BUILDING BACK BETTER
Case Study of the 2010-2011 Canterbury, New Zealand Earthquake Sequence

February 2014

A Learning from Earthquakes Report

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A report prepared by the Earthquake Engineering Research Institute in collaboration with the New Zealand Society for Earthquake Engineering and the Natural Hazards Platform for the Global Facility for Disaster Reduction and Recovery of The World Bank

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I. INTRODUCTION

The World Reconstruction Conference (WRC) in Geneva in May 2011 recommended the development of an internationally applicable disaster recovery framework to assist governments in achieving resilient recovery. As no global standard has yet been adopted by countries for planning and managing the recovery process from beginning to end, The European Union (EU), United Nations Development Program (UNDP), and the World Bank Global Facility of Disaster Reduction and Recovery (WB GFDRR) agreed to develop a best practice guide on planning and managing post-disaster recovery processes.

The preparation of the Disaster Recovery Framework (DRF) Guide is supported by a series of country case studies and thematic reports on recovery and reconstruction experiences that draw from a broad sample of disasters around the world over the last two decades. One of the themes is building back better (BBB) after a major disaster. The concept requires viewing a disaster as an opportunity for improvement rather than solely a crisis requiring prompt restoration of services and repair of physical assets (Cosgrave, 2007; Kennedy et al., 2008). BBB involves linking relief, reconstruction, and recovery with hazard mitigation and potential loss reduction to minimize conditions that could result in a similar disaster in the future (Clinton, 2006; FEMA, 2000; Kennedy, 2009; Monday, 2002).

The thematic report on BBB is based on literature review, analysis of preliminary damage and needs assessment (PDNA) documents, and field visits to Sri Lanka and New Zealand to analyze the application of BBB principles in 2005 post-tsunami and 2011 post-earthquake reconstructions, respectively. For the 2010-2011 earthquake sequence in the Canterbury region of New Zealand, WB GFDRR contracted with the Earthquake Engineering Research Institute (EERI) to analyze the application of BBB principles after the earthquakes). EERI assembled and coordinated a team made up of experts from the United States and affiliates of the New Zealand Society for Earthquake Engineering (NZSEE).

A team comprised of EERI, NZSEE, and GFDRR representatives visited New Zealand during September 12-25, 2013. Information contained in this report is based on team-member interviews with a wide range of representatives from central government, local government, and area universities. Information derived from interviews was supplemented by site visits, government documents, and other research literature.

While this report focuses on engineering aspects, it also explores the economic and social impacts of BBB decisions. In accordance with the original mission, the team collected quantitative and qualitative evidence of BBB in three affected sectors: residential housing, commerce, and water and sanitation.

EARTHQUAKE SEQUENCE

A magnitude7.1 earthquake struck the Canterbury region of New Zealand's South Island on September 4, 2010; the epicenter was located near the town of Darfield, approximately 35 kilometers west of Christchurch on the previously unknown Greendale fault. The earthquake caused widespread damage in the region and generated hundreds of perceptible aftershocks, with four equal to or greater than magnitude 6.

Six months later, on February 22, 2011, another powerful earthquake struck the same region, severely damaging Christchurch, and killing 185 people. The epicenter of the 6.3 magnitude quake was near Lyttleton, 10 kilometers southeast of the center of Christchurch, on another previously unknown fault. The earthquake extended the aftershock sequence of the 2010 quake considerably eastward, although the fault was not believed to be a projection of the Greendale fault (EERI, 2011). The 2011 earthquake generated more than 7300 felt aftershocks in the first year.

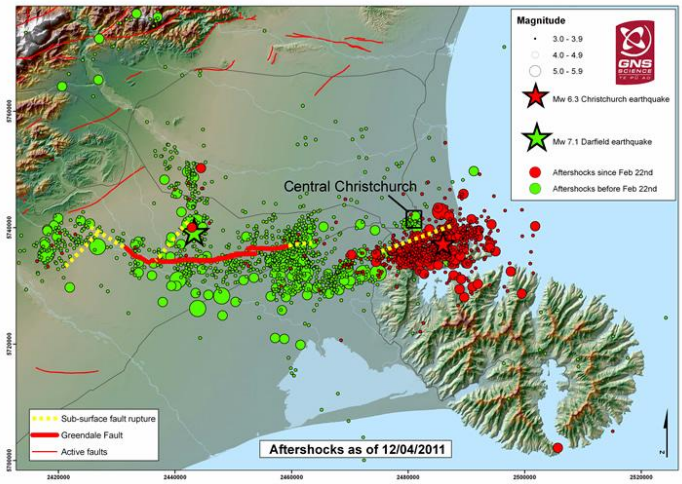

Figure 1: Location of main shocks and aftershocks

The fault rupture occurred at a shallow depth of approximately 5 km, causing high intensity ground shaking. The ground motion was largely horizontal but also included significant vertical accelerations. In some locations close to the epicenter, the vertical acceleration far exceeded the the horizontal acceleration. The vertical peak ground acceleration (PGA) in central Christchurch exceeded 1.8g (i.e., 1.8 times the acceleration of gravity), with 2.2g in some areas, the highest ever recorded in New Zealand and one of the highest recorded worldwide. This PGA is considered unusually high for a M6.3 quake. As a comparison, the 2010 Haiti earthquake was a magnitude 7.0 with an estimated 0.5g PGA.

DAMAGES

Christchurch is New Zealand's second-largest city, with approximately 340,000 inhabitants, though combined with surrounding suburbs the Christchurch metropolitan area has almost 450,000 inhabitants. Christchurch accounts for approximately 20% of the national economy. Until the 2010 quake, this area had been considered a region of moderate seismic hazard (0.22g design Peak Ground Acceleration) compared to Wellington (0.4-0.6g design Peak Ground

Acceleration, when considering near fault effects) and other parts of NZ, and the most recent building code and its enforcement corresponded to this assessment.

Most of the buildings in the region were not designed to withstand the high PGA of the 2011 quake; furthermore, many had been partially damaged and weakened in the 2010 earthquake. Most of the 185 deaths (72%) took place in the collapses of two multistory downtown buildings, designed and constructed in the mid-60's and mid-80's, respectively. More than 7000 people were treated for injuries, 220 of them with major trauma.

The high shaking intensity, the simultaneous vertical and horizontal ground movement, and the extreme liquefaction caused significant damages, undermining many building foundations and destroying infrastructure. In central Christchurch and its eastern suburbs, at least 80% of the water and sewerage system was severely damaged (Clifton, 2011).

In the city center a large number of buildings sustained damage beyond repair, including several landmark buildings, hotels, local council buildings, and the Christchurch cathedral. Damage was highest in older unreinforced masonry buildings--constructed before strict earthquakes codes were introduced; high rises built within the past 30 years performed well. Though two building collapses accounted for the majority of deaths, many other modern buildings and unreinforced masonry buildings collapsed or partially collapsed, though fortunately fatalities were minimal.

Following the 2011 quake, 4,000 downtown buildings were inspected, with the result that access to 45% of them was banned for safety reasons and 1000 buildings were marked for demolition. Out of 220 buildings with five or more stories, 110 have been demolished. Most of these buildings were in the Central Business District.

A high proportion of Christchurch residents live in single family homes in the suburbs that were also heavily affected. Roughly 7,500 houses required demolition (CERA, 2014), while almost 100,000 units needed repairs (Stuff.co.nz, 2011). Because landslides, subsidence, and liquefaction played an important role in classifying homes for demolition, some parts of Christchurch will not be allowed to be rebuilt.

The Treasury estimates the capital cost of the Canterbury earthquakes to be around $40 billion. The Government, on behalf of New Zealand taxpayers, is making a significant contribution to the rebuild of around $14.9 billion, including the Earthquake Commission (New Zealand Treasury 2013).

RECOVERY

In March 2011, the Canterbury Earthquake Recovery Authority (CERA) was established to lead the earthquake recovery over five years in cooperation with government agencies, local councils, and residents. Locally, within ten weeks of the quake the Christchurch City Council launched the "Share an Idea" public engagement campaign to maximize the community's involvement in the redevelopment of central Christchurch (CERA et al, 2011).

The redevelopment is slated to take ten years and cost more than NZ $2.3 billion. This number does not include the reconstruction of the residential sector; of utilities--power, telecom, gas and fuel supply - or of the recovery needs of the Canterbury region.

The estimated total cost of reconstruction is NZ $40 billion, according to an April 2013 government assessment (New Zealand Treasury, 2013). The fund sources will be a combination of insurance --government and private insurance, government sources (including local government resources and borrowing), and private savings. New Zealand's Earthquake Commission (EQC), a government organization, provides earthquake insurance at a very low rate to residential policyholders.

II. HOUSING

The February 2011 earthquake caused significant liquefaction in areas throughout the southern and eastern suburbs of Christchurch, which damaged foundations on thousands of houses there and in areas surrounding the CBD. Landslides also contributed to residential damages. In general, houses performed well with respect to ground shaking. According to the Canterbury Earthquake Recovery Authority (CERA), approximately 7,500 houses were damaged to the point of being designated as uninhabitable and required demolition, out of approximately 100,000 houses damaged in Christchurch (CERA, 2014).

A large majority of residences in Canterbury consisted of single-family wood-frame houses. Thus, housing sector impacts were primarily borne by individual homeowners. Full reconstruction of damaged houses is expected to take 5-10 years. Two issues heavily influence the overall reconstruction process for the housing sector, as well as opportunities to build back better: changes in residential land use, and residential earthquake insurance.

LAND USE

Land use planning has been the most important tool for ensuring future seismic safety and promoting BBB. The primary land use planning strategy for BBB was the regulation and reclassification of residential land uses based on how the land is likely to perform in future earthquakes. Mannakkara and Wilkinson (2012) discuss determining appropriate land-uses based on risk zone maps and relevant building regulations. New land use classifications were based on hazard assessments determined by identifying liquefaction and landslide hazard areas designated prior to the earthquake sequence as well as observed impact data gathered after the sequence from central government agencies and private consultants. The new land use designations dictate where residential building can occur in the future as well as areas where rebuilding is not allowed due to unreasonably high hazard risk. Land use designations were also informed by the changes in building codes and regulations, where code changes required different structural requirements for houses, especially for foundations. Observation of actual damage was also used to assess future land use.

Government officials used specific criteria to determine the suitability of allowing rebuilding in hazard areas. The first criterion was life safety of building occupants. This criterion was almost exclusively applicable only to hillside houses exposed to landslide hazards; for the most part, life safety is not an issue for houses exposed to liquefaction hazard. The second criterion was the financial feasibility of rebuilding homes, given the specific susceptibility of damage to structures and infrastructure in future quakes. This criterion was mostly relevant to flat areas susceptible to liquefaction hazard, where affordable mitigation is sometimes available, depending on the degree of liquefaction susceptibility. Conversely, mitigation of landslide-vulnerable hillside houses to meet life safety requirements may be possible, but is generally cost prohibitive.

Building Back Better

Although typically the domain of local government, responsibility for reclassifying land use was taken by the central government through CERA. CERA established new land use designations within Christchurch coupled with specific building requirements for each designation. Four land zones characterize the full range of potential seismic hazard, and for some BBB practices were required. The first zone (Technical Category 1, or TC1) designates areas where future damage is unlikely and the commonly used house foundations meet standard design codes. In New Zealand, these are typically slab foundations or suspended timber floors. The second zone (TC2) designates areas with minor to moderate hazard. Houses in this zone are required to use more robust foundation designs, including timber-piled foundations, suspended timber floors, or enhanced concrete-slab foundations. In the third zone (TC3), moderate to significant damage is expected, requiring site-specific geotechnical investigation and a custom-engineered foundation design. The fourth zone (TC4), commonly referred to as the red zone, identifies the highest liquefaction or landslide hazards. The TC4 zone prohibits rebuilding based on the criteria identified above (CERA).

Red zone designation was done by a parcel-by-parcel basis. A parcel was designated as lying within the red zone if any portion of it overlapped an area of high hazard. CERA established a buyout program for homeowners who found themselves in the red zone, and to date properties in the red zone have for the most part been acquired and cleared of structures and other hardscape like driveways. Property owners were compensated for their property based on the most recent (2007) Rateable Value (RV) of the property. Due to the unbalanced demand versus supply and resource constraints, the price of properties, rental costs, and land have significantly increased since the earthquake, in many cases significantly exceeding the 2007 RV, thus reducing the buying power and options of the red-zoned property owner. A general revaluation of city properties due in 2010 was delayed by the earthquakes and has been carried out in 2013, using a special post-quake valuation method (Christchurch City Council, 2013). The government has yet to announce a specific plan for future land uses within the red zone. Potential land uses include recreational and park spaces, as well as agriculture.

Lessons

Central government interventions in land use planning can be effective for BBB. At the same time, these interventions can have unintended consequences, particularly with respect to homeowner reactions. In Canterbury, some homeowners objected to having their property red zoned based on only a small portion of the parcel being hazardous, especially when no structure existing within the hazard zone or a next-door neighbor was not red zoned. Conversely, some homeowners who were not red zoned but were surrounded by red zone parcels also contested the designation because they were ineligible for buyouts and had concerns about losing property value or utility services.

The central government established a fixed timeframe for homeowners to accept compensation offers and leave red zoned properties. Though many homeowners complied, some applied for extensions for accepting their offers. Many of these homeowners have gone into protracted negotiations with the central government to challenge the amount of compensation offered. Some have requested financial assistance to make improvements to their houses or to make up for lost equity. Though repeated earthquakes and multiple instances of liquefaction have likely lead to higher compliance than would have occurred otherwise, a small percentage of

homeowners with red zoned houses decided not to accept government compensation or leave their property. At this time, it is unclear what will happen to these holdouts, though local government is no longer obligated to provide utility services or improvements beyond the prescribed timeframe.

Some people are concerned that the central government will acquire their property only to turn around and sell it for economic development purposes, a worry caused or exacerbated by the central government's failure to announce plans for future land use in the red zone for fear of influencing insurance settlements. This underscores the importance of timely governmental decisions, comprehensive information for residents, and transparency. Uncertainty and speculation can have significant impacts on the local real estate market and property values.

Uncertainty around red zone land has also raised some tensions between local planning and the central government, leading to challenges for local government planning, particularly around existing local long-term growth plans. The reduction of housing supply and buildable land has potential negative effects for residents, such as higher house prices, higher rents, fewer houses, and smaller parcels and houses.

EARTHQUAKE INSURANCE

Home mortgages in New Zealand require the purchase of earthquake insurance. The Earthquake Commission (EQC) was established by the central government in 1993 to provide residential earthquake insurance and manage an associated national disaster fund. Annual premiums for EQC insurance have historically been extremely low; deductibles are similarly very affordable. Earthquake insurance is automatically obtained when a homeowner takes out a fire insurance policy—also required for home mortgages—through a private insurance company. EQC covers the first $100,000 in residential building damage, the first $20,000 in building contents, and 100% of land damaged within a fixed distance of the residence. Additional coverage is offered through private insurers, who are able to offer coverage at similarly affordable levels due to the substantial reduction in risk through EQC coverage. In the event of a claim, EQC provides payouts to the insurance company of the homeowner, rather than directly to the homeowner. This reduces the complexity of the claims process for homeowners as the private insurers manage this process. By the end of May 2011, the EQC had received over 133,000 claims for the 22 February event (EQC).

Building Back Better

Building back better requires financial resources. Unlike the case in most other similar-scale disasters around the world, a large majority of residential losses, 80%, in the Canterbury earthquake sequence was covered by insurance. The high insurance penetration in New Zealand protected the central government's fiscal health after the earthquakes, in addition to the high global re-insurance coverage of the EQC. This allowed the central government to allocate financial resources to other aspects of rebuilding.

EQC policies prior to the earthquakes covered the repair or rebuilding of homes to a condition similar to that just prior to the earthquake. The objective of the large majority of insurance policies for damaged homes in Canterbury was "like for like" for repairs or replacement, rather than explicitly providing the means to build back better; however, new construction results in BBB by virtue of meeting current codes and standards for construction, utilizing state-of-the-practice construction methods and materials, and complying with new zoning and land use

designations. Within the constraints of insurance payouts, for example, homeowners could improve their foundations to meet the requirements of their new land use hazard zone, and could use lighter roofing and cladding materials than those previously available, which are less susceptible to future shaking damage.

If a homeowner's house was given a red zone designation, the central government offered compensation to encourage residents to rebuild on less hazardous land. Homeowners received one of three compensation options, tied to insurance status. Insured homeowners could receive a payout equivalent to 100% of the most recently assessed property value of buildings, land, and fixtures. After acquisition, the central government assumed responsibility for negotiating insurance claims on the property. Alternately, insured homeowners could receive a payout equivalent to 100% of the most recently assessed land value only and negotiate directly with their insurer for compensation for the damaged building and contents. Uninsured homeowners were eligible to receive 50% of the most recently assessed land value, but were not eligible to receive compensation for damage to buildings or contents.

Lessons

The EQC has struggled to process claims in a timely manner due to an unprecedented number of claims: over 400,000 for house damage and over 130,000 in land claims. Additionally EQC had just 26 employees prior to the earthquake – a number which grew to over 1,300 at one point after the earthquakes. There was difficulty in determining how to separate multiple claims on the same property from damage sustained in the two major earthquakes and many aftershocks. In many cases, claims negotiations from the September earthquake were already underway when additional damage occurred in the February earthquake, causing confusion for both homeowners and insurers. The earthquake sequence resulted in 15 separate claimable earthquake events, and private insurance companies and the EQC had to negotiate how to apportion claimed losses to different earthquake events. EQC and private insurers had also offered varying policies over the years, and the wide variety of policies confused the claims process because the details of each policy had to be determined and applied. Many homeowners remained in their damaged houses for an extended period after the earthquakes, unable to make repairs until their insurance claims were settled.

Aside from increased seismic safety, there are other opportunities to improve the quality of the residential sector during the rebuilding process, but the Christchurch rebuild was unable to capitalize on many of these opportunities. Improvements such as increasing energy efficiency or sustainability through greener construction techniques, water management, or renewable energy generation in rebuilt homes meant an additional cost that was not covered by insurance. Most homeowners were either not aware of the possibilities or were not able to spend an additional $5,000 for sustainability or efficiency upgrades. There were few or no financial incentives to incorporate sustainable practices in rebuilding, and in fact EQC often did not allow owners to make improvements, even at the homeowners' expense, due to time constraints. This move was highly criticized, but EQC maintained that it was not their responsibility to improve a home, only to fix them to a pre-earthquake standard. The New Zealand Green Building Council developed a handful of demonstration projects throughout the area to encourage adoption of energy efficiency improvements, but the practice has not become standard.

By and large, BBB is not an explicit interest of insurance companies, and convincing already financially stressed homeowners to implement additional BBB practices can prove difficult in the absence of special programs or incentives.

III. COMMERCE

The central Business district (CBD) is a significant and symbolic component of Christchurch's commerce. According the Statistics New Zealand, the CBD had the highest employment density in Christchurch in 2010; employment within the four streets defining the CBD accounted for 28% of the total employment in Christchurch. There was a large concentration of financial, insurance, real estate, and professional services business, as well as a retail sector and nightlife. Damage and disruption to the CBD was deleterious to Canterbury's commerce.

In general, the level of shaking intensity in the CBD was very high. The ground accelerations during the February 2011 earthquake were more than twice that in the building code design current at the time, which corresponds to a 500-year event and, in some cases, to a 2,500-year event--greater than the maximum credible earthquake (EERI, 2011). Considering the high level of shaking, the response of modern reinforced concrete structures—the dominant type of multi-story building in the CBD—was satisfactory from the perspective of expected design performance (Kam et al., 2011, Pampanin, 2012) and life safety. However, because of significant structural damage, a high proportion of relatively modern buildings (mid-1980's and onwards) were deemed too expensive to repair, particularly because of options provided to building owners through insurance—discussed further below.

The severe damage in the CBD led to the cordoning off of 75 blocks within ten days of the earthquake (EERI, 2011). While that area was reduced over time, some parts of the CBD were cordoned off for over two years. In the CBD center, many structures were damaged beyond repair, including several landmark buildings, hotels, local council buildings, and the cathedral (EERI, 2011). Damage was concentrated in older unreinforced masonry structures built before strict earthquake codes were introduced. Most of the human losses (135 out of 185) were concentrated in the collapse of two modern reinforced-concrete buildings, one built in the 1960's and the other in the 1980's. The latter building was found to have critical design and construction deficiencies by the Canterbury Earthquake Royal Commission of Inquiry.

Following the February earthquake, approximately 3,000 CBD buildings were inspected, 24% given a red-tag designation indicating the need for demolition, and 23% given a yellow-tag designation indicating severe damage requiring restricted access for an extended period of time (Kam and Pampanin, 2011). Ultimately, approximately 1,600 buildings were identified for demolition within the CBD (though many of these were not severely damaged, but demolished to accommodate the new plan for the CBD) , with 110 of 220 buildings of five-stories or more being demolished; almost all in the CBD.

With respect to commerce, three influences on, or approaches to BBB can be identified: private insurance, seismic design policy, and commercial redevelopment.

INSURANCE

As already noted, the capacity to build back better is tied to the availability of financial resources for building owners. Fortunately, most of commercial buildings in Christchurch were covered by

private earthquake insurance, due in part to mandatory residential earthquake insurance. In effect, private insurers are subsidized by the EQC in offering insurance to private businesses because they do not have to bear the entire financial burden of offering earthquake insurance to all policyholders.

Building Back Better

As with the residential insurance sector, the earthquake sequence raised many issues with respect to commercial earthquake insurance, and the scale of damage resulted in multiple sources of uncertainty and complexity. Claims payments to building owners have been delayed and complicated because of the confusion surrounding multiple damaging earthquakes leading to multiple insurance claims. Some commercial building owners dealt with as many as 13 different insurance assessors as part of their claims process. Many commercial building owners have been unsure about the wisdom of remaining in, or returning to their buildings in light of these challenges.

An apparent unexpected side effect of high insurance penetration is a large number of commercial building demolitions, particularly in the Christchurch central business district. Many of the demolished buildings were repairable, but the new costs of insurance coverage discouraged this option in many cases. The cost of owning and operating buildings that do not meet current seismic design requirements has gone up because insurance premiums have gone up significantly for such buildings. Unlike residential policyholders, commercial building owners did not necessarily have full coverage for their building, and rebuilding instead of repairing and possibly strengthening was the cheaper option. In many cases, it was a win-win situation for both the insurers and building owners, with the insurers paying off a cash settlement (around 70-80% of building value) instead of entering into costly and time consuming litigations, and the owners had the possibility to get cash for a new building with the freedom of not having to build on the same site (depending on policy).

Lessons

Many commercial building owners did not fully understand their coverage and were surprised by the outcomes of their claims. Similarly, many businesses failed to update their policies to cover their real insurance needs as their businesses changed or grew. Protracted insurance negotiations can be harmful to any business, as can be seen in the case of the largest store in Kaipoi, a suburb of Christchurch, closing in 2012 because of insurance payout issues, not earthquake damage. Research suggests that small businesses may have had poorer insurance outcomes than larger businesses because of less time and fewer financial resources to negotiate with insurance companies. While insurance plays an important role in enabling reconstruction and BBB, business surveys conducted after the earthquakes show that insurance was not the most important influence on the ability of a business to recover from the earthquake. Instead, customer demand, business type, financial assistance and subsidies, hard work, and location were most significant. Additionally, the government provided an earthquake support subsidy, giving businesses NZ $500 per employee for six weeks, with the possibility of extension for another six weeks. This allowed businesses to continue operation and was very important in keeping small businesses going (https://www.msd.govt.nz/about-msd-and-our-work/newsroom/media-releases/2011/millions-for-christchurch-quake-employment-support.html).

SEISMIC DESIGN CODE

The Christchurch earthquake sequence changed the way the government thought about earthquake-safe design and construction. New Zealand's seismic design requirements originated after the 1931 Hawk's Bay earthquake in Napier, when the central government banned the construction of new unreinforced masonry buildings (URMs). In 1960, the regional government in Canterbury required the removal of unreinforced parapets. In 2004, through the Building Act, the government enacted a policy for improving the seismic safety of buildings which required owners of commercial and public buildings to increase the seismic safety of older buildings to greater than 33% of the New Building Standard (simplistically associated to the seismic hazard factor, a localized score reflecting anticipated ground movements in a likely earthquake, also called the Z factor). The requirement for assessing the vulnerability of a building was however triggered only when a change of use or a structural modification was planned for the building. It was also left to the local authorities (city council) to decide on whether to take a more active approach or maintain such a passive strategy.

Following the earthquake sequence, a new Earthquake Prone Building Policy has been introduced national-wise in 2013, which makes mandatory for all buildings, private, public or historic/monumental to be assessed within a very precise timeframe (5 years at the latest) and, if found to be Earthquake Prone, thus below 33% of the New Building Standard, they would be required to be strengthened (within 15 years from the new policy) above that level (New Zealand Parliament Bills Digest 2013). (http://www.parliament.nz/en-nz/pb/legislation/bills/digests/50PLLaw21111/building-earthquake-prone-buildings-amendment-bill-2013).

Building Back Better

The seismic hazard factor for the Canterbury region was increased from 0.22 to 0.3 after the earthquakes to account for increased seismic activity within an estimated 10-20 year period after the February 2011 earthquake. The seismic hazard factor is used to calculate the level of ground accelerations that local buildings must be designed to withstand, and it varies across New Zealand based on each region's assessed risk from earthquakes. The change in Canterbury affects mostly public and commercial buildings, particularly in the central business district of Christchurch. This change will result in BBB in the form of higher seismic safety for new or future retrofitted buildings.

Local governments also modified their building policies. As stated above, prior to the sequence, local governments required earthquake-prone buildings to be strengthened to 33% of the current seismic design code if triggered by change of use or structural modification. The new policy now requires that all buildings be assessed within 5 years and be strengthened to 33% within 15 years.

Lessons

The combination of the increased seismic hazard factor and the changes to the local government building policies meant that many undamaged buildings, if found to be Earthquake Prone, cannot be occupied until seismic improvements are made. For BBB, this had a significant impact on areas of Canterbury than earthquake damage. Because these buildings were not heavily damaged, many owners did not receive insurance payouts to pay for seismic upgrades. Debates and legal disputes have arisen over whose responsibility it is to upgrade (versus simply repair to the status before the earthquake) these previously acceptable buildings. Of particular

concern is the impact on small towns that rely on heritage buildings as tourist attractions. There are currently no specific policies for heritage building preservation with respect to earthquake risk, and the closure or removal of these buildings due to policy changes might reduce the economic viability of the small towns.

REDEVELOPMENT

The earthquakes provided an opportunity to build back better with respect to economic redevelopment, as well as seismic safety, in the central business district. Prior to the earthquakes, Christchurch's CBD was experiencing some level of disinvestment and losing both businesses and residents to more affluent suburbs. The need to reconstruct downtown buildings was seen by many as an opportunity to rethink the CBD, improving its amenities and economic viability. A primary role of CERA is to coordinate the rebuilding of Christchurch and oversee the CDB redevelopment.

Building Back Better

In partnership with CERA, the Christchurch City Council created a redevelopment plan for the CBD within 100 days of the February 2011 earthquake, well before repairs and reconstruction were allowed in the CBD (CERA et al 2011). Within ten weeks of the earthquake, the Christchurch City Council launched a public engagement campaign to maximize the community's involvement in the redevelopment of central part of Christchurch, soliciting over 100,000 redevelopment ideas. These ideas were incorporated into the final draft of the plan. There is no explicit timeline for this aspect of BBB because there are many variables such as securing sources of funding for the many ambitious components of the plan and market desire for development. One estimate is that CBD redevelopment will take well over 15 years, with an estimated cost of more than NZ $2.3 billion, not including infrastructure reconstruction (Canterbury Development Corporation 2014).

The CBD redevelopment plan calls for a wide variety of changes. The CBD will have a smaller, more compact footprint, accomplished in part by restricting construction within a buffer along the Avon River. The buffer will reduce liquefaction and flood risk to future development, provide more recreational space, and encourage ecological restoration. A cornerstone of the plan is the establishment of different themed districts in the CBD: an arts district, a sports and recreation district, and an innovation district geared towards technology companies and startups. Further stimulation for redevelopment will be provided by two large anchor projects under development by the local government—the river park and a major convention center.

The redevelopment plan includes more multi-family housing than was in the CBD prior to the earthquake. Changes to zoning will result in lower overall density of development in the CBD. The plan reduces allowable building heights in the CBD to increase sun exposure; furthermore, residents view lower buildings as more seismically safe because of the damage to taller buildings during the quake, notably the fatalities in the collapse of the two multistory buildings. Though taller buildings are not necessarily less safe, a feeling of public safety is of great importance to Christchurch residents and the safety of the CBD is seen as a feature of its revitalization.

Lessons

There are fears that the redevelopment of the CBD will result in commercial rents that are unaffordable to small businesses. The rents for multi-family residences are likely to be much higher as well. To facilitate the large-scale redevelopment plan, the central government utilized

compulsory land acquisition powers established specifically for recovery. Prior to the earthquakes, compulsory land acquisition was only used for public works projects. These powers are being used to demolish buildings with uses that do not fit in the new districts outlined in the redevelopment plan, and to compile parcels large enough for major development projects. This practice has led to the demolition of several commercially viable buildings that were undamaged or minimally damaged in the earthquakes. Not surprisingly, there has been resistance on the part of landowners to the taking of their property. The local government has also had difficulty coordinating existing property owners to assemble parcels large enough to be attractive to developers.

IV. INFRASTRUCTURE

The February 2011 earthquake damaged and disrupted the main lifelines systems of the city, including roads, water and wastewater networks, and the electricity transmission systems (Giovinazzi et al., 2011). Electric power was restored to 98% of occupied homes within two weeks of the earthquake. Roads and bridges were extensively damaged by the significant liquefaction and lateral spreading caused by the earthquakes.

Water and wastewater systems were severely disrupted, largely because of widespread liquefaction and lateral spreading around pipes. The Christchurch City Council received 36,000 water and wastewater service requests in the five months following the earthquake. A month after the earthquake, over 95% of occupied units outside the cordoned area of the Christchurch CBD had water; however, a boil water order was in place for over six weeks across most of the city due to potential contamination from the damaged wastewater system. Water conservation orders were in place for over a week as a result of damage to key water reservoirs, damage to wells, and breaks water distribution pipes. By the end of August 2011, work was completed on all public sewer pipes, but around 800 houses were out of service due to damage to their private sewer pipes (Stevenson *et al.* 2011). The water system restoration activities in Christchurch, completed within six months, included repair of 60 water supply wells, construction of 12 km of water mains, and repair or reconstruction of 150 km of water mains, as well as of 100 km of sub-mains. The resulting liquefaction in the eastern suburbs caused bridge approaches to settle, water pipes to fracture, waste water pipes and access points to surface, roads to sink, land to shift laterally, houses and buildings to tilt and blanketed the area with foul smelling silt. The need for port-a-loos was immediate recognized on Day 1 and certainly by Day 8 they had been deemed “assets of importance” to be distributed by order of CDEM (Potangaroa et al, 2011). Port-a-loos added considerably to assisting with the initial recovery as the wastewater system was so badly damaged. The last port-a-loo was removed in January 2014.

The September 2010 earthquake caused extensive liquefaction damage in the Waimakariri District; the February 2011 quake caused similar damage in Christchurch. These locations are under the jurisdiction of two different authorities: Waimakariri District Council (WDC), and Christchurch City Council (CCC). We developed two small case studies related to infrastructure reconstruction: one for the central city associated with CCC, and one for the outer suburbs associated with the WDC. BBB and lessons learned are discussed with each case, below.

CENTRAL CITY

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is a temporary authority legislated by the central government about five months after the February 2011 earthquake.

SCIRT is scheduled to sunset in December 2016, although this will be reviewed one year prior. SCIRT took over the local government's Infrastructure Rebuild Management Office (IRMO) which had been set up in response to the September 2010 earthquake. SCIRT's scope is broader and more long-term than IRMO's.

In essence, SCIRT is a program of reconstruction projects defined by an agreed-upon organizational structure and decision-making process. SCIRT's model is based on alliance contracting, also known as relationship contracting, a procurement and contracting arrangement previously used for other construction projects, particularly in Australia, but not at this scale or in relation to disaster reconstruction. Alliances are designed to share risk among parties and deal with large, highly complex projects that involve a significant amount of uncertainty. In the SCIRT organizational structure, stakeholders from local government and the central government act as the client, and work with a large team of design consultants, contractors, and a management and services team responsible for overall coordination and management.

Because each client stakeholder of SCIRT brings different cultures, pre-existing protocols, time requirements, and needs, a client-governance group assists in developing a shared understanding of the reconstruction. The designers and other technical staff within SCIRT were temporarily assigned to the organization from four private consulting companies, with the designers still in the employ of their companies. Within SCIRT, however, designers do not identify themselves by their employer, but rather as part of four internal SCIRT teams. SCIRT managers evaluate individual staff performance and communicate this to the individuals' companies in instances where performance is poor.

Five contractors—called delivery teams—are defined within the SCIRT organization, selected because of their size, past performance, and pre-existing familiarity with the clients. The SCIRT team defines each project, designs the solution, and sets a fixed project budget for the delivery team. This process avoids individual bidding or budget negotiation. SCIRT does not dictate how contractors deliver projects or how they engage subcontractors, only the project budget they must meet. Rather than requiring delivery teams to compete for individual projects, SCIRT offers a project to a particular contractor based on a variety of factors, and the chosen delivery team is free to take on the project or not. Whether a contractor is offered a project is influenced by a performance score based on the delivery of previous projects. Half of the score is based on the cost of delivery, while the other half is based on other factors such as time, safety, and environmental impact. Innovation is one of the key performance indicators, where contractors and designers are incentivized to innovate through the scoring process. Over 400 innovations to processes and products have been through the stage-gate process to date. If a contractor manages to complete a project under budget, the surplus is shared among all the clients and the other alliance contractors—50% to the clients and 50% to the contractors. The reverse is true if a project goes over budget. These risk-reward incentives are intended to create a culture of competitive collaboration among contractors.

SCIRT and its clients agreed on an overall budget of NZ $2.5 billion for infrastructure reconstruction, intended as a fixed target. This budget evolved from early field-based damage assessment to establish ranges of estimated cost, ranges eventually given fixed values as the result of more formal analysis and deliberation with the clients. Only approximately NZ $200

million of the reconstruction budget was covered by insurance, which is mutually funded by local authorities across New Zealand.

Building Back Better

SCIRT's stated mission is "creating resilient infrastructure that gives people security and confidence in the future of Christchurch." SCIRT's goal is implementing seismic improvements to the extent possible given time and resource constraints. For SCIRT, improving resilience includes replacing system components with better materials and overall systems with improved technology (e.g., pressurized sewer networks). It also includes decisions regarding system layout and service delivery that avoid hazards, minimize failure impacts, or facilitate easier future repairs. SCIRT's goal, as it relates to BBB, does not include other forms of betterment like increased service levels (e.g., wastewater treatment capacity) or the transition to greener infrastructure technology. However, in specific instances, SCIRT can accommodate such betterment when it's feasible and outside funds are available.

Initially, SCIRT took a damage-based approach to repair or replacement decisions. A formal technical guideline was used to determine whether a particular component of the system should be repaired or replaced. After initial work, the technical guideline was revised by SCIRT to reflect a service-based approach to project definition, prioritization, and selection. A service-based approach facilitates decisions to reconstruct infrastructure in liquefiable zones or to adopt a more resilient system layout. This contrasts with a one-for-one replacement of damaged components.

Project priorities are determined using multi-criteria analysis, the criteria related to service operations—the condition, serviceability, criticality, and maintenance costs of proposed repair or replacement. Projects are grouped with respect to system interdependencies (hydraulic and proximal) to create potential groupings. Other criteria are then considered including interdependence with critical facilities and construction impacts on businesses or the environment. Priorities are recalculated each quarter. SCIRT attempts to define projects with budgets around NZ $10 million that take about five months from concept to design. Approximately 700 projects will be defined by SCIRT. Once a project has been defined, it moves to design and ultimately delivery (construction).

Lessons

It is likely that many elements of the SCIRT model could be transferred to other disaster recovery processes, at least conceptually. SCIRT management affirms that the contractors played a positive role in setting up SCIRT, motivated by the chance to assist in recovery, not only to secure contracts. A positive element in SCIRT's process is getting early contractor input on project designs; this streamlines project design and delivery. Another aspect of SCIRT's process is the location of clients, design firms, contractors in the same office. This appears to encourage focus, collaboration, and timeliness.

The apparent success of SCIRT is clearly tied to the strength of its leadership. The feasibility and effectiveness of a similar organizational structure in future disasters will depend on the particular context and leadership. For example, it is possible that in future disasters there will be political or public fears about the potential for financial corruption in a new contracting process. Particular challenges for SCIRT include managing the complex information flow and set

of diverse relationships; such challenges will arise in future disasters and can be addressed only by future evaluation of SCIRT's approach and performance.

OUTER SUBURBS

The Waimakariri District, encompassing the towns of Kaiapoi and Rangiora, represents the outer Northern suburbs of Christchurch. The district was home to approximately 42,000 people in 2011 and has experienced significant growth over the past two decades. The Waimakariri District Council (WDC) employed a traditional contracting and project management structure for reconstruction, similar to reconstruction efforts for other disasters.

Building Back Better

In the immediate aftermath of the earthquake, BBB was not an explicit goal for the WDC. The primary challenge was restoring service to the 13,000 homes without service, even if it meant using temporary means such as above-ground water pipes or portable toilets. During the restoration phase, specific priorities and strategies were typically determined in the field by WDC engineers in consultation with private contractors. In a few instances, urgency to restore services resulted in use of less than optimal pipe material because of its shorter installation time. The focus on temporary service restoration lessened the importance of including longer-term options in decision making, for example, future loss reduction. Prior to the earthquake, only age and condition were considered in maintenance and replacement decisions.

Similar to SCIRT, the WDC's approach to BBB is founded on the provision of service, rather than specific repair or replacement of pre-existing physical assets. WDC had multiple strategies with respect to increasing seismic resilience. When feasible, pipe material was improved. In general, polyethylene pipe was used in high liquefaction hazard zones and polyvinyl chloride pipe was used in moderate ones. Assets were removed from some liquefaction-prone areas. WDC reduced the time and cost of future repairs and replacement by co-locating assets and burying wastewater pipe shallower to make it easier to access. New technologies, such as pressurized wastewater networks, were considered and, in some instances, installed in areas with high liquefaction hazard. Lastly, redundancy was improved by altering pre-existing system layout. WDC estimated that the process of optimizing system resilience increased reconstruction time and cost by 20%.

For the WDC, BBB explicitly includes betterment beyond seismic improvement. The WDC went beyond the goal of restoring the same level of service and reliability as that before the earthquake. When possible, it intentionally increased the level of service (e.g., wastewater capacity). The increased level of service was determined based on pre-existing growth management plans developed by the WDC prior to the earthquake in anticipation of significant population growth in the near future. Increased population growth, combined with increased property taxes, is expected to pay for bettering their infrastructure beyond just seismic safety.

Lessons

The tradeoffs encountered in reconstruction are perfectly exemplified in the WDC's choice of a new sewer system. A pressurized sewer system is more resilient than a gravity system in the event of differential settlement due to liquefaction or lateral spreading. However, pressurized systems are more expensive than traditional gravity systems. A pressurized system can also cause controversy with homeowners because of space and electricity costs associated with

pumps on their property. Furthermore, a pressurized system may not be feasible because of technical incompatibility with existing system components.

The existence and strength of WDC's growth management plans was invaluable. Having made growth and asset management plans before the earthquake is cited by WDC as improving their ability to build back better with respect to both increased seismic resilience and better of service.

V. CONCLUSIONS

For the housing sector, land use and insurance had a major influence on the application of BBB principles. Land use policy was actively and extensively used to improve future resilience to liquefaction- and landslide-induced damage in future earthquakes. Future applications of land use policy will need to consider the technical and political process of assigning zones to particular parcels to ensure equity and minimize public complaints. In addition, attention should be given to whether the same land use policy tool should be used for multiple types of hazard (e.g., liquefaction and landslides).

The prominence of insurance payouts is potentially unique to New Zealand disasters. Nonetheless, this case sheds light on the uses and limitations of insurance in the recovery process. Private or government insurance policies could include specifications about claims when damage is caused in a sequence of damaging earthquakes (or other hazards). In general, policies can be more standardized to simplify claims negotiations. While insurance can provide critical financial resources, there is potential for the claims process to delay reconstruction or create unintended consequences. Though the promotion of BBB is not likely to be a goal of common insurance policies available today, betterment is accomplished through renewal of building stock to current design codes and construction practices.

For recovery of the commerce sector, insurance played a role similar to that within the housing sector. The planned redevelopment of Christchurch's CBD is a good example of the BBB tenet of using disaster as an opportunity. The inclusion of public ideas in Christchurch's redevelopment plan exemplifies a useful strategy for empowering the public in BBB. Making time for public involvement in BBB does not necessarily slow recovery planning. The higher-than-expected shaking intensity raised concerns about the adequacy of current design codes. These concerns led to a more stringent code for Canterbury, at least temporarily. The earthquake sequence does not necessarily indicate that the seismic hazard of Christchurch was underestimated prior to the earthquake since it may have been an extremely low-probability event. With respect to BBB, the issue became a public discussion of "how safe is safe enough?" and what tradeoffs, such as the demolition of functional buildings, are acceptable in increasing safety during the recovery process.

The impacts of the earthquake sequence on water and wastewater infrastructure highlight different approaches to BBB according to size of jurisdiction, federalism, and organizational structure. The extensive damages in Christchurch required a larger role for the central government than in the outer suburbs. The large-scale impacts and involvement of the central government influenced the approach to BBB, for example, by limiting BBB to seismic resilience and not other forms of betterment. The complexity of reconstruction and BBB in the CBD motivated innovation in organization--for example, SCIRT's alliance contracting model—to deal

with a diverse range of needs, resources, clients, and contractors in a relatively time-efficient manner. While the structure may not be directly transferable to other cases, it demonstrates that new structures appropriate to various contexts can be created. For better or worse, the suburban context illustrates a simpler process, with more flexibility in budgeting. This flexibility combined with plans for population growth (or climate adaptation), can promote forms of betterment beyond seismic resilience.

The Canterbury case demonstrates the feasibility of BBB in a highly developed economy. The development of BBB guidelines will increase the credibility of the approach and, ultimately, the success of BBB efforts during the recovery after future disasters.

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VII. REFERENCES

Canterbury Development Corporation (2014). Christchurch Economic Infrastructure Situation Report. January. http://www.cdc.org.nz/documents/2014/01/infrastructure-situation-report-january-2014.pdf

Canterbury Earthquake Recovery Authority (2014). Zoning Milestone for the Flat land residential red zone. Greater Christchurch Recovery Update February. http://cera.govt.nz/sites/cera.govt.nz/files/common/greater-christchurch-recovery-update-issue-29-february-2014.pdf

Canterbury Earthquake Recovery Authority et al. (2011). Christchurch Central Recovery Plan. http://ccdu.govt.nz/the-plan

CERC (2011). Canterbury Earthquake Royal Commission, Technical Reports. http://canterbury.royalcommission.govt.nz/. (1 Sept, 2011).

Christchurch City Council (2013). Earthquake Rates Relief. http://www.ccc.govt.nz/homeliving/ratesvaluations/ratesrelief.aspx

Clifton, Charles (2011). Christchurch Feb 22nd Earthquake, HERA Structural Systems http://www.hera.org.nz/Story?Action=View&Story_id=1398 March.
Clinton, W. J. (2006). Lessons Learned from Tsunami Recovery: Key Propositions for Building Back Better. New York: Office of the UN Secretary-General's Special Envoy for Tsunami Recovery.
Cosgrave, J. (2007). Synthesis Report Expanded Summary: Joint evaluation of the international response to the Indian Ocean tsunami. In: Houghton, R. (ed.). London: Tsunami Evaluation Coalition.
EERI (2011). The M 6.3 Christchurch, New Zealand, Earthquake of February 22, 2011, Earthquake Engineering Research Institute Special Earthquake Report May 2011, p. 16.
EERI (2010). The Mw 7.1 Darfield (Canterbury), New Zealand Earthquake of September 4, 2010, Earthquake Engineering Research Institute Special Earthquake Report November 2010, p. 16.
FEMA (2000). Rebuilding for a More Sustainable Future: An Operational Framework. FEMA Report. Washington, DC: Federal Emergency Management Agency.
Giovinazzi, S., Wilson, T., Davis, G., Bristow, D., Gallagher, M., Schofield, A., Villemure, M., Eidinger J., & Tang, A. (2011). Lifelines Performance and management following the 22 February 2011 Christchurch Earthquake, New Zealand: Highlights of Resilience. NZSEE Bulletin, Vol. 44 (4), December, pp.402-417.
Kam, W.Y. and S. Pampanin (2011). "General Performance of Buildings in Christchurch CDB after the 22 Feb 2011 Earthquake: a Contextual Report," (prepared for the Department of Building and Housing) Department of Civil and Natural Resources Engineering, University of Canterbury.
Kam, W.Y., Pampanin, S., Elwood, K. (2011). Seismic Performance of Reinforced Concrete Buildings in the 22 February Christchurch (Lyttleton) Earthquake, Special Issue, Bulletin of the New Zealand Society of Earthquake Engineering, Vol. 44(4), 239-279, ISSN 1174-9875
Kennedy, J. (2009). Disaster mitigation lessons from "build back better" following the 26 December 2004 Tsunamis. In: Ashmore, J., Babister, E., Kelman, I. & Zarins, J. (eds.) Water and Urban Development Paradigms. London: Taylor and Francis Group.
Kennedy, J., Ashmore, J., Babister, E., & Kelman, I. (2008). The Meaning of 'Build Back Better': Evidence From Post-Tsunami Aceh and Sri Lanka. Journal of Contingencies & Crisis Management, 16, 24-36.
Khasalamwa, S. (2009). Is 'build back better' a response to vulnerability? Analysis of the post-tsunami humanitarian interventions in Sri Lanka. Norwegian Journal of Geography, 63, 73 - 88.
Mannakkara S, Wilkinson S (2012) Build back better' principles for land-use planning; Urban Design and Planning, Volume 166, Issue 5, pages 288 –295
Monday, J. L. (2002). Building Back Better: Creating a Sustainable Community after Disaster. Natural Hazards Informer, 3. Online: http://www.colorado.edu/hazards/publications/informer/infrmr3/informer3b.htm
New Zealand Parliament (2013). Bills Digest. http://www.parliament.nz/en-nz/pb/legislation/bills/digests/50PLLaw21111/building-earthquake-prone-buildings-amendment-bill-2013.
New Zealand Treasury (2013). Budget Policy Statement. 13 December 2013. http://www.treasury.govt.nz/budget/2014/bps/bps-14.pdf
Pampanin, S. (2012). Reality-check and Renewed challenges in Earthquake Engineering: Implementing low-damage structural Systems – from theory to practice, Bulletin of the New Zealand Society for Earthquake Engineering, 45(4), pp. 137-160, December, ISSN 1174-9875
Parker, M. and D. Steenkamp (2012). The economic impact of the Canterbury earthquakes, Reserve Bank of New Zealand Bulletin, 75(3), pp. 13-25.
Potangaroa, R., Wilkinson, S., Zare, M., & Steinfort, P. (2011). **The Management of Portable Toilets in the Eastern Suburbs of Christchurch after the February 22, 2011 Earthquake**. Australasian

Journal of Disaster and Trauma Studies, 2011, 2 (Special Issue - A Focus on the Canterbury Earthquakes), pp. 39-48

Roberts, P. (2000). The Evolution, Definition and Purpose of Urban Regeneration. In: Roberts, P. & H. Sykes (eds.) Urban Regeneration: A Handbook. London: Sage Publications.

Stuff.co.nz (2011). Thousands of earthquake damaged Christchurch homes face demolition http://www.stuff.co.nz/national/christchurch-earthquake/4740358/Thousands-of-Christchurch-homes-face-demolition 7/3/2011