Empirical prediction of debris flow avulsion and runout exceedance probability using a debris flow inventory from Southwestern British Columbia

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EXTENDED ABSTRACT
With the growing need to expand development into mountainous regions, many communities and infrastructure projects are built upon alluvial fans, which may be subject to episodic debris flows. Debris flows can occur with little or no advanced warning, attain extremely rapid velocities, and impact areas far from their source. Debris flow runout is controlled by many competing factors, including topography, event volume, water content, and rheology (Hungr et al. 1984; Rickenmann 2005; de Haas et al. 2015). Further complicating runout is avulsion, which occurs when part or all of the flow suddenly leaves the established channel and directs flow elsewhere on the fan. Currently, there is limited guidance for predicting debris flow avulsion scenarios.

Many tools have been developed to delineate potential inundation areas, ranging from simple empirical correlations to numerical models. Numerical models can be powerful predictive tools, but their use can also be limited by inadequate knowledge of initial conditions or material properties. Input parameters used in semi-empirical numerical models such as DAN3D (McDougall and Hungr 2004) require calibration through back-analysis. With every numerical model, simulating the appropriate volume and character of material that is entrained from the path can be particularly challenging.

Empirical methods provide a simple yet practical alternative for predicting debris flow runout, relying on observations of past events. Many empirical methods use geometric scaling correlations between event volume and travel angle or inundation area (e.g. Corominas 1996; Iverson et al. 1998). The inherent variability in observed runout trends can be used to establish limits of confidence in runout estimates for probabilistic hazard assessments (e.g. Schilling et al. 2008; McDougall 2016). Figure 1 shows an example of a probabilistic approach for predicting runout exceedance on a debris flow fan.

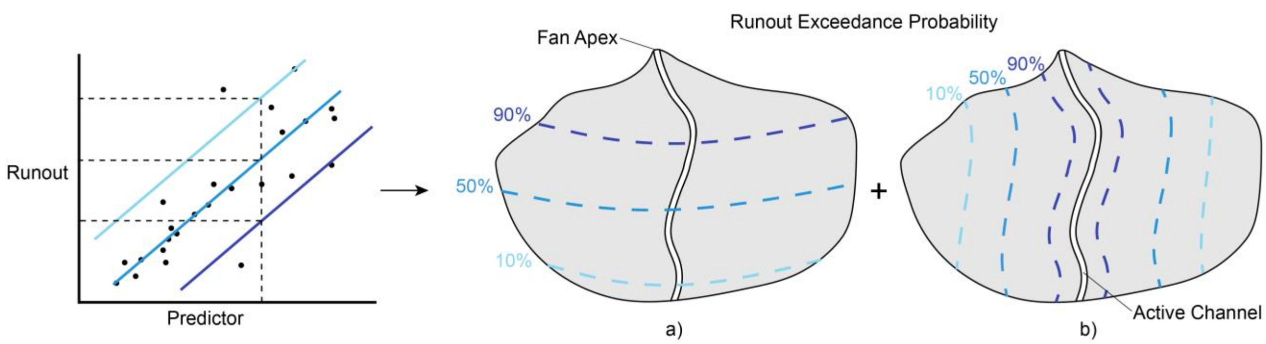

Figure 1. Probabilistic runout exceedance prediction framework for a debris flow fan based on a) distance from the fan apex and b) distance from the active channel.

de Haas et al. (2017) studied the spatio-temporal patterns of debris flow activity by mapping debris flow deposits and summarizing the lobe evolution with flow direction, runout, and fan gradient, all measured relative to the fan apex. Based on these methods, a new probabilistic empirical approach to predicting debris flow avulsion and runout is proposed by employing a normalized fan mapping method. This method is a way to systematically map debris flow deposits normalized to the fan dimensions and can capture runout phenomena like spreading and avulsion. Figure 2 demonstrates the normalized fan mapping method. The x-axis represents distance from the fan apex to the toe measured along the active channel, and the y-axis represents relative fan inundation based on measurements along concentric circles with a centroid at the fan apex. By systematically mapping numerous fan deposits, trends can be used to estimate runout exceedance probability on a fan relative to the fan area, given an estimated event magnitude and certain geomorphic conditions.

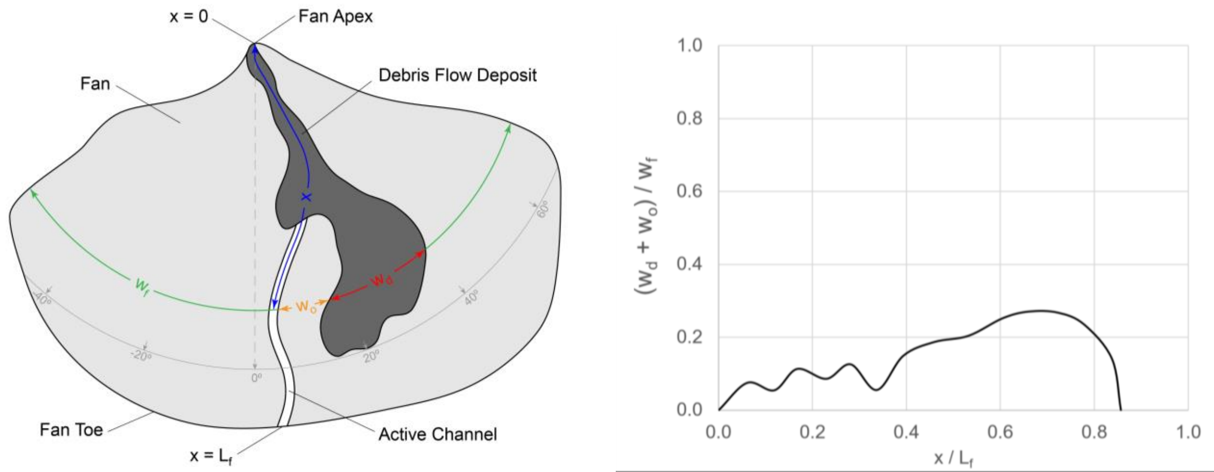

Figure 2. Example of the normalized fan mapping method used to graphically represent debris flow runout. (x) is distance along the active channel from the fan apex; (L_f) is the total fan length measured along the active channel from apex to toe; (w_o) is the offset of the deposit from the active channel; (w_d) is the deposit width; and (w_f) is the fan width.

An inventory of over 400 debris flow events in Southwestern British Columbia is being compiled, with dates spanning 1770 to 2017. For approximately 60 to 70 fans in the dataset, debris flow runout is being mapped using the normalized fan mapping method with available aerial imagery, LiDAR data, field observations, existing engineering reports, research publications and theses. In addition, morphometric parameters of the watershed, channel and fan area are being collected. The dataset is being used to develop and test empirical relationships for predicting probability of channel avulsion and runout exceedance. Trends can be used to inform hazard intensity maps and as a regional screening tool for risk-based land-use decisions in British Columbia. Extension of these methods to other geological, physiographic, and hydroclimatic regions could be possible with local calibration of the empirical relationships.

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