What is a tsunami?

- A tsunami is a series of ocean waves with very long wavelengths (typically hundreds of kilometres) caused by large-scale disturbances of the ocean. The deeper the water, the greater the speed of tsunami waves will be.
- Tsunami retain their energy, meaning they can travel across entire oceans with limited energy loss.
- Most tsunami are generated by large magnitude, shallow earthquakes under the sea floor.

Tsunami in New Zealand

New Zealand sits at the convergent boundary of the Pacific and Australian Tectonic Plates, making New Zealand vulnerable to tsunami hazard, from distant, regional and local sources.

The Kermadec Trench is formed at this boundary and is one of earth's deepest oceanic trenches. The trench is thousands of kilometres long and subduction occurs along the trench to the east of the North Island of New Zealand. Subduction at this point of the Kermadec Trench is known as the shallower Hikurangi Trench. The Hikurangi Trench has a maximum depth of approx. 3,750 metres and comes within 80km of New Zealand's coastline (Figure 1).

Because of its tectonic setting New Zealand is subject to many possible tsunami scenarios. These include tsunami generated by local land or submarine landslides; earthquakes from distant, regional and local sources; and offshore volcanoes, for example White Island and numerous submarine volcanoes between New Zealand and Tonga. In addition, inland volcanic eruptions can create atmospheric pressure waves that cause tsunami.

Based on research and historical records, New Zealand has experienced around 10 tsunami greater than 5m in height since 1840. These were generated by distant source earthquakes and seafloor earthquakes off the New Zealand coast (80% local, 20% distant source). Three of these had run-up heights greater than 10m, which has been observed from field research.

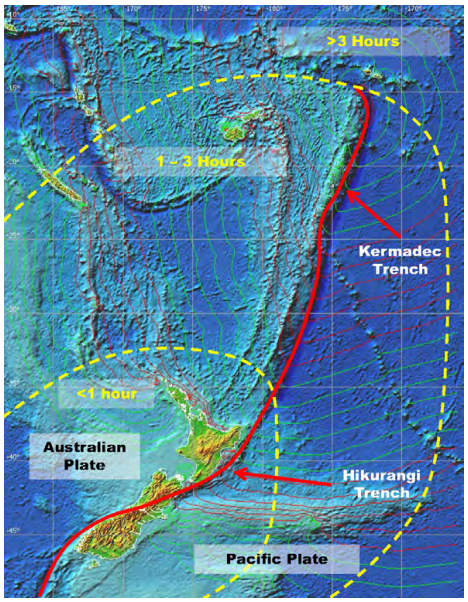

Figure 1: Regional and distant. source zones for tsunami impacting New Zealand. Zones are calculated by the distance to nearest part of the New Zealand coast

Ministry of Civil Defence & Emergency Management
Te Rākau Whakamarumaru

NATIONAL EXERCISE PROGRAMME
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How are tsunami waves different to wind waves?

With tsunami the entire water column from sea floor to the surface is moving, whereas wind waves move only the surface of the ocean. This is why people sometimes use the word “surge” to describe how tsunami waves behave, however it is important to remember that tsunami are very different phenomena. A storm surge is a rapid rise in coastal sea-level caused by a significant meteorological event (e.g. cyclones).

The wavelength of tsunami waves decreases as the water gets shallower because the leading waves slow down as the water gets shallower and there is greater friction (Figure 2). The following waves are still travelling at open ocean speed and push up behind the slower leading waves. This makes tsunami waves “bunch up” and increase in height as they approach the shore.

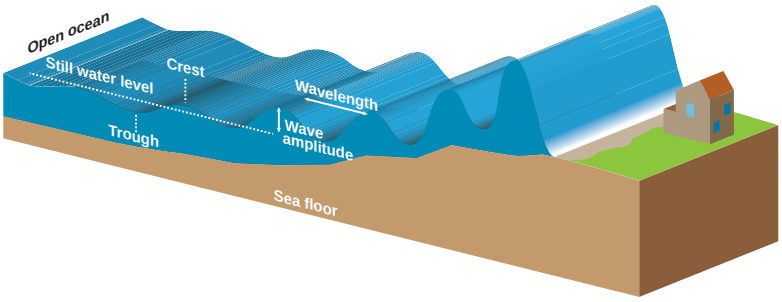


Figure 2: Change in wave length and height as a tsunami approaches the shore

The “bunching up” effect makes tsunami waves run-up to greater heights on steep slopes (tsunami run-up) or travel further inland on gentle slopes (inundation distance) than wind waves (Figure 3). Tsunami wave run-up can be double that of the wave height at the coast on steep slopes.

Because of the high energy and rapid velocity of tsunami waves, waves smaller than 1m can cause dangerous and damaging currents and wave action in coastal zones. Some areas of New Zealand (e.g. Tutukaka marina) have experienced these damaging currents in recent, relatively small events.

Tsunami waves over 1m can be much more damaging than wind waves due to their velocity and debris load (see Tsunami impact).

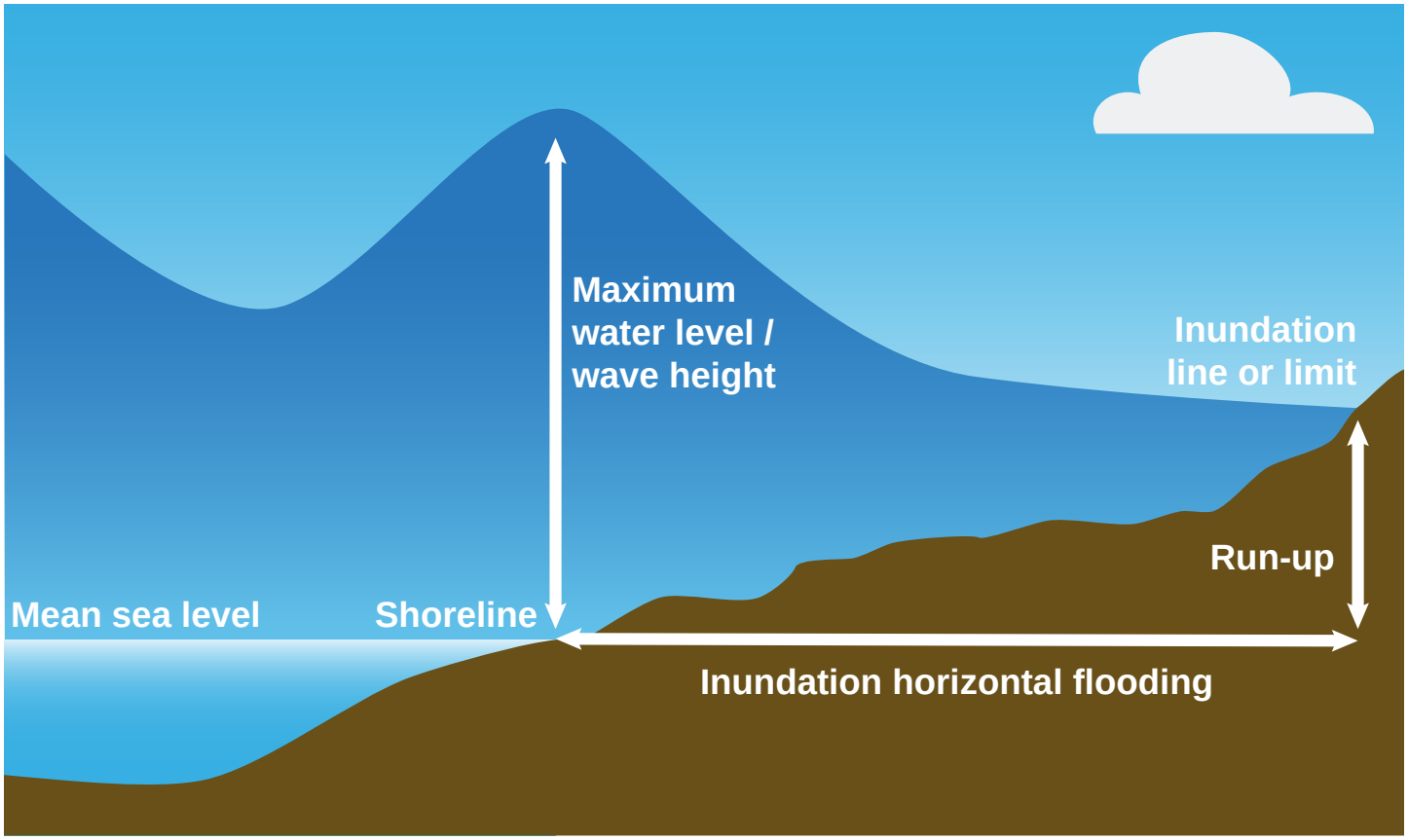


Figure 3: Tsunami wave run-up (height above mean high tide level) and inundation limit (distance inland)

Local, regional and distant source tsunami

In New Zealand, for planning and warning purposes, tsunami are classified as either **local**, **regional** or **distant** source events (Figure 4).

In the local source context tsunami generation is resultant of an earthquake off the New Zealand coast. **Local source events** have travel times of less than one hour to the nearest New Zealand coastline.

Regional source events are generated by earthquakes from areas along the Tonga-Kermadec Trench (subduction zone) or the Southern New Hebrides Trench. They have travel times to New Zealand of one to three hours.

Distant source events are generated by earthquakes from any location around the Pacific Rim. They have a travel time to New Zealand of greater than three hours and for more remote sources such as Peru or Chile the arrival of the first waves in New Zealand may take at least 12 hours from when the tsunami is generated.

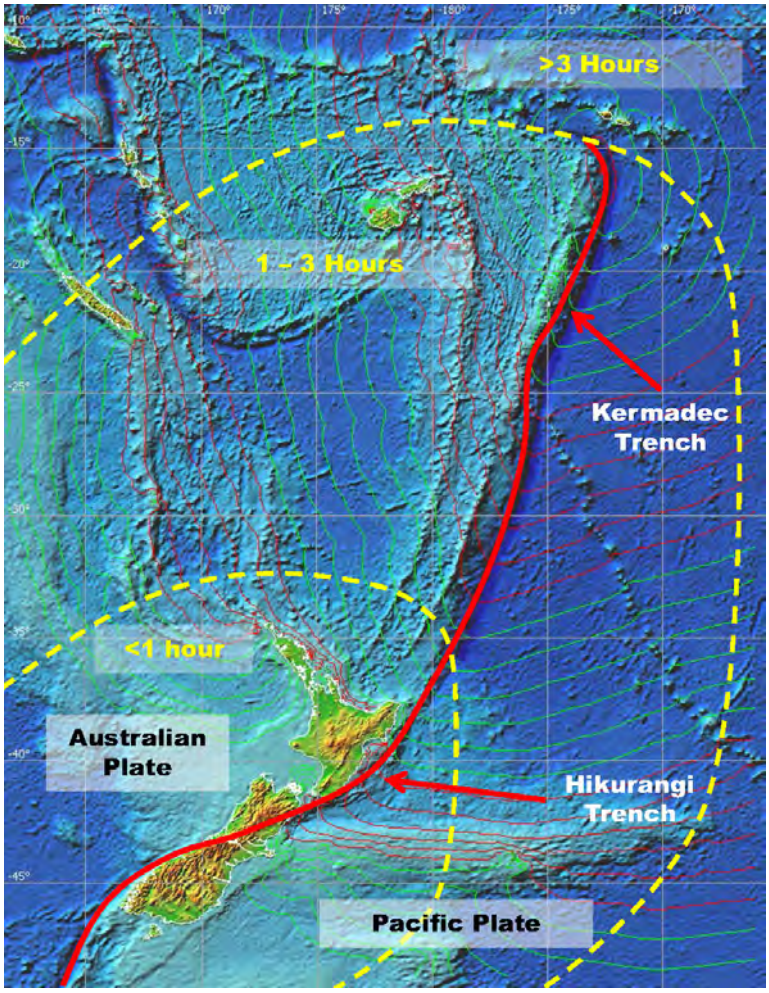


Figure 4: Map showing tsunami arrival times

- Tsunami are a series of waves; the first wave will not necessarily be the largest and large waves may continue to arrive many hours after the arrival of the first wave.
- Unusual and hazardous currents and surges, especially in areas where waves can resonate in bays and harbours, may continue for hours to days after the largest tsunami waves have passed.

Tsunami arrival times

Local	Regional	Distant
Less than 1 hour – **could arrive in minutes**	1 to 3 hours	More than 3 hours

Tsunami preparedness

New Zealand's entire coast is at risk from tsunami. Damaging tsunami are relatively low frequency events for New Zealand so planning and preparedness are essential for this unfamiliar threat. The short warning time for local source events (several minutes to one hour) is a barrier to official warnings reaching those in danger in a timely manner. All public education and official advice states that a long or strong earthquake (longer than one minute OR so strong it is difficult to stand or walk) is the warning that should trigger evacuation and the public should not wait for official warnings before taking action. Practicing rapid evacuation with getaway kits, designated evacuation routes and identified safe locations, aids preparedness.

Regional source events provide limited time for official warnings (one to three hours) and these warnings may be provided with a greater degree of uncertainty using a precautionary approach if the estimated arrival time is closer to one hour than three hours. Typically the process of scientific assessment of the earthquake and tsunami wave height estimation takes 30 minutes to one hour. This is not a problem for distant source tsunami as there is still sufficient available time to generate and distribute official warnings. However, for regional events, the time for scientists to analyse the event is compressed due to the imperative for officials to providing timely warnings.

For large, regional source earthquakes, more rapid decision-making is required from all involved: to analyse the potential threat (scientists), to issue warnings (civil defence emergency management) and to process warning information and take action (all at risk). Civil defence emergency management planning should include identification of tsunami risk zones, public alerting planning and testing and public education on evacuation zones, natural and official warnings and preparedness for evacuation (getaway kits).

If you are at the coast and experience any of the following:

- Feel a strong earthquake that makes it hard to stand up, or a weak rolling earthquake that lasts a minute or more,
- See a sudden rise or fall in sea level,
- Hear loud and unusual noises from the sea,

Move immediately to the nearest high ground, or as far inland as you can.

Tsunami impact

Tsunami impacts in New Zealand can range from unnoticeable to devastating. Effects/impact are dependent on the characteristics of the event that generated the tsunami, for example the size and type of the event (earthquake magnitude and type), and the configuration of the bathymetry (that is the depth of water in oceans) along the coast that the tsunami is approaching. Tsunami waves could smash into the shore like a wall of water or move in as a fast moving flood or tide.

Tsunami can destroy or severely damage structures including ports, buildings, and lifeline utilities, reducing structures to fragments and hollowed out shells (Figures 5 and 6). Tsunami can also collect large amounts of debris. The greatest risk to people is drowning but the entrained debris can create further impact damage and increases the injury or fatality risk to people. Because tsunami can travel large distances inland or up slopes evacuation is critical for life safety. The casualties from very large events illustrate how damaging and dangerous tsunami waves can be (e.g. Boxing Day tsunami of 2004: ~230,000 fatalities, Tohoku, Japan 2011: ~16,000 fatalities).

The amount of damage caused by tsunami is dependent on the wave run-up height and the exposure of assets (how many and what value). For smaller tsunami, less than 1m in height at the coast (run-up up to 2m above high tide), the threat is largely in the coastal marine area, particularly inlets and enclosed bays. The main danger arises from turbulence and strong currents, and there is potentially a risk to moored vessels and coastal infrastructure such as undersea pipes. Tsunami of these heights do not generally constitute a danger to life unless a person is in the ocean or on the beach.

Tsunami arriving at the coast between 1 and 3m (run-up 2 to 6m) can produce on land flow depths of a few metres in coastal areas. These should be considered potentially lethal. Waves of this height can cause damage to more fragile coastal infrastructure and buildings (e.g. timber structures and mechanical or electrical equipment) through scouring and debris load impact and deposition.

Figure 5: Tsunami waves "surging" into a coastal community.

Wave heights of 3 to 5m (run-up of 6 to 10m) can be expected to produce widespread inundation and damage. Lighter construction buildings (e.g. timber) are particularly vulnerable but damage to reinforced concrete buildings can also be expected due to waves and debris impact. Floatable assets caught up in the incoming waves, such as boats and shipping containers, may make flow more hazardous. Waves of this height should be considered potentially lethal. Coastal infrastructure such as waste-water treatment facilities, coastal roads, rail and pumping stations are likely to be damaged, with bridge abutments scoured and low lying bridges overtopped. Ground based electrical facilities and equipment are also vulnerable.

Figure 6: aftermath of tsunami impact.

Tsunami of 5 to 8m (10 to 16m run-up) will produce widespread inundation and damage. Buildings are likely to be washed away or have infill walls blown out. Waves of this height are potentially lethal. Widespread washout and damage to infrastructure (including roads, bridges and lifeline utilities) is expected.

Wave height	Run-up	Possible impacts
Under 1m	**Up to 2m above high tide**	Threat is largely in the coastal marine area particularly inlets and enclosed bays. Turbulence and strong currents. Potential risk to moored vessels and coastal infrastructure such as undersea pipes.
1 to 3m	**2 to 6m**	**Potentially lethal.** Damage to more fragile coastal infrastructure and buildings such as timber structures and mechanical or electrical equipment.
3 to 5m	**6 to 10m**	**Potentially lethal.** Widespread inundation and damage. Damage to reinforced concrete buildings can also be expected. Coastal infrastructure is likely to be damaged.
5 to 8m	**10 to 16m**	**Potentially lethal.** Widespread inundation and damage. Buildings are likely to be washed away or have infill walls blown out. Widespread washout and damage to infrastructure (including roads, bridges and lifeline utilities).

References

Ministry of Civil Defence &Emergency Management, 2010. Working from the same page. Consistent messages for CDEM.

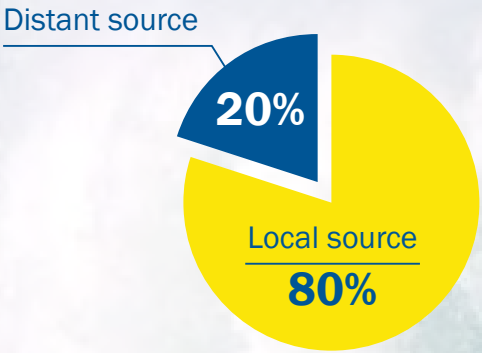
Burbidge, D. et. al., 2016. The tsunami scenario for the Exercise Tangaroa 2016. GNS Science Consultancy Report 2016/20. February 2016.

Tsunami in New Zealand

New Zealand's entire coast is at risk of tsunami. A tsunami can violently flood coastlines, causing devastating property damage, injuries and loss of life.

Since 1840 New Zealand has experienced around

10 tsunami greater than 5m in height



Tsunami arrival times

Local	Regional	Distant
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Tsunami can be caused by

Earthquakes from distant, regional and local sources

Local land or submarine **landslides**.

Offshore **volcanoes** and submarine volcanoes.