

Depositional Characteristics and Sediment Availability Resulting from the Post-Schultz Fire Floods of 2010

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Introduction

Wildfire is a major land management concern due to direct impacts of fire on forest resources, and potentially negative effects on landscape processes by increasing rates of runoff, erosion, downstream sedimentation, and overall site degradation (DeBano et al. 1998, Neary et al. 2005, Robichaud et al. 2010). In the United States the number of fires has been increasing over the last decade, as have fire size and severity (National Interagency Fire Center 2009).

The largest and most detrimental of fire of the 2010 fire season in northern Arizona was the Schultz Fire. From June 20th to July 30th 2010, the Schultz Fire burned 6,100 ha on the eastern slopes of the San Francisco Peaks, (Fig. 1). This was a wind driven fire, consuming approximately 60% of the total burn area in the first day. Ponderosa pine and mixed conifer forest on steep to moderate slopes of the mountain front and upper piedmont zone of 11 ephemeral watersheds (Table 1) were impacted.

Prior to the fire and subsequent flooding, the upper mountain had few defined channels consisting largely of ridge-swale topography with thick mixed-conifer forest cover and a well-developed O horizon (10-30 cm). These swales become more defined channels in the ponderosa pine-dominated piedmont zone. Before the fire these channels rarely carried flows. The slope varies from 60% to >100% on the upper mountain face to 30% to 60% in the piedmont zone and to 5% to 7% at the head of the alluvial fans. Scattered housing developments, most of which are less than 40 years old, occupy the fans.

The onset of the monsoon season in mid-July 2010, the 4th wettest on record, resulted in debris deposition on the alluvial fan with a series of discrete flood events over the following 6-weeks of summer precipitation. Over 1000 residents in this area were evacuated from their homes during the fire itself and many experienced damages to property due to repeated post-fire flooding.

Objectives

This study examines depositional processes from the piedmont zone to the outwash plain by determining variability in grain size of post-fire flood deposits. Data from the steep channels of the mountain front are excluded from this analysis because currently these channels are predominantly erosive supplying the material that is deposited below. The purpose of this research is to better inform land and civic managers on post-fire sedimentation and depositional processes, and to assist efforts managing post-fire flows and recovery.

Materials and Methods

The depositional characteristics of post-Schultz Fire flooding were evaluated by sampling sediments across landscape features to capture variability in grain size of material transported by the flows. Sampling techniques were based on landscape position within two primary

zones: the confined channels of the piedmont zone, and the outwash plain of the depositional fan where flood-impacted developments are situated.

Basin 7 (Fig. 1), was sampled to determine sediment characteristics and availability for future transport from the piedmont zone. This watershed was chosen because it had direct impact on the developments downstream of the burn area. The focus of this analysis is the depositional area from the piedmont zone downstream. Basin 7 ranks high (2nd of 11, Table 1) in the percentage of high-severity burn, and has had debris flows in every tributary, providing ample sediment source for fluvial transport.

The second landscape zone sampled was the depositional fan across the flood area between several developments that were inundated (Fig. 1). Sampling was restricted to public lands to limit disturbance of flood deposits from human activities (e.g. the removal or reorganization of material), and the ability to determine what was indeed a recent flood deposit.

Sediment samples within the piedmont channel of Basin 7 were taken at randomly selected cross-section locations. Sample depths and cross-section measurements were used to estimate the volume of sediment available for future mobilization. At each cross-section location the depth of the recently disturbed layer (flood deposited material) was determined at the channel thalweg and a sediment sample was taken. The depth of the flood deposit and the associated sediment sample were determined by excavating the channel bed until small intact tree roots (<1mm diameter) were present, indicating the boundary of the flood deposit and the preexisting material. At each cross-section location 1-2 sediment samples were taken.

Sheet flow flood deposits on the fan were sampled along twelve randomly selected transects situated perpendicular to the direction of flow (Fig. 1). On each transect 3-4 points across the flood deposit were sampled at undisturbed locations. The depth of the fresh deposit was measured down to the previous ground surface, as indicated by the presence of cinders and organic matter, and a sediment sample was taken.

Outwash plain sediments were analyzed using the hydrometer method. Hydrometer readings and the temperature of the sample are taken after 30 and 60 seconds, 90 minutes, and again after 24 hours. Hydrometer readings are corrected for temperature and then the proportion of sand, silt, and clay particles are calculated as a percent and sediments are classified in a textural class.

Results and Discussion

Grain-size distributions determined by sieve analysis of within channel deposits at 10 cross-section locations in the piedmont zone of Basin 7 are summarized in Fig. 3. The median particle (D_{50}) for these samples ranges from approximately 1-8 mm. Within channel deposits are dominated by coarse sands and gravel, with coarser deposits generally occurring further upstream. The proportion of fines (<0.074mm) is less than 4% for all samples within the channel. Sediments in the piedmont zone channels are granular, with minimal cohesion, and readily available to be transported downstream. These sediments were deposited by several flood events that occurred during the 2010 monsoon season following the Schultz Fire. Initially the channels were incised between 0.3 and 1 m. While much of this scour may have occurred during the July 20, 2010, event, which was the highest intensity storm of the season over the burn area, scour may also have occurred during the July 22, 2010, event, when soils likely had higher antecedent moisture content. After this initial incision, sediments were deposited in the channels, often times raising the pre-fire channel thalweg. Average depths of post-fire flood deposits in the piedmont range from 0.5 to 1.4 m. In channels located in the lower portion of the piedmont zone, post-fire sediments have raised the pre-fire channel bed elevation. Infilling of the channel in this manner is consistent with typical alluvial fan formation (Blair and McPherson 1994).

Hydrometer method analysis indicates that 65% of outwash plain sediments are silts (0.074mm – 0.05mm) (Fig. 3). Ten of the twelve composite samples are texturally classified as silt-loams, while the other two transects, which are also the furthest upstream, are loams.

The fine sediments deposited across the outwash plain were the result of extensive sheet flows originating in the confined channels of Schultz Fire burn area. The fresh deposits of silt and clay across the outwash basin differ from the previous soil surface. Prior to the post-fire flooding of 2010, the soil was well-drained and very cindery loamy sand (Coconino National Forest 2001). It is likely that a depositional event of this magnitude has not occurred on this landscape since Sunset Crater erupted, nearly 1000 years ago. Silty loam sediments from post-fire floods cover ~75km² of the outwash plain, and are superimposed on lapilli tephra (cinders) from an eruption that occurred sometime between 1080 -1150AD.

Extensive deposition of fine sediments on the toe of the fan and outwash plain created an impermeable layer on the alluvial surface easily observed during and after flood events. Also known as depositional crusts, the impermeable layer observed in the outwash plain reduces infiltration and limits plant establishment (Valentin and Bresson 1992).

Grain size analysis of samples taken from post-fire flood deposits in the piedmont zone of Basin 7, and the alluvial surface and outwash plain between downstream housing developments indicate a reduction in particle diameter from gravel and coarse sand to silts and clay. At the transition between the piedmont zone and the head of the alluvial fan the slope is 5 to 7%. On the alluvial fan the slope lessens to 2 to 4%, and decreases further in the outwash plain to less than 2%.

Channel confinement also decreases with slope. There are no channels extending from the alluvial fan to the outwash plain. The decrease in slope and lack of confinement caused flow velocity to drop off substantially driving differential deposition between landscape features.

The burnt slopes of the San Francisco Peaks lost a substantial amount of material during the 2010 monsoon season following the Schultz Fire. Debris flows scoured material from the channel beds of several watersheds across the burn area supplying coarse sediments to the piedmont channels below. Hillslope erosion, facilitated by rill and gully formation across the landscape, supplied fine sediments and ash to form hyperconcentrated flows. Initial flood events of hyperconcentrated flow transported fine grained sediments and ash across the alluvial fan and outwash plain effectively sealing the previous surface of cinders. Surface flood deposits of fine sediments across the 75+ km² flood area of the alluvial fan and outwash plain, along with the scoured channels of the basins above caused secondary flood events to respond more quickly with increased sensitivity to precipitation.

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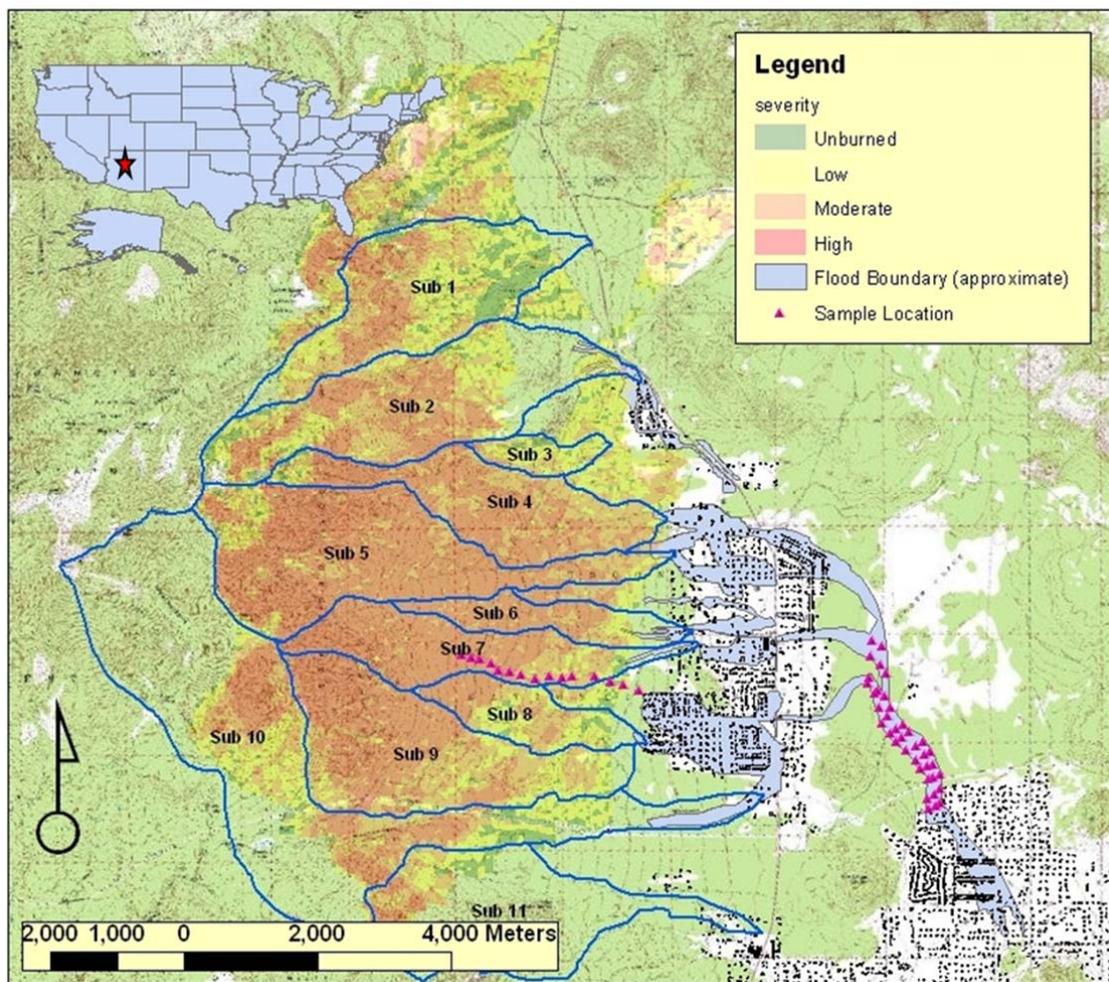


Fig. 1 Schultz Fire boundaries with severity classification, watershed delineation, post-fire flood flow boundaries, and sediment sample locations.

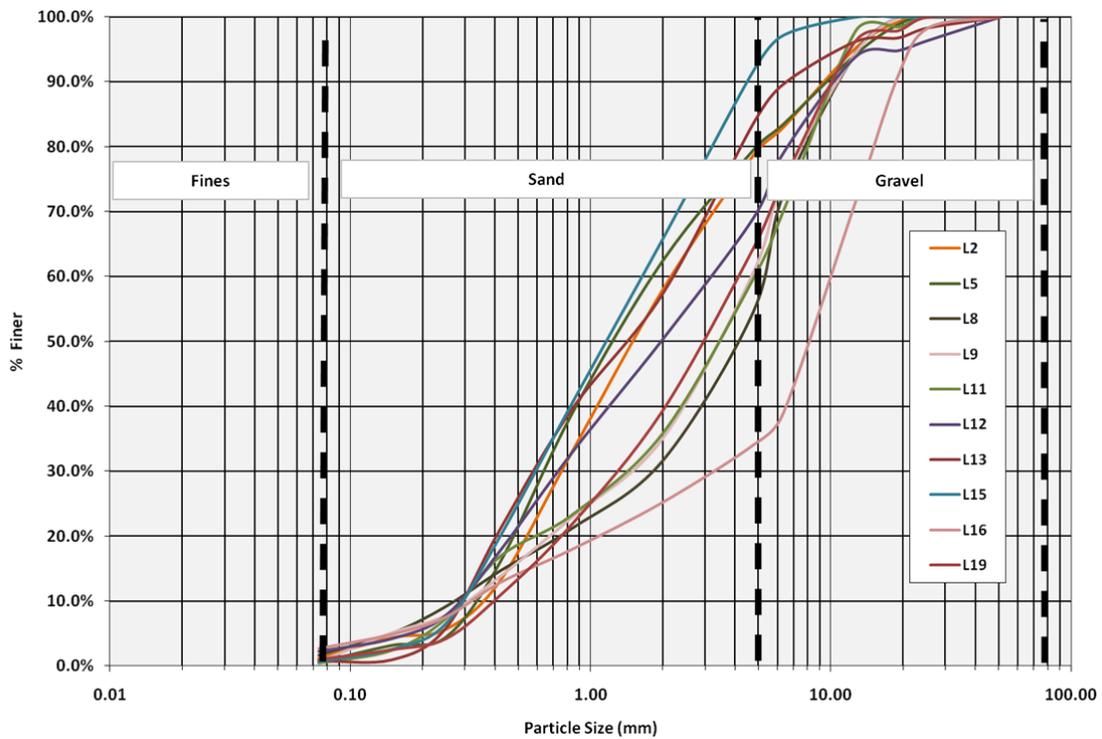


Fig. 2 Grain-size distribution determined by sieve analysis for piedmont sediments at 10 cross-section locations. L2 is the furthest downstream, L19 the furthest upstream.

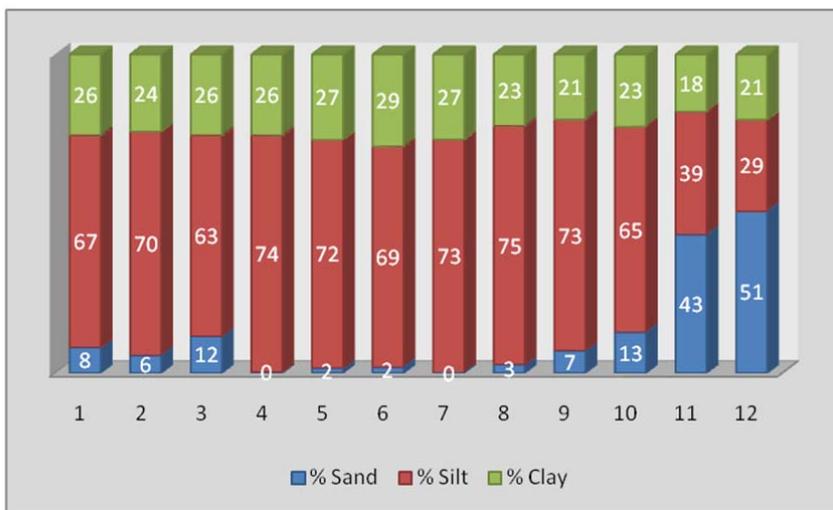


Fig. 3 Outwash-plain particle size using the hydrometer method. Sand: 2- 0.074 mm, silt: 0.74-0.005mm, clay: <0.005mm.