Controls on Debris Flow Bulking in Proglacial Gullies on Mount Rainier, Washington

Introducing Controls on debris flows initiated by sediment bulking - where debris sources are distributed rather than discrete - can be poorly understood. This study identifies some of these controls in glaciated basins on Mount Rainier where bulked debris flows have been generated in proglacial gullies during recent storms, and a desire exists to understand related hazards.

Hypothized Controls on Bulked Debris Flow Generation in Gullies

• We hypothesize on a basic level that a combination of bulk debris supply and debris-source area determines bulk flow occurrence. We work backwards in the above flow diagram from 1a-Energy Bulking Potential (large section below right) and Debris Supply Bulking Potential (large section below left), respectively.

• We pay specific attention to geomorphic factors as opposed to meteorological contributing to debris flow bulking.

Pyramid Gully Methods

• Used 2006 and 2009 NAF imagery and LiDAR to document gully change;

• Measured gully to measure downstream variations in change and then calculated change for each segment (see figure to right for volume calculations);

• Extracted segments of hillside contributing area above the east (left) gully and to elevation hillslope controls on landward into the gully (see above right).

• Used an estimate of flood discharge for the 2006 storm to estimate sediment discharge rates and debris flows durations to test whether gully walls alone are sufficient to generate bulked debris flows. (see inset to right)

Analysis of slope and drainage area in debris flow gullies and surrounding proglacial networks extracted from LiDAR DEMs in debris flow and non-debris flow basins (DFB and NDFB).

• Measured slope and drainage area at upstream (cressus below, analogous to x = 0 m on Pyr. gully; Regression (Panel B) divided by (Proglacial Area) suggested Gully; Regression (Panel B) divided by (Proglacial Area) suggested Gully; Regression (Panel B) divided by (Proglacial Area) suggested Gully; Regression (Panel B) divided by (Proglacial Area) suggested Gully; Regression (Panel B) divided by (Proglacial Area) suggested

Longitudinal Measurements of Gully Change and Morphology

• Three sub-mutual display distinct yield rates. Similar patterns in yield rates along debris flow gullies in burned areas have been attributed to increasing sediment concentrations and corresponding enhanced ability of the flow to entrain material, particularly at the abrupt increase at 500-1000m (Sanet al. 2008). By implication, this suggests a gully must be sufficiently long for the bulking process to develop.

• Spikes in hillside contributing area may promote discrete landwinning into the gully where walls are sufficiently steep and high.

• Bedrock exposures in gullies were associated with little observable width change.

• Variations in local longitudinal gully slope appear unimportant for yield rate, however, minimal yield rate in sub reach 3 and moderate slopes suggest there are likely threshold slopes required for bulking.

Conclusions

• Apparent dependence on steep slopes found in a-S trends suggests steep gullies have generated debris flows.

• Drainage network analysis of the two basin types (above) suggests that gullies produce debris flows to identify controls on debris flow initiation. Identifying these controls will allow us to make interpretations of debris flow-gully relationships.

• With glacier retreat, can we expect amplified debris flow hazards?

• Our study's approach: Measure debris flow gullies and catchments and compare with areas unassociated with debris flows to identify controls on debris flow initiation. Identifying these controls will allow us to make interpretations of debris flow-gully relationships.

• Despite extensive study of Mount Rainier hazards, the debris flow record is short and incomplete, extending to low slopes.

• We measured hillslope angle (θ), gully length (L), and gully segment length for segment volume (V) contributions.

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• Flood discharge (Qf) can help identify debris flow initiation:

• Sediment discharge (Qs) = Qf - f(1 + a) - (f - a)

• Debris flow duration (Df) = (Qf - f(1 + a) - (f - a))/Qs

• A 2006 video-taped debris flow on Mount Rainier lasted 6.5 hours, placing our calculation in reasonable range.

Implications for Debris Flow Hazards in Glaciated Catchments

• Apparent dependence on steep slopes found in A-S trends suggests steeper gullies have generated debris flows.

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• Drainage network analysis of the two basin types (above) suggests that gullies produce debris flows to identify controls on debris flow initiation. Identifying these controls will allow us to make interpretations of debris flow-gully relationships.

• Areas with bedrock exposures in gullies were associated with little observable width change.

• Variations in local longitudinal gully slope appear unimportant for yield rate, however, minimal yield rate in subreach 3 and moderate slopes suggest there are likely threshold slopes required for bulking.