The Hikurangi subduction zone Response Planning Toolbox
Contents

Note: TBD properly after content agreed and feedback incorporated.
1.0 Acknowledgements

This toolbox acknowledges the funding received from the NEMA-administered Resilience Fund, GNS scientists and input from other experts, the Hikurangi Response Planning project team and the East Coast Life at the Boundary Steering Group. In addition, this toolbox acknowledges the valuable contribution of response planning outputs from the following initiatives, which have helped inform the content of this toolbox:

- SAFER South Island/Te Waipounamu Alpine fault earthquake response framework
- Wellington earthquake National initial response plan (WENIRP)
- Wellington region earthquake plan (WREP)
- National and regional lifeline studies

2.0 Introduction

The National Disaster Resilience Strategy\(^1\) seeks to identify and understand risk scenarios (including the components of hazard, exposure, vulnerability, and capacity), and use this knowledge to inform decision-making. This toolbox seeks to build a greater understanding of a Hikurangi earthquake and tsunami risk scenario, to ultimately inform regional response planning and decision-making in response to this significant threat.

The toolbox has used a credible magnitude 8.9 earthquake and tsunami planning scenario, developed by GNS Science, to understand the consequences of a large Hikurangi event (detailed in Volume I, Appendix A). The toolbox and its planning outputs are not exclusive to the credible scenario but intended to be scalable to a range of scenarios on the Hikurangi subduction zone.

The term ‘a large Hikurangi event’ is used in this toolbox to describe the credible scenario, and variations of this scenario, which would lead to a catastrophic disaster in New Zealand. Catastrophic disasters are widespread in their devastation, defined as overwhelming the capacity of local communities, and local and national organisations, to respond to an event (HBCDEM, 2019). This toolbox therefore seeks to provide a suite of resources to aid regional response planning to manage the consequences of such an event.

The toolbox has been primarily developed for the five Civil Defence and Emergency Management (CDEM) Groups likely to be the first and most impacted by a large Hikurangi event (Figure 1.0). These Groups include:

- Bay of Plenty CDEM Group
- Tairāwhiti (Gisborne) CDEM Group
- Hawke’s Bay CDEM Group
- Manawatu-Whanganui CDEM Group
- Wellington CDEM Group

The consequences of a large Hikurangi event will stretch wider than one CDEM Group’s boundaries. This toolbox therefore seeks to encourage inter-regional planning where appropriate to enhance the effectiveness of response to a large Hikurangi event. Although developed for the five CDEM Groups above, the content in this toolbox is applicable and adaptable to all CDEM Groups in New Zealand at risk from a large Hikurangi event.

Three volumes are included in the toolbox, outlining the risk posed by the Hikurangi subduction zone, regional response planning considerations and a regional response concept paper.
designed for the five CDEM Groups (Figure 1.0) involved in the project.

Figure 1.0: The five Civil Defence and Emergency Management (CDEM) Groups involved in the Hikurangi Response Planning Project.

2.1 Scope

Consideration of the impacts and consequences of a credible magnitude 8.9 Hikurangi subduction zone earthquake and tsunami planning scenario on the five CDEM Groups (Figure 1.0) involved in the Hikurangi Response Planning Project is in scope for this project.

Due to the impact of a large Hikurangi event on all of New Zealand, the toolbox does consider that other CDEM Groups may not be able to support the five CDEM Groups involved in the development of this toolbox. The toolbox does not consider likely impacts on, or response arrangements in CDEM Groups not included in the Hikurangi Response Planning project.

1 The National Disaster Resilience Strategy, NEMA 2019
CDEM Groups who are likely to be affected by a large Hikurangi event and who were not involved in the development of this toolbox are encouraged to use this toolbox where applicable to develop their own regional response plans for this event.

The toolbox is not a National plan, nor an all of New Zealand plan or a multi-agency plan. The toolbox does not seek to task regional and national responding agencies with specific response actions. Responding agencies have helped in the development of this toolbox however responding agencies are expected to have or develop plans specific to their areas of expertise in relation to a large Hikurangi event.

Economic impacts and recovery were considered as part of toolbox development however detailed recovery planning is not included in the toolbox. Social requirements arising from the scenario consequences, community consequences and animal welfare were considered and included in the toolbox.

2.2 Audience

This toolbox has been designed primarily for the five CDEM Groups identified above (Figure 1.0), with the purpose of informing regional response planning for a large Hikurangi event.

With adaptation, resources within this toolbox are also applicable to:
- CDEM Group partner organisations,
- The National Emergency Management Agency (NEMA) and the National Crisis Management Centre (NCMC),
- Central Government agencies (including all emergency services, the New Zealand Defence Force (NZDF), health and disability services, welfare service agencies, and transport, energy and telecommunications regulating agencies involved in the response,
- Iwi,
- Crown owned entities,
- Lifeline utilities (particularly national service providers serving more than one CDEM Group area) and the FMCG sector,
- Private sector organisations involved in response and recovery,
- Non-government organisations (NGOs) involved in the response and recovery,
- All science research entities (including Crown Research Institutes (CRIs) and universities with interests or intention to be involved in, support or study community and managed responses to significant Hikurangi subduction zone earthquake and/or tsunami even.

2.3 Geographical Context

The five CDEM Groups included in the project were selected as they were deemed likely to be the most significantly impacted by a large Hikurangi event due to their proximity to the subduction zone on the lower North Island. Whilst the toolbox is designed for these five Groups it is important to note the ‘wider picture’– that a large Hikurangi event will have significant impacts across all New Zealand.

Group boundaries have proved to be an effective method of developing the toolbox by constraining the scope of the project, however these boundaries do not accurately reflect the interconnected and interdependent nature of services, agencies, people, communities and infrastructure which operate across these boundaries.
2.4 Legislative Context
The CDEM Act 2002 and National CDEM Plan 2015 govern emergency response in New Zealand and have informed the content of the toolbox (Figure 1.1)

This toolbox, the SAFER Framework and plans of partner agencies provide a link between these legislative and National documents with CDEM Group statutory plans, arrangements and operational procedures.

Figure 1.1: The wider context of where the toolbox fits within current legislation and other frameworks/plans.
Volume I
Risk Toolbox

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1.0 Hazard
The Hikurangi subduction zone is located off the east coast of New Zealand, stretching offshore from Gisborne in the North Island to Kaikoura in the South Island (Figure 1.0). The Hikurangi subduction zone is one part of a longer tectonic plate boundary between the Australian and Pacific tectonic plates, forming New Zealand’s largest and most active fault. Connecting the Hikurangi subduction zone with the Puysegur subduction zone below the South Island is a transform fault boundary, the Alpine Fault. Above the Hikurangi subduction zone the plate interface continues, marked as the Kermadec trench.

Subduction zones are known for producing the largest earthquakes and tsunamis in the world. The most recent subduction zone event occurred on the Japan Trench in 2011, North East of mainland Japan, producing a magnitude 9.0 earthquake and tsunami—leading to a catastrophic disaster which resulted in approximately 21,000 fatalities and missing, and an estimated $210 billion in economic damage, making it the costliest earthquake in world history.

2.0 Likelihood
The record of historic earthquakes and tsunamis generated by the Hikurangi subduction zone is poorly constrained, compared to the Alpine Fault where the paleoseismic record is long and accessible, allowing accurate return periods to be calculated. Despite this scientists know the Hikurangi subduction zone can produce large earthquakes and tsunamis, and that these events have occurred in the past.

The last earthquake that probably ruptured the most of the Hikurangi subduction zone (i.e. from Cook Strait to near Gisborne) was about 800-900 years ago, and probably had a magnitude between 8 and 9, based on the latest geological evidence. In total, there have been between 6 and 10 Hikurangi subduction zone earthquakes over the last 7000 years. The last one was about 500 years ago, and it appears to have mostly impacted the southern part of the subduction zone (Wellington and Wairarapa). Earthquakes that affect parts (but not all) of the east coast have recurrence intervals that vary from 350 to 1700 years. Geological evidence is not precise enough to give us the recurrence interval of the credible magnitude 8.9 scenario used as a planning tool for this toolbox.

Figure 1.0: The Hikurangi subduction zone (marked as Trough).
3.0 Vulnerability

The 2006 New Zealand census showed that 75% of New Zealanders live within 10 kilometres of the coast, whilst 65% lived within five kilometres of the coast. This number is much higher in regions where main centres are located near the coast such as Nelson (99% within 5km), Auckland (96%) and Gisborne (86%) (2006 Census, Stats NZ).

The positioning of large populations near the coast increases vulnerability to large tsunami as issues such as traffic congestion (both foot-based and vehicle based) during tsunami evacuation become more prevalent and problematic. Problems with traffic congestion and bottlenecks and during evacuation were observed during the 2004 Indian Ocean Tsunami and 2011 Great Eastern Japanese Tsunami (Mas et al., 2015) and mitigation work in a New Zealand context using agent-based modelling is currently working to address this in a New Zealand context (Power et al., 2019). These large populations also require critical infrastructure and engineering lifelines to be positioned in coastal areas to support these populations, resulting in a significant amount of infrastructure in New Zealand being susceptible to tsunami inundation.

In addition to having a large coastal population, New Zealand has not yet experienced a catastrophic disaster in living memory such as the Great East Japan Earthquake (2011) or the Indian Ocean Tsunami (2004). Public memory is important, as evidenced following the Christchurch Earthquakes in 2011 and Kaikoura-Hurunui earthquakes in 2016, where preparedness levels for natural hazards were seen to increase across the country and then quickly stall, as public memory faded of the events (NEMA Disaster Preparedness Survey, 2019). Having not yet experienced a large Hikurangi event in living memory, this may represent a factor increasing New Zealanders vulnerability to this significant hazard.

Appendix A: The credible planning scenario

The toolbox has been developed using a credible magnitude 8.9 earthquake and tsunami planning scenario as a tool. The scenario has been developed by GNS Science, to help identify the consequences of a large Hikurangi event (herein referred to as ‘the scenario’).

Several variations of the credible scenario were developed by GNS Science however one scenario was selected to identify the consequences of a large Hikurangi event with stakeholders (see ‘Volume II: Planning Toolbox’ for consequences), detailed in the table below.

<table>
<thead>
<tr>
<th>Stakeholder workshop scenario parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td>9am, a winter’s school day</td>
</tr>
<tr>
<td><strong>Magnitude (Mw)</strong></td>
<td>8.9</td>
</tr>
<tr>
<td><strong>Location of slip concentration</strong></td>
<td>Southern Wairarapa**</td>
</tr>
<tr>
<td><strong>Peak slip</strong></td>
<td>~18 m (non-uniform slip)</td>
</tr>
<tr>
<td><strong>Average slip</strong></td>
<td>9-10 m</td>
</tr>
</tbody>
</table>

The above scenario was chosen as it showed a strong concentration of slip in the southern Wairarapa. The Wairarapa has been found to feature strong coupling on the plate interface according to geodetic studies and therefore represented a plausible scenario (Wallace and Beavan, 2010).
The earthquake
A credible, magnitude 8.9 earthquake will generate extreme (MMI X) ground shaking along the east coast of New Zealand (Figure 1.1, Figure 1.2). The shaking is prolonged, with MMI 7 and above shaking lasting for minutes in places (Figure 1.1(b)).

Intense shaking of MMI 8.0-10.0 occurs along the east coast of the North Island between Wellington and East Cape; Marlborough and parts of the Central North Island experience shaking of MMI 8.0-9.0; and most of the rest of the North Island and northern South Island experience shaking above MMI 7.0. Between Mahia and East Cape the duration of intense shaking is very long, amplified by the thick sedimentary rock, with durations of severe ground shaking of more than 60 seconds. Aftershocks occur, further detailed in Appendix (A).

The tsunami
An offshore magnitude 8.9 earthquake will initiate a large tsunami due to displacement of the
seafloor. Deep water wave heights are displayed in Figure 1.3(a), and Figure 1.3(b-e) shows detailed tsunami inundation modelling for, (b) Napier, (c) Wellington, (d) Gisborne, and (e) Tauranga. Wave heights will significantly increase as the tsunami shoals when approaching the shoreline.

Tsunami will be an ongoing hazard as multiple waves will arrive – the first wave will not necessarily be the biggest. It will represent an ongoing challenge for the initial response, reducing access to large portions of the coastline damaged by the initial earthquake. Earthquake aftershocks (refer to Appendix A) may also bring risk of further tsunami, dependent on the degree of seafloor displacement/earthquake magnitude and epicentre.
Figure 1.3: (a) Maximum water surface elevation for the Mw 8.9 Hikurangi subduction zone credible scenario. The colour scale is limited so that water heights above 5m appear as 5m, (b) maximum flow depth (height of water above ground level) for Napier, (c) maximum flow depth (height of water above ground level) for Wellington, (d) maximum flow depth (height of water above ground level) for Gisborne, (e) maximum flow depth (height of water above ground level) for Tauranga.
Other secondary hazards

The following secondary and compounding hazards have been identified for the credible scenario however this list is not exhaustive. Secondary and compounding risks will complicate initial response activities and reduce the mobility of responders in the regions most affected. Any adverse weather concurrent with the earthquake will further complicate response and search and rescue activities.

a) Earthquake Aftershocks (Refer to Appendix A)
Aftershocks will occur for a prolonged period following the initial earthquake. Aftershocks may lead to further landsliding, uplift/subsidence, liquefaction, tsunami and lateral spreading. Building and asset inspection may need to be repeated following large aftershocks. Ongoing aftershocks may impact the psychological wellbeing of those affected.

b) Uplift/Subsidence
Significant uplift/subsidence will occur in places, particularly the North Island East Coast, which will change the landscape. People, ecosystems, infrastructure and assets will be vulnerable as the landscape changes and adapts to its new equilibrium. An altered landscape from subsidence/uplift may become more susceptible to other hazards, e.g. liquefaction due to a change in level of ground water table, which will need to be considered during response.

c) Liquefaction
Liquefaction will be a significant secondary hazard, enhanced by changes to the ground water table due to land subsidence, impacting the efficiency of responding agencies travelling within and between regions. Liquefaction may also pose a hazard for those trying to evacuate.

d) Infrastructure Damage
Infrastructure may be destabilised or damaged by the initial earthquake and subsequent aftershocks. Un-reinforced masonry, tilt slab concrete features, bridge approaches, flood protection structures and embankments will be particularly at risk of damage/collapse.

e) Landslides
Following the initial earthquake and any subsequent aftershocks, landslides and rockfalls will be extensive, particularly in steep terrain. Slopes will become instable, vulnerable to further landsliding. Landslides may isolate communities for significant periods of time and will pose a threat to people, buildings and assets. Tertiary hazards may occur, where landsliding dams water bodies/courses, increasing the vulnerability of downstream communities to flash flooding. It is envisaged a significant amount of slope stabilization will need to occur during the response and recovery phase.

f) Communicable Human Diseases
Lack of sanitation, potable water contamination and delays in medical treatment may lead to transmission of diseases such as gastroenteritis, placing further pressure on the health system. Disease may spread rapidly where there is a lack of sanitation or concentration of displaced persons in emergency accommodation.

Following the initial earthquake, tsunami inundation may severely damage buildings in inundation zones and distribute large debris further complicating response and recovery operations. Tsunami debris may be contaminated with hazardous waste and therefore the disposal of this will need to be addressed.
Appendix B: Aftershock sequence

To further understand the consequences of a large Hikurangi event GNS Science modelled an aftershock sequence based on the credible magnitude 8.9 earthquake and tsunami scenario (Burbidge et al., 2019)

The modelling translated the 2011 Tōhoku aftershock sequence onto the Hikurangi subduction zone and resized the size of magnitude of the mainshock and aftershocks to match the credible scenario (Figure 1.4).

Key findings from the modelling are:

- Over the first year following the mainshock, the east coast of the North Island has close to 100% probability of experiencing shaking greater than MMI 6 from an aftershock.
- A year after the mainshock there is still a significant (about 50%) probability of an offshore magnitude 7 or greater earthquake over the following year. This will obviously have significant implications on the response and recovery efforts of affected regions.
- The magnitude 9.1 Tohoku earthquake was followed by three earthquakes above magnitude 7.0 in the first few hours. The modelled sequence placed a magnitude 7.7 aftershock underneath the Wellington Region half an hour after the mainshock (Note, this is not a prediction of where the largest aftershock will occur).

In terms of response planning, we should expect, and therefore plan, for aftershocks from a large Hikurangi event to:

- Slow down self-evacuations following the mainshock,
- Slow or restart initial response efforts in some areas, e.g. emergency service personnel in tsunami evacuation zones are likely to have to repeatedly evacuate these areas every time there is a large aftershock, and,
- Create additional secondary hazards, e.g. new landslides.

Figure 1.4: Modelled aftershocks (above Mw 4.9) from the credible scenario using the 2011 Tōhoku aftershock sequence

For further information, please refer to the full aftershock study report (Referenced in Volume II, Appendix B ‘Reference material and other useful information’).