

# Response of the Regional Health Care system to the 22nd February 2011, Christchurch Earthquake, NZ

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## SUMMARY:

The magnitude 6.3 earthquake that struck the city of Christchurch on 22 February 2011 caused 185 fatalities, a large number of injuries, and resulted in widespread damage to the built environment, including significant disruption to the lifelines networks and to the main health care facilities. Healthcare delivery facilities are essential in disasters: they provide emergency medical care related to the event and regular health services required to maintain the health of the community they serve. This paper presents the physical and functional impact of the earthquake on the regional healthcare system and shows how the compromised system adapted to respond to the emergency and to continue to provide health services. Particular focus is given to the analysis of how the reduced functionality of the road, power, and water and wastewater networks, all heavily affected by the earthquake, impacted on the single facilities and on the redundancy of the health system.

*Keywords: functional loss, critical facilities, healthcare*

## 1. INTRODUCTION

On February 21, 2011, at 12:51 pm, a moment magnitude 6.1 earthquake occurred at longitude 172.71 and latitude -43.60, 3 miles southeast of Christchurch, New Zealand. The event is classified as part of the aftershock sequence from the magnitude 7.0 September 3, 2010 Darfield earthquake and is related to the boundary deformation of the Australian and Pacific plates. There were 185 people killed and an estimated 1,500 injured, almost all in the city of Christchurch. There are a total of 4 hospitals in Christchurch, but only one with comprehensive services and trauma care, the Christchurch Hospital. Christchurch Hospital operates 600-650 beds and its emergency department treats 65,000 patients annually.

Functioning hospitals are an essential component of disaster response following any type of event. They not only must provide emergency medical care related to the event, but also must continue to provide the health services necessary to maintain the health of the community they serve. The ability of hospitals to delivery healthcare services is affected by internal and external impacts following a disaster. External impacts result from the loss of critical infrastructure such as power, water, sewers and telephones. Internal mechanisms include structural and non-structural damage and damage to equipment and supplies as well as the loss of personnel.

Despite national and international efforts, earthquakes severely impact hospital services. The 2003 magnitude 6.6 Bam Iran earthquake destroyed most health facilities in the affected area with the loss of almost 50% of the health staff. The 2005 Pakistan earthquake measuring magnitude 7.6 closed 68% of the health facilities in the affected region. After the 2007 magnitude 7.9 earthquake in Peru, 60% of health facilities in the affected area reported some damage and four were destroyed, but 80% continued to provide services after the event. Perhaps the most devastating event was the 2010 Haiti earthquake struck of 2010 that destroyed or severely damaged 22% of the hospitals in the entire country.

Following the 22<sup>nd</sup> February Christchurch earthquake, damage to facilities and lifelines placed considerable strain upon the Canterbury health care system, specifically Christchurch's network of private/public hospitals, GPs, and elderly care facilities. To cope with demand, the health system has had to utilize the entire health network's capacity.

This paper analyses the response of the Canterbury Regional Health Care system to the 22nd February 2011, Christchurch Earthquake in terms of: 1) the physical damage to structures, infrastructures, non-structural elements and medical equipments; and 2) the resulting functional impact on patient care and other services. A special focus is given to the analysis of the physical and functional impact that the earthquake had on main regional hospital, the Christchurch Hospital.

## **2. SURVEY METHOD**

Following the 22<sup>nd</sup> February earthquake a specific project “Hospital Functions and Services” was granted by the Natural Hazard Research Platform, NHRP, in New Zealand and by the State of California (Alfred E. Alquist Seismic Safety Commission under Standard Agreement No. SSC 2011-03) to support the Canterbury Health District Board (CDHB) and the Canterbury Primary Response Group (CPRG) to collect and analyse seismic reconnaissance data associated with the healthcare system damage and response to the 22<sup>nd</sup> February Canterbury Earthquake. The survey tool used in this study was originally designed by co-authors Kirsch and Mitrani-Reiser and their colleagues (Mitrani-Reiser et al., 2012) to capture standardized qualitative and quantitative information on the effects of earthquakes to hospital functionality. The original survey was modified to adapt it for the CDHB Health Care System characteristics and the 22nd February 2011 context.

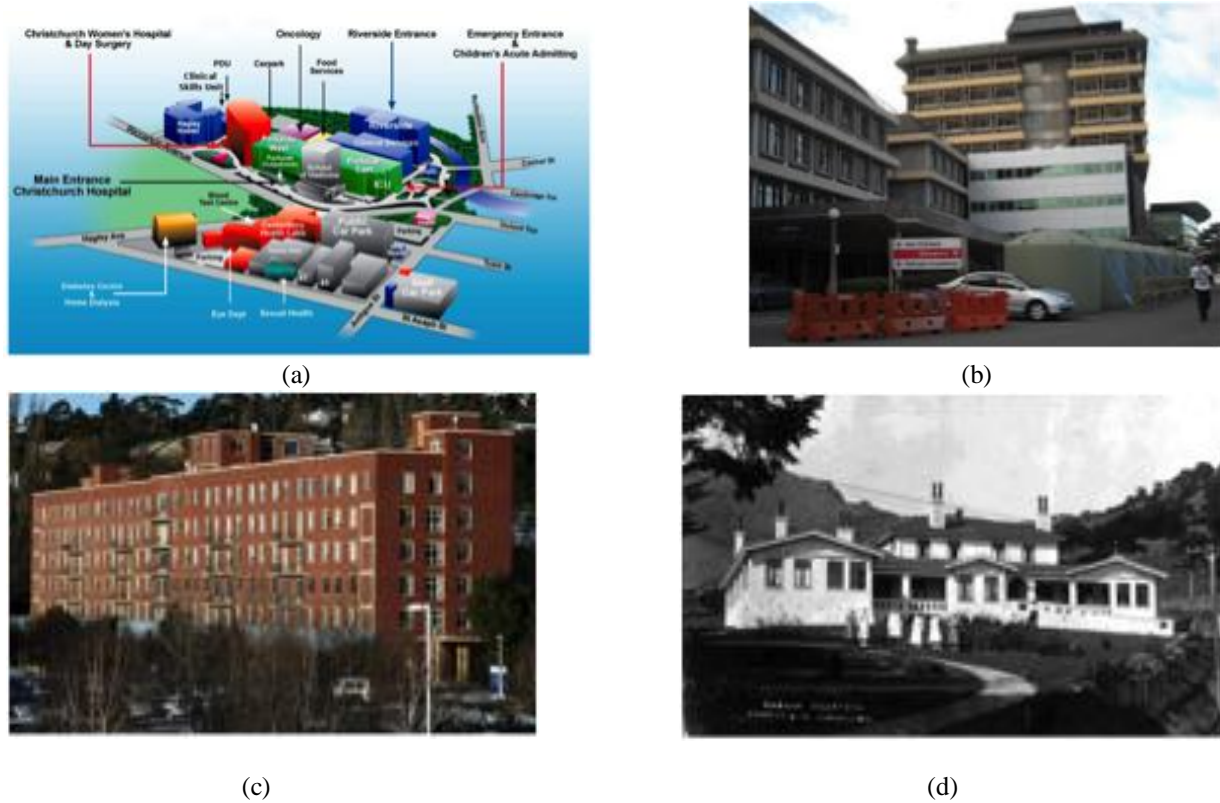
The refined ‘Health System Impact Survey’ includes two main separate surveys, where one is focused on all physical damage and engineering aspects, and the other is focused on related healthcare and service-area functional impacts. Each of these surveys has multiple sections and can be completed in an hour with relevant hospital personnel. The engineering survey is typically completed based on interviews with facility managers and/or engineers. This survey includes the following sections: site and structural description and impact, non-structural description and impact, geotechnical description and impact, supporting documentation (e.g., floor plans or damage photos), and summary of damage and functional disruption to hospital service areas (e.g., emergency department, kitchen, etc.). The healthcare survey is typically completed based on interviews with chief medical officers, nursing directors and/or emergency planners, and includes the following sections: baseline hospital information, event impact assessment, response (e.g., number of personnel available in the hours/days following the event) to the earthquake, and final observations (e.g., the major lessons learned after the event).

The surveys described above were conducted after the Christchurch earthquake by a multi-institutional (University of Canterbury and JHU faculty and students), multidisciplinary team composed of experts in structural and earthquake engineering, risk assessment, disaster medicine, and international health. The interviews were completed between 8-15 August 2011 via phone and face-to-face interviews with facilities management staff, nurse managers, emergency planners and clinical staff across the CDHB. The interviews targeted all the publicly owned hospitals that provide the majority of secondary and tertiary medical care in the Canterbury region, and two main private hospitals in Christchurch. Table 1 summarizes the hospitals that were contacted to be interviewed, the type of personnel that completed the damage and healthcare impact surveys with the research team, and the status of the interviews. As noted in Table 1, the researchers in New Zealand and the US continue to collaborate to complete the interviews in the remaining ten hospitals. This work includes remote interviews, and in-person meetings with stakeholders from the CDHB and the RHISE (Research re the Health Implications of Seismic Events) network.

### **2.3. A summary of the surveyed healthcare facilities**

Canterbury’s Health system is comprised of 14 publicly owned hospitals, which provide the majority of secondary and tertiary medical care (Table 1). Half of them, namely, Rangiora, Waikari, Oxford, Akaroa, Kaikoura, Darfield and Ellesmere, are Regional Hospitals (<20 beds) primarily handling elderly and maternity patients. A smaller not-for-profit private hospital sector specializes mainly in elective surgery and long-term care (Table 1). The private hospitals are operated directly or subsidised by the Canterbury District Health Board. The “third sector” providers, composed of non-profit non-government organizations (Health, M. O. 2011), offer other services, including general practitioners (GPs), nursing homes, and ambulance service. CDHB public and private hospitals have different specialities. Ashburton Hospital, located outside of Christchurch, mainly performs lab work and radiology, as well as providing

maternity and physiotherapy services. Burwood Hospital specializes in recovery. Hillmorton Hospital accounts for most of Christchurch’s mental health facilities. Princess Margaret Hospital (Fig. 1c) provides predominantly geriatric care and includes psychiatric wards. Private hospitals St. Georges and Southern Cross provide maternity care and elective surgery. Med laboratory, Canterbury laboratory, and Christchurch Hospital (Fig 1a) laboratory are responsible for most of the blood tests from GPs and hospitals within Canterbury (Health, M. O. 2010). All hospitals in the region actively liaise with one another in order to provide efficient care and cope with capacity shortages.



**Figure 1.** Photos of hospitals visited during the damage/impact study: a) Christchurch Hospital campus; b) Christchurch Hospital; c) Princess Margaret Hospital; and d) Akaroa Hospital.

### 3. PHYSICAL AND FUNCTIONAL IMPACT OF THE 22<sup>ND</sup> FEBRUARY 2011 CHRISTCHURCH EARTHQUAKE ON CHRISTCHURCH HOSPITAL

Christchurch Hospital is the largest and central hospital for the Canterbury Region. Christchurch Hospital operates the only Emergency Department (ED) and Intensive Care Unit (15 ICU beds) in Canterbury and performs the majority of elective surgeries. The hospital serves a population of 560,000 with 650 total beds and is the largest health district (CDHB) in New Zealand geographically. The inpatient wards provide services to over 35,600 inpatients each year, of which approximately two-thirds are admitted acutely; a further 13,000 people are day patients. There are 16,000 theatre visits each year and over 197,000 outpatient attendances, excluding those for radiology and laboratory services. The hospital operated 600–650 beds before the earthquake, including 15 ICU beds, 18 high-dependency beds, and 9 step-down beds (4 neurosurgery and 5 respiratory). Before the earthquake, the hospital typically operated at around 98% occupancy with a 48% admission rate from ED to other wards. The hospital complex, shown in Figure 1a, is made up of several buildings constructed during different time periods and made of concrete-shear-wall or reinforced-masonry construction. The buildings on the hospital campus include: the Parkside Building (built late 80s to early 90s), the Riverside Building (built in the 1970s), the Nurses Hostel (built in 1931, vacant prior to earthquake for scheduled demolition), the Diabetes Centre (built in late 1950s early 1960s), and the Christchurch Women’s Hospital (built in 2005 and the only base isolated structure in the South Island). The clinical buildings are bordered by the Avon River and because the

hospital was the only one in the city with an ED and comprehensive services it became the center of the healthcare response despite suffering significant damage. The following sub-sections provide an overview on the physical damage occurred to the Christchurch hospital structures, infrastructures and

### 3.1. Geotechnical Failures and Structural Damage

Geotechnical failures caused widespread damage to the hospital campus. For example, liquefaction caused flooding in the basements of all the buildings, including the Women's Hospital. The Parkside and Riverside buildings suffered the worst flooding. All the retaining walls between the river and the hospital failed, and the lateral spreading near the river caused severe damage to sewage lines (Figure 2a). Additionally, the tunnel that connects clinical facilities and non-clinical facilities across Riccarton Avenue was knee-deep in water after the earthquake.

There were no catastrophic structural failures (i.e., local or global collapses) to any of clinical or non-clinical buildings of Christchurch Hospital that were operating at the time of the 22<sup>nd</sup> February earthquake. However, severe structural damage did cause some forced closures to the underground tunnel carrying lifelines running below Riccarton Ave was still unusable at the time of interviews (Figure 2b).

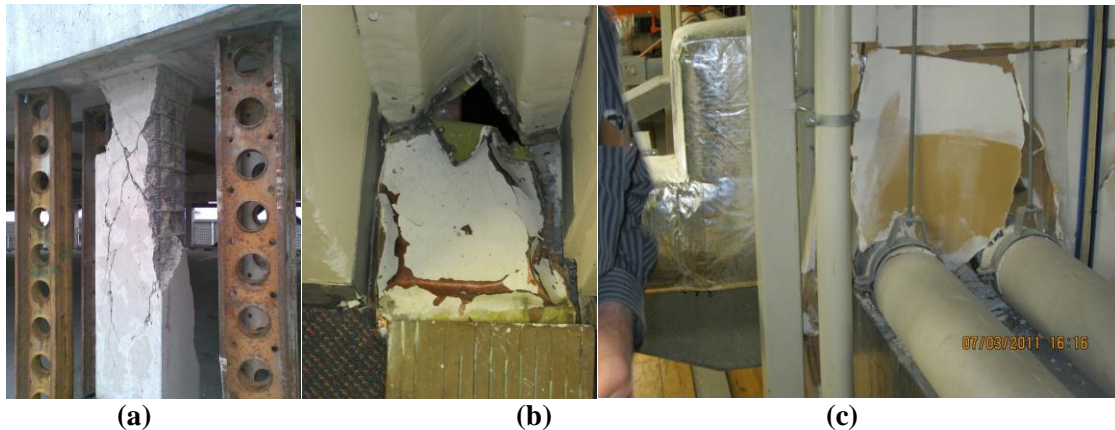


**Figure 2.** Observed damage throughout hospital campus: a) liquefaction-induced damage to the main sewer line, and (b) damage to Riccarton underground tunnel (photo credit, Alan Bavis).

Two administrative buildings on St. Asaph Street (see Fig 1a) also had to be closed. The latter building suffered damage to the connection of the roof to the walls. The hospital's parking structure did experience extensive structural damage, including spalled concrete of its beams and columns and cracking of its steel bracing. The cost to repair the parking structure's damage is estimated to be NZ\$2 million. Figure 3a shows damage to concrete columns on the ground floor of the parking structure. There was also widespread evidence of minor to moderate structural damage in several other buildings, including the Riverside Building, some non-clinical buildings, and the hospital's boiler stack. The Riverside Building, for example, suffered shear wall cracking, where some of these cracks went all the way through the wall. All clinical buildings suffered roof damage. Also several buildings experienced damage across separation joint and firewalls. Figures 3b and 3c show examples of damage found on the Christchurch Hospital campus, including damage to a separation joint in the Riverside Building and damage to a firewall in the CWH, respectively.

In AS/NZ 1170.0 (SNZ 2004), critical facilities like hospital buildings are categorised with importance Level 4. The code provisions require that the buildings remain operational, particularly under 500 year serviceability limit state, SLS2, earthquakes (Uma and Beattie 2010). Christchurch Hospital buildings were designed and built as predominantly rectangular buildings with no L- or T- shaped structures, no abrupt discontinuities along the height of the buildings, and no large overhangs. The lack of these building features, along with the presence of separation joints in most buildings, and the base isolation of the CWH likely mitigated structural damage. Additionally, several older buildings on campus had been seismically upgraded before the earthquake. Those with retrofits only suffered cosmetic damage.

Structural building initiatives and regulations alone cannot guarantee uninterrupted operation of a hospital following a large earthquake. Many other factors affect hospital functionality, such as lifelines and support agencies. Damaged non-structural components of a hospital system are typically the most disruptive factor following an earthquake (FEMA 2007). Damage to non-structural components of Christchurch Hospital are described below.



**Figure 3.** Observed structural damage in non-clinical and clinical buildings: a) spalled concrete in ground-floor column of a parking structure, b) separation joint damage in Riverside Building, and c) damage to firewalls in the CWH (photo credit, Alan Bavis).

### 3.3 Non-Structural Damage

As is expected in other countries with similar design codes (FEMA 2007), the effects of damage to non-structural building components and equipment, as well as breakdowns in public services (lifelines), transportation, re-supply, and other organizational aspects, were far more disruptive to the functioning of Christchurch Hospital than the minor structural damage observed in buildings and facilities. The non-structural damage included the failures of many components: windows, non-load bearing ceilings, partition walls, floor coverings, medical equipment, and building contents.

The failures of suspended ceilings, particularly the plaster tiles constructed with tongue-and-groove joints, proved to be one of the most disruptive non-structural failures in Christchurch Hospital. These heavy, thick ceilings act as effective fire barriers; however, when damaged, these older tiles are dangerous falling hazards. When the plaster tile ceilings were first installed, they were diagonally braced to the walls. However, at some point after construction, these diagonal braces were replaced with less effective vertical ties that make the ceilings more susceptible to damage. Fallout and sagging (identified by laser level analysis) of ceiling tiles throughout the hospital campus necessitated the replacement of these non-structural components with lightweight ceiling tiles secured to the ceiling grid with clips and diagonal bracing. The ceiling repairs have required parts of the hospital to be closed down for periods ranging from hours to days; these repairs have been going on for months after the earthquake. Most of the inpatient wards were disrupted for two weeks while fire retardant tiles covering suspended ceilings were replaced. Many light fittings became dislodged and had to be replaced alongside ceiling tiles. The failures of suspended ceilings in particular led to precautionary evacuations immediately after the event.

Non-load bearing wallboard partitions were also heavily damaged throughout the hospital. This mostly cosmetic damage did not cause loss of function immediately after the earthquake, but the areas damaged have had to be shut down for repair work months later. Severe plaster and concrete wall damage as well as damage to ceilings and glazing in the Diabetes Centre caused it to close for an entire month for repairs. Building components that are critical to vertical egress were also damaged during the earthquake. Most staircases in the clinical buildings were damaged and had to be propped up to remain operational in the emergency phase of the disaster. The stairs were eventually taken out of service one at a time and repaired during the recovery phase. The reason that so many staircases were damaged is that they were constructed with rigid connections to adjacent floors, which led to extensive cosmetic cracking in stairwell walls. Issues with power described in Section 3.4 also caused the emergency lights in some staircases to fail. Vertical egress was further impaired by damage to elevators. All elevators are traction elevators, except for one hydraulic elevator in the kitchen. Most elevators were out of function for a couple of hours because of activated seismic switches that force them to lock out in the event of an earthquake. The damage to these critical means of egress complicated regular hospital function immediately following the earthquake; however, hospital personnel continued to provide healthcare services and move patients through whatever means necessary, including carrying patients through darkened stairwells with the use of torches.

The majority of all pumps and chillers in rooftop plant rooms jumped off their mounts due to strong shaking, even though the snubbers themselves were not damaged. They were on seismic mounts according to NZ standards, NZS 4219:2009 (SNZ 2009). NZS 4219:2009 provides design guidelines for better seismic performance of engineering systems, requiring that all the proprietary components manufactured in New Zealand or overseas need to be verified for the performance level required (i.e. to be operational under serviceability level earthquake for hospital buildings) (Clause 2.4, SNZ 2009). In the CWH chillers moved around and piping for the condenser collapsed.

The most functionally significant non-structural damage was to internal and external roof coverings and roof top water tanks in the Riverside Building. The consequent ingress of water into the top two (5<sup>th</sup> and 6<sup>th</sup>) floors of this building caused the immediate evacuation of five adult medical wards, with about 30 patients each. There are no horizontal evacuation routes from these wards, so vertical egress was required. As was previously mentioned, the emergency lighting in the stairwells was not functional, so this patient evacuation took about 35 minutes to complete with flashlights. This was the only permanent loss of capacity at Christchurch Hospital

### **3.3 Loss of Internal and External Services and Damage to Back-up Systems**

During the 22<sup>nd</sup> February earthquake, all of the Municipal utility lifelines were damaged to varying degrees (Table 2). The main wastewater, water, and power distribution networks were completely off line (Giovinazzi et al. 2011). Additionally, the hospital suction and back-up power systems experienced partial to complete loss of function for a short period of time.

Loss of power was one of the most major obstacles to the functionality of hospital services. Both the Parkside and Riverside Buildings lost power for one and a half hours. The hospital had back-up generators with 1.5 Megawatt capacity and one and a half days of fuel stock that were regularly tested. However, some of these generators malfunctioned or were damaged, which effected the immediate functionality of the emergency power supply system. For example, the oil pressure gauge on the Riverside generator broke during the earthquake, which caused that generator to shut down immediately after turning on. The Parkside generators initially ran for a couple of hours, but stopped working because of clogged filters due to sediment in the tanks that had been disturbed by the ground shaking. The filters were replaced, but there some difficulty priming the fuel pumps. This was eventually corrected by syphoning fuel from a groundskeeper's car to prime the pumps. In addition, shortages to the main low-voltage switchboard caused small fires, damaging the main electrical panel and further complicating the power restoration efforts.

Damage to water and sewage systems, including fire sprinkler systems, also proved a major obstacle. Broken sewage pipes had to be replaced. Main water was out completely for a couple of days, and full water pressure was not restored for a week. The hospital had back-up water supplies (<1 day's worth), and access to artesian wells, but these did not prove entirely sufficient. Some water could be successfully extracted from the boreholes immediately after the earthquake, but the silt content in that water was initially too high, which caused issues in moving the water from the ground to the storage tanks. Even when this issue was resolved, the water from the borehole could not be used for drinking. The lack of water impaired other systems as well, including the fire sprinklers, which could not be pressurized. Fortunately, there were no major fires after the event. To prevent this situation from occurring in any future disasters, a ½ million-litre capacity tank system was installed to provide emergency water for crucial systems, including the fire sprinklers.

Suction in the Riverside building was also damaged, but was quickly restored by connecting the Riverside suction systems to the Parkside suction systems via a bypass in CWH. The ventilation system is highly important in maintaining an appropriate pressure gradient in different areas of the hospital. In infection-controlled areas, malfunction of this ventilation system could create a risk of infection to patients and staff (FEMA 2007). The ductwork was un-operational for 30 minutes following the earthquake. Suction was regained by joining Parkside to Riverside buildings via the CWH bypass.

### **3.3 Impact on Hospital Functionality and Residual Capacity of Health Care Delivery**

The day of the earthquake, 22nd February 2011, Christchurch Hospital admitted and dealt with 160 casualties. The triage after the quake was set up in the parking lot in front of the Emergency Department.

There were no deaths related to the 22nd February Earthquake in Christchurch hospital patients or staff, though four staff members were injured during the evacuation of some of the hospital wards. Evacuations of sick or injured patients are potentially dangerous events under any circumstances, but particularly are risky when moving a large group of patients with limited personnel, no power, and no elevators. Due to water damage from leaking roof tanks, the top two floors of Riverside Building, including five adult medical wards, were evacuated immediately after the earthquake. The darkness of the stairwells and the unavailability of elevators made evacuation very difficult. Most patients were able to walk down on their own, but some had to be carried down five to six flights of stairs in the dark. Many patients and some staff self-evacuated after the event to areas perceived as safer locations outside the buildings. The third floor of Riverside Building was evacuated in a subsequent phase. All evacuations after the initial Riverside evacuation were simply horizontal movement. These evacuations were triggered by failures of suspended ceilings, the lack of functionality of fire sprinkler system, and the lack of sufficient pressure in the back up water system. The charted oncology unit was also moved to Christchurch's Women Hospital. A total of 350 patients were evacuated from the hospital overall. The Oxford Clinic, a general practice located down the road, evacuated to Christchurch Hospital.

Supplies and non-clinical services were mostly undamaged. The kitchen maintained its functionality, guarantying the provision of food. However, the laundry was shipped out for two days because of short-staffing and lack of water; half of the laundry was handled by Timaru Hospital during this time. Drinking water was provided in bottles brought by a private company. The pharmacy did not run out of pharmaceuticals, blood products, dressings, splints, surgical supplies, or other any other treatment supplies. Similarly, there was no loss or shortage of lab supplies, radiological supplies, or other diagnostic supplies. Two off-site laboratories used by the hospital, one of which was located in the CBD, were shut down, but the onsite laboratory remained functional. All the shelves containing the records tipped over.

The hospital never closed completely. The adult wards on the 5th and 6th floor of Riverside were the only closures during the quake, making 106 adult medical beds unusable (or a 16% loss in capacity) One child assessment unit had to be temporarily repurposed to treat adults. Twelve ICU patients were evacuated to other ICUs in the North Dunedin, Nelson and the North Island.

Christchurch hospital stopped all elective surgery and outpatient services immediately after the emergency in order to surge capacity. This decision greatly reduced the number of patients in the clinical buildings. There were approximately 320 inpatients in the hospital after 24 hours, 270 after 72 hours, and 400 after 7 days

Nuclear medicine and clinical engineering were undamaged, but had staffing problems. The Dialysis Centre closed for repairs after the earthquake, though it moved and reopened elsewhere. Outpatient services were lost for one day after the quake, and reduced for the next two weeks. Rehabilitation, and physical therapy were also lost for the first day and partially down for a week.

The evacuation of adult wards in the Riverside building top two floors (5<sup>th</sup> and 6<sup>th</sup>) and transfer to Princess Margaret Hospital, to date has been the only permanent loss of capacity at Christchurch Hospital. Due to the lack of horizontal egress and the presence of only a single stairwell, the decision was made to permanently change the use of those floors from clinical wards to administrative space. The loss of those Riverside wards means that 106 beds were lost, which is 16 per cent of the hospital's normal capacity. About 70 beds at Princess Margaret Hospital (PMH) and another 10 beds at Ashburton Hospital were created for long-term care to compensate for the loss. Initiatives like Community Rehabilitation, Enablement and Support Teams, CREST, have been used to reduce the pressure on Christchurch Hospital; the initiative caters to some 240 clients a day. The CDHB predicted a shortfall of 740 elective surgery cases for the year, down 5 per cent on the annual target. About 500 elective surgeries such as hip replacements were contracted out to the private hospitals Southern Cross and St Georges (The Press 2011).

#### **4. FUNCTIONAL IMPACT OF THE 22<sup>ND</sup> FEBRUARY 2011 CHRISTCHURCH EARTHQUAKE ON THE CANTERBURY REGION HEALTH-CARE SYSTEM**

The February Canterbury earthquake widely impacted the all aspects of the health care system. The health system has had to utilize the entire health network, often relying on previously un-connected

organisations in order to cope with demand. Patients from Christchurch Hospital were transferred to Timaru Hospital 163 kilometres away, and an in-patient ward was opened at Princess Margaret Hospital which usually provides long term care for the elderly. The Canterbury District Health Board (CDHB) coordinated health and medical support across the city, cancelling elective surgery and outpatients, and evacuating existing patients from hospitals to other centres to increase capacity in expectation of a mass causality event. The CDHB also managed primary care facilities (pharmacies and general practice) and organised evacuations from damaged aged care and disabled care facilities to other NZ centres.

The medical response was supported by clinical staff from around New Zealand. Public Health issues such as contamination and infection control were also managed by the CDHB. A 75 bed Australian field hospital was set up in the eastern suburbs two days after the earthquake. Australia provided counsellors and a disaster medical assistance team comprised of 23 emergency and surgical personnel. It was equipped to provide triage, emergency care, maternity, dentistry and isolation tents, and also primary care services since most general practices in the area were unable to open (Dick 2011).

Both Canterbury and med labs were badly damaged following the earthquakes

**Table 2. Number of Days services Lost or Reduced, Canterbury Province, New Zealand, 2011**

|                             | Christchurch Hospital | PMH Hospital | St George's Hospital | Kaikoura Hospital | Akaroa Hospital | Ellesmere Hospital |
|-----------------------------|-----------------------|--------------|----------------------|-------------------|-----------------|--------------------|
| <b># beds before EQ</b>     |                       |              |                      |                   |                 |                    |
| <b>Inpatient Services</b>   |                       |              |                      |                   |                 |                    |
| Inpatient wards             | 14 d                  | -            | 14 d                 | Normal            | Normal          | Normal             |
| Surgical                    | 14 d                  | NA           | 30 d                 | NA                | NA              | NA                 |
| Obstetrics- gynaecology     | 14 d                  | NA           | 30 d                 | Normal            | Normal          | NA                 |
| Pediatric                   | 14 d                  | NA           | NA                   | NA                | NA              | NA                 |
| Psychiatric                 | -                     | Normal       | NA                   | NA                | NA              | NA                 |
| Dialysis                    | -                     | NA           | NA                   | NA                | NA              | NA                 |
| <b>Outpatient Services</b>  |                       |              |                      |                   |                 |                    |
| Emergency department        | Normal                | -            | NA                   | NA                | Normal          | NA                 |
| Outpatient clinics          | 2d                    | 14 d         | NA                   | NA                | Normal          | NA                 |
| Psychiatry                  | -                     | NA           | NA                   | NA                | NA              | NA                 |
| Rehabilitation              | 7d                    | NA           | NA                   | NA                | -               | NA                 |
| <b>Support services</b>     |                       |              |                      |                   |                 |                    |
| Plain radiographs           | normal                |              | 30 d                 | Normal            | CHCH            | NA                 |
| Computed tomography         | 11 hr                 | NA           | 14 d                 | NA                | CHCH            | NA                 |
| Ultrasound                  | Normal                | NA           | 7 d                  | NA                | -               | NA                 |
| Laboratory                  | Normal                | Normal       | Normal               | Normal            | CHCH            | NA                 |
| Blood bank                  | Normal                | 1 d          |                      | Normal            | 3 d             | NA                 |
| <b>Nonclinical services</b> |                       |              |                      |                   |                 |                    |
| Administration              | Normal                | Normal       | Reduced              | Normal            | Normal          | Normal             |
| Medical records             | Normal                | Normal       | Normal               | Normal            | Normal          | Normal             |
| Food Preparation            | Normal                | 3 d          | Off site             | Normal            | Normal          | Normal             |
| Laundry Services            | 2 d                   | 7 d          | Off site             | Normal            | Did own         | Normal             |

**Table 3. Summary of Services Loss by Hospital**

|                          | Christchurch Hospital | PMH Hospital | St George's Hospital | Kaikoura Hospital | Akaroa Hospital | Ellesmere Hospital |
|--------------------------|-----------------------|--------------|----------------------|-------------------|-----------------|--------------------|
| <b>External Services</b> |                       |              |                      |                   |                 |                    |
| Electricity              | Y                     | Y (4hr)      | Y                    | N                 | Y (1dy)         | N                  |
| Backup electric          | Y (1.5hr)             | N            | N (4dy)              | N                 | N               | N                  |
| Water                    | Y (1wk)               | Y (12hr)     | Y (14dy)             | N                 | Y (3dy)         | N                  |
| Sewer                    | N                     | Y (2wk)      | Y (3dy)              | N                 | N               | N                  |
| Telephones               | Y (20min)             | Y (6hr)      | Y                    | N                 | Y (1dy)         | N                  |
| <b>Internal Services</b> |                       |              |                      |                   |                 |                    |
| Computers                | N                     | N            | N                    | N                 | N               | N                  |
| Medical gases            | N                     | N            | Y (4dy)              | N                 | N               | N                  |
| Suction                  | Y (30min)             | N            | Y (3dy)              | N                 | NA              | NA                 |
| Total Services lost      | 4                     | 4            | 4                    | 0                 | 3               | 0                  |

#### 4.1 Princess Margaret Hospital

The hospital is a 149 bed geriatric facility that focuses on out-patient and long term care. It does not provide surgical, intensive care or emergency services. The Hospital lost water main water completely



for 12 hours and did not regain full water pressure for a week. Sewage systems were damaged, and may have been inoperable for as long as two weeks. Separation joints in the hospital experienced some damage, and most walls sustained plaster damage. The buildings of PMH are concrete with brick veneer. That brick veneer had vertical, diagonal, and horizontal cracking, generally ranging from 1-4 mm. There were, however, no structural failures to the concrete structure. Water and sewage pipes for this hospital were damaged and diffusers popped out. There was minimal impact on its services and no patients were injured or killed as a result of the earthquake.

It did provide unique and important in- and out-patient services after the event. Injured, ill and peripartum people from the nearby community came even though there is no emergency department. As a result the staff quickly established a triage area to screen and treat these patients. The first crush victim arrived within 20 minutes, but they also treated a patient with a myocardial infarction and another in active labor. The triage center was open for 24 hours a day for a total of 72 hours after the event. Two patients were admitted to Princess Margaret and many were transferred to other hospitals, including Christchurch for definitive care.

Less than 12 hours after the earthquake (shortly after midnight), 14 patients from Christchurch hospital were transferred in on a furniture truck. That same morning around 9:30 a rest home closed and sent 33 residents to Princess Margaret even though there were no beds. By day three, the hospital opened a new ward by turning an area that was previously offices into bed space. Patients from the welfare center and Christchurch went there. By the end of the first week, they had 30 extra beds occupied in the hospital. There was a very high turnover, since rest-home patients were sent to other rest-homes within 24-48 hours. Additional nursing staff from Christchurch Hospital came to care for the new in-patients on the fifth day.

#### **4.2. St. George Hospital**

St George hospital is a private specialty surgery hospital providing multiple different surgical procedures and OB/GYN services. The hospital has 101 beds with 80 adult surgical beds and 21 obstetric and also has 23 post-anesthesia care unit (PACU) beds. It was the only hospital in the area with sufficient damage to close after the earthquake. Because all the services provided by the hospital were elective they were able to close the entire facility 4 days after the earthquake for a total of 12 days. The Hospital was closed completely due to structural damage to the maternity ward (permanently closed awaiting demolition) and liquefaction damage to the Cancer Centre and widespread non-structural damage to walls.

#### **4.3. Southern Cross Hospital**

Southern Cross hospital is a private surgical hospital with 87 beds and provides multiple different surgical procedures to 9,500 patients annually. Immediately after the earthquake, the hospital facilities were used as an acute triage centre. Southern Cross staff performed surgical assessments and, in some cases, emergency surgery for those injured, while also continuing to care for existing patients in the hospital. Elective surgery at the facility was not resumed until more than 2 weeks later, mostly due to the disruptions in water and sewer services.

#### **4.4. Canterbury District Hospitals**

There are eight rural hospitals located across Canterbury, with Ashburton Hospital being the largest and central point for the other smaller hospitals. Ashburton Hospital is located an hour from Christchurch and has 74 beds and 5000 annual admissions, cares for 2600 day patients and 15,000 out-patient clinic visits. There are 1500 operative procedures each year on a day and short stay basis. Ashburton services include Inpatient and Outpatient as well as radiology, laboratory, and physical, occupational and speech therapy. General Surgery and Gynaecology are available for referred Day Surgical Procedures. The remainder of the hospitals are very small, with limited in-patient beds and often offering convalescence care from procedures or deliveries at Christchurch Hospital.

Akaroa Hospital has a total of 7 beds (5 medical and 2 obstetric) with a 1 bed 'emergency department' and no laboratory or radiology services. It serves mostly as a convalescent hospital, they received a total of 7 patients transfers from Christchurch Hospital in the first week after the earthquake. The hospital lost electricity and water but had sufficient backup systems (Table 2). Akaroa experienced only minor non-structural cracking following the February 22<sup>nd</sup> earthquake; however, it was closed down for one week

after the 4<sup>th</sup> September Mw 7.1 earthquake due to damage to the chimneys, which were subsequently removed.

Burwood Hospital is a rehabilitation only facility and does not provide acute or clinical care.

Darfield Hospital has a total of 10 beds and provides in and outpatient primary care and obstetrics/gynaecology services.

Ellesmere Hospital has 6 beds devoted long-term care for the elderly and for convalescence from procedures conducted at Christchurch Hospital. There are no outpatient services offered. Their services were not affected by the earthquake and they received 2 transfers from Christchurch during the first week after the event.

Kaikoura Hospital has 26 beds- 6 medical, 3 obstetric and 17 long term care and does not provide outpatient services. They had no damage from the earthquake and received only one patient transfer from Christchurch in the first week.

Oxford Hospital has 15 beds- 4 medical and 11 long term and respite care. It did not lose any services after the earthquake.

Rangiora Hospital is a maternity and convalescent facility north of Christchurch. It did not lose any services after the earthquake.

Waikari Hospital has 10 beds- 8 convalescent and 2 maternity outside of Christchurch. It did not lose any services after the earthquake.

## 5. CONCLUSION

The damage that impacted the Christchurch Hospital following the 22<sup>nd</sup> February Earthquake included minor structural damage to both clinical and support buildings, non-structural damage to ceiling tiles and light fittings, outages of all the city lifelines systems, and damage to internal services and back-up generators. For all the CDHB hospital facilities, the widespread non-structural damage was more disruptive than the minor/moderate structural damage sustained by the buildings. All buildings had been built or retrofitted to comply with the requirement of NZ Seismic Design Standards (SNZ 2004). In Christchurch Hospital, non-structural damage to suspended ceilings, light fittings, and water piping forced wards to be evacuated during the emergency phase and to remain closed in the longer-term, as well as requiring lengthily disruptive repairs to be carried out in the following months. The loss of water, sewage, power, caused disruption to the hospital's functionality and to the delivery of health care in the days and weeks following the earthquake. Hospital planning activities should focus on identifying non-structural and functional vulnerabilities within all critical service areas and mitigating their possible impact with engineering interventions, redundancy systems or alternative resources.

Considerations on the physical impact on the other hospital of the system...regional response, regional surge capacity

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