Development and Construction Planning
Lessons Learned from the Earthquake(s)

Mark Allan NZIS President
Learned Response

- Christchurch Earthquake Sequence
- Kaikoura Earthquake Sequence
- Alliance Models SCIRT NCTIR
- Christchurch Property Boundaries and Related Matters Act
- Geotechnical Engineering
- Civil Engineering
Kaikoura
14 November 2016
Magnitude 7.8
Canterbury Earthquake Sequence

- September 4th 2010 – Magnitude 7.1
- February 22nd 2011 – Magnitude 6.3
- June 13th 2011 – Magnitude 6.0
- December 23rd 2011 – Magnitude 6.0
  More than 18,000 aftershocks

Kaikoura Earthquake Sequence
- November 14th 2016 – Magnitude 7.8
  More than 18,000 aftershocks
Alliance Models

- SCIRT - Stronger Christchurch Infrastructure Rebuild Team
- NCTIR - North Canterbury Transport Infrastructure Recovery
- Alliances formed between Owner Participants, Non Owner Participants and Sub-Contractors
About SCIRT

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) was created in 2011 by the Canterbury Earthquake Recovery Authority to rebuild Christchurch’s earthquake damaged horizontal infrastructure.

SCIRT’s job was to provide a cost-effective and efficient vehicle to quickly get the city's civil infrastructure back on its feet.

SCIRT is an alliance partnership between:
Owner Participants - Christchurch City Council (CCC), Canterbury Earthquake Recovery Authority (CERA), New Zealand Transport Agency (NZTA) and Non-Owner Participants – contractors; City Care, McConnell Dowell, Downer, Fletcher, Fulton Hogan.
About SCIRT

SCIRT was defined very early as a 5 year programme, transitioning from emergency recovery to a more business as usual approach as works progressed.

SCIRT was based on an alliance agreement between national and local government and five civil engineering contractors, but was not a conventional alliance.

The contractor delivery teams competed for construction work, which was allocated according to performance in both cost and non-cost Key Result Areas (KRAs). Strong drivers were created for both competition and collaboration.
"Those companies who performed better were allocated more work," said SCIRT Executive General Manager Ian Campbell. "Delivery teams were paid a fee based on the target cost of work done. Poor performance therefore meant less fee earned; good performance increased the fee."

The difference between target cost (budget) and actual cost for each project was added to a gain share/pain share pot, a share of which (nominally 50% but variable depending on non-cost performance) was paid to (or paid by) the contractors at the end of the programme according to the amount of work each had done.

This encouraged collaboration because all contractors needed to perform to ensure an overall "gain" rather than "pain" result.
About SCIRT

All contractors started out being allocated an equal amount of work; however, each company's share altered over the course of the programme.

Because all the contractors shared pain or gain, it was in all their interests to help each other deliver the best possible outcome.
About SCIRT

SCIRT’s $2.2 billion, five-and-a-half year programme was funded by the New Zealand Government and Christchurch City Council.

It involved more than 700 individual projects across the city repairing and rebuilding underground sewage, storm water and fresh water pipes, rebuilding wastewater pump stations as well as roads, bridges and retaining walls.

Multiple contractors collaborated with government agencies for the greater good of an earthquake-battered community.
About NCTIR

The North Canterbury Transport Infrastructure Recovery (NCTIR) has been set-up by the government under the Hurunui/Kaikoura Earthquakes Recovery Act 2016 to repair and get the road and rail networks re-opened by the end of 2017.

The North Canterbury Transport Infrastructure Recovery is an alliance representing the NZ Transport Agency and KiwiRail on behalf of government, to repair by the end of 2017, the road and rail networks between Picton and Christchurch following the November 2016 Kaikoura earthquake.

NCTIR is an alliance partnership between:
Owner Participants the NZ Transport Agency and KiwiRail and Non Owner Participants – contractors; Fulton Hogan, Downer, HEB Construction and Higgins.
About NCTIR

NCTIR was setup as an emergency response alliance with an expected lifetime of 8 months to reinstate a level of service due to the impact of the main trunk railway line being out of service.

NCTIR has just recently had an improvements package added on to it’s scope of work resulting in likely addition of 2 years.

The NCTIR alliance is set up differently to the SCIRT alliance in that the non-owner participants are not competing against each other for work.
Move mountains to Reconnect Communities

1. Keep the Lewis Pass and Inland Road roads open
2. Re open the Main North Line
3. Re open State Highway 1 North and South
4. Open the Kaikoura Harbour
The Scale of the Damage
20 rail tunnels damaged
300 m with major damage
50 rail bridges need repairs
6 major damage
3 full replacement
190 km rail affected
50,000 m³ of ballast produced to repair rail corridor
The phases

1. Clean the tops of the slips
2. Clear away the slip with machinery
3. Keep the slips from blocking the road and or rail
4. Build the rail and road
5. Make the road and rail resilient
Moving mountains to reconnect communities
Progress Report

Project Dates

2 June 17
14 June 17
9 July 17
1 Aug 17
10 June 17
22 May 17
27 April 17

Key:
- Open for Work Trains and Track Repairs in Progress
- Civil Works in Progress
Stabilising Slip Faces

Before Sluicing and Scaling

After Sluicing and Scaling

Before Sluicing and Scaling
Slip material lands and accumulates on the engineered bench rather than the transport corridor.
Relocate Road and Rail

- Rail and road moved away from landslides
- Rock armouring to protect rail from the sea
- Slips deconstructed
- Bunds and catch pits between the slips and the transport corridor
Stabilising Slip Faces Using Mesh

[Image of a slope covered with mesh]
Catch Bunds and Fences

- Catch area behind bund to collect landslide material
- Remote monitoring sensors on the fence to detect slope failures
- Fence to catch airborne rocks (see next slide)
- Rail & road moved away from slip
- Bund to create catch area and to protect railway
Rockfall Trajectory Analysis

Rockfall trajectory analysis to help design the:
- Height of the fences
- Strength of the fences
Remote monitoring sensors on the fence to detect slope failures to warn trains before they enter the area. Weather also monitored.
Rockfall Fences
Rockfall Fences
August 2017 – slip material barriers near site 27
Rock Fall Shelters

Rockfall Risk
Containers – Temporary Bunding
Main North Line Rail Network

August 2017 – Final rail weld at site 4. MNL reconnected nine months after quake.
Expect trains

Work trains are now running day and night between Blenheim and Christchurch
Data Capture

Ground topo, scanner, mobile scanner, UAV, Point Clouds, Big Data, GIS
Where to Start?
LiDAR and Aerial Photography

- Concept design able to start quickly
- Allows large surfaces to be modelled quickly
- Images allow comparison between Pre and Post Quake
Detailed Design = Detailed Survey

- Accuracy?
- Datums?
- Methods of Capture?
- Deliverables Required?
- End User?
Quality of Design, Setout and Construction are a direct result of the quality of the original survey.
NCTIR Control Network Installed

- Framework that the entire project is based on
- All control marks in terms of each other
- Marks in terms of project datum
- Allows surveys to be started confidently
NCTIR Survey Specification Created

- All consultants able to provide consistent deliverables
- 7 Consultants being used
- Accuracies specified
- Data capture methodology specified
- System setup for easy flow of data through data system (delivery and QA)
Surveying - Equipment

GPS

Scanning

Total Station
Data Management - 12d

- 12d Model and 12d Synergy Utilized
  - 12d Synergy – Data management with traceability
  - 12d Model – Civil Engineering and Survey Software
- Allows the maintenance of a live database
  - Model sharing
  - 120+ Designers
- New Surveys and data added everyday
  - Design jobs refresh to show new data captured
Unmanned Aerial Vehicle (UAV) - Drone

- Gather Data Quickly
- Creates Both Surface models and Aerial Image
- Survey Dangerous Locations
- Integration with other survey methods
Primary Data Delivery;
• 12d
  ➢ 3D Surface
  ➢ Attributed line strings
• Local Control Tied into NCTIR Control Network
Viewers
Sketch Fab - Geotech
Recap - Designers
Integrated Design and Survey
Capture /As-built

Construction

Survey
Project Life Cycle

Setout

Design
Mobile Laser Scanning for Improvements Package

- GPS for Location
- Internal IMU for accurate solution
- 10mm Accuracy
- Large areas Surveyed Quickly
- Digital String Extraction
- Essential in large improvement package
- Continuous Site not isolated locations
Note: The provisions of this act do not apply to the Kaikoura Earthquake Sequence.

Surveyors need to take into account earthquake-related land movement when locating property boundaries in Christchurch.
The Act

The Canterbury Property Boundaries and Related Matters Act came into force on 29 August 2016.

The purpose of the act is to provide certainty to surveying and titles in greater Christchurch following the Canterbury earthquakes, to support recovery and the rebuild and to maintain public confidence in the cadastre.

"Greater Christchurch" is defined as the districts of the Christchurch City Council, the Selwyn District Council, and the Waimakariri District Council, and includes the coastal marine area adjacent to those districts.

The "Canterbury earthquakes" are defined as any earthquake in Canterbury between 4 September 2010 and 13 February 2022 and including any aftershock in that period.
The Act

The legislation takes a pragmatic view by saying boundaries have moved with the land.

In most instances, this means that boundaries will be where property owners expect them to be, as marked by features like fences. This legislation will reduce the potential for future boundary disputes and conflicts.

The Surveyor General will consult with surveyors on proposed rules to implement the new legislation.

There is a possibility that there will be boundary conflicts as a result of earlier approved surveys that did not take land movement into account.
The Act

Coverage and impact of the legislation
Sections 7 and 8 of the new Act set rules applying to all boundaries that determine the spatial extent of land.

Section 7(2) says the boundaries are deemed to have moved or to move with the movement of land caused by the Canterbury earthquakes (whether the movement was horizontal or vertical, or both), unless the movement was a landslip.

This does not affect the validity of an estate or interest in land, "and the land (as moved) continues to be the same land, and affected by the same interests, as before the movement".

It also does not affect the boundaries within greater Christchurch defined before 29 August 2016.
The Act

**Section 8** states that a cadastral survey will continue to determine the boundaries of any land surveyed within greater Christchurch if it was done in good faith and without negligence between 4 September 2010 and 29 August 2016, and its cadastral survey dataset was determined to comply with **section 9(a)** of the Cadastral Survey Act 2002 in that period.

**Section 10** removes liability for cadastral surveys or boundary determinations between 4 September 2010 and 29 August 2016 if the liability would not have arisen if the survey or determination had been done on the opposite basis to that used - ie, that the boundaries did or did not move with the movement of land caused by the earthquakes.
## Sector Leaders Group

<table>
<thead>
<tr>
<th>Scenario 1: Status quo</th>
<th>Scenario 2: Boundaries moved with the land</th>
<th>Scenario 3: Boundaries did not move</th>
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</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Legislation is introduced to state that legal boundaries in Canterbury move where there is shallow ground movement over a large area. This will include a clear definition of where and when this applies to avoid unintended conflation of existing common law or subsequent application in inappropriate situations. This is how most surveys have been conducted since 2010, and accounts for what landowners would generally expect but is likely to be inconsistent with current common law.</td>
<td>Accept (legislative if required) that legal boundaries do not move where there is shallow surface movement over a large area. This approach is likely to be consistent with the current common law but is a change to survey practice in Christchurch and will mean most surveys completed (and approved) since 2010 will be “wrong” and is likely to trigger a large number of boundary adjustments.</td>
</tr>
<tr>
<td><strong>Implications</strong></td>
<td>Legal boundary will generally align with occupation or property and infrastructure owners will retain ownership of and access to their physical assets. Completed results will generally be within legal boundaries. The survey plan supporting the legal title may not reflect the current legal boundary. This means a reassessment is required for any property-related transactions and improvements and/or investment by the Crown to reduce uncertainty.</td>
<td>Legal title will sometimes not align with occupation causing problems with access, safety, usability, insurance, and maintenance where physical assets sit across legal boundaries. Some assets will need to be relocated. Rebuilds completed since 2010 may be miscalculated with the legal boundary. Many landowners are likely to seek boundary adjustments to realign legal title with occupation.</td>
</tr>
<tr>
<td><strong>Landowners</strong></td>
<td>There is scope for surveyor judgement and interpretation of evidence that may lead to inconsistent or conflicting boundary determinations, which increases cost to landowners.</td>
<td>There is less scope for surveyor judgement requiring meaning and potential liability to surveyors might be reduced and surveys much more costly to complete.</td>
</tr>
<tr>
<td><strong>Surveyors</strong></td>
<td>The spatial representation of boundaries in the cadastral and land titles system, which will be difficult to address — even through an increased level of survey activity to support property-related transactions and improvements.</td>
<td>The digital cadastral will accurately reflect legal title, but will differ from occupation.</td>
</tr>
<tr>
<td><strong>Landsesa</strong></td>
<td>All increased level of survey activity to support property-related transactions and improvements may be required to satisfy regulators, banks and insurers.</td>
<td>Boundary adjustments, or asset relocation, will be needed to finance and insure assets that fall outside the legal boundary. Council may need to seek retrospective consent for structures that no longer fit with planning code.</td>
</tr>
<tr>
<td><strong>Solutions</strong></td>
<td>Surveyor-General issues new cadastral Principles and Rules for locating new position of earthquake-affected boundaries that includes relying on page and marks on maps that have shifted due to earthquake land movement and places reliance on physical monuments and evidence of occupation.</td>
<td>Surveyor-General issues new cadastral rules for locating new position of earthquake-affected boundaries that includes geographic coordinates in the hierarchy of evidence.</td>
</tr>
</tbody>
</table>

### NZIS Institute of Surveyors

[Logo]

[Website]
Sector Leaders Group

Definitions:
There are 3 inter-related concepts relating to boundaries. The alignment between each is different under each option.
- **Cadastral**
  The repository of all accepted Cadastral Survey Data sets held by LINZ.
- **Legal boundary**
  The boundary that applies to a specified parcel of land as described in the survey plan supporting the legal title.
- **Physical boundary**
  The boundary as represented by the landowner’s occupation of the land. Generally represented by structures and fences.

Measuring performance of the options:
The following objectives have been established to assess the options, and identify where trade-offs arise.
- **Landowner rights**
  Are the rights of landowners to undisturbed possession maintained? Are additional costs and delays in property transactions minimised?
- **Certainty**
  Do landowners have a clear understanding of their legal boundary? Are the rules, practices and legal position associated with surveying areas subject to shallow surface movement clear and without unintended consequences?
- **Accuracy of the cadastral**
  Does the cadastral provide an accurate presentation of legal title to support efficient property transactions and improvements?
- **Timeliness**
  Can the solution be implemented quickly?
- **Support rebuild activity**
  Does the solution provide confidence to all parties that survey practices, and any associated legal and planning processes, to continue rebuild activities?

Analysis of the options:
In deciding between these options, trade-offs emerge between continuing to realise the benefits of an accurate digital cadastral, certainty about the location of the legal boundary, and minimising disruption and cost to landowners.
- **Status quo**
  Essentially a ‘wait and see’ approach that embeds current uncertainty for all parties until a legal precedent is established.
  Possible that emerging legal precedent is unpalatable, requiring subsequent policy and legal intervention anyway.
- **Boundaries moved with the land**
  Provides the most intuitively correct outcome for landowners, and other parties, and is how most (but not all) surveys have been undertaken since 2010.
  Means that legal boundary as defined in a survey plan may not be an accurate representation of the current legal boundary. This could add costs to property transactions and reduce the value of affected land if LINZ does not intervene.
  Outstanding policy question about the area over which this should be implemented.
- **Boundaries didn’t move with the land**
  Provides a simple approach to surveying, with limited scope for judgement and dispute.
  Cadastral is accurate and legal boundaries are appropriately defined in the survey plan.
  Counter-intuitive outcome will create a bow wave of boundary adjustments so realign with occupation. These costs will need to fall somewhere.
Geotechnical Engineering

Canterbury and Kaikoura earthquake sequences resulted in intense ground shaking

Large areas of saturated alluvial soils across the eastern parts of Christchurch liquified resulting in significant damage to land, buildings and services

Many areas were affected by lateral spread

Significant cliff collapse and rockfall in the Port Hills and Banks Peninsula surrounding Christchurch
Christchurch – Whitewash Head
Christchurch – Deans Head
Christchurch - Redcliffs
Geotechnical Engineering
Geotechnical Engineering

Since the Canterbury earthquakes, it is now recognised that specialists in geotechnical engineering is needed to assess the ground conditions at a site.

Geotechnical engineers need to work closely at an early stage with the surveyors, civil and structural engineers, architects, planners, Local Authorities and the owner/developers to determine the site constraints, understand geotechnical risks, and to identify design solutions.
Geotechnical Engineering

The Ministry for Building, Innovation and Employment have produced a number of guidance documents that outline various geotechnical and foundation options that can be considered for residential development and are considered to be an acceptable solution.

Foundation options will vary and are typically controlled by the liquefaction hazard, risk of lateral spreading, and the bearing capacity of the insitu ground conditions.

Guidance is now available on assessing and mitigating the risk of rockfall.
‘The New Zealand Geotechnical Database’ has been established to provide a valuable resource for geotechnical engineers to review existing geotechnical data of an area and review the earthquake performance of land.

The database also contains records of surveys, peak ground accelerations in the various earthquakes, groundwater models, flood hazard modelling, geological mapping, active fault mapping, aerial photography taken after each of the significant earthquakes, and more.
Geotechnical Engineering

Methods of deep ground investigation include deep boreholes with SPT testing, DMT, MASW, ground radar, and CPT testing.

There are also specialist deep ground improvement contractors operating in the City that can provide bespoke ground improvement/densification solutions to mitigate the presence of soft or liquefiable ground conditions.
Civil Engineering

We have seen many changes to Civil Engineering design specifications and construction standards.

Most are directly related to the geotechnical classification of the land TC1, TC2 and TC3 or equivalent and the designed resilience of the structures in a specified SLS (Static Limit State) and ULS (Ultimate Limit State) event.
Civil Engineering

Examples
Drainage - use of tractive force sewer design using minimum grades and flow rates to provide for more shallow sewers < 2.5m
Use collector sewers and lift stations to compensate for maximum depth specification for sewers and pump stations
Construction of wrapped gravel rafts to support infrastructure including pipelines and manhole structures
Wrapping of pipe joints
Provision of yield joint connections to solid infrastructure, interruption of concrete haunched yield joints and corbels with soft joint
Use of short pipes and long sockets as yield joints
Use of pressure sewers in soft ground
Use of PE pipe - more resilient than uPVC
Civil Engineering

Examples
Roading
Increased pavement depths
Reinforced metalcourse construction - geogrid
Flexible pavements – polymer asphalt solutions

Earthworks TC2 – TC3
Ground improvement - deep compaction - impact rolling
Ground densification – stone piling – grouting and cement stabilisation

Building Foundations TC2 – TC3
Ribraft
Piling – timber, concrete, screw piles
Footings backfilled with hardfill

Cost
All measures are adding significantly to the cost
Thank you

Questions?