An initial assessment of the effects of seismically induced ground deformation on the occurrence of localised instability following rainfall in the Port Hills, Christchurch

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ABSTRACT

Seismic activity during the 2010/2011 Canterbury Earthquake Sequence (CES) caused widespread damage to sloping ground in residential areas on the Port Hills in Christchurch. Much of the damage manifested as cracking and displacement of the ground surface. While actions were taken to repair some damage, it was largely untreated in the short term, resulting in concerns about the effect that this may have on the stability of the affected slopes in future rainfall events.

This paper presents the preliminary findings of an assessment of the occurrence and nature of small scale (<100 m^2) land instability that occurs on residential properties in Port Hills suburbs, as a result of rainfall events, using insurance data obtained before and after the CES. Using insurance claims as a proxy for small scale landslips on Port Hills suburbs shows there is no distinct change in the frequency of small scale landslip activity since the beginning of the CES.

1 INTRODUCTION

The Port Hills form part of the Banks Peninsula volcanic complex located to the south of Christchurch City. The 2010/2011 CES comprised four major earthquake events and many aftershocks. These include the 4 September 2010 (Darfield) event, 22 February 2011 (Christchurch 1), 13 June 2011 (Christchurch 2), and the 23 December 2011 (Christchurch 3) events. The Christchurch 1 and 2 events were centred beneath the Port Hills and caused most of the observed earthquake induced land damage on the sloping ground.

Types of land damage that occurred include displacement of the ground surface, causing ground cracks, and also deformation related to retaining wall failures. Much of this land damage was largely untreated in the short term, and concerns were raised about how the untreated damage may affect the stability of the affected slopes in future rainfall events.

Land damage as a result of rainfall is typically characterised by small scale land instability. When occurring on specific parts of a residential property, this type of land deformation is covered by the New Zealand Earthquake Commission (EQC) insurance, as a landslip claim. The period of rainfall that generates landslip claims is referred to as a ‘rainfall event’.

The aim of this paper is to determine if the number and location of landslip claims have changed since the CES began; and also to determine any patterns or thresholds for smaller scale land instability occurring on residential properties as a result of rainfall.

1.1 Background

The EQC engaged the authors firm to undertake site investigations on residential land on the Port Hills, due to the land deformation caused by the CES. This work was conducted to assist with insurance settlement on EQC insured residential land only. The work discussed in this paper was undertaken to assess the impact of land deformation caused by the CES on the incidence of rainfall induced landslip claims on the Port Hills. To accomplish this, insurance data for landslips occurring on EQC insured residential land, before and after the CES, was obtained from the EQC.

Between September 2010 and December 2011, no rainfall event that generated landslip claims to the EQC was noted. However, rainfall in July and August 2012 generated landslip claims.

2 EQC LANDSLIP CLAIM INFORMATION

Insurance data for landslip claims on the Port Hills was provided to the authors firm by the EQC, covering the years 2000 to 2012. This data included locations of properties where claims were submitted, attributed to specific EQC defined rainfall events which occurred throughout this period. This data does not separate land damage on the Port Hills where the damage is the result of further deformation of earthquake induced land damage due to rainfall, or where claimants have not submitted a separate landslip claim for this additional damage.

2.1 Location and number of EQC landslip claims

The location of landslip claims lodged with the EQC between 2000 and 2012 are shown on Figure 1. The landslip locations are observed on residential land on the Port Hills.

There is no spatial pattern observed on the residential land for historic (pre 2010 earthquake) landslip claims. The location of landslip claims made after the CES, in July and August 2012, occurred in similar locations to those claims prior to the CES.

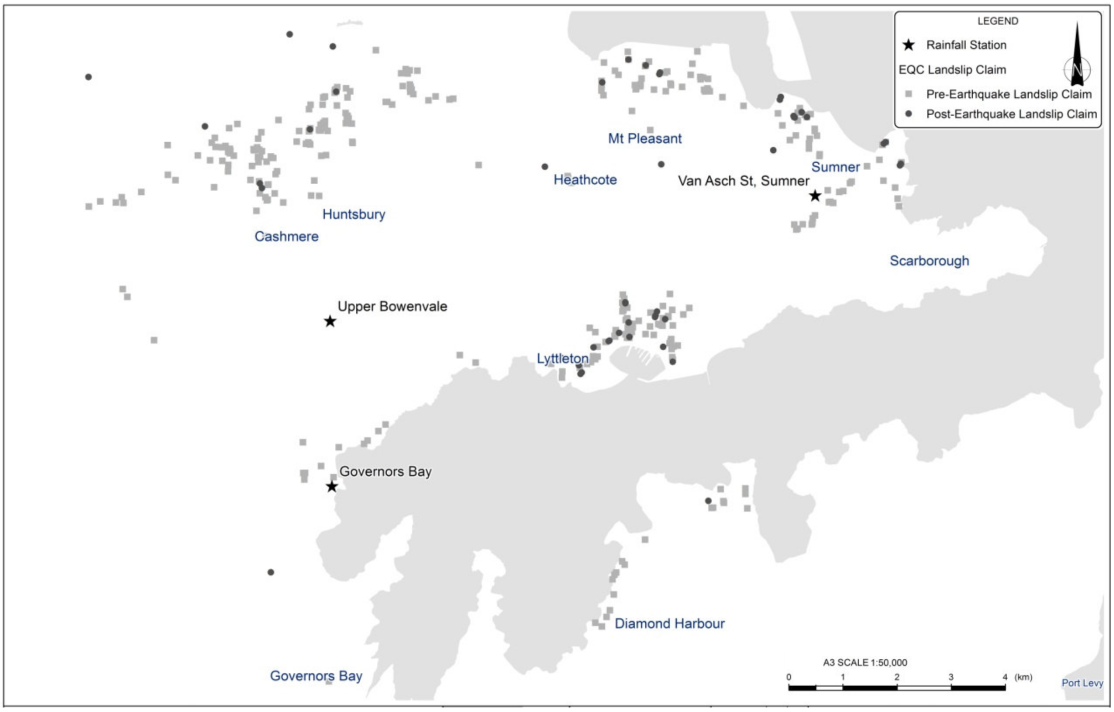

Figure 1: Occurrence of landslip claims on the Port Hills before and after the CES.

There is no indication that landslips have clustered in areas where the author's firm mapped earthquake induced land damage following the CES, compared to landslips in these areas prior to the CES.

Between 2000 and 2012, 74 rainfall events generated landslip claims on the Port Hills. The number of claims generated for a specific event ranged from 1 to 63. For comparison purposes, a rainfall event having 10 or more claims has been classified here as a 'significant claim event'. Rainfall events resulting in lower numbers of claims were considered to represent background levels and these have not been addressed further.

Eight rainfall events, between 2000 and 2012, generated over 10 landslip claims. This included the August 2012 event. The total number of claims lodged for these eight 'significant claim events' are shown in Table 1.

Table 1: Summary of landslip claim numbers for 'significant claim events'

	EQC Rainfall Event	Number of Claims on Port Hills
Prior to CES	October 2000	63
	January 2002	16
	June 2006	12
	August 2006	54
	July 2008	19
	August 2008	35
	August 2010	24
Post CES	August 2012	58

Five of the eight 'significant claim events' generated between 10 and 40 landslip claims on the Port Hills. The remaining three 'significant claim events' resulted in over 50 landslip claims. With the exception of 2004, the 'significant claim events' show a two year pattern.

Considering the amount of landslip claims shown in Table 1, the number of claims from the August 2012 rainfall event fall within the range of claim numbers generated before the CES. Interestingly, the number of claims lies at the highest end of this range.

3 RAINFALL ANALYSIS

The CCC and NIWA have provided 24 hour rainfall data between the years 2000 and 2012 from four selected rainfall stations around the Port Hills. The four stations chosen for this study provided data from various places around the Port Hills, including a range of elevations, to take into account rainfall which may vary geographically and topographically. The four selected rainfall stations are known as Christchurch Gardens, Governors Bay, Upper Bowenvale and Van Asch Street, Sumner. The stations are located on Figure 1, except for Christchurch Gardens which lies to the north of the area shown in Figure 1, in the city centre.

Historic rainfall information from these stations was used to develop an understanding of soil moisture conditions at the time of rainfall events which resulted in landslip claims. Changes in soil moisture conditions influence the stability of sloping ground, as does the degree of slope modification; building loads; and the type and amount of vegetation and drainage. These other factors are not discussed further in this paper.

Rainfall intensities can be used to calculate return periods for rainfall events. The CCC (2011) calculated these for various time periods using Christchurch Gardens rainfall data, representing rainfall on the flat land of Christchurch. These were scaled up to represent rainfall levels on the top of the Port Hills, at Upper Bowenvale station, using an isoline map created by NIWA (2009) which show increased rainfall with increasing elevation over the Port Hills. The return period levels discussed in this paper are shown in Table 2 for both 24 hour and 96 hour time periods.

Table 2: Rainfall return periods for Christchurch Gardens and Upper Bowenvale stations

Rainfall Station	Duration (hours)	Return Period Rainfall (mm)		
		2 Year	5 Year	10 Year
Christchurch Gardens	24	58	80	97
	96	88	122	147
Upper Bowenvale	24	85	119	143
	96	130	181	218

3.1 August 2012 rainfall event

The Christchurch Gardens rainfall station has been recording since 1873. Figure 2 shows rainfall records for each 24 hour period obtained from this station over the last 40 years. The line indicates the 58 mm/24 hour level, equal to a 2 year return period event on flat land. The graph shows varying levels of rainfall. The August 2012 rainfall peak is shown as one of two rainfall events of this scale recorded at this station over the last 20 years, and one of 11 such events in the last 40 years. This suggests that the August 2012 rainfall was an event of low frequency recorded at Christchurch Gardens.

The rainfall recorded over four days, from the 12-15 August 2012, resulted in 58 landslip claims. It is the only 'significant claim event' to have occurred on the Port Hills since the CES began. The rainfall peak measured at Christchurch Gardens was 61 mm/24 hrs. The peak measured at Upper Bowenvale was 96 mm/24 hours. Both rainfall measurements exceed the 2 year return period levels shown in Table 2 for 24 hour rainfall.

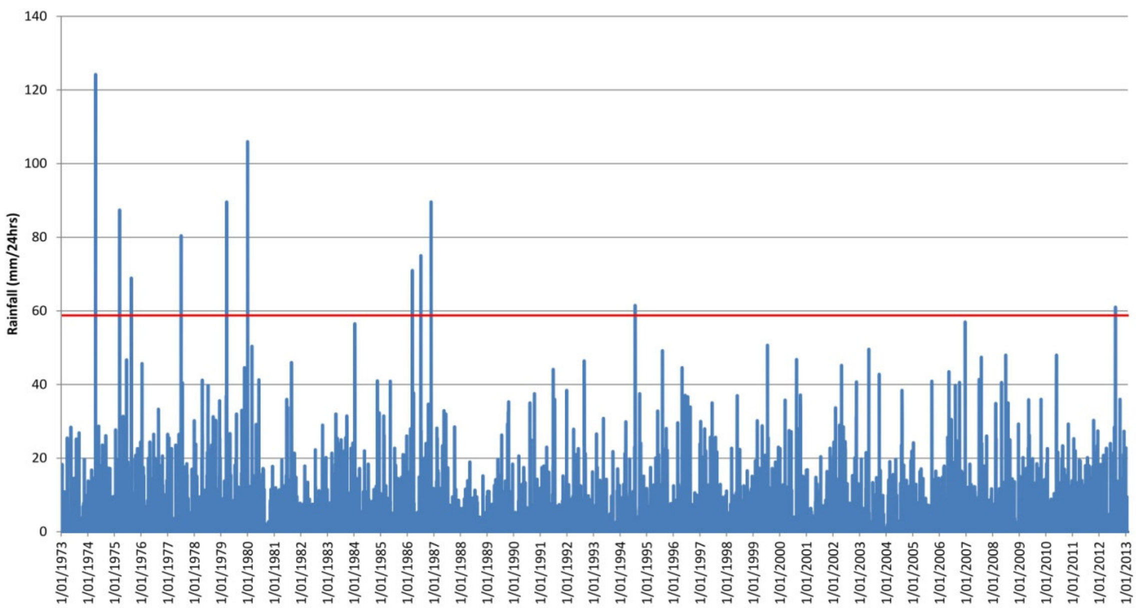

Figure 2: Rainfall measured at the Christchurch Gardens station over the past 40 years (line indicates 58 mm/24 hrs)

Over the four day period, rainfall measured a total of 92 mm/96 hours at the Christchurch Gardens station, and 200 mm/96 hours at the Upper Bowenvale station. These values exceed the calculated 5 year return period levels shown in Table 2. This implies that the August 2012 rainfall was also a low frequency event for a longer duration of rainfall.

Prior to the August rainfall, on the 31 July 2012, a high 24 hour rainfall level was measured at all four rainfall stations, generating one landslip claim. The peak rainfall was 59 mm/24 hours measured at the Governors Bay station. This rainfall event may have increased soil moisture conditions on the Port Hills, impacting slope stability prior to the August 2012 rainfall event.

4 COMPARING RAINFALL TO NUMBERS OF EQC LANDSLIP CLAIMS

For all of the 74 rainfall events that generated landslip claims on the Port Hills between 2000 and 2012, the maximum rainfall measured at each of the four rainfall stations has been plotted against the number of claims for each event. The results are shown on the graph in Figure 3. The main observations made from the results displayed in Figure 3 are discussed below.

- The majority of rainfall events generated less than 10 landslip claims, and typically less than 50 mm/24 hours, which were discussed earlier as background levels for landslip claims;
- The rainfall for the eight 'significant claim events' are easily identified as the eight rainfall events with the highest number of landslip claims;
- Five of these 'significant claim events', which generated between 10 and 40 landslip claims, show a small range in recorded rainfall between 20 and 50 mm/24 hours;
- The three largest 'significant claim events', with over 50 landslip claims, stand apart from the other rainfall events on this graph;
- These three rainfall events have higher rainfall measurements over a larger range between 30 and 160 mm/24 hours across all four rainfall stations on the Port Hills;
- There is no distinct threshold of rainfall which results in land deformation leading to the generation of landslip claims.

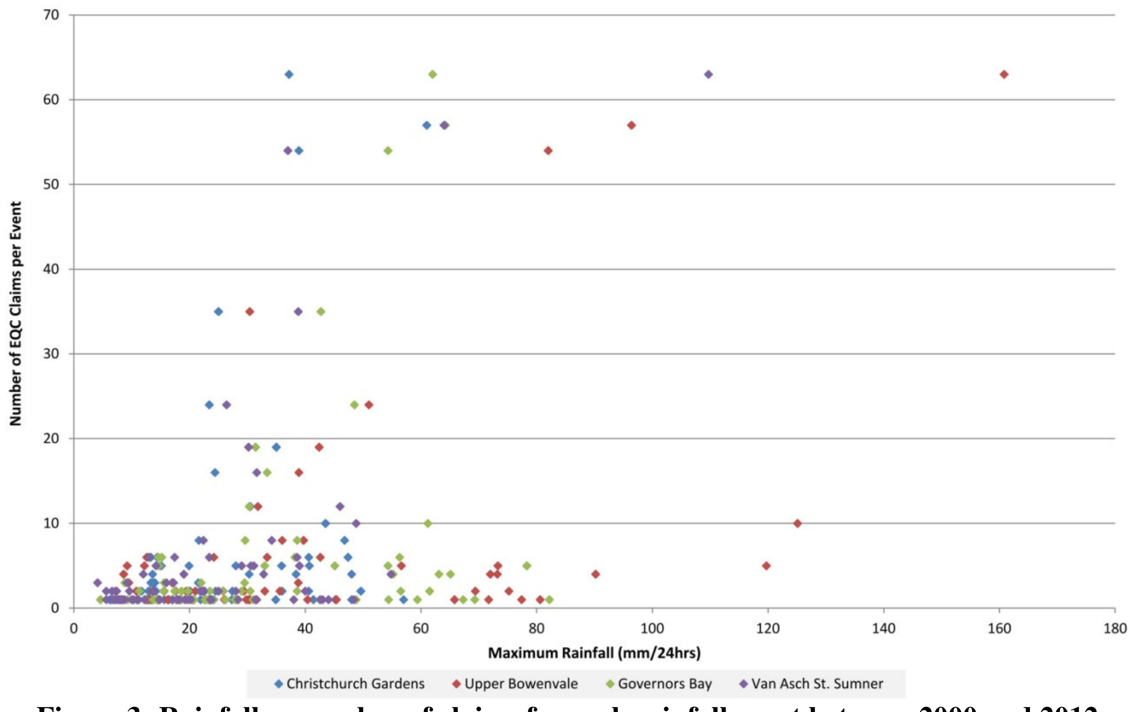

Figure 3: Rainfall vs number of claims for each rainfall event between 2000 and 2012

It could be expected that for higher rainfall levels, increased numbers of landslip claims might occur. To examine this, Table 3 outlines the three 'significant claim events', which generated the highest number of landslip claims shown in Figure 3, in further detail.

Table 3: Details of the three 'significant claim events'

Event	Duration	Upper Bowenvale Rainfall		Rainfall Conditions
		24 Hour	96 Hour	
October 2000 (63 Claims)	4 days	160 mm	190 mm	The 24 hour rainfall exceeds the 10 year return period for this rainfall station. The rainfall over 96 hours exceeds the 5 year return period. Two rainfall events before this event, one in August and one in September 2000, generated landslip claims on the Port Hills.
August 2006 (54 Claims)	4 days	82 mm	161 mm	The rainfall over 96 hours exceeds the 2 year return period, close to the 5 year value. Two rainfall events before this event, one in June and one in July 2006, generated landslip claims on the Port Hills.
August 2012 (58 Claims)	4 days	96 mm	200 mm	The 24 hour rainfall exceeds the 2 year return period for this rainfall station. The rainfall over 96 hours exceeds the 5 year return period. A rainfall event at the end of July 2012 generated one landslip claim before this rainfall event on the Port Hills.

All three 'significant claim events' discussed in Table 3 occurred over a number of days. In contrast, the other 'significant claim events' generating lower numbers of claims were of shorter durations. The 96 hour rainfall measurements for all three events are close to, or exceed, the 5 year return period values for the Upper Bowenvale rainfall station. The August 2012 'significant claim event' was a major rainfall event for both 24 hour and 96 hour rainfall durations. The August 2012 claims showed numbers similar to the other two larger 'significant claim events'.

Additionally, rainfall prior to these 'significant claim events', also generated landslip claims. It is likely that the antecedent rainfall events increased the soil moisture and decreased the stability of the sloping ground, lowering the trigger level for future rainfall to initiate slope instability. The August 2012 rainfall event fits this pattern.

5 CONCLUSIONS

- The location of rainfall induced landslip claims on the Port Hills, between 2000 and 2012, are focussed on residential land;
- The location of landslip claims on the Port Hills generated by the rainfall in August 2012 shows no spatial difference to the location of claims generated prior to the CES;
- Eight rainfall events between 2000 and 2012 generated above background levels of landslip claim numbers;

- The number of landslip claims lodged for the August 2012 rainfall lie at the higher end of the range of claim numbers observed for 'significant claim events' occurring before the CES;
- The August 2012 rainfall event was a low frequency event, over a longer duration and showed higher rainfall than background levels for rainfall events;
- No distinct threshold is observed for rainfall levels which caused land damage resulting in landslip claims;
- Comparing rainfall with the number of landslip claims for rainfall events, between 2000 and 2012, shows higher rainfall can generate higher numbers of rainfall claims on the Port Hills;
- Where high numbers of landslip claims have been recorded (over 50), it was noted that rainfall prior to the event also generated small numbers of landslip claims, which could suggest that the sloping ground of the Port Hills was prone to land instability prior to the high levels of rainfall in the 'significant claim events'.
- There is little evidence so far, using the August 2012 rainfall event information, that supports the argument that increased rainfall induced land deformation will occur on the Port Hills as a result of the CES and associated land damage;
- The August 2012 rainfall was a major rainfall event recorded on the flat land and the top of the Port Hills over both 24 hour and 96 hour durations; using EQC claims data for Port Hills suburbs, shows there is no distinct change in the occurrence of small scale lands instability since the beginning of the CES.

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REFERENCES

Christchurch City Council (2011) Chapter 21 – Rainfall and Runoff. *Waterways, Wetlands and Drainage Guide.* Christchurch City Council.

Griffiths, G. et al (2009) *Review of the frequency of high intensity rainfalls in Christchurch.* National Institute of Water and Atmospheric Research.