MANAGING RAIL RESOURCES & INFRASTRUCTURE TO RESTORE AND MAINTAIN OPERATIONS IN THE AFTERMATH OF MAJOR EARTHQUAKES

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SUMMARY

The Canterbury region has been struck recently by a number of significant earthquakes. On 4 September 2010 a 7.1M event was followed by a 6.3M event on 22 February and two earthquakes of 5.6M and 6.3M on 13 June 2011. In addition to these major events there have been in excess of seven thousand[i] aftershocks. These have caused additional damage and required ongoing work to assess the condition of buildings and infrastructure and to maintain business operations. The ongoing series of earthquakes have presented challenges to KiwiRail in maintaining our services and activities.

These events have been the most damaging earthquakes ever recorded in New Zealand and have been of international scientific interest for their severe shaking characteristics. The death toll of the February event was the greatest in NZ since the 1931 Napier earthquake. For Christchurch, and the railway, the particular significance was that there had only been 3 moderate earthquakes in this region in the previous 40 years and the earth movement plus structural damage was at a level well beyond any earlier assessment of risk and consequences.

Rail transport plays a significant part in the economy of the Canterbury region with an operational scope covering tourist passenger, intermodal, FMCG line haul and bulk freight operations. The area is geographically challenged for infrastructure with significant bridges crossing braided rivers to the north and south of Christchurch and mountainous terrain to the west.

To ensure business improvement was achieved the Railway needed to examine the impact of the earthquakes on rail infrastructure and operations. Critical components of this review included business responses, infrastructure management, emergency liaison arrangements, recovery plans, and the fundamental importance of people management in our recovery process.

First proposed after the Canterbury earthquake of 4 September 2010 there have been more major earthquakes that affected Christchurch and the Canterbury area. This paper aims to cover KiwiRail's experiences for all three major events which have allowed us to develop and refine our operational procedures for earthquake management and business continuity response.

INTRODUCTION

NZ has a long history of seismic activity. Since European settlement commenced, there have been more than 30 major earthquakes and a number of these have caused significant damage and fatalities, notably the Wairarapa Earthquake of 1855 and the Hawkes Bay earthquake of 1931. As of the start of 2010, the last fatality had been in 1968, and Canterbury had not experienced an earthquake of any significance since 1946.

KiwiRail's procedures for assessing risks after an earthquake and responding have been tested repeatedly through the sequence of Canterbury earthquakes over the past year and we have developed modified local response procedures as a result of this. This paper describes our learnings relating to earthquake response from the events in Canterbury since September 2010.

After the September event there was a risk review for service resumption which considered inspection requirements and limitations for train operation. The large number of small and moderate aftershocks as well as the major events listed above allowed these procedures to be tested repeatedly and these were adjusted on the basis of this experience.

EARTHQUAKES AND DAMAGE

Earthquakes and earthquake damage are quantified by specifying magnitude and/or intensity. Magnitude is a measure of earthquake size based on the amplitude of seismic waves recorded instrumentally and is a characteristic of the earthquake at its source. Magnitude is stated as a decimal, typically to the nearest tenth.

Intensity is a measure of the intensity of ground shaking at a particular location, determined according to criteria based on observations involving varying degrees of subjectivity. Several intensity scales have been formulated. In general the lower intensities are based on perceptions of ground motion and the higher intensities on the extent of damage. Intensities for an earthquake usually decrease, with increasing distance, from a maximum near the source to the minimum value in the scale.

SEISMIC ACTIVITY AND RAIL IN NEW ZEALAND

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Canterbury experienced moderate earthquakes in 1869, 1870, 1881, 1888, 1901, 1922, 1929 and 1946. These earthquakes were either sufficiently small, or sufficiently far away from the Canterbury plains that little damage was caused.

Beginning with the first rail developments New Zealand railway organisations have had to deal with earthquakes as a risk issue. In managing natural hazards and their risks railway procedures considered earthquakes only as one of a range of potential causes of line damage up to the end of the 20th Century. Over this period we responded to a number of significant earthquake events, the most notable of which was the 1931 Hawkes Bay earthquake which damaged the track up to 80 km from the epicentre. After this earthquake, repairs were completed to allow restricted running within two days, which enabled rail to play a significant role in evacuation and supply for the Hawkes Bay region subsequent to this event.

The Inangahua Earthquake of 1968 and the Edgecumbe earthquake of 1987 both delivered shaking that was severe enough to derail and overturn rolling stock.

Figure 1: Inangahua Earthquake, 1968

Figure 2: Edgecumbe Earthquake, 1987

KIWIRAIL NETWORK'S EARTHQUAKE RESPONSE PROCEDURES

From 2001, KiwiRail's Infrastructure Maintenance Handbook has included guidelines for actions after earthquakes. These are based on the Modified Mercalli (MM) Earthquake Intensity Scale, which measures the level of shaking experienced and relates this to visible damage and perceived movements in any location. This provides a better measurement of earthquake intensity for managing our network than the Richter Scale which measures the energy released by an earthquake.

Where an earthquake is shallow, the intensity of shaking near the epicentre will be greater than for a deep earthquake and the MM intensity will be higher. An additional influence which is captured by the MM intensity is the effect of the earthquake shaking on the soils in any area, which can increase or reduce the felt shaking for any set Richter level.

This difference between Richter and MM scales is well demonstrated by recent events. The February Christchurch event was 6.3 on the Richter scale with up to 9 on the shaking intensity scale, while the 2011

Tohoku Japan earthquake, was 9 on the Richter scale but being offshore, land based shaking intensity was up to 7 on the seismic intensity scale.

The KiwiRail Infrastructure Handbook provides information to allow rail network personnel to use their judgement to work out what inspections should be undertaken after an earthquake.

KiwiRail receives notification of earthquakes by email, text message and fax from GNS Science, the Crown Research Institute responsible for seismic monitoring. These notifications advise the Richter magnitude and the faxed information provides a map showing an assessment of areas of differing shaking intensity generated by the earthquake and are usually received within a few minutes of an earthquake. Rail personnel will also advise of an earthquake by phone to Train Control so that the GNS Science information is used to define the affected area and plan response activities.

Where the shaking intensity is advised as 6 or higher, the following standard procedures are followed:

A Notification of Earthquakes is provided by GNS as follows:

- By text message to the Operations Support mobile phone
- By text message to the Network Control Manager's mobile phone
- By text message to the Manager Network Operations and Network Support Manager
- By email to the Network Control Manager

The notification text message will contain a "MM Intensity Scale" measure. This is a measure of geological severity and is the information required to inform the action of Infrastructure Staff. Note: The "MM Intensity Scale" is not provided by email.

A sample text message format is (Note the MM Intensity is shown in bold red):

"Re: Eq Rpt: MAG 3.3, MM6, FD 7, LOC 40km NE of Gisborne, TIME 03:53 AM, 25/01/2010"

Immediately upon receipt of an earthquake notification where the "MM" scale is 6, or the felt intensity is consistent with MM 6:

- Operations Support must advise Train Control and the Area Manager.
- The Area Manager shall advise Train Control what action is to be taken if any.
- The Network Control Manager must contact Train Control to confirm Train Control's receipt of the alert and actions being taken.

Immediately upon receipt of an earthquake notification where the "MM" scale is 7 or greater, or the felt intensity is consistent with MM 7 or greater:

- Operations Support must advise Train Control, and
- Train Control must stop all trains in the surrounding area (at least a 150 km minimum radius of earthquake centre), and
- Operations Support must advise the Area Manager.
- The Area Manager shall advise Train Control what action is to be taken if any. This may include resumption of services, adverse weather speed restriction, or track inspection.
- The Network Control Manager must contact Train Control to confirm Train Control's receipt of the alert and actions being taken.
- The Manager Network Operations must contact the Network Control Manager to confirm Train Control's receipt of the alert and actions being taken.

CANTERBURY'S RAILWAY NETWORK

The Canterbury region has approximately 600 km of rail. With the operational terminal in western Christchurch acting as a centre hub, lines extend in three directions to the north, south and east. Northward the railway connects to Picton and the Interisland rail ferry operations providing a continuous rail link with the North Island. To the south the railway extends to Bluff, the southern-most port in New Zealand. At Rolleston, 18 kilometres to the south of Christchurch the line branches off to become the Midland Line. After leaving Rolleston the Midland Line crosses the Canterbury Plains in a westerly direction then climbs almost continuously from close to sea level to the summit at Arthurs Pass, 737 metres above sea level.[ii]

In addition to the 2.4 km Lyttelton Tunnel, constructed in 1867, which passes under the Port Hills to Lyttelton Canterbury network includes a number of significant bridges, which are multi span simply supported structures up to 1.7 km in length on the plains and four long span viaducts on the Midland Line as it climbs from the plains to Arthurs Pass and the Otira Tunnel.

4 SEPTEMBER 2010 EVENT

The first of the 2010/2011 Canterbury earthquakes was a magnitude 7.1 event at 4:35 am on September 4 2010, where the epicentre was 40 km west of Christchurch city at a depth of 10 km, close to the town of Darfield on the Canterbury plains.

> This earthquake "…*was caused by the rupture of a fault network deep beneath the Canterbury Plains. The rupture started at 10 km below the surface, and then broke open a 24 kilometre rent across the surface of the plains. In the days following the quake, geologists from the University of Canterbury and GNS Science mapped the location of the surface rent, which extended from Greendale to near Rolleston, and named it the Greendale Fault*."[iii]
>
> The City of Christchurch is located adjacent to Pacific Ocean on the edge of the Canterbury Plains. "*The Canterbury Plains are covered with river gravels so we cannot see the evidence for past active faults in this region, as they are now buried. It is believed that the newly-revealed Greendale fault was pre-existing, and a patch was reactivated during the Darfield earthquake. Large (up to 700 km long) normal faults with the same strike (direction) are numerous on the Chatham Rise, out to sea east of Banks Peninsula*.[iv]

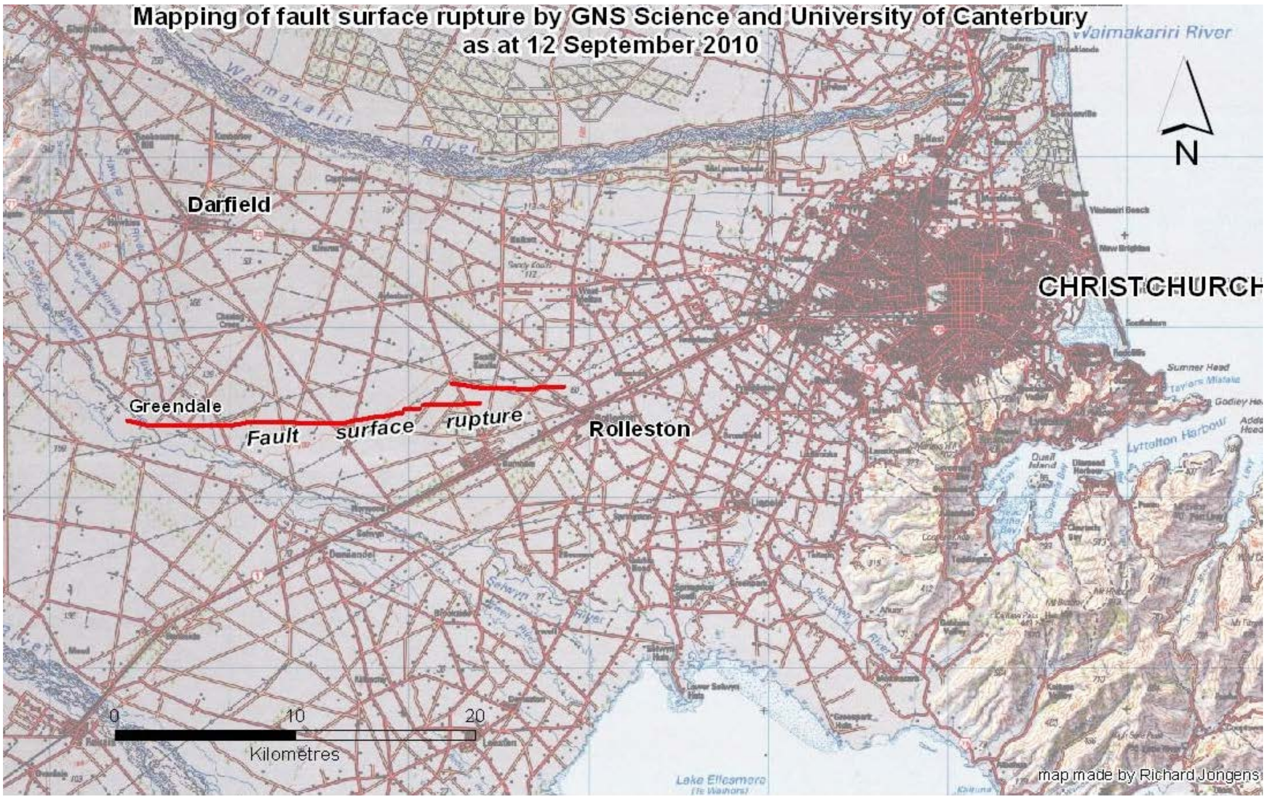

Figure 3: Mapping of fault surface, 2010 - source www.geonet.org.nz

While there was widespread damage, there was no loss of life largely as a result of the time of the event. For KiwiRail a critical task at this time was to establish contact with each of our employees and determine if they or their immediate family required support. In the worst cases where cellular or telephone contact could not be achieved this necessitated a personal visit by four wheel drive vehicle through streets buried under the effects of liquidation.

Damage to the railway and adjacent areas included:

- Severe liquefaction and lateral spreading of embankments between 0km to 10km MSL and 0km to 20km on the MNL resulting in vertical and horizontal track geometry issues.
- Abutment movement caused by embankment liquefaction to Bridge 18 MNL closed the track until the bridge approaches, abutment and rail buckling in the vicinity was repaired in the following days.
- There was a severe track buckle at Rolleston across the fault trace where the track gang removed 26 metres of rail and replaced it with a 20 metre length. A light locomotive stopped immediately short of this buckle after the earthquake.

One of the most notable accounts of the earthquake was from the Locomotive Engineer of a light locomotive at Rolleston. He described how the loco bucked and the headlight beam moved up away from the ground. He stopped the locomotive immediately and found that he was a few metres away from the track buckle.

With notification to Train Control, all services on the Midland, Main North and Main South Lines were stopped pending infrastructure inspections.

Figure 4: Main North Line Track Damage

Figure 5: Midland Line – Buckle at Rolleston

TRACK AND STRUCTURES INSPECTIONS

Work on assessment of the state of the railway network commenced with daylight. The track damage was quickly identified, while Structures inspectors commenced bridge inspections. The area covered by intensity 6 shaking extended well to the west and included four viaducts and more than 100 bridges on the Midland line and over 50 bridges on the Main South and Main North lines. The area involved, number of bridges and the size of some of the structures meant that inspection work continued for three days.

The size and frequency of the aftershocks presented a challenge for inspection and response. One aftershock on 7 September caused further buckling at the fault trace site at Rolleston. By 8 September we had inspected all bridges twice and had determined that only one needed immediate repairs. Repairs on the severely damaged Bridge 18 MNL were completed to allow restricted operation on 7 September.

EMERGENCY OPERATIONS

Requests for rail services into the city were received from our Freight customers on the Sunday morning once they had assessed the gravity of the situation facing them. Significant volumes of foodstuffs in supermarkets and food supplier distribution warehouses had been destroyed or damaged requiring urgent linehaul replenishment from Auckland.

With the Main North Line closed for track and bridge repairs to the north of the City the requirement for supplying the city required us to use an emergency railhead at which containers could be swung off wagons and onto trucks. Reconnaissance determined a suitable site near Amberley, some 30 km north of the city and operation commenced with support from local Police to provide road closures under emergency provisions.

A critical role fulfilled by the Rail Liaison Officer at this point was to embed himself in the local Civil Defence HQ to support recovery efforts and gain support from other agencies for railway objectives.

One significant benefit from this liaison was the granting of an emergency resource consent to extract river gravels from the adjacent Waimakariri River for use as railway ballast. This consent removed the need to run ballast trains from outside of the immediate area and significantly reduced the time required for track restoration work on this line.

RISK REVIEW FOR RESUMPTION OF SERVICES

By 5 September it was clear that we would be able to restore the complete rail network to operation within a few days, but the Canterbury area was continuing to experience significant aftershocks that would impact on the operation of trains. We determined that we should undertake a formal risk review of resumed operation.

In addition to input to the risk review by KiwiRail Network Mechanical and Structural Engineering staff, we invited input from two external Structural Engineers and a Seismic/Geological expert. One of the engineers specialised in Seismic Risk Assessment, and had provided input to an insurance risk assessment of the Midland Line for KiwiRail while the other had lead the design of a number of KiwiRail bridges. Both were overseas, which was fortunate as all locally available engineers with seismic assessment expertise were working in Christchurch.

Using a phone conference, the risk assessment covered:

- Expected aftershock occurrence.
- Duration and ground acceleration for aftershocks
- Overall exposure of a moving train to an aftershock
- Rolling stock performance in an earthquake and overturning loads
- Inspection records for the structures from post earthquake inspections

The specialists considered that failure of a bridge under earthquake load to be highly unlikely. The assessed lateral acceleration on bridges in the affected area during a MM 5 shock was considered to be less than approximately 0.05G at the epicentre which is well below the rolling stock design roll over load. Accelerations would reduce away from the epicentre. The potential for an earthquake to affect a train was assessed as a medium risk, which could be partially mitigated by speed restrictions and inspections. Resumption of service was considered acceptable.

Mitigations to be used were determined to be:

- The viaducts between Springfield and Cass should be assessed under load before a final decision is made to running loaded freight trains and passenger trains on the Midland Line. A Structures Engineer and Inspector to travel in the locomotive of an empty train or light loco from Springfield to Cass. As the train approaches each of the viaducts, it must stop, to allow the Engineer and Inspector to alight, and wait until both are in a suitable position to observe the viaduct. The train should travel over the viaduct at 25kph.
- 25 km/h restriction to apply over all bridges in the Canterbury area until regularity/intensity of aftershocks reduces.
- Any subsequent aftershock measuring MM 6+ will require consideration of further visual bridge inspections.
- A general speed restriction of 40 km/h would apply to all train services the area subject to the general Canterbury area being subjected to aftershocks. This restriction is consistent with KiwiRail's heat management procedures and reflected the similar risk of track instability under an operating train.

AFTERSHOCKS

Over the days following the initial earthquake, Canterbury experienced hundreds of aftershocks, a number of which were MM6 or greater in intensity, each of those above MM6 required cessation of train services until further inspections of infrastructure assets were completed. This work placed a significant burden on local Structures Inspectors who also had to manage family concerns caused by the ongoing aftershocks. To minimise this burden qualified Inspectors from around the country were brought in to assist.

The ongoing sequence of aftershocks also caused KiwiRail to review and adjust response procedures:

- For MM6 aftershocks, train operation was to be allowed to continue under the general 40km/hr/Bridges 25km/hr speed restrictions already initiated. The Area Manager and Structures Engineer were to be to be advised so that they could consider if further inspection of "at risk" infrastructure was necessary.
- For aftershocks between MM7 and MM7.9. The Area Manager was to arrange track inspection within the MM7 affected area. Bridges within this area were to be inspected for line and top track faults as part of Track inspection. Additionally, the location of trains was to be considered in relation to bridges and any bridge which may have a train passing over it during an earthquake to be inspected.
- For MM8+ aftershocks. All services were to be immediately stopped and a full track and structures inspection within the MM8+ area completed. The specific requirements for bridges over which trains may have passed during the event was to also be applied in detail. During these inspections trains would be permitted to follow the Inspector on a section by section basis as clearance for each section was given. By mid-September, the aftershock sequence had reduced sufficiently that trains were allowed to run at line speed, with temporary speed restrictions remaining only in areas where repaired track damage had not yet settled.

These procedures were used to respond to the ongoing series of aftershocks between September and February 2011. We continued to monitor earthquake for shaking intensity, and check train location at the time of each of the larger events. No trains were found to be on a bridge for any of the aftershocks during this period.

22 FEBRUARY 2011 EVENT

At 12.51 pm on 22 February 2011 Christchurch experienced a second devastating earthquake of the series with magnitude 6.3 at a depth of 5km under the Heathcote Valley 10 km south east of the centre of Christchurch:

> "…*another length of fault ruptured at the eastern end of the aftershock zone. This fault cut through the bedrock underlying the volcanic rocks of the Port Hills, but the break did not reach*

> *the surface. The rupture was less than five kilometres from Christchurch's central business district, and generated a powerful magnitude 6.3 earthquake with unusually violent ground movements. The earthquake brought down buildings, caused liquefaction in large areas of Christchurch and triggered numerous rockfalls on the Port Hills*."

The historic city centre within the four avenues was significantly damaged with a number of older brick and some more modern concrete buildings being irreparably damaged or collapsing. The sense of relief that had occurred after the September event was erased forever from the minds of Cantabrians and the nation. The City and surrounding suburbs had been struck a deadly blow over the busy lunch hour resulting in a death toll of 181.

The Network Area Manager phoned Train Control within 30 seconds of the earthquake, to find that Train Control had already received three phone calls. A similar process occurred at the Freight headquarters on Auckland's Northshore,1100 kms away from the epicentre. When initial reports were "confused", and telephones overloaded the "CNN" approach was taken to gain an accurate picture. The HSQE Manager along with his Lead Rail Accident Investigator (an ex Christchurch Locomotive Engineer who could comment on the footage) commandeered the TV in an adjacent bar to monitor the live media coverage beginning to stream out from the crippled city. This decision was to prove its worth almost immediately.

Although local management assurance was that external support was not required the "CNN approach" was the deciding factor that enabled a rapid assessment to be made on the likely extent of damage and disruption to the railway operational business, the homes, families and welfare of our people. Without delay, a decision was executed that resulted in the immediate deployment of expert rail personnel into the City from around the Country to provide Civil Defence liaison, to manage operations and to support the regeneration of train, rail yard and container terminal operations.

In the post event review of our response to the earthquake, local management acknowledged that this support played a critical part in the rapid regeneration of operational capability.

Figure 6: Christchurch City Centre from the Port Hills immediately after the 21 February 2011 event - source: www.stuff.co.nz

This earthquake caused damage and destruction out of all proportion to its magnitude, with 181 dead and damage cost estimates exceeding $20 billion. The primary reason for this extreme level of destruction was the short sharp nature of the shaking. In comparison with the 45 second duration of the September event, this earthquake was only approximately 10 seconds long but during this period, large areas of Christchurch had vertical ground accelerations of well over 1 gravity were recorded, backed up by widespread observations of cars and other large objects being thrown off the ground.

The damage to the city has been widely described and documented. For the railway the situation was:

- Bridge 3 on the Main South Line in the Heathcote valley close to the epicentre had its brick abutments shattered. A train had been passing over the bridge during the earthquake and had derailed on the bridge
- There had been abutment movement caused by liquefaction affecting bridges on the MSL between Middleton and Lyttelton.
- There had been embankment slumping affecting the track between 0.0km to 10.0km MSL and 0.0km to 20.0km MNL
- At the Port of Lyttelton there had been significant rockfalls onto the railway corridor from the cliffs around the edge of the port area.
- There had been a number of slips near the portals of the Lyttelton tunnel
- A wagon had fallen into the wheel lathe pit at the Addington depot
- Other depot areas, particularly the Lynwood depot had suffered liquefaction and building damage.

Figure 7: Lyttelton Tunnel West Portal

Figure 8: Bridge 3 MSL Abutment

The operational response to this event was based on the lessons learnt from the September experience.

Train operations were suspended and the response plan developed during September for an emergency Container Transfer site to the north of the city was activated. This action ordered resources, personnel and equipment to mobilise and move without delay to establish the forward operating position at which emergency freight would transhipped by crane to road for local delivery. When it became clear later that afternoon that the main north line had not been significantly damaged and that it would be restored within two hours of the emergency site becoming operational these elements were redirected toward supporting other emergency work. With significant damage occurring at the adjacent Port of Lyttelton establishing the railway an operating pipeline was to be critical for resupply of the City.

Fuel, both diesel and petrol was critical to maintaining railway operations following the February event. With the Port of Lyttelton damaged, fuel supplies were limited and rationing was implemented at service stations after panic buying by residents.

Locomotive fuel conservation measures were immediately implemented to minimise drawdown from local depot tanks by ensuring locomotives were fully fuelled at remote depots before heading toward Christchurch. Where a return journey could be achieved without fuelling this occurred, when not possible a minimum top up was made to ensure as much fuel as possible was retained locally.

KiwiRail's participation in earlier National Civil Defence exercises and the Transport Cluster emergency response group also played a vital part at this time and was the enabling factor that resulted in unrestricted access to road vehicle fuel being achieved from the Service Station which had been closed to the public and general businesses and restricted to emergency response service providers and the road vehicles required to support these operations.

ADJUSTED RESPONSE PROCEDURES

By May the ongoing aftershocks had resulted in repeated implementation of the response procedures and multiple inspections of the track and structures. No track or structural faults had been found for any earthquake with intensity level of 7 or less. Adjusted response procedures were implemented:

For MM Intensity 6:

- The Area Manager would be advised by email. No specific inspections are required.
- For MM Intensity 7:

- Train speeds in the MM 7 area are reduced to a maximum line speed of 40km/hr, with Locomotive Engineers advised to observe and notify Train Control of any concerns or observed damage.
- Notification of the Area Manager who will arrange track inspections at the first practical time for a daylight inspection
- Notification of the Structures Manager who will assess the location of trains in relation to bridges and consider the need for a structures inspection. Inspections would be only for bridges with previous earthquake damage or those which may have been supporting trains at the time of the earthquake.
- Line speeds resume following inspections and clearances.

For MM Intensity 8 or greater:

- Stop trains in area experiencing MM8 or greater shaking.
- Full track and structures inspections before resuming service.

These procedures were in place at the time of the June 13 aftershocks and allowed KiwiRail to be in a position to resume services within 6 hours, which was well in advance of the Lyttelton Port's ability to receive and handle trains.

The adjusted procedures have been allowed only for the Canterbury area. This was because there had been repeated inspections with no damage found and the long series of aftershocks had given us an excellent understanding of how the network and bridges perform under different levels of shaking. We do not have that level of understanding elsewhere, and the lower level of shaking of our original procedures are appropriate where an earthquake occurs elsewhere around our network.

13 JUNE 2011 EVENT

On 13 June 2011 there was a further event with a shallow magnitude 6.3 earthquake at 1420 at a depth 6.0 km, about 13 km from Christchurch preceded about 20 minutes by a magnitude 5.6 quake. The maximum intensity for the larger earthquake was MM 8.

These earthquakes were relatively close to the location of the February event, and to a large extent this caused further damage to structures and ground that had already been damaged by the February event. For the rail network, the most significant effects were:

- A number of buildings and walls on neighbouring properties adjacent to the rail corridor in the east of Christchurch had partially collapsed, sending debris onto the rail corridor.
- Damage to rail depot buildings and facilities.
- Limited embankment movement between 0.0km and 10.0km.
- Rockfall from the Port Hills affecting the railway close to the portals of the Lyttelton tunnel and around the Port.

Engineering and operational responses to this event were based on the February experience. Engineers were sent from Wellington to inspect bridges and KiwiRail buildings, and senior staff sent to assist as backup to local managers. Although train operations were mostly suspended for the remainder of the day while the welfare of our people was again checked to determine who needed family support from the Company there was no requirement for external resources to be brought in.

There is no doubt that for a number of our people and their families the ongoing series of earthquakes has been fatiguing, disconcerting and stressful. This is especially so for those employees with young families as children do not rationalise the events in the same way as adults, where significant property damage has occurred to their homes or where elderly parents require their care or evacuation from damaged retirement homes. Contracted Employee Assistance Services were established immediately after the initial September event and continue to be available to any employee who requires ongoing support.

LEARNINGS FOR THE FUTURE

This series of earthquakes has provided strong confidence for KiwiRail in our general and special Canterbury response procedures. It has confirmed that our use of MM intensity for identifying the need to respond is sound. This is interesting as a brief search indicates that for other countries where rail networks have seismic risk, the Richter scale, relating to earthquake energy is used to trigger response procedures.

The long series of aftershocks has meant that we have been able to consider adjusted procedures to fit the local Canterbury situation. These reflect the local rail network features as well as the geology and topography. We do not propose to extend these elsewhere in NZ.

Our initial risk review identified the risk posed by a train being on a bridge during an earthquake. The event of February 22 can be considered to prove this risk, but the severity of the earthquake in the Heathcote Valley is such that the Martindale road bridge may well have been damaged without the additional loading of a train passing. The process of identifying train location in relation to bridges at the time of an aftershock has been well developed and will be able to be used in future to assist us in earthquake response.

Our systems for responding to earthquakes rely on receiving information from GNS Science after an event or receipt of a phone call by Train Control, and radio communication out to trains. While loss of railway communications did not occur for any of these earthquakes, a severe earthquake could result in loss of our phone and radio systems, so that the most rapid information path currently possible is not available to us. While this may seem to present additional risk to train operations, there is limited potential to provide improved procedures.

Any severe earthquake is normally felt on a train (as was observed in Canterbury) and the Locomotive Engineer will stop the train. Systems to directly advise earthquakes from seismographs to trains are in use in Japan. Experience is that these can provide advance warning of some seconds to the train. However the stopping time for a train is such that the train will inevitably still be in motion when the earthquake arrives.

KiwiRail has a number of systems which communicate directly to train radios and we are investigating the potential for adding direct earthquake notification to the radio system.

CONCLUSION

Although the June and February events primarily affected the Christchurch urban area the rail emergency response was still critical to ensure that the "supply chain pipe" was reopened without delay for the delivery and sustainment of emergency supplies and foodstuffs. By acting quickly and effectively, having reflected on the practice that we had gained during the September event, this objective was achieved. Although the three events tested us in different ways KiwiRail responded with a three layered strategic, operational and tactical level response using well established procedures and emergency management response plans. While local employees delivered results well above what was expected of them in very difficult circumstances the deployment and importing of specialist railway personnel from outside of the region to support and manage recovery efforts without a doubt made a significant contribution in our ability to maximise KiwiRail's contribution to not only our freight customer's needs but the immediate needs of the City and its residents as a whole. Provision of a Rail Liaison Officer to Civil Defence headquarters is but one example of this wider support which in September added considerable value to the rail recovery effort while in February this same approach provided an expert resource with road transport operations and logistics support to the Civil Defence HQ Staff.

In closing, the importance of planning for a significant emergency by developing and testing emergency management and business continuity procedures coupled with developing strong links with territorial authorities, Civil Defence groups and "lifeline" service providers is critical. These actions will only be fully effective when the welfare of your people and their families at a time of crisis is given immediate consideration.

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[i] http://www.quake.crowe.co.nz

[ii] http://wwww.doc.govt.nz/parks-and-recreation/tracks-and-walks/caterbury/north-canterbury-and-arthurs-pass/arthurs-pass-avalance-peak-route/

[iii] http://www.naturalhazards.org.nz/NHRP/Hazard-themes/Geological-Hazards/February-22nd-aftershock/February-2011-aftershock

[iv] http://www.geonet.org.nz/earthquake/historic-earthquakes/top-nz/quake