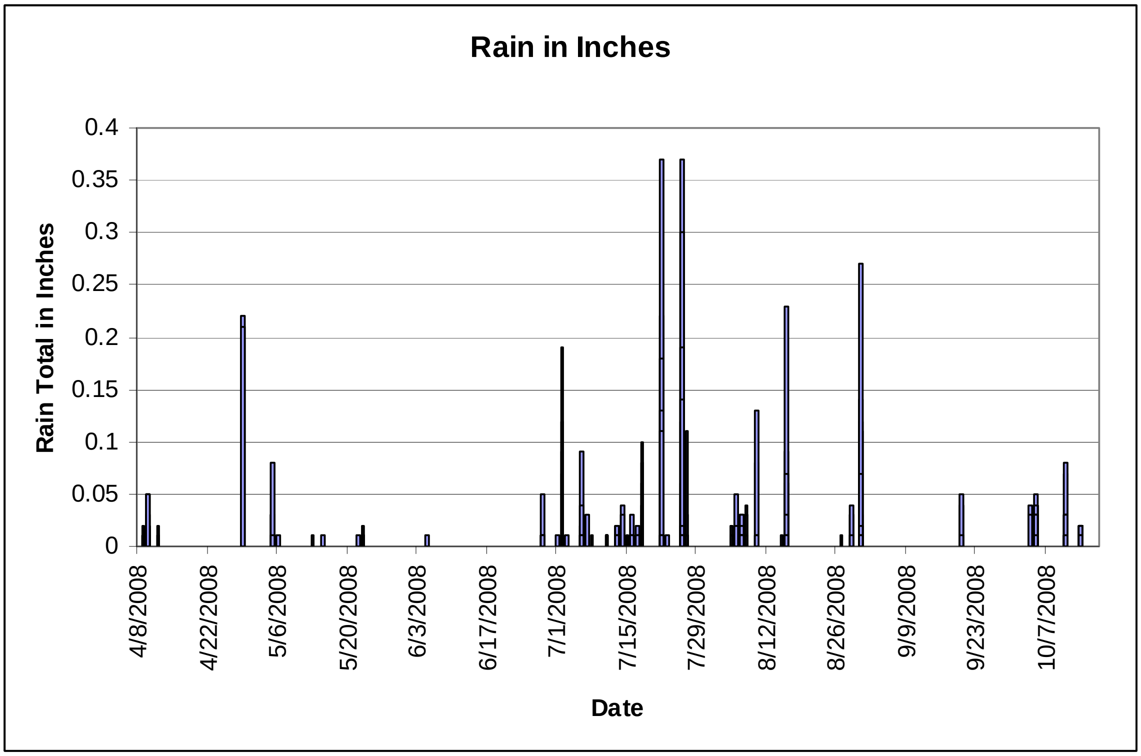

Figure 99. Precipitation at South Mountain Weather Station in inches, April–October 2008

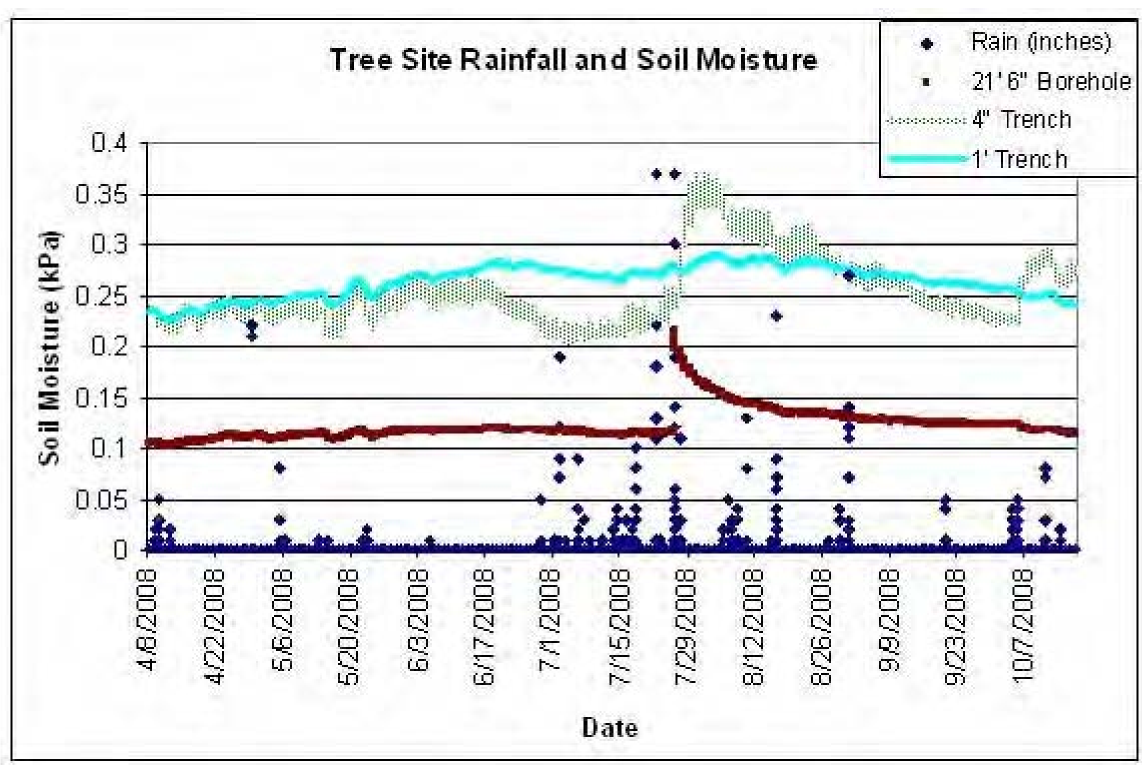

Figure 100. Tree site soil moisture levels and precipitation, April–July 2008.

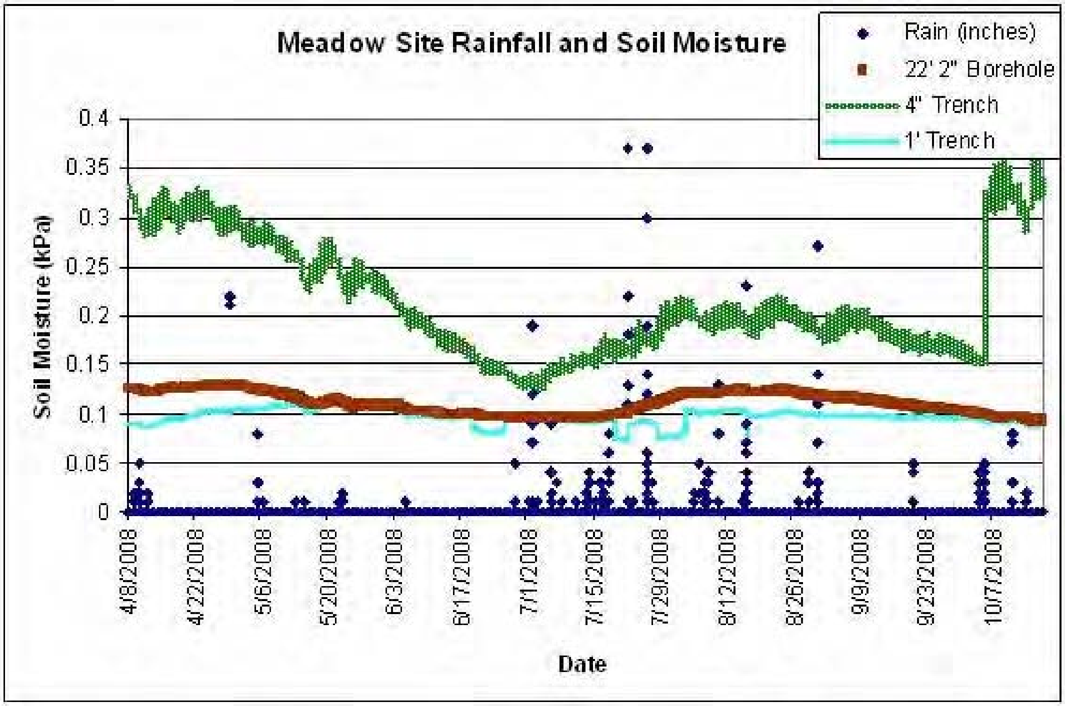

Figure 101. Meadow site soil moisture levels and precipitation, April–July 2008.

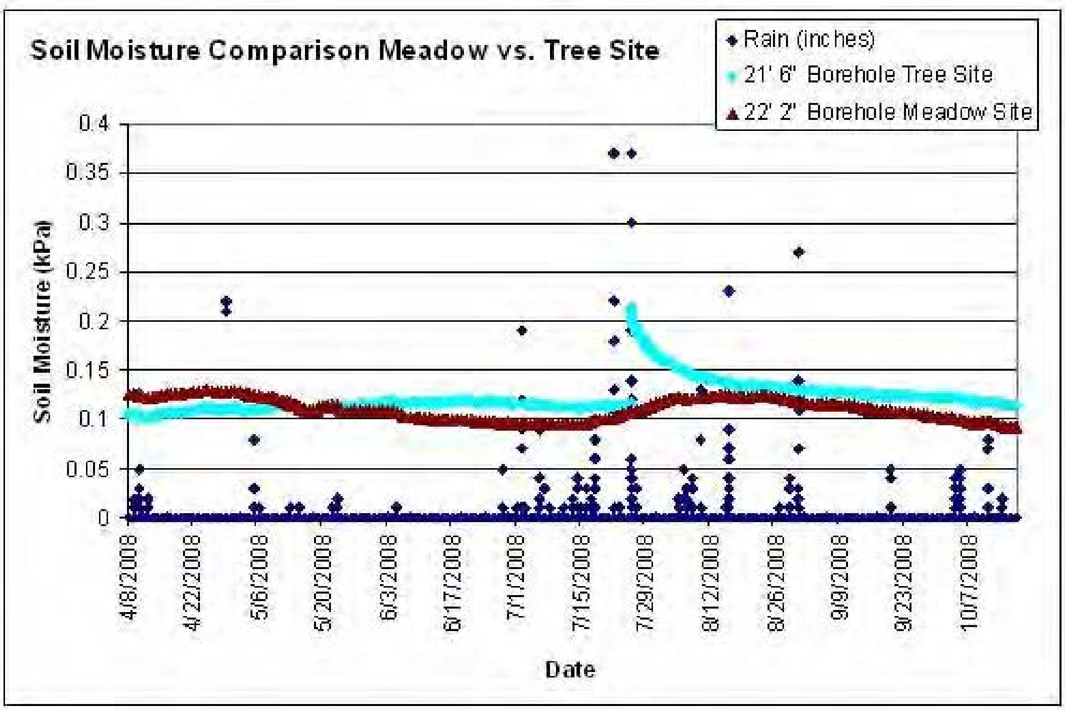

Figure 102. Comparison of Tree and Meadow site soil moisture levels at above 20-foot depths, along with precipitation.

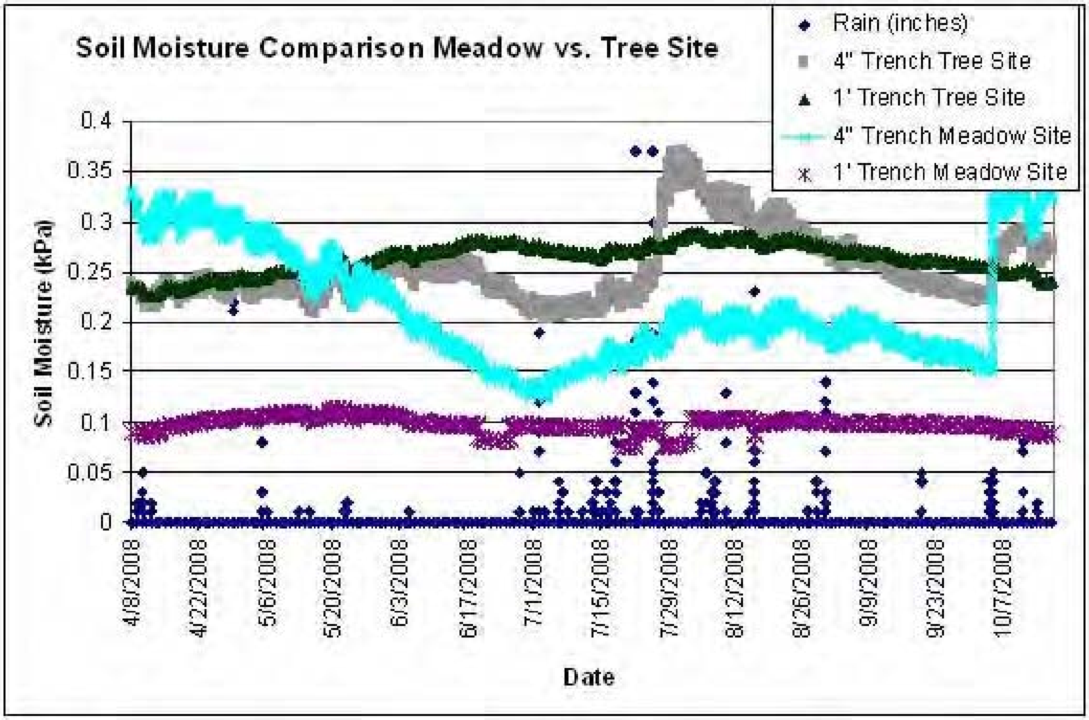

Figure 103. Comparison of Tree and Meadow site soil moisture levels at 4-inch and 1-foot depths, along with precipitation.

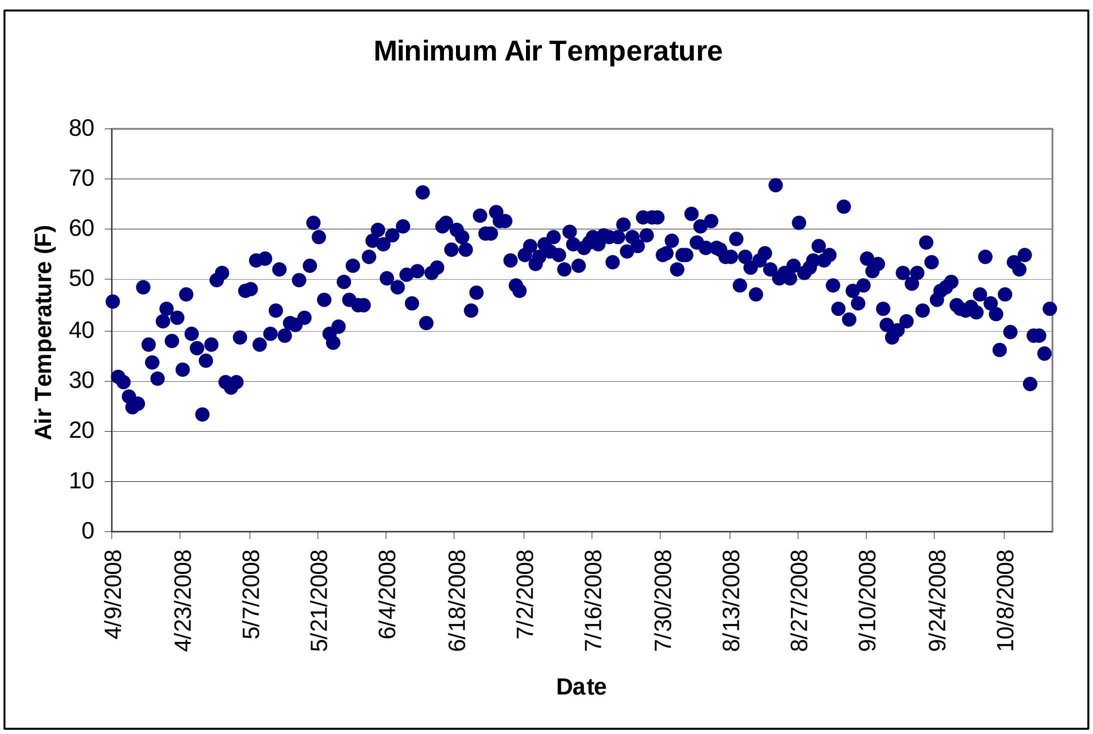

Figure 104. Daily minimum air temperature (Fahrenheit) recorded at 3:00 AM, April–October, 2008.

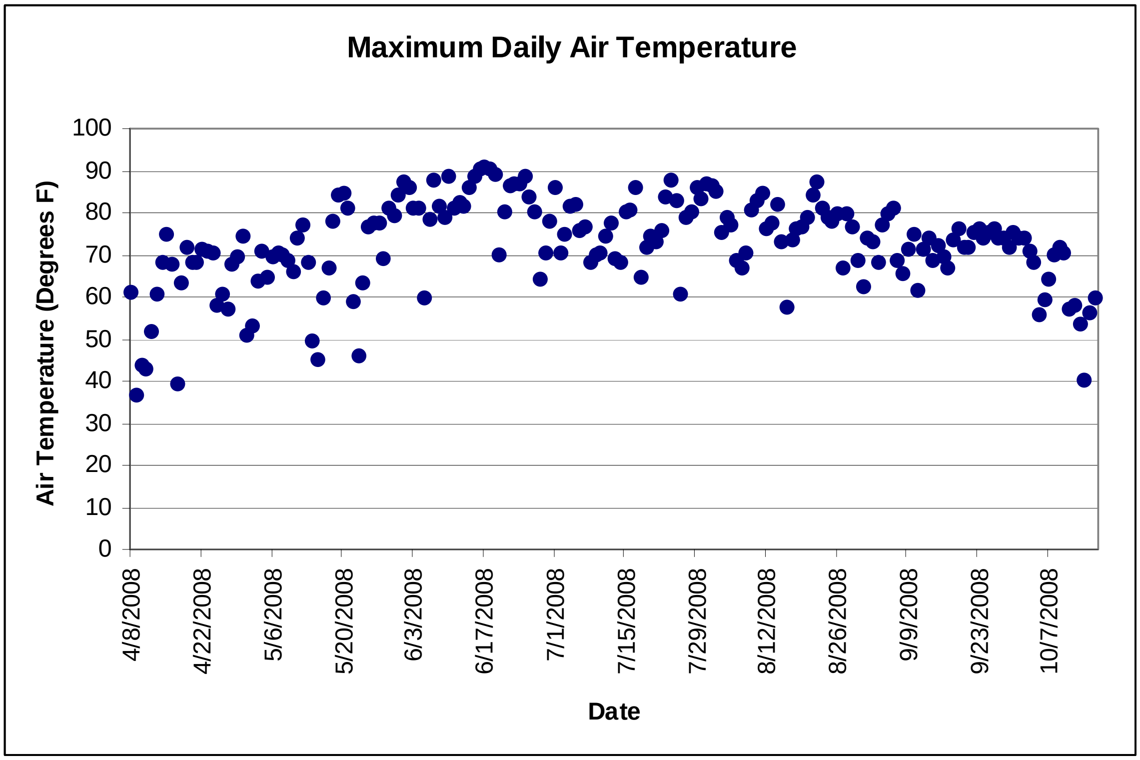

Figure 105. Daily maximum air temperature (Fahrenheit) recorded at 3:00 PM, April–October, 2008

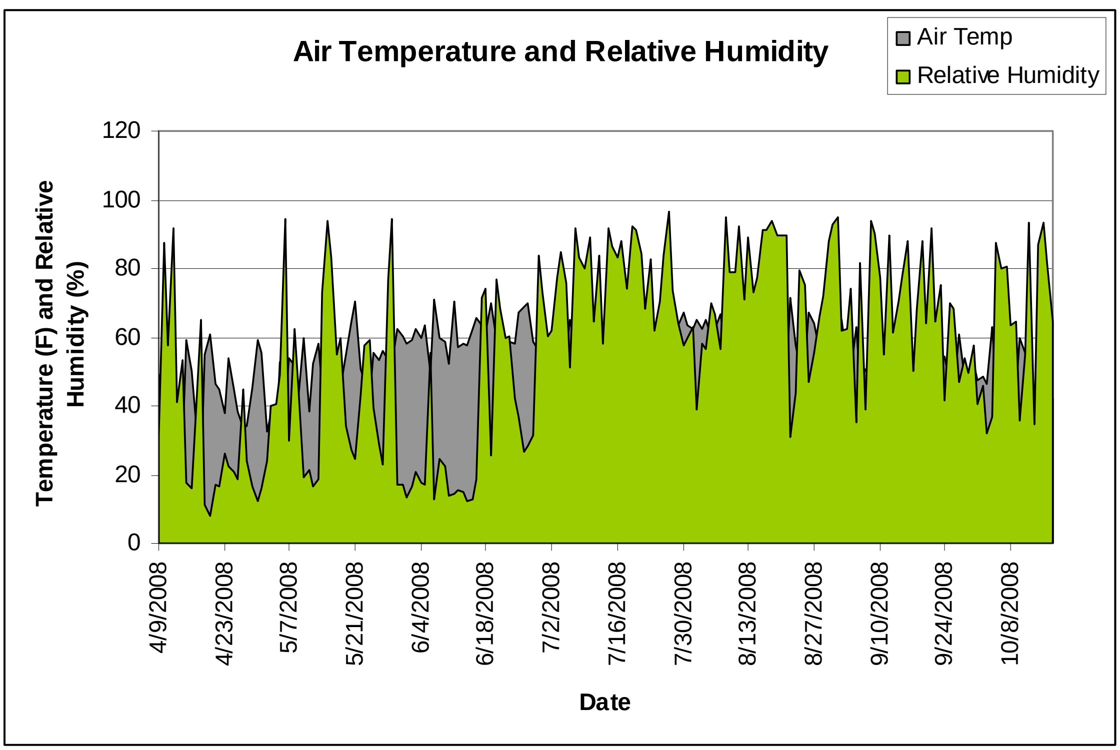

Figure 106. Temperature data and relative humidity 12:00 AM, April–October 2008.

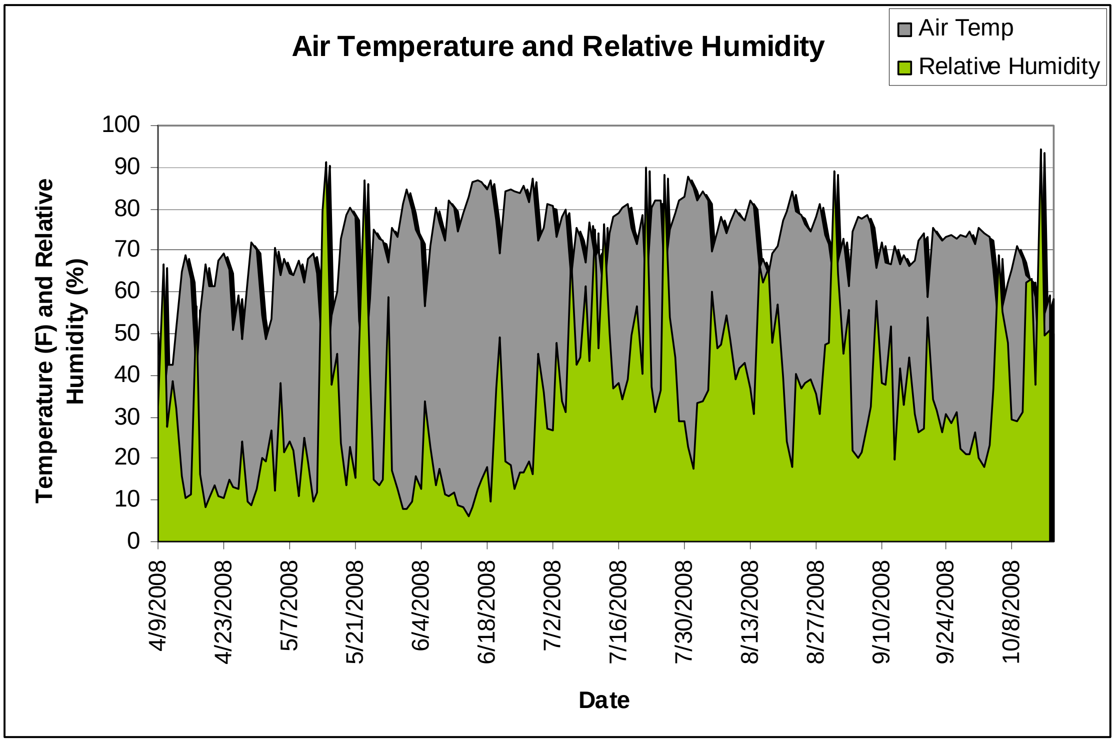

Figure 107. Temperature data and relative humidity 12:00 PM, April–October 2008.

INTERPRETATION OF 2008 DATA

The overlay of precipitation and soil moisture showed little correlation between precipitation and soil moisture levels during the April–October 2008 time period. The difference between the Tree and Meadow sites was more pronounced at the 4-inch and 1-foot trench levels, but it is unclear how much of this variance can be explained by the difference over the spatial variances between the sites. Not surprisingly, the closer to the surface, the faster the soil moisture values seem to respond to precipitation levels recorded at SMWS.

The atmospheric data collected at the SMWS can be used as a reference about particular storms. It also will provide the ability to compare meteorological data from 2008, 2009, and future data. For example, next year it will be possible to compare 2007–2009 precipitation data and daily maximum temperatures. The SMWS will provide an interesting comparison to the WatchDog Mini Weather Stations installed in and around the Trigo fire burn area perimeter.

Maximum air temperature and minimum temperature readings are recoded every 10 minutes. Because the frequency of data collection, attempts to graph or average maximum or minimum air temperatures are distorted by the diurnal temperature cycle. Daily air temperatures at 3:00 AM (see Figure 104) were analyzed as a proxy for daily low temperature, but it should be noted that this may not be truly reflective of the lowest recorded temperature for a given day. Similarly, daily air temperatures at 3:00 PM (Figure 105) were recorded to provide a gauge of general daily high temperatures throughout the year. This too may not reflect the highest daily temperature reading, but should provide a way of measuring seasonal changes in minimum and maximum air temperatures.

PLANNED MONITORING FOR YEAR TWO (2009)

SWCA will continue the current monitoring efforts for year two of this project, including the operation of South Mountain Weather Station. Forest thinning treatments will be implemented in the autumn and winter of 2009/2010, and we will then begin to monitor post-thinning treatment conditions in spring 2010. SWCA will continue to manage the South Mountain Weather Station and the weather data, however based upon advisement from the Steering Committee, data recordings on the data logger will be changed from every ten minutes to hourly recordings.

Post-wildfire monitoring will continue through 2009, and perhaps beyond depending on the availability of funding. At this time, we do not anticipate changes in the current monitoring designs or methods for forest thinning monitoring. Reporting will include regular monthly progress reports, a Year Two 2009 annual report, and a Composite Burn Index - Burn Severity report. The following additional measurements will be taken for Trigo fire monitoring:

Spring (May) 2009:

- Understory vegetation – line-intercept and quads to determine presence of spring annuals
- Fuels transects on each tree plot to determine fuel loading; fuels were not measured in fall 2008 due to snow
- Seedling and sapling count
- Oak species – trees greater than 5 cm (2 inches) DRC will be monitored and tagged

Autumn (September/October) 2009:

- Understory vegetation – line-intercept and quads to determine changes in composition from fall 2008 measurements
- Fuels transects to determine the addition of downed woody material
- Seedling and sapling counts to determine the recovery of woody species
- Tree mortality of tagged trees to determine the survivorship of scorched or partially consumed ponderosa pine
- Soil loss – Soil erosion bridges will be used to continue to quantify soil loss

ACKNOWLEDGEMENTS AND CONTRIBUTORS

The New Mexico Water Trust Board provided funding for this project. The Estancia Basin Water Planning Committee also contributed funding to install the new Chilili ponderosa pine monitoring study site. The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee provided oversight and coordination of this project, in cooperation with the New Mexico Forest and Watershed Restoration Institute and New Mexico State Forestry. Deirdre Tarr of the Claunch-Pinto Soil and Water Conservation District and Ken Smith from the New Mexico Forest and Watershed Restoration Institute provided valuable oversight and support. The, Bouton, Candelaria, Kelly, Mitchell, Neff, Salazar, Sanchez, Vigil, and Wester families kindly offered access to their land to conduct forest thinning and monitoring research, along with the Chilili Land Grant and the Manzano Mountain Retreat. New Mexico State Forestry, the U.S. Forest Service, the U.S. Geological Survey, and the Claunch-Pinto, East Torrance and Edgewood soil and water conservation districts have all provided advice and support. Vernon Kohler and Kelly Archuleta from the Claunch-Pinto and Edgewood soil and water conservation districts have been assisting with field data collections. Mike Matush from the New Mexico State Environment Department, Surface Water Quality Bureau, has been helpful in designing and installing stream monitoring stations.

SWCA staff Joseph Fluder, Duncan Wadsworth, Terri Thompson, Ryan Trollinger, Kina Murphy, Matt McMillan, Heather Timmons, Anne Russell, Justin Elza, and Sheri Waldbauer contributed to this report and data collection efforts.

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APPENDIX A
LIST OF PLANT SPECIES ENCOUNTERED ON FOREST MONITORING STUDY PLOTS.
TAXONOMY AND NAMES FOLLOW SIVINSKI (2007)

Group/Family	Genus	Species	Form	History
Bryophytes	Bryophyte	sp.	cryptogam	perennial
	Microbial crust		cryptogam	perennial
Gymnosperms				
Cypressaceae	Juniperus	deppeana	tree	perennial
Cypressaceae	Juniperus	monosperma	tree	perennial
Cypressaceae	Juniperus	scopulorum	tree	perennial
Pinaceae	Pinus	edulis	tree	perennial
Pinaceae	Pinus	ponderosa	tree	perennial
Angiosperms: Dicotedons				
Amaranthaceae	Amaranthus	albus	forb	annual
Amaranthaceae	Amaranthus	palmeri	forb	annual
Anacardiaceae	Rhus	trilobata	shrub	perennial
Asclepiadaceae	Asclepias	sp. 1	forb	perennial
Asteraceae	Achillea	millefolium	forb	perennial
Asteraceae	Artemisia	dracunculus	forb	perennial
Asteraceae	Artemisia	ludoviciana	forb	perennial
Asteraceae	Artemisia	sp.	forb	perennial
Asteraceae	Bahia	dissecta	forb	annual
Asteraceae	Brickellia	sp.1	forb	perennial
Asteraceae	Brickellia	sp. 2	forb	perennial
Asteraceae	Chaetopappa	ericoides	forb	perennial
Asteraceae	Circium	sp.1	forb	annual
Asteraceae	Circium	sp. 2	forb	annual
Asteraceae	Conyza	sp.1	forb	
Asteraceae	Erigeron	flagellaris	forb	biennial
Asteraceae	Erigeron	sp.	forb	
Asteraceae	Gutierrezia	sarothrae	shrub	perennial
Asteraceae	Gutierrezia	sphaerocephala	forb	perennial
Asteraceae	Heterotheca	villosa	forb	perennial
Asteraceae	Solidago	sp. 1	forb	perennial
Asteraceae	Stephanomeria	exigua	forb	perennial
Asteraceae	Tetraneuris	argentea	forb	perennial
Asteraceae	Thelesperma	megapotamicum	forb	perennial
Asteraceae	Townsendia	eximia	forb	perennial
Asteraceae		sp.	forb	
Berberidaceae	Mahonia	repens	shrub	perennial
Brassicaceae	Arabis	sp.	forb	perennial
Brassicaceae	Lepidium	montanum	forb	perennial
Brassicaceae	Lepidium	sp. 1	forb	perennial
Brassicaceae	Schoenocrambe	linearifolia	forb	perennial
Brassicaceae	Streptanthus	sp.1	forb	annual
Brassicaceae	Streptanthus	sp. 2	forb	annual
Cactaceae	Cylindropuntia	imbricata	succulent	perennial
Cactaceae	Echinocereus	viridiflorus	succulent	perennial
Cactaceae	Grusonia	clavata	succulent	perennial
Cactaceae	Opuntia	engelmannii	succulent	perennial
Cactaceae	Opuntia	macrorhiza	succulent	perennial
Cactaceae	Opuntia	polyacantha	succulent	perennial
Cactaceae	Opuntia	seedling	succulent	perennial
Cactaceae	Opuntia	sp.	succulent	perennial
Chenopodiaceae	Chenopodium	graveolens	forb	annual
Chenopodiaceae	Chenopodium	sp. 1	forb	annual
Chenopodiaceae	Chenopodium	sp. 2	forb	annual
Euphorbiaceae	Chamaesyce	sp. 1	forb	annual
Euphorbiaceae	Chamaesyce	sp. 2	forb	annual

Fabaceae	Astragalus	mollisimus	forb	perennial
Fabaceae	Astragalus	nuttallianus	forb	perennial
Fabaceae	Astragalus	sp.	forb	annual
Fabaceae	Dalea	sp. 1	forb	perennial
Fabaceae	Lotus	wrightii	forb	perennial
Fabaceae	Robinia	neomexicana	tree	perennial
Fabaceae		sp. 1	forb	
Fabaceae		sp. 3	forb	
Fabaceae		sp. 4	forb	
Fagaceae	Quercus	gambelii	tree	perennial
Fagaceae	Quercus	turbinella	tree	perennial
Geraniaceae	Geranium	caespitosum	forb	perennial
Geraniaceae	Geranium	sp. 1	forb	perennial
Linaceae	Linum	sp.1	forb	perennial
Malvaceae	Spheralcea	angustifolia	forb	perennial
Malvaceae	Spheralcea	coccinea	forb	perennial
Monotropaceae	Monotropa	hypopithys	forb	perennial
Nyctaginaceae	Mirabilis	linearis	forb	perennial
Nyctaginaceae	Mirabilis	sp.	forb	perennial
Nyctaginaceae	Boerhavia	sp.	forb	annual
Onagraceae	Oenothera	sp.	forb	annual
Polemoniaceae	Gilia	sp. 1	forb	annual
Polemoniaceae	Ipomopsis	aggregata	forb	annual
Polygonaceae	Eriogonum	microthecum	shrub	perennial
Polygonaceae	Eriogonum	racemosum	forb	perennial
Portulaccaceae	Portulaca	oleracea	forb	annual
Portulaccaceae	Portulaca	pilosa	forb	annual
Ranunculaceae	Thalictrum	fendleri	forb	perennial
Scrophulariaceae	Castilleja	angustifolia	forb	perennial
Scrophulariaceae	Cordylanthus	tenuis	forb	annual
Scrophulariaceae	Penstemon	barbatus	forb	perennial
Scrophulariaceae	Penstemon	sp. 2	forb	perennial
Scrophulariaceae	Penstemon	sp. 3	forb	perennial
Solanaceae	Physalis	hederifolia	forb	perennial
Solanaceae	Solanum	elaeagnifolium	forb	perennial
Solanaceae	Solanum	sp. 1	forb	perennial
Viscaceae	Phoradendron	macrophyllum	shrub	perennial
Angiosperms: Monocyledons				
Agavaceae	Yucca	glauca	succulent	perennial
Commelinaceae	Commelina	dianthifolia	forb	annual
Cyperaceae	Carex	sp. 1	grass	perennial
Cyperaceae	Carex	sp. 2	grass	perennial
Liliaceae	Allium	sp. 1	forb	perennial
Poaceae	Alopecurus	sp.	grass	
Poaceae	Andropogon	gerardii	grass	perennial
Poaceae	Aristida	purpurea	grass	perennial
Poaceae	Aristida	sp. 1	grass	perennial
Poaceae	Blepharoneuron	tricholepsis	grass	perennial
Poaceae	Bouteloua	curtipendula	grass	perennial
Poaceae	Bouteloua	gracilis	grass	perennial
Poaceae	Bouteloua	aristidoides	grass	annual
Poaceae	Bromus	sp. 1	grass	annual
Poaceae	Elymus	hystrix	grass	perennial
Poaceae	Eragrostis	ciliaris	grass	annual
Poaceae	Eragrostis	sp.	grass	annual
Poaceae	Lolium	perenne	grass	annual

Poaceae	Muhlenbergia	minutissima	grass	perennial
Poaceae	Muhlenbergia	montana	grass	perennial
Poaceae	Muhlenbergia	torreyi	grass	perennial
Poaceae	Munroa	squarrosa	grass	annual
Poaceae	Oryzopsis	micrantha	grass	perennial
Poaceae	Pascopyrum	smithii	grass	perennial
Poaceae	Pleuraphis	jamesii	grass	perennial
Poaceae	Sporobolus	cryptandrus	grass	perennial
Poaceae		sp. 1	grass	
Poaceae		sp. 2	grass	
Poaceae		sp. 3	grass	

APPENDIX B
ANIMAL SPECIES RECORDED FROM FOREST MONITORING WILDLIFE STUDY PLOTS.

Bird Species List

Common Name	Genus	Species
American Crow	Corvus	branchyrhynchos
American Robin	Turdus	migratorius
Ash-throated Flycatcher	Myarchus	cinerascens
Bewick's Wren	Thryomanes	bewickii
Black-capped Chickadee	Poecile	atricapillus
Black-throated Gray Warbler	Dendroica	nigrescens
Broad-tailed Hummingbird	Cynanthus	latirostris
Chipping Sparrow	Spizella	passerina
Common Raven	Corvus	corvax
Common Nighthawk	Chordeiles	minor
Cooper's Hawk	Accipiter	cooperii
Dark-eyed Junco	Junco	hyemalis
Finch sp.	Carpodacus	sp.
Grace's Warbler	Dendroica	graciae
Hermit Thrush	Catharus	guttatus
Juniper Titmouse	Baeolophus	ridgwayi
Organge Crowned Warbler	Vermivora	celata
Mountain Chickadee	Poecile	gambeli
Mourning Dove	Zenaida	macroura
Northern Flicker	Colaptes	auratus
Plumbeous Vireo	Vireo	plumbeus
Pinyon Jay	Gymnorhinus	cyanocephalus
Pygmy Nuthatch	Sitta	pygmaea
Red-breasted Nuthatch	Sitta	canadensis
Red Crossbill	Loxia	curvirostra
Red-tailed Hawk	Buteo	jamaicensis
Ruby-crowned Kinglet	Regulus	calendula
Rufous Hummingbird	Selasphorus	rufus
Sharp-shinned Hawk	Accipiter	striatus
Spotted Towhee	Pipilo	maculatus
Stellar's Jay	Cyanocitta	stelleri
Swainson's Thrush	Catharus	ustulatus
Townsend's Solitaire	Myadestes	townsendii
Turkey Vulture	Cathartes	aura
Western Bluebird	Sialia	mexicana
Western Meadowlark	Sturnella	neglecta
Western Scrub Jay	Aphelocoma	californica
White-breasted Nuthatch	Sitta	carolinensis
Wild Turkey	Meleagris	gallopavo
Yellow-rumped Warbler	Dendroica	coronata

Rodent species list

Common Name	Genus	Species
Colorado chipmunk	Tamias	quadrivittatus
Deer mouse	Peromyscus	maniculatus
Pinyon mouse	Peromyscus	truei
White-footed mouse	Peromyscus	leucopis
White-throated woodrat	Neotoma	albigula

APPENDIX C
POST-FIRE MONITORING STUDY

SCOPE OF SERVICES FOR THE ESTANCIA BASIN WATERSHED HEALTH, RESTORATION, AND MONITORING PROJECT

POST-FIRE MONITORING STUDY

Prepared for

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SWCA Project No. 12996
July 25, 2008

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SCOPE OF SERVICES FOR THE ESTANCIA BASIN WATERSHED HEALTH, RESTORATION, AND MONITORING PROJECT

In April 2008, a large area of the Estancia Basin watershed was burned in the 13,709-acre Trigo wildfire (Figure 1). This burn area encompassed a large portion of the Cibola National Forest and also included 3,712 acres of private land on its eastern fringe. Fire creates significant impacts to watershed health, which in turn impacts water yield and groundwater recharge. Since three large wildfires (Ojo Peak, Trigo, and Big Spring) have now burned a considerable portion of the eastern slopes of the Manzano Mountains (see Figure 1), the impacts of wildfire on Estancia Basin watershed health are likely significant. SWCA Environmental Consultants (SWCA) is currently monitoring the effects of thinning treatments in the area as part of the Estancia Basin Watershed Health, Restoration, and Monitoring Project since 2007. That project is overseen by the Estancia Basin Watershed Health, Restoration, and Monitoring Steering Committee (EBWHRMSC), with funding from the New Mexico State Water Trust Board. The EBWHRMSC recently awarded SWCA additional funding to develop and implement post-fire monitoring to evaluate wildfire impacts to Estancia Basin watershed health. SWCA developed this proposed scope of services, task list, study plan, and budget that will investigate the impacts of wildfire on forest and watershed health, enhancing our knowledge of forest disturbances and their impacts on hydrology of the Estancia Basin. Of the three major wildfires, Ojo Peak, Trigo, and Big Spring, we have chosen to focus efforts on the Trigo fire. Replicated study sites across watersheds will be more comparable if they are located within an area that burned at about the same time. The Trigo fire also was the largest of the three, it was centrally located within the study region and relative to our existing forest thinning monitoring site, and it burned more watersheds than the other two (see Figure 1).

SWCA's proposed tasks, literature review, proposed monitoring plan, proposed budget, and proposed schedule for Estancia Basin post-fire monitoring are provided below.

TASKS

The proposed fire monitoring study is partitioned into five tasks:

Task 1 - Literature Review and Plan Development

SWCA has completed a review of forest fire monitoring literature for hydrology, vegetation, soils and erosion, and wildlife parameters. This review will provide us with information on the most current and best approaches for monitoring appropriate parameters. The results of that literature review are presented below (Literature Review of Fire Monitoring Protocols).

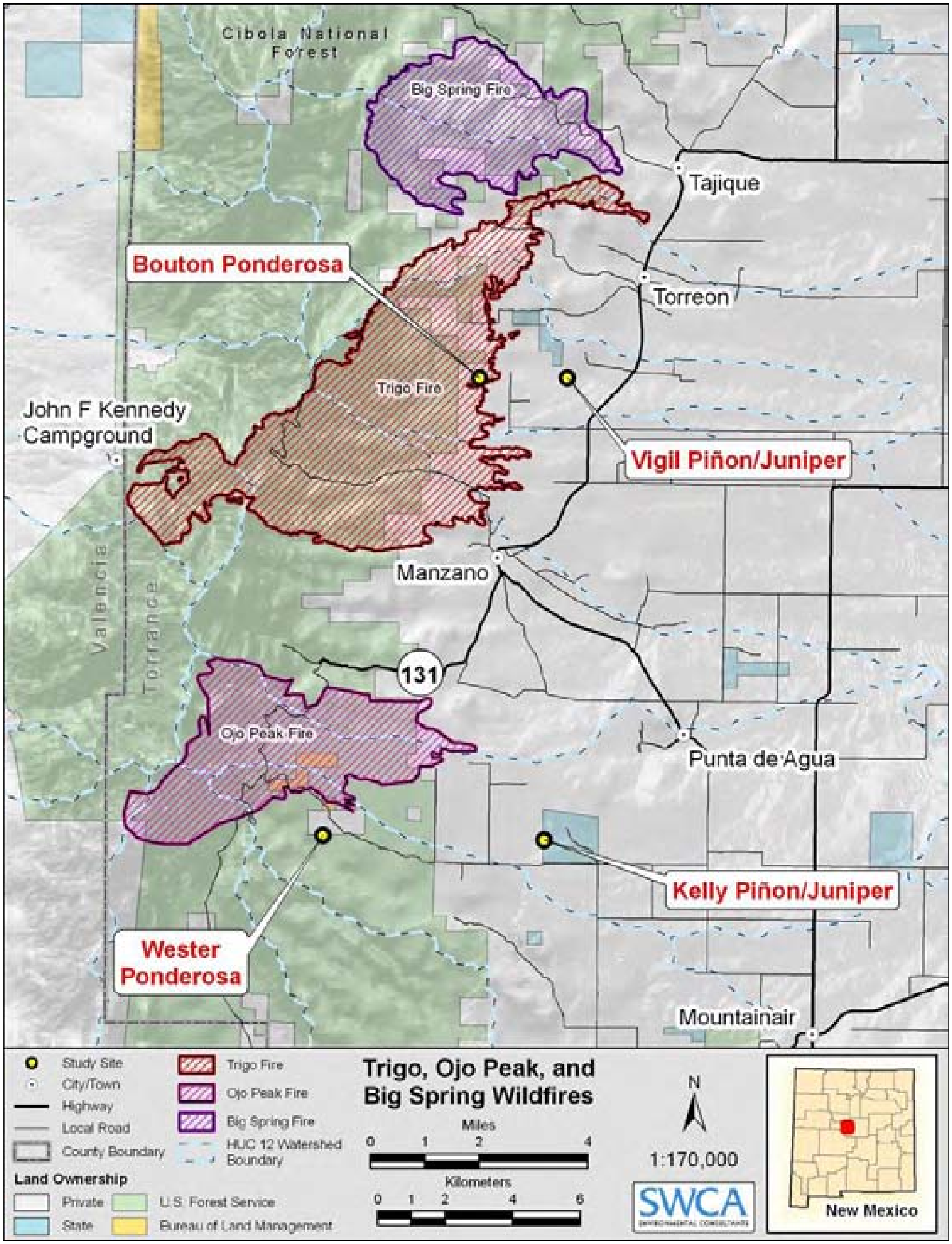

Figure 1. Map of the Manzano Mountains showing the locations of the Ojo Peak, Trigo, and Big Spring wildfires and existing Estancia Basin Watershed Health, Restoration, and Monitoring Project study sites.

This document will serve as the post-fire monitoring plan and has been developed in accordance with literature findings and the guidance of the EBWHRMSC and other specialists in the field. Other monitoring projects being conducted by other agencies are also in progress on the Trigo burn site, and efforts will be made to collaborate with principal investigators from each of these projects to extend our span of knowledge and data collection.

A meeting with other organizations (e.g., U.S. Forest Service [USFS], U.S. Geological Survey [USGS], New Mexico State Forestry, and New Mexico Environment Department) conducting or planning post-fire monitoring on the east slopes of the Manzano Mountains, including the Ojo Peak, Trigo, and Big Spring wildfires, was hosted by SWCA on July 16, 2008. The purpose of the meeting was to develop collaborative efforts for post-fire monitoring for environmental conditions, and to develop communications and data sharing across studies. Summary notes for that meeting are attached (Appendix A).

Task 2 - Study Site Locations and Installations

Study site selections will be made in August 2008. Potential landscape areas appropriate for sampling will be determined using geographic information system (GIS) overlay technology to overlay and isolate environmental factors of interest (elevation, slope, soil types, vegetation types, burn severity, etc.). Study sites will be located on private land on the eastern fringes of the burn and will be distributed across four watersheds in order to enable analysis of burn impacts on a landscape scale.

A total of 21 plots will be established across three watersheds (six plots in each watershed) and will be permanently marked for repeat measurements, initially over a three-year period with the available funding. Plots will be located within ponderosa pine stands and stratified by burn severity (as determined by the Burned Area Emergency Response [BAER] team) into three low and three high severity plots within each watershed and three unburned reference plots spread across the three watersheds. Within each of these monitoring plots, hydrologic and soil monitoring will be conducted using the protocols outlined below (Monitoring Parameters and Metrics).

One of the existing forest thinning monitoring sites (Bouton ponderosa pine) burned in the Trigo fire (see Figure 1). SWCA had already begun measurements of rainfall and runoff at this site prior to the fire. One of the paired study plots was intensely burned, and the other was lightly burned. We will continue monitoring that site, but now for post-fire environmental changes. The understory measurements will continue to follow the methodology applied on the other thinning plots, but the tree monitoring will follow the fire monitoring protocol. Data from the Bouton ponderosa site will then be used to compare the intensely burned plot to the lightly burned plot, the post-fire monitoring study proposed below, and the remaining unburned forest thinning monitoring study sites.

Task 3 - Initiate Monitoring Measurements

Monitoring parameters will include measurements of vegetation, hydrology, soils, and wildlife. All monitoring will occur within the plot design or adjacent to the plot. Hydrological monitoring will also encompass major drainages within or originating from each watershed studied. Measurements will be initiated in September and October 2008.

Vegetation monitoring parameters will be measured on a biannual basis—in the early (May) and late (September) summer—while some soil and wildlife parameters will require monthly data collection, and weather and hydrological measurements will occur year round. Three automated wildlife cameras will be erected in each severity type and rotated between the three watersheds on a monthly cycle. The monitoring plan is designed to be carried out over a three-year period, with the intention of expanding that period to 10 years; however, this will be contingent upon future funding.

Task 4 - Data Management

Data for all parameters will be complied in a central database managed by SWCA (computer directory and folder system) in Microsoft Excel format files. Summaries of data will be produced as Excel graphs and will be produced annually. To ensure data quality, an inspection of the collected data will be performed biannually, including visual assessment of data ranges and points for potential errors.

Task 5 - Reporting to the Estancia Basin Watershed Health, Restoration, and Monitoring Steering Committee

The data and summary graphs will be provided to the New Mexico Forest and Watershed Restoration Institute (NMFWRI) for public access via their website on a quarterly/annual basis. An annual report will be provided to the EBWHRMSC after the end of each calendar year (February of each year), presenting summary graphics, data, and interpretations of the previous year's findings. After each annual report has been approved by the EBWHRMSC, the reports will be submitted to the NMFWRI for posting on their website. However, for the first year of the project, SWCA will provide the first annual report one year after initiation of monitoring, and then move to the February reporting schedule for subsequent years (see Schedule below).

LITERATURE REVIEW OF FIRE MONITORING PROTOCOLS

INTRODUCTION

Large, high-severity wildfires are now commonplace in southwestern ecosystems and are associated with a number of significant and undesirable ecological impacts (Covington and Moore 1994; Fulé et al. 1997). Following high-intensity crown fires, timber resources are often damaged or destroyed; wildlife habitat is transformed, affecting its suitability for some species; soil nutrient stores are depleted; soil hydrology is altered; and duff, litter, and vegetation layers are removed exposing soil to rapid erosion events which in turn overwhelm riparian areas, streams, and rivers (Campbell et al. 1977).

In order to learn from the impacts of recent fires in the southwest, burn monitoring is carried out to inform rehabilitation efforts and future forest management. Choosing and implementing the appropriate monitoring protocols is a critical step in the execution of a fire monitoring program. There are a myriad of monitoring methods that can be employed by fire management professionals. The criteria for method selection includes complexity of methodology, prospects for long-term consistency, and time and funding available for implementation. Some of the most popular fire monitoring designs used by agencies follow the National Park Service Fire Monitoring protocol and USFS Forest Inventory and Analysis (FIA) plot designs. The following provides a summary of peer-reviewed literature of monitoring protocol that has been utilized in projects similar to the Estancia Basin Watershed Health Post-fire Monitoring Study.

VEGETATION RESPONSE POST FIRE

Many studies have assessed the impact of fire on vegetation response and the time required for re-establishment of native species. Monitoring methods that assess species cover and richness vary. Methods that best measure richness of an area (e.g., timed meander) are limited by a qualitative estimate of species importance and an inability to define other vegetation patterns (Palmer et al. 1995). Likewise, those methods that enable a researcher to quantify the relative importance of each species and other patterns (e.g., systematic plots/grids) are limited by cost and time to adequately sample enough area for a full flora record (Stohlgren et al. 1998). A sampling design that detects rare species, such as early establishing exotics, but is also capable of defining vegetation patterns and individual species' relative importance is desired.

Four main monitoring techniques can be readily applied to detect species abundance and cover: varying intensity-systematic plot, stratified-random plots, modified-Whittaker plots, and timed meander. Huebner (2007) employs all four methods in assessing the abundance of invasive species following a burn and provides an evaluation of each.

The systematic-plot method contained 32 1-m^2 plots arranged along a 200-m central transect. Four plots placed at each cardinal direction were arrayed 1 m away from a point 15 m on either side of the transect at 50-m intervals along the transect. Percent cover of herbs, shrubs, and vines rooted in the plots and percent cover and density of the tree seedlings under 1 m in height and rooted in the plots were measured for all plots. Cover was estimated to the 0.25% level using a plastic Mylar circle that was 0.5% of the 1-m^2 area.

The stratified-random plot method was composed of 60 plots, 40 of which were 1 m^2 in size and 20 of which were 10 m^2 in size. These plots were stratified every 10 m along the 200-m central transect at random distances (within the boundaries of the plot and not overlapping the plots on the transect) perpendicular to the transect. Percent cover in all 1-m^2 plots was estimated as described in the systematic method.

The modified-Whittaker method included one large 1,000-m^2 rectangular plot centrally located in the stand with one rectangular 100-m^2 plot, two circular 10-m^2 plots, and 10 circular 1-m^2 plots nested within the 1,000-m^2 plot (Stohlgren et al. 1995, 1997; Yorks and Dabydeen 1998). (Note: The modified-Whittaker plot design is often altered to best meet the resources and objectives for a project.) Percent cover and density of each tree seedling species rooted in the plot were estimated as in the previous two methods. If species were present in any of the nested plots, they were not counted again in the 1,000-m^2 area.

The timed-meander method entails thoroughly walking each site for one hour noting the time every 10 minutes as new species are tallied (Goff et al. 1982). Because this is a plotless method, any variables based on plots cannot be analyzed. This method samples 100% of each site.

Plot efficiency is important in any monitoring design. In general, timed-meander methods are thought to take 30 minutes, the systematic method 1 to 2 hours, the random method 2 to 4 hours, and the modified-Whittaker method 2 to 3 hours (for two botanists to complete). Sampling time includes plot setup (Hunter et al. 2006; Freeman et al. 2008).

Huebner (2007) found that the timed-meander method and, to a lesser extent, the random method resulted in the highest estimates of species and, thus, best defined the flora and invasive exotic species of each site for herbs, vines, shrubs, and tree seedlings. The timed-meander method detects more species of all species categories than any other method, but it still failed to detect some species of sedge and grass. The timed-meander method is also limited in its ability to detect changes in species abundance and their relative importance because of the method's reliance on presence-absence data. Furthermore the time meander method is also dependent on the skill of the botanist, so results could vary widely. The modified-Whittaker plot failed to detect a large number of species, thought to be an artifact of its central design (Huebner 2007). This method was also time consuming to set up and complete. The random method detected a large amount of species relative to other methods, which is often attributed to its greater sampling intensity (Palmer et al. 1995).

Many researchers support the use of variable plot sizes in order to maximize species detection (Barnett and Stohlgren 2003; Frischknecht 1981; Stohlgren et al. 1997). Smaller plot sizes are thought to be best suited to patches of vegetation that are relatively dense, while larger plots are more likely to detect species in widely spaced vegetation (Chambers and Brown 1983; Mosley et al. 1989). Huebner's (2007) results support the use of variable plot sizes to increase intensity, instead of increasing the number of plots. Huebner's study (2007) found that the random method estimated species cover from a larger area than the systematic and modified-Whittaker methods, and it predicted more species than the systematic method. The modified-Whittaker method which is composed of multiple scales did comparatively well in estimating richness, but its abundance estimates and importance values are based on a much smaller sample area compared to the random method. Consequently, this method, which has been suggested as a standard sampling method (Barnett and Stohlgren 2003; Chong et al. 2001; Stohlgren et al. 1995, 1997), is considered by Huebner (2007) as unsuitable for some monitoring.

The author concludes that the random method came closer to defining true diversity, evenness, and species abundance. If the management goals of a site require only documentation of all species present and information on the relative abundance of such species is not important, the timed-meander method is the best of the four methods (Goff et al. 1982; Palmer 1995; Palmer et al. 1995). However, if abundance of a given species increases over time with a subsequent decrease in abundance of associated species, the random method will be the best of the four methods to capture this change (Huebner 2007). This approach is also recommended as part of the National Park Service (NPS) monitoring protocol.

In the NPS protocol, plots can be variable in size depending on the objective of the study and the vegetation type, but the recommended dimensions are 50m x 20m split into quarters (Figure 2). Herbaceous vegetation is measured using a point intercept approach, which is suitable for measuring relative and percent species cover by species over time. In areas with high shrub density a belt transect is recommended and should be measured along the point intercept transect. Woody debris and litter are recorded following similar protocol to the Brown transect method (Brown et al. 1982). Any shrub re-sprouts should be recorded and tallied. New seedlings are measured in a density plot and recorded only after the second year of survivorship. In high density areas the density plot can be sub-sampled and extrapolated for total density. Herbaceous layer species density is measured using a density sampling frame along the plot transects. Overstory tree data include measurements of diameter at breast height (DBH), crown position, crown description and diameter at root crown and are carried out on the entire plot area.

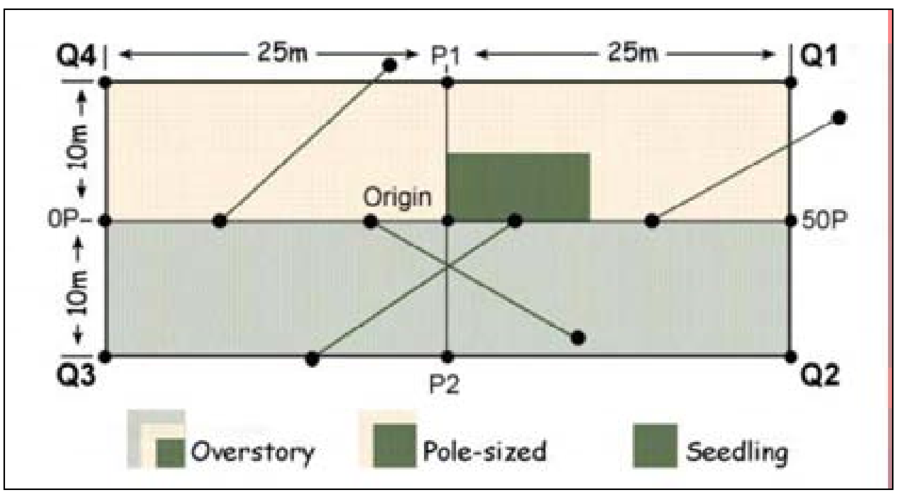

Figure 2. The NPS protocol plot design

Keyser et al. 2008, assessed ponderosa pine regeneration following a mixed severity fire in the Black Hills utilizing a randomly generated plot approach similar to the NPS protocol. Within each regeneration plot, the number of seedlings less than 1.4 m in height was enumerated. To determine whether seedlings germinated postfire or were fire survivors, each seedling was aged by back-counting the bud scale scars from current year growth. Only seedlings that germinated postfire were counted and included in the analysis.

The FIA plot design utilizes 3 transects in a Y shape, along which square plots are erected for carrying at percent cover and species composition counts. Transect lines have been utilized by a number of researchers as a means to decrease plot set up times and thereby increase efficiency. The Forest

Service Region 3 fire monitoring protocol is in the process of being designed to use a similar transect approach. Ffolliott et al. (2000) carried out systematic sampling of understory response using permanent sampling plots located at regular intervals along a series of transect lines. Transect lines were orientated to maximize the variability in measurements on sample points along the lines. The author used approximately 200 sampling points. Plot understories were monitored using point sampling techniques and a basal area factor of 25 was used to select tally trees. Stocking of small trees were used to estimate stand density and change over time.

Diaz-Delgado et al. (2003) took a different approach to assessing plant response to fire. They looked at consumption of fine branches on woody plants classifying damage into 7 classes based on the degree of consumption. This methodology is only really suitable where fire effects are easily differentiated into classes; in some vegetation (for example piñon-juniper) fire doesn't produce such a refined scale of damage.

BURN SEVERITY/ FUELS

Burn severity is a nebulous term with numerous definitions in the literature (Wang 2002; Wells et al. 1979; Chappell and Agee 1996; FIREMON 2003); the most widely accepted definition is that of Ryan and Noste (1983) who suggest that burn severity should be a combination of soil and overstory effects- "fire effects that incorporate both upward (fireline intensity) and downward (heat-per-unit-area) heat pulses." Therefore the most damaging fire is not always those that consume overstory trees but also burns that damage underlying duff and forest floor; deep charring of the ground surface may cause numerous species to be lost from the site (Ryan and Noste 1983). The Ryan and Noste definition is readily adopted by researchers and agencies and incorporates parameters that are easily measured in the field.

The attributes of burn severity as defined by Ryan and Noste (1983) can be measured through assessment of scorch height and ground char depth. Using this definition Omi and Martinson (2002) in a study of fuels treatments, evaluated fire severity in terms of stand damage – percent scorch, and percent consumption throughout the sample plot, and downward heat pulse- existence of unburned litter and duff and changes to mineral soil color and texture. Omi and Martinson (2002) utilized a modified-Whittaker plot design (Stohlgren 1997) measuring ground char on 10 1m^2 subplots and stand damage on a variable radius based on basal area. Tree height, DBH, position, height to pre fire live crown, highest scorched needle, highest point of bole char, percent canopy scorch, and percent canopy consumed are measured.

The modified-Whittaker plot design has been adopted in a number of burn severity studies (Omi and Kalabokidis 1991; Cram et al. 2006; Freeman et al. 2008; Hunter et al. 2006). Adjustments have been made to the original proposed size and shape of the plot and subplots (Stohlgren 1997) in order to reduce time for monitoring (Freeman et al. 2008). The Ryan and Noste protocol has also been implemented and adapted on variable radius plots (Cram et al. 2006). Surface damage parameters were adapted from Ryan and Noste (1983) (table 1) and crown damage followed Omi and Kalabokidis (1991) criteria (table 2). Most studies that include ocular estimates task these measurements to one researcher in order to remain consistent throughout the study.

Table 1. Ocular estimates of surface damage following wildfire (Source: Cram et al. 2006 - adapted from Ryan and Noste 1983)

Unburned- 0	The fire did not burn on the forest floor. Some damage may occur due to radiated heat from adjacent areas.
Light surface char-1	Leaf litter charred or consumed. Surface appears black immediately after fire. Upper duff may be charred. Woody debris partially burned. Some small twigs and much of the branch wood remain. Logs scorched or blackened but not charred.
Moderate surface char- 2	Litter consumed. Duff deeply charred, but mineral soil not visibly altered. Light-colored ash immediately after fire. Woody debris largely consumed. Some branch wood remains, but no foliage or twigs remain. Logs deeply charred.
Deep surface char- 3	Litter and duff completely consumed; mineral soil visible. Structure of surface soil may be altered. Twigs and small branches are completely consumed. Few large branches may remain, but deeply charred. Sound logs deeply charred; rotten logs completely consumed.

Table 2. Ocular estimates of crown damage following wildfire (Source: Cram et al. 2006- adapted from Omi and Kalabokidis 1991)

Unburned- 0	Fire did not enter stand.
Light- 1	Surface burn without crown scorch.
Spotty- 2	Irregular crown scorch.
Moderate- 3	Intense burn with complete crown scorch.
Severe- 4	High intensity canopy burn with crowns totally consumed.

Battaglia et al. (in press) also assessed severity based on basal charring of each tree in their overstory plots, hypothesizing that cambial damage can impact long term tree survival. Severity was rated from 0-3 based on classification developed by Ryan (1982). Moderate and deep basal charring is thought to be sufficient to kill the cambium and therefore increase tree mortality post fire (Thies et al. 2006).

In 1999 Key and Benson developed a new severity index and burn monitoring protocol termed the Composite Burn Index (CBI). This protocol became part of the FIREMON protocol for measuring fire effects. The CBI adopts a multi-strata approach (including small trees and shrubs) to monitoring burn severity, differing from the Ryan and Noste (1983) approach of only a two strata assessment. The CBI approach breaks plot vegetation down into Understory vegetation- substrates, herbs, low shrubs, small trees, tall shrubs and sapling trees, and Overstory- Intermediate pole sized trees (subcanopy) and big trees (mature dominant canopy). Each strata is rated in terms of the degree of damage- %green (unburned), % black (torched), % brown (scorched/girdled) and % canopy mortality. Substrate damage is measured in terms of scorching and consumption of litter and duff, consumption of fine and heavy fuels and changes to soil color and cover. The CBI plot design and protocol have been tested throughout the country and have proven to be a fast and efficient way of monitoring burn severity (Freeman et al. 2008; Cocke et al. 2005).

CBI plots are also designed for ground truthing satellite classification of burn severity and have been tested against other protocol. Cocke et al. 2005 compared Normalized Burn Ratio (Landsat derived satellite classification of burn severity) and CBI plots- They used the NBR classification to select plots stratified by burn severity- low-extreme. Key and Benson (1999) recommend sampling 20-40 plots per severity type. Some researchers have adapted the CBI plot to also include measured parameters such as fuels (Freeman et al. 2008; Cocke et al. 2005). Cocke et al. (2005) also carried tree measurements including tree species, DBH, height and condition. Seedling trees (those below 2.5 cm DBH) were tallied by species, condition and height class in a 50m2 subplot. Understory vegetation cover and tree canopy cover were sampled along point-line intercept transects. Forest floor and woody debris were measured along 4 16m planar intersect transects (Brown et al. 1982). Fuels were recorded by 1-100hr fuel particle size and duff depths were measured at intervals along each transect line. Post fire measurements were monitored using the National Park Service protocol- tree condition class, char height, scorch percent.

WOODY DEBRIS AND FUELS

Varying levels of fire severity can affect the structure and composition of the surface woody fuel bed, this has implications for vegetation response, erosion potential and wildlife habitat availability. After fire, there is often an immediate decrease in the abundance of both coarse woody debris (CWD) and fine woody debris (FWD) (woody biomass _7.6 cm diameter) (Fulé and Laughlin 2006). In ponderosa pine stands that experience high tree mortality, the decrease in surface fuels is short-lived as fire-killed snags quickly transition from the canopy to the surface fuel bed (Passovoy and Fulé 2006). A number of authors have studied tree mortality and woody debris in ponderosa pine stands burned under varying fire severities (Keyser et al. 2008; Battaglia et al. in press; Freeman et al. 2008)

Keyser et al. (2008) quantified the effects of wildfire on the forest floor by measuring litter and duff depth and surface woody fuel biomass. Litter and duff depths were measured every 2 m along a 60-m transect. Litter was measured annually in order to determine a yearly site average. Both FWD (Mg/ha) and CWD (Mg/ha) were sampled at each site using the planar intersect method (Brown et al. 1982). Fine fuels were measured along 10 m of the 60-m transect and coarse fuels were measured along the entire transect. Browns transects are the most commonly applied approach for quantifying coarse woody debris and fuels.

A well utilized approach is to establish permanent study sites in burned and unburned stands, with replicates in each fire severity class. Plots can often be assigned based on estimates of crown and forest floor damage from aerial photographs. Measurements include: tagging all trees over 1.4 m in height, recording species and tree mortality, and measuring DBH (diameter at 1.4 m above the soil surface), tree height (m), and the prefire height to the base of the live crown (m). On each tagged tree, crown and stem damage should be measured (Keyser et al. 2008) following burn severity protocol such as Ryan and Noste (1983) or Key and Benson (2003). Keyser et al. (2008), Lentile (2004) McHugh and Kolb (2003), Sieg et al. (2006) also monitor basal char, which serves as a proxy for cambial injury (which can girdle and subsequently kill a tree) and is measured as the percentage of the bole circumference charred below a height of 30 cm.

Claunch-Pinto SWCD has been working on a Collaborative Forest Restoration Project that assesses the ecological effects of thinning in the Cibola National Forest. Monitoring indicators and methods were developed using the guidance of the CFRP Monitoring Technical Assistance Team and Handbook 4: Monitoring Ecological Effects of CFRP projects (available on line at http://www.fs.fed.us/r3/spf/cfrp/monitoring/). The monitoring, which utilizes local high school children, includes measurements of adult tree size, density of saplings, Understory cover, Canopy cover, Surface fuels, and photo points. The study utilizes a 300 foot transect with varied plot sizes located at points along it. Tree measurements are made in 30 x 30 ft plots, while understory cover is measured in 3 x 3 ft plots. Surface fuels are measured along a conventional Browns transect, 30 ft in length.

TREE MORTALITY

Many authors have attempted to quantify tree mortality following wildfire. Studies have shown that in general, larger diameter ponderosa pine trees can survive proportionally greater crown damage than smaller trees (Stephens and Finney 2002; McHugh and Kolb 2003; Keyser *et al*. 2006; Sieg *et al*. 2006). The mortality thresholds are often dependent on tree diameter, bark thickness, pre-fire vigor, crown ratio, and the presence/absence of other fire-related injuries. Heating of the soil from surface fuel and forest floor consumption can also damage the fine root system (Smith *et al*. 2004; Hart *et al*. 2005) and contribute to tree mortality (Swezy and Agee 1991; Stephens and Finney 2002). Because root damage is inherently difficult to assess without excavation (Ryan 1982; Swezy and Agee 1991), the amount of charred ground is often used as a surrogate measure (Ryan and Noste 1985).

Battaglia et al. (In press) measured post-fire mortality of ponderosa pine seedlings and saplings on five dormant season prescribed fires. The authors use transects 200 m long with the direction of each randomly chosen. A plot (n=five per transect) was established every 50 m along each transect within a burn unit. A nested plot design with a 2 m radius circular plot to sample ponderosa pine seedlings (trees<137 cm tall) and a larger 5m radius circular plot to sample saplings (tree 0.25 to 10 cm dbh) was used on all sites. The sapling plot radius was expanded where 5-m radius did not include enough saplings. Fire damage variables similar to those described by Keyser et al. (2008) were measured for each seedling and sapling on each plot.

The NMFWRI have been working on a study of the impacts of the Ojo Peak fire that assess post burn severity and mortality. NMFWRI are using a modified FFI/FIREMON sampling method that utilizes a 1/10 acre circular plot for measuring overstory trees and 1/100 acre plot for saplings. Surface fuels are also measured using a 75 ft Browns transect.

INVASIVE SPECIES

Large and severe wildfires can increase tree mortality, decrease grass cover and increase seed bank mortality. Following severe wildfire there is also high incidence of exposed bare soil and low tree canopy cover which increases the potential for non-native invasions (Wolfson et al. 2005; Hunter et al. 2006). Many burn areas are treated with grass seed applications which can be controversial because mixes often contain non-native seeds (Robichaud et al. 2000). A number of studies have been carried out in recent years that assess the impact of fire on non-native species invasions.

Hunter et al. 2006 carried out a study to determine factors that relate to heavy infestation of invasives- i.e. soil fertility, disturbance severity, dominant native species cover, non-native species propagule pressure, native species richness. Sampling sites were selected randomly within the following strata- veg type, aspect, burn severity, post fire mitigation. Monitoring utilized the modified-Whittaker plot (Stohlgren et al. 1998) and similar studies of invasive species have adopted the same approach (Freeman et al. 2008; Omi and Martinson 2001). Burn severity was monitored following the Ryan and Noste (1985) methodology. Soil samples were taken from each corner and center of the plot. Soils were analyzed for carbon and nitrogen. Botanists identified and measured cover and height of all species in each $1m^2$ subplot. The remainder of the plot is searched for any species not discovered in the sub-plots. Freeman et al. (2007) used a smaller version of the modified-Whittaker plot that has been found to be successful in capturing trends in dominant vegetation and environmental gradients (Barnett and Stohlgren 2003). Omi and Martinson (2001) also used the modified- Whittaker plot design to determine plant response and non-native species invasions. Vegetation data were grouped according to biotic predictor variables most likely to impact non-native species cover, i.e. cover of dominant native species (native grass cover), propagule pressure of non-native species through application of potentially contaminated seed mixes (seeded grass cover), and native species richness.

Huebner (2007) states that If the goal of a study is solely to detect the presence of invasive exotic species (or all species), the timed meander method (or a similar method) is most suitable. However, detection is rarely sufficient when evaluating success or failure of control strategies and management or impacts of invasion. Huebner considers the random method (or a method of similar intensity) to be the strongest for estimating changes in relative abundance. If significant changes in composition are suspected (i.e., after a disturbance or environmental stress event), it is advisable to use the timed-meander method periodically to assess the detection strength of the random method.

Soils

Often wildfire disturbances result in increased nutrient availability, which is also shown to increase ecosystem invasibility (Stohlgren et al. 1999). Once established, invasive species may alter nutrient cycling, creating an environment more suitable to further invasion (Evans et al. 2001).

Many studies that assess vegetation response after burns involve an assessment of soil nutrient parameters. Hunter et al. 2006 and Freeman et al. 2008 both collected soil samples from the corners and center of the their modified-Whittaker plot design to determine the degree to which soil nutrients were influencing post fire species abundance. Soil samples were collected, air dried, sieved and ground using a standard roller mill. Soils were analyzed for percentage of total carbon and nitrogen using a LECO-1000 CHN analyzer (LECO Corporation, Saint Joseph, Missouri, USA) and measured inorganic carbon using the modified pressure-calcimeter method (Sherrod et al. 2002).

Wildlife

A vast number of variables come into play when determining suitable wildlife habitat and this coupled with the unpredictable nature of fire and its effects on the landscape mean that determining how a species or group of species will respond to fire is an almost impossible task. Whelan (1995) suggests that the response of an animal to fire is likely to operate parallel to the reaction of vegetation due to the importance that vegetation has for habitat. Many researchers have followed this perspective and wildlife studies are often inferred from stand structure and species composition changes post fire. There has been a general lack of post fire monitoring of species, particularly those that are not deemed as game species such as deer and elk. Studies also tend to be biased towards easily monitored species such as birds and small mammals. Many studies of wildlife and fire make inferences based on fire effects on vegetation instead of direct species counts. This is often attributed to a lack of resources to monitor wildlife and logistical difficulties in long term monitoring of species. Fundamentally there is funding need for greater monitoring of population changes across a range of species types (Baird et al. 1994).

Bock and Bock (1983) studied the response of birds and deer mice to fire in ponderosa pine forests in South Dakota where two controlled burns had occurred. Study plots were created prior to the burns, and vegetation cover transects were conducted pre and post burn. Surveys conducted two years after the fires showed a reduced litter-cover in the burn areas as well a reduction in saplings. Breeding birds (7 songbird species were monitored) and deer mice were more abundant two years after the burn on the burn sites than the control plots. Small mammals are popular indicators of wildlife response to wildfire because of their ease of study and the fact that predator/prey inferences can often be made.

Converse et al. (2006) also studied small mammal response to fire in thinned versus unthinned stands. Habitat availability and species density of four small mammal species, deer mice (*Peromyscus maniculatus*), gray-collared chipmunks (*Tamias cinereicollis*), golden-mantled ground squirrels (*Spermophilus lateralis*), and Mexican woodrats (*Neotoma mexicana*) were studied. The study utilized mark-recapture techniques to assess population density. The results of the thinning and prescribed burn 2-3 years after the burn was an increase in herbaceous vegetation and decreased shrub density. Animal species were monitored relative to individual habitat traits, and a variety of relationships were discovered. For example, "deer mouse densities were negatively related to tree densities", and "Gray-collared chipmunks were negatively affected by treatment, negatively related to tree density, and positively related to woody debris" (Converse and White 2006). Browns transects were employed in determining density of woody debris.

Hobbs and Spowart (1984) studied nutrient content of foliage in mountain sheep and mule deer range following a burn in Colorado by taking cuttings of known forage species. The study found an increase in available protein for sheep and mule deer during the winter for two years after prescribed fires in the Front Range of Colorado. The study found no change in protein availability during other periods of the year.

Randall Parker and Miller (2002) evaluated habitat availability in wildland areas. The study involved a catalog of wildlife habitat, primarily the availability of woody debris, primarily logs, snags, and oaks before and after five prescribed burns. The methodology "evolved from a variable plot method to a grid method through a series of sites" (Randall and Miller 2002). The final technique utilized the identification of all habitat items using aluminum tags. The findings state over 50% of all downed trees were consumed in the burns, and roughly 20% of all snags were burned.

Smucker et al. (2005) used a "before-after/control-impact (BACI)" (Smucker et al 2005) approach to study bird assemblages after a wildfire in the Bitterroot Mountains in 2000.

The methodology included the conduction of bird surveys every 10 minutes. Additionally vegetation surveys were used at 13 burn and 13 control sites. This data was available in the area before the fire, as well as after. The variance in vegetation density three years after the fire between burned and unburned areas was a function of burn severity. The abundance of nine birds species at sites was significantly different between the pre-burn and post-burn time frames at the burn sites. There was a strong variance in the post-burn habitats specific bird species would utilize.

Chambers and Mast (2005) studied the effects of fire on ponderosa pine snags. The study involved the creation of six, 1 hectare (2.5 acre) plots in Northern Arizona at recent fire sites. Six sites of the same size were created as control sites. Snags were mapped, and characterized. The results suggest the burned areas were characterized by a higher prevalence of snags and habitat cavities within ponderosa.

HYDROLOGIC RESPONSE & EROSION

Wildfire alters the hydrologic response of watersheds, including peak discharge resulting from rain events, transport of sediment, and rate of erosion and deposition (Moody 2001; Veenhuis 2002; Gallaher 2004; Martin and Moody 2001; Moody and Martin 2001a, Moody and Martin 2001b). Flooding and erosion following wildfires are a well recognized phenomena in montane areas of the western United States (Martin and Moody 2001). The removal of duff litter and the forest canopy along with the physical and chemical alteration of soil by fire change the erosional threshold of burned watersheds (Martin and Moody 2001). A relationship referred to as the rainfall-runoff relation indicates that a threshold of rainfall intensity exists, above which sever flash floods occur (Moody and Martin 2001b). Various methods of measuring these post-wildfire watershed changes have been practiced throughout the west.

Silt fences are considered an economical technique for measuring hillslope erosion (Robichaud 2002). Installing silt fences and tipping bucket rain gauges to measure onsite hillslope erosion provides a versatile method for measuring hillslope erosion in various settings (Robichaud 2002). Tipping buckets are a practical tool for measuring flow and is widely used in rain gauges (Black and Luce 2007). Black and Luce describe how to install and implement tipping bucket design for measuring plot discharge up to 35 gallons per minute. Also a system for measuring complete sediment budget for the plot, including necessary time and equipment is explained in the paper *Measuring Water and Sediment Discharge from a Bordered Road Plot using a Settling Basin and Tipping Bucket*.

A wide variety of methods have been used to quantify erosion after wildfires under natural conditions at different temporal and spatial scales. These methods can be grouped as: i) plot method; ii) silt fences; iii) reservoir trapping method; iv) suspended sediment method; and v) the erosion-pin method (Moody et al. 2007).

Volumes of eroded sediment after wildfires vary substantially throughout different geologic terrains across the western United States. These volumes are difficult to compare because they represent the response to rainstorms and runoff with different characteristics. By measuring the erosion response as the erodibility efficiency of water to detach and transport sediment on hillslopes and in channels, the erosion response from different geological terrains can be compared (Moody et al. 2007).

Numerous methods have been devised to directly and indirectly measure soil erosion due to water. Two field methods that are applicable to non-forested upland include an indirect measure of the change in elevation of the soil surface and a direct measure of the sediment produced from a defined area. Many other techniques have been developed that are highly sophisticated and are primarily suitable for research (Wirth and Pike 2007).

Digital data loggers are widely used for monitoring physical conditions in aquatic ecosystems (Dunham 2005). Protocols provided in *Measuring stream temperature with digital data loggers: a user's guide* demonstrate guidelines for selecting and programming data loggers, sampling water temperatures in the field, data screening, analysis, and data archiving (Dunham 2005).

WATER QUALITY

Increased storm runoff and transport of contaminants by runoff after a wildfire raises concerns about water quality (Gallaher 2004). After the Cerro Grande, runoff events were monitored and sampled throughout the summer runoff seasons of 2000 - 2003. Environmental samples of runoff and baseflow were compiled with the results of the Water Quality and Hydrology Group at Los Alamos National Labs and New Mexico Environment Department sampling to provide a comprehensive evaluation of the effects of the Cerro Grande on the environment (Gallaher 2004).

The labs use two types of sampling methods: automated sampling equipment and manual. After samples have been retrieved, they are sent to a DOE approved commercial analytical laboratory for analysis (Los Alamos National Laboratories 2007-2008).

After the wildfires experienced in southern California, the U.S. Geological Survey collected ash and burned soils from about 28 sites in the areas of southern California affected by wildfires from November 2 - 9 2007. Researchers applied a variety of analytical methods to these samples to help identify characteristics of the ash and soils from wildland and suburban areas that may be of concern for their potential to adversely affect water quality, human health, endangered species and debris flow or flooding hazards (Plumlee et al. 2007).

Effectiveness of Restoration

A white paper by Pyke et al. (2002) suggests that in the absence of intensive post-fire rehabilitation of native species, non-native species will out-compete many native plants, increasing fire risk and changing the age structure of the wildland area (Pike and McKinley). For example, the paper suggests a change is likely resulting in a move from perennial to annual plant species, reducing available winter habitat and food availability for animal species.

Monitoring the effectiveness of rehabilitation is important in determining which types of restoration strategies are successful. Recent reviews have found that existing data from monitoring and research at Emergency Stabilization and Rehabilitation (ES&R) and Burned Area Emergency Response (BAER) treatment areas are insufficient to evaluate the effects of the treatments. The purpose of the report *Monitoring Post-Fire Vegetation Rehabilitation Projects: A Common Approach for Non-Forested systems* is to i) document what monitoring methods are generally used by personnel in the field, ii) describe approaches and methods for post-fire vegetation and soil monitoring documented in agency manuals, iii) determine the common elements of monitoring program recommended in these manuals, and iv) describe a common monitoring approach to determined effectiveness of the future ES&R and BAER treatments in non-forested regions (Wirth and Pyke 2007).

Existing literature on treatment effectiveness is limited, thus making comparisons difficult. Contour felled logs, seeding, and reduction of road failures with treatments such a properly placed spaced rolling dips, water bars, and culvert relief to move water past the road prism and channel treatments are some of the methods discussed. Robichaud et al recommend increased treatment effectiveness monitoring at the hillslope and sub-catchment scale, streamlined postfire data collection needs, increased training on evaluation of postfire watershed conditions and development of an easily accessible knowledge base of BAER techniques (Robichaud 2000).

Evangelista et al 2004 monitored three burn sites in the Grand Staircase-Escalante National Monument which had received restoration treatments. One burn site along with its neighboring control site was treated with reseeding of native grasses, another pair of burn and non-burned sites was reseeded with non-native grasses and the final pair of sites were left to regenerate naturally. Burn sites regardless of treatment had high levels of non-native species encroachment. The study found that one particular non-native species, Cheatgrass (*Bromus tectorum*) was encroaching on all sites, providing a fire hazard for the future, which leads to an increase in probability of conditions favoring further non-native species proliferation, reducing native landcover and threatening juniper woodlands (Evangelista et al. 2004).

Wohlgemuth et al. 1998 evaluates the need for a more quantitative analysis of post-fire impacts on land cover and soil. Erosion was measured during the wet and dry seasons both before and after a burn. Unburned test plots were also monitored, serving as a control group. Erosion levels were aggregated over the season. Some plots were randomly reseeded with grasses after the fire. The results were unclear as the data recorded in this experiment could not be normalized. It is uncertain whether reseeding grasses had an impact on erosion rates. Reductions in erosion were significantly reduced with time; most sites saw a reduction in erosion to pre-fire levels within 2-4 years of the burn, though it should be noted the prescribed burn was described as less intense than recent wildfires in the surrounding area.

MONITORING PLAN

MONITORING OBJECTIVES

The broad objective of this post-fire monitoring study is to determine how wildfire affects Estancia Basin water recharge and water quality. Numerous environmental variables influence water yield and water quality, including soil parameters, and vegetation cover, structure and species composition. In order to quantify the impacts of these variables on hydrology, the fire monitoring study will incorporate monitoring of burn severity, vegetation response, non-native plant species invasion, and soil- erosion, infiltration, and stability. Wildlife habitat measurements and wildlife abundance measurements will also be made as an index to forest and watershed health. The monitoring will be carried out across 3 watersheds impacted by the Trigo fire. This scale of study enables us to determine the landscape level effects of the fire on watershed processes and water recharge.

SAMPLING/STUDY DESIGN

Locations

Sampling locations are stratified by: landownership (private land only), watershed, burn severity and existing monitoring study locations. Other variables that will be controlled for include- vegetation type, treatment history, soil type, geology, aspect, slope, and elevation. Plots are also selected based on access and distance from roads.

Because these plots are limited to private land on the eastern edge of the burn, the intent is to place plots in areas that can be compared to existing or future monitoring that is occurring in the upper watershed on USDA Forest Service land. Landscapes that exhibit the correct potential monitoring environments based on slope, aspect, and former forest vegetation type are shown in Figures 3 and 4.

Plots will be distributed randomly in three watersheds impacted by the fire. Within each watershed 3 plots will be located in high severity burn areas, 3 in low severity burn areas and 3 reference plots will be established in unburned areas. Exact plot locations will be randomly generated within available private land controlling for the variables listed above. Figure 5 illustrates the sampling design for the study.

A set of three wildlife cameras will be purchased and erected on one high, low and unburned study plot of the watershed. The cameras will be rotated between watersheds on a monthly basis, year-round.

Locations of hydrologic monitoring will be as close to the monitoring plots as possible. The proximity of the hydrologic monitoring relation to the plots will be a function of the exact location of monitoring sites. During the final site selection phase, the proposed sites will be mapped using GPS technology.

Study Plot Design

The study plot design is based upon a number of existing monitoring protocol including the NMFWRI monitoring design, the USFS Forest Inventory Analysis plots and the USFS Region 3 monitoring protocol (in progress). This plot design was chosen because it is rigorous but also efficient, allowing a greater number of plots to be completed with the available resources.

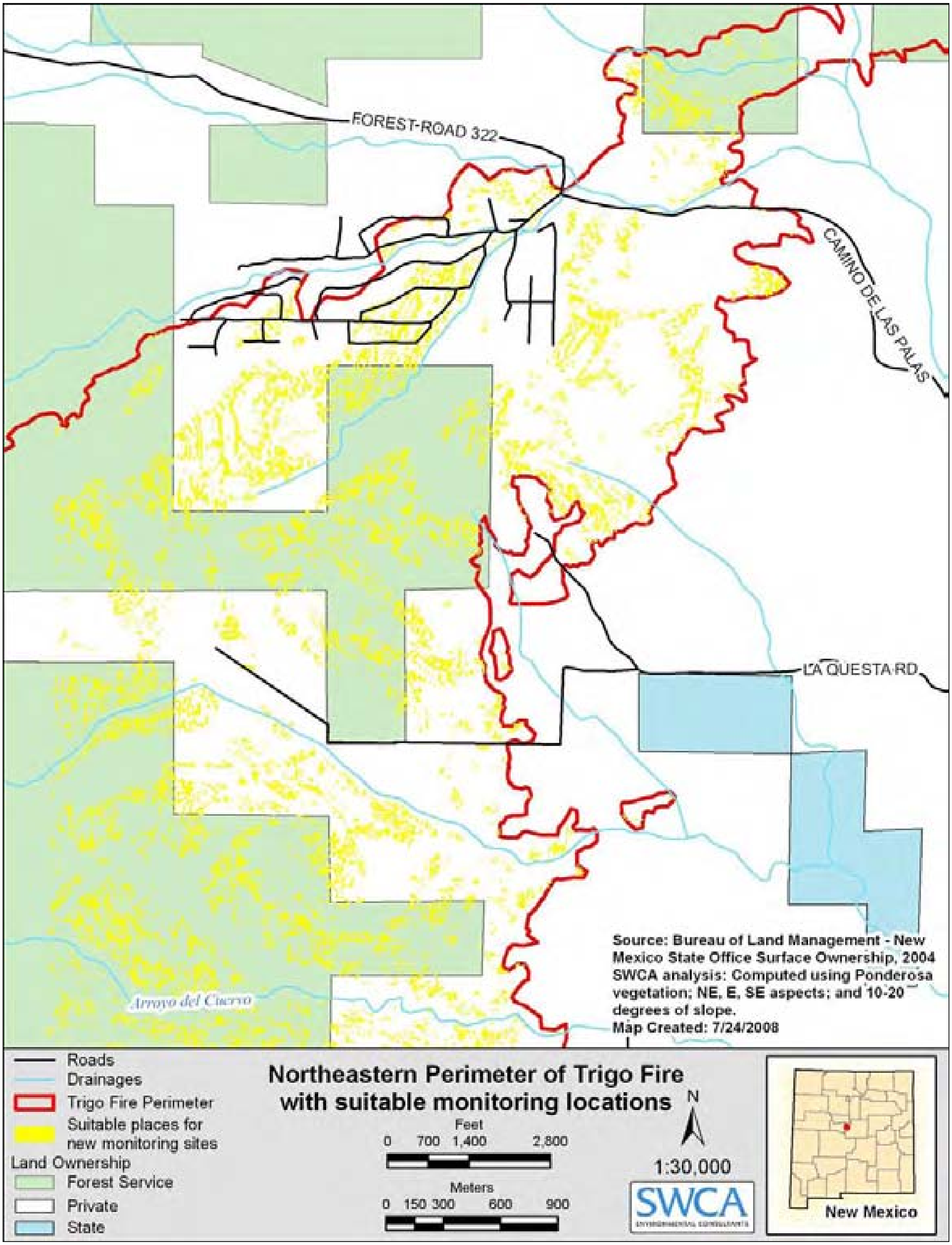

Figure 3: Northeastern Perimeter of Trigo Fire with suitable monitoring sites.

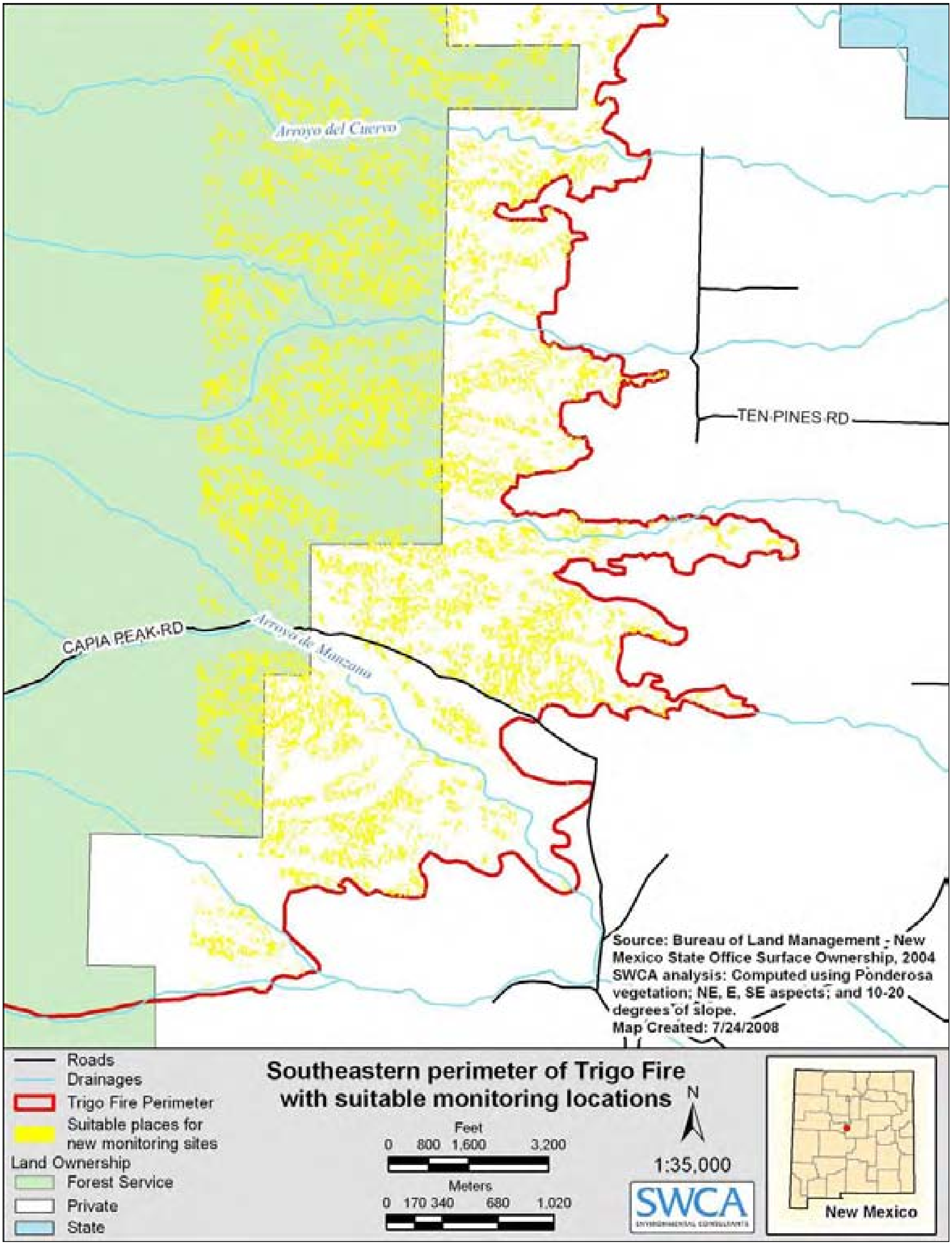

Figure 4: Southeastern Perimeter of Trigo Fire with suitable monitoring sites

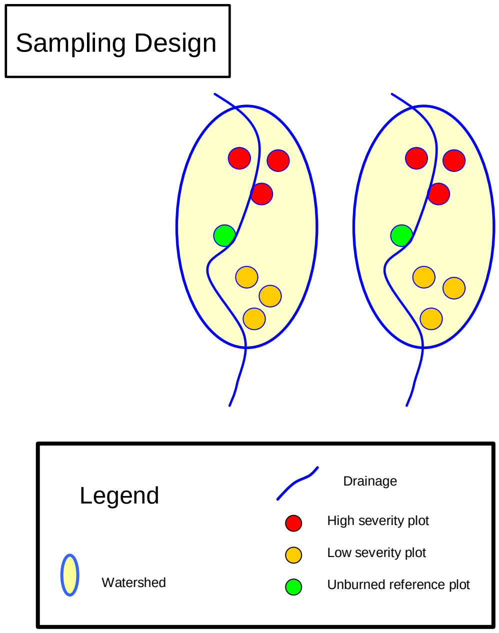

Figure 5. Sampling Design
Note: this diagram is a schematic, actual plots representing treatment types will be intermixed on the landscape in each watershed, not grouped together as in diagram.

Study Plot Installation

All study plots will be installed prior to monitoring and marked using a T-post at the center and rebar at the end of each transect line. The plot center will be recorded with Geographic Positioning System (GPS) Coordinates in order to allow future navigation to the site. Plots will be labeled using aluminum tags.

Each study plot will be composed of four 75ft (22.9m) transects in each cardinal direction (figure 6). Along each transect, vegetation line intercept measurements will be made to determine species composition and cover of understory species. Three 1m^2 subplots will be located along each transect at the 25 ft, 50ft and 75ft marks. These quadrants will be used to measure species composition, and percent cover. One Browns fire fuel transect will be completed on a random azimuth. The azimuth will then be marked and staked for future fuels monitoring.

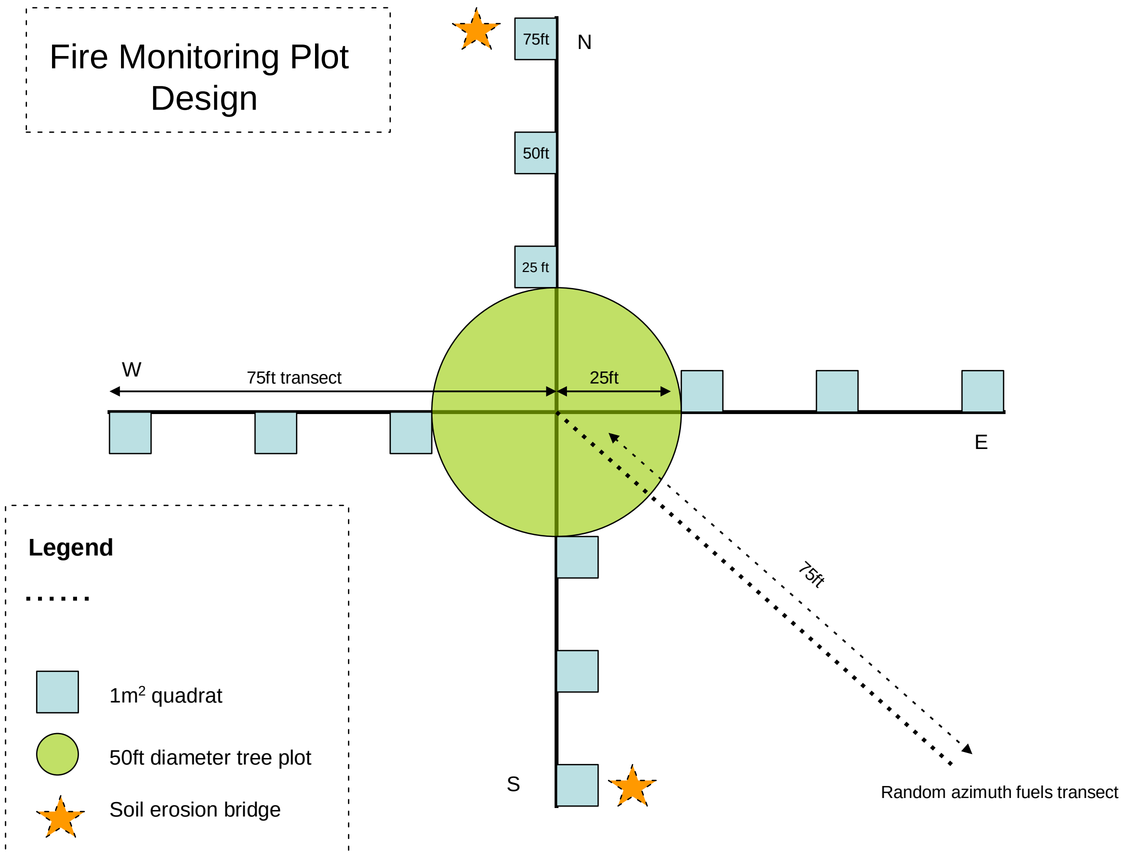

Figure 6. Proposed study plot design.

Plot Description

Each plot will be given a plot number that will be recorded on the data form and labeled in the center of the plot on a white PVC tube. Plot coordinates, elevation, slope and aspect will be recorded on data forms prior to monitoring.

Digital photos (6mp) will be taken from the plot center in each cardinal direction. A white board with plot number will be placed in each picture. The photos should also encompass the general landscape to identify edge effects. One photo will also be taken of the canopy and the ground at plot center as well as a photo along the fuels transect.

Monitoring Parameters

Automated rain gauges with data loggers, including ambient and soil temperature, and soil moisture (-10cm) will be installed on one of the two replicate plots representing high burn severity, low, and unburned reference, in association with each group of plots in each water shed. Graduated cylinder rain gauges will be installed at the other plot representing each treatment type plot pair, and readings taken monthly. Placing automated rain gauges at only one of the two plots representing each pair will be done simply to reduce costs. Soil moisture and temperature readings will be taken monthly on each plot with portable TDR and temperature probes. Most of these parameters will be measured monthly by either SWCA or CPSWCD field technicians. The proposed parameters to be measured include:

Rainfall, Soils and Hydrology

- Precipitation
- Precipitation/soil Infiltration Rate
- Soil Erosion/Sediment Load
- Suspended Sediment Load, Nutrients
- Total Sediment Load
- Runoff Salinity
- Temperature
- Groundwater Recharge
- Flow Duration
- Flow Stage
- Flow Flashiness
- Soil Temperature
- Soil Moisture
- Sodium
- Soil Nitrogen (NO_3)
- Phosphorous
- Potassium
- Soil Stability
- Soil Surface Erosion
- Soil Surface Stability

Vegetation

Vegetation monitoring will occur within each plot and will be measured bi-annually. The proposed parameters to be measured include:

- Growth form and life-history composition
- Species composition
- Species density
- Percent cover by cover class- grass, forb, shrub, tree
- Density of invasive species
- Canopy cover
- Stand structure
- Fuel loading
- Understory burn severity
- Overstory burn severity

Wildlife

Wildlife species (ground squirrel sized and larger) abundance's will be recorded within each watershed and each burn severity type by use of stationary infrared cameras, and track and scat counts on vegetation quads and lines. Wildlife habitat also will be assessed based upon the vegetation and fire fuels measurements. The proposed parameters to be measured include:

- Species abundance/presence
- Wildlife habitat- based on vegetation and coarse woody debris measurements

METRICS

Consistency in data collection is paramount. Each member of the field crew will be trained on proper use and maintenance of each measurement device. They will also be instructed on the units in which data shall be recorded. Parameters will be monitored by measuring the following metrics:

Plot Description

- Plot number
- Coordinates of center and end point of each transect
- Azimuth of fuels transect
- Elevation
- Slope
- Aspect

Rainfall and Hydrology

- Runoff flow (cubic feet per second)
- Piezometers (mm Hg)
- Stage Height (inches)
- Total Suspended Solids (mg/liter)
- Turbidity (Nephelometric Turbidity Units)
- Bed load

Soil

- Rainfall (mm)
- Temperature (Celsius)
- Piezometers (mm Hg)
- Sodium (parts per million)
- Nitrogen (parts per million)
- Potassium (parts per million)
- Phosphorus (parts per million)

Vegetation

Understory

- Species type
- Species density
- Plant height
- Species percent cover

Overstory

- Species
- Tree count
- Tree status- live/dead
- Height
- DBH
- Crown position
- % Consumed
- % Scorched
- Basal Char

Severity Measurements

- Composite Burn Index (CBI) classification, ocular assessment of entire plot:
    - Understory - litter consumption, duff consumption, ground char, soil color.
    - Overstory- crown scorch, crown consumption, char height, bole char.

Wildlife Habitat

Track and scat

- Species ID

Presence- infra red camera

- Species ID

HYDROLOGIC MONITORING

In order to quantify fire effects on water yield and recharge to the Estancia Basin we will be carrying out monitoring of a number of hydrologic parameters. These include:

- Manual collection of water quality samples in downstream washes
- Monitoring of shallow groundwater levels using piezometers
- Surface stage and water quality measurements
- Stock tank monitoring

Monitoring at research sites

Periodic infiltration measurements will be determined using a double-ring infiltrometer located at each vegetation plot. Infiltration will also be monitored using nested soil moisture probes. Because there is potential for significant erosion on burned sites, soil erosion and sediment load will be quantified using silt fence plots and erosion bridges located within or adjacent to vegetation plots. Suspended sediment load and nutrient load will also be determined using manual samplers.

Piezometers and stream stage monitoring

Piezometers will be installed in major drainages that drain each site in order to monitor shallow groundwater. Instrument piezometer with Troll or multi-parameter probes will be used to measure water level, temperature, and total dissolved solids (TDS).

To quantify flow duration, flow stage, and flow flashiness, surface monitoring points will be installed with turbidity or other available water quality sensors.

NOTE: This approach can not be used to determine real flow rate measurement, only stage. This will not quantify any increases in flow coming off of burned watersheds.

Water Quality Sampling

- Arroyo Water Samples

When a flow event happens, technicians will collect water samples to assess total sediment load and nutrient load; parameters measured will include suspended sediment, bed load, and water quality parameters (nutrients, cations/anions, organic load, TDS). Flow events will be monitored manually from a suitable location (e.g. bridge). A portable nutrient sampling device will be used to analyze samples.

- Stock Tank Survey

If possible we propose identifying the nearest downstream stock tank from the burn site on each wash. This could be used to establish a benchmark and conduct baseline topographic survey to determine volume of each stock tank.

Periodic (quarterly) topographic surveys would be carried out to determine the volume and estimate sediment load of wash. In addition water quality will be monitored.

SOIL

Data collection will use a rigorous methodology that will be standardized for all sample sites. All data collection efforts will follow the standard site-specific methodologies including staying on fixed paths within the site to reduce soil disturbance.

Rainfall will be recorded in hourly intervals automatically, no manual data collection is necessary. The data will be downloaded from the data logger every 3 months, and will be integrated into the data set.

Soil Temperature

Soil temperature also is important to plant survival and growth, and affects soil water content by affecting evaporation and plant root uptake. Soil temperature also may change as a result of forest thinning because of reduced forest canopy cover and increased insulation. Portable, 10 cm digital soil moisture temperature probes will be used to measure soil temperature at 10 cm below the soil surface at the same locations and at the same times that soil moisture is measured as described above. The permanently placed soil temperature probe associated with the rain gauge on one of each treatment study plots will provide continuous study site reference soil temperature data for depths of 10 cm below the soil surface, relative to the interval temperature data collected with the portable temperature probe. Temperature will also be recorded automatically. Like rainfall, the automatic data logger will be programmed to record hourly measurements, and like the rainfall gage, this instruments data logger will be downloaded every three months.

Soil Moisture

Soil moisture is critical to plant survival, growth, and species composition. Subsurface soil moisture varies as functions of surfacewater infiltration, soil particle water retention, and water loss through evaporation or uptake by plant roots. Input from infiltration and loss due to evaporation or plant uptake may change as a result of forest thinning resulting from soil disturbance and changes in plant canopy cover and composition.

We will use a portable time domain reflectometer (TDR) soil moisture meter to measure soil moisture on the study plots. TDR meters determine soil moisture by measuring the rate that an electromagnetic wave travels along a waveguide (the device rods) within the soil matrix. The speed of the wave through the soil is a function of the bulk dielectric permittivity of the soil, which in turn is a function of soil water content. The TDR converts dielectric permittivity to water content and provides a measure of soil volumetric water content. The TDR device is equipped with two 12 cm rods, which will be inserted to a depth of 12 cm into the soil at each measurement point. The TDR will provide an average water content of the soil for a cylinder of soil 9.3 cm across and 12 cm deep at each measurement point.

We will measure and monitor subsurface soil moisture and temperature from 12 systematically located points on each of the vegetation/soils monitoring plots. Each measurement point is located immediately outside of the outer-center of each of the small 0.5 × 2 m vegetation measurement subplots, four of which are in each corner of the three 30 × 10 m vegetation subplots. Measurements will be taken once every 2 months throughout the year, for a total of 6 readings each year (February, April, June, August, October, December), across the four seasons. The permanent soil moisture probe associated with the rain gauge on each study plot will provide continuous study site reference soil moisture data for depths of 10–15 cm below the soil surface to relate to the TDR interval data.

Salinity

Salinity is important because high salinity levels can lead to reduction in native vegetation. Sodium will be measured monthly using a soil nutrient meter. This meter will measure sodium content in parts per million.

Macronutrients

Macronutrients are necessary for plant growth. A lack of one particular macronutrient can result in sub-optimal yields. Macronutrients will be measured using portable devices. These devices will be utilized to analyze samples collected in the middle of each of the four watersheds.

Soil Stability

The soil surface stability test developed by Herrick et al. (2005) provides information on soil texture, the extent of soil structural development and resistance to erosion, and the biological integrity of the surface organic matter and soil biota. Fire can cause short term impacts to soil stability and stability can decline if plant recovery is slow, due to the reduced fungal and litter inputs necessary for soil aggregate formation. Intense high severity fires can increase soil stability by making it hydrophobic. These surfaces however repel water increasing the potential for downslope erosion.

Soil surface stability reflects the presence of both abiotic and cryptobiotic surface crusts. The test measures the stability of the soil matrix when exposed to rapid wetting, such as occurs during intense rainfall. Unstable soil surfaces are prone to erosion when exposed to intense rainfall. Surface stability also indicates general stability of the soil surface when exposed to wind and other disturbances (Herrick et al. 2005). One sample point will be randomly located along each vegetation line, 1 m from and perpendicular to the line. The test will be repeated along the same lines, but not at the same points, once each year, during the dry season (May).

Soil Erosion

Soil surface erosion is an important aspect of watershed and forest health. Soil surface erosion will be measured by use of soil erosion bridges (Shakesby 1993) on each of the study plots. The erosion bridges are similar to those used by Shakesby (1993) and White and Loftin (2000) and consist of two permanent 0.5 inch diameter steel rebar support posts and a portable aluminum square pipe bridge with a series of pin-drop holes, and 1 cm diameter by 60 cm long aluminum rod drop pins. The steel pipe support posts are 1.2 m apart, and support a 1.2 m portable bridge approximately 30 cm above the initial soil surface. 20 pin-drop holes are distributed at 5 cm intervals along the bridge, for a horizontal measurement area of 100 cm (1 m) across the soil surface. Repeat measurements will be made from the permanently positioned top of the bridge to the soil surface once each year in May. Silt fencing will also be used to measure the amount of sediment loss off of a given plot. The sediment will be retained in the fencing.

Soil Water Infiltration

Water infiltration into the soil surface is an important component of rainwater availability to vegetation and groundwater, in contrast to the destructive effects of surface runoff and erosion. Water infiltration will be measured at one randomly located point along each vegetation line, each at a point 1 m from and perpendicular to the line. Water infiltration will be measured using the single-ring infiltrometer methods described by Herrick et al. (2005) during the dry season (May).

VEGETATION MONITORING

Understory measurements

Understory vegetation measurement and monitoring protocols will follow the methods developed by Herrick et al. (2005). Two different methods will be used to characterize the plant species composition and foliage canopy profile up to 1 m above the ground surface- point line-intercept and 1 m^2 quadrats (positioned along each transect at 25 ft, 50ft and 75ft). Gap line-intercept will be used to measure both plant canopy horizontal cover and soil surface cover, including bare soil, rocks, cryptobiotic crusts, leaf litter, and dead and down woody material. Point line-intercept data will provide height measures for all plants less than 1 m in height. Tree canopy measurements will provide heights for all plants greater than 1 m in height on the study plots. Plant heights will be measured once each year in September. Invasive species will be measured and documented in the same way as all other ground cover. Total plant species lists will be compiled from the line-intercept and quadrat data to provide species composition and diversity information.

Plant cover will be measured from the gap line-intercept transects and species composition and percent cover will be measured in the $1m^2$ quadrats to provide measures of plant cover by species, growth-form, life history, and total plant foliage cover. Plant canopy cover will be measured once each year at the end of the growing season in September, and monitored over time. As well as documenting native species the study will also focus on documenting non-native invasive species that may respond positively post fire.

Understory Burn Severity

Understory burn severity will be measured using the CBI methodology.

Downed fuels

Protocol for the fuels transect measurements follow the NMFWRI Data Collection Field Guide. One fuesl transect will be measured on each fire plot. The fuels transect is 75ft long- a tally of 1hr (1/4 inch or less) and 10hr fuels (1inch or less) are taken at 15-21 ft, 100hr (3 inch or less) at 15-50 ft and 1000 hour (greater than 3 inch) at 15-75 ft. Duff and litter depth measurements are made at 45 ft and 75ft points along the transect. Fuel particles sizes are determined using the conventional go-no-go gauge (Figure 7).

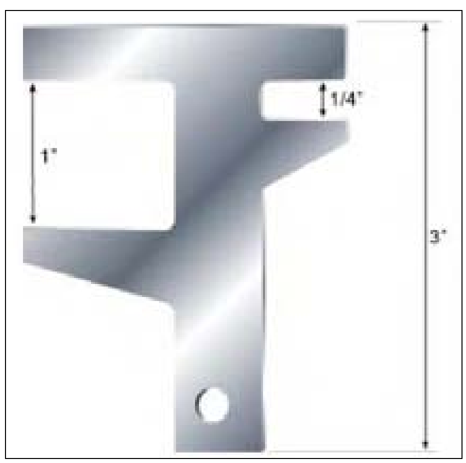

Figure 7. Go-no-go Gauge

Overstory Measurements

Overstory measurement protocols are developed from a number of sources- the NMFWRI protocols, the USDA Forest Service region 3 monitoring protocols (in press), USDA FIA protocols (2005), and protocols adapted from a number of peer reviewed authors [Ryan and Noste (1982), Battaglia et al.

(in press), Omi and Kalabokidis (1991), Freeman et al. (2008)]. Overstory measurements are made to determine stand density, species composition, and fire effects such as percent crown scorch and tree mortality.

Overstory measurements are made in two circular fixed radius plot. Measurements on trees and snags (greater than 4.5ft) are made in a 1/10 acre (37.2ft radius) plot and measurements of regeneration and saplings (less than 4.5ft) are made in a 1/100 acre (11.8ft radius plot). Measurements should start from the north and continue in a clockwise direction. Measurements include: tree count, species, DBH, height (ft),) crown position/class (dominant, co-dominant, intermediate, overtopped) and tree damage (insect kill, drought, lightning, missing top).

Canopy density is determined using a densiometer which will be read facing each cardinal direction from the center of the plot.

Overstory severity measurements will be made using the CBI methodology.

Fire effects on Trees

Overstory burn severity measurements will be made on trees greater than 4.5ft in the 1/10 acre plots. Tree mortality will be noted of seedlings and saplings in the 1/100 acre plot. Measurements include ocular assessment of percent crown consumption (percent of previous live crown where needles have been fully consumed), percent crown scorch (percent orange needles) and bole char, (Table 3-based on Ryan 1982). These measurements provide an overall assessment of fire effects to the canopy and bole. Heights will be measured using a digital hypsometer for accuracy and reduced measurement error.

Table 3. Bole Char Estimates: assessed on the first 5cm of the bole above the ground

0- unburned	
1- light	light scorch or char on the edges of the bark plates
2- moderate	bark is uniformly black with the possible exception of the inner depths of prominent fissures, but bark characteristics are still discernable.
3- deep	bark is deeply charred, but not necessarily to the wood and surface characteristics have been lost.

Burn Severity

The overall burn severity to the plot will be measured using the CBI methodology. A CBI plot will be overlayed at the center of each fire monitoring plot; the CBI plot radius will therefore by 25ft. CBI measurements comprise ocular assessment of damage to individual strata throughout the CBI plot; the value of the CBI methodology is that it includes measurements of both overstory, understory and mid canopy fire damage, providing a comprehensive classification of fire severity to the plot. Figure ** is a CBI data sheet that lists the strata and measurement criteria.

As part of the Fire monitoring project we carried out an assessment of burn severity on plots selected within the Trigo Fire perimeter. Plots were randomly selected and stratified by thinned and un-thinned area. We measured 68 plots in total, all in ponderosa pine and all on private land at the eastern edge of the fire perimeter. We chose to use the Composite Burn Index (CBI) methodology (Key and

Benson 1999) to classify severity because it allowed quick and accurate measurement of burn severity across a large area. CBI measures burn severity of a plot on a scale of 0-3:

- CBI: 0-0.5 = unburned
- CBI: 0-5-1.5= low severity
- CBI: 1.5-2.5= moderate
- CBI: 2.5-3.0= high

CBI plots are circular nested plots with a 20ft radius plot nested inside a 25ft radius plot. The smaller plot is used to measure fire effects to the understory strata which includes parameters- soil, litter, duff, herbaceous vegetation and shrubs (understory). The larger outer plot is used to measure fire effects to the sub-canopy and dominant canopy strata, which include trees greater than 16 ft (5 meters) (overstory). All measurements are ocular estimates of fire damage to parameters across the plot and measurements are made by the same person in order to limit error through subjectivity. CBI values are calculated for the understory and overstory strata and then a total plot CBI average is calculated from these two values. An example of the CBI data form is included in Appendix A.

FIELD SAMPLING SCHEDULE

The measurable effects of wildfire on plants and soil surface characteristics will occur over long periods. For this reason this study project is initially proposed for a three year period but should be extended to 10 years based on available funding. Measurements will begin in September of 2008 and plots will be sampled during two field-sampling periods each year (September and May). Soil surface characteristics are best measured when surface soils are relatively dry, so those measurements will be taken during the typical dry season during the late spring and early summer, in May. Vegetation measurements will be taken in the spring and then again during the end of the typical growing season in late summer/early autumn, in September. Animal abundance (track and scat observations) will be measured at both times of the year to provide additional data to monitor changes in relative densities and species composition. Wildlife cameras will be in operation year round on a monthly rotation cycle between watersheds.

Field crews will be made up of at least 4 individuals in both spring and fall and survey periods are likely to be for 8-9 days. Plot set up will occur in mid August 2008 prior to the first round of monitoring. Monthly measurements of soil moisture and cycling of the wildlife cameras will be carried out by CPSWCD and Edgewood SWCD technicians. Care will be taken to avoid trampling of the plots, particularly along point line intercept transects and quadrants.

SAMPLING FREQUENCY

Plots will be sampled twice a year in the spring and fall. Hydrological measurements will be monitored monthly by either SWCA or CPSWCD technicians. Soil measurements will be taken monthly at the same time the hydrologic parameters are tested.

SAMPLING DURATION

Sampling will initially be carried out for three years with the intent to gain extra funding to sample over a ten year time period.

SCHEDULE

Trigo Fire Burn Monitoring by SWCA: Year One													
Project Task Description	Task	Date											
		July08	Aug08	Sep08	Oct08	Nov08	Dec08	Jan09	Feb09	Mar09	Apr09	May09	Jun09
Task 1: Literature Review and Monitoring Plan Development													
Literature search and compilation	001												
Plan Development	002												
Error! Reference source not found.: Study Site Locations and InstallationsError! Reference source not found.													
GIS analysis of environmental variables	001												
Field verification	002												
Installation of vegetation plots	003												
Installation of hydrologic instruments	004												
Installation of soil instruments	005												
Error! Reference source not found.: Initiate Monitoring Measurements													
Vegetation	001												
Hydrology	002												
Soil	003												
Wildlife	004												
Error! Reference source not found.: Compile Data and Analyze													
Compilation of new data	001												
Quality control of data	002												
Summary Statistics	003												
Error! Reference source not found.: Error! Reference source not found. Basin Watershed Health, Restoration and Monitoring Steering Committee													
Post data analysis to SWCA ftp site	001												
Develop annual summary report	002												
Post annual report on NMFWRI website	003												

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