

Post-Wildfire Erosion in the Chiricahua Mountains

Ann Youberg

Arizona Geological Survey, Tucson, Arizona

Daniel G. Neary, Karen A. Koestner, and Peter E. Koestner

USDA Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona

Abstract—The Horseshoe 2 Fire burned 90,226 ha (222,954 ac) of the Chiricahua Mountains in the Coronado National Forest of southeast Arizona from May 8 to June 25, 2011. This mountain range in the Madrean Archipelago was burned by widespread fires prior to 1890, numerous small fires after 1890, and, more recently, the 11,129 ha (27,500 ac) Rattlesnake Fire in 1994. The latter fire resulted in significant erosion during post-fire monsoon storms that eroded deep gullies (~10 m) in Ward Canyon (upper West Turkey Creek). Post-fire runoff deposited large amounts of sediment in lower channels, particularly in Rucker Creek and in Rucker Lake. The Horseshoe 2 Fire burned approximately 70% of the mountain range with a mosaic of fire severities. Post-fire erosion from floods and debris flows produced additional erosion and sedimentation that is currently being evaluated through fieldwork and repeat aerial photography. This paper discusses ongoing work regarding post-fire erosion and the impacts on channel systems in the Chiricahua Mountains.

Introduction

Record-setting wildfires burned across Arizona in 2011. The human-caused Horseshoe 2 Fire burned 11,110 ha (222,954 acres) of the Chiricahua Mountains between May 8th and June 25th, 2011, on the Coronado National Forest (CNF) (<http://inciweb.org/incident/2225/>). This fire burned approximately 70% of the mountain range (fig. 1) and currently stands as the 4th largest wildfire in state history (Southwest Coordination Center: <http://gacc.nifc.gov/swcc/predictive/intelligence/intelligence.htm>). Monsoon rains often follow immediately after the wildfire season and are often how fires are ultimately extinguished. Short-duration, intense bursts of rainfall from relatively common (<2-5 year frequency) storms can generate large floods and debris flows in watersheds disturbed by wildfires (DeBano and others 1998; Jenkins, 2011; Neary and others 2005). U.S. Forest Service (USFS) Burned Area Emergency Response (BAER) assessments were completed for the burned area. The soil burn severity map shows 12% of the Horseshoe 2 Fire burned at high severity and 30% at moderate severity (fig. 1). The BAER team conducted a hydrologic analysis of post-burn conditions using a 5-year return interval storm with an intensity of 12.5 mm/hr (0.5 in/hr), and a geologic analysis using burn severity, basin morphometrics, and soil characteristics to assess the potential for post-fire debris flows. These analyses indicated that post-fire peak discharges might increase from 2-15 times pre-fire conditions, and several watersheds had a high potential for debris flows (USDA Forest Service 2011).

Moody and Martin (2009) compared post-fire sediment yields across the western United States with 30-minute rainfall intensity from 10 rainfall regimes. They found that generally channels contributed ~75% of the post-fire sediment yield while hillslopes contributed ~25%, although most of the runoff came from hillslopes (Moody and Martin 2009). Understanding the sources of sediment from burned areas is important for assessing post-fire geomorphic responses of basins and the effectiveness of post-fire mitigation measures, both of which inform resource management decisions (Robichaud and others 2000). To understand sediment sources, baseline conditions must be established. Due to the short window of opportunity in Arizona between fire containment and the first monsoon storms, these data can be difficult to acquire. This study established post-fire, pre-storm conditions using aerial photographs flown immediately after the fire. Channel and hillslope conditions were monitored through the summer to document basin responses to significant rainfall. The objectives of this study are to monitor, document, and quantify post-fire erosion from channels and hillslopes, on a broad scale, in the Chiricahua Mountains following an approach used after the 2010 Schultz Fire in northern Arizona (Youberg and others 2011). The goals of this study are to document burned basin responses (floods vs debris flows) to significant rainfall, and the locations of post-fire erosion (channels vs hillslopes) to understand how post-fire erosion and deposition change over time, and how those changes influence post-fire flooding and sedimentation or recovery. The objectives of this paper are to report on the current status of the project and to discuss some of the basin responses from rainfall during the 2011 monsoon.

Background

Following the 2010 Schultz Fire near Flagstaff, Arizona, debris-flow and flood deposits were identified and mapped to assess basin response to rainfall. Limited channel measurements were collected, including an evaluation of available sediment in one small sub-basin following the 2010 monsoon (Carroll 2011), and a single series of

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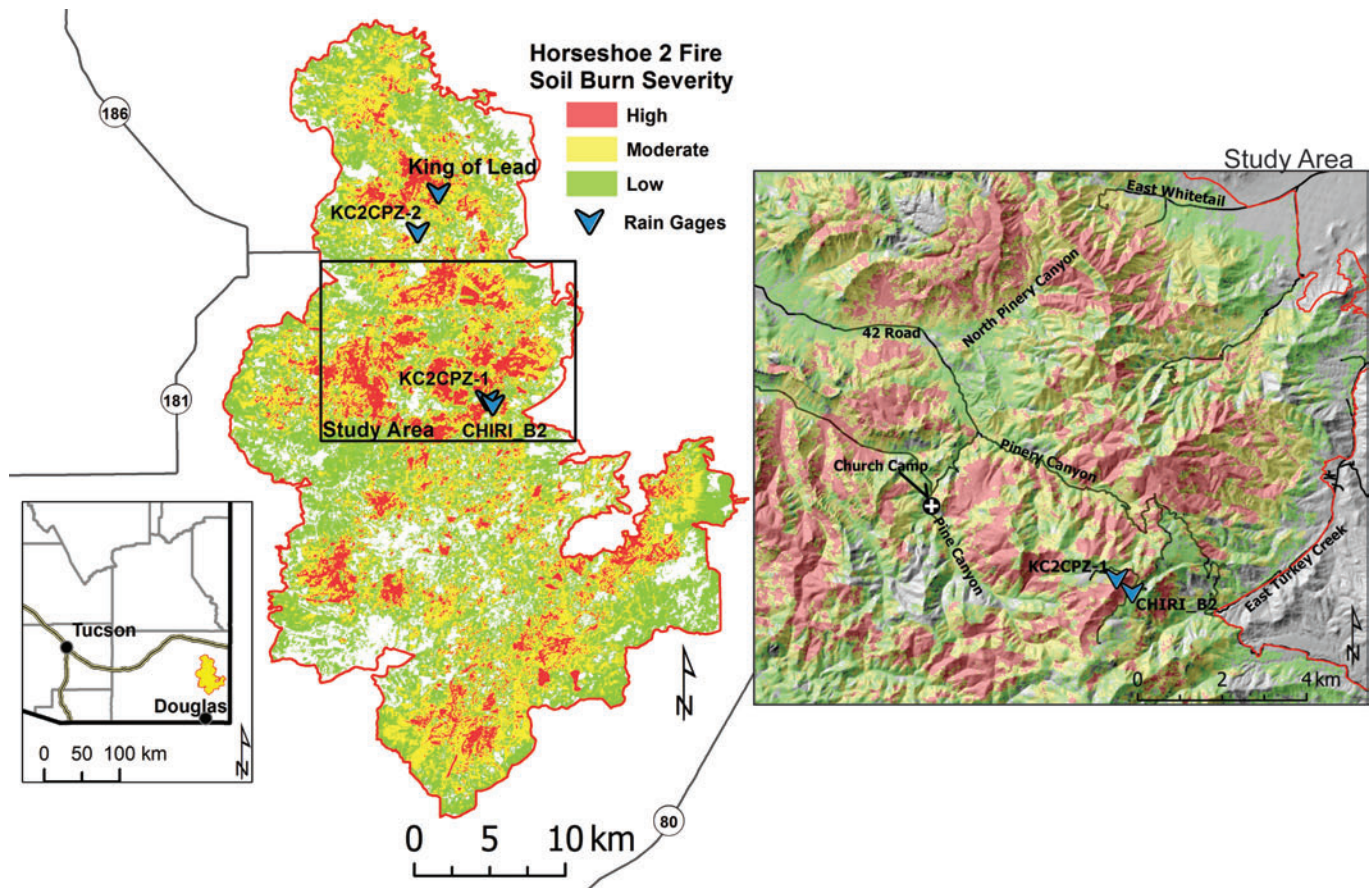


Figure 1—Location map of the Horseshoe 2 Fire with burn severity. Lower left inset panel shows the location of the Horseshoe 2 Fire in southeastern Arizona. The map of the fire shows soil burn severity map, location of rain gages, and study area outlined in box. The right image shows the study area.

cross-section surveys used to estimate peak flows from a productive runoff event across the burn area (Koestner and others, in press). No hillslope measurements were taken. Thus, to assess post-fire erosion following the Schultz Fire, aerial photography (scale 1:12 k) was flown after monsoon to capture initial post-fire erosion. The aerial imagery provided both a visual record of erosion and a means to create high-resolution (15 cm - 1 m) digital elevation models (DEMs) from the digital data using photogrammetric analysis. This method is also being utilized on the Horseshoe 2 Fire to monitor and assess post-fire erosion via a collaborative effort between the CNF, the U.S. Forest Service Southwestern Regional Office (RO), the Rocky Mountain Research Station, and the Arizona Geological Survey.

Extensive erosion following the Horseshoe 2 Fire was anticipated, given severe erosion previously observed after the 1994 Rattlesnake Fire. Tree-ring data show that the Chiricahua Mountains were burned by widespread fires prior to 1890 and numerous small fires after 1890 (Swetnam 2005). Due to fire suppression and livestock grazing, the fire regime changed during the 20th century (Swetnam 2005). The 1994 Rattlesnake Fire, which burned ~11,110 ha (27,500 ac) along the crest of the range (MTBS 2012), is considered one of the earliest large fires of the current fire regime. Approximately 21% of the total area was burned at high severity and 12% at moderate severity (CNF files). The monsoon rains following the 1994 Rattlesnake Fire caused significant post-fire erosion. Rucker Lake, at the south end of the range, had high sediment input prior to the fire and required frequent dredging to keep the lake open (Lefevre and Neary 1999).

During a post-fire monsoon storm multiple debris flows initiated in upper Rucker Canyon, and coarse sediment filled Rucker Lake. This event was unprecedented, delivering approximately three times the pre-fire sediment load to Rucker Lake (Lefevre and Neary 1999). Some of the most impressive erosion occurred in upper Ward Canyon on the steep western flank of Chiricahua Peak, where a 10-m gully formed. By 2004, the gully bottom had filled in approximately 4-5 m and widened 2-3 m through mass wasting processes (P. Pearthree, personal communication).

Study Area

The study area was selected using several criteria including burn severity, accessibility, proximity to communities, and the potential for significant post-fire erosion. The study area encompasses several canyons in the northern part of the burn area including Pinery, North Pinery, Pine and East Whitetail Canyons, and East Turkey Creek (fig. 1). Pinery Canyon and East Turkey Creek are dissected by the 42 Road, the only major east-west road through the mountain range, and East Turkey Creek contains the small community of Paradise. North Pinery and East Whitetail both have extensive areas of high burn severity (>70%), and East Whitetail also contains a small community. Pine Canyon was partially burned in the Rattlesnake Fire with significant post-fire erosion. A church camp is also located within Pine Canyon and extensive patches on the steep northern slopes above the camp and in the upper canyon were burned at high severity.

Methods

Aerial Photography

The CNF with assistance from the RO GIS/Photogrammetry Program had aerial photography flown in the northern portion of the fire with the goal of capturing post-fire, pre-storm conditions of the study watersheds. The air photos were flown on July 1, 8, 14 and 15 at a scale of 1:12000. In addition to these photos, the RO collected aerial photographs in August and September as part of their ~5-year cyclical resource aerial photography program. These resource photos are digital with a resolution of 25 cm (10 in).

Precipitation Data

The first rain gage (CHIRI_B2) within the burned area was installed on the east side of Buena Vista Peak, near the 42D road, on July 1 by the University of Arizona/Biosphere 2. A temporary weather station with a recording gage (KC2CPZ-1) was installed on July 26 on top of Buena Vista Peak at the Barfoot Lookout location by the National Weather Service (NWS). A second temporary weather station (KC-2CPZ -2) outside our study area was installed by the NWS within Chiricahua National Monument on August 3. Two permanent ALERT gages were installed by the Arizona Department of Water Resources (ADWR) on August 26. One is co-located on top of Buena Vista Peak and will remain after the temporary weather station is removed. The second (King of Lead) is at the headwaters of East Whitetail Canyon, also outside of our study area near the King of Lead mine. In October, the USGS installed a stream warning system and a rain gage in Chiricahua National Monument.

Field Monitoring and Other Data

Visits to key study areas were conducted as soon as possible following significant storm events during the monsoon of 2011. Smaller storms were monitored remotely and basin responses determined from reports, videos and photographs taken by BAER Implementation team members, local residents and district personnel. Field visits covered as much of the study area as possible, focusing on those areas that had received significant rainfall, to document and photograph hillslope erosion and channel condition. Channel deposits were classified, when possible, as either flood flow or debris flow. In Pinery Canyon tributary, channel material was deposited on the 42 road, providing very good exposures of deposits for flow-type classification. In East Turkey Creek, however, the channels above the road have fairly deep basins. Often during field visits these deposits were either entirely buried leaving no cross-sectional exposures to characterize deposits or, more likely, the road crew had already cleared the road and cleaned out the basins leaving no undisturbed deposits to evaluate. Numerous photos and reports from these locations during the largest storms provide some information regarding basin responses.

Results

The first few rains that fell on the study watersheds were of moderate intensity and duration. They moved some sediment and ash in and through the channels, resulting mainly in nuisance flooding. Hillslope rilling was noted in the study area following a June 29 storm. The first major rainfall occurred on July 11 (fig. 2). The CHIRI rain gage recorded 54.4 mm (2.14 in) in 1 hour, 38 minutes, with a peak 30-minute intensity of 35.6 mm (1.4 in) (Steve DeLong, unpublished

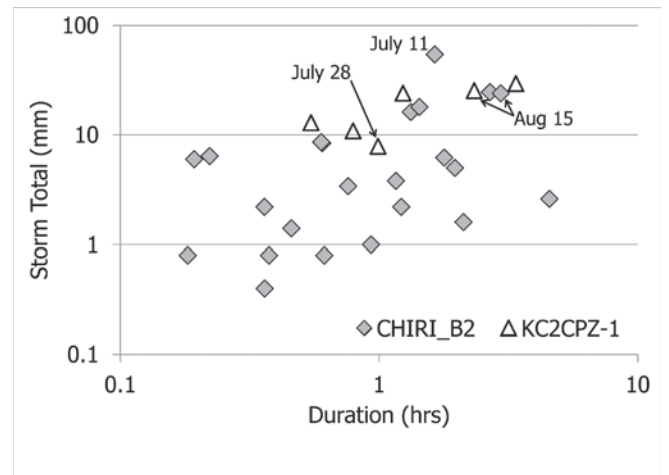


Figure 2—Rainfall storm totals with dates of debris-flow producing storms. The University of Arizona's rain gage, CHIRI_B2, was installed on July 1st and is located along the 42D Road. The NWS weather station, KC2CPZ-1, is located on top of Buena Vista Peak and was installed on July 26th.

data). The online NOAA Atlas 14 (<http://dipper.nws.noaa.gov/hdsc/pfds/>) classifies this 30-minute intensity as a 2- to 5-year frequency storm. On the east side of the range, where the rain gage sits, floods were observed in the East Turkey Creek drainage. On the west side of the range, debris flows occurred in several tributaries of Pinery Canyon, depositing debris on the 42 Road, and in tributaries to Pine Canyon above the church camp. Numerous storms throughout the summer produced large enough floods to generate documentation via reports, photos and videos. Additional debris-flow producing storms occurred on July 28, with a debris flow noted in a tributary to East Whitetail Canyon, and on August 15 with evidence of debris flows in Pine Canyon and East Turkey Creek (fig. 2). This storm significantly impacted the church camp with debris flows depositing just upstream and flooding throughout the camp. No debris flows were observed in North Pinery Canyon. Some landslides had been observed in this canyon during the BAER assessment (Youberg 2011) but no additional movement was noted over the monitoring period.

The aerial photographs flown in July to capture post-fire, pre-storm watershed conditions were actually flown over 4 days. The east side of the area was flown on July 1 and 8, prior to any significant rainfall, and the west side was flown on July 14 and 15 following the first debris-flow producing storm. There is a slight overlap in two flight lines along the ridge crest that captures the post-fire, pre-storm condition and the watershed condition after the first major storm. This is particularly evident at the top of Pine Canyon in an area that had been burned by the Rattlesnake Fire. The pre-fire imagery shows limited vegetation with large areas of grass cover. The soil burn severity map shows low to moderate burn severity in this area, while the vegetation burn-severity shows high burn severity. The removal of vegetation and the intensity of the rainfall were sufficient to cause dense rilling and to re-incise gullies that had begun to fill in after the post-Rattlesnake Fire erosion.

Discussion and Ongoing Work

During the summer of 2011 basin responses to rainfall were documented for five canyons burned by the Horseshoe 2 Fire. Debris flows occurred in Pinery and Pine Canyons on July 11, in East Whitetail

on July 26, and in East Turkey Creek and Pine Canyon on August 15. Channels affected by debris flows are being significantly altered as pulses of sediment are transported downstream with subsequent flows. As a result, channel cross-section areas are changing with each flow event. All other storms throughout the summer produced flood flows. Hillslope rilling, however, began with the first few minor storms in areas of high soil burn severity. Subsequent, more intense rains contributed to additional rilling and erosion.

A review of the channel conditions in Rucker, Ward and upper Pine Canyons show channels and hillslopes that had not recovered by 2011. In the upper canyons, prior to the summer storms, oversteepened channel banks of gullies had laid back and the bottoms had started to fill in (fig. 3). Following the summer storms, however, evidence of re-incised gullies and new hillslope rills and gullies are present in all of these canyons (fig. 3). In lower Rucker Canyon the post-Rattlesnake gravel/cobble channel bed had re-established a low-flow channel in some areas but not in others. As new sediment moves through the system these low-flow channels will once again fill with coarse sediment. Long-term disturbances such as these should be expected in canyons burned at moderate to high burn severity by the Horseshoe 2 Fire.

It was difficult to assess rainfall intensity associated with different flow events throughout the study area. There were only two gauges for the first half of the summer and they were essentially co-located. Rainfall intensity can sometimes be assessed for larger areas by

comparing gage data with radar data. This has been done for the 2010 Schultz Fire and is being done for the 2011 Monument Fire in the Huachuca Mountains (Youberg, unpublished data). Unfortunately, the Chiricahua Mountains are far from the surrounding radar stations, consequently, the beam is too far above the top of the mountain and often does not reliably capture rainfall on the mountains. Thus, no definitive conclusions can be drawn regarding rainfall intensity and return frequency for any of the study basins except for the headwaters of Pinery Canyon and a few tributaries to East Turkey Creek, which contain the CHIRI_B2 and KC2CPZ-1 gages. The largest storm recorded during the summer had a 2- to 5-yr, 30-min return interval.

This project is ongoing as funding allows. Aerial photographs will again be flown for the study area prior to the 2012 monsoon. This imagery will capture the first full year of erosion with snapshots in the August/September timeframe when the resource photos were flown. DEMs have not yet been developed but coarse-scale mapping of the deposits has occurred. Although there are several limitations to this study, including detailed hillslope and channel measurements, results from this study will help provide a broad understanding of post-fire erosion in the Chiricahua Mountains. Data from other studies (Gibson and others this volume) will be combined with the aerial imagery data to provide a clearer picture of sediment sources. In the long-term, these data will help inform resource decisions regarding post-fire land management.

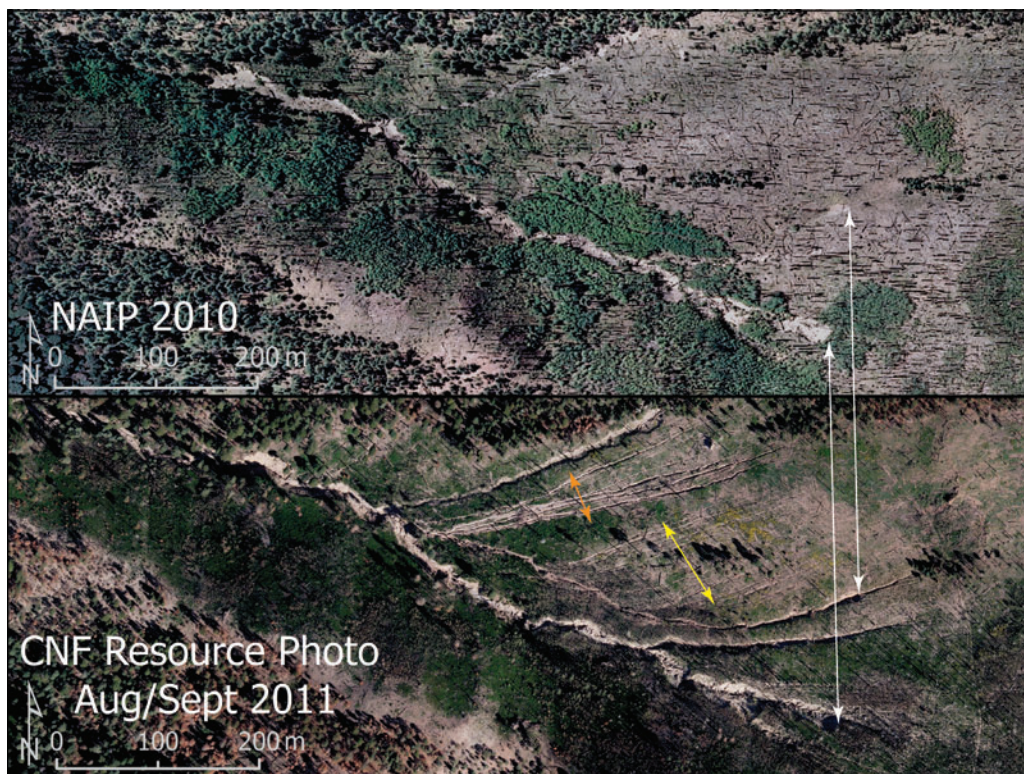


Figure 3—Ward Canyon in the headwaters of the West Turkey Creek drainage. The top photo is a NAIP 2010 image showing the post-Rattlesnake burned area and erosion. After the 1994 fire, post-fire runoff carved a ~10-m deep gully. By 2010 the gully banks had laid back and the gully was partially filled. Bottom photo was taken during late summer as part of the 2011 USFS resource photo acquisition program. This photo shows post-Horseshoe 2 Fire erosion from mid August storms with new rills (yellow arrow) and gullies (orange arrow), and re-incision and headward migration of previously existing gullies (white arrows).

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