Application of the Unity Rockfall Model to Variable Surface Material Conditions

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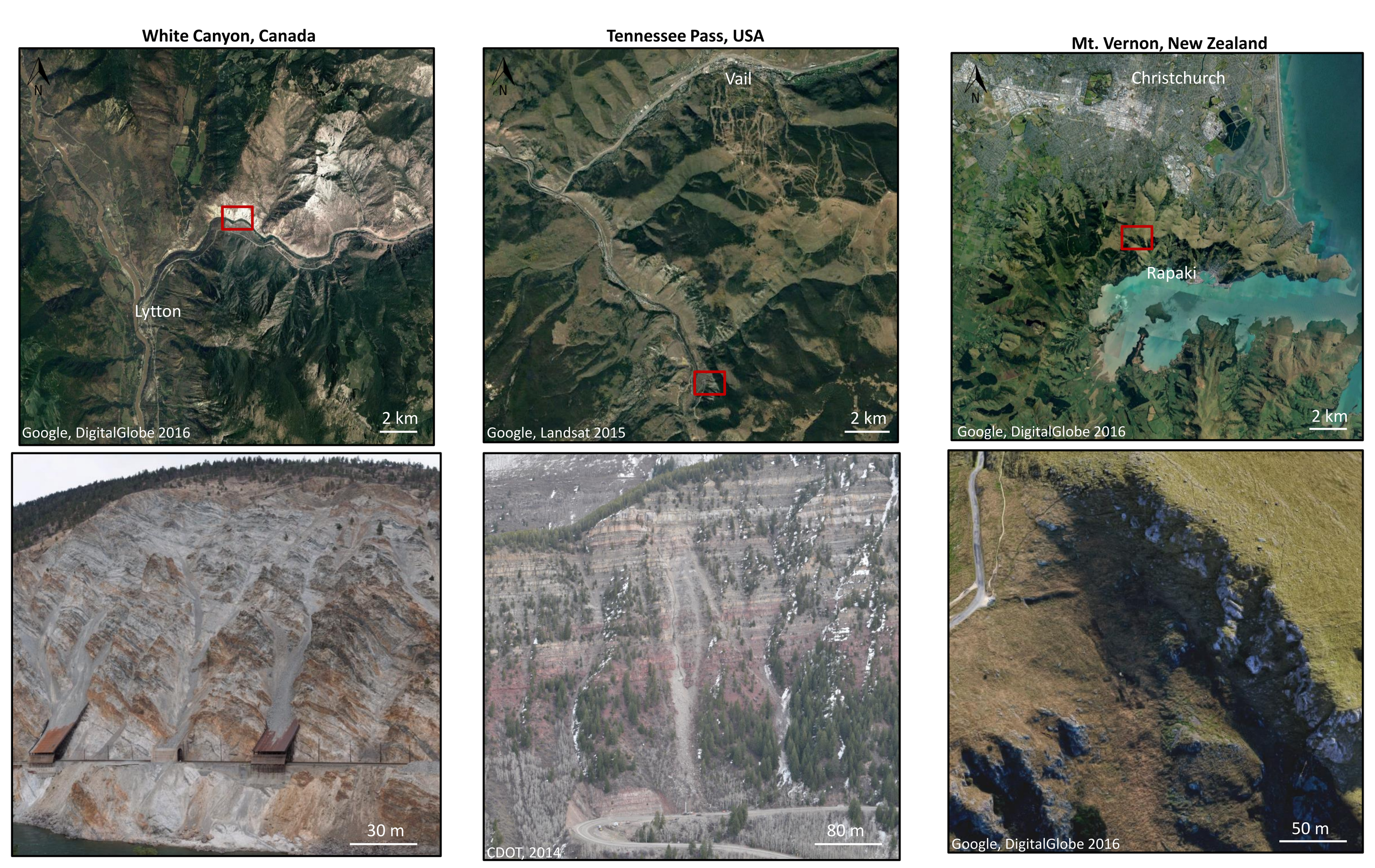
Introduction

Rockfall is a geological process that poses risks to the safe operation of transportation corridors in mountainous environments world wide. The Unity rockfall model was developed as part of the Railway Ground Hazards Research Program, leveraging high resolution 3D data to study geotechnical hazards along Canadian railways. The original goal of the Unity model was to demonstrate the capability of 3D video game engines for the realistic simulation of rockfall events (Ondercin, 2016). Further development of the Unity model is currently ongoing with a focus on model calibration from event case studies. In order to characterize the risk posed by rockfall at a given site, rockfall modelling is often carried out attempting to quantify potential block trajectories and impact energies. The use of a given model requires model calibration, showing the suitability of the model for accurately representing rockfall processes. The purpose of this work is to showcase the ability of the model to simulate rockfall runout at three different sites with variable slope conditions and release mechanisms.

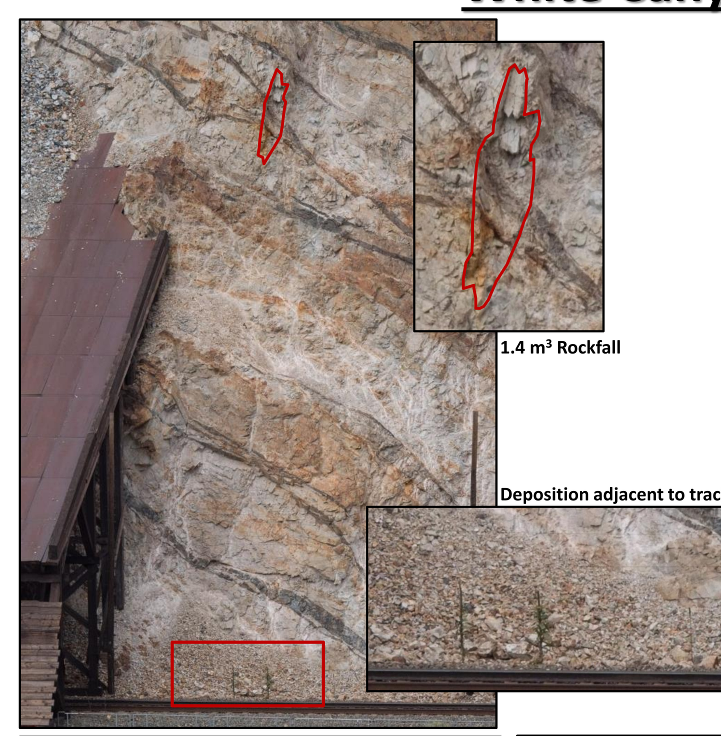
Study Sites

The three different sites considered for this study were the White Canyon, Tennessee pass, and Mt. Vernon. Each of these sites presents a different combination of slope geometry and surface materials. The data used for modelling at each of the sites was collected using a variety of remote sensing techniques including aerial and terrestrial LiDAR scanning, as well as aerial photogrammetry.



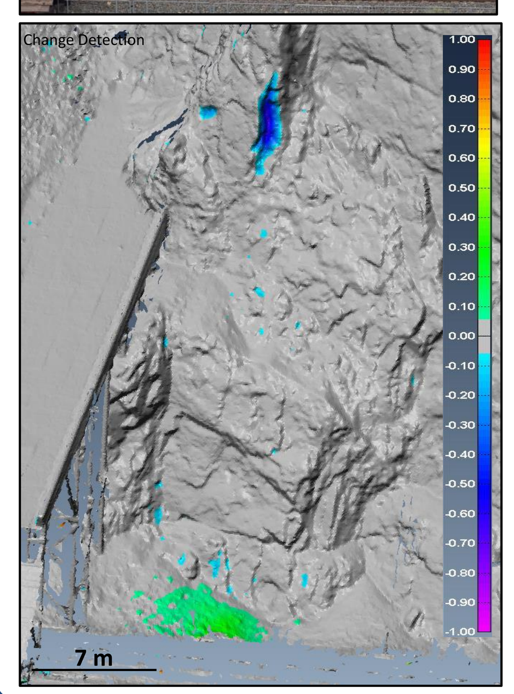
Site	Location	Source Characteristics	Runout	Slope Conditions	Data Collection
White Canyon	South-central British Columbia, Canada	Irregular elongate shaped block sourced from jointed rock mass on near-vertical face. Approximate Dimensions (m): 4.5 x 1.1 x 0.3	Distance: 8 m Angle: 68°	Near-vertical jointed rock faces with mid-slope bench and piles of accumulated talus at track level.	• Sequential centimeter scale terrestrial LiDAR • Gigapixel resolution site photos
Tennessee Pass	Central Colorado, United States	Pseudo-rectangular pillar standing on detached, failing rock mass. Toppling or sliding mechanism expected. Approximate Dimensions (m): 11.0 x 3.5 x 4.0	Distance: 342 m Angle: 65°	Steep gullied topography with talus filled debris channels, outcropping rock and sparse tree cover.	• Sequential oblique aerial photogrammetry • Site photos pre and post rockfall event
Mt. Vernon	Rapaki Bay, Canterbury region, New Zealand	Pseudo-elliptical block released from source-socket using airbag and crowbars. Approximate Dimensions (m): 1.7 x 1.0 x 0.8	Distance: 140 m Angle: 30°	Steep outcropping source zone with comparatively shallow lower slope. Lower slope substrate is a mix of loess colluvium and soil with grassy scrub cover.	• 1 m resolution aerial LiDAR • 0.1 m resolution aerial imagery • Multi-vantage video of rockfall event • Kinematic information from embedded rockfall sensors

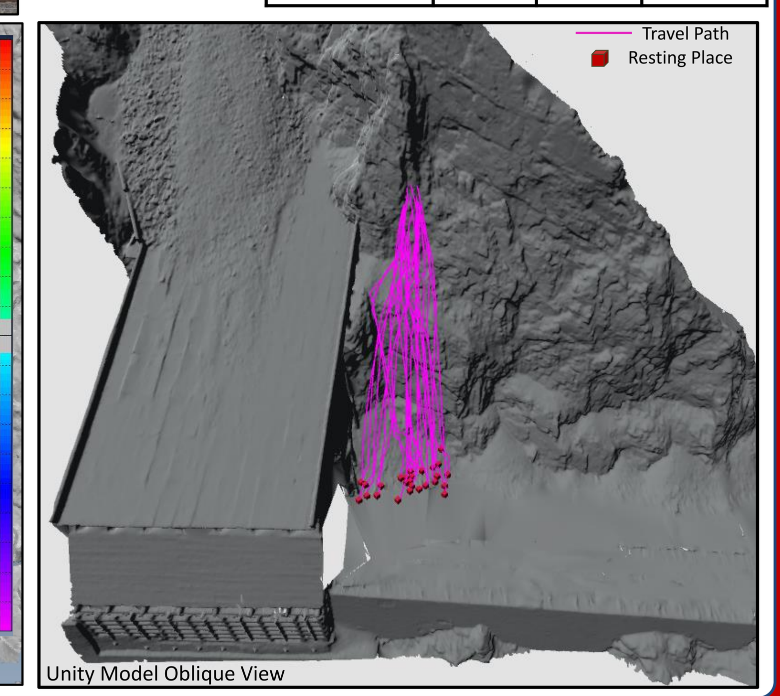
White Canyon



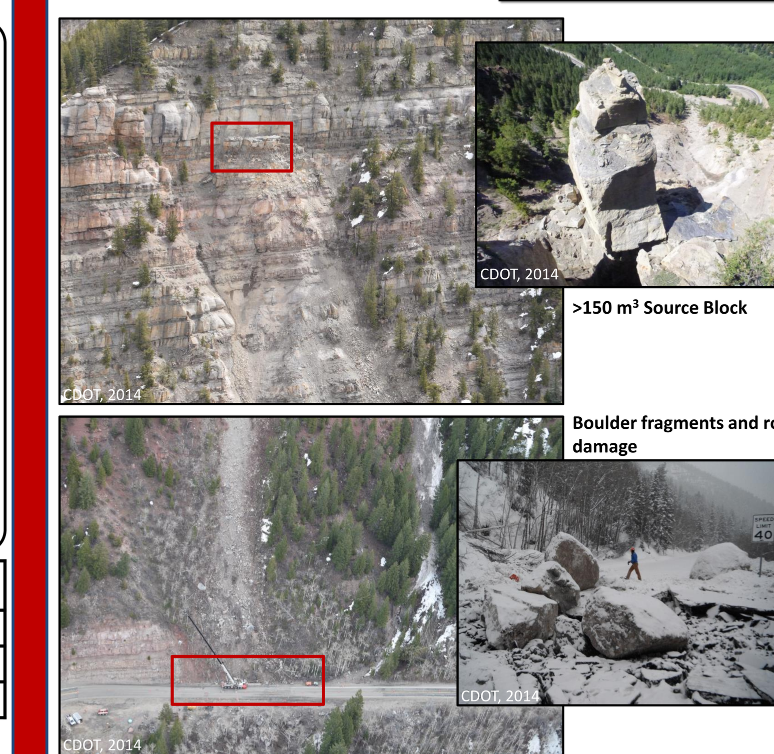
The WC failure mass was simulated using a cluster of 26 cube shaped bodies released simultaneously. This was done to better replicate the expected block fragmentation and accumulation of smaller debris seen in the talus pile at track level.

Material	COR	DF	Ground Damping
Outcrop	0.2	0.7	0.0
Thin Bench Debris	0.1	0.6	0.0
Thick Talus Cover	0.05	1.5	0.8



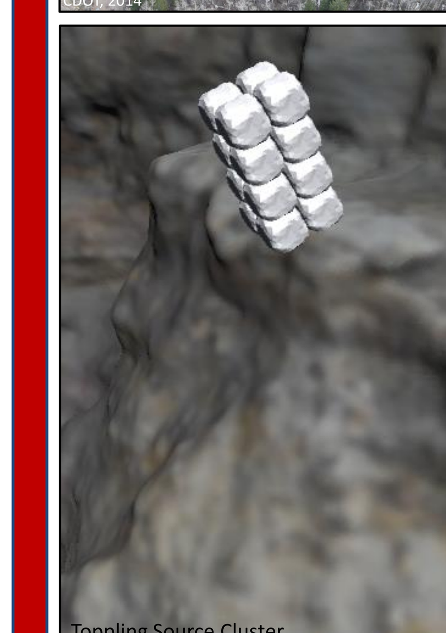


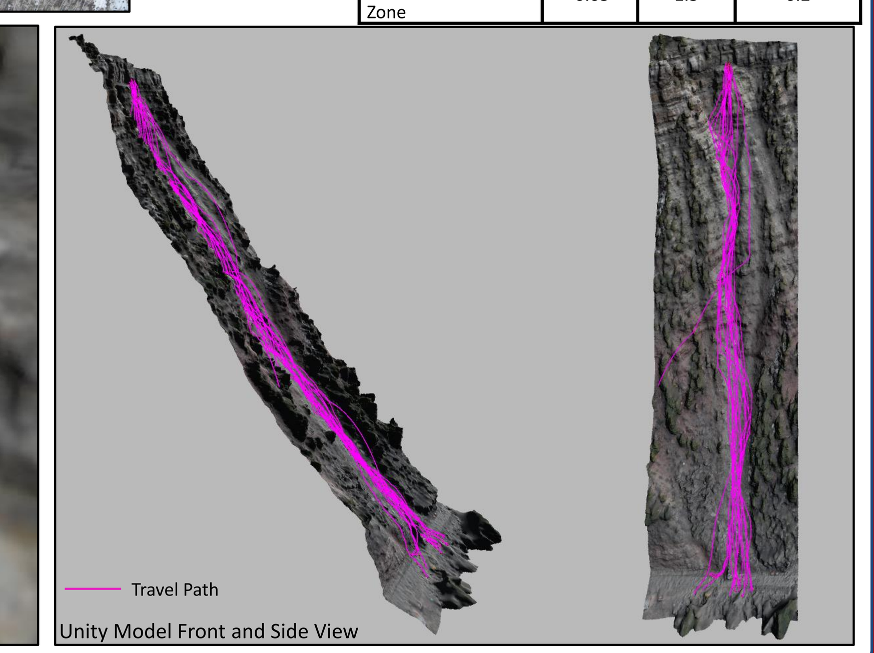
Tennessee Pass



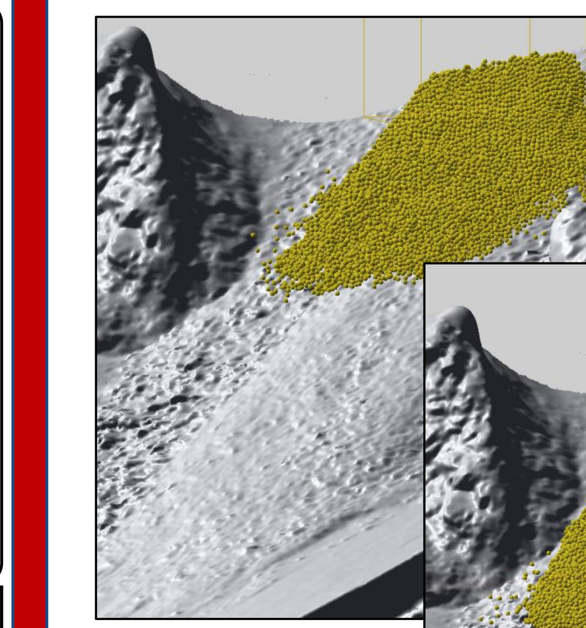
The TP failure mass was simulated using a pillar comprised of 16 rounded-cube polygons, similar in size to boulders reaching the highway. The block cluster was released at the edge of the source zone in an attempt to mimic toppling of the rock mass.

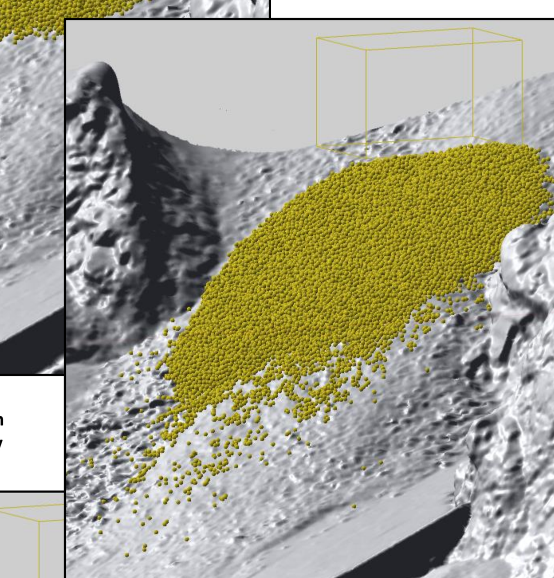
Material	COR	DF	Ground Damping
Outcrop	0.1	0.8	0.0
Thin Channel Debris	0.1	0.6	0.0
Talus and Rubble Zone	0.05	1.5	0.2



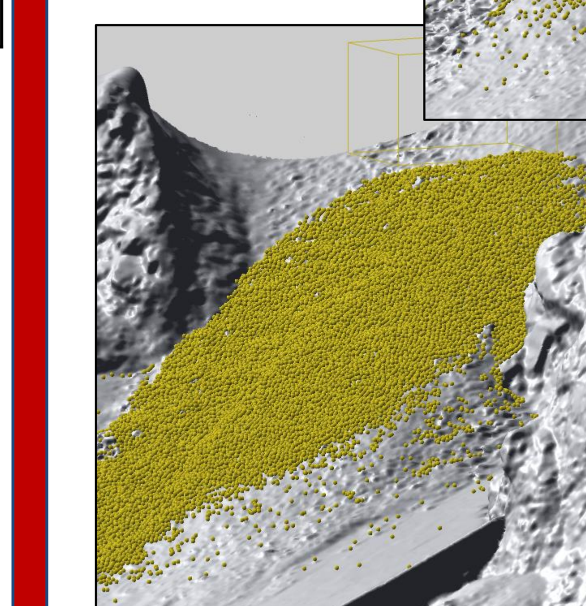


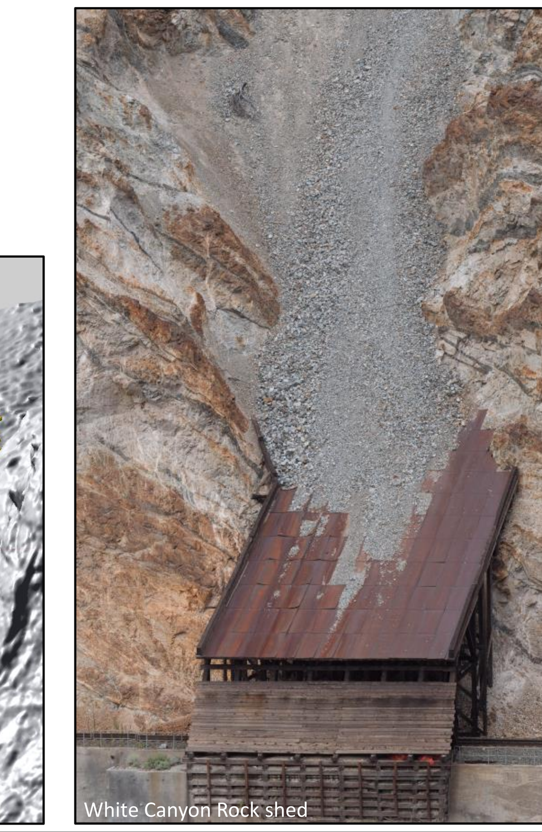
Slope Debris Modelling





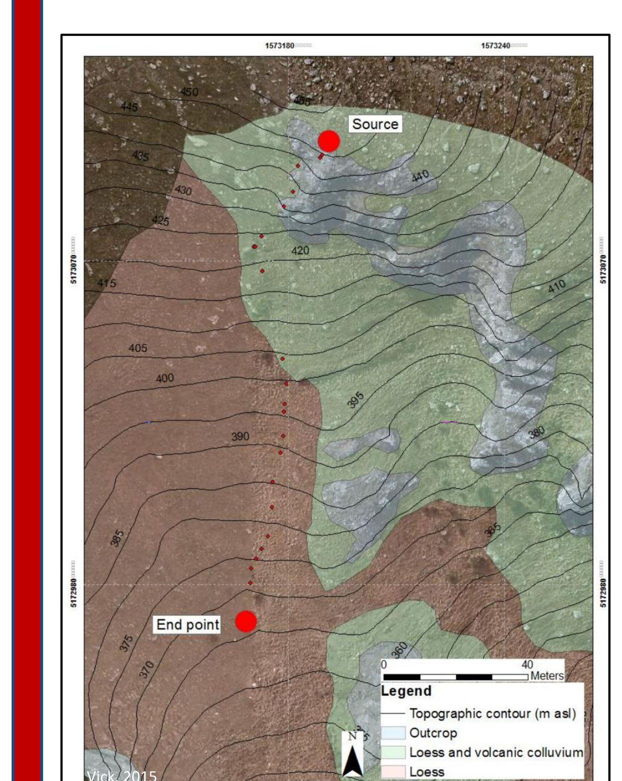
Granular particle system with over 35,000 particles in Unity

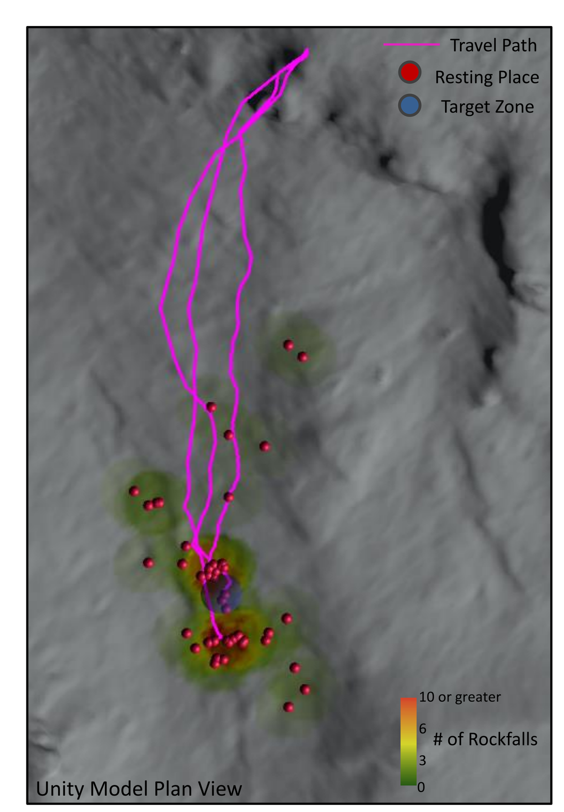


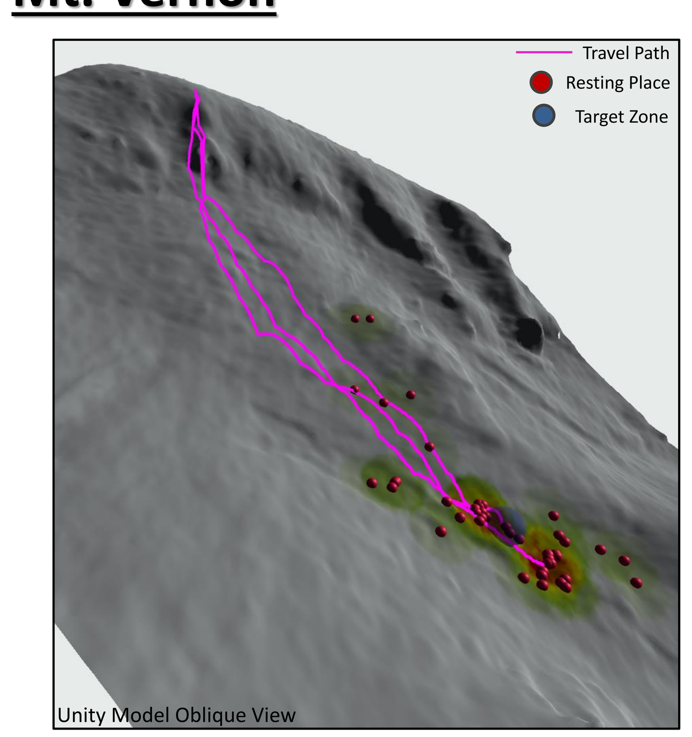


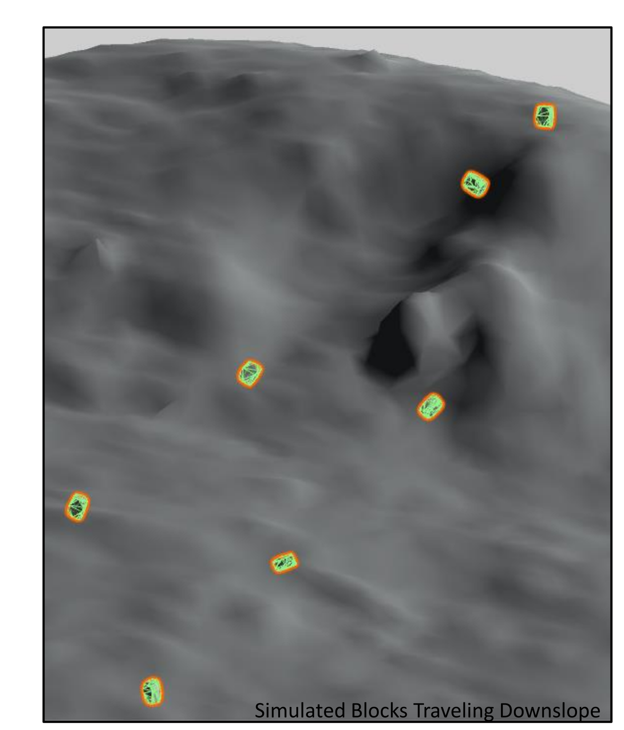
The representation of talus and slope debris is currently being experimented with through the use of constraint based particle systems. These systems, originally developed for fluid visualization, allow for the simulation of granular materials with each individual particle interacting with its neighbours. Further development of this technique could allow for the simulation of talus mobilization in debris channels as well as improved rockfall-talus interaction.

Mt. Vernon



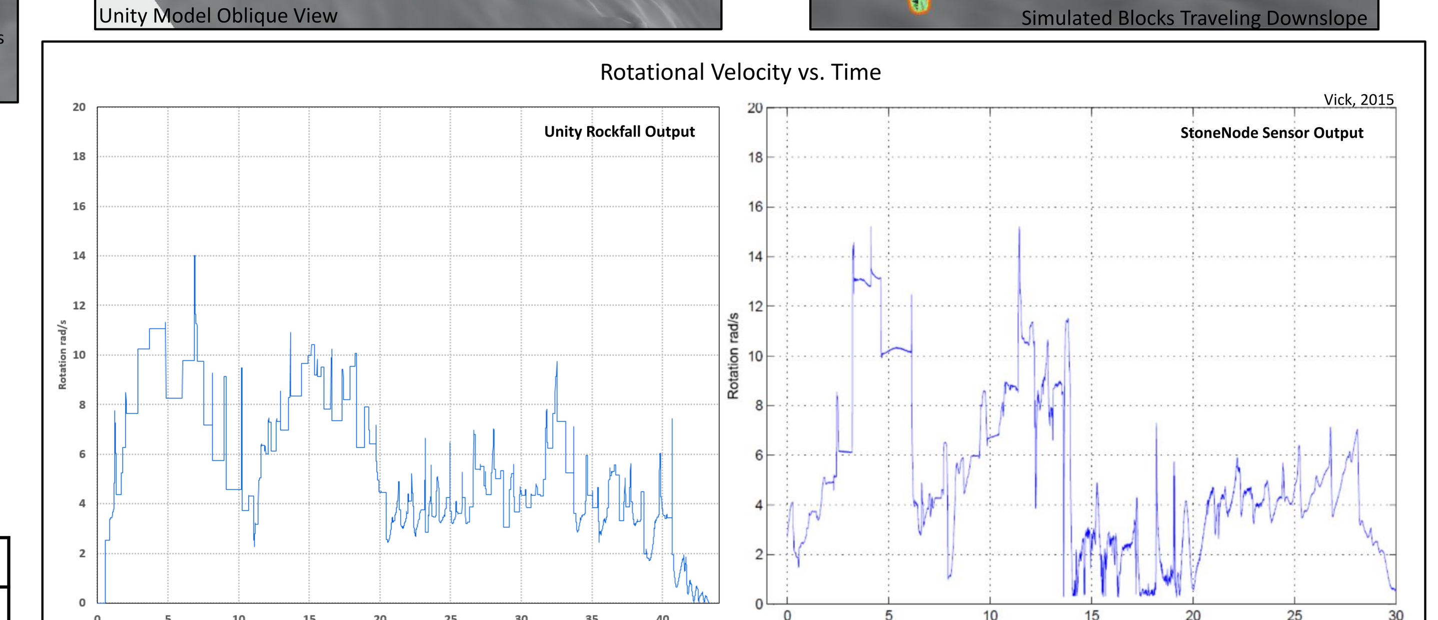






The MV rockfall was simulated as a single rounded-rectangular polygon. The long axis of the block was shortened to 1.4 m to account for a portion of the block which was lost during rock on rock impact early on in the block movement. The above figures show the finishing points for fifty simulated blocks, released with varying initial x, y, z positions and rotations. A comparison of simulated to measured rotational velocity can also be seen for one of the trajectories shown above.

Material	COR	DF	Ground Damping
Outcrop	0.3	0.8	0.0
Soil Cover	0.1	0.6	0.25



Conclusions and Future Work

The results of the modelling exercises carried out at each of the study sites show that using the Unity rockfall model, it is possible to produce 3D trajectories that correspond well with the observed runout. Comparison with the measured rotational velocity profile from the Mt. Vernon rock-rolling experiment shows that the magnitude and timing of rotation taking place in the model also aligns reasonably well with field observations. This comparison provides a means of assessing not only travel path and final deposition but the kinematic motion of the block along its trajectory. While these cases have provided initial calibration examples for the model, it is acknowledged that further examples, as well as an in-depth sensitivity analysis, are needed to better understand the effects of each parameter controlling rockfall behaviour. In future versions of the model the use of simulated granular material will be explored as a substitute for viscoplastic ground drag, with the goal of better representing block entrainment and debris-rock frictional processes.

REFERENCES

1. Ondercin, M. 2016. An exploration of rockfall modelling through game engines. M.A.Sc thesis, Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada.
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3. Colorado Department of Transportation. 2014. Tennessee Pass site photos.

Acknowledgements

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