Paired Watershed Study to Track Soil Moisture and Alluvial Water Response Before and After Brush Treatments in the Gila Watershed Region, New Mexico

FINAL REPORT, 2011

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This project encompasses two study areas, in the Burro Mountains and at Stiver Canyon in the Gila River headwaters. This report accompanies the CD containing all data collected through June 2011 since mid-2008. Data from the start of the project were included with reports in 2008 and 2009. Copies of the 2009 and 2010 reports are also included on this CD. Report contents are organized as shown below.

BURRO MOUNTAINS STUDY AREA

All soil moisture instrumentation in the study area in the Burros Mountains was replaced in late August, 2010, just prior to thinning treatments at the site. Sensors and other instruments are downloaded at least quarterly. Table 1 summarizes the data collection sites and data collection periods since study inception in November 2007. Soil moisture data collection sites, identified by letters, are shown on the map below. The map also shows thinning treatment zones established in conjunction with Gila National Forest staff. Treatments were completed between September and December 2011, as planned.

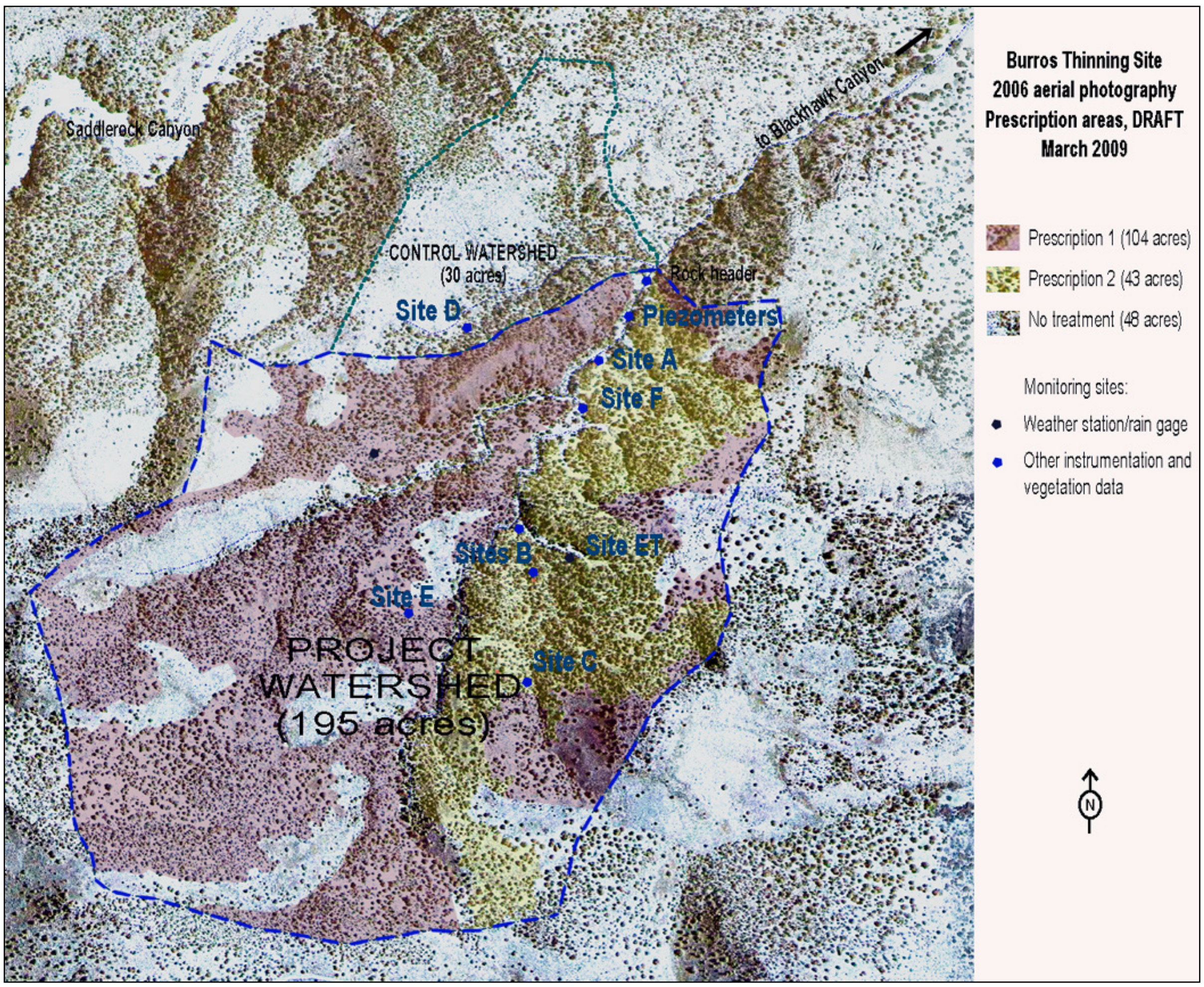


Table 1. Data collected at Burro Mountains project area since project start, November 2007.

	Archived data			
Site	**Alluvial and soil moisture**	**Vegetation**	**Climate**	**Other**
Site A				
Deep	11/2007-4/2009			
Canopy	11/2007-10/2008			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Soil samples (sensor calibration)				11/2007
Site B1 (upper)				
Canopy	11/2007-5/2011			
Open	11/2007-5/2011 (gap 8/2008)			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Site B2 (lower)				
Deep	11/2007-5/2011			
Open	11/2007-5/2011			
Soil samples (sensor calibration)				11/2007
Site ET				
Veg. transects		4/2008		
Veg. biomass		3/2009		
Temperature/RH/ wind speed/soil temperature/solar radiation/ precipitation			12/2008-5/2011 (gap 7/2009-11/2009)	

Table 1 continued.

Site C				
Deep	11/2007-4/2011			
Canopy	11/2007-4/2011			
Dripline	11/2007-7/2008; 9/2008-4/2011			
Open	11/2007-4/2011			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Veg. richness		11/2008		
Temperature			11/2007-8/2010	
Soil temperature			11/2007-5/2011	
RH			11/2008-8/2010	
Soil samples (sensor calibration)				11/2007
Site D (control)				
Deep	1/2008-5/2011			
Open	1/2008-5/2011			
Canopy	1/2008-5/2011			
Site E				
Deep Canopy Dripline Open	5/2008-6/2008; 9/2008-3/2011 (all sensors)			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Soil samples (sensor calibration)				8/2008
Site F				
Deep Canopy Dripline Open	5/2008-5/2011 (3 of 4 sensors)			
Veg. richness		11/2008		
Soil samples (sensor calibration)				8/2008
Site UV				
Veg. transects		4/2008		
Piezometers				
01 (below spring)	12/2007-5/2011			
02 (above spring)	12/2007-5/2011			
Barologger (ambient temp.)	12/2007-5/2011			

Table 1 continued.		
Precipitation		
Recording rain gage	11/2007-5/2011	
Snow gage	12/2009-2/2010; 11/2010-4/2011	
Bird count (Audubon)		4/2009
Bird survey (Hawks Aloft)		1/2009; 5/2009

Sensor regression analysis

The data analysis will seek to combine data from as many sensors of each type as possible, in order to increase the robustness of the data set's applicability across the project area. Previous years' data sets were evaluated by regression analysis, and the first step in statistical analysis will be to re-run regressions for the entire data collection period. Sensor data are grouped by type (e.g., "canopy," "open") and the mean values for all sensors of each type are calculated for each 15-minute time step. A simple regression curve compares the data collected by individual sensors of each type and the mean for all sensors of that type. In the data sets collected through May 2010, r^2 values ranged from 0.683–0.972. Variations in the intercept values were generally small, except for the "open" sensor at Site D, where the intercept for the 2009–2010 data set was –0.11. This suggests that sensor calibration is needed, as the sensor is reporting readings of << 0 during very dry periods.

Calibration uses a set of soil samples that were collected at the start of the project at a number of sites (Table 1). Soil moisture contents were calculated by bulk density and gravimetric analysis (DB Stephens and Associates). Each sample corresponded to a sensor of a particular type (e.g., “deep”). Results of each analysis were compared to the soil moisture level reported by the sensor at the time of collection. Variance at each collection site except Site D, the control, was < +/- 1.5% . A new soil moisture station will be added within the control area in July 2011, at a location more similar to most sites in the treated area than the existing control. Site D will also remain in place, and soil moisture data will be collected there for at least three more years; data from the two control sites will be evaluated for consistency. Additional soil samples will also be collected at Site D for gravimetric analysis of moisture content under varying soil moisture conditions to refine the sensor calibrations at that site. Calibrated data will also be evaluated against data collected at the new control site.

Data sets: *Recording soil moisture sensors*

All soil moisture sensors in the Burro Mountains project area, except those at the control site, were replaced in August, 2010. Most sensors were nearing the end of their 3-year reliable calibration period (sensors at the control site were originally placed a few months after those at the treatment sites). Replacing the sensors immediately prior to the thinning treatments also provided a brief period during which data continuity could be checked. In fact, soil moisture levels recorded by the sensors dropped after replacement; most recovered to earlier levels after rainfall in early September, 2010. The drop in recorded levels is likely because the soil contact with each sensor is lessened during replacement; although the soil around each new sensor was tamped down as well as possible, we did not "water" the sensors as during initial placement. With relatively high monsoon activity during August, we wanted to avoid the artificial spikes in soil moisture that occur after watering the sensors and the possibility of conflating those with actual changes in soil moisture due to rainfall at the site. By contrast, the sharp reductions in soil moisture levels recorded after placement are easily seen in the data and will be removed before data analysis. The local climate was helpful in this regard. As shown in the data graphs that follow, average rates of precipitation declined substantially during the period September through May 2011 relative to the 3-year baseline period. As occurred throughout the area, the Burro Mountains site experienced deep drought conditions, receiving less than one inch of precipitation during the 9-month period.

The final data download for the project period through June 2011 was on May 20. Soil moisture data collected at 5-min time steps were again filtered into averaged 15-min data. The resulting data sets were evaluated for sensor errors (i.e., during frozen soil conditions) and damage. Invalid data, excluding those resulting from sensor replacement, were removed. (The data will be re-evaluated prior to selecting the period for which data from all sensors at the site will be excluded.) The graphs that follow the text of the report show the resulting data sets, since the start of the project in November 2007. Site locations are shown on the map.

The data gaps that have developed at some sites over time suggest that site visits should be scheduled more frequently than quarterly, and probably as often as once per month. Rodent activity and possibly, outright vandalism have been problematic at Site A (the most accessible soil moisture station), and all sensors at both Site C and Site E were destroyed in late March or early April, 2011. Those have been replaced.

Alluvial groundwater

The most recent data downloaded from the two site piezometers were collected in May 2011. A data communications failure in the transducer from P02 (above the spring) that occurred last June was repaired by manufacturer, who was also able to download all of the data collected during the 3-month interval. All piezometer data were checked against manual water level measurements made during site visits. Variance between manual measurements and levels recorded by transducer were < 0.07 ft. Graphs of all piezometer data collected since the project began in November 2007 are plotted following the report text.

Soil temperature and climate data

Hourly soil and ambient temperatures have been collected at Site C since December 2007. A recording relative humidity sensor was added at the site in November 2008, but was returned to the manufacturer for reporting inconsistent data. Its replacement was returned to the site in early August. 2010, but was found to have been destroyed in December 2010. It has not been re-replaced. As a consequence, no ambient temperature or Rh data are available from Site C for the period; data of both types are collected by the weather station, and the site Barologger also collects ambient temperature data. These data will be used instead. These data were not graphed for the report, but are included on the report CD.

Data collected by the weather station between December 2008 and May 2011 are included on the project report CD but are not plotted here due to the large variety of data types.

Vegetation transects and biomass plots

Detailed ground and canopy cover data were collected throughout the project area (Table 1) by the end of 2009. All vegetation data, graphs, and photos from each data collection site were included with the final report for 2009.

These sites will be re-measured in the fall of 2011 and periodically thereafter in order to 1) document vegetation response to treatment and 2) provide representative vegetation data against which estimates of evapotranspiration can be calibrated.

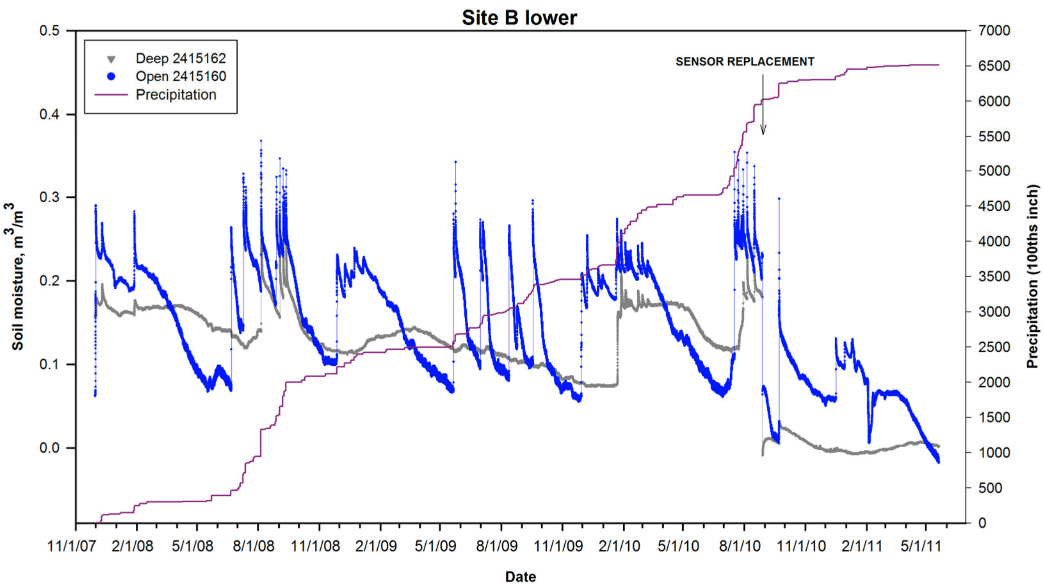
Preliminary data evaluation

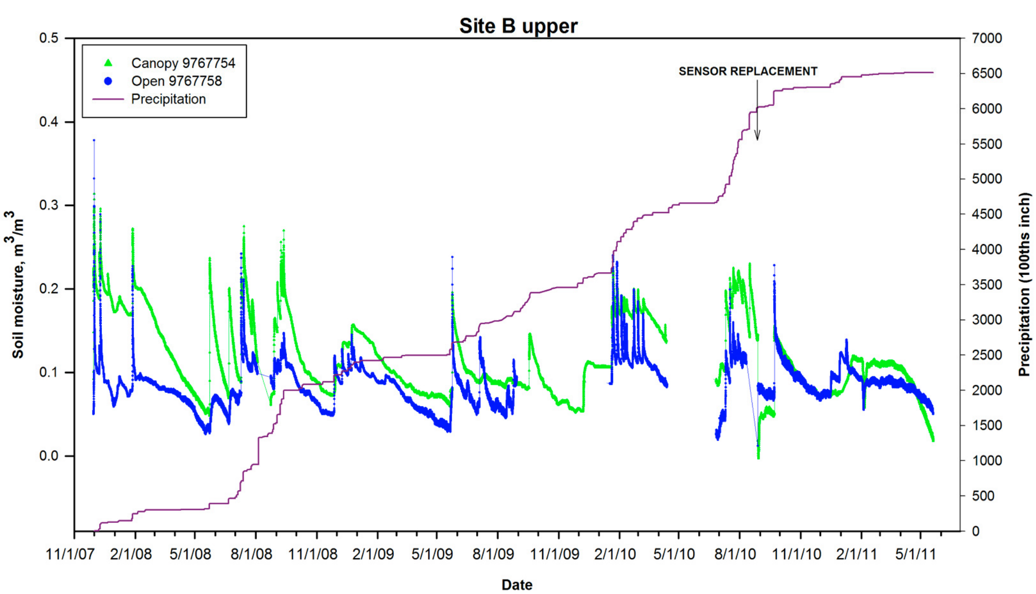
The data graphs on the following pages depict early soil moisture and alluvial groundwater responses to climate following the thinning treatments. More substantive data analysis will begin after monsoon season, 2011—assuming that the site does receive rainfall this summer. The extended drought that began almost simultaneously with thinning treatments provides no comparative data for evaluating the treatment effects on moisture retention at the site. The effects of the drought are evident in the soil moisture graphs, which generally show a long, slow decline in moisture levels between late September 2010 and the spring months of this year. Interestingly, at the treated sites where "deep" sensors have been placed, those sensors have recorded a slow *rise* in soil moisture levels even as moisture levels near the ground surface have fallen. Conversely, at the control site, the "deep" sensor recorded falling moisture levels that leveled out in early April and remained relatively constant thereafter.

Similarly, alluvial groundwater levels have fallen less than might be expected under the current drought conditions. Through May 2011, groundwater levels in both piezometers remained elevated above the lowest levels recorded prior to the treatments, particularly in the piezometer upstream of the seep area. For the years during which precipitation data have been collected at project area, the period most similar to the current drought occurred between November 2007 and May 2008. Groundwater levels in both piezometers declined rapidly during the period, although slightly more precipitation fell at the site during those months than during November 2010–May 2011. Of course, at this point any comparison is only conjecture, as we have no data on antecedent rainfall conditions at the site for the earlier period. This research was established as a long-term study because 1) we believe that the robustness of a 3-year baseline data set and 10-year post-treatment data set will significantly increase the validity of the study results, and 2) the long-term moisture effects of the treatments, if any, are of more interest than any short-term results.

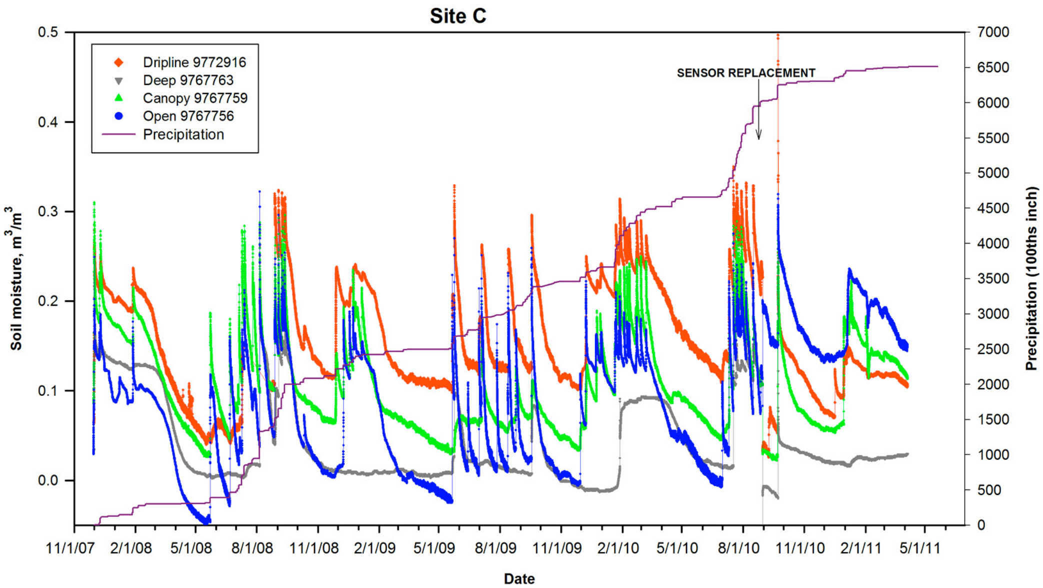
DATA GRAPHS: BURROS SITES, 2007-2011

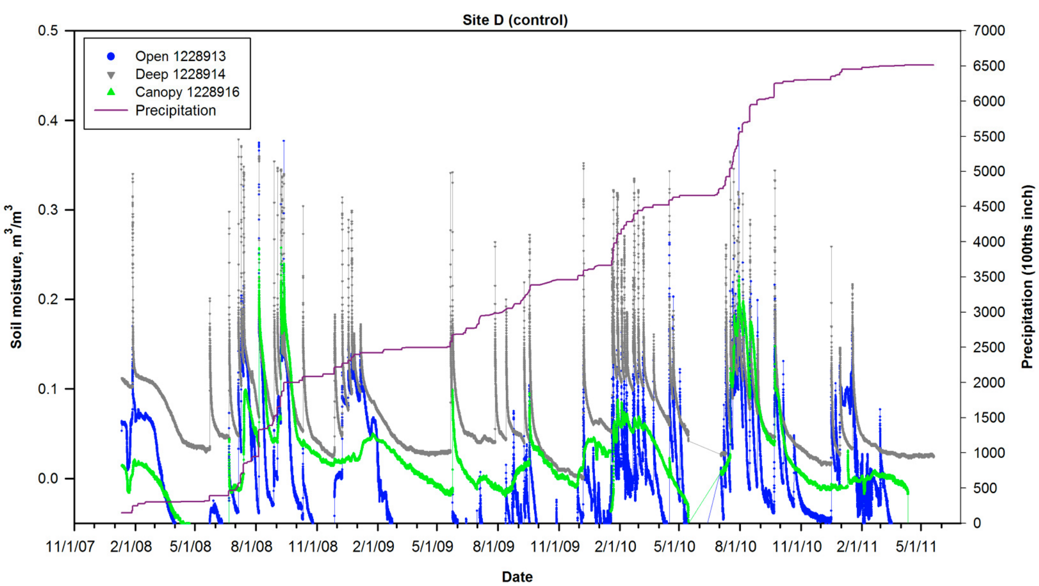
Soil moisture and precipitation, B sites



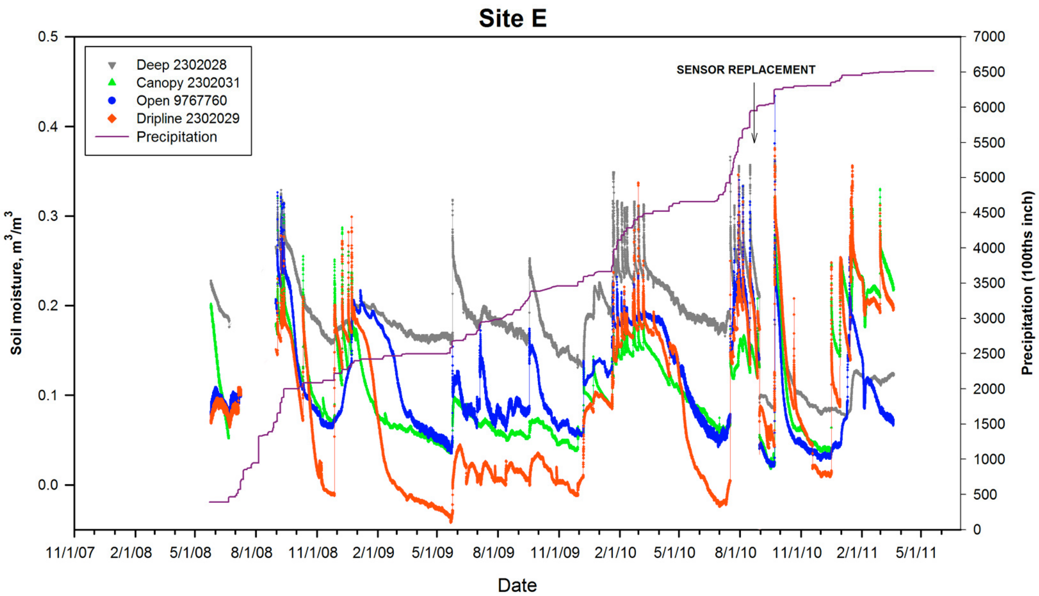


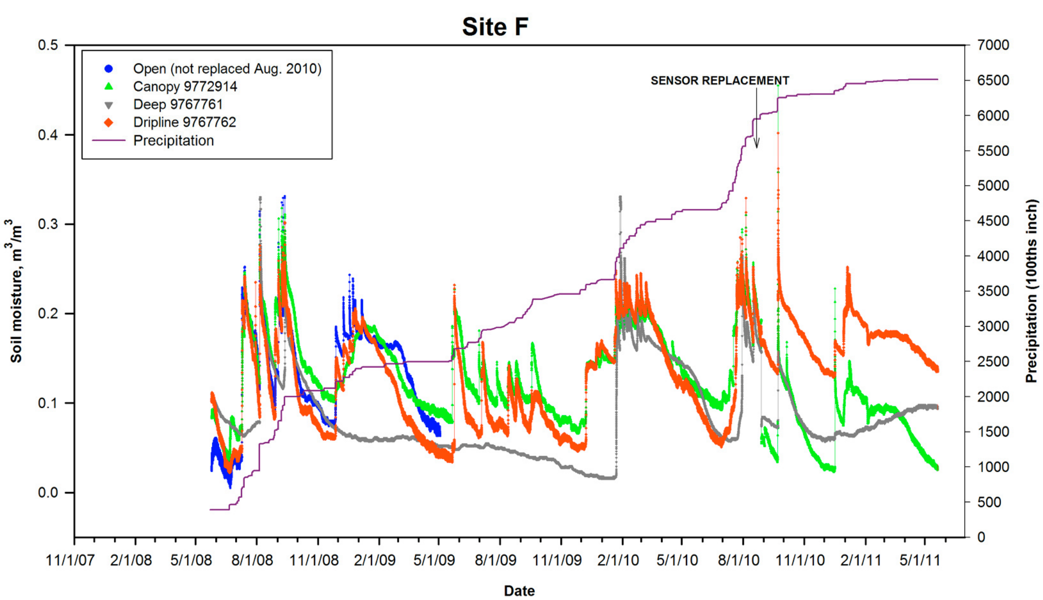
Soil moisture and precipitation, C and D sites



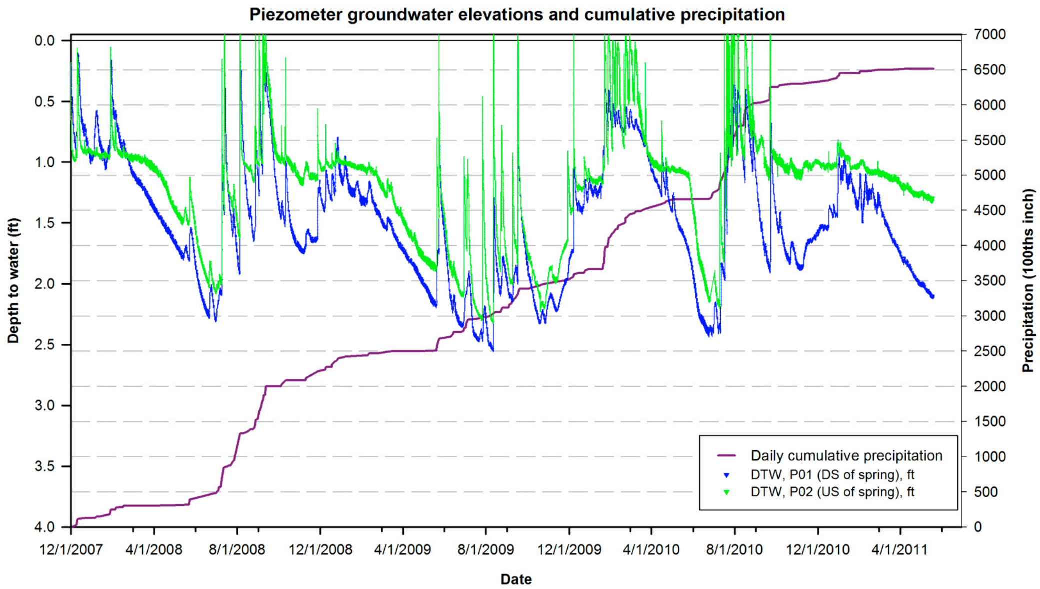


<u>Soil moisture and precipitation, E and F sites</u>





<u>Alluvial groundwater and precipitation</u>



STIVER CANYON STUDY AREA

Most instrumentation at the Stiver Canyon site has been in place since April 2009; the weather station was completed in June 2009.

Installed instrumentation has been downloaded periodically, more frequently during this project year than in previous years. Nonetheless, rodent and (most likely) bear activity continue to plague the study. Numerous data gaps have developed, although among all of the sensors, complete data sets still exist for both sites. As at the Burro Mountains site, monthly site visits are probably needed, but the very remote nature of the Stiver site makes this difficult. The final data collection run for this project year was on June 19. Table 3 summarizes the data collection sites and valid data periods since study inception in November 2008. Soil moisture and climate data collection sites are shown on the map below. Vegetation transects are located at the soil moisture sites.

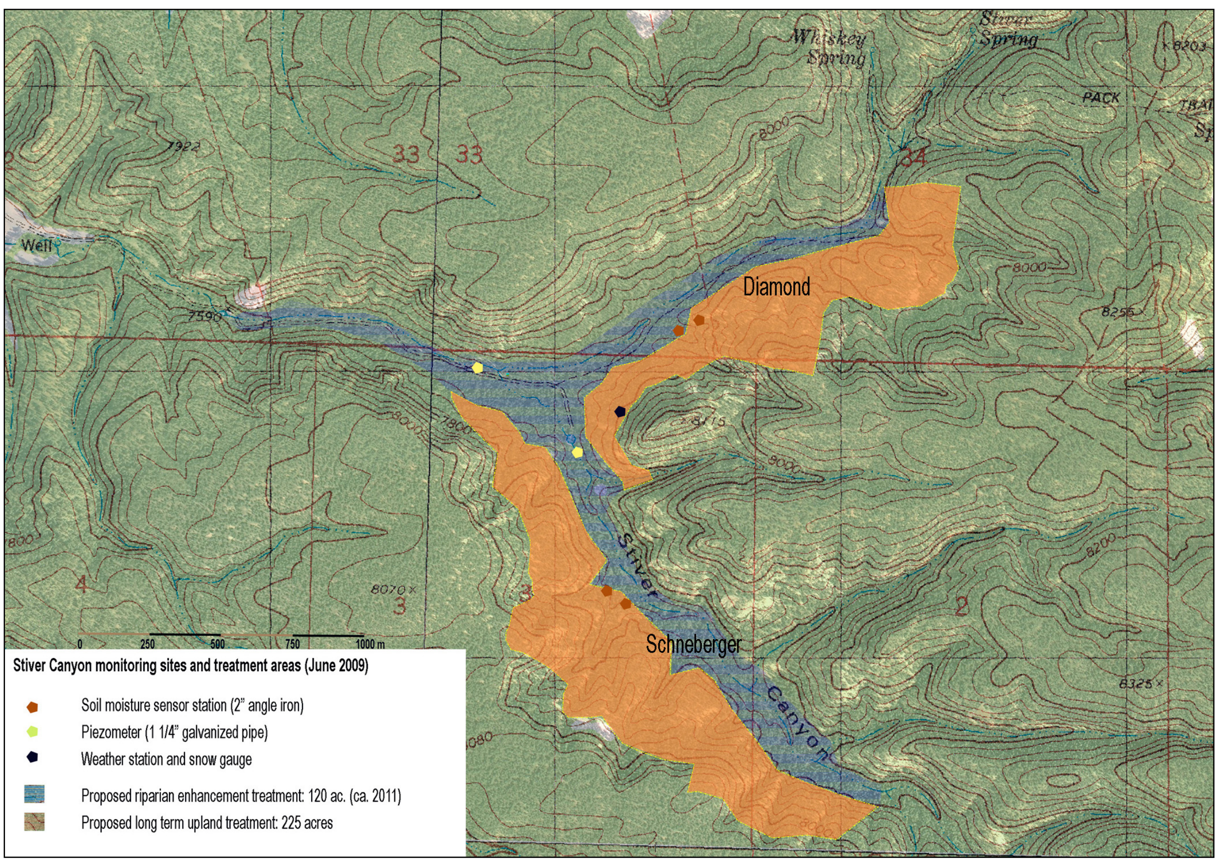


Table 3. Data collected at Stiver Canyon project area since project start, November 2008.

	Archived data			
Site	**Alluvial and soil moisture**	**Vegetation**	**Climate**	**Other**
Diamond control				
Canopy Open Dripline	12/2008-10/2010; 12/2010-6/2011 (all sensors)			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Diamond treatment				
Canopy	12/2008-4/2009			
Open	12/2008-4/2009			
Dripline	12/2008-4/2009			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Schneberger control				
Canopy Deep Dripline	12/2008 – 9/2010; 12/2010-6/2011 (3 sensors)			
Open	12/2008-6/2010; 12/2010-6/2011			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Schneberger treatment				
Canopy	12/2008-6/2011			
Open	4/2009-6/2011			
Dripline	12/2008-6/2011			
Deep	4/2009-6/2011			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Temperature			2/2009-6/2010	
Soil temperature			11/2008-6/2011	
RH			2/2009-4/2009	
Soil samples (sensor calibration)				11/2008

Table 3 continued.

Site ET (weather station)			
Temperature/soil temperature/RH/wind speed/solar radiation/ precipitation			4/2009 – 6/2011
Piezometers			
DS (below confluence)	11/2008-6/2011		
US (Schneberger)	11/2008-6/2011		
Barologger (ambient temp.)	11/2008-6/2011		
Precipitation			
Recording rain gage			11/2008-6/2011
Snow gage			11/2008-6/2011
Riparian vegetation mapping (*populus/salix*)		4/2009	

Sensor regression analysis

Although complete data sets exist for each of the two study sites in the project area, the numerous data gaps for many of the individual sensors preclude examining correlations among the usable data collected by similar sensor types (e.g., "canopy," "open") within sites. Regression analysis of similar sensor types from both sites, using the first years' data sets, showed that conditions at the sites themselves are dissimilar enough to invalidate grouping the data collected by all sensors of each type across the entire study area. The aspects of the two canyons in which the sites are located are nearly perpendicular; the "Diamond" drainage runs east-west while the "Schneberger" drainage runs generally north-south. However, the analysis also showed only minor variations in all sensor intercept values, suggesting that little or no calibration of the sensors is needed. Any calibration will utilize data from soil samples collected early in the project period (Table 1). Soil moisture contents were estimated by bulk density and gravimetric analysis (DB Stephens and Associates). These values will be compared to recorded soil moisture levels at the time of sample collection from the corresponding sensor site.

Data sets: *Recording soil moisture sensors*

Soil moisture sensor site locations are shown on the map above.

Soil moisture data collected at 5-min time steps were again filtered into averaged 15-min data. The resulting data sets were evaluated for sensor errors (i.e., during frozen soil conditions) and damage. Sensors and data loggers at all sites experienced continued animal disturbance; virtually no data were recorded at the Diamond treatment site (excluded from the graphs at the end of the report). Valid data collected between November 2008 and June 2011 by the sensors at the other three soil moisture sites and by the rain gauge are graphed in the section that follows.

Alluvial groundwater

Data from transducers in the two site piezometers were collected in June 2011. All piezometer data were checked against manual water level measurements made during site visits. Variance between manual measurements and levels recorded by transducer were < 0.07 ft. Graphs of all piezometer data collected since November 2008 are plotted with cumulative precipitation in the section below. Extreme drought has prevailed at the project area since the fall of 2010. The graphs clearly show the drought's effects on alluvial groundwater levels.

Soil temperature and climate data

The available data for soil and ambient temperatures from the extra sensors (in addition to the weather station sensors) at the project site are included on the report CD, but are not graphed separately here. (Daily cumulative precipitation is plotted on the soil moisture and piezometer graphs as described above.) Conditions at the Stiver site have been dry for longer than at the Burro Mountains site; the Stiver rain gauge recorded total precipitation of just over 12 inches from June 2010 through June 19, 2011. Of that total, however, only 1.5 inches of precipitation have fallen since October 1 of last year. There was no significant snowfall at the site this past year.

Data from the weather station are also included on the report CD but are not graphically represented here.

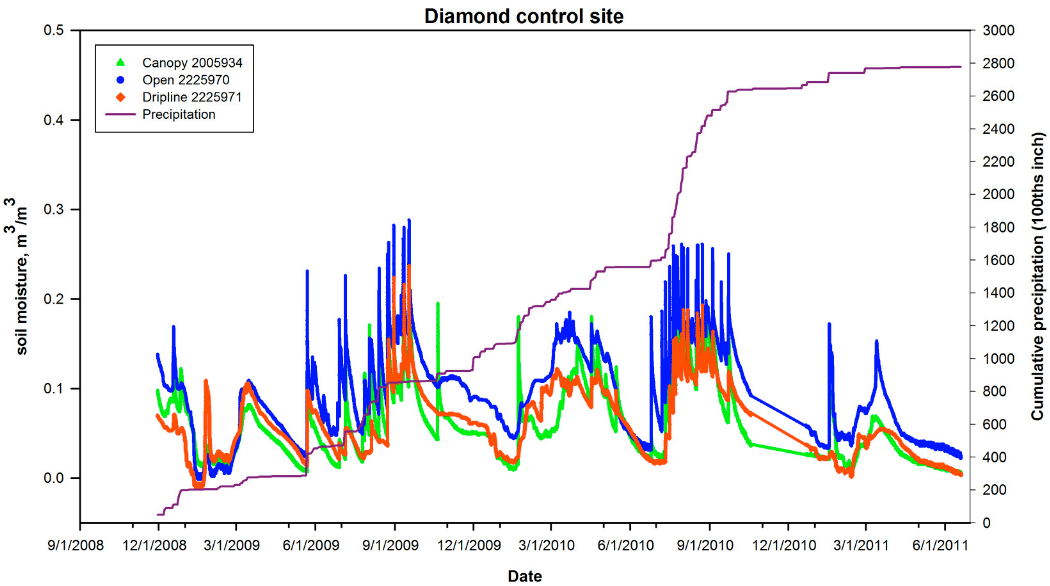
Vegetation transects and biomass plots

Detailed ground and canopy cover data have been collected at each of the soil moisture data sites (Table 3). All existing riparian vegetation (e.g., *salix, populus tremuloides*) were also mapped by high-accuracy GPS. All baseline vegetation data and data collection site photos were reported with the 2009 annual report.

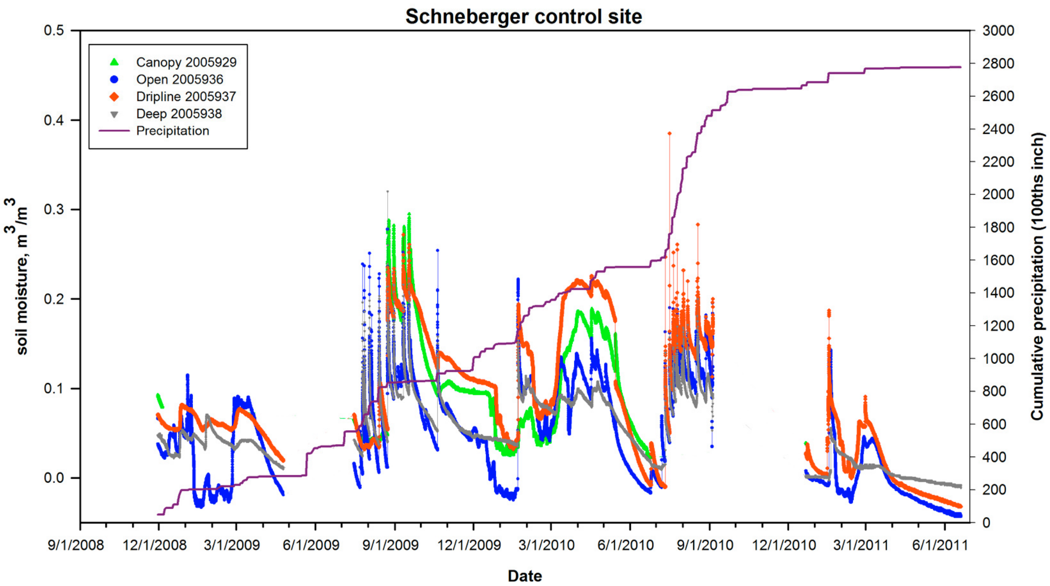
These sites will be re-measured following treatment and periodically thereafter in order to 1) document vegetation response to treatment and 2) provide representative vegetation data against which estimates of evapotranspiration can be calibrated.

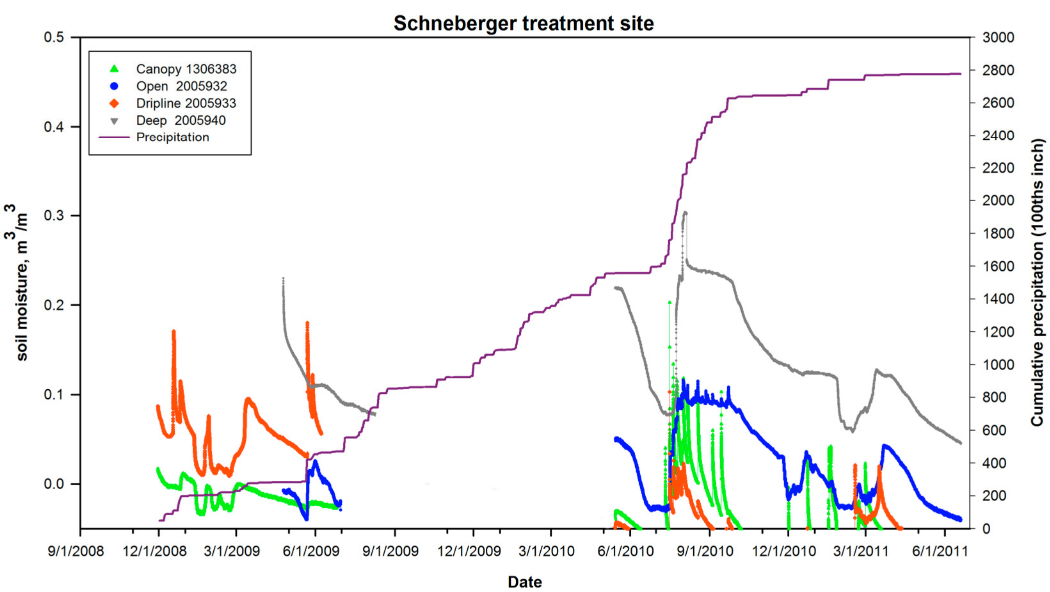
DATA GRAPHS: STIVER SITES, 2008-2011

Soil moisture and precipitation, Diamond control site

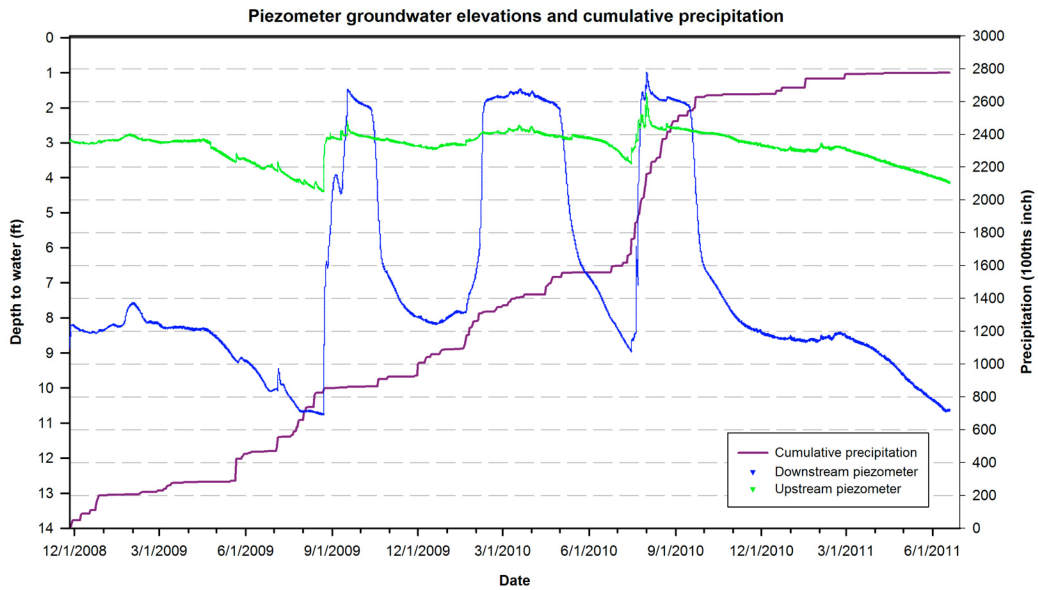


Soil moisture and precipitation, Schneberger sites





Alluvial groundwater and precipitation



STATUS OF TREATMENTS

Burro Mountains site

Gila National Forest and Grant SWCD signed an agreement in 2010 for thinning within the approximately 40-acre intensive cut zone (Prescription 2 on Map 1); thinning occurred between September and December 2010. One- to three-acre areas surrounding the soil moisture stations at Sites A through C and at Site F were essentially clearcut; thinning through the rest of the intensive cut zone was heavier than under the standard Forest Service prescription. A local contractor completed all work in the standard-prescription thinning area (including Site E; Prescription 1 on Map 1) during the same time frame. All treatments were funded under a workplan and contract between Grant SWCD and NM State Forestry.

Stiver Canyon site

Gila NF Black Range District had planned to conduct a prescribed burn in the spring of 2011 that included the Stiver Canyon bottom. However, funding and staffing restrictions forced the District to re-schedule the burn to the spring of 2012. Most soil moisture sensors at the site will have to be replaced by early 2012, so the schedule should allow adequate time to collect data that can be evaluated for the effects of soil disturbance on contact between the sensors and surrounding soils. All instrumentation at the site will have to be removed prior to the burn, of course, and a decision about whether to "water in" the sensors after replacement will depend on local climate conditions at the time. The possibility of a future post-burn thinning treatment remains open, but will require in any case a final series of bird surveys and development of thinning plan details. Updates will be provided to all study partners as available.

DATA ANALYSIS

Multivariate or cluster analysis of the data sets from each study area has been somewhat postponed, as described earlier in the report for each site. Data analysis from the Burro Mountains site will begin following the arrival of hoped-for monsoon precipitation in the summer of 2011. Preliminary analysis will be directed at identifying specific climate factors with the strongest influences on rates of soil moisture loss or retention. Results will be supplied to all project partners.

COROLLARY STUDY

Funding provided by New Mexico State Forestry also enabled establishment of a corollary study, at a small inholding called the Burro Mountain Homestead. The area is a mixture of Ponderosa pine and Pinyon pine ecotypes, in the southern portion of the Gila National Forest. This study will monitor soil moisture levels in two adjoining microwatersheds (< 1 acre each) for three years. One microwatershed was thinned according to the same prescription applied to the rest of the inholding; the other will remain an untreated control during the 3-year project. The study design and site are described in more detail in the attached Appendix. Thinning within the treatment area was completed on May 6 this year.

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APPENDIX

Report on the Establishment of Three-Year Soil Moisture Monitoring Study, Burro Mountain Homestead Paired Watershed/ Hazardous Fuels Project Site Near Silver City, NM, 2011

Synopsis. As part of the ongoing study of soil moisture response to thinning treatments in the Gila River watershed, New Mexico, a new site at the Burro Mountain Homestead (BMH) property near Silver City, NM was established in late March, 2011. The study site is located within a New Mexico State Forestry-funded Hazardous Fuels Reduction project area and is slated for treatment in May, 2011. Two micro-watersheds, each encompassing about 0.5 acres, were instrumented with three recording soil moisture sensors (SMC-005, Onset Corporation). A recording rain gauge (Onset Corporation) was placed at the extreme upslope end of the divide between the two micro-watersheds. Existing Ponderosa pine and juniper in the treatment watershed will be thinned according to treatment prescriptions already in place for the BMH project; the other will remain an untreated control area during the study period. The three-year data sets will be analyzed for significant variance between soil moisture levels and retention following precipitation events.

Site description. The study site is located in an area designated as Block 4 of the ongoing BMH Hazardous Fuels Reduction project, roughly the northwest portion of the BMH property (see Map 1). Elevation at the study site is about 6,670 feet above mean sea level. Vegetation cover is predominantly Ponderosa pine, juniper and oak species, and scattered areas of blue grama grass and forbs. The soils are granitic, forming a uniformly loose, gravelly/sandy loam. Under denser canopy areas, forest duff covers the soil to a depth of 2–4 inches. Much of the area is nearly barren of ground cover with only sparse blue grama and forbs present. According to thinning contractors who have worked at the site for a number of months, heavy rainfall can cause substantial amounts of surface runoff and sheet erosion across much of the project area.

The Hazardous Fuels Reduction project on the BMH is ongoing and treatments outside the study area are nearly complete. New Mexico State Forestry funds associated with this soil moisture study will also be used to treat approximately 30 acres on the Gila National Forest (GNF) just outside the southeast corner of the BMH property in April 2011; other GNF lands surrounding the property have also undergone a series of thinning treatments in previous years.

Two nearly identical, adjacent swale features were selected for the study site. Each trends south-southwest and drains an area of slightly less than 0.5 acres. Each drains into a small, ephemeral channel that empties into the larger channel feature that roughly bisects Block 4 from southwest to northeast (Map 1). Tree cover on each watershed is similar. Existing basal area was estimated at about 120 by the thinning contractor in March, 2011. Selection of the treatment micro-watershed was based on the sun's position relative to existing canopy at the site, to minimize the protective effects of shading from the control site.

Instrumentation. Both micro-watersheds were instrumented on March 31, 2011 (Table 1). A Hobo datalogger (Onset Corporation) was installed just above the west-facing bank of each swale, about 10 feet above its confluence with the west-flowing tributary (see photos). Three soil moisture sensors (SMSs); Onset Corporation SMC-005) are attached to each datalogger; all were placed near the top of each channel's west-facing bank. As at our other study sites, the sensors were placed at three locations relative to existing Ponderosa pine cover: under the canopy, at the dripline, and in the open. Each was buried at a depth of 0.5 feet, firmly packed, and watered to ensure good contact with surrounding soil. The data recording interval was set to 15 minutes. The sensor cables were buried and the soil and any duff were replaced to minimize evidence of ground disturbance. Cages constructed of hardware cloth were placed over the dataloggers as protection against damage from rodents.

Table 1. Instrumentation placement summary, BMH study site.

Location	UTM location (m, NAD83)	Date/time placed (MST)	Sensor positions	Recording interval
Control	3612087 N, 740229 E	Mar 31, 2011/ 1145	Canopy, dripline, open	15 min
Treatment	3612083 N, 740237 E	Mar 31, 2011/ 1300	Canopy, dripline, open	15 min
Precipitation	3612102 N, 740255 E	Mar 31, 2011/ 1245	Open meadow	100^{th} inch precipitation

Treatment. The thinning contractor, Glenn Griffin, heavily flagged both the control and treatment areas while the instrumentation was being placed to ensure that no trees are cut within the control area. Thinning in the treatment area will occur in May 2011, allowing a brief period to collect baseline data. Baseline data will be evaluated for correlation between sensor types (e.g., control and treatment canopy sensors). Thinning prescriptions vary across the larger BMH Fuels Reduction project; thinning in the study treatment area will follow the more intensive of the prescriptions. The contractor estimates that about 24 Ponderosa pine will be cut within the treatment area, reducing basal area by more than 50%. Photos taken post-thinning and again near the end of the study period will document changes in vegetation cover at the site.

Data collection and analysis. Data will be downloaded from all instrumentation on a quarterly basis through April 2014 and archived in two locations. The near proximity of the two soil moisture sites and the rain gauge (< 100 feet) virtually eliminates one of the most confounding variables for these studies: the highly localized nature of monsoon precipitation. Therefore, multiple regression analysis and nonparametric analysis of the data sets as paired groups will be used to examine for significant variances in soil moisture volumes and retention between the two sites and between similar sensor types at each site. Subsets of the data collected during and after precipitation events will also be evaluated separately. All data and analyses will be provided by Grant Soil & Water Conservation District to New Mexico State Forestry and made available to all other project partners.

Submitted by Ellen S. Soles,
on behalf of Grant Soil & Water Conservation District
April 2011

BMH study area, March 2011

BMH study sites, March 2011; photos taken from the bottom of control and treatment micro-watersheds, standing at each swale's confluence with a small ephemeral channel draining from east to west. Top, control site, looking upstream along swale feature to the ridgeline defining the top of the micro-watershed. Bottom, treatment site, looking upstream along swale to ridgeline. The rain gauge, located on the divide between micro-watersheds, is visible center left.