

**Practice Guidelines
for
Cadastral Surveying
in
Areas Affected by Ground
Movement Caused by Earthquakes
in Canterbury**

Initiated by:



NZIS/ICS Working Party 2015 – Earthquake Affected Boundaries

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1. Introduction

1.1 Background

This document was initiated by the NZIS/ICS Working Party who were convened in February 2015 to respond to issues related to cadastral survey definitions in earthquake affected areas following the 2010-11 Canterbury Earthquakes.

The Working Party was established primarily to provide expert advice and commentary to Land Information New Zealand (LINZ). The responses provided to LINZ were based on the collective expertise of the Working Party members gained from undertaking cadastral definitions in greater Christchurch.

As representatives from a range of firms of various sizes, the group was able to utilise and share their own cadastral experiences as well as canvas the wider wisdom of their professional colleagues.

The major outcome of the communications with LINZ resulted in the belief that boundaries within greater Christchurch are deemed to have moved with the movement of land caused by the Canterbury earthquakes.

1.2 Intent

The intent of this document is to provide a written resource option for cadastral surveyors to utilise in the course of their cadastral surveying work when undertaking surveys within areas affected by ground movement following an earthquake(s).

Following the initial draft prepared by the Working Group, the document was disseminated to the wider NZIS Canterbury Branch membership; the Cadastral Stream of the NZIS; the ICS Executive Team; University of Otago School of Surveying; and LINZ for review, comments and expansion.

The document is anticipated to be an evolving source of information that will assist all surveyors in understanding the important aspects of cadastral survey definition over and above the normally expected "good survey practice" in a post-earthquake environment.

This document assumes that the basic cadastral survey definition processes are understood and already employed. The points included within this document therefore supplement and expand upon the historically proven and established principles of cadastral survey definition in New Zealand.

In addition, the document comments are intended to be compatible with all current legislation and common law, as well as complement the Rules for Cadastral Survey and any additional Guidelines that may be published by LINZ.

Whilst the specific comments contained herein relate to cadastral surveying definitions within greater Christchurch, it is acknowledged that the approach may be potentially applicable to other areas of New Zealand in a similar post-earthquake cadastral environment.

Note that proposed new legislation relating to locating legal property boundaries on land affected by movement resulting from the 2010 and 2011 Canterbury earthquake sequences was tabled in Parliament on 22nd October 2015 - entitled the "Canterbury Property Boundaries and Related Matters Bill" (82-1).

1.3 Acknowledgements

As noted above, the release draft version was distributed to the wider surveying industry for review and comment. A number of surveyors provided contributions that have been incorporated into the document, and they are warmly thanked for their feedback

1.4 Feedback

Any feedback, contributions, comment or constructive criticism should be directed to the Secretary of the NZIS Canterbury Branch - canterburybranchnzis@gmail.com

2. Data Research

Thorough pre-survey data research will provide a surveyor with a broad range of spatial information relating to the area under survey. It will lead to a better understanding of the nature and extent of any ground movement.

2.1 The Need to Search Deeper (Pre-survey data search)

In order to recreate and reinstate a legal boundary with confidence and with certainty, it is necessary to search all available data.

In essence the objective is to ascertain what data/evidence is relevant and has the least doubt when it comes to relocating or defining a boundary. The search should also go beyond the immediate underlying survey area to ensure that other witness and boundary marks are searched for when field observations begin. In addition, other evidence that may assist in the correct location of a boundary (eg: occupation or evidence related to localised land movement) should be incorporated into the search regime.

If an underlying plan shows a calculated boundary offset from a permanent structure, and the plan has a field note reference, the field note forms an important part of a surveyor's data search. Such ties can be used as evidence to support a boundary definition or potentially reinstate a boundary based on an historical tie to a permanent structure – as long as the ties are of sufficient accuracy and the fixture point can be sufficiently identified.

Similar ties are sometimes shown to existing fence lines and form the basis of boundary to occupation offsets. Again, such ties can be used to determine the intent of the boundary being defined.

Obtaining the survey report associated with the underlying survey plans can also aid the surveyor in understanding the underlying boundary definition logic.

1. Search and obtain field notes and survey reports as part of any boundary definition. Go the extra mile and examine beyond the immediate underlying survey to ensure other marks or evidential data is not missed.

2.2 Make Contact with Other Surveyors

If a calculation compared to an adjacent survey needs clarifying, make contact with that surveyor.

If contacted by another surveyor, it is in everyone's best interest that a sound definition is determined. It should not be taken as a threat.

Obtaining historical field notes that are not available in the public record may help determine the best possible solution. An example of this is historic flat plan field notes that were not lodged.

2. Sharing data that is not in the public record will help surveyors determine the best possible boundary solution.

2.3 Coordinates

Post-earthquake SDC coordinates are available on the LINZ Data Service (<https://data.linz.govt.nz>). They are available in two separate datasets, one for non-boundary marks and the other for boundary marks. These coordinates were computed by adding the effects of deep-seated movement to survey points that had survey-accurate digital cadastral (SDC) coordinates immediately prior to 4 September 2010 (the first Canterbury earthquake). Comparing these coordinates with coordinates for the actual (observed) post-earthquake positions will provide an indication of the direction and magnitude of localised horizontal ground movement (and vertical movement where Z values are available).

A vector diagram is a good way to visualise this, providing a graphical presentation of the direction and magnitude of movement.

Note that these coordinates are specific to the Canterbury Earthquake sequence and the same information may not be produced after other earthquakes.

3. Treat the pre-earthquake and post-earthquake coordinates as a tool only.

2.4 Other Data Sources

There are other sources of data available to the surveyor that were not available before the 2010-2011 Canterbury earthquake sequence. These resources should be fully utilised as part of the initial data assessment process before and during a survey – particularly within areas that have been affected by ground movement.

Government departments as well as private sector agencies have made their data available in various formats. Utilising these resources may help determine the best outcome for a survey definition in your area of interest. Some examples are:

- **LINZ Data Service – Post-Earthquake Aerial Photography**

Orthophotography of the area affected by the Christchurch Earthquake, 22 February 2011.

Imagery was captured by NZ Aerial Mapping Ltd to support the response to the 22 February 2011 earthquake in Canterbury and offers high resolution imagery (10cm pixel resolution). The imagery provides a good overview of any particular area including the extents of liquefaction.

- **Canterbury Geotechnical Database¹**

This is an extensive database offering a wide variety of datasets. Once you have registered, the datasets can be viewed on Google Earth.

Collated Investigation Data includes Aerial Photography, Areas of Liquefaction (from both Aerial Photography and from ground observations), Observed Crack Locations, LIDAR and Digital Elevation Models, Vertical and Horizontal Ground Movement

There is also data detailing the Mass Movement and Surface Deformations relating to the Port Hills, along with ground motion models.

¹ [now the New Zealand Geodetic Database – Jun-16]

- **GNS Report on Mass Movement Areas**

These are detailed reports that defined the areas of mass movement within the Port Hills. They are extensive reports compiled for risk assessment by the Council.

This report needs to be read in context. It was prepared for a particular purpose and was not issued specifically for surveyors for the purposes of providing precise or complete data for the determination of cadastral boundaries.

- **LINZ Ground Movement Map**

LINZ have compiled a map that shows where ground movement from lodged datasets have shown differential ground movement.

4. Additional external data sources include:

- <https://data.linz.govt.nz/>
- www.koordinates.com
- <https://canterburygeotechnicaldatabase.projectorbit.com>
- <https://www.nzgd.org.nz>
- <http://www.ccc.govt.nz/environment/land/slope-stability/port-hills-gns-reports/>
- http://www.linz.govt.nz/system/files_force/media/file-attachments/Indicative%20shallow%20surface%20movement%20in%20Christchurch.pdf?download=1

With any data set, the user needs to be mindful of the data source, the methods employed to acquire such data and any updates to the data set being analysed. These are great tools to obtain a better understanding of the area of interest and are indicative of how boundaries may have moved with the movement of land caused by the Canterbury earthquakes.

3. Good Survey Practice

3.1 Pre-Field Calculations

With the advent of LandonLine and survey software it is very easy to extract a lot of mark positions and vectors to get calculations started.

Running some closes of previously measured (rather than calculated) vectors between traverse marks or pegs can give a good idea of the integrity or real accuracy in the underlying work. Working from the plans rather than XML data can also help identify which marks may be already destroyed and which marks need to be looked for to determine a definition. Rather than closing between 6th Order 2000 marks from LandonLine, which can contain a degree of network adjustment error, consider doing a closed traverse loop from one mark only and building up a cadastral model from there.

It is useful to find nearby post-earthquake datasets to get an idea of the potential movements that have been measured between existing marks or mentioned in the accompanying survey reports.

These calculations are also useful to create point files that can be uploaded into survey controllers to assist with finding survey marks in the field. When staking out for these marks the controller will give position deltas between the measured and calculated positions. This is useful as a quick field check that you have the right mark, but it should not supersede careful analysis of the vectors between measured positions to determine what local movement has really happened.

1. Always endeavour to work with measured vectors from the source plans to build up a picture of the integrity of the underlying cadastral work, both pre- and post-earthquake. While coordinates are compatible for our survey equipment software, it is the measured vectors that we should be analysing for our survey definitions.

3.2 Field Equipment and Methodology

A mixture of equipment types will be used when undertaking surveys in a post-quake environment. GNSS receivers will provide an orientation in terms of Geodetic Datum 2000 even when measuring between adjacent marks affected by ground movement. It is unwise to use just a total station for local orientation because this won't be able to pick up any rotation distortion, even though you might be able to measure the same distances between three old marks.

Although a community or CORS base station data service can be very useful for quickly finding old marks or establishing an origin over a long line, it is preferable to obtain GNSS observations using a local base and rover RTK configuration. There is a need to minimise the measurement errors introduced so that the amount of ground movement involved can be accurately determined. Sometimes it is worth the effort to use a total station to accurately determine if traverse marks are still in a straight line.

In an area of ground movement, measurement of vectors between adjacent old marks may differ from the original observations but the marks still end up being accepted as undisturbed. It is therefore important to take good independent check measurements to the old marks so that there is confidence in the observations when analysing the data back in the office.

If taking GNSS measurements in RTK mode it is good to be able to side-step a number of systematic errors by getting a set of check shots from a different base station at a different epoch in the day. Total station check measurements could involve starting a new station setup in the controller and a different back-sight from the first set of measurements. Using both GNSS measurements in tandem

with total station observations is the most effective methodology in areas affected by ground movement.

Surveyors should be cognisant of the accuracy of the field observations and the rounding of bearings when making a comparison of the field observations to previous observations of the same vectors. Be aware of the operating environment affecting your observations e.g. high nearby vegetation affecting GNSS or nearby construction affecting total stations.

2. Use the right equipment and methodologies for the circumstances when undertaking cadastral surveys in areas affected by ground movement. It is important to have complete confidence in the accuracy of the measurements to correctly analyse the ground movement when determining a boundary definition.

3.3 Searching for Old Marks

“Search and search well. If it is there, find it. If it isn’t, be able to say with certainty that it isn’t there.”
(E.K. Elder (1973) *“Monuments – When are they in Control”* Journal of Surveying and Mapping)

Ground distortions can vary widely across the area so it is important to find witness and boundary marks as close as possible to the property corners being re-defined. Long range adoptions can have a significant effect on the location of local boundaries so it is important to look for evidence for the determination of boundaries as close as possible to the site.

However, more should be done than just finding three marks along the road frontage and re-defining boundaries based on that. It is important to find marks at the rear of the property or other side of the block to ensure you have sufficient evidence in order to support your definition. If the survey is the first to make a definition in an area such as a city block, then it is very helpful for those who follow if measurements are undertaken to the terminal marks of the block and a determination as to whether they are disturbed or not is made.

3. It is important to look for old marks close to the boundaries to minimise introducing errors from the land movement, but cast the net wide to ensure that you have all the relevant evidence and that your definition is sound.

3.4 Placement of New Marks

Thought needs to be taken when placing new traverse marks to minimise their chances of moving differently to the surrounding ground during a future earthquake event. Marks should not always be placed in long rigid structures such as concrete kerbs because structures like these can suffer significant damage as they have no elasticity to move with the ground surrounding them. The same caution should be applied to drainage structures such as manholes, which can shift vertically when liquefaction occurs. Permanent reference marks should also not be placed near the banks of water features or on areas of uncontrolled fill. Buried marks appear to perform the best relative to the land around them during an earthquake event.

Similar care should also be taken with the placement of boundary marks as you consider their performance during an earthquake. Boundary nails or disks that are placed at height on a fence rail or post can easily move differently to the ground around the structure. It is therefore worth taking the time to place a peg at ground level if at all possible.

4. Careful placement of traverse or boundary marks needs to be undertaken so that their positions do not shift differently to the ground around them. This will ensure that they remain the best evidence available to reinstate the associated boundaries after an earthquake event.

3.5 Plans and Supporting Documents

Thorough reporting is of course essential for LINZ plan processing and subsequent surveyors to understand the definition decisions made. Refer to Section 7 Survey Reporting below for more detailed guidance on this topic.

The relationship of occupation to boundaries on existing pre-quake plans becomes critically important when trying to reinstate boundaries in areas of ground movement. When the witness and boundary marks have moved or been destroyed in the subsequent reconstruction works, measurements to structures such as buildings, retaining walls and fences that are recorded on earlier plans or field notes can help give confidence when re-establishing the boundary. Therefore, taking the time to prepare unambiguous occupation diagrams, or submitting fixes of boundary occupation on field notes or field file printouts, will prove invaluable for future surveyors.

In a post-quake environment where ground movement has occurred, it often becomes necessary to formally re-define and peg boundaries and submit a dataset to LINZ. At a minimum the system requires a SO Redefinition plan to record the marks placed, which is more than adequate if the title dimensions are not to change. The notation of the changed dimensions on the survey diagram is advantageous.

Where there is conflict to be resolved however, and the documentary title dimensions are to change, you should consider lodging a land transfer (LT Definition) plan instead – although this is not a requirement of LINZ. For minimal extra cost a land transfer plan allows the owner and their solicitor to deposit the plan and update the title dimensions should they so wish. The land transfer plan generates a diagram of parcels which, for example, architects can use as a base for the redesign of a building on the property. The production of a LT Definition dataset should be recommended to clients in this instance.

5. Providing thorough and unambiguous documentation with a dataset, particularly regarding measurements to boundary occupation, can be valuable information when reinstating boundaries after an earthquake event. Consider lodging land transfer (LT Definition) plans to deal with boundary conflict so that the opportunity remains for the owner to raise a new title.

3.6 Bearing Adjustments

(See also section 7.2)

Bearing adjustments between Old Cadastral, Geodetic 1949 and Datum2000 plans are already part of the survey definition process. In an environment where there has been ground movement, there will be difficulties in confirming or determining bearing corrections due to the random nature of the land movement. Therefore, generic adjustments or rotations based on post-earthquake observations are not recommended, and should only be employed when there are consistent pre- and post-earthquake differences observed through multiple observations on different orientations.

4. Mark Reliability

4.1 Undisturbed Original Monuments

Undisturbed original boundary monuments preside as the highest form of evidence next to natural boundaries. This has been established in common law and is a hierarchy that does not need to change. Refer to Section 5 below for a more detailed discussion on this.

These principles prevent the creation of conflicts in the recorded cadastre and are perhaps more valid now than at any time in the past.

1. Legal precedent has established that boundary lines of surveyed parcels of land are governed by the position of original pegs placed (original undisturbed boundary monuments), even if this conflicts with records and their mathematical relationships.

4.2 'Disturbed' and 'Undisturbed' in Areas Ground Movement

In recent times 'documentary evidence' has perhaps become disproportionately weighted within the hierarchy of evidence. Mathematical disagreement between marks and records has commonly been used by surveyors as the sole basis to dismiss a mark as 'disturbed'. This is a reflection on the dependability of our recorded cadastre (ie: the generally high level of consistency between field measurements and official records).

As a result of the earthquake induced ground movement the land has moved inconsistently, and it's now common for survey mark measurements and records to disagree mathematically beyond expected survey tolerances. The approach in the paragraph above no longer suffices as a means to dismiss marks as disturbed as such we need to redefine our understanding of the difference between 'disturbed' and 'undisturbed' monuments.

To simply use a mathematical test would inevitably see many well established and reliable survey marks disregarded, only for a different surveyor (using a different sample of marks) to find mathematical reason to deem them as reliable. In the interim period (a few years after the earthquakes) this problem manifested itself and became widespread.

2. If an original survey mark remains firmly and vertically implanted within the immediate ground as it was originally placed, then it's unlikely to be disturbed. This remains the case even if the survey mark (and the immediate land surrounding it) has shifted due to earthquake induced land movement.

4.3 Assessing Mark Reliability

Given that mathematical disagreement does not necessarily constitute a mark as disturbed, surveyors must now apply considerably more judgment in assessing mark reliability. This includes gathering and analysing all relevant evidence which could indicate if a survey mark has

moved differentially to the ground around it. This is no longer a simple assessment to make and requires a level of judgment from the surveyor. See section 4.4 below.

3. When assessing survey mark reliability, surveyors must use sound judgement and investigate evidence beyond the mathematical relationships of marks and their records.

4.4 Gathering Evidence of Mark Reliability

Gathering evidence has never been as critical or required as much work as it does after an earthquake. In the absence of mathematical agreement there are many additional clues as to whether a mark may be undisturbed.

- Mathematical agreement with records (usually conclusive, providing there is no other conflicting evidence).
- The age, nature and depth of mark agree with the records.
- The mark is vertical (or the building/structure to which the mark is fixed is stable and vertical).
- The mark maintains its pre-earthquake relationship to nearby physical features or occupation.

See Section 5.2 below for a discussion about old pegs 'no record'.

The following scenarios are examples of when survey marks are likely to be disturbed:

1. Survey marks fraudulently moved by non-surveyors. Common examples including marks that have been:
 - repositioned to allow for a fence post
 - moved by a neighbour to falsely indicate a boundary position
 - accidentally knocked out, and repositioned as a best guess

Clues may include numbers facing the wrong direction, marks non-vertical or standing proud, the age of the occupation post-dates the survey mark, a conflict between marks and occupation in records, or the mark being displaced by a disproportionate magnitude to similar marks in the area.

2. Accidentally disturbed by a heavy vehicle.
Clues would generally be limited to the mark being non-vertical.
3. Disturbed by the movement of an adjoining structure. Examples could include marks which are fixed to:
 - a kerb, bridge or manhole
 - a building

Clues may include the relevant marks being out of position by a magnitude greater than similar marks in the area, a building or structure being damaged (ie: non-vertical, cracked, or suffering severe structural damage).

While undisturbed boundary monuments have a high weighting in the hierarchy of evidence, surveyors should be mindful that they have a higher risk profile than buried marks. Given that they often sit proud and are more visible to the public, they are prone to being disturbed and should be treated with caution.

There are often pre-earthquake records which give clues about the relationships of survey marks and nearby occupation or physical features. If the post-earthquake relationship between these measures the same or similar, this can be used as evidence to support the reliability of a survey mark.

4. To assess whether a mark is disturbed requires a determination if that mark has moved inconsistently to the immediate ground around it. If a survey mark maintains its original relative relationship to its surrounding physical features, then it is unlikely to be disturbed.

To deem a mark as disturbed a surveyor must determine whether or not a mark has been moved by an influence additional to earthquake induced ground movement.

5. Hierarchy of Evidence

Traditionally the hierarchy of evidence for boundary definition has been weighted as follows:

1. Natural Boundaries
2. Monumented lines (original marks)
3. Old occupation, long and undisputed
4. Abuttals
5. Mathematical evidence of position

Contrary to the perception of many surveyors the order of the hierarchy of evidence has not been clearly set in New Zealand legislation. The order was established by common law principles and court case precedents from other countries such as Australia, Canada, South Africa and the United States. However, several New Zealand case law decisions have been made which confirmed the relative importance of pegs, plans and occupation as ordered in the hierarchy above. [Refer *Equitable Building and Investment Co Ltd v Ross* (1886) 5 NZLR 229; *Cable v Roche* (1961) NZLR 614]

Note that the order of the hierarchy of evidence for boundary definition is not absolute, although it gives a good guide when there are conflicts between types of evidence.

While this hierarchy of evidence was not developed for the purpose of boundary definition in areas with earthquake ground movement, the principles are still very relevant.

5.1 Natural Boundaries

With the principle of boundaries moving with the land due to ground movement as a result of earthquakes, it follows that natural boundaries will move with the land. Therefore, boundaries defined by natural features will have the highest weighting of all the evidence.

Water boundary movement resulting from the earthquake sequence should not be confused with avulsion. Avulsion is defined as the rapid removal or addition of material from or to water's edge/bank. Earthquake movement generally results from shallow surface lateral spreading towards a watercourse. For the avoidance of doubt, lateral spreading is not considered as avulsion.

Natural boundaries that have moved as a result of the earthquake sequence will remain as the boundary feature. However, care needs to be taken to gather all evidence of the definition of water boundaries to determine if there has been any accretion, erosion or avulsion prior to or after the earthquakes as well as any earthquake related ground movement. Water boundaries can move from a combination of accretion/erosion and earthquake movement therefore these factors will need to be assessed.

1. Clearly defined natural boundaries (free of pre and post-earthquake accretion erosion and avulsion) should have the highest weighting when determining boundary positions.

5.2 Monumented Lines (Undisturbed Boundary Marks)

Original boundary marks found undisturbed are conclusive. Undisturbed boundary marks overrule measurements and areas shown on any plan or document.

The key word is undisturbed and this is discussed in depth in Section 4 above.

Old boundary marks with no record need to be treated with caution. However, they should not be completely ignored as they may assist in confirming reliability of other types of evidence, and/or other evidence proves its position as the boundary. An old boundary mark (with no record) found in isolation with no corroborating evidence has no weight.

Secondary to boundary marks are their related PRM, witness or traverse marks. These are accessory to the boundary marks but if found undisturbed can confirm the location of an old boundary mark or, define the location of former boundary monument.

Where boundary marks do not exist or have been disturbed then the accessory (PRM, witness or traverse) mark can be used to determine the position where the original mark was placed, provided there is no other conflicting evidence closer to the boundary. The further an accessory mark is from the boundary position, the less weight it has in defining that boundary and closer evidence lower on the hierarchy list may be given more weight.

If a boundary mark and its near/adjacent accessory mark are both found to be undisturbed, but their relationship is different from pre-quake records, then the boundary mark will define the boundary location.

Another source of accessory evidence is recorded pre-quake fixes to buildings or permanent structures near boundaries shown on approved plans/datasets and field notes. Cross lease plans, field notes and pre-earthquake Council building location certificate documents should be searched and investigated as these can often contain information about the buildings pre-quake relationship to the boundary.

The building to boundary offsets can be a reliable source of evidence to confirm other evidence or define a boundary alignment. However, the surveyor will need to evaluate the reliability of the building fixes/offsets to determine if it is the same structure and if the same feature/cladding has been measured to. Building offsets should be considered to have the lowest weight of monumentation evidence. This is due the lower standard of quality assurance applied and unknown accuracy from the pre-quake surveys and the difficulty in identifying and observing to the same feature on the building pre and post quakes.

A good quote:

“A found undisturbed original monument expressing the intent of the parties fixes a point, which between them, has no error in position. All non-original monuments set by measurements have some error in position” (E.K. Elder)

2. Old 'reliable' boundary marks will govern the boundary location and overrule any measurements and areas shown on any plan or document. Reliable boundary marks also overrule reliable accessory marks (witness or traverse).

5.3 Occupation

Of all of the types of boundary definition evidence, occupation is the one that is most commonly misunderstood.

Occupation is defined in the Rules for Cadastral Survey 2010 as 'the physical feature that describes the extent of an occupier's use of the land'.

1. Old Occupation

For occupation to have high weighting as evidence for boundary definition it should be classed as 'old'. Case law has shown that 'old' occupation must be a physical feature placed prior to or near time of the original survey, and on the line of the original surveyed boundaries. Additionally, it could have a recorded offset to the boundary line. It must also be undisputed.

Pre-earthquake occupation constructed after but not near the time of the original survey would have some weight, however this would need to be carefully considered and assessed alongside other types of evidence.

Buildings that were recorded to be on the boundary could be classed as evidence of old occupation. However, they could be also considered as a boundary monument and therefore have higher weight than other old occupation. This increase in the weighting would require certainty around the original position of the building/wall defining the boundary line or corner, and the manner in which the building moved during the earthquake relative to the ground around it.

A building that is not on the boundary but has a recorded mathematical relationship to the boundary is also a form of occupation evidence but could be classed as a permanent structure that witnesses the boundary. The building could be considered to be an accessory mark, which would have less weight than boundary monuments but more than occupation (old or new). The building would need to be assessed for its reliability due to any recladding and alterations, confidence about where the building to boundary offset was recorded from, and how the building might have moved relative to the ground during the earthquake.

For further thoughts on using historic building fixes as monuments or permanent structures refer to section 5.6 below.

2. Pre-Quake Occupation

Occupation that was constructed pre-quake and after but not near the time of the original survey would be classed as 'pre-quake'. These features have a reasonable probability that they were constructed without knowledge of the location of the boundary monuments and therefore have less weight than old occupation. However, if there is evidence that the occupation was constructed on the original boundary it will have similar but slightly less weight than 'old' occupation.

Buildings constructed pre-earthquakes, not recorded in the cadastre and which are on or close to boundaries may have required the boundary to be determined for their construction. In these cases, Councils may hold setting out or building location certificates that record the building's relationship to the boundary.

3. New Occupation

Occupation constructed after the earthquakes (especially without boundary monuments present) would have less weight than old occupation as it is unlikely to represent the ground movement that resulted from the earthquakes.

If an occupation feature was constructed based on boundary monuments from a post-quake CSD, the surveyor will need to determine which principle the CSD was carried out under (ie boundaries move or don't move with the land).

New occupation based on monuments from a 'boundaries move with the land' CSD will have some weight in the absence of monuments.

New occupation based on monuments from a 'boundaries don't move with the land' will have very little weight as evidence.

4. Reliability

If using occupation as boundary evidence all relevant information about the feature should be investigated and analysed to confirm that it can be used to for boundary definition. This would include the following tests:

- Is the occupation old, pre-quake or new?
- Is the occupation undisputed?
- Is it the same feature that has a recorded relationship to the boundary?
- Is the movement of the occupation representative of the land movement of the boundary?

5. Occupation in the absence of other evidence

In situations where all of the local monuments have been destroyed occupation along boundary lines may need to be used. Occupation of all ages would be used as evidence but the old recorded occupation will hold much more weight than newly constructed or unrecorded fences. The surveyor will need to analyse occupation for multiple lots on either side of the subject lot and parcels dimensions overlaid to confirm the reliability of the occupation evidence.

3. For occupation to have a high weighting as evidence it must have been constructed prior to or near the time of the original survey and constructed on the original surveyed boundary.

5.1 **Abuttals**

No boundary can be re-established in isolation. This principle remains especially valid in areas of earthquake ground movement.

Every boundary by definition is common to a neighbouring parcel. Therefore, when defining a boundary of a subject lot, the evidence for the neighbouring parcel must also be taken into account.

The effect of the boundary definition on neighbouring parcels should be assessed and reported.

4. Evidence for neighbouring parcels must be taken into account when defining boundary locations.

5.2 **Mathematical Evidence**

In the absence or uncertainty of the above mentioned evidence, mathematical adoptions from other undisturbed marks are ordinarily the next best and most reliable definition. However, adoptions made from remote undisturbed marks have little weight in defining boundary locations in areas affected by ground movement. They are problematic as undisturbed marks remote from the boundary location are likely to have moved differently and can produce sizable misalignments of the boundary with occupation. This makes it unlikely that a reinstated boundary mark would be placed in the location of the original mark had it not been removed/destroyed.

Long adoptions may also be unreliable due to the accumulation of errors in the old and new surveys. In these cases, old occupation may be found to be more reliable.

Shortages and excesses will be very common in areas of ground movement. Mathematical apportionment should be the last resort for distribution. The weighting of evidence highlighted in this section should be used to determine the apportionment of the shortages and excesses.

Furthermore, where there has been minimal ground movement, shortages and excesses shouldn't be apportioned by mathematical means unless it is supported by occupation.

- Where there is an excess and no parcel is short, then the owner in possession of excess is entitled to retain it.
- Where there is a shortage and an owner is occupying no more than their title dimension, they should not be required to give up part to satisfy a neighbouring parcel who is short.

6. Mathematical adoptions are to be used when all other sources of evidence are exhausted.

5.6 For Discussion:

Should a building with a recorded relationship to a boundary be considered a permanent structure that monuments or witnesses the boundary or as occupation evidence only?

The authors of this document have debated this question and are open to additional views on this issue.

Points for building evidence to be classed as monumentation:

- Buildings with recorded relationships to boundary should be raised above occupation to reinforce their importance in defining a boundary. This will increase the chance that surveyors will search for building pre-quake records before undertaking the survey and ensure that the correct features of the buildings are surveyed.
- Currently the rules do not allow for survey fixes of buildings to be shown on survey sheets of CSD's. If buildings could be considered as accessory marks or monuments (and therefore not occupation), surveyors could show their measured ties to existing buildings, along with the pre-quake offset/vector, to show and prove how the boundary was defined.
- Buildings should not be automatically classed as occupation. A common perception is that buildings are occupation because they are a feature which occupies the part of the property. However, on researching the definition of occupation it becomes apparent that occupation should be considered as a feature which limits what one occupies. The Rules for Cadastral Survey 2010 (RCS) definition is *'the physical features that describe the extent of an occupier's use of land'*. While sometimes buildings do limit ones use of the land, they don't always.
- Buildings can be classed as a permanent structure. The RCS definition for a permanent structure is 'a building or recognisable physical structure that is likely to remain undisturbed for 50 years or more'. Where a building has been survey fixed and has a recorded offset to the boundary, the building should be able to be classed as a permanent structure. The obvious caveats would be the RCS definition, the building being the same as recorded in the cadastre and the same cladding/feature has been surveyed. These questions would need to be evaluated and weighted by the surveyor.
- While permanent structure boundaries in the RCS 2010 is currently only specified for unit titles, this document will guide and assist LINZ in the formulation of Rule 20 (Cadastral Survey Rules for Canterbury).
- The fixes to buildings and calculated offsets have not had the same accuracy or QA as boundary monuments or survey marks, however they are more accurate than offsets to general occupation. It is more likely that you can replicate a survey fix of a building as previously surveyed than compared to an occupation feature such as a fence, which may have been surveyed at the centre of the post line or at the post and rail interface. Also building offsets are generally measured and shown to the centimetre where occupation (ie: fences and walls) are normally shown to the decimetre.
- While we are not aware of any NZ legislation or case law that has reference to buildings being able to be classed as a boundary monument, other countries such as Canada define a boundary monument as being 'placed or recognised by survey'. Therefore, a building with a corner referred to on an approved survey as being the boundary corner could be

considered to be the boundary monument. Likewise, an approved survey with a building wall recorded as being on the boundary could also be considered a monument.

- A boundary offset from a permanent structure should be classed as 'monumentation' and above 'occupation' evidence. Where a building has been recorded in the cadastre as being on the boundary line, or the building corner being the boundary point, this should be able to be defined as a permanent structure boundary as it monuments the boundary. Where a building has a recorded offset to a boundary line, the permanent structure witnesses the boundary and therefore is should be classed as an accessory mark, albeit with less weight than normal accessory / witness marks.
- Therefore, buildings (with recorded boundary offsets) should be in the monumentation category. However, they would generally be at the bottom of this category (behind boundary and witness/accessory marks) due to the confidence a surveyor can have that the surveyed feature/cladding is the same as recorded in the cadastre. That said, it would be difficult to dispute the evidence of the clearly defined feature of a building recorded as the boundary line.

Points for building evidence to be classed as evidence of occupation:

- This guideline should not make the statement that a building fix should confer the status of 'permanent structure' on that building. A permanent structure is to be used in conjunction with a 'permanent structure boundary', the purpose of which is clearly defined in Rule 6.9. A boundary such as this is used for defining units, cross-leases or secondary rights that are time-bound or linked to the life of the structure itself. Therefore, it will be confusing to confer a status on a piece of cadastral evidence that is not supported by the Rules.
- This guideline should not extrapolate that the building becomes a form of monumentation that witnesses the boundary. The fixes shown on the old plans were usually taken to clearly show which side of the boundary the building sits and were possibly done without independent checks. It can also be hard to know exactly where on the building the old fix was taken and to therefore replicate that. The surveyor taking the measurements would not necessarily have done so anticipating that they would be elevated up the hierarchy of evidence. There will also be some investigation needed to ensure that the building did not move in a manner differently to the surrounding land during the earthquake. They should therefore stay as evidence of occupation so that a surveyor will approach them with appropriate caution, but the discussion is included in this document so that people realise the value of this cadastral information in a post-quake environment.
- It is beyond the purpose of this guideline document to make the statements about buildings possibly being considered permanent structures or a form of monumentation. It is more appropriate that those sorts of statements be covered in a LINZ interpretation guide.

6. Permanent Structure and Stratum Boundaries

6.1 Redefining Permanent Structure Boundaries after an Earthquake

The approach that boundaries move with the land can also be applied to permanent structure boundaries. As these boundaries were originally defined by a permanent structure, then they continue to be defined by this structure after an earthquake.

Difficulties will arise if the structure defining the boundaries has been damaged or destroyed by the earthquake. In this case all available evidence should be looked at to determine where the boundary used to be. The primary record of this will be dimensions or descriptions on a survey plan. This could also include physical evidence, if this still exists, as well as as-built plans or other records.

1. If a boundary is defined by a permanent structure then it continues to be defined by this structure even if the structure is moved by an earthquake.

6.2 Permanent Structure Boundaries for Cross Leases and Units

The re-definition of cross-lease or unit boundaries after an earthquake will depend on how the boundaries were initially defined on the plan. There are many variations on the quality of the information shown on plans.

The original position of the boundaries can be determined through the following hierarchy:

1. Permanent structure boundaries: If the boundaries are described as following a permanent structure then this takes precedence. For example: external face of wall or fence.
2. Dimensions: Some flats plans show dimensions between permanent structure boundaries, or from a permanent structure to primary parcel boundaries. These dimensions may be the most relevant evidence to establish these boundaries. Where possible dimensions should be respected to ensure that the lease agreement is valid and there is no conflict with the flats plan.
3. A post-earthquake topographic survey may have been undertaken prior to the buildings being demolished and this could have fixed the structures the boundaries were based upon. It may also be possible to request the field book fixes from the original survey firm, if available.
4. Scaling information off plans: This can be used as a last resort if there is no other information to locate the flat boundaries.

If possible the original buildings and any other features defining cross-lease boundaries should be surveyed before they are demolished to remove any doubt about their post-earthquake location, or location relative to the 'current' primary boundary. Then it can be proven that the new buildings match the original location and do not conflict with the original plan.

2. Gather all available evidence to determine the position of the permanent structure boundary.

6.3 Stratum Boundaries

Stratum boundaries also move with the land as a result of earthquake related ground movement. Measurement to the vertical control including the origin of levels, the site benchmark as well as the site and boundary in question, need to be undertaken as structures may have performed differently to the surrounding land. For example, a building that is piled may not have dropped to the extent that the surrounding land has.

Where differential movement has occurred, examination of the original intent of the boundary should to be undertaken. For example, it was common for a stratum boundary to be struck in the centre of a floor slab or at an offset to the top of a roof line.

3. Examine the original intent of the stratum boundary and ensure measurement is not only taken to the structure but the site, the benchmarks and the origin of levels.

7. Survey Reporting

7.1 Completeness of Information

The first item in the report should be a single statement indicating whether the survey involved (or did not involve) a boundary that has been affected by the Canterbury earthquakes.

“This survey does/does not involve boundaries that have moved with the movement of land caused by the Canterbury earthquakes”.

It is important to make clear the conditions encountered on site and how this has affected the survey. The conditions encountered will determine how the site has been affected by earthquake related movement and thus how it is reported. For example:

“The site has experienced significant liquefaction as evidenced by images from Canterbury maps and ground measurement evidence and has thus been determined as being affected by earthquake related ground movement”.

Details of underlying surveys and when they were completed can influence how the measurements from the area are treated. In other words, are they pre-earthquake sequence, post-September 2010, or post-February 2011 definitions? Also consider if adoptions directly from plans that were completed pre-earthquake are appropriate when the new measurements show different relationships to pre-quake measurements.

In addition, the date of a post-earthquake boundary definition may also be a factor that needs to be noted within the report. During the period from mid-2014 to February 2015 many boundary definitions were required to maintain documentary dimensions, at the expense of the physical evidence available. These definitions may now be in conflict with the current “boundaries have moved with land movement” edict.

1. Be clear what has been encountered on site and how it has been determined that the boundary is subject to ground movement.
2. Provide details about the survey plans used, their vintage and how it has been determined that they are affected.
3. Provide other information relating to the assessment of land movement where it relates to the determination of the boundary.

7.2 Bearing Adjustments

Bearing adjustments that are applied to underlying surveys will affect the location of adopted positions that may in turn affect the definition decisions of others. Some surveys may have multiple corrections based on different road alignments and it is important to detail this within the survey report as only one can be entered in LandonLine or on the header sheet. Some plans may appear to have a bearing correction on first look, but closer examination shows this not to be the case and this needs to be reported so other surveyors know why a correction has not been applied without having to critically examine the survey data.

Also consider that valid bearing adjustments need to be determined by direct comparison of previously directly observed line(s) – preferably the origin, or at least a good spread of common line pairs over the survey area.

(See also section 3.6)

4. Report on decisions in relation to what adjustments have, or have not, been applied and why.

7.3 Old Survey Marks

Old survey marks will form the basis of definition for boundaries affected by ground movement. It is thus a very important section of the survey report and care needs to be taken to ensure there is a detailed list of marks found, looked for and not found, and found but determined as being disturbed, as well as the decisions made around those old marks.

As it is not clear from the plan which marks were looked for and not found, a list will enable surveyors to quickly assess which marks were in fact looked for. The reason they were not found should also be reported. For example:

- in recent trench;
- within house platform;
- within road rebuild area.

This will enable surveyors to assess whether other marks in their vicinity are likely to be destroyed in a similar fashion.

Old marks not looked for and the reason they were not looked for should also be detailed so that surveyors following can assess whether they should look for them. For example, old marks that were under a temporary site office and could not be looked for may be able to be looked for after the site office has been removed.

From time to time there will be old marks that have moved differently for a reason other than ground movement and which will have been deemed disturbed. For example, all marks from a survey are in the ground and/or kerb and one mark is placed in a manhole lid which has been uplifted, and so it may be considered disturbed. These decisions need to be reported with their reasoning which will enable surveyors to understand why some marks have been relied upon and not others.

A diagram of old marks searched for showing those not found, found disturbed or found undisturbed can be a useful tool for future surveyors working nearby.

5. Old survey marks will form the basis of definition for boundaries affected by ground movement. Ensure the report contains a detailed list of marks found, looked for and not found, and found but determined to be disturbed, and the reasons and decisions made concerning those old marks.

7.4 Boundary Definition and Conflict with Cadastre

The boundary definition needs to be explained clearly so surveyors can follow the definition decisions made during a survey. Key points include:

- Which boundaries are affected boundaries and which are not;
- The basis of the definition decision(s);
- What marks were held and why;
- Were any marks ignored and why;
- Which lines were recalculated and why;
- What role did occupation and other evidential items play in defining the boundaries and why;
- Confirm the differences between the defined boundaries and the title boundaries including orientation of the lines;
- Can the title dimensions of the abutting parcels still be respected;
- What decisions were made in accounting for a shortage or excess;
- Has this meant the area is less/more than the underlying title.

6. Clearly report how each of the boundaries was defined and how that affects the title dimensions. Report how the resulting definition impacts on adjoining parcels or the balance of the block.

7.5 Occupation

Occupation will play an increasing role in assessing boundary definition and will be carefully examined by LINZ and future surveyors.

Provide information about the pre-earthquake relationship of the occupation to the boundary. For example, this may be the case where a pre-earthquake survey was begun but not completed; or occupation from underlying plan matches occupation noted on underlying survey.

Confirm the role that occupation played in defining the boundaries from knowledge that the occupation was on the boundary pre-earthquake and held on the boundary, to occupation matched well with the defined boundaries, but had no role in defining the boundaries.

7. What role occupation played in the definition and why.
8. Clearly report on any significant differences between redefined boundaries and current occupation, or with known pre-earthquake boundary/occupation relationships

8. Professional Courtesy

Practitioners should be aware of their legal obligations and professional responsibilities when undertaking boundary definition surveys. These obligations apply regardless of whether a survey dataset is prepared or not.

The survey professional should undertake the survey task with an impartial view so that a boundary is interpreted using the available evidence and best practice processes and is not influenced by the client's personal or business objectives.

8.1 Legacy Data

In a post-earthquake environment, it is of particular benefit to leave a good survey information trail for others to follow. This links back to full, accurate and unambiguous survey reporting, as well as complete supporting documents such as field notes; calculation sheets and supporting graphics as applicable.

1. All data can be good data. A thorough and complete dataset will contribute to the integrity of the cadastral record and benefit future surveyors who have cause to follow a definition.

8.2 Communication

When commencing survey work that will result in the submission of a dataset, it is good practice to assign a Landonline survey reference in the location of the survey as early as practicable. Therefore, any subsequent information search will signal to other surveyors that someone is undertaking - or are planning to undertake - a survey in that area.

When working over prior surveys that are in conflict with a definition, it is beneficial to maintain open lines of communication with the other signing surveyor. Discussing and sharing the definition decisions will provide both parties with a greater understanding of the evidence gathered, the issues addressed, and the solution(s) reached.

2. Communication amongst survey practitioners working in the same areas in a post-earthquake environment is helpful and beneficial to both parties.

9. Further Considerations

Additional issues and items that may need to be considered include:

a) Parcel boundaries may no longer be straight lines

- Differential land movement between boundary marks may cause the creation of new boundary angles or bends in what were originally straight boundaries

b) Road boundary alignments

- Road boundaries may no longer remain straight lines but may have multiple angles along their alignment according to differential land movement along the road
- Original road widths of 100 links or 20.00m may be unable to be maintained and so the road parcel may be wider or narrower
- Curved boundaries may no longer be able to maintain a constant radius along multiple parcels

c) Relocating unmarked boundary positions

- The relocation of unmarked primary boundary points will be similar in process to any other marked primary boundary point where the mark no longer remains
- For unmarked non-primary boundary points, the issues are different. These points are often referenced mathematically to the underlying primary boundaries and if these underlying primary boundaries have been bent, rotated, extended or contracted, there may be issues with determining if it is appropriate that referenced non-primary boundaries also reflect these changes. For example, a pre-earthquake ROW may (or may not) have remained 3m wide even if the underlying primary parcel boundaries have contracted say 1m closer together. Each case will need to be assessed on its particular merits noting that often the non-primary parcels were often set out to create rights over a physical entity (eg: wall, pipeline, cable) and this intent should be preserved.

d) CSD integration

- Mark linking – ensure that old marks have been correctly identified in the field and are linked to the appropriate existing mark node. This can be confusing due to some marks now having multiple nodes in LandonLine. Seek assistance from LINZ if uncertain.

e) Connections to cadastral survey network marks

- Wherever possible, surveys should be connected by direct observation or post-earthquake adoptions to 6th Order or better geodetic marks that have been established or re-surveyed (as a geodetic control network) post-earthquake.

f) Landslips

- Landslips, as defined by the Bill are ‘the movement by way of falling, sliding, or flowing of materials that (a) formed an integral part of the ground before the movement; but (b) had become loose material after the movement (other than by liquefaction)’.

It is the intention of the new legislation that in the case of typical landslips (as defined above), boundaries do not move with the land.

Generally speaking, the 'boundaries move' principle intends to preserve the relationships between boundaries and their immediate physical environment. The 'landslip' exclusion applies to localised land movements where the extents can be clearly defined, and unlike most other earthquake land movements are entirely destructive in nature.

For avoidance of doubt the definition of landslip excludes large areas of land, which although may have moved independently, were left largely intact. An example includes the 'Mass Movement Areas' in the Port Hills of Christchurch. For the purpose of these guidelines, these types of movements do not constitute landslips and therefore boundaries should generally move with the movement of the land.

The judgment on whether a land movement constitutes a landslip will reside with the surveyor.