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Harper Hills Landslides, Canterbury

Following the Mw=7.1 Darfield earthquake on 4th September 2010, a local farmer (Mrs Christine Denisse of Steeles Road) identified several cracks on the hillside above her property.

On 17th September 2010 David Petley, Nick Rosser (both of Durham University, UK) and Chris Massey (GNS Science) carried out a walkover of the Harper Hills area to make a preliminary assessment of the likely origin of the cracks.

Figure 1. Google earth image of the Harper Hills area

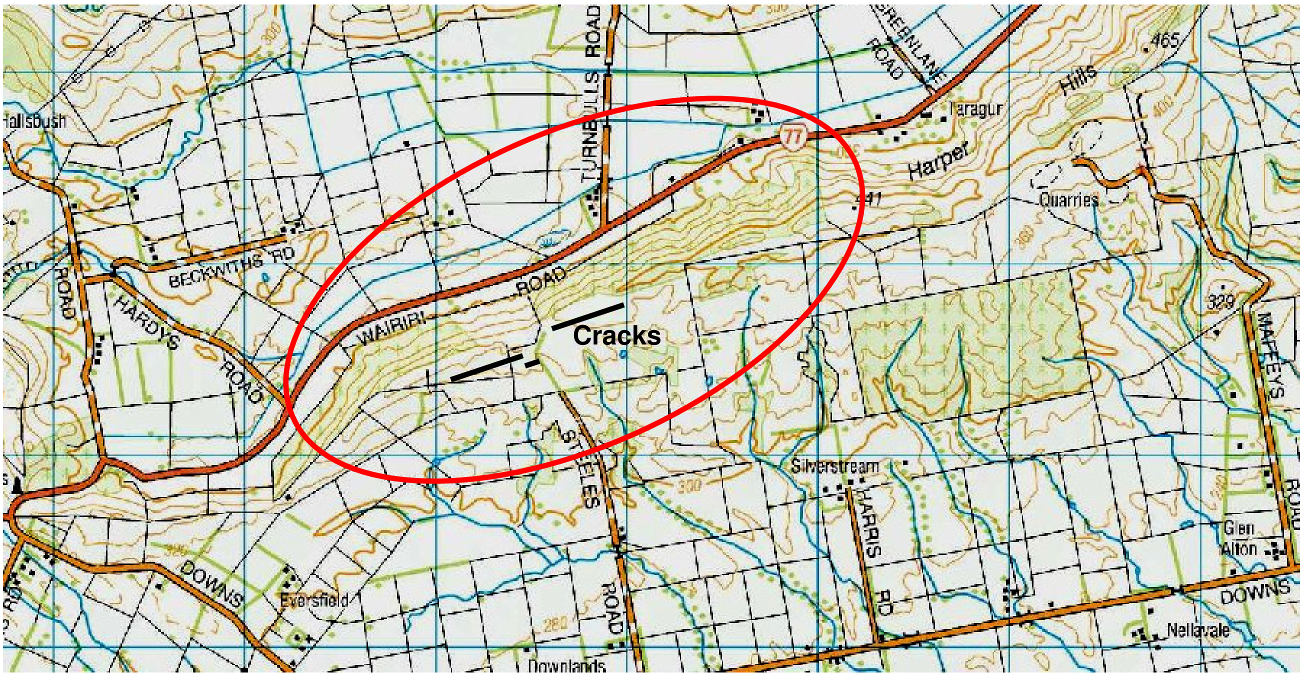

Figure 2. Extract from the LINZ topographic map of the area

Background information

According to the Institute of Geological and Nuclear Sciences 1:250,000 Geological Map 16, the Harper hills area is within the Burnt Hill Group, which comprises the Harper Hills Basalt (dark grey basaltic lava flows with smectitic clay) overlying basalt breccia, tuffs, sandstones and smectitic claystones, all of lower Tertiary age (?).

Bedding is shown to dip about 30° to 35° towards the southeast (down slope in the area of the cracks above Steeles Road, Figure 2).

These materials are shown to have been disturbed by landsliding and several landslide scarps are present on the map in this area.

The Harper Hills area had been historically mined for Bentonite.


Figure 3. Aerial oblique view of cracks (taken by Mark Quigley, Canterbury University)

Findings from the walkover

- The morphology of the Harper Hills comprises an area of steep (c.35° to 45°) slopes that dip towards the northwest, and to the south an area of less steep (c.20° to 30°) slopes that dip towards the southeast. The southeast dipping slopes are concordant with bedding and form dip-slopes, while the northwest dipping slopes form scarp-slopes.

- The dip-slope morphology of the area comprises rounded and hummocky terrain with ponded water, abundant seepages and consistently deformed surface vegetation such as bent over trees (Figure 4), all of which are indications of ongoing landslide activity. At the time of the walkover survey the surface of the slopes was saturated, with small puddles forming in hollows and depressions.


Figure 4. Consistently deformed trees on the dip slope.

- Below the ridge top (towards the southeast) the dip slopes contain several large, arcuate steps, comprising concave and convex breaks-in-slope. These steps appeared to be consistent with an old landslide head scarp and graben features.

- A prominent linear concave break-in-slope appears to mark the toe of the dip slope about 1 km southeast from the ridge crest.

- Several new prominent and persistent (several hundreds of meters in length) cracks were apparent in the pastureland at the top of Steeles Road, above and to the western side of the road. These cracks, which were noticed after the earthquake, are reasonably linear and stepped (Figures 3 and 5), and were located about 100 m below the ridge top on the southeast facing dip-slope. The cracks through the pastureland extended for about 100 metres. The cracks appeared not to be affected by minor changes in the topography, for example cutting across a pond.

- The cracks showed varying magnitudes of offset, but typically comprised about 0.2 m of each of vertical and horizontal displacement (opening). There was no indication of lateral horizontal displacement. Vertical displacement was consistent with a lowering of the ground surface down slope towards the southeast, indicating down-dip extensional gravitational movement.

Figure 5. Photograph showing the tension cracks towards the west of Steeles Road

- A second set of cracks extended from above the top of Steeles road towards the east traversing the edge of a pine plantation.

- These cracks were below the ridge top on the southeast facing slopes and were located upslope of a subtle concave depression.

- Although these cracks were linear in parts they appeared to be more arcuate in form than those towards the west of Steeles Road. These cracks also displayed larger vertical and horizontal displacements, typically 0.5 m vertical and about 0.5 to 1 m horizontal. In some locations these cracks were up to 4 m deep.

- Vertical displacements across these cracks were consistent with a lowering of the ground surface towards southeast, indicating down-dip extension.

- Additional cracks had also been identified part way up Steeles Road by University of Canterbury scientists. However, at the time of this walkover, surface evidence of these cracks had been removed by the farmer. At the time of this walkover a team of Scientists from Canterbury University were carrying out geophysical measurements at this location.

Figure 6. Photograph showing the tension cracks towards the east of Steeles Road

Interpretation of Geomorphology and landsliding

- Based on field mapping and existing information the dip slopes of the Harper Hills area appear to host multiple old landslides. Down slope of the cracks in pastureland there is an area of woodland that contains multiple signs of previous landslide events, including scarp slopes, lobes and hummocky terrain. The trees show extensive, exceptionally well-developed stem bends in a down slope direction, consistent with landslide movement in the early part of their growth cycle.

- The regional geology suggests landslide movement may comprise down-dip translation along one or more smectite layers within the Harper Hills basalt.

- Considering the geometry of these landslides it is likely that large-scale historic/pre-historic movements would have been deep-seated as the debris appears to comprise multiple relatively intact displaced blocks. Shallower, more superficial landslides probably occur on the displaced blocks periodically, possibly slowly reducing stability through breakdown of the toe support for the slope.

- It is therefore likely that the recent cracking, which is assumed to have occurred in response to the Darfield earthquake, relates to minor reactivation of these pre-existing, slowly creeping old landslides.

- No deformation of the slide blocks down slope (southeast) of the cracks was identified during the walkover.

- However, several other linearly persistent cracks were identified outside these two areas by Mark Quigley (University of Canterbury) during a helicopter flight of the area. The topographic positions of these cracks (below the ridge top on the southeast facing dip slope) appear to be consistent with those cracks near Steeles Road, although these additional cracks were outside the area covered by this walk-over inspection.

Conclusions

- The Harper hills area comprises multiple old landslides located on the dip-slope (southeast) side, parts of which show evidence of ongoing creep.

- These landslides mainly comprise deep-seated, possibly translational, displacements controlled by the regional geology (as at Abbotsford), with secondary shallow flow-type displacements occurring within the debris of the larger slides.

- The tension cracks identified in the area are located on the dip slope side of the Harper Hills below the ridge tops. Vertical and horizontal (opening) displacements comprise extension and lowering of the ground surface towards the southeast.

- It is likely that the persistent and stepped tension cracks are related to the reactivation of several pre-existing landslides in response to ground accelerations caused by the Darfield earthquake. This is one of the few recorded observations in New Zealand of incipient earthquake-induced cracking on a pre-existing large complex dip slope failure (pers. Comm. G Hancox).

Recommendations

1. Ongoing monitoring of the tension cracks following periods of heavy rain (typically >50 mm of rain over consecutively wet days), and after large aftershocks.

2. Monitoring should comprise the already installed "knock-out" pegs located either side of the tensions cracks west of Steeles Road, plus additional pegs located either side of the tension cracks towards the east of Steeles Road. However, these pegs should have nails installed on them to improve measurement quality. Ideally the local landowner should be responsible for monitoring the pegs

3. More detailed mapping should be undertaken of all of the slope cracks in this area, including those identified during previous helicopter flights

4. Attention should be made to the area east of Steeles Road as the cracks are upslope of a residential property.

5. More detailed geomorphological mapping should be carried out to identify and determine the extent of the older landslide features, including accurate delineation of areas with evidence of active creep movements.

6. InSAR monitoring of the area should be carried out to check for larger-scale slope displacements.

7. Numerical back analysis of these displacements should be undertaken to assess the magnitude of the ground accelerations required to initiate movement

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Reviewer
Graham Hancox