Executive Summary

Post-Wildfire Salvage Logging, Soil Erosion, and Sediment Delivery—Ponderosa Fire, Battle Creek Watershed, Northern California

Preliminary Results

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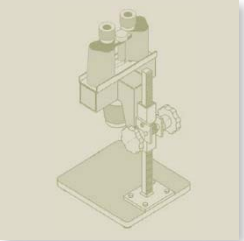

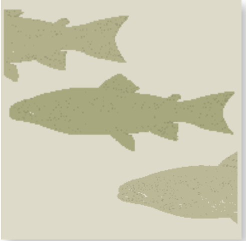

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Executive Summary[1]

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Counterintuitively, first-year data from a post-wildfire soil erosion study show that control sites disturbed only by fire produced substantially *more* water runoff and soil erosion than did sites that received post-wildfire salvage logging. These results have important implications for the use, treatment, and restoration of post-wildfire landscapes, suggesting that salvage logging can reduce soil erosion.

Introduction

Within 40 days of the 27,676-acre, high severity Ponderosa Fire (Figure ES-1) being contained on August 31, 2012,[3] we developed and implemented a study to identify the effects of wildfire and salvage logging on hill slope soil erosion. Although this study follows established protocols from previous wildfire erosion studies, it is—to our knowledge—the only study initiated before a rainfall event. Consequently, this study has captured all rainfall and erosion events after both a wildfire *and* subsequent salvage logging. This report describes the study design and presents preliminary results, observations, and interpretations based on data from the 2013 Water Year (WY) of October 1, 2012, to September 30, 2013—essentially the first winter season following the Ponderosa Fire.

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[1] This document is a non-technical summary of the longer Preliminary Results report: James, C. 2014. *Post-Wildfire Salvage Logging, Soil Erosion, and Sediment Delivery—Ponderosa Forest Fire, Battle Creek Watershed, Northern California—Preliminary Results*. Research and Monitoring Department, Sierra Pacific Industries, 18pp.

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[3] See http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=722.

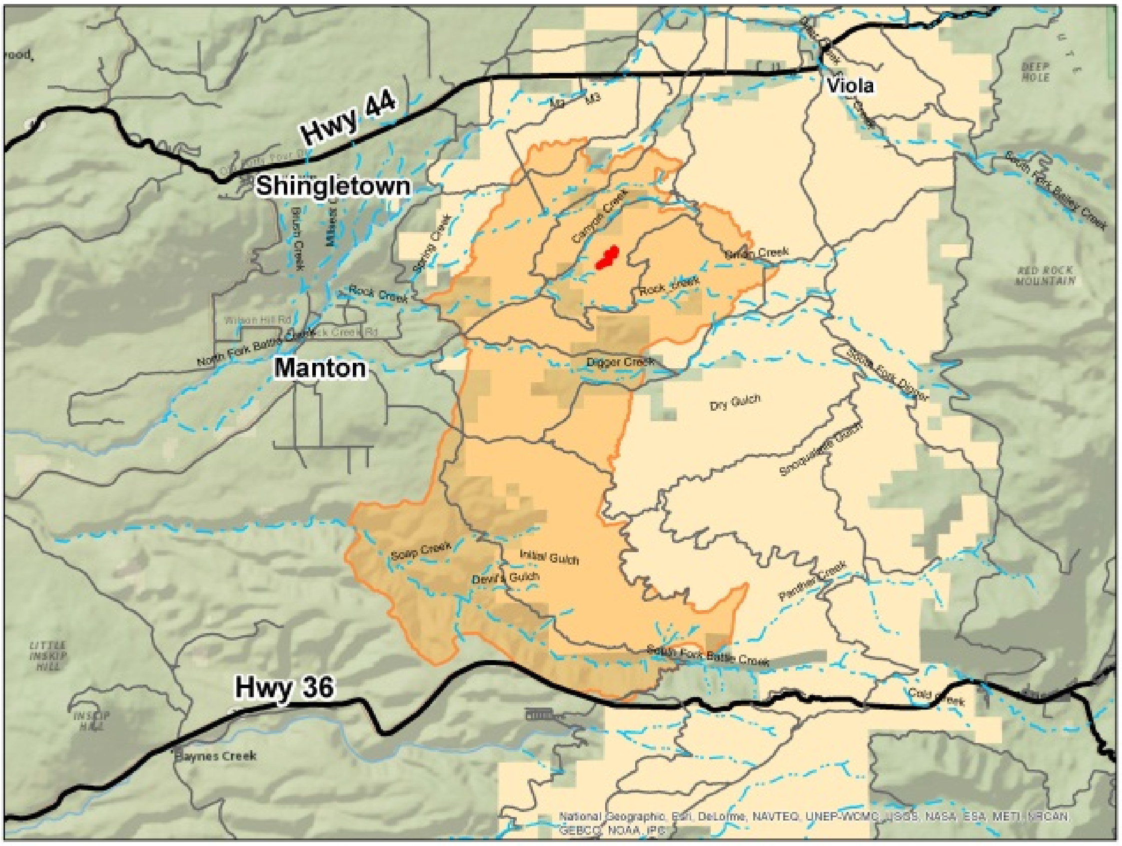

Figure ES-1. The extent of the Ponderosa Fire within the Greater Battle Creek Watershed is shown in orange. The Sierra Pacific Industries property is shown in tan, and its overlap with the Ponderosa Fire area is shown as a variation of the orange color. The erosion study area is shown in red.

Study Sites and Treatments

All salvage logging operations performed in this study complied with the State of California's Forest Practice Rules, which prescribe specific erosion-control measures and watercourse zone buffer widths. Operations were covered under a Notice of Emergency Timber Operations (RM-67), filed by Sierra Pacific Industries and accepted by the California Department of Forestry and Fire Protection. Timber operations conducted under Emergency Notice must comply with all operational provisions of the Forest Practice Act and District Forest Practice Rules applicable to Timber Harvest Plans. Wildlife and archaeological resources must also be evaluated and considered prior to operations. The emergency salvage logging operations conducted following the Ponderosa Fire and for this study followed these requirements.

Ten headwater swale study sites were established on Sierra Pacific Industries forest land within the area affected by the Ponderosa Fire (Figures ES-1 and ES-2). Of these, three were control sites disturbed only by fire; the remaining seven were salvage-logged using mechanized equipment to cut the burned timber and yard it to landings for loading on trucks (Figure ES-2 and Table ES-1). On the seven salvage-logged sites, we applied combinations of two different treatment types: logging intensity and contour subsoiling.

Logging intensity consisted of two different levels of tree removal. The lower-intensity salvage method consisted of removing all merchantable trees greater than 12 inches diameter breast height [DBH] with a mechanized cutting head mounted on a tracked machine (often called a feller buncher). This lower-intensity treatment represents a typical fire salvage logging operation where trees are removed down to a certain tree diameter established by the landowner. The second, higher-intensity salvage method included biomass removal where all trees were removed regardless of size in addition to the lower-intensity salvage logging method described above. Salvage harvests that include biomass removal are not a typical salvage logging method following a large fire; it was performed strictly for this study to determine if this level of disturbance contributes to post-wildfire sediment production off hill slopes. In total, three sites were treated with the lower-intensity salvage method, and four sites were treated with the higher-intensity salvage method.

After harvesting contour subsoiling was applied to four of the salvaged logged sites (two of which received salvage logging, two of which received salvage logging plus biomass removal); this ground-based treatment helps prepare the land for subsequent replanting. These four sites were mechanically subsoiled on contour using a D-6 tractor that created furrows at 7- to 10-foot intervals to a depth of approximately 20 inches.

Table ES-1 lists the treatments each of the 10 sites received.

By using multiple treatments, we were able to compare the hill slope erosion produced on the salvage-logged sites to that on unlogged control sites. We are also able to examine if logging intensity results in different levels of erosion, and if preparing the ground for planting using contour subsoiling also plays any role in changing the amount of water and sediment produced from salvage logging versus untreated control hill slopes.

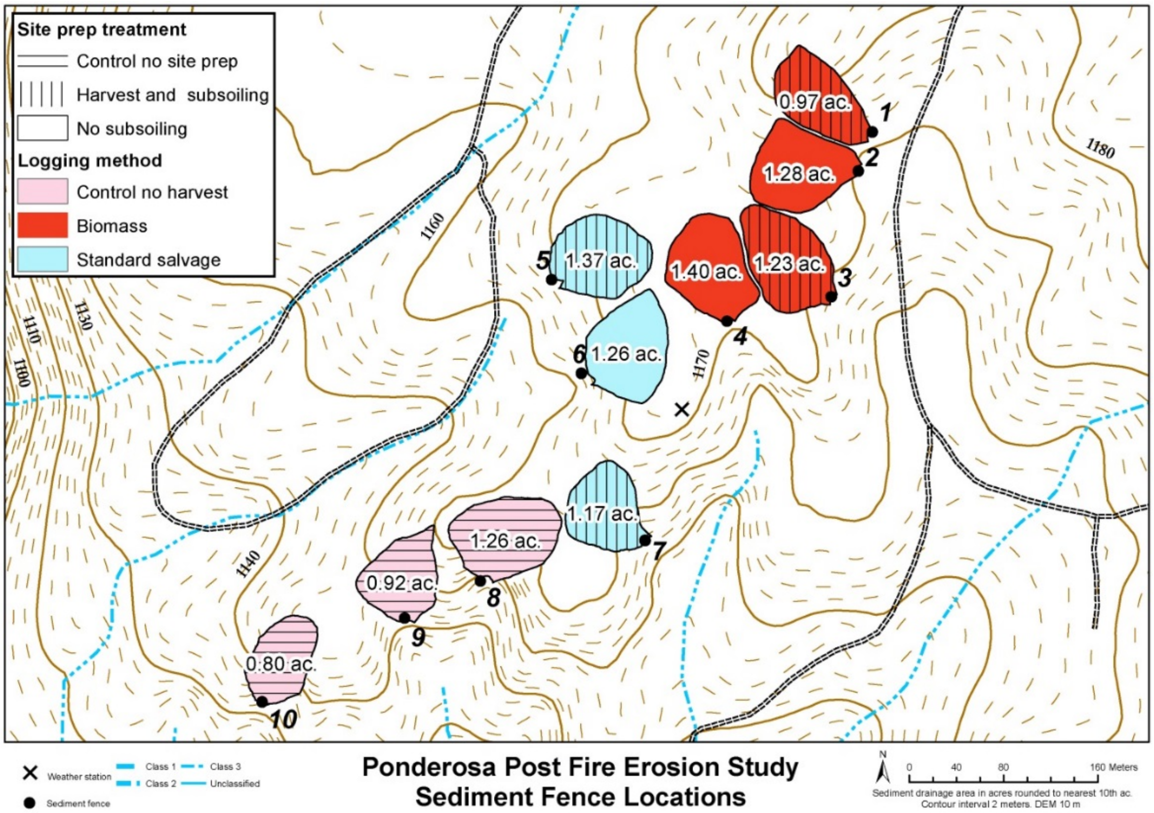

Figure ES-2. This map of the study area shows the distribution, size, and treatment assignments for the 10 study sites. It also shows sediment fence locations, topographic contours, stream channels, and logging roads. Seven of the sites were treated with a combination of two treatment types: logging intensity and contour subsoiling; the remaining three sites were designated as controls with no treatments. The weather station location is shown by the 'X'.

Table ES-1. Control Sites and Treatment Sites

	Site Number (Acres)									
	1 (0.97)	**2** (1.28)	**3** (1.23)	**4** (1.40)	**5** (1.37)	**6** (1.26)	**7** (1.17)	**8** (1.26)	**9** (0.92)	**10** (0.80)
Control Sites										
Control: no salvage logging, no contour subsoiling								**X**	**X**	**X**
Treatment Sites										
Salvage logging, no contour subsoiling						**X**				
Salvage logging plus biomass removal, no contour subsoiling		**X**		**X**						
Salvage logging, contour subsoiling					**X**		**X**			
Salvage logging plus biomass removal, contour subsoiling	**X**		**X**							

Study Sites Instrumentation and Data Collection

A weather station was established near the study area (Figure ES-2). Sediment fences were constructed at the downslope end of each site to capture and measure water and sediment (Figures ES-2 through ES-6). The top of each sediment fence had a spillway at its center to allow water to escape if it was entirely filled (Figure ES-3). Water depth sensors were placed at each fence to track and quantify the depth of the water and soil that accumulates behind the fences over time. Cameras were also placed at each fence so that 30-minute time-lapse photographs could be assembled into videos that show water filling and draining with associated sediment accumulation.

Accumulated sediment was removed by hand crews using shovels and buckets. Wet and dry weight as well as organic matter content was determined (Figure ES-6). In summer 2014, field topographic surveys were conducted to map and characterize the size, shape, and position of rills that developed over WY 2013.

Figure ES-3. This photograph shows the upslope view at the back of a control site sediment fence. In this view both the sediment fence structure and most of the contributing swale can be seen. The spillway in the center of the fence is evident and the fence is braced with a post to counter the weight of captured sediment. Because it is a control site, this swale was not salvage-logged nor contour subsoiled and was disturbed only by the Ponderosa Fire itself. Note the relatively uniform nature of the soil surface which is covered by ash, the remnant dead trees evident throughout the burned swale and that there is no obvious stream channelization in the swale prior to the occurrence of post-wildfire rain. Although undisturbed by any post-wildfire treatment, the control sites produced the highest water runoff and average soil erosion during the over the first winter season (see Figures ES-7 and ES-8).

Figure ES-4. This photograph shows a closer view (compared to Figure ES-3) of a control site looking upslope from the downslope side of its sediment fence. Note the relatively uniform nature of the soil surface which is covered by ash, the remnant dead trees evident throughout the burned swale and that there is no obvious stream channelization in the swale prior to the occurrence of post-wildfire rain. Because it is a control site, the swale was not salvage-logged nor contour subsoiled and was disturbed only by the Ponderosa Fire itself. Although undisturbed by any post-wildfire treatment, the control sites produced the highest water runoff and average soil erosion over the first winter season (see Figures ES-7 and ES-8).

Figure ES-5. This photograph shows the downslope view from near the top of a swale treated with salvage logging plus biomass removal and contour subsoiling. The sediment fence is visible towards the upper left of the photograph (white arrow). The approximately 20-inch-deep furrows created by the subsoiling and the loose soil piled along their sides are evident throughout the swale. The furrows are oriented on contour with the slope or perpendicular to the downslope swale direction and interrupt water and sediment movement down the swale center. Note that the furrow orientation is not contour parallel on the contributing slopes. This combination of treatments produces the most site disturbance. Despite this visually stark and high level of disturbance, sites receiving these treatments produced substantially *less* water runoff and average soil erosion over the first winter season compared to the control sites (see Figures ES-7 and ES-8).

Figure ES-6. This photograph is looking upslope during a sediment fence cleanout of a control site. Note the people for scale. Sediment has been removed from within the sediment fence, weighed, and then piled on the sides and downslope of the sediment fence. As a control site, this swale received no salvage logging nor contour subsoiling. Note that on the control sites rill erosion features began forming on the burned hill slopes immediately after rainfall events. At this control site a main channel has begun to form; it shows as the lighter brown streak extending uphill from the fence through the middle of the swale. The sediment pictured accumulated during the first 3 months following fire containment.

Although undisturbed by any post-wildfire treatments, the control sites produced the highest water runoff and average soil erosion over the first winter season (see Figures ES-7 and ES-8).

Preliminary Results and Observations

The time-lapse camera photographs and software-assembled photographic time-lapse videos provided useful visual records of the activity in individual swales. This time-lapse video (http://www.spi-ind.com/research/Control_Sediment_Fence_Feb_18_through_Mar_12_2014.mp4) shows the fence filling with water and sediment in response to precipitation events occurring upslope and then emptying, draining, and drying over time. The activity was recorded at a control site fence between February 17 and March 18, 2014.

This time-lapse video (http://www.spi-ind.com/research/Control_Sediment_Fence_Cleanout_Feb_2014.mp4) shows a sediment fence clean out in one of the control sites in February 2014. During the cleanout, the images were recorded every minute to capture work activity rather than every 30 minutes for general observations.

Field data confirmed satellite imagery classification of high severity fire (no ground vegetation, no soil duff layer, no surface fuels, tree trunks charred to greater than 6 feet). Field data also showed that the sites had hydrophobic soil conditions (i.e., water-repellant soil created by the fire which increases the rate and quantity of water runoff). No hydrophobicity was detected post-salvage logging in any of the sites.

A total of 35 inches of rainfall was recorded during WY 2013, primarily during the winter season. There were 20 rain events with 0.5 inch or more falling in 24 hours. Two events, with greater than 1 inch of rainfall in 24 hours, were significant sediment producers and necessitated fence cleanout to maintain capacity.

Erosion results for WY 2013 show that immediately following the fire, the control sites by far produced more sediment than the salvage-logged sites (Figure ES-7). Overall the control sites averaged greater than 30,000 pounds of sediment per acre. By contrast, the sites treated with salvage logging and contour subsoiling produced the least amount of sediment, averaging 1,000 pounds and 4,000 pounds per acre, with and without biomass removal, respectively. The sites treated with salvage logging without contour subsoiling produced an intermediate amount of sediment, averaging 8,000 pounds and 11,000 pounds per acre, with and without biomass removal, respectively.

The amount of water runoff from the control sites is also higher than the runoff from the treatment sites due to lack of infiltration. Figure ES-8 shows the runoff results from a rainstorm for five sites. The most significant difference between the sites is the relatively large amount of water and sediment measured in the control site (the brown line) and the smaller amounts of water and sediment measured in the treatment sites (Figure ES-8). That is, the brown line (control site) is highest, and all other lines (treatment sites) show much lower depths and associated water volume runoff.

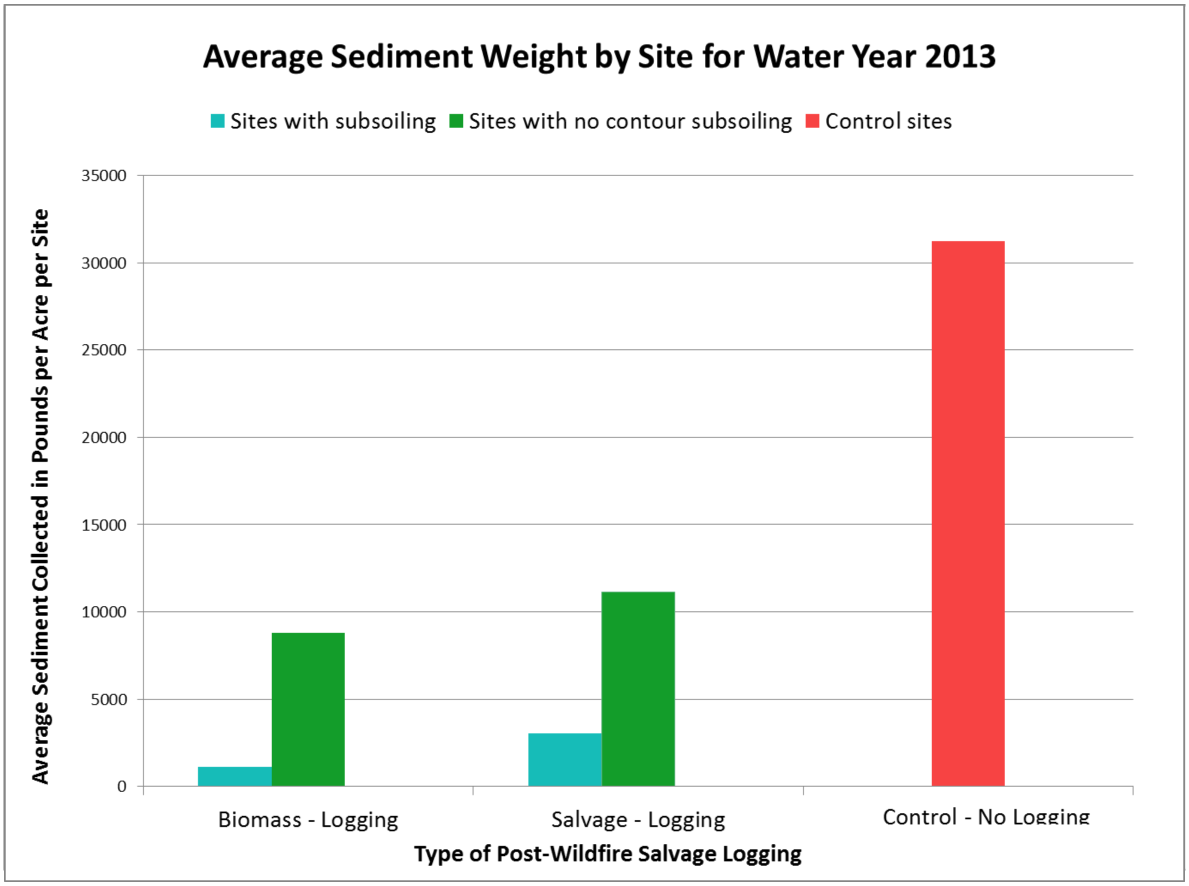

Figure ES-7. This bar chart shows the results of the first winter season average sediment weight (pounds per acre) for the controls and the treatment groups. Although undisturbed except for the Ponderosa Fire, the control sites (the red bar labelled Control—No Logging) showed the most soil erosion, producing an average of more than 30,000 pounds of sediment per acre. The sites with treatments having the most disturbances—salvage logging and contour subsoiling, with or without biomass removal—had the least amount of soil erosion (the light blue bars). Specifically, salvage logging plus biomass removal *combined* with contour subsoiling produced an average of approximately 1,000 pounds of sediment per acre. Salvage logging *without* biomass removal but *with* contour subsoiling produced an average of approximately 4,000 pounds of sediment per acre. Salvage logging *without* contour subsoiling produced an intermediate amount of soil erosion, averaging approximately 8,000 pounds and 11,000 pounds of sediment per acre, with and without biomass removal, respectively.

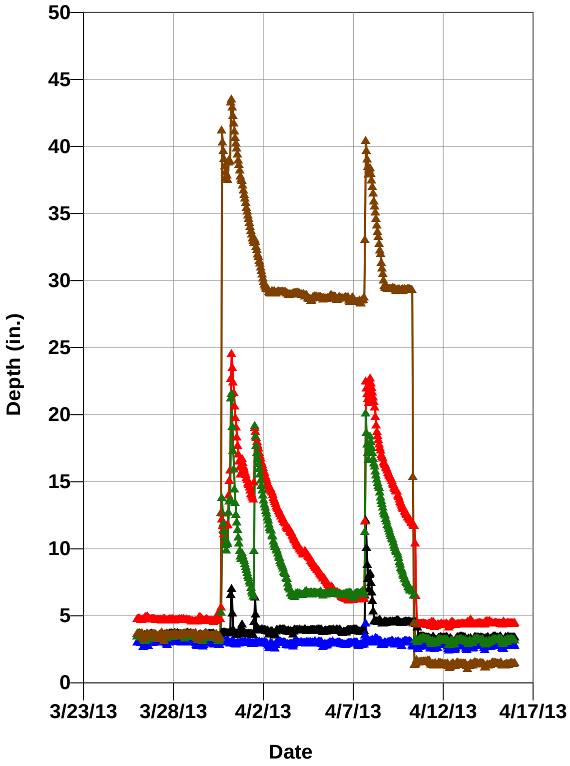

Figure ES-8. This graph shows the water depths for five sediment fences during a rainstorm between March 30 and April 9, 2013. These water depths are a measure of each site's water runoff volume. The most significant difference between the sites is the relatively large amount of water runoff measured in the control site (the brown line) and the smaller amounts of water runoff measured in the treatment sites. The brown line is highest, and all other lines show much lower water depths (runoff volume). The amount of water runoff affects the amount of soil erosion that can occur in a site. The cumulative water runoff from the sites over the winter season is a major determinant of the amount of soil erosion (average sediment weight per acre) that occurred, as shown in Figure ES-7. The brown line shows a control site (no salvage logging or contour subsoiling); the blue line shows a site that received salvage logging plus biomass removal and contour subsoiling; the black line shows a site that received salvage logging plus biomass removal but no contour subsoiling; the green shows a site that received salvage logging and contour subsoiling; and the red line shows a site that received salvage logging and no contour subsoiling.

Conclusions

This ongoing Ponderosa Fire soil erosion study was designed and implemented before any rainfall event and, consequently, has captured all rainfall and erosion events after both the forest fire *and* subsequent salvage logging. We know of no other forest fire erosion study that has been able to accomplish this result.

Although runoff from individual swales varied slightly by storm and is still being analyzed, it is evident that the control sites (no salvage logging or contour subsoiling) exhibited the most water runoff and soil erosion. The preliminary interpretation of the lower runoff volumes for the treatment sites is that this disturbance decreased or eliminated soil water repellency (hydrophobicity) and increased rainfall infiltration. Additionally, when runoff occurred during rainfall, the swales with more ground surface disturbed slowed the runoff velocity and decreased soil erosion. In particular, the furrows created by deep contour subsoiling slowed the runoff velocity and trapped water and sediment, resulting in less average soil erosion and sediment delivery.

Counterintuitively, the field data show that the *least* disturbed sites actually produced the *highest* average hill slope soil erosion while the *most* disturbed sites produced the *lowest* average hill slope soil erosion. Specifically, the control sites, which were disturbed only by the Ponderosa Fire, produced the *highest* average erosion rates. This result is counterintuitive because the visually stark soil disturbance that is evident in sites that received salvage logging plus biomass removal and contour subsoiling (e.g., Figure ES-5) suggests that substantial soil erosion should occur at these sites during a rainfall event. However, in contrast to expectations based on the visual appearance of the sites, the first year data demonstrate the exact opposite: the site disturbance eliminates soil hydrophobicity, increases rainfall infiltration, reduces runoff velocity, shortens the hill slope length, and thereby substantially *reduces* overall average soil erosion and sediment delivery. These results and observations have important implications for the use, treatment, and restoration of post-wildfire landscapes, showing that salvage logging and contour subsoiling can result in less soil erosion. Including these treatments in the restoration toolbox would provide greater flexibility in many landscapes and contribute to an overall reduction in water quality degradation post-wildfire.