Reconstruction of a Geomorphically-Effective Flood Following the 2012 High Park Fire
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Introduction
After a wildfire, watersheds are extremely vulnerable to geomorphic change due to the altered physiographic properties of the landscape. In June 2012, the High Park Fire burned over 353 km² near Fort Collins, Colorado, making it the third largest fire in Colorado’s recorded history. Our monitoring began immediately after the fire, and we have had the unusual opportunity to compare channel changes from rainstorms and snowmelt with two extreme events, a short-duration high-intensity thunderstorm on 6 July 2012 that generated severe flash flooding and erosion downstream, and the long-duration, lower-intensity 200-300 mm rainstorm from 9-15 September 2013. These storms provide an opportunity to examine how the spatial and temporal dynamics of precipitation interact with watershed topography to produce persistent geomorphic changes in burned areas.

The objectives of this poster are to: 1) document channel changes from multiple rain and snowmelt events over time; 2) relate the spatial pattern and intensity of rainfall to the both the type and magnitude of channel changes; and 3) evaluate the models. The primary study areas are Skin Gulch and Hill Gulch, which are about 15 km² watersheds with similar orientation that respectively had 62% and 68% of their area burned at moderate or high severity (Fig. 1).

Methods
The data being collected include airborne LiDAR surveys of watershed topography, repeat surveys of monumented cross-sections and their associated longitudinal elevation profiles, and terrestrial LiDAR surveys of channel heads and selected in-channel locations. Precipitation is being characterized by a dense network of tipping bucket rain gages plus radar data from the NEXRAD WSR-88D radar in Cheyenne, WY, and the CSU-CHILL radar station 60 km east of the study area. The high temporal resolution of the field observations allow us to quantify the spatial and temporal patterns of flash-fire erosion and deposition through much of the main channel network. Both 1D (HEC-RAS) and 2D (Navy2D) hydraulic models to are being used to compare spatial distributions of velocity and boundary shear stress for a range of discharges, and these results will allow us to better quantify and understand the physical mechanisms responsible for the observed erosion and depositional patterns in response to different rain and snowmelt events.

Field Observations
Our observations and field surveys (Figs. 2, 3) show that the watersheds are following a geomorphic sequence similar to the classical Schumm (1977) channel evolution model. In general, increased post-fire runoff and hillslope erosion during summer thunderstorms increase sediment supply to the channels and lead to considerable deposition (Figs. 2A, 2B, 3). These deposits remained largely intact during the relatively dry fall and winter (Fig. 2C). Large snowmelt events and low intensity rainstorms during the late spring generated little or no erosion from the hillslopes, and the supply-limited streamflow eroded much of the previously deposited sediment (Fig. 2D). The cycle repeated during the second summer after burning (Figs. 2E, 2F, 3). The extreme storm in September 2013 caused dramatic erosion and bed armoring in the upper part of the basin and significant deposition lower in the basin (Fig. 2F).

Modeling Results
Precipitation: Despite relatively modest storm-total precipitation (Fig. 4A), the western portion of Skin Gulch was heavily impacted by a convective thunderstorm on 6 July 2012 (Fig 2A). Radar time series suggest that a short-duration (<50 min) high-intensity (>90 mm/h) storm cell over the western part of the watershed that burned at high intensity (Fig. 4B) led to the runoff responsible for the severe localized geomorphic response. The recurrence interval for these two precipitation maxima (Figs. 4, 5) are 5-25 and 2-10 years, respectively (NOAA). In contrast, a pre-200-300 mm storm on 9-15 September 2013 storm had a relatively low intensity with a recurrence interval of 200+ years (NOAA). This storm caused dramatic erosion and bed armoring in the upper basin but significant deposition in the lower basin (Figs. 2, 3).

Flood Reconstruction: The peak discharge (Q) along with the associated velocity and shear stress for the 6 July 2012 event were estimated by matching the inundated area and the water surface elevation calculated from the 1D and 2D models, respectively, to field surveyed high water marks (HWM). Simulations suggest a magnitude of 4000 m³/s for this high-intensity, fast-rising hyetograph. A pre-recurrence interval of 50-100 years based on the USGS StreamStats model (Capusus and Stephens, 2009) 2D modeling suggest that constrictions and expansions associated with downstream changes in valley width control locations of erosion and deposition in the channel. The computed shear stresses (Fig. 6B) are competent to mobilize boulders >500 mm in diameter, corresponding to field observations of imbricated boulders. We can further constrain our best estimate of the peak discharge by comparing model-predicted surges to the observed HWMs (Fig. 5). This exercise suggests the discharge for this event was on the order of 100 m³/s.

Conclusions
• The two main study watersheds follow a consistent post-fire geomorphic sequence of deposition during summer thunderstorms and incision during spring snowmelt. The unusual storm event of September 2013 produced erosion in the headwaters and deposition downstream. The effects of this event will be investigated in future research.
• Moderately intense precipitation localized over high severity burn areas in Skin Gulch on 6 July 2012 resulted in massive hillslope erosion and channel deposition causing a geomorphically significant event with a likely “pre-fire” recurrence interval of 50-100 years.
• Downstream variations in valley width control locations of incision and deposition. Model results suggest shear stresses in constant portions of the channel were competent to mobilize boulders; lower shear stresses in valley expansions correspond to areas of deposition.

Acknowledgements
This research is funded by a RAIPD grant from the National Science Foundation. Thank you to all for assistance in the field, private landowners for permission to work on their property and the USFS for permitting us to work in the burn area.

References