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Lifeline Utilities Restoration Times for Metropolitan Wellington Following a Wellington Fault Earthquake

Report to the Wellington CDEM Group Joint Committee from the Wellington Lifelines Group

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Foreword by Fran Wilde, Chair of the Wellington Lifelines Group

Charles Darwin once said it was not the strongest nor the most intelligent species that survived when threatened, but the most adaptable – and that holds true for our communities too.

We live in a region facing a serious and well-documented earthquake risk. Experience has shown it doesn't take a catastrophe to interrupt our enjoyment of life; a simple traffic accident has at times brought Wellington to gridlock.

Various disasters around the country in recent years have had a profound impact on individual communities, and many of us naturally have asked ourselves: how well would we have coped in the same situation?

To answer such a question, we need a good understanding of the state of our region's infrastructure. The layout of that infrastructure has been strongly influenced by the region's topography. We have, for example, well-defined road and rail corridors vital to the flow of commerce and social interaction. Other infrastructure essential to our day-to-day lives and continuing prosperity includes telecommunications, water, wastewater and energy equipment, as well as the port and airport. There has been considerable investment over the years – and there continues to be investment – in strengthening this infrastructure against the day when a powerful quake hits the region. Great effort has also gone into providing an effective civil defence response system. The safety and wellbeing of our families, neighbourhoods, businesses and communities will largely depend on the resilience of those infrastructure networks and the companies managing them.

The contents of this report make sober reading. The complexities of restoring essential services after a severe earthquake are considerable and the job will not be achieved quickly. The bottlenecks created by the region's topography do not help matters. It's important to note, however, that the restoration times quoted in this report represent a worse-case scenario (7.5 on the Richter scale) that would feature multiple failures of infrastructure.

I note that, although not addressed in substance in this report, there is also a role here for every individual, family and neighbourhood in the region. It is critical each one of us takes personal responsibility for being prepared in the event of a big shake. The findings should make all of us stop and reassess our personal preparedness. Over-reaction will not be helpful, because preparedness is a long-term, continuous process literally incorporating new ways of doing things into our every day life.

In the meantime, good progress is being made with earthquake-strengthening vital infrastructure. Many infrastructure companies are already well down this path. The region's councils are also heavily engaged in upgrading their networks to provide greater certainty of service following a major event. The work being done on all these fronts is outlined in the report.

There is much at stake. Not only does the region comprise 11 per cent of the country's population, but it also generates 15 per cent of its GDP. Wellington is the seat of government and the transport hub between North and South islands. Many organisations have their national headquarters in the capital's CBD so that a severe earthquake would affect operations far beyond the city.

Under the umbrella of the Wellington Lifelines Group, the region's infrastructure providers are working to ensure they can quickly recover from a serious earthquake. We have all learned much from the tragedies of Christchurch and those lessons are now being applied in a practical way here. Together we need to continue to work in our homes, businesses and communities to build a more resilient region.

Fran Wilde, Chair

Executive summary

This report follows a preliminary report to the Wellington CDEM Joint Committee presented on 29 June 2012. It provides a summary of likely restoration times for key lifeline utility services, following a major earthquake involving a rupture of the Wellington Fault. The report focuses on the Wellington metropolitan area – Upper and Lower Hutt, Wellington and Porirua. However, because important transport routes servicing this area run through Kapiti and the Rimutaka range, these areas are referenced in some of the discussion.

A rupture of the Wellington Fault is considered to represent a worst-case, but realistic, scenario for planning purposes. It is acknowledged that it is but one earthquake scenario, with at least four other active faults and the subduction interface beneath Wellington affecting the Wellington region. It is acknowledged that there are higher-likelihood but less damaging earthquake scenarios affecting the region. In understanding, and planning for, the larger events, the region will be better prepared for all, no matter what scale.

Different utility assets behave in varying ways in an earthquake – an overhead electrical cable will be affected quite differently from a buried water main. Describing the effects of an earthquake in any part of the Wellington region, with its specific topography and utility networks, is not a simple task. While such a description could become overly simplistic, it is useful to consider the overall effects, such as the indicative restoration times and dynamics of this type of event. The restoration of road access into the Wellington metropolitan area is a key issue. With the current state highway network configuration, land access could potentially be cut off for up to 120 days (New Zealand Transport Agency estimate). This would be reduced to 40 days if the Transmission Gully Motorway were constructed, A detailed report by the Wellington Lifelines Group on transport restoration times is being undertaken but was not available at the time of writing this report. Water restoration time frames are generally shorter close to the water sources and increase with distance. Power restoration times are different for each part of the Wellington metropolitan area, but it is reasonable to expect restoration within 20 to 95 days. Restoration times should be read in conjunction with the level of service descriptions in the report and the restoration assumptions in Section 3.2, which contains a summary of restoration times.

In reflecting on the lifeline utility response to the September 2010 and February 2011 Canterbury earthquakes, it should be recognised that the Wellington region is very different to the flatter topography around Christchurch. Additionally, the two cities' utility assets of the two cities are quite different. The differences indicate that lifeline restoration times will be considerably longer in Wellington.

There are many activities progressing across all utility sectors to mitigate against specific seismic vulnerabilities in the Wellington metropolitan area. Some activities provide quick improvements. However, most will progress over many years or take many years to investigate, consult on, agree on funding sources, design and construct. This report presents a snapshot of the current state of resilience and work planned for the future. Continued work on improving the seismic performance of assets does provide greater resilience. An overview of the various activities and projects under way is presented in Section 5.

It should be noted that, no matter what seismic upgrades are made to the Wellington lifeline utilities, the earthquake risk cannot be eliminated. The topography, which determines the layout of the utilities, and the seismicity of the region, mean that while resilience can be increased, vulnerabilities will remain even once infrastructure is seismically upgraded. Work on emergency planning, both by the lifeline utilities themselves and by the Wellington Region Emergency Management Office, will continue to address this gap in future years.

An earlier report by BERL took interdependency principles into account when assessing the economic impact of restoration times. However, a further detailed interdependency modelling exercise has not been carried out because of the complexity that such an exercise would entail. This highlights the fact that the nature of the restoration times presented in this report is indicative only.

There are seismic vulnerabilities in Wellington's infrastructure. This report sets a point of reference – a starting point. It is the intention of the various lifeline utilities involved to improve upon the status quo and the later sections of this report will provide an outline of those plans. With the continued efforts of the lifeline utilities and continuing facilitation by the Wellington Lifelines Group, it is expected that the vulnerabilities will be progressively worked upon to create a more resilient infrastructure base. An understanding of vulnerabilities is therefore essential to create a more robust base on which to build forward work programmes.

1. Introduction

This report follows a preliminary report to the Wellington CDEM Joint Committee presented on 29 June 2012. It provides a summary of likely restoration times for key lifeline utility services, following a major earthquake involving a rupture of the Wellington Fault. The work draws from a range of reports that have been completed over the years. Recent work - particularly in the transport, water and power supply sectors - has, however, strongly influenced the updated restoration times. The report also summarises the work proposed by the lifeline utilities and WeLG to address the issues that have arisen and ties in closely with the *It's Our Fault* project led by GNS Science.

The physical vulnerability of Wellington's roading and utility networks to earthquake, in conjunction with the strong ground shaking and permanent ground deformation associated with a major fault rupture, results in substantial estimated times to restore lifeline utility services to the community. The implications of these timeframes for the community and local and central government are significant. Risk reduction and readiness initiatives to address the community impacts require careful planning and prioritisation. It should also be noted that the 2010 and 2011 Canterbury earthquakes, although occurring in a quite different context to that of Wellington, have led to a new appreciation of the impacts that a major earthquake would have in this region.

A rupture of the Wellington Fault is considered to represent a worst-case, but realistic, scenario for planning purposes. It is acknowledged that it is but one earthquake scenario, with at least four other active shallow faults, and the subduction interface about 25km beneath Wellington, affecting the Wellington region. The hazard context is discussed in Section 2.

Section 3 presents the restoration assumptions, and details on how the different infrastructure types will be restored, as well as giving a summary of restoration times.

Section 4 outlines the differences between the Wellington and Christchurch contexts, explaining how the sets of infrastructure are different and why restoration times in Wellington will be different.

Section 5 outlines what Wellington Lifelines Group members are doing to mitigate against the risks. The work being carried out includes upgrading the physical resilience of infrastructure and emergency planning for an earthquake.

Sections 6 and 7 present conclusions and recommendations from this report.

The report sets a point of reference, a starting point. Lifelines utilities all recognise that there is more work to be done in creating a resilient region and overcoming the seismic vulnerabilities in Wellington's infrastructure. There are now a number of major work streams in place and the facilitation provided by WeLG in providing coordination will continue. It is expected that this work will progressively create a more resilient infrastructure base. A key part of this is a clear understanding of vulnerabilities and, in this respect, the work that has been undertaken so far has created a robust base on which to build forward work programmes.

This report covers the Wellington metropolitan area, includes the Porirua, Upper Hutt, Hutt and Wellington cities. As a Wellington Lifelines Group document, it does not cover the Wairarapa, as this area is covered by the Wairarapa Engineering Lifelines Association. However, the report does reference transport routes in an out of the metropolitan area through Kapiti and across the Rimutaka Hill.

2. Context – the earthquake scenario

Due to its topography, Wellington is particularly susceptible to a major local earthquake. Although such events are rare, a 'direct hit' from a large event would have serious consequences for the region. The recent earthquakes in the Canterbury region have demonstrated the vulnerability of infrastructure to such events. Wellington's hilly terrain and relatively restricted corridors mean that its infrastructure is more vulnerable.

There are two measurement scales regarding earthquakes – the Richter magnitude scale and the Modified Mercalli (MM) intensity scale. The Richter magnitude outlines the amount of energy released in a seismic event. The larger the number, the more energy released. Each earthquake has just one Richter magnitude. The Modified Mercalli intensity measures the strength of shaking the event creates. The higher the number, the higher the shaking intensity, as detailed in Table 1. Intensity varies from place to place, and decreases as you move away from the epicentre. Hence some seemingly smaller Richter events can cause more damage at the surface if the event is shallow or nearby. For example, the magnitude 6.2 Christchurch February 2011 earthquake caused more city centre damage than the previous magnitude 7.1 Darfield September 2010 earthquake because it was closer to Christchurch's city centre and was a shallow event.

The research project *It's Our Fault*, led by GNS Science, identifies that there is a 10% probability of a major rupture of the Wellington Fault within the next 100 years. Such an event would be of a magnitude of about Richter 7.5. The Wellington Fault ruptures on average every 840 years, with the last major rupture around 300 years ago. In terms of actual shaking effect, the majority of Wellington's infrastructure lies within a zone that would be subjected to shaking intensity of MM9 or MM10. At the fault line itself, it is anticipated that a Wellington Fault rupture would produce a maximum of 4m to 5m in horizontal movement and up to 1m in vertical movement. The Wellington Fault is, however, just one fault that may produce earthquakes affecting the region.

For the purposes of this report, we have assumed the worst case scenario of a 'direct hit' Richter magnitude 7.5 rupture on the Wellington fault, with the epicentre located in the Wellington Harbour area. The level of shaking from a quake of this magnitude located close to Ngauranga is likely to be strong over a relatively wide area, as shown in Figure 1.

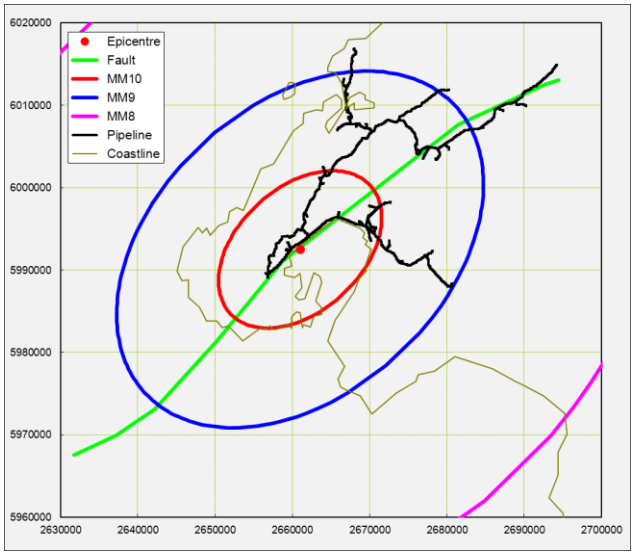


Figure 1 - Isoseismal map for a magnitude 7.5 earthquake on the Wellington Fault, with the epicentre near the centre of the fault which is a worst-case location (GNS Science, 2012).

While the above represents a worst-case scenario, Table 1 shows the expected return periods of various scales of earthquakes and their effects. The scenario of a Richter 7.5 Wellington Fault rupture, with an 840 year return period can be expected to give shaking in the MM9 to MM10 plus range. While the scenario taken in this report is considered a very damaging scenario, it should be noted that many other scenarios exist, which include at least moderate shaking.

Table 1 - Modified Mercalli events in the Wellington Region and their effects (GNS Science, 2012)

Shaking intensity	Average Return period	Last event	People	Structures	Environment
MM6	8 years	1/11/1968	Felt by all.	Damage to a few weak domestic chimneys, some of which may fall.	Loose material may be dislodged from sloping ground, e.g. existing slides.
MM7	30 years	24/6/1942	Difficulty experienced in standing.	Unreinforced stone and brick walls cracked.	Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings.
MM8	120 years	22/11/1848	Steering of motorcars greatly affected.	Weak masonry buildings heavily damaged, some collapse.	Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings.
MM9	400 years	23/1/1855		Many weak masonry buildings destroyed.	Landsliding general on steep slopes.
MM10	1,500 years in Ngauranga Gorge location	No known		Reinforced masonry buildings heavily damaged, and some collapse.	Landsliding very widespread in susceptible terrain.

This shaking and fault rupture would have considerable effects on the Wellington lifeline utilities, and this is broadly summarised in Table 2.

Table 2 - Overview of key lifeline vulnerabilities in relation to the Wellington Fault

Hazard/ Threat	Example Locations	Lifeline utility affected
Fault Rupture	From Karori through to Kaitoke	Bulk water network (five locations)
		State Highways and local roads
		Bulk gas
		33KV fluid and gas-filled buried power cables and substations
	Silverstream crossing	Bulk water and wastewater pipelines
Landslide	The four land entry-points to Wellington (SH1 Paekakariki to Pukerua Bay, the Paekakariki Hill Road, the Akatarawa Road and SH2 Rimutaka Hill Road)	Roads and local power infrastructure
	SH58 Haywards and SH2 Horokiwi	State Highways and rail (Horokiwi only)
	All areas, but particularly in hill-side locations	Roads and rail lines and local power infrastructure
Shaking		Some Wellington Electricity substation buildings.
Liquefaction	Petone/Seaview	Access to the fuel terminals at Seaview, roads, 33KV fluid-filled buried power cables, and buried water and wastewater pipes
	Porirua CBD	Water, wastewater, roads, gas and power
	Cobham Drive and Moa Point, near airport, Wellington	Roads and power infrastructure
	Aotea Quay	Container terminal

3. Summary of likely restoration times

3.1. The context of estimating restoration times in the Wellington region

The complexity of describing the restoration of single lifeline utilities, quite apart from combining across a number of different types of utilities, means that summarising overall effects from a single earthquake becomes relatively simplistic. The earthquake scenario of a Richter 7.5 event and its effects are also hard to accurately predict. This is why the restoration times and their assumed interdependencies can be indicative only. The effects of one earthquake may also be magnified or diminished simply through the availability of one section of road, or one part of a water network. So, while all of the lifeline utilities have participated in producing the 'restoration times' summary, the times given must be taken to be indicative and not definitive.

3.2. Restoration assumptions

In order to have a common basis across lifeline utilities, a number of assumptions have been made to establish a common understanding of restoration times. Without these base assumptions the analysis of the restoration times would have become overly complicated, to the point where realistic assessment would become impossible. Although highly simplified, the assumptions take into account likely scenarios regarding damage incurred in such an earthquake, and the likely assistance from outside the Wellington region. The common assumptions are as follows:

- Road access, for response and recovery of the water and gas networks, has been assumed to be that shown on the road vulnerability mapping, as included in appendix 2. It is nevertheless accepted that road access in some locations may be very restricted at the time that access is required for inspection and repairs. Due the complexities of analysis, road access for power (electricity) and telecommunications has been assumed to be 'single lane with speed restrictions, priority usage' in all locations.
- The majority of the expected damage will be caused by the initial fault rupture and earthquake. Significant aftershocks would potentially cause further damage and therefore potentially lengthen restoration times.
- Sufficient standby generators are locally available for key infrastructure facilities and can be provided within 5-10 days.
- Diesel for standby generators and utility vehicles/machinery is locally available and transportable.
- The majority of necessary materials for asset damage repair are either locally available or can be externally provided within 10-20 days.
- The majority of necessary skilled resource and associated equipment is locally available or can be provided within 5-10 days.
- Civil machinery is locally available for asset repairs.

3.3. Restoration levels of service

In order to explain restoration times, the levels of service to which lifeline utilities will be progressively restored need to be characterised. For the purposes of this study, the definitions shown in Table 2 have been used:

Table 3: Description of 'emergency', 'survival' and 'operational' levels of service

	Emergency level of service	Survival level of service	Operational level of service	Full (normal)
Land access	The availability of the roading network has been assumed to be that shown in the 'availability' and 'outage' state mappings appended to this report. Note – the mappings must be read in combination with each other. A 'Single Lane' availability will be 'out' for the time shown in the 'Outage State' mapping.			
Water	Site storage by end users / distribution of stored water in reservoirs / temp plants (Assume 20 litres/person/day.)	Limited/ intermittent supply to reservoirs; requires boiling; restricted in volume.	Treated water reticulated to consumers, in quantity allowing businesses to resume, but subject to frequent disruptions for local network repairs.	Meet Drinking Water Standards at quantities normally available with only occasional service disruptions
Power	Hand-held/battery powered appliances and local standby generators.	Power reconnected to selected critical facilities to ensure a level of service that sustains life.	Power reconnected with regular outages for repair work. Businesses will be able to resume operations on this basis.	Meet normal reliability of supply standards.
Gas	BBQ bottles for appliances designed to operate on LPG.		Gas reconnected with regular outages for repair work. Businesses will be able to resume operations on this basis.	Meet normal reliability of supply standards.
Telecommun-ications		Cellular text and voice services will be operating at limited functionality	Voice and data services, and landlines, would be available in most locations at reliability levels adequate for most normal business purposes	Meet normal reliability of supply standards.

Note – the above definitions of levels of service have been altered from those presented in the June 2012 background report to the CDEM Joint Committee. The updated definitions allow for better sector integration between levels of service and incorporates latest information and thinking.

3.4. Descriptions of restoration times for each type of utility

Following a major earthquake of the magnitude outlined above, the various lifeline utilities would have different challenges in restoring services. These can broadly be summarised as follows:

3.4.1. Land access

The State Highway network is managed by NZTA, the local roads are managed by the various local councils and the rail network is managed by KiwiRail.

Road networks would be heavily affected, with some road structures, particularly bridges, suffering major damage. Large landslips, such as seen at the 2011 Manawatu Gorge landslip, can be time-consuming to clear, particularly where the slip must be tackled 'top-down', or from each end of the slip working towards the centre. The road seismic vulnerability mapping in Appendix 2 demonstrates the likely 'availability' and 'outage' times from such an event. The four roads accessing the region – SH1 Paekakariki to Pukerua Bay, the Paekakariki Hill Road, the

Akatarawa Road and the SH2 Rimutaka Hill Road would all be out of use for ‘at least three months’. It is anticipated that SH1 Paekakariki to Pukerua Bay would be reopened first, at up to 120 days restoration time for truck access. If the Transmission Gully route were to be developed, it is estimated it would cut restoration time down to 40 days. Anticipated slips at SH58 Haywards and SH2 Horokiwi would fragment the region for at least 55 days. Figure 2 depicts the key road access issues following a major Wellington earthquake.

Regarding food supply into the region, under normal circumstances the two major supermarket chains, Progressive and Foodstuffs, truck provisions to the Wellington Metropolitan area from major logistical hubs located in Palmerston North. Due to the nature of the sector, most provisions are transported and stored on a just-in-time basis. This means that while supermarket shelves are normally well stocked, if the transport routes are disrupted for lengthy periods, there are no large back-up stores of provisions within the region to maintain supply to the supermarkets. Provisions would therefore have to be transported to supermarkets via alternative routes. Routes and arrangements for such alternative routes are outlined in Section 5.3.

Rail access will be affected similarly to the road network. The rail network follows a similar route to SH1 between Paekakariki and Pukerua Bay. Although the Rimutaka Rail Tunnel itself may be relatively unaffected, access to the portals of the tunnel is likely to be heavily affected.

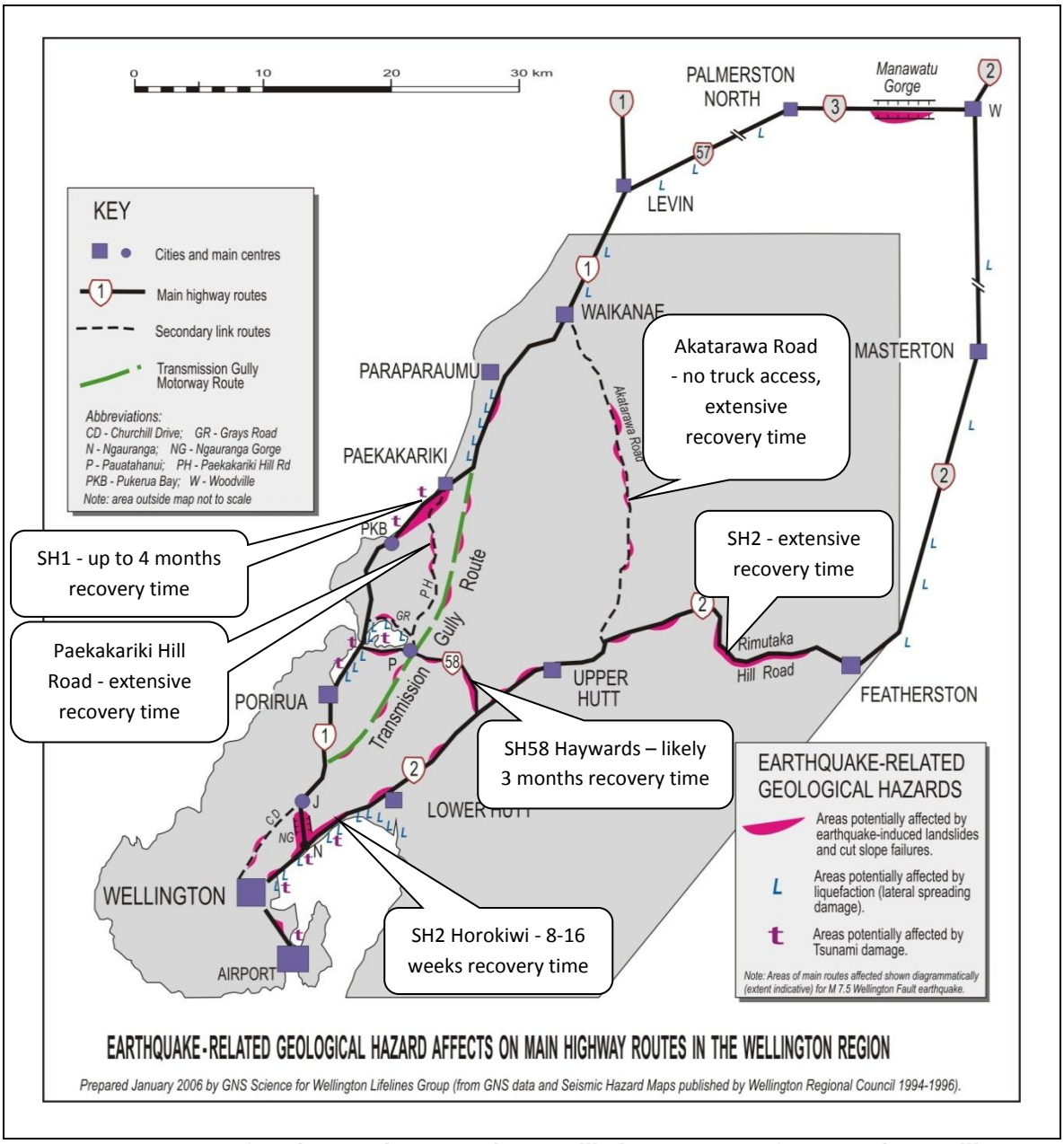


Figure 2- A summary of major road access issues likely to occur after a major Wellington earthquake

3.4.2. Plans for restoring land access

Contingency plans exist for exploring alternative land-access routes into the region following an earthquake. This task will be carried out primarily by the NZ Defence Force units prepared for the task. It is unlikely that good transport routes will be discovered. However, in such a situation all options will be explored and the investigation of any and all feasible routes will be carried out.

NZTA has contingency plans for restoring access along the State Highway 1 and 58 corridors, and are presently finalising contingency plans for SH2. Some of these plans are aided by the close proximity of available earthmoving machinery to predicted landslip areas. For example, the quarrying, concrete supply and asphalt plant contractors located at Kiwi Point (about half way up the Ngauranga Gorge) have signed an agreement with NZTA, Wellington City Council and

KiwiRail on restoring access in the Johnsonville to Thorndon corridor following an event. Similar agreements are planned at other key locations around the Wellington region.

In addition to the above, the WeLG and WREMO have collaborated with the various transport asset owners to establish feasible means of transporting freight around the region following a major earthquake. This work is expected to be complete in early 2013. The initial piece of work may be used by the other lifeline organisations and other sectors for planning purposes. Follow-on work is outlined in Section 5.3.

3.4.3. Water and wastewater

Potable water

The bulk water supply and distribution is managed by the Wellington Regional Council, the local reticulation is managed by Capacity (for Upper Hutt City Council, Hutt City Council and Wellington City Council) and by Porirua City Council.

Three operational water treatment plants provide bulk water to the primary reservoirs of the region's four cities. Except for river and stream crossings, the pipelines are underground. The supply pipeline from the Te Marua treatment plant to Porirua and Wellington crosses the Wellington Fault at Te Marua, Silverstream and Karori. Supply pipelines from the Waterloo and Wainuiomata treatment plants cross liquefaction-prone areas in Petone, and the Wellington Fault at Korokoro and Thorndon. At each fault crossing the pipe will be fractured and displaced and the area may be eroded by escaping water. In addition, multiple breaks are expected along the length of each pipeline from ground acceleration and movement, yet the likely location of damage is difficult to predict.

Repair of the bulk water pipeline is a linear process from the point of supply, involving testing, repair and retesting. A reduced level of bulk water will be restored earlier to reservoirs closest to the source of supply (such as in Upper Hutt and Lower Hutt). Thus restoring any supply to Wellington City and system-remote reservoirs such as Pukerua Bay is expected to take many weeks.

Although obvious breaks in city reticulation systems could be repaired soon after the event, the reticulation system will be progressively repaired from reservoir to consumers once a source of water is available to fill and pressurise the pipes to identify leaks. The planned approach is to test and repair a section of the reticulation main and then test and repair each branch fed from it, until all lateral connections to consumers supplied from that section have been repaired. After a section of the main pipe and all its connections have been repaired, the process is repeated with the next section. In this systematic way, areas of the region will be progressively reconnected to the water supply. Separate teams working on different mains or branches and at multiple locations will speed up the time needed for repair.

Without an alternative source of water to use for supply or repair, a decision will need to be made on whether to use some of the stored water in reservoirs for testing and repair before the bulk supply is at least partially restored.

Metropolitan Wellington's average residential consumption varies by city and was between 200 and 225 litres per person per day over the 12 months to June 2012. In a major emergency, the plan is for a restricted volume of water (20 litres per person per day) to be available from stored water held in city reservoirs. This is only 10% of normal consumption and around the minimum recommended by aid agencies.

The water will need to be collected by individuals in containers from distribution points (emergency level of service). When the bulk supply is first restored to the reservoirs it will be in reduced quantity and possibly untreated or partially treated, but a *boil water* notice may be necessary (survival level of service). At this stage the volume of water should be sufficient for the 20 litres per person per day to continue and testing/repair of the reticulation system to proceed.

It is intended that an increased supply of treated bulk water would be restored to the reservoirs by the time the pipework to consumers is repaired to a functioning level (operational level). The quantity available at this stage may be less than normal but more than adequate for commercial activities to continue. Network repairs and improvements will continue for months before normal supply is restored to consumers.

Some communities will experience a greater water shortage than others. Upper Hutt and Hutt City have access to aquifers that will provide a faster solution to restoring water supply. Porirua and Wellington cities, however, have few options for an alternative emergency water supply, although these alternative options are being investigated. As a result, planning for the reinstatement of bulk water places an emphasis on restoring at least a partial supply of bulk water to Porirua and Wellington central, western and the northern suburbs. This will allow repair of the reticulation to eastern and southern suburbs of Wellington City to proceed sooner.

For restoration times of the water network, see the timeframes given in Table 4 and Table 5 in Section 3.5. Additionally, for more detail, see Appendix 1 for 'contour mappings' of water network recovery times. Note in Appendix 1 that the time taken to restore water supply to the relevant reservoirs is the 'survival' restoration time given in Table 4. The time to restore water to reservoirs plus the time to restore the reticulation is the 'operational' restoration time given in Table 5.

Wastewater system / Sewage disposal

The wastewater infrastructure in Wellington urban areas is expected to be severely damaged in a significant earthquake event. The recent Christchurch earthquakes have demonstrated the serious effects of liquefaction and ground shaking on wastewater pipes, especially old ones, and the extended duration of repair and recovery of the gravity networks to basic operational level due to land deformation (months).

Some damage is expected to the wastewater treatment plants and pumping stations. However, the major damage anticipated to the wastewater pipelines and combined with the lack of normal water supply would severely reduce the immediate volume of sewage requiring pumping or treatment.

The hilly terrain of the Wellington region makes the provision of emergency sewage disposal particularly challenging and the community may be expected to be self-sufficient for a longer period than that experienced by Christchurch residents following the Christchurch earthquakes.

3.4.4. Power

The Transpower transmission network (national grid) supplying the Wellington metropolitan area has a degree of redundancy and, being a predominately overhead network, is expected to perform well in an earthquake. Additionally, Transpower's substations and equipment are designed and constructed to a high level of seismic performance, as work on this issue has been going on for a number of years. Note, in Section 4.3, the performance of the transmission system

in the Christchurch February 2011 earthquake. The supplies for the Wellington metropolitan area come from two major nodes (Haywards and Bunnythorpe) in the lower North Island. Bunnythorpe is near Palmerston North.

Wellington Electricity Lines Ltd's (WELL) power distribution network is recognised as a reliable network. With 60% of the assets located underground, it provides a reliable supply system which is largely unaffected by the high winds synonymous with the Wellington region. However, the benefit of buried cables in high-wind conditions could become a vulnerability during an earthquake because the ground movement may cause multiple cable failures, both at cable joints and at equipment terminations.

The majority of WELL's 33kV sub-transmission cables, which form the backbone of the distribution network, are relatively mature and have been constructed as pressurised fluid-filled cables. The network has the majority of these cables installed under busy roads, along clear areas like river banks or through structures such as bridges, some of which cross fault lines. These cables will be very vulnerable to failure from ground deformation caused by an earthquake. Repair to an extensively damaged cable would take many weeks due to the specialised materials and skilled resource required to carry out the repair.

WELL owns 489 substation buildings, with approximately 300 built before 1976. The buildings contain the higher-cost equipment (transformers and high-voltage switchboards), which has long lead times to manufacture and deliver. The pre-1976 buildings, although compliant with the relevant building code when constructed, now require a further structural assessment to confirm that their seismic performance would meet a fitness standard within the current Building Act. It is important that the electrical assets remain available for service following a significant seismic event, so WELL must ensure that the building does not collapse and damage equipment, or endanger the public and surrounding buildings. This may require a reinforcement programme of selected buildings, which WELL is currently assessing.

The projected peak load in the Wellington Metropolitan area for 2012 is 550 to 570 MW. West Wind Generation (the wind turbines at Makara) may contribute a maximum of 143 MW (depending on wind speed), and is connected between Wilton and Central Park on the Transpower 110kV system. Unfortunately, the wind turbines require the grid to be energised to be able generate power, so cannot run independently.

The greatest vulnerabilities to the Wellington region that would impact power restoration timeframes are the region's topography, both from the perspective of the steep hilly terrain and the limited number of narrow road and transportation access corridors. Each access corridor is susceptible to subsidence and landslides in areas. Key network vulnerabilities include the scores of 33kV fluid-filled sub-transmission cables, which would readily fail if subjected to ground deformation and would require lengthy repair times.

WELL utilises telecommunication services from a number of different telecommunication utilities such as leased fibre cable, wireless and cellular radio services. These services are used extensively in the operational control of the power distribution network for the remote control and monitoring of distributed assets (SCADA system) and for operational communications to co-ordinate field activity. The ability for these telecommunications services to remain functional following an earthquake will be vital in WELL's response to power restoration.

Asset assessment and repair for the power distribution network are also a linear process, working from the higher supply voltages at the 33,000V sub-transmission level and then down through the 11,000 V distribution feeders and 400V segments of the network. Supply to the distribution line network cannot occur until the network connections are established, with successive repair and livening work through the voltage hierarchy of 33kV, 11kV and finally 400V

networks. This would progressively restore power to required areas, with critical loads such as hospitals and water pumping stations being given a high priority for restoration. Some individual homes and dwellings, depending on the damage incurred, may first need to be cleared for electrical safety by an electrical verification inspection which WELL would need to arrange and coordinate through independent electrical inspectors. This recognises that dwellings and business premises may be damaged to an extent that they would be unable to be safely connected to a restored street supply.

It is important to note that there are key regional and power network differences between Christchurch and Wellington, which will be reflected in the considerably longer restoration times required for Wellington. The restoration timeframes for the Wellington zones shown in Table 4 and Table 5 incorporate the Wellington regional and WELL network vulnerabilities, the event scenario and the restoration assumptions. The differences between the Christchurch and Wellington networks are reflected in Section 4.3.1.

3.4.5. Telecommunications

Telecommunications is a relatively complex sector compared to other infrastructure sectors. Nine Telecommunications Service Providers (TSPs) are active in Wellington, each delivering different services (e.g. voice, data/internet, SMS in access and back-haul networks) using different asset types (in roof-tops, on surface and underground). Usability depends not just on TSP performance but also on users' devices beyond TSP's immediate control (e.g. accessing telecommunications via cordless phone needs power, cell phones also need re-charging etc.).

These matters complicate the TSP restoration story, making simple / single restoration times difficult to derive and support. The following provisional estimates are to be read against these caveats.

The provisional estimates below distinguish *survival* from *operational* levels of performance. Illustratively, *survival* can be taken to mean that cellular text and voice services (but perhaps not data) will be operating at limited functionality, i.e. at performance levels noticeably lower than normal (e.g. with reduced coverage and building penetration and often with extensive redialling). Performance may be more favourable in these first days in areas where mains power is available, but can be expected to deteriorate following aftershocks due to congestion. Resumption of landline services is not included in this survival performance level. *Operational* performance means voice and data services, and landlines, would be available in most locations at reliability levels adequate for most normal business purposes.

Assuming shaking comparable with Christchurch, and assuming favourable post-earthquake conditions, restoration of cellular services at most locations, to *survival* level, might be expected quite quickly – e.g. within three days (provisional estimate), albeit with congestion following aftershocks. It should also be noted that battery reserve on cell sites is likely to enable *survival* level cell phone service for a period of hours in the immediate aftermath, with expected high levels of network congestion. Note that, in the absence of mains power, this estimate assumes continuing local road access and availability of petroleum for generators and vehicles. It also assumes ready access into Wellington and availability of water.

Restoration of services to *operational* level might take 10 days (provisional estimate). The assumptions in the preceding paragraph also apply here. The pace of repairs to underground cables is also likely to impact on the rate of restoration to operational service levels. Resumption of landlines may well take longer than cellular and landline customers with cordless phones will need to await restoration of mains power supply before their phones can be used.

These provisional estimates will need to be extended if power, access to and within Wellington, petroleum and/or water supplies are unreliable. The estimates would need to be extended if numerous repairs to underground cables are required.

There is a clear need for the TSPs and emergency management planners, possibly with the input from the fuel supply companies, to better understand how the emergency distribution of fuel to critical cell sites would be undertaken in the days and weeks following a major earthquake.

3.4.6. Gas

The bulk gas supply network is managed by Vector, with the local supply network managed by Nova Energy and Powerco.

As a predominantly buried pipe network, the gas network is affected by the same hazards in an earthquake as the water network and buried electrical cables. Similarly, the restoration of the gas network is carried out first from the bulk mains, with repair works progressing towards the consumer. The restoration of the gas network is different from other utilities, however, because repaired lines must be formally certified before being used. Unlike water, it is therefore not possible to fill the pipework with a limited supply. Rather, once recovered, the gas network would run at normal levels. Restoration of the gas network is strongly influenced by the reopening of the road network, as the gas main network is largely in the road corridor. Restoring the gas network will take longer if water seeps into the gas pipework system.

A further complication with breaks to gas networks is the danger posed by leaks. For this, the energy sector, in association with WeLG, has created a protocol for reconnections of their respective networks in order to ensure that faulty gas mains and electric cables in combination do not cause additional hazards. Despite this, if the gas network does leak, this may cause general delay and recovery co-ordination issues in the vicinity of the leak.

3.4.7. Fuels

Fuel supply has not been addressed as part of this report. A draft regional fuel emergency response plan is not yet finalised, commenting at this stage on fuel supply restoration times would not be of value. Discussions are continuing between WeLG, WREMO and the fuel companies on this issue, and it is recommended these be progressed. Assumptions made regarding land access could, however, be taken into account regarding fuel supply.

3.5. Summarised restoration times for gas, power and water

The following are summarised restoration times, to the levels of service outlined in Table 3. Note that restoration times are the grid/bulk supply times combined with local distribution (for gas, combined Vector, Powerco and Nova Energy, for power combined transmission [Transpower] and distribution [Wellington Electricity], for water, bulk supply [Wellington Regional Council], and local reticulation [Capacity and Porirua City Council]).

Due to the complexity of the telecommunications sector restoration times (see section 3.4), the telecommunications restoration times are not included in tables 3 and 4.

The estimated restoration times have been summarised for whole suburbs or areas. It should be noted that some pockets of earlier recovery may be possible depending on a range of factors such as proximity to key distribution nodes of networks.

Table 4: Summarised *survival* restoration times

	Gas restoration time (days)	Power restoration time (days)	Water restoration time (days)
Upper Hutt and Stokes Valley	80	20	20
Hutt Western Hills	80	30	30
Hutt Central	80	30	20
Wainuiomata	80	20	20
Hutt City Harbourside	80	30	25
Mana, Plimmerton and Pukerua Bay	60	20	50
Porirua Central	60	20	35
Pauatahanui – Haywards	60	20	25
Northern Wellington suburbs	60	30	30
Western Wellington suburbs	60	30	40
Wellington CBD	80	50	50
Central Wellington suburbs	80	30	50
Roseneath, airport and Southern Bays	80	30	65
Eastern Wellington suburbs	80	30	65

Table 5: Summarised *operational* restoration times

	Gas restoration time (days)	Power restoration time (days)	Water restoration time (days)
Upper Hutt and Stokes Valley	80	50	30
Hutt Western Hills	80	60	40
Hutt Central	80	60	25
Wainuiomata	80	50	35
Hutt City Harbourside	80	70	40
Mana, Plimmerton and Pukerua Bay	60	40	75
Porirua Central	60	40	75
Pauatahanui – Haywards	60	40	35
Northern Wellington suburbs	60	60	45
Western Wellington suburbs	60	60	55
Wellington CBD	80	95	55
Central Wellington suburbs	80	60	55
Roseneath, airport and Southern Bays	80	60	70
Eastern Wellington suburbs	80	60	70

While the above restoration times take into account interdependency principles, a detailed interdependency modelling exercise has not been carried out. This is largely due to the complexity that such an exercise would entail. This again highlights the indicative (rather than definitive) nature of the restoration times presented in this report.

4. Comparing the Wellington and Christchurch metropolitan areas

4.1. Topography

In reflecting on the lifeline utility response to the September 2010 and February 2011 Canterbury earthquakes, it should be recognised that the Wellington region is very different from the flatter topography around Christchurch. Christchurch is situated between the Canterbury plains and Banks Peninsula. The majority of the city, apart from residences around the Port Hills, is situated on flat terrain with a grid road layout. In contrast, Wellington city (with half the region's population and a large proportion of its daytime workers) is built around a harbour with the majority of residences located in hill and valley suburbs, and the CBD built on a narrow flat area between a fault line and reclaimed harbour frontage. The various utilities that supply Wellington are constructed around and over hills and slopes. Additionally, the wider Wellington region is constructed along corridors – the Hutt Valley and Tawa being examples. Some of the corridors are narrow and take a wide range of utilities, such as through the Thorndon Quay area, which contains key roads, water mains, gas mains, electricity and telecommunications cables and gas mains, all located within the road corridor. Such a concentration of utilities in a confined area creates a greater combined risk in the event of a natural hazard event. It should be noted that the Wellington fault crosses this key area. Wellington City Council and WeLG are working together to mitigate some of the risk in this key area. The greater repair and reconstruction challenges in Wellington are reflected in the longer recovery times that would be required following a 'direct hit' earthquake in the Wellington region.

The February 2011 earthquake significantly affected the Port Hills in Christchurch, with their topography broadly similar to that in Wellington. In Christchurch, the local CDEM restricted utility access due to landslips, falling rocks and general ground instability. This issue will present an ongoing safety hazard during response and repair in Wellington.

4.2. Transport Access

The grid layout of Christchurch's road network is a key difference to that of Wellington. A grid road network, as at Christchurch, provides a large diversity of routes should a road or bridge be affected by earthquake. Due to its topography, Wellington's road layout is less networked, particularly for main routes – as demonstrated in the road seismic vulnerability mappings in Appendix 2 and also as demonstrated in Figure 2. Because of this, in Wellington, if one road is disrupted, there may be limited, or no, alternative routes. Other lifeline utilities face similar layout issues, with few alternatives if one key corridor or part of a network is compromised.

4.3. Christchurch case studies

The following are case studies outlining restoration times from the different context of the recent Christchurch earthquakes. These outline how and why restoration times in Wellington will be different.

4.3.1. Christchurch's power

During the February 2011 earthquake, Transpower's equipment was returned to service within four hours. Orion, the Christchurch electrical distribution business, was able to restore power to

approximately 90% of customers within 10 days, excluding the CBD red-zoned area. Orion's electrical network is fundamentally different to the WELL power network. Over a period of 15 years prior to the September 2010 earthquake, Orion had invested approximately $6 million in seismic strengthening programmes, such as reinforcing over 100 substation buildings and supporting sub-transmission cables in vulnerable locations. This investment is estimated by Orion to have saved them approximately $50 million in damaged assets and direct asset replacement costs. Restoration times to both the September and February earthquakes would have been significantly higher had the seismic strengthening works not been undertaken. Orion also has a different network architecture from that of WELL, with more redundancy of supply in its 11kV network, which allows for a higher level of interconnection of alternative supplies.

In addition to the Christchurch CBD, which contains 6,600 connections and was ring-fenced and isolated as a "red zone", only approximately 10% of Orion's power network was actually affected with large areas receiving little or no damage at all. The Wellington region would clearly be more vulnerable to loss of power than Christchurch. (See Section 5.1 regarding upgrading the resilience of Wellington region infrastructure.)

4.3.2. Christchurch's telecommunications

Immediately after the Christchurch earthquakes, cellular performance suffered for some hours due to extreme congestion (exacerbated as batteries ran down). In homes and workplaces, cordless PSTN phones ceased to work where electricity failed.

Numerous faults occurred in the local access copper network and many PSTN copper and lead-covered cables were damaged. On the other hand, roadside cabinets were generally undamaged. Some microwave dishes were misaligned. Fibre and radio services held up well.

In the following hours and days, cellular performance temporarily declined as batteries at cell sites depleted, then improved as generators and mobile sites were deployed (around 200 mobile generators were used). Generator refuelling presented major logistical challenges due to road conditions and traffic congestion. Vodafone for example reported that refuelling was a 24 hour operation in the first three to four days, with eight people working in 12 hour shifts. Petroleum was generally available for generators and vehicles.

Landline availability declined a little as cabinets batteries depleted. Performance then improved progressively as generators were deployed, numerous telephone cable faults were repaired and electricity was restored at customer premises.

Main nodes / exchanges (where back-up electricity supplies are available) and connections to other parts of New Zealand held up well.

TSPs have improved emergency capability in the months since the main Christchurch earthquakes, likely to favourably impact on service restoration. However, TSPs note that in Wellington's case:

- Extensive shaking and slope failure could cause greater damage to sites (including monopoles and towers) and cables than experienced in Christchurch.
- Difficulties may arise in transporting needed equipment including generators to Wellington. Difficulties may also arise in accessing main telecommunication nodes and other sites - access is expected to be more challenging in Wellington given the topology and the greater incidence of equipment on high-rise buildings.

Availability of petroleum and ongoing road access for frequent refuelling may be more problematic.

4.3.3. Christchurch's water supply

Christchurch was able to reinstate a basic mains water supply to 50% of the city three days after the February 2011 earthquake and to 89% of the city after two weeks. The water still needed to be boiled and was intermittent due to ongoing repair of distribution pipes. This will not be the case for a major earthquake in Wellington due to the fundamental differences in the water supply network. Christchurch's water is fully supplied from underground aquifers below the city. Water is extracted from wells at over 50 locations around the city and pumped untreated into interconnected distribution networks to consumers. Pressure in the network is maintained by the pumps and assisted by a small number of reservoirs that also serve the hill suburbs.

In comparison, approximately 60% of metropolitan Wellington's water supply relies on remote 'run of river' sources and the treated water being piped through long trunk mains - for example the Te Marua to Wellington pipeline is 56km long. The remaining 40% is supplied by the Waiwhetu aquifer in the Hutt Valley from eight wells in one area and piped to the Waterloo treatment plant for treatment and supply. With only a few exceptions, the bulk water from all sources is piped to reservoirs and distributed from the reservoirs to consumers. Emergency cross-connections between the bulk water trunk mains and the city distribution network have been pre-installed at strategic locations to bypass reservoirs. An emergency cross-connection between the aquifer well outlet and the Hutt City distribution network is planned. These connections are intended to speed up the reinstatement of water supply in specific areas but in general still rely on the repair of the trunk main.

4.3.4. Christchurch's gas

In Christchurch there is a shorter reticulated gas system (130km) none of which was in the CBD. During the recent earthquakes, as the pipework was constructed of polyethylene, no breakages occurred, except to around three overground meter sets. Wellington's gas network is much larger with relatively more natural hazard vulnerabilities to contend with, meaning that recovery times are anticipated to be longer.

5. What the individual lifeline utilities and WeLG are doing for mitigation and preparation

Wellington lifeline utilities are working on two fronts to address the seismic vulnerabilities outlined in this report. Firstly they are working on the long term task of reducing the existing infrastructure vulnerabilities. Secondly, they are planning emergency responses.

5.1. Providing more resilient infrastructure

Lifeline utilities review the resilience of their assets against relevant seismic codes. Reducing existing vulnerabilities to earthquakes is a task that can be approached in two ways. Firstly, through the day-to-day maintenance and renewals work that is carried out by utilities. For example, where old (and brittle) reticulation pipes require replacement for maintenance reasons, they are often replaced with strong but flexible polyethylene pipe (both water and gas networks) which performs much better under earthquake loading. Although this is a simple example, similar changes are also being made through the day-to-day maintenance work of the other lifeline utilities.

The second action to reduce infrastructure earthquake vulnerabilities is through one-off projects. An example of such a project is the current seismic upgrade of the Te Marua reservoirs, which will improve the earthquake resilience of the water supply to the Wellington metropolitan area.

There are many other examples of day-to-day maintenance/renewal upgrades that, over a period of years, provide improved earthquake resilience. An excellent example of the benefits of progressive infrastructure upgrades is the work that has been going on in Christchurch, as outlined in a recent New Zealand Lifelines Committee report. Seismic retrofitting has been proved to be relevant, worthwhile and economically justifiable.

5.2. Projects providing greater resilience

The following section outlines projects in, or affecting, the Wellington region that have already or will at completion have a positive effect on the seismic resilience of the region.

5.2.1. Power

Power transmission

Transpower are taking the following actions which will improve power transmission resilience to the Wellington region:

Recent work carried out

- Kaiwharawhara – two new transformers installed with foundations to new seismic standards.
- Haywards – HVDC Pole 3 project – extensive upgrading on site to new seismic standards

Planned work

- Foundations of two replaced to new seismic standards at the Central Park substation
- A rebuild of a 110kV structure at the Wilton substation to provide better diversity
- Replacement of a Wilton outdoor 33kV structure with indoor 33kV switchgear to meet new seismic standards

- An additional 220/110kV interconnector transformer for Wellington – location still to be determined
- Inter-phase spacers to be installed on the Takapu Road – Wilton 110kV circuits 1 and 2 to improve the performance in snow storms (as an outcome of the 15-16 August 2011 snow storm).
- Deployment of nine hardwood poles into the Wellington region as a contingency if the roads are blocked from the north. (Temporary towers are located in Palmerston North which can be flown in by helicopter)

Studies

- A 'High Impact Low Probability' (HILP) and diversity study is now under way for Central Park, Wilton, Kaiwharawhara and associated transmission lines. This is due for completion in February 2013.

Power distribution

From a power resilience perspective, WELL has adopted a substation building seismic policy. This provides the methodology for the risk assessment of WELL's substation buildings for seismic strengthening and includes a priority ranking system. This policy is driving a 10 to 15-year seismic assessment and strengthening programme of substation buildings.

As outlined in Section 3.4.4, buried 33kV fluid-filled sub-transmission cables can be vulnerable to seismic events with repair to extensively damaged fluid-filled cables possibly taking a number of months, depending on the extent of damage on each individual cable. WELL is engaging with Wellington City Council to develop protocols regarding the emergency installation of overhead 33kV lines should sub-transmission cables become unavailable for an extended period following a seismic event. The selection of the proposed overhead 33kV contingency routes will consider all risks within their immediate vicinity such as earthquake-prone buildings, vegetation, topography, ground conditions and ease of access for construction. Engagement with the remaining Wellington-area councils will commence following completion of the Wellington CBD study.

WELL is also working with Transpower to investigate further options to improve the transmission supply security and diversity into the Wellington CBD. The increased security and diversity at transmission level will assist in quicker response times for power restoration.

In addition to the initiatives above, the following projects and actions have been undertaken which will improve power distribution resilience to the Wellington region:

- Transpower's Wilton Grid Exit Point to Moore St 33kV cable replacement – two fluid-filled 33kV buried sub-transmission circuits (5km in length) have been replaced with modern XLPE cable at a cost of $9 million.
- Adelaide Rd substation – the front façade has been seismically strengthened and the roof replaced resulting in a high level of National Building Standard compliance and providing seismic protection to the internal assets and public safety.
- Restraining substation equipment – Major equipment within zone substations has been seismically restrained and non-service spares removed to a central store.
- Numerous seismic structural assessments have been completed and strengthening remedial works will be programmed into future capital works programmes.

5.2.2. Telecommunications

Telecommunications Service Providers (TSPs) with Wellington operations are taking many steps to improve post-earthquake services. The scope covers both assets and organisational response. Some examples include the following:

- Stocks of generators have been reviewed with deployment at cell sites, cabinets etc in mind. Steps are being taken to increase the number available and improve their portability, connection characteristics and fuel capacity
- Improvements are being made to air conditioning and switch-board / generators at key Wellington exchanges (proposed changes to air conditioning will improve resilience by reducing dependency on mains water supply)
- Work is underway by at least one major TSP to check and enhance Wellington earthquake relationships with suppliers, and to identify specific points where fibre may be vulnerable to fault rupture – mitigation is planned to follow
- Intra-TSP emergency response arrangements have been reviewed following Christchurch experience and improvements are under way (development of "war rooms" and mapping capability are examples)
- The Telecommunications Emergency Forum has been expanded and now covers all TSPs with operations in Wellington (the Forum facilitates inter-TSP communication and co-operation in emergencies, and also enhances engagement with the CDEM response)

These and other steps arise from specific internal reviews by TSPs of their Christchurch experience, ongoing capital expenditure programmes and regular capability reviews.

5.2.3. Water

Bulk water supply

Wellington Regional Council has spent more than $20 million in the past 20 years earthquake-strengthening its bulk water supply network. This investment has also boosted its ability to restore services faster after a big earthquake.

The regional council regularly reviews the bulk water network to identify and prioritise areas of potential vulnerability. This includes such things as supply intakes, treatment plants, pipelines, pumping stations and reservoirs. There is $5.4 million allocated in the current budget for earthquake-strengthening work.

The biggest and most expensive of these is the strengthening and expansion of two reservoirs at Te Marua. Work on the first of the Stuart Macaskill Lakes has been completed; work on the second will start this summer. The cost of strengthening the embankments is $10 million.

Another big project in the current year is replacement of the suction main to Point Howard pumping station at a cost of $1 million. The existing pipeline passes through a liquefaction-prone area of Seaview and is old and brittle. The replacement pipe will follow a more secure route and be better able to supply the suburb of Eastbourne after an earthquake.

The regional council has a policy that, where cost-effective, critical water supply buildings should be 100% of New Building Standard to ensure greater certainty of supply after a major earthquake. All such buildings and structures have been prioritised for structural assessment over the next three years. Strengthening of the Kaiwharawhara pumping station is currently in the

design stage, while structural assessment of buildings at three water treatment plants has recently been commissioned.

Local networks

Earthquake-strengthening the local networks that feed out from the bulk network to consumers is equally important to the overall resilience of the region's water supply. A considerable programme of work is under way to replace critical pipelines with pipes made of materials more able to withstand seismic shocks. To date, 35% of water mains in Wellington have now been replaced with pipes constructed of more resilient materials. In Lower Hutt and Porirua, the figure is 40%, and in Upper Hutt it is 60%. Porirua is also installing flexible seismic connections at critical locations in its network.

In 2008, a group was set up to co-ordinate a regional approach to emergency water supply. The Water Services Emergency Preparedness Group has representatives from Capacity, the Wellington Regional Emergency Management Office, the regional council and local councils in Wellington, Porirua, Lower Hutt and Upper Hutt. The group has developed a plan to tackle short and medium-term challenges to supplying emergency water until normal operations resume.

The regional council, Capacity and the councils of Wellington, Lower Hutt, Upper Hutt and Porirua have been working to install emergency cross-connections at key points between the bulk water and local networks (city reticulation systems). Cross-connections have been installed in each city. These cross-connections, activated after a big earthquake, will allow bulk water to flow directly into city reticulation systems, rather than via reservoirs. The net result will be a faster restoration of supplies to consumers.

This financial year a key cross-connection will be installed in Lower Hutt between the Waiwhetu aquifer wellheads and the Lower Hutt reticulation system in Knights Road. This will allow aquifer water to be piped directly into the Lower Hutt network within days of a big earthquake and also allow tankers to be filled for emergency distribution.

Shut-off valves activated by seismic shocks prevent the loss of water held in reservoirs. They also activate when they sense the excessive outflows caused by broken mains. All the main reservoirs – accounting for 90% of the Wellington metropolitan area's water storage capacity – have now been fitted with automatic shut-off values, and work is turning to their installation at smaller reservoirs in Wellington.

A feasibility study into a sea water desalination plant on Wellington's south coast was recently completed. A plant was found to be unsuitable for use solely in emergencies because it would be slow and technically difficult to start up, and also uneconomic to operate on an occasional basis. It would also be costly to build. However, small mobile plants remain an option under consideration.

Emergency storage

The storage of emergency water supplies is one means of enabling services to resume more quickly. This would be of most benefit to Porirua and Wellington, which are the greatest distance from the region's water sources and whose supplies would be the last to resume. Upper Hutt and Lower Hutt both have access to water from aquifers.

The regional council has begun identifying sites to build covered emergency storage ponds close to where they are most needed. These ponds could have capacities ranging up to 500 million

litres. Eventually, such ponds have the potential to provide emergency water to both Porirua and Wellington cities until bulk supplies restart.

A reservoir with a capacity of 35 million litres is currently being designed for daily use by Wellington's CBD and eastern and southern suburbs (including the regional hospital). In an emergency, almost two-thirds of the reservoir's capacity would be set aside solely for use by the hospital.

Porirua is investigating the use of the old Kenepuru Dam as an emergency water supply.

The installation of emergency storage tanks at strategic places in local communities is another means of dealing with disruptions until normal supplies resume. In Wellington, Porirua and Lower Hutt, local councils have installed such tanks in schools and community centres. Porirua City Council has installed 62 (with a combined capacity of 1.5 million litres); Hutt City Council has installed 25, and Wellington City Council has installed nine (and plans to have 50 in place by 2015). Existing tanks have capacities ranging from 5,000 litres to 25,000 litres.

Domestic rainwater tanks are one more way of dealing with a disruption to service. Kapiti Coast District Council requires all new homes to have a 10,000-litre rainwater tank, or a 4,000-litre tank as well as a system to reuse grey water. Capacity and the regional council encourage, and provide information on, installing rainwater tanks. The Wellington Regional Emergency Management Office has advice on its website about how to capture rainwater in an emergency.

<u>Planning for emergency water supply until normal operations are restored.</u>

The following investigations and activities are under way:

- Arranging to source mobile water tankers for local distribution. Water for these tankers can be sourced from either the Hutt Valley artesian system or though navy based tankers bringing water from other regions. This includes:
    - Construction of mobile tanker filling facilities in Lower Hutt using the artesian well collection pipeline
    - Joint planning with the NZ Defence Force to ferry tankers into the region where land transport access is compromised
- Installation of a new bore in Lower Hutt and retrofitting of existing private bores in the Hutt Valley for public supply.
- Investigations are continuing into the availability of bore water in Wellington and Porirua
- Identification of available surface water at several sites and collection at a higher level than buildings to avoid contamination with sewage throughout the region, suitable for recharging the networks to hasten repairs and for public use
- Taking advantage of and treating existing ground water seepage. The Tawa NIMT rail tunnel for example produces about a third of Wellington's emergency water needs.
- Exploring the possibility of installation of small scale desalination plants especially around the eastern and southern suburbs of Wellington where normal water supply operations will take longer to be restored.

The Water Services Emergency Preparedness Group (WSEPG) is working closely with Wellington Lifelines Group and the Wellington Regional Emergence Management Office in the delivery of projects to improve utility resilience.

Wastewater system and sewage disposal

WSEPG has developed a regional plan that identifies potential options available for the disposal of sewage following a major earthquake.

The options identified in the short term following an event will require residents to bury their waste on site, where possible, or contain it for collection and disposal by the authorities. Other options include:

- The procurement/installation of long drops and composting toilets
- The procurement and distribution of port-a-loos to hospitals, welfare centres and within communities for public use
- The procurement and distribution of chemical toilets to households.
- A composting toilet system, which is currently under trial and, if successful, could assist in the management of sewage in an emergency.

Investigations are continuing to identify the risk and options available within areas of each of the respective cities in the region.

5.2.4. Transport / access

What is the transport sector doing for mitigation and preparation?

Wellington's state highway and local road network currently has low to medium resilience particularly due to the limited alternative routes in, out and around the city. However important work has been completed over the last decade. The NZ Transport Agency along with Wellington City Council, Hutt City Council, Upper Hutt City Council, Porirua City Council and Kapiti Coast District Council has invested in preventative maintenance and seismic strengthening work to help reduce critical vulnerabilities across the region's transport networks.

What has been achieved to date?

Key work programmes completed have included:

Wellington City

- Strengthening of bridges on SH1 Shell Gully and the SH1 Thorndon Overbridge (Wellington Urban Motorway)
- A $50 million upgrade of the Terrace Tunnel to improve the safety of this tunnel during an emergency.
- Ngaio Gorge. A decade long programme of road risk mitigation works has been completed to improve the seismic stability of this route which could be a critical corridor in an emergency.
- Churchill Drive. Road risk mitigation including road retaining wall improvements and preventative maintenance has been conducted at Churchill Drive (Churton Park) which is also a potential strategic recovery corridor.

Porirua City

- Preventative maintenance on the Paekakariki Hill Road to mitigate critical vulnerabilities along the corridor
- Seismic strengthening of SH1 Pukerua Bay Rail Overbridge

Hutt City

- Preventative maintenance at the Connolly Street Stopbank to realign road and raise the stop bank to reduce the risk of flooding in low lying areas of Hutt Valley that may flood following natural event.

Upper Hutt City

- Seismic strengthening SH2 Pakuratahi River Bridge
- Strengthening of the Silverstream Bridge.

Kapiti Coast

- Seismic strengthening SH1 Waikanae River Bridge and SH1 Otaki River Bridge

Work that is currently underway includes

- Work is about to begin on reinforcing the portals of the Mt Victoria Tunnel, strengthening of the Karori Tunnel Portals and nearby banks is nearly complete.
- In the 2012-15 National Land Transport Programme funding has also been allocated to begin construction on the MacKays to Peka Peka section of the Kapiti Expressway and to investigate improved connections between Petone to Grenada and between SH2 and SH58, with an aim of improving resilience and creating alternative routes.

What still needs to be done?

In the medium term (2015 and beyond) major investment is planned to construct Transmission Gully and work on the other Wellington Northern Corridor Roads of National Significance (RoNS) projects. The RoNS programme will strengthen the resilience of State Highway 1 out of Wellington, and the connection between the inner city and the Wellington Regional Hospital in Newtown. Investment is also planned for further work on connections between SH1/ SH2 and SH58 to improve connectivity in and out of the Hutt Valley.

NZTA's programme of future investment will be targeted to address the most significant regional vulnerabilities where are the most substantial improvements to restoration times. The NZTA is now beginning work with local authorities in the Wellington metropolitan region to develop a substantial package of network resilience activities to mitigate risks identified in this report.

Port

CentrePort's infrastructure used for the berthing of vessels and transfer of cargoes includes wharves, seawalls, pavements and cargo handling equipment. The port's facilities and infrastructure are predominantly located on areas of reclaimed land.

CentrePort understands the importance of its infrastructure in facilitating recovery operations following a significant natural disaster event and has as a key strategy the maintenance of a Business Continuity Plan which is subject to regular update and review.

Post-disaster, based on the port's Business Continuity Plan, assessments by CentrePort will be able to identify wharves and pavements which are, or are likely to be, the most suitable for

mooring ships and handling of emergency recovery cargo. This will have important implications for the planning of the type and size of ship which can be berthed at Wellington after a major earthquake

The Airport

An engineering study for Wellington Airport shows that some areas of the runway will incur damage in a major earthquake. Following any seismic event above MM 4.1 on the airport's accelerometer, an infrastructure assessment will be undertaken. Subject to that assessment, the runway is presently expected to be operational for helicopter and military aircraft within hours. Airport engineers are now undertaking further assessment on what is likely to be required to reinstate full operations after a major earthquake.

The rail network

KiwiRail is carrying out the following work regarding the improvement of seismic resilience in the region:

- Asset studies recently carried out on slope stability risk in the Wellington area have resulted in a funding stream and work programme to lower these risks. Slope stability is a key consideration in weather and seismic resilience. This work will be carried out over multiple years.
- Track and structure renewals, carried out in accordance with KiwiRail's asset management system, are to current design standards, taking earthquake and flood risk into consideration.
- Contingency planning for an emergency event is continually updated, company-wide. For example, emergency bridging stock is available, and resources outside the region are in place to aid recovery.

5.3. Planning transport access responses to a major event

Work carried out in during September and October 2012, facilitated by the Wellington Lifelines Group and the Wellington Region Emergency Management Office with the respective transport asset owners has highlighted the means by which food, fuel and freight would be transported into and around the region following a major earthquake, and the principles of recovering transport links. The Wellington region was considered in five "areas", with key findings as follows: -

<u>Wellington Port, CBD and the airport</u>

This area is at the start of the food/materials delivery supply chain, assuming supply by sea into Wellington Port, but the end of the lifeline chain for water and electricity supply. Water and power availability will present additional challenges in this area for both community and lifelines response and recovery. The following concepts have been developed for transport relating to this area: -

- As a first priority, create an access corridor along the route from the airport to Wellington Hospital, and the port, and from there to the 'Wellington West' area.
- The airport is central for rapid response, evacuation and urgent/high-priority supplies.

Centreport have achieved an average of 25 to 30 containers handled an hour using existing container cranes. If these cranes are unavailable (no power, jumped off rails, collapse or equipment failure), it should be expected that containers are delivered by conventional ships with onboard cranes that would be used for off-loading, at a rate of six to 10 containers each per hour. Additional supplies could be delivered via 'roll on roll off' vessels such as quarter deck car carriers.

'Wellington West'

The 'Wellington West' area has been assumed to incorporate Johnsonville at its northernmost extreme, the Ngauranga Gorge, and the Wellington City suburbs west of the Wellington fault line (i.e. Crofton Downs, Khandallah, Karori). The fault line was chosen not just for the likelihood of its rupture (which represents only one earthquake scenario for the region) but because adjacent to the faultline is a steep hill (from Wadestown to Kelburn) which must be traversed to gain access to the other side of the faultline. This presents a natural barrier for transport access in the region, particularly following a major local earthquake, and is therefore a logical boundary for the eastern side of the 'Wellington West' area.

The key actions following an earthquake will be to establish which are the most viable routes in this corridor for restoring access from Wellington City through to Porirua and the Hutt Valley. This will be achieved through early reconnaissance operations and through co-operation between NZTA, WCC, KiwiRail and key contractors, as identified in the 'Thorndon Critical Area plan for road access Ngauranga to Thorndon (May 2012)'. A concentration of available resources will be given to the best access route once this has been identified.

Restoring an access route between Johnsonville and the Karori tunnel area will be an early requirement. For improved connectivity between CentrePort and other Wellington metropolitan areas, the recovery of the Hutt Road between Ngauranga and Thorndon will be vital.

Access via the Crofton Downs-Wilton-Wadestown route is likely to be the route opened earliest (even though with restricted capacity, being a narrow road). Access into Karori is likely to be through the Crofton Downs-Wilton-Karori route.

Porirua and Tawa

Priorities for restoring transport access into and around the Porirua and Tawa areas will be, with top priority first: -

- Restore access, via Johnsonville, to the Wellington Harbour area (likely to take, in total, around three weeks). Whilst this work progresses:
- Restore access around the Porirua and Tawa areas.
- Until access to Wellington Harbour is achieved, create a barging access into Titahi Bay for supply of food and materials to the Porirua and Tawa area.
- Start earthmoving operations to re-open State Highway 1, starting at Pukerua Bay and working north towards Paekakariki.
- Investigate the viability of using the Old Coach Road over the Belmont Hills towards the Hutt Valley.

The Hutt Valley

Food, fuel and materials will be transported into the Hutt Valley via the harbour foreshore, via CentrePort or from a ship moored in the harbour off-loading direct to barges, supplemented by air delivery and 'four wheel drive transport.

The long-term priority will be on restoring access from Wellington via State Highway 2, Petone to Ngauranga. NZTA's SH2 contingency plan estimates it will take eight to 12 weeks to restore truck access along this corridor. Restoring access over the SH2 Rimutaka Hill Road and through SH58 Haywards is anticipated to take 'more than three months'. Therefore getting direct transport access to the Hutt Valley without any use of State Highway 2 or State Highway 58 should be developed for the short to medium term of the response and recovery.

Fuel deliveries through the Seaview area remain critical for the response and recovery activities of the region, and access through this area requires particular attention. The Seaview Marina will probably present the most viable location for loading/unloading barges and landing craft.

Within the Hutt Valley, effort would be concentrated on establishing a route from Seaview and Petone to Te Marua. As SH2 is likely to be heavily affected in this area, the local road route would provide the most feasible access option. The most likely difficulties in this corridor would be the road structures across the Waiwhetu Stream in the Seaview area, the road at Taita Gorge and the road at Brown Owl.

Kapiti Coast

Due to likely large landslips south of Paekakariki on State Highway 1, on the Paekakariki Hill Road and the Akatarawa Road, transport access to the Wellington Metropolitan area will be cut by land. Food, fuel and materials will be transported into the Kapiti Coast via State Highway 1 and via the rail network from the north. Earthmoving operations are likely to be staged from the Kapiti Coast area for restoring land access to the Wellington metropolitan area and a large logistical operation will be based at Paraparaumu airport to manage helicopter access around the region.

Although time frames for restoring access from further north (the Manawatu area) can only be broadly assumed as a matter of five to 20 days, this does not change the strategy of securing access along the State Highway 1/rail network spine as the most convenient, and probably highest-volume access route.

It is recommended that further planning be carried out by the other lifeline utilities and other sectors on the basis of the findings of the above item of work.

5.4. Limits to infrastructure resilience

It should be noted that, no matter what seismic upgrades are made to Wellington lifeline utility networks, the earthquake risk cannot be eliminated. The topography, which determines the layout of the utilities, and the seismic nature of the region, mean that whilst resilience can be increased, vulnerabilities will remain.

5.5. Planning for an emergency event

Wellington lifeline utilities regularly review their business continuity and emergency response plans. Such reviews are being updated in the context of learning from the recent Christchurch earthquakes. Emergency response planning is being carried out by affected utilities for locations identified as critical utility infrastructure areas. To date, reviews have been carried out on Thorndon and the Petone-Seaview areas.

Overarching the above plans is the Ministry of Civil Defence and Emergency Management "Wellington Earthquake National Initial Response Plan" which outlines actions in the first few days of response after a major earthquake.

Of course earthquakes are not the only natural hazard facing the region, so plans are also in place for other hazards such as tsunamis and floods.

5.6. Future WeLG co-ordination work on improving resilience

Regarding co-ordination of effort on understanding better restoration times, and on ensuring that infrastructure resilience efforts are co-ordinated, the work undertaken by WeLG and the various lifeline utilities to understand the vulnerabilities of the region's own networks and assets has led to the identification of the following current and future projects:

- **Transport access** is a key issue that underpins the operations of many lifeline utilities. WeLG is leading a new project to better understand the nature of land access vulnerabilities, which will build on recent and continuing work being carried out by NZTA and the various roading authorities in the region. Preliminary findings of this project have been included in Section 5.3 of this report.
- Further work on the **Priority Sites for Utility Restoration** project will lead to a greater understanding of interdependencies of the various lifeline utilities, and provide a better platform to plan for a range of hazard events.
- Further work on the **Critical Areas** set of projects, including more work on the Thorndon and Seaview 'Critical areas'.

It is anticipated that WeLG will co-ordinate the following potential future projects/actions:

- Create a better understanding of **emergency regional fuel supply** arrangements.
- Create a better understanding of the **emergency distribution of fuel supply to telephone cell sites**.
- Undertake additional **sector planning activities** in regards to improving earthquake response and recovery times, for example to ensure electricity lines-truck access to parts of the Wellington metropolitan area following an earthquake.

All of the above work will be carried out in conjunction with the final phase of the *It's Our Fault* project led by GNS Science. This project will continue to actively engage with lifeline utility providers, regarding the effects of a rupture of the Wellington fault.

WeLG is working with the Wellington Regional Emergency Management Office to co-ordinate the above work with the organisations involved.

5.7. Personal resilience preparedness

Although this report is about the resilience of our lifelines and infrastructure, it is important to note that personal preparedness is critical as, in a major disaster, there will be significant gaps in the performance of our infrastructure. However, the impact will be lessened considerably by people and, by inference, their families and neighbourhoods, being prepared.

Preparing for a disaster is easy. The simple actions of having a conversation with everyone in your household about how they will connect after an event, storing basic emergency items around the house and knowing which neighbours can lend a hand or need a hand can prove invaluable. Christchurch demonstrated both the power of communities looking after one another and the importance of ensuring no one 'falls through the gaps'. The Wellington Region Emergency Management Office dedicates the majority of its efforts and resources to helping people and communities take responsibility for their own their preparedness.

This is accomplished through proactive engagement with the public, private and health sectors, NGOs, educational institutions and a wide array of community groups to develop appropriate preparedness outcomes; this is Community-Driven Emergency Management (CDEM). Resilience examples include building capacity across the 4Rs (Reduction, Readiness, Response and Recovery) through training CDEM Volunteers, facilitating Community Response Plans and Business Continuity Plans for Small and Medium Enterprises, ensuring agencies responsible for vulnerable communities have strong links to their clients and many other activities that increase connectedness of our people and foster co-operation.

To assist individuals, families and neighbourhoods, the Wellington Region Emergency Management Office has produced a simple guide called *It's Easy, Get Prepared for an Emergency*. This document forms the basis of engagement at this level and includes advice on:

- Understanding risks and hazards in your community;
- Family meeting places;
- Arrangements for collecting children;
- Knowing the location of utilities;
- Determining evacuation routes;
- Knowing where you can find information and advice in an emergency;
- Knowing what warning systems mean;
- Knowing where local Civil Defence Centres are;
- Knowing your neighbours;
- Having sufficient water for emergencies;
- Having survival items (food, torch, radio, medications etc); and,
- Having a readily accessible getaway kit (for home and work)

5.8. Response planning

In addition to the vital role of engagement to build resilience in our people, families, neighbourhoods, businesses, and ultimately our communities, the Wellington Region Emergency Management Office also has a key role in building capacity and systems to enable our communities to respond effectively during a disaster.

Section 64 of the Civil Defence Emergency Management Act 2002 states that a local authority must plan and provide for civil defence emergency management within its district; and must

ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency. To facilitate this, the Wellington region has a network of Emergency Operations Centres (EOCs) in Wellington, Hutt City, Porirua, Paraparaumu, and Masterton as well as an Emergency Coordination Centre (EOC) in Wellington City. These facilities are further supported by a network of Civil Defence Centres and Incident Management Teams reaching even further into the community

This network acts as a central command and control facility responsible for directing and co-ordinating the actions of council, emergency services and other groups conducting emergency response operations in a disaster event. Its success is determined by its ability to understand and influence the "big picture" and its main functions are to: gather and analyse data, make decisions that protect life and property, mitigate the effects of the disaster, provide comfort, maintain continuity, and facilitate the flow of information to and from all response agencies and individuals concerned.

The Wellington region ECC/EOCs functions, according to Co-ordinated Incident Management System (CIMS) principles, comprise the following teams: Planning/Intelligence, Operations, Logistics, Welfare, Lifelines and Public Information Management (PIM).

In anticipation of emergency operations, the Wellington Region Emergency Management Office places considerable emphasis on building strong relationships with key response partners, particularly the Ministry of Civil Defence Emergency Management, the NZ Defence Force, emergency services, government departments, NGOs, infrastructure companies and groups capable of helping during an emergency. The Wellington Region Emergency Management Office conducts regular response training and also produces and exercises various plans and frameworks designed to promote speedy and effective response efforts.

6. Resilience investment

6.1. General resilience investment issues

Lifeline utilities make decisions on future investments based on a number of issues, with trade-offs made against a variety of competing investment factors. Investment trade-offs in their nature are similar for the majority of the lifeline utilities. Utility resilience to hazards is only one part of the equation of maintaining a utility, with other considerations such as day-to-day maintenance, population size and location changes and usage patterns all having an effect on network investment decisions. Resilience investment cannot be viewed in isolation, as the impacts of all of the above issues will affect the way in which a utility invests in upgrades to its network. All investments must be made with the impact on cost to the shareholders and consumer in mind.

6.2. Regulatory investment issues

Some of the Wellington Lifeline utilities are regulated monopolies. Wellington Electricity notes that it is a regulated monopoly Lines Business and is subject to Price Quality regulation under Part 4 of the Commerce Act. Under the current Default Price-Quality path price (DPP) increases are limited to the rate of inflation although Wellington Electricity is able to apply for a Customised Price-Quality Path (CPP) if the DPP does not meet its individual circumstances. The regulatory framework encourages WELL to consult with customers and carefully consider the price-quality trade-off for what level of customer funded resilience investment is warranted to improve resilience. A significant programme of work is still required to engage with the wider Wellington community to discuss the value with the customers of paying for some smaller investments ahead of an event for stronger infrastructure rather than face higher costs and longer delays post event due to the weaker infrastructure remaining. It is important to strike the right balance that allows affordability, quick economic recovery and return to community activity following a major event.

7. Conclusions and Recommendations

7.1. Conclusions

Technical studies have been conducted by various Wellington lifelines organisations over recent years. Viewed together, these studies clearly demonstrate the vulnerability of Wellington's infrastructure to a large Magnitude 7.5 earthquake.

Some examples of potential restoration times are provided in section 3. It should be noted, however, that summarising restoration times involves a range of assumptions and uncertainties. This means that figures should be regarded as being indicative only.

An earthquake involving rupture of the Wellington fault would be a worst-case event, with the likelihood of occurrence being 10% within the next 100 years. Active planning for such an event (or other earthquake events of lower magnitude but collectively a higher likelihood) is prudent, and the Wellington lifelines utility organisations are continuing to work proactively on this issue.

Planning for such an event is a task for the Wellington Region Emergency Management Office (WREMO), alongside the Wellington lifelines organisations that are responsible for the various items of infrastructure. Specifically, work continues on better understanding these vulnerabilities, and the potential consequences to the population. Also, discussions are underway regarding logistical arrangements that may be put in place to get essential supplies to Wellington by means other than road – by air and sea.

Investment decisions on making infrastructure more robust cannot be taken in isolation from investment decisions on other aspects of utility upgrades. Infrastructure upgrades are ongoing, both through business-as-usual maintenance and renewals programmes and through specific seismic-upgrading projects.

7.2. Recommendations

The Wellington Lifelines Group:

1. Recommends that the CDEM Group Joint Committee

    a. Notes the report;

    b. Directs WREMO to incorporate the findings of the report into planning assumptions;

    c. Recommends that local councils and their relevant lifelines infrastructure entities incorporate the findings of the report into their infrastructure and civil defence planning; and

    d. Encourages other lifeline utilities to incorporate the findings of the report into their infrastructure planning.

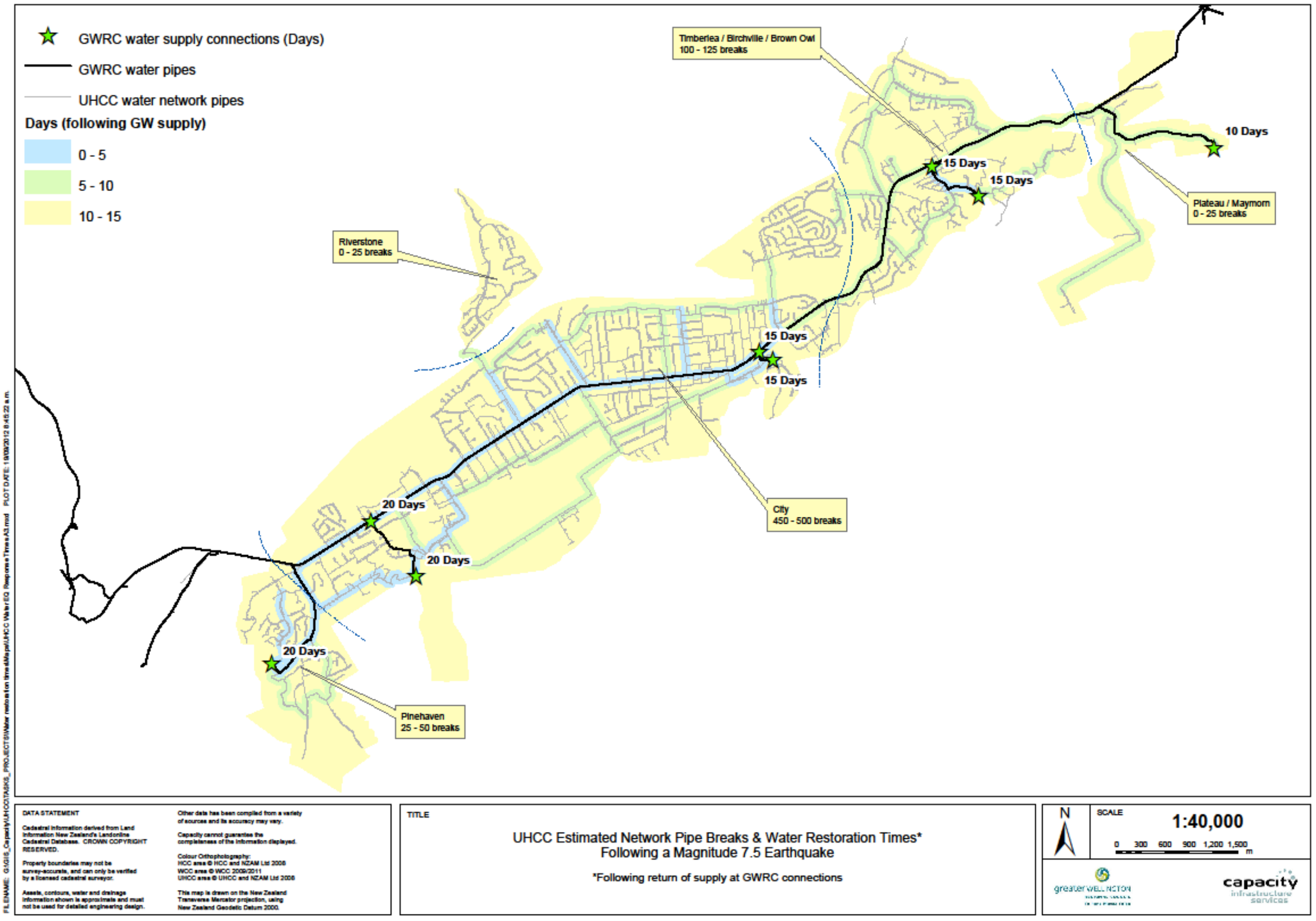
2. Tasks the Wellington Region Emergency Management Office to promote a high level of preparedness in the community to bridge the gap between a disaster and the resulting emergency management response.

Appendices

Appendix 1 – Water restoration times mappings

Appendix 2 – Road seismic vulnerability mappings

Appendix 1 – Water restoration times mappings


GWRC water supply connections (Days)
GWRC water pipes
UHCC water network pipes
Days (following GW supply)
0 - 5
5 - 10
10 - 15
Timberlea / Birchville / Brown Owl
100 - 125 breaks
10 Days
15 Days
15 Days
Plateau / Maymorn
0 - 25 breaks
Riverstone
0 - 25 breaks
15 Days
15 Days
20 Days
20 Days
20 Days
City
450 - 500 breaks
Pinehaven
25 - 50 breaks
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DATA STATEMENT
Cadastral information derived from Land Information New Zealand's Landonline Cadastral Database. CROWN COPYRIGHT RESERVED.
Property boundaries may not be survey-accurate, and can only be verified by a licensed cadastral surveyor.
Assets, contours, water and drainage information shown is approximate and must not be used for detailed engineering design.
Other data has been compiled from a variety of sources and its accuracy may vary.
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Colour Orthophotography:
HCC area © HCC and NZAM Ltd 2008
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This map is drawn on the New Zealand Transverse Mercator projection, using New Zealand Geodetic Datum 2000.
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UHCC Estimated Network Pipe Breaks & Water Restoration Times*
Following a Magnitude 7.5 Earthquake
*Following return of supply at GWRC connections
N
SCALE
1:40,000
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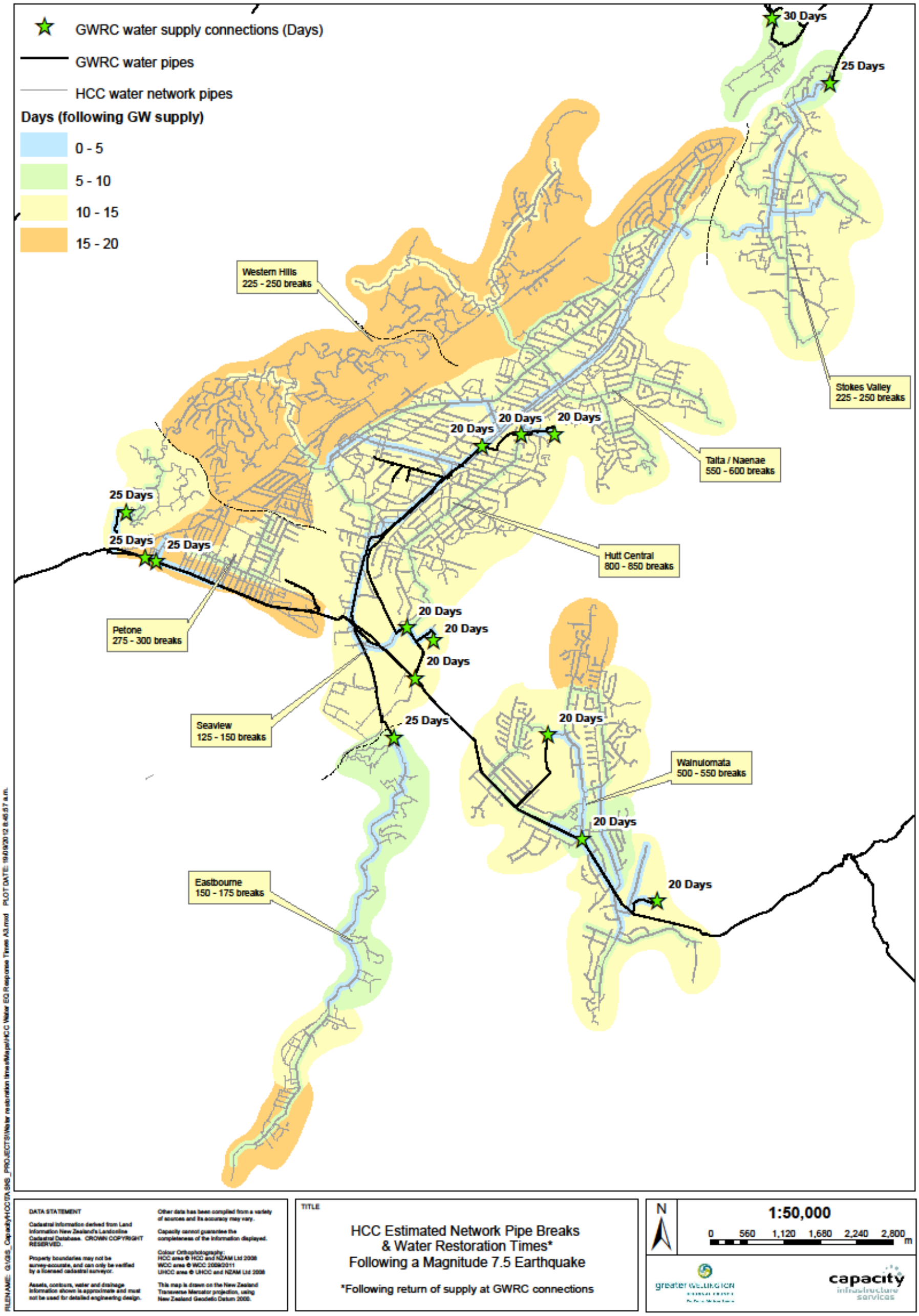
greaterWELLINGTON
capacity
infrastructure services


GWRC water supply connections (Days)
GWRC water pipes
HCC water network pipes
Days (following GW supply)
0 - 5
5 - 10
10 - 15
15 - 20
30 Days
25 Days
Western Hills
225 - 250 breaks
Stokes Valley
225 - 250 breaks
20 Days
20 Days
20 Days
Tawa / Naenae
550 - 600 breaks
25 Days
25 Days
25 Days
Hutt Central
800 - 850 breaks
Petone
275 - 300 breaks
20 Days
20 Days
20 Days
Seaview
125 - 150 breaks
25 Days
20 Days
Wainuiomata
500 - 550 breaks
20 Days
Eastbourne
150 - 175 breaks
20 Days
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DATA STATEMENT
Cadastral information derived from Land Information New Zealand's Landonline Cadastral Database. CROWN COPYRIGHT RESERVED.
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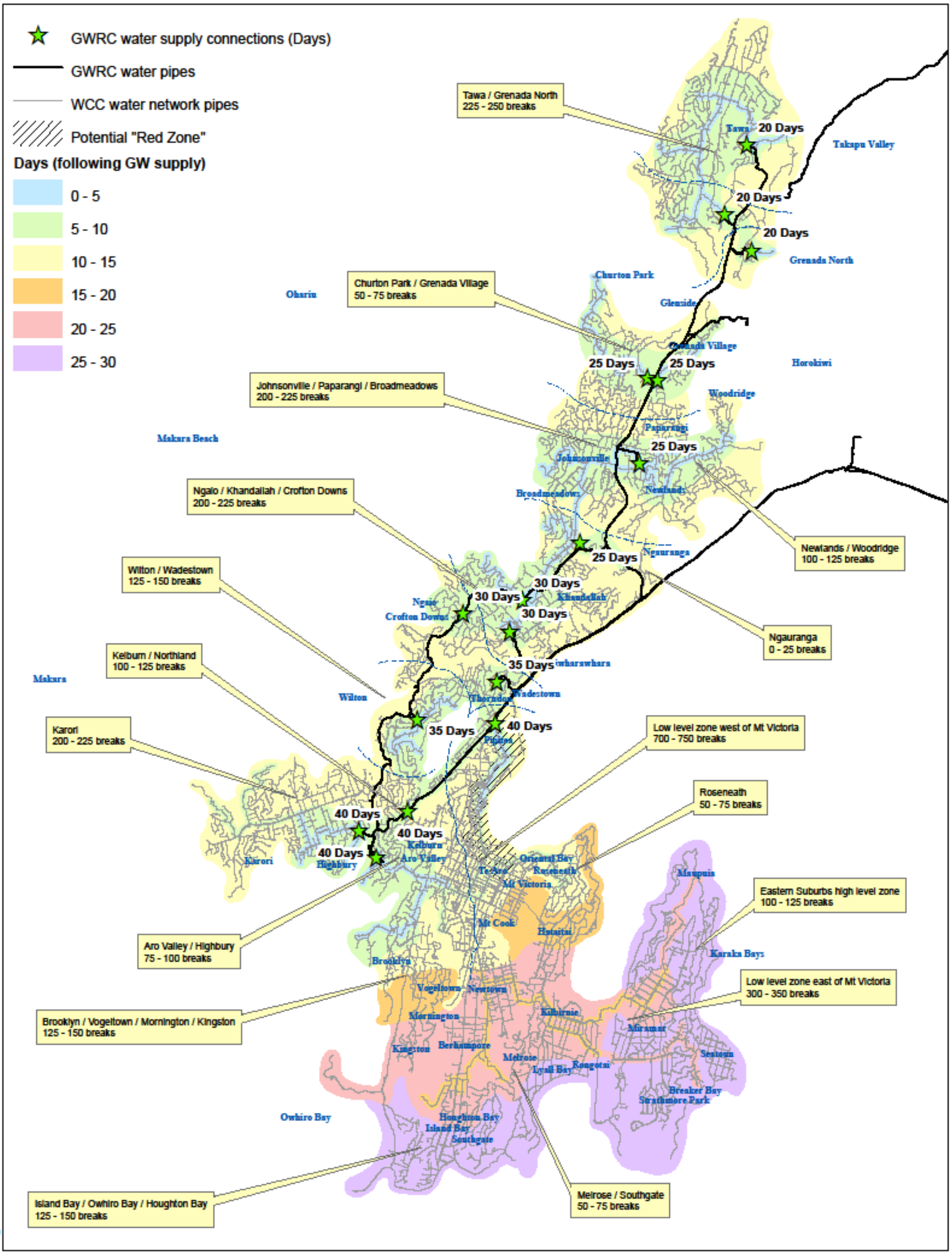
UHCC area © UHCC and NZAM Ltd 2008
This map is drawn on the New Zealand Transverse Mercator projection, using New Zealand Geodetic Datum 2000.
TITLE
HCC Estimated Network Pipe Breaks
& Water Restoration Times*
Following a Magnitude 7.5 Earthquake
*Following return of supply at GWRC connections
N
1:50,000
0 560 1,120 1,680 2,240 2,800 m
greater WELLINGTON
capacity infrastructure services


GWRC water supply connections (Days)
GWRC water pipes
WCC water network pipes
Potential "Red Zone"
Days (following GW supply)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
Tawa / Grenada North
225 - 250 breaks
Churton Park / Grenada Village
50 - 75 breaks
Johnsonville / Paparangi / Broadmeadows
200 - 225 breaks
Ngaio / Khandallah / Crofton Downs
200 - 225 breaks
Wilton / Wadestown
125 - 150 breaks
Kelburn / Northland
100 - 125 breaks
Karori
200 - 225 breaks
Aro Valley / Highbury
75 - 100 breaks
Brooklyn / Vogeltown / Mornington / Kingston
125 - 150 breaks
Island Bay / Owhiro Bay / Houghton Bay
125 - 150 breaks
Newlands / Woodridge
100 - 125 breaks
Ngauranga
0 - 25 breaks
Low level zone west of Mt Victoria
700 - 750 breaks
Roseneath
50 - 75 breaks
Eastern Suburbs high level zone
100 - 125 breaks
Low level zone east of Mt Victoria
300 - 350 breaks
Melrose / Southgate
50 - 75 breaks
20 Days
25 Days
30 Days
35 Days
40 Days
Takapu Valley
Grenada North
Churton Park
Glenside
Grenada Village
Horokiwi
Woodridge
Paparangi
Johnsonville
Newlands
Broadmeadows
Ngauranga
Khandallah
Ngaio
Crofton Downs
Thorndon
Wadestown
Pipitea
Kelburn
Aro Valley
Highbury
Karori
Oriental Bay
Roseneath
Te Aro
Mt Victoria
Mt Cook
Hataitai
Maupuia
Karaka Bays
Brooklyn
Vogeltown
Newtown
Mornington
Kilbirnie
Miramar
Kingston
Berhampore
Melrose
Lyall Bay
Rongotai
Seatoun
Breaker Bay
Strathmore Park
Houghton Bay
Island Bay
Southgate
Owhiro Bay
Wilton
Makara
Makara Beach
Ohariu
DATA STATEMENT
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TITLE
WCC Estimated Network Pipe Breaks
& Water Restoration Times*
Following a Magnitude 7.5 Earthquake
*Following return of supply at GWRC connections
N
1:65,000
0 730 1,460 2,190 2,920 3,650 m
greaterwellington
capacity infrastructure services
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Appendix 2 – Road seismic vulnerability mappings

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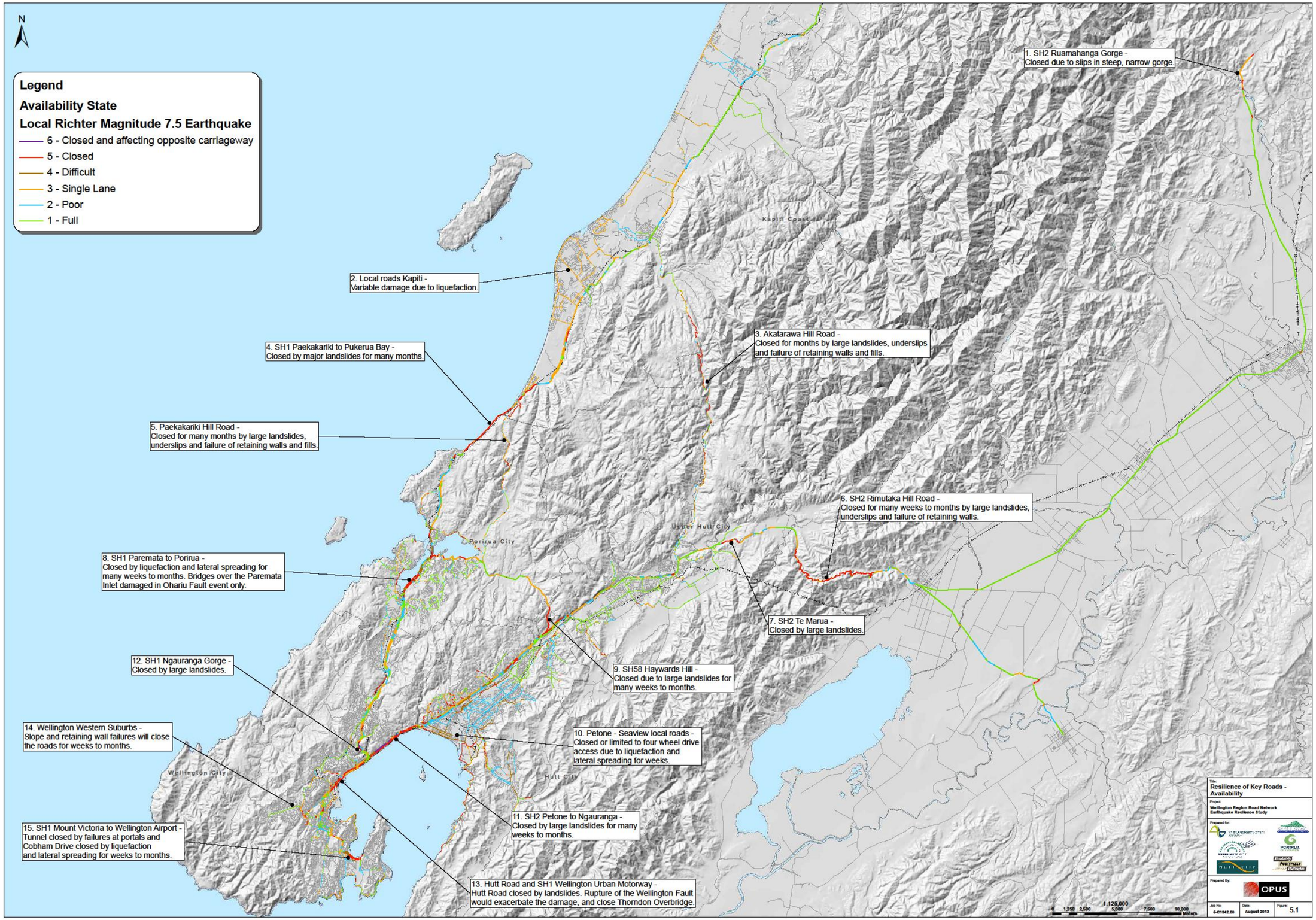

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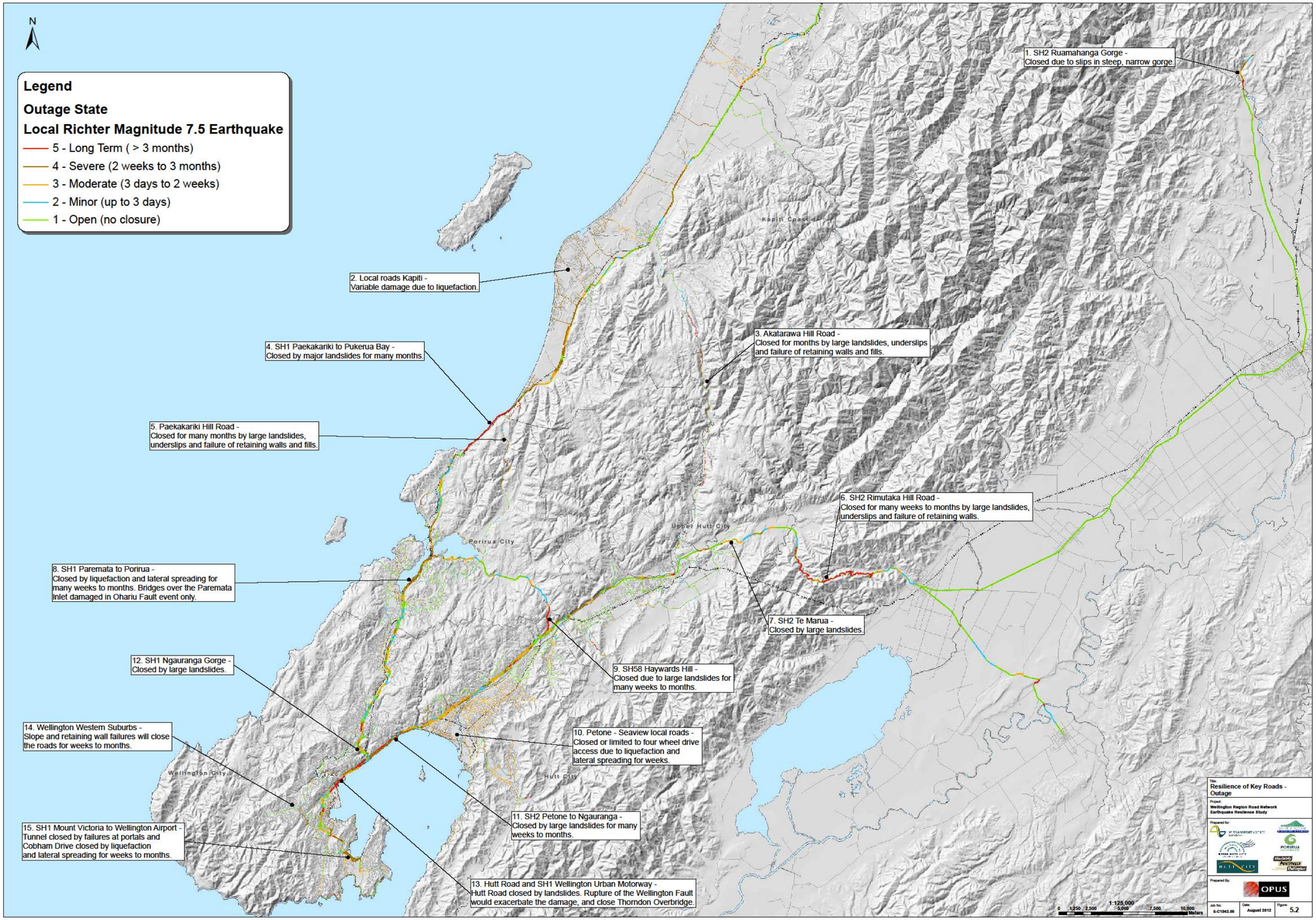

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