The seismic impact on chemistry teaching and research at University of Canterbury*

Bryce Williamson and Richard Hartshorn

Department of Chemistry, University of Canterbury, Christchurch, New Zealand

(*email: bryce.williamson@canterbury.ac.nz, richard.hartshorn@canterbury.ac.nz*)

Owing to its location at the boundary of the Pacific and Australian tectonic plates, New Zealand is regularly jolted by earthquakes. The strongest since scientific records began was in the Wairarapa region in 1855, and is estimated to have been of a magnitude between 8.1 and 8.3 on the Richter (M_W) scale (Grapes, 2000). Every one to three years there is a quake of magnitude greater than 7, but generally these have caused little in the way of damage to society or loss of life,[#] largely because of the fortuitous location of epicentres away from major population centres and (more recently) informed and conscientiously implemented design and construction standards.

New Zealanders live with prospect of "The Big One," a once-every-few-hundred-years $M_W > 8$ rupture of the system of major fault lines that is associated with the plate boundary and which runs along the west of the South Island and through the southern part of the North Island. The Wellington area was widely considered to be the most likely location of "The Big One" (Grapes, 2011). The closest approach of this fault system to Christchurch is the Alpine Fault, about 130 km west of Christchurch, so the city was generally not regarded as being particularly affected by earthquakes. Indeed, GNS data confirm that its locale has been seismically rather quiescent in comparison with other parts of the New Zealand.

When the population of Christchurch and surrounding districts was awoken by violent shaking at 4.35 am on the morning of Saturday 4 September, thoughts naturally turned to 'The Big One' and to: "if it's this bad here, it must be devastating at the epicentre." We soon learnt that it was "only" a magnitude 7.1 event. However, it was shallow (focal depth 10 km) and close to the city, involving a previously undetected fault with an epicentre just 40 km to the west of Christchurch. Remarkably, and perhaps uniquely for such a strong shock in a moderately populated area, there were no deaths and only

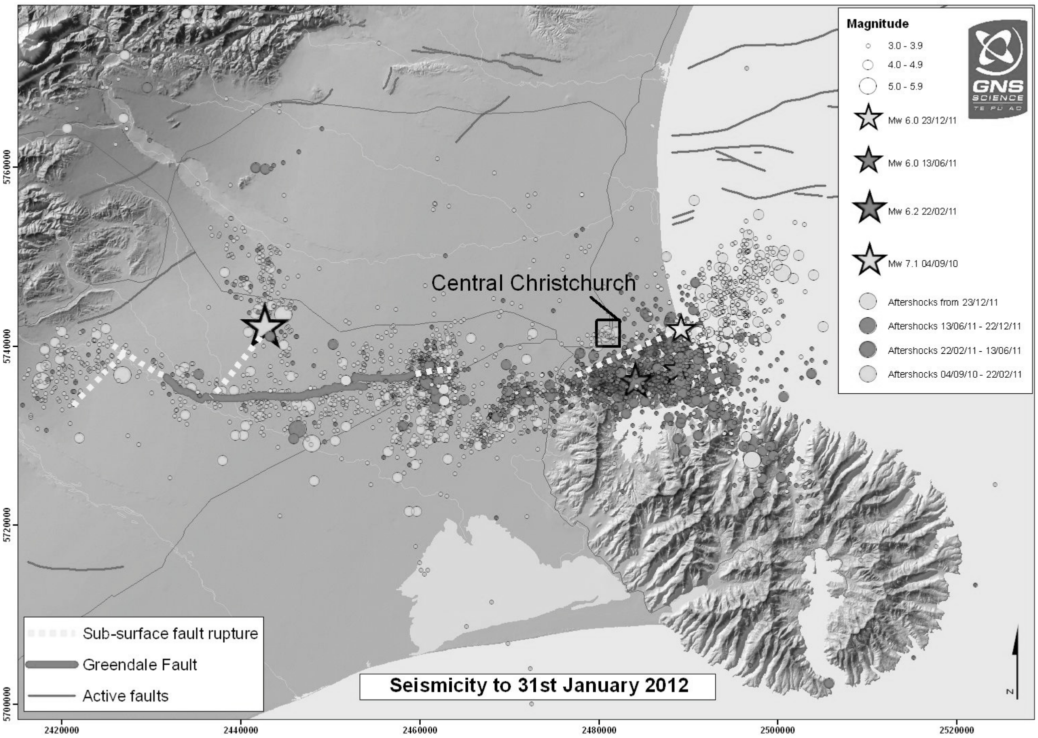

***Fig. 1:** Seismicity of the area around Christchurch city since the initial magnitude 7.1 earthquake on 4 September 2010. Since then the aftershock sequences resulting from earthquakes on 22 February, 13 June and 22 December 2012 have migrated in an easterly direction. (Image from: http://www.geonet.org.nz/var/storage/images/media/images/news/2012/chch_seismicity_31_01_2012/59313-1-eng-GB/Chch_Seismicity_31_01_2012.jpg)*

[*] Modified and updated from an article that appeared in *Flashpoint (Journal of the NZ Institute of Hazardous Substances Management)*, Spring 2010, pp 4-7. (www.nzihsm.org.nz).

[#] An exception was the magnitude-7.8 Hawke's Bay earthquake on 3 February 1931, which caused 256 deaths and thousands of injuries (Ansell & Taber, 1996, p. 84).

a couple of major injuries – again a testament to a combination of good luck (regarding the time of the quake) and generally good building standards.

Since that day, there have been more than 10,000 aftershocks, many of them of a magnitude 5 or greater, including the deadly magnitude-6.3 aftershock of February 22 (Fig. 1). The 185 deaths and the devastation of the city centre from that aftershock shows that proximity and shallowness of an earthquake can be much more significant than its magnitude. The effect of multiple significant earthquakes on the strength and structural integrity of buildings and other structures is the subject of much current debate, but it undoubtedly was a contributing factor to the death toll on February 22. Many residents have suffered trauma through loss of loved ones, homes and occupations, but we can be genuinely thankful that our situation is vastly better than those resulting from events of similar magnitude in other parts of the world.

Fig. 2: *Superficial mess in an upper-floor office.*

After the initial quake, and having established that family and neighbours were "shaken" but unhurt, our thoughts turned to the University of Canterbury and particularly to the Department of Chemistry. This is certainly the first time that a New Zealand university has been subjected to anywhere near the shaking that Canterbury and Lincoln universities experienced that morning. In retrospect, we have learnt many lessons, and it is the objective of this article to share some of those lessons with the wider scientific and educational communities.

With electricity and water off, and electronic security systems defeated, the University of Canterbury campus was almost immediately closed down and the emergency management plan was activated. The university's Emergency Response Team was on site and functioning within 90 minutes of the event (4.35 am on Saturday morning) and, as qualified staff arrived on campus, an initial assessment of the situation was undertaken and response priorities were identified. By early the next day, engineers had verified the structural soundness of the chemistry building and the Head of Department, Professor Alison Downard, accompanied by Associate Professor Emily Parker, Professor Peter Harland and two members of the University Facilities Management Unit, inspected the department. Their assessment was that there were no particular chemical, biological, fire, explosion or flooding hazards; and their recommendation to the Emergency Response Team was that the department should implement its recovery process. The first step in that process was to ensure that critical equipment (mostly refrigerators and freezers) was connected and switched on to protect valuable samples and minimise hazards when the power was returned to the building. All non-critical equipment was disconnected until electrical testing could be conducted.

Monday 6 September: senior technician Wayne Mackay and one of us (BEW) were given the task of performing a more detailed assessment and formulating a recovery plan. From the fifth floor down (mostly administration and the teaching laboratories) damage was negligible; but it was significant and progressively worse on the three higher floors. Books, computer monitors, pot plants and filing cabinets were strewn around offices (Fig. 2). Damage in the research labs was widespread but apparently superficial, principally involving broken glassware, toppled bench-top instruments and silicone-oil spills. Chemical containment vessels and cabinets appeared to have stood up well, although some had migrated by as much as a few metres across laboratory floors. From a cursory external inspection, there was no glaring evidence of damage to major instruments, although subsequent testing was to reveal significant and irreparable internal damage to a new mass spectrometer, an X-ray diffractometer, and lesser damage to several other instruments.

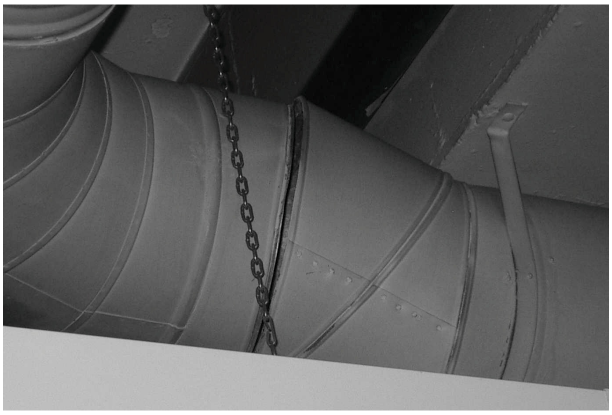

Fig. 3: *Broken fume-hood ducting*

The major part of the recovery process was implemented over the next four days as follows:

Tuesday 7 September: Seven staff members (Wayne Mackay, Laurie Anderson, Alistair Duff, Matt Polson, Rob Stainthorpe, Nick Oliver and Bryce Williamson), with skills in areas ranging from photography to hazard management, worked to identify, document and undertake first-order mitigation of hazards. Our principal aim was to make the department safe for other workers to start their clean-up procedures. Secondary aims were to generate records for insurance purposes (and posterity) and to establish priorities for action over the following days. Most of the work involved photography, picking up equipment and containers, sweeping up broken glassware, and initial efforts at cleaning up oil and chemical spillages. Freezers and refrigerators were sealed, to be dealt with by a more specialised group on the next day.

Wednesday 8 September: In the morning, appropriately skilled technical and academic staff made initial assessments of the condition of major equipment (X-ray diffractometer, NMR and mass spectrometers) prior to contacting manufacturers and service companies. At the same time, a subgroup of the departmental Safety Committee collated and examined inventories of refrigerator, freezer and cold-room contents, in order to identify toxic or particularly reactive substances. During the afternoon this latter group unsealed and inspected most of the refrigerators and freezers, leaving a couple of especially hazardous substances to be dealt with later when breathing apparatus became available. In the event, those materials had been very securely protected and isolated, and presented no actual hazard.

Thursday 9 September: Academic and technical staff were invited in to tidy their offices and workshops, and to inspect their laboratories. A small group of PC-trained research students assisted with the assessment and tidying of the department's PC2 lab and technical staff started the testing and safety certification of electrical equipment. General clean-up procedures continued and by the end of the day the laboratory floors were completely cleared of silicone oil.

Friday 13 September: All staff and research students were permitted back into the department to proceed with cleaning up and damage amelioration, with the proviso that no research was to be undertaken until laboratories had been certified safe by the department's safety officer, Professor Ian Shaw.

By the end of that week, the department was well down the track to recovery. With the assistance of Facilities Management personnel, most of the infrastructure had been restored. Fume hoods were still switched off, awaiting confirmation that ducting was intact, and the restarting of major instruments was stalled while advice was sought from manufacturers and service companies.

We could have resumed undergraduate teaching in the following week, but other sections of the university (particularly the libraries) were taking longer to recover. With the added stress of the on-going aftershocks, it was determined that undergraduates would not be permitted back on to campus until the following Wednesday, with teaching starting on 20 September. By shortening the study break and delaying the start of examinations, only a week of teaching time was lost and the overall effect of the September earthquake on the undergraduate academic programme of the university was surprisingly small. The effect on the postgraduate students and research programmes in the Department of Chemistry was much larger. The damage on the research floors, which are largely sited higher in the building, was greater than in the teaching spaces, and the loss of samples and instrumentation put some students back by months.

So what did we learn from this first major event?

Firstly, owing to numerous incremental earthquake mitigation modifications prior to the event, we were actually very well prepared. Perspex guards mounted around chemical shelving and laboratory bench dividers were extremely effective at preventing chemical containers from spilling on to the floor or bench tops. Storage-shelf lips of as little as 2-cm height seem to have entirely prevented equipment falls, whereas books and papers stored on office shelves with no lips were liberally scattered around offices. Evidently, items on flat surfaces had mostly shuffled laterally during the shake rather than bouncing. Substances in refrigerators and freezers that had been well contained in plastic trays and sealed plastic containers proved to be particularly safe for holding hazardous materials

A few things didn't fare so well. Chains used to fix light fittings to the ceiling and (in a couple of instances) gas cylinders to walls had been shaken off open-loop hooks. Items left on un-lipped bench tops fell to the floor resulting in a lot of broken glassware. The latter problem was exacerbated by the fairly extensive spillage of silicone oil (used as an inert heating-bath medium). The mixed glass and oil was both the greatest hazard and the most difficult to clean up.

Our response plan and actions went well, without resulting in any harm to personnel or additional damage to the building or its contents. The photographs of the affected rooms prior to, and during, cleanup provided comprehensive records for insurance claims and also an opportunity for a post-clean-up departmental slide-show. The stepped progression of activities meant that we could exercise control over access, particularly at the time when some potential hazards had not been specifically identified and aftershocks were at their most numerous. Staff and students were generally very patient about being excluded in the early stages. Perhaps the only real flaw in our arrangements was the difficulty of obtaining a list of contact phone numbers. We had such a list on a university server, but disruptions to the University's infrastructure meant that we could not access that list for the first few days after the September 4 earthquake, the period when we trying to check on people's welfare as well as form task teams and gather information about stored materials.

By February of 2011, the staff and students of the department were earthquake veterans. We had discovered that good housekeeping in relation to instrumentation, equipment, glassware, sample and chemical storage could minimise damage from aftershocks. Indeed, there had been very little damage from the significant aftershocks on Boxing Day, 2010.

February 22 was the second day of the 2011 academic year. Just before 1.00 pm Christchurch was hit by the deadly aftershock. The epicentre was very close to the city and very shallow. The shaking was shorter than in September, only ~20 seconds rather than ~40, but the motion had a much greater vertical component. This vertical motion likely contributed to the collapse of facades and buildings in the city, and critically damaged many of the buildings that had remained standing in the city. Many of those are now being demolished.

At the University of Canterbury, buildings were evacuated without incident and the campus closed once again. Within the Department of Chemistry, the damage was again worse higher in the building, but the improved housekeeping limited problems with glassware and chemicals. A more significant issue was that the building and its fixtures had been hit hard. Fume-hood ducting was damaged (Fig. 3) and, in some laboratories, other fixtures broke away from the ceiling and ended up resting on the sprinkler pipes (Fig. 4). The placement of sprinkler pipes may have been fortuitous, but is something for which the workers in those labs might be grateful. Significant cracking was caused in some beams high in the building (Fig. 5), and the effect on cylinder restraints (Fig.6) is both remarkable and sobering. The scratches made by the chain on the cylinder show the intensity of the vertical motion, and the effect on the attachment of the hook to the wall should cause others to reassess the nature of their cylinder restraints and the integrity of the structures to which the hooks are attached. Once again, our instruments suffered. One NMR spectrometer did not survive the earthquake, while the X-ray diffractometer and a replacement mass spectrometer were damaged.

Fig. 4: *Ceiling mounted services broke free and finished up resting on sprinkler pipe-work.*

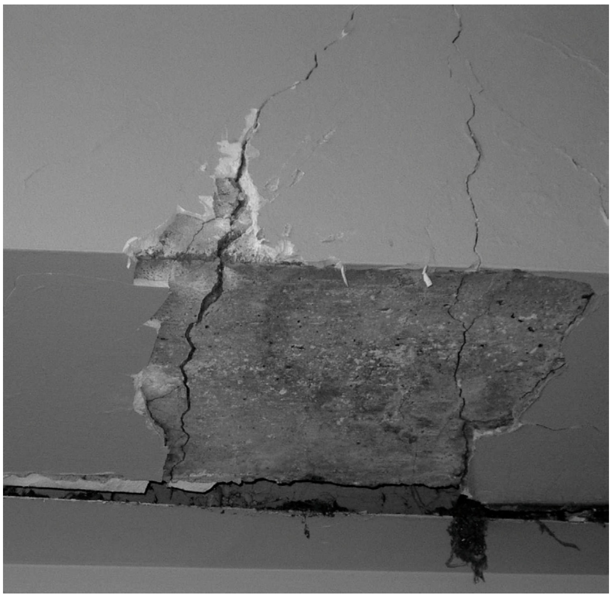

Fig. 5: *Cracked beam on Level 8 of the Rutherford Building.*

Fig. 6: *Damage to cylinder mounting. This cylinder did not topple, but in other cases hooks were snapped off or straightened and the cylinders fell to the floor.*

Following declaration of the Civil Defence emergency, and in light of problems with water and sewage infrastructure in the city, the University was clearly to be closed for longer than in September. Ultimately, the semester break was brought forward and field trips that would normally have been conducted in that break were 'front-ended' in their courses. Courses were converted to on-line formats, with limited face-to-face time being available in marquees and smaller teaching spaces in buildings that had received structural clearance. These measures allowed time for ceiling tiles in large lecture theatres to be replaced with light-weight types and for complete structural checks on large buildings to be initiated. It was nearly three months before the Department of Chemistry could be reoccupied. Laboratory classes were cancelled or postponed, with online packages such as BestChoice (Woodgate, 2012) being used to supplement teaching and support learning. Teaching in tents continued until Easter, the semester was extended by a week, and the examination period was compressed. All examinations were shortened to two hours, so that three examination slots were available each day.

The extension of the teaching semester meant that the aftershocks of June 13 (fortunately) fell in the study week rather than on the first day of examinations. The university was again closed, this time for a week. The lack of access to libraries and study spaces, together with major disruption of the city, so close to examinations meant that all students were allowed to apply for special consideration. Ultimately, about two-thirds of them did so, but most did just as well in their examinations as they had done in other assessments.

While undergraduate teaching could be resumed after the 2011 earthquakes, admittedly in less than ideal circumstances, research programmes were once again severely affected by the series of aftershocks and the long period of the building closure. Laboratories and instruments were inaccessible and there were clearly severe limitations on what could be achieved without such facilities. A significant number of research students relocated to other universities in New Zealand and overseas. We are very grateful to those who hosted our students, to those who made offers of support that were not taken up, and to those who made contact with us in the immediate aftermath of the earthquakes. It was a significant consolation to know that so many of you were thinking of us.

We owe a great deal to the University's Emergency Response Team and Facilities Management personnel. The overall emergency preparedness of the university was tested to a degree far beyond anything else in its history and shown to be well up to scratch. A strong co-operative relationship between the pan-campus controlling body and the departmental response teams greatly facilitated our efforts. Information and assistance was provided promptly, as and when we needed it without unnecessary bureaucratic overheads. At the departmental level we are indebted to members of the technical staff who implemented the invaluable pre-quake mitigation measures and carried out the majority of the post-quake clean-up workload. These people put aside their personal concerns and anxieties at a time when magnitude-5 aftershocks were still a regular occurrence.

In light of our experience, what would be our recommendations to other similar departments? Here is a list of things that come to mind.

1. For items (such as gas cylinders) secured by chains, closed-loop chain-hooks should be used with attachment by way of karabiner-like shackles. Open-loop hooks permit the risk that the chain will jump free during shaking. Adding a second chain at a lower height should be considered, and the strength of the structures to which the hooks are attached should be carefully assessed.
2. Guards (for example Perspex or wire) should be affixed to any shelves or sills where loose items (sample vials, chemical jars, desiccators etc.) are likely to be stored This includes the tops of cabinets, refrigerators, ovens and any other places that are likely to provide tempting places for storage.
3. Low lips should be considered for the edges of research-laboratory benches to limit the possibility of items rolling off the bench on to the floor. Bench-top instruments (chromatographs, ovens, spectrometers etc.) should be fixed to the bench and stacks of such items should be strapped down (Fig. 7).

Fig. 7: Unsecured stacks of bench-top equipment are prone to toppling.

4. Spilt silicone oil is very problematic (Fig. 8, Fig. 9). Where appropriate, alternatives to oil-bath heating should be used. If oil-bath heaters are required, splash-proof baths should be employed (we need a design) and the oil should be returned to a sealed container when not in use.

***Fig. 8**: Sub-optimal storage of silicone-oil baths (top) and desiccators on unguarded sills. Fortunately, these items had not fallen, but silicone oil had splashed down the wall on to the floor.*

***Fig. 9**: Spilt silicone oil presented a major slip hazard and was very difficult to clean up.*

5. Items and substances stored in freezers, refrigerators and cold rooms should be contained in (preferably sealed) plastic boxes or trays. Refrigerators and freezers should carry physical identification information that clearly specifies any hazardous substances they contain and the person who should be contacted in case of an adverse event. Glass-fronted refrigerators offer the clear benefit of allowing potential hazards to be seen before opening the cabinet.

6. Wheeled storage cabinets had migrated by as much as a few metres (Fig. 10). We wonder whether such cabinets should be fitted with wheel locks. However, it is possible the motion of the cabinet as a whole dampens the risk of items toppling within the cabinet. This is a question that could do with investigation.

7. Half-sized filing cabinets should not be stacked on top of each other (Fig. 11). Filing-cabinet drawers should be closed with the key in the locked position to prevent drawers from shaking open and overbalancing the cabinet. Cabinets and bookcases should be fixed to walls.

***Fig. 10**: Wheeled storage cabinets in research laboratories had migrated by as much as several metres. All of the cabinets in this photo had originally been under fumehoods or benches*

***Fig. 11**: A consequence of stacked filing cabinets. Toppled cabinets would have presented a significant threat to personnel if offices had been occupied during the September earthquake.*

8. Several specified members of staff should carry a full list of contact phone numbers in a cell phone directory. All staff in the department should know who carries those directories and how to contact them.

9. The department should have a generic emergency response plan that can be readily adapted to any adverse event. The people and teams assigned to tackle each type of predictable task should be known by all staff.

10. In case of a power outage, an accessible list should be available as to which instruments should re-

main switched off or be urgently restarted when power is returned.

References

Ansell, R., & Taber, J. (1996). *Caught in the crunch – Earthquakes and volcanoes in New Zealand*. Auckland: HarperCollins.

Grapes, R. (2000). *Magnitude eight plus – New Zealand's biggest earthquake*. Wellington: Victoria University Press.

Grapes, R. (2011). *The visitation: The earthquakes of 1848 and the destruction of Wellington.* Wellington: Victoria University Press.

Woodgate, S.D. (2012), BestChoice, *http://bestchoice.net.nz*, University of Auckland