Locating property boundaries after shallow land movement – the Canterbury experience

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Key words:

Cadastre, earthquake, legislation

SUMMARY

In 2010 and 2011 the Canterbury region of New Zealand experienced a series of earthquakes (the Canterbury Earthquake Sequence) that caused extensive damage to buildings and infrastructure and caused the deaths of 185 people. Shallow land movement triggered by the earthquakes caused uncertainty in the surveying environment as, in the worst affected areas of Christchurch City, accepted survey practices were no longer sufficient to provide certainty on the location of property boundaries. These accepted survey practices were also resulting in different weightings being placed on evidence leading to different property boundary determinations. After listening to the concerns of surveyors in Christchurch, the Surveyor-General and Land Information New Zealand established a programme to investigate the problem and develop a solution in consultation with affected parties. The aim of this paper is to explain the issues Licensed Cadastral Surveyors experienced following the earthquakes and detail how the Surveyor-General and New Zealand Government plans to address these problems. This paper provides a brief overview of the Canterbury Earthquake Sequence and the impact land movement had on the surveying and legal environment. It then goes on to describe the Canterbury property boundaries problem and the implications for affected parties. The potential options for resolving the problem are then outlined including the outcomes that potential solutions were assessed against.

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1. INTRODUCTION

In 2010 and 2011 the Canterbury region of New Zealand experienced a series of earthquakes that caused extensive damage to buildings and infrastructure and caused the deaths of 185 people (New Zealand Police, 2012). The reason for such extensive damage was primarily the location and depth of the earthquakes and the resultant land movement that occurred. In 2011 the cost of rebuilding and repairing Canterbury was estimated at NZ$20 billion (Parker & Steenkamp, 2012). This increased to $40 billion in 2014 with $16.5 billion being contributed by the New Zealand Government (New Zealand Government, 2013).

A significant part of the rebuild and repair of Canterbury is based on knowing precisely where property boundaries are. However, because widespread land movement caused by the Canterbury Earthquake Sequence (CES) disturbed all phyiscal evidence to some degree, this has become more difficult to accurately determine. In New Zealand, property boundaires are determined by Licensed Cadastral Surveyors who gather evidence, apply relevant law and make a determination (as per rule 6.1 in Rules for Cadastral Survey 2010). New Zealand land law is based on Common Law and does not have a legal coordinate cadastre. Surveyors must meet the standards set by the Surveyor-General including compliance with relevant law and comply with principles underpinning survey practice. Since the rebuild started, surveyors have experienced a considerable increase in work. Initally, surveyors dealt with shallow land movement by applying generally accepted survey practices, however as surveyors began working in the worst affected areas, they began to raise concerns that these practices and relevant law were insufficient. These concerns included existing survey practices not being suitable to deal with the shallow land movement; the lack of clarity about how to deal with the movement; their personal liability in determining boundaries in the worst affected areas; the effect the lack of clarity might have on the rebuild and consequential impacts on property owners. After listening to these concerns, the Surveyor-General and Land Information New Zealand (LINZ)[1] responded by establishing a multi-disciplinary programme to investigate and define the problem and then develop potential solutions.

The aim of this paper is to provide context and explain the issues Licensed Cadastral Surveyors experienced following the CES as well as how the Surveyor-General and New Zealand Government plan to address these problems. The paper provides overview of the Canterbury Earthquake Sequence (CES) and the impact land movement had on the surveying environment. It then goes on to describe the Canterbury property boundaries problem and the implications of the problem for affected parties. The potential solutions developed are then outlined including the outcomes the potential solutions were assessed against.

[1] LINZ is a government department who verifies surveys and integrates them into the cadastre.

2. 2010-2012 CANTERBURY EARTHQUAKE SEQUENCE

The CES began with the M_W7.1 Darfield earthquake on 4 September 2010, centred 40 km west of Christchurch (Gledhill et al., 2011). The earthquake occurred on the previously unidentified Greendale fault and produced the strongest earthquake ground shaking ever recorded in New Zealand (GNS Science, n.d.). Several thousand people were injured (Johnston et al., 2014) with damage to buildings and infrastructure estimated at NZ$4 billion (Gledhill et al., 2011). It resulted in maximum net horizontal ground displacement of 5.3 ± 0.5 m, average horizontal net displacement of 2.5 ± 0.1 m (Quigley et al., 2011) and 1 m of vertical movement (Blick et al., 2011). The Darfield earthquake was followed by a series of aftershocks in late 2010 and early 2011.

The smaller but more damaging M_W6.2 Christchurch earthquake then occurred on the 22 February 2011. The earthquake was also located on a previously unknown fault approximately 7 km east-southeast of Christchurch City centre at a depth of approximately 4 km (Beavan et al., 2011). It caused 185 deaths (New Zealand Police, 2012) and extensive damage to buildings and infrastructure in Canterbury. The earthquake was followed by a long series of aftershocks with the most damaging occurring on 13 June 2011 (M_W6.0) and 23 December 2011 (M_W5.8 and M_W6.0) (Bannister & Gledhill, 2012; GeoNet, 2012). Figure 1 shows the location of these earthquakes and aftershocks and the location of the Greendale fault in relation to Christchurch City.

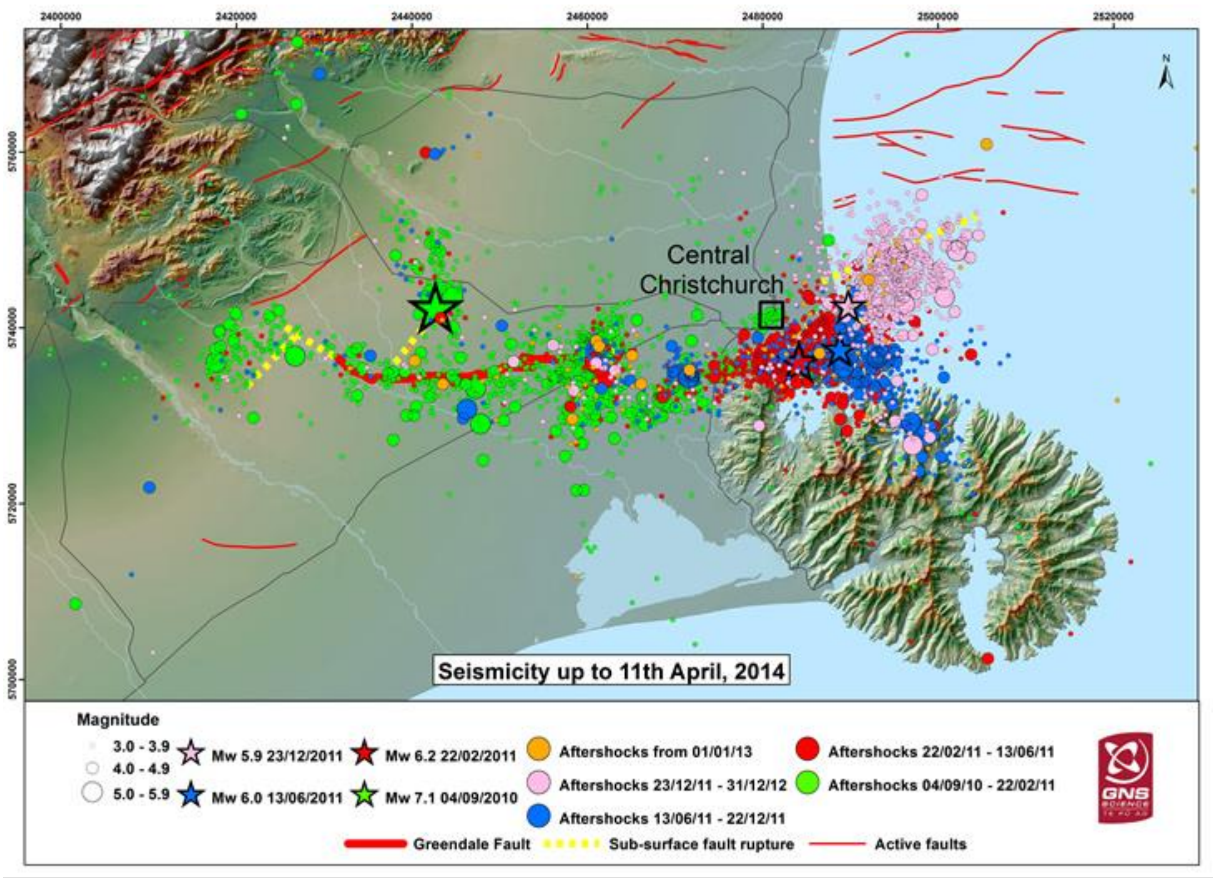

Figure 1: Location of the main earthquakes and aftershocks that occured in Canterbury between September 2010 and April 2014 (source: GNS Science, 2014)

2.1 Geological setting

The region affected by the CES can be divided into two distinct geological areas – the Port Hills to the south of Christchurch City, and the Canterbury Plains. Both areas responded differently to the CES because of their geology. The Port Hills are part of an extinct volcanic complex that is overlain with loess (fine wind-blown silt). The Canterbury Plains (referred to as flat land) were formed by braided rivers flowing eastward from the Southern Alps/Kā Tiritiri o te Moana. Under Christchurch City, these rivers deposited more than 400 m of interlayered gravels, sands and silts on the underlying basement rock over the last half a million years (Tonkin & Taylor Ltd, 2015). There are also fine-grained marine/estuarine sediments up to 15 km inland from the present day shoreline (Brown & Weeber, 1992; Forsyth, Barrell & Jongens 2008; Suggate, 1958). The city of Christchurch is predominantly located on the flat land and is particularly vulnerable to shaking and liquefaction because of the alluvial sediment foundation (Potter et al., 2015).

2.2 Land movement

The earthquakes that occurred in the CES caused both deep-seated and shallow land movement. These movements were expressed on the surface of the land in different ways depending on the characteristics of the individual earthquake (e.g. depth, magnitude, direction of rupture) and the geology of the area. For example, the most significant difference between the September and February earthquakes was the 29.5 km long surface rupture caused by the Darfield earthquake (Quigley et al., 2011) whereas no rupture occurred in the Christchurch earthquake. Table 1 describes the movement mechanisms and how the movement was expressed on the surface of the land in Canterbury. It also notes where the movement occurred.

Table 1: Physical expression and location of movement mechanisms in the CES

Movement mechanism	Description	Physical expression on the surface	Where this movement occurred
Deep-seated movement	Deformation of bedrock and overlying sediments caused by fault rupture. Occurred hundreds of metres deep.	Rupture on the land surface	Greendale Fault (Quigley et al., 2011)
		Very gradual (tens of centimetres) land movement over large distances (several kilometres) (Beavan et al., 2012) and uplift or subsidence	This movement occurred across the Canterbury region (Tonkin & Taylor Ltd, 2015) with the greatest vertical movement measured around the Estuary of the Heathcote and Avon Rivers/Ihutai (uplifted up to 400 mm) and central and northeastern area of Christchurch City (subsided up to 150 mm) (Tonkin & Taylor Ltd, 2015)

Shallow land movement	Deformation of near-surface soils between the ground surface and approximately 20 metres depth caused by earthquake-induced shaking	Small-scale rockfall and large-scale earthquake-induced landslide	Port Hills (Tonkin & Taylor Ltd, 2015)
		Tension cracks and ground extension (caused by lateral spreading), ground bulging and buckling and ground cracking (caused by liquefaction induced ground oscillation) and area-wide ground stretching (Tonkin & Taylor Ltd, 2015)	Flat land (Tonkin & Taylor Ltd, 2015)

2.3 CES effect on the surveying environment

The New Zealand cadastre is based on physical evidence (monuments) - it is not a coordinate cadastre. Boundaries are fixed, except for water boundaries such as river banks that can legally move according to long established doctrines. It supports multiple tenure systems including the land transfer system and provides certainty of land ownership and other rights in land as well as the ability to confidently establish and understand property rights on the ground (Clouston, 2015; Grant, Haanen & Dyer, 2014).

As deep-seated and shallow land movement resulted in different physical expressions on the surface, the movements affected surveying infrastructure (monuments) differently. Deep-seated movement resulted in uniform translation and rotation over small areas resulting in the ground surface and everything located on it moving approximately the same distance and direction. The movement altered the spatial position of all geodetic and cadastral marks in Canterbury (Blick et al., 2011). Although deep-seated movement affected the location of survey infrastructure, the movement was considered uniform across the relatively small area of a typical survey and the relative distance and angles between survey marks did not alter.

Deep-seated or tectonic movement occurs constantly in New Zealand (due to its location straddling the Australian and Pacific tectonic plates (Berryman & Beanland, 1988)) and is addressed by adjusting the cadastre periodically to account for this absolute movement. This adjustment ensures that the depiction of the legal boundaries in the cadastre more accurately reflects the legal position in the real world. Although the movement that occurred during the CES was significantly larger than ‘normal’ it was addressed in the same way as ‘normal’ movement - by updating the New Zealand Geodetic Datum 2000 Deformation Model and using it to update coordinates in official geodetic and cadastral databases to reflect deep-seated movement (Grant et al., 2015). The Surveyor-General also issued guidance to assist surveyors in conducting cadastral surveys that were affected by deep-seated movement. Cadastral Survey Rules were subsequently published by the Surveyor-General that reflected this guidance and required surveyors to adjust boundaries to account for the distortion caused by the movement.

Shallow land movement caused greater issues for the surveying environment because of its non-uniformity over small areas. The liquefaction-induced movement generally resulted in the extension or contraction of the land. In many cases, this meant that the relative measurements between survey marks in the ground no longer matched those recorded on the official survey plan. The scale of such movements were such that, in some cases, extension had stretched land in a neighbourhood block so an extra 1 m of land now existed that needed to be accommodated. It was the relative movement between monuments on a single parcel that caused issues for surveyors in determining boundary dimensions.

Shallow land movement also caused significant issues for survey marks. When movement occurred on flat land away from a free-face and there was no preferential direction of land movement (Tonkin & Taylor Ltd, 2015), it caused the ground to move back and forth and then settle again once shaking ceased. Any survey marks that were located in land that was affected by this oscillation had moved but as there were generally no observable physical signs on the surface (e.g. buckling, bulging, cracking) it could be difficult to determine on visual inspection if the survey marks settled back in their original position or not. These marks were often deemed unreliable based on survey measurements.

3. THE CANTERBURY PROPERTY BOUNDARIES PROBLEM

Rebuilding and repairing damaged buildings and infrastructure is a critical part of the recovery phase of the Canterbury earthquakes. In order to complete rebuild or repair work, properties were re-surveyed to provide certainty that assets, property and land rights were aligned and so local government could ensure planning rules and building requirements were met. Before construction work began, many property owners needed to settle insurance claims with their insurance companies. The more complex of these claims, and therefore the ones that took longer, were largely located in areas most affected by land movement. As these claims were settled and construction contracts were issued, cadastral surveyors began surveying in these worst affected areas. Surveyors quickly realised that land movements were well outside of accepted survey tolerances; in some cases relative horizontal movements of 1 m or more were measured. Variation in movement was also causing concern. For example one end of a city block may have extended by 1 m where the other end may have extended by 0.5 m in the opposite direction. As surveyors became more uncomfortable working in these areas they began to request guidance from the Surveyor-General as to how they should undertake surveys in the worst affected areas. As LINZ received more surveys the nature and extent of the problem became clearer as it became increasingly difficult to reconcile individual survey boundaries with others in the cadastre.

In order to fully understand the problem and work towards finding a solution, the problem was split into two parts. These were;

1) in some areas of Christchurch most affected by land movement, accepted survey practices were not sufficient to provide certainty of where to locate property boundaries, and;

2) accepted survey practices were resulting in different weightings being placed on evidence

which was leading to different property boundary results - in other words, two surveyors could survey the same parcel of land and come out with two significantly different locations for the boundaries.

The map in Figure 2 shows the extent of shallow land movement in Christchurch. It uses data up to 26 March 2015 to indicate the general extent of horizontal shallow land movement resulting from the Canterbury earthquakes. It presents average movements that have been measured at a network of geodetic and cadastral survey marks around Christchurch, which in some cases are spaced hundreds of metres apart. Movement at the individual property level may be significantly more or less that the value indicated by the map however, particularly where the property is not close to one of the survey marks. Movements in excess of 1m have been observed. For surveyors, it indicates the likelihood of finding undisturbed survey marks when commencing a survey to locate property boundaries.

One key reason for these two problems was the lack of law directly relating to how boundaries move with earthquake-induced land movement. The common law that exists covers landslips and accepts that boundaries are fixed. But as this law did not directly cover earthquake-induced shallow land movement, there were differing opinions as to whether the basis of the common law could be inferred. If it was inferred on the basis of the treatment of landslips, it would mean that boundaries did not or had not moved with the shallow land movement in Canterbury. This would result in physical boundaries (e.g. fences, physical structures and monuments) not being aligned to legal boundaries.

The problem was initially seen as a technical problem for surveyors with the main implications being:

- A difference of opinion on how to apply existing survey practices
- A possible increased risk of future liability and involvement in future boundary disputes
- Potential changes in supply and cost of Professional Indemnity insurance due to increased risk of future liability
- Work in the worst affected areas being considered too risky and therefore turning down work in these areas.

Further analysis and feedback however revealed that, while in part it was a survey problem, the main issue was the lack of legal clarity. The problem also had consequences for a wide range of parties both now and in the future including property owners, local and central government, lawyers, utility companies and insurance companies.

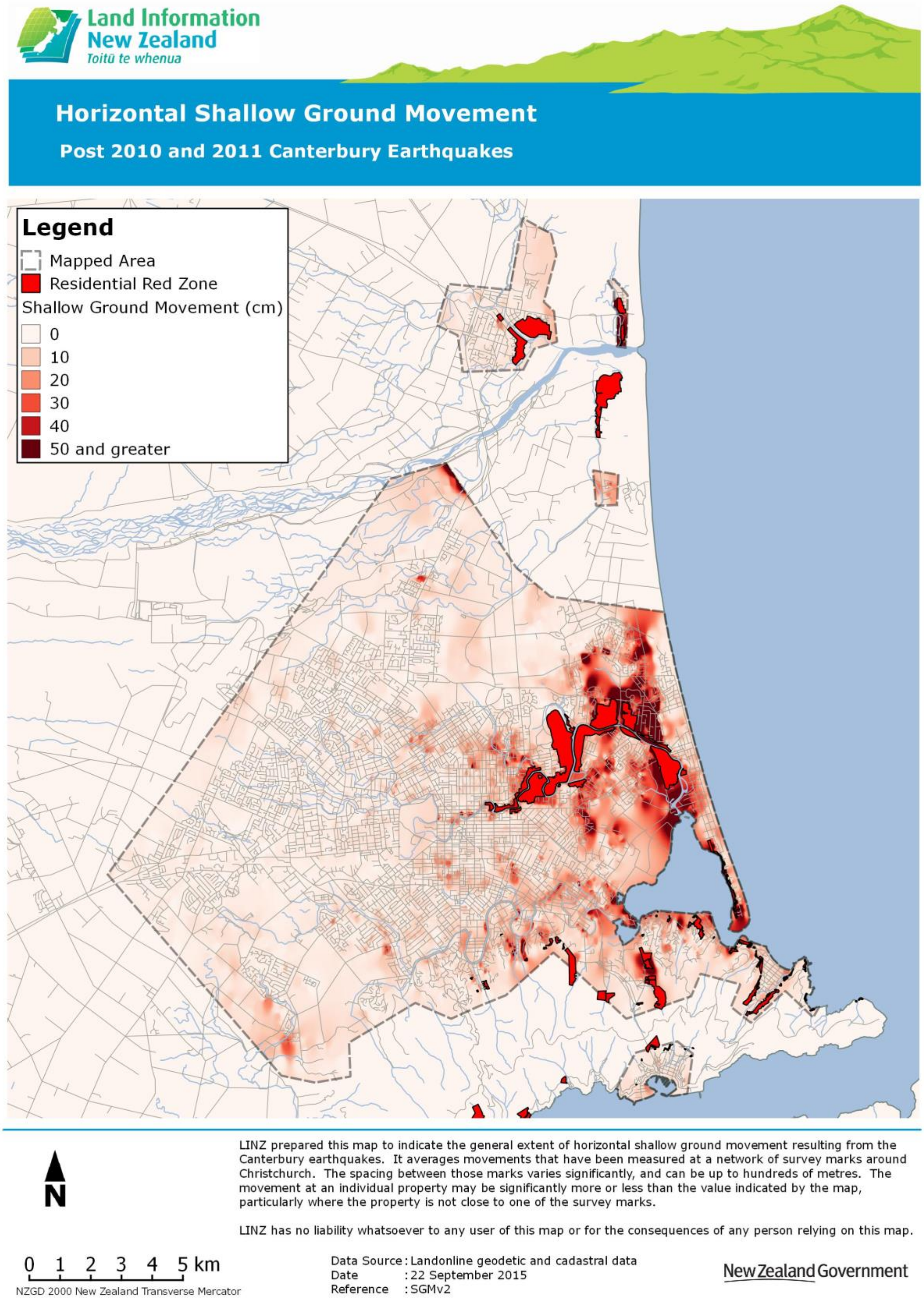

Figure 2: Horizontal shallow land movement in Canterbury caused by the CES.

4. POSSIBLE SOLUTIONS

A programme was established within LINZ to develop a solution or solutions to the determination and re-establishment of boundaries on land subject to land movement. As well as regulators and technical experts, the programme included a group of sector leaders, lawyers and a working group of licensed surveyors based in Canterbury. The groups were established to provide a perspective from affected parties and those that might need to implement the solution. They provided real, on-the-ground experience and expert knowledge to inform, test and support the work. In developing potential solutions, the programme worked to define the problem including the extent and identified desired outcomes, assessed potential solutions against them.

4.1 The options

As well as needing to develop practical, timely and enduring solutions, there was a need to be sensitive to the broader context in which the problem had manifested. Many property owners in Canterbury have been working hard to progress to the point where they could repair or rebuild their houses, particularly in areas affected by shallow land movement. The Canterbury rebuild is a high priority for government and although progress is being made in many areas there are points of frustration for property owners and other affected parties. Any issue that might impact on the progress of the rebuild needed to be addressed as a high priority to eliminate or minimise any possibility of further delays or additional costs.

In considering options, potential solutions were assessed against two high level outcomes. These were:

- ensuring the Canterbury rebuild continues and barriers, costs and delays were reduced, and;
- ensuring the continued integrity of the property rights system to encourage trade, commerce and wellbeing.

Any solution needed to be transparent, timely, cost efficient, result in minimal boundary disputes and ensure these were predictable and no greater than in non-earthquake affected areas, and ensure title information is reliable. To provide this, the legal framework within which surveying occurs earthquake affected areas needed to be clarified. The key question was whether legal boundaries moved with shallow land movement caused by the CES or not and whether there was a genuine need to clarify this. Three possible answers to this question were analysed and are presented in Table 2. These were to maintain the status quo and allow case law to emerge over time, accept that boundaries had not moved and, if required, legislate for this or accept that boundaries had moved with the land and, if required, legislate.

Table 2: Three high level options for a solution to the Canterbury boundaries problem

Possible solution	Description	Implications

Status quo	Surveyors are expected to apply standard practices. Case law will emerge over time to establish whether boundaries moved or did not move with the land.	Continued uncertainty and costs for all parties until case law emerges. Surveyors may continue to apply different approaches for determining legal boundaries increasing the risk of boundary disputes. This may slow down the rebuild and cost property owners more.
Boundaries did not move with the land	Accept that boundaries did not move where there was shallow land movement and clarify this through legislation (if required).	Legal boundaries will sometimes not align with physical occupation. Some assets, including completed rebuilds may need to be relocated to within the legal boundaries or land owners would need to seek boundary adjustments to realign legal title with occupation.
Boundaries moved with the land	Accept that boundaries in Canterbury moved where there was shallow land movement and clarify this (through legislation if required).	Legal boundaries will generally align with occupation so completed rebuilds will generally be within legal boundaries. However, boundaries, as seen on the ground, may not align with the legal boundaries recorded in the cadastre.

The status quo option was not preferred as it would not resolve the problem and would result in an increased number of potential boundary disputes both now and in the future. The option where boundaries did not move with the land would result in the legal boundaries being misaligned with physical occupation creating encroachments and limitations on building work. It would also result in additional costs, delays and potential disputes as boundary adjustments would be required. The last option, where boundaries did move with land performed best as it takes into account the realities of land movement, recognises rebuild activity that has already occurred, protects the rights of property owners, minimises cost and disruption to property owners, and does not delay rebuild activities.

4.2 The possible solution

The option that is being worked on in more detail is to accept that legal boundaries did move with shallow land movement caused by the CES. This will result in surveyors having to take account of this movement when locating property boundaries. This solution best meets the desired outcomes and minimises costs for property owners as it will not result in the need for more boundary readjustment surveys and associated costs for local government approval, neighbour negotiation and legal representation, and more boundary disputes. The possible solution provides certainty to surveyors and others on how to deal with land movement.

The solution is proposed to only apply to the greater Canterbury region and land movement caused by the CES to avoid unintended consequences. The particular land movements experienced in Canterbury may not necessarily occur in future earthquakes in Canterbury, or elsewhere in New Zealand, and therefore the solution may not be applicable in other situations. Similarly, it would not be preferable to restrict the possible solution to small defined areas within Canterbury because data on land movement is not dense enough to tightly define affected areas and could result in people perceiving these defined areas as having lost monetary value.

For property owners this possible solution would mean their legal boundaries will continue to align with where they think they are located. It would also mean that, unless building or subdividing, property owners would not need to do anything, ensuring they do not incur any extra costs when the possible solution is implemented.

5. CONCLUSION

The problem faced by surveyors in locating property boundaries following the CES is more complex than first thought. It has implications for a wide range of parties and could, if not addressed, negatively impact the Canterbury rebuild. Many parties have been involved in developing a practical, timely and enduring solution that will provide people with certainty when locating property boundaries. The possible solution being worked on in more detail is that boundaries did move with shallow land movement during the CES.

Due to its geological setting, New Zealand will always experience earthquakes. Although the majority of these will be minor, a small percentage will have the potential to cause significant damage to infrastructure, buildings and loss of life and/or injuries. Any lessons learnt from the work to address the impact of land movement on Canterbury property boundaries have the potential to be transferred to other earthquake events. However the precise solution needed for another event will need to be considered in the context of that earthquake as land movement and its consequences experienced in any future earthquake may not be the same as that experienced in Canterbury. This provides the opportunity to further investigate the resilience of the cadastre and surveying profession to future natural hazards. For example, are we able to pre-plan for the future events? Is the cadastre capable of adapting to the demands, challenges and changes encountered during and after an event (Paton & Johnston, 2006) (a new normal)? What role might surveying and surveyors play in community resilience?

6. ACKNOWLEDGEMENTS

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BIOGRAPHICAL NOTES

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Nic Donnelly is a Geodetic Surveyor in the National Geodetic Office. His areas of interest include reference frame maintenance, deformation modelling, geodetic cadastres and the use of radar in the geodetic system. He is currently Chair of the 3D Reference Frames Working Group for FIG's Commission 5 - Positioning and Measurement.

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