THE EASTERN COROMANDEL TSUNAMI STRATEGY

Managing tsunami risks in Matarangi and Whangapoua


Matarangi Beach


Whangapoua Beach

December 2015

Why are we working on the Eastern Coromandel Tsunami Strategy?

The recent release of the "Review of Tsunami Hazard in New Zealand (2013 Update)"[1] indicates that the risk of tsunami hitting the east coast of the Coromandel Peninsula is higher than we previously understood. The massive earthquakes which led to devastating tsunami events in Japan in 2011 and in South-east Asia in 2004, highlights the risks that New Zealand faces from large earthquakes and their tsunami-generating potential.

Recently completed tsunami modelling work confirms that Matarangi and Whangapoua are vulnerable to the effects of tsunami events – similar to the rest of the north-east coast of the North Island[2].

While the new information does not provide cause for immediate alarm, Thames-Coromandel District Council and Waikato Regional Council are consulting with east coast Coromandel communities about the future management of tsunami risks. Consultation is part of the on-going Eastern Coromandel Tsunami Strategy – an initiative that seeks to improve tsunami risk management along the east coast of the Coromandel Peninsula.

The councils started this consultation process in Whitianga in 2011, since it is considered the centre most at risk from the impacts of tsunami, and followed up with Tairua and Pauanui in 2013/14 and Whangamata in 2014/15.

This summary document outlines the tsunami hazards for Matarangi and Whangapoua, the issues and options for managing the risks from tsunami, and the process for deciding how best to manage tsunami risks in Matarangi and Whangapoua.

Given the potential for significant loss of life and property damage in a large tsunami, we are very keen to hear from the Matarangi and Whangapoua communities about how they want to manage the risks going forward.

Please look through this summary document and give us your thoughts at the open days (see p. 15 for details). If you can't make it to the open day and have questions or ideas, you can call or email TCDC customer services at 07 868 0200 or customer.services@tcdc.govt.nz.

[1] Power, W. L. (compiler). 2013. Review of Tsunami Hazard in New Zealand (2013 Update), GNS Science Consultancy Report 2013/131. 222 p.

[2] Borrero, J. C. 2015. Numerical modelling of Tsunami Inundation along the Kennedy Bay to Opito Bay coast, Coromandel Peninsula, New Zealand. eCoast Limited report commissioned by Waikato Regional Council, Hamilton.

Tsunami terminology

What's in a wave?

Run-up: Is a measure of how high the wave reaches above normal sea level when it hits the land. It depends upon the slope of the land and land use. It can also refer to how far inland water will reach. So, for example, a 5 m wave at the shoreline may actually run up to 10 m above normal sea level where the shoreline is steep, and may run inland for a kilometre or more in areas that are low-lying, such as rivers and estuaries.

Wave height: A measure of the trough-to-crest height of a tsunami wave. The trough may be below normal sea level due to tsunami behaviour (such as the 1960 Chilean tsunami waves that uncovered the wreck of the Buffalo in Whitianga).

Wave length: The distance between two consecutive wave crests.

Wave period: The time between two consecutive wave crests passing a point.

Wave amplitude: The vertical distance from the still water level to the crest of the wave.

Flow depth: The depth of water and debris flowing over the ground.

The above definitions are useful to remember when it comes to understanding tsunami[3] and their impacts.

For many people, the run-up may be the most useful measure, as this describes the actual impacts of tsunami as they reach land.

But factors like wave period and the actual volume of water in tsunami waves may be just as, if not more important when it comes to their destructive impact.

Tsunami facts and figures

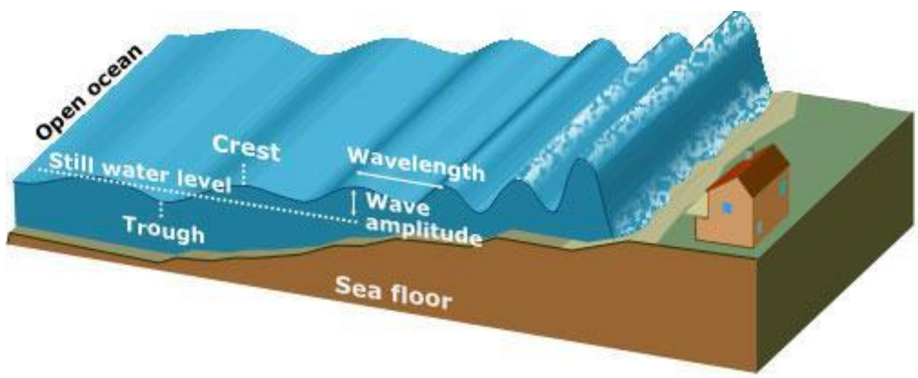
A tsunami is a series of water waves. The most common cause is a seafloor earthquake. Other triggers are undersea landslides, undersea volcanic eruptions, and less frequently, meteorite impacts.

[3] "Tsunami" is a Japanese word that is literally translated as "harbour wave". In Japanese, the word means both singular and plural, and this original usage of the word is adopted within this document.

Tsunami are not like wind-generated waves. Wind-generated waves may, for example, be 10 seconds apart and the distance between wave crests might be 150 metres. Tsunami waves may be an hour apart, and the distance between crests 100 kilometres or more in the deep ocean. Tsunami waves are therefore not just one wave but rather a series of waves. The first wave reaching the shoreline is often not the most damaging wave.

In the open ocean, tsunami waves travel at up to 700 kilometres per hour. In the deep ocean, the waves may be as little as 60 centimetres high, passing ships unnoticed. As they encounter shallow water, they slow down to about 30 kilometres per hour and can increase dramatically in height – see Figure 1.

Figure 1: Change in tsunami wave shape as it approaches land.



Matarangi and Whangapoua tsunami wave threats

The immense volumes of water and debris tsunami waves contain and the speed with which they can travel are the core threats to people and property in coastal and low-lying estuarine areas. Tsunami may rapidly flood and damage coastal communities, with the damage compounded by the impacts of debris they pick up along the way.

A central element in responding to these threats is the time people have to respond to a tsunami warning.

Therefore, the source of tsunami that can affect Matarangi and Whangapoua is a crucial factor in our considerations of what to do. Examples of the sorts of warning times Matarangi and Whangapoua could expect are:

- **Near source:**
  - **Local:** travel time between the source - such as an earthquake on a fault line just offshore - and impact is one hour or less.
  - **Regional:** travel time between the source - such as an earthquake in the Tonga-Kermadec Trench - and impact is between one and three hours.
- **Distant source:** travel time between the source and impact is greater than three hours. Travel times for distant source tsunami from South America are usually 12-15 hours.

Our understanding about tsunami on the east coast of the Coromandel

Distant source tsunami

Studies have indicated the most significant distant sources for tsunami are large earthquakes in South America. The following table provides a summary of large earthquake events in South America since 1562 that have produced significant run-up in South America, and are either known to have, or are thought to have, affected New Zealand.[4]

Large South American earthquakes since 1562 and their impacts

Year	Source	Earthquake magnitude[5]	Maximum run-up in NZ (m)	Maximum run-up in the source region (m)
1562	South-central Chile	Unknown	Unknown	16
1575[6]	Central Chile	“	“	25+
1586	Off Lima, Peru	“	“	26
1604	Arica, Northern Chile	“	“	16
1730	Valparaiso, Chile	“	“	16
1746	Callao, Lima, Peru	8.6	“	24
1835	Conception, Southern Chile	Unknown	“	14
1868	Arica, Northern Chile/ Southern Peru	9.1	10 (Chatham Islands); 4 (Mainland)	18
1877	Inquique, Northern Chile	9.0	3.5	21
1960	Southern Chile	9.5	5	25

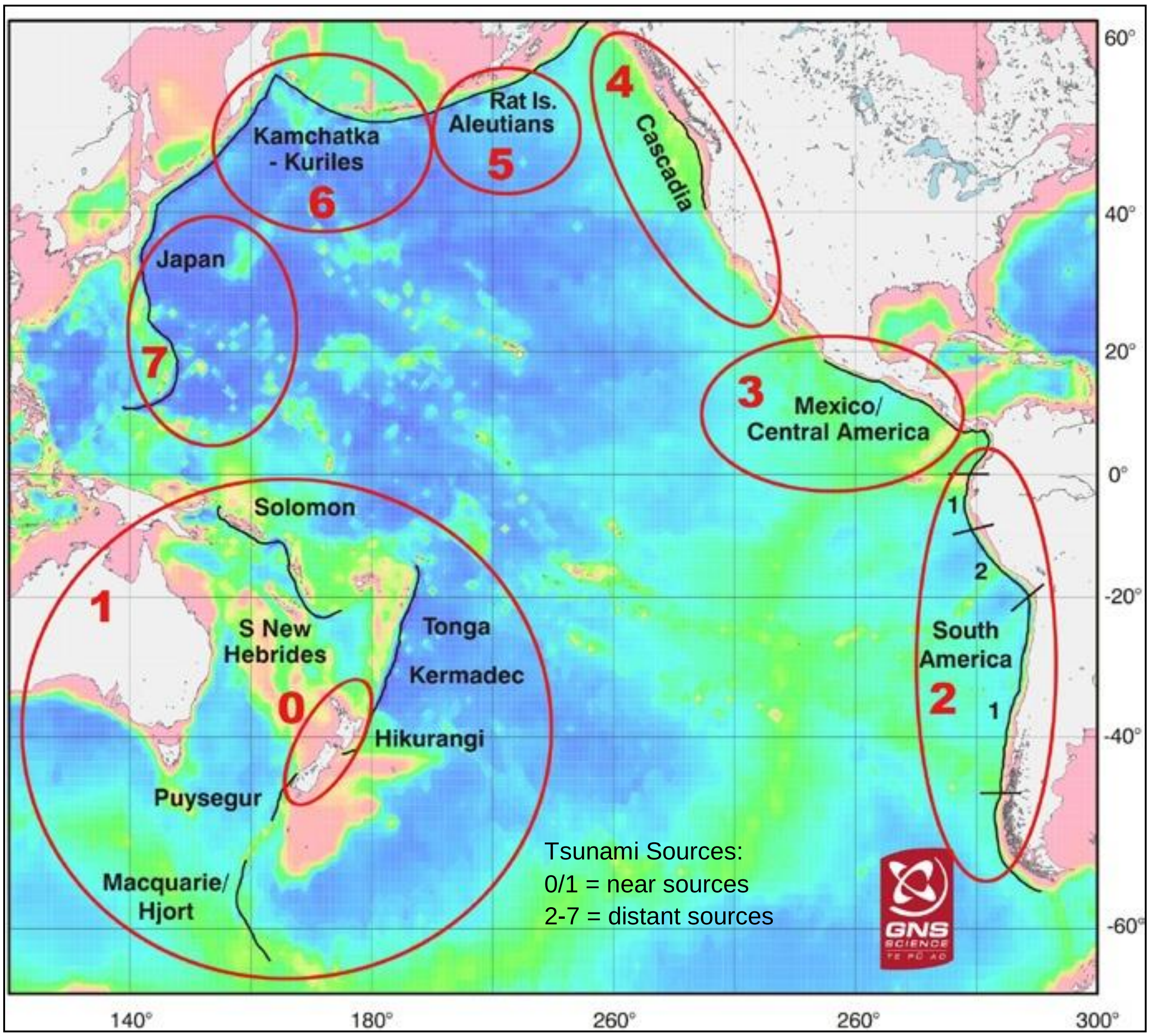
In the past century, the largest distant source tsunami event known to have caused significant run-up in parts of the Coromandel Peninsula was the Chilean earthquake event in 1960. The 1960 Chilean tsunami had a wave height in excess of 5m at Whitianga, inundated parts of Whitianga town, and caused significant currents to flow in and out of harbours around the Coromandel Peninsula. The most recent distant source tsunami to hit the eastern Coromandel Peninsula was the 2011 Japan tsunami.

[4] NIWA (2004); GNS (2005); NIWA (2008).
[5] Mw – moment magnitude
[6] NIWA (2008), p. 20.

The 2011 Japan tsunami had a wave height of 1.6m at Whitianga Harbour, produced strong currents in harbour entrances, and inundated parts of the foreshore at Port Charles

While the exact impacts on Matarangi and Whangapoua from other large distant source earthquake events are unknown, it is likely that many had similar or greater impacts on Matarangi and Whangapoua, especially those from southern Peru. On the basis of historical information, we can conclude that Matarangi and Whangapoua may be impacted by a large distant source tsunami about once every 50-100 years. Figure 2 shows the main tsunami sources that affect New Zealand – including distant sources.

Figure 2: Main sources of tsunami in New Zealand



The results from recent modelling work indicate that the threats to Matarangi and Whangapoua from distant source tsunami are largely confined to the marine environment – there would be little or no inundation of land. However, distant source tsunami can cause significant dangerous currents, especially in and around the Whangapoua harbour entrance, and the entrance to the Pungapunga River at Whangapoua.

Near source tsunami

Previous scientific studies commissioned by Thames Coromandel District Council and Waikato Regional Council indicate that a large earthquake event along the Tonga-Kermadec Trench to the north-east of New Zealand represents the most significant near-source tsunami threat for the east coast of the Coromandel Peninsula[7].

Recent modelling work indicates that inundation of Matarangi and Whangapoua may occur as the result of large earthquake events from the Tonga-Kermadec Trench. Figure 3 shows the segments of the Tonga-Kermadec Trench[8]. Since 1904, there have been at least six earthquakes of magnitude 7.0 or above along the Tonga-Kermadec Trench, including one earthquake of magnitude 8.3 in 1986. Matarangi and Whangapoua are particularly at risk from earthquakes from segments 1 and 2 because these segments produce greater wave impacts on the eastern Coromandel and shorter wave travel times than the other segments.

The recent modelling work considered a number of different earthquake scenarios from the Tonga-Kermadec Trench – all with slightly different assumptions. Figure 4 shows the likely inundation area for Matarangi and Whangapoua at high tide from an earthquake event similar to the Japan 2011 event – an event which the Tonga-Kermadec Trench is thought to be capable of producing.

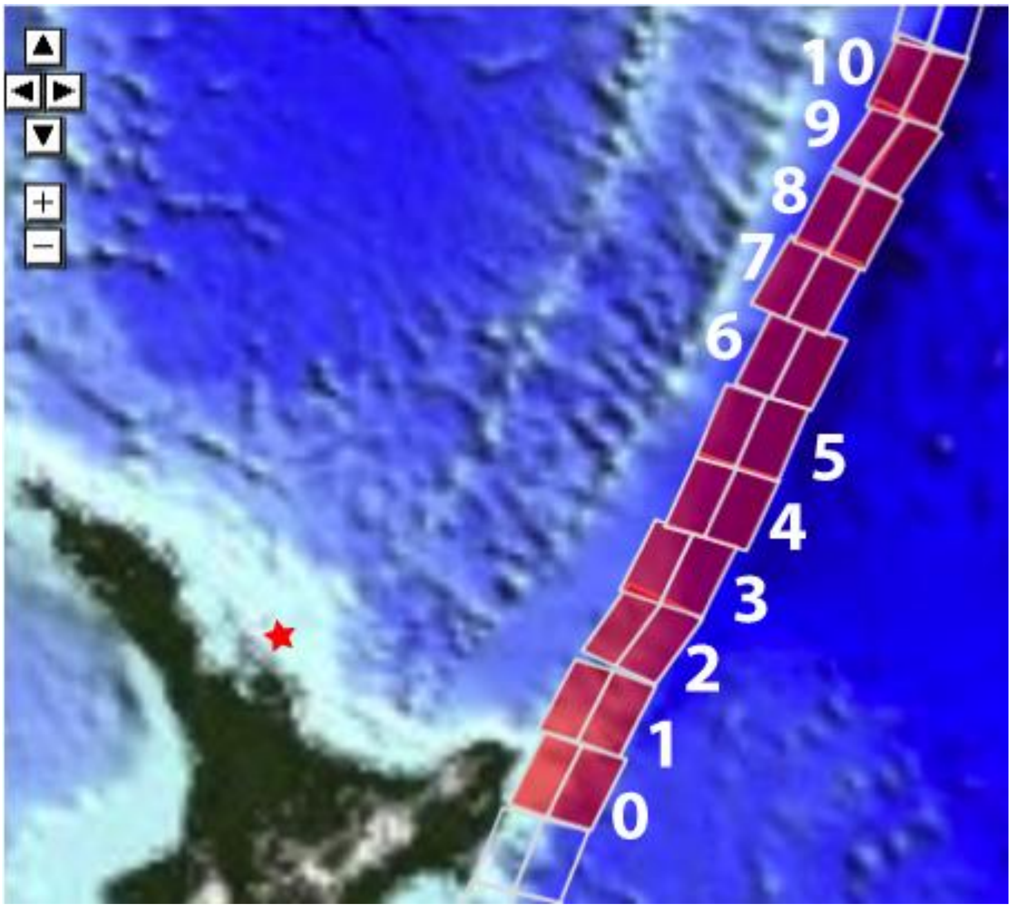
Other recent scientific work completed in the Bay of Plenty has identified several additional local tsunami sources – the Astrolabe, Volkner and White Island faults[9]. Modeling of these sources indicates that tsunami generated by these faults do not cause impacts as great as the Tonga-Kermadec Trench event at Matarangi and Whangapoua. The Bay of Plenty work is new information that helps to further refine our understanding about tsunami risks to Matarangi and Whangapoua.

[7] Bell, R.G. (NIWA), Goff, J. (GeoEnvironmental Consultants Ltd), Downes, G. (GNS), Berryman, K. (GNS), Walters, R. A. (NIWA), Chagué-Goff, C. (NIWA), Barnes, P. (NIWA), Wright, I. (NIWA) 2004. Tsunami hazard for the Bay of Plenty and Eastern Coromandel Peninsula: Stage 2. Report prepared for Waikato Regional Council (WRC Technical Report 04/32), Hamilton; Goff, J., Walters, R., Callaghan, F. 2006. Tsunami Source Study. Report prepared by NIWA, on behalf of Environment Waikato, Auckland Regional Council, Environment Bay of Plenty, Northland Regional Council (Technical Report 2006/49), Hamilton.

[8] Borrero, J.C. 2015.

[9] Walters, R., Callaghan, F., Goff, J. 2006. Wairakei/Te Tumu tsunami inundation study. Prepared by NIWA for Environment Bay of Plenty. NIWA Client Report CHC2006-020.

Figure 3: Fault segments along the Hikurangi/Tonga-Kermadec Trench likely to affect the east coast of the Coromandel (Red Star)

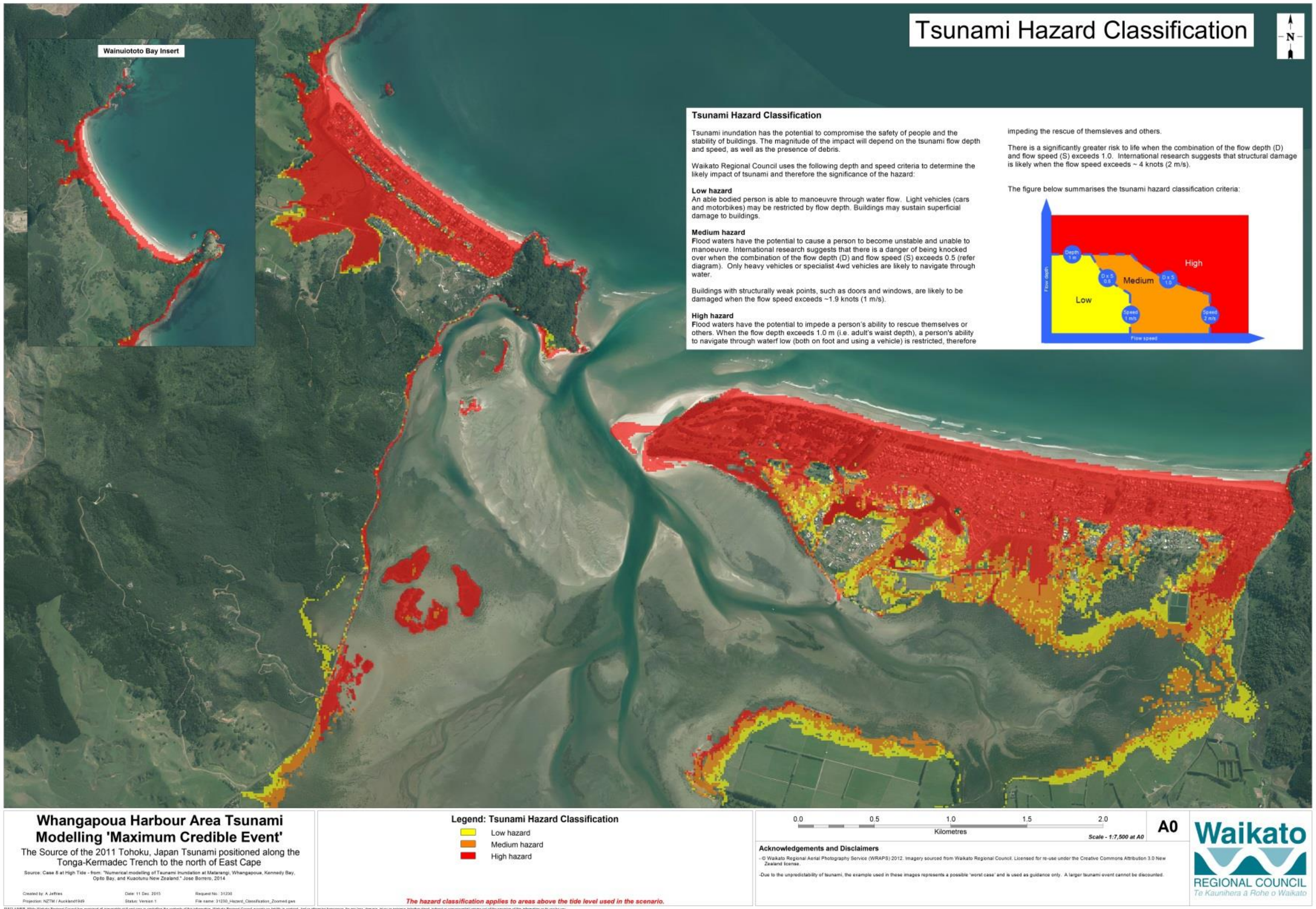


Matarangi and Whangapoua have two main sources of tsunami – near source and distant source.

For Matarangi and Whangapoua, the travel time from a near source Tonga-Kermadec Trench event from segments 1 and 2 is around one hour, while the travel time from a distant source South American event is usually 12-15 hours.

The level of potential inundation of Matarangi and Whangapoua from a large near source event is significantly greater than for the largest distant tsunami events.

Figure 4: ‘Maximum Credible Event’ Tsunami inundation hazard due to Tonga-Kermadec event– using similar parameters as the Japan 2011 tsunami event (Magnitude 8.8, variable slip model, event occurs on Segment 1 – just off East Cape)



Current emergency response arrangements

Thames-Coromandel District Council has been working with east coast communities for many years, including Whangamata, to help them prepare for and respond to tsunami events.

In Matarangi and Whangapoua, work with the community is ongoing via the local Community Emergency Response Group, involving the rural fire force, Thames-Coromandel District Council and community groups.

The following arrangements are in place in Matarangi and Whangapoua.

Near source tsunami (around one hour warning such as the Tonga-Kermadec Trench)

With a ***near source*** tsunami, the only probable indicator will be a major earthquake or signs of unusual coastal activity such as:

- A sudden rise or fall in the level of the ocean accompanied by fast-moving currents and/or a "roaring" sound similar to a noisy jet engine.

With near source tsunami the priority is for self-evacuation to above the 20 m contour line. In this situation emergency services will also be self-evacuating to ensure they can respond following any tsunami impact on your communities. Official warnings such as the sirens may not be able to be activated so you must respond to the nature signs. You must have a self-evacuation plan and know how to get to locations above the 20 m contour from your home, workplace and/or recreational places. You may not be able to use a motor vehicle after a significant earthquake so plan to self-evacuate on foot with a Go Bag.

It may be advisable to walk quickly to higher ground if there is a traffic jam, and you are able to do so.

The general guidance for earthquakes that may generate a local source tsunami are those that:

- Produce violent shaking, where people are unable to stand up or
- Those that last for one minute or longer, but are less violent.

The sirens may be sounded for near source tsunami if there is time and they are still operational, but <u>their use cannot be guaranteed</u>.

If people feel a large earthquake, they should not wait for sirens, but evacuate to higher ground immediately.

Distant source tsunami (greater than 3 hours warning)

When a ***distant source*** tsunami warning is confirmed, the following actions will be taken to warn the Matarangi and Whangapoua communities:

- The Matarangi and Whangapoua fire brigades will have been alerted and will be operating from the fire stations
- The local communications plan will be activated and essential personnel deployed
- Fire appliances and other emergency vehicles will travel around the area announcing the impending arrival and time of a tsunami and giving advice on what to do
- Television, radio and other media will have constant updates on the situation.

While there is little threat of land inundation from large distant tsunami, strong currents may be produced for up to 16 hours following the first wave arrival, and the largest waves arrive between two and six hours following the first wave arrival.

During a distant tsunami event, stay out of the marine environment and stay clear of beaches

Matarangi and Whangapoua tsunami evacuation zones

Evacuation Zones

Under current emergency management arrangements, local authorities and emergency services believe that in the event of a tsunami warning or event, residents should evacuate to at least 20 metres above sea level to ensure they are not affected by tsunami waves or debris and to reduce congestion for emergency services in the affected areas.

While the "Maximum Credible Event" shown in Figure 4 is our current best estimate, the complexities of estimating tsunami generation mean that a larger tsunami event cannot be discounted. However, we are confident that tsunami inundation is unlikely to occur above the 20m lines as shown in Figures 5 and 6.

Figure 5: Matarangi Tsunami Evacuation Zone

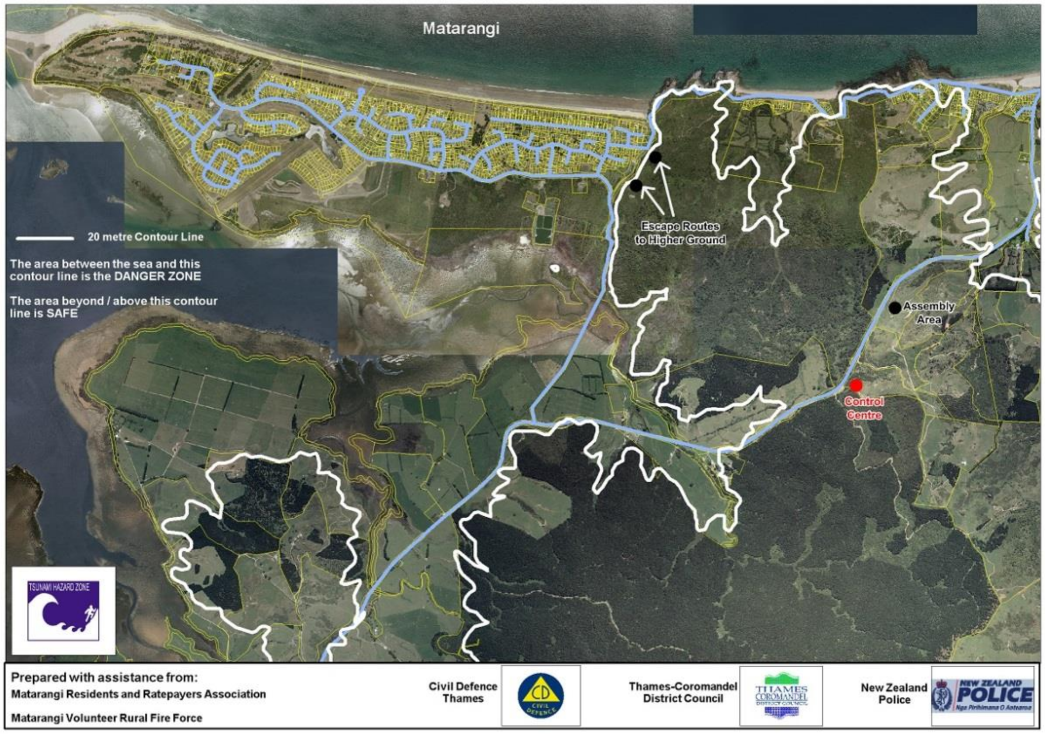
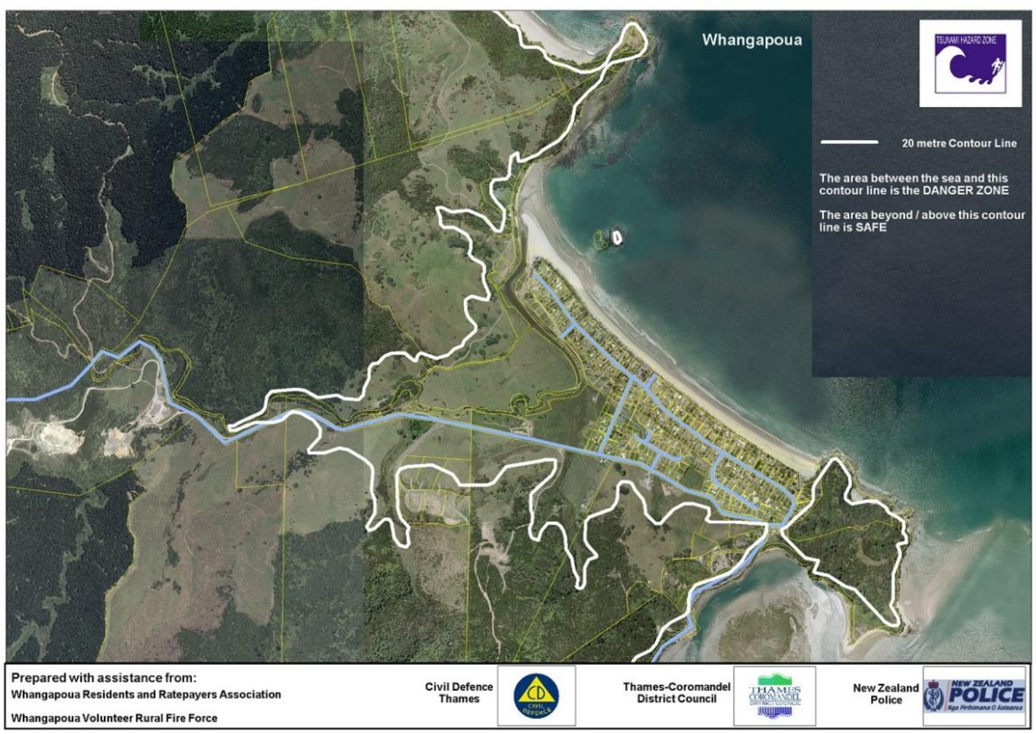


Figure 6: Whangapoua Tsunami Evacuation Zone



Who is responsible for managing tsunami risks?

Organisations

The primary organisations responsible for managing the risks from tsunami are:

- Local government – Thames Coromandel District Council and Waikato Regional Council (including issuing local emergency warnings for tsunami, and for research and public education and awareness)
- Emergency services – including Police, fire service and ambulance responders
- The Ministry of Civil Defence & Emergency Management (including issuing warnings for regional and distant source tsunami)
- Welfare organisations.

Local communities

While the primary responsibility for local tsunami risk management sits with local government, the role of communities and local individuals is critically important.

The National Civil Defence Emergency Management Strategy reinforces this within its first principle:

> **Principle One:** *"Individual and community responsibility and self-reliance"*
>
> *Individuals and communities are ultimately responsible for their own safety and the security of their livelihoods. CDEM arrangements in New Zealand support and encourage local ownership of this responsibility. Individuals and communities must be able to care for themselves and each other, as much as possible, when the normal functions of daily life are disrupted. Arrangements to support this are best developed at the local level. Local and regional efforts contribute to the overall national capability. Central government intervenes where an event is beyond the capacity of local resources.*

Partnership is essential

So, in summary, the responsibilities for managing tsunami hazards in Matarangi and Whangapoua primarily fall on local government, emergency services and the communities.

The successful management of risks will continue to require a strong partnership approach between these parties.

What can we do to better manage risks?

Risk management goals

Defining goals for risk management can help confirm what aspects of risk are most important. We are suggesting the following tsunami risk management goals in Matarangi and Whangapoua:

- The protection of human life and ensuring community safety is the most important priority.
- The community – in partnership with Thames-Coromandel District Council, Waikato Regional Council, civil defence and emergency services – could build its awareness of the risks associated with tsunami.
- Armed with that extra awareness, the community could work more closely with councils and emergency services to help avoid death and injury during tsunami, and damage to property. This could include considering changes to land-use regulations in the community as a longer-term management option.

Options for managing tsunami risks

Essentially the options going forward seem to boil down to the following:

1. **Status quo:** Stick with current arrangements.
2. **Improve local emergency management arrangements:** Put in place improved systems for warning the community about tsunami and evacuating people.
3. **Improve public education and awareness:** Provide people with more information to make good decisions about personal safety and avoiding property damage.
4. **Land use planning:** we can either avoid or mitigate risks (or both):
   (a) **Avoid risks (change local policies and rules):** Put in place new rules and policies about how land can be used and what buildings can go where.
   (b) **Mitigate risks:** Involves physical works to reduce the consequences of a tsunami event.
5. **More insurance:** Using more insurance to insulate the community from the financial effects of tsunami damage.

Effectively improving risk management for tsunami would probably require a combination of these sorts of options.

Further information on these options is provided within Appendix 1.
Have a look at these options and tell us what you think at the open days (see p. 15 for details).
If you can't make it to the open days and have questions or ideas, you can call or email TCDC customer services at 07 868 0200 or customer.services@tcdc.govt.nz.

Where to from here?

The Thames-Coromandel District Council and Waikato Regional Council believe the participation of the Matarangi and Whangapoua communities in developing a tsunami risk management plan is essential if solutions are to work effectively.

Those solutions should be tailored to suit community requirements, and have broad agreement and acceptance in the community.

During 2016, the two councils will undertake the following steps:

1. Hold two open days on tsunami hazards and risks to encourage community awareness, understanding and feedback on solutions.

> **Tsunami open days on Auckland Anniversary weekend 2016:**
>
> **Saturday 30 January**, 10.00am – 3.00pm, Matarangi Fire Station
> **Sunday 31 January**, 10.00am – 3.00pm, Whangapoua Fire Station

2. Development of a proposal for tsunami risk management plan for Matarangi and Whangapoua.
3. Further consultation with the community regarding the proposal.
4. Council consideration of the proposal in light of community feedback.

Once a proposal is signed off, we expect that implementation of the risk management plan will happen from mid-2016 onwards. We will be providing the community with further information about opportunities for input into the plan next year.

In the meantime, if you can't make the open days and have questions or ideas, you can call or email TCDC customer services at 07 868 0200 or customer.services@tcdc.govt.nz.

Staff from Waikato Regional Council can also answer questions on 0800 800 401, or may be contacted via email:

- Adam Munro, Team Leader Regional Hazards (adam.munro@waikatoregion.govt.nz)
- Rick Liefting, Senior Regional Hazards Advisor (rick.liefting@waikatoregion.govt.nz)

The following link is useful if you want to access the technical data and maps that underpin the information in this summary document:
http://www.waikatoregion.govt.nz/Services/Regional-services/Regional-hazards-and-emergency-management/Coastal-hazards/Tsunami/Eastern-Coromandel-Tsunami-Strategy/

Appendix 1: Options for managing tsunami risks

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    a. **Avoid risks (Change local policies and rules):** Put in place new rules and policies about how land can be used and what buildings can go where.
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5. **More insurance:** Using more insurance to insulate the community from the financial effects of tsunami damage.

Effectively improving risk management for tsunami would probably require a combination of these sorts of options.

1 – Status quo

While the status quo must always be considered as an option, it is unlikely that keeping the status quo would provide benefits to the community – including possible reductions in the number of lives lost during tsunami events.

Given the new hazard information, there may be a community expectation that further actions need be taken to help raise awareness and lower the risk to life.

2 – Improve local emergency management arrangements

The commonly recognised effective emergency management responses for tsunami are:

- Provision of warning systems and alerts
- Evacuation planning

The critical link to public education and awareness initiatives is noted.

Warning Systems and Alerts

The arrangements in place for warnings systems are outlined earlier in this document.

We are keen to hear what more the community thinks should be done aside from current arrangements – that is, whether people would like to see more use of other forms of public alerting. The following information is drawn from the MCDEM Public Alerting Options

Assessment guideline[10], and provides a brief overview of warning systems and available in New Zealand and overseas.

The following thirty public alerting mechanisms are available in New Zealand and overseas. Warning systems are divided into four categories:[11]

1. Natural warnings;
2. Independent and self-maintained networks;
3. Mechanisms reliant on third party hardware and/or staff; and
4. Mechanisms that require dedicated hardware (but controlled by the warning agency).

1. Natural warnings (identification and response based on natural signs)

2. Independent and self-maintained networks (door-knocking, local community response procedures)

3. Mechanisms reliant on third party hardware and/or staff (siren mechanisms are highlighted)

- Aircraft banners
- Aircraft PA loudspeakers or sirens
- Billboards
- Break-in broadcasting (not currently available in New Zealand)
- Call-in telephone line
- E-mail
- GPS receivers (not currently available in New Zealand)
- Marine Radio
- Mobile-device Broadcasting (not currently available in New Zealand)
- Mobile PA announcements – NZ Police & Fire Service
- Pagers
- Power mains messaging
- Radio and TV broadcasts
- Route alert (door-to-door)
- Smartphone apps [added 2013]
- SMS-PP (Short Message Service - Point to Point)
- Telephone auto-dialling (landline)
- Telephone trees
- Tourist advisory radio
- Websites/WAP [includes social media]
- Website banners

4. Mechanisms that require dedicated hardware - but controlled by the warning agency (siren mechanisms are highlighted)

- Fixed PA loudspeakers
- Mobile PA loudspeakers
- Flares, explosives
- Radio data systems
- Radio (UHF, VHF and HF)
- Sirens (tone, no voice capability)
- Tone-activated alert radio (not currently available in New Zealand)

[10] Ministry of Civil Defence & Emergency Management (2010) Public Alerting: Options Assessment Information for the CDEM sector [IS 10/09], Wellington.

[11] Refer to p. 11.

Evacuation planning

Successful tsunami evacuation planning involves:

- Confirmation of evacuation zones and boundaries (based on hazard mapping).
- Identification of pre-agreed evacuation routes, vertical evacuation sites and safe areas.
- Provision of signage showing evacuation routes, vertical evacuation sites and safe areas.
- Wide distribution of evacuation maps and information, and ongoing maintenance of signage.
- Regular exercises and monitoring of evacuation effectiveness.

Again, we would like the community's views on options such as improved signage and more evacuation exercises.

Advantages and disadvantages of improving local emergency management arrangements

Methods	Advantages	Disadvantages
Provision of warning systems and alerts	Vital to any strategy that aims to reduce risks to life; provides assurances to community; practical; can be incorporated into existing emergency management systems; benefits when dealing with seasonal population influx; fulfils statutory responsibilities	Difficult to cover all potentially affected people; level of community understanding of warnings systems can be hard to maintain over time; some systems can be unreliable; warning time is short for local event
Evacuation planning	Identifies best possible routes and safe areas in advance; engages local community in owning the plans; visible reminder of the hazards and risks via signage; helps to save lives	Difficult to maintain high level of community awareness beyond initial work; may promote complacency with respect to other methods once complete; maintenance of signs

3 – Improve public education and awareness

A community that is well-informed about tsunami risk and what to do in an emergency is better placed to respond when the “real thing” happens.

There are numerous public education methods that can be used to boost awareness such as information leaflets, press releases or advertisements, fridge magnets, static displays, media campaigns, workshops, coastal signs and evacuation plan testing.

Advantages and disadvantages of improving public education and awareness

Methods	Advantages	Disadvantages
Public education and awareness	Critical link between community and Councils/emergency response organisations; critical component of warning systems and evacuation planning; engages community in knowledge of hazards, risks and decision-making	Time-consuming; may lead to “saturation” of messages; recent small events may lessen understanding and increase complacency

4 – Land-use planning – avoid or mitigate risks

a. Avoid risks

Avoiding new development within high hazard areas, and/or restricting the type and extent of new development, is one way of helping avoid tsunami risks.

The primary tool available for such local tsunami hazard avoidance measures is the Thames-Coromandel District Plan.

Possibilities include:

- Designation of tsunami hazard areas for open space uses;
- Acquisition of land in high hazard areas for open-space uses;
- Restriction or prohibition of new development within high hazard areas;
- Restriction of the type and extent of new development within existing developments;
- Locating and/or relocating critical infrastructure and facilities away from the high hazard zone;
- Managed retreat (i.e. making changes in a phased way) if possible;
- Establishing links to complementary hazard management policies such as coastal erosion and flooding;
- Creation of reserves between the coast and new development; and
- Policy and planning provisions for post-tsunami reconstruction.

Any new district plan could be reinforced by Waikato Regional Council's (Operative and Proposed) Regional Policy Statement, which sets high level regional objectives for managing tsunami hazards.

Advantages and disadvantages of avoiding risk

Methods	Advantages	Disadvantages
Planning for open spaces in high hazard areas	Avoids new development; allows for complementary soft solutions such as vegetation	Limited areas for additional open spaces
Buying land in high hazard areas for open-space uses – such as reserves	Avoids new development; allows for complementary soft solutions such as vegetation	Costly (becomes public cost to protect private property); limited areas for additional open space
Restriction or prohibition of new development within high hazard areas	Keeps density and potential damage lower	Legal challenges to policies from developers; undeveloped land inequity for landowners
Restriction of the type and extent of new development within existing developments	Keeps density and potential damage lower	Legal challenges to policies from developers; undeveloped land inequity for landowners
Locating and/or relocating critical infrastructure and facilities away from the high hazard zone	Provides long-term solution to risk to life and property; complementary to other methods	Existing use rights often difficult to change
Managed retreat	Strategic, long-term approach; links to management of other coastal hazards	Costly (no compensation mechanism); private property rights make this difficult without purchasing land; few strong drivers available
Establishing links to complementary hazard management policies	Strengthens argument for open spaces and development restrictions	No direct effect on risks by itself
Policy and planning provisions for post-tsunami reconstruction	Strategic - allows for long-term land use change towards open space usage	Difficult to enforce; may be politically unacceptable after an event

b. Mitigate risks

Mitigating risks generally involves some form of physical works or design standards to reduce the severity of damage from tsunami.

Physical works are normally classified as follows:

- **Structural (hard):** Involves putting up coastal defence structures such as sea walls, rock revetments, breakwaters and stop gates across harbour and river mouths. It can also include building up areas of coastal land such as vulnerable coastal highways or causeways, and infilling low-lying coastal areas
- **Non-structural (soft):** Involves working with natural systems to enhance their tsunami mitigating effectiveness. This dune and coastal vegetation stabilisation and restoration, planting or enhancement of coastal forests and recreating coastal/estuarine wetlands or marshes. It can also include raising of low points in natural dunes systems, increasing the "roughness" of reserves by planting vegetation, and changing beach access routes so they don't "channel" tsunami flows.

Design standards are rules and regulations that govern how buildings and infrastructure are developed within tsunami hazard zones. The following are some common methods of hazard mitigation for buildings:

- Locating and configuring new development to minimise future losses by[12]:
    - Site-specific planning to reduce risk such as avoidance of maximum inundation areas and designing sites to slow, steer and/or block currents and forces;
    - Providing maximum spacing between buildings;
    - Using larger hardened buildings to provide shelter for at-risk buildings; and
    - Placing primary access roads outside inundation areas and secondary access roads perpendicular to the shore.

- Designing and constructing new buildings to minimise tsunami damage and maximise mitigation opportunities by:
    - Raising floor levels above known levels of inundation.
    - Deepening and reinforcing the foundations of dwellings.
    - Improving the tie-downs to foundations.
    - Opening up the ground floors of engineered buildings to allow for flows.
    - Ensuring that appropriate building design standards are adopted and enforced.
    - Defining the expected performance level of buildings.
    - Requiring that new multi-storied buildings are available for people to evacuate to so they can avoid tsunami waters.

- Protection of existing development through renovation, retrofit and redevelopment. This can not only be used to protect buildings within the high hazard zone but decrease the amount of debris created that can damage other buildings. Renovation, retrofit and redevelopment will almost certainly require the development of local policies and rules, as building standards do not currently address tsunami risks.

- Locating and designing infrastructure and critical facilities to minimise tsunami damage.

Advantages and disadvantages of mitigating risk

Methods	Advantages	Disadvantages
Physical works		
Structural (hard)	Seawalls and breakwaters modify hazards prior to impacting infrastructure or people, stop gates beneficial for slowing and re-directing flows	High costs associated with construction and maintenance; often incompatible with other uses such as coastal vegetation and natural character; poor visual amenity; beach access issues; lack of room for development; may promote intensification of development; not guaranteed to work as designed in all events (as in Japan in 2011)
Non-structural (soft)	Compatible with and helpful for other coastal uses and values; often cost effective; blends with natural environment	Coastal vegetation may cause additional debris damage if not well managed
Building design standards		
Locating and configuring new development to minimise future losses	Takes advantage of site-specific conditions; practical; ensures development geared towards minimising risk	Adds to cost of design and building; does not prevent development within hazard areas
Designing and constructing new buildings to minimise tsunami damage	Practical; focussed on minimising damage to infrastructure, but considerable benefits to saving lives via building strength and vertical evacuation	Adds to cost of design and building; does not prevent development within hazard areas
Protection of existing development through renovation, retrofit and redevelopment	Practical; focussed on minimising damage to infrastructure, but considerable benefits to saving lives via building strength and vertical evacuation	Potentially high costs to individuals; existing use rights; does not prevent development within hazard areas
Locating and designing infrastructure and critical facilities to minimise tsunami damage	Ensures greater sustainability of assets over time; helps reduce risks to human life; greater ability to recover following a	Existing use/private property rights; critical facilities often located near shore to get other benefits

Methods	Advantages	Disadvantages
	tsunami event	

5 – More insurance (risk transfer)

Risk transfer involves shifting risk via an insurance policy. These sorts of commercial decisions are largely part of individual and organisational decision-making processes.

Advantages and disadvantages of transferring risk

Methods	Advantages	Disadvantages
Insure against losses	Moves financial burden of losses away from local community; simple method	Does not reduce damage over time; no benefits to saving human lives; does not lower overall risk - simply spreads it wider; no guarantees of ongoing coverage through time; applies to individuals, and cannot be relied upon as a single method