INFRASTRUCTURE RESTORATION AND RESILIENCE AFTER NATURAL DISASTERS- WHAT CAN WE LEARN FROM CHRISTCHURCH, PACIFIC ISLAND AND AUSTRALIAN EXPERIENCES ?

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ABSTRACT

The Christchurch experience has challenged the New Zealand water industry in many ways, both in initial response, subsequent recovery and the on-going rebuild program. The urgent initial need for making safe, assessing damage to water and wastewater infrastrcuture, restoration of essential services and then planning and building more resilient infrastructure have all presented new paradigms.

Pacific Island nations have also recently faced similar challenges posed by significant natural disasters. The 2009 tsunami in Tonga and Samoa, the 2007 cyclone in Niue and recent floods in Fiji have meant that infrastructure managers have also had to deal with similar urgent tasks, often with limited funds available. Similarly, Queensland suffered significantly in 2011 from floods in Brisbane and cyclones in North Queensland.

These sorts of natural disasters are also possible in New Zealand. As infrastructure managers, how would we respond in such events? What can we learn from what has happened in these Pacific Island nations and Australia that is relevant for us here? How relevant is the Christchurch experience ?

This paper looks at real case studies from all three locations to understand what happened to water and wastewater infrastructure during these natural disasters and how managers coped with the various challenges that arose. Comparisons are made between the case studies with the intent of providing delegates who are responsible for water and wastewater infrastructure management some perspectives on what may constitute good risk management and response practice.

1. INTRODUCTION

A number of significant natural disasters have seriously challenged water and wastewater infrastructure managers across New Zealand, Australia and also the South Pacific in the last 3 years.

Be it the Christchurch earthquakes of 2010 and 2011, the Black Saturday bushfires in Victoria in 2009, tsunami in Samoa and Tonga of September 2009 or the impacts of Cyclone Yasi mainly in North Queensland in February 2011, each of these disasters have disabled key water supply and wastewater infrastructure.

The provision of safe and reliable drinking water and the removal and treatment of wastewater are key functions of our sector, our *raison d'etre*. Their restoration as soon as possible after such a natural disaster not only restores anticipated levels of service for these basic necessities, but is also a key means of preventing the outbreak of water borne diseases after such events. Such rapid restoration is an expectation in a first world country such as ours.

What is clear from an analysis of these events is that whilst not a lot can be done obviously to prevent the disaster itself, the amount of good planning, risk management and contingency planning significantly influences the time taken to restore service.

With the possible exception of the Black Saturday Bushfires in Victoria, all of the above natural disasters are very real possibilities in New Zealand.

2. CASE STUDY A - CHRISTCHURCH 2010-2011 EARTHQUAKES

2.1. DISASTER DETAILS

Much of the data and detail on the Christchurch earthquakes has already been published and shared with the WaterNZ fraternity. On the assumption that a lot of this information is already known and understood only brief coverage of it will be given here.

A shallow magnitude 7.1 earthquake occurred on 4 September 2010 on a previously unknown fault near Christchurch. Widespread damage resulted throughout the city and the surrounding area. A second shallow earthquake, magnitude 6.3, occurred closer to Christchurch on 22 February 2011. There were 181 deaths. Damage from this earthquake significantly exceeded the September event, including collapse of many buildings.

Underground infrastructure assets (pipes and cables) were particularly impacted. Unreinforced masonry structures and a number of reinforced concrete structures, including many owned by lifeline utilities, were also damaged.

2.2. CCC RESPONSE

2.2.1. Initial Response

After the February earthquake, more than 260,000 people were without water, about 40% of the city was without power and as a result, much of the city did not have a functioning wastewater system. No wastewater arrived at the Bromley Treatment plant in the 24 hours after the earthquake.

The resources inputs in the initial response phase were significant including the following -

1. Dealing with the contamination risk posed to the groundwater supply of a possibly broken and leaking wastewater system

2. Providing supply of water to areas where the system was down

3. Providing some form of operating wastewater system, albeit with , in some areas, significantly diminished levels of service

4. Managing the public’s expectation and risk exposure about the emergency discharge of raw sewage to the Avon and Heathcote Rivers and the city’s beaches.

5. Coping with the demand on callouts for system repairs etc.

Figures 1 and 2 illustrate this increase in demand for this work for the water supply and wastewater network respectively with significant differences apparent in the volume and timing of these requests.

Figure 1 - Water Supply System Works Requests

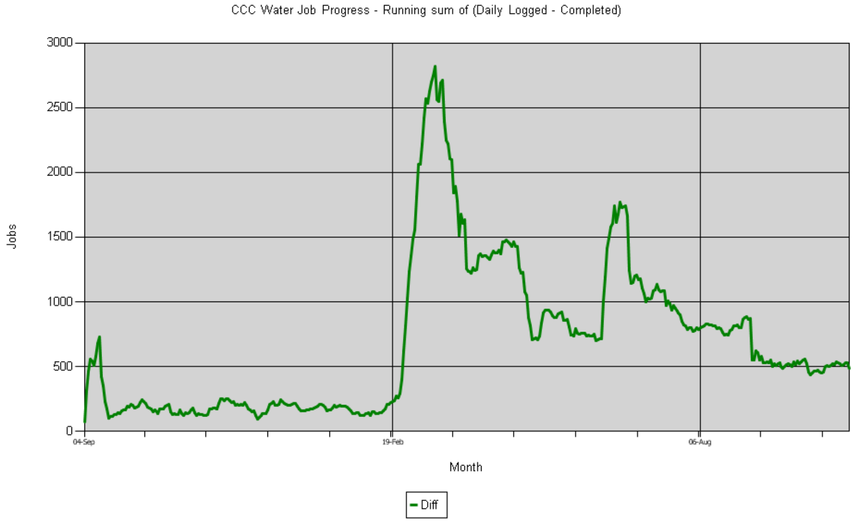
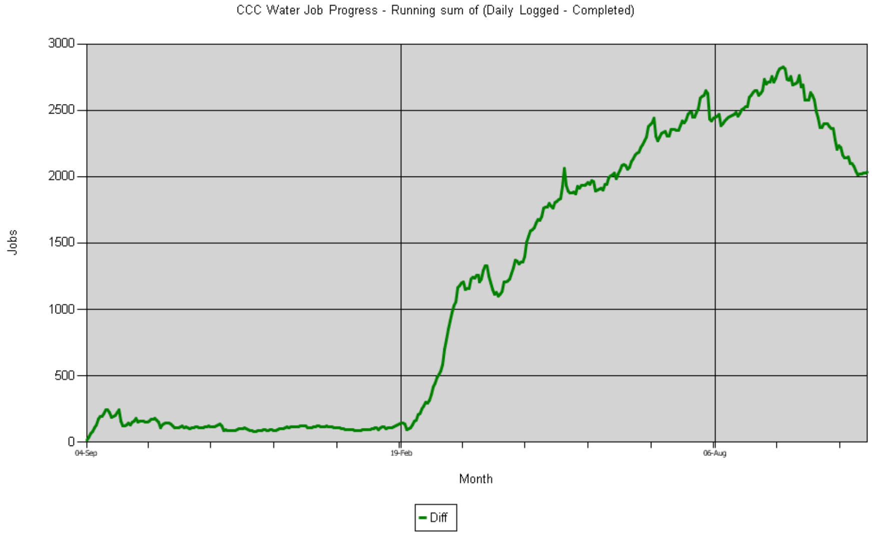


Figure 2 - Wastewater System Works Requests



2.2.2. Repair and Recovery

Significant repair works are now underway via the SCIRT alliance. Estimates of the costs of horizontal infrastructure are in the order of $2Bn. It is currently planned that this work be completed within a 5 year timeframe.

Baseflows due to groundwater infiltration have been estimated to have increased by up to 50% due mainly to shifts in the groundwater table and deterioration of the pipe network. Rainfall dependent inflow and infiltration has also increased significantly in some areas. Both of these present significant challenges to designers of wastewater system works.

Increasing the resilience of the infrastructure is a key focus of the on-going work. This has involved the following

- rapid review and renewal of various infrastructure design standards

- Consideration and implementation of new technologies considered to be more resilient such as pressure sewers and vacuum sewers.

- Implementation of new pipe inspection technologies

2.2.3. Long Term Implications

The “retreat” suburbs in the eastern area adjacent to the Avon River. Relocation of these people to alternative parts of the city challenges the infrastructure planners when the east-west nature of both the city’s wastewater and water supply are considered.

Having all the city’s wastewater going to the one plant that is located within the high liquefaction risk zone is also a particularly challenging question.

2.3. KEY “TAKE-AWAY POINTS”

Summarising a few of the key points arising,

1. Being able to provide safe water in a hurry is seen as critical during the initial response phase. A large number of low-volume distribution points is considered the most appropriate arrangement.

2. Contingency for critical assets is very important.

3. Storage of key mapped information in multiple forms and at multiple sites is important

4. Coordination across different Council response and repair activities and also with other utilities agencies is key.

5. Four wheel drive vehicles are an essential part of the access requirements for site inspections

6. Keeping messages contained in media releases and public information as simple as possible is required.

7. Be flexible to change targets to drive recovery progress

3. CASE STUDY B - VICTORIAN BLACK SATURDAY BUSHFIRES

3.1. DISASTER DETAILS

After a period of prolonged drought and weeks of oppressive heat on Saturday February 7 2009, extreme fire danger conditions existed. Background temperatures near Melbourne reached 46 degrees C with north-easterly winds in excess of 100km/hr with relative air humidity at only 4%. A cool front then hit the state early in the evening, bringing with it cooler temperatures but gale-force winds in excess of 120km/hr. This wind change caused fires that had started earlier in the day, either by arson, fallen power lines or lightning to become massive firefonts that burned with speed and ferocity towards towns that had earlier escaped the fires.

By the end of the day, 173 people had died, 120 of them in a single firestorm and more than 2000 houses and 3500 other structured had been destroyed, with thousands more damaged. The main firestorm in the Kinglake- Marysville area, the cause of the majority of deaths was estimated to release as much energy as that released by 1500 Hiroshima-sized atomic bombs.

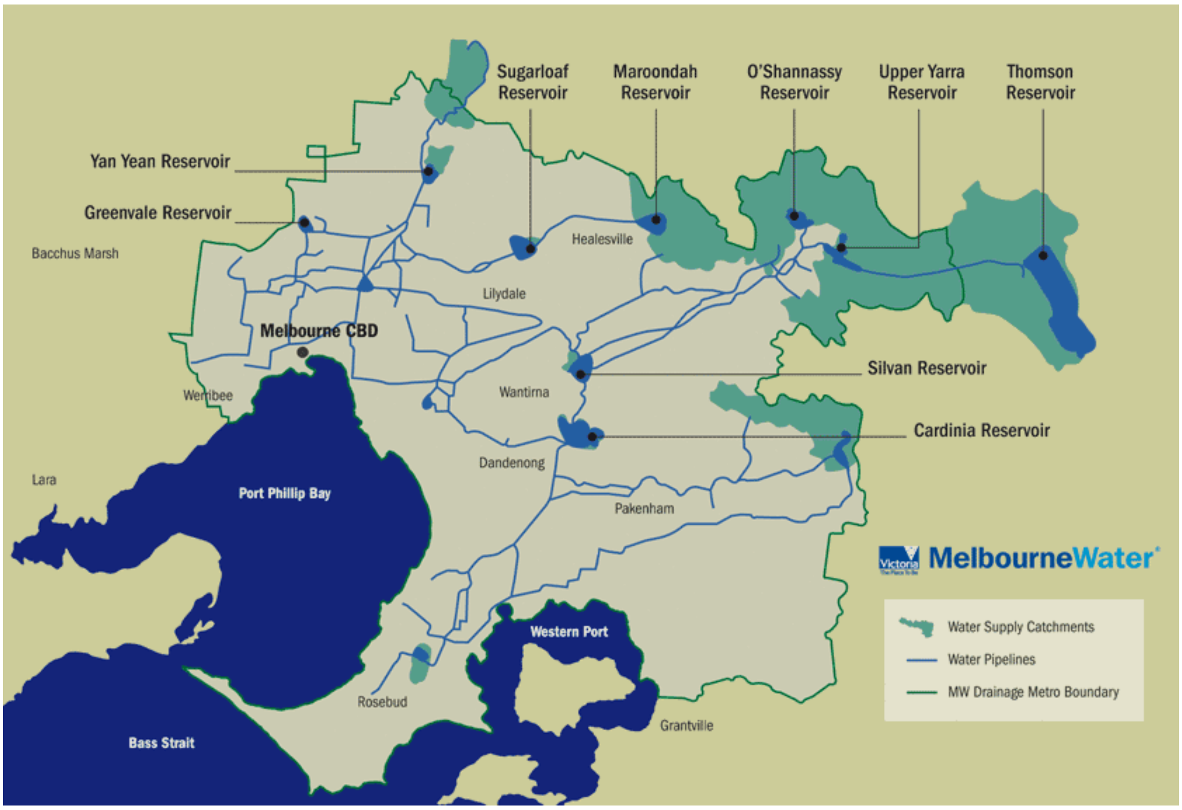
The resulting Bushfires Royal Commission gave a conservative estimate of the total cost of the Black Saturday bushfires of $AUD4.4Billion.

3.2. MELBOURNE WATER RESPONSE

3.2.1. Initial Response

As shown in Figure 3, Melbourne Water owns and manages forested catchment areas supplying five of Melbourne's ten major reservoirs, with the worst affected being the Maroondah Reservoir and O'Shannassy Reservoir. The vast majority of these are closed catchments covered in native forest with no human access permitted. With the exception of the Sugarloaf, Tarago and Yan Yean Reservoirs (totaling less than 9% of storage capacity) which have full conventional filtration systems, Melbourne's water supply receives chlorination and fluoridation only.

Figure 3 Melbourne's Water Supply System



With such limited treatment facilities, the vulnerability of water quality to the effects of the bushfires in the forested catchments is significant.

To mitigate this risk, as of 17 February 2009, over 10 billion litres of water had been shifted out of affected dams into others. At the time, Melbourne Water had planned to decommission affected reservoirs where the contamination from ash and other material was significant enough.

3.2.3. Long Term Implications

Melbourne Water have estimated that aside from added sediment loads caused by now bare ground in the burn-out forested catchments, forest re-growth in the burn out catchment areas could reduce runoff yields by up to 30% over the next 3 decades.

Melbourne has 10 supply dams, although the largest, the Thomson Reservoir has 55% of the total storage capacity and is in a heavily native forested catchment and hence is a critical infrastructure asset. The third largest, the Upper Yarra Reservoir, with 12% of total storage capability is also in a native forested catchment.

Given the long-term storage capacity across this reservoir system, current plans for managing the impact on these storages of a disaster such as the Black Saturday fires involve -

- Keeping the catchments closed from human entry
- Maintaining fire-fighting capability
- Transferring water between sources prior to it being affected by the fires and associated runoff as happened after Black Saturday and
- Using alternative sources of water for extended periods.

With the recent construction of the desalination plant, this will provide further risk mitigation, albeit at a more significant production cost.

3.3. KEY "TAKE-AWAY POINTS"

The fact that the majority of our water supplies are now treated and with the risk of a bushfire adversely impacting on water supply catchments in New Zealand being far less than it is in Australia, this case study may be considered less relevant.

However, the points to be taken out of this case study that are relevant more relate to vulnerability and criticality of water supplies and sources. Such water supplies in New Zealand could be damaged by any of earthquakes, floods, cyclones or volcanic activity. Risk identification and reduction measures adopted by Melbourne Water are therefore relevant in this context, particularly having multiple sources.

New Zealand examples where multiple sources mitigate this risk exposure include Auckland (Waikato River, Hunua Dams and northern sources), Wellington and Palmerston North (both have sizeable surface and groundwater sources).

4. CASE STUDY C - SAMOA TSUNAMI - SEPTEMBER 2009

4.1. DISASTER DETAILS

In the morning of 29 September 2009, a powerful earthquake struck south of the main Samoan Island chain with its epicenter 190 kms south of Apia. In only a few minutes later, a series of quakte triggered tsunami waves hit the southern coasts of American Samoa, Samoa and the small northern island of Niuatoputapu in Tonga. Up to 6 metres high, the tsunami waves caused fatalities and serious damage to villages and infrastructure, particularly along the south eastern coast of the island of Upolu in Samoa.

The death toll in Samoa alone was over 150 people, with up to 40 villages affected, 20 of them completely destroyed. Approximately 3200 people were rendered homeless. The Samoan Government estimated the cost of the damage to infrastructure at around the equivalent of $NZD 200M.

The most significant damage to water-wastewater infrastructure was in the south eastern area of Upolu where the deaths occurred and complete villages, including their water supplies were destroyed.

The main on-sea floor water supply pipeline to supply water to the 1500 residents of Manono Island from the larger of Upolu was disabled.

4.2. AGENCY RESPONSE

4.2.1. Initial Response

Coordination of humanitarian activities was managed by the Samoan Government supported by the FRANZ collaboration (France, Australia and NZ) which had been set up for the purposes of responding to disasters in the Pacific.

New Zealand Navy divers reconnected the water mains to Manono Island by October 4. This solution was not permanent however, with a limited non-potable use being established at this time.

Tankered water, supplied under management of the Samoa Water Authority was the main form of water supply for several months.

With all affected villages not having reticulated wastewater, septic tanks were continued to be relied upon for treatment and disposal of wastewater.

4.2.2. Repair and Recovery

Funding the necessary repairs to water supplies has been a key issue with aid funding the primary source of this capital.

An alternative emergency water source has been investigated developed for villages on the south east area of Upolu. Most of these villages have relocated to adjacent areas at higher elevation and complete new water sources are required. Funding has now been secured for a new on-sea floor pipeline to Manono Island.

4.3. KEY “TAKE-AWAY POINTS”

Two key points arise that are relevant for New Zealand water and wastewater providers arising from this experience are

a. the vulnerability of coastal above-ground infrastructure assets. Can the assets be located further away from the coast on higher ground ? This challenges gravity pipeline and wastewater treatment systems in coastal areas.

b. Infrastructure resilience, including back-up and contingency operational capability in these areas

5. CASE STUDY D - NORTH QUEENSLAND - CYCLONE YASI

5.1. DISASTER DETAILS

Severe Tropical Cyclone Yasi was a tropical cyclone that made landfall in northern Queensland, Australia in the early hours of Thursday, 3 February 2011. Yasi originated from a tropical low near Fiji. The system intensified to a Category 3 cyclone at about 5pm AEST (07:00 UTC) on 31 January 2011. Late on 1 February the cyclone strengthened to a Category 4 system, then early on 2 February, the cyclone intensified to a Category 5 system.

By the time Yasi crossed into Australian basin, preparations for the storm were under way. Media outlets referred to the storm as "what could be the state's worst cyclone in history".[20]

Because of its great size, many feared that the tropical cyclone could cause damage more severe than Cyclone Larry in 2006 or Cyclone Tracy, which severely damaged Darwin in 1974.Thousands of residents in the path of the storm were urged to evacuate by Queensland Premier Anna Bligh. Thirty thousand people were evacuated from Cairns, including all patients from Cairns Base Hospital and Cairns

Private Hospital who were airlifted by the Royal Australian Air Force and other agencies (such as the Royal Flying Doctor Service) to Brisbane. The Queensland state emergency coordinator warned residents that they would be on their own for up to 24 hours, as the conditions would be too dangerous for emergency responders.

Waves as high as 12 m (39.37 ft) were predicted to hit the north Queensland coast as the storm surge caused by Cyclone Yasi combined with a high tide of up to 7 m (30 ft) above average.

In Mission Beach near where Cyclone Yasi made landfall, wind gusts were estimated to have reached 290 km/h , leaving behind significant damage. A storm surge estimated to have reached 7 m destroyed several structures along the coast and pushed up to 300 m inland

5.2. AGENCY RESPONSE

5.2.1. Initial Response

A number of water-wastewater agencies, operating as business units or imbedded functions within local Councils, has assets severely impacted by Yasi from near Cape York in the North to south of Townsville in the south. Major population centres of Cairns and Townsville, each with populations in excess of 1000 people are included in this region.

For municipal water and wastewater providers, most severely impacted was the Cassowarry Coast Regional Council, which will be the focus of this discussion.

Figure 4 Cassowary Coast Region

As shown on Figure 4, The Cassowary Coast covers 4,701 square kilometres from Garradunga in the north to Cardwell in the south and the East Palmerston district in the west. Its major population centres are Innisfail, Tully, Cardwell and Mission Beach. The region is home to almost 30,800 people and hence is similar in size and population spread to a number of New Zealand councils.

The Australian Defence Force (ADF) response was designated Operation Yasi Assist. The ADF established Joint Task Force 664, based at Lavarack Barracks in Townsville for operational command on 2 February 2011. Cleanup and provision of tinkered fresh water supply were the main function of the ADF whose deployment lasted nearly 3 weeks with up to 800 personnel mobilised.

Damage to council's water supply, wastewater and stormwater assets was due to both cyclonic winds and also storm sea surge in coastal areas. All reticulated water supplies and wastewater systems in the district had been disabled. Tankered water was made available to the communities where boiling of reticulated water was not possible.

Electricity networks and landline and mobile phone communications had been severely damaged in some areas and this further hampered initial response efforts.

5.2.2. Repair and Recovery

Boil water notices were lifted within 2 weeks of the cyclone as water treatment systems were restored. Otherwise unforeseen issues that the Council had to deal with in this phase included

- Retrieval and disposal of asbestos building material from damaged or destroyed buildings and structures

- Health risks caused by the damage and its effects including reported cases of

  - dengue fever, tetanus, melioidosis (a pneumonia like illness caused my mobilised germs pre-existing in the soil) and Leptospirosis (a fever and nausea illness caused by disease carried by rats

  - Infestations of electric ants

- Snake migration to areas not previously inhabited by them before

Council's estimates for costs, inclusive of damage repair and short-term counter disaster operations was approximately $175M, or approximately six times Councils budgeted capital program.Council's inspections of 140 water, stormwater and sewerage infrastructure sites generated 250 defect reports with an estimated cost of rectification of these defects of $5.3M.

Council issued 135 media releases in the first four weeks after Yasi, as well as 18 region-wide newsletters. Seven information sheets were distributed to individual communities in the first week.

5.2.3. Long Term Implications

The Australian Federal and Queensland Governments provide funds to assist local governments with infrastructure repair the Restoration of Essential Public Assets (REPA) component of the Natural Disaster Relief and Recovery Arrangements (NDDRA). A defined process is required to be followed in order to receive money from this source.

Repair work as such is on-going, with infrastructure resilience from storm surge , particularly in coastal areas being a key focus.

5.3. KEY "TAKE-AWAY POINTS"

It is not unreasonable to think that New Zealand's coastline could at some stage be impacted on by such a cyclone. With the similar propensity for low-lying coastal towns and villages as in the Cassowary Region, we could face similar issues.

As per the Samoa tsunami example, the vulnerability and resilience of water-wastewater assets in low-lying coastal areas is a key consideration in the repair of these systems.

Communications immediately post-event is also a key issue. Use of satellite phones is considered to increase the resilience of telephone and data systems.

6. WHAT DOES LIFELINES SAY WE SHOULD DO?

As Lifelines utilities agencies, all councils and water companies in New Zealand are encouraged and required to plan for and then mitigate risks posed by such disasters.

The Civil Defence and Emergency Management (CDEM) Act Section 59 requires that every lifeline utility, must take all necessary steps to undertake civil defence emergency management or to perform those functions and duties required by the CDEM Act or any regulations made under the CDEM Act, or within any civil defence emergency management plan.

In terms of readiness activities, this means lifeline utilities are expected to:

- Develop, review, and improve their emergency plans
- Maintain arrangements to respond to warnings
- Incorporate risk management principles to form part of normal business operations
- Incorporate emergency response and recovery planning into their business continuity arrangements and
- Plan, train, exercise, and equip themselves in coordination with interdependent agencies.

In terms of response activities, this means lifeline utilities are expected to:

- Remain responsible for the management of their own response
- Respond to an emergency by activating their own plans and co-ordinating with the lead agency;
- Assess the impact of an event on their own staff, assets, and services
- Maintain or restore the services they provides
- Communicate with lead agencies, other responders, and the public;
- Align response activities with other agencies to avoid gaps and duplications;
- Coordinate with MCDEM or through established clusters to provide integrated and coordinated inter-agency responses

The CDEM Act requires lifeline utilities to be able to continue functioning to the fullest possible extent during and after an emergency, albeit this may be at a reduced level. It is essential lifeline utilities are resilient to emergencies and that their emergency planning is integrated with the wider community's CDEM planning, so that both are effective. This can only be achieved by cooperative planning between utilities, local government and the emergency services to ensure that plans are effective, thereby minimising loss and hastening a return to business. The focus is on business continuity planning and planning to ensure essential services are continued or restored to key facilities and customers on a priority basis.

Fortunately many New Zealand utilities practice sound risk, asset and emergency management and cooperate through arrangements such as Lifelines Groups.

New Zealand Lifelines, in its June 2012 report, reviewed what difference pre-existing Lifelines work had made to the recovery time and cost of the Christchurch earthquakes. Much of this work was prompted by the 1990s report "Risk and Realities."

Much of what is contained in this work, whilst developed specifically for earthquakes is, when considering the other types of natural disasters that have hit water and wastewater providers in recent years as outlined in the case studies is relevant for many natural disaster scenarios.

This report considers the need for both risk reduction, readiness and perseverance. The main elements that contributed most strongly are as follows:

Asset Risk reduction: identifying points of particular vulnerability.

Issues likely to arise include surveying for site-specific risks,(for example buildings that do not meet AS/NZS1170), loading standards (including where assets are placed on top of existing structures), and where liquefaction is possible identifying likely fracture points (for example, where cables and pipes enter structures such as buildings and bridges) and identifying cases where restraints to restrict movement of sensitive and critical equipment are needed.

Readiness: taking steps to improve organisational performance in emergencies,

Issues such as: ensuring fit-for-purpose operating frameworks for business continuity working collaboratively with other lifelines and relevant agencies on common issues such as looking for key interdependencies, examining generator sufficiency , establishing lifeline utility coordination arrangements to facilitate emergency response, ensuring that engineers and contractors are available quickly to meet emergency needs and managing spare parts to promote availability when unexpected pressures arise.

Perseverance: maintaining the effort over time while communicating realistic expectations:

Lifeline utilities that have retained a consistent focus on seismic mitigation have benefitted most significantly (asset management planning and similar annual-cycle processes provide an appropriate setting for much of the required work), improving end-user knowledge of infrastructure reliability and encouraging users (particularly organisations with emergency response roles such as hospitals) to plan for alevel of infrastructure outage in the more extreme events.

A range of overseas studies have found substantial benefits from seismic and other mitigation. For example, the United States-based Multihazard Mitigation Council (MMC), reporting on its landmark study on the value of hazard mitigation, concluded that, “a dollar spent on mitigation saves society an average of $4”.

It is reported that Orion Electricity’s seismic strengthening programme, commenced in 1996 and progressed systematically each year cost $6M and is estimated to have saved $60 to $65M in direct asset replacement costs and repairs.

Related issues have also been explored elsewhere within New Zealand by lifeline groups and others. For example, modelling by Market Economics associated with Exercise Ruaumoko, a recent large civil defence exercise based on a volcanic eruption in Auckland, suggested the Auckland region would suffer a 47 per cent reduction in GDP, but that this could be reduced to 40 per cent if businesses had effective mitigation measures in place.

7. CONCLUSIONS - COMMON THREADS - WHAT DO WE LEARN FROM THESE?

From all of these case studies common threads emerge. These relate to

1. The role the military can play in initial response phases

2. The immediate need for the provision of a safe, freshwater supply, albeit of reduced level of service.

3. Additional vulnerabilities of water and wastewater assets located in low-lying coastal areas that may have a higher risk of storm surge and cyclone impacts. These need to be considered in the development of asset management plans.

4. The need for adequate backup systems for power and telecommunications

5. The need for current and up -to-date data, asset and mapping records, that can be accessed from multiple locations.

6. The desirability of redundancy of critical assets

7. The inevitable need for external agency funding eg central government or aid agencies to fund the repair works that are necessary and the adequacy of reserves built up for these funds.

8. The need for working closely with other agencies in the restoration of services