Canterbury Earthquakes Royal Commission
Te Komihana Rūwhenua o Waitaha

FINAL REPORT

VOLUME 5
SUMMARY AND RECOMMENDATIONS IN VOLUMES 5-7
CHRISTCHURCH, THE CITY AND APPROACH TO THIS INQUIRY

A. A bird's eye view of Banks Peninsula and the Canterbury Plains (source: Alexander Turnbull Library)

B. Manchester Street, looking towards the Avon River, circa 1868 (source: Christchurch City Libraries)

C. An aerial photo of Christchurch central city taken in October 2012 after many of the buildings had been demolished (source: Canterbury Earthquake Recovery Authority)

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Letter of Transmittal

To His Excellency, Lieutenant General The Right Honourable Sir Jerry Mateparae GNZM, QSO Governor-General of New Zealand

Your Excellency

Pursuant to the Orders in Council dated 11 April 2011, 7 February 2012 and 23 October 2012 appointing us to be a Royal Commission of Inquiry into Building Failure caused by the Canterbury Earthquakes and to provide a Final Report not later than 30 November 2012, with a first part delivered by 29 June 2012 and a second part delivered on 10 October 2012, we now humbly submit the third and final part of our Final Report for Your Excellency's consideration.

We have the honour to be

Your Excellency's most obedient servants

Hon Justice Mark Cooper (Chairperson)

Sir Ronald Carter

Adjunct Associate Professor Richard Fenwick

Dated at Wellington this 29th day of November 2012.

Introduction

Volumes 5, 6 and 7 of this Report complete the reporting of the findings and recommendations of our Inquiry into building failures caused by the Canterbury earthquakes. These Volumes must be read in the context of the earlier volumes of our Report: Volumes 1–4. Those Volumes include a detailed discussion of the nature of the Canterbury earthquakes and the earthquake risk that must be taken into account by building designers in New Zealand (see section 2 of Volume 1); and the findings of the study of the representative sample of buildings, including all those buildings whose failure caused death (see Volumes 2 and 4) except for the CTV building, which is reported in Volume 6.

They also include our recommendations about matters to consider:

- when designing new buildings (see section 4 of Volume 1, and Volumes 2 and 3);
- when assessing existing buildings; and
- when dealing with those buildings that are considered to be earthquake-prone or potentially earthquake-prone (see Volume 4).

This is the third, and final, part of our Final Report. The first part (Volumes 1–3) was delivered in June 2012; the second part (Volume 4) was delivered in October 2012. The Terms of Reference for our Inquiry are set out again, for ease of reference, in Appendix 1 of this Volume. The matters dealt with in Volumes 5, 6 and 7 relate to the:

- Inquiry into specified buildings, namely the Canterbury Television (or CTV) building (Volume 6);
- Inquiry into the adequacy of legal and best-practice requirements for the design, construction, and maintenance of buildings in central business districts in New Zealand to address the known risk of earthquakes and, in particular–
  - the legal and best-practice requirements for the assessment of, and for remedial work carried out on, buildings after any earthquake (section 2 of Volume 7); and
  - the roles of central government, local government, the building and construction industry and other elements of the private sector in developing and enforcing legal and best-practice requirements (sections 3, 4 and 5 of Volume 7).

Volume 5 sets out our approach to the Inquiry as a whole and includes a brief description of the city of Christchurch and the impact of the Canterbury earthquakes.

One of the most significant and tragic consequences of the 22 February 2011 earthquake was the rapid and total collapse of the CTV building, which is the subject of Volume 6. We extend our sympathy to all those who lost a family member or friend in the collapse of that building and acknowledge their grief. We have endeavoured in our Inquiry to be thorough and to find the reasons why this building suffered such a catastrophic collapse. We hope that the investigation we have carried out, and the findings we have made, will provide some of the answers people have sought. In Volume 6 we have set out the facts, and our analyses of the building's design, construction, assessment following the September earthquake, and collapse.

Volume 7 addresses matters relating to the systems and skills we have in New Zealand to ensure that buildings are well-designed and well-built, and that following an event such as an earthquake, damage to buildings can be assessed and appropriate actions taken. Section 2 of Volume 7 addresses the latter subject in some detail: we have reviewed the building safety evaluations that occurred after the September and Boxing Day 2010 earthquakes, and the subsequent processes, and conclude that the system and skills we have are adequate but that there is a significant gap in respect of those buildings whose rapid assessment resulted in a "green placard". In sections 3 and 4 of Volume 7 we have discussed, and made recommendations for changes to, the regulatory requirements for what we have called "complex structures". For these buildings, we have recommended a new requirement, that their design be certified by Recognised Structural Engineers, intended to be structural engineers highly experienced in the design of complex structures. This, in our view, will achieve an increased level of quality assurance in the design of such structures. We have also made recommendations that are intended to strengthen the leadership role of the Ministry of Business, Innovation and Employment. These include the development by the Ministry of a policy and regulatory work programme, in consultation with various parties. We have also concluded that the various documents that support compliance with the Building Code need to be reviewed and updated regularly, and have made recommendations for this to occur.

Other subjects we address in Volume 7 include the training and education of civil engineers and the organisation of the civil engineering profession. Among the recommendations that we make are a proposal that there should be an ethical obligation to advise the relevant territorial authority and the Institution of Professional Engineers New Zealand about structural weaknesses that have been discovered in buildings.

An issue at the margin of our Inquiry is the subject of subdivision and land use. We considered how various relevant resource management powers had been exercised by the Canterbury Regional Council (CRC) and Christchurch City Council (CCC), since one way of minimising the risk of building failure in the future is to ensure that land development rules take into account the effects that earthquakes might have on the land. Recognising the inherent uncertainties in dealing with issues of earthquake risk, we nevertheless conclude that the Resource Management Act 1991 should more explicitly acknowledge the potential effects of earthquakes and liquefaction, and we make recommendations accordingly.

Section 1: Summary and recommendations – Volumes 5–7

In these last three Volumes of our Report, we make a number of recommendations for changes to the legislation, policies and practices for the prevention or minimisation of the failure of buildings in earthquakes, on the legal and best-practice requirements for the management of buildings after earthquakes and for the design of new buildings. The numbering of the recommendations we make continues sequentially from the recommendations made in Volumes 1 to 4 of our Report

Volume 5: Christchurch, the City and approach to this Inquiry

Section 2 of Volume 5 provides a brief history of the city of Christchurch, its buildings and its economy. It also describes the impact the Canterbury earthquakes have had on the city and its population.

In section 3 of this Volume we have set out our approach to this Inquiry, including communications with the families of those who lost their lives in building failures in the 22 February 2011 earthquake, the public hearings we conducted and the other ways in which we gathered information, investigated matters and received submissions. We have also described the way in which we managed the thousands of documents we received in the course of our Inquiry, and the reporting structure we have followed.

Volume 6: CTV building

The CTV building, designed and constructed in the mid-1980s, collapsed during the earthquake that struck Christchurch at 12:51pm on 22 February 2011. The collapse resulted in the death of 115 people and others suffered serious injuries.

Our Terms of Reference directed us to inquire into:

- whether the building as originally designed and constructed, and as altered and maintained, complied with legal and best practice requirements;
- whether the building was identified as earthquake-prone or was subject to any measures to make it less susceptible to earthquake-risk before 4 September 2010;
- the nature of the land associated with the building;
- the nature and effectiveness of assessments and remedial work after the earthquakes on 4 September and 26 December 2010;
- why the building failed on 22 February 2011;
- why the failure caused extensive injury and death;
- why it differed from other buildings in the extent to which it failed; and
- whether any particular features of the building contributed to the failure.

The Terms of Reference precluded any inquiry into questions of liability. However, this did not prevent consideration of errors or failings in design, permitting, construction, inspection or any other matter that might explain why the CTV building failed and why the failure caused such extensive injury and death.

In Volume 6 we have set out our findings on these matters. The collapse of the CTV building caused much more injury and death than any of the other building failures on 22 February 2011. Even though it was designed under relatively recent building codes, its failure was severe and resulted in the floor slabs collapsing on top of one another, leaving most of those inside the building with no chance of survival.

We do not summarise our conclusions here. Readers wanting to see a summary of those findings are directed to section 9 of Volume 6, where we set out the principal conclusions we have reached. That section was also written with a view to it being translated into the languages spoken by many of the bereaved. Unusually for a New Zealand tragedy, many of those who died were foreign nationals. Resources have not permitted the full report to be translated. However, section 9 of Volume 6 has been translated into Japanese, simplified Chinese, Thai and Korean.

The engineering design of the building was deficient in a number of respects. While there were elements of the applicable codes that were confusing, a building permit should not have been issued for the building as designed. There were also inadequacies in the construction of the building. The post-earthquake inspections of the CTV building also illustrated areas in which building assessment processes could be improved. As noted above, a summary of all our findings in respect of the CTV building is set out in section 9 of Volume 6 of this Report.

We mention here matters that are the subject of specific recommendations arising from our inquiry into the CTV building.

The CCC issued a number of permits and consents (including resource consents) for work on the CTV building between the time of its original construction and the September earthquake. In most cases, the approved work would have had no impact on the structural performance of the building in an earthquake. A penetration was cut in the floor of level 2 for installation of an internal staircase during a fit-out in 2000. We are satisfied that the penetration would not have affected the seismic performance of the building. However, in our view particular care should be taken to ensure that damage to critical reinforcing does not occur when buildings are altered.

Recommendation

We recommend that:

107. Where holes are required to be drilled in concrete, critical reinforcing should be avoided. If it cannot be avoided, then specific mention should be made on the drawings and specifications of the process to be followed if steel is encountered, and inspection by the engineer at this critical stage should be required.

Following the earthquake, Urban Search and Rescue engineers working on the CTV site, Mr Graham Frost, Dr Robert Heywood and Mr John Trowsdale, took extensive photographs and labelled building elements. Their public-spirited initiative created an excellent record of the state of the building and individual elements following collapse. There was no formal system whereby this information was collected and the Royal Commission commends these engineers for their very thorough documentation and assessment of the collapse debris.

Overall, we consider that the evidence provided an adequate basis to make findings about the state of the building after its collapse and to draw conclusions about possible collapse scenarios. However, implementation of practice guidelines for forensic engineering is warranted to ensure that high quality forensic work is guaranteed for future investigations.

Recommendation

We recommend that:

108. The Ministry of Business, Innovation and Employment should consider developing guidelines for structural failure investigations, including circumstances in which sites should be preserved for formal forensic examination.

It is important to identify other buildings in New Zealand that have characteristics that might lead to their collapse in a major earthquake, so that appropriate steps can be taken to reduce the potential hazard posed by these structures.

Recommendation

We recommend that:

109. In the assessment of buildings for their potential seismic performance:

- the individual structural elements should be examined to see if they have capacity to resist seismic and gravity load actions in an acceptably ductile manner;
- relatively simple methods of analysis such as the equivalent static method and/or pushover analyses may be used to identify load paths through the structure and the individual structural elements for first mode type actions. The significance of local load paths associated with higher mode actions should be considered. These actions are important for the stability of parts and portions of structures and for the connection of floors to the lateral force resisting elements;
- the load path assessment should be carried out to identify the load paths through the different structural elements and zones where strains may be concentrated, or where a load path depends on non-ductile material characteristics, such as the tensile strength of concrete or a fillet weld where the weld is the weak element;
- while the initial lateral strength of a building may be acceptable, critical non-ductile weak links in load paths may result in rapid degradation in strength during an earthquake. It is essential to identify these characteristics and allow for this degradation in assessing potential seismic performance. The ability of a building to deform in a ductile mode and sustain its lateral strength is more important than its initial lateral strength; and
- sophisticated analyses such as inelastic time history analyses may be carried out to further assess potential seismic performance. However, in interpreting the results of such an analysis, it is essential to allow for the approximations inherent in the analytical models of members and interactions between structural members, such as elongation, that are not analytically modelled.

110. Arising from our study of the CTV building, it is important that the following, in particular, should be examined:

- the beam-column joint details and the connection of beams to structural walls;
- the connection between floors acting as diaphragms and lateral force resisting elements; and
- the level of confinement of columns to ensure that they have adequate ductility to sustain the maximum inter-storey drifts that may be induced in a major earthquake.

In sections 8 and 9 of Volume 2 and section 6.2.5 of Volume 4 of our report we discuss other issues related to the assessment of the potential seismic performance of existing buildings.

Volume 7: Roles and responsibilities

Section 2: Building management after earthquakes

This section considers the management of buildings after an earthquake, both during and after a state of emergency. We briefly outline New Zealand's civil defence and emergency management framework and give an overview of the building safety evaluation process used to assess buildings after an earthquake.

We consider that, overall, New Zealand was very well served by the engineers, building control officials and others who volunteered in the building safety evaluation process carried out after the Canterbury earthquakes. We appreciate the valuable evidence many of these volunteers gave the Royal Commission to assist us to make recommendations for improvements to the management of buildings after earthquakes.

The Royal Commission considers that life safety should be the main objective for managing buildings after earthquakes. We consider that current legislation provides for New Zealand's building safety evaluation process, but we recognise that proposals to introduce new emergency management provisions into the Building Act 2004 may address some of the problems that occurred when the process transitioned from civil defence to normal building control arrangements controlled by territorial authorities.

Recommendations

We recommend that:

111. Life safety should be the overarching objective of building management after earthquakes as communities both respond to and recover from the disaster.

112. The building safety evaluation process should be used following a range of disasters.

113. Legislation should provide that a building safety evaluation operation should only be commenced during a state of emergency.

114. The Ministry of Business, Innovation and Employment should progress its proposals to incorporate new emergency risk management provisions into the Building Act 2004 to:
    - make the Ministry of Business, Innovation and Employment responsible for the development and maintenance of New Zealand's building safety evaluation process;
    - make territorial authorities responsible for delivering a building safety evaluation operation; and
    - give the Ministry of Business, Innovation and Employment a formal role within national civil defence and emergency planning arrangements.

115. The Ministry of Business, Innovation and Employment should continue working with the Ministry of Civil Defence and Emergency Management on the detail of the above proposals.

As well as considering the process of building safety evaluation, we have discussed and made recommendations about the way in which engineers evaluate buildings when carrying out rapid assessments and detailed engineering evaluations after earthquakes. We also make recommendations about the way that building safety evaluators should be identified and trained.

Recommendations

We recommend that:

How evaluators assess buildings after earthquakes

116. The Ministry of Business, Innovation and Employment, the Ministry of Civil Defence and Emergency Management, GNS Science, the New Zealand Society for Earthquake Engineering and other engineering technical groups should research how and when building safety evaluators should account for aftershocks.

117. The building safety evaluation process should set out the factors evaluators need to take into account when considering how a building will respond in an aftershock, including:
    - how close the main shock was to an urban centre that could be affected by an aftershock;
    - the direction of the main shock and any likely aftershocks; and
    - how soil, ground conditions and any other relevant factors may affect the intensity of the ground motions in an aftershock.

Mobilising a sufficient number of skilled building safety evaluators

118. The Ministry of Business, Innovation and Employment should progress their proposal to establish a core team of building safety evaluators that the Ministry could call on.

119. The Ministry of Business, Innovation and Employment should carefully consider the merits and detail of any proposals about the size of this group of building safety evaluators.

120. The ability to supplement this team with more evaluators who have received basic training should be maintained.

121. Legislation should continue to provide for a waiver of liability for building safety evaluators carrying out rapid assessments.

122. The liability waiver for building safety evaluators should be aligned with the building safety evaluation process instead of being restricted to an operation carried out in a state of emergency.

Guidelines for building safety evaluators

123. The Ministry of Business, Innovation and Employment should work with the New Zealand Society for Earthquake Engineering, the Structural Engineering Society New Zealand and others with appropriate experience and expertise to finalise guidelines for Detailed Engineering Evaluations as soon as possible.

124. Guidelines should be developed that assist building safety evaluators to assess when and how to enter a damaged building.

125. These guidelines should be based on the Urban Search and Rescue training on when and how to assess entry to a damaged building.

126. These guidelines should be attached to the guidelines that the Ministry of Business, Innovation and Employment is developing on the way in which engineers should carry out Detailed Engineering Evaluations after earthquakes.

127. New Zealand's building safety evaluation guidelines should incorporate detailed guidance to engineers about the way they should assess the damage to particular building types.

128. The field guide for building safety evaluators should be finalised.

Training for building safety evaluators

129. The building safety evaluation process should incorporate a training programme for all building safety evaluators.

130. Such training should cover:

- what the building safety evaluation process is and how it works; and
- how to identify and assess the damage evaluators observe in buildings after an earthquake.

131. This training programme should be developed using the New Zealand Society for Earthquake Engineering's building evaluation resource and training capability objectives framework, in which building safety evaluators are split into three different groups and each group receives a different level of training.

132. The core group of building safety evaluators who are a national resource capable of leading a building safety evaluation operation, and those Chartered Professional Engineers, structural engineers and senior building officials who wish to be building safety evaluators, should be required to attend compulsory training.

133. Only trained building safety evaluators should be authorised to participate in a building safety evaluation operation unless the circumstances of a particular disaster make this impractical.

134. If the scale of the emergency requires the mobilisation of the largest group of potential building safety evaluators, who have not received the compulsory training, these evaluators should work, wherever practicable, under the supervision of those evaluators who have attended the compulsory training.

135. Territorial authority staff with civil defence and emergency management responsibilities should be required to attend the compulsory building safety evaluator training as part of their job training.

Indicating that evaluators have the right skills

136. The Ministry of Business, Innovation and Employment should keep a list of the people who complete the compulsory training for building safety evaluators and should make this list available to all territorial authorities.

137. Where available, only Chartered Professional Engineers should carry out Level 2 Rapid Assessments.

Despite some problems, we consider that, overall, the building safety evaluation operations after the Canterbury earthquakes were well delivered. We recommend that a number of changes are made to improve the delivery of New Zealand's building safety evaluation process, which follows current international best-practice.

Recommendations

We recommend that:

138. The Indicator Building model should be incorporated into New Zealand's building safety evaluation process.
139. The Ministry of Business, Innovation and Employment should provide guidance to territorial authorities to support their plans to carry out a building safety evaluation process.
140. Territorial authorities should be required to plan their building safety evaluation process as part of their civil defence and emergency management plans.
141. Only official building safety evaluators should be authorised to place, change or remove placards, and to carry out rapid assessments for this purpose.

Recommendations related to the placards

142. The placards placed as a result of the building safety evaluation process should be rewritten in a plain English format.
143. In principle, the colour of the green placard should be changed to white. The Ministry of Business, Innovation and Employment should consult with the international building safety evaluation community about the merits and detail of the change before deciding whether or not to do this.
144. Formal procedures should be developed that set out when and how the status of a building could be changed. The placard on a building should only be changed if the formal procedures are followed.

Communication and information management

145. The Ministry of Business, Innovation and Employment should be responsible for developing and releasing public communication materials about building management after earthquakes and other disasters during and after the state of emergency.
146. GNS Science should develop protocols and plans to ensure that it is ready to advise the Ministry of Business, Innovation and Employment, other government agencies, local authorities and the wider public after an earthquake.
147. Information management systems should be developed as part of planning for New Zealand's building safety evaluation process.
148. The Ministry of Business, Innovation and Employment should work with territorial authorities and other relevant agencies to develop a way for territorial authority building records to be electronically recorded and stored off-site.
149. A clear system for identifying individual buildings should be developed and included in the plans for a building safety evaluation process.
150. Land Information New Zealand should continue to work on initiatives that develop consistent national addressing protocols and make this information available to the general public.

The Royal Commission heard evidence that there were significant issues in the transition of responsibility for the building safety evaluation process from civil defence to normal building management arrangements governed by territorial authorities. We discuss and make recommendations about the need for transition mechanisms and about the way in which territorial authorities should manage buildings after earthquakes. We consider that all buildings should be assessed further after the rapid assessment phase of the building safety evaluation operation. This assessment should be based on the nature of the event, the type of structure and the level of damage observed. The Royal Commission has heard evidence regarding the barriers faced by some building owners motivated to address the damage to their building after the September earthquake. We consider that some of these barriers are indicative of issues with the management of earthquake-prone buildings and we make recommendations about these specific issues in Volume 4 of our Report.

Recommendations

We recommend that:

151. After an earthquake that has given rise to the declaration of a state of emergency, buildings should be assessed in accordance with the following process:

   a all buildings should be subject to a rapid assessment process;

   b for the purposes of subsequent steps, buildings should be placed in the following categories:

      i) Group 1: non-unreinforced masonry buildings that do not have a known critical structural weakness, and either,

         - in the case of concrete buildings, were designed to NZS 3101:1995 or later editions of that Standard;
         - in the case of structural steel buildings, were designed to NZS 3404:1992 (informed by the Heavy Engineering Research Association guidelines published in 1994) or later editions of that Standard;

         or have been subject to an evaluation that has shown that the building has 67% ULS or greater (we discuss the term "ULS" in section 6.2.4 of Volume 4);

      ii) Group 2: buildings designed between 1976 and the mid-1990s, but not included in Group 1;

      iii) Group 3: buildings designed before 1976, but not included in Group 1; and

      iv) Group 4: unreinforced masonry buildings;

   c buildings used for residential purposes that are three or less storeys in height should be excluded from Groups 2 and 3. In the case of those buildings, a pragmatic approach needs to be taken to assessment and occupancy, which balances the need for shelter with safety considerations. Other commercial and residential buildings should not be occupied unless approved for occupancy in accordance with the process outlined below;

   d legislation should require territorial authorities to classify buildings in their districts in accordance with the preceding Recommendation within the timeframes established under Recommendation 82 in Volume 4 of our Report (Recommendation 82 requires the assessment of earthquake-prone and potentially earthquake-prone buildings);

   e where the rapid assessment process had identified the need for further evaluation of a building in one of these defined Groups, the building should not be occupied until the Civil Defence Controller or the territorial authority (as appropriate) has approved the occupancy of the building after the following assessments:

      i) for Group 1 buildings:

         - where no significant structural damage was seen, a Level 2 Rapid Assessment;
         - where significant structural damage was seen, a Plans-Based Assessment for lower levels of structural damage and a Detailed Engineering Evaluation for higher levels of structural damage;

      ii) for Group 2 buildings:

         - where no significant structural damage was seen, a Plans-Based Assessment;
         - where significant structural damage was seen, a Detailed Engineering Evaluation;

      iii) for Group 3 buildings:

         - for all levels of damage, a Detailed Engineering Evaluation;

      iv) for Group 4 buildings:

         - where no significant structural damage was seen and the building has been retrofitted to 67% ULS or greater, a Plans-Based Assessment;
         - where significant structural damage is apparent and where the building has not been retrofitted to 67% ULS or greater, a Detailed Engineering Evaluation;

f arranging for the Plans-Based Assessments and Detailed Engineering Evaluations should be the responsibility of the owner of the buildings concerned; and

g the Ministry of Business, Innovation and Employment should further develop the Plans-Based Assessment concept, in consultation with the New Zealand Society for Earthquake Engineering and the Structural Engineering Society New Zealand, and set out the Plans-Based Assessment in published guidelines.

152. Plans-Based Assessments and Detailed Engineering Evaluations should include checking the vulnerabilities observed after the Canterbury earthquakes that the Royal Commission describes in Volume 2, section 6.2.5 of Volume 4, and section 6.3.8 of Volume 6 of this Report.

153. Any Plans-Based Assessment and Detailed Engineering Evaluation of a building after an earthquake should begin with a careful examination of the building's plans.

154. The Plans-Based Assessment and Detailed Engineering Evaluation should confirm that all known falling hazards and other vulnerabilities have been assessed and secured or removed.

155. A copy of the Plans-Based Assessment and the Detailed Engineering Evaluation should be given to the relevant authorities.

Cordon management

156. Civil defence and emergency management should be responsible for setting up and maintaining cordons during the state of emergency.

157. Territorial authorities should be responsible for maintaining any cordons that are in place at the end of the state of emergency until the public space or building they surround is made safe.

158. Territorial authorities should be able to recover the costs of maintaining any necessary cordons from the building owner after three months.

159. The roles and responsibilities of decision makers should be described in the building safety evaluation process. The roles and responsibilities should allow for flexibility of operation according to the circumstances and scale of the event.

Buildings that act as one structure in an earthquake

160. The building safety evaluation process should direct evaluators to assess properties that act as one structure in an earthquake as one structure, rather than as separate buildings.

Transition mechanism

161. The building safety evaluation and wider building management after earthquakes (and other disasters) framework should be developed and provided for in legislation.

Section 3: Roles and responsibilities

Through the course of our Inquiry, we identified some systemic issues relating to the regulatory framework for buildings, such as misunderstanding of the framework, a complex and confusing suite of regulatory documents, and quality assurance issues. These issues relate to the design and construction of complex, new buildings.

Quality assurance is vital in the structural design of complex buildings. Quality assurance occurs at a number of levels throughout the design and construction of such buildings. The currently large number of building consent authorities results in inconsistent application requirements and consent decisions around the country, and varying levels of capability within these authorities.

The experience and skill of structural engineers designing such structures also may vary, with reliance placed on the building consent authority to provide a check.

This poses risks for the quality of our buildings. We have concluded that the design of complex buildings (as defined in section 3.3.8.2 of Volume 7 of this Report) requires a higher level of competence. We consider the appropriate regulatory procedure to ensure this occurs is through the preparation and submission of a Structural Design Features Report at the start of the building consent authority's assessment of a building consent application. The building consent authority would, on the basis of this report and criteria to be developed, determine if the structure is a complex one. If it is determined to be a complex structure, a "Recognised Structural Engineer" would be required to certify the structural integrity of the design. The building consent authority would then determine whether it has the staff with the appropriate competency to process the consent application in-house (and whether any additional peer review certified by a Recognised Structural Engineer is required), or whether it needs to refer the application to another building consent authority that has the staff with the appropriate competency to process the application. If the structure is determined to be not complex, the engineer who provided the Structural Design Features Report would certify the structural integrity of the building's design. These recommendations would give further assurance of building quality and reduce reliance on the building consent authority.

Recommendations

We recommend that:

162. Building consent applications for:

- buildings in importance levels 3, 4 and 5 in Table 3.2 of AS/NZS 1170.0:2002;
- commercial buildings comprising three or more storeys; and
- residential buildings comprising three or more storeys with three or more household units

should be accompanied by a Structural Design Features Report, which describes the key elements of the design, including the foundations and gravity and lateral load resisting elements.

163. A structural Chartered Professional Engineer should be engaged at the same time as the architect for the design of a complex building.

164. After consideration of the Structural Design Features Report, the building consent authority should decide whether or not the structure should be regarded as complex.

165. The Ministry of Business, Innovation and Employment should develop criteria to be applied in determining whether a structure is complex, in consultation with the Structural Engineering Society New Zealand, the New Zealand Society for Earthquake Engineering, the New Zealand Geotechnical Society and other relevant groups, including building consent authorities. When developed, the criteria should be given regulatory force.

166. If the structure is determined to be not complex, the engineer who provided the Structural Design Features Report should certify the structural integrity of the building's design.

167. If the structure is determined to be complex, a Recognised Structural Engineer should be required to certify the structural integrity of the design.

168. On receipt of the building consent application, the building consent authority should decide:
   a whether it has the staff with the appropriate competency (qualifications and experience) to process the application in-house (including any decision as to whether the structure is complex and whether any additional peer review certified by a Recognised Structural Engineer should be required); or
   b whether it needs to refer the application to another building consent authority that has the staff with the appropriate competency (qualifications and experience) to process the application.

We have also reviewed the leadership structures within the building sector, as they relate to the matters we are concerned with, and consider that the role of Chief Engineer within the Ministry of Business, Innovation and Employment should be strengthened and supported with additional capability.

Recommendations

We recommend that:

169. The role of Chief Engineer should be renamed Chief Structural Engineer to reflect a greater focus on the structure of complex buildings and should be further strengthened and supported with additional capability.

170. The Chief Structural Engineer should have the statutory power to collect consent applications for complex structures (as part of the Policy and Regulatory Work Programme in Recommendations 173 and 174 below) for the purpose of analysing trends, identifying issues and risks, and sharing knowledge with the building and construction sector.

171. The Engineering Advisory Group should continue as an ongoing function to provide expert advice to the Chief Structural Engineer.

172. The Ministry of Business, Innovation and Employment should consult with learned societies, such as the New Zealand Society for Earthquake Engineering, the New Zealand Geotechnical Society and the Structural Engineering Society New Zealand, about the ongoing membership of the Engineering Advisory Group. The membership of the Group should always include senior practising structural engineers.

We discuss the role of Standards in New Zealand's "performance-based" regulatory system and note that the suite of Standards supporting the Building Code plays a vital role in ensuring our buildings are designed well and built well. We have concluded that these Standards should be regularly reviewed and updated.

Recommendations

We recommend that:

173. The Ministry of Business, Innovation and Employment should develop, lead and fund a Policy and Regulatory Work Programme in consultation with the Institution of Professional Engineers New Zealand, the New Zealand Construction Industry Council, Standards New Zealand, the Building Research Association of New Zealand, the New Zealand Geotechnical Society, the New Zealand Society for Earthquake Engineering and the Structural Engineering Society New Zealand.

174. The Policy and Regulatory Work Programme should identify the priorities for the development, review and update of compliance documents and Standards, and define the status of compliance documents and guidance material. Work relating to Standards prioritised for update as part of the Policy and Regulatory Work Programme should be funded as part of the work programme.

175. Standards referenced in the Building Code should be available online, free of charge.

176. The Policy and Regulatory Work Programme should be the responsibility of the Chief Structural Engineer.

177. A communications plan should be developed by the Ministry of Business, Innovation and Employment to communicate the Policy and Regulatory Work Programme and ensure information is effective, and targeted for different participants in the sector. There should be clarity about the status of information provided to the sector; for example, whether it is a compliance document, Standard or guidance.

Section 4: Training and education of civil engineers and organisation of the civil engineering profession

In this section of our Report, we have reviewed the training and education of civil engineers and the organisation of the civil engineering profession.

International agreements underpin the nature and content of engineering education in New Zealand. The Royal Commission has heard nothing that suggests there should be a change in the structure of the Bachelor of Engineering degree. Rather, key matters for further consideration are in post-degree training and continuing education through provision of tailored block courses for those who are working, and mentoring within engineering firms.

Life safety is and should remain the paramount objective in the design and construction of buildings to resist earthquake motions. This is best achieved by having highly experienced people performing the highest risk activities. In this regard, the Royal Commission has heard proposals and views from interested parties as to the merits, issues and risks of implementing a two-tier certification system that would raise the level of training and experience required of a structural engineer who certifies engineering design plans for complex structures. We consider there is merit in this concept and recommend the creation of the role of "Recognised Structural Engineer" for these purposes (see also section 3 of Volume 7 of this Report).

We have also reviewed the competence requirements against which engineers are assessed for registration as a Chartered Professional Engineer (CPEng). We recommend the introduction of an additional competence measure against which every structural engineer must be assessed – "a good knowledge of the fundamental requirements of structural design and of the fundamental behaviour of structural elements subjected to seismic actions".

Recommendations

We recommend that:

178. The Institution of Professional Engineers New Zealand (as the Registration Authority) should publish on the Chartered Professional Engineer register information about a Chartered Professional Engineer's area of practice, and any other information that may further inform consumers of engineering services of the competence of individual engineers, under section 18(1)(d) of the Chartered Professional Engineers of New Zealand Act 2002.

179. There should be ongoing provision of post-graduate continuing education for engineers through the provision of block courses, mentoring within engineering firms and courses suitable for those who are working.

180. The universities of Auckland and Canterbury should pursue ways of increasing the structural and geotechnical knowledge of civil engineers entering the profession.

181. Legislation should provide for Recognised Structural Engineers to be responsible for the certification of the design of complex buildings as described in Recommendations 162–168.

182. The Ministry of Business, Innovation and Employment should develop prescribed qualifications and competencies for "Recognised Structural Engineers" in consultation with the Chartered Professional Engineers Council, the Institution of Professional Engineers New Zealand, the Structural Engineering Society New Zealand and the New Zealand Society for Earthquake Engineering. These prescribed qualifications and competencies should be a more specific prescription of the qualifications and competencies of the role, and require more extensive design experience of the type required for the design of complex structures than that required for a Chartered Professional Engineer. These should be included in an appropriate regulation.

Members of the Institution of Professional Engineers New Zealand (IPENZ) are required to act in accordance with the IPENZ Code of Ethics, and Chartered Professional Engineers (CPEng) are bound to a Code of Ethical Conduct. Both codes are identical in the obligations they impose on the registered engineers. The key matters of interest to the Royal Commission have been the clauses governing the requirement not to misrepresent competence (IPENZ clause 4 and CPEng rule 46) and the obligations to report buildings and structures that place the public's health and safety at risk (IPENZ clause 11 and CPEng rule 53). We consider that reviewing structural engineers should have a clearly expressed ethical duty to disclose the existence of a critical structural weakness, in a process which protects them from any liability where they have acted in good faith.

Recommendation

We recommend that:

183. The Institution of Professional Engineers New Zealand should provide clarification of its codes of ethics, in respect of the following matters:

   a the test for taking action should be well understood by engineers – i.e. ensuring public health and safety;

   b each clause in the codes of ethics stands alone and no one clause can override another. In the case of a perceived conflict between two or more clauses, the question as to which clause should carry most weight in the circumstances presented should be a carefully considered matter of judgement; and

   c reporting obligations of engineers when a structure has been identified that presents a risk to health and safety. There should be clarity as to the point at which an obligation of a reviewing engineer to report is extinguished, and where the accountability for addressing the matter and rectifying any weaknesses rests.

184. Part 3, clause 6 of the Institution of Professional Engineers New Zealand Code of Ethics and Rule 48 of the Chartered Professional Engineers Rules of New Zealand (No 2) 2002 should be amended to provide for an obligation to advise the relevant territorial authority and the Institution of Professional Engineers New Zealand in circumstances where a structural weakness has been discovered that gives rise to a risk to health and safety.

A particular feature of the engineering profession is the existence of learned societies dedicated to particular fields of engineering practice. Membership of the individual societies largely consists of engineers practising within the society's particular field, although many engineers are multi-disciplinary and are therefore members of more than one society.

These learned societies include the Structural Engineering Society New Zealand (SESOC), New Zealand Society for Earthquake Engineering (NZSEE), New Zealand Concrete Society (NZCS), New Zealand Geotechnical Society (NZGS), New Zealand Timber Design Society Incorporated, Cement and Concrete Association of New Zealand (CCANZ), the Heavy Engineering Research Association (HERA) and others.

The work undertaken by the societies' members includes both contributing to formal processes for reviewing and updating New Zealand Building Standards, and issuing guidance on best-practice for the profession and industry, some of which is paid work but much of which is not. Society members also contribute technical papers for conference proceedings and provide guidance on best-practice to industry. Processes in which guidance is given are informal, and do not pass through the scrutiny of a regulatory review process: the best-practice advice is not formalised as legal requirements, and therefore may or may not be utilised or taken into account by practitioners.

There are risks in the informal component of this approach. These include whether the necessary expertise will remain available on a voluntary basis to enable the process to continue over time, and the absence of an objective process that tests the content and assesses the consequences of the best-practice guidance by formal regulatory review. Assessment of consequences would include examining the costs of the best-practice standards and requirements to determine value in the context of the risks being managed. In addition, without any formal recognition, the adoption of the recommended best-practices is difficult to monitor and cannot be enforced. This makes it unlikely that they will be consistently applied by practitioners.

As discussed above, we consider that the Ministry of Business, Innovation and Employment (MBIE) should develop a policy and regulatory work programme to identify priorities and clarify roles. In doing this work, MBIE should consult with the engineering profession's learned societies as to where best-practice guidance is required, and the appropriate process for achieving it, including the need to codify any parts of the advice into regulations or Standards, and whether the issues should be led by the regulator, or left to the societies.

The professional and learned societies play an important role in facilitating information sharing, debate, and problem resolution across the various disciplines within the engineering profession. Of particular interest to the Royal Commission is the need for collaboration between structural and geotechnical engineers. The societies also endeavour at times to bring engineers together with other intersecting professions within the construction industry (for example, constructors, manufacturers and architects).

The Royal Commission considers there is a reasonable level of constructive engagement between the different branches of engineering. However, there is scope for more constructive, and early, collaboration between architects and engineers.

Recommendation

We recommend that:

185. The Institution of Professional Engineers New Zealand, the New Zealand Institute of Architects, and the New Zealand Registered Architects Board, supported by the Ministry of Business, Innovation and Employment, should work together to ensure greater collaboration and information sharing between architects and structural engineers.

Section 5: Canterbury Regional Council and Christchurch City Council – management of earthquake risk

As part of our Inquiry into the Canterbury earthquakes, we considered it would be inappropriate to ignore entirely the fact there has been unnecessary damage and costs sustained as a result of the development of land subject to a risk of liquefaction without duly considering that risk. Apart from anything else, an understanding of how that has been possible under the existing regulatory system might enable better outcomes in the future.

As a result of our Inquiry into these matters, we conclude that there should be better provision for the acknowledgment of earthquake and liquefaction risk in the various planning instruments that are made under the Resource Management Act 1991. One way of minimising the failure of buildings in the future is to ensure that the land on which they are developed is suitable for the purpose. Having said that, we need to emphasise that it is not possible to predict with any certainty when an earthquake will occur and, in reality, the public and private investment in the country's cities is such that it is not realistic to redirect development from the existing central business districts. However, when zoning for new development areas is in contemplation, we consider that it would be appropriate for the risks of liquefaction and lateral spreading to be taken into account.

Recommendations

We recommend that:

186. Sections 6 and 7 of the Resource Management Act 1991 should be amended to ensure that regional and district plans (including the zoning of new areas for urban development) are prepared on a basis that acknowledges the potential effects of earthquakes and liquefaction, and to ensure that those risks are considered in the processing of resource and subdivision consents under the Act.

187. Regional councils and territorial authorities should ensure that they are adequately informed about the seismicity of their regions and districts. Since seismicity should be considered and understood at a regional level, regional councils should take a lead role in this respect, and provide policy guidance as to where and how liquefaction risk ought to be avoided or mitigated. In Auckland, the Auckland Council should perform these functions.

188. Applicants for resource and subdivision consents should be required to undertake such geotechnical investigations as may be appropriate to identify the potential for liquefaction risk, lateral spreading or other soil conditions that may contribute to building failure in a significant earthquake. Where appropriate, resource and subdivision consents should be subject to conditions requiring land improvement to mitigate these risks.

189. The Ministry for the Environment should give consideration to the development of guidance for regional councils and territorial authorities in relation to the matters referred to in Recommendations 186–188.

Section 2: Christchurch, the City

2.1 Introduction

In preparing this section of our Report, the Royal Commission consulted a variety of sources. For the early history of Christchurch, we turned to *Te Ara*[1], the online encyclopaedia of New Zealand, Michael King's[2] *Illustrated Penguin History of New Zealand* and John Wilson's[3] contextual history of Christchurch City. Wilson provided information about Christchurch's built heritage, as did Professor Geoffrey Rice. Professor Rice provided the Royal Commission with draft material and we also consulted his publication *Changing Christchurch: An Illustrated History*[4]. For modern Christchurch, and the impact of the February earthquake upon the city and the Canterbury region, we consulted the December 2011 Briefing to the Incoming Minister for Canterbury Earthquake Recovery[5] by the Canterbury Earthquake Recovery Authority (CERA) and their *Greater Christchurch Recovery Update*[6]. We also consulted the Christchurch City Council's[7] (CCC) draft Central City Plan. The Stronger Christchurch Infrastructure Team's[8] website describes the impact of the Canterbury earthquakes on Christchurch's infrastructure. Christchurch Psychology's website provided valuable information about the impact that the February earthquake has had on Cantabrians, particularly those who lost loved ones.

2.2 Māori Settlement in Ōtautahi (Christchurch)

Canterbury was first settled by Māori 600–700 years ago. Archaeological sites at Redcliffs and on the shores of the estuary, especially near the mouth of the Avon River, have provided evidence that Māori lived in the Christchurch area in the earliest years of Māori occupation of New Zealand.

The predominant iwi in Christchurch is Ngāi Tahu, the main iwi of the South Island. Originally from the East Coast of the North Island, the Ngāi Tahu people migrated south to Wellington, and then to the South Island. As they moved south they fought several battles with two tribes already living in the South Island, Ngāti Māmoe and Waitaha, and today's iwi members are linked to these earlier peoples.

Figure 1 shows the Canterbury landscape, which is characterised by its flat plain, Banks Peninsula, and the distant relief of the Southern Alps in the west.

The Christchurch area had plentiful resources for Māori including eel and other freshwater species in the rivers, flounder and other fish and shellfish in the estuary, and birds in the forests on the Port Hills and the plains. To ensure easy access to food, the early Māori lived mainly by the wetlands near the coast, and around Te Waihora (Lake Ellesmere) and Wairewa (Lake Forsyth). Artefacts have also been found inland at camps for expeditions to gather moa, weka, eels and rats. Horomaka (Banks Peninsula) was important because it combined the resources of forest and sea. By 1800, as many as 5000 Māori may have lived in central Canterbury, most of whom were at Kaiapoi and Banks Peninsula.

There were smaller pā and seasonal kāinga on the swampy area of plains now occupied by Christchurch. The most notable of these was located at Pūtaringamotu (in the area we now know as Riccarton) and Papanui. Both kāinga were on higher, drier, forested land surrounded by tussock grassland and swamp. Tautahi, the Ngāi Tahu chief whose name forms part of Ōtautahi, the Māori name for Christchurch, had a pā located near the position of the Barbadoes Street bridge. There were also urupā on the corner of Manchester and Kilmore Streets, and on the corner of Cambridge Terrace and Hereford Street.

The biggest pā site was located at Kaiapoi. This was Ngāi Tahu's largest and most important pā: it may have housed 1000 people at its peak. It was a centre of trade in pounamu from the West Coast. In the early 1830s, the Kaiapoi pā was sacked by the North Island Ngāti Toa chief, Te Rauparaha, but overall his raids were unsuccessful and Ngāi Tahu kept their ownership of Canterbury.

Figure 1: Bird's eye view of Banks Peninsula and the Canterbury Plains (source: Alexander Turnbull Library)

2.3 European settlement

The first Europeans who settled the Canterbury Plains established themselves at Banks Peninsula as they felt the land there was more viable than the swampland on the plains. In the 1830s, shore whaling stations were established with small settlements in the southern bays of Banks Peninsula. Organised settlement began when French (and some German) settlers founded Akaroa in August 1840. By this time, approximately 80 Europeans were living at Banks Peninsula.

In 1840, whalers based at Oashore established a farm at Pūtaringamotu (Riccarton) but abandoned the venture after 18 months. Brothers John and William Deans established a farm on the same site in 1843. They remained the only permanent European residents on the Canterbury plains until the Canterbury Association immigrants arrived in 1850.

With the support of prominent Anglican clergy, John Robert Godley and Edward Gibbon Wakefield formed the Canterbury Association in 1848 to develop an Anglican settlement in Canterbury. Over a decade earlier, Wakefield had established the New Zealand Company, a private business venture, to settle New Zealand using a planned colonisation scheme. In 1848, they sent Captain Joseph Thomas, an experienced New Zealand Company surveyor, to select the site of the new Canterbury venture.

2.3.1 The site chosen for the settlement

Captain Thomas initially planned to establish the main Canterbury settlement at Port Cooper, which is now known as Lyttelton. After realising the amount of reclamation needed at the Lyttelton site to produce the necessary flat land for the Canterbury Association's plans, Captain Thomas moved the main town to the proposed satellite settlement on the plains. This settlement became Christchurch.

The site had previously been rejected by New Zealand Company agents (who went on to establish the Nelson settlement) and the Scottish Free Church (who founded Dunedin). They noted, as did Captain Thomas when he originally chose the Lyttelton site, the extensive swamps, the lack of timber, and the difficult access between the only suitable port site on Banks Peninsula and the plains.

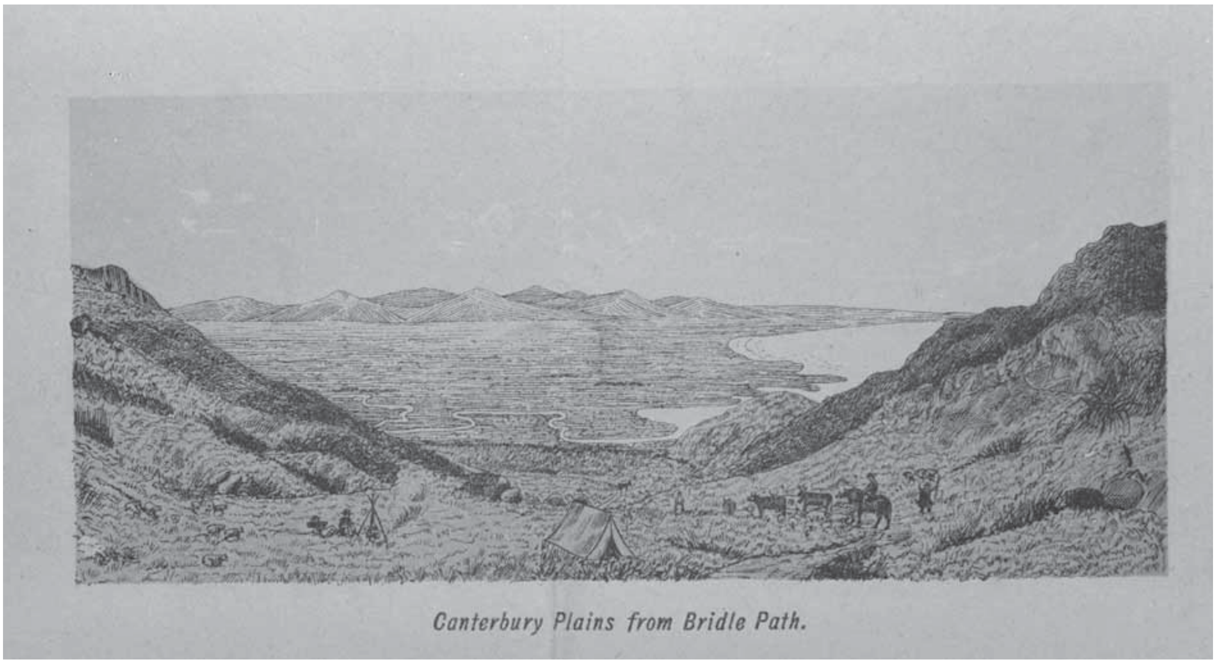

Figure 2: Sketch of the Canterbury Plains from the Bridle Path, Port Hills, circa 1850 (source: Christchurch City Libraries)

2.3.2 The land Christchurch is built on

In section 4 of Volume 1, we describe the soils found in Canterbury. As Figure 2 illustrates, the Canterbury plains consist of a 300–500m thick layer of alluvial gravel formed from ice age glaciers and rivers. Wilson[3] suggests that by 1850 the plains were characterised by a mosaic of lobes of shingle and other deposits from the Waimakariri River. Swamplands and waterways lay to the south-east of the shingle lobes. The Heathcote and Avon Rivers created an estuary where they drained into the sea from the swamplands. There were also belts of sandhills parallel to the coast. Even though the settlement was sited on higher, drier land further up the Heathcote and Avon Rivers, it was still built on fluvial deposits and loose soil in older river beds. Traces of Christchurch's former topography can be seen in the creases in North Hagley Park and the sandhills in Linwood.

The site for the Canterbury settlement was also characterised by poor drainage, high groundwater levels and flooding (although the European settlers did not appreciate the extent to which it was a flood plain for the Waimakariri River until major floods in 1868). Early maps of Christchurch show the extensive network of streams and surface water associated with the spring-fed Avon River, which bisected the original settlement. The water table in Christchurch's Central Business District (CBD) sits at a depth of 1–1.5 metres, increasing to 5 metres west of the CBD. There are also aquifers in the top 25 metres of the ground. Cathedral Square is only 4.7 metres above the high water mark for spring tides, although western parts of the city are about 15 metres above that mark. This combination of a high water table, aquifers and loose alluvial soil composition makes Christchurch prone to liquefaction during severe earthquakes. Liquefaction occurred in Amuri (North Canterbury) after an earthquake in 1888 and in Kaiapoi as a result of the 1901 Cheviot earthquake. The attempt to address the issues presented by Christchurch's swampy ground did not begin until the Drainage Board was formed in 1875–76.

2.3.3 The development of Christchurch

Captain Thomas founded the port town of Lyttelton, laid out the plains town of Christchurch, and began a road over the Port Hills before the first settlers arrived. Between 1850 and 1853, 3,549 settlers arrived, most of whom originated from southern England. Of these, 400 were land purchasers, and the rest were mostly labourers and servants. Christchurch was the settlement that came the closest to realising Wakefield's vision of transplanting a cross-section of class-based British society into a farming community with a strong urban hub.

As set out in Figure 3, the central city and early suburbs were laid out in a regular grid pattern on a north-south orientation, straddling the Avon River. Christchurch's CBD now covers Captain Thomas' original settlement. The banks of the Avon were gazetted as public reserves, forming a green corridor through the built-up area, and Cathedral Square (actually a cross shape), Cranmer Square and Latimer Square (both of which are rectangular) were set aside as public spaces. In addition, Hagley Park and the Government Domain were reserved from private development. These green spaces, along with fenced and well planted gardens offering protection from the wind, led to the city becoming known as the "Garden City" from the beginning of the twentieth century.

As European settlement on Banks Peninsula was more established when Christchurch was founded in 1850, Lyttelton was the principal Canterbury settlement until the 1860s. From 1855, small satellite settlements developed in Sumner, New Brighton, Linwood, Richmond, Papanui and Upper Riccarton. Julius Vogel's assisted immigration schemes spurred the rapid growth of the city in the 1870s, when the suburbs of Addington, Spreydon and St Albans became well established. In the late nineteenth and early twentieth century, Christchurch expanded into the foothills of the Port Hills at Cashmere. Further suburban development occurred over the course of the next century.

2.4 Christchurch's built environment

Like other European settlements in New Zealand, the first residential and commercial buildings in Christchurch were constructed from wood. Victorian New Zealanders soon replaced their wooden public and commercial buildings with structures comprised of more permanent materials (see Figure 4). In 1864, the first stone church was constructed in Christchurch. This building, the Durham Street Methodist Church, completely collapsed in the February earthquake, tragically killing three people. Rice[4] contends that the rebuilding of earlier wooden churches in stone during the early 1870s was a sign of Christchurch's increasing maturity and prosperity: more substantial masonry buildings were perceived as indicating greater wealth and status. In addition, as European settlers moved down the South Island they found few large forest stands to log for building materials; this encouraged stone and masonry construction. As the city prospered, at the turn of the century, most (but not all) of the remaining older wooden buildings were replaced by larger, masonry commercial buildings.

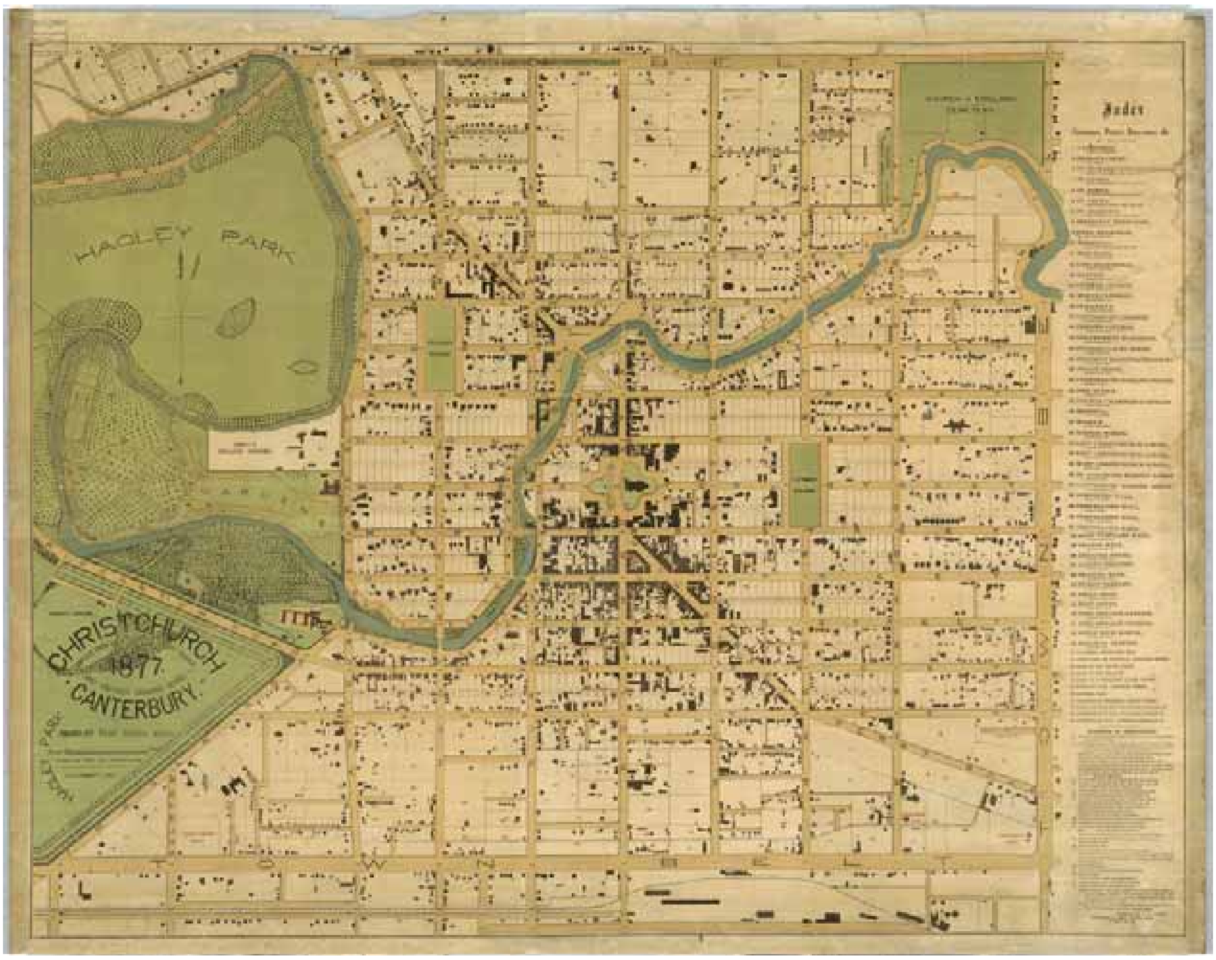

Figure 3: A map of Christchurch central city dated 1877 (source: Alexander Turnbull Library)

Figure 4: Manchester Street, looking towards the Avon River, circa 1868 (source: Christchurch City Libraries)

European immigrants to New Zealand looked to re-create in the new, unfamiliar environment the familiar landscapes and built environment they had left behind. Consequently, they built their new homes and public and commercial buildings in the architectural styles popular in Victorian and Edwardian Europe. Early buildings in Christchurch were constructed in the neo-Gothic style popular in England for most of the nineteenth century. Christchurch's commercial buildings in the late nineteenth century echoed the Gothic theme with variations on Venetian Gothic and Renaissance styles.

By the beginning of the twenty-first century, Christchurch architecture was distinctive in combining Victorian and Edwardian architecture with Modern and Post-modern innovation. Although Christchurch has relatively few Art Deco buildings, Cecil Wood produced several buildings that combined Modernist features with Stripped Classicism (a simplified Classical style). From the 1960s to the early 1990s, older commercial buildings were replaced with large, modern high-rise office blocks and hotels. In this period, Sir Miles Warren and Peter Beaven were the most well-known proponents of the form of Modernism that became known as the Christchurch Style of architecture. The Christchurch Style combined the structural expression and clear exposure of construction materials that characterised Brutalism, and the Scandinavian and Japanese commitment to straightforward design.

2.5 Christchurch before the earthquakes

Christchurch is the largest city in the South Island. Christchurch City includes Akaroa and Banks Peninsula, but does not include adjacent satellite centres such as Kaiapoi, Prebbleton, Rolleston, Lincoln or Tai Tapu. It is the market town and transport hub for the Canterbury plains, the largest area of relatively flat farmland in New Zealand. Canterbury comprises 9.3 per cent of New Zealand's land area, at 25,252 sq km. According to the 2006 Census, its inhabitants make up 11.4 per cent of the country's total population. Canterbury's regional population was around 522,000, of which two thirds lived in Christchurch.

In the 2006 Census, Christchurch City was New Zealand's second largest population district after Auckland. The city is home to 9.1 per cent of New Zealand's total population. Modern Christchurch, the urbanised area within a radius of 30 km of Cathedral Square (excluding Banks Peninsula), contains approximately 370,000 people. The city comprises a third of the South Island's population, and about 70 per cent of the Canterbury population. Before the Canterbury earthquakes, Christchurch's population had increased by 7.5 per cent between 2001 and 2006 in response to a growing regional economy.

Figure 5: Christchurch and the Canterbury Plains, August 2011

2.6 Economic activity of the region and city

In the nineteenth century, Christchurch's early development was driven by the city's physical growth and rapidly increasing production from the farms developing in north- and mid-Canterbury. Canterbury farmers contributed to the New Zealand economy by producing large amounts of wool, wheat and (from the 1880s) frozen meat for export. In addition to farm-related industries, Christchurch developed a strong manufacturing sector. At the turn of the nineteenth and twentieth centuries, brands originated in Christchurch that became household names throughout Australasia, including Aulsebrooks biscuits, Edmond's baking powder, Sanitarium health foods, Kaiapoi woollen goods, and even cough remedies such as Bonnington's Irish Moss.

The reliance on supporting the farming industry, both in manufacturing and handling farm produce, has given Christchurch an industrial history that differs somewhat from that of other New Zealand industrial centres. Although the economy diversified in the twentieth century, the structure of industry in Christchurch changed little until the deregulation of New Zealand's economy in the mid-1980s and 1990s. The Canterbury regional economy is driven largely by agriculture, manufacturing and tourism. Christchurch City contributes around 8 per cent of the national Gross Domestic Product (GDP) from economic activities.

2.7 Impact of the earthquakes

The scale of the damage in the September earthquake resulted in the declaration of a local state of emergency. A national state of emergency was declared after the February earthquake, due to the size of this event and its impact on Christchurch.

During the February earthquake, 185 people tragically lost their lives and many more were injured. Those who lost their lives as a result of the February earthquake came from all corners of the world, including New Zealand, Australia, Japan, China, the Philippines, Thailand, Great Britain, Korea, Turkey, Ireland, Malaysia, Taiwan, United States of America, Israel and Canada. Of those who died in the earthquake, 77 were foreign nationals. Much of the loss of life was due to the catastrophic collapse of two multi-storey office buildings: the CTV and PGC buildings where 115 and 18 people died respectively. Other building failures caused the deaths of a further 42 people. Other deaths attributable to the earthquake arose from causes not related to building failures. They included those attributable to rock falls.

A significant number of people were also injured to varying degrees in the earthquakes and immediately afterwards. By 27 January 2012, the Accident Compensation Corporation, which provides personal injury insurance cover for all New Zealand residents and visitors to New Zealand, had accepted 12,984 earthquake-related claims. Soft tissue injuries, such as bruising, strains and sprains, accounted for the majority (over 9,500) of these claims. The next most common category of injury was lacerations and puncture wounds (around 1,500 claims), followed by fractures and dislocations (770 claims). Six people had limbs amputated.

Figure 6: The eastern suburbs suffered repeatedly from liquefaction. This aerial photo shows a street in Bexley after the June 2011 aftershock (source: Fairfax Media/ The Press)

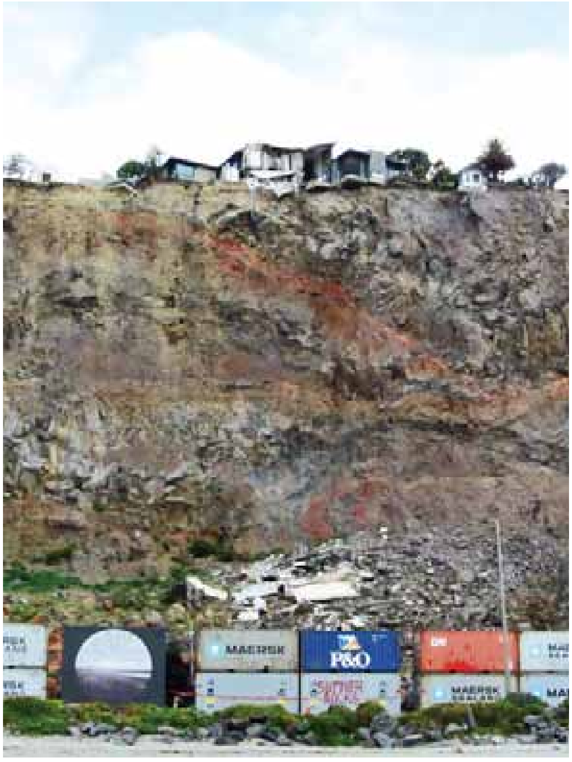

Figure 7: Collapsing rocks in the suburb of Sumner caused houses to fall down the cliff. A row of shipping containers was installed to protect the busy road below from danger (source: Flickr/newtown graffiti)

In the larger earthquakes that occurred in Canterbury there was extensive liquefaction, particularly in the eastern suburbs near the sea (Figure 6 shows the liquefaction in the eastern suburb of Bexley). Hill suburbs experienced cliff collapse and rock fall, as Figure 7 illustrates. In the Port Hills, especially Lyttelton, moving land, collapsed cliffs, and rockfall caused severe damage to retaining walls. Damage to the land under the CBD is described in section 2 of Volume 1.

Christchurch citizens were affected by widespread damage and interruptions to infrastructure including roads, fresh water, waste water systems, storm water systems, electricity and telecommunications networks. Rebuilding the city's damaged street-level civic infrastructure to the same level of infrastructure service that existed before the earthquakes is likely to cost around $2 billion dollars and will take several years to complete.

Figure 8 shows the road damage caused by the Canterbury earthquakes. An estimated 1,021 kilometres of road need to be rebuilt due to earthquake damage. This is 52 per cent of Christchurch's urban sealed roads. There will be major renewal projects to rebuild these roads and in some cases the road will need full reconstruction.

The earthquakes damaged 51 kilometres of water supply mains, excluding those yet to be properly assessed because they are under roads. However the damage was far less than it might have been a few years ago because a proactive programme was already underway to strengthen the fresh water pipe network. Huntsbury reservoir, the city's biggest, was seriously damaged, placing significant pressure on the water supply. Pump station buildings are operating but will need to be repaired properly in the future.

Figure 8: Road damage caused by the earthquakes (source: Michael Campbell)

Because of a higher proportion of old materials used in waste water pipes than in fresh water pipes, around 528 kilometres, or about 31 per cent, of the sewer system was damaged and 100 sewer pumping stations were identified as needing to be repaired or rebuilt. For health reasons, restrictions on recreational use of the waterways around Christchurch were imposed because of the effects of the damage. The main causes of ocean and waterway contamination were leakage of waste water and the temporary pumping of waste water into waterways as an emergency diversion after severe aftershocks.

The earthquakes badly damaged the Christchurch waste water treatment plant and its oxidation ponds, although it continued to operate at a reduced capacity. As a temporary measure, for a short period, the effluent that was pumped into the ocean was not treated to the usual safe level.

Fortunately, the earthquakes left the storm water system largely in a functional state. There was still some damage, but the system is catching most storm water and most breaks have been temporarily repaired. At the time of writing, about one fifth of the storm water system had been properly assessed for damage; however CCC advises that the system is performing acceptably with only moderate impact from the damaged parts.

Some of the stopbanks by the Avon River settled and cracked so that a spring tide could flood the land. Contaminated tidal water came onto roads through broken drainage pipes. Banks and pipes failed because the ground moved toward the river and settled in a lower position than it had been. All of the stopbanks by the Avon River were at least weakened by the shaking. They need to remain raised, firm, and uncracked to function effectively. The city needs another four kilometres of stopbanks along the Avon River because the surrounding land is lower than before the earthquakes.

The city's electricity distribution networks were severely affected by the earthquakes. Earth movement stretched some underground power cables up to a metre in the February earthquake and caused more faults than would usually be seen in a decade. The June 2011 aftershocks caused further cable damage.

Only four of 314 substations were severely damaged in the February earthquake, including the Pages Road substation, which sank two metres into the ground. The good performance of the substations was largely due to an extensive seismic strengthening programme started in the 1990s by the network's owner, Orion New Zealand Limited. Without this work, the impact of the earthquakes would likely have been significantly worse. Telecommunications were also damaged and temporarily overloaded during the earthquakes.

Many educational facilities were damaged. Consequently, some schools were temporarily closed and the students shared premises with other schools until they were repaired. In the long term, schools may be permanently closed, merged, or relocated because of damage or falling rolls due to migration.

At the time of writing, the Earthquake Commission (EQC) had received 459,325 claims for damage to residential buildings, personal property (contents) and land in the Canterbury earthquakes. The red placards affixed to unsafe residential homes in Operation Suburb, the rapid assessment operation CCC carried out after the February earthquake, meant they could not be occupied. By the end of September 2012, CERA had red zoned 7,859 residential properties as unsuitable for long-term reoccupation and therefore likely to be demolished.

Figure 9: An aerial photo of Christchurch central city, October 2012, taken after many of the buildings had been demolished (source: Canterbury Earthquake Recovery Authority)

Figure 10: In October 2011 a temporary shopping precinct was set up to attract people back into the city. The Re: START project, located in Cashel Street, makes use of shipping containers to house a variety of businesses (source: Paul Roper-Gee)

Because of the danger posed by damaged buildings, parts of the CBD were cordoned off after both the September and February earthquakes. After the February earthquake, the CBD Red Zone covered a significant area of the city (as Figure 9 indicates). More than 3,000 of the 5,000 businesses in the CBD were displaced, many migrating to the suburbs. There has been a general shift of activities, such as retailing, away from the damaged CBD and eastern and riverside suburbs to the south and south-west. Retailers also moved into temporary premises (for example, the shipping container mall in Figure 10) in Cashel Mall and elsewhere. More than 1,200 Christchurch CBD buildings require full or partial demolition or deconstruction, including heritage buildings. As the demolitions are completed the cordon is progressively reduced, enabling further access to the central city.

2.7.1 The economic impact of the earthquake

Estimates of net departures from the region vary, but are generally reported[10] at between eight and ten thousand in the year to June 2011. It has been suggested that net departures continued at a slower rate in the second half of 2011, and in the last few months there have been more arrivals than departures, due possibly to the inflow of workers to assist with the rebuild.

Population loss has a flow-on impact to a number of economic indicators, as discussed further below.

Economic commentators note the difficulties inherent in isolating the effects of the earthquakes from other economic developments. In addition, data often lags well behind an actual event. It is noted that New Zealand had, at the time of the September earthquake, made a modest recovery from recession, and was looking at a positive medium-term outlook.

The Reserve Bank of New Zealand (RBNZ) has characterised the Canterbury economy as having been "reasonably resilient to the impact of the earthquakes" and stated that the New Zealand economy "appears to have been little affected". In particular, the RBNZ noted in September 2012 that exports and manufacturing activity have held up well and that the agricultural sector was largely unaffected. It noted that:

> …disruption to industrial production, goods exports and activity was relatively short lived as the region's manufacturing hub escaped significant damage. But Christchurch is the tourist gateway to the South Island; accommodation capacity has been greatly reduced and tourist numbers have fallen considerably.

In its 2011 Fiscal Strategy Report, the Treasury estimated that the impact of the February earthquake would be a reduction in GDP growth for 2011 of around 1.5 per cent from what it would have otherwise been. It noted that the impact would be offset as the reconstruction commences, resulting in higher growth from 2012.

2.7.1.1 Capital costs

These costs are largely related to the repair and rebuild of commercial buildings, infrastructure and residential housing.

Damage to buildings can be defined in a number of ways, but we adopt the RBNZ definition as the cost of rebuilding and repairing in 2011 dollars. Building damage resulting from the earthquakes is estimated at around $20 billion. This equates to approximately 10 per cent of annual GDP. The RBNZ estimates $13 billion for dwellings (estimates are that 150,000 homes, around 75 per cent of Christchurch's housing stock, have sustained some damage, and 20 per cent have sustained damage exceeding $100,000 in value), $4 billion for commercial buildings and $3 billion for infrastructure. In comparison, the Japanese earthquake and tsunami caused damage equal to 3–4 per cent of GDP.

2.7.1.2 Funding the rebuild

The Treasury and the RBNZ note that much of the damage is covered by private insurance and EQC, and reinsured through overseas insurance companies. This will help to fund rebuilding, and lead to a large boost to economic growth from reconstruction activity.

Central and local government are also contributing to the costs of repairing and replacing infrastructure. Residents of Canterbury will bear some of the cost through increased rates – an average 7.8 per cent for 2012/13 over 2011/12, of which approximately 3.7 per cent is to fund earthquake-related costs (e.g. repair of 10 major community facilities) and replace lost revenue.

Since the earthquakes, there has been limited new insurance cover available for earthquakes in Canterbury. Some owners of earthquake-prone buildings and infrastructure can no longer obtain insurance cover in Canterbury or elsewhere in New Zealand. Reinsurance premiums have increased substantially, some more than doubling.

2.7.1.3 Economic impact

As stability has returned in Canterbury with the reduction of aftershocks and a clearer plan for the future, the economy is settling as the region's population gets back to business as usual. Nevertheless there continues to be disruption to business through, for example, the red-zoned CBD being unavailable to businesses, the city's roading being subject to major repair and a lack of facilities catering to tourists at present. There remains, at present, a drag on the region's economy. We now discuss the major impacts on business profitability.

Retail sales are estimated to currently be around 10 per cent behind the rest of the country, probably as a result of the loss of premises in the CBD and the decline in population. Retail trade has increased by around 7.7 per cent in nominal terms nationwide since September 2010, but only by 1.3 per cent in Christchurch.

The Treasury indicates that employment in the Canterbury region was 8 per cent lower in the year to September 2011 over the previous corresponding period. The New Zealand Institute of Economic Research reported that to September 2011, there had been around 27,000 job losses and the RBNZ noted that the decline in employment has been mostly in the retail, accommodation and food services sectors with the loss of some 12,000 jobs between June 2010 and June 2012. However, Westpac Bank notes that the unemployment rate in the region has remained low because of strong demand in certain industries and for particular occupations. Between June 2010 and June 2012, there has been an increase in jobs in the construction sector of an estimated 6,000. There is evidence that it is now becoming difficult to recruit labour for skilled jobs in Canterbury because of the miss-match of the skills of those who lost jobs after the earthquakes and the skills needed for the rebuild.

Business profitability has been impacted by earthquake damage to capital items (e.g. machinery) and buildings that reduced the production capacity of businesses, damage to roads and other infrastructure that has impeded their ability to carry out their operations, and changes in demand for goods and services from a reduced number of clients (e.g. tourists). Some businesses benefitted from increased clientele, especially where they were located outside the worst affected areas.

The housing market initially turned down with uncertainty over repairs and ability to get insurance, but signs of it rising in Canterbury while being flat nationwide were being seen by November 2011. The reduction in population appears to have been exceeded by the reduction in the housing stock, which has put upward pressure on prices. New property rental agreements have seen rents increased by 18 per cent in Christchurch since the end of 2010 compared with a seven per cent increase nationwide, with higher rentals being achieved in the south-western suburbs.

2.7.2 The cultural impact of the earthquakes

Before the earthquakes, Christchurch had one of New Zealand's best-preserved heritage townscapes. New Zealand is internationally recognised for the quality of its Victorian and Edwardian architecture. The preference of its early settlers for neo-Gothic architecture in its churches and public buildings gave Christchurch a distinctive character, and prompted visitors to comment on its "Englishness". Christchurch had the only intact surviving set of government buildings from the period of provincial government in New Zealand (1852-76), and the interior of Benjamin Mountfort's great debating chamber was widely recognised as the finest neo-Gothic interior outside England. Christ Church Cathedral was the city's centrepiece since 1881, a rare example of Sir Gilbert Scott's work outside England. The 1906 Cathedral of the Blessed Sacrament in Barbadoes Street (Figure 11) was one of the finest classical buildings in New Zealand. Christchurch Arts Centre (Figure 12), the former buildings of Canterbury University College before the university's move to its suburban campus at Ilam, together with the nearby Canterbury Museum, formed a neo-Gothic precinct unique in New Zealand.

Figure 11: The Cathedral of the Blessed Sacrament, also known as the Catholic Basilica, after the Canterbury earthquakes

Figure 12: The neo-Gothic-style Christchurch Arts Centre (source: Roger Wong)

Of these buildings, only the Canterbury Museum has emerged from the February earthquake without significant damage. Much of Christchurch's heritage townscape was destroyed in the Canterbury earthquakes. Many adjacent Victorian and Edwardian buildings act as one structure in an earthquake. In the February earthquake, whole streetscapes were lost when the façades of an entire block of interconnected buildings rotated outwards onto the street. This was particularly noticeable in Colombo Street, where two buses were trapped under fallen façades, tragically resulting in loss of life in one of them.

While they did not collapse as substantially as Christchurch's older unreinforced masonry buildings, the February earthquake damaged many of Christchurch's Modernist buildings beyond repair. Notable demolitions include Beaven's Southland Building Society building, his central city Holiday Inn, and Warren's Crowne Plaza building (Figure 13). The Christchurch Town Hall also sustained major damage and, at the time of writing, has an uncertain future.

Figure 13: The Crowne Plaza Hotel, formerly the Park Royal Hotel, was damaged by the earthquakes and demolished in 2012 (source: Gudrun Gisella)

Since the February earthquake, and the closure of the CBD, many businesses have shifted to the west of the city. Colombo Street south of Moorhouse Avenue, Sydenham, Addington, Riccarton and the light industrial area surrounding Christchurch airport have all grown since 2011. New residential subdivisions are also emerging in Christchurch's satellite towns.

2.7.2.1 Impact of the Canterbury earthquakes on individuals and the community

The Canterbury earthquakes have changed the people of Christchurch. The psychological impact of the earthquakes has been complicated by the many aftershocks since the first earthquake on 4 September 2010. The continuous aftershocks have kept people in a prolonged state of hypervigilance and exposed them to recurrent acute stress. This unpredictable and uncontrollable stress has affected some people physically and emotionally. Some relationships that were already under stress before the earthquakes have been unable to survive under the constant stress.

Post-traumatic stress can arise following a traumatic event that threatens people's safety. It is characterised by symptoms of re-experiencing the original trauma(s) through flashbacks or nightmares, avoidance of stimuli associated with the trauma, and increased arousal such as difficulty in falling or staying asleep, anger, and hypervigilance. While most Cantabrians would not be classified as having post-traumatic stress disorder, many are experiencing or have experienced varying degrees of post-traumatic stress symptoms. For some people this now manifests as a "startle response" or feeling "jumpy" when they hear or feel a bus go past their house, or a hypervigilance regarding their personal safety or that of their family members. Post-traumatic stress disorder develops when these symptoms do not lift and people remain stuck in a state of psychological shock.

Many Christchurch people have experienced an enormous sense of loss including the loss of work and businesses, homes and the lives they had before. Those who were seriously injured in the earthquakes have experienced the loss of their former selves, independence and autonomy. The sense of loss is, of course, most profound for those who lost a loved one in the February earthquake.

For some people, the earthquakes have been a chance to reassess and re-evaluate their lives to determine what is really important. As time goes on, some people who have lived through the earthquakes are able to feel that new opportunities have emerged from it all, opening up possibilities that were not there before. People have displayed extraordinary innovation, adapting to the new situation by creating exciting new projects. People and communities banded together and offered support to each other following each major earthquake, developing stronger relationships with others in their community as a result of a collective understanding because of a collective experience. For many people, it appears that living through this disaster has given them a greater appreciation of life in general and a sense of what is really important to them. Many Cantabrians now have a reduced attachment to material things and a new appreciation for what is truly important in life. For many, the earthquakes have given them a chance to stop and reconsider their priorities; to focus on what they still have despite all that has been lost.

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10. For example, the Reserve Bank of New Zealand and Westpac Bank discuss net departures from the Canterbury region.