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Rapid landscape change during the 18th March 2007 lahar at Mt Ruapehu, New Zealand

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Sediment load within dilute lahars and other outburst floods is well known to be highly transient. Sediment in transport affects flow hydraulics through density, viscosity and turbulence modification, and exerts rapid landscape change through erosion and deposition. The failure of most previous models of dilute lahars and outburst floods to include sediment transport processes is thus serious, though perhaps understandable given the lack of field and experimental measurements on flow-bed interactions. This paper applies a fluid dynamics model with a coupled sediment transport module to numerically calculate flow conditions and rapid landscape change due to a dilute lahar from Mt Ruapehu, New Zealand. We take full advantage of an exceptional and unprecedented dataset on i) pre- and post-event LiDAR-derived topography, and ii) hydraulic, geomorphological and sedimentological measurements of the lahar, to run and validate the model, respectively. Modelled bed shear stress was dominantly controlled by channel gradient and to a lesser degree by topographic confinement. Within the upper reaches of the Whangaehu Gorge bed shear stress was > 9000 Nm-2, whilst across the Whangaehu Fan values of < 2500 Nm-2 were more common. Modelled bed shear stress dramatically increased by > 600 Nm-2 per 10 minutes within the flow front and this was probably the period of greatest erosion. Modelled bed erosion within the Whangaehu Gorge was typically < 5 m and this value matches that of the LiDAR data. However, besides bed erosion, the LiDAR data also revealed significant lateral inputs of sediment including bank erosion, talus slope collapse, and a major landslide. Total modelled erosion was 3.36 x 106 m3 and 75 % of this was achieved between 10 and 40 minutes from the event initiation. In contrast 45 % of modelled deposition occurred between 40 and 140 minutes of event initiation. Modelled deposition occurred in zones along the Whangaehu Gorge that alternated between 6 - 8 m versus 1 – 3 m deposit thickness. Across the Fan, modelled deposition was < 1m. Overall, we find that the model can replicate the LiDAR-derived pattern of erosion and deposition. Discrepancies in absolute values are due to the model calculating total rather than net volumes. Furthermore, the model cannot account for lateral inputs of sediment. However, we hereby offer new insights and quantification of dilute lahar and outburst flood behaviour, particularly of transient hydraulic conditions and bed elevation changes. This hydraulic modelling method therefore has considerable advantages for process-product studies and for hazard management.