LANDSLIDES CAUSED BY THE 14 NOVEMBER 2016 KAIKOURA EARTHQUAKE, SOUTH ISLAND, NEW ZEALAND.

*Sally Dellow[1], Chris Massey[1], Simon Cox[1], Garth Archibald[1], John Begg[1], Zane Bruce[1], Jon Carey[1], Jonathan Davidson[2], Fernando Della Pasqua[1], Phil Glassey[1], Matt Hill[1], Katie Jones[1], Barbara Lyndsell[1], Biljana Lukovic[1], Sam McColl[3], Mark Rattenbury[1], Stuart Read[1], Brenda Rosser[1], Corinne Singeisen[4], Dougal Townsend[1], Pilar Villamor[1], Marlene Villeneuve[2], Jonathan Godt[5], Randall Jibson[5], Kate Allstadt[5], Francis Rengers[5], Joseph Wartman[6], Ellen Rathje[7], Nick Sitar[8], Adda Athanasopoulos-Zekkos[9], John Manousakis[10], Michael Little[7]

1. GNS Science, NZ, 2. Canterbury Univ. NZ, 3. Massey Univ. NZ, 4. ETH Zurich, Switzerland, 5. US Geological Survey, USA, 6. Univ. Washington, Seattle, USA, 7. Univ. Texas, USA, 8. Univ. California, Berkeley, USA, 9. Univ Michagan, Ann Arbor, USA, 10. Elxis Group, Greece

At 12.03 am local time on 14th November 2016 (UTC: 11.03 am 13th November 2016) a shallow magnitude 7.8 earthquake, with an epicentre located near Waiau in North Canterbury, struck the North Canterbury and Marlborough regions of NZ. The strong ground shaking caused widespread damage to buildings and infrastructure across the sparsely populated areas of the northeast of the South Island. The most visible consequence of the strong ground shaking was widespread landslides. Given the sparsely populated area affected by landslides, only a few homes were impacted and there were no recorded deaths due to landslides.

Tens of thousands of landslides were generated over 10,000 km^2 of North Canterbury and Marlborough, with the most intense landslide damage concentrated in 3500 km^2 around the areas of fault rupture. Landslides caused major disruption with all road and rail links with Kaikoura being severed. The landslides affecting State Highway 1 (the main road link in the South Island of New Zealand) and the South Island main trunk railway extended from Ward in Marlborough all the way to the south of Oaro in North Canterbury.

A feature of this earthquake is the large number (more than 200) of valley blocking landslides it generated. This was partly due to the steep and confined slopes in the area and the widely distributed strong ground shaking. The largest landslide dam has an approximate volume of 12(±2) M m^3 and the debris from this travelled about 2.7 km down slope where it formed a dam blocking the Hapuku River. The long-term stability of cracked slopes and landslide dams from future strong earthquakes and large rainstorms are an ongoing concern to central and local government agencies responsible for rebuilding homes and infrastructure. A particular concern is the potential for debris floods to affect downstream assets and infrastructure should some of the landslide dams breach catastrophically.

The majority of landslides occurred in two geological and geotechnically distinct materials: Neogene sedimentary rocks (sandstones, limestones and siltstones) where first-time and reactivated rock-slides were the dominant landslide type, and; Torlesse “basement” rocks (greywacke sandstones and argillite) where first-time rock and debris avalanches dominated.

At least thirteen faults ruptured to the ground surface or sea floor, with these surface ruptures extending the Emu Plain in North Canterbury to offshore of Cape Campbell in Marlborough. The mapped landslide distribution reflects the complexity of the earthquake ruptures. The landslides are distributed across an elongated area consistent with the elongated area affected by fault ruptures and intense ground shaking. The landslides are not clustered around the earthquake epicentre. Initial results from our landslide investigations suggest: predictive models relying only on ground-shaking estimates may underestimate the number and size of the larger landslides that occurred. The largest landslides triggered by the earthquake are located either on or adjacent to faults that ruptured to the ground surface. Surface faults

may provide a plane of weakness or hydrological discontinuity and adversely oriented surface faults may be indicative of the location of future large landslides.

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